The New Development for Low Carbon Technology

Bing-Chwen Yang*, Team Leader
Kenji Kobayashi, President
*Asia Pacific Energy Research Center, The Institute of Energy economics, Japan
E-mail: yang@aperc.ieej.or.jp, Phone: +81-3-51448552, Fax: +81-3-51448555
Inui Bldg., Kachidoki 11F, 1-13-1 Kachidoki, Chuo-Ku, Tokyo 104-0054, Japan
Yie-Zu Hu, Deputy General Director
Green Energy & Environment Research Laboratory
Industry Technology Research Institute, Hsinchu, Taiwan

Abstract

Reduction of the Green House Gas (GHG) or Carbon emission has become a major concern for everyone. More and more low-carbon technology (either energy conservation or renewable energy) was employed to operate the energy consumption system in a more efficient way. In this study, the zero emission building concepts was highlighted as an example for the implementation and integration of energy conservation technology, renewable energy, and energy information communication technology (EICT). Some key technology development was also studied in this paper to gain some feeling about the technology development and application trend.

Introduction

In the oil depletion and global warming trends, how to reduce the Green House Gas (GHG) or carbon emission has become a major concern for everyone. According to the forecast by IEA [1], the carbon emission will reach 57GT in 2050. It is no doubt that global warming effect and climate anomalies has created great impact and deterioration to our living environment, the fluctuation of energy price also slow down and distortion the development of global economic. The issue about the energy and environment has become the most urgent problem need to be solved by our community. Most of the country already put their efforts to develop new energy technology, covered from the supply side to create new energy source and demand side to save energy. We need more actively to promote the development of the so-called low carbon technology or approach to reduce the carbon emission, such as adoption of carbon capture and storage (CCS) technology, employment of renewable energy or alternative energy, improvement of energy efficiency, and/or application of nuclear power as shown in Figure-1. Then we can reach the vision for GHG deduction and sustainable development.

In order to implement the low-carbon technologies, most of the country has set up the strategy to develop the so-called zero emission building or energy smart community as the major mission. Asia-Pacific Economic Cooperation (APEC) also fund a low carbon model town project to launch the low carbon town mission in APEC region through the development of low carbon town concept [2]. It aims to integrate the energy conservation technologies (such as building envelop, high-quality air-conditioning, lighting, district heating and cooling, etc.), building load simulation and energy management systems, smart grid, renewable energy and energy storage technologies into a structure for so-called smart green building/community as

shown in Figure-2. The living laboratory with all these facilities will also be constructed to demonstrate the real function and contribution for energy conservation and carbon reduction.

This will also create a chance for the coming of so-called low-carbon economic and birth of green energy industry. The emerging of green energy industry not only can provide the necessary technology to protect our environment but also can play the key role for the new era of economic development in each country. This will also benefit for each government to promote their energy conservation and carbon deduction policy/strategy.

In this paper, we will base on the zero emission building concepts to discuss the major technology requirement and new development for both energy conservation and employment of renewable energy.

Concept of zero emission building

As shown in Figure-2, the zero emission building is an integration system to combine with all possible energy conservation device/technology and available renewable energy. Then, it also needs smart energy management tools/system to operate the building in its optimum condition for high energy efficiency with low carbon emission in an annual base. Based on the energy consumption and living environment requirement, the most common energy conservation technology employed will be high-efficient lighting, air-conditioning, and refrigerator except the building envelop material. It is expected to reduce the energy consumption at least 50% compared with the traditional building by the employment of energy conservation technology with building load analysis (i.e., 4D dynamic simulation by considering the transition load variation for a building) and building energy management system (BEMS). After that, the renewable energy will be installed to satisfy the remaining electricity (energy) requirement to reach the vision of zero emission. However, due to the uncertainty between the demand side and supply side, the smart grid system with energy (electricity) storage device should be incorporated into this building to dynamic adjust the load variation during the operation period. In order to dynamic adjust the energy requirement, the energy information communication technology (EICT) should be introduced to act as the information communication between the demand side and supply side. The enough information on both demand and supply sides can provide the necessary information for BEMS to adjust the energy requirement simultaneous. In this case, the energy shortage for a building can be supplied by the energy storage device or grid system. However, the surplus of energy will be feedback to the grid or recharge to the energy storage device. Overall speaking, the total energy consumption and the energy supplied by the renewable energy will be balanced in the annual base.

The first step for design a zero emission building is to reduce the building load by the employment of different kind of energy conservation technology. It covers from the high-performance envelop material and high-efficient appliances. The second step is to adopt the available renewable energy supply for the remaining energy requirement. The third step is to employ the smart management system to handle the supply and demand side simultaneous for the system optimization. The last step can be done by careful application of EICT to get the transition and exact information on both supply and demands for immediately adjustment by BEMS.

The development of energy conservation technology will focus on smart green building based on advanced air-conditioning facility, new generation of lighting device/system, and others feasible technology. In the renewable energy part, the efforts will put on the promotion of photovoltaic and wind power generation system or other low carbon energy supply.

Energy conservation technology

Air-condition and lighting consumes more than 50% of building total energy consumption and plays the important role for the energy consumption inside a zero emission building. It also posses the most potential for reducing the building load. The new development for air-conditioning and lighting technology will be discussed and followed by the key consideration for the integration of energy conservation technology toward the design of zero emission building.

Advanced Air-conditioning technology and application

In recent years, most of the small room air conditioners gradually increase the function of inverter-control and air cleaning capability except the original cooling and heating purpose. In order to improve energy efficiency and environmental protection, the technology development not only facing the requirement for energy conservation and increasing energy efficiency but also challenging from the phase out of CFCs (chlorofluorocarbon) and HCFC (Hydrochlorofluorocarbons) refrigerant due to their depletion on the ozone layer. Therefore, variable refrigerant flow (VRF) technology and employment of alternative or natural refrigerant has become the major development trend for air-conditioning technology.

Another requirement for the chiller units employed in the central air-conditioning system is to reduce the weight and noise with the increase of energy efficiency. In order to fulfill this purpose, the centrifugal compressor with magnetic bearing has become the mainstream of technology development. The introduction of magnetic bearing to replace the traditional bearing can reduce the requirement for the lubricant in the refrigerant. It can reduce the amount of lubricant that accumulated inside the heat exchanger and induced the decay of heat transfer efficiency. This can improve compressor efficiency by 33-50%, reduce vibration and noise values, 50% reduction in machine size, and only about quarter of weight by comparing with the conventional machine.

The other important issue is the refrigerant restriction set by Montreal Protocol and Kyoto Protocol. Refrigerant is the important working fluid in an air-conditioning unit or system. Either CFC (cause for the depletion of ozone layer & greenhouse effect) or HCFC (cause for the greenhouse effect) is under the control by Montreal Protocol (refrigerant control to avoid the gradual destruction of the atmosphere's ozone layer) and the Kyoto Protocol (greenhouse gas control to avoid the deterioration of our environment due to greenhouse effect). This already causes a considerable extent on the development of air-conditioning technology. It also pushes the development for the alternative or new refrigerants that can be employed to the air-conditioning units or system with the similar thermal performance as the current refrigerant. The current CFC refrigerant has been completely phase out in the first phase of control roadmap set by the Montreal Protocol and the stepwise reduction of HCFC refrigerant is also going on in the second phase of the control roadmap. The

general trend for the refrigerant employment is shifted from the sequence of: CFC → HCFC → HFC (hydrofluorocarbon) → natural refrigerant (carbon dioxide, CO_2; Ammonia gas, NH_3; hydrocarbon, HC; etc.). Although there are still lost of technology problem need to be solved for the application of natural refrigerant, but in general it still remains as optimistic as the longer-term trend of substitution. Therefore, the development trend for air conditioning technology still focuses on the products and technology that employ the natural refrigerant as its working fluid.

Next generation lighting technology and application

The high efficiency lighting fixture is certainly the top priority. However, the innovation lighting system has evolved into high-quality lighting and light environment with energy saving and environment protection. The concept is not only to satisfy the lighting requirement but also to incorporate the human requirements. It means that a new generation of lighting technology development includes comfortable lighting environment, high-efficiency, safety, convenience and low environmental pollution by considering the light source, control modules and lighting performance evaluation.

The characteristic of light source plays a key role for the performance and visual quality of lighting situation. So, the development of light source towards the new and high efficiency light sources, mainly focus on the following three directions.

(1) High optical performance and diversification for the lighting visual feeling
(2) Enhance the luminous efficiency
(3) Environment friendly and low pollution

By viewing this development trend, the LED (light-emitting diodes) has become the mainstream for technology development. Due to LED lighting has the advantage of high efficiency, long life, and environmentally friendly, so the technology development has been moved from luxury goods or display into the functional lighting (such as traffic lights, indicate lights ... etc.). As technology advances, the replacement of traditional incandescent bulbs, mercury vapor lamps will be the highlight in the short term. It will also gradually enter the general lighting purposes and combine with the consideration of human factor in the long term.

Another important issue for lighting is to design in and incorporate with the development of smart home or community to form a so-called elite lighting environment. This will push the power electronic technology to integrate into the new lighting fixture with the digital control concept and capability. This will further upgrade the status and enhance the universal product trend for the lighting technology development. This will also give birth for the international standards on the digital addressable lighting interface.

Another lighting potential should also be addressed in here, i.e., OLED (organic light emitting diodes). OLED possess the characteristic of inherently environmentally friendly, planar light source, high efficiency, low cost and lightweight. It is estimated that the cost in 2016 can be competed with fluorescent lamps and has the potential to replace the existing indoor lighting device. It also estimated that the applications of OLED lighting device in 2016-2020 will have 5% in most of the developed countries [4]. Because of its planar light source features, the preferred development priorities at this stage include indicating lighting, advertising

lighting, architectural lighting, backlight (LCD liquid crystal display), etc.

Integration of building energy conservation technology

The concept for the integration and implementation of energy conservation technology to design a zero emission building can be shown in Figure-3. As shown in the figure, high-efficient equipment, optimum sub-system, and proper installation/operation will form the important three pillars for a zero emission building to optimize the health, comfortable, and sustainable requirements for the building and its residents. The integration process can be explained as following:

(1) The high efficient appliance or equipment should build in with the inverter and smart control device to adjust their operation mode more flexible according to the transition load condition.
(2) The equipment should be designed according the operation and environment condition by the combination with other equipment to form an optimum sub-system for best performance.
(3) Introduce information communication technology (ICT) to communicate between different sub-systems and integrate all of them into a whole system.
(4) The monitoring and measuring device should be incorporated to analyze the environment and energy consumption situation for immediate reaction and management.
(5) The energy service company (ESCO) can be involved in order to introduce the professional engineer for optimum operation and maintenance. This will guarantee the high-performance during the building's life time.

Renewable energy technology

Due to the low-carbon or carbon-free power generation characteristics for photovoltaic (PV) and wind power generation, they have become the main flow for low carbon power generation systems. They are also one of the most feasible renewable energy that can be incorporated with the building design to supply the necessary electricity to reach the so-called zero emission building. The renewable energy also contributes to the global CO_2 emission reduction about 17% (as shown in Figure-1). In the photovoltaic part, due to the policy of subsidies or incentives by Government, the installed capacity is push to a new high and most countries have more than 30% of growth rate in 2010 [3]. Based on this deployment trend, the technology development will also shift from the pursuit of high-efficiency for PV cell and module to the requirement of overall system stability, reliability, and the reduction of power generation cost. In the wind power generation part, due to the land-based wind power technology has become mature, so the focus has gradually shifted to the development of offshore systems.

Photovoltaic application and technology

Due to the necessity of reduction of CO_2 emission and plus the subsidies by most of the country, the solar industry grow about 126% from 7.3 GW in 2009 to 16.5 GW in 2010 [3]. During this fast growing period, the technology development is focused on the improving the efficiency and increasing the product yield to reduce the cost. The more actively efforts involved in the development of next generation PV technology is to develop new concept of PV cell, such as compound solar cell, dye sensitized solar cells, etc.

However, from the application side, the development will be focused on the PV modules and system integration. The three key technology developments for PV modules are: (1) reduce production costs, (2) enhance the conversion efficiency, and (3) increase the reliability and set up the test process/standards. The key issue for the PV system is the evaluation of performance and reliability. The PV system performance, stability, and reliability analysis can help the industry to establish performance measures and system/product evaluation mechanism. This will benefit for setting up the standardization of system components and gain the public confidence on PV system.

Another future potential for PV application is the dye sensitized solar cells. Dye-sensitized solar cells are the third generation of organic solar cells with the similar characteristics for low-cost and similar energy conversion efficiency as silicon thin film solar. In addition, dye-sensitized solar cells is not only low cost, only about 1/5 ~ 1/10 cost of traditional silicon solar cell substrate (depending on the process and the organic material costs may be), but also the semi-transparent properties, suitable for building materials (particularly in the construction window material) [4]. It can be employed in the modern glass curtain building to serve as the sun shedding, thermal insulation and power generation and achieve building energy conservation and power generation at a same time. It is likely to become the widely used and development focus for the next generation solar energy technology

Wind power application and technology

The wind power generation is another hot source for the employment of renewable energy. The total installed capacity of wind turbines worldwide was 196.6 GW (accumulated at the end of 2010) and provided 430 billion kWh of electricity, about 2.5% of the global electricity demand in 2010 [5]. Among this capacity, about 37.6 GW was installed in 2010 with 23.6% growth from 2009. It is also estimated the total capacity will be around 1,500 GW by 2020 [6].

In view of existing wind power generation capacity, the majority of the installed wind turbine is the land-based wind turbine at this time. The installed capacity of offshore wind turbines is only about 3.1GW (1.6%) [4]. However, the offshore wind condition has the characteristics of uniform speed and stable by comparing with the onshore. This will provide the opportunity and advantage for the development of offshore wind turbine. It estimates that the future market growth rate will be much higher than the land-based wind turbine. Currently the single unit capacity for offshore wind turbine is about 3.0 ~ 5.0MW and will increase to about 10 ~ 20MW in 2020. In view of the development from land-based to offshore wind turbine, the future technology development will be focused on the following area: (1) wind power assessment technology, (2) large-scale wind turbine system technology, and (3) offshore marine Engineering technology.

As mentioned in the previous, the wind power can generate the electricity to fill the energy requirement for a zero emission building. This will create the opportunity for the development of small wind turbine. In recent years, a steady and significant growth with an average annual growth rate of 26.4% for the small wind turbine. It is also estimated that the small wind turbine has the market potential about 11~33% by 2020 [5]. The stability and low noise is the most concern point for the small wind turbine technology development and application.

Energy Information Communication Technology (EICT)

As shown in the Figure-2, EICT can be employed between the building and grid system to balance the requirement on both sides. In order to fulfill this function, the major contents for the EICT technology should cover from sensing, measuring, transmission, to management. In view of this, the important technology development can be classified into 4 groups.

(1) Intelligent sensing and transmission technology development

The goal is to increase the stability and reliability of different sensor and meter. The major requirement for sensing and metering technology is not only to enhance the measuring accuracy but also to incorporate with the remote transmission capability. The major requirement for the transmission is to increase the flexibility for the sensing and metering signal can be transferred to the energy management system for further control or adjustment of the operation condition.

(2) Energy demand analysis and energy-saving software development

The core technology for the EICT is to analyze the energy supply and demand simultaneous and feedback to energy consumption management system for optimum operation. This will create the necessity for the professional software to do the job. It should cover the capability for the demand response in order to predict the future energy demand and exact adjust the supply side to match the requirement.

(3) The energy supply and demand balance control technology

The technology development should cover receiving the signal from the software and matching with the action of control device.

(4) Energy monitoring and management platform

The requirement for the platform is function oriented and easy to operate. So, the technology development is focus on the interaction energy management technology.

EICT not only can apply to the smart community to balance the demand and supply side but also can employ to the district energy system (DES), industry zone, convenient store, etc. The purpose to adopt EICT is to collect the enough and exact energy supply/consumption information for the management system to optimize the whole system. The concept for the employ of EICT to the DES can be shown in Figure-4 [4]. As shown in the Figure-4, the application of the EICT technology should have at least 3 different category of device: sensing and metering technology, signal transfer technology, and communication technology.

Conclusion Remarks

In order to reach the carbon emission deduction goal for the environment sustainable development, the first step is to reduce the system load then to employ the low carbon or carbon-free energy to fulfill the remain requirement. The technology employed to either reduce the system loading or with low or zero carbon emission is the so-called low carbon technology. So, the low carbon technology should cover both energy conservation technology and employment of renewable energy or other low emission energy source. As the

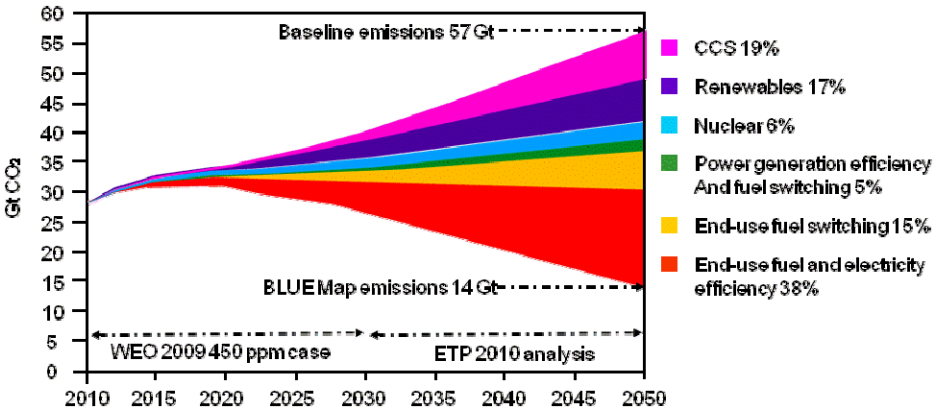
zero emission building shown in this paper, the EICT also the necessity to operate the building in a more efficient way for either zero emission or providing comfortable and healthy living environment.

Acknowledgment

We would like to express the sincerely thanks to the financial support from Bureau of Energy, MOEA of Taiwan. Authors also extend this thanks to the Asia Pacific Energy Research Centre for its support during my writing this paper.

Reference

1. IEA Energy Technology Perspective 2010
2. Low carbon town concept, APERC, 2011
3. Global Market Outlook for Photovoltaic until 2015: European PhotoVoltaic Industry Association (EPIA), 2010
4. Energy Technology and Industry Development White Paper, Bureau of Energy, MOEA, Taiwan, 2010
5. World Wind Energy Association WWEA 2011, “World Wind Energy Report 2010”, April, 2011
6. Companiesandmarkets.com, “Small Wind Turbines (less than 100kW) - Global Market Size, Analysis by Power Range, Regulations and Competitive Landscape to 2020”, 2011



Source: IEA Energy Technology Perspective 2010

Figure-1 Trend for global carbon emission

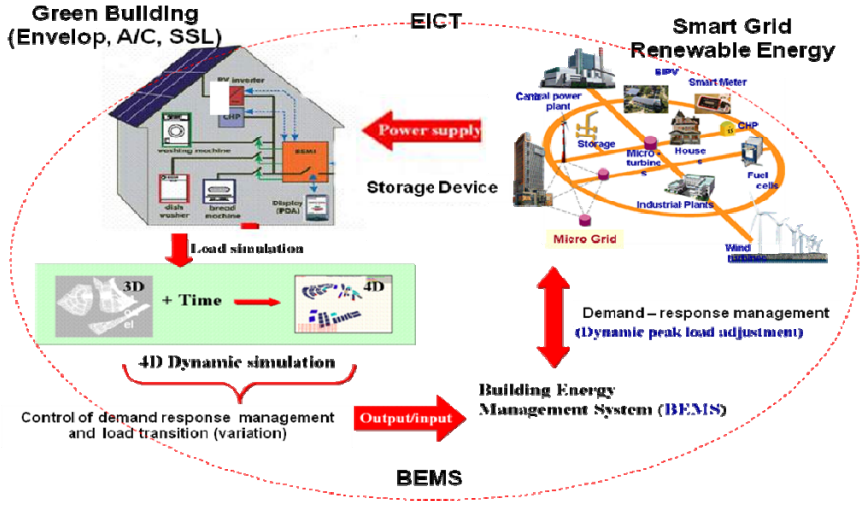


Figure-2 Concept of zero energy (emission) building

Figure-3 Concept for the integration and implementation of energy conservation technology

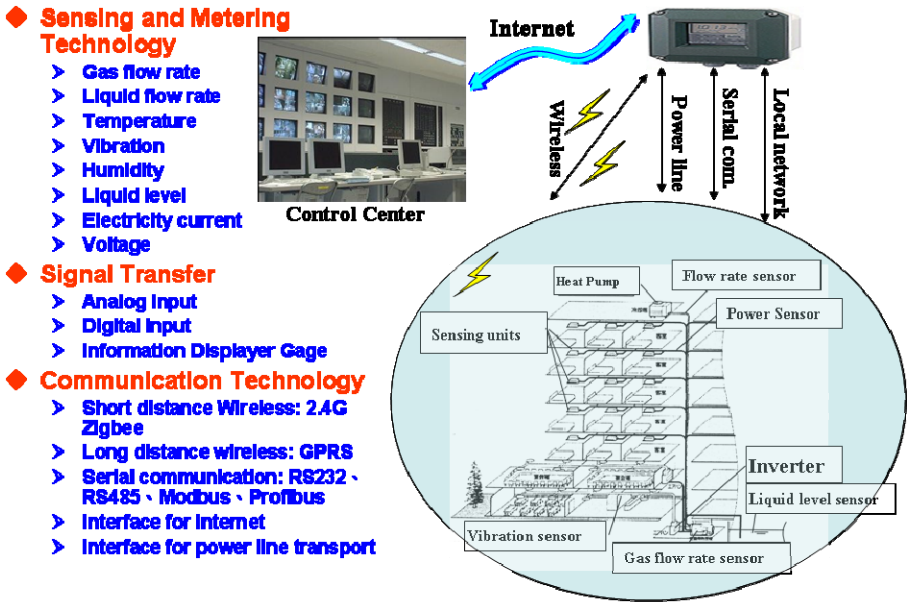


Figure-4 The concept for the application of EICT in district energy system