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The Research of Taiwan Green Building Materials (GBM) system and GBM Eco-Efficiency Model on Climate Change

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***Abstract*—**The globe Sustainability has become the subject of international attention, the key reason is that global climate change. Climate and disasters around the abnormal frequency multiplier, the global temperature of the catastrophe and disaster continue to occur throughout the world, as well as countries around the world. Currently there are many important international conferences and policy, it is a "global environmental sustainability " and "living human health " as the goal of development, including the APEC 2007 meeting to "climate Clean Energy" as the theme Sydney Declaration, 2008 World Economic Forum's "Carbon - promote Cool Earth energy efficiency improvement project", the EU proposed "Green Idea" program, the Japanese annual policy, "low-carbon society, sustainable eco-city environment (Eco City) "And from 2009 to 2010 to promote the "Eco-Point" to promote green energy and carbon reduction products .And the 2010 World Climate Change Conference (COP16 United Nations Climate Change Conference Copenhagen), the world has been the subject of Negative conservative "Environmental Protection ", "save energy consumption, " into a positive response to the "Sustainable " and" LOHAS", while Taiwan has actively put forward eco-cities, green building, green building materials and other related environmental response Measures, especially green building construction environment that is the basis of factors, the most widely used application level, and direct contact with human health and the key to sustainable planet. "Sustainable development "is a necessary condition for continuation of the Earth, "healthy and comfortable" is a necessary condition for the continuation of life, and improve the "quality" is a necessary condition for economic development, balance between the three is "to enhance the efficiency of ", According to the World Business Council for Sustainable Development (WBCSD) for the "environmental efficiency "(Eco-Efficiency) proposed: " the achievement of environmental efficiency, the price to be competitive in the provision of goods or services to meet people's needs, improve living Quality at the same time, the goods or services throughout the life cycle. Its impact on the environment and natural resource utilization and gradually reduced to the extent the Earth can load. "whichever is the economy "Economic" and " Ecologic". The research into the methodology to obtain the Taiwan Green Building Material Labeling product as the scope of the study, by investigating and weight analysis to explore green building environmental load (L_n) factor and the Green Building Quality (Q_n) factor to Establish green building environmental efficiency assessment model (GBM Eco-Efficiency). And building materials for healthy green label products for priority assessment object, the object is set in the material evidence for the direct response to the environmental load from the floor class-based, explicit feedback correction to the Green Building environmental efficiency assessment model, "efficiency " as a starting point to achieve balance between human "health "and Earth "sustainable development of win-win strategy.

The study is expected to reach 1.To establish green building materials and the quality of environmental impact assessment system, 2. To establish value of GBM Eco-Efficiency model, 3. To establish the GBM Eco-Efficiency model for application of green building material feedback mechanisms.

***Keywords*—**Climate Change, Green Building Material (GBM), Eco-Efficiency, Life Cycle Assessment, Performance Evaluation

I. Introduction

GREEN building material is one of the basic elements of a sustainable building. The serious energy and natural resources shortage that our living environment is currently facing shows an imperious demand on developing a better building material certification and management mechanism. Followed by the promotion of green building evaluation and labeling more than a decade, the Architecture and Building Research Institute (ABRI) of Taiwan proposed the Green Building Material (GBM) Labeling system in 2003 and officially launched in 2004, shown in figure 1. The system aimed to promote a sustainable built environment for the earth and a healthier living quality for human beings. It was established based on ISO15686 series, ISO21930 series,ISO14040 series, as well as the Integrated Building Performance (IBP) system proposed by the EU, to ensure the evaluation criteria and standards meeting the current development trend of the world. Both of the global and local environmental issues, such as anticipated exhaustion of fossil fuels, increasing and fluctuated energy prices [10], environmental pollution problems, high dependency on imported resources, high temperature and high humidity, a large amount of CO_2 emission from the building industry, as well as over 10 million-ton construction wastes generated annually, must also be taken into consideration to develop a comprehensive assessment tool for green building materials. In general, the assessment of green building materials begins with establishing criteria for evaluating the environmental performance of building materials.

The criteria may incorporate low toxicity, minimal emissions, low-VOC assembly, recycled content,resource efficiency, recyclable and reusable materials, energy efficiency, water conservation, IAQ improvement, locally products, etc [11]. The GBM evaluation system of Taiwan systematically comprises of four categories, including health, ecology, recycling, and high-performance. Its assessment mainly adopts the life cycle assessment approach, covering four stages of the life cycle of a building: resource exploitation, production, usage, and disposal and recycling.

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Fig. 1 Taiwan green building material label

Among the above categories, healthy green building material is the major promotional emphasis in the system. With extensive material usage of indoor decoration and remodeling for housing, the formaldehyde(HCHO) in building materials and volatile organic compounds(VOCs) emitted in a warm environment can result in fairly high risk to be harmful to health (Shao et al,2003). According to relevant research results (Wu et al., 2003), the risk values of carcinogens such as the formaldehyde in building materials and VOCs in office spaces in Taiwan are 100 to 1,000 folds over the WHO standard, causing people to suffer from respiratory and skin diseases. With respect to the relationship between the GBM labeling system and the current EEWH green building evaluation system in Taiwan, analyzed as table 1, the GBM system can typically contribute to a healthier indoor environmental quality. The issues of indoor air quality (IAQ) (Wolkoff 1998), indoor environmental quality (IEQ), and indoor environmental health (IEH) have been addressed and being further studied. From the perspective of the "Architecture Doctor (AD)" concept, now researchers and experts would diagnose causes of IEQ problems and prescribe recipes, for instance, strategies of green building and green building material application. The GBM labeling system can thus provide for architects or designers with proper measures that are capable of accommodating local climatic conditions and meeting people's health needs. For ecology, recycling, and high-performance, the GBM evaluation items can also effectively correspond to green building evaluation indicators and feed back to green building design.

Since July 2006, the mandatory green building material utilization has been involved into Taiwan's building code. For indoor decoration and floor materials in buildings, green building materials shall cover at least 30% of the total indoor decoration and floor material uses. Fulfilling the requirements of ecological, recycling, healthy, and high-performance attributes, the green building material regulation may effectively reduce environmental impacts and improve the IEQ, so as to gradually achieve "human health and global sustainability."

TABLE I
RELATIONSHIP BETWEEN TAIWAN'S GREEN BUILDING EVALUATION AND GREEN BUILDING MATERIAL APPLICATION

Green Building Rating System EEWH		Green Building Material
Category	Evaluation Indicators	Applications
Ecology	Bio-diversity	--
	Greenery	--
	Water Soil Content (Water infiltration and retention)	High-performance GBM (permeability), Ecological GBM, Recycled GBM
Energy Saving	Energy conservation	High-performance GBM (energy saving)
Waste Reduction	CO2 emission reduction	Ecological GBM, Recycled GBM
	Construction waste reduction	Ecological GBM, Recycled GBM
Health	Indoor environment	Healthy GBM, Ecological GBM, Recycled GBM, High-performance GBM (sound insulation)
	Water conservation	High-performance GBM
	Sewage and garbage improvement	--

II. EVALUATION SYSTEM, IMPLEMENTATION AND MANAGEMENT

The major purposes of the GBM labeling system can be described in three aspects: 1) promotion of high-quality and healthy life; 2) protection of ecological environment; and 3) enhancement of industry competition ability. The system focuses on the entire building quality and effective management and control of human health risk factors. Its general requirement includes basic environmental protection aspects, such as no asbestos, no heavy metal, no radioactivity, etc. The evaluation system consisting of four categories is illustrated as figure 2 and described as follows:

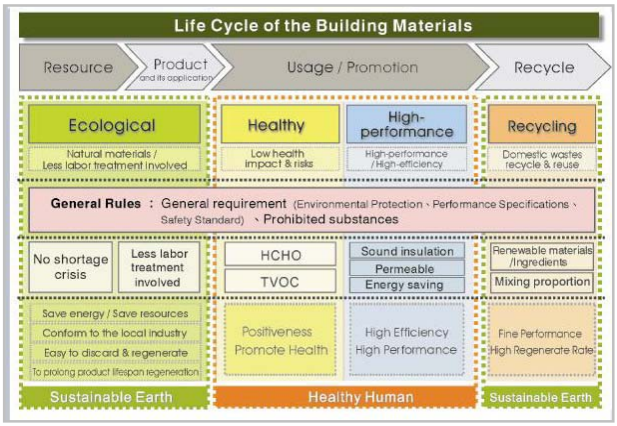

Fig. 2 Framework of Taiwan green building material evaluation system

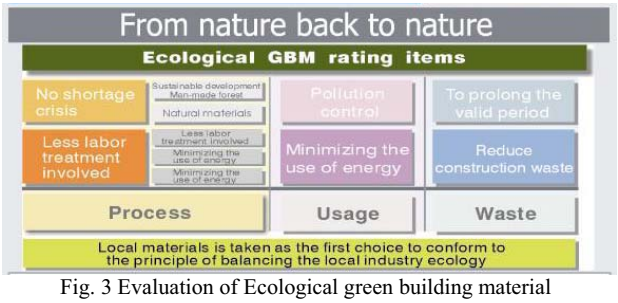

Fig. 3 Evaluation of Ecological green building material

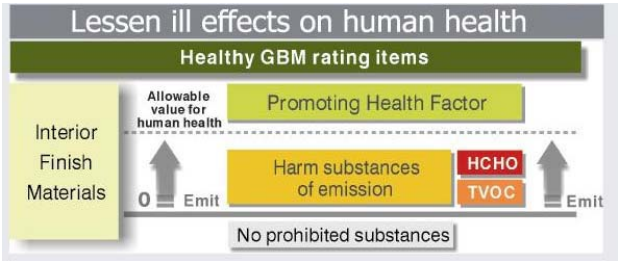

Fig. 4 Evaluation of Healthy green building material

Fig. 5 Evaluation of High-performance green building material

Fig. 6 Evaluation of Recycling green building material

A. Ecological GBM

What is taken from nature shall be used in nature. The Ecological GBM is that, during its life cycle, the building material fulfills general requirements, uses natural materials (Berge 2001) without shortage crisis, consumes minimal resources and energy, requires less labor treatment, or possesses recycled characteristics after disposal. The goal is to promote the natural building material that is good for both the environment and human health. For example, ecological wooden structure materials shall come from the forest with sustainable management. The assessment includes the certificate of FSC (Forest Stewardship Council), PEFC (Programme for the Endorsement of Forest Certification schemes), or other certificates of origin, shown as figure 3.

B. Healthy GBM

Since formaldehyde contained in building materials, and VOCS added during the production of indoor construction materials, application and glue preparation, under the climate condition of high temperature and humidity, harmful chemical substances may be emitted in the air and directly affect human health and indoor environmental quality (Chen et al. 2006). Thus, the system focuses on the management and control of the relevant hazards. The test is based on ISO16000, and the standard is HCHO is less than 0.08 mg / m^2·hr and TVOC less than 0.19 mg / m^2 ·hr, shown as figure 4.

C. High-performance GBM

In response to the green building issues, such as building environment noise, poor ground water retention, glazed curtain wall causing energy consumption, and the problem of dazzling sunlight, the environmental performance of a building material should be concerned and involved. By improving building materials to resolve the problems and increase efficiency, the system intends to promote building quality and standard of the living environment (noise insulation, permeability, etc), and also reduce entire energy consumption, which is in the scope of high performance green building material. The assessment includes ISO717-1, ISO717-2, ISO11654, and the test follows ISO140-3, ISO140-8, ISO354, and ISO9050, shown as figure 5. The approach also presents the harmonization with the ISO standards in Taiwan's GBM system, shown as figure 5.

D. Recycling GBM:

In order to reduce construction waste, and to reuse and recycle the materials, the system focuses on the regeneration of green building materials, in order to ensure basic functional demand, and improve reuse rate of waste materials, in order to achieve a sustainable society, which is in the scope of recycled green building materials. The assessment includes the types of recycled materials, their sources, and recycled content percentage, and its test is based on the ISO and Taiwan's CNS standards, shown as figure 6.

III. Evaluation Results and Market Trend Analysis

By the end of February 2012, 686 Labels have been conferred covering 6,812green products. Among these products, the healthy material occupies 77%, and followed by the high-performance 14.98%, recycling 8.11%, and ecological 0.21%, shown in figure 7.

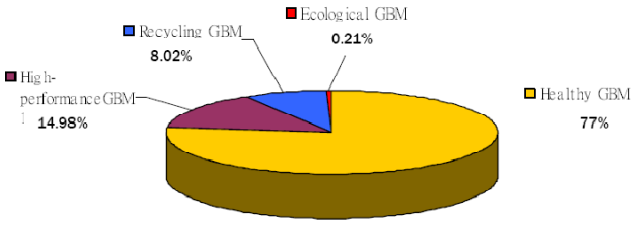

Fig. 7 Percentage of four categories of GBM labeling promotion

The percentage distribution indicates the health issue has been highly emphasized and points out the development trend of the building material market in Taiwan.

Currently, the ratio of new and existing buildings is 3% to 97% in Taiwan. Using green building materials and green technology to improve indoor environmental quality and architectural environment, people can renew, reuse and prolong the life cycle and value of old buildings.

Meanwhile, interdisciplinary integration of architecture, medicine, ecology, interior design and material technology transform traditional construction into a sustainable and circulating industry. Starting from energy saving and resource

efficiency by combining an ecological circulatory system, corresponding local environment, community civilization, as well as historic and regional features, the GBM system creates a core concept of sustainable built environment in Taiwan.

IV. Eco-Efficiency Model

As defined by the World Business Council for Sustainable Development (WBCSD), "Eco-Efficiency(1) is achieved by the delivery of competitively priced goods and services that satisfy human needs and bring quality of life, while progressively reducing ecological impacts and resource intensity throughout the life-cycle to a level at least in line with the Earth's estimated carrying capacity." In short, it is concerned with "creating more value with less impact."

In other words, "eco-efficiency is all about combining the goals of business excellence and environmental excellence, and creating the link through which corporate behavior can support sustainable development"(Bjorn Stigson, President WBCSD).

$$\text{Eco-Efficiency} = \frac{\text{Quality (Qn)}}{\text{Load (Ln)}} \quad (1)$$

The eco-efficiency module is a compilation of learning materials and exercises from which users may pick and choose in order to raise awareness and foster implementation at different levels within their organizations. There is a choice of activities, all of which are flexible enough to suit a wide range of audiences, to be delivered by people from a variety of functions and to be customized to the needs and concerns of a particular organization.

The module contains a background briefing paper designed to give a comprehensive overview of eco-efficiency and a resources section with case studies, quotes and references. In addition there are three learning units - understanding, exploring and implementing – with a combination of conceptual and practical tools and methods.

The understanding unit introduces the concept of eco-efficiency through a range of basic exercises around definitions, drivers and trends. In the exploring section, participants can understand eco-efficiency and seek to deepen their skills and knowledge through dilemmas and case exercises, applying different approaches and solutions. Implementing will teach participants how to take stock of current performance and to integrate eco-efficient decisions into an organization.

V. GBM Eco-Efficiency Model on Climate Change

"Sustainable development "is a necessary condition for continuation of the Earth, "healthy and comfortable" is a necessary condition for the continuation of life, and improve the "quality" is a necessary condition for economic development, balance between the three is "to enhance the efficiency of ", According to the World Business Council for Sustainable Development (WBCSD) for the "environmental efficiency "(Eco-Efficiency) proposed: " the achievement of environmental efficiency, the price to be competitive in the provision of goods or services to meet people's needs, improve living Quality at the same time, the goods or services throughout the life cycle. Its impact on the environment and natural resource utilization and gradually reduced to the extent the Earth can load. " whichever is the economy "Economic" and " Ecologic". The research into the methodology to obtain the Taiwan Green Building Material Labeling product as the scope of the study, by investigating and weight analysis to explore green building environmental load (Ln) factor and the Green Building Quality (Qn) factor to Establish green building environmental efficiency assessment model (GBM Eco-Efficiency) (2).And building materials for healthy green label products for priority assessment object, the object is set in the material evidence for the direct response to the environmental load from the floor class-based, explicit feedback correction to the Green Building environmental efficiency assessment model, "efficiency " as a starting point to achieve balance between human "health "and Earth "sustainable development of win-win strategy.

$$\text{Gbm Eco-Efficiency} = \frac{\text{Gbm Quality } (Q_n)}{\text{Gbm Load } (L_n)} \quad (2)$$

VI. Conclusion

The research is expected to reach 1.To establish green building materials and the quality of environmental impact assessment system, 2. To establish value of GBM Eco-Efficiency model, 3. To establish the GBM Eco-Efficiency model for application of green building material feedback mechanisms. Concrete results is divided into four levels: the national sustainable development policy, the government actively to create high-quality and healthy eco-city built environment, policies can be implemented to understand the application of green building materials and environmental efficiency and effectiveness; For academic researchers, Green building materials can provide the environmental efficiency of a systematic assessment model, to do more in response to changes in indoor environmental quality, green, ecological communities as well as the quality of the built environment to ensure that research in the future; For planners and designers, it can be possessed to provide a more diverse environment for numerical efficiency assessment of green building materials, to facilitate the use and construction materials and interior decoration materials, the basis for estimating environmental efficiency; For the general public, it may be through the contribution of this research, access to real effectiveness of the application of green building materials to ensure that the health of man. The goal of sustainable development and the provision of government departments to promote Green Building Material Labeling System and green building regulations the basis of the results. Using efficiency as a starting point, this research strived to achieve a win-win strategy of balancing human health with the Earth's sustainable development.

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