Clean Building Technologies in Architecture

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ABSTRACT

This paper presents an overview of clean building technologies, their use in architecture, and introduces an ongoing research project about the development of a green-wall system incorporating these technologies. We introduce the development of green hybrid technologies that eliminates the traditional insulation materials, and reduces the heat loss by 70% with a very low energy and minimal CO_2 emission. This innovative system has the potential to change the design and function of the architectural enclosure systems and living environments.

The resulting prototype will be used as an independent enclosure system and incorporate emerging technologies in visual display and lighting, energy collection and energy-retention. Flexible sheets supporting these technologies are printed out and pressed together and/or laminated against a structural support to form the green wall element [1-3]. The prototype is designed based on three important tenets: (1) Green-energy wall system, (2) Low-energy printable electronics and (2) Unified surface element with multi-visual properties.

The green-energy wall system tenet refers to the development of a new wall concept, which includes smart materials, such as thermo- and piezo-electric and photovoltaic systems as embedded in the wall. Low-energy printable electronics include all electrical appliances in the enclosed environment including lighting. The total energy needed for this wall is self-generated and only a fraction of today's average room energy consumption. Unified surface element tenet focuses on one of the biggest problems in architectural wall systems: the window openings. The openings are usually the weakest points for the retention of the gained energy within enclosed environments. The air is usually escaped from the connection points where the wall and the window meet, and the air transfer between indoor and outdoor usually takes place at these connections. This problem gets even worst if a façade requires multiple windows at different locations. Our green-wall prototype uses a single unified paneling system where the openings are defined by the users. The approach eliminates the connection points and therefore significantly contributes to the sustainability of the building. This new green-composite has its own sensors, solar cells, and computation firmware built-in in its layers [3, 4]. Based on this integration, this clean technology can perform multiple functions by changing its properties dynamically in direct response to user's preferences and demands.

The scope of this research is highly multi-disciplinary, and lays the fundamental groundwork for a new paradigm in green-architecture that may be of considerable significance in architectural engineering, construction industry, materials science, and entertainment industry. We believe that this approach can be an important step towards clean building technologies and Zero-energy architecture.

Keywords: Architecture, Building, Technology, Clean, Materials

1 INTRODUCTION

Since the emergence of architecture, walls have always been the main components of habitable environments. The basic definition of a wall is a vertical architectural element, which creates and defines an area, delineates the space and supports the structure of a building. Walls have different roles, uses and attributes. While some walls are used primarily for structural reasons, others might be used for non-structural purposes, such as dividers, protectors, territory definers and some walls are used solely for non-functional, aesthetic reasons.

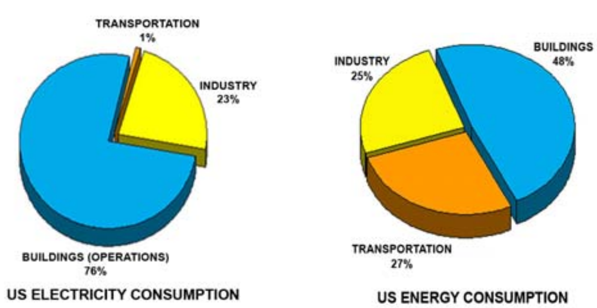

Figure 1 & 2: Energy and Electric Consumption in the US

Regardless of their use, however, walls have common properties in various degrees, such as privacy, territoriality, and visual composition. Structural or not, exterior walls also provide protection from weathering, such as snow, rain, heat and wind. This particular function makes them one of the main components of the retention of the energy within the building. Therefore, the relationship between the energy and architectural wall systems has the primary importance, especially when we look at their massive utilization and use. This issue is especially imperative in the architectural field, where buildings account for nearly half of all greenhouse gas emissions and energy consumption around the globe. Although most of the media buzz surrounding the global warming has concentrated on the transportation sector, it is the building sector that is largely responsible for our overall energy consumption and electric use. According to Energy Information Administration data, commercial and residential buildings account for 48% of the energy consumed and 76% of electricity use within the U.S (See figures 1 & 2.).

The main problem is that most of our buildings' construction systems and materials are old, inefficient, and cannot retain the necessary energy in the building long enough to sustain the indoor air quality levels. As a result, most energy is wasted and constantly replenished.

2 APPROACH

This paper introduces the project, which offers a solution to this problem by developing the technology basis for a new architectural green wall system prototype - Energy-Efficient Green Wall (EGWA), which integrates all electronic components as a unified composite, produces its own energy, and retains 75% more treated air inside the contained volume. EGWA is a new green architectural composite system which will supplement, and possibly replace, bricks and mortar in our buildings in the future. This flexible, polymer-based material includes active circuit elements such as transistors, resistors, capacitors, diodes and solar cells. It will offer a range of computational, insulation and energy generating capabilities that enhance the living environment in many different ways.

Printable semiconductors and flexible plastic substrates represent enabling materials for new types of smart materials that can be fabricated by continuous, high speed reel-to-reel processing techniques. The resulting prototype can be used as independent enclosure systems and/or they can be applied on top of the wall surface, just like conventional add-on material. The major difference however, is that EGWA will incorporate emerging technologies in visual display and lighting, energy collection and retention. Flexible sheets supporting these technologies will be printed out and pressed together and/or laminated against a structural support to form the wall element.

EGWA is designed based on three important tenets: (1) Green-energy wall system, (2) Low-energy printable electronics and (2) Unified surface element with multi-visual properties.

The green-energy wall system tenet refers to the development of a new wall concept, which includes smart materials, such as thermo- and piezo-electric and photovoltaic systems as embedded in the wall. Low-energy printable electronics include all electrical appliances in the enclosed environment including lighting. *EGWA* is designed to reversibly switch its visual properties in response to an external demand. On *EGWA*, colors, patterns can be set, changed, and adjusted to different tastes, furniture, mood and design trends. Various visual projections –or presentations- would be available, too. For example, picture frames can be created on defined areas on demand and in theory every wall could become a TV screen, including the ceiling. On *EGWA* , circuits and pixel elements primarily provide necessary lighting and display. The total energy needed for this wall is only a fraction of today's average room energy consumption..

Unified surface element tenet focuses on one of the biggest problems in architectural wall systems: the window openings. The openings are usually the weakest points for the retention of the gained energy within enclosed environments. The air is usually escaped from the connection points where the wall and the window meet, and the air transfer between indoor and outdoor usually takes place at these connections. This problem gets even worst if a façade requires multiple windows at different locations. EGWA uses a single unified paneling system where the openings are defined by the users. The approach eliminates the connection points and therefore significantly contributes to the sustainability of the building.

3 METHODOLOGY

Energy-Efficient Green Wall (EGWA), will exhibit the following characteristics (see Figure 3): (1) Sheltering and Enclosure (provided mainly by the structural element that serves as the support for the active multilayer films); (2) Lighting and Display (provided by the circuits and pixel elements); (3) Sensing (provided by the integrated sensors); and (4) Power Generation (provided by photovoltaic cells).

In order to provide and maintain these characteristics, various layers of Green-Wall components are identified; their functions will be defined and combined together by lamination techniques. This new polymer composite has its own sensors, solar cells, and computation firmware built-in in its layers (see Figure 4). Based on this integration, this new composite can perform multiple functions by changing its properties dynamically in direct response to user's preferences and demands.

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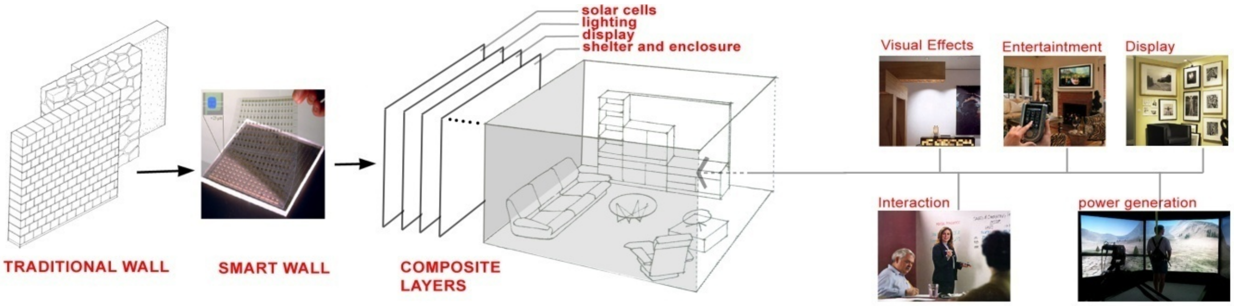

Figure 3: "*Energy-Efficient Green Wall*" is designed to respond to multi-modal design demands by simple property changes to the material with control systems

Materials: Top down patterning techniques coupled with anisotropic wet etching chemistries can produce high quality semiconductor micro and nano- elements– platelets, disks, ribbons, wires, etc. – from bulk, low cost single crystal wafers. A large collection of such elements constitutes a type of material that is referred as a microstructured semiconductor material (μs -Si). This μs -Si can be dry transfer printed or solution cast onto plastic sheets for high performance, flexible transistors. As an example, anisotropic etching of a GaAs wafer can form single crystal wires with triangular cross section [5]. The fabrication in this case begins with a GaAs wafer with its surface oriented along the (100) direction. Polishing the wafer prepares it for another run of wire fabrication. Repeated application of this process from a single GaAs wafer with diameter of 10 cm and thickness of 450 m generates enough wires (~2 billion) to cover the surface of a plastic substrate with an area of ~2 m^2, using the wire geometries shown here [5]. Similar procedures can be used to generate single crystal elements of InP, GaN, Si and other materials. Figure 5 shows some preliminary results [1, 5, 6]. A key aspect of this approach is that it exploits fully the highly developed wafer scale crystal growth and doping technologies that have emerged from decades of effort in the semiconductor industry. It also takes advantage of deterministic lithographic control of wire dimensions (lengths, widths, etc.) and positions. These features represent significant advantages compared to the types of bottom up growth procedures that are widely studied for fabricating semiconductor nanowires. Nevertheless, considerable challenges will need to be overcome to fully port the advantages of conventional high performance device processing methods to the analogous printable systems

4 CONCLUSION

The scope of this project is highly multi-disciplinary, and lays the fundamental groundwork for a new paradigm in Clean Building Design that may be of considerable significance in architectural engineering, construction industry, materials science, and entertainment industry. In architecture and construction industry, this approach can make significant changes in green building design, especially in wall-systems and enclosures. More importantly, it can play an important role on the integration of clean technologies and construction industries. We believe that this project can be an important step and the first working prototype towards sustainable clean building technologies and Zero-energy buildings.

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