MOEA

Overview and Case Studies on Green Energy in R.O.C. 2013

APO Center of Excellence on Green Productivity

Center of Excellence on Green Productivity
Asian Productivity Organization

About the APO

The Asian Productivity Organization (APO) is a non-profit, non-political international partnership of Asian countries established by its member countries to provide technical and management service to industrial, agricultural and service sectors in order to promote economic prosperity and improve the living standards of people living in those countries.

The APO was established in Tokyo on May 11, 1961. The organization currently includes twenty member countries: Bangladesh, Cambodia, Republic of China(ROC), Hong Kong, Fiji, India, Indonesia, Iran, Japan, Korea, Laos, Malaysia, Mongolia, Nepal, Pakistan, Philippines, Singapore, Sri Lanka, Thailand and Vietnam (Hong Kong 1997 suspension). Member countries are represented through each country's National Productivity Organization (NPO). The ROC representatives participate in APO projects through China Productivity Center (CPC).

About the APO COE GP

In 2013 the Asian Productivity Organization established the Center of Excellence on Green Productivity (APO COE GP) in ROC. ROC is a founding member of APO and has been pursuing success in the field of green productivity for a long time. The Government of ROC commits to share with member countries in the pursuit of this aspiration and would like to be a catalyst through hosting the APO COE GP.

We look forward to using this platform to share ROC's experience, contribute to the green growth of other member countries, promote regional innovation and sustainable development, and jointly with member countries to enhance green productivity and competitiveness.

The APO Center of Excellence will ensure ROC's long-term cooperation with member countries in APO projects and domestic and foreign investment experts. Through training exercises and benchmarking visit exchanges, APO will assist Member Countries in enhancing green productivity and innovation to create a sustainable green economy.

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APO Center of Excellence on Green Productivity

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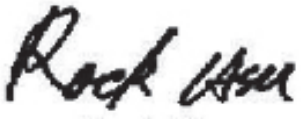
Foreword

The 55th session of the Asian Productivity Organization (APO) Governing Body Meeting in Tokyo in May 2013 approved the establishment of the APO Center of Excellence (COE) on Green Productivity in the Republic of China. Managed by the China Productivity Center, this center supports the APO in promoting and implementing related projects and is an example of the importance of the GP issue across the world.

At a time when environmental awareness is becoming increasingly important and consumers favor environmentally friendly products and services, this manual looks at ways to support APO member countries in the implementation of GP models in the fields of Resource Recycling, Green Energy, Green Factory and Ecological Agriculture Innovation, including the diffusion of related tools and techniques for GP models.

I would like to take this opportunity to thank the APO and the local implementing organizations for their hard work in making this manual available. My special thanks also go to the R.O.C. government's Ministry of Economic Affairs, Ministry of Foreign Affairs, Council of Agriculture and Environmental Protection Administration for their guidance and support.

The implementation of the COE plan is of great significance in terms of the effectiveness of industrial upgrading and international linkage. We hope to use this opportunity to share the results of the promotion of GP and to promote the sharing of knowledge and cooperation opportunities. It is hoped that through close interaction with APO members, all stakeholders worldwide will jointly improve GP in the Asia-Pacific region.



Mr. Sheng-Hsiung Hsu
December 15, 2013
Chairman of the APO Center of Excellence on Green Productivity Advisory Committee
APO Director for Republic of China (R.O.C.)
Chairman of China Productivity Center

Message

Against simmering concerns over climate change and energy resources, the world is being driven to go green. Governments across the world now promote low-carbon economies and industrial upgrades while fine-tuning domestic energy and trade policy decisions. It remains to be seen how the world facilitates the synergy of industrial growth, improvements in entrepreneurship and leverages competition in the name of sustainable development.

As one of the Asian Productivity Organization (APO) founding members, the Republic of China (R.O.C.) is active in relevant events and has witnessed the socioeconomic development of member countries for five decades. The APO Center of Excellence (COE) on Green Productivity (GP) symbolizes the arrival of a new era in green technology, one in which R.O.C. and other APO members will play key roles in the green economic development of the Asia-Pacific region.

The Industrial Development Bureau is proud to have received the affirmation of the APO and its members by having the APO COE GP established in R.O.C. and has given its full support. We aim to use this platform to engage in close cooperation with the APO Secretariat and APO members, especially in the fields of Resource Recycling, Green Energy, Green Factory and Eco-Agriculture. It is also hoped that these publications encourage businesses worldwide to work together to promote green productivity for future sustainable development.

We would like to express our sincere thanks to everyone who has been involved in creating this manual and we appreciate the invaluable support from APO and R.O.C.'s cross governments. In the near future, the IDB looks forward to bridging the cooperation opportunities with member countries and working closely with industry to jointly promote green productivity for industrial development.

Industrial Development Bureau
Ministry of Economic Affairs, R.O.C.
December 15, 2013

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This manual was made possible by the vision of individuals in both the public and private sector who recognize the importance of renewable energy development in emerging economies of Asia. In particular we would like to express our deepest gratitude to the following corporations and organizations that have granted us interviews and site visits, and assisted us in editing the case studies in this manual: Lawson Transworld Inc., Darfon Electronic Corp., Easy Champion International Ltd., NexPower Technology Corp., HELIO Optoelectronics Corp., PrimeVOLT Corp., HiVAWT (R.O.C.) Technology Corp., FormoLight Technologies Inc., Forhouse Corp., Tennrich International Corp., Hengs Technology Corp., LCY Chemical Group, SunnyRich System Co., Ltd., and Kaohsiung World Game Stadium. We would also like to thank those who worked tirelessly with us on editing this volume: Ms. Yiting Wu, Ms. Karen Ma, Mr. Jay Wang, Ms. Deaphne Guo, Ms Ida Chen, Ms. Joanna Chen.

Asian Productivity Organization, China Productivity Center and Industrial Technolgy Research Institute co-hosted the Workshop on Development of Model Project for Green Productivity in Taipei during Nov. 4-8, 2013. The presentations and insights from the workshop were invaluable to this study. We are also grateful to all the foreign and local speakers who contributed to the discussions.

Finally and most important, we would like to thank the R.O.C. Bureau of Energy, the R.O.C. Industrial Development Bureau and the Industrial Technology Research Institute whose generous supports make this project possible.

1. Introduction

The Republic of China (hereafter "R.O.C.") is recognized as a global leader in sustainable development and has been awarded the honor of hosting the Center of Excellence on Green Productivity (COE GP) by the Asian Productivity Organization (APO). The COE GP was launched in June 2013 with the mission of enhancing, demonstrating and sharing with other APO member countries the experience of the R.O.C. on green productivity. In order to fulfill this goal, a series of activities including workshop learning, dispatch of expert delegates and research have been and will be implemented from 2013 to 2015.

The COE GP is charged to prepare manual containing technological information and applications of four separate themes: Resource Recycling, Green Energy, Green Factory and Agricultural Innovation. The manual includes the global situation, technological development and corresponding policies of the individual themes. The current 2013 manual is based on independent study by leading research institutes of R.O.C. The case studies therein demonstrate the best practices on policy implementation and technology application of public and private establishments of R.O.C.

With the publication of the 2013 manual on Green Energy, COE GP wishes to convey its utmost sincerity in leading the international community toward a more productive and sustainable future.

2. Global Situation and Trend on Green Energy

Energy is the utmost important thing in the human being's pursuit of a better living. Based on the estimate of International Energy Agency (IEA)[1], nearly 1.3 billion people, or 18% of the world population, did not have access to electricity in 2011. More than 2.6 billion people, or 38% of the world population, relied on the traditional use of biomass for cooking in 2011. Achieving universal access to modern energy services remains a challenge for national governments.

Furthermore, the world's population is expected to increase persistently, from around 7 billion today to 8.5 billion in 2035[2], with main growth coming from the developing and emerging economies, such as India, Brazil, Indonesia, Pakistan, Bangladesh and Nigeria, etc. These nations are also undergoing rapid industrialization, driving up the demand for energy resources. According to IEA, global energy demand will increase by one-third from 2011 to 2035, and emerging economies account for more than 90% of the global net energy demand growth. While energy demand growth is led by the People's Republic of China (P.R.C) in the 2010s, it will shift to India and Southeast Asia after 2025. The Middle East will also emerge as a major energy consumer of natural gas and oil.

If the developing countries follow the same energy consumption pattern as the developed countries did in the past 50 years in their pursuit for prosperity, our planet will be overwhelmed with serious environmental and social challenges that were already witnessed in the last decade. The new development pathway should decouple the economic growth from making environmental impacts, and the energy issue is central to this transformation.

Scientific studies have confirmed that the consumption of fossil fuels accounts for the majority of global anthropogenic greenhouse gas (GHG)[3] emissions , which are believed to be the source of global warming. There are multiple ways to lower the GHG emissions from the energy system, such as energy conservation and efficiency, fossil fuel switching, renewable energy, and nuclear; each has its advantages and barriers. Among these options, renewable energy, if implemented properly, could have wider benefits such as ensuring energy security and expanding local employment[4] in addition to solving climate problems.

In the Republic of China (R.O.C.), the concept of green energy contains both expanding the use of renewable energy and promoting advanced energy efficient products. This report will give an outline of the global trend and R.O.C.'s promotional policies on green energy technologies, with special focus on solar photovoltaic (PV), wind power and light-emitting diode (LED) lighting as they have experienced particularly strong growth in recent years and the trend is expected to continue.

1. OECD/IEA (2013). World Energy Outlook 2013, International Energy Agency, Paris, France.
2. UN DESA (2012). World Population Prospects: The 2012 Revision, Department of Economic and Social Affairs, Population Division, New York, USA.
3. UNEP (2013). The IPCC Fourth Assessment Report (AR4), Intergovernmental Panel on Climate Change, Geneva, Switzerland.
4. Potsdam Institute-UNEP (2011). IPCC Special Report: Renewable Energy Sources and Climate Change Mitigation, Potsdam Institute for Climate Impact Research, Geneva, Switzerland.

▶2.1 Recent Global Development

Renewable Energy

Renewable energy has three forms of final consumption: electricity, heat and transport. Due to the strong policy support, double-digit growth rates have been observed in the last decade in the installation of solar panels and wind turbines for electricity generation. Using renewable energy for heat, such as solar water heaters and ground-source heat pumps, is growing more slowly and the potential is largely unexploited. Using biofuels in transport experienced rapid expansion for a period of time, but the growth rate slowed down due to lower harvest and rising sustainability concern.

Based on statistics released by BP[5], the electricity generation from renewable sources (including wind, geothermal, solar, biomass and waste, excluding hydro) reached 1,049 TWh in 2012, of which 50% came from wind power generation, 41% from geothermal, biomass and waste, and 9% from solar. The penetration rate of renewable energy into the electricity sector has been increasing steadily, from 1.5% in 2000 to 4.7% in 2012, as shown in Figure 2-1.

The United States led the world in terms of the Twh of renewable power generation, followed by P.R.C. and Germany, as shown in Figure 2-2, which illustrates the top 10 countries using renewables for power generation and the composition of their renewable power sources. Together, these 10 countries accounted for 75% of the electricity generated from renewable sources globally in 2012. To make the numbers more meaningful to readers, let us take the figure of the U.S. as an example. According to the U.S. Energy Information Administration, in 2011, the average annual electricity consumption for a U.S.

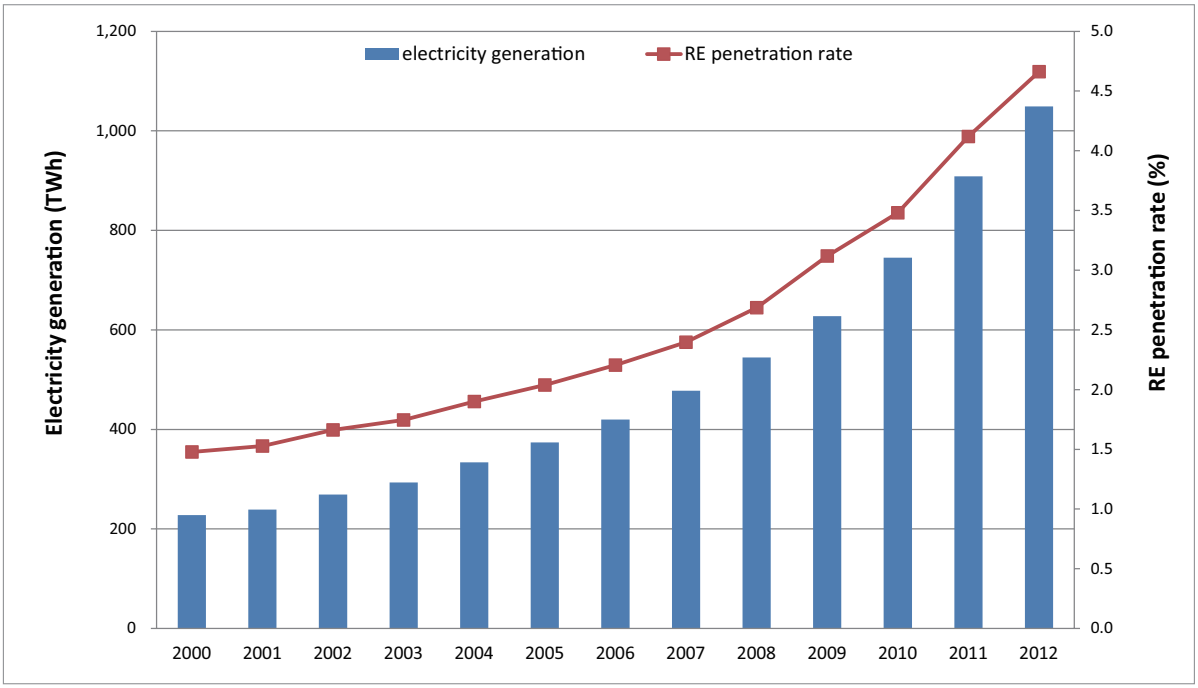

Figure 2-1. Renewable power generation and its penetration rate into the electricity sector, 2000-2012

(Source: BP (2013/06); ITRI/IEK Analysis)

[5]BP (2013). BP Statistical Review of World Energy 2013, British Petroleum, London, UK

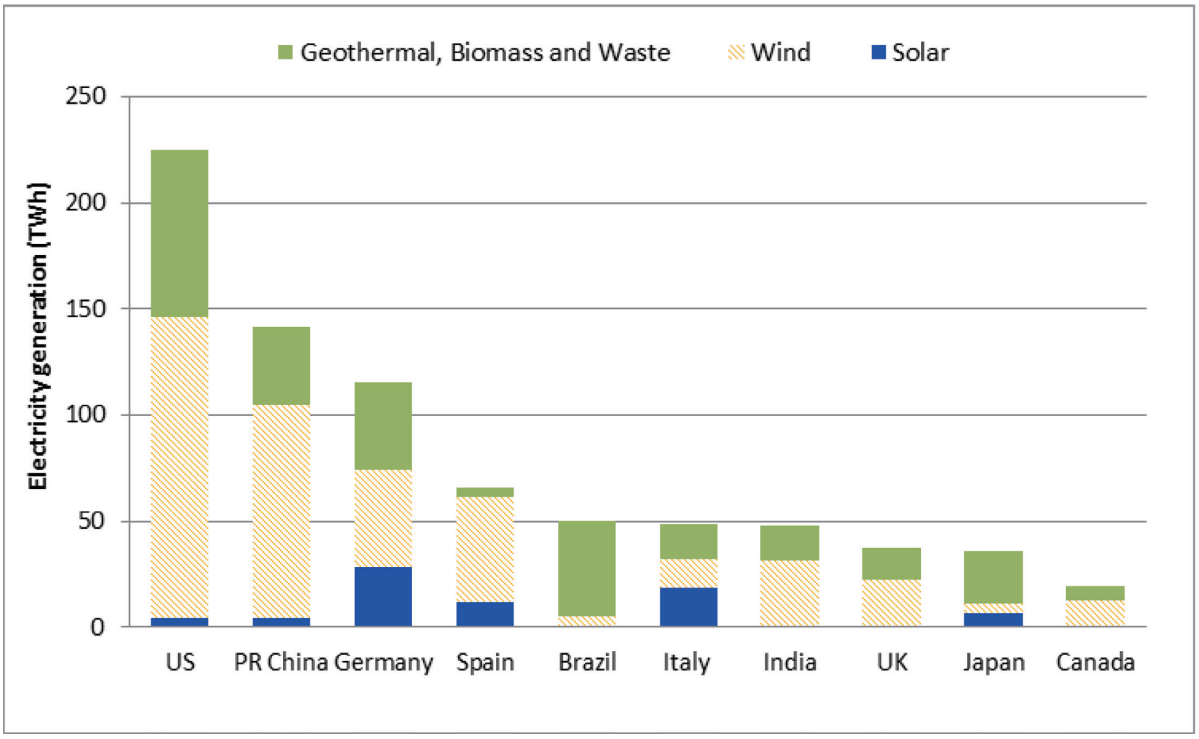

Figure 2-2. Top 10 countries of renewable power generation, 2012

(Source: BP (2013/06); ITRI/IEK Analysis)

household customer was 11,280 kWh[6]. The 224.2 TWh hours of electricity generated from renewable energy in 2012 are sufficient to supply the electricity demand of 19.87 million households, around 17% of the total number of U.S. households.

However, if considering the penetration rate of renewable energy in each country's power system, European countries take the lead, as shown in Figure 2-3. Electricity generated from renewable energy accounted for 22.2% of the total electricity generation in Spain and 18.6% in Germany in 2012, two pioneering countries in renewable energy promotion.

Although solar energy contributed only 9% of the renewable power generation in 2012, it attracted 57% of the renewable energy investment in the same year, followed by wind at 33%[7]. The rapid cost reduction of solar and wind power generation has made them two most prominent renewable sources for investment, as shown in Figure 2-4. It is also notable that the investment in renewable energy, USD 244.5 billion in 2012, was down 12% from the record figure of USD 279 billion in 2011, reflecting both the uncertainty in support policies at the time of economic downturn and sharp falls in technology costs.

Despite weaker investment, the number of renewable power megawatts installed actually increased in 2012, triggered by the continued cost reduction in renewable energy technology. According to Bloomberg New Energy Finance, the utility-scale and residential PV system costs fell by around 40% and 30% respectively between 2011 and 2012. The installation of PV systems increased to 31 GW in 2012 from 30 GW the previous year. About the same situation, the wind installation hit the record of 45 GW in 2012 from 42.5 GW in 2011.

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[6] US Electricity Consumption (2013). US Environmental Information Agency. Retrieved from http://www.eia.gov/tools/faqs

[7] Frankfurt School-UNEP Centre/BNEF, (2013). Global Trends in Renewable Energy Investment 2013, Frankfurt School of Finance and Management & Bloomberg New Energy Finance, Frankfurt, Germany.

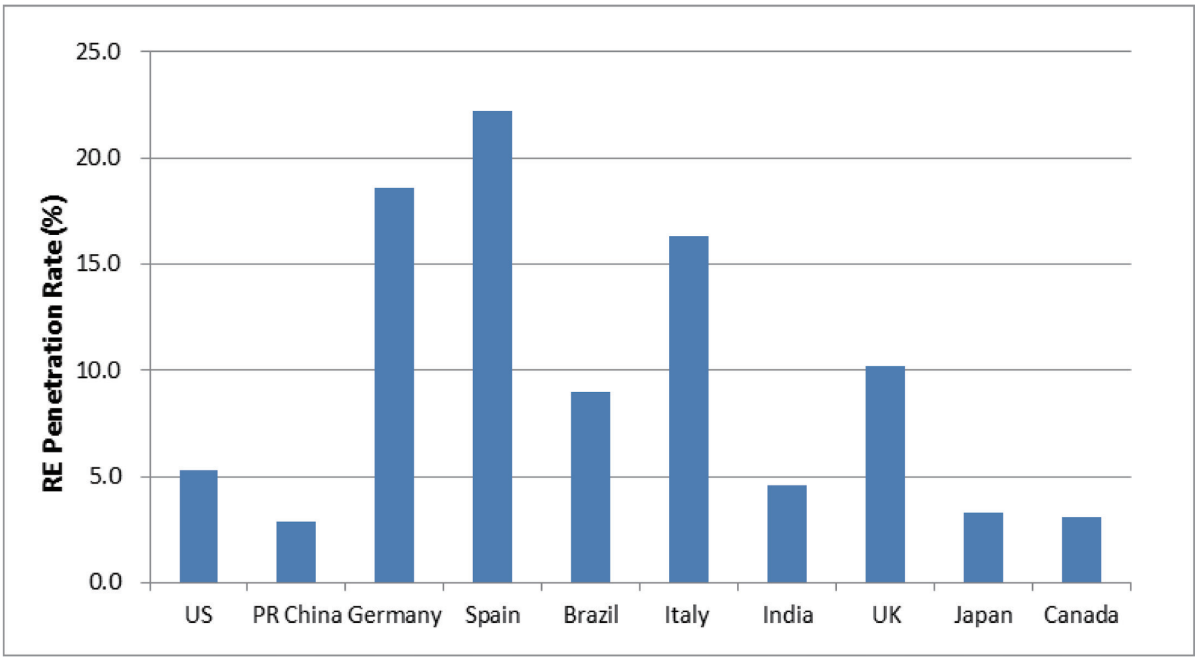

Figure 2-3. Renewable energy penetration rates in top 10 countries of renewable power generation, 2012

(Source: BP (2013/06); ITRI/IEK Analysis)

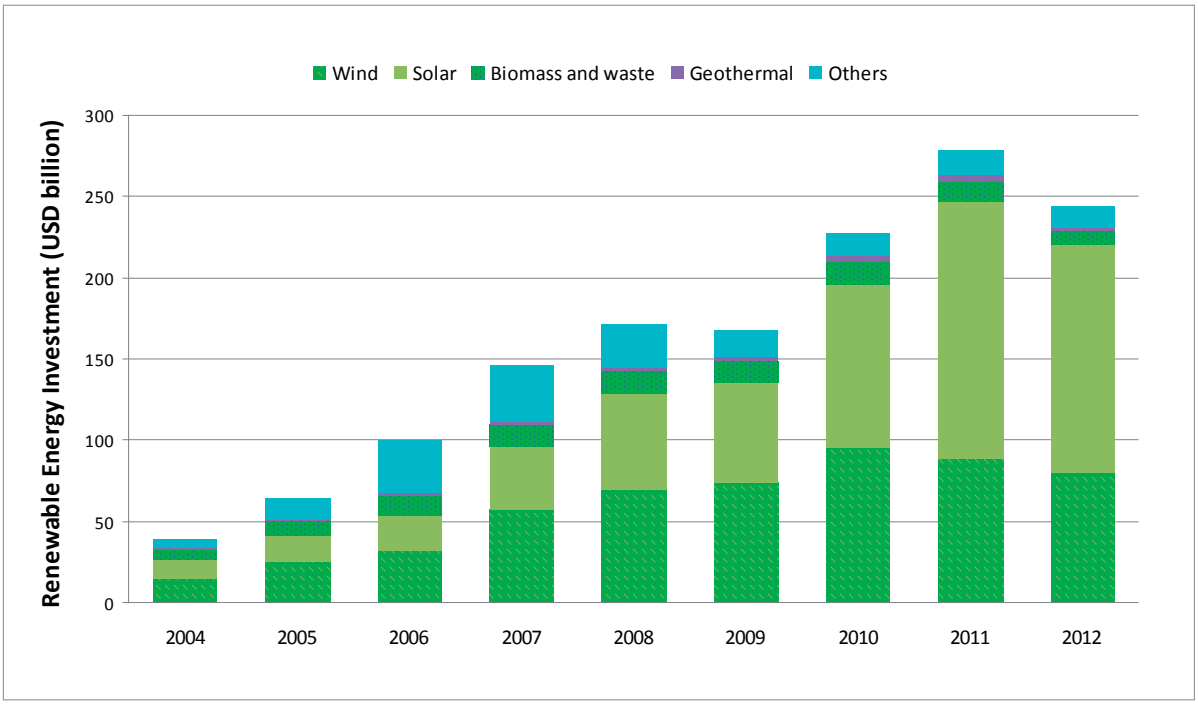

Figure 2-4. Trend in renewable energy investment

(Source: Bloomberg New Energy Finance (2013); ITRI/IEK Analysis)

The improved cost competitiveness of solar and wind also helps spread the technology from developed countries such as Germany and USA to emerging economies such as Brazil and South Africa. As Figure 2-5 indicates, developed countries accounted for 80% of the renewable energy investment in 2004, the figure dropped to 54% in 2012. The trend shows that the majority of renewable energy investment will come from developing countries in the next few years.

Figure 2-5. Developed vs. developing countries in renewable energy investment

Note: developed countries are based on OECD countries excluding Mexico, Chile and Turkey.

(Source: Bloomberg New Energy Finance (2013); ITRI/IEK Analysis)

Energy Efficiency

In addition to supply-side options, improving energy efficiency in buildings, industry and transport, etc. is essential to achieving a sustainable energy future. Policies to improve the efficiency of energy use usually deliver quick benefits such as cutting household energy bills, enhancing industrial competitiveness and reducing local air pollution. However, since efficiency is difficult to be seen or priced, energy efficiency measures, though very important, are not as visible as supply-side options.

According to World Energy Council, the global final energy intensity, measured as the amount of energy consumed to produce a unit of GDP, declined gradually from 0.165 koe/$05p in 1990 to 0.117 koe/$05p in 2011, decreasing 1.62%[8] annually , as Figure 2-6 shows. The decrease in energy intensity is primarily driven by technological advancement that improves the energy efficiency of energy-consuming equipment, such as vehicles, appliances, heating facilities and manufacturing processes. Increasing government policies such as energy efficiency standards, financial incentives, and promotional policies accelerate the energy efficiency improvement. In addition, rising energy prices and more intense market competition also force the enterprises to lower their energy consumption.

[8] WEC (2013), World Energy Insight 2013, World Energy Council, London, U.K.

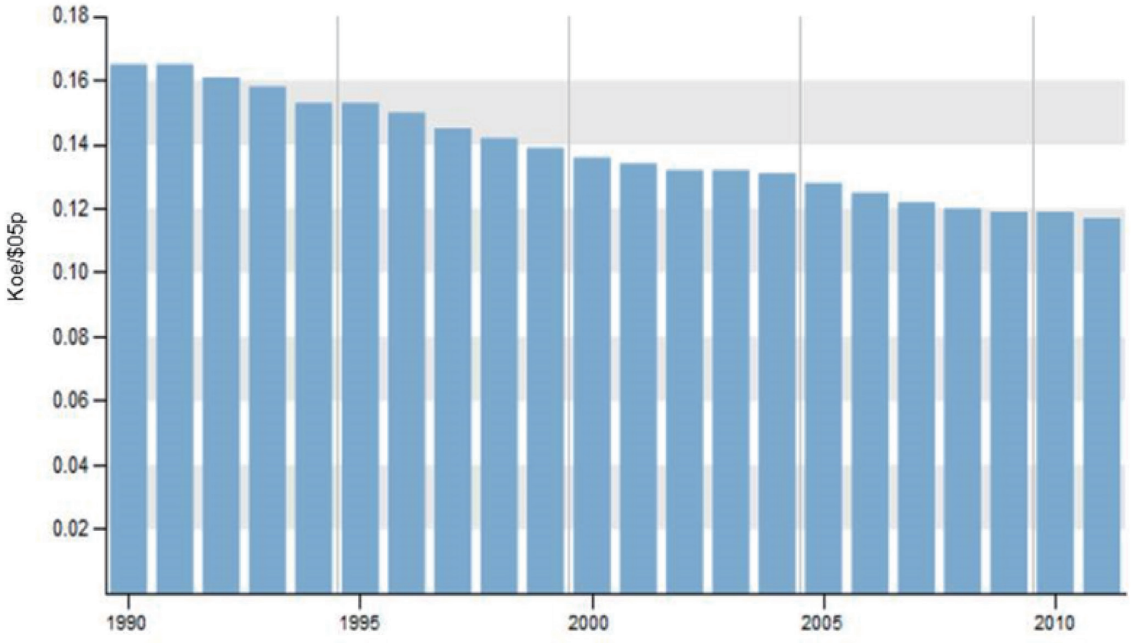

Figure 2-6. Global final energy intensity trend, 1990-2011
(Source: WEC (2013); ITRI/IEK Analysis)

Buildings, industry and transport are three major sectors of energy consumption, with each consuming about one third of the global final energy use. Methods to reduce energy consumption can be grouped in three categories: policies such as rising energy prices that lead to reductions in the demand for energy services; promoting fuel and technology switching products such as heat pumps to reduce energy consumption; and focusing on energy efficiency improvements, i.e. providing the same energy services with more energy efficient technologies.

Lighting is a major energy consumer in the buildings sector. According to IEA, lighting represents around 15% of electricity consumed in the residential sub-sector and about 25% of electricity used in the services sub-sector. In developed countries, lighting typically represents less than 20% of residential electricity consumption and less than 25% of services electricity consumption. However, in developing countries, lighting can represent as much as 45% of electricity consumption in buildings.[9] Lighting has significant energy efficiency improvement potential, especially in the services sub-sector. This report will give special focus on LED lighting, an emerging high efficiency lighting technology that is already economic in certain markets.

▶2.2 *Main Promotional Policies*

Renewable Energy

The main purposes for renewable energy investment are for energy independence, economic stimulation and increase of the employment rate. Therefore small-scale deployment is encouraged through subsidies even when cost of renewable energy is significantly above grid rate. The incentives are expected to allow the industry to achieve economies of scale and eventually reach grid parity. Incentives to encourage renewable energy installation include financial incentives and regulatory policies. Depending on local policies, some incentives are offered in combination.

[9] OECD/IEA (2013). Transition to Sustainable Buildings, International Energy Agency, Paris, France.

Financial Incentives

Financial incentives for renewable energy include subsidies and tax incentives. With investment subsidies, the government refunds partial cost of system installation. Subsidies are paid according to the nameplate capacity of the installed system and not according to actual power yield over time.

Production Tax Credit (PTC) and Investment Tax Credit (ITC) are important incentives for utility-scale projects, most commonly initiated in markets with mature tax frameworks such as the United States. PTC is a commercial tax credit that applies to bulk wind electricity generators based on the amount of energy they generate. ITC is a tax credit for certain investment types such as wind farms.

Regulatory Policies

Regulatory policies are the most common ways of promoting renewable energy. Major methods include feed-in-tariffs (FIT), utility quota obligation, net metering and renewable energy certificates. With FIT, the utility company buys electricity from the renewable energy power generator under a multiyear contract at a premium rate but does not fund system installation. This incentive system rewards actual kWh produced over time at a price that exceeds the price of grid electricity. However, the current trend in most countries is to reduce FIT rates year by year based on shifting economic and market conditions.

Net metering is a policy designed to encourage private investment in renewable energy. Originated from the United States, net metering program serves as an important incentive for consumer investment in on-site renewable energy generation. It enables customers to use their own generation from on-site renewable energy systems to offset their consumption over a billing period by allowing their electric meters to turn backwards when they generate electricity in excess of their demand, enabling customers to receive retail prices for the excess electricity they generate[10].

Under the Renewable Portfolio Standard (RPS), utilities are obligated to generate a certain amount of electricity from renewable sources or purchase Renewable Energy Certificates (REC) on the open market to fulfill this requirement. For instance, the Solar REC (SREC)[11] program is a way for solar energy credits to be created for each MWh of electricity produced. SRECs could be sold to electricity suppliers needing to meet their RPS quota. The sales of SRECs are intended to promote the growth of distributed solar systems by shortening the time for the system to make a positive return.

Energy Efficiency - Lighting

Lighting is one of the heaviest aspects of energy consumption and an obvious target for energy efficiency programs. With energy efficient equipment and lighting practices, there is high cost effective savings potential. Policies that address efficient lighting are generally targeted at the energy performance of certain lighting components. Specific programs or certifications are initiated to promote the performance of entire lighting systems or to transform the current lighting market. Two most important movements in promoting efficient lighting are the use of energy labels, ratings and certification schemes, and the global shift of incandescent light bulbs to LEDs.

Energy labels show the efficiency of the product as defined by a common metric, and inform consumers about the energy use and environmental impacts of their purchases. There are three main types of labels: comparison labels, endorsement labels and eco-labels. Comparison labels indicate the energy efficiency of a product relative to its competitors on the market and are mostly mandatory. Endorsement labels, also known as quality marks, are affixed on

[10] Net Metering (2011). US Department of Energy. Retrieved from http://apps3.eere.energy.gov/greenpower/markets/netmetering.shtml.
[11] NREL (2011). Solar Renewable Energy Certificate (SREC) markets: Status and Trends, National Renewable Energy Laboratory, Denver, U.S.

products that meet or exceed a certain level of energy efficiency. Eco-labels indicate the environmental parameters associated with the manufacturing, use and disposal of a product. Energy labels are usually designed to be displayed at the point of sale, specifying the performance of the model. However, many products are never presented to the end-user and installed internally. In this case, energy ratings are indicated in product directories or promotional materials rather than displayed on the product itself. Certifications are usually administered by a reputable third party such as government or industry associations or non-governmental organizations.

The banning of low efficiency incandescent light bulbs began in 2005 with Brazil and Venezuela. The Energy Independence and Security Act (EISA) of 2007 detailed changes in lighting legislation for the United States. The EISA regulated performance standards and the phase-out of incandescent lighting to require the use of more efficient lighting equipment. Efforts to increase lighting efficiency were also demonstrated by the Energy Star program and efficiency goals by 2011 and 2013. In 2009, the European Union started the promotion for energy labels for lighting and joined the bandwagon for restricting incandescent bulbs, it is expected that the transition from incandescent to energy efficient lighting will succeed by 2016. Various regulations and restrictions have enhanced sales for new compact fluorescent lamps (CFLs) and LEDs.

▶2.3 Current Status and Future Trend of Major Green Energy Technologies

Solar PV

The global solar PV market has expanded remarkably since 2010. According to statistics released by the European Photovoltaic Industry Association (EPIA), at the end of 2009, the world's cumulative installed PV capacity was about 24 GW. By the end of 2012, more than 100 GW of PV were installed globally, with about 70 GW installed in Europe, followed by P.R.C. (8.3 GW), the USA (7.8 GW) and Japan (6.9 GW)[12] – refer to Figure 2-7 for global cumulative solar PV installation. Europe will remain the largest market for solar PV in

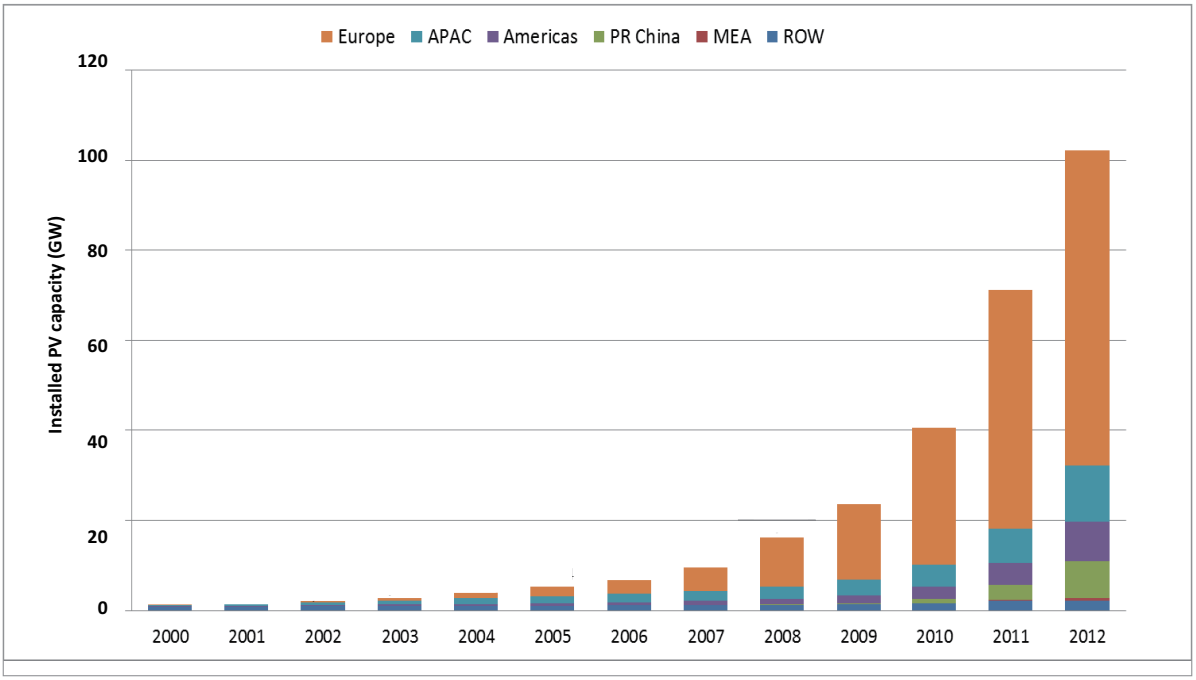

Figure 2-7. Global cumulative solar PV installation, 2000-2012

Note: APAC-Asia Pacific, MEA-Middle East and Africa, ROW-rest of the world

(Source: EPIA (2013))

[12] EPIA (2013). Global Market Outlook for Photovoltaics, 2013-2017, European Photovoltaic Industry Association,

the foreseeable future, however, its market share will decrease continuously as falling prices in the initial investment cost of PV systems is expanding the technology to new markets such as Latin America and Asia Pacific.

Mainstream PV applications include ground-mounted PV systems, commercial rooftop systems and residential rooftop systems. Ground-mounted systems are mostly utility-scale projects built over vast amount of land, very often desert regions, polluted areas or waste lands. The installed capacity of ground-mounted systems could range from 1 MW to several hundred MW. Commercial rooftop systems are installed over commercial buildings such as municipal structures, school rooftops, airport terminals, and factories, etc. The installed capacity of commercial rooftop systems is usually between 10 kW and 2 MW. Residential rooftops systems are generally less than 10 kW, due to the limited rooftop space for panel installation. Residential PV systems could subsidize household electricity and the owner could also sell generated power through the grid to the utility provider.

The selection of different solar PV application types is closely related to government policies, consumer preference and natural conditions. Generally speaking, markets with abundant flat land that could be obtained at low cost are suitable for developing utility-scale ground-mounted systems. Populated areas are suitable for rooftop systems. However, government polices play the decisive role in determining the local application market trend. According to the research by Industrial Economics and Knowledge Center (IEK), out of the 31 GW new installations in 2012, 42.4% are commercial rooftop projects, 37.8% are ground-mounted PV systems, and 19.6% are residential rooftop installations[18].

Commercial rooftop systems are mostly installed on the roofs of office buildings, plants, school buildings, superstores, and hospitals. The large areas of commercial rooftops are ideal for installing solar panels. If the electricity generated by PV systems is used to support part of the building electricity demand, it also helps decrease the electricity expenses of the commercial entities as well as reduces the CO_2 emission of the buildings. In addition, since the installation of PV systems can also increase the value of buildings, it is quite attractive for companies, schools, supermarkets, etc. to install PV systems on their building rooftops. Therefore, the market share of commercial rooftop systems has remained steady since 2010 at around 40-50%, higher than the share of other types of installations. Stable power generation performance, high rate of return on unit area, reasonable operation and maintenance cost and precise prediction on electricity generation are important factors for commercial users. Most commercial rooftop projects are currently located in Germany, France, P.R.C. and USA, with India and Australia also potential markets with high growth.

Ground-mounted applications are most preferable in countries that have just launched PV promotional policies due to its relatively low power generation cost. Fast-developing PV markets such as P.R.C., Japan, India, USA, South America and the Middle East have become the new investment targets for ground-mounted PV plants. Although the availability of vast idle lands is essential for developing ground-mounted applications, government incentives play decisive role in stimulating the market growth. Japan is the most notable case for promoting ground-mounted PV plants even if the country is highly populated and its sunshine conditions are not as good as those in India or California. The high feed-in tariff rate launched after the nuclear accidents caused by the disastrous Tohoku 3/11 earthquake in Japan has attracted large and medium-sized enterprises to turn their idle lands into the sites of solar PV plants. Since July 2012, the total approved capacity for utility-scale PV plants above 1 MW has exceeded 19 GW. However, in Europe, the traditional leading PV market, government policies have intentionally cut the feed-in tariff rates of ground-mounted applications and raised the rates of rooftop systems to encourage the commercial and residential applications.

[18] IEK (2011). Global Energy and Green Industry Trend Outlook, Industrial Technology Research Institute.

Due to the small system capacity, the market share of residential rooftop systems remains the lowest at around 20%. High system efficiency is the top priority for consideration in selecting residential rooftop systems. Furthermore, the quality and appearance of modules, as well as maintenance services are also very important for family users. In high labor cost area such as Europe, the requirement for system quality is even higher in order to reduce maintenance expenses. Led by Germany, a number of European governments have been strengthening the support policies for residential systems to encourage household power generation while reducing the subsidies for ground-mounted PV plants. In 2013, Germany officially launched the policy to provide subsidies for energy storage facilities of PV systems, signaling the market trend toward residential applications. As more governments inaugurate policies that subsidize power generating households, slow but steady growth can be expected for residential rooftop systems.

Wind Power

In 2012, more than 40 countries installed a combined 45 GW wind turbines raising total installed capacity to 282.5 GW, as shown in Figure 2-8. Europe, Asia and North America accounted for 38%, 35% and 24% of the accumulated installation respectively[14].

The wind power market is heavily influenced by local policies and geographic factors. In 2012, the United States surpassed P.R.C. as the largest market in terms of new installations. Compared with 2011, wind installations on the American continent grew by a total of 12.3%. Together, the United States and the P.R.C. accounted for nearly 60% of global wind market in 2012. Germany, India and U.K. are distant followers. Others in the world's top 10 of newly added capacity are Italy, Spain, Brazil, Canada and Romania. All together, the top 10 countries accounted for more than 85% of the global capacity, but the market is

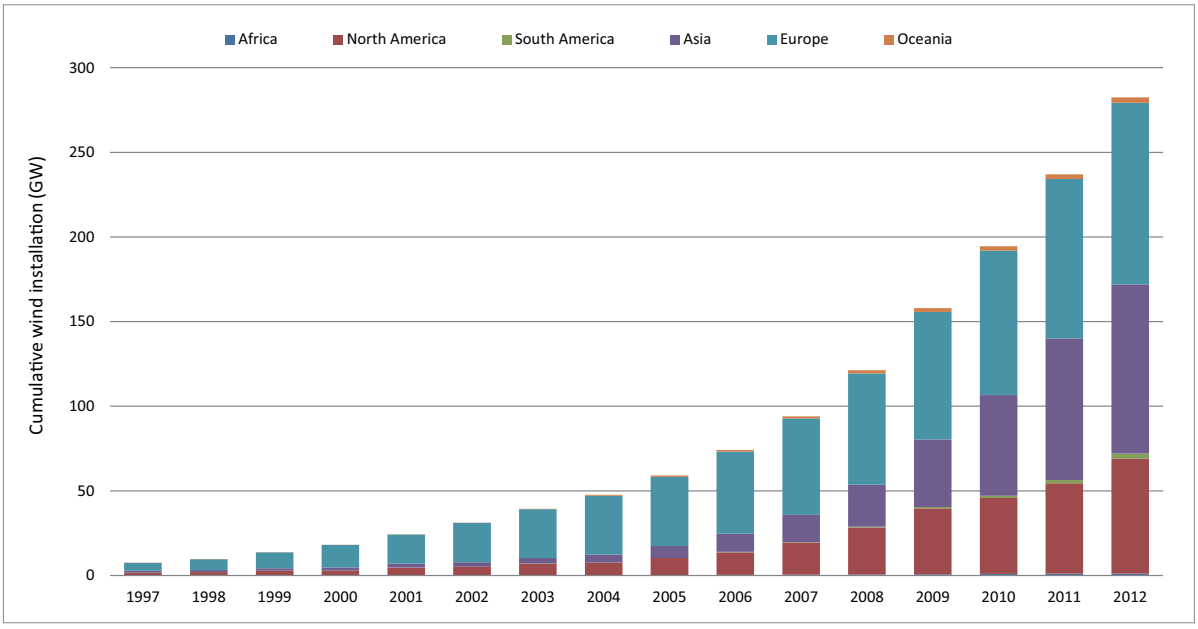

Figure 2-8. Global cumulative wind power installation (GW), 2000-2012

(Source: thewind.power.net)

[14] IEK (2013). 2013 Global Wind Power Generation Technology Development Trends, Industrial Technology Research Institute.

continuing to broaden, reaching emerging markets in the form of small or hybrid wind power systems. As the wind market continues to evolve, the penetration of wind power in the world's electricity supply has reached 2.62%[15].

There is also a big shift in the rankings of the top 10 wind turbine suppliers. Chinese companies now have a strong presence in the top 15 wind turbine suppliers. The European wind power industry has refocused on off-shore technologies and is now seeking development in Eastern Europe and other emerging economies. By 2013, Brazil was home to 11 turbine manufacturing plants and India had 19 plants with aggregate annual production capacity over 9.5 GW. However, the manufacturing industry was affected by reductions in government support, overcapacity and rising material costs. US companies in the wind energy supply chain closed facilities due to policy uncertainty. Danish manufacturer Vestas has been displaced from the No. 1 position for the first time since claiming the top spot in 2000[16].

By application, land-based installations are still the mainstream with 96.8% market share of all installations. Only 3.2% of the installations in 2012 were off-shore projects. The installation capacity of off-shore wind turbines is more than doubled that in 2011, with more than 4 GW currently under construction. However, the technology for off-shore wind turbines is still in development, with most installations only pilot projects.

According to BTM Consulting, 242 GW of new wind capacity will be added through 2017. The average growth rate for new installations from 2013 to 2017 is expected to be 5.1%. Due to technological innovation, wind energy costs are now lower than that of most other renewable energy sources and close to competitiveness with new coal and gas power generation. About 75% of the cost of a wind farm is related to installation costs of the turbine tower, electrical equipment and grid connection and has low ongoing cost.

Key driving forces in the wind power market are government subsidies and policy support. Though there are also market obstructions due to lack of grid infrastructure in emerging markets and cost competition with traditional energy sources. However, there is increasing concern in substitutes. Many wind power countries use natural gas as a substitute energy source. Therefore the willingness for wind power installation is affected by natural gas prices.

LED Lighting

2011 marked a milestone year for LED lighting as the efficacy achieved by the best available 1 W commercial package exceeded 100 lm/W, a threshold for LEDs to be adopted in general lighting. In 2012, Cree, the leading LED company, announced it had commercial products that could achieve 200 lm/W. The efficacy of LEDs is no longer a barrier for general lighting applications. Cost has become a decisive factor for market expansion.

According to the research by McKinsey, the global LED lighting market was estimated at USD 6 billion in 2011, and grew 73% to USD 10.4 billion in 2012. With the strengthening policy support and continued price reduction, the market scale is expected to reach 46 billion in 2017, with annual average growth rate of 49%[17].

Figure 2-9 shows the trend of the market shares of different LED lighting applications. Residential is the largest sector for LED lighting application, accounting for 35% of the total LED lighting market in 2012, with market size of around USD 3.6 billion. It is estimated the residential sector will grow to USD 20.7 billion in 2017, or 45% of the LED lighting market. The

[15] IEK (2013). 2013 Global Wind Power Generation Technology Development Trends,Industrial Technology Research Institute.
[16] Wind Energy Foundation. Retrieved from: www.windenergyfoundation.org
[17] McKinsey & Company, Inc. (2012). Lighting the way: Perspectives on the global lighting market, Vienna, Austria

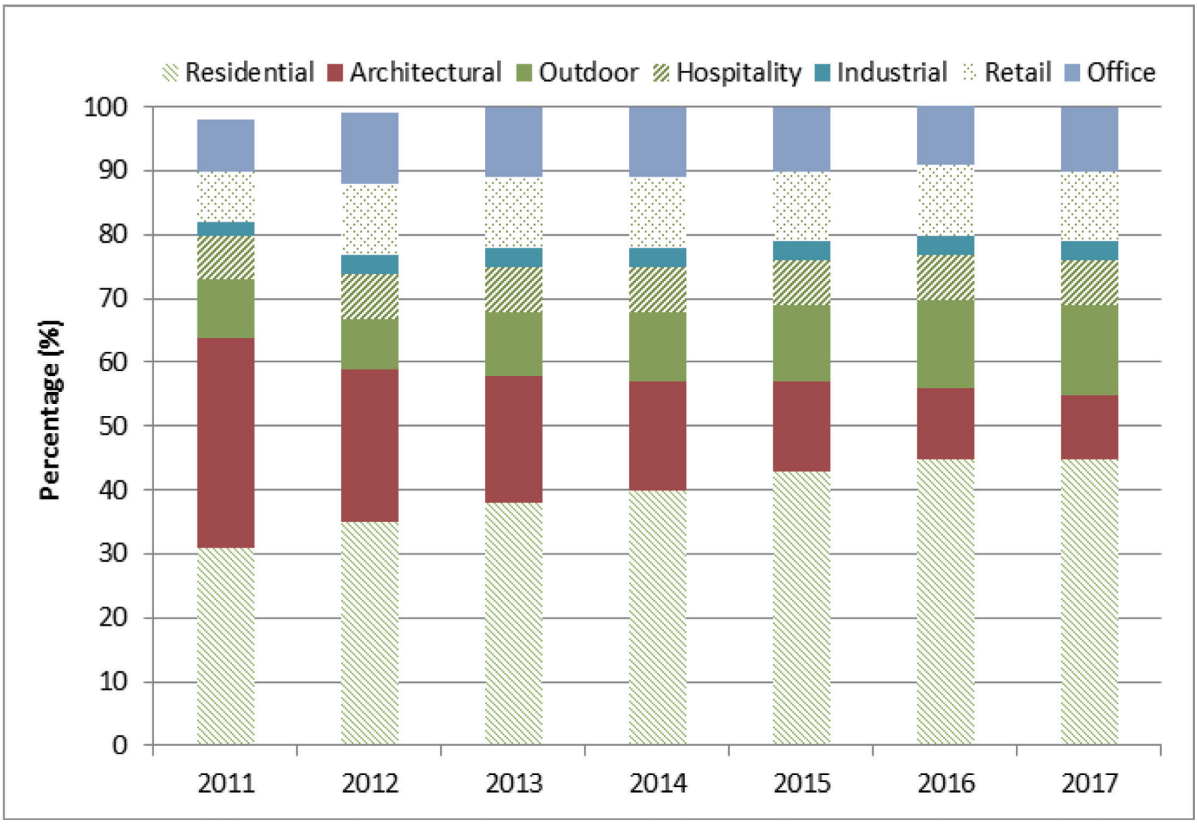

Figure 2-9. Global LED lighting application market trend, 2011-2017

(Source: McKinsey, ITRI/IEK Analysis)

application of LEDs in architectural lighting has been saturating gradually, further market penetration into this sector would be limited. Niche markets such as outdoor, hospitality and retail are expected to grow, albeit slowly, due to falling LED prices and higher efficiency. Lighting for industrial purposes requires strong, all-encompassing illumination, which is not an advantage of spot light sources such as LEDs, therefore the industrial market share of LED lighting maintains at only 3%. Although office lighting has a big potential market, without strong incentives, private companies are usually reluctant to switch to LEDs due to high initial investment. Therefore, the market share of office lighting sector is estimated to remain at around 10%.

By geographic region, Asia, Europe and North America are top three LED application markets in the world. With high population and strong policy support, Asia is the largest LED lighting market. The market value in 2012 was estimated at USD 4.7 billion, accounting for 45% of the global LED lighting market[18]. P.R.C. and Japan, the two largest LED lighting markets in Asia, both have active support policies. P.R.C. promotes LED streetlamps in major cities and has subsidy programs for LED lighting. After the 3/11 earthquake, Japan also launched more progressive policies supporting applications of LED lighting. Emerging markets that have high economic growth and increased investment in local infrastructure would stimulate development opportunities. Emerging economies in the Southeast Asia are particularly

[18] IEK (2013). 2013 Global LED Component Industry Review and Outlook, Industrial Economics and Knowledge Center, Industrial Technology Research Institute.

attractive investment spots for the LED lighting businesses in East Asia. As incandescent light is scheduled to be faded out by 2016, the demand for high efficient LED lamps will grow. It is estimated that the LED lighting market in Southeast Asia will reach at least USD 750 million by 2016.

The European market is traditionally more willing to pay higher price for renewable energy and energy efficient products. The penetration rate of LED lighting is higher in Europe than in any other region. The European LED lighting market size reached USD 2.9 billion in 2012, accounting for 28% of the global market. North America is a more price-sensitive market than Europe. The region's LED lighting market size reached USD 2 billion in 2012 with 19% of the global market share.

Latin America, the Middle East and Africa are still relatively small markets for energy efficient lighting. Although some countries in these regions have initiated support policies for LED lighting, the actual impact on the market is still very low. It is estimated that these emerging markets would take 10% of the global market share by 2017.

Bioenergy

Other than being a source for fiber, livestock feed and food, biomass is now the world's fourth largest source of energy, after oil, coal and natural gas and accounts for over 10% of global primary energy. Global total primary energy from biomass increased 2-3% to 55 EJ in 2012. Traditional biomass is generated into useful heating such cooking, but suffers heavier end-use losses through burning. Heat from modern biomass can be sold or used on-site for buildings and industry, and other forms of energy such as electricity and biofuels can be stored, transported and used in other formats. In comparison with 2011, there was 1-2% increase in bio-heat production for building and industry sectors worldwide. Electricity generation from bioenergy, including combined heat and power plant production, increased by 4%, while biofuel production declined by 1%[19].

By the end of 2012, global capacity of bio-power neared 83 GW, a 12% rise from 2011, with significant increases from emerging economies. By averaging national bio-power generation over the 2010-12 period, the US ranked number 1 with a significant

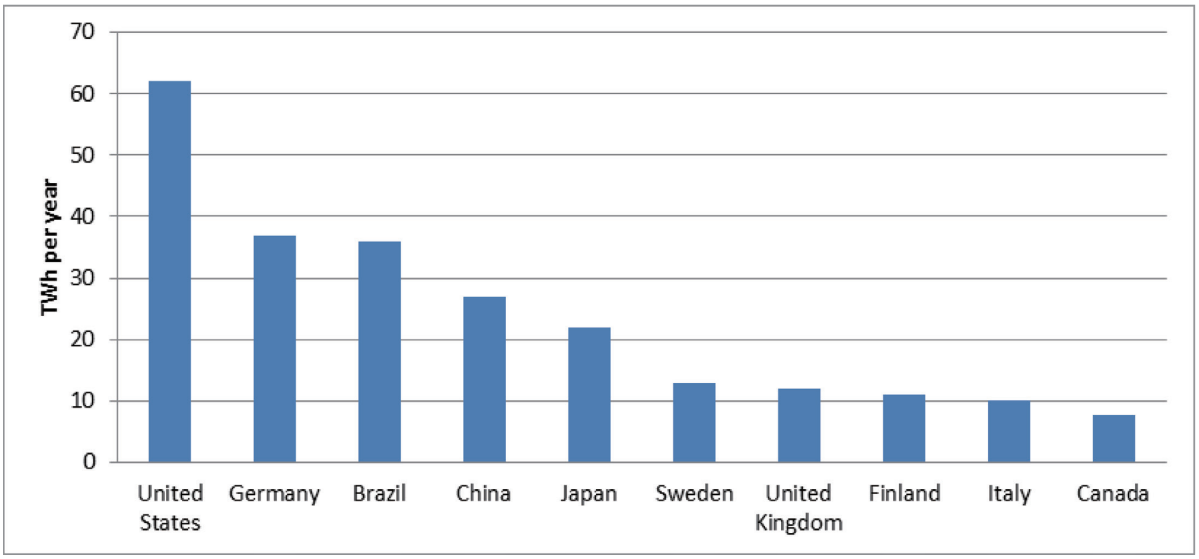

Figure 2-10. Top 10 bio-power generation countries, annual average 2010-2012

(Source: REN21, ITRI/IEK Analysis)

[19] REN21 (2013). Renewables Global Status Report 2013, Renewable Energy Policy Network

lead, with Germany second, while Brazil and China followed close behind. In the US, 100 new bioenergy projects of 543 MW were implemented in 2012, bringing total capacity of bioenergy in the US to 15 GW, around 18% of global supply. Germany increased its bioenergy generation to 41 TWh in 2012, with half coming from bio-gas. Brazil increased its bio-power installed capacity by 8% in 2012 to 9.6 GW and generation rose to 40TWh. China, an energy powerhouse in Asia, increased capacity by 14% to 8 GW in 2012 (Figure 2-10). While the US has a steady lead in bioenergy capacity, new construction is slowing in Germany while production is accelerating in emerging countries.

The broad definition of the bioenergy industry includes biomass suppliers and processors, delivery firms, manufacturers and distributors, and manufacturers of appliances for the harvest or conversion of bio-materials. Many players in the supply chain use technologies that are not exclusive to bio-energy production, such as harvesters, trucks and steam boilers. The bio-refinery industry is a growing sector because of the increased value and profitability of co-producing other products from biomass feedstocks while reducing GHG emissions.

Geothermal Heat and Power

Geothermal resources produce energy in the form of electricity and direct heat. In 2012, a total of 223 TWh was supplied globally through geothermal, two-thirds of the output was used as direct heat, while one-third was delivered as electricity. Direct use of geothermal energy for heating cooling continued to increase globally. Although available data on geothermal energy growth is limited, output of direct use is known to have grown by an average of 10% annually from 2005 to 2010. Assuming that the growth rate remained consistent during 2011 and 2012, global geothermal heat capacity has reached about 66 GW worldwide by the end of 2012[20]. China is the presumptive leader in direct geothermal heating with 21 TWh in 2010, followed by the US with 18.8 TWh, Sweden, Turkey and Iceland ranked third, fourth and fifth in geothermal use respectively.

Data for geothermal electricity generation is more easily acquired. In 2012, global geothermal electricity generating capacity grew by 300 MW and reached 11.7 GW in total, with contributions from the US (147 MW), Indonesia (110 MW), Nicaragua (36 MW) and Kenya (7.5 MW). The new geothermal facility in the US was the first facility to combine solar PV with geothermal generation. Indonesia has large natural geothermal resources but has not added much capacity in recent years. However, Indonesia targets 12.6 GW of geothermal capacity by 2025 and has initiated loans for developers in 2011 to push for a 1,000 MW geothermal investment program, making Indonesia very attractive for geothermal development. The 2012 establishments by Nicaragua is the second phase of the country's San Jacinto-Tizate project, amounting total capacity to 72 MW, which is large enough to supply 17% of the nation's electricity needs. Kenya is the largest producer of geothermal power in Africa and is now entertaining possible public-private partnerships for future projects.

A large number of players in the geothermal heating industry operate in the US and Europe, while manufacturers in the power sector are located around the world. The five leading turbine manufacturers in terms of capacity in operation are Mitsubishi, Toshiba and Fuji of Japan, Ansaldo/Tosi of Italy and Ormat originating from Israel. These five manufacturers account for more than 80% of capacity in operation worldwide. In addition to geothermal giants, many companies also manufacture small scale power units that could be built offsite and integrated into a system later.

[20] REN21, (2013). Renewables Global Status Report 2013, Renewable Energy Policy Network

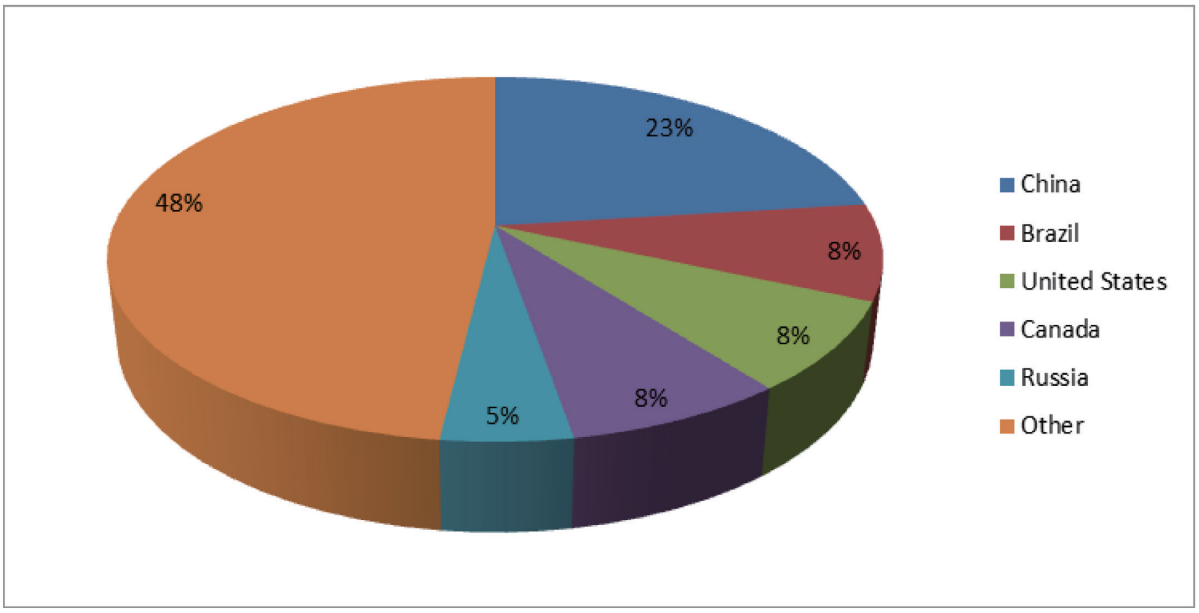

Figure 2-11. Hydropower global capacity, 2012

(Source: REN21, ITRI/IEK Analysis)

Hydropower

About 30 GW of new hydropower installations were added in 2012, bringing total global installed capacity to 990 GW, with an estimated 3,700 TWh of hydroelectricity generated during 2012. Major countries of hydro capacity are China, Brazil, US, Canada and Russia, these five countries account for a total of 52% of total installed capacity. China was the leader of new hydro additions in 2012 with 15.5 GW increase, totaling 229 GW of installed capacity. Hydropower capacity is fast increasing in Turkey with 2 GW added in 2012, ending the year with 21 GW installed. Brazil is third with 1.86 GW put into operation for a total of 84 GW by the end of 2012. Vietnam added 1.8 GW, raising its total capacity to 12.9 GW; its recent operations are working toward completing a 2.4 GW hydropower plant, reported the largest hydropower project in Southeast Asia[21].

Leading hydropower research and manufacturing companies are Alstom of France, Andritz of Austria, IMPSA of Argentina and Voith of Germany, together these companies represent more than half of the international market. Alstom is currently joined with Russian owned RusHydro to initiate construction of a joint hydropower equipment manufacturing plant. IMPSA which holds 30% of the Latin Market in the hydropower sector opened a new unit that doubles its production capacity to meet demand on the continent. Voith on the other hand, increased its focus on research and development of pumped storage technology.

[21] IHA, (2013). 2013 IHA Hydropower Report 2013, International Hydropower Association, UK

3. Core Technologies

▶3.1 PV

Photovoltaic, abbreviated as PV, is a method that utilizes solar radiation to generate electrical power. PV devices can be powered by simply facing sun light, instead of traditional thermal and turbine mechanical process that could generate pollution or noise. By this mechanism, PV possesses a great advantage to penetrate all sunshine areas, even specific fields such as aerospace or residential power. When light shines on a PV panel (or solar panel), the electrons within the devices will be agitated and directed by circuits, then transform to alternating current by inverter for users (Figure 3-1).

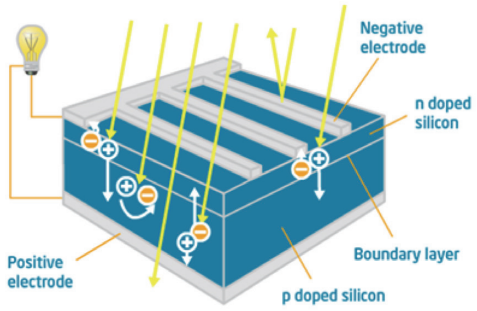

Figure 3-1. PV cell reaction

The generation efficiency depends on the technology of the solar cell. So far, four major PV technologies have been commercialized: crystalline silicon, silicon thin-film, cadmium telluride (CdTe) and copper indium gallium selenide (CIGS). There are also some other special types such as concentrated PV, dye sensitized solar cell and organic PV. The performances and features of major technologies are listed and compared in Table 3-1.

	Christalline-Silicon	Silicon Thin-Film	CdTe	CIGS
Best efficiency records in lab, %	Mono-25.0 Multi-20.4 HIT 23.0	a-Si 12.5 Multi-Junction 16.7	18.0	20.8
Best efficiency records of commercialized module, %	SUNPOWER 20.1	NexPower 9.7 (Tandem) SHARP 9.1 (Tandem)	First Solar 11.1	Solar Frontier 12.2 Q-Cells 12.3
Cost per Watt (module), USD	0.65	0.68	0.7	About 0.8
Market positioning	Rooftop/general	Power plant/BIPV	Power plant	General/power plant

Table 3-1. Important features of major PV technologies (2012)

(Source: ITRI/IEK (2013/12))

C-Si Technology

C-Si (Figure 3-2) is the most mature PV technology in the current market. Its stable production process makes it more reliable in performance and easier to lower the cost by scale of economies. The value chain of C-Si products can be divided into four production stages - polysilicon, wafer, cell and module.

Polysilicon is the purified silicon material that can be used to produce semiconductor and solar cell. Polysilicon plants are usually set up in the desert or petro-chemical industrial regions to avoid silane poisoning since the toxic gas is produced in the manufacturing process. Wafer, made from polysilicon, is the base material of C-Si solar cell. The manufacturing process composes of two steps - crystal-growing or casting, and slicing to chips under 200 m in thickness and 156 x 156 mm in dimension. C-Si cell production is the key stage that affects the performance of solar panels. The wafer is coated with silver and aluminum pastes and goes through wet etching, diffusion, anti-reflection deposition, screen printing and metallization process to form P-N junction devices. Such fabrication process is similar with that of semiconductor technologies.

C-Si module (Figure 3-3) is the so-called “solar panel”, the end product to sell to consumers. In this stage, C-Si cells are assembled and packaged using materials such as wire, glass, encapsulation and backside protection films, and attached to a junction box on the panel to conduct electricity to the inverter. A 240-250 W module (assembled by 60 pieces of cells) could be 20-30 kg in weight.

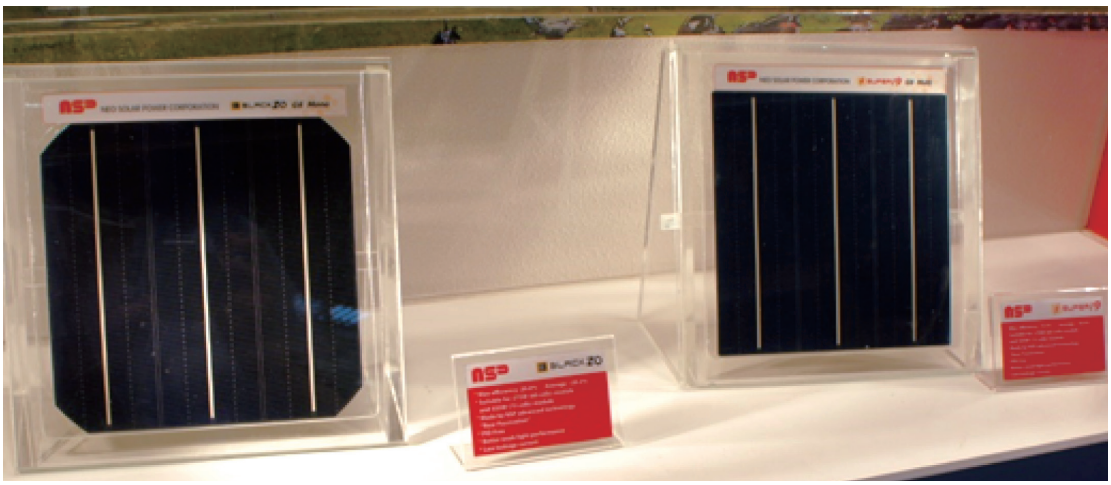

Figure 3-2. C-Si solar cell

(Source: Neo Solar Power)

Figure 3-3. C-Si solar Module

(Source: Inventec Energy)

Thin-film Technologies

Thin-film solar technologies possess advantages such as light weight, fewer material consumption, and potential flexibility, so that it differs from C-Si and could reach some special application markets. However, due to lower efficiency and higher cost, thin-film products are currently used in limited fields, especially in ground-mounted power plants.

Among three major thin-film technologies, CdTe is the most successful and occupies almost half of the thin-film market. First Solar, the global leader in this field, is dedicated to scaling up and driving down the cost of this product, and has made CdTe more competitive with C-Si or other thin-film products. However, since it contains the toxic element cadmium with potential adverse environmental impacts, its applications are kept away from residential areas.

Silicon thin-film is the earliest commercialized PV technology (Figure 3-4). Since 1970s, the technology has been used to power some small electronic items like table calculators. Between 2007 and 2008 when the silicon price sky-rocketed, the expansion of the production scale was greatly accelerated. After the investment fever cooled down and the industry began restructuring, only a few companies survived and tried to focus the application to specific areas such as BIPV (building-integrated PV).

Figure 3-4. Silicon Thin-film solar module (transparent BIPV type)
(Source: NexPower)

With 13-14% efficiency, CIGS (Figure 3-5) has the potential to compete with C-Si for commercialized thin-film products. It had initiated another investment boom after silicon thin-film. However, the complicated fabrication caused by four-element-composition (copper, indium, gallium, and selenium) has slowed down the mass production progress. Many start-up companies are currently dedicated to this technology.

Figure 3-5. CIGS solar module
(Source: TSMC Solar)

▶3.2 Wind Turbine

Wind turbines, also commonly called wind energy conversion systems in Europe, are apparatuses extracting energy from the wind and originated in ancient old civilizations like Persia and China. Historically, wind energy has been applied in agricultural irrigation, grain-milling and ship-sailing. Modern wind turbines feature high energy conversion efficiency and low cost of energy, and therefore have been installed more than any other types of renewable energy facilities during the recent two decades. Nowadays wind farms or wind parks with clusters of wind turbines are often installed in wind-abundant areas like coasts or hills and function like traditional

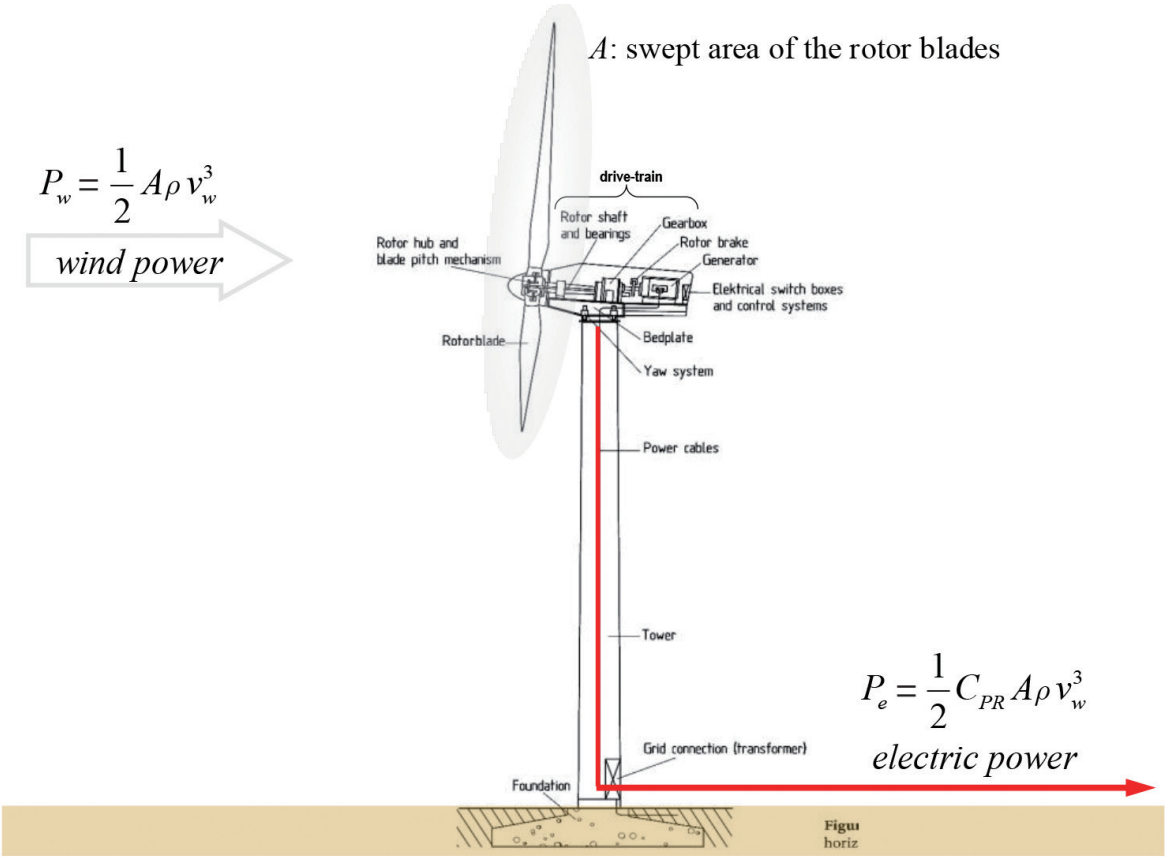

Figure 3-6. A typical large wind turbine and its power flow

(Source: ITRI)

power plants to generate huge amount of electricity. They have become new terrain sceneries in countries that pursue sustainable energy policy.

As shown in Figure 3-6, a typical wind turbine generally consists of rotor blades, a drive-train, gearbox and coupling, a generator, a power converter, a tabular or lattice tower, and a foundation. The rotor blade is the most critical component that dominates the system efficiency of a wind turbine, thus to attain competitive performance. The rotor blade shall be designed in accordance with the latest technology development in aerodynamics, aeroelasticity, composite materials and structure dynamics.

Based on the orientation of the center axis of the rotor blades, wind turbines can be categorized as either horizontal type or vertical type:

- Vertical axis wind turbine: the center axis is vertical to the inflow wind and the rotor blades can be rotated by 360° inflow winds around the wind turbine.
- Horizontal axis wind turbine: the center axis is parallel with the inflow wind and the wind turbine must provide a passive or active yaw mechanism for aligning the rotation plane of the rotor blades with the inflow wind.

Due to the high efficiency and aesthetics of balance, the three-bladed horizontal axis wind turbine is now the most popular.

Drive-train aspect of wind turbines

The tangential tip speed of rotor blades generally is limited to about 80 m/s due to system design considerations, thus the rotational speed of rotor blades becomes slower as the length of the rotor becomes larger. A large wind turbine normally has a rated rotational speed of less than 30 rpm, while an off-the-shelf electric generator generally has a rated speed between 1400-2100 rpm. So if a generator based on the traditional design is preferred, it is often necessary to mount a step-up gearbox inside the wind turbine nacelle to increase the shaft speed to meet the specification of the generator. Thus a traditional drive-train is generally composed of a main shaft, main bearings, a step-up gearbox, and a coupling. The design of a drive-train is very complicated and must take into consideration the loading spectrum, the support mechanism and the layout of drive-train, and cover the detailed analysis and synthesis of the gearbox with the associated relevant issues of lubrication, cooling and maintenance.

Innovative designs on the drive-train to enhance the reliability and mitigate the troublesome maintenance burdens have been proposed continually and realized successfully in some commercialized wind turbines. Based on the drive-train designs, wind turbines can be categorized as below:

- Traditional geared wind turbines: to fit the traditional rated speed of the generator as mentioned above, a step-up gearbox of a high gear-ratio (about 90-125) is adopted in this design. This is the most mature approach.
- Compact geared wind turbine: a compact or integrated gearbox with a gear-ratio of 10-35 is adopted and the generator must be designed to cope with it. This approach is claimed to have the highest power/mass ratio and improved reliability, thus becomes the most popular one among the new drive-train designs.
- Gearless or direct-drive wind turbines: There is no step-up gearbox in this design, and the generator becomes the heaviest critical component in the wind turbine. The total number of components of a wind turbine can be reduced by half to two thirds, so even if the transportation or lifting can be challenging, the benefits of higher reliability and lower maintenance can usually justify this design.

Quite interestingly, the installed number of gearless wind turbines (Figure 3-7) is similar to that of traditional geared wind turbines in on-shore wind farms of R.O.C.

Figure 3-7. Gearless wind turbines installed in R.O.C. (Source: ITRI)

Speed-control aspect of wind turbines

It is the power converter that adjusts the rotational speed of rotor blades according to the command issued from the wind turbine system controller and thus with the power converter a wind turbine is capable of making the speed of rotor blades variable to track the inflow wind speed and catch as much wind power as possible.

The more significant benefit with a power converter is that the impact loading of the drive-train can be reduced because the speed of rotor blades is allowed to increase so that the inertia of the rotor blades can absorb the extreme wind power from the gusts. Moreover, the power converter can improve the quality of power fed into the grid and support the transmission

system operators to secure the stability of the power system.

On the other hand, however, power converters are mainly composed of power electronics and high speed micro-processors, which can be made advent due to the rapid progress of the semiconductor industry during the last two decades. Most commercialized variable-speed wind turbines therefore did not emerge until this decade and there are still many traditional fixed-speed wind turbines operating in old wind farms. Thus based on the speed-control characteristics, the wind turbine can be categorized as below:

- Fixed-speed wind turbines: The speed variation of rotor blades is normally within 2% of the rated speed of the wind turbine. Only limited power electronics are used.
- Limited-variable-speed wind turbines: The speed variation of rotor blades is within 5-10% of the rated speed, yet with this speed-control range the performance of wind turbine is improved significantly.
- Variable-speed wind turbines: The speed variation of rotor blades is generally over 50% of the rated speed. Almost all the large wind turbines installed today are of this type.

Much progress has been made on modern wind turbines in terms of the length of the rotor blade, the design innovation of drive-trains, and the superior control performance of power converters, etc. However, with more and more wind turbines installed, the negative effects such as noise and visual impacts of wind farms also become social concerns nowadays. To move the large wind farms off-shore into the sea is gradually becoming a compelling mission for countries with limited land area.

▶3.3 LEDs

A LED is a semiconductor device that emits incoherent narrow spectrum light when electrically biased in the forward direction of the *p-n* junction. LEDs are used as indicator lamps in many devices and are increasingly used for general lighting. LEDs can be classified into two categories-visible and invisible lights (eg., infrared light). Visible light is at a wavelength of approximately 680-450 nm and invisible light at about 850-1150 nm.

The first LED was discovered by accident in 1907, and LED was introduced as practical electronic component in 1962. In early stages, all devices emitted low intensity red light and were limited only to signal applications. In 1990s, the first blue LED was demonstrated by Shuji Nakamura of Nichia Corporation. After that, white LEDs were created and LED technology developed quickly. There are three methods to generate white LEDs: coating blue LED with yellow phosphor, mixing RGB LEDs, or coating UV LED chip with RGB phosphor. Nowadays, LEDs have the efficiency range of about 120-180 lu/W and are used in different commercial products. By mixing different colored LEDs, LEDs can create a variety of colors. Therefore, LED is regarded as a new light source that will lead to a lighting revolution. Refer to Figure 3-8 for LED value chain and products.

LEDs have many advantages over incandescent light sources, including higher level of brightness and intensity, higher efficiency, low voltage and low electric current requirements, lower heat radiation, higher reliability (resistant to shock and vibration), no UV rays, longer lifespan and can be easily controlled and programmed. However, LEDs that are powerful enough for general lighting are relatively expensive compared to the traditional light source, and require more precise electric current and heat management than the CFL for comparable output.

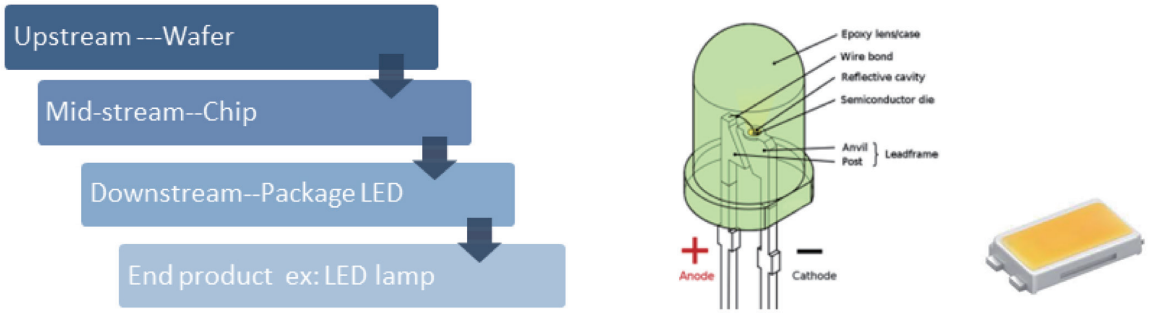

Figure 3-8. LED value chain and products

(Source: LED Companies)

When LEDs are categorized by performance, they can be divided into low-, mid- and high-power types, depending on specification; or into normal brightness or high brightness. Also, by packaging method, LEDs can be categorized into four main types, including: Lamp, SMD (Surface Mount Device), COB (Chip on Board) and display. Based on different application requirements, LEDs are designed in different sizes, driving current, power, and heat dissipation methods. Currently, SMD type is the mainstream while COB is increasing in lighting application.

Lamp LED is the traditional LED packaging type and is used in several different applications such as indoor/outdoor display, traffic signal, Christmas tree lamps and indicator lighting for consumer application. SMD LED has two types: side-view type and top view type. It is mainly used for handset panel and LCD panel

	Low Power	Mid Power	High Power	Jumbo LEDs/ Multichip Arrays
Specification	Driving Current: 5-20 mA Bias voltage: 2.9 to 3.5 V Power < 500 mW Brightness: 4 to 15 lm	Driving Current: 50-150 mA Bias voltage: 2.9 to 3.5 V Power: 0.5 to 1 W Brightness: 12 to 65 lm	Driving Current: 350 mA Bias voltage: 2.9 to 3.5 V Power: 1 to 3 W Brightness: 70 to 120 lm	Driving Current: 350 mA Bias voltage: 2.9 to 3.5 V Power: 1 to 3 W Brightness up to 6000 lm
Packaging Type	Lamp SMD	SMD	SMD	COB Power package-arrays
Application	Mobile phone: keypad lighting and LCD panel backlight Small LCD panel backlight Signs, large displays	TV backlight Interior Automotive Lighting Large displays General lighting	Automotive head lamps Projector General lighting	Automotive head lamps Projector General lighting

Table 3-2. High brightness LED packaging segmentation

(Source: Yole Research, LED companies)

backlight to reduce panel thickness. In recent years, the price of SMD LED has dropped quickly, therefore, it has become the main LED type in general lighting especially for mid-power models. COB is a new technology of LED packaging mainly used in LED light engine. Basically, multiple LED chips are packaged together as one lighting module and when it is lit up, it illuminates sheet-like light. The most attractive advantage of COB module manufacturing is not only cost reduction but also production ease and convenience. Refer to Table 3-2 for LED Packaging Segmentation.

The lumen output of commercially available LEDs increased dramatically with CREE's offering of cool white LEDs at 200 lu/W at the end of 2012. Cree is one of the leading companies of LEDs, especially in high power LEDs. The company announced that its cool white LEDs efficacy was measured at 276 lu/w, at a correlated color temperature of 4401 K and 350 mA in laboratory conditions in early 2013. Currently, the average efficacy of LEDs in mass production is about 120-140 lu/W.

4. Key Policies of R.O.C. on Green Energy

Due to the scarcity of natural energy resources, 98% of energy used in R.O.C. relies on imports. Under the challenges of rising energy prices and pressure to reduce GHG emissions, the R.O.C. faces the heavy task of developing new energy sources and improving energy efficiency. Under the new Energy Development Policy of 2012, the R.O.C. set the core goal for developing safe, efficient and renewable energy, in order to establish a safe, stable, effective and clean energy provision system and achieve a more sustainable energy situation for the country.

▶4.1 Energy Mix of R.O.C.

In 2012, the total energy supply of the R.O.C. reached 140.8 million kloe, of which, crude oil and petroleum products accounted for 48%, coal 30%, natural gas 12%, nuclear energy 8.3%, and renewable energy 1.9%, as shown in Table 4-1. Compared with neighboring countries, the dependence on fossil fuels is significantly higher.

Despite the lack of indigenous energy resources, domestic energy supply increased 209 thousand kloe in 2012, of which, hydro power increased 41.7% from 2011, natural gas production increased 33.9%, biomass and waste energy decreased 2.8%, solar and wind power increased 1.5% and solar thermal power increased 0.7%[22].

In terms of electricity produced, gross power generation in 2012 reached 250 TWh, a 0.71% decrease from that of 2011. Of the total, thermal power contributed 78.44%, nuclear power 16.14%, conventional hydro power, geothermal, solar and wind power 4.24%, and pumped-storage hydro power 1.17%.

Unit: 10^3 kloe	2012		
Item	Quantity	%	Growth Rate %
Total Energy Supply	**140,768**	**100.0**	**1.8**
Coal & Coal Products	41,788	29.7	-3.7
Crude Oil & Petrol. Products	67,518	48.0	5.8
Natural Gas	17,087	12.1	5.0
Biomass and Waste Total	1,861	1.3	-2.8
Conventional Hydro Power	542	0.4	41.7
Nuclear Power	11,706	8.3	-4.0
Solar Photovoltaic and Wind Power	152	0.1	1.5
Solar Thermal	114	0.1	0.7

Table 3-2. High brightness LED packaging segmentation.

(Source: Energy Statistical Annual Report 2012, Bureau of Energy, R.O.C)

[22] BOE (2013). Energy Statistical Annual Report 2012, Bureau of Energy, R.O.C.

▶4.2 Green Energy Policies of R.O.C.

To achieve higher energy independence, promoting green energy is one of the key energy policies of the R.O.C. Due to limitations in natural resource and geographic environment, renewable energy with matured technology and low generation cost has priority in development policies. The promulagation of the Renewable Energy Development Act (REDA)[23] on July 8, 2009 signifies the attempt to advance the R.O.C. toward a clean energy future. The REDA sets the renewable energy installation target, establishes the FIT mechanism, and defines grid connection and power purchasing obligations, etc. The main content of the REDA is shown in Table 4-2.

Target	Increase the renewable energy installation target by 6.5-10 GW in 20 years.
Tariff Payment Duration	20 years
Targeted Technologies	Solar energy, biomass energy, geothermal energy, wind power, ocean power, hydro power, waste to energy, excluding non-river-stream based hydro power and direct incinerating technologies
Power Purchase	Mandatory grid connection and power-purchasing obligations
Tariff-setting Method	1. The Tariff Committee is composed of 17-21 members. 2. Tariffs are reviewed and adjusted by the Committee annually. 3. The Committee decides tariffs for different renewables categories.
Grants for Thermal Utilization	Solar water heating, biomass, and other renewable thermal technologies
Financing Scheme	1. Financed by Renewable Energy Fund with revenues collected from power generators using fossil fuels and nuclear energy. 2. The government allocates extra funding from the national budget. 3. Other funding sources include the Petroleum Fund and Agricultural Development Fund.
Supplementary Measures	1. Capital grants and demonstration grants. 2. Exemptions of import tax, various licensing and land-use requirements. 3. Dispute mediation mechanism

Table 4-2. Overview of the Renewable Energy Development Act

(Source: Bureau of Energy, R.O.C)

The quest for green energy can be divided into two general directions: (i) developing renewable energy resources; and (ii) practicing energy conservation. The former involves finding new sources and promoting renewable energy sources such as solar PV, wind power, biomass, fuel cells, geothermal, and ocean energy. The latter entails the conservation and reduction of energy usage through energy-saving practices such as efficient lighting and transportation systems, green buildings, energy-saving appliances, refrigeration, and air conditioning.

To meet the upcoming goals of energy diversification, GHG reduction and green energy expansion, the renewable energy installation target was revised later to reach 9,952 MW by 2025 and 12,502 MW by 2030, higher than the one set in the REDA. The installation target for each type of the renewable energy is shown in Table 4-3.

[23] BOE,(Jul, 2009). Renewable Evergy Development Act, Bureau of Energy, Ministry of Economic Affairs.

Unit: MW

Energy Source	2012	2015	2020	2025	2030
On-shore wind	621	866	1,200	1,200	1,200
Off-shore wind	0	15	600	1,800	3,000
Hydro power	2,060	2,052	2,112	2,502	2,502
Solar PV	201	492	1,020	2,500	3,100
Geothermal	0	4	66	150	200
Biogas	9	29	29	31	31
Waste to energy	792	848	925	1,369	1,369
Ocean energy	0	1	30	200	600
H_2 & Fuel Cells	0	7	60	200	500
Total	3,683	4,314	6,042	9,952	12,502

Table 4-3. Renewable energy installation target of R.O.C.

(Source: Bureau of Energy, R.O.C)

Energy Source	Type	Capacity (kW)	Tariff Rates (USD/kWh)	
			Period 1	Period 2
PV	Roof type	≥ 1 - < 10	29.0	28.2
		≥ 10 - < 100	26.0	25.3
		≥ 100 - < 500	24.5	23.8
		≥ 500	21.8	20.6
	Ground type	≥ 1	20.6	19.4
Wind power	On-shore	≥ 1 - < 10	25.4	
Hydro power		≥ 10	9.1 (with LVRT*)	
Geothermal	Off-shore	--	19.2	
Biomass	Stream type	--	8.5	
Hydro power	--	--	16.6	
Geothermal	No biogas equipment	--	8.5	
Biomass	With biogas equipment	--	9.7	
Waste to energy (Refuse-Derived Fuel)	--	--	9.7	
Others	--	--	8.5	

Table 4-4. 2013 FIT rates for renewables in R.O.C.

Notes: *LVRT-low voltage ride through; Exchange rate: USD 1 = NT$ 29

(Source: Bureau of Energy, R.O.C)

The FIT mechanism which gives 20-year electricity purchasing warranty is utilized to support the renewable energy expansion. The tariffs and formula are reviewed annually based on technical advancement, cost variation, and target achievement status, etc. Table 4-4 shows the FIT rates for electricity from renewables in 2013. For solar PV, the Bureau of Energy currently announces the capacity quota every year. PV systems above or equal to 30 kW are subject to competitive bidding process to decide the tariffs. Developers proposing higher discount rates will have the priority to get the quota.

To fulfill the aggressive solar and wind power installation targets, the Bureau of Energy has implemented two promotional projects — "Million Solar Rooftop PVs" and "Thousand Wind Turbines", that aim to facilitate the promotional process.

Solar PV Policies and Goals

The current solar PV installations in the R.O.C. are shown in Figure 4-1. Based on local conditions, the Million Solar Rooftop PV Project set the target to install 3,000 MW rooftop systems and 100 MW ground-mounted systems by 2030. The short-term and mid-term targets are: 845 MW by 2015, 1,020 MW by 2020, and 2,500 MW by 2025. Besides the FIT system implemented by the central government, some local governments also grant extra capital subsidies and have local promotional methods for building PV-equipped structures. To encourage residential

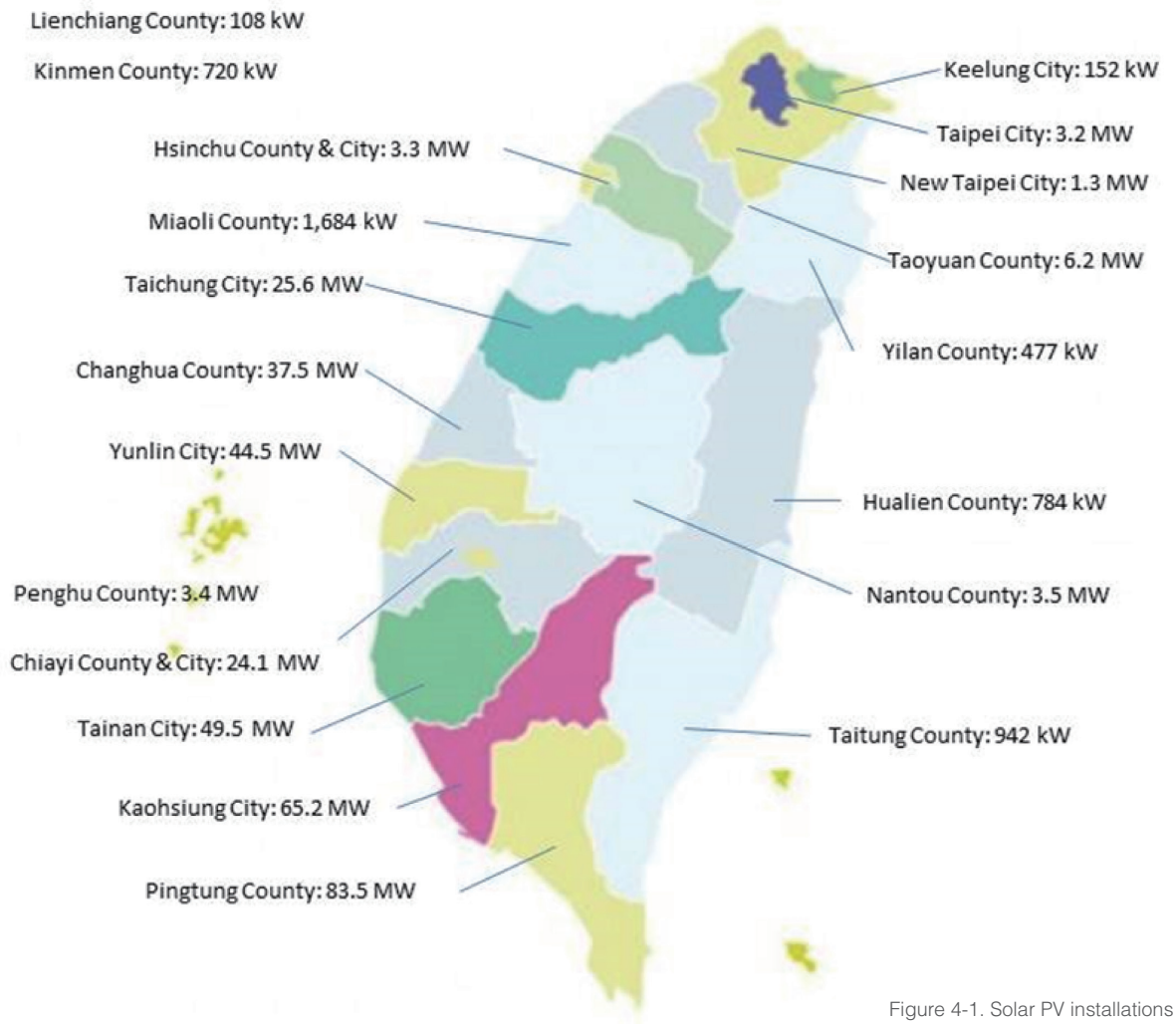

Figure 4-1. Solar PV installations in the R.O.C.
(Source: ITRI/IEK (2013))

participation, PV-Energy Service Company mechanism has been established that incentivizes the residential customers to rent their roofs to PV system companies who sell electricity to the power company and give part of the electricity selling income to the roof owners as the rent[24].

In addition to long-term development plans, smaller special projects are also underway to promote green energy and assist the local community. The "PV Farming to Conserve Water" project carried out from 2011 to 2013 enlists the help of private industries such as LCY Group and SunnyRich to rehabilitate typhoon struck areas and transform the region into a PV farm. Efforts to promote resource conservation on the Penghu Islands also promote the introduction of solar heating systems, LED lamps and other energy efficient home electronics. In power connection advancement, smart grid systems are in discussion and under development by local research institutes.

Wind Power Policies and Goals

The current wind turbine installations in the R.O.C. are shown in Figure 4-2. According to the estimation by the Green Energy & Environment Research Labs of the Industrial Technology Research Institute (ITRI), R.O.C. has 9 GW on-shore wind development potential and 48 GW off-shore wind development potential. The aim of the Thousand Wind Turbines project is to install 1,200 MW on-shore wind turbines by 2020 and 3,000 MW off-shore wind turbines by 2030. The development

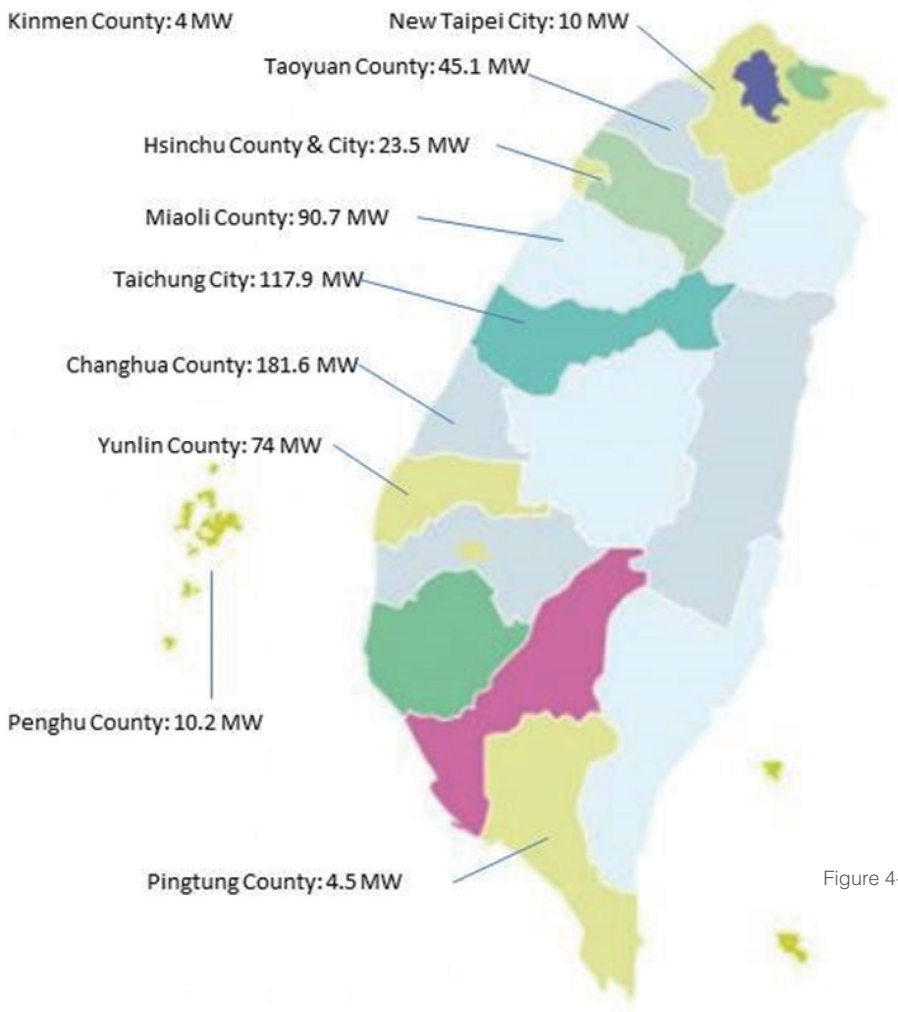

Figure 4-2. Wind turbine installations in the R.O.C.
(Source: Taipower, ITRI/IEK (2013))

[24] Million Rooftop PVs Website, (2014). R.O.C. Bureau of Energy. 陽光屋頂百萬座(2014). 中華民國經濟部能源局，工業技術研究院Retrieved from http://www.mrpv.org.tw/

strategy is to develop on-shore wind farms prior to off-shore wind farms, and develop shallow water area before 2020. Large off-shore wind farms possessing economic scalability are expected to be developed between 2021 and 2030[25]. As a test platform for off-shore wind development, an off-shore wind demonstration project with government capital grant support was kicked off in 2013. The project aims to set up two off-shore wind turbines by 2015.

In order to promote sustainable development and to maintain diverse natural ecosystems in R.O.C., the government has already started to address climate change and to fulfill its duty as a member of the global village. The cabinet approved the program--"Green Energy Industry Development Program" developed by the Ministry of Economic Affairs on April 23, 2009 selecting solar PV, wind power, LED lighting, biofuels, hydrogen energy and fuel cells, Energy Information and Communication, and electric vehicles as focus industries. The government invested USD 0.86 billion to implement renewable energy and energy conservation in facility and subsidy, and USD 0.69 billion on research and development for the next five years.

LED Policies & Electricity Consumption

This program was expected to stimulate USD 6.9 billion private investments based on the estimation of scale of production. Moreover, the government is expected to promote LED lighting industry and push LED lighting industry to become the biggest supply chain of LED light source and LED light engine in the world by 2015.

The consumption of electricity from lighting was around 26 billion kWh in R.O.C., accounting for 11.3% of total 2,298 billion kWh of electricity consumption. To promote energy conservation in lighting, the Bureau of Energy has initiated R.O.C.'s "lighting revolution" with preludes of "promoting 585 incandescent replacement program" in 2008.

This program was to encourage people to use high-efficiency lighting rather than use high power-consuming incandescent lights in government agencies, schools, residences, markets, hotels, department stores and others. Meanwhile, the government also launched a "demonstration program" on promoting energy efficient new technology LED lightings such as full traffic LED lights and LED street lighting etc.

According to the statistic from the Bureau of Energy, the total quantity of incandescent bulbs in R.O.C. dropped from 22.18 million in 2007 to 15.31 million in 2010. The overall energy savings amounted to 249 million kWh in electricity, reducing nearly 152,000 tons of carbon dioxide emissions.

Besides replacing incandescent lights, the R.O.C. government also launched a fluorescent street lamp replacement project to reduce R.O.C.'s carbon footprint and help nurture the domestic light-emitting diode industry in 2012. This project valued at USD 66 million was used to help local governments install 326,000 LED street lamps in place of existing mercury vapor lamps. After installation, the energy savings amounted to 110 million kWh or the elimination of 67,500 metric tons of carbon dioxide emissions.

This program not only provided the nation with energy efficient lighting, but also gave local LED manufacturers a tremendous boost, as the experience they acquired from manufacturing and installing the new lights could help them be more competitive internationally.

[25] Thousand Wind Turbines Wind Power Information Integration Platform, (2012). R.O.C. Bureau of Energy. Retrieved from http://wind.itri.org.tw/

Green Energy Tariff Rate

Details for a "green energy tariff rate" is planned to be announced this September and executed in 2015 (Table 4-5). The new power source selection policy would allow residents of the R.O.C. to choose their electricity generation source from renewable sources at about USD 0.14/kWh, which is 45% higher than the conventional power tariff. The vice minister of the Ministry of Economic Affairs states that while the renewable energy surcharge is mandatory, the green energy tariff rate is entirely voluntary. Revenue from the green energy tariff will be included in the renewable energy fund as a financial source for renewable energy power purchase agreements. This tariff rate will be test-run for three years to examine the public acceptance of a higher renewable energy power rate. [26]

Green Energy Tariff Rate	USD 0.14/kWh for both industrial and home use.
Timeline	To be announced in Sep. 2014, implemented in Jan. 2015.
Implementation	Voluntary
Pricing considerations	Renewable energy costs, international comparison, global carbon trade cost.
Execution	3-year test run, tariff adjusted each year.

Table 4-5. Green energy tariff rate of the R.O.C. for 2015

(Source: Bureau of Energy, MOEA)

As global awareness of carbon footprint reduction rises, global manufacturers are increasingly mindful of energy conservation and purchase of green energy. The Ministry of Economic Affairs and Taipower will issue carbon reduction certificates to companies that have achieved significant green energy efforts.

The rate of USD 0.14/kWh was acquired by considering domestic green energy generation costs, international green energy tariffs and international carbon reduction costs. The final calculation added USD 0.05/kWh to the original power tariff of USD 0.09/kWh. The original power tariff of the R.O.C. was already much lower than the international standard, therefore, even at the new green energy tariff rate, our electricity tariff is still globally competitive.

Biomass and Biofuel Policies

Biomass energy is an important type of green energy as it takes advantage of waste materials generated from manufacturing processes, wastewater, food waste, and domestic and international agricultural waste by employing anaerobic technologies to produce methane gas or direct heat in order to replace imported fossil fuels. In 2012, the installed capacity of biomass power generation in Taiwan was 822 MW, generating a total of 3.49 billion kWh of electricity and accounting for 1.11% of the island's entire power supply. By 2025, biomass fuel is expected to grow 1.7 times and account for 2.58% of Taiwan's total installed capacity for power systems[27].

As reserve for fossil fuels diminish, nations are gradually substituting petroleum for biofuels to decrease fossil fuel consumption and carbon dioxide emissions. The Bureau of Energy of the R.O.C. enacted a B1 mandate in 2008 for the blending of 1% of biodiesel to traditional diesel. This mandate made the R.O.C. the first country in Asia to promote biofuel use without government subsidies. The 1% mark was later raised to 2% in 2010.

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[26] Green energy tariff rate to be applied next year (Feb. 2014). UDN News. Retrieved from: http://udn.com/NEWS/FINANCE/FIN1/8466603.shtml#ixzz2sVK8CypI

[27] Chen, Liang-dong, (2013). Future Development of Green Energy Resources, Industrial Development Bureau, MOEA

The promotion of biofuels in transportation included four stages. Stage one started with the "Green Bus" plan in 2007. 428 public buses covering 59 major lines in Kaohsiung City ran on biofuel, Kaohsiung became the first city in the R.O.C. and the second city in Asia to have an entire fleet of public transportation operating on biofuel. Chiayi County implemented the Green Bus plan later in the year. Stage two of the promotion was the "Green County Application Promotion Plan", initiated in July 2007. Taoyuan County, Chiayi County and Chiayi City were designated as biofuel demonstration regions that offered B1 biofuel in gasoline stations for the purchase of private vehicles. Stage three more widely promoted biofuel nationwide by announcing that all diesel sold on the island must include a 1% ester blend. Finally, in stage four, the blend target for biofuel was raised to 2% by June of 2010[28].

Electric Vehicle Subsidy

The R.O.C. has been promoting the purchase of electric vehicles (EVs) since 2009 and has resulted in steady growth in the demand of EVs. Due to technological limitations on the development of fully electric sedans, government subsidies focus mainly on electric scooters. In 2013, buyers of "Taiwan E-scooter Standard" (TES) vehicles could receive USD 240-333 in subsidies. To fulfill the Penghu Low Carbon Island Project, residents of the Penghu Islands could receive USD 567-800 for the purchase of an EV. The targets of the subsidy include citizens or corporate entities of the R.O.C. From Figure 4-3 below, we could see that demand for EVs are most significant in populous cities and counties, with the exception of Penghu County, where the subsidy for EV is higher.

Although the subsidy was initiated in 2009, more significant results appeared later in the promotional timeline. In 2012, 7,850 EVs were sold, which was a 10% growth from 2011. By 2013, 24 models from 10 local corporations were TES approved. To provide consumers with a wider choice of more powerful EVs, the administration will amend certain technical requirements for the inclusion of approved scooters. Battery output will be raised from under 60 V to under 120 V, maximum motor power output will be raised to 6 kWh, making the performance of future available EVs comparable to 100-125 cc gasoline scooters[29].

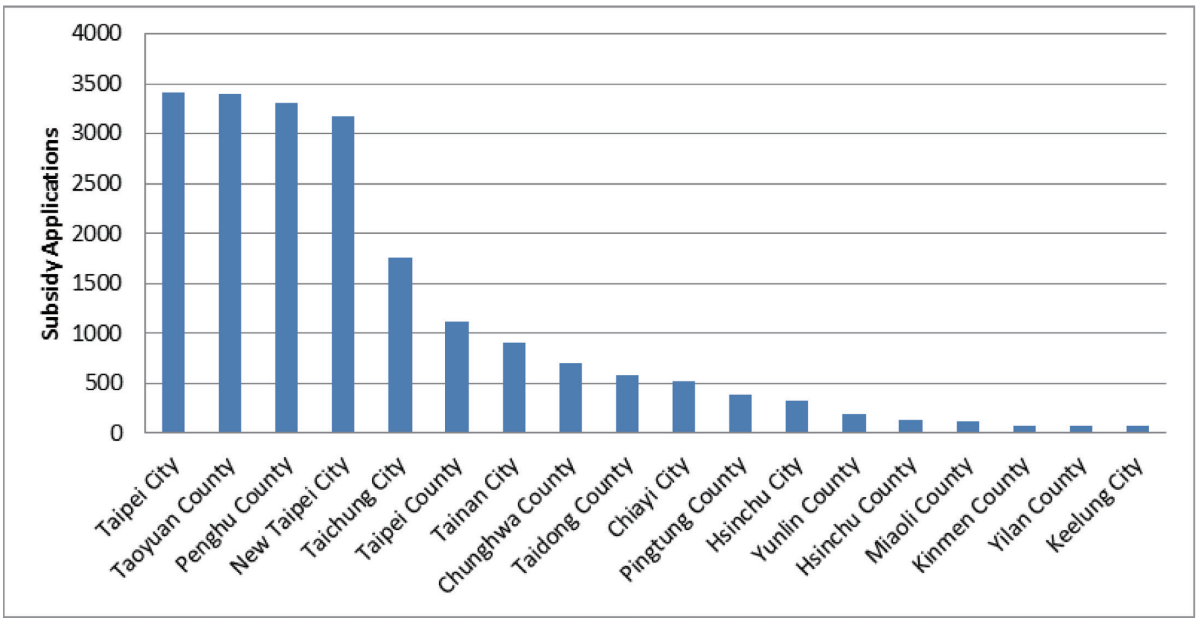

Figure 4-3. EV purchases in the R.O.C., 2012

(Source: MOEA/IDB, ITRI/IEK (2013))

[28] Vehicle diesel with 2% biodiesel blend, (2014). ITRI, Retrieved from: http://www.biodiesel-tw.org/index.htm
[29] Taiwan E-scooter Standard Testing and Service Center, (2011). Retrieved from: http://www.tes.org.tw/testest.htm

Smart Grid Implementation Plan

The Smart Grid Implementation Plan was conceived in 2011 and passed by the Executive Yuan in August of 2012. The plan was constructed with 6 dimensions including power generation and dispatch, smart transmission, smart distribution, smart customer promotion, laws and regulation development, and research on technology and standards. The plan draws out an execution timeline from 2011 to 2030 which includes the cooperation of several government units, Taipower and domestic research institutions.

From the aspect of smart generation and dispatching, the plan will upgrade traditional thermal power generation efficiency and integrate large scale renewable energies. Grid transmission efficiency and reliability will also be increased by using new technologies and enhancing capability of asset management. For developing smart distribution, reliability of the distribution network and increasing the penetration of distributed green energy are key elements. Also, energy usage efficiency will be improved through customer participation and reduction of peak load by way of demand response[30].

Item	2030 Target
Ensure stable electricity supply	1. Implement automatic power distribution and decrease power failure time by 5.5 minutes for each user. 2. Enhance power grid management and decrease power loss of 1,060 TWh per year.
Enhance energy conservation	Decrease carbon dioxide emission by 115 million tons through energy management techniques and use of low carbon energy.
Increase green energy use	Increase percentage of on-grid renewable energy to total grid power to 30%.
Lead low carbon industries	Lead the development of smart grid related industries and create USD 23 billion in production value.

Table 4-5. Green energy tariff rate of the R.O.C. for 2015

(Source: MOEA, ITRI/IEK (2012))

▶4.3 Green Energy Industry of R.O.C.

With the expansion of the domestic green energy applications, the R.O.C. government also encourages industry players to consolidate their R&D and manufacturing capabilities. Since 2009, the Ministry of the Economic Affairs has initiated "Green Energy Industry Program" for the promotion of the green energy industry, which incorporates five key strategies and measures[31]:

1. Technology Breakthrough: establish independent technology and improve key technology efficiency;
2. Critical Investment: targeting major green energy investments as a high investment priority for the National Development Fund;
3. Environment Infrastructure: establish international labs and create proper regulations and standards to form a better environment for development;
4. Export Market Expansion: support manufacturers in expanding to global market and overseas business; and
5. Domestic Market Growth: promote a more reasonable electricity purchasing price and stimulate the renewable energy market; require 6% of green energy to be used in public buildings to create demand.

[30] NSTPE (2012). R.O.C. Smart Grid Implementation Plan and Quantified Targets, National Science & Technology Program-Energy
[31] MoEA (2011). Development of Green Energy Industry in Taiwan, Department of Investment Services, Ministry of Economic Affairs, Taipei, R.O.C.

The solar PV and LED lighting industries are currently regarded as the two "pillar" green industries that possess sufficient manufacturing and innovation capacity and are ready for fast growth.

Solar PV Industry

The production value of R.O.C.'s solar PV industry was USD 4.4 billion in 2012 with expected production value of USD 15 billion by 2015. The main export markets are the P.R.C, Japan and Europe. R.O.C. solar companies are specialized in C-Si solar manufacturing, with a complete value chain established. Table 4-5 shows the current main solar players in the R.O.C.

Value chain	Players
Polysilicon	LCY TPSi
Wafer	AUO Crystal, Danen, Eversol, Green Energy Technology, Sino-America Silicon Products, UTECH Solar, etc.
Cell	AUO, Big-Sun Energy, E-ton, Ever Energy, Gintech Energy, Inventec Solar, Ming Hwei Energy, Mosel Vitelic, Motech, Neo Solar Power, Solartech, Sunengine, Sunrise Global Solar, Tainergy, TSEC, Topcell Solar, Unitech, etc.
Module	Ablytek Solar, Apex Solar (Solartech), Apollo Solar Energy Corp., AUO, GES (Neo Solar Power), Inventec Energy, Ligitek PV, PCM, Topper-Sun, Tynsolar, Winaico, etc.
Thin-film	• Silicon thin-film Auria, NexPower, SunWell • CIGS Axuntek, TSMC Solar, SunShine PV

Table 4-5. Main players of the R.O.C. PV value chain

(Source: ITRI/IEK)

Among these sectors, the C-Si cell manufacturing is the strongest of the R.O.C. industry, with global market share second only to that of the P.R.C. The advantage is contributed by the well-trained engineers of the semiconductor sector, in which semiconductor fabrication process is similar to that of C-Si solar cell. Combined with performance experience of key electronic component industries, solar cells from the R.O.C. have been widely accepted by global solar module customers. Neo Solar Power (NSP), Gintech and Motech are among the top ten solar cell makers in the world.

NSP is the largest solar cell manufacturer in the R. O.C., with annual production capacity of about 1.9 GW globally. The technical team of NSP is from ITRI, the most important research institute of R.O.C. With the acquisition of DelSolar, another ITRI-tech-based cell company under renowned power electronics manufacturer Delta group in 2013, NSP became the No. 3 solar cell manufacturer in the world. Besides its cell business, NSP is also developing new modules and PV systems with its subsidiary General Energy Solutions to better manage its product channel.

Gintech has annual cell production capacity of 1.5 GW, slightly lower than that of NSP. Different from NSP, Gintech focuses only on cell manufacturing. It initially started operation with Monsanto Electronics Materials Company, a major US wafer supplier, and quickly gained the leading position in the R.O.C. market. With the drastic fall of wafer price during 2009, Gintech successfully resolved the crisis caused by long-term wafer supply contract and kept its business growing.

So far, Gintech has expanded its capacity and upgraded its technology simultaneously to gain more orders from European and Japanese customers.

Established by Dr. Simon Tsuo with his experiences and professional knowhow from the National Renewable Energy Laboratory in 1999, Motech is the earliest C-Si cell manufacturer of R.O.C. It is also the only solar company from the R.O.C. that is among the top 10 global ranking since its establishment. Currently it has cell production capacity of about 1.3 GW in both R.O.C. and P.R.C., and operates module business in Japan and USA. Supported by semiconductor tycoon Taiwan Semiconductor Manufacturing Corporation (TSMC) since 2009, Motech is the company with the highest R&D investment in production improvement and new types of solar cells in R.O.C.

Sino-America Silicon Products (SAS) and Green Energy Technology (GET) are two big wafer suppliers in the R.O.C. SAS has long experiences in silicon wafer manufacturing that started from supplying semiconductor material for power devices, and now it also provides high efficiency solar wafer as well as sapphire wafer for LEDs. GET, the subsidiary of Tatung Group, a famous local electronics brand, owns the largest solar wafer manufacturing capacity on the island and is able to provide large quantities of high quality solar wafers.

AU Optronics, a world-class display panel maker, is the only global solar company to invest in the complete C-Si value chain. It acquired the Japanese silicon and wafer producer M.Setek, and formed a joint venture with the American high efficiency solar producer SunPower in Malaysia. It also erected module assembly plants in Czech, and constructed wafer to module factories in Taichung, R.O.C. AUO utilizes the complete supply chain jointly with their BenQ brand to develop system business in USA, Europe and some emerging markets.

NexPower, backed by another big semiconductor corporation United Microelectronics Corporation, is the largest thin-film manufacturer in the R.O.C. It started producing silicon thin-film products in 2008. To distinguish its application market from that of C-Si competitors, NexPower is developing BIPV solutions for global customers.

Although the R.O.C. has excellent PV supply chain and the second largest solar cell production capacity, the domestic market is small due to geographic limitations. With the Million Solar Rooftop project launched in 2012, more ambitious solar targets could be predicted. In another approach, the government also tries to expand global market for domestic PV players. In 2012, the Ministry of Economic Affairs integrated resources of several departments to start the "Overseas PV Market Expansion" project, which targets to strengthen the global competitiveness of R.O.C.'s PV industry and boost the related product export. The government has also prepared funding of about USD 333 million[62] that companies could loan for developing solar power systems abroad. This project has allowed many domestic companies to gain valuable experiences in developing PV systems in the U.S., Europe and Southeast Asia, etc.

Solar PV is one of the best energy solutions for residential users due to its clean, noiseless and fuel-free features. With improving technology and reduced production cost, solar PV will be more affordable for families and more prevalent in all types of application fields, as well as free from government subsidies in the future.

With the complete PV supply chain, R.O.C. companies will play an increasingly important role in supplying high quality products globally and in helping customers construct cost-efficient solar systems. After the global PV industry restructuring in 2012, only truly robust PV firms could continue on the solar playing field. The existing R.O.C. solar companies have developed into healthy and agile partners for global clients. With close international cooperation, a better energy environment in the R.O.C. can be expected.

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[62] MOI (Sep. 2012). Green Energy and Industry Equipment Export Loan Guidelines, National Development Fund Management Committee, Ministry of the Interior, R.O.C.

LED Industry

Despite of the economic downturn, the global optoelectronics market continues to grow. The production value of R.O.C.'s LED industry reached USD 6.8 billion in 2012 and is expected to grow to USD 18 billion by 2015. Similar to the solar PV industry, the strength of R.O.C.'s LED industry also comes from the strong semiconductor manufacturing base. Furthermore, the R.O.C. possesses complete LED industry clusters within 400 km that facilitate LED chip manufacturing, light module fabrication and packaging. The whole supply chain is composed of up-stream wafer and chip manufacturers, mid-stream packaging players and down-stream lighting producers, as shown in Figure 4-1. At present, there are approximately over 150 companies involved in the LED industry in the R.O.C.

In terms of the whole supply chain, the R.O.C. enjoys high market share in LED packaging. According to Strategies Unlimited, a research company specialized in the LED industry, the global shipments of LED packaged devices were estimated to be USD 13.8 billion in 2013. By geographic distribution, the R.O.C. ranked the third at 15%, after Japan (30%) and Korea (28%), as shown in Figure 4-4.

Epistar is the world's largest manufacturer of red and yellow chip and the largest high brightness LED chip maker in the R.O.C. Established in 1996, the company specializes in high-brightness LED products used in general lighting, traffic signals, and various consumer products such as mobile phones and laptop computers. Epistar currently holds over 1000 LED patents. It ranks the second in terms of the LED chip production capacity, after Japanese company Nichia.

Forepi is a famous chip manufacturer in the R.O.C. Incorporated in 1999, Forepi has devoted itself to pure-play high power InGaN LED wafer and chip manufacturing. The company possesses the capability of offering full spectrum LEDs, including high power InGaN Blue, Green and near-UV LEDs. Forepi has secured about 190 core technology patents, 50% of which are invention patents. The company is the supplier to many reputable manufacturers throughout Korea, R.O.C., U.S., and P.R.C.

Everlight is the biggest LED packaging house in the R.O.C. Founded in 1983, it has branches located around the world to provide immediate service and prompt delivery to customers. Everlight extended its business from mid-stream LED packaging to LED up-stream wafer/chip manufacturing by investing in

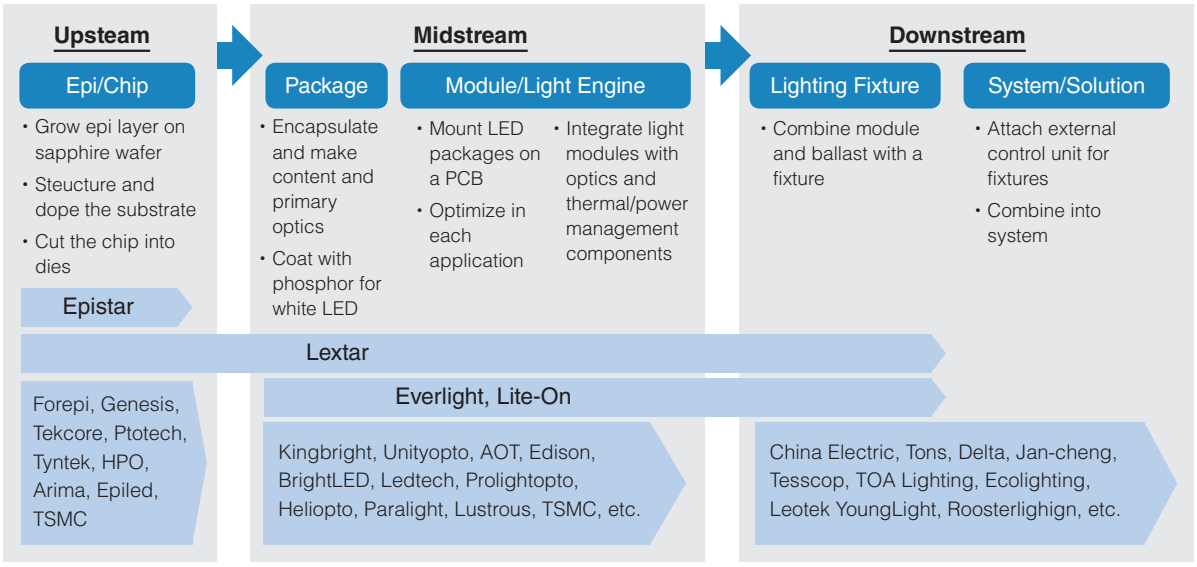


Figure 4-4. Main players of R.O.C. LED lighting value chain

(Source: ITRI/ IEK)

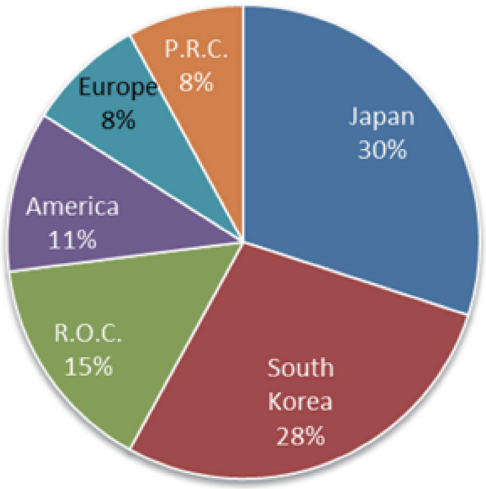


Figure 4-5. LED packaged device revenue by country, 2013

(Source: Strategies Unlimited (2013))

Techcor, a wafer/chip company in the R.O.C. to integrate LED technology and enhance cost competitiveness. Moreover, the company also made enormous efforts to establish its own “Everlight” brand in the LED lighting industry.

Lite-On started producing LED packaging products in 1975 and has steadily grown into one of the world's largest optoelectronic component manufacturers by providing customers with both visible and infrared LED product solutions. In 2007, Lite-On merged LED lighting company Leotek Electronics, a global pioneer in solid-state LED technology with focus on traffic signals and commercial and industrial applications.

Lextar Electronics Corporation is a subsidiary of AU Optronics, the leading TFT-LCD and solar PV manufacturer. With over 1,500 patents worldwide, Lextar is an innovator of product applications; its products include LCD backlights, luminaire, and various lighting solutions. Lextar also offers customized solutions to different markets and clients, including original equipment manufacturing and original design manufacturing services for international brands, as well as provide total solutions for light modules.

Other Energy Conservation and Carbon Reduction Trends

The R.O.C., for the most part, has an intact and complete industry supply chain for energy production. However, the island relies too heavily on imported raw materials and energy resources required for the production process. In cases of global energy shortages, Taiwan can only resort to improving its energy efficiency in order to reduce production costs and maintain its international competitiveness. In light of this, the government has amended the Energy Management Law, setting phases for developing energy efficiency regulations to eliminate sub-standard equipment; and implemented development stipulations for renewable energy resources to guarantee high purchase prices for renewable energy. A draft has been formulated for the GHG Reduction Act to control GHG emissions and establish a trading system for these emissions; and a draft for the Energy Tax Code is designed to levy a GHG emissions tax on the usage of fossil fuels. In addition, the government also carried out the following measures to assist industries in adjusting to new energy conservation and carbon reduction trends:

1. The Industrial Development Bureau introduced industrial GHG inventory methods to advise manufacturers to conduct inventory according to ISO 14064-1 standards. The Bureau of Energy advised the energy industry to implement inventory and verification processes. The Environmental Protection Administration established a registration platform for GHG emissions and, in 2012, not only stipulated CO_2 as air pollutants in accordance with the Air Pollution Control Act but also ordered the inventory and registration of every major source of emission by law.
2. The largest source of reduction comes from the agreements signed between the associations and the government concerning energy conservation and voluntary reduction of GHG emission, which induces manufacturers to practice energy conservation and carbon reduction. An example of this is the Industrial Development Bureau’s

agreement with steel, petrochemical, cement, papermaking, and other industries for their participation in voluntary carbon reduction. Between the years 2005 and 2012, 245 manufacturers jointly implemented 4,840 reduction measures, reduced 8.4 million tons of carbon dioxide, saved 2.09 million kloe (which is equivalent to the annual amount of carbon dioxide emitted to produce electricity in Taipei City). In total, manufacturers invested a combined sum of USD 1 billion, resulting in high energy-savings.

3. By commissioning professional agencies to counsel small and medium enterprises, the government expands the adoption of energy-saving technologies. Furthermore, experts on energy conservation and carbon reduction within large enterprises ensure that company factories implemented corresponding measures, helping satellite factories and important customers institute energy-conservation improvements. The Industrial Development Bureau also formed a team of experts specializing in energy conservation and carbon reduction in the manufacturing industry. From 2009 to 2012, this team provided carbon reduction consultation services for 6,690 cases, visited and advised 1,796 plants, and recommended over 6,860 measures for improvement in this area. After these improvements, the manufacturing industry saw a reduction of 1.61 million tons of carbon dioxide emissions and conserved 539,000 kloe. The USD 0.6 billion generated from energy conservation policies has spurred investments for improvements in this area that exceed USD 55 million.
4. While the Industrial Development Bureau launched its carbon footprint counseling program for manufactured products, the Environment Protection Agency issued certification requirements for obtaining carbon labels in the R.O.C., accepted certification applications from manufacturers for their products, and encouraged consumers to choose and purchase products with these labels. When manufacturers pursue the goal of reducing their product's carbon footprint, they will intrinsically reduce the use of energy resources in the manufacturing process, from the use of raw materials to product design phase including every production phase.
5. The Industrial Development Bureau executed a counseling program to advise manufacturers on how to establish and install ISO-50001 energy management systems. Through this program, the Bureau seeks to nudge manufacturers into utilizing ISO-50001's systematic method to find ways to adopt energy conservation practices and implement continuous improvements. At the same time, the Bureau also hopes to use counseling funds to cultivate domestic consulting companies that specialize in this area, enable relevant personnel to gain real factory counseling experience, create subsequent service capabilities, and ultimately establish a solid energy services industry in the R.O.C.
6. The Green Factory Label is one of the first certification systems of the R.O.C., which requires factories to obtain the green building certification issued by the Ministry of Interior as part of its criteria. Factories honored with this certification are forerunners in the area of energy conservation and carbon reduction. The manufacturing process in these factories must pass through the cleaner production evaluation system of the Industrial Development Bureau in order to be certified and awarded a green factory label. The certification process involves factories reaching industry benchmarks for energy-saving manufacturing processes, low pollution, resource minimization, eco-friendly product design, and other merits.

Green energy resources are the inevitable direction for future industrial development, and in the years to come, an increasing amount of green energy resources will be consumed. Since the green energy industry is the emerging industry of the future, products that take into consideration key features of green energy resources in their R&D, design, and manufacturing phases will certainly have a competitive advantage.

Over the last three decades, Taiwan has been actively promoting green industries, and the development of green energy resources has played an important role in bringing about the greenification of industries. In 2012, the APO established its COE GP in the R.O.C., thereby affirming the island as a leader in the area of green productivity. Putting much effort into topics such as green energy, green factory, and resource recovery, the R.O.C. has utilized these as essential tools to help enhance the green productivity of 19 other APO member-nations with the hope of jointly cultivating green growth, fostering green collar human resources, establishing green jobs, moving towards green economic development, and thus raising the overall green competitiveness of all APO member-nations.

5. Case Studies

The R.O.C.'s achievements in green energy can be seen in the development of innovative products and socially responsible public and private projects. In this case study chapter, four public solar system projects are showcased as a testament of superior technological ability and intelligent policy-making.

In addition, five companies and their innovations are featured to demonstrate the creativity of our industry, including a world-class energy technology giant, a leading thin-film PV technology implementer, an independent solar generation system manufacturer, a superior LED banner innovator, and a professional small wind turbine maker.

Three prominent projects in this booklet were exhibited to the APO member country delegates during their visit to the R.O.C. from November 4 to 8, 2013. Their first destination was the National Taiwan Museum of History PV Cloud Wall, a 15.5-m high, 148-m wide PV panel wall set outside a history museum in the southern part of the country. The construction served a dual purpose in aesthetics and power generation. Another case features the "Photovoltaic Farming to Conserve Water" project in Pingtung County that turned a typhoon disaster area into the R.O.C.'s largest solar power generation site with 20 MWp power output. The National Stadium is a green building commissioned by the Kaohsiung City government to host the 2009 World Games. The stadium's solar rooftop has output capacity of 1 MWp and is the sport stadium with the highest independent power generation capacity in the world.

With the presentation of these cases, this report strives to provide inspiration for future innovations in renewable power technology worldwide.

▶5.1 Penghu Low Carbon Island Project

Case name	Penghu Low Carbon Island
Case location	Penghu Island
Erection style	Green Infrastructure
Owner	Government
System type	Integrated green energy system

In recent years, climate change and carbon reduction are the most concerned issues in the global society. Governments around the world are working hard to find ways to reduce carbon emission. On World Environment Day, 2009, The Administrative Yuan of the R.O.C. government passed a set of guidelines named "Framework of the Sustainable Energy Policy", declaring its intention to develop renewable energy and reduce carbon emission. The Administrative Yuan also laid out the "Save Energy and Reduce Carbon Emission" comprehensive plan in March of 2010 to reduce the country's carbon emission to the 2005 level by the year 2020. Year 2010 was designated as the Year of Energy Saving and Carbon Emission Reduction.

The development of low carbon society was included in the conclusions of the Third National Energy Conference held in 2009. The approaches of constructing low carbon society include carbon capture with forestation, low carbon towns in local governments, and renewable energy living area (with

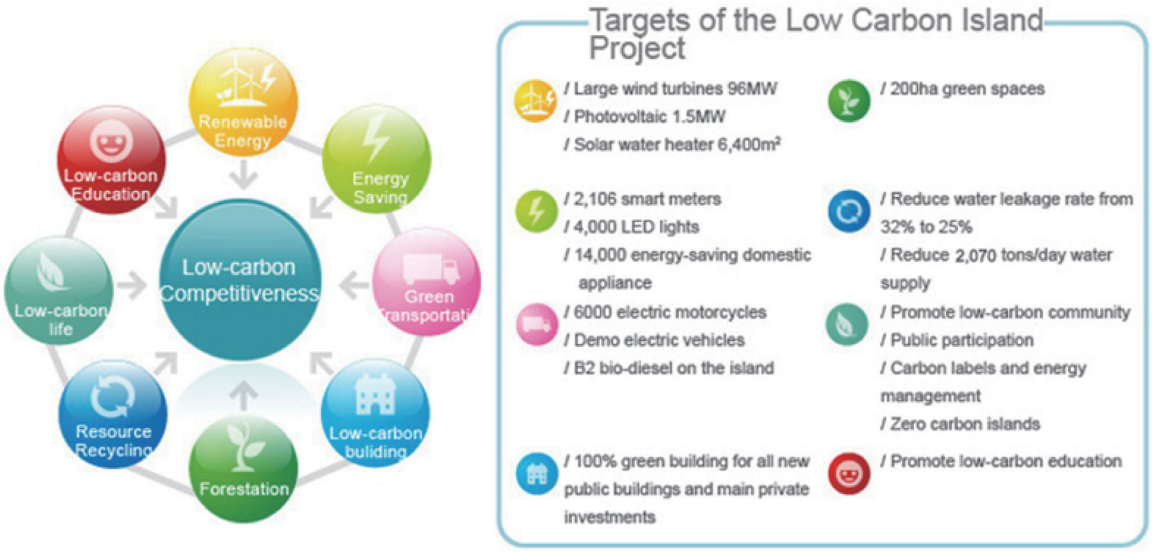


Figure 5-1. Penghu Low Carbon Island Project framework

(Source: Bureau of Energy, R.O.C.)

over 50% of total energy consumption coming from renewable energy accounts). Every county is expected to establish two low carbon communities by 2012. Six low carbon cities are to be completed by 2016. As a result, four districts of Taiwan, including Northern, Middle, Southern, and Eastern districts, will be transformed into low carbon society by the year 2020. The existing regional development plan will be revised to promote "produced locally and consumed locally" style "sustainable local economy" and low carbon style production and marketing system. Low carbon emission cities and towns will then be established with a virtuous cycle to renewable energy efforts. Thus, how to go from merely setting GHG emission reduction goals at the central government level to actually carrying out the projects and achieving the goals through each and every local government level is something to be watched both closely and continuously

The Ministry of Economic Affairs of the R.O.C. chose the Penghu Islands as the place to build the country's first model renewable energy community. The implementation of the Penghu Low Carbon Island project will introduce green energy and recycling system into all aspects, including technology, measures, services, and R&D accomplishments. Over half of all the islands' energy demand will be met by renewable energy, so as to make the island a world-class paradigm for all low carbon island projects. The total time required for implementing the project is set to be five years. Refer to Figure 5-1 for Penghu Low Carbon Island Project Framework.

(1) The Vision and Mission of the Penghu Low Carbon Island Project

The aim of the Penghu Low Carbon Island project is to bring all kinds of low carbon technology into application to forge out an example clean living environment for the nation. Economic development will further be achieved by incorporating local features into the project; making these low carbon islands a tourist attraction of international renown. Through the implementation of this project, low carbon living services and low carbon technology will be applied. The application of green energy products will be broadened and related industries are expected to be promoted.

Major objectives:

- To create a living environment by implementing low carbon emission technology, services and measures.
- To provide power with at least 50% of energy from renewable sources.
- To broaden the application of renewable energy and green energy products through the demonstrative Low Carbon Islands project; and to further promote industry development and gradually extend the project to the construction of low carbon communities, in the effort to urge the R.O.C. to join the cluster of advanced low carbon countries as the final goal.

The specific content of the Low Carbon Islands project comprises execution plans in five major aspects: renewable energy, energy conservation, green logistics, green construction, and resource recycling. In the aspect of renewable energy, the project will install new multi-megawatt wind turbines with a total capacity of 96 MW, construct an exemplary megawatt level PV structure, and achieve the goal of having over 50% of energy consumed from renewable energy. To achieve energy conservation, the project will install smart meters, LED street lights, and promote energy-efficient household appliances. To promote green logistics, the project will encourage motorists to trade in fuel powered cars for hybrid models and restrict fuel use on the islands to only B2 diesel and E3 alcoholic gasoline. For green construction, the project requires that all new public structures and major civilian investment projects are certificated as green buildings. Finally, in the aspect of resource recycling, the project will work to diversify water resources, including establishment of smart water supply network, rainwater storage, treated water recycling, etc. Zero-waste policy will also be achieved by promoting garbage recycle and reuse systems. All the above measures, when fully in effect, are expected to reduce the emission of GHG by 62%, or reduction of 302 thousand tons CO2 in 2015.

(2) Expected Benefits of the Project

- The Penghu Low Carbon Island Project Outlook is illustrated in Figure 5-3.

Figure 5-2. Penghu Low Carbon Island Project outlook

(Source: Bureau of Energy, R.O.C.)

- Total carbon emission of 2015 will be 60% less than expected Business-as-Usual and 50% less than that of 2005.
- Total electricity generated by renewable energy exceeds total local demand.
- CO2 emission per capita per year drops from 5.4 tons (2008) to 2.1 tons (2015).
- Total investment is expected to be recovered in 6.8 years.
- Further promotion of local tourism industry.

▶5.2 *Photovoltaic Farming to Conserve Water*

Case name	Photovoltaic Farming to Conserve Water
Case location	Pingtung County
Erection style	High ground-mounted PV panels
Owner	Government
System type	Solar PV
System power output	20 MWp
Energy company	LCY Chemical Group
Completion date	2011

Among the 31 recipients of IBM's Smarter Cities Challenge Grant of 2013 is Pingtung County, a region outside the normal hustle and bustle of the R.O.C. industries. Although Pingtung is not a core location of the R.O.C.'s technological advancements, the county has been striving successfully toward clean energy production. The Photovoltaic Farm to Conserve Water Project is a testament to this effort.

In an effort to promote a nuclear-free town, Pingtung has been encouraging renewable energy industries to set up shop locally. This move is also expected to invigorate local economy. The PV Farm project brought together the county government, energy companies and local landowners. The technology and construction involved also helped upgrade the electricity infrastructure, advance electrification and even increase employment.

(1) Typhoon Morakot and the Pingtung County Disaster Relief Policy

The PV Farm concept was originated in the wake of Typhoon Morakot, a super-storm in 2009 that devastated Southern R.O.C. and left USD 3.3 billion in damages. Many areas in Pingtung are originally low-lying areas, added to the fact of over-pumping of underground water by local aquaculture industry; the typhoon resulted in serious flooding, causing land salination and subsidence in agricultural areas. After the typhoon, Pingtung County government proposed a land restoration policy in 2010 that supports the development of green energy industry in disaster stricken areas. By August of the same year, corporations were selected as partners to work toward the goal of renewable energy development and community reconstruction.

Despite changes in electricity purchase price and rises in raw materials on the eve of contract signing, many companies held steadfast in their agreement to assist the Pingtung community in local investment. By October 2013, the PV farming project yielded USD 14 million in solar infrastructure investment, 23.5 kW of installed solar energy capacity and conserved 45 hectares of badland. Municipal and school buildings were commissioned for solar rooftop power farms with investment from private organizations. In addition to solar power, wind power, firedamp technology and biomass energy generation were also integrated in

High Mounted PV Farm
(Source: ITRI/IEK)

Pingtung County's green energy enterprise. Agriculture was also combined with renewable energy efforts in solar powered greenhouses.

Because large areas of farmland were destroyed in the storm, existing cultivatable land became more precious. Solar power system integrators in the R.O.C. combined PV technology with traditional greenhouse concept to increase productivity on limited farmland without putting extra burden on the natural environment. A series of self-reliant, solar powered greenhouses that increased harvest rates for crops were constructed. The greenhouses became the first establishments to integrate steel solar panel scaffolding with greenhouse construction design in the R.O.C. The solar greenhouses apply three-dimensional cultivation method to grow more than 10 kinds of organic fruits and vegetables. Each item gives farmers several harvests per year, increasing the added value of the limited farm space. The greenhouses also attract agricultural experts and students to work on and study the operation of the innovative farming practice. The aggregate performance of government, businesses and local communities in Pingtung is heartwarming. It is a perfect example of how a united society could bring technology and humanity together to create a better future.

(2) LCY Group and the 20 MW PV Farm

Among the many organizations that worked on the project, LCY Group was the most generous contributor to the solar power initiative. Established in 1965, LCY Group is the largest solvent manufacturer in the R.O.C. The company is the second largest TPE manufacturer and the top ten polysilicon manufacturer by capacity in the world. The company has a significant global presence with four factories in the R.O.C., four in the P.R.C., One in Qatar and one in the USA. LCY is also the founding member of the R.O.C. Responsible Care Association.

After the storm, Pingtung County and LCY Group promoted the PV Farm to Conserve Water concept to make use of the uncultivable land and assist local farmers in industrial restructuring. Salinated land and destroyed fish ponds are rented to the energy company for mounting PV panels. Fish ponds were transformed into water conservation pools and farm land is given time to recover. Meanwhile, landowners and farmers were given positions as manager or director of the PV power plant. According to policies and reports in 2011, 170 landowners who joined the project were offered USD 1,670 to USD 2,000 per year for every 970 square meters rented. This is five times

the common farm land renting rate. Moreover, more than 500 jobs were created in the community for the project. As of September 2013, LCY Group announced that the PV Farm capacity has reached 20 MW and will steadily increase annually by approximately 7 MW. LCY Group's success in Pingtung has also attracted many other solar energy companies and related industries to set up in Pingtung County.

The PV Farm to Conserve Water project was able to turn destroyed farmland into solar power generating areas and safeguard the county's underground water source. This creative project also allowed local farmers to farm electricity and turn Pingtung into the most productive solar powered region in the R.O.C. It seems that Typhoon Morakot brought with it not only destruction, but also hope and innovation.

Project Results as of October 2013:

- Attracted USD 14 million solar power plant investment in Pingtung County.
- 31 million kWh generated per year from solar energy sources.
- Conserves 9.8 million cubic meters of underground water per year.
- Local land owners received USD$ 734,000 in total rent income.
- Decreased CO2 emissions by 19 thousand tons per year.
- 177 articles of land commissioned for PV farming, directly increased 80 employment opportunities for farmers and raised income for 168 families.

LCY Group Green Energy Promotion Hall

(Source: ITRI/IEK)

▶5.3 National Stadium (2009 World Game Main Stadium)

Case name	2009 World Game Main Stadium
Case location	Zuoying, Kahohsiung
Erection style	Green Architecture
Owner	Government
System type	BIPV
System power output	1 MWp
Energy company	Delta Electronics
Completion date	2009

Chinese people are known to be descendants of the Dragon, which is why the dragon image exists on much of our architecture, not only on traditional structures, but also on our modern Kaohsiung Stadium. The city of Kaohsiung enjoys 2,212 hours of sunlight per year, therefore it is ideal to promote solar power generation with modern construction. One of the leading solar projects in Kaohsiung City is the National Stadium. National Stadium, also known as the 2009 World Game Main Stadium, not only differs from classic stadiums in design and construction, but also in power consumption. The stadium roof consists of 8,844 solar panels and self-supports 80% of all electricity consumed by the stadium.

(1) Technological and Architectural Design of the National Stadium

Designed by Japanese architect Toyo Ito, the National Stadium opened in July 2009 for the 2009 World Games held in the R.O.C. The stadium is designed with an open circle with roof top solar panels that resembles a scaly dragon wagging his tail. Such a design is not only for aesthetic or auspicious reasons, but also due to local weather conditions. From the analysis of the Central Weather Bureau, it was understood that a semi-open stadium could create a passage through which summer wind may pass, refreshing the audience during Kaohsiung's humid summers. It is due to this cooling design that air-conditioning is not needed even in summer.

National Stadium
(Source: ITRI/IEK)

The surrounding environment of the stadium is landscaped with palm trees and plants imitating a tropic forest. Its open design and wind-sun-conforming orientation provide a welcoming and comfortable sports ambience. The solar panels allow 30% of total sunlight to shine into the stadium, so the audience may enjoy natural outdoor sunlight. Spectators can observe the spiral steel bracings of the roof through the transparent glass roof, thanks to the BIPV technology implemented here.

The stadium was commissioned by the Kaohsiung City Government with the assistance of Dow Chemicals and Fu Tsu Construction. The solar power system was integrated and constructed by Delta Electronics Group, including the design and manufacture of the cells and modules. Delta Group is a leading corporation in power and thermal management solutions. Many significant achievements led Delta to receive many awards for innovation and design worldwide. The transparent solar panels were all designed and manufactured in-house. The panels cover a surface area of 14,155 square meters integrated into the roof construction. The stadium's solar energy system also uses Delta's energy inverters to convert DC to AC power and to feed electricity into the grid with inverting efficiency of 98%. The stadium is certified by the International Association of Athletics Federations as a first-class sports arena and is the largest solar powered sports stadium in the world. The building was constructed with spiral steel girders that support a saddle-shaped solar cell roof which occupies 19-hectares. It consists of three floors above ground and two basement levels with housing capacity for 55,000 spectators. A reinforced concrete base is used to hold a complex structural framework of pipes and steel beams that supports the 8,844 BIPV panels mounted as the roof. In addition to the solar power roof, all construction materials used are 100% recyclable and manufactured in the R.O.C.

(2) Green Energy Output

The stadium's 8,844 panels generate an average of 3,000 kWh per day and supply up to 1.14 GWh of electricity annually. With the installation of 279 units of 3.6 kW solar inverters, the PV roof could support the 3,300 lu of illumination within the stadium. As exhibited in the photos, the solar panels covering the vast external face of the stadium are able to generate most of the power required for its operation. The power generated from the panels allows the stadium to support 80% of its own electricity consumption and sell excess power to Taiwan Power Company, saving a large percentage of its electricity bill and reducing 660 tons of carbon dioxide emission. During the non-games period, the surplus energy can be saved and sold. Its solar energy system meets 1 MWp capacity and can generate 1.1 GWh of electricity annually. Moreover, the stadium roof also collects rainwater for use inside the stadium. A system of pipes carries rainwater to underground storage facilities where it is sterilized and reused.

National Stadium Rooftop BIPV Panels

(Source: National Stadium Headquarters, Sports Affairs Council)

Design, construction and material use were all new challenges for all parties involved in the National Stadium project. The stadium was to conform to international sports standards while at the same time demonstrate its qualities as an innovative green building. Some of the barriers needed to overcome were optimal energy transfer rate from the PV panels, weather tight performance, and thermal and acoustic designs. With the assistance of construction geniuses from Japan, the US and R.O.C., National Stadium has become a proud milestone in green architecture application.

▶5.4 National Museum of Taiwan History

In response to the GHG emission restriction rule of the Kyoto Accord, countries worldwide are further investing in renewable energy and substitute energy development. Currently, 98% of energy consumption in Taiwan relies on imports. For the benefit of national economic development and social-environmental protection, the Bureau of Energy launched a set of policies and goals for the development of solar energy in 2006 to establish the industry environment and popularize the application of solar power.

(1) 2006 Solar Energy Development Project and its Resultant Establishments

Though solar energy policies have evolved since 2006, the mission and goals of the 2006 mandate sprouted many inspiring projects and public constructions that are still admired today.

Goals and Strategy of the 2006 Solar Energy Development Guidelines[33]:

- To actively promote demonstrative projects and strengthen the promotion of project establishment.
- To enforce the establishment of emergency solar power systems in distant regions and off-shore islands.
- To accelerate development in the industry by investing in technological advancement and cost reduction, actively assist corporations in domestic market cultivation and foreign trade expansion, and to promote BIPV technology. The goal for BIPV systems was set to reach 100,000 to 120,000 homes by 2025.

Planned Policy Measures:

- Solar City: The Solar City project plans to build solar powered buildings, municipal infrastructure or landmarks in several different locations in the city in order to boost the image of solar application. Details of installation projects would be proposed by the local city or county government, and project subsidies would be evaluated by the Bureau of Energy.
- Solar TOP: This measure differs from Solar City in that the project aims at constructing large, demonstrative solar power integrated establishments at key locations with high visibility. The constructions are to be designed with artistic diversity, cultural sensitivity and high technology. By combining public construction with solar power, the administration wishes to convey its seriousness of purpose in promoting renewable energy in Taiwan. Establishments are divided in two categories: (1) Structures with at least 60 kWp and structural groups of at least 100 kWp, and (2) Transport facilities of at least 60 kWp.
- Emergency Disaster Prevention for Distant Regions: This measure planned to promote independent solar power systems in distant regions with limited access to grid power. It was estimated that at least one solar power system was installed in 50 mountainous counties and off-shore islands.
- Solar Roof: For the Solar Roof plan, solar modules are encouraged to be installed on existing buildings. The administration would subsidize USD$ 5000 for every kWp installed but under 50% of installation cost of the project, in order to promote solar rooftop projects.

The solar power installation outside the Museum of Taiwan History was the result of the Solar TOP project initiated in 2006. Standing outside the museum is a beautiful solar panel wall stretching 148.2 m in length and 15.57 m in height. This magnificent BIPV structure was sponsored by the Bureau of Energy and erected by Hengs Solar Corp. as a testament of the R.O.C.'s achievements in technology and culture. Established in 1998, Hengs is a professional company specialized in monitoring system integration. The company

[33] MOE (2006). June 2006 Energy Monthly Report, Bureau of Energy, Ministry of Economic Affairs, R.O.C.

founded its natural energy department in 2002 and has since focused on renewable energy system integration for public construction projects at home and abroad. Since its completion in 2009, the cloud wall has been a model structure in green architecture and a local landmark. Its construction was meant to play double roles, firstly as an integrator of modern science and traditional culture, and secondly as a successful solar power generator.

(2) Green Energy Output

Case name	National Museum of Taiwan History PV Cloud Wall
Case location	Tainan County
Erection style	Ground mounted architecture
Owner	Government
System Type	BIPV
System power output	195 kWp
Engineering interface	Hengs Technology Corp. Ltd. & King Polytechnic Engineering Co., Ltd.
Completion date	2009

According to the museum image designer, the integration of the solar wall was a happy coincidence. The original design called for the incorporation of the concept of the Taiwan history into an ornate outer wall for the museum. The theme was to include images of ocean crossing and blue skies on the intended structure. BIPV was the best material for such a design.

National Museum of Taiwan History BIPV Cloud Wall

(Source: ITRI/IEK)

The semi-transparent quality of BIPV reflects perfectly the clouds in the sky, imitating the blue waters through which our ancestors dared hundreds of years ago. The wall consists of 1700 pieces of PV modules, including 400 pieces of ceramic silkscreen glass that spells the words NATIONAL MUSEUM OF TAIWAN HISTORY. Behind the wall, a corridor leads visitors to a museum showroom, turning the structure and its scenic surroundings into a tourist attraction.

National Museum of Taiwan History PV Corridor
(Source: ITRI/IEK)

In its role as a solar power generator, the BIPV wall has an installed capacity of 195 kWp. It generates 280,000 kWh of energy annually, equal to conserving 145 tons of carbon dioxide. The power generated also helps the museum save more than USD 23,000 on electricity bills every year. The effort of National Museum of Taiwan History using solar technology is an example in model green construction. It was an innovative project for the museum, the solar panel provider and the construction team. Thanks to their efforts, the people now have a beautiful green landmark.

▶5.5 Delta Electronics

Case name	Ring of Celestial Bliss
Case location	Parts redistributed nationally
Erection style	Temporary Green Structure
Owner/Technology Provider	Delta Electronics
System type	LED installation art

Delta Group was founded in 1971 and is a leading corporation in power and thermal management solutions. The company is dedicated to developing innovative products for energy efficiency and invests over 5% of sales revenue in R&D annually. From the aspect of services, Delta has developed efficient switching power supplies at more than 90% efficiency, telecom power at 97% and PV inverters up to 98%. Many significant achievements led Delta to receive many awards for innovation and design worldwide. In 2012, Delta was selected for the Dow Jones Sustainability Index and ranked first in the Electronic Equipment sector. Since 2010, the company is also the winner of 47 international awards, including CES Innovation, Reddot and iF. Delta has been active in several green energy initiatives in R.O.C. and a virtuous cycle of reusing and recycling materials from its Ring of Celestial Bliss has led to various energy efficient projects, including supporting the Min Chuang Elementary School in Namasia and the LED lighting sculpture in Taichung City.

(1) Ring of Celestial Bliss

One of the greatest displays of the 2013 Taiwan Lantern Festival was the "Ring of Celestial Bliss," a 70-meter wide, 270-degree projection screen and LED lighting show in the form of a partial ring, the largest of its type in the world. The Ring and its surrounding construction were based on low carbon concepts. The main body of the structure was built with reusable steel framework and the external skeleton was made of Taiwanese bamboo. In addition to recyclable materials used in the construction, the Ring also employs 155 LED strips for illumination, which can save up to 80% of the energy used by more common halogen lights. Short films on sustainability were projected on to the Ring during the festival to raise public awareness on environment sustainability and renewable energy application.

The construction process of the Ring was carefully monitored and adjusted to fit green architecture regulations. After careful calculation of the structure's life cycle, it is estimated that the construction process of the Ring emitted 80% less GHG compared to that of a concrete building of the same size, equaling to conserving 350 tons of carbon dioxide emission. GHG emission by using reusable steel skeleton and bamboo façade is 20.8% of common concrete auditoriums. High efficiency lighting and video projection consumes only 65.4% of energy than normal circumstances and waste processing consumes only 14.8%. In other words, the Ring's 15-day exhibition period only emitted 94.7 tons of CO2 compared to 430 tons emitted in one night during the Taipei 101 New Year fireworks.

Delta Electronics Ring of Celestial Bliss at the 2013 Taiwan Lantern Festival (Source: Delta Electronics Foundation)

(2) Namasia Region Min Chuang Elementary School

The main contributions of the Ring are not limited to its function as an educational public art display, but rather in the reuse and recycling of its construction materials after the closing of the Lantern Festival activities. The steel framework was given to the Min Chuang Elementary School in Namasia for typhoon reconstruction. Namasia is a mountainous district in Kaohsiung and is the water source for two major rivers. During Typhoon Morakot in 2009, Namasia fell victim to serious flooding and landslides, resulting in the complete destruction of three elementary schools in the area. Fortunately, due to joint efforts from the Kaohsiung City government, Delta Electronics Foundation and other public and private organizations, the Min Chuang Elementary School was rebuilt into the first Net-Zero Energy Campus of the R.O.C.

The new Min Chuang Elementary School is designed to weather extreme natural conditions and double as a disaster command center for the region during storms. Metal framework from the Ring of Celestial Bliss plays a big part as steel foundations for the school's rooftop solar panels. Over 59 tons of metal are reused in the construction of the school and its related green energy infrastructure. The current installed solar capacity at the school is 40 kW. It is expected that the renewable energy generated on-site would balance out the energy consumed by the school and eventually reach Net-Zero Energy Campus status.

Namasia Region Min Chuang Elementary School Net-Zero Energy Campus

(Source: Taiwan Environmental Information Center)

(3) Taichung City National Museum of Natural Science LED Display

In addition to donating the steel framework to disaster stricken school districts, other materials from the Ring were redistributed for other uses. The bamboo façade was dismantled and given to the Earth Passenger Environment Workshop, an organization devoted to sustainable design and environmental education, for the construction of a classroom. The projection screen canvas was recycled and manufactured into eco-friendly canvas bags. The LED lights used in the Ring were given to the National Museum of Natural Science in Taichung as a beautiful energy-saving light sculpture.

The LED light sculpture adorns the 8-story tall façade of the museum's rainforest greenhouse. 234 sets of LED lights form the theme of "Magical Rainforest – Four Seasons Symphony". The light display tells the story of biodiversity and environment sustainability of rainforests, promoting the concept of nature conservation while serving as a brilliant decoration for the community. Due to the use of efficient LED bulbs, the electricity cost is only USD 1.2 per day. The light show gives the greenhouse a new life at night, turning it into a new landmark in Taichung City area. It also gives an impactful performance with brilliant lights and symphonic music, leaving a deep impression in the hearts of its audience, reminding them of the importance of green technology and environment preservation.

National Museum of Natural Science LED Display
(Source: Taichung Natural Museum of Natural Science)

▶5.6 NexPower Technology Corp.

Although solar power generation depends on sunshine, it is a well-known fact that heat would hamper power generation efficiency. Unfortunately, many developing countries are located in heat belts. Therefore high efficiency affordable solar technology is very sought after in these areas. NexPower Technology is a subsidiary of United Microelectronics Corporation semiconductor foundry. The company focuses on thin-film technology development and its applications. NexPower is one of the world's leading manufacturers of thin-film technology. By utilizing high quality thin-film PV, the company is able to develop a wide range of system solutions for tropic regions.

System Specifications

1. Max output: 4000W
2. Output voltage: 120/230/240V AC
3. System Capacity: 2300Wh
4.

Package	Specs	Quantity
PV panel	150W 64V	20
Charger	3000W	2
Inverter	4000W	1
Battery	12V 100Ah	12

System Features

1. High performance in hot seasons and heat belts compared to other similar PV systems.
2. Higher power generation under low irradiance.
3. Ranks 3rd worldwide in power generation systems in cold weather.
4. Longer effective power generating time.

Thin-film solar cells are most suitable to be used in BIPV projects. By integrating power generating cells with the construction, the eco-building concept could be achieved. With BIPV, the architecture could produce solar electricity while simultaneously achieving thermal insulation, sound protection and shading. Multicolored BIPV panels could also be used for more creative façade design. In installation potential, BIPV could be used as building skylight, façade or roofing tile. Vertical installation is also a possibility in public spaces as noise reduction fences with power generating capacity.

NexPower's thin-film panels could absorb a wider spectrum of light and are less sensitive to dimming in sunlight and more resistant to heat, resulting in longer power generating time. Coupling higher power generation efficiency with low installation cost, the system is particularly suitable for tropic regions. In a photon module field test in Singapore, it was proven that thin-film PV could produce 50% more power than crystalline cells under 28 °C (Figure 5-13). Another advantage of thin-film technology compared to common crystalline cells is the bi-facial power generating ability.

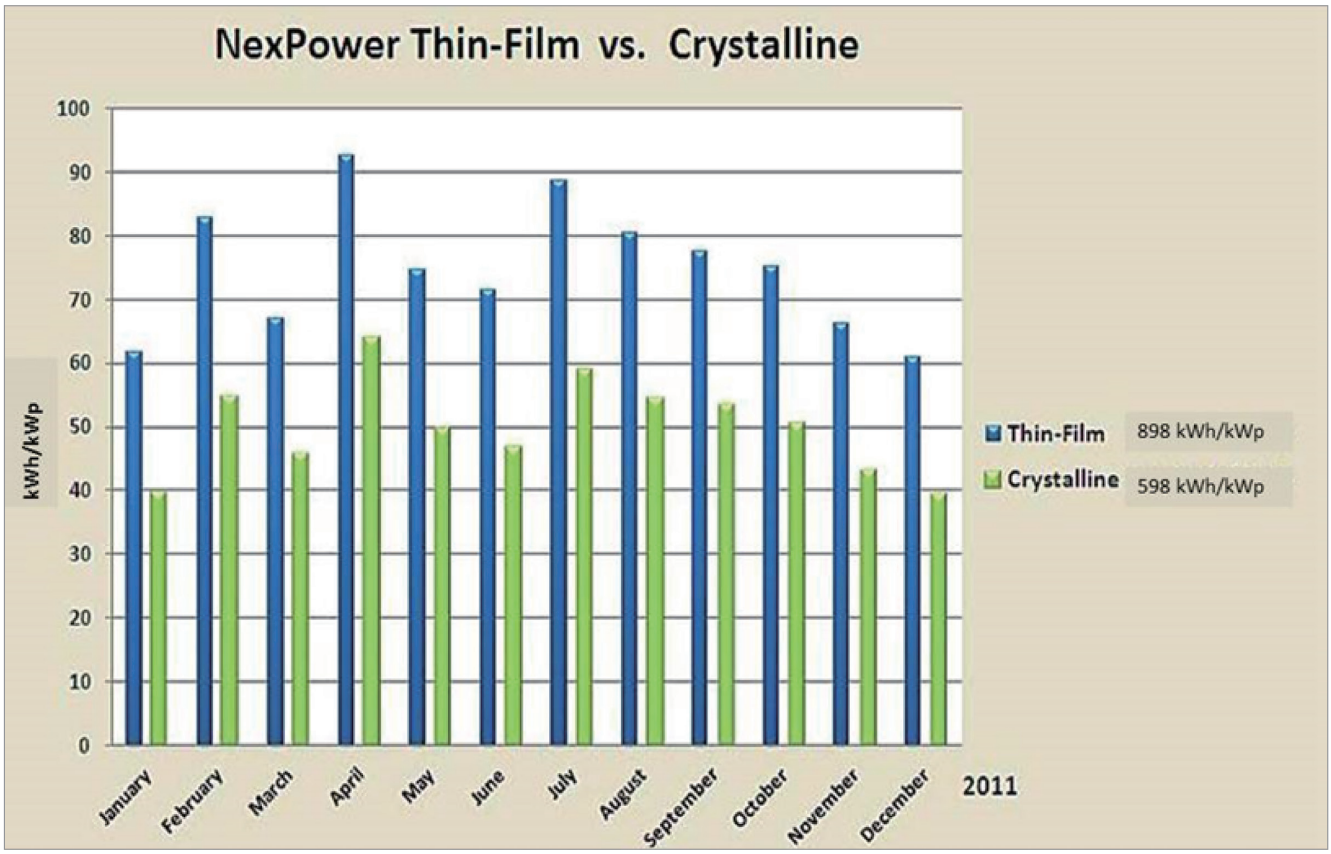


Figure 5-3. Efficiency comparison between thin-film and crystalline

(Source: NexPower Technology Corp.)

(a) NexPower Demo House

(b) Collaborated BIPV Project in Japan

Figure 5-14. NexPower demo house and BIPV project

(Source: NexPower Technology Corp.)

Currently, NexPower's tropic system solution is installed in India, Thailand and Indonesia as off-grid or hybrid systems for home use, telecom stations and water pumps. After the 2004 tsunami in Indonesia, NexPower's solar systems for public clinics near coastal areas played a large role in providing continuous health care for the local people. In addition to tropic solar systems, BIPV is also one of NexPower's greatest advantages. Some of their largest BIPV projects were cooperated with architects in Europe and Japan.

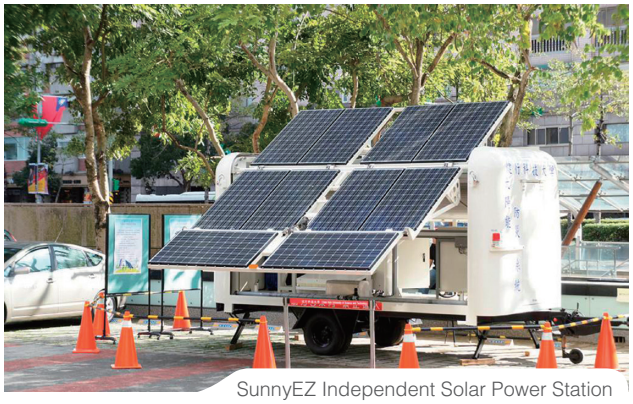
▶5.7 *Lawson Transworld Inc.*

The geographic environment of the Southeast Asia makes electricity distribution very difficult. High mountains, archipelagoes and frequent natural disasters all make grid power costly to set up and maintain. Therefore, independent power systems are in high demand in these areas.

To cope with various power distribution barriers, Lawson developed a mobile solar power station. The power station is designed to provide electricity to disaster stricken regions, remote areas or act as an island-to-island communication system. In many areas of the world where a large part of the population has no access to reliable electric power, the power station could alleviate the urgent need for electricity.

The system's greatest advantages are its operability and mobility. In case of disaster where residents are cut off from outside resources and access to electricity, SunnyEZ could be transported into the area to provide emergency power. The system could be operated by a single person and takes only 120 seconds of start-up time. The disaster area could be up and running again with basic lighting, communication and medical services in a matter of minutes.

System Specifications	System Features
1. PV array watt: 2400 W 2. Cell type: Panasonic HIT 3. Panel efficiency: 19% 4. AC output voltage: 120 V/60 Hz (230 V/50 Hz available) 5. Rated AC output power: 3600 VA (surge 6000 VA) 6. Output wave form: Pure sinewave 7. Battery bank: 48 V/400 Ah (Lithium polymer)	1. Fully automatic single operator system startup within 120 seconds. 2. Complete power solution with components fully integrated in a mobile cabinet. 3. Light weight and high efficiency LiNiCoMn battery bank. 4. Low maintenance and sturdy body to counter harsh environments. 5. Expandable system supports scaling of up to 30 kW for large power demands.



SunnyEZ Independent Solar Power Station

(Source: Lawson Transworld)

Rumdual Island School Rooftop PV

(Source: Lawson Transworld)

Besides disaster relief, the system is also designed for military defense and research stations. It is currently used in regions with harsh weather conditions as power supply for communications relay stations. Due to its diverse applications, the system could be partially customized to suit the needs of its mission.

As one of the pioneers in marketing solar power products in the R.O.C., Lawson mainly provides package solutions and consulting for independent solar power systems. The company also has abundant experience in the Southeast Asia including installing power systems for private villas in Singapore and power supply for farming water pumps in Thailand.

One of their most prominent projects was on Rumdual Island in Cambodia as part of the Koh Rumdual Island Project initiated by the Family Care Foundation. The project was an international effort to provide basic resources for the island's residents. Lawson Transworld was a key player in setting up the roof solar system of the Rumdual Island School. With six hours of abundant sunlight per day, the school is now entirely self-sufficient in power supply.

▶5.8 HiVAWT Technology Corp.

Many remote telecom stations and research bases are set up in mountainous areas with little to no access to grid power. Independent renewable energy generators are often considered to augment electricity consumption in these areas. Though solar power is currently the most economical green energy to generate, cloudy weather, heavy shading incurred by trees and hills, or heavy snow coverage restricts solar power generation in mountainous areas. Very often, wind power is the dominant renewable energy in these areas, which enables an ideal source complementary to solar power. However, destructive gusts and harsh environments often destroy common wind turbines. In this case, high quality and reliable turbines are extremely important.

Small vertical axis wind turbines developed by HiVAWT are among the sturdiest in the world. These turbines are designed to withstand difficult weather conditions and provide high level power to remote locations for telecommunication or weather observation.

System Specifications (DS-3000/DS-700)	System Features
1. Rated Power: 3000 W/700 W 2. Rated Wind Sped: 12 m/s 3. Rated Speed: 205 rpm/405 rpm 4. Survival Wind Speed: 60 m/s 5. Blade material: Anodized aluminum 6. Axis material: Galvanized steel SS400 /Anodized aluminum 7. Automatic Braking: Over speed short circuit braking system	1. Design compliant with IEC-61400-2 certification. 2. High immunity against turbulence and could survive winds at 3-sec gust 60 m/s 3. Excellent wind direction adaptability compared to horizontal turbines. 4. Integrated blade design, creating low wind self-start and high wind efficiency. 5. Runs silent and fit to install in urban areas. 6. Brushless PMG generator without the cogging torque.

HiVAWT's turbine design integrated both the Darrieus and the Savonius Blade, enhancing advantages in high wind efficiency and low wind self-start. The Savonius Blade used by HiVAWT could self-start at wind speeds lower than 3 m/s, while the Darrieus Blade enhances rotor efficiency. Moreover, small wind turbines have the advantage of taking up limited land space and can be installed on mountainsides, distant reefs and even boats. One of HiVAWT's standalone turbines provides power for a monitor station at Terra Nova Bay in Antarctica. Besides remote areas, small vertical turbines are also installed in urban areas as an on-grid power supply. Its eye-catching design is favored by corporations and government sector and often installed as a public facility to remind people of energy conservation. In comparison with vertical axis turbines, vertical turbines generate less noise and have excellent wind direction adaptability. Vertical turbines also have the advantage in self-starting in low wind conditions. These benefits make small or micro turbines a superior choice to horizontal turbines in urban areas or locations with irregular wind flow.

Among the many applications of the vertical turbine, the hybrid street lamp is the most popular variation of micron turbine application. Hybrid street lamps combine power generating solar panels and wind turbines with LED lighting. Such an item integrates three very celebrated technologies in renewable energy and presents itself as the pinnacle of energy efficiency. Some of HiVAWT's hybrid models are installed in the P.R.C., Japan, Germany and the United States, across three continents.

Another worthy mention in the application of vertical turbines is the installation of the DS300 on fishing trawlers. In some situations, fishing activities take place at night where high powered lights are used to attract catch. These fishing lights are extremely energy consuming and would quickly deplete the vessel's battery. With small vertical turbines installed on board, trawlers could self-generate power at night and decelerate power exhaustion.

Since 2005, HiVAWT has been the designer, manufacturer and patent owner of several vertical axis wind turbines dedicated to corporate and government sectors. HiVAWT is especially experienced in turbine installations for telecommunication stations. Some of their projects include providing for SK Telecom in Busan, Chunghwa Telecom in R.O.C. and China Mobile in Xinjiang, Gansu and Tibet.

(a) Hybrid street lamp in Kunsan, P.R.C.,

(b) DS700 trail project in Xingjian, P.R.C.

HiVAWT Small Wind Turbine Projects

(Source: HiVAWT)

▶5.9 FormoLight Technologies Inc.

As world population grows and traffic becomes more congested, travelers need more detailed and up to date information on traffic conditions of the road ahead. So, static traffic signs are no longer enough for busy and complicated roads. Now, LED variable message signs have become a familiar sight on motorways and major highways of many countries. They provide road users with information on road conditions ahead, improving safety and reducing congestion. FormoLight's LED signs can display distinct Chinese and English characters and also color graphic messages. Moreover, full matrix signs are fully programmable to create text and pictograms with infinite number of configurations.

System Specifications (Full matrix VMS)	System Features
1. LED lamp: Red, Green, Blue 2. Pixel Pitch: 30 mm 3. Resolution: 65(H)*128(W) pixels 4. Brightness: R: 6500 cd/m2, G: 15000 cd/m2, B: 2400 cd/m2, W: 23900 cd/m2, Y: 21500 cd/m2, Purple: 8900 cd/m2 5. Display dimension: 1920(H)*3840(W) mm 6. Power consumption: 2830W(max.) by PFC power supply	1. Compliant with international standard protocols NTCIP, Madbus, etc. 2. Power saving mode when unit block displays no message. 3. Real-time self-diagnostic pixel failure, power supply failure, photo-sensor failure and communication failure detection 4. Robust design for easy maintenance and repair efficiency.

Some of the company's achievements in R&D include the ability to switch to power saving mode. Whenever pixels of a unit block have no need to show any message, the driver IC enters power saving mode, reducing power consumption by 50% compared to conventional LED banners. FormoLight's LEDs are also driving by low voltage which significantly reduces heat dissipation. Special optical designs are also implemented to allow for 30% increase in light output while consuming the same amount of energy.

Clever design and quality in production have significant impact on local traffic safety and cost management. Traffic signs are exposed to wind, rain, sun and snow. While the industry only offers a 3-year warranty, FormoLight's signs could last more than 10 years. One sign in Hong Kong held a record for operating for 17 years. In addition, real-time monitoring

(a) Integrated ERP signage in Singapore


(b) Broadcast screen in Allianz Arena, Germany

FormoLight LED Display Projects

(Source: FormoLight Technologies Inc)

systems are integrated with citywide message signs. Operators can quickly detect and analyze the downed module and determine whether it is hazardous to traffic control and if maintenance or repair of the banner is immediately necessary.

FormoLight Technologies Inc. is a professional manufacturer specialized in LED applications. The company has been producing LED display systems for traffic applications and full color display since late 1980s. FormoLight's traffic sign products have achieved acclamation worldwide for its robustness and system stability. Some of their successful references in different protocols worldwide include the Electronic Road Payment System in Singapore, Lane Signal Unit in New Zealand and traffic control and surveillance systems, etc.

Being selected for the Allianz Arena in Germany to broadcast the 2006 FIFA World Cup was a nod to FormoLight for its high quality standard. While many internationally renowned brands were used for other World Cup stadiums, FormoLight's screen remained the only LED display with zero failures during the games. Though FormoLight is a relatively quiet brand, it demonstrates its ability to compete with big brands through action.

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