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POLYGENERATION ENERGY SYSTEM BASED ON OXYGEN-BLOWN COAL GASIFICATION[1]

Environmental pollution has become the bottlenecking of the sustainable economic development of China. The business-as-usual energy system in China is not suitable for sustainable need. It is well known that China has to use coal as the main primary energy for quite a long term. Under such special conditions, it is an urgent strategic problem to be studied and carried out step by step from now on to plan and construct the integrated sustainable energy system with optimal benefits in resource and energy utilization and environmental emission. By introducing the international study and new development in sustainable energy systems, this paper put forward that poly-generation strategy based on coal gasification is the trend for future development of our domestic energy industry. The framework of polygeneration system based on oxygen blown gasification is described and its benefits are analyzed. Finally, the starting procedure, government role and policies for the implementing of poly-generation strategy in China are proposed.

The Business-as-usual Energy System of China is Unsustainable. ***The Averaged Energy Consumption Per Capita Will Irreversibly Increase.*** The present averaged annual energy consumption per capita in China is approximately 1 tce, which is relatively low compared to 11 tce in USA and 5∼6 tce in Japan, Germany and Russia. Due to the limit of natural resources and environmental capacity, it is not possible for us to pursue high energy consumption and we should find the thirsty living styles that is suitable to China. However, along with the development of society and technology and with the uprising hope for better living standard, the energy consumption per capita will nevertheless increase. In accordance to the prediction of different organizations, the annual energy consumption per capita in China will be 2.5 to 3 tce by the year 2030. Neither administrative instructions nor willingness of people will be able to change this trend.

Natural Resources and Environment Are Unendurable by Using the Business-As-Usual Technologies. At present, the averaged electrical capacity per capita is only 0.2 kW. The well-to-do living standard will require at least 1.0 kW per capita, i.e. more than 4 fold increase. By then, the emission of CO_2, SO_2, NO_x and TSP will increase accordingly, if the existing coal-fired power generation technologies are continued. This means that the existing technologies are not sustainable.

[1]Статья публикуется в авторской редакции.

Besides, the urbanization is also irreversible in China and the pollution in large cities is becoming more and more severe. The main pollution source is the exhaust of vehicles. It is reported that in the top ten polluted cities, China has seven and Beijing is shamefully ranked the third.

Petroleum and Natural Gas Reserves is Relatively Indigent. The reserve and exploitation ratio of petroleum in China is only 15, much lower than world's averaged value of 40. Though the prospect of natural gas is better because of the revealing of some new reserves recently and planning to import natural gas from Hasakstan and Russia, the fraction of natural gas in total energy mix will not increase greatly. The capacity of the West to East natural gas transportation plan (4200 km long pipeline, more than 100 billion yuan investment) is only 12 billion cubic meters per year, which composes only 1.2 % of the total energy mix. Now the natural gas in energy mix is only 2 percent. The most optimistic estimation of this number is 10 percent by the year 2030.

It is estimated that the annual production of petroleum in China in the coming years will be 160 to 200 million tons and will not increase greatly. But the demand for liquid fuel is increasing and causes the increase of import of petroleum. In 1999, 40 million tons petroleum was imported. In the year 2005 and 2010, 90 and 16 million tons are going to be imported. These numbers are really astonishing, because on the one side, a lot of valuable foreign currency will be consumed and makes our economy subject to the impact of international oil price, and on the other side, the situation is serious from the point of view of national energy security.

Furthermore, the import of oil has caused another problem. The business-as-usual refinery process and equipment in China are not suitable for the refinery of cheap, high sulfur content raw oil, which results the produced gasoline and diesel products are too high in sulfur content compared with the international standard. It could cost hundred billion of investment to retrofit the existing refinery process and equipment.

Renewable Energy Could Compose Only a Small Fraction in the Entire Energy Mix. In China, the renewable energy such as wind, solar and biomass energy should be emphasized to develop. However, it can not compose a great fraction in the entire energy mix. The most optimistic estimation will be 10 percent in the future.

Therefore, considering the reality of China, under the condition of coal as the main primary energy, it is an important strategic problem to develop the sustainable integrated energy system of resources, energy and environment. The key point is how to make best and cleanest use of coal by integration of different industries in China.

Polygeneration Based on Coal Gasification will be the New Trend for World Energy Utilization. From the point of view of the whole world, industrial development and large-scale utilization of fossil fuels have brought the home of human being, the earth, with deteriorated environment and there continues to have even more serious challenge. Therefore, all

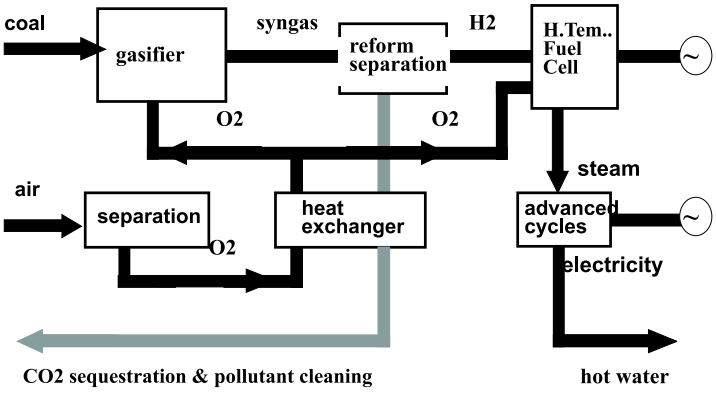

Fig. 1. Vision 21 energy system [1]

the countries and different industries are looking for new systems with less resource consumption, high energy-conversion efficiency and low emission. For example:

Department of Energy (DOE) of United States has put forward the Vision 21 energy system [1] (Fig. 1). Its idea is to get syngas through coal gasification. The syngas could be used to produce hydrogen as the fuel for fuel-cell automobiles in one way. In another way, the syngas could be used in the hybrid cycle of high temperature SOFC and gas turbine to produce electricity. Its efficiency could reach 50. . . 60 %, pollutant emission could be negligible and economic features could be 10 percent better than conventional pulverized coal boiler power plant.

Shell Company has put forward the concept of Syngas Park. In this park, coal or residual oil is gasified. The produced syngas can be used to produce electricity with IGCC, to produce methanol and fertilizer in "once through" way and can also be used as town gas supply [2] (Fig. 2).

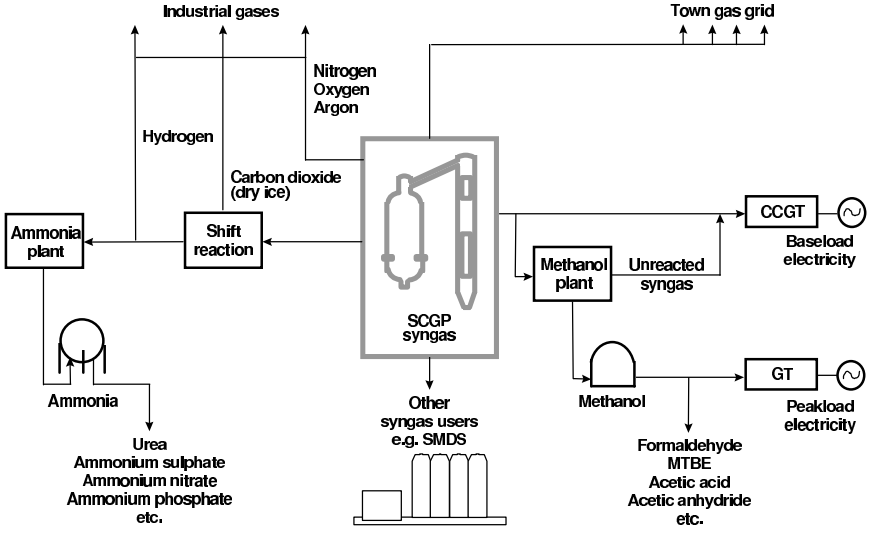

Fig. 2. Syngas Park Concept by Shell Company [2]

Some IGCC power stations have also been established in petrochemical enterprises. They use cheap residue oil, pitch, petrocoke or orimulsion as feedstocks to produce syngas. Syngas can either be used as raw materials for production of value–added chemicals or to provide electrical power and steam for the production processes. This makes the production of electricity and heat closely incorporated with chemical production processes and decreases the costs for both chemicals and electricity. Up to now, tens of such facilities have been put into operation all over the world, and more are under development. One typical example is the facility in Italian ISAB Company with a power output of 512 MW.

The above examples show that, many developed countries are seeking the efficient solutions to resource shortage and environment pollution problems. However, due to the traditional separation of different sectors, every sector is looking for optimal solutions in its own field. Actually, these optimal solutions can hardly be the best as the society is concerned as a whole. Polygeneration is intended to be a highly flexible and optimal integrated resources, energy and environment system from the angle of whole society and breaking up the existing separation of different sectors.

The Framework of Polygeneration System Based on Oxygen Blown Gasification. The polygeneration system is proposed from the point of view of comprehensive optimization, which is a highly flexible and cross-sector integrated system of resources, energy and environment. Fig. 3 is its basic framework. The main points are:

1. Using coal, petrocoke or heavy oil residues with high sulfur content as feedstock, syngas (main contents are $CO+H_2$) is produced through oxygen

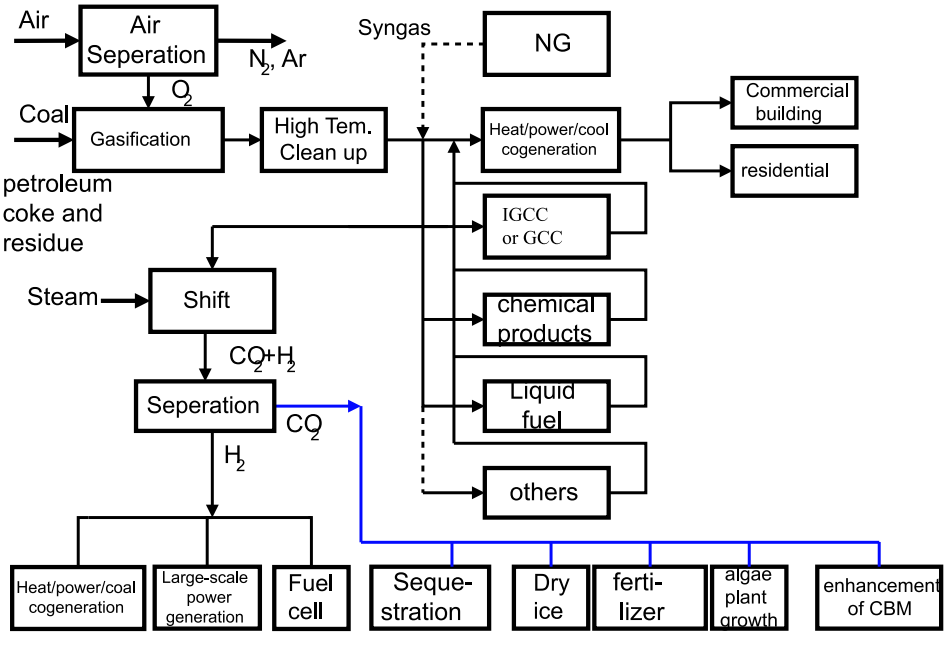

Fig. 3. Integrated system for resource, energy and environment

blown gasification. After cleanup and purification of syngas, elementary sulfur could be obtained as by-product.

2. There are diverse ways of utilization for obtained syngas:

— town gas for cooking and heating, for distributed power, heat and cool co-generation;

— large-scale power generation (fuel cell or gas/steam combined cycles);

— methanol production via "once through" liquid phase reactor;

— liquid fuel production (synthetic fuel and dimethyl ether) via "once through" liquid phase reactor;

— other chemical products (NH_3, urea, middle distillate).

The other part of syngas can be reformed to produce hydrogen. With the development of PEM fuel cell technology, hydrogen can be used as fuel for vehicles and solve the transportation emission of large cities eventually, i.e. near zero emission. From the long term point of view, hydrogen as the energy carrier, could be utilized as cleanest fuel for distributed power, heat and cool cogeneration for realizing local zero emission as well.

3. The treatment of separated CO_2. When combustion process is properly controlled, burning of cleaned syngas causes much less pollution than conventional power plant with direct firing of coal. Therefore, the key issue will be the treatment of green house gas CO_2. For the proposed polygeneration system, because of the separated CO_2 is nearly pure (99 %) instead of mixed with 75 % nitrogen in the flue gas of conventional power plant, CO_2 could be used as feedstock for different products, such as urea, dry ice, etc. (The new development of inorganic membrane is very promising for more efficient and economic way for CO_2 separation [4]). It can also be used for enhancement of plant growing and other industrial purposes. In recent years, a Canadian company is conducting the research and experiment for enhancement of coal bed methane (CBM) production by injecting the CO_2 to the coal seam (the depth is more than 2 km) in Albert area. Since coal as a micro-porous substance has the greater absorption capability to CO_2 than to CBM (mainly CH_4), thus, the valuable CH_4 could be "squeezed out" and the CO_2 be sequestrated. There are also a lot of other ways for CO_2 sequestration, e.g., to deep sea, to depleted oil and gas fields or to saline aquifers. Surely these kinds of concepts are only on the stage of preliminary study, the detailed technical, environmental assessment should be conducted. But anyway, pure CO_2 will be much easier to be treated than CO_2 in the flue gas of conventional power plants.

4. Close inter-coupling of production processes. The core of the proposed polygeneration system is the close coupling of the production processes of different products. For instance, after passing through the "once through" liquid phase reactor to produce methanol (or DME), the unreacted syngas could be directed to IGCC for power generation instead of subsequent separation and recycling to the reactor again as it is in conventional stand-alone methanol production. Therefore, the capital

investment, maintenance cost and environment impact will be significantly reduced, and consequently the price of these products could be reduced as well. Furthermore, because of the co-production, the "peak and valley" of each product (especially power generation) could be adjusted more easily according to the demand.

5. "Open" and highly flexible. Under the concrete circumstance of China, in the coal abundant areas, polygeneration system is quite beneficial. It could be implemented step-by-step or phase-by-phase according to the technical advancement and the availability of capital investment. For example, for the first phase, only power, heat and methanol could be co-produced, some more other products could be arranged later when financial situation is improved.

Fig. 3 only shows the preliminary framework of polygeneration. The detailed material flow, energy flow, information flow and multi-target (technology, economics, resources utilization, environment) optimization for each related subsystems should be carried out in the future through sophisticated study of complex systems and taking the local concrete conditions into account.

A Quantitative Example of the Benefit of Polygeneration System. The base case for comparison is the stand-alone production of power, heat, methanol and syngas by conventional power plant, industrial boilers, traditional technology for methanol production, and coal gasifiers correspondingly. The outputs are respectively 400 MW_e, 400 MW_{th} and 400 MW equivalent.

Compared with stand-alone production, quad-generation of these four products leads to the following benefits: reductions of capital investment by 38 percent, cost for unit energy by 31 percent and coal consumption by 22.6 percent [3] (see Fig. 4).

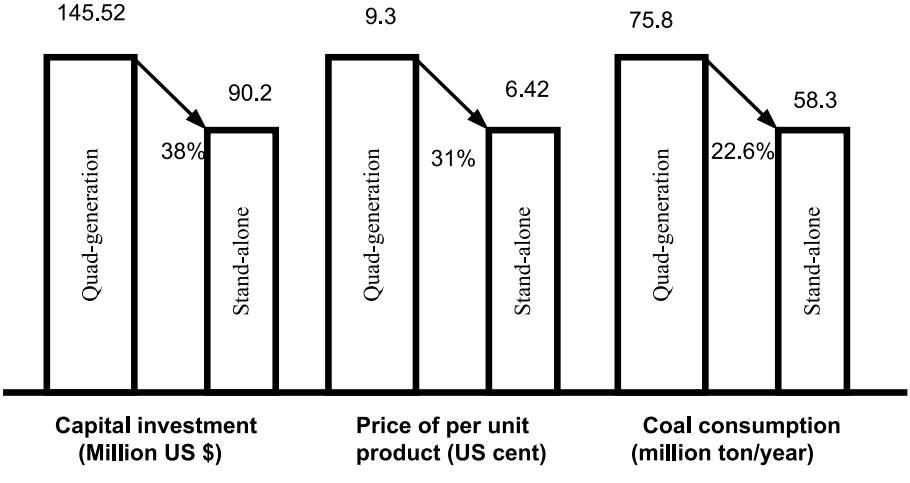

Fig. 4. Benefits of investment, energy consumption and environment for quad-generation

Though the above-mentioned results are rather simplified and should be adjusted according to the concrete situation, the potential benefits of polygeneration system are no doubt obvious.

The Grand Western Development of China is a huge project in the 21st century. The target is to change the backwardness of west regions, to develop the regional economy, to cultivate the new educated generation and to improve the living standard of local people. However, the target can be hardly realized by only exporting the natural resources in raw form. Some new innovative approaches should be adopted to make the natural resources be more value-added. To this point, the concept of polygeneration could be a good enlightenment.

The Policy Support and Starting Steps for the Development of Polygeneration System in China.

1. Because polygeneration is a large cross-sector system, its development depends on the support and coordination of different industry sectors (such as chemical and power generation sectors) and Central Government from the standing point of whole nation's benefits. Therefore, the boundary between different sectors must be broken at first.

2. State Development and Planning Commission (SDPC), State Economic and Trade Commission (SETC) and Ministry of Science and Technology (MOST) must have a concordant action and multi-layer arrangement. For instance, the fundamental study of this system should be conducted via State Key Fundamental Research Program, the industrial demo of the system should be supported by S-863 Program, etc. Besides, a favored policy under the guidance of government should be issued, since every new technology and system will have buy-down process. It is irrelevant to claim unreasonable high request from the very beginning.

3. The utility must loose the regulation of grid connection. Therefore, the owner of polygeneration system can sell the generated electricity to the grid at reasonable price.

4. There are two starting options: firstly, in the coal abundant region (especially coal with high sulfur content), to set up an industrial scale demo with co-production of power, methanol and syngas using once-through liquid-phase reactor. It could be expanded according to the availability of investment, and will serve a impressive example for other regions and particularly for the West Part of China. Secondly, in the vicinity of oil refinery, to construct a polygeneration plant using the high sulfur content residues as feedstock and hence to solve the problems caused by high sulfur content crude oil.

5. Utilizing the achievement obtained by many research institutes and enterprises in China, to organize a coordinated team for designing and construction of polygeneration system with our own intellectual properties.

6. Clean utilization of coal and mitigation of CO_2 emission are the global issues. Support and donations from international organizations, such as UNDP, World Bank, Asia Development Bank, GEF, should be pursued.

7. International partnership and cooperation with famous foreign enterprises, universities and research institutes should be carried out

8. Just from now on, to arrange a sophisticated and detailed study of the feasibility of polygeneration system.

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