Scientific Research

Accelerating Development of Renewable Energy Resources in Guangdong

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Abstract: The energy status and trend of Guangdong Province have been evaluated from 1980-2009 in this paper, which maybe is one of the most populated and prosperous areas in China. Based on the analysis of energy system for Guangdong, an integrated optimal energy system model has been established in order to promote renewable energy utilization in large-scale and support provincial sustainable development, and case study of a district of 18km^2 area shows that with the current technologic and economic condition, renewables goal of realizing 10% of total energy consumption is possible in Guangdong. Case selected was very common, which can be a model of cycle-economic and ecological district in Guangdong, even China.

Keywords: Renewable energy, Energy systems model, Regional energy planning

1. Introduction

In recent years, Guangdong has experienced equally rapid increases in economic expansion and energy consumption. As a result, energy induced environmental degradation has also increased in Guangdong, especially in areas of Pearl River Delta. When this fact is coupled with further energy demand to meet the economic expansion, it is clear that the province faces great challenges in balancing its goal of economic growth with environmental sustainability. Therefore, renewable energy utilization is an effective way to improve the energy structure as well as increase the energy supply for Guangdong's long-term energy, economic and environment interest.

A development plan of the renewable energy put forward by State Development and Reform Commission (SDRC) requires that renewable energy reach 10% and 15% of total amount of national energy consumption by 2010 and 2020[1], especially, it will be 30% share of install capacity of electric power system by 2020. A report forecasted the renewable energy including solar energy, wind, and other new energy resource would share 5~10% of total amount consumption before 2025, and even reach 20~50% in 2040 worldwide[2]. As shown in the Figs. 1 and 2, share of renewables in Guangdong is only 0.22% of the total installed capacity of provincial power system, and the amount of supply even less than 0.1% of the final total power consumption[3].

Considering the health impairment effects and depleting nature of commercial energy sources, it is necessary to analyze renewables status in Guangdong to promote its commercial utilization. Simultaneously, an optimal energy planning should be set up for the renewables development as well as sustainable development.
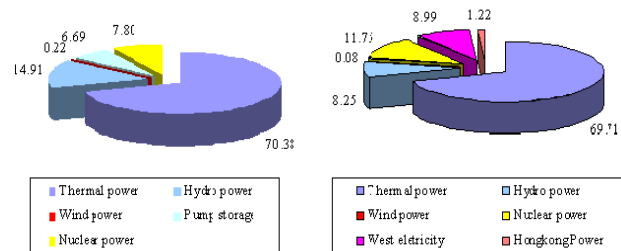
Fig.1&2 Install capacity and supply structure of Power System in Guangdong

2. Prospect of renewables in Guangdong

Being poorly in fossil fuel, Guangdong is endowed with rich renewables resources such as wind energy, solar energy, biomass energy, and hydro-energy and so on.

2.1 Scene of renewable energy resource

Guangdong lies on the coast of South China Sea dotted with about 1,000 islands. With coastline of 4300km and strong subtropical monsoon round Guangdong all year, theoretical wind energy reserves amount up to 96,980MW in land, and 6,000MW is exploitable, an equivalent of the exploitable capacity of Guangdong hydroelectricity . Considering these area close to sea, the available off-shore wind energy for installed capacity will be 30,000MW, boasting a great potential[4,5].

Solar energy is regarded mildly rich in Guangdong. Apart from high solar radiation density, Guangdong suffers 1,400 and 2,200 hours solar radiation time per year, and average solar irradiance is 1,250kW·h/m^2 annually. So far, two solar power facility are operating, one in Shenzhen, and another is a 6.5 kW photovoltaic panel system for lighting in a primary school on a island [6].

Guangdong is also abundant of biomass energy resources, where approximately 600 million tons of biomass is produced per year[4,6]. By far, most of the bio-

mass was burnt inefficiency for heat production. Municipal solid waste (MSW) is also considered as another renewable energy sources belong to biomass. The province produces 26 thousand tons municipal wastes every day involving in 15 thousand tons in the delta pearl rive areas. MSW grows at an annual rate of 8% [7], which is eventually large enough to produce electricity.

Micro-hydropower stations have been developed very rapidly in rural areas of Guangdong. Most of rivers in the province have already been exploited. Currently, there is about 10,284MW of hydro-powers installed, very little remains to be exploited[8]. There are more than 200 geothermal sites in the Guangdong province. More than 30 of them have temperatures over 80°C. Three power stations have been built including a 26-kW unit using a 91℃ source, a 300-kW unit using a binary cycle and a 300-kW grid-connected unit[6].

Based on analysis above, solar energy, wind, and biomass (include MSW) are considered potentially feasible for wide-scale application in Guangdong, while other resources of Renewables including geothermal energy, hydro power and tidal and wave power have limited potential for development in most areas of Guangdong.
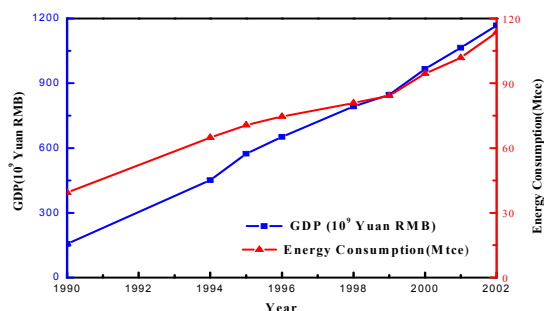
2.2 Market demand

Figure 3. Changes in TEFC and GDP of Guangdong since 1990.

Guangdong province is the most rapid developed province in China. The energy demand especially for electric power in Guangdong increases more rapidly than other provinces. As it can be seen in Fig. 3, the TEFC (Total Energy Final Consumption) reached 244 Mtce in 2009, took up 8% of the national gross, whose growth rate is 9.6% annually since 1980. Although Guangdong's electric industry is China's most developed power market judged by per capita installed capacity and per capita electricity consumption, economy growth has been constrained by severe shortage of electric power supply for almost 20 years since 1990's[1,2]. It is estimated that a capacity of 32,360 MW should be added during the eleventh five-years plan[8]. The installed capacity will reach 136,120 MW by 2020. However, the current installed capacity is only 64,908 MW. Given 10-30% share of the total energy supply, the installed capacity of renewables will reach to 13,612 or 40,836 MW in 2020,

however, the current renewables capacity is about 10,573 MW, the gap between the goal and reality is large, thus, opportunity and market for renewable energy is huge.

2.3 Solid economical base

Guangdong's GDP reached ¥ 3908.1 billion RMB in 2009, which accounted for 11.7% of the national total, ranking No 1 in China, while the population is only 1/15 of the national total. The province absorbed almost one third of the foreign investment in China. More than 50,000 registered capital foreign and private enterprises have invested more than $50 billion in Guangdong. The province's exports capital account for 36% (118.61 billion in 2002) of the national gross. Total tax income share more than 1/8 of the national total. Therefore, its financial power is strength enough to invest on renewable energy development.

2.4 High energy price in Guangdong

Being poorly in fossil fuel, more than 90% of consumed energy resources must be imported, which result in high energy price such as electricity in Guangdong[9]. Environmental impacts are not fully included in cost of electricity. The areas covered by acid rain caused by fossil fuel have dominated 70% of the province's total, which have led annually ¥4 billion RMB loss directly[10]. When fully consider social and environmental cost, price of fossil fuel will be higher, which provide renewables with a good external circumstance.

Guangdong's rich renewable energy resources, huge potential market, higher energy price and current rapid development lay a solid basis for renewables development. Yet despite favorable conditions, renewables still developed slowly in Guangdong for lacking of system planning and optimization through policy interventions,.

3. Physical structure model of energy system

3.1 Primary energy supply sector

The energy system can be described as a network of energy conversion chains, starting from all kinds of primary energy and ended in end-use sectors. The energy system structure model(Figure 4) shows that each end-uses demand can be met by various energy conversion chains. The energy system divides into three sectors.

The primary supply sector includes fossil fuels (coal, oil, natural gas, etc.), nuclear and local renewable energy. This sector provides for power and heat deriving from large-scale as well as small-scale technologies and for other needs directly in end-use sector.

3.2 Intermediate conversion of primary energy

The large-scale technologies are adopted both for centralized electricity generation and for industrial power and steam production, whereas small-scale technologies are distributed energy system by local renewable exploitation and civil thermal/electric energy production. All of

them connected to power grid. The total generation capacity to be installed takes into account the possibility to export/import energy to the neighboring regions. Various

technologies, such as conventional CHP plants, combined cycle plants, PV, micro-turbine and etc., have been supposed for intermediate conversion of primary energy.
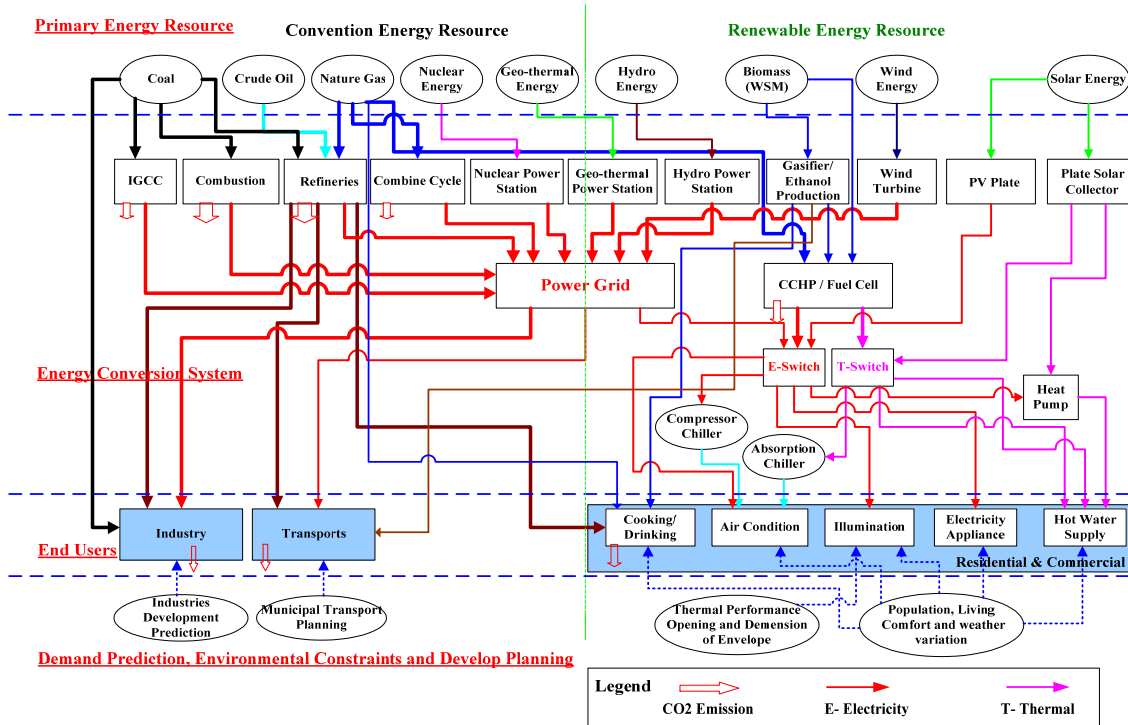

Figure 4. The physical model of total energy system.

3.3 End-use sector

The end-use subsystem defines a set of energy demand disaggregated in power, industrial process steam, civil heat and other needs(natural gas for cooking systems, petrol and diesel oil for means of transportation). In particular, civil and industrial users can satisfy their electricity needs both withdrawing energy by the grid and self-producing power.

End-users often select the minimal price. Thus, the most competitive energy product is those whose cost is minimal. Energy product cost is depended on many factors such as scale, efficiency, operation cost, investment, environmental cost, social cost and so on. Evaluation of environmental cost and social cost are difficult. The polluter always avoid pay the cost, therefore, several energy supply system models have been developed previously to Optimal energy system[11-13]. In these modeling exercises, critical parameters such as reliability, security of energy systems were not considered. These cost factors that were identified to be the mathematical model presented in this paper, which have been included and analyzed in order to obtain an economic, social and environmental security energy supply system.

4. Integrate energy optimal model

The schematic representation of the optimal energy system model is shown in Fig. 5. Renewable energy systems typically have higher capital costs than fossil-fueled systems. Emphasis on life-cycle costs and reduction of the risks of high capital investments are necessary for the success of renewable energy. On the other hand, technologies should be improved to make more efficient use of renewable energy. In this model, the prime factors of cost were considered in the objective function. Minimization of cost was the main objective function of the model. The key constraint of the model was reliability constraint, demand constraint, potential constraint, environmental constraint, and economic security, etc.

The model comprises fuzzy parameters and intelligent expertise system in order to handle adequately the uncertainties regarding energy costs, also provides a set of efficient solutions, each one characterized by quantification of the risk associated with the uncertain energy costs. It was recognition of the complexity associated with energy investment decisions in individual.

The model revealed that cost are highly critical factors in the utilization of energy resources, and that factors such as technology, availability and reliability should be

considered in order to select the appropriate energy systems for different end-user. For optimization, cost and efficiency were chosen as objective function and minimization of function was carried. The ultimate aim was to secure enough energy supply with low cost and economic sustainable development as well as environment.
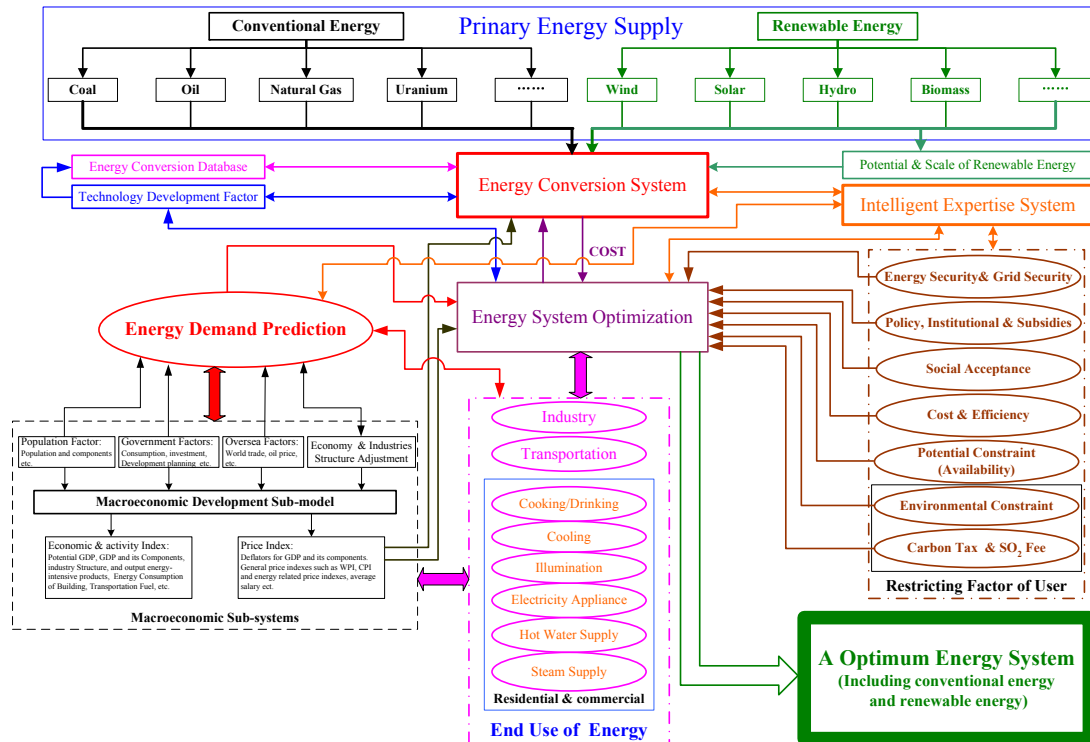

Figure 5. The structure of integrate energy optimal model.

5. Case Study

Renewable energy sources are likely to play a significant role in meeting the future energy requirement of Guangdong. The effect of introducing renewables on commercial energy scene may have to be analyzed carefully. Aiming at promoting development of renewables, case study was used to analyze feasibility on every planning scheme using renewables under various technology and economy condition.

A new district with 18km^2 area in Guangzhou was chosen for study. This district was set up blank space and will be a sensitive ecosystem center of the city's blueprint in future. The population is expected to reach to 250 thousand people, which have little changes in the future and need no high electric density. The regional energy supply system was optimized and planning by the model.

Sited the central of Pearl River Delta, renewables in this district are relative abundant. Annual average solar radiation is 4.5-5GJ/m^2 and the annual total radiation times above 2,000 hours, which is sufficient to provide adequate energy for solar thermal applications. The district is abundant of wind energy; wind speed is above 5m/s at 50m altitude. With a high population density, the daily waste output is 324 ton, about 100,000t/y. In addition abundant water and geothermal energy, this district has great advantage to utilization of renewables.

The forecasted mainly energy demands of the system are power and heat. Being no large industry, heat demand is fewer comparing with the electric power demand. The total electric power demand is expect to 860,720 MW per year. Therefore, following the modular structure illustrated in Fig.5, the variation of end-use demand is regular. The energy supply sector is power from power-grid, wind power, waste incinerate power and PV power (PV power is expensive at present, so it is only fit for moderate use for outdoor light). For the district energy systems, the optimal model was aiming at providing the district with sufficiently and low price power.

Wind power

Wind power developed faster and the cost decreased rapidly in world-wide. It has dropped to roughly 4¢/kWh today on prime wind sites[14], which can be seen from **Figure 6**. Some recently signed U.S. and U.K. long-term supply contracts are providing electricity at 3¢/kWh. If wind turbines are mass-produced on assembly lines, cost of wind-generated power could drop more [15].

However, it is still higher than the conventional power plants without considering harmful emissions and other environmental damages. Documents have been issued by government to encourage wind power development such as multi-channel financing, privilege to incorporate to grid, higher price of incorporated power, less than 10% of return rate on capital investment, 15 years depreciation, tax reductions or exemptions, etc...

Based on government document and present wind turbine price, cost of wind power would be ¥0.6/kWh without tax, similar with the current civil electricity price. By using the model mentioned above, it is estimated that with the state-of-the-art, wind power can reach 2.4MW in low return. Along with the advance of technology, wind power can reach 30.4 MW with high return.

Solid waste incineration

Solid waste incineration are used to power and heat. Result has been shown in table 1 by using this model.

Table 1. Profit variation of MSW power under public subsidy

Public subsidy	Electricity (MWh)	Total cost (¥/t)	Price (¥/t)	Profit (¥/t)
50¥/t	44,800	54,000,000 (36,000,000*)	0.63	-20,780,000 (-2780000*)
80¥/t	44,800	54,000,000 (36,000,000*)	0.63	-17,780,000 (220,000*)

* The condition of tax exemptions

Table 2. Final optimal scheme of renewables in case region

Renew-able Energy	capacity （MW）	Electricity （MW·h）	Investment （RMB¥）	Investment （¥/kW）
Solar	0.1	200	4,000,000	40,**000**
Wind	30.4	30,**000**	304,**000**,000	10,**000**
MSW	7/**20**	44,800/**130**,000	26,300	37,500/35,000
Total	37.5/50.5	75,000/**16**,020	46,300	

After considering all the constraints, including geographical limitations, legislation and institutional restrictions, technology development, commercial viability and social acceptability, an optimal scheme has been obtained(Table 2), in which a Wind Farm with install capacity of 20MW, and a power plant of 7/20 MW by MSW incineration would be installed by 2010, with capital payback time about 10 years. All the vent of the waste incineration is rigorously limited under standard of Europe. Up to 2020, the wind electricity installed would reach 30MW, and share of renewables would reach 10% of final total consumption. it reasonable that this district should adopt renewable resource targets of 5% in 2010, and 10% in 2020.

6. Conclusion

1) The profile and constraints of renewable energy resources in Guangdong has been assessed in this paper. To cope with its increasing energy demand and protect environment, Guangdong should expand it renewable energy market and accelerate technology improvements.

2) An integrated optimal energy system model has been established in order to promote renewable energy utilization in large-scale and support the provincial sustainable development. With the aid of this model, it is feasible not only to point out striving direction to exploitation of technology utilization of renewables, but also to enhance quantitative objects of competition and direct the decision-making for energy planning policies.

3) Case study showed that with current technologic and economic condition, renewables share goal realizing 10% of energy consumption is feasible in Guangdong.

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