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Daylight as Starting Point For Retrofitting Residential Buildings and Cities

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Abstract

The paper will examine the current state of the practice using daylighting design conducted by leading practitioners within the field of architecture, emphasizing on the methodology used by designers to refine their designs informed by daylight assessment and simulation and perceiving how daylight changing conditions will interact with space geometry and glazing properties to create the adequate daylighting conditions. As architects, we must pursue daylight as an compulsory quality of our built environment. The new digital simulation tools could help us train our sensitivity and feelings for daylight and achieve a more accurate design outcome, which can be energy efficient, poetic and delightful. Daylight is an element that must be used to create an experience of space, to provide character and a sense of time. Daylight has a wide impact on the human well-being and represents a tremendous potential for harvesting energy savings in renovation, modernisation and transformation of cities and buildings, reducing the energy demand of buildings, increasing user comfort and having an important contribution to the attractiveness of any interior space. Adequate daylighting can increase the market value for all properties. This paper focuses on the benefits, opportunities and challenges of implementing daylighting strategies for retrofitting European existing building stock, at three different scales: urban district, building unit, individual apartment.

Rezumat

Lucrarea analizează nivelul actual al practicii designului de ilumininat natural a unor birouri de arhitectură recunoscute în domeniul arhitecturii, punând accent pe metodologii utilizate în adaptarea proiectelor de arhitectură ca urmare a analizei rezultate prin evaluarea și simularea performanței luminii naturale, perfecționându-le în funcție de modul în care dinamismul luminii naturale va interacționa cu geometria spațiului proiectat și cu tipul de vitraj ales pentru a crea condițiile unui iluminat natural adecvat. Lumina naturală reprezintă o calitate importantă a mediului construit, iar utilizarea conștientă a acesteia trebuie să constituie un important obiectiv de urmărit în arhitectură. Noile instrumente digitale de simulare aflate la dispoziția arhitecților pot avea un aport major la creșterea sensibilității față de utilizarea luminii naturale și la realizarea cu acuratețe a produsului finit de arhitectură, eficient energetic, poetic și încântător. Lumina naturală este un element care trebuie să fie utilizat pentru a crea o experiență spațială și pentru a conferi personalitate și temporalitate locului. Lumina naturală are un impact considerabil asupra stării de bine și reprezintă un potențial enorm în ceea ce privește economisire a energiei în renovări, modernizări și transformări inevitabile ale a orașelor și clădirilor, reducând necesarul de energie

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utilizată de clădiri, contribuind la creșterea confortului utilizatorilor și având un aport considerabil asupra atractivității oricărui spațiu interior. Utilizată adecvat, lumina naturală va crește valoarea de piață a proprietăților imobiliare. Această lucrare se concentrează pe beneficiile, oportunitățile și provocările implementării strategiilor de iluminat natural în procesul de reabilitare a fondului construit existent european la trei scări urbane diferite: cartier urban,clădire și apartament individual.

Keywords: daylighting, retrofitting, sustainability, opportunities, residential architecture, scalar interventions.

1. Understanding sustainability

Starting from Wendell Berry's premise that we don't inherit the world from our ancestors, but we borrow it from our children [1], we can define sustainability not just in terms of energy savings, but also in terms of maintaining human advancements with a minimum impact on Earth, with the purpose of improving the quality of life.

Within the science of building, sustainability seems to be the most important development since modernism, having the ability to alter the concept of beauty as we knew it. The building performance gains credit and it becomes part of the beauty of architecture. The design solution is the layout of the whole process of sustainable development and it gets its validation at the moment it manages to create a social change.

The propaganda for the new aesthetics of the modernist movement was based on a very clear slogan: 'light, air, sun', using terms borrowed from hygienics. The sunlight was seen as a treatment for diseases as well as a purifier and hygienics was a new science that started to have a strong standpoint when the new buildings norms were elaborated. The modernists managed to shift the emphasis from bad air, the menace of the 19th century, to bad light, as a source of bad health effects, succeeding in creating a new social need that architecture mainstream embraces today: brighter = better, conferring daylight a leading role in the process of space planning for health benefits.

The 21st century is a New Era and health promotion seems to be the favoured theme, taking over from the theme of information and knowledge. This takes us to the point where health and well-being should become leading paradigms for planning our dwellings.

2. European residential building stock

According to the survey "Europe's buildings under the microscope" run by the Buildings Performance Institute Europe in 2011, the residential buildings account for 75% of the total building stock in Europe [Fig. 1][2]. Close to 40% of our residential buildings were constructed before 1960s [Fig. 1], a period when energy-efficient regulations were not applied and one in three of these buildings are more than one hundred years old, in need for retrofitting. Moreover, an increase of the number of buildings raised between 1961-1990, in a time when most of the multi-story slab-construction apartment blocks were built at great speed, having very high energy consumption rates on the long term, leaves us with approximately 15% of buildings that are constructed in the last 20 years according to some energy building regulations. Therefore, because of these facts, we must be aware that retrofitting the existing building stock is a must.

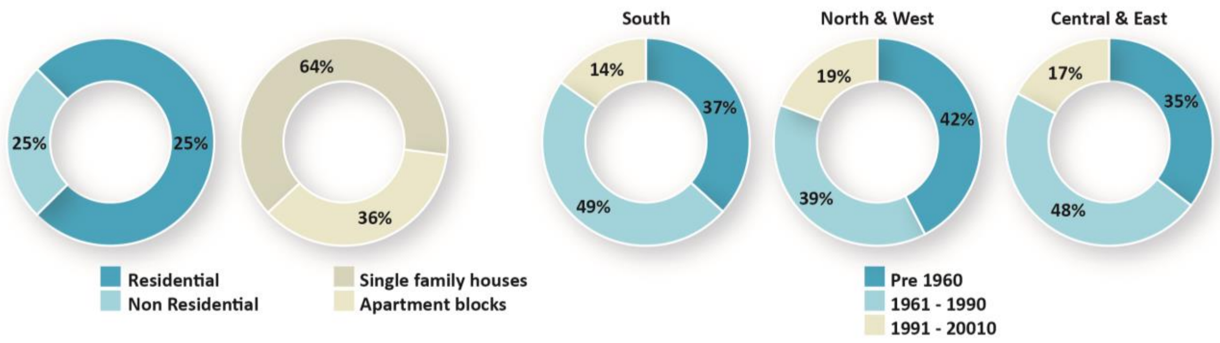

Figure 1. Residential building stock (m2) and age categorisation of housing stock in Europe

Between 50-75% of the current global building stock will still be standing in 2050, depending on the country. The entire building stock will be undergoing refurbishment within 65 years from now, with thorough renovation occurring every 35 and 45 years in the life of a building [3].

2.1. The need for refurbishment

Europe is confronted with a constant deficit for social housing, therefore the adaptation of existing buildings to accommodate contemporary living standards is a much more efficient, economic and qualitative approach. When using an existing building, in comparison with building a new building, approximately 60% of the material used during the construction and use phases can be saved. Important savings of the raw materials used in construction is possible by more efficient use of existing residential buildings, energy renovations, using district heating, increasing the use of inner-city area for housing and increased use of renewable raw materials and recycled construction materials. The design process will focus on reducing energy used by buildings, using high-performance construction materials and improving the conditions of existing buildings.

Marketing campaigns for retrofitting and living in existing buildings could be used to make dwellings in more attractive and at the same time increase the knowledge of users on how to improve these buildings.

3. Retrofitting with daylight

Energy renovation is a specific measure required to realise the resource potential of the existing building stock, especially when considering dwellings. The primary elements that affect the heating, cooling and ventilation loads are the building envelope elements: walls, windows, foundations, roofs with their associated air leakage. Considering the fact that over a third of global energy is used to make buildings comfortable for occupants [3], advanced or retrofit building envelopes will be essential to reduce energy consumption.

Minimising heating and cooling loads requires an integrated view of building design. Sunlight is freely available, and maximising its benefits to reduce heating and lighting needs is part of an integrated design. Similarly, thermal mass, insulation, shading, reflective surfaces and natural ventilation can help minimise heat gains in summer and thus energy needs for cooling.
Daylight is an instrument that has implications on different building scales, not just in the residential unit: the city and the urban district as well as the building and property value are affected by daylight.

Fig. 2 shows a selection of most used interventions for energy renovation with an indication of the scales they are primarily relevant to [4]. Daylight and materials are the only two instruments that have implications at all scales. Hence these two instruments that can provide the greatest benefit when looking holistically at the urban settlements.

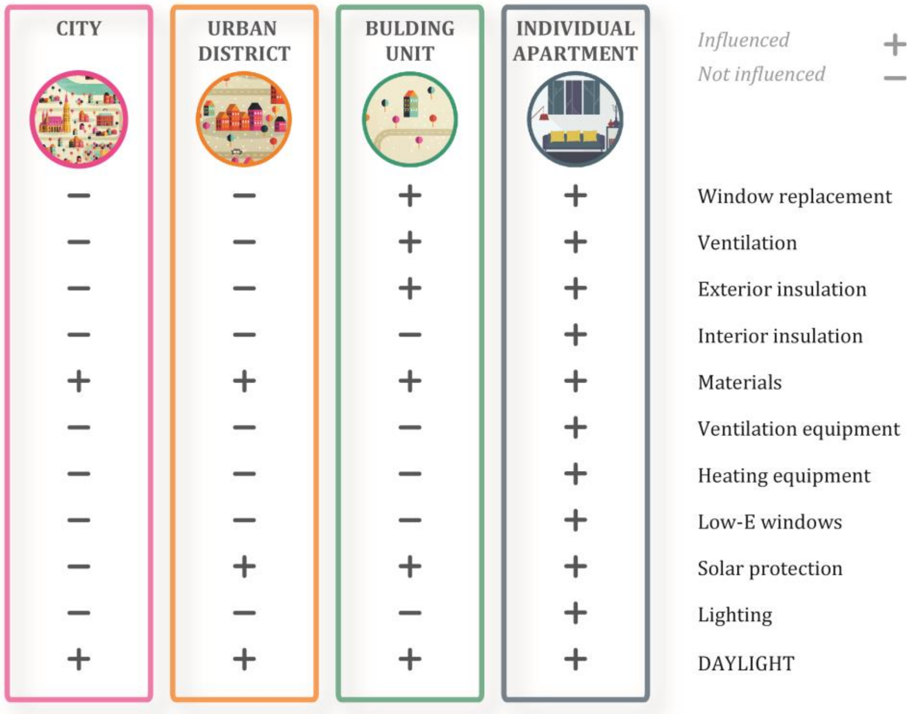

Figure 2. Scalar retrofit interventions

3.1. Daylight – impact and value

Daylight is an important and available resource in retrofitting cities and buildings, as shown in Fig.3. First of all, exposure to daylight and access to views are associated with important health benefits, and recent research conducted by physicians, photobiologists, psychologists, architects and lighting designers indicate that interior space with good daylighting enhances the comfort, health, well-being and productivity of the occupants [5]. Secondly, daylight has an important contribution to the attractiveness of any interior space. Thirdly, using daylight adequately represents a tremendous potential for increasing energy savings in buildings and last, but not least, daylight increases the market value for properties, adding both social and financial value.

If bringing into discussion the current practice of daylight design, we can notice that most architects are currently using a variety of non-standardized daylight prediction methods – 'rules of thumb'. Furthermore, there is no common method of how to assess the performance and quality of daylighting in terms of energy savings, glare prevention, daylight factors and the view to the outside.

The architects have compelling evidence of the importance of daylight as a premise for architecture, they must learn how to integrate it in their daily designs.

3.2. Daylight as a design tool

"What about daylight?" is an elaborate study made by a group of seven Danish architects working at Henning Larsen Architects (DK), together with Peter A. Sattrup (Technical University of

Denmark) and Charlotte Algreen (Algreen Arkitekter), assessing daylight strategies implementation when working with the built environment on three different urban scales. The study coins the term "daylight refurbishment" of cities and buildings, defining a new separate activity field in the process of building design.

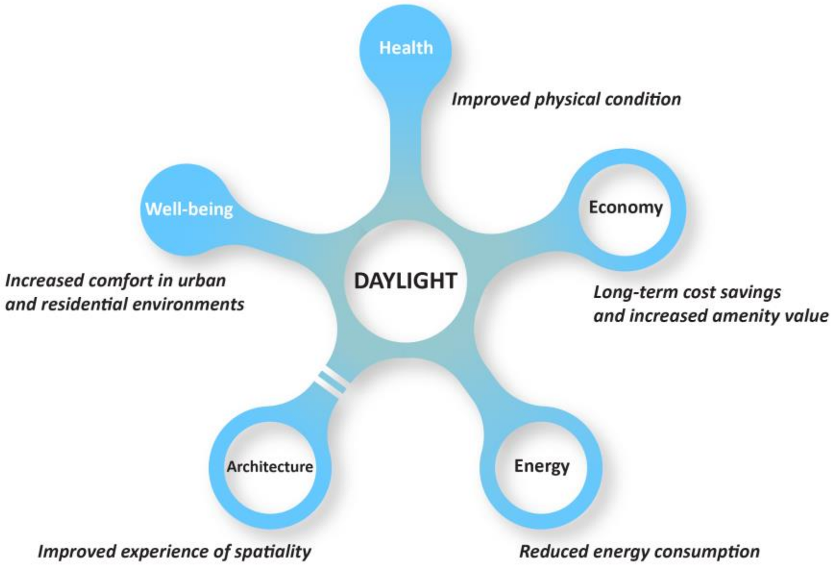

Figure 3. Impact of daylight in buildings

The comprehensive study presents a well-structured methodology for practical implementation of a refurbishment strategy based on daylighting improvements, being a very useful toolbox for architects to work on an operational level with daylight. The summary of the study exposing the benefits resulted from calculation was mailed to all the architects in Denmark. The study analysed a typical high-density residential district in the city of Copenhagen, but can be applied as a refurbishment strategy for many cities within the Northern climate and not only. The methodology is presented at the end of this chapter in Fig.8, as a conclusive example to be followed.

The approaches for improving daylight conditions are effective at all scales of architecture and can be implemented at 3 urban scales: urban district, building unit and individual apartment. Those that use combinations of the 3 strategies are more effective than single-track approaches, based on a cumulative effect. As follows, each of these assessment levels will be briefly exposed, with their associated benefits. Fig. 4 is presenting the methodology used in this study, with the investigation methods using daylight simulation techniques and the suggested measures to be applied, based on the simulation results [4].

3.3. Urban district assessment level

Working at the urban level is part of a long-term strategy, which can offer benefits for environment and social capital. Breaking up the monotony and ensuring a variety of housing typologies is the most effective measure to be applied at the urban district level, in order to increase sunlight access to all dwellings and public space in between the buildings. A greater variety in types of buildings, height and spacing allows for new ways of using buildings and more diversified open spaces, improving the daylight availability and quality of life in the city district. When buildings are sitting very close to each other and the courtyards are too narrow, the possibility of creating open spaces comes from selected demolition of certain building parts or less important buildings, creating new passages through the built tissue. Another intervention is to add up square meters, building over existing buildings, especially at building corners, creating small towers that will not overshadow the neighborhood.

The simulation results of applying these methods indicated that smart densification in the studied area brought an increase of sunlight level in the urban areas and showed a 10-15% increase of solar radiation on the facades and 15-20% increase of solar radiation at ground level (Fig.4), creating higher quality outdoor areas and green spaces.

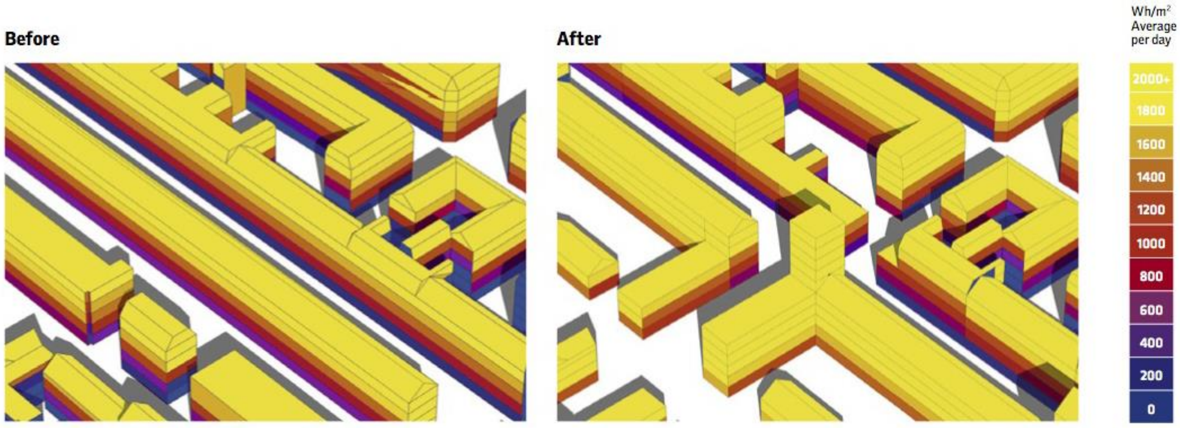

Figure 4. Average solar radiation. Simulation by Henning Larsen Architects, "*Hvad med dagslys?*"

3.4. Building unit assessment level

The interventions at the building scale are a mid-term strategy and present a financial turnover for the building owner. The use of bright coloured façade materials, with a high reflectivity and matt finish improves the amount of light reflected in the interior courtyards and at street level by up to 15% [7] (Fig.5) Another measure to consider is to position extensions of the buildings (e.g. balconies) according to the dynamics of the sun, following a shading analysis of the facades. Optimizing building solar geometry might lead to selected demolitions of certain building parts that shade the facades and courtyards.

Erick van Egeraat Architect - Sumatrakontor, Hamburg, photo: Collingridge J.

Figure 5. Facade reflectivity – bricks reflect 13% light; white plaster reflect 90% light

As far as extending the square meters of living space within existing buildings, one of the traditional methods is attic interventions, whether roof extensions or unused attic conversion [8],[9]

(Fig.6). Coupling small apartments on vertical rather than horizontal, can increase daylight penetration in lower level apartments, creating high two-level rooms that can benefit from direct sun radiation deep into the building.

left: Mikado Architects, photo: Bruno Klomfar, right: Lakonis Architekten, photo: Hertha Hurnaus

Figure 6. Loft conversions in Vienna (2014)

The simulation results of applying these methods showed an increase of 10-20 % in daylight levels in urban areas and backyards and a potential density increase.

3.5. Individual apartment assessment level

Zooming in to approaches of refurbishing an individual apartment, we face a short-term strategy, bringing benefits for the residents, improving their quality of life. The study analyzes a room in a typical apartment block built in the early 1900s situated at the second floor. The single-glazed windows are facing southwest, therefore getting the direct sun radiation in the evenings. The façade is made of unplastered brickwork and can only be insulated from the inside. A multitude of the refurbishing methods were analyzed, ranging from simple thermal insulation to increasing the glazing surface by creating bigger windows or even balconies. The team of architects created seven different scenarios for analyzing the interaction between energy consumption, supply of daylight and costs, as shown in Fig.8. The most economical method for retrofitting is adding thermal insulation of the exterior wall, reducing the energy consumption, but reducing the amount of daylight in the interior, due to the increased wall thickness and deeper window reveals. Similar results are obtained when replacing the windows with higher energy performance new ones with double or triple glazing. The triple glazing has a much lower visible transmittance and compared to double glazing, it reduces the energy consumption very little. Better improvements in both energy and daylight performance are seen in the case where windows are replaced with bigger ones, but the benefits are coming with a higher cost of the investment (Fig.7).

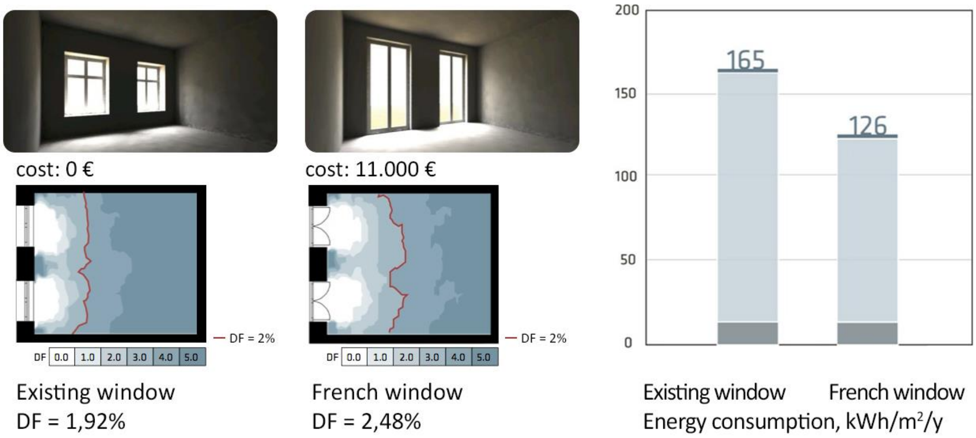

Figure 7. Daylight factor improvements when increasing the window size.
Simulation by Henning Larsen Architects, "*Hvad med dagslys?*"

However, excessive use of glazing with poor optical properties and without proper shading is a delicate issue, as it leads to excessive solar heat gain during summer. The ratio of glazing to opaque exterior wall, the choice of glazing, the availability and use of shading, and the position of the glazing relative to the interior work surfaces, must be carefully balanced. When using balconies, these should be carefully placed on the façade, according to the orientation, as not to overshadow the apartments below.

Almost a quarter of the energy consumption can be reduced when replacing existing windows with French windows and the apartment increases its energy efficiency with the increased window area, due to the installation of better performance windows (lower U-value). Because of larger window area, the daylight availability improves, with an increase of daylight factor up to 30%. The cost is a one-time investment with a high amenity value from day one and an increased financial value of the property for a future selling situation.

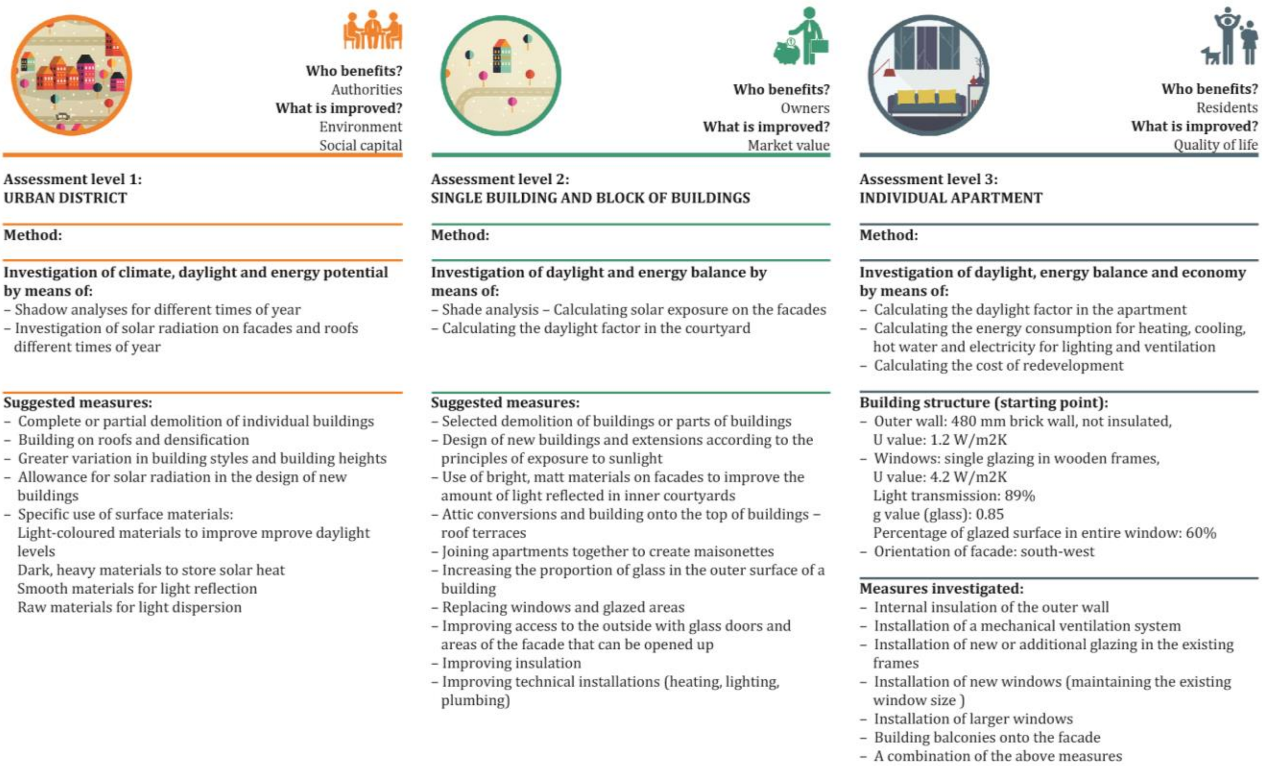

Figure 8. Daylight refurbishment implementation methodology,
Henning Larsen Architects, "*Hvad med dagslys?*"

Regarding property value, the sale price for a 80 square meters apartment in Copenhagen increases by approximately 20.000 € with every additional floor above ground level, simply due to increased daylight, view and privacy [6]. The market value for a new apartment in Chicago (Aqua Tower) increases with 50.000$ for better views. The price differences between spaces with or without daylight or with or without a view are substantial and they are a proof of how much people praise daylight in everyday life. Features like skyline views, lake views, floor to ceiling windows or private terraces are listed as first buying arguments in the sales description of real estate. The pricing is not only made for square meters, but it also quantifies both daylight and surrounding views.

4. Alternatives for demolition: refurbishment without relocation

The large multi-story residential buildings of the 50s, 60s and 70s often represent a problem – whether in the West or in the former Communist East. They are outdated regarding today's energy standards or to the requirements generally expected of flats today. Demolition is often considered as a possible solution, but there are alternatives.

The architects Anne Lacaton and Jean Philippe Vassal compiled a study commissioned by the French Ministry for Culture in 2004 on how to deal with large housing estates. This study claimed that their low density and unobstructed view of the surrounding landscape has a potential that makes transformation a better prospect that demolition [10]. Following this study, Frêdêric Druot and Lacaton &Vassal have refurbished the Tour Bois-le-Prêtre, a residential building built in 1959 by the architect Raymond Lopez, to demonstrate what a modern renovation might look like (2005 - 2011). Tour Bois de Prêtre is a 17-storey tower block on the outskirts of Paris and 100 apartments were renovated in order to ensure the living standards of the 21st century [11] (Fig.9). Calculations were made for the two following scenarios: demolition and reconstruction versus refurbishment. From the financial point of view, the refurbishment was the winning situation, with a cost 60% lower than the other scenario (100.000€/apt transformation vs.170.000€/apt. demolition & rebuild).

Figure 9. Tour Bois-le-Prêtre evolution in 40 years (1964-1990 rehabilitation-2006 transformation)

On the exterior, all flats were given a conservatory and a balcony zone with a new glass frontage, increasing depth by more than 3m. The asbestos facade was put down and the existing exterior walls were replaced with glass walls with sliding doors. Extremely generous outdoor spaces were created, with a graduated system of sun protection and shade. New plumbing, bathrooms, ventilation, and electric systems were installed, together with improved acoustics for the apartments. Quoting Anne Lacaton, the architects approach on this project was "to make the most of existing building methods and technologies and to help people achieve improved liveability so they feel they have good living condition. That will naturally inspire residents to assume more responsibility for taking better care of the environment and their surroundings, so that they too get involved in saving energy".

The outcome of the major transformation of Tour Bois-le-Prêtre is a design that accomplishes a good balance between daylight, energy consumption and cost-efficiency, which is humanistic and aesthetically convincing. The project won the Design of the Year by the UK's Design Museum in 2013. The practice has received several awards, among them the Erich Schelling Award in 2006, the International Fellowship of the Royal Institute of British Architects in 2009, and the Daylight and building components Award of the Villum Foundation, Copenhagen, 2011.

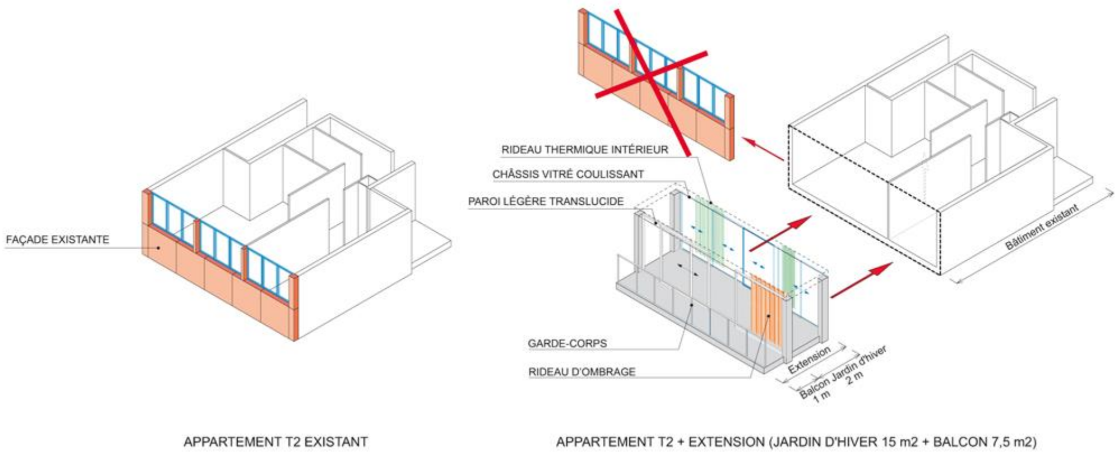

Figure 10. Tour Bois-le-Prêtre transformation strategy. Graphics: Lacaton & Vassal

5. Lighting up dark towns to provide a sense of place

Daylight is a productive component; it doesn't contain value, but it creates value. Still, there are cases where human settlements are set in geographical locations where sun can be witnessed only in summer. The small towns of Rjukan, Norway, and Viganella, Italy, are set in deep valley between high mountains which block sun access for more than half of the year, during the months of low sun elevation. Both villages came up with an innovative approach that transformed the life of their inhabitants: they have installed giant computer-operated mirrors that follow the path of the sun and redirect its rays downwards in the main square of the villages, allowing people to experience direct sun exposure which wouldn't otherwise be possible.

Figure 11. Rjukan main square, illuminated with reflected light. Photo: Tore Meek

The 600 square meter main square in Rjukan benefits form the focused beam of sunlight reflected by three 17 square meter glass mirrors placed on the mountain peak [12] [Fig.11]. The innovative way of approaching lack of sun became a landmark for the city, increasing the number of tourists and investors in town. This intervention is about how we use materials and solar energy in a way that creates a meaningful message for the people living in towns and it proves that solutions can always be found, as long as people acknowledge what they need, in this case - sunlight.

6. Conclusions

Successfully designing daylighting into buildings in a way that leads to high levels of visual comfort and also reducing energy use of the building is a complex and challenging process, demanding daylighting considerations at all stages of the building design process, from site planning through architectural, interior, and lighting design evaluation, to the conscious design of the building elements such as windows and skylights, which admit daylight in buildings. The three refurbishment approaches presented, the first based on rigorous simulation results and the second and third based on intuition, sensitivity and common sense are both valid as long as the output is a building where people experience a sense of place and a meaningful connection to nature, with the associated psychological and social benefits.

The successful implementation of daylighting retrofit procedures at all urban scales (city, district, building unit and individual apartment) presents an unprecedented opportunity to trigger a major shift towards an innovative approach when renovating the existing building stock in order to create improved living standards and increased property value. The high amount of buildings in need for retrofitting brings an opportunity for transformation of how daylighting is controlled both in the architectural project and in the residential buildings, as experienced by users. The successful deployment of daylighting retrofitting strategies will reduce energy use, provide attractive dwellings and financial gains and significantly impact climate change.

However, the opportunity is complicated and presents several challenges regarding both funding and city development strategies. The article tried to quantify the potential savings and recommends a series of actions that can ensure that the urban environments harvest the great potential of daylighting.

To conclude with, the fact that a daylight awarded building will always be associated with a very attractive interior leaves us thinking of the importance of the practice of daylighting design in every architecture office.

Acknowledgements

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