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Development of a Passive and Active Technology Package Standard and Database for Application to Zero Energy Buildings in South Korea

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Abstract: There is much research on zero energy buildings. In this paper, technologies and policies to improve the building energy efficiency of zero energy buildings are presented. The zero energy building certification system in Korea is introduced, and the evaluation is carried out based on the energy self-reliance rate that enables zero energy buildings. Zero energy buildings are able to minimize energy consumption due to the application of highly efficient building materials and equipment technology. In this research, to increase the prevalence of zero energy buildings in Korea, the authors propose a zero energy building technology package. Using a passive and active technology package, we confirmed the necessity and detailed requirements of each technology parameter. We analyze and classify Korean building material testing methods and performance standards, and propose passive and active technology packages, modules, material performance testing methods and minimum requirement performance standards. Finally, this study proposed a table presenting the test methods, standard and minimum value of performance. By these results, the authors confirmed the effectiveness and availability of passive and active technical packages.

Keywords: building energy; passive architecture; test method; energy performance standard; zero energy building; technology package

1. Introduction

The demand for zero energy buildings is increasing in order to reduce the energy consumption of buildings, Technologies and policies to improve building energy efficiency for zero energy buildings are presented, and there is much research on zero energy buildings. As part of this trend, the zero energy building certification system in Korea is introduced, and the evaluation is carried out based on the energy self-reliance rate that enables zero energy buildings. The mean of self-reliance is the ratio of the amount of energy generation through the renewable energy system in a building to the building's energy consumption. A "zero energy building certification system" is executed in Korea. Zero energy buildings apply thermal insulation, double-glazed windows, etc., to minimize the amount of energy lost to the outside through the building's outer skin, utilizing renewable energy such as sunlight and geothermal heat, etc. It refers to a building that minimizes energy consumption by tailoring it to the energy used. In Europe, it is defined as a building with extremely high energy performance in terms of the building and equipment. This performance concerns zero energy building heating, cooling, hot water supply, lighting, ventilation and the like. At this time, the meaning of zero energy incorporates renewable energy produced in or on the ground. Zero energy buildings in Japan use the energy consumption (including CO_2 emissions) of buildings to improve the energy-saving performance of buildings/facilities and utilizes renewable energy in the premises to reduce annual energy consumption (CO_2 emissions); "0" is when the building is closed. A zero energy building in the United States is defined as an "energy-neutral building" that supplies energy to the building's energy supply network. This refers to buildings' yearly energy consumption and energy sources produced [1–3].

In Korea, authors focused on zero energy buildings have studied passive houses. Shim confirmed the economic feasibility of passive houses in Korea [4]. Authors who have proposed passive house alternatives show a short payback period and positive life cycle cost (LCC) results compared to the reference building's life cycle period. Passive houses are acceptable and the possibility of their implementation is high, considering the willingness to pay (WTP) of Korean investors or end users. The term passive house generally refers to a type of low-energy house [5,6]. Kim et al. [7] calculated the energy requirements that satisfied the insulation standards of the Building Energy Conservation Standard (BECS) for building parts by region according to regional climate conditions using the methodology of ISO 13790 and presented the insulation standards that satisfied the passive building standards for each of the regional climate conditions. Oh et al. [8] carried out a state-of-the-art review on the recent studies regarding the implementation strategies of nearly zero energy buildings (nZEBs). As a result, papers related to nZEB can be classified into two categories: passive strategies and active strategies. Based on the results of a case study in Spain, the nZEB definition by Collaboration for nearly zero-energy housing renovation (COHERENO) was adopted to evaluate several energy renovation packages in a given building, which is also representative of the Spanish building stock [9].

Zero Energy Building is able to minimize energy consumption due to the application of highly efficient building materials and equipment technology. In addition, since zero energy is achieved by producing and supplying renewable energy, it is difficult to disseminate zero energy buildings due to an increase in construction costs compared with general buildings as a result of the materials and facilities added. However, since there is a high necessity for various aspects such as a reduction in energy consumption costs at the maintenance and operation stage and national greenhouse gas reduction, much effort has been made by many researchers to construct a zero energy building there.

When implementing a zero energy building, the designer's performance prediction tool is utilized in the design phase. However, in Korea, the performance prediction is managed at the institutional level by evaluating the energy efficiency of the building, and the designer predicts the energy requirement amount and the primary energy requirement by utilizing the certification program ECO 2 (v20170122, Korea energy Agency, Korea) in other parts written as ECO2–us a consistent style. Since these design programs can derive different results according to the input level of the user, the program generates a difference in the analysis result if there is no same input value by the same user. Due to the difference in analysis results, problems arise in the reliability of the program. Even with the same input value, when the performance numerical value input is not the performance measured in the same test environment, the result of the program will be different. When applying the program results to buildings, there are various difficulties, for example, sometimes the results differ from the expected results. In order to solve this, highly reliable guidelines constructed with proven materials and facilities are required, and it is necessary to unify the performance test method and the test environment so that the performance can be compared. The manufacturing process of existing building materials is commercialized by combining materials according to the purpose. Since the connection (or parameter) material is necessary for bonding between the products, there is a problem of compatibility between each product as well as a reduction in production efficiency of the building material. Therefore, it is necessary to consider the parameters required for coupling between the materials and equipment that constitute the zero energy building.

This research, which proposes a zero energy building technology package, will contribute to increasing the prevalence of zero energy buildings in Korea. In addition, the technical package proposed in this research was divided into a passive technology package and an active technology package, and a database (DB) configuration is proposed. Finally, we present the minimum performance standards that must satisfy the packages and constituent materials of the technology used for zero energy buildings according to the circumstances of Korea. So, the results of this research can be utilized to build an actual zero energy building.

2. Zero Energy Building in Korea

2.1. Current Status of Zero Energy Building in Korea

A zero energy building uses thermal insulation, double-glazed windows, etc., to minimize the amount of energy lost to the outside through the building envelope. Utilizing renewable energy such as sunlight and geothermal power, it covers the energy used for heating and cooling buildings to minimize energy consumption. Unlike general buildings, zero energy buildings will enhance the efficiency of the facilities necessary for the operation of buildings and energy production facilities, in addition to the outer skin composition using energy-efficient building materials. This minimizes the energy consumption of zero-energy buildings, and the energy produced through renewable energy facilities is the greatest. It also aims to distribute and operate the appropriate renewable energy production and to maintain the comfort of residents with the unique production energy of the building without requiring external energy. These zero-energy buildings are relatively difficult to disseminate, as construction costs are set relatively high compared to general buildings, and the installation costs of facilities also increase. Integrated design is not achieved through a specification-oriented design using a simple combination of high-performance elemental technologies. It is necessary to consider compatibility between elemental technologies at the planning stages, and between elemental technologies considering organic collaboration combination. In the case of South Korea, the industrial technology market for improving building energy efficiency, renewable energy, maintenance and management is valued at about 750 million dollars. In Korea, Zero Energy Building Certification has been carried out by the Green Building Composition Support Law. Zero Energy Building Certification subjects are new buildings and existing buildings for all uses, which are the same as those of the building's efficiency evaluation, so we request a building energy efficiency grade of 1++ or higher through the existing energy performance evaluation. According to the energy independence rate, it is classified into five grades from grade 1 to grade 5. In response to the activation of the certification system, various technological developments are being conducted in order to revitalize the dissemination of zero energy buildings. The energy independence rate is similar to the self-reliance rate. It is determined based on the percentage of energy consumed and produced in a building in the absence of an external energy supply. Grade 1 is 100% of the energy independence rate. The zero energy building certification system grants grade 2 if the percentage of the energy independence rate is 80% or more, grade 3 if it is 60% or more, grade 4 if it is 40% or more, and grade 5 if it is above 20%. The amount of energy consumption and production was based on annual primary energy obtained by the simulation results of ECO2. However, compared to the level of building materials that can be actually applied and the development level of high efficiency equipment, development of the parameters that apply this is limited. Furthermore, performance prediction through application between technologies is lacking. Compatibility and organic collaboration with technology to solve these problems has become important, and the technologies reflecting this have received a lot of attention.

2.2. Database for Implementing Zero Energy Building

The database of existing building materials is constructed according to the development of Building Information Modeling (BIM). The zero energy building database can be constructed in the same way as the BIM database. Especially in the BIM field, despite vast research on the composition of DB, the spread of BIM technology is insufficient in the Korean construction industry. The spread of BIM is insufficient because it is difficult to apply to in construction practice due to a lack of a library DB at the time of basic design and the use of BIM in the basic design. In the case of building materials necessary for building construction, foreign libraries are transformed and used. DB and libraries are greatly required for materials actually applied to construction work in Korea. In addition, individual technologies at the stage of the project are applied, and based on the fact that other libraries are constructed according to the purpose, there is a situation in which compatibility between each library is insufficient. As a result, much research into unifying the file format of the DB is underway, and there are increasing cases of studying BIM libraries (or databases) in consideration of business models based on building materials and information systems. Because this is based on the basic objective for constructing BIM, it is difficult to confirm the effect of combining materials, because it is composed of classification by construction and classification by material. In particular, the means of confirming the performance (or test method), which should ensure the reliability of the performance required for energy analysis, is not immediately applied as the energy analysis and construction cost estimates are configured at the same time, so a difference in performance can occur.

2.3. Energy Performance Evaluation Tool of Zero Energy Building

When designing a zero energy building, we use not only a method of calculating room cooling and heating loads through indoor and outdoor temperature differences and internal heat gains but also use an energy performance evaluation tool (ECO2, EnergyPlus, etc.) for heating and cooling energy consumption due to a change in the indoor and outdoor environment. Additionally, the designer must consider the supply of energy from renewable energy sources to the heating and cooling system in the building. The energy performance calculation tool has to consider the heat flow based on the temperature and weather data from the area where the building is located. So, this calculation method algorithm must be authorized through international standard organization (ISO). Based on the evaluation results, we estimate the building's energy consumption and present various options to reduce it. These options consist of the application of building materials and technology. In this chapter, we apply each technology package of the energy performance analysis tool and confirm the energy saving effect. Additionally, to determine the energy consumption of the building, performance evaluation tools were compared and analyzed based on the ECO2 program. Moreover, the same energy performance evaluation tool was used to confirm the areas of improvement through comparative analysis.

In Korea, when designing a new building, the designer must calculate the energy consumption of the building using ECO 2. ECO 2 uses the ISO 13790 and DIN V 18599 as tools to evaluate the energy efficiency of buildings, and based on the monthly average weather data, the monthly energy demand of the building according to the performance of the system forecast quantity. Additionally, the evaluation is based on the primary energy requirement (kWh/m^2·year) per unit area per year. Energy requirements are classified into heating, cooling, hot water supply, lighting and ventilation energy. System performance inputs are classified into conditioning processing, heating equipment, heating supply system, heating distribution system, cooling equipment, and cooling distribution system regeneration equipment. Based on this, the ECO 2 program calculates the primary energy requirement per unit area using five items: heating, cooling, lighting, hot water supply, and ventilation system.

As with ECO 2, the Passive House Planning Package (PHPP) is a spreadsheet-based Excel program based on the ISO 13790 standards. Detailed criteria are based on the DIN V 18599 and DIN 4108 standards, as well as on many other DIN regulations and EN regulations. According to the input value of the user, PHPP applies the item, the value of the climate data utilizes the international weather measurement data of Switzerland, and 82 climate data values are registered in Korea. In Korea, in order to enhance the thermal insulation performance of buildings, the thermal insulation performance notation is unified and used as the heat transmission coefficient (U-value). The heat transmission coefficient value of the structure constituting the outer skin of the building such as the roof, the wall, the floor, etc., is calculated, and the indoor and external surface heat transfer resistance value follows the international standard EN ISO 6946. The heat loss of the structure is directly divided into the outside air and the floor directly adjacent to the boundary of the generation. Each zoning adopts the defense coefficient, etc., of the solar radiation absorption coefficient and the reflectance according to the finish. The cooling and heating areas of buildings in PHPP are calculated based on the inside dimension, considering the heat exchange at the joint of the structure and the heat exchange where the insulation is cut or connected. The design of passive houses using PHPP is done in the following order: the energy demands of buildings can be calculated through the selection of climate data, setting the heat transfer coefficient by site, design of hulls, heat exchange analysis, design of foundations and basement, windows (solar control device), design of ventilation and design of the equipment system. The aim is to verify that the final primary energy requirement is less than 120 kWh/m^2 years. The heat exchange calculation takes into consideration the linear heat transmission coefficient according to the external reference dimension, and utilizes the length of the heat exchange part, the linear heat transmission coefficient, the temperature reduction coefficient, the heating city and is included in the heat loss of the structure. The linear heat transmission coefficient is calculated based on the ISO 10211-1 standard by using another 2D heat flow calculation program. The thermal bridge installation takes advantage of 2D heat flow calculations and uses the specified certificate.

EnergyPlus (v9.1.0, U.S. Department of Energy's, USA) is a tool developed by integrating the advantages of conventional interpretation tools DOE-2, BLAST, and COMIS. In this program, incomplete room temperature prediction is possible with the existing analysis tool using the calculation algorithm of wall heat transfer. By choosing the transfer function method and the finite difference method, the program can calculate the heat transfer of the building and calculate energy usage via feedback between buildings, systems and plants. The modular structure is flexible, and its Open Source format has an extendable interface. However, in order for the user to use the interpretation tool, basic knowledge is necessary for building energy analysis. Additionally, the user needs expert knowledge of each input variable. The user interface of EnergyPlus is relatively complicated. Therefore, there is a problem that interpretation of the result differs depending on the user's level of knowledge. The construction of the walls and the arrangement of the walls by zone can be input and arranged by layer structure of building materials like ECO 2, and facilities can be placed and divided by zone. Considering the air infiltration by zone, it is possible to calculate the detailed load, and set in detail the indoor occupancy situation according to the schedule and the operating condition of the equipment. As recently as 3D modeling through Openstudio plug-in, Sketch up plug-in, etc., additional plug-in is introduced for the user's convenience. Table 1 shows the features of ECO 2, PHPP and EnergyPlus which are energy analysis tools.

Table 1. Features of ECO 2, PHPP and EnergyPlus.

Category	ECO2	PHPP	EnergyPlus
Weather data	Monthly (Non modification)	Hourly (Modification)	Hourly (Modification)
Insulation thermal bridge	Non user input	Detail calculation	Non user input
Window thermal bridge	Non user input	Detail calculation	Non user input
Infiltration	Fix	Detail calculation	Detail calculation
Human	Sensible heat	Simple input	Detail calculation
Equipment	Sensible heat	Simple input	Detail calculation
Input level	Simple input and default input	Simple input	Detailed user input
Usability	User-friendly	User-friendly	Complex user interface

2.4. Technology Packaging for Zero Energy Building

The technology package for the implementation of zero energy building consists of a combination of modules consisting of a combination of building materials. The technology package can also be constructed with building materials, equipment and technical elements, etc., so that it can be provided in packages adapted to meet the objectives. Technical packages ensure the reliability of information through DB conversion of materials and facilities, and enable users to update information. Therefore, in order to achieve a zero energy building, technology packages need to be distinguished, in order to study the compatibility between the technology as well as the thermal performance estimate of the building. In this research, it consists of passive technology packages constituting the form of building based on building materials and an active technology package which constitutes a facility system concerning the air conditioning and lighting, etc., of buildings. In addition, we proposed the composition concept of each technology package. Figure 1 shows the application package of the technical package and a conceptual diagram of the packaging structure of the whole technology. The Zero Energy Building Technology package is composed of material-module-package. Modules of combined forms of high performance/high efficiency building materials and equipment constitute each part of the building. Each module is integrated into a wall-like technology package using connection technology for coupling between the modules to maintain performance and construct the building with multiple technology packages. At this time, the equipment technology package is composed of a combination of the respective equipment modules and is applied according to the needs of the building.

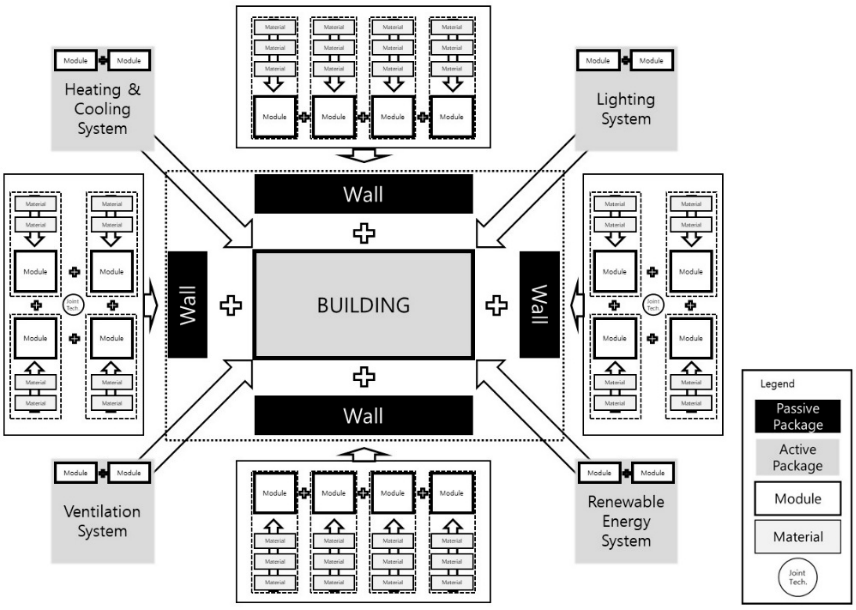


Figure 1. Technical package composition in the building.

2.5. Performance Test Method of Building Materials and Equipment for the Construction of the Zero Energy Building Technology Package

Due to the construction of the Zero Energy Building Technology Package, the performance of building materials and equipment of the Zero Energy Building Technology Package is composed of various materials and equipment. The components and equipment of the technology package therefore require selection criteria. Therefore, in this research, we propose a performance measurement method and performance criteria based on the performance measurement method of the test which is currently utilized in Korea. Korean Industrial Standards (KS) is the government standard according to the law for industrial standardization of Korea. This standard is announced by the chief of the Korean Agency for Technology and Standards. Based on the World Trade Organization (WTO)/Technical Barriers to Trade (TBT) Agreement and the recommendation by Asia Pacific Economic Cooperation (APEC)/Sub-Committee on Standards and Conformance (SCSC), the standard corresponding to the international standard operates in conformity. KS consists of 21 areas from basic section (A) to information section (X). This is divided into three parts. First is the standard of product (shape, size, quality); second is the standard of method (test, analysis, examine, operation standard); last is the standard of transmission (term, technique, unit). The Korean government has undertaken three energy efficiency management programs to increase the energy efficiency of appliances: energy standards and labeling, high-efficiency equipment certification, and e-Standby [10]. Having been implemented since 1992, the energy standards and labeling program mandates all manufacturers to attach an energy efficiency label with a rank from 1 to 5 to their energy-intensive and highly disseminated appliances. Appliances failing to meet the minimum energy performance standards (MEPS) will be terminated from production and sales. The program targets 37 appliances including home appliances, lighting products, vehicles and tires. In addition to these domestic standards, we examined the international standard (ISO), the international standard (ASTM), and the passive house standard (PHI), which is the building-related standard. In this research, we selected the necessary performance measurement method and performance standard.

3. Proposed Technology Package Composition

3.1. Structure of the Passive Technology Package

The passive technology package for zero energy building installation considers the thermal insulation performance to reduce the load of cooling and heating energy of buildings based on the ability to resist the external environment through the building envelope. In Korea, after the legalization of the criteria for the application of thermal insulating materials for the outer skin of buildings since the 1970s, the thermal insulation standards of the insulation materials and the outer walls have been steadily strengthened, and insulation equipment such as windows, doors, etc., has been refined. Recent building materials also consider insulation performance according to the temperature difference between the inside and outside of the room and the solar heat gain coefficient, which is the amount of the solar heat gain from windows. Therefore, when building materials are combined, in addition to the building envelope composition having high heat insulating performance, a combination of building materials capable of exhibiting various levels of performance is required. In the case of building walls with high thermal insulation performance, it is possible to effectively block the heat exchange phenomenon generated by the connection with the dysentery material, and the insulation organize method is used. In the case of using the internal insulation, constructors use high performance materials such as vacuum insulation materials with low thermal conductivity while reducing the insulation material thickness when using the insulation organize method. In other words, it is a method of improving the heat insulating performance while making it easy to secure a large internal space. In the case of using high performance materials (e.g., low value of U-value) or using materials that prevent heat exchange (e.g., using thermal breaks), it is necessary to consider the accessory materials necessary for bonding between materials. Additionally, due to the difference in construction method, it is necessary to set it according to the package. The packages of these technologies can be composed of modules such as walls and windows via a step-by-step combination between building materials. In addition, when systemized (or packaged) via coupling between modules, it is possible to ensure performance according to the requirement of building energy performance.

Additionally, we can be satisfied with the expected performance at the design stage even after construction. The proposed configuration of the packages of these technologies is the same concept as the "application of material performance-construction of building structure-part of building" procedure used in the energy analysis tool. Based on these results, an integrated module of building materials becomes possible. Integration module means the combination of different building materials depending on the standards and sizes between various building materials and design standards. Further, it is possible to improve construction efficiency by modularization. A passive technology package can be configured as follows.

We construct a module through a combination of building materials and apply a joint technology for joining modules to construct a package. Finally, buildings can be constructed by coupling packages. Figure 2 shows the overall configuration of the passive technology package.

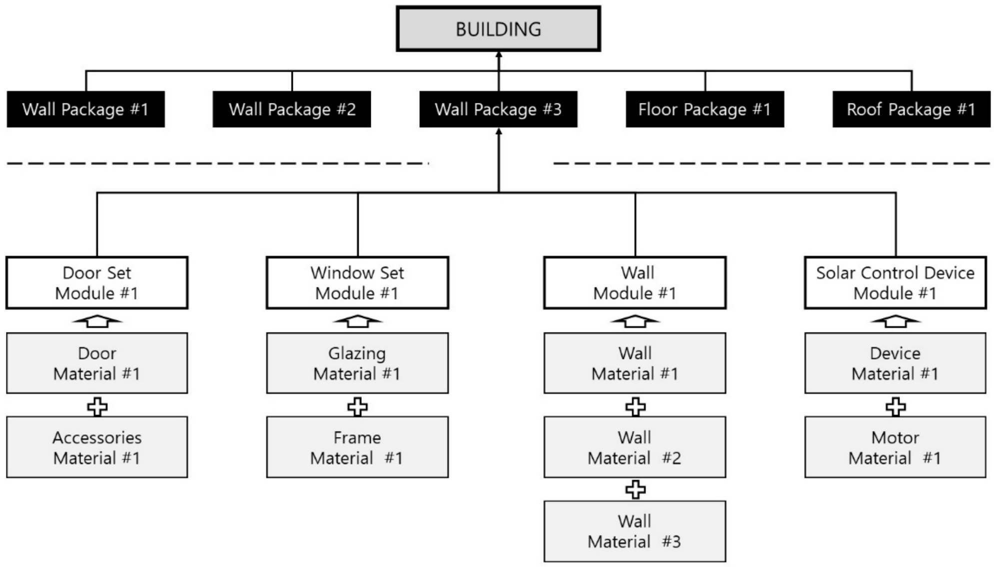


Figure 2. Passive package composition.

3.2. Structure of the Passive Technology Package Module

The modules of the passive technology package can be composed of a wall, a window, a door and a solar control device, respectively. The wall module contains information on multiple layers such as the insulation, structure, exterior material and interior material of a building material constituting the outer skin of the building. In addition to performance information including confidential performance, etc., obtained by checking the thermal resistance (or heat transmission coefficient) of the wall, the wall module also needs to include basic material information including durability and strength. The window module was constructed based on a window set consisting of a glazing and a window frame. For the window module, the product that is applied at the site installation is the standard. The window frame is made of an aluminum alloy material, a steel material, a synthetic resin material, wood, etc. Glazing is composed of multiple layers such as single glass and double glass. The door module was constructed based on a door set consisting of a door frame and a door. For the door module, the product that is applied at the site installation is the standard. The door set comprises hinged and sliding doors that are used internally and externally. Depending on the material of the main part of the door, it is divided into aluminum alloy material, wood, steel material, synthetic resin and stainless steel. The constituent materials of the inquiry are classified into a core material, a finishing material and an accessory. The solar control device module includes all devices capable of adjusting the functions of sunshade and solar introduction. Depending on the installation location, it can be distinguished between inside, outside, and glass. In addition, this module can be classified into a fixed type and a variable type according to the presence or absence of movement. Therefore, the solar control device module can be distinguished from the constituent material such as the slat, the louver and the drive motor.

3.3. Structure of the Active Technology Package

The air conditioning equipment consumes energy for the operation of buildings connected to the renewable equipment to achieve zero energy consumption of the building. Additionally, designers need to consider the compatibility between facility size setting and facilities. For proper design, it is necessary to calculate the capacity of equipment and the structure of the system. Cooperation between different systems can be performed using thermal-based technology (heat storage) and power-based ESS. The BEMS can be maintained and operate efficiently in order to conform to the load considered at the design phase. The heat source package of renewable energy is created by combining the heat source equipment package and the renewable energy heat source equipment element, which is performed by coupling the elements constituting the heat source equipment. Additionally, parameters that can cooperate with each other are applied. As a result, it is possible to derive an alternative system suitable for the purpose and type of each facility. It is possible to improve the energy independence rate and quality of living environment at the operation stage through BEMS. Providing continuous technology updates and appropriate solutions to problems, it is possible to control the energy consumption of the building through cooperation with the passive technology package. Figure 3 shows the overall configuration of the active technology package.

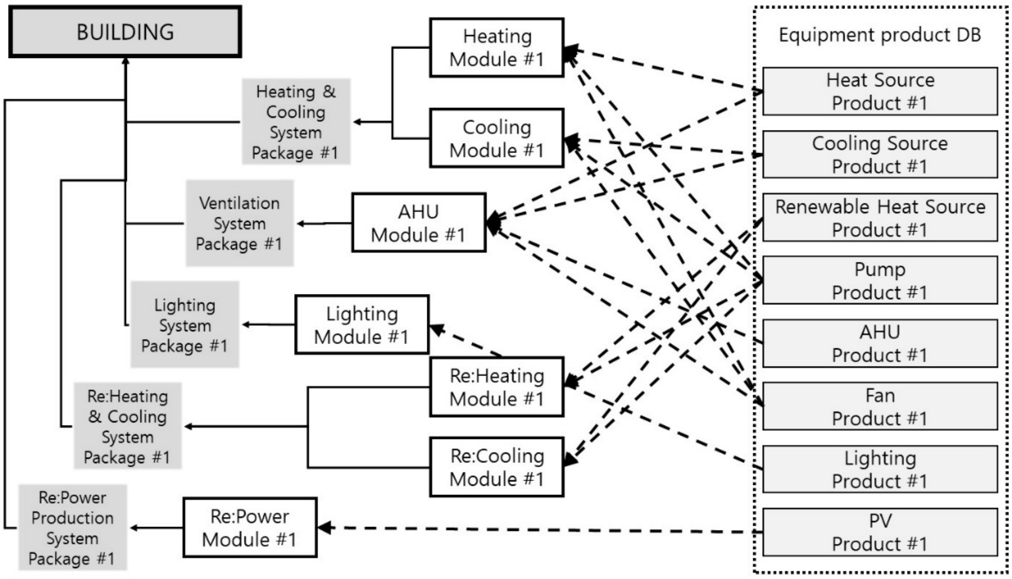


Figure 3. Active package composition.

3.4. Structure of the Active Technology Package Module

Active technology package modules can be distinguished as heating, cooling, air conditioning, ventilation, lighting, heat source of renewable energy, and power of renewable energy. Unlike the modular configuration of the passive technology package, the active technology package module can be constructed based on the building's air conditioning equipment plan. As shown in Figure 4, it is possible to add or delete constituent facilities depending on the configuration order of modules and the nature of modules. After calculating the capacity according to the initial load calculation and choosing the cooling and heating method, the application system of renewable energy is selected according to the final setting of the cooling and heating system and the lighting method. Then, the module of the system that distributes it in order is selected.

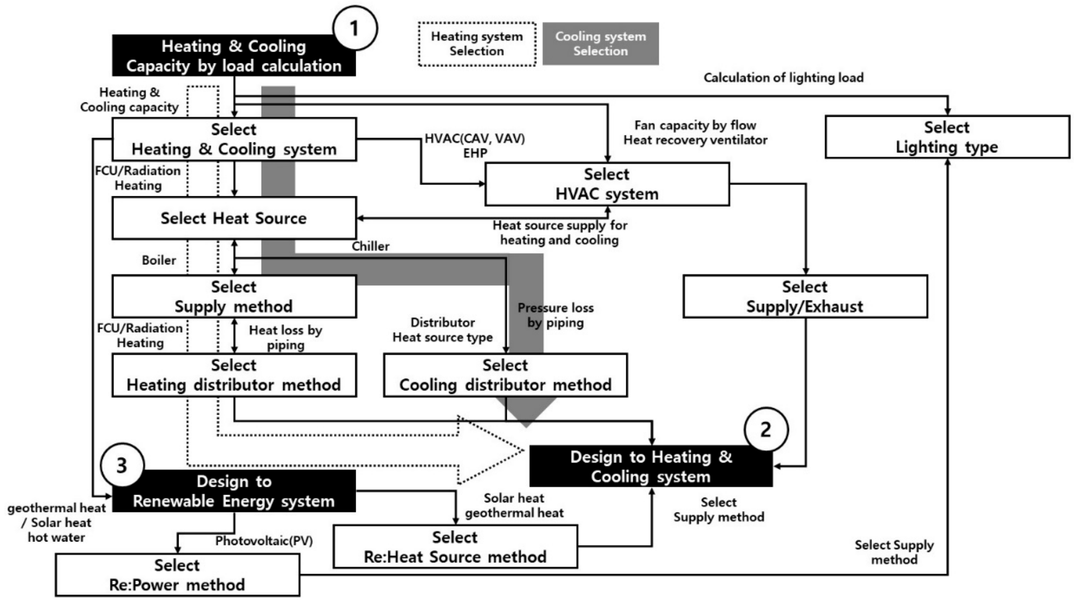


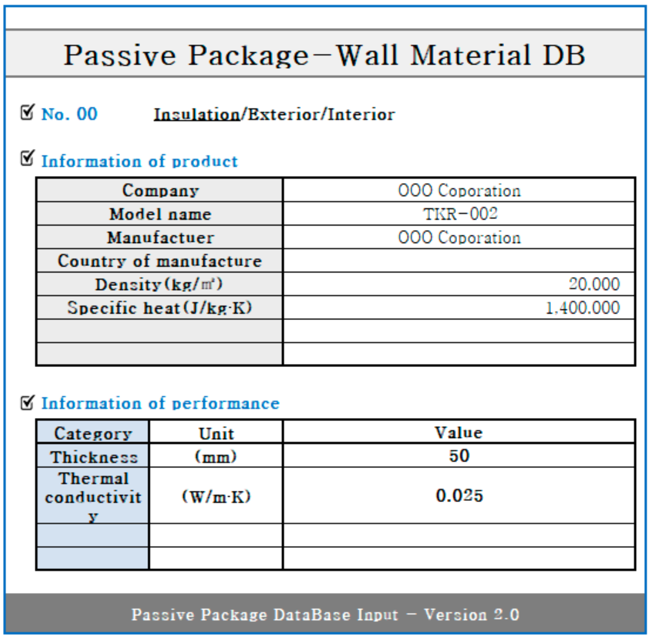
Figure 4. Process of the active technical package.

In the heating module, a boiler (or heat source) is selected according to the selection of the heating method, and a pump attached to the heat source equipment and the supply distribution-related equipment can be selected. The heating module is configured according to the product of the boiler facility. For this reason, a module of a structure that depends on the heat source product is configured via a product type DB. In addition, when utilizing renewable energy equipment, it can be integrated into or replaced by the air conditioning renewable energy module. The cooling module selects the refrigeration equipment according to the cooling mode selection, and selects the pump and the supply distribution-related equipment attached to the refrigerator equipment. The cooling module is configured according to the product of the refrigerating machine equipment. Refrigerator products are selected by DB for each type of product, and modules are configured with a structure that depends on this. Additionally, when utilizing renewable energy equipment such as a heating facility, the refrigerator can be integrated into or replaced by a cooling/heating renewable energy module. The configuration of the air conditioning ventilation module can be changed by an air conditioner and a fan installed based on the cooling/heating method inside the building and the internal ventilation method. Accordingly, a module of a structure that is dependent on the product is configured so that the accessory materials and equipment required for the configuration of the air conditioner (or fan) can be selected. The lighting module consists of main lighting and accessory material. The main lighting considers the purpose of the lighting's installation place and the arrangement of the lighting equipment. The lighting module thus constitutes a module via the lighting fixture and the accessory material DB. The renewable energy heat source module consists of solar power generation and geothermal power that can supply heating and cooling energy for buildings. Solar power generation systems convert solar radiation energy into thermal energy. This system consists of a solar collector and a condenser. The geothermal system utilizes the thermal energy of soil, rock and ground-water to utilize the temperature difference from the atmosphere. Additionally, in order to distribute and utilize the produced cooling and heating energy, cooperation with the heating/cooling module is considered, so the renewable energy module is structured to be compatible with other modules. The renewable energy power module utilizes renewable energy equipment for the purpose of producing necessary electricity for buildings. The photovoltaic power generation system is a representative module. In the module, the production module corresponding to the generator that generates electricity is composed of a power storage device with a power storage function, a power conversion device, etc., accessory.

3.5. Passive and Active Technology Packaging Materials and Equipment DB Composition

The building material DB constituting the passive module is made up of a wall material (Material); a glass part (Glazing) and a window frame (Frame); an inquiry core material of doors (Material) and attached materials (Accessories); a solar control device component (Material) and a driving motor (Motor). The wall material consists of DB of insulation material/structure/exterior material/ interior material. So, the material information was composed of the company name, model name, manufacturer, country of manufacture, density (kg/m^3), and specific heat (J/kg·K). The performance information was composed of thickness (mm) and thermal conductivity (W/m·K). The glass part (Glazing) of the windows was constructed to be able to enter the company name, model name, manufacturer, manufacture and type of glass and air gap details. The performance information composed of the heat transmission coefficient (W/m^2·K) of the glass part, SHGC, and visible light transmittance (VT). As for the glazing, the material of the window frame was made up of the company name, model name, manufacturer, and country of manufacture. As for the material of the window frame, material, thermal break and drawings are included. The performance information of the window frame was selected by the heat transmission coefficient (W/m^2·K). As a result, it is possible to confirm the thermal performance according to the area of the glazing and the window frame. The material DB of the door was composed of a core material (insulation material)/constituent material/thermal break. Material information was composed of the company name, model name, manufacturer, country of manufacture, density (kg/m^3), specific heat (J/kg·K), absorption rate, and tensile properties. Performance information consisted of thickness (mm) and thermal conductivity (W/m·K). Attachment material DB includes hinge/door lock/other attached hardware. Material information is composed of the company name, model name, manufacturer, type, material, and shape (drawing). The constituent material DB of the solar control device included slat/louver and the like, and the material information was composed of the performance of the company name, model name, manufacturer, country of manufacture, type, solar discoloration and discoloration. In the case of the drive motor, the material information was composed of the company name, model name, manufacturer, type, driving power, and repeated driving performance. The facility product DB constituting the active module can be classified into a heat source, a cooling source, a pump, air conditioning (AHU), a fan, lighting, a renewable heat source, and a renewable power source. We constructed DB for all equipment. Heat sources are domestic gas boilers, electric air-conditioners, multi-electric heat pump systems, gas boilers for industrial purposes and buildings, direct-fire absorption-type cold water heater, oil combustion hot water boiler, gas heat pump (GHP), and gas vacuum hot water boiler of the equipment DB. Each piece of equipment information is configured in a different way, but the thermal efficiency (%), the heating capacity (kW), and the supply water/return water temperature (°C) are commonly configured for the performance information. The cooling source can be electric heaters, electric air-conditioners, multi-electric heat pump systems, centrifugal screw refrigerators, direct-fire absorption type cold and hot water heaters, gas heat pumps (GHP), and medium temperature absorption refrigerators. Similar to the heat source, each piece of equipment information was constructed in a different way, but the capacity (W), the efficiency (%), the coefficient of performance (COP), and the supply water/return water temperature (°C) are common to the performance information. Since the pump is applied to various heat sources and equipment, the equipment information is composed of the company name, model name, manufacturer, country of manufacture, format, capacity, efficiency (%), rotation speed (rpm), and discharge amount (m^3/min). For performance information, we chose power (kW). The equipment information in the DB of the air conditioner was composed of the company name, model name, manufacturer, and control method. The performance information includes the maximum air volume (CMH), supply air volume (CMH), exhaust air volume (CMH), air supply fan pressure loss (Pa), exhaust fan pressure loss (Pa), heat recovery rate (%) and fan efficiency (%). In the case of a fan DB, the device information includes the company name, model name, manufacturer, and manufacturing. Performance information consisted of power (kW) and pressure loss (Pa).

In the case of lighting, LED lamp/LED appliances were constructed by separating equipment information by company name, model name, format, power factor, lighting factor, compensation rate, light source color, and harmonic content ratio. The performance information consisted of initial luminous flux (lm), light efficiency (lm/W), color temperature, color rendering property and power (W). The heat source of renewable energy was classified into solar heat and geothermal heat pump. The equipment information consisted of company name, model name, manufacturer, and type of driving. In the case of solar heat, the type of system and the type of heat collector were added. The performance information of solar heat was classified into capacity (kW), efficiency (%), pump power, and thermal storage tank capacity (L). The performance information of the geothermal source was capacity (kW), rated capacity (kW) of the heat exchanger, COP (cooling/heating), pump power (kW), presence and amount of expansion tank, total pipe length (m), and thermal conductivity of piping (W/m·K). The photovoltaic (PV) equipment information was classified into company name, model name, manufacturer, country of manufacture. The performance information was selected for capacity (kW). Figure 5 shows an example of passive technology package DB.



Passive Package—Wall Material DB

☑ No. 00 Insulation/Exterior/Interior

☑ Information of product

Company	OOO Coporation
Model name	TKR-002
Manufactuer	OOO Coporation
Country of manufacture	
Density (kg/m³)	20.000
Specific heat (J/kg·K)	1.400.000

☑ Information of performance

Category	Unit	Value
Thickness	(mm)	50
Thermal conductivity	(W/m·K)	0.025

Passive Package DataBase Input – Version 2.0

Figure 5. Example of passive technology package DB.

4. Proposed Performance Standard of Passive and Active Technology Packages

4.1. Performance Classification of the Passive Technology Package

The performance of building materials for zero energy buildings can be divided into energy performance and other performance. Energy performance is classified into insulation materials and airtight performance, which affect the energy consumption of buildings. Other performance is related to the durability and weather resistance of materials. The performance items of the materials constituting the wall module were classified into heat insulation materials and internal and external materials.

The performance of building materials for zero energy building can be divided into energy performance and other performance. Energy performance is classified into insulation materials and airtight performance, which affect the energy consumption of buildings. Other performance is related to the durability and weather resistance of materials. The performance items of the materials constituting the wall module were classified into heat insulation materials and internal and external materials. Thermal insulation was classified into thermal conductivity of energy performance and other performance, fire resistance and absorption rate. Since the inner and outer packaging material varies according to the shape of the material and the method being applied to the structure, the energy performance can be divided into the heat transmission coefficient, the thermal conductivity, and the thermal resistance. In addition, other performances can be confirmed by the properties of each material, adhesion strength, length change rate, fire protection performance, peel resistance, moisture content, salt spray test, and impact resistance. The window set module is divided into a glass part and a window frame. The energy performance of the glass part consists of the heat transmission coefficient and the solar heat gain coefficient (SHGC). Additionally, sound insulation performance is checked further. The window frame confirms the energy performance through the heat transmission coefficient. In addition, the modules of the door set were classified as insulation. The thermal conductivity of the insulation was chosen as the energy performance. The solar heat gain coefficient was chosen as the energy performance of the solar control device module separated by a slat, louver and blind. It was classified on the basis of the internally and externally installed materials. It consisted of wind speed resistance, salt spray, tensile strength, yield strength, elongation, and accelerated weather resistance of externally placed material. Tension strength, yield strength, elongation, and accelerated weather resistance were taken into consideration for the internally installed materials. Furthermore, the loading load, head trapping, durability of the fixing device, prevention of entanglement and cumulative confirmation performance were taken into consideration. The performance of the drive motor takes into consideration the performance of repeated operation. Table 2 shows the material performance list.

The performance criteria of each module were suggested by the testing method of the constituent materials and the testing method of the modules. The wall module selected thermal insulation performance as energy performance. Energy performance of the window set module consists of the performance of the heat transmission coefficient, the air flow rate and the solar heat gain coefficient. Other performance consists of condensation prevention, wind pressure, water-tightness, discoloration/bleach prevention, handle strength, opening and closing forces, repetitive operation of opening and closing and sound insulation.

In addition, the energy performance of the door set module consists of the heat transmission rate and the air flow rate. So, other performance of the door set module consists of condensation prevention, wind pressure, water-tightness, fire-proof, smoke penetration prevention, stability, opening and closing forces, discoloration/bleach prevention and sound insulation. Finally, energy performance of the solar control device module consists of the solar heat gain coefficient. For other performance, wind pressure, proof against climate performance, durability, repetitive operation and stability were selected. Table 3 shows the module performance list.

Table 2. Material performance contents.

Category	Material Type	Name of Performance	Type of Performance *
Wall-Material	Insulation	Thermal conductivity	E.P
		Fireproof	O.P
		Water absorption	O.P
	Interior/Exterior	Thermal conductivity	E.P
		U-value	E.P
		Thermal resistance	E.P
		Bond strength	O.P
		Length change	O.P
		Fireproof	O.P
		Peel resistance	O.P
		Water absorption	O.P
		Salt spray resistance	O.P
		Impact resistance	O.P
Window-Glazing	Glazing	U-value	E.P
		Solar heat gain coefficient (SHGC)	E.P
		Flame interruption performance (LIP)	O.P
Window-Frame	Frame	U-value	E.P
Door-Material	Insulation	Thermal conductivity	E.P
Solar Control Device-Material	Slat/Louver/Blind (Exterior)	Solar heat gain coefficient (SHGC)	E.P
		Wind pressure	O.P
		Salt spray resistance	O.P
		Tensile strength	O.P
		Yield strength	O.P
		Elongation	O.P
		Accelerated weathering	O.P
	Slat/Louver/Blind (Interior)	Solar heat gain coefficient (SHGC)	E.P
		Tensile strength	O.P
		Yield strength	O.P
		Elongation	O.P
		Accelerated weathering	O.P
		Weight load	O.P
		Head stuck	O.P
		Durability	O.P
		Prevention of tangling	O.P
		Accumulation device	O.P
Solar Control Device-Motor	Motor	Repetitive operation	O.P

* E.P: Energy Performance, O.P: Other performance.

Table 3. Module performance contents.

Category	Name of Performance	Type of Performance
Wall-Module	U-value	E.P
	Linear transmittance	E.P
Window Set-Module	U-value	E.P
	Air flow rate	E.P
	Solar heat gain coefficient (SHGC)	E.P
	Condensation prevention (TDR)	O.P
	Wind pressure	O.P
	Water-tightness	O.P
	Discoloration/Bleach prevention (DBP)	O.P
	Handle strength	O.P
	Opening and closing forces (OCF)	O.P
	Repetitive operation of opening and closing (ROOC)	O.P
	Sound insulation(R)	O.P
Door Set-Module	U-value	E.P
	Air flow rate	E.P
	Condensation prevention (TDR)	O.P
	Wind pressure	O.P
	Water-tightness	O.P
	Fireproof	O.P
	Smoke penetration prevention (SPP)	O.P
	Stability	O.P
	Opening and closing forces (OCF)	O.P
	Discoloration/Bleach prevention (DBP)	O.P
	Sound insulation(R)	O.P
Solar Control Device-Module	Solar heat gain coefficient (SHGC)	E.P
	Wind pressure	O.P
	Proof against climate performance (PACP)	O.P
	Durability	O.P
	Repetitive operation (RO)	O.P
	Stability	O.P

4.2. Method of Measureing the Performance of the Passive Technology Package and Minimum Performance Standard

In order to construct a zero energy building, the components of the passive technology package should be constructed of high efficiency/high performance construction materials. The performance of construction materials should be evaluated under the same conditions using a certified measurement method. The minimum performance criteria and performance test methods are proposed for zero energy buildings. The performance test method was based on the KS standard provided by the National Institute of Technology Standards. Additionally, in some cases, we selected the national examination and the performance measurement method of the material.

In the case of wall insulation, KS L 9106, KS F 2277 and "Building Energy Conservation Design Standard (BEDS)" were selected according to the test method of energy performance. Other performance test methods referred to KS F ISO1192, KS F ISO 5660-1, KS F 2271, KS M ISO 2896, and KS M ISO 4898. The performance test method and performance standard for thermal conductivity, fire protection performance and the absorption rate of wall free insulation material are proposed. The test methods and performance standard of the interior and exterior materials suggested thermal conductivity, thermal transmittance, and thermal resistance performance of energy performance.

We also proposed test methods and performance standards for other performances such as Bond strength, Length change, Fireproof, Peel resistance, Water absorption, Salt spray resistance and Impact resistance. In relation to the glazing, the author proposed the test method and performance standard of the U-value of energy performance and the performance of the solar heat gain coefficient.

The authors also proposed the test method of Fire resistance performance (F.R.P) which is the other performance. Frame and door insulation test methods were proposed for U-value and thermal conductivity test methods, and BEDS performance standards were selected. The slats/louvers/blinds of the solar control device were divided into indoor and outdoor, and performance test methods and the performance standard were proposed, respectively. The solar heat gain coefficient of energy performance is commonly applied to the other performances (Wind pressure, Salt spray resistance, Tensile strength, Yield strength, Elongation, Accelerated weathering, Weight load, Head stuck, Durability, Prevention of tangling, Accumulation device) individually. In addition, for the drive motor, we have proposed a performance test method and performance standard for repetitive operation performance. Table 4 shows the Test methods and performance reference of the material [10–28].

Table 4. Test methods and performance reference of the material.

Material Type	Name of Performance (Unit)	Performance	Test Method	Performance Standard
Insulation	Thermal conductivity (W/m·K)	▼ 0.034	KS L 9106	BEDS
	Fireproof (-)	Pass	KS F ISO 1182 KS F ISO 5660-1 KS F 2271	BEFS
	Water absorption (%)-EPS	▼ 6	KS M ISO 2896	KS M ISO 4898
	Water absorption (%)-XPS	▼ 1		
	Water absorption (%)-PUR	▼ 4		
	Water absorption (%)-PF	▼ 4		
Interior/Exterior material	Thermal conductivity (W/m·K)	▼ 0.15	KS F 2277	BEDS
	U-value (W/m^2·K)	▼ 0.071	KS L 9016	KS F 4040
	Thermal resistance (m^2·K/W)	▲ 0.043	KS F 2277	KS F 3504
	Bond strength (N/mm^2)	▲ 0.1	KS F 4716	KS F 4040
	Length change (%)	▼ 0.5	KS F 2424	KS F 4040
	Fireproof (-)	Pass	KS F ISO 1182 KS F ISO 5660-1 KS F 2271	BEFS
	Peel resistance (-)	Pass	KS F 3504	KS F 3504
	Water absorption (%)	▼ 3	KS F 3504	KS F 3504
	Salt spray resistance (-)	Pass	KS F 9502	KS F 4760
	Impact resistance (-)	Pass	KS F 4760	KS F 4760
Glazing	U-value (W/ m^2·K)	▼ 0.9	KS F 2278	BEDS
	SHGC (-)	▲ 0.5	KS L 9107	PHI
	F.I.P (min)	-	KS F 2845	-
Frame	U-value (W/m^2·K)	▼ 0.9	KS F 2278	BEDS
Door Insulation	Thermal conductivity (W/m·K)	▼ 0.034	KS L 9106	BEDS
Slat/Louver/ blind (Exterior)	SHGC (-)	-	KS L 9107	-
	Wind pressure (-)	Pass	ASTM 331	ASTM 331
	Salt spray resistance (RN)	▲ 8	KS D 9502	KS D8334
	Tensile strength (N/ mm^2)	200 ~ 260	KS B 0802	KS B 0802
	Yield strength (N/ mm^2)	200 ~ 240	KS B 0802	KS B 0802
	Elongation (%)	5 ± 3	KS B 0802	KS B 0802
	Accelerated weathering (-)	Pass	KS C 8568	KS C 8568
Slat/Louver/ blind (Interior)	SHGC (-)	-	KS L 9107	-
	Tensile strength (N/mm^2)	200 ~ 260	KS B 0802	KS B 0802
	Yield strength (N/ mm^2)	200 ~ 240		
	Elongation (%)	5 ± 3		
	Accelerated weathering (-)	Pass	KS C 8568	KS C 8568
	Weight load (-)	Pass	APP.7	APP.7
	Head stuck (-)	Pass		
	Durability (-)	Pass		
	Prevention of tangling (-)	Pass		
	Accumulation device (-)	Pass		
Motor	Repetitive operation (Time)	▲ 100,000	KS C 6021	KS C 6021

▲: or More ▼: or less.

In the case of passive modules, the performance can be verified by the coupling of performance between materials, and the performance can be verified through the actual physical testing method of the module. At this time, it provides the durability of the module and other performances to satisfy the basic required performance. It can also confirm the energy performance suitable for the purpose of the zero energy building, as well as various performance test methods and the proposed performance standard. In the case of the wall module, the test method of U-value and linear U-value is proposed and the performance standard of BEDS is proposed. The performance test method and performance standard of the window module are proposed. The performance standard of U-value, air tightness, and solar heat gain performance to energy performance is also proposed. Additionally, the performance test method and performance standard of other performances are proposed. For the door module, the author determined the performance test method of U-value and air tightness performance, and proposed other performance (TDR, Wind pressure, Water-tightness, Fireproof, SPP, Stability, OCF, DBP, sound insulation) test methods and performance standards. In order to satisfy the energy performance, a performance test method of solar heat gain performance was proposed in the solar control device module. To ensure the durability and maintain the function, we also proposed various other performance test methods and performance standards. Table 5 shows test methods and the performance reference of the module [29–42].

4.3. Performance Classification of the Active Technology Package

Unlike passive technology packages, active technology packages applied to zero energy buildings select the products of each facility in order to determine the cooling/heating, lighting, ventilation equipment, etc., required for each building. Therefore, we confirmed the performance of the products of each facility. We also confirmed and configured the performance confirmation items of the conventional high efficiency certified products that can reduce energy consumption and the highest grade products of the efficiency evaluation. The equipment of the active technology package is divided into heat source, cooling source, pump, fan, lighting and renewable heat source.

Moreover, on the basis of each installation product, the heat source comprised domestic gas-fired boilers, electric chillers and heaters, a multi electric heat pump system, gas-fired boilers for industry and buildings, direct fired absorption cold and hot water dispensers, oil-fired hot water boilers, gas-fired heat pumps, and gas-fired vacuum hot water boilers. The cooling source comprised refrigerators, electric chillers and heaters, a multi electric heat pump system, centrifugal and screw chillers, direct fired absorption cold and hot water dispensers, gas-fired heat pumps and medium-temperature absorption chillers. The pump consisted of a single item and the fan consisted of an energy recovery ventilator and a centrifugal fan. The lighting equipment consisted of external convertor-type LED lamps, recessed LED luminaires and fixed LED luminaires, tubular LED lamps and LED lamps for replacing fluorescent lamps. Additionally, the renewable heat source consisted of solar thermal collectors and the ground source heat pump unit. Table 6 shows the performance contents of the equipment.

Table 5. Test methods and performance reference of the modules.

Category	Name of Performance (Unit)	Performance	Test Method	Performance Standard
Wall-Module	U-value ($W/m^2 \cdot K$)	▼ 0.15	KS F 2277	BEDS
	Linear U-value ($W/m \cdot K$)	▼ 0.4	ISO 10221-1	BEDS
Window Set-Module	U-value ($W/m^2 \cdot K$)	▼ 0.9	KS F 2278	BEDS
	Air flow rate ($m^3/h \cdot m^2$)	▼ 1.0	KS F 2292	ESL
	SHGC (-)	▲ 0.5	KS L 9107	PHI
	TDR (-)-by each local area	▼ Standard	KS F 2295	DCCP
	Wind pressure (-)	Pass	KS F 2296	KS F 3117
	Watertightnes s(-)	Pass	KS F 2293	KS F 3117
	DBP (-)	Pass	KS C 8568	KS C 8568
	Handle strength (-)	Pass	KS F 2239	KS F 3117
	OCF(N)	▼ 50	KS F 2237	KS F 3117
	ROOC (time)	▲ 10,000	KS F 3109/4534	KS F 3117
	R (dB, 500 Hz)	▼ 40	KS F ISO 10140-2	KS F ISO 10140-2
Door Set-Module	U-value ($W/m^2 \cdot K$)-Door	▼ 0.9	KS F 2278	BEDS
	U-value ($W/m^2 \cdot K$)-Fire door	▼ 1.4		
	Air flow rate ($m^3/h \cdot m^2$)	▼ 1.0	KS F 2292	HEC
	TDR (-)-by each local area	▼ Standard	KS F 2295	DCCP
	Wind pressure (-)	Pass	KS F 2296	KS F 3109
	Watertightness (-)	Pass	KS F 2293	KS F 3109
	Fireproof (-)	Pass	KS F 2268-1	KS F 2268-1
	SPP ($m^3/min \cdot m^2$, $\triangle$25 Pa)	▼ 0.9	KS F 2846	KS F 2846
	Stability (-)	Pass	KS F 3109	KS F 3109
	OCF (N)	▼ 50	KS F 2237	KS F 3109
	DBP (-)	Pass	KS C 8568	KS C 8568
	R (dB, 500 Hz)	▼ 40	KS F ISO 10140-2	KS F ISO 10140-2
Solar Control Device-Module	SHGC (-)	-	KS L 9107	-
	Wind pressure (-)	Pass	ASTM 331	ASTM 331
	Salt spray resistance (RN)	▲ 8	KS D 9502	KS D8334
	Tensile strength (N/mm^2)	200 ~ 260	KS B 0802	KS B 0802
	Yield strength (N/mm^2)	200 ~ 240	KS B 0802	KS B 0802
	Elongation (%)	5 ± 3	KS B 0802	KS B 0802
	Accelerated weathering (-)	Pass	KS C 8568	KS C 8568
	Weight load (-)	Pass		
	Head stuck (-)	Pass		
	Durability (-)	Pass	APP.7	APP.7
	Prevention of tangling (-)	Pass		
	Accumulation device (-)	Pass		
	Repetitive operation (Time)	▲ 100,000	KS C 6021	KS C 6021

▲: or More ▼: or less.

Table 6. Performance contents of the equipment.

Category	Equipment Name	Name of Performance
Heat Source	Domestic gas-fired boilers	Heating thermal efficiency
	Electric chillers and heaters	HSPF
	Multi electric heat pump system	COP
	Gas-fired boilers for industry and buildings	Thermal efficiency
	Direct fired absorption cold and hot water dispensers	IPLV
	Oil-fired hot water boilers	Heating efficiency
	Gas-fired heat pumps	Heating COP
	Gas-fired vacuum hot water boilers	Heating efficiency
Cooling Source	Refrigerators	CSPF
	Electric chillers and heaters	CSPF
	Multi electric heat pump system	IEER
	Centrifugal and screw chillers	Energy efficiency
	Direct fired absorption cold and hot water dispensers	IPLV
	Gas-fired heat pumps	Cooling COP
	Medium-temperature absorption chillers	IPLV
Pump	Pump	Efficiency
Fan	Energy recovery ventilators	Heat transfer efficiency
	Centrifugal fans	Efficiency
Lighting	External convertor type LED lamps	Luminous efficiency
	Recessed LED luminaires and fixed LED luminaires	Luminous efficiency
	Tubular LED lamps	Luminous efficiency
	LED lamps for replacing fluorescent lamps	Luminous efficiency
Renewable Heat Source	Solar thermal collectors	Collector performance
	Ground Source Heat Pump Unit	COP

4.4. Method of Measuring the Performance of the Active Technology Package and Minimum Performance Standard

As mentioned above, the active technology package is composed of each facility based on the proposed module configuration of the technology package, so this chapter proposes the performance test method and performance standard of each facility product. These products are used based on the "Energy Efficiency Labeling and Standard (ELS)" and "High-efficiency Appliance Certification (HEC)" managed by the Korea Energy Corporation, and the performance test methods provided by each rule are used. It was divided into performance item and performance standard based on whether the performance standard was met.

For the performance test method and performance standard of the heat source, the highest performance of Energy Efficiency Labeling and Standard to heating thermal efficiency, the heating season power efficiency (HSPF) and COP were selected. Additionally, integrated power level value (IPLV), heating COP, and thermal coefficient were selected by referring to High-efficiency Appliance Certification. The cooling season performance efficiency (CSPF) and the integrated electric energy rate (IEER) were selected as the testing method and performance standard of the cooling source, respectively, referring to the highest rating of Energy Efficiency Labeling and Standard. Additionally, with reference to High-efficiency Appliance Certification, the authors proposed energy efficiency, integrated performance level value (IPLV), and cooling coefficient of performance. The pump performance standard and test method were selected based on the efficiency of Energy Efficiency Labeling and Standard as the performance standard. The performance of the fan was selected based on the heat transfer efficiency of the High-efficiency Appliance Certification and the nominal efficiency was selected as the performance standard. The luminous efficiency of the lighting was selected with reference to High-efficiency Appliance Certification. The performance standard and test method of renewable heat sources were divided into the solar power generation system and the geothermal heat pump system. This selection was determined with reference to KS B8295 and KS B8292, respectively, as well as the performance of the collector and the heating and cooling efficiency. Table 7 shows the test methods and performance reference of the equipment [43,44].

Table 7. Test methods and performance reference of the equipment.

Equipment Name	Name of Performance (Unit)	Performance	Reference Standard
Domestic gas-fired boilers	Heating thermal efficiency (%)	▲ 91.0	ELS
Electric chillers and heaters	HSPF (-)	▲ 5.0	ELS
Multi electric heat pump system	COP (-)	▲ 5.0	ELS
Gas-fired boilers for industry and buildings	Thermal efficiency (%)	▲ 88	HEC
Direct fired absorption cold and hot water dispensers	IPLV (-)	▲ 1.41	HEC
Oil-fired hot water boilers	Heating efficiency (%)	▲ 82	HEC
Gas-fired heat pumps	Heating COP (-)	▲ 1.4	HEC
Gas-fired vacuum hot water boilers	Heating efficiency (%)	▲ 88	HEC
Refrigerators	CSPF (-)	▲ 5.0	ESL
Electric chillers and heaters	CSPF (-)	▲ 5.0	ESL
Multi electric heat pump system	IEER (-)	▲ 5.0	ESL
Centrifugal and screw chillers	Energy efficiency (-)	▼ 0.7	HEC
Direct fired absorption cold and hot water dispensers	IPLV (-)	▲ 1.41	HEC
Gas-fired heat pumps	Cooling COP (-)	▲ 1.2	HEC
Medium-temperature absorption chillers	IPLV (-)	▲ 0.83	HEC
Pump	Efficiency (-)	Pass	HEC
Energy recovery ventilators	Heat transfer efficiency (%)	▲ 45 (Cooling) ▲ 70 (Heating)	HEC
Centrifugal fans	Efficiency (-)	Pass	HEC
External convertor type LED lamps	Luminous efficiency (lm/W)	▲ 85	HEC
Recessed LED luminaires and fixed LED luminaires	Luminous efficiency (lm/W)	▲ 95	HEC
Tubular LED lamps	Luminous efficiency (lm/W)	▲ 130	HEC
LED lamps for replacing fluorescent lamps	Luminous efficiency (lm/W)	▲ 105	HEC
Solar thermal collectors	Collector performance (MJ/m^2)	▲ 7.64	KS B 8295
Ground Source Heat Pump Unit	COP (-)	▲ 3.78	KS B 8292

▲: or More ▼: or less.

5. Conclusions

In order to set up a zero energy building, the authors confirmed the conventional concept of zero energy building introduced in Korea and proceeded with research based on the existing research results. In this study, we proposed a package of passive and active technologies to facilitate the spread of zero energy buildings that suit Korea's situation through the application of appropriate building materials and building equipment. The results of this study are as follows:

(1) In Korea, ECO2 is used in building design. Therefore, in order to construct a technology package and express energy performance, it is necessary to indicate the performance value required by ECO2. Therefore, this study proposes measures to improve ECO2 by comparing analysis tools. The zero energy building concept in Korea and the energy performance evaluation tool for constructing zero energy buildings were confirmed. Then, the performance of the building materials and building equipment required for zero energy buildings was derived. Based on these results, it was necessary to unify the method used to test the performance of building materials and building equipment by utilizing the energy performance evaluation tool for buildings. Also confirmed was the necessity of declaring the method used to test the performance. We also confirmed that it is necessary to consider the extensibility by introducing technology packaging to convert DBs of building materials and building facilities.

(2) Based on building materials, we provided passive technology packages, and proposed active technology packages based on building equipment. Using passive and active technology packages, we confirmed that the technology of each technology parameter is necessary, and confirmed the detailed requirements of each technology. We implemented passive and active technology

packages using the proposed configuration, and we proposed the necessary DB configuration for this.

(3) We analyzed and classified the Korean building materials testing methods and performance standards, and proposed passive and active technology packages, modules, material performance testing methods and minimum requirement performance standards. Based on these results, we proposed the technical performance required for a zero energy building—not a simple energy saving technology description.

The results of this study can be used as the basic data of the future technology level. The passive and active technology packages provided by this research will be updated in the future as each DB is converted. Additionally, it is necessary to improve the test method required for DB and derive a new test method. Through future research, we will try to derive the performance test method of the technology package and the required performance standard at the package level.

As the Korea Zero Energy Building Technology Package represents an area of ongoing research, there are no concrete results yet. However, as a result of this research, the concept of the technology package is applied and DB is constructed, as in Figure 5. In future research, we will present the results of the development of specific technology packages.

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