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Editorial

Special Issue "Environmental Technology Applications in the Retrofitting of Residential Buildings"

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1. Introduction

The architectural and construction professions are in a state of major transition. The imperative that the industry must embrace is 'sustainability', and with that imperative is the requirement to develop applications that make buildings energy-efficient, eco-friendly, resilient, inclusive, and overall 'greener'.

For much of history, building was understood as merely a craft with no overt underlying philosophy. This changed when, in 1414, a manuscript written some 2000 years ago by the Roman engineer Marcus Vitruvius was 'rediscovered' in the library of Saint Gall Monastery, Switzerland. Vitruvius' dictum '*firmitas*, *utilitas*, *venustas*' demands that all buildings fulfill three requirements. They must be structurally sound, serve the purpose for which they were built, and inspire the human soul. Works such as Vitruvius' led to the Renaissance, and with it, the rise of science and the broader debate about humankind's place in and responsibility for the world in which we all live.

As simple as Vitruvius' message may appear to be, it is fair to say that all architectural theorizing that has followed in the six centuries since Vitruvius was brought into the spotlight have revolved around defining and redefining his three terms. Environmental awareness first came into prominence in the 1970s, and this soon filtered into the world of construction. *The Limits of Growth*, published in 1972, popularized the terms 'sustainable development,' and 'sustainable life-style.' In 1987, the UN's Brundtland Commission released its report, *Our Common Future*, in which it defined sustainability as '*the development that meets the needs of the present without compromising the needs of future generations*' [1]. Today, it is hard to imagine architects or builders daring to operate in opposition to that sentiment. Vitruvius' requirements that buildings exhibit 'strength, utility and beauty' are now bound be expectations that they be environmentally friendly, non-polluting, carbon-neutral, and even recyclable. That is, only sustainable buildings are beautiful and fitting to the moral human.

The question then shifts as to how best to create an environmentally friendly built environment. Much attention in this regard has been levied on new buildings. Indeed, the race to showcase flagship corporate headquarter edifices with five-star sustainability ratings is very much the new game in town. While such activity positively brands those enterprises that invest in such 'virtue signaling,' the overall impact of such icons on cities and on the environment in general remains minimal. The truth is that cities, and the bulk of the materials, energy, and resources taken up by them, lie in its residences and houses. And while we should be constructing new houses with the best sustainability practices available, the truth also remains that most of the city is already built—80% of which are established homes [2].

The greatest hope that we have in effecting a transition to an environmentally friendly, sustainable built environment, therefore, lies in the mission of refurbishing and retrofitting

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existing residential buildings. How ought this be done? The collection of papers in this Special Issue offers valuable insights into a sustainable way forward.

2. Special Issue Content

This collection showcases 11 studies that investigate applications of environmental technology tailored to improving the sustainable performance of existing residential buildings.

The first paper, "Mapping research trends in residential construction retrofitting", Ref. [3] is a scientometric literature review that lays out the state-of-play regarding research in this field. Only as recently as 2011 were more than 20 studies published annually, revealing the novice nature of this important research domain. Of these, the majority relate to energy consumption and efficiency, with scant mention of related relevant themes, such as air quality, insulation, energy policy, or occupant behavior. Thus, residential retrofitting remains a topic ripe for further investigation.

The second paper, "Radiant conditioning retrofitting for residential buildings", Ref. [4] begins with the premise that conditioning system retrofitting affords the greatest opportunities for winning significant comfort and energy savings outcomes. The technology is already out there in the marketplace but has yet to be implemented widely in homes. In fact, lightweight radiant systems can be as much as 40% more energy-efficient than conventional systems, while delivering response times of under 15 min.

The third paper, "Guidance on implementing renewable energy systems in Australian homes", Ref. [5] is an empirical case study that establishes guidelines for determining the size of photo-voltaic (PV) arrays to be installed in homes, along with an assessment of the viability of accompanying battery installations. PV size is shown to depend on four factors: daytime house load, night-time load, PV solar rating, and tariff rates charged.

The fourth paper, "Applying solar PV to heat pump and storage technologies in Australian homes", Ref. [5] looks at achieving a net zero energy goal for houses. It concludes that for a modest-sized house in Melbourne, Australia, it is possible to meet electrical, heating, and cooling loads with a heat pump that draws as little as 1 kW. While conventional systems tend to be designed to service maximum loads, net zero can in fact be achieved by judicious utilization of existing off-the-shelf PV arrays, heat pumps, and batteries.

The fifth paper, "Automatically creating HVAC control strategies based on building information modeling (BIM)", Ref. [6] presents a method for optimizing building heating using BIM data. While BIM data are created during the design and planning phases of a building, they can also be re-accessed in commissioning. Heat provisioning and distribution can be programmed to prioritize non-fossil fuel energy sources over fossil fuels, through intelligent BIM centered controls.

The sixth paper, "IFC BIM model enrichment with space function information using graph neural networks", Ref. [7] aims to improve room function classification precision. This study compliments the preceding paper in that enhancing information on rooms, such as kitchen, lounge and bedrooms, are a precursor to enhanced BIM modeling performance. A three-step method is proposed and then tested on residential building IFC models, showing an improvement in accuracy.

The seventh paper, "Development and evaluation of occupancy-aware HVAC control for residential building energy efficiency and occupant comfort", Ref. [8] recognizes that residential HVAC systems tend to be manually controlled and are therefore prone to be wasteful in heating or cooling houses beyond what is needed. Smart devices can be used to measure occupancy patterns and develop occupancy predictions, which can be linked to HVAC controls. Empirical tests on six homes in Colorado, USA, found that savings from the use of predictive algorithms that optimize thermal comfort against energy costs can be as much as 13%.

The eighth paper, "Efficiency of energy consumption between reinforced concrete structure and cross-laminated timber-based hybrid structure in east Asian cities", Ref. [9] proposes a novel approach to multi-story residential refurbishment. When reinforced

concrete (RC) structures come to the end of their useful life, they can be torn down or renovated. While wooden structures are known to have superior energy saving properties as compared with RC structures, this study establishes that hybrid refurbished structures in which RC beams and columns are retained, while floors and walls are replaced by new timber laminates, results in lighter, cheaper buildings, with energy performance superior to the replaced fully RC structures, yet only marginally less efficient than full wooden buildings.

The ninth paper, "Impact of enclosure boundary patterns and lift-up design on optimization of summer pedestrian wind environment in high-density residential districts", Ref. [10] tackles the problem of low wind velocities at street level in dense, high-rise residential environments. Summer heat can be alleviated by light cooling winds. However, the presence of dense high-rise buildings stifle street-level air movement, raising temperatures and increasing pedestrian discomfort. Using simulations, this study reveals that astute enclosure design of buildings can improve wind velocity by 70%, with accompanying comfort levels reaching 200%.

The tenth paper, "Camera-driven probabilistic algorithm for multi-elevator systems", Ref. [11] offers a new means for optimizing the allocation and dispatch of elevators in high-rise complexes. Information obtained through surveillance cameras, feed into an artificial intelligence algorithm, was shown though simulations to reduce lift passenger travel times by up to 40%.

The eleventh paper, "Bushfire: retrofitting rural and urban fringe structures", Ref. [12] reviews extant research on bushfire behavior and its impact on residential structures. As a consequence of global warming, Australia and other parts of the world increasingly suffer from the devastation of bushfires. This final paper documents the main cause of structural damage to be attributable to fire embers, while the main cause of human fatalities arises from smoke inhalation. In view of these findings, houses at risk ought to be appropriately sealed to keep embers and smoke at bay, and practical remedies for retrofitting are offered.

3. Closing Remarks

Buildings consume 50% of the world's energy, while the urban environment generates 80% of the world's greenhouse emissions. Added to this, 80% of the world's buildings are people's homes. Existing residential buildings, therefore, represent the real coal face in responding to climate change. However, as this Special Issue reveals, research into this area has only just begun. The papers presented here add to the knowledge in finding needed effective responses. They also reveal much work is yet to be done.

It is hoped that the reader will take away a better understanding of the innovations that have been taking place that impact residential retrofitting. It is also hoped that the reader will see more clearly the many directions and opportunities laid bare inviting future research in this field.

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