STRATEGIJE DEKARBONIZACIJE KOMERCIJALNIH ZGRADA

DECARBONIZATION STRATEGIES FOR COMMERCIAL BUILDINGS

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Komercijalne zgrade uopšte, a posebno tržni centri, spadaju među zgrade koje troše najviše energije, sa odgovarajućim uticajem na životnu sredinu, što je veoma dobro oslikano njihovim ugljeničnim otiskom. U isto vreme, komercijalne zgrade su kapitalno intenzivna sredstva sa visokim operativnim troškovima, koja primaju veliki broj posetilaca kao kupaca i mesta su preduzetništva u lokalnim privredama. Oni su takođe znamenitosti sa visokom vidljivošću, pa su stoga idealna mesta za promociju tehnologija dekarbonizacije.

Vlasnici i menadžeri zgrada počeli su da shvataju da holistička strategija dekarbonizacije ima mnoge prednosti koje se mogu izmeriti, osim regulatornih pritisaka. To uključuje, između ostalog, smanjene operativne troškove, povećano blagostanje koje dovodi do većeg zadovoljstva kupaca, povećanu produktivnost osoblja i smanjen rizik zbog moguće izloženosti nepovoljnim uslovima. Oni takođe pokazuju visoku korporativnu odgovornost i, na kraju, poboljšani korporativni identitet koji rezultira marketinškim prednostima, kada se zasniva na vidljivoj posvećenosti smanjenju emisije ugljenika. Dati su primeri mera sanacije omotača zgrade kako bi se pokazalo da je to samoplatan i isplativ način za postizanje svih ovih ciljeva, što ga čini privlačnim investitorima.

Ključne reči: *komercijalne zgrade; renoviranje; omotač zgrade; energetska efikasnost; ugljenični otisak*

Commercial buildings in general, and shopping malls in particular, are amongst the highest energy consuming buildings, with a respective environmental impact, which is depicted very well by their carbon footprint. At the same time, commercial buildings are capital intensive assets with high operational expenses, which receive a great number of visitors as customers and are venues of entrepreneurship in local economies. They are also landmarks with a high visibility, hence ideal places for the promotion of decarbonization technologies.

Building owners and managers have begun to realize that a holistic decarbonization strategy has many and quantifiable benefits, apart from regulatory pressures. These include amongst other, reduced operational costs, increased well-being leading to higher customers' satisfaction, increased productivity of the staff and reduced risk due to possible exposure to unfavorable conditions. They also demonstrate high corporate responsibility and, eventually, improved corporate identity that results marketing benefits, when based on the visible commitment to reduce carbon emissions. Some examples of measures of refurbishment on the building envelope are given so as to demonstrate that it is a self-paying and cost-effective way to achieve all those goals, which makes it appealing to the investors.

Key words: *commercial buildings; refurbishment; building envelope; energy efficiency; carbon footprint*

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1 Introduction

The building sector and the construction sector combined are responsible for 36% of global final energy consumption and nearly 40% of total direct and indirect CO2 emissions. Energy demand is expected to increase rapidly by 2040 (~48%). Despite the progress in renewables, the use of fossil fuels remains the basic source of energy. Rational use of energy and energy conservation is the most cost-effective energy source. [1]. These figures quite impressively similar all over the world, and it is of interest to notice that commercial buildings account for approximately 11% of the total final energy demand in Europe and in Australia, 12% in Singapore and Hong Kong, 8% in Southeast Asia in general and 4% China, respectively [2]. Regarding the specific energy consumption per square meter on European average this is estimated to be 415 kWh/m²a, while in the USA, commercial buildings consume about 620 kWh/m^2a [3]. It is impressive to notice that in absolute figures, commercial buildings in the USA consume more than 5,300 TWh of primary energy, representing 46.0% of building energy consumption and 18.9% of total USA energy consumed [4].

Still, it is very interesting to consider for reasons of comparison similar values for Asia and Australia, to underline that these high energy consumption figures are of global significance. In Malaysia, energy consumed by commercial and residential buildings accounted for about 13% and 48% of the total energy and electricity consumption between 2000 and 2010 [5]. In addition, Jakarta, populated with 170 shopping malls operating seven days a week, is regarded as one of global cities with the most shopping malls in the world. This large quantity of retail space area generates equivalently excessive amount of energy consumption. Eight of ten largest power consumers in Indonesia are shopping malls located in Jakarta, the rest two are major international airports of Indonesia. At its peak, use of electricity in a large shopping mall in Jakarta could reach 40 MW [6]. At the same time, investigating the annual energy usage of 30 commercial office buildings in Hong Kong, 68% of energy on average is consumed by Heating Ventilation Air-Conditioning (HVAC) system, while lighting accounted for 14% and the other systems share the else 18% of consumption. Compared with other countries, HVAC systems in Hong Kong commercial buildings consume the highest proportion of energy among all end-user systems, namely between 74 - 529 kWh/m^2a with an average value of 236 kWh/m^2a. Significant amounts of energy are also consumed by commercial buildings in Singapore [7]. Further analyzing energy consumption in China, it is worth noting that during the 31-year period from 1970 to 2000, in subtropical Hong Kong, air conditioning and electric lighting were the major electricity end uses in commercial sector, accounting for about 85% of the total building energy use. Electricity use per unit gross floor area ranged from 391 to 454 kWh/m^2a, with an average of 430 kWh/m^2a [8]. Particular interest has the fact that in Vietnam, commercial sector contributes only to 3.7% to the total energy consumption, while the largest consumer of energy is the industrial sector, contributing 35.4% to the total energy consumption, followed by the residential (31.8%), transport (21.5%), and other sectors [9]. In Australia, the commercial sector accounts for 8–10% of greenhouse gas emissions and consumes about 300 kWh/m2a. Simulations indicate that the building archetypes had an average energy breakdown of 49.6% HVAC, 28.5% ICT, 29.6% lighting, 1.4% Hot Water (HW) and 1% other electrical processes [10].

In that sense, commercial buildings are major energy consumers with significant saving opportunities, making low carbon refurbishment not only an environmental necessity but an appealing option. However, refurbishment measures in commercial buildings are normally part of a complex real estate project and in order to succeed, they have eventually to be linked to increasing the building's market value. Selection of retrofit measures should therefore not only be driven by financial or commercial considerations, but also by other factors, including managerial and organizational aspects. A further issue is the lack of understanding of available decarbonization technologies. Studies carried out in Europe, in North America and in Australia, showed that commercial property owners often admit having rather limited understanding of the range of retrofit measures available and, what is more important, there is a significant concern about the level and duration of disruption caused by the refurbishment [10, 11, 12].

This concern is consistent with the focus of owners and their managing agents being on simply operating their buildings whilst minimizing the impacts on occupiers and reducing complaints, rather than on proactively decreasing carbon emissions and energy use. On the other hand, it is of interest to notice that the same studies do not identify lack of funding as a barrier for Low Carbon Refurbishment (LCR). Owners of commercial property are highly experienced at accessing capital for promising investments, and this includes raising capital and arranging financing [12, 13]. Hence, if there is a sound justification for the investment, capital will usually be found.

Aim of this paper is to show that promoting decarbonisation of commercial buildings is mainly in need of an integrated methodological approach, which will based on the best available energy conservation technologies. Those must be chosen and applied in a way that will ensure the least possible disruptions to the building's operations. Furthermore, the results of the refurbishment have to be quantified and visualized by means of a validated methodology, like the Carbon Footprint Analysis, emphasizing on the benefits achieved over the building's life cycle.

2 Methodological Approach

A combination of strategies has to be adopted to turn an energy wasting, environmental harmful commercial building into a low-carbon, sustainable one. It includes defensive techniques, aiming at the reduction of energy requirements, like thermal insulation, advanced glazings, use of cool materials, use of more efficient HVAC and lighting systems etc., as well as offensive techniques, including the direct harvest of renewable energies, like solar and geothermal, or even advanced heat pumps drawing low enthalpy energy from the ambience.

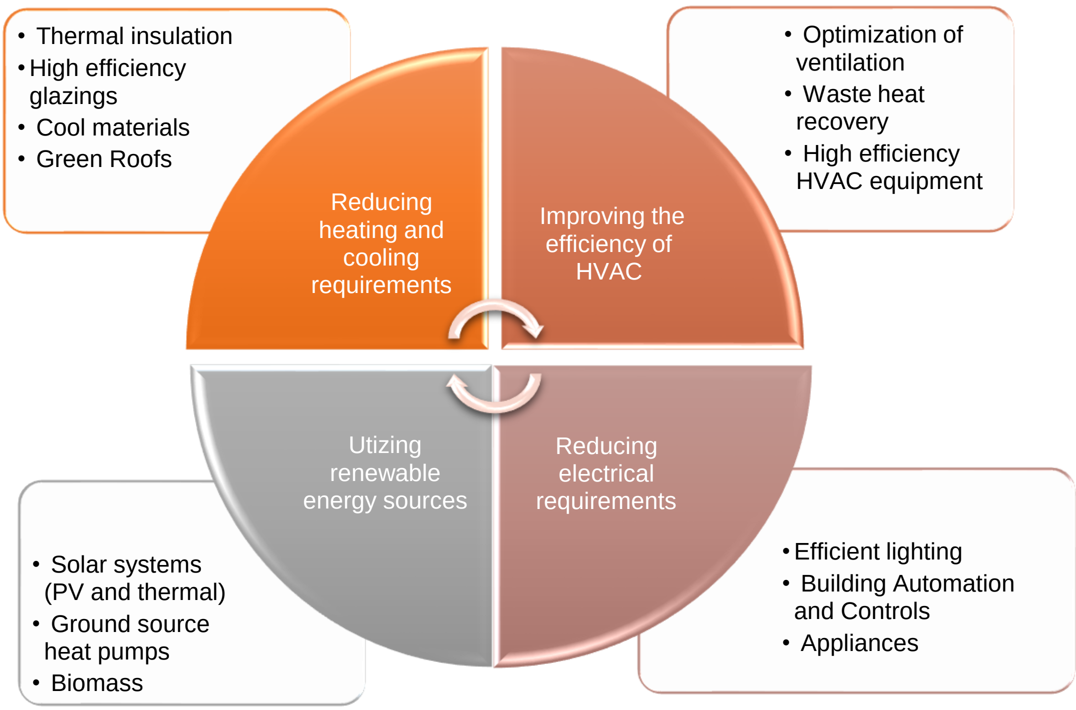

Figure 1: Strategy for reducing a commercial building's carbon footprint

Considering the building's life cycle, it is the use of energy during its operation that accounts for up to 80% of a commercial building's carbon footprint. It is therefore only reasonable to focus on the buildings' energy performance. This having been said, one should not overlook the embodied energy in the building elements and the opportunities provided, especially in refurbishment, by increasing recycling of the construction waste along with the use of recycled and less energy-intensive materials.

One can determine four distinct areas of decarbonization, as depicted in Figure 1. A successful refurbishment plan has to utilize the best available technologies in the most efficient way, starting from the reduction of the losses through the building envelope and working towards the maximization of renewables.

The economics are obviously important, since they are the key argument for most market stakeholders, being expressed by the well-known indicators like the return on investment or the payback period or, even better, the life cycle costing. They also work in the clockwise motion indicated in Figure 1, since reducing the energy requirements is almost always more cost effective than utilizing RES.

One of the difficulties in promoting LCR in commercial buildings is the need to avoid disruption of operations. It is hence vital to consider the duration of works and the impact they cause in operations and determine the level of refurbishment, accordingly, as shown in Table 1. Within this paper emphasis is being placed on the refurbishment of the envelope, which is the interface between the building and its environment.

Table 1: Levels of Low Carbon Refurbishment, depending on the works, their impact and duration.

Level	Typical works	Impact on tenants	Duration of works
Maintenance	Regular maintenance works to HVAC systems.	None.	One to few days.
Minimal	Minor repairs to building envelope and HVAC systems.	Minimal, can be carried out outside office hours.	Few days, depending on the scope.
Minor	Upgrading HVAC system, works in common areas and external elements of the building envelope.	Limited disruptions, services may be temporarily unavailable.	Few weeks, depending on systems.
Major	Replacement of central plant and sub-systems of HVAC, lighting etc. Replacement of building elements.	Depending on intervention: floor by floor, separate wings etc.	6 to 12 months, depending on the case.
Total	Strip back to basic structure. Remove all façade elements and HVAC systems.	Tenants have to move out.	1 to 2 years. Requires licenses and approvals like a new project.

3 Refurbishment of the building envelope: reducing the requirements

Main goal of an effective refurbishment is to reduce unwanted heat fluxes, and this can be done with the interventions that include thermal insulation, use of cool materials, green roofs and high efficiency glazings.

3.1 Thermal insulation

Thermal insulation is rightly considered to be a key aspect for the energy efficiency in buildings. It is particularly effective in regions with significant temperature variations, mainly in cold climates, but even in hot climates, insulating exposed surfaces is a vital parameter in reducing cooling loads and improving thermal comfort conditions. Structural insulated panels (SIPs) are most commonly used in new buildings, as prefabricated insulated structural elements for use in building walls, ceilings, floors, and roofs. They are usually made of galvanized steel and filled with Polyurethane / Polyisocyanurate (PU/PIR) foam or, when fire resistance is required, with stone wool. Their thermal transmissivity (U-values) varies between 0.3 and 1 W/m^{2}K, depending mainly on the thickness and the thermal conductivity of the insulation material. The thermal conductivity value of commercially available insulation materials is depicted in Figure 2.

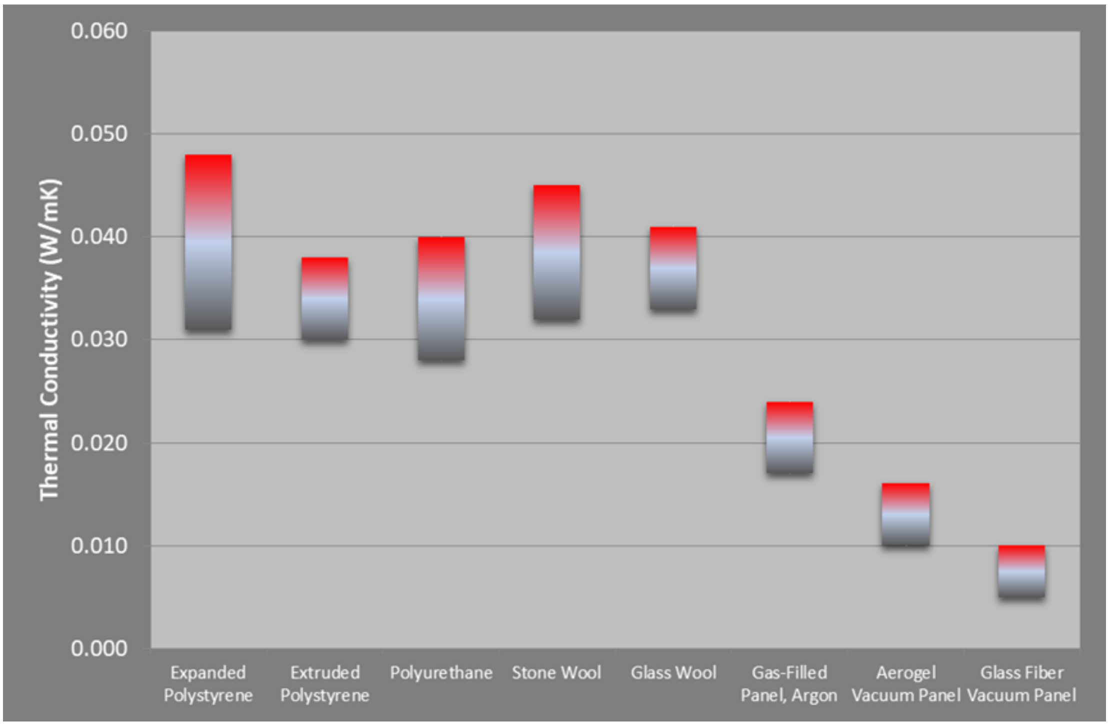

Figure 2: Thermal conductivity values of thermal insulation materials

However, in the case of minor refurbishment works, when existing building elements with complex geometries have to be insulated, applying on-site prepared PU or PIR foam is the obvious choice. Considering the effectiveness, for the same thickness of thermal insulation, all solutions ensure the same energy savings: compared to an uninsulated building element, even the application of a minimum thickness of 5 cm achieves a reduction of thermal losses by more than 60% for Mediterranean or sub-tropical climate conditions [14].

3.2 Cool materials

A cool roof can reflect the thermal part of solar radiation and emits absorbed radiation back into the atmosphere at a higher rate than a roof cladded with conventional materials. The two basic characteristics that determine the ‘coolness’ of a roof are its Solar Reflectance Index (SRI) and the Thermal Emittance (TE). There is currently a great variety of cool paints available commercially for buildings and also other surfaces in the urban environment, with SRI values from 0.4 to 0.85 and TE values of more than 0.85. By applying those materials, one can reduce peak surface temperatures of roofs from 20 to 40oC, compared to conventional materials, and achieve a temperature drop of 3 to 7oC in the occupancy zone under the roof [15, 16]. The latter corresponds to reductions in the cooling energy requirements for retail stores between 7% and 17%. Those big differences become particularly important in the case of typical galvanized steel roofs, which are frequently met in commercial buildings [16, 17]. It is of interest to notice that applying cool paints is not only useful for the roofs, but also for the HVAC equipment located on the roof and exposed to solar radiation, including the main cabinet and the air-handling unit, the attendant ductwork and also the apron around the air intake. In this way the efficiency of the HVAC system can be improved, particularly under peak summer conditions.

Integrated thermal insulation – cool materials are one of most ongoing recent research topics: they have SRI values of more than 0.70, which significantly reduce cooling loads in summer, by up to 21% compared to conventional materials, whilst they maintain their thermal insulation propertied with thermal transmissivity values of no more than 0.5 W/m2K for thicknesses of up to 0.15.They are also fairly light, not exceeding 32 kg/m2, and hence applicable to existing building. Ensuring that they will maintain their properties over time is an issue still to be tackled, before they can enter the market [18].

3.3 Green roofs

Green roofs have become quite popular over the last decades, as they improve the quality of the urban built environment providing energy environmental and economic benefits, but also aesthetic and social ones. They are particularly well suited for retrofitting in commercial buildings. Their most important contribution lies in mitigating locally the urban heat island effect, reducing the peak discharge flow rates into the water drainage system and creating a space for human and wildlife interaction. They also contribute to the reduction of cooling loads, by limiting the impact of incident solar radiation utilizing the thermal capacity of the soil and the evaporative transpiration of the plants. Studies have shown that the cooling requirements can be reduced by 2-10%, depending on the building type, its use and the climate conditions [19]. There are points that have to be considered when refurbishing existing buildings, like the additional weight load and the green roof's water consumption. The latter may not be a problem in areas with high precipitation like Western and Central Europe, or Southeast Asia, where the roof's water balance is positive, in the sense that it helps in avoiding flash flooding during heavy rainfalls. It is, however, a considerable problem in regions like the Mediterranean, where the water balance is almost always negative and irrigation is an issue.

3.4 Advanced glazings

Low emissivity (low-e) glazings have become popular since the late 1990s, as they minimize the amount of infrared radiation that can pass through glass without compromising the amount and quality of visible light that is transmitted, having emissivity factors as low as 0.02. Compared to conventional double-glazed windows, they can on average reduce the total annual energy requirements of buildings with a big window to wall ratio, by 8 to 15% [20]. Still, they cannot adapt to the variation of daily solar radiation, a task for which dynamic glasses have been developed: these change their physical properties either passively, when glass responds to radiation intensity, or actively, by means of electrical control. The former are photochromic glasses, the latter electrochromic ones. Photochromic glass has certain drawbacks, the most important being degradation after a lifetime of 15 – 20 years. Electrochromic glasses can shield up to 95% of incurring solar radiation, hence reducing respectively the air-conditioning requirements. This would save up to 20% of a commercial building's electricity consumption. Furthermore, they can be combined with advanced automation systems to establish optimized indoor environmental conditions at minimum operational costs [19]. They are however up to 2 times more expensive than photochromic glazings and up to 4 more expensive than low-e ones. Contemporary commercial buildings should hence feature low-E glazings as the expected energy savings and reductions in peak cooling loads can be up to 15% and respective reductions in CO_2 emissions. Pay-back periods of 5 – 8 years have been reported for retrofitting projects in multiple climate zones [21]. The refurbishment of a commercial building, based on a combination of those technologies, can result in significant energy and emission reductions, up to 50%, as a series of studies has shown [8, 22, 23]. But this must be proven by means of a validated method and depicted in an effective way, which is precisely what the Carbon Footprint Analysis does.

4. Carbon Footprint Analysis: Measuring the impact of decarbonization

The carbon footprint of a building and its operation can serve as an excellent indicator to measure the impact of the greenhouse gases (GHG) emitted [23] and it is therefore an ideal indicator of a building's decarbonization. The legislative framework for GHG emissions is supported by a series of international standards such as the Greenhouse Gas Protocol Initiative, the ISO 14064-65 series of standards and the EN ISO 14067:2018 for The Carbon Footprint of Products, which are fully compatible with the ISO standards for Life Cycle Analysis ISO 14040 and ISO 14044. It includes all six greenhouse gases, namely carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFC), and perfluorocarbons (PFC), and sulfur hexafluoride (SF_6), which are normalized with respect CO_2.

In order for the Carbon Footprint Analysis to be effective, one has first to carry out the benchmarking analysis, as depicted in Figure 3, with a target that should ideally be based on a comparison with relative sectorial averages. Choosing the appropriate indicators is also vital, in the case of commercial buildings being typically kgCO2eq/m^2 or kgCO2eq/customer etc.

Figure 3: Benchmarking for sustainability process

The results of the Carbon Footprint Analysis can also be combined with one of the environmental rating systems like Building Research Establishment Environmental Assessment Method (BREEAM), Comprehensive Assessment System for Built Environment Efficiency (CASBEE) and Leadership in Energy Environmental Design (LEED). All those systems adopt the 'cradle to grave' approach and thus set the boundary of the analysis from the production and procurement of building materials to the construction and from the building's operation to its eventual dismantling and the disposal of the material. It can therefore be used to quantify and visualize the LCR's performance both to the company itself and to the market.

5. Concluding thoughts

The decarbonization of commercial buildings is a challenge and an opportunity because these buildings are complex energy systems, with high and varying requirements by often many tenants with different operational patterns and with often contradictory priorities on behalf of the developers, owners and managers. Eventually, it is a challenge because commercial buildings are significant, capital-intensive investments that are being valuated with different criteria by the stakeholders.

It is precisely for those reasons that commercial buildings also present an opportunity: Their refurbishment can have a significant impact on the drive towards a low carbon economy, the tenants have frequently specific requirements on sustainability and are willing to pay a premium on this and the owners have as a rule the financial ability to implement refurbishment measures, without requiring financial incentives, as is the case with residential buildings.

There is certainly no lack of expertise and of technological solutions for Low Carbon Refurbishment. State of the art thermal insulation, cool materials, glazings and green roofs, when used combined and on the base of the building's specific needs, can reduce energy demand and emissions by a factor of 2. What is really needed, is an integrated strategy, that will work out against a background of assessing not only the decarbonization's immediate return on investment, but that will take into account the building's impact over its life-cycle and will also include the corporate social responsibility approach which is becoming a goal of a productive, yet sustainable low carbon economy.

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