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Coal Gasification-based Polygeneration (CGP): Potentially Strategic Technology in the Chinese Energy Sector

What is the potential role of CGP? What are the obstacles to its business implementation? How can its implementation be accelerated?

Ning Wang

Supervisors

Thomas B. Johansson

Lars Hansson

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Published in 2006 by IIIEE, Lund University, P.O. Box 196, S-221 00 LUND, Sweden,
Tel: +46 – 46 222 02 00, Fax: +46 – 46 222 02 10, e-mail: iiiee@iiiee.lu.se.

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Ning Wang

Abstract

Coal gasification-based polygeneration (CGP) technology provides an opportunity for China to help to solve the main challenges it is facing in the energy sector. On the one hand, it can greatly mitigate the conflict of energy demand and supply in China, by generating electricity and co-producing liquid fuel without China becoming overly dependent on imports; on the other hand, it can dramatically decrease the level of environmental impact and also facilitate the capture of carbon dioxide in the process.

The research shows that the barriers to CGP implementation do not originate from a financial or technical perspective. In fact, the financial internal rate of return (FIRR) and investment profit margin (IPM) of the proposed CGP project prove to be excellent. Besides, the success of small-scale demonstration projects indicates that issues relating to technology cannot be considered to be significant obstacles either.

Through the research, the author finds that it is the problem of market access that constitutes the prime barrier for CGP business implementation, because the potentially huge demand for CGP products in China (e.g. DME as a substitute transportation fuel) can only be accessed when the appropriate conditions are achieved. These conditions include the following: support of large energy distributors and governments from all levels, specialized infrastructure, the availability of national technical standard and regulation in downstream phase, the specification and confirmation of optimum technologies. Without these, the uncertainty in market access blocks the development of CGP technology implementation.

Accelerating the establishment and development of a demonstration city for CGP product implementation is recommended as an urgent issue, which may lead to the achievement of market access in host cities and trigger the leap of CGP implementation.

Executive Summary

The energy supply (especially the shortage of liquid fuel), environmental pollution and greenhouse gas (GHG) emission caused by conventional coal combustion (CCC) power plants constitute the main challenges facing China's energy sector in the 21st century. Accordingly the three E's strategy for economic development, energy security, and environmental protection was defined by the 16th Party Congress in October 2002 as the guideline for government action.

To achieve these goals and mitigate the main challenges, coal gasification-based polygeneration (CGP) technology is put forward as one potentially strategic technology. CGP refers to a system which produces synthetic gas for power generation, clean fuel for transportation and cooking, and heat for domestic and industrial purposes, on the basis of coal gasification technology. The advantages of the CGP system include environmental benefits, substitute fuel for transportation and cooking, and the facilitation of CO_2 capturing and storage.

Here, the feasibility of the CGP business project is evaluated on the basis of the project loan assessment system (PLAS) of the Industrial and Commercial Bank of China (ICBC), assuming a virtual project operator is applying for a project loan to fund the construction of the CGP project (with electricity and DME as co-products). The PLAS is the main method used to examine the business feasibility of a project in this bank, and the bank's decision regarding a loan is mainly based on the result of PLAS.

According to PLAS, the virtual CGP project proves to be "good to excellent" from a financial perspective, since the internal rate of return (IRR) is approximately 17% (DME used in a cooking fuel scenario), and the investment profit margin (IPM) is approximately 16% (also in a cooking fuel scenario). However, the loan application for the virtual CGP can hardly be approved at current conditions because of its weakness regarding the present market access for DME.

From the perspective of PLAS assessment (without considering the qualifications and financial status of the potential project operator), the main barriers to the implementation of the CGP project include, for example, that the technology hasn't been specified and confirmed through large-scale implementation in the production and downstream phase, and also that long-term contracts with large amounts are not presently available in the market.

However, upon further consideration of these barriers, the research shows that the technologies used in the CGP system have largely been proved, that some elements of this technology are already in use (especially in China's chemical industry) and that the success of existing small-scale demonstration projects demonstrates that the technical problem can't be the main barriers in the production and downstream phases. As for the market problem, the demand for fuel for transportation and household cooking in China is massive and will be increasing in the long term.

So, based on the research, the essentials of the problem may lie mainly in the matter of market access, i.e. how to transform the potentially huge demand for substitute fuel into present demand in the market. The difficulty originates from the complexity of this system, as it involves a large number of stakeholders, different industries and masses of end-users, enormous capital investment and comprehensive technology.

In general, the CGP project can be the perfect target for a business bank if only this temporary barrier can be overcome.

To illustrate the potential significance of CGP technology, a feasibility comparison and an overall cost benefit comparison between the proposed CGP project and the mainstream technology project (i.e. combined heat and power (CHP) plant) are carried out. The following conclusions have been identified.

The commercial feasibility of a conventional coal combustion (CCC) plant, the type now dominating the power generation market with a market share of over 80%, proves to be good, with the advantages of less obstacles in implementation, mature technology, stable market and profit (7% FIRR), and much lower capital input (67% lower). However, when considering the overall social cost and benefit, the huge external social and environmental cost of CCC technology means that it simply cannot compete with CGP technology: i.e. if one applied the external cost of 0.43 cent/KWh to the cost of the CCC plant, the profit of the CCC project would become negative.

The potential significance of CGP in energy and clean fuel supply, environmental protection, GHG mitigation, the adaptability to the features of Chinese resources and the optimistic financial prospects in business implementation make it possible for it to be the strategic technology in China's energy sector.

In order to solve the current obstacles to CGP business implementation, the following recommendations are proposed.

Establish demonstration cities and push forward the co-development of a demonstration project and a demonstration city

The significance of a demonstration city can be profound. It can help solve the obstacles in the implementation process, e.g. examine the feasibility of the proposed technology for large-scale business implementation in order to specify an optimum technology, establish a typical manner for the cooperation between a CGP project and downstream energy distributors, acknowledge the financial perspective and environmental benefit, etc. Another important point is to provide a clear illustration of the feasibility of CGP technology. The public, local government and energy companies can recognize the huge societal and economic benefits, and can then be encouraged to take part in the promotion process.

From the Central Government's perspective, the following approaches can be considered to help achieve a successful demonstration city:

- Specify and authorize the demonstration city. The central government can choose several cities to be a demonstration city, according to its geographical and economic condition, taking into consideration the condition of existing demonstration projects. Generally speaking, the local governments can be interested in CGP technology implementation because the potential economic, societal and environmental benefits can be huge. The authorization of the central government can provide the demonstration city's government with the responsibility and driving force to push forward CGP implementation.
- Constitute the development programme of the demonstration city, specifying the plan, approaches, and responsible organization, the target for each phase at both national and local level and other pertinent elements.
- Obtain the support of the headquarters of top energy companies in cooperating with the CGP

operator and the demonstration city in downstream phase. Without approval from the headquarters, there can be some uncertainties for the downstream cooperation in the demonstration city, since the branches usually have no right to deal with such affairs by themselves. This support can create favoured circumstances for the success of the demonstration city.

- Provide technical and managing support from relevant departments of the Central Government.
- Provide incentives through tax or fiscal policy. It should be noted that as a country in a phase of transition, the Chinese economy is different from those of developed countries. That is to say, China's economy is not totally a market economy, and market tools such as price and profit sometimes do not play the key role in resource allocation on the market, and that the financial approaches would achieve better result if used together with other approaches, e.g. administrative methods.

Set up a special leading organization at a high level of government (a combination of people from appropriate departments in central government) in charge of CGP implementation and decision-making

The significance of CGP can only be established when the partition of departments is broken. Furthermore, the potential significance of CGP to both economy and society, its complex technological system, and that it involves multi-industries and the lives of millions of people, make it rational to set up a special leading organization for the researching and implementation of the CGP system.

The proposed organization can be a non-standing organ within the National Development and Reform Committee (NDRC), with the NDRC as the leading department and relevant departments in supporting roles. The key issues for this organization now should be to constitute the overall CGP development programme and accelerate the establishment and development of a demonstration city and a demonstration project.

Try and gain support from the provincial government

The role of provincial government can be crucial in coordinating the relationship between cities and in avoiding the negative impact of local protectionism. Generally speaking, from a provincial perspective, the implementation of CGP technology may bring about huge benefits, so the provincial official can view this positively. But the central government still needs to bring incentives to provincial and regional government to push them to be more active in this process, e.g. through the provision of fiscal subsidies or tax reductions. One important approach could be to adjust official assessment system, e.g. to apply the environmental protection index to local government assessment (the Green GDP Assessment System has been piloted for the evaluation of local officials in some cities already in China).

Encourage the participation of top energy companies in CGP technology implementation

One possible method is to attempt to establish cooperative relationships with the top energy companies, e.g. establish a business project together with SINOPEC, or sell stock share to them to develop both sides' mutual interests. In addition, the substitute fuel produced from the CGP system can also be attractive to these energy companies, when compared with importing petroleum from abroad. In fact, these energy magnates can be the best investor in the CGP technology project as they have a petro-chemical industry background and the competitive advantage in the downstream phase.

Constitute an implementation plan and specify the responsibilities of each organization and the targets for each phase

Because the CGP system involves a comprehensive practical situation, without a clear plan from the national level the implementation can arouse disorder, which may increase the obstacles to its implementation. Hence, a clear plan from the central government level is needed to direct the overall process through specifying the organization responsible, the targets for each step of development, and the approaches needed.

The plan and the approaches should be planned carefully and discussed by experts from different field before it is carried into action.

Set up an overall programme for pipeline infrastructure construction and management at both regional and national level, and in both the upstream and downstream phases

Because the construction cost of the infrastructure for fuel supply and usage is huge and not conceivably likely to change within a rather long period, it is reasonable to consider the perspective of implementation of substitute fuel in the downstream field, i.e. to take the usage of CGP product into consideration in long term pipeline development plans, and to make CGP development comply with the energy plan as a whole. This can enable the avoidance of the incorrect allocation of resources and funds, and help to reduce blocks for the use of a cleaner fuel in the future.

Decrease the profits of conventional coal combustion power plants

A power plant in construction now will be in use for at least the following twenty years, causing huge environmental and societal damages, and will not be replaced within a long time because of the high withdrawal cost. Furthermore, these newly planned CCC plants can influence the fate of the CGP project, as they will be occupying the market in the future. So more rigorous requirements should be put into practice and more costs should be reduced from the on-grid price of power from CCC plants.

Stimulate the participation of the motor car industry

For the motor industry, applying themselves to motor improvement to make it suitable for a cleaner fuel such as DME would be a strategic decision for these motor producers to obtain some competitive advantage in the market. Besides, this can greatly reduce the huge risks caused by stringent exhaust regulation they are likely to face in the near future. The following policies and measures could be used by the government can do to stimulate the motor industry to work in this direction:

- Apply fiscal subsidy on the technical alteration.
- Technical support.
- Update and improve the industrial policy to encourage more investment in approaches to reduce downstream pollution.
- Reduce tax on the sales of motor vehicles using substitute fuel.

Try and gain support from the public and NGOs

The public, communities and NGOs can play a key role in this process, e.g. in public education, breaching of department partitions, and bringing pressure on the government. The possible approaches include the following:

- Educate the public through the media about the negative impact of current technology.
- Illustrate the huge external benefit of CGP technology to the public.
- Organize discussion, lectures and other actions with local communities, NGOs and other stakeholders.
- Provide more material to NGOs interested, or
- Accelerate the establishment of an NGO with a different industrial background focused on CGP implementation.

The implementation of the CGP system is a comprehensive activity, which requires government, industry and experts alike to break through the industrial partition and to constitute a development programme from an overall perspective to direct the process.

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1 Introduction

Together with the rapid development of its economy, China has started to face huge and unprecedented challenges. Among them, the highest priority of the government has been given to energy related issues because of China's unique situation (which is to be discussed in a later part of this paper). Besides, it is widely acknowledged in China that the environmental problems caused by the energy sector have produced severe threats to both public health and economic development, and moreover, these threats seem to become more dangerous with the development of the economy. Against this background, the coal gasification-based polygeneration (CGP) technology system was proposed by some energy experts as an effective solution for the problem at a reasonable cost.

1.1 Objective and research questions

In this paper, the complex situation in China's energy sector regarding energy production, demand and environmental issues is to be discussed and analyzed, as well as the introduction and development and current condition of CGP technology in China. On the basis of which, CGP technology is to be evaluated from a business bank perspective, to seek the business feasibility of this technology in the "real world". The other objective of this paper is to reveal the ultimate factors which are blocking the implementation of CGP and to search for new methods to overcome these obstacles and increase incentives for companies to promote this technology.

For these objectives, the following research questions will be addressed in this paper:

How would a business bank evaluate the economic feasibility of coal gasification-based polygeneration(CGP) projects in China? At the present time, what could be the obstacles for a real polygeneration project to meet the requirement of the project loan assessment system of a business bank in China?

What are the ultimate reasons for the obstacles which block the implementation of this technology system? Compared to the conventional coal combustion technology and other options, how to evaluate the role of CGP technology in China's energy sector from a society perspective?

What is the main point in promoting the implementation of this technology system in China?

1.2 Methodology

With the aim of obtaining a full understanding of the objectives which this paper is focused on, different methodology is applied including literature review (including internet, books, and other secondary data sources), interviews (through telephone, email or other primary data sources), virtual case research and system assessment approach implementation, and calculation.

The research process of this paper can be divided into two main parts. One process is to establish and develop the logic of the paper (logic process), i.e. to develop the consequences step by step and rationalize the conclusion within a convincing logic structure; the other process is to find the data needed for the development of the paper (data process).

With the aim of addressing the research questions, the logic structure of the paper is established as 4 phases as the following.

- According to the special feature of China's energy sector, research on the potential role of CGP technology as a part of the solution for the hard challenges facing China.
- Research on what are the obstacles blocking the practical implementation of CGP technology given the current conditions in China.
- Based on the findings of the previous phase, research on what is ultimately causing the inferior position of CGP in relation to the dominant technology in the market.
- Discuss what should be done based on the reason identified in the previous research phase, with the aim of achieving sustainable development in China.

1.3 Research steps and general methods

Though the research steps in this paper can be simplified as desktop research, analysis, and synthesis of the findings, the steps and approaches are always linked and combined together in the process of research. However, to obtain a full understanding of the issues involved in the process of consequences, several research methods are applied in different research steps and phases, including literature review and interviews, through which the data and information needed and the prime data in the research can be obtained. Besides, interviews of people with different backgrounds provide the opinions on the proposed issues from different points of view, which helps to avoid unilateralism in research. Questionnaire and email is also used in almost all the processes of the research.

1.4 Assessment method and case research method

With the aim of illustrating the logic in Phase 2, a special method is employed as a tool to evaluate the business feasibility of CGP technology, i.e. the project loan assessment system in a business bank, the Industrial and Commercial Bank of China (ICBC). The reason for the implementation of this assessment system is to be described in a latter part of the paper together with a brief introduction of it. The assessment system will be used to assess a virtual case in a real world conditions, assuming that a loan applicant is applying for a long term loan to establish a CGP technology project in Zao Zhuang, a city with rich coal deposits in the north-east part of China. Thus the business feasibility of the CGP technology project is evaluated according to a business bank's requirement based on the technical and economic parameter of a virtual project in a real world background.

To illustrate the logic in Phase 3, the project assessment tool will also be applied to make a comparison between CGP technology and other dominant technology. Besides, external costs will be taken into consideration in this phase to gain a more comprehensive understanding of the objective.

1.5 Scope

The scope of this paper is focused on the business feasibility of CGP technology. However, to provide a better understanding of the proposed technology, other issues involved with the implementation of CGP are also covered in this research.

The geographic scope of the case research is within the boundary of Zao Zhuang city of China, which is supposed be the host area for the proposed CGP project. However, regarding the thesis itself, the geographic scope can be extended and the conclusions can be applied to the country as a whole, since the proposed technology is considered and assessed as a solution for the overall energy challenge in this country.

The author assumed that the reader of this paper has a good understanding of the terms in the energy sector, and is generally familiar with the meanings of financial terms and calculations used in the loan assessment system.

1.6 Limitations

One main things that may cause some uncertainty is that the data of the virtual CGP project is established based on the data collected from an American condition, i.e. the overnight capital cost and production cost of the project may distort the calculation in some sense, and thus influence the final conclusion of this paper. However, the distortion has already been controlled in some degree as the data has been converted into a Chinese scenario by applying a converting index, and from an overall perspective the data of total cost in the virtual project can be regarded as approximately accurate, given that the real cost of CGP input in China may be even lower because of the much lower equipment price in China. Anyway, as there is no large scale business project with CGP technology yet, the lack of real world data for CGP implementation in China necessarily increases the uncertainty of the research.

Given the length of the paper and the limited amount of time to carry out the thesis, some parts of the loan assessment requirement are simplified or omitted, which may cause some distortion on the conclusion, though they do not significantly influence the result.

1.7 Outline

Chapter 2 provides an introduction of the feature of China's energy sector, accounting for the huge energy and environmental challenges facing China, and especially pointing out the role of coal in this field. Based on this, CGP technology is introduced and analyzed as a proposed solution, and its strategic role will be illustrated in this chapter.

Chapter 3 assesses the business feasibility of CGP according to the business bank perspective, and to achieve this certain special financial indicators are applied. The assessment process is implemented after the introduction of the virtual project and the assessment method. At the end, the bank's conclusion is provided to provide an overall comment on this technology project.

Chapter 4 makes a further assessment on the CGP project by comparing it to the dominant project in the current market. In the first half, different projects are compared from a business perspective applying the same assessment tool. In the second half, the final conclusion is illustrated through the implementation of a comparison at a more comprehensive standard, with the overall costs taken into consideration.

In Chapter 5 and Chapter 6, factors contributing to the current situation are illustrated and analyzed. Based on the analysis, a deeper understanding of the situation can be obtained, and innovations and recommendation are identified and discussed.

Chapter 7 concludes the thesis and answers the research questions. Besides, further recommendations are proposed.

2 Main energy challenges and the proposed approaches for sustainability

As a result of the rapid development of China's economy since 1978, the domestic production capacity and consumption demand in the country boosted sharply, which accelerated the accumulation of wealth and the development of living standards. However, together with these positive aspects, unprecedented energy challenges and the environmental crisis resulting from this abrupt development also befell the country. Nowadays, as one of the main restriction factors to society development, the energy and environment problem has led to pervasive disquiet among the people, which may trigger a profound social crisis if improperly dealt with. Furthermore, the transnormal energy demand and potential environmental risks will heavily increase the level of uncertainty in the process of the development of the world economy and society, and produce chain reactions in the world economy and then counter-act on China itself, which has already deeply integrated with the world economy, causing ultimately a lose-lose situation.

This chapter will explain the complex situation in which China's energy sector is in, and based on this show how and why CGP technology can be seen as the best way to solve this predicament.

2.1 China's energy safety problem

The "energy safety problem" refers to the risk that energy demand can not be reached by provision, thus causing catastrophic consequences in China's economy and society. In table 1 below, one can see the energy self provision rate of China in recent years. Compared to the average energy self provision rate of OECD countries (approximately 70%)[1], China's rate is very high. Taking 2005 as an example, the energy self provision rate of China is 22.8% higher. Thus it seems that there is no problem with China's energy safety issue. However, looking deeper at the practical situation and its future prospects, huge risk is revealed beneath this optimistic data.

Table 2-1: Self provision rate of China in recent years, unit: billion tec[2].

Year	Total energy production	Total energy consumption	Self provision rate
2002	1.38	1.48	93%
2003	1.60	1.71	94%
2004	1.85	1.97	94%
2005	2.06	2.22	93%

Source: National Bureau of Statistics of China (NBS, 2006)

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[1] Guo Chongqing. (2006). *Implementing strategy to improve China's innovating and marketing ability* China Machinery Engineering Magazine, Volume 97, p.7,. Beijing: : Chinese Mechanical Engineering Society.(Chinese)

[2] Refers to equivalent ton of coal.

As a matter of fact, China's energy safety problem has its roots in the petroleum provision issue. In other words, China's energy safety problem can be equated to the petroleum provision problem. China's petroleum provision faces huge risks at present, and more importantly this risk can grow significantly in the future if the problem is not sufficiently dealt with. The petroleum safety issue has its origins in 5 main aspects.

Compared to the total prime energy consumption, oil consumption is not as high as coal in China's energy structure, but the share of oil has increased very rapidly in these years, now exceeding 20% (see Table 2-2). And more importantly, the special role of oil currently in China rest on 4 main issues: low reserves; large consumption and high dependence on imports; its core role in economy; and that it is irreplaceable in the short term.

Table 2-2: Energy share in total consumption.

	Total energy consumption	Share in total consumption (%)			
	(Unit: Million tec[3])	Coal	Oil	Natural gas	Hydropower
1991	1038	76.1	17.1	2.0	4.8
1995	1312	74.6	17.5	1.8	6.1
1999	1301	68.0	23.2	2.2	6.6
2000	1303	66.1	24.6	2.5	6.8
2001	1349	65.3	24.3	2.7	7.7
2002	1482	65.6	24.0	2.6	7.8
2003	1709	67.6	22.7	2.7	7.0
2004	1970	67.7	22.7	2.6	7.0

Source: NBS (2006).

[3] Equivalent ton of coal.

2.1.1 Low reserves vs. high consumption

Table 2-3: Oil reserves at end 2005, unit: Gt.

	Oil reserves	Share in the world	Reserves per capita (tonnes)
China	16.0	1.3%	12.3
Total world	1201	100%	185

Notes

1. The population of China in 2005 is assumed to be 1.3 billion, the population of the world in 2005 is assumed to be 6.5 billion.[4]
2. Data for total reserves based on *BP Statistical Review of World Energy 2006*.

From the above table, we can observe the modest reserves of oil in China. Also, because of large population, the oil reserves per capita in China are as low as 6.66% of the average reserves per capita in the world. This determines the low self provision rate of petroleum.

Compared to the low reserves, the oil consumption boosted abruptly especially in recent years (see Figure 2-1), and since 2004 China has became the second largest oil consuming country in the world(see Table 2-4 below).

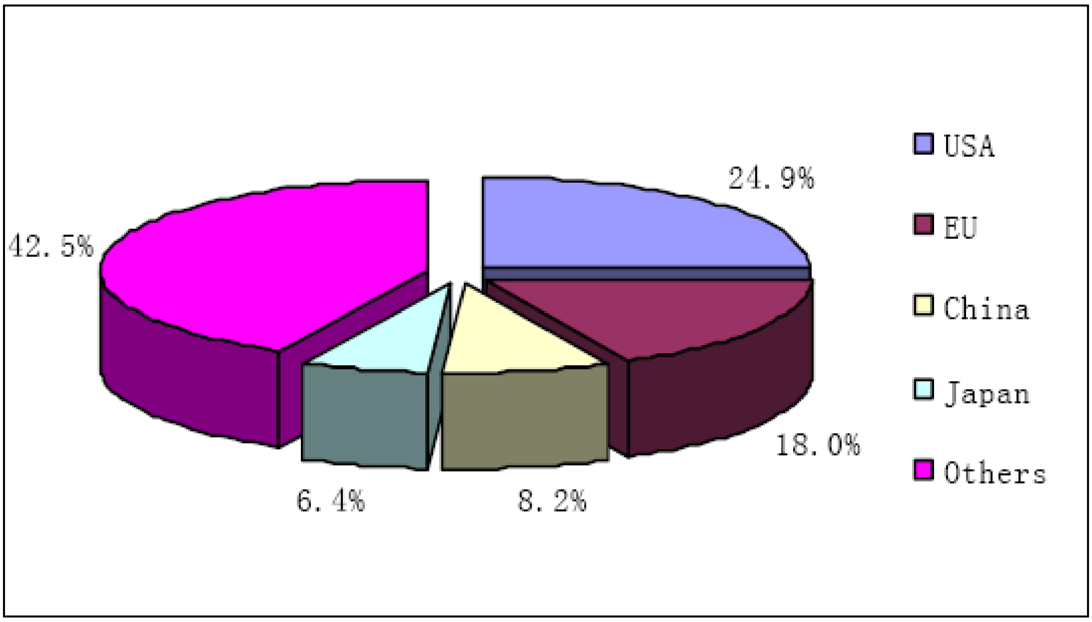

Figure 2-1: Global oil consumption share, (BP, 2005).

[4]National Population & Family Planning Commission of China. (2005)

Table 2-4: Oil output & consumption, unit: Gt.

Item	1990	1995	2000	2002	2004	2005
Total output	0.14	0.15	0.163	0.167	0.175	0.181
Total consumption	0.115	0.161	0.224	0.248	0.29	0.30

Source: NBS(2006).

From Table 2-5, we can see the gap between output and consumption has increased rapidly, though the production capacity has also improved rather quickly annually. The reason rested on that the increase of the speed of demand highly exceeded the increase of the speed of production. From 2001-2004, the level of oil imports increased surprisingly, reaching 15.2%, 31.3% and 34.8% respectively. Although oil imports in 2005 were kept at the same level as in 2004 because of the intentional control of the central government, the oil imports have increased as expected since the beginning of 2006. The accumulated petroleum imports reached 61.55 Mt from January to May; moreover, the imports of refined oil at the corresponding time reached 14.15 Mt, an increase of 10.9% compared to the same time last year. In fact, in 2005, China became the second largest oil imports country in the world, with 0.127 Gt oil imports.[5]

Thus, the high self provision rate at present can not cover the large amount of oil imports and high foreign dependence on oil provision.

2.1.2 The current role of petroleum in China's industry and economy

Petroleum now plays the core role in the economy. Except for providing energy for production and households, it is the main material in petroleum-chemical industry. According to the average value from 1999-2003, the total output of petroleum-chemical industry accounted for 14.4% of the total industrial output in China, and the sales share in the total national industry exceeded 14%.[6] Moreover, the more important role is its fundamental function of providing basal material for the national economic development. In other words, we can say the role of petroleum is irreplaceable in the current situation. According to the present demand and the poor capacity to produce oil alternatives, the impact will be fatal to the overall economy if oil provision fluctuates or is even intermittent.

2.1.3 The amazing oil demand in the future

Actually, the oil safety problem is mainly referred to as a huge risk in the future, although the petroleum provision is already a severe problem at present, because the prospect of energy embarrassment China will face in ten or twenty years time could be much worse .

The energy problem in China is determined by the striking increase in the potential energy demand. As described above, China's oil consumption has become the second largest in the world since 2004. Considering GDP per capita in China was only approximately $1700 in

[5] China Customs. (2006).

[6] Ye. (2005)

2005 and the high annual increase rate (exceeding 7% within the last 20 years), the large amount of oil consumption at current condition in China is only a start. And one can forecast how large the oil demand will be in China in 20 years time by taking the following concrete aspects into consideration.

The increase of motor vehicles

The main increase of oil demand will come from the increase of motor vehicles. From 1985 to 2004, the number of motor vehicles increased from 3.3 million to 28.2 million, with 12.1% as the average annual compound rate of increment. Based on the prediction of experts, from 2004 to 2020, this number will continue to increase to 160 million with 11.6%[7] as the average annual compound rate of increment. Based on the fact that the oil consumption for motor vehicles is about 0.12 Gt, as 40% of the total oil consumption in China in 2005,[8] if we omit other impacting factors in calculation, then, according to the same annual increment rate of 11.6%, the annual oil demand for motor vehicles in China in 2010 will reach 0.252 Gt, exceeding the overall oil production in 2005; and if we go further to 2020, the annual oil consumption for motor vehicles in China will reach 1.11 Gt, 18% higher than the annual oil consumption in America in 2004.

The demand for industrialization

Now China is starting to enter the mid-term stage of industrialization, as characterized by the fast development of heavy industry and petroleum-chemical industry. During the period of the 11th 5-year plan (2006-2010), China is supposed to be the largest refinery-chemical production and consumption country in Asia, as well as the main destination of petroleum-chemical project investment.[9]

It should be noted that the high speed development of industrialization is inevitable in China, because it is not only the requirement of the economy, but also more importantly the rigid requirement of politics and society. Only a high speed industrialization process can create a large number of new jobs, which can mitigate the pressure of unemployment; or social turbulence will be inevitable because of the accumulation of a high unemployment rate. However, this rigid demand of high speed industrialization will intensify the risks of oil provision, since it makes much more demand and further worsens the situation if something should happen to the oil provision.

In addition, the moderate reserves of natural gas and the large demand of household cooking fuel constitutes another energy safety problem. The natural gas reserves in China has been proved to be only 2 trillion m^3 approximately in 2005,[10] and reserves per capita are only 5% of the average reserves per capita in the world; whereas, along with the development of urbanization, fuel demand for house cooking boosted rapidly. In 2005, China became the third largest country of LPG imports with imports of approximately 6 Mt[11]. Experts predicted that the process of urbanization in China will last several decade at a high speed, thus, China

[7] BOC International. (2005).

[8] Liu. (2006).

[9] Ye. (2006).

[10] BP Statistical Review of World Energy 2006. (2006).

[11] China Customs. (2006).

may also face the problem of how to guarantee the demand of household cooking fuel in the future.

Besides the issues mentioned above, it should be noted that the price of oil is also supposed to be a potentially big threat to China. Economics point out that the Chinese economy would be greatly damaged if oil price increased abruptly.[12] The political risks could also cause a fatal result to China, since 50% of the oil imports are from the middle-east with a long-distance sea transportation line. Oil crises could be triggered by the block in this transportation line, as the international situation in this area is not stable.

As analyzed above, the ultimate reason for oil safety problem in the foreseeing future of China is the unsustainable demand of oil caused by the processes of urbanization and industrialization in China.

2.2 The role of coal in China's energy sector and in the power generation field

As the main part of China's energy structure (see Table 2-6), coal is the main contributor to the high energy provision development in recent years. China is a country with abundant coal reserves. The established coal reserves are 189.1 Gt up to 2002 (National land & resource bureau), another proposed figure is 114.5 Gt according to BP, which amounts to the third largest reserves with a share of 12.6% in the world. In 2005, China was the largest coal producing country, as well as the largest coal consuming country, both exceeding 1/3 of the total world share.

Table 2-6 shows that coal production in China can totally meet the demand of coal consumption. Coal is the fundamental and main part of China's energy supply. Though the proportion of oil has been rising since the beginning of the 1990's, the proportion of coal has always remained over 65%. The coal production in 1990 was only 1.08 Gt, while it increased to 2.19 Gt in 2005, with a growth rate of 102.03%. It is the development of coal production that guaranteed that the self energy provision rate remained at approximately 90% despite the amazing increase in energy demand.

Table 2-5: Coal output and consumption[13]

Item	1990	1995	2000	2002	2003	2005	Share of world (2005)[14]
Output	10.8	13.6	10.0	13.8	16.7	21.9	38.4%
Consumption	10.6	13.8	12.5	13.7	16.4	21.4	36.9%

Source: NBS (2006).

[12] Huang. (2006).

[13] NBS.(2006b).

14 BP: Statistical review of world energy 2006(2006).

The role of coal can have been further strengthened because of the high increase of proved reserves in recent years. It was reported that only in 2005, the newly proved coal reserves reached 69.8 Gt[15]. Because the corresponding data in the BP report hasn't been updated since 1997, the data of 114.5 billion may not represent the present condition of proved reserves of coal in China. According to the updated data, the actual coal reserves would exceed 250 Gt. Thus, the proved coal reserves are of a similar level to those of America. Actually, the proven coal reserves are continuously increasing during these years because of the low proving rate earlier. Based on the new data, the coal reserves in China can fulfil the demand of more than 100 years even at the speed of 2.2 Gt consumption per year.

2.3 Coal-burning electricity generation and its environmental impacts

As the main supplier of China's energy consumption, the main purpose of coal is to generate electricity. Table 2-7 shows that the proportion of fired power in the total electricity consumption has kept over 80% from 2000. The power demand has boosted at a startling speed since the middle of the 1990's, from 1002.3 KWh in 1995 to 2474.7 KWh in 2005 with a growth rate of 147%. Now the power capacity in China is second only to America in the world, and firepower generation rose accordingly from 804.3 KWh in 1995 to 2018 KWh in 2005 with a growth rate of 151%. At the present time, the growth speed of power generation has exceeded the speed of GDP, and up to April of 2006, the average growth rate of power generation per month has remained in double figures within the recent 40 months. It is the increment of coal-burning generation that meets the highly increasing demands of economy and society.

However, because the utilization level of coal in China is still very low, coal-burning electricity generation has became one of the main pollution resources in China, which has placed high pressure on the environment of China.

Table 2-6: Electricity output and consumption in recent years, unit TWh.

Item	1990	1995	2000	2003	2005
Total power consumption	623.0	1002.3	1347.1	1903.2	2474.7
Thermal power generation	494.5	804.3	1116.5	1580.4	2018.0
Share of thermal power in total	79%	80%	83%	83%	82%

Source: NBS (2006c).

[15] NBS. (2006a)

The huge power demand resulted in the high proportion of coal used for power generation. In 2003, more than 50% of coal was used for the energy provision of power generation plants. At the same time coal supported the power generation, however, the economy and society paid a high cost for the environmental pollution caused by this high proportion of coal-burning power generation. The direct burning of coal with low efficiency greatly destroyed the environmental condition, and directly caused the severe coal-burning type of air pollution in China. The main problems will be described at the following section.

Table 2-7: Total coal consumption and main distribution in 2000, unit: Mt.

Total consumption	**Power industry**	Metallurgy industry	Construction material	Chemical Industry	Household Fuel
1,245	**592**	101	154	79	123

Source: Huang, et al. (2003)

2.3.1 SO_2 emission

SO_2 emission is one of the main impacts caused by the direct burning of coal. Generally speaking, because 80% of the sulphur in coal is combustible, most of this will be released to the air in the form of SO_2. Now, China has been the country with largest SO_2 emission since 1995. Among them, the industrial sector is responsible for the main part of emission, and coal-burning plants accounted for the biggest contributor with an emission share of around 41% of the total emission amount in 2004 (see Table 2-8). It should be noted that the emission increment was caused totally by the development of the conventional coal combustion power industry, considering the 12.5% annual increment in the industrial field and the -1.0% in the household field. Experts have predicted that, in the long term, coal-burning electricity will be the key factor which decides the amount of SO_2 emission, as the proportion of coal for household purpose would be decreasing because of the application of cleaner fuel in cities, while the increasing power demand will make it more difficult to reduce SO_2 emission within a rather long time period.

Table 2-8: SO_2 emission distribution in 2004, unit: Mt.

	In total	Household	Industry	CCC[16] power
Emission amount	22.5	3.63	18.9	9.3
Share in total	100%	16%	84%	41%
Annual increment rate	4.5%	-1.0%	5.6%	12.5%

Source: SEPA (2005).

[16] Conventional coal combustion.

One of the main negative impacts caused by SO_2 emission is acid rain. Now, China has become a country with one of the heaviest acid rainfalls in the world. Over 30% of the overall area in China has been greatly damaged by acid rain, with the annual average pH of precipitation of 70.6% of the area being lower than 5.6.[17]

Acid rain can acidify large areas of plantation and lakes, disrupt the ecology, and greatly reduce the output of crops. In recent years, acid rain has been increasingly worsening China's land ecology, becoming one of the main restricting factors upon the development of agriculture and economy. Furthermore, it could make forests atrophy and result in the erosion of buildings and metal facilities.

Large amounts of SO_2 emission are very harmful to human health. Especially when it forms into sulphate and sulphate fog in the air and enters into people's lung together with small amounts of dust; the result can be very dangerous, potentially leading to bronchitis, pneumonia and other malignant diseases.

2.3.2 CO_2 emission

As the biggest coal-burning country in the world, China became the second largest country in CO_2 emission, with 3.05 Gt of CO_2 emissions in 2000. And it is also coal that played the main role in the CO_2 emission field (see Figure 2-2). In 2001, 77% of CO2 emission was originated from coal combustion, 21% from oil, 2% from natural gas, with an annual emission growth rate of about 4%(Ni, 2004). It should be noted that, according to the trend of coal consumption and historical experience, the CO_2 emission will keep on increasing in the long term.

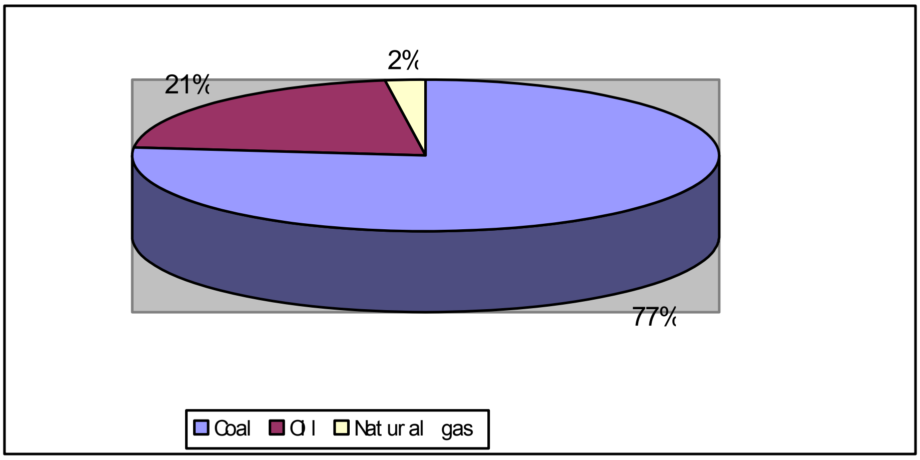

Figure 2-2: Contribution of coal on CO_2 emission in China,(Ni, 2004)

2.3.3 NO_x emission

NO_x refers to NO and NO_2 which are also part of the composition for the gas emits from the combustion of coal. It was estimated that the NO_x emission from coal combustion was about 10.15 Mt, approximately 65% of the total emission in China. SEPA predicted that NO_x emission will reach 21.94 Mt in 2010.

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[17] Huang. (2003).

NO can be of high toxicity in high concentration, which can cause reduction of oxide transportation capacity in human blood, and is regarded as the inducement of asthma; while NO_x can destroy a human's aspiratory system, causing bronchitis and emphysema.

NO_x is one of the main resources to form photochemical smog, which is seen as one of the main air polluters in China's cities, causing the degradation of regional air quality and the ecological system. In addition, NO_x can accelerate the worsening of acid rain through a series of chemical and physical reactions.

2.3.4 Emission of soot

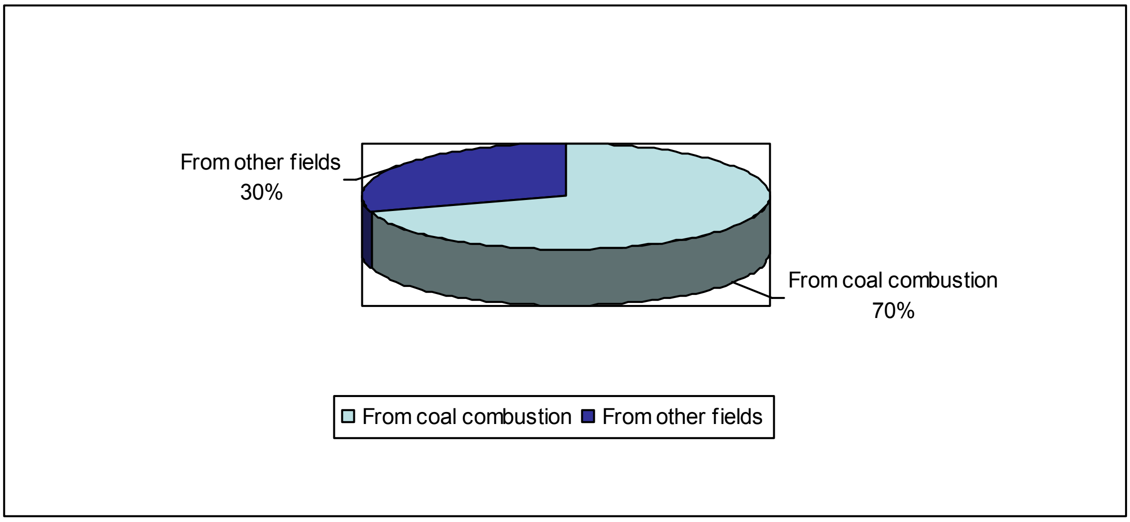

Figure 2-3: Contribution of coal combustion on soot emission in China in 2000, (SEPA 2005).

Soot is another problem mainly caused by coal combustion. The soot in the atmosphere is very dangerous to human health. The soot grain with a diameter less than 5μm can cause blood poisoning after entering human lungs and being absorbed by the lung alveolus. And according to SEPA (2005), in 2000 coal combustion produced 11.65 million tonnes of soot, about 70% of the total soot emission in China.

2.3.5 Motor vehicles exhaust

Motor vehicles exhaust has become one of the main air pollution resources in cities of China. In 2005, China became the second largest market, and the number of private cars increased to 28.2 million, at the same time, the corresponding oil consumption proportion accounted for approximately half of the total oil consumption, which is bringing far-reaching impact on the environment—air pollution in cities is in the transition process from soot-originated type to motor-exhaust-originated type. Nowadays, over 60% of the total air pollution including 80% of CO and 40% of nitrogen oxide compound originates from motor vehicles exhaust in the biggest cities such as Beijing and Shanghai.[18]

These kinds of pollution can cause serious harm to both people and ecology. Because of the low level emission of motor vehicles exhaust, it is very easily absorbed by people, thus causing obvious harm. E.g. CO and nitrogen oxide compound can reduce people's oxide

[18] Wang. (2005).

transportation capacity in their blood, and particles can absorb carcinogenic material in the air and bring it into human's body through respiration. Besides, this emission is one of the main resources for the photochemical smog in cities, which has a deeper impact on human health and the ecology system.

From above, we can see that coal-burning power generation and motor vehicles exhaust will be the hardest challenge China is facing in the long term, considering that the electricity and car consumption will increase for a long time since the power capacity per capita is only 1/13 of America in 2000 (1.06 MWh consumed per capita vs. 13.47 MWh per capita in 2000) and car consumption is just starting to boost these years from a very low tenure rate per capita. Besides, because of the application of the Kyoto Protocol, China has to face much stricter requirements in the energy sector in the near future. At the same time, China's highly increasing demand for liquid fuel for motor cars and household cooking enhances the risk of energy safety, but on the other hand, the advantages of abundant coal reserves cannot be utilized in a proper way.

All the above are extremely important issues to China, each of which can individually threaten the economy development and society stabilization if not dealt with in an appropriate way. Fortunately, energy experts have brought forward a plan which is intended to be a good solution for all the hard challenges above mentioned, i.e. coal gasification-based polygeneration.

2.4 The introduction of CGP

The polygeneration technology can be seen as a coupling system which integrates the driving force (electricity, heat, etc.), production and chemical (liquid fuel and chemical) production process in the traditional industrial field. It refers to "the use of gasification technology to produce synthetic gas for power, clean fuels for transportation and cooking, and heat for both domestic and industrial heating applications, to replace coal combustion technology and oil imports".[19] The system is a highly flexible and cross-sector integrated system with different techniques and production processes, most of which are already known and proven and many which have been practiced in China for years. The figure below shows a basic vision of polygeneration. The following is a brief illustration of the CGP technology system (oxygen-blown gasification).[20]

[19] Task Force on Energy Strategies and Technologies. (2003).

[20] Li, et al. (2003)

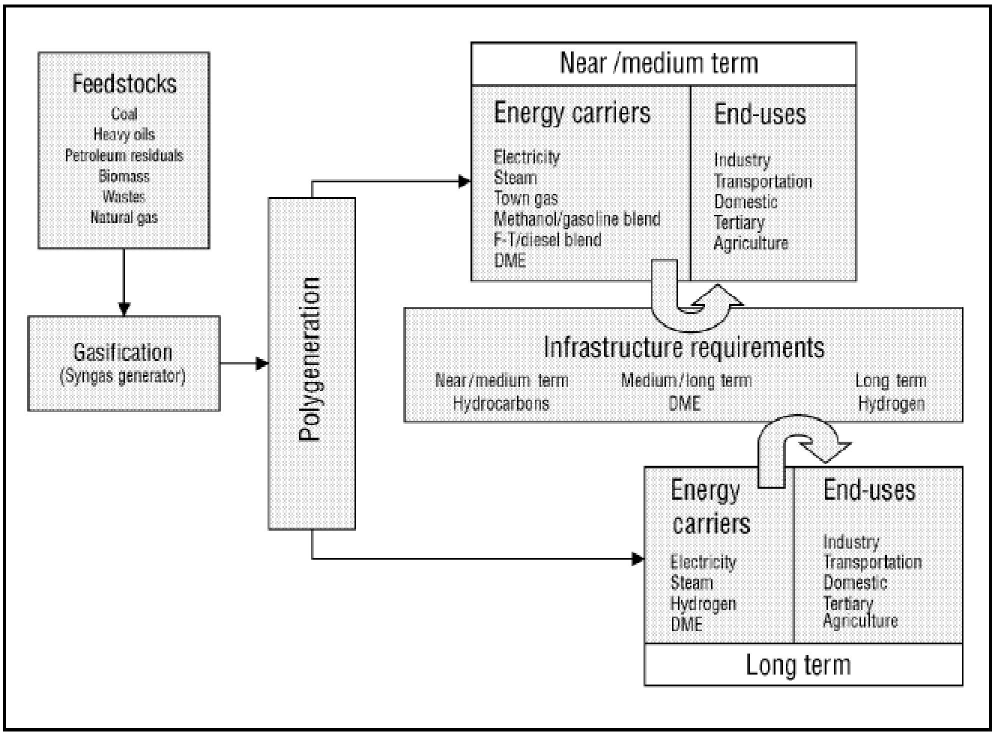

Figure 2-4: Visions for CGP system(TFEST, 2003)

Coal, petro-coke or heavy oil residues with high sulphur content can be used as feedstock to produce syngas with the main components of CO and H_2. Sulphur in the coal is collected from the clean-up and purification process as a by-product.

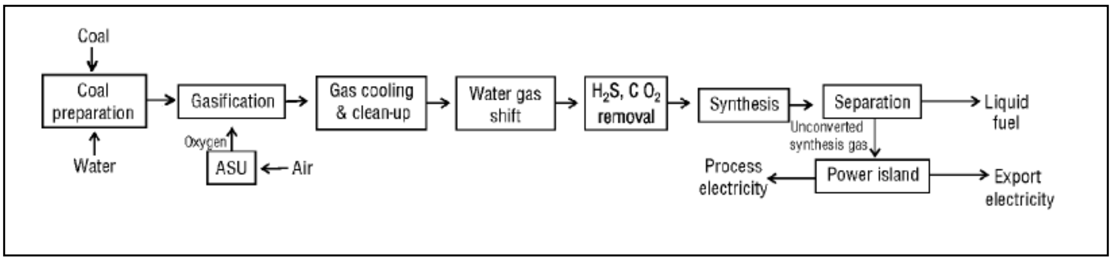

Figure 2-5: Basic process configuration for the co-production of power and liquid fuel(Larson, 2003).

The product of a CGP plant can be electricity, clean fuel for transportation and household cooking, e.g. methanol, dimethyl ether (DME), F-T, steam (for heating), town gas (for cooking and heating, distributed power, heat and cooling co-generation), and other chemical products (NH_3, urea, etc.).

The advantage of this system stems from its close coupling of the production processes of different products, which can reach better utilization of energy and material than a stand-alone IGCC or traditional liquid fuel production. For example, in a "once-through" configuration, the syngas is only once passed through the synthesis reactor; unreacted syngas is used as fuel for power generation instead of subsequent separation and recycling to the reactor again as in a traditional methanol production. Thus, the maintenance is correspondingly decreased in a rather high degree.

2.4.1 The potential significance of CGP technology in energy sector

2.4.1.1 Clean power from coal

On one hand, CGP technology takes full advantage of China's coal reserves, with large reserves making it easy to meet the increasing energy demand at a comparatively low price. On the other hand, because of the gas clean-up process, most of the traditional pollutants such as SO2, NOx, soot, particles and other emissions, are proposed or obtained according to the production process, which makes CGP almost as zero emission. Thus, the huge power demand can be reached by this clean power generation, i.e. the environmental challenge which is described in the previous section can be solved together with the problem of power security.

2.4.1.2 Clean fuel for transportation and cooking

Because the components of syngas are almost all CO and hydrogen, the fuel produced from this syngas is much cleaner than the traditional gasoline or diesel. For example, DME, as a CGP system product, is relatively inert, non-corrosive, non-carcinogenic, almost non-toxic, and does not produce sooting as it contains no carbon-carbon bonds, and NO_x emissions are lower than diesel fuel. Moreover, this solution is based on the fact that CGP can fulfil the fuel demand of motor vehicles and household cooking without increasing oil imports. Instead, in the long run, high implementation of coal gasification production can ensure energy security by reducing the proportion of oil production. In fact, most of chemical material used in the petro-chemical industry can be replaced by the CGP product. It should be noted that all of this can be produced by coal in clean production.

2.4.1.3 CO_2 mitigation

The implementation of CGP creates opportunities for China to collect CO_2 in the future at quite a low price. Because CO_2 collected in the production process is almost pure (99%), it is much easier to capture or deal with this gas compared to a conventional power plant where CO_2 is emitted together with 75% nitrogen and other impurity in the flue gas.[21] Furthermore, as a result of the high purity of CO_2, CGP technology can even provide the potential to use this emission as feedstock in the future for different purposes, such as dry ice.

2.4.2 Other potential benefits

CGP makes it possible for industries to develop the technology to produce even cleaner products which can meet more stringent requirement in the future. In the long term, the hydrogen produced in this system can be used as the cleanest fuel for vehicles and other energy demands, and also totally solve the problem of transportation emission.

In addition, CGP can reduce the loss caused by the rise of international oil price, thus strengthening energy security in China. It should be further noted that the implementation of CGP will not only reduce and replace oil imports, but also increase the domestic production and consumption capacity through large purchase, i.e. stimulate the exploitation of coal, and drive development of related industry, which can then benefit wealth distribution in China. CGP technology can even create the competitive advantage of the motor production industry

[21] Li, et al. (2003).

through the promotion of compression ignition engine vehicles research, which is suitable for DME or methanol as product of a CGP plant.

2.4.3 The introduction and development of CGP in China

Construction of the first CGP plant, Shanghai Coking Plant, begin in 1991 and the project was completed in 1998, with a production capacity of 1.7 million m^3/d, methanol 200Kt/a, power capacity 70 MWh. Yet the initial introduction of CGP as a national strategy in China was put forward by the Task Force on Energy Strategies and Technologies (TFEST)[22] of the China Council for International Coorperation on Environmental and Development (CCICED). CCICED is a high level international advisory board, which was set up in 1992 with the purpose of putting forth policy recommendation and carrying out policy and project demonstrations on major and urgent issues. In this context, TFEST has been focusing on the implementation of CGP technology in China since their establishment. They brought forward clean coal strategy in 1992, and recommended that the Chinese Government establish a polygeneration demonstration project, and then in 1999 proposed to push the implementation of CGP technology, and pointed out that clean and efficient coal technology should be given priority when a new power plant is to be established.

In fact, the Chinese Central Government established the Clean Coal Technology Leading and Promoting Organization in 1995. However, because of the organization adjustment within central government, they were cancelled without making a big progress in this field except producing the 9th FYP of clean coal technology. Thus, there is no leading organization to promote CGP technology now.

Despite these disadvantages, the development of CGP implementation has become faster since the beginning of the new century. Among several demonstration projects, the project in Yankuang Group is regarded as the most successful one, with 76 MW power capacity and 240Kt/a methanol production. In 2008, the group will install the 300 MW IGCC project and at the same time complete the coal indirect liquefaction demonstration project. In Shanghai, another CGP demonstration project is reported to be aiming at completion within the next few years. It should be noted that these two projects still cannot be seen as large-scale demonstration projects as they are not sufficiently large. And to the present day the demonstration city for the implementation of clean fuel produced in CGP project has not been available either.

[22] Ni Weidou as Chinese Co-Chair, Thomas B. Johansson as International Co-Chair.

3 Loan assessment on a CGP project

CGP, as a technology system that may greatly benefit Chinese sustainable development, ensure energy safety and help avoid environmental pollution, has already gained the support of central government and been taken into the priority industries list in development plans, being written into the 10th and 11th FYP in China. However, in practice, the implementation of CGP technology has not been as smooth as expected. Few CGP demonstration project had been completed up to the end of 2005. What then are the obstacles in the process of CGP project implementation? As described in the above paragraphs, the social and environmental benefits of the implementation of CGP technology are quite clear, whereas, at current condition, the fate for a business project is not only dependent on its social benefit, but also on its business potential. What is the business feasibility of the CGP technology project? To make it clear in a more comprehensive and more practical view, the author will analyse this issue with the help of a systematic method applied in a Chinese business bank to evaluate the business feasibility of a CGP project, i.e. the project loan assessment system (PLAS).

Through the research on the business feasibility of CGP, the perspective of business risks and benefits can be illustrated, based on which investors can decide if this project is cost-efficient. And among all the methods, PLAS can be one of the most suitable assessment methods for the CGP project. On one hand, the CGP project needs abundant capital investment, so it is highly likely that the project operator and investors would look to banks for financing, and the subsequent possibility of gaining a loan would lie mainly on the result of PLAS. On the other hand, for the construction of a project with the help of a loan, generally speaking, the input of the bank would be much higher than the input of the loan borrower (major part of capital input depends on the loan in a general condition), but the return for the loaning bank would be much less since the interest benefit would be much less than the income of the investor generally with a fixed interest rate. So, the bank would be both keenly aware and conservative regarding the potential risks of the proposed project, which can help explain the uncertainties in project implementation. Prudence and systematisation constitute the main features of PLAS. This, plus the considerable length of its practical application, makes PLAS one of the suitable methods to evaluate the business feasibility for the CGP project, with an integrating assessment from both the macroscopical and the individual perspective, paying attention to both long and short term foreground.

From the assessment through PLAS, the following can be analysed and illustrated: the precondition of implementation, the uncertainty the projects are facing, the weak parts in the CGP technology implementation and the advantages, obstacles and the financial perspective. The conclusion for the application of a project loan would be provided at the end based on the process of PLAS, which can provide helpful information for the potential CGP investors, the operators, researcher, and decision makers.

To develop the project loan assessment, a virtual case is established based on the assumptions in the following and in the assessment part of this paper, as PLAS can only be undertaken according to a concrete project, and assessment must be developed based on a concrete local market. In this paper, the host place for the CGP project and for assessment bank is assumed to be Zaozhuang City (a city with rich coal reserves) in the east of China. Though the project is a virtual one, the diameter and all the input and output is established according to a real world base, which is to be illustrated in the latter part.

This chapter is divided into 3 parts. The first part provides a brief introduction to the PLAS system as well as the general conditions of the proposed project. The second part is focused on the assessment step by step with the condition and diameter assumption as the preconditions of PLAS.

Then the conclusion and the judgement of CGP will follow at the end.

3.1 PLAS system introduction

In this paper, the requirements of PLAS are based on the corresponding standard in the Industrial and Commercial Bank of China (ICBC), which is the biggest business bank in China. Project loan assessment system (PLAS) is the only loan analysis tool used for the decision of long-term loans in the ICBC. Through the application of a series of quantity and quality indicators, the purpose of PLAS is to disclose the feasibility of loaning to a proposed project by predicting and analyzing the preconditions and market prospects of the project, the costs and profits generated, the obstacles and uncertainty factors and other risks the project faces in reality.

PLAS can be divided into the following key steps: borrowers' assessment; product market assessment; investment prediction and fundraising assessment; project profit assessment; guarantee assessment; project risks assessment; and conclusion.

The borrowers' assessment step is focused on the evaluation of the overall condition of the loan borrower, including mainly: financial capability, management capability, risks resistance capability and the prospect in the market. In this part, the borrower of the project is assumed to be complying with the requirement of the borrower in PLAS, since the purpose is to assess the feasibility of the project instead of the qualification of the borrower. Thus, we omit the step of borrower assessment with the acquiescence that the borrower can reach the requirement of the PLAS.

Investment prediction and fundraising assessment are concentrated on the calculation of the project cost, the analysis of the rationality of the data of project investment reported by the project operator, and assessment of the eligibility of the resources and proportion of project funds. It should be noted that as a project in the power generation industry, the funds owned by the borrower must be no less than 20% of the total project investment.[23] As this paper does not focus on the assessment of the financial condition of the borrower, the author assumes that the investment and fundraising of the project can meet PLAS's requirements. In addition, for the same reason, the guarantee assessment step is also omitted in the process of PLAS, assuming that the project can reach the requirement of loan guarantee. However, the requirement and influence of these three omitted steps in the assessment system is to be discussed and analyzed later in the conclusion part to provide a deeper understanding of the loan feasibility.

In this way, the procedures of project assessment in PLAS applied in this paper are as the following:

- *Project profits assessment with a sensibility analysis;*
- *Project general condition assessment;*

[23] ICBC. (2005). The requirement of assessment is based on ICBC regulation if not specified otherwise.

- *Product market assessment;*
- *Conclusion.*

The applicability of PLAS

This assessment is carried out on the basis of PLAS as mentioned previously in the above paragraphs. It should be noted that the assessment, which does not represent the opinion of ICBC, is not an official document on loan examining and approving process. In this assessment, only the articles involving the project itself are applied according to the author's estimation, while the parts about the qualification requirement and loan guarantee assessment are not to be considered correspondently. Though the requirement of the borrower is also to be described in the latter part of the paper, it will not be analysed in detail.

Besides, in order to simplify the assessment, and given that some parts involve business secret clauses, the author does not apply all the assessment clauses and parameters, but accordingly simplifies and adjusts the assessment procedure with the precondition that the essential requirement of PLAS is applied to ensure the credibility of this assessment.

The author assumes that readers have a general knowledge of economics and finance and will thus not explain the concepts and terms in common use, though the important terms will be defined and demonstrated.

3.2 The introduction of CGP project

The project is designed to co-produce dimethyl ether (DME) and electricity based on coal gasification-based technology. The host place of the project is Zaozhuang city (see Figure 3-1), which covers an area of 4550 km^2. With coal-related industry as the major part of local production, this area is heavily reliant on its rich coal reserves, which have proved to be 4.5 Gt as exploitable reserves.[24]

[24] Zheng Hongtao, Li Zheng, Ni Weidou, Eric D. Larson, Ren Tingjin, 2003. *Case-study of a coal gasification-based energy supply system for China*, Energy for Sustainable Development, Volume 7 No.4, p.63.

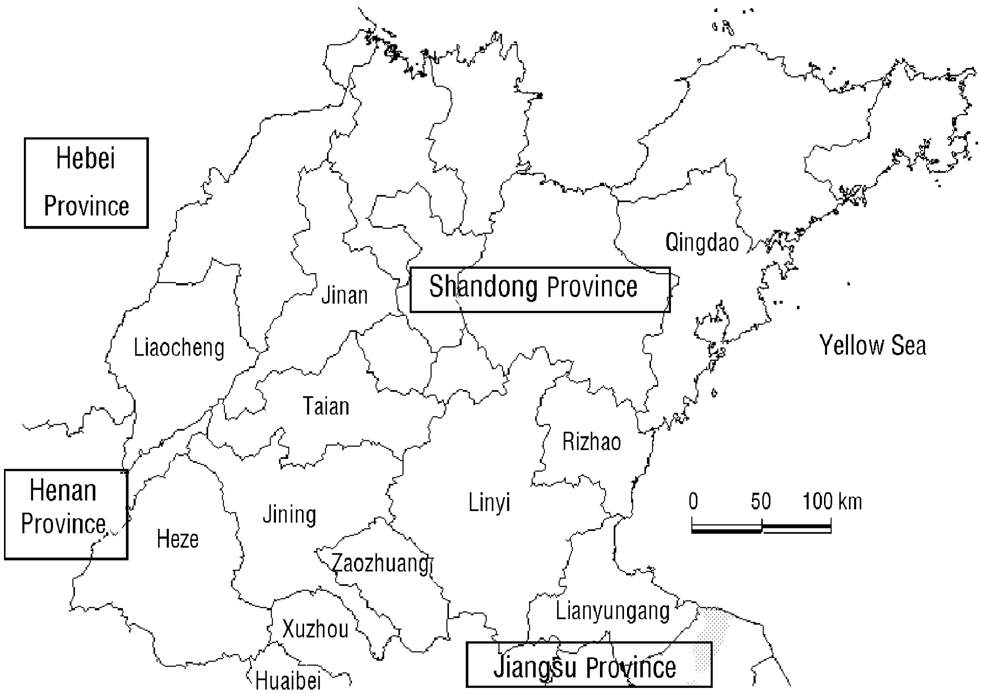

Figure 3-1: Location of Zaozhuang, Shandong Province, China. (NGCC,2003).[25]

3.2.1 Assumption on project capacity[26]

The production capacity designed is 600 MW (1795 tonnes/day) of DME together with 490MW of electricity, the feedstock is local coal, i.e. bituminous coal, and the proposed plant is assumed to be mine-mouth plant.

The project is presumed to be operating in a VENT scenario, i.e. the CO_2 is vented with all H_2S captured. Besides, the author chooses "once-through" configuration as the default condition for production process, where the syngas is passed only once through the synthesis reactor, and the unconverted gas is used as fuel for a gas turbine to raise steam to drive a steam turbine, together with waste heat recovered from all the production process, to generate electricity.

Table 3-1 Mass and energy balance[27]

Coal input, MW_{th}(LHV)	Total internal power use, MWe	Net power output, MWe	DME output, MW_{th}(LHV)	Total efficiency, % of coal LHV
2203.1	137.4	490.3	600.2	49.5

Source: Celik, et al. (2004)

It should be noted that DME produced in the proposed CGP project is supposed to be consumed in two scenarios. One is as a substitute of LPG, i.e. a house cooking fuel; the other

[25] National Geomatics Center of China(NGCC). (2003). Refer to Zheng Hongtao, et al (2003)

[26] All the assumptions are based on the data established according to real world examples. Source: Celik, et al (2004).

[27] Celik, et al. (2004).

is as a substitute of diesel, i.e. a transportation fuel. Hence, the revenue of the project is to be calculated separately in the two different scenarios, and the market prospects of the CGP product are also to be evaluated separately.

3.2.2 The capital costs of the project

To work out the capital cost estimates and levelized cost of DME and electricity, the project condition and the corresponding parameter are demonstrated as the following.

Capital costs were estimated for commercially-mature systems by major equipment area for manufacture and construction according to a United States location.[28] The capital cost estimates in an America condition are the following.

Table 3-2 *Overnight installed capital costs*[29] *in an America condition (million ,$)*[30]

Coal storage, preparation, handling	92.80	Other capital costs	3.01
Gasifier (4 trains)	190.24	Fuel area BOP	91.61
Air separation (2 trains)	103.28	Gas turbine	108.40
Upstream WGS area	10.35	Steam turbine and HRSG	113.82
Rectisol	80.91	Power island BOP	73.18
DME distillation	44.21	Saturators	0.25
Sulfur Recovery (Claus, SCOT)	55.82	Downstream WGS area	
DME synthesis	26.46	Syngas expander	1.69
DME distillation	44.21	Methanol dehydration	1.69
Total overnight capital cost: 998 (997.73)			

Source: Celik, et al. (2004)

Transformation into a Chinese scenario

The capital investment required to build the electricity and DME co-production project in a China location is estimated as being much lower than in an America location because of the lower manufacturing and construction costs. For DME-related portions of the plant in China,

[28] Celik, et al (2004).

[29] Overnight capital cost refers to the capital cost of a project if it could be constructed overnight, which does not include the interest cost of funds used during construction. Source: Harvest Energy (2006).

[30] Celik, et al (2004).

capital cost will be 0.75 times that in America; while for power-related portions, capital cost will be 0.664 times. According to Celik et al., 63% of the total capital cost is for fuel-related and 37% is for power-related investment.[31]

Based on the above, the ***total overnight capital cost in China*** is assumed to be: 997.73 * 0.63 *0.75 + 997.73 * 0.37 *0.664 = 471.22 + 245.12 = 716.34 = ***716(million, $).***

Operation and maintenance (O & M) cost is assumed as 4% of overnight capital/year. So, ***O&M*** = 716.34 * 4% = 28.65 = ***29 (million, $).***

According to Eric, the cost of coal feedstock is 1.39 times of the cost of O&M (3.67/2.64) in an America location, thus, ***coal feedstock*** =997.73 * 4% * 1.39 = 55.47 = ***55(million, $).*** And the cost of coal feedstock in a Chinese location is estimated as the same as in an America location.

From the above, we can figure out the basic cost data in a Chinese location.

Table 3-3 Basic cost estimates in a Chinese location, (million, $).

	American condition	Transformation	Chinese condition
Total overnight capital cost	997.73	997.73*0.63*0.75 + 997.73*0.37*0.664	716
Operation and maintenance cost	716.34	716.34*4%	29
Coal feedstock cost	55.47	Same	55

3.3 The project profit assessment

The project profit assessment is the core of PLAS. It aims at specifying the basic financial data, and working out a financial sheet according to the current fiscal and tax system based on financial cost and benefit caused during the project term. The purpose of this assessment is to evaluate the profit making capability, the debt reimbursing capacity and risk resisting capacity of the project, in order to provide evidence for the decision-making of the loan.

3.3.1 Indicators

To simplify the calculation, only the essential financial data is considered. The main indicators used in the project profit assessment include financial internal rate of return (FIRR), net present value (NPV) and investment profit margin (IPM). The equation of these indicators are the following.

FIRR is the discount rate that makes the present value of cash flow equal to zero. The FIRR is the discounted rate at which NPV of the investment is sum to zero.

[31] Source: Larson, et al. (2004).

n

Σ(CI-CO)t(1+FIRR)- t=0[32]

t=1

n

NPV=Σ(CI-CO)t(1+i)-t[33]

t=1

IMP= (average annual profit)/total capital investment

The calculation of IRR and NPV is based on the data of net cash flow within the project term. It should be noted that the cash flow is established assuming all the capital investment is self-owned funds without considering the negative cash flow of interest, because the purpose is to evaluate the FIRR of the proposed project under an overall investment scenario. The financial impact of the project loan is to be assessed through the calculation of IPM.

The following are necessary assumptions which should be identified before the calculation.

3.3.2 Assumptions set for the financial calculation of the project

3.3.2.1 General assumption

The project term is assumed to be ***25 years*** - according to PLAS the maximum is 30 years. According to the Bank's regulations, the depreciation period of houses is 25 years, the depreciation period of equipment is 15 years; in this paper, to simplify the calculation, ***the depreciation period*** of total overnight capital is assumed to be ***20 years*** , and the ***remnant value rate*** is assumed to be ***5%***.

The project capacity factor is assumed to be ***80%***.

3.3.2.2 Assumptions of the cash flow

The basic discounting rate is assumed to be 8.85%, which is used to calculate the net present value of the net cash flow produced in the project term.

The capital distribution in construction period is ***30%, 40%, 20% and 10%*** respectively from the first year to the last year, i.e. the cash outflow in construction period which is used in the making of the cash flow sheet.

[32]CI—cash inflow, CO—cash outflow, n—project period

[33]i—the discount rate

The exchange rate of RMB to US$ is assumed as ***8:1,*** since the current exchange rate in the beginning of 2006 is approximately 8:1.

3.3.2.3 Assumptions of the loan items

The project loan is assumed to be 80% of the total overnight investment, i.e. 716.34 * 0.8 = ***573.07(million, $).***

The interest rate for the long term loan is assumed to be ***6.39%***, which is the interest rate used by the ICBC at the beginning of 2006.

Construction period: 4 years, and the loan interest rate is 6.39%, and the loan distribution in the first four years in construction period is 30%, 40%, 20% and 10%.

The total amount of capital loan after construction period

Every year, the interest caused would be reckoned in the principal of the next year without reimbursement since there is no revenue to reimburse the debt at the construction period. The principal is assumed to be made according to the following formula: principal = the loan at the beginning of the year + the increased loan of the year/2, and annual interest = principal * interest rate.

Based on this assumption, the total capital loan after construction period can be obtained from the following.

The interest caused in the first year = 573.07 * 30%/2 * 6.39% = 5.49 (million, $).

The interest caused in the second year = (573.07 * 30% + 5.49 + 573.07*40%/2)*6.39% = 292.0325 * 6.39% = 18.66 (million, $).

The interest caused in the third year = (171.92 + 5.49 + 229.23 + 18.66 + 573.07 * 20%/2) * 6.39% = 482.607 * 6.39% =30.84 (million, $).

The interest caused in the last year of construction period = (171.92 + 5.49 +229.23 + 18.66 + 114.61 + 30.84 + 573.07 * 10%/2) * 6.39% = 599.4 * 6.39% = 38.3 (million, $).

The total capital loan after construction period = 573.07 + 5.49 + 18.66 + 30.84 + 38.3 = 666.36 = ***666 (million, $).***

The annual interest payable during the project term (after construction period) is assumed to be the total capital loan after construction * annual interest rate = 666.36 * 6.39% * *=42.58* ***= 43 (million, $).***

3.3.2.4 Assumptions of the taxes

Transaction tax and income tax are considered in this paper as the tax expenses for the project.

The transaction tax is assumed to be ***7.56% of the turn over*** (as the average tax rate of the power industry, and a little higher than the chemical industry).

The income tax rate is assumed as ***33% of the annual profit***.

3.3.2.5 Assumptions of the market condition

When DME is used as a substitute for LPG: the price of LPG is used as a reference for the price of DME, assuming it to be sold as household cooking fuel. In this paper, to simplify the calculation, only heating value difference is taken into consideration to convert DME to the equivalent LPG. Considering the heating value of DME (i.e. 28.4MJ/kg, LHV) and LPG (i.e. 46MJ/kg, LHV) the heat value ratio between them is 28.4/46=0.62; thus we can estimate that 1 ton of DME is equal to 0.62 ton of LPG in the market. The price range of LPG is from around $600/t (August, 2005) to more than $ 800/t (Spring, 2006)[34]; it then fell down to $600 again in August, thus ***$372/t*** (600 * 0.62) is assumed to be ***the reference price of DME*** based on the prudence principle in PLAS.

When DME is used as a substitute for diesel: the price of 0# diesel is used as reference of the price of DME. ***The reference wholesale price of 0# diesel is assumed to be $600***, based on the fact that the price at the beginning of 2006 was approximately $600, and raised a little above this price in July.[35]

The electricity on-grid price is supposed to be ***$ 0.04875/KWh***, which is based on the sales price of a power plant in Zaozhuang city.[36]

The coal price for a mine-mouth plant is assumed to be $1/GJ$_{LHV}$ =$23.5/t .[37]

3.3.3 Calculation of FIRR & NPV (with DME as a household cooking fuel)

Based on the above assumption and parameters designed, we can proceed with the calculations.

Cash outflow items consist of capital distribution during the construction period, O&M, coal feedstock, transaction tax, income tax, and DME transportation cost; while cash inflow items consist of revenues from electricity and revenues from DME

To calculate the annual cash flow (after the construction period), the following formula is applied.

Annual net cash flow = total revenue - O&M – coal feedstock – transportation cost – transaction tax – income tax

The calculations of the factors influencing the cash flow are the following.

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[34] Sohu Co. (2006).

35 Sohu Co. (2006).

36 Shandong Price Bureau. (2004).

[37] The price is used as a city-gate price by Celik, et al. (2004), which now can be applied as mine-mouth price because of the increase of coal price, according to Shanxi Coal Industry Association. (2006).

3.3.3.1 Positive cash flow

Revenue from electricity = electricity capacity * hours/day * 365day *capacity factor * unit price = 0.49 * 24 * 365 * 0.8 * 0.04875 = 176.4 (million, $).

Revenue from DME = unit price * DME production capacity * tonnes/day * 365 day*0.8 = 372* 1795 * 365 * 0.8 = 194.98 (million, $).

Total revenue = 176.4 + 194.98 =371.38***= 371 (million, $).***

3.3.3.2 Negative cash flow

Annual transaction tax = total revenue * 7.56% = 28.08 (million, $).

Annual depreciation = total overnight capital cost *(1-5%)/20 = 716.34 * 0.95 /20 =34.03 (million, $).

Annual DME transportation cost per ton can be calculated through the following formula: 9.83+(0.051*D), [38] where D is the transportation distance in km and assuming the distance between the mine and Zaozhuang city or other target market such as Jining city(see the above map) is 150 km; thus DME transportation cost per ton =$17.5, total cost = $17.5/t * 1795t * 365d * 0.8 = $11.5(million, $).

The calculation of income tax

Annual income tax = annual profit * 33%

Annual profit (without considering loan interest= total revenue - transaction tax - O&M cost - coal feedstock - DME transportation cost - depreciation = 371.38 – 28.08 – 28.65 – 55.47 – 11.5 – 34.3 = ***213.38 (million, $).*** It should be noted that for the last year of the project term, there will be no depreciation since the depreciation period is 1 year shorter than the project term, thus, ***the annual profit for the last year*** = 213.38 + 34.3 = ***247.68 (million, $).***

Thus, ***annual income tax for the initial 20 years period after construction*** is 213.38 * 33% = ***70.42(million, $)***, and ***for the last year, =*** 247.68 * 33% =***81.73(million, $).***

3.3.3.3 The outcome of annual net cash flow after construction

Based on the above formula, ***annual net cash flow (for the initial 20 years period after construction period)*** = 371.38 – 28.65 – 55.47 -11.5 – 28.08 – 70.42 = ***177.26 (million, $), for the last year, =165.95 (million, $).***

3.3.3.4 Capital distribution

The capital distribution during the construction period (negative cash flow within the initial four years in project term):

[38] Feng. (2003), source Eric, etc. (2004).

Capital distribution (assuming all the capital investment is from self owned funds) in construction period is 716.34 * 0.3 = 214.9 (the first year), 716.34 * 0.4 = 286.54 (the second year), 143.27 (the third year), 71.64 (the last year in the construction period).

3.3.3.5 Result of calculation

Apply the corresponding data gained above to make up the cash flow sheet, the NPV and IRR data for the project (*with DME used as a cooking fuel*) can be worked out as the following.

NPV= 583.61 (million, $)

FIRR= 17.41%

Period of financial return = 10.46 years

3.3.4 Calculation of NPV & FIRR (with DME used as transportation fuel)

3.3.4.1 The revenue of DME

When DME is used as an alternative to diesel, on the basis of the difference of LHV between DME and 0# diesel in the market (i.e. LHV of 0# diesel is approximately 40.6GJ/t[39], and of DME is approximately 28.4MJ/kg, i.e. 28.4GJ/t) then one can establish that ***one ton of DME is equal to 0.70 ton of 0# diesel (only heating value difference is considered).***

Then the annual output of DME (unit: tonnes of equivalent 0# diesel) = DME production capacity/day * 365 day * capacity factor * 0.7 = 1795 * 365 * 0.8 * 0.7 ***= 366898 tonnes***

The reference wholesale price of 0# diesel is assumed to be $600, based on the fact that the price at the beginning of 2006 and in July was approximately $600.[40]

Thus, the revenue of DME= annual output * unit price = 366898 * 600 = 220.14 (million, $), then ***the total revenue = 220.14 + 176.4 =396.54 (million, $).***

3.3.4.2 Negative cash flow

Annual net cash flow = total revenue - O&M – coal feedstock – transportation cost – transaction tax – income tax.

Annual transaction tax = annual revenues * 7.56% = 396.54 * 7.56 = 29.98 (million, $).

Since the wholesale price applied already includes the transportation cost, there is no more transportation cost involved in the calculation.

The calculation of annual income tax

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[39] Jinhua Huaxing Xinhuaqian Co. (2005)

[40] Sohu Co. (2006c).

Annual profit (without considering loan interest)= total revenue - transaction tax - O&M cost - coal feedstock - depreciation = 396.54– 29.98 – 28.65 – 55.47 – 34.3 = ***248.14(million, $), the annual profit for the last year*** = 248.14 + 34.3 = ***282.44 (million, $).***

Thus, ***annual income tax for the initial 20 years period after construction*** is 248.14 * 33% = ***81.89 (million, $)***, and ***for the last year, =*** 282.44 * 33% =***93.21 (million, $).***

3.3.4.3 Annual cash flow

Based on the above formula, ***annual net cash flow (for the initial 20 year period after the construction period)*** = 396.54 – 28.65 – 55.47 – 29.98 – 81.89 = ***200.55 (million, $), for the last year, =189.23 (million, $).***

3.3.4.4 Result of calculation

Applying the above data and capital distribution data into the calculation tool, the following result can be obtained.

NPV = 674.70(million, $)

IRR = 18.20%

Period of financial return = 10.28 years

3.3.5 The calculation of investment profit margin (IPM)

IPM is the important index used to evaluate the profit-making capability of the project. The cost of the project loan is considered to gain a practical assessment of the project.

*IPM = average annual profit / total investment * 100%,* in this formula, annual interest must be taken into consideration in the calculation of annual profit, for IPM is based on the actual cost and actual revenue in the process of project operation.

3.3.5.1 In a house cooking scenario

For DME used as cooking fuel, annual profit (except the last year in project term) = the previous annual profit – annual interest = 213.38 – 42.58 =170.8 (million, $), minus income tax (170.8 * 0.33 =56.36m), then ***net profit = 170.8 – 56.36=114.44 (million, $).***

The annual profit for the last year =247.68 -39.64 = 205.1(million, $), minus income tax (205.1 * 0.33 =67.68m), thus ***net profit for the last year = 205.1- 67.68 = 137.42 (million, $).***

From above, ***average annual profit =*** *total profit/(project term- construction period)* ***= (114.44 * 20 +137.42)/21 = 115.53 (million, $).***

IPM (cooking fuel scenario) = 115.53 /716.34 = 16.1%.

3.3.5.2 In a transportation scenario

For DME used as a diesel alternative, annual profit (except the last year in project term) = 248.14- 42.58= 205.56(million, \$), minus income tax (205.56 * 0.33=67.83m), then ***net profit =205.56 – 67.83 = 137.73m;*** and *annual profit for the last year* = 282.44 - 42.58 =239.86m, minus income tax (239.86*0.33=79.15m), thus ***net profit = 239.86 – 79.15 =160.71m.***

From above, ***average annual profit*** = total profit/ (profit term –construction period) = (137.73*20 +160.71) /21 = ***138.82m.***

IPM (transportation fuel scenario) = 138.82/716.34 = 19.38%

3.3.6 Project sensibility analysis

The main factors which can influence the profit of the project consist of the feedstock cost, the capital investment and the price of the products, because O&M cost and other costs are comparatively stable or minor, which can hardly impact the financial perspective equally, and the changes of revenue mainly depends on the unit price.

Hence, the unit price of coal, DME and electricity can be regarded as the decisive elements if not considering the amount of capital investment. In this part, only the scenario in which DME is used as a household cooking fuel is considered in order to simplify the calculation and analysis, and furthermore the financial condition does not differ significantly when DME is used as a transportation fuel. In this calculation and analysis, the difference in profit caused by the depreciation is not considered, i.e. to assume the appreciation of last year of the project term the same as the initial 21 years.

Data used based on the previous calculation is the following (unit: million, \$).

The annual profit (before minus income tax) = 171, coal feedstock cost = 55, electricity revenue = 176 (with a unit price of 0.04875 \$/KWh), DME revenue = 195 (with a unit price of 372\$/tone), and the total revenue = 371.

3.3.6.1 When the price of feedstock rises

If the unit price of coal increases by 50%, i.e. the feedstock cost rose to 83 (million, \$), the annual profit would be decreased to 143 (million, \$), i.e. 16% less when coal price increased 50%. That shows that the project is risk resistant to the fluctuation of coal price.

3.3.6.2 When the price of electricity changes

If the unit price of electricity falls 10% (which can be regarded as a major change in the price of electricity) while the DME price remains the same, then electricity revenue would fall 10% to 158 (million, \$).

The total revenue = 158 + 195 =353 (million, \$). The annual profit = total revenue – transaction tax – O&M –coal feedstock – DME transportation cost – depreciation – interest = 353 – 27 -29 -55 -12 -34 – 43 = 153 (million, \$), i.e. 10% lower in profit. When the electricity price rises 10%, the extent of the profit increase is similar.

Hence, the profit of the project is not sensitive to the price changing of electricity. In fact, the adjustment of electricity is generally accordant with the direction of the price fluctuation of coal, though the degree of fluctuation of electricity is usually less. Hence, from an overall perspective, the increase in coal cost would lead to the increase in electricity revenue, thus, the impact on the profit can be offset in some sense.

3.3.6.3 When the price of DME changes

If the unit price of DME falls 50% while the price of electricity remains the same (since the fluctuation of DME price can generally be comparatively higher in the market), the DME revenue = 98 (million, $), then the total revenue = 274 (million,$), then the profit = 274 – 21 – 29 – 55 -12 – 34 - 43 = 80 (million, $). 53% lower in profit.

3.3.6.4 Conclusion

From above, the impact caused by the changes in the unit price of electricity and coal feedstock can be minor and offset by each other, while the fluctuation of DME price can lead to larger changes in the project profit. However, even in the case of a heavy drop in the DME unit price, the project can still make a profit, which shows the high risk resisting ability of the CGP project.

In addition, for the feature of Chinese condition, the capital investment for the construction of the project can be even lower than the estimated situation. In fact, as the author found out during the thesis work, the capital investment of a demonstration project in Zaozhuang is much less than the estimated financial input assumed in this paper. This can make a positive impact on the sensibility analysis of the project.

To sum up, the CGP project has high profit-making ability under the circumstances of the price fluctuation of the sensitive factors, which illustrates its high risk resisting ability in this scope.

3.3.7 Conclusion for project profit assessment

The profit assessment shows that the CGP project has high profit-making capability, and strong debt reimbursing capability, and the sensibility analysis illustrates its high risk resistance to the price fluctuation of feedstock and products.

From the project profit assessment perspective, the CGP project is considered as a project which can totally comply with the requirement and has a high score for its good performance in this point.

3.4 General condition assessment

The purpose of this part is to evaluate the general condition of the CGP project, the essentials including assessment on the project necessity, applicability of technology, construction and production condition and the procedure of official approvals.

3.4.1 Necessity assessment

The key points of necessity assessment include: the industrial analysis according to national policy on industry, business environment analysis of the project host place, the significance analysis on the implementation of the project.

The implementation of the CGP project can develop the energy provision level and the industrial technology level, while simultaneously protecting the environment. It is approved by the central government and by the 10th FYP and 11th FYP, and is included in projects with high priority in the National Medium & Long term Science & Technology Development Plan (2006-2020). Thus this project accords with the national strategy.

The local condition is suitable to the implementation of the project, based on its rich coal reserves, stable society environment and potential development prospects. The annual GDP increment rate of Zaozhuang before 2010 would be around 11% according to an official prediction of SCP.[41]

The implementation of the project can adjust the structure of domestic industry and has the potential to improve the overall level of the energy industry. At the same time, the project can stimulate the development of both upstream and downstream industries, which provide high significance for the local development and a better wealth distribution.

Conclusion: the proposed project accords with the requirement of this item.

3.4.2 Technology assessment

The purpose of this part is to evaluate the applicability of the project technology and technique, in order to avoid potential risks afterwards. The principle is that neither laggard technology nor technology too advanced to be adapted at present condition be included for business implementation. The technologies used for the CGP project are mostly proven, and a demonstration project in Tengzhou, Zaozhuang city is in a good operation condition with a production capacity of 60 MW IGCC power generation and 240 kt methanol per year. However, the proposed project is designed to produce 600 MW (1795 tonnes/day) of DME with a co-production of 490 MW net electricity export which is an unprecedented large-scale business case without any pre-existing real world example in China. The CGP system is a cross-sector integrated system integrating production processes of different products, which needs much data and experience gained from large-scale demonstration project. On the world scale, the history of the implementation of large scale IGCC projects is not so extensive. It should also be noted that the application of technologies involved with so many different production process needs a long time to reach systematic integration. Besides, the complex system requires high level technicians and management people for operation and maintenance, who are however currently in short supply. There is no doubt that only a few big companies can satisfy this requirement.

In addition, there are major uncertainties in the downstream implementation phase of DME. The concrete analysis on the technology feasibility is the following.

There is no technical standard for downstream implementation at national level, which obviously blocks DME promotion. Because the business implementation can involve millions of people, city construction, industrial management and supervision, and other important factors, national technical standard is extremely important in this situation. Without it, large-scale implementation in downstream is impossible.

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[41] Shandong Construction Department. (2005). .

DME is a suitable fuel for compression ignition engine vehicles, but this kind of motor car is not presumed to be widely used in China in the near future, thus the purpose of DME implementation is for the existing motor vehicles, i.e. to be used through blending with diesel. Several plans and technologies have been put forward that can solve this problem. However, the mature technology accepted through business implementation in this field has not been specified nor confirmed through the large-scale implementation to date.[42]

DME as a substitute for LPG in city gas is feasible in technology, but the supply region is fairly restricted because of the physical feature of DME, which would block its large-scale implementation.

Conclusion: the lack of a national technical standard for DME implementation and operation, and a successful large-scale business implementation record of this CGP production and downstream operation constitute the main obstacles which brings major uncertainty for DME implementation.

3.4.3 Construction and production condition

Generally speaking, in China construction and production condition is not a significant problem if the project is permitted by the authority.

Land Application Approval from the authorities is needed. The main feedstock for the production is coal, which is supposed to be 2.36 Mt per year[43]- according to the coal reserves and the assumption of this assessment, we regard the supply of coal feedstock reliable.

One obstacle though is the demand of water, which is supposed to be solved by the project operator themselves through the application of underground water or other water resources such as a local sewage plant, since at a mine-mouth plant no other water supply is available.

Conclusion: no major problem for this item.

3.4.4 Official approval from economic management department of government and from environmental protection department of government

Official approval is needed as the precondition, which is assumed to be obtainable according to the assumption part.

3.4.5 Domestic production capacity and competitive advantage of CGP

The overall output of DME in 2005 in the world was approximately 200 thousands tonnes, of which China produced approximately 30 thousands tonnes.[44] Compared to the huge demand in the energy field, the production capacity is incommensurate. From a long term perspective, there can be huge market space. One advantage of CGP technology is that it can update the technology and product step by step based on the development of the situation. For example,

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[42] Lin, etc. (2006).

[43] Based on Celik et al. (2004).

[44] Ma. (2006).

for the first phase power, heat and DME can be co-produced, and some other products such as downstream chemical products of DME can be implemented when the financial or technical standard is met. Beside, the CGP system can adjust the proportion of power, heat and chemical products in the overall output, which could enhance the ability to bear the price fluctuation of some products.

The project's competitive advantage is created by its large-scale, high input-output ratio, low price feedstock and abundant supply of coal. As illustrated in the profit evaluation, the products produced from the CGP project can obtain the advantage of relatively low costs compared to products in the current market, e.g. DME vs. LPG.

Another competitive advantage is created by the environmental achievement it can make, which could bring political advantage and risks reduction for regulation must be getting more stringent in the future.

3.5 Product market assessment

Product market assessment is one of the key parts in this PLAS since for a business project the market is always regarded as the most import factor. The purpose is to specify the sales prospects of the project's products according to the research on supply and demand conditions in the market for the proposed product and its substitutes. In this part, DME is to be analysed mainly, as the enormous demand for electricity has already been shown in the previous section.

3.5.1 The potentially huge market demand for DME

As a clean fuel, DME is a very good substitute for LPG as a household cooking fuel and for diesel as a transportation fuel, which has an excellent market prospect. The target market in the short term includes Zaozhuang and the neighbouring area such as Jining and Xuzhou (see the above map) firstly, and in the longer run, the market can cover all the east part of China, so the demand for DME potentially can be tremendous. The following is the description and analysis of the market of DME.

3.5.1.1 As a substitute to diesel

The potential market for DME is very huge since diesel consumption is predicted to continue rising for a quite long time (as discussed in above paragraphs). From 2000 to 2005, the diesel consumption rose abruptly from 67 Mt to 110 Mt, with an average annual increment rate of 8.6%.[45] From the technical perspective, DME can be used as transportation fuel by itself, or mixed with diesel at certain proportion. Hence, as a clean alternative of diesel, the potential demand of DME is large enough in theory. Assuming the substitute rate is 10%, the demand for DME in China will be approximately 15 Mt in 2010.[46]

[45] Dai. (2006).

[46]Lin, et al. (2005).

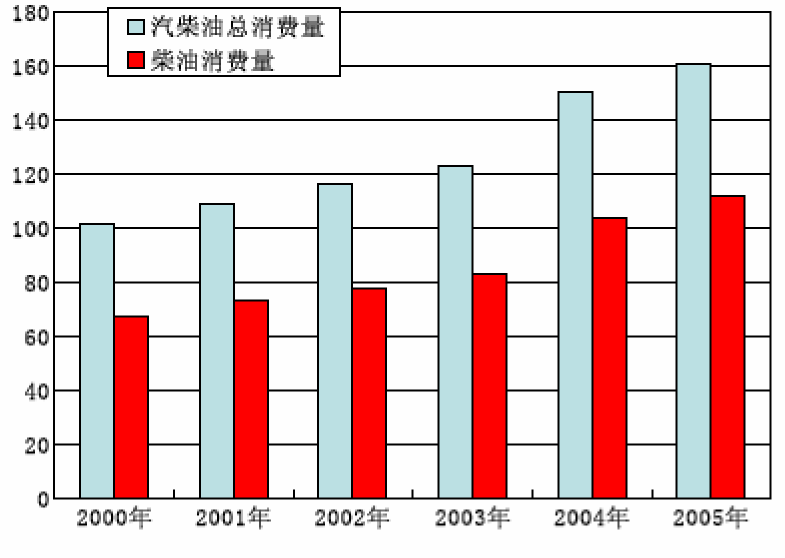

Figure 3-2: Diesel and gasoline consumption in China, red column (dark) is for diesel, light is for the total consumption of diesel and gasoline, unit: Mt. (Dai.2006)

3.5.1.2 As a substitute to LPG

The potential market for DME as a household cooking fuel is also huge, since DME is a very good fuel which can be used by itself in addition to together with LPG as a mixture. Plus the popularization of LPG in many of China's cities creates excellent conditions for the implementation of DME.

Nowadays, the domestic LPG provision cannot meet the demand; the proportion of LPG imports in total LPG consumption rose abruptly from 4.6% in 1990 to 31.7% in 2004. In 2004, the total LPG consumption was 20.1 Mt with LPG imports of 6.39 Mt.[47] Hence, if we consider that 20% of LPG consumption can be replaced by the implementation of DME, the size of the potential market will be approximately 4 Mt LPG equivalent, if 10% of LPG consumption can be replaced, the potential market for DME will be approximately 2 Mt LPG equivalent. This demand is estimated to continue increasing for a long period as a result of the urbanization process in China.

3.5.1.3 To sum up for the potential demand of DME

The potential market turns out to be huge. Yet compared to the vast size of potential demand, the DME production output of China was only 30 thousand tonnes in 2005. Furthermore, the market is increasing every year at a rate exceeding 13% in recent years.[48]

3.5.2 The obstacles in realizing these demands

However, despite all this, the implementation of DME has to face huge disadvantages in marketing, which can be regarded as the main factors that block DME business implementation in China. The obstacles in marketing are to be described in the following section.

[47] Yu. (2006).

[48] Yu. (2006).

3.5.2.1 Market obstacles when DME is used as transportation fuel, i.e. an alternative of diesel.

At current condition, the implementation of DME has to face the barriers in large-scale implementation technology and in downstream channels.

Barriers in large-scale implementation technology

The implementation of DME can be divided into three types, i.e. chemical blending method, physical pressurization method and sole DME method.[49] The classification is based on the types of input of DME and if the engine system has to be refitted. For the chemical blending method and the physical pressurization method, DME is blended with diesel, but the latter requires some changing in oil box and oil input system of the vehicles in order to make it bear higher pressure, while the front refers to only chemical blend at a certain proportion.

As a matter of fact, each of the three methods has its own drawbacks in practice.

When DME is blended together with diesel through a chemical blending method, the implementation is much easier than the physical pressurization method (to be described in the following part), since it's unnecessary for car owners to refit their engine or other parts. But at present the optimum technology for this purpose has been neither specified nor confirmed through large-scale business implementation,[50] and no large-scale demonstration project for this purpose exists.

When DME is blended with diesel through a physical pressurization method, one obstacle is that it needs to install a modest pressurization facility to store it as a liquid. This would increase the cost for car owners and involves different stakeholders such as consumers and vehicle management authority. Besides, there is no large-scale demonstration project existing to confirm the feasibility of this technology.

When DME is used alone without diesel, the engine has to be changed, which is considered much more complex than the above two methods. Now, the main motor producers in China have promised to launch the production of DME driven engine cars from now, but in the near future large-scale DME driven cars can hardly be put onto the market.

To sum up for this part, it should be noted that multiplicate technical solutions for the above problems have already been proposed,[51] but none of them are commonly accepted by the industry mainly because none of them has been proved through business implementation in a large-scale demonstration city. Due to the complexity of DME implementation, it requires financial feasibility, technical feasibility, management feasibility, and support from a large number of stakeholders, which increases the uncertainty of DME in the market. Only after the large-scale implementation in a demonstration city, can the optimum technology and the feasibility of CGP product be specified and confirmed.

Uncertainties in downstream channels

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[49] Lin, et al.. (2006).

[50] Lin, et al.. (2006).

[51] Chapman. (2004).

One of the main obstacles for DME to obtain market access is from the monopolization of national oil companies. At present time, the downstream market is mainly dominated by two big companies, i.e. China Petroleum & Chemical Corporation (SINOPEC Corp.) and China National Petroleum Corporation (CNPC). Most of the gas stations in China belong to these two companies, and the headquarters or regional headquarters control the supply of oil and gas for all their distribution organizations. They have abundant production capacity in the upstream phase of the energy industry and can be reluctant for the implementation of DME from a company other than their own. In addition, the local gas station has no right to purchase any product without higher level authorization. Moreover, the implementation of DME also needs alteration to the current gas station facility, which increases the difficulty of the first step in DME promotion.

It should be noted that this is not to say these main energy distributors will oppose DME implementation, but that the barriers lie on the uncertainties in the downstream phase, which is caused by the involvement of large number of stakeholders including large distributors, supervising organizations, national industrial standard, technological issues and infrastructure, public preference and other factors. The point is that the downstream oil distributors can hardly provide CGP operators with long-term contracts in large amounts at current condition. Without contracts, there would be potential risks in the market for the proposed project, because of its abundant capital input, large-scale output and long project term.

From the above analysis, we can consider that the DME market in this field can not be ensured without obtaining long term contracts from SINOPEC or CNPC.

3.5.2.2 Market obstacles when DME is used as a household cooking fuel, i.e. an alternative of LPG

The marketing problem can be analysed in two different scenarios. One is in the city pipeline gas scenario; the other is the bottled gas scenario, since they constitute the main channels to distribute LPG in the downstream market.

City pipeline gas scenario

In China, in order to plan the underground city pipeline as a whole, there is generally only one gas company in the same city district responsible for building up and maintaining the pipeline and providing cooking gas through this pipeline. As mentioned above, the price of DME will be more competitive to the local city gas companies compared to LPG in the market, but good price alone is not enough. The application of DME as a city pipeline gas needs much more.

Firstly, there is no national technical standard for the DME implementation, which is the precondition of large-scale business implementation. Without this, the authority cannot check up and assess the eligibility of DME business, and hence cannot grant permission to implement the business in order to avoid potential risks.

Secondly, the implementation of DME is a systematically societal project, including storing, distribution, retail and terminal consumption phases. Plus every phase involves stakeholders from different fields and different issues such as public safety, environmental protection and supervision. Such a complex system needs plenty of data, mature technology and seasoned management. However, there is still no large-scale demonstration city in the world, which is one of the biggest drawbacks of this technology. This restricts the implementation of DME to small-scale only, which cannot thus occupy the main market of pipeline gas.

Thirdly, the sole implementation of DME without mixing with LPG is feasible through a pipeline, but the transportation area is fairly limited as the absolute pressure within the pipeline needed cannot be very high for DME.[52] This restriction, plus others factors such as local protectionism, can also block the large-scale implementation of DME.

Bottled gas scenario

In this field, there are more companies dealing with the cooking fuel distribution to terminal consumption. For DME producers, it is much easier to enter this market as the competition in this field is much harder among suppliers and price is much more important. They don't rely on large-scale business demonstration projects and the technology in bottled gas scale is fairly mature, e.g. as one of the largest private energy company, Xinao Group has already implemented DME as a household cooking fuel in the form of bottle gas blended with LPG.[53] Another important reason is that the mechanism in these companies is more flexible and more market-oriented.

The drawback in this matter is that the marketing cost would be increased since more resources should be put into marketing and technical training, and besides, generally speaking, the size of these distributors are much smaller, so it's hard for the CGP project to ensure the market through these companies.

3.5.3 Conclusion for market assessment

From above, we can see that there are uncertainties in the demand realization of DME whether as a household cooking fuel or a transportation fuel at current condition. The essential of this problem is that it's hardly possible for this CGP project operator to obtain the long-term contracts from the large downstream energy distributors. And without these contracts, the market of DME in this field can not be ensured. Another matter is that, although some experts declared that they have discovered the optimum technology for CGP implementation, the feasibility of this technology hasn't been specified and confirmed through the large-scale business implementation. One more obstacle is that vehicles with suitable engines are not widespread.

It should be noted that the research shows the demand for DME can be extremely huge in the near future, in fact, even now the demand could be far exceeding the current output. That this potential demand is not fulfilled is mainly because of temporary obstacles in China today. The success of small-scale projects both in the production phase and in the downstream phase shows that the technical issue cannot be a major drawback for CGP technology.

The advantage of DME includes comparatively low price, environmental friendly, good performance in usage. Such features can ensure it becomes incomparable as a strategic product to meet the huge energy demand in China, without China becoming overly dependent on imports.

However, the complexity of the CGP system, which involves large number of stakeholders, multi-industries, mass of end-users, means that it requires a better condition to be pushed

[52] Huicongnet. (2006).

[53] Wang. (2006).

forward. For example, the huge demand of CGP technology can hardly be realized in the market unless a better condition is established.

Conclusion: the market of DME has not been ensured at current condition though the potential demand is huge.

3.6 Guarantee assessment and qualification assessment on borrower

Besides the above assessment procedure in PLAS, the guarantee assessment and the qualification evaluation on the project loan borrower are regarded as among the most important factors for the fate of the project loan. Though the paper is focused on the project itself instead of the borrower's qualification or the issue of guarantee, it is better to give a brief description about the requirement of these two procedures to provide a better understanding about the proposed project.

Since the CGP project investment amount is very large, it requires that the borrower must have very high qualification and very good credit degree in the bank. To obtain the loan, the borrower must rank at top place in the energy industry, i.e. strong technical strength, huge size, good management, and more important abundant profit and excellent financial data. The Bank has systematically quantitive and qualitative requirements to evaluate the qualification of the borrower. Generally speaking, the bigger the project loan that is applied for, the higher the requirement will be. Hence, only the industrial magnates in China's energy sector can be qualified. Without considering foreign companies, these magnates refer to only the top groups in the Chinese energy sector all of whom have a national background, e.g. SINOPEC in petrol-chemical industry and Yankuang Group in coal-chemical industry.

Guarantee assessment in PLAS intensify this requirement on the qualification of an eligible borrower, since no companies except the above mentioned ones can offer a guarantee for such a large loan sum. And according to the Bank's regulation, the loan will never be granted without sufficient guarantee unless the borrower is among the list of top customers, which mainly refers to companies like SINOPEC.

Though the attention of this part is on the business feasibility of the project itself, rather than the project operator, the role of the borrower can be vital for the loan application. For the top companies in the energy sector, their high credit level and risk-resisting ability make it much easier for them to obtain a project loan, which makes them the most suitable potential operators in China.

3.7 Conclusion for PLAS

From the above assessment on the CGP project, we can consider that its financial perspective is very good because of its high IRR and high IPM. Besides, the implementation of CGP technology is encouraged by the national industrial policy because of its potential role in energy safety and its huge environmental benefits. Most technologies used in the CGP system are proven. The competitive advantages and the potentially huge demand make it very attractive as a business project.

However, from an overall perspective, at current condition, the implementation of CGP project has to face obstacles which can cause problems and uncertainties in market access for DME. These obstacles mainly include the following.

- The uncertainties in downstream channel.
- Lack of necessary infrastructure.
- The proposed technology hasn't been specified and confirmed through large-scale implementation.
- Lack of national technical standard in downstream phase, e.g. in gas stations and in pipeline.
- Lack of management regulation.

Though these obstacles can be estimated as temporary problem in today's China, the solution to the above obstacles need much implementation data and experience, especially the large-scale implementation in a demonstration city. At current condition, the project loan cannot be granted as there could be risks caused by the above obstacles.

It should be noted that, because of the huge advantages of CGP project both in economic and in societal perspective, this project can be seen as the perfect target for a business loan in the near future.

4 Comparison between a conventional coal combustion (CCC) project and the CGP project

In order to gain a deeper understanding of the CGP project, in this section the author will introduce a project loan assessment on a conventional coal combustion power and heat co-production project. From the assessment, the advantage and disadvantage of CGP can be more easily revealed through comparison with such a mainstream technology.

4.1 General description of the CCC project

This case study is based on the real world example, according to the business database of the Industrial and Commercial Bank of China (ICBC). As a result of ICBC regulation and that the loan applicant prefers to remain anonymous, the author will not show the names of any concrete places or plants involving the project in this paper.

The project is set up based on the conventional combined heat and power (CHP) co-production technology. The production capacity is 200MW, and after construction the annual energy supply should be 1709 MWh and 6.97 million GJ. The main equipment of the project includes two condensing steam generators (670t/h), plus two pulverized coal boilers and corresponding desulphurization equipment.

The total overnight capital investment amount is $238.5 million (1908 million54), the amount of project loan applied is $175 million (1400 million), own capital $63.5million (588million) with a proportion of 26.6% in total overnight capital investment.

The on-grid price of electricity is assumed to be $0.042/KWh, which is the unified price for power generated from a plan installing desulphurization equipment (0.015 higher than power generated from a plant without desulphurization equipment). The city gate price of coal feedstock is assumed to be $57.13/ton (457/ton).

Compared to the corresponding price used in the assessment of the CGP project, i.e. $0.04875/KWh as electricity on-grid price, and $1/GJ_{LHV}$ ($23.5/t) as the coal mine-mouth, the price for electricity is 13.8% lower, and coal is 143.1% higher, the distortion caused is analysed and the modified result is provided in the following part.

The borrower assessment, guarantee assessment and other requirement is omitted for the same reason mentioned previously.

The resource is based on the business documents of ICBC.

4.2 The project loan assessment on CHP project

To simplify the assessment, only primary procedures of ICBC's PLAS are taken into consideration.

[54] The exchange rate between US dollar and RMB is supposed to be the same as the previous part, i.e. 1:8.

The assessment will be developed based on the real condition of the host city and the proposed project, e.g. the price and other financial data used is estimated according to actual conditions in the market.

4.2.1 Assessment on general condition of CHP project

4.2.1.1 Necessity assessment

In the National Medium and Long Term Plan for Energy Saving (2005), CHP technology (co-production of heat and power) is among the list of supporting industries. And the production capacity of the proposed project, i.e. 200MW, make it comply with the requirements of authority (i.e. the small scale power project below 100 MW is much more difficult to obtain an approval).

4.2.1.2 Official approval from economic management department of government and from environmental protection department of government

Both of the approvals are available. In China, conventional coal combustion plant is not prohibited according to government regulations, despite the fact that newly established projects are required to install desulphurization equipment.

4.2.1.3 Technology assessment

The technology is mature, and a complete unit of equipment produced by Haqi Group, one of the biggest companies in China, can meet the requirements of production. The quality and function of this type of equipment has been proved through the successful business record of several projects including Pingdingshan Heat & Power Plant and other plants.

4.2.1.4 Project construction and production condition assessment

On-grid approval assessment

On-grid approval from the national grid organization is submitted as the assumption of this assessment.

Land application approval assessment

The plan that 20.83 ha. of land is made out for the project construction is approved by the National Land Resources Department and other related authorities.

Coal feedstock supply and other construction assessment

The demand of coal feedstock is estimated as 10.5 Mt per year, which will be provided by the Shanxi Xishan Coal Company during the project term, and the contract to assure that the provision is available. The water usage plan is approved by the provincial authority with approximately 1.6 million cubic meters for boiler and living usage, and 6.6 million cubic meter sfor circularly condensing purpose. The water is from the local water company and sewage treatment plant. The contracts between provision and demand parts have been signed.

4.2.2 Market assessment

4.2.2.1 Heat market

In the host city, there are three heat supply resources for household purpose; however, it is unavailable for many residents in certain districts, as the heat provision area is limited and cannot cover the larger part of the city. The project will be the only heat resource for the planned district and the market is ensured by the City Central Heat Supply Plan signed by the local authority.

The heat demand for the planned district in the recent years is estimated as the following.

Table 4-1: Heat demand of proposed district

Heat load	Unit	At present	2010
Heating area	Mil.m^2	1019	1225
Heat demand	GJ/h	2405	2891

Source: ICBC database

Beside, the industrial heat demand in the planned district can also be met by the project, since it can provide heat under the standard of 0.981MPa and 298 with a production capacity of 320t/h.

The heating pipeline construction is to be carried out by the local heat supply company.

Power market

The power market has enough capacity for the project output. The calculation and analysis is omitted for the condition is similar to the CGP project host place.

4.2.3 Project profit assessment

To simplify the assessment process, the calculation is omitted in this paragraph, and the result of the financial parameter is the following.

The assumption is that the project term is 23 years with a construction period of 3 years. The average annual sales is estimated to be $77.8million (623 million), annual profit is $11 million (□88 million), with ***the investment profit margin (IPM) of 4.52%***, and sales profit margin of 14.08%. ***The financial NPV*** of the project is estimated to be ***$7.4 million (***59million), ***financial internal rate of return (FIRR) is 7.46%,*** and ***the period of investment return is 13.4 years.***

4.2.4 Conclusion for the project loan assessment on CHP project

Through the above project loan assessment process, the Bank considers that the CHP project has the following advantages.

- The project complies with the national industrial policy.
- The technology is mature.
- The market of heat and power is large enough for the CHP product.
- The long-term contracts are available.
- The financial perspective is stable and rather good for the debt reimbursement.

To sum up, the CHP project complies with the requirement of PLAS.

4.3 Projects comparison between CGP project and CCC project

From the opinion of the Bank on these two different technologies, we can see that the CGP project has to overcome some obstacles in the process of implementation. As is widely acknowledged, CGP is a technology embracing a very wide implementation prospect, and is among the priority list in the national industrial policy. Then why can't CGP technology compete with conventional coal combustion technology when applying for a business loan?

Without considering the qualifications of borrower, guarantee requirement, the fate of the project loan depends on the following factors according to the project loan requirement of the Bank.

- Industrial policy.
- Technology feasibility.
- Project operation and management stability.
- Product market: current condition of the demand and provision, competitiveness and future prospects.
- Project profit prospects.
- Project risk control.

4.3.1 Comparison in project profit perspective

Among the above factors, obviously, the CGP project holds a great advantage in the project profit assessment (see the following table), which is regarded as the core factor in the project loan assessment system (PLAS). FIRR of the CGP exceeds that of co-production of heat and power (CHP) project by approximately 10 percent. Further, the IPM of CGP is as high as 16.4% even if taking interest cost into consideration.

Yet as described at the beginning of this chapter, compared to the corresponding price used in the assessment of CGP project, i.e. \$0.04875/KWh as electricity on-grid price, and \$1/GJ_{LHV} (\$23.5/t) as the coal mine-mouth, electricity price applied in the CHP project is 13.8% lower, and coal price is 143.1% higher. The difference of price in coal is because the CGP price is a mine-mouth price, while the CHP price is a city-gate price. And the difference of price in electricity originates from regional difference. Though the difference is rational and the low price of coal is one the advantage for the CGP project to be established at mine-mouth, the financial result can be modified to make the two projects more comparable, i.e., apply the price of CHP to a CGP scenario.

In this case, the IPM for CGP can be obtained as the following.[55]

IPM = average annual profit/total capital investment.

The average annual profit can be gained from calculation as approximately 45(million, $), and total capital investment is 666(million, $), then ***IPM = 45/666 =6.8%, 36% higher than IPM of the CHP project.***

Hence, whether based on the CGP price or on the CHP price, the financial perspective of CGP can have some advantage compared to the CHP project.

Table 4-2: Financial perspective for the two proposed projects

Financial item	DME & power co-production	Heat & power co-production
Overnight capital cost(million, $)	717	239
NPV(million, $)	584	7
FIRR	17%	7%
IPM	16%	5%

Note 1. The financial data used for CGP project is estimated based on DME being used in a household cooking fuel scenario as analysed in previous part.

Hence, from the project profit assessment perspective, the conventional coal combustion CHP project cannot compete with the CGP project. But when we turn to others items in the project loan assessment system, we can see that, from an overall project assessment perspective, CHP project can be more feasible for business implementation (see the Table 4-3).

4.3.2 Comparison with all items of PLAS

In Table 4-3, the advantage and drawbacks of the two technologies are illustrated and compared correspondingly.

The advantages of CHP technology include the lower financial input, comparatively simple technology, stable demand and financial return, and less obstacles and low risks in the market. The investment profit margin of CHP is not as high as CGP, but it's steady with less uncertainty in business implementation, which is just the drawback of the CGP project. For the latter, one of the main barriers is that the large-scale implementation in the downstream phase needs the support of a large number of stakeholders, which causes some uncertainty in the market. Investors, of course, usually prefer to choose the project with less uncertainty, and with less capital investment.

[55] The new financial calculation based on the new data input is developed in the same way according to the calculation in the sensibility analysis in the assessment on the CGP project, i.e. small difference will not be taken into consideration, such as the difference of annual depreciation, and only DME in a house cooking fuel is taken into comparison.

Table 4-3: Comparison between the two technologies based on PLAS

Items of the loan requirement	DME & power co-production	Heat & power co-production
National industrial policy	Supportive.	Not prohibitive
Technology feasibility	No large-scale demonstration project in production or downstream field. DME & power co-production technology in large scale is not confirmed by large-scale implementation.. DME implementation technology in large-scale is not mature.	Mature. Large-scale implementation in China for a long time.
Capital investment	Huge	Much less
Product downstream implementation	No national technology standard in DME implementation, No demonstration city for DME implementation. No contracts available from downstream companies. The physical condition for large-scale use of DME is not reached at present. Involving large number of stakeholders and public preference.	Contracts signed with downstream companies. Market ensured through central heat supply plan signed by regional authority. Heat demand can't be met without this project.
Competitiveness status in market	Uncertainty with the cooperation with downstream magnates. Competitive in price.	Long term contract ensure its market status.
Operation and management perspective	Complex for the involvement of coupling of different industrial process and technology Not proved through large-scale implementation. .	Much less complex. Mature industry.

Profit making perspective	High	Moderate and stable
Project risk	Uncertainty	Low
Social benefit	High for pollution mitigation and GHG mitigation.	Social cost is high.
Other benefit	Enhance energy security, especial by liquid fuel supply.	No help for the substitution of transportation and cooking fuel.
Judgement at current condition	***Uncertainty existed.***	***High feasibility***
Judgement for long term	***High feasibility***	***Would be eliminated***

4.3.3 Discussion of the comparison

However, it should be noted that the disadvantages of CGP in implementation are totally different from the disadvantages of CHP. For the former, these disadvantages can be seen as the problem in the process of development. Most of which turn out to be contemporary problems, which are caused mainly by the complex feature of the CGP system in marketing, supervision and technology. These problems can be solved in the near future along with the development of economic and society. But for conventional coal combustion project, the disadvantage of high societal cost and comparatively low IPM should cause it to be removed from the list of good projects in the future.

In practice, however, viewed from a business bank perspective, the prospect of huge profits are not so attractive as the return from the project loan for the bank is fixed, based on a certain interest rate; although the bank will mostly endure the potential risks. So, it's common that a business bank generally prefers projects with stable profit prospects rather those with a potentially high profit but far greater risks. Furthermore, the huge capital investment in a CGP project could make the bank more conservative in order to avoid a major funds loss.

Yet in the longer term this attitude towards the promising technology can bring some risks to the bank. On the one hand, the conventional coal combustion plant already faces the potential risks of policy and cost, whereby the risk resistance of the CCC plant can actually be less because of its low IPM and huge societal cost. This can make the loan bank be in a bind. On the other hand, the support for the promising technology can establish first-class customers, and bring long term relationships with these customers. The huge environmental benefit and potential role in the energy sector can create incomparable competitive advantages for CGP technology. It can be a wise act to support CGP technology even at the current condition if other requirement such as the qualification of the borrower can be reached.

It should be noted that the assessment on the CGP project based on PLAS in the previous part only serves to illustrate the weak part of CGP in business implementation, which does not mean the CGP project can't be supported by a business bank if the potential risk can be limited within a small scope. As discussed before, the qualification of borrower can be a vital factor for the approval of the project loan. In fact, in the process of the realization of this paper, the author discovered that the ICBC has already taken the role of supporting a CGP demonstration project, i.e. the small scale project co-producing methanol and power in Zaozhuang city, and the financial performance has turned out to be good.

5 Societal cost and benefit analysis on conventional coal combustion plant and on CGP plant

As described in the first section, the conventional coal combustion (CCC) plant is no doubt the mainstream technology in the present power sector, dominating more than 80% of the power generation market. Furthermore, as illustrated in the above paragraph, its commercial feasibility is greater than CGP technology, with the advantage of mature technology, stable market and profit, and comparatively low capital input. However, the financial performance of the CCC plant mentioned above has vital drawbacks, in fact, for it does not cover external costs resulting from the pollution emission produced during the CCC production process. In this chapter, the author focuses on illustrating the potential strategic role of CGP based on the analysis of the societal cost of CCC technology and the societal benefit of CGP technology

5.1 External cost of CCC project

5.1.1 The calculation of external cost per unit

As described previously, the emission from the CCC plant includes mainly SO_2, nitrogen oxides (NOx), CO, ash, total suspended particulate (TSP). If taking no account of external cost caused in the upstream phase of CCCP, the emission condition in different technology scenario can be seen from the following table.[56]

[56] The following data used in Table 5-1 is based on Zhu Baotian. (2005).

Table 5-1: Emission comparison among different technology

Technology type		SO_2	NOx	CO_2	CO	TSP	Ash
CCCP	10^4t/a	5.1343	2.2819	493.75	0.0074	0.1141	39.933
	g/KWh	8.5571	3.8032	822.91	0.1236	0.1902	66.555
CCCP with FGD	10^4t/a	0.4671	1.2455	533.94	0.0807	0.0202	65.580
	g/KWh	0.7784	2.0758	889.90	0.1345	0.0336	107.63
USC[57]	10^4t/a	4.3897	1.9477	421.43	0.0633	0.0974	34.084
	g/KWh	7.3161	3.2461	702.38	0.1056	0.1623	56.806
USC with FGD[58]	10^4t/a	0.3944	1.0518	450.88	0.0681	0.0171	55.379
	g/KWh	0.6574	1.7529	751.47	0.1136	0.0284	92.298
IGCC	10^4t/a	0.3057	0.4302	384.00	0.0088	0.0091	22.198
	g/KWh	0.0509	0.0717	640.00	0.0147	0.0151	36.981

Notes 1.The data is based on the precondition that the power capacity is assumed to be 1000 MW, with a running time of 6000 hours per year and 21.2 MJ/kg, LHV as the lower heating value per unit of coal.

[57] USC refers to ultrasupercritical technology.

[58] FGD refers to flue gas desulphurization.

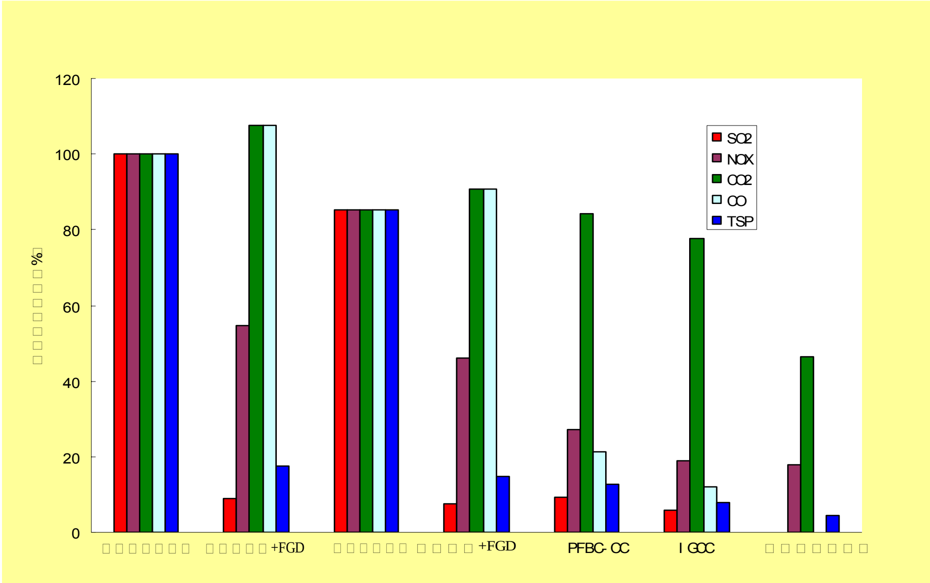

Figure 5-1[59]: Emission comparison, from left to right: CCC, CCC with FCD, USC, USC with FCD, PFBC[60], IGCC[61] and IGCC with natural gas as feedstock. Source: Zhu. (2005).

From the above figure and the table, we can see that the emission from a CCC plant even with a FCD is much more than an IGCC plant. Furthermore, the severe environmental and health impacts caused have been discussed in the above chapters. In this section, the impacts are quantified based on Zhu Baotian's calculation as the following.

Table 5-2: External cost of emission per uni , unit: $/Kg.

	SO_2	NO	CO	CO	TSP	Cinder	Waste water
External cost	0.9375	1.25	0.00375	0.15625	0.34375	0.01875	0.000125

Applying these data into the production scenario, the monetary cost for different technology can be carried out based on the same production condition assumed above.

Table 5-3: External cost for the proposed technology per KWh, unit: cents/KWh.

	CCC	CCC with FCD	USC	USC with FCD	IGCC
External cost	1.71875	0.875	1.46875	0.73875	0.4475

59 Zhu. (2005).

60 PFBC refers to pressurized fluid bed combustion.

61 IGCC refers to the integrated Gasifier combined cycle, the environmental effectiveness of power plant of CGP system can be seen as the same of IGCC.

5.1.2 The estimated financial condition of CCC plant considering external cost

Based on this, the financial performance of the proposed CHP project can be very different. According to the assessment, the total power generation capacity is assumed to be 1.79 billion KWh, then ***the reduction in revenue = 1790 * 0.00875 = 15.66 (million, $)***, and ***the total profit per year for the project is only 11 million (without considering external cost)***. Obviously, the profit will become negative in this case. Hence, we can see that taking the external cost into account the CHP project cannot survive in the market.

5.2 Benefit analysis on CGP project

In contrast to the CCC plant, the implementation of CGP technology can bring huge external and societal benefits, most of which cannot be achieved through the implementation of CCC technology, which gives it incomparable advantage in becoming a strategic technology in the Chinese energy sector.

5.2.1 Huge environmental benefit for the substitution of CCC power plant

As illustrated in the previous part, the huge external cost caused by the CCC power plant can be dramatically decreased by the implementation of the CGP project. Compared to the CCC power plant, emissions from a CGP plant are much less, for most emissions including SO_2, TSP, and NO_x would be reduced (see Table 5-1), considering that 70% of smoke dust, 90% of SO2, 67% of NOx and 82% of acid rain can be traced back to coal combustion,[62] and CCC power generation is supposed to be the main component for the purpose of coal combustion. So, the potential significance for the CGP project in this phase is unbelievably huge. For example, according to CCICED, in the proposed CGP implementation scenario, SO_2 emissions are estimated to be reduced from 23.7 Mt in 1995 to 16.2 Mt in 2020 and 8.8 Mt in 2050 which would greatly reduce acid rain and air pollution in China.

5.2.2 Strategic significance for facilitating GHG mitigation

CGP system provides a good opportunity for CO_2 treatment and mitigation in the long run, which may potentially be seen as the most effective method for CO_2 mitigation in the world, as China will be the largest GHG emission country in the future and coal combustion accounts for 76.8% in total CO2 emission of China.[63] In a CGP system, CO_2 can be used as a feedstock for different products, such as dry ice, as CO_2 separated from the CGP system is nearly pure (99%); or it can be injected underground. All these treatments are much easier than in a conventional power plant, as latter CO_2 emission is combined with a large proportion of nitrogen and other substances.

Climate change is one of the biggest challenges for the whole world. As one of the biggest countries and potentially the biggest GHG emission country, China must take its responsibility. It can be a strategic act for China to reach its target of CO_2 mitigation in a

[62] Zheng. (2003), (Zheng Fangneng2003, *Research and development of clean coal technology in China*, Energy for Sustainable Development Volume 7, no. 4, p.20)

[63] Ni Weidou. (2005).

much easier and cheaper way through the implementation of the CGP system as the substitute technology for the CCC plant.

5.2.3 Potentially vital role in energy security, especially in meeting the increasing demand of transportation fuel and household cooking fuel

As previously illustrated, the increasing demand on energy, especially for power and quid fuel constitutes the main challenge of energy security. The CGP system can make China meet the huge demand in power, as well as in transportation and household cooking fuel without depending on imports.

Another advantage of CGP in this scope is that CGP can make a full use of abundant coal reserves in China. Compared to importing oil and petrochemicals from abroad, the CGP system spends mainly funds in domestic business and domestic human resources, which is estimated as another of the main benefits caused, since it can realize a better wealth distribution and internal demand, thus the societal benefit caused is huge and profound. For instance, thinking that about 20% of the transportation oil in 2010 (252 Mt as estimated in previous part) can be replaced by DME produced through the CGP system, unbelievable societal benefit can be brought out without increasing costs (transforming the funds payable for oil imports to domestic consumption).

5.2.4 The perfect financial perspective

CGP system has a good financial perspective, with an IRR as high as 17% based on the projected term in this paper. It means, from a business point of view, that the CGP system can cost-competitively transform coal into electricity, clean fluid fuels and various chemicals without even considering its effect of dramatically reducing air pollution. Compared to the financial index of CCC power plant (8% as the average sales profit margin in coal combustion power industry),[64] the high rate of investment return of the CGP project provides itself a strong basis of business implementation.

CGP technology can overcome the restriction of region because of the broad distributed coal reserves (see Figure 5-2), which is one of the main factors that makes it possible for CGP to spread much wider than hydropower or other clean technology in China. Another advantage caused by this is a better wealth distribution among different region as more regions can benefit from the implementation of CGP.

[64] Xu Yingzhen(2006) Changjiang Power Research Institute, www.finance.sina.com.cn 0810

Figure 5-2 The provinces of China with coal-rich and low-income provinces highlighted, source: Perry-Castaneda Library Map Collection, University of Texas, Austin[65].

5.2.5 Other benefits from CGP industry upstream and downstream

Besides the above, the implementation can achieve more benefit through promoting the development of upstream and downstream (see the figure below).

[65] Larson, et al. (2004).

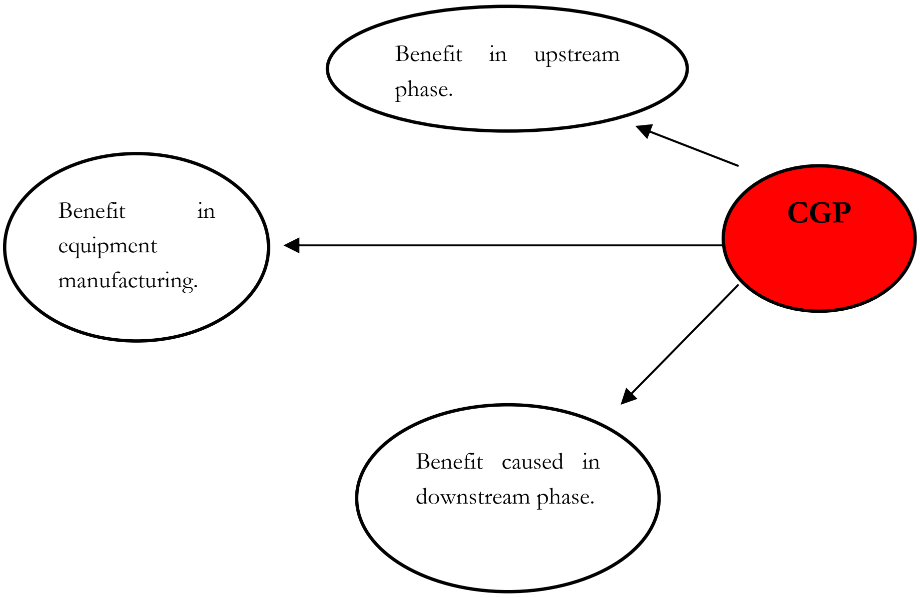

Figure 5-3 Other benefits in the whole industrial chain

5.2.5.1 External benefit in downstream phase of CGP

One main advantage of the CGP system is the abrupt external cost reduction in the downstream phase, as the product of CGP can achieve huge environmental benefit compared to the current products in the market. For example, the feature of DME can reduce most of the harmful substances in the vehicle exhaust if used as a substitute for diesel (see Figure 5-4). In fact, the implementation of CGP can provide a radical cure not only for soot-type air pollution but also for car exhaust-type air pollution.

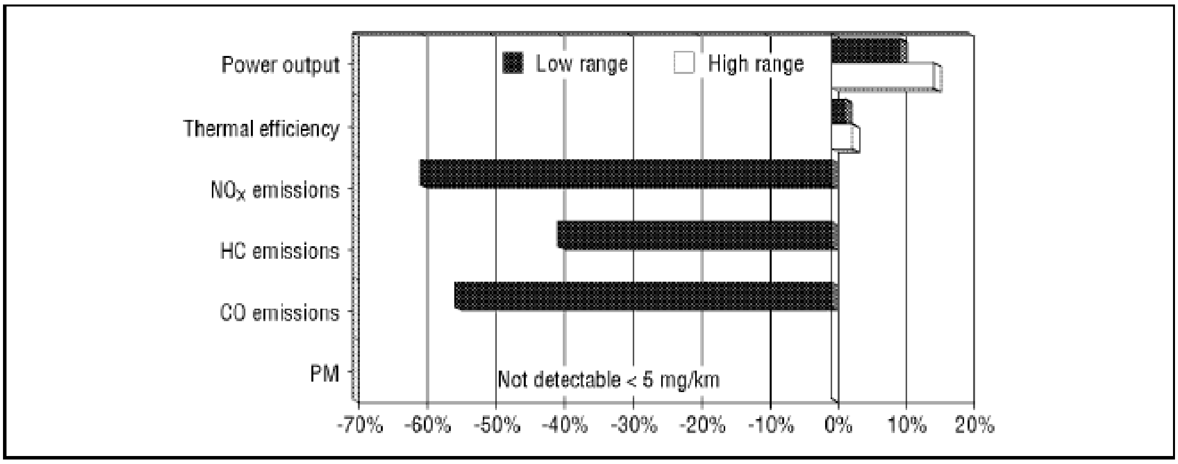

Figure 5-4: DME for diesel engines: performance and emissions compared to diesel fuel, (Ford diesel engine tested at Xian Jiaotong University with Chinese diesel fuel).[66]

[66] Walsh. (2003).

The implementation of high-quality European diesel can also meet the stringent standard of environmental protection; however, the implementation of DME in China can potentially help China reach high standard in environmental protection without focusing on developing the refining technology of diesel.

In addition, the implementation of DME and other clean fuel provides a good opportunity for the motor industry in China to achieve a competitive advantage in the market through the research and through manufacturing new vehicles with engines suitable for DME or other cleaner fuels.

5.2.5.2 Promoting the development of coal mining industry

One of the biggest contributions of the CCC plant is that it greatly mitigates the hard pressure of employment by providing millions of job opportunities. Despite the mass employees in the power generation industry (mainly composed of coal combustion plants), only the number of employees in the upstream industry exceeded 5 million in 2005. It should be noted that in China the issue of employment has been one of the most severe challenges facing the country, considering that there is more than 20 million incremental posts in demand every year. Without mitigating this challenge, potential societal turbulence can be intensified and triggered. Fortunately the implementation of CGP can make the same contribution which would not impact the development in upstream industry; and the huge demand for coal would even promote and advance the structure of coal mining industry, i.e. the large amount of supply and demand of coal requires large-scale coal mines, thus the number of small-scale coal mines can be reduced.

5.2.5.3 Accelerating the establishment and development of CGP equipment manufacturing industry

The CGP industry has not been seen as a mature industry even from a world perspective. The perfect conditions in China (e.g. rich coal reserves, large demand, good experience in chemical and power industry, etc.) make it suitable to develop a CGP industry there and gain competitive advantage in the future.

5.3 Conclusion

In this section, the author evaluates the feasibility of CGP system as a substitute technology for conventional coal combustion power generation technology based on the following indicators: whether CGP can solve the challenges faced by China, and whether this substitute can create the huge external benefit achieved by CCC technology and also greatly decrease the external cost.

Obviously, CGP system can comply with all of these requirements. It can ensure energy safety on the basis of a full use of the abundant coal reserves, while the huge demand of transportation fuel, household cooking fuel and petro-chemicals can be satisfied without being overly dependent on imports. At the same time, the severe air pollution can be dramatically reduced; and the capture and treatment of carbon dioxide in the process is possible, which could be the most effective method to reach CO_2 mitigation in the future of China.

For the evaluation on external benefit and external cost, we can see that the CGP system can abruptly decrease the latter, while the former is to be simultaneously maintained and enlarged.

Compared to other potential substitute technology such as hydropower or wind power, CGP undoubtedly has incomparable advantages.

Based on the above, plus the high profit making ability of CGP, which is the basis for the business promotion of CGP, we can draw this conclusion on the matter: CGP can meet all the requirements to be the strategic technology in the energy sector of China.

6 How to accelerate the implementation of CGP technology

Potentially, CGP can be the mainstream technology in the energy sector; however, as analysed in a previous part of this paper, from a business perspective the implementation of CGP is still facing a large number of obstacles, e.g. uncertainties caused by the dominating energy distributors, lack of infrastructures, and lack of a national technical standard in the products' usage phase, etc. The rate of progress in its business implementation process lies on how fast these problems can be solved.

Based on the research and analysis on the proposed project, the following recommendations are proposed.

6.1 Establishment and development of a demonstration project in both the production and usage phase

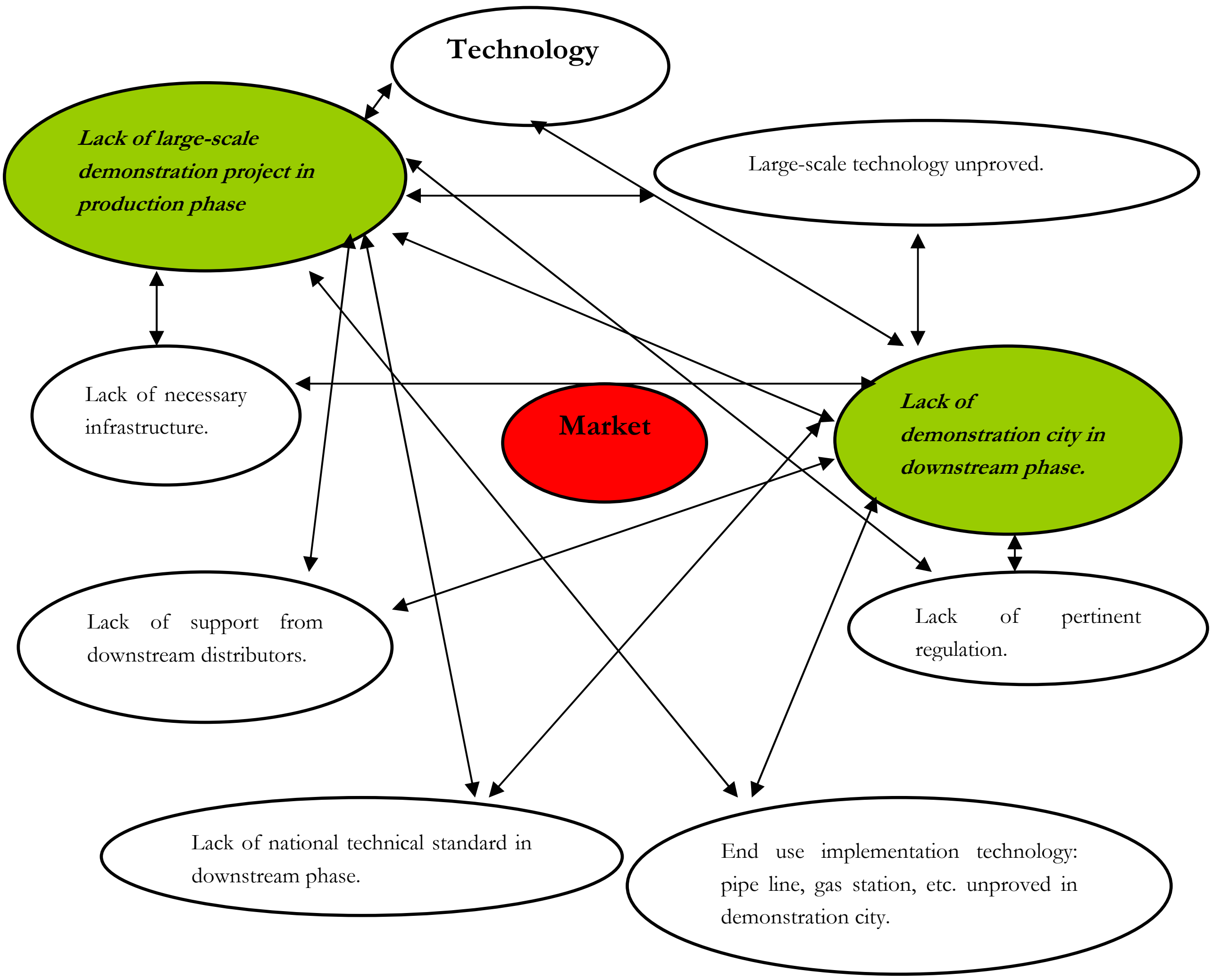

Figure 6-1: The correlation of obstacles in the technological and marketing fields of CGP system

The matter of technology and market problems involves a series of factors (see the above figure), each of which are deeply interconnected. The complex interaction between them makes it more difficult to eliminate the obstacles in the process of CGP implementation. Whereas, if we consider the correlation of these obstacles we can find that **the lack of a large-scale demonstration project (including in the production phase and downstream phase), especially the lack of a demonstration city is the decisive factor.**

Without a large-scale demonstration project, the technological feasibility cannot be evaluated, though most of the technology involved has been proven already. The point is not to invent a new technology but to reach the optimum level through scientific integration and coupling of the production processes of different products. Hence, the implementation of a large-scale demonstration project is especially important, as it could provide the necessary data and accumulate experience, based on which the optimum integration level can be worked out and proved.

In fact, during the period of the fulfilment of this paper, the author found out that the CGP demonstration project in Zaozhuang city functions very well: with a production capacity of 240 thousand tonnes methanol per year and the IGCC power capacity of 60 MW.[67] But at present, the usage of methanol is mainly in the chemical industry, without involving the fuel substitute in the downstream phase. According to a member of its financial staff, the financial condition of the project is good and the profit making ability has proved to be high.[68] It should be noted that this financial condition is achieved on the basis of a comparatively small scale project, and the financial perspective for a large-scale project could be better because of the benefit of scale effect. All this can strongly support the author's findings, and furthermore proves that the ***technology matter is not the core problem at least in the production phase***, because in this demonstration project the production and management are already performed smoothly.

Though the technology is not actually presumed to be the core obstacle, without a demonstration project the feasibility of the technology cannot be proved and evaluated. So, in the condition of lacking a demonstration project, technology would become one of the main obstacles as illustrated in the previous part of this paper. On one hand, the CGP system demands safe and effective operation from a technical perspective; on the other hand, it requires the best input and output ratio from an economic and energy perspective. Hence, only on the basis of a demonstration project, can the technological matter be researched and solved, with the purpose of meeting both the technical and economic requirement simultaneously.

In the research, the author found that the establishment of a demonstration city can be the key factor in the CGP implementation process. The CGP demonstration project in production phase cannot be pushed forward without the help of a demonstration city. Actually, the fate of CGP technology can be more dependant on the downstream phase since the success of a demonstration project in the production phase may rest on the long term and huge demand from the market, and the latter is hard to achieve without the establishment of a successful demonstration city.

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[67] Geng. (2006), China Energy Science & Technology (2006).

[68] Shen. (2006).

6.1.1 The establishment and development of a demonstration city

6.1.1.1 The potential significance

The establishment of a demonstration city can bring about the mitigation of the obstacles, including the following.

It can provide a demonstration solution for how to utilize the current infrastructures and facilities used for LPG, and how to fulfil the physical requirement of downstream implementation.

It can provide experiment data and large-scale implementation data for the establishment of a national technological standard.

It can prove the potential societal and economic benefits to the public. The public opinion thus generated could impact the decision making process in the host city, greatly accelerate the implementation speed, and cause advertising effectiveness.

It can evaluate and prove the optimum solution for technical matter in downstream phase. For instance, through the large-scale implementation, the blending technology for DME and diesel can be examined and developed, and the appropriate technology can be finally chosen and promoted to wider implementation.

It can provide a series of regulations and standards for industrial management and supervision, which can be adapted as the basis of national industrial regulation. Besides, it can provide management with experience for other potential implementation places.

One of the most important points is that it can stimulate the cooperation between the CGP operator and downstream energy distributors, both the small companies and the magnates. In a demonstration city, it can be much easier to make the energy magnates like SINOPEC cooperate with the CGP operator because of government pressure and also the potentially high profit-making prospects resulting. Once the demonstration condition is proved to be good in operation and finance, the cooperation can be stabilized and improved to a higher level. For other downstream distributor such as city gas pipeline companies, the situation can be similar.

To sum up, the main significance of the establishment of demonstration city is that it can help solve the obstacles in the implementation process, and more importantly, provide a clear illustration for the feasibility of CGP technology. The public, local government and energy companies can recognize the huge societal and economic benefit, and can then be appealed to take part in the promotion process.

Moreover, a successful demonstration city can bring about even more profound effectiveness. As a potentially strategic technology, the implementation of CGP technology must be based on stringent evaluation and feasibility analysis. The establishment of a demonstration city can provide central government with the essential data and information from different angles, including product storage, transportation, treatment, usage, management, environmental benefit and business feasibility. Since both the societal and economic benefit can be huge, the success of a demonstration city can make the decision makers lose their apprehension, and take more measures to accelerate the implementation.

6.1.2 The role of government in the process of the establishment and development of a demonstration city

The demonstration city and demonstration project in production phase consist of a paradox of the provision and demand. Without the establishment and development of demonstration city, the problem of market access can hardly be overcome. While without a large-scale project, there would be no product to meet the demand of a demonstration city. Hence, only when the provision and demand comply with one another, can the project go smoothly and stably. In fact, considering the large overnight capital investment, the CGP project cannot be established without the guarantee of long term contracts from the market. Furthermore, without being proved by the success of a demonstration city, there will be no contracts either. This shows the significance of the establishment of a demonstration city, and moreover thats that both the project in the production phase and the usage phase should be developed gradually from small scale to large scale step by step.

The establishment of a demonstration city involves masses of people, many stakeholders, which makes it very tricky to deal with. Also taking the DME co-production project as an example, in the downstream phase, the usage of DME involves underground pipeline, gas station, refitted bus and other factors. Plus the substitute of DME for diesel or for LPG would concern vested interest parties, and the implementation of DME can occupy some market proportion of other products. It involves furthermore a mass of end-users and car owners. At the present time all these would need to be proceeded without a national technical standard or official industrial regulation. It is beyond the capability of a CGP operator to deal with all these affairs. In fact, as things are, only the government can play the leading role and create a favoured circumstance to promote the establishment of demonstration city.

6.1.3 Recommendations for the establishment of CGP demonstration city

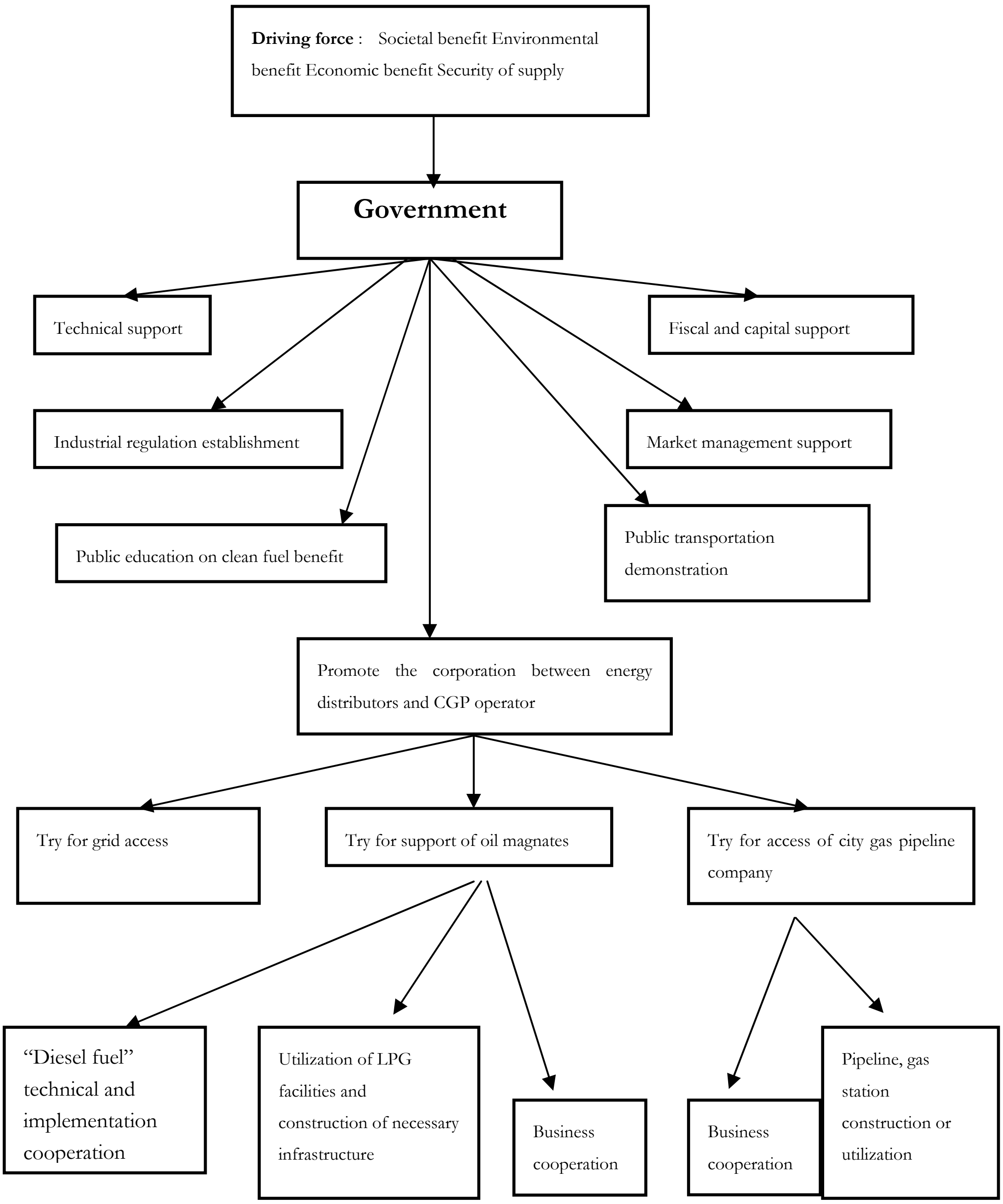

Figure 6-2: The function of government in a CGP demonstration city

From the above figure, we can see the key role of government in the establishment of the CGP demonstration city.

The implementation of the demonstration city needs the authorization of central government, so **the urgent affair for the central government at present is to choose an appropriate place as a demonstration city**. Generally speaking, it would be more cost efficient and more feasible from a business perspective to have a demonstration city near the CGP production project, e.g. Zaozhuang City can be an option since there is a CGP project already in this city.

Thus, we can assume that Zaozhuang City is chosen as a demonstration city for the implementation of DME as a substitute fuel. As shown in the above figure, it is a good opportunity for the Zaozhuang Government to achieve huge environmental and economic benefits, and furthermore this new technology complies with the supreme objective of the central government (i.e. the establishment of harmonious society) as the implementation of the CGP project can greatly mitigate air pollution and improve wealth distribution (see the previous parts of the paper). Hence, local government can be active in taking the opportunity. Once Zaozhuang is chosen to be a demonstration city, it can obtain technical and management support from the central government, which can accelerate the speed of implementation and reduce risks. Besides, some fiscal or tax support approaches can be provided together.

One of the main significances of government is its influence on the energy distributors, including oil magnates, city gas pipeline companies and national power grid companies. Because of the special condition of China's economy (i.e. transition from planning economy to market economy) the market sometimes fails to play a decisive role in resource allocation. In such a condition, only applying an economic approach may not be so effective. Though the financial perspective of CGP project can be excellent, as illustrated in earlier paragraphs, the attitude of these distributors to the substitute fuels produced from CGP projects can be less active. For oil magnates, such as SINOPEC, the local companies have no right to purchase the product produced by another company, and the headquarters may treat the CGP operator as a potential rival in the energy sector, and thus feel reluctant to go further. In this situation, the opinion of local government is not to be considered as decisive. However, once the demonstration city is decided, the situation can be changed. All these energy distributors are nationally owned companies, the strategy of these companies are determined by the economic benefit and national policy. The decision of these oil magnates must comply with the requirement of the establishment of the demonstration city. To establish a successful demonstration city, the central government can begin to establish cooperation between the CGP project operator and the oil magnates. For the local gas pipeline company, the cooperation between them can be easier, because of the competitively low cost of DME (unlike SINOPEC, the local gas company has no affiliation with upstream companies, which makes them more independent and the comparatively low price of DME can be more attractive). Besides, local government can play a more decisive role, since the local city gas company usually originates from a department of local government.

To sum up, the local government can obtain the support of central government once the city has been chosen to be a demonstration city. The composition force of different levels of government, together with the promotion of the CGP project operator, can overcome the potential obstacles illustrated above. This may trigger the leap in CGP technology implementation since almost all the main stakeholders including the public, energy distributors, and government can obtain benefit from it. Plus the success of the demonstration city can result in the confirmation of a national technical standard, the technical maturity in large-scale business implementation, the optimum utilization of existed infrastructure, public preference, business feasibility and financial perspective, and the societal and environmental benefit. Based on this, industry, business and government can go further.

From the Central Government perspective, the following approaches can be considered to help achieve a successful example of a demonstration city.

Specify and authorize the demonstration city. The central government can choose several cities to be demonstration cities according to their geographical and economic conditions, taking into consideration the condition of existing demonstration projects. Generally speaking, the local governments can be interested in CGP technology implementation because of the potentially huge economic, societal and environmental benefits. The authorization of central government can provide the demonstration city government with the responsibility and driving force to push forward CGP implementation.

Constitute the development programme of the demonstration city, specifying the plan, approaches, and responsible organization, the target for each phase both at the national and local levels and other relevant issues.

Obtain the support of the headquarters of top energy companies regarding their cooperation with the CGP operator and the demonstration city in downstream phase. Without the approval of headquarters, there can be some uncertainties for the downstream cooperation in the demonstration city, since the branches usually have no right to deal with such affairs by themselves. The support can create favoured circumstances for the success of demonstration city.

Provide technical and managing support from relevant departments of the Central Government.

Provide incentives through tax or fiscal policy. It should be noted that as a country in a transitional phase, China's economy is different from developed countries (i.e. the economy in China is not a totally market economy, and market tools such as price and profit occasionally do not play the key role in resource allocation in the market) and the financial approaches would achieve better result if used together with other approaches e.g. administrative methods.

6.2 Other recommendations

Besides the establishment of the demonstration project and demonstration city to promote the CGP technology, more approaches can be taken into consideration as it is a comprehensive system involving different scopes in both the economy and society.

6.2.1 Set up a special leading organization in charge of CGP implementation at a high level of government (a combination of people from appropriate departments in central government)

Considering the strategic role of CGP technology, its potential significance in the economy and society, its complex technological system, and its involving multi-industries and the living of millions of people, it is rational to set up a special leading organization for the research and implementation of the CGP system.

At the present time, the main departments involved in CGP technology implementation include the following.

- National Development and Reform Commission (NDRC) is responsible for the evaluation and approval of large scale project in energy sector, and the setting of price for oil, gas and power in upstream and middlestream.
- Ministry of Commerce is responsible for the management of the projects and the national oil

companies, and the approval of oil and gas stations.

- AQSIQ[69] and fire department is responsible for technical safety during transportation, storage and usage.
- State Electricity Regulatory Commission (SERC) is responsible for the regulating of power transmission and distribution, and monitoring the electricity market's operations.[70]
- National Construction Ministry is responsible for the management of underground city pipelines.
- The Environmental Protection Agency is responsible for the management of the environment.

Without the support of a corresponding organization in central government, department partition can greatly block the speed of implementation. The proposed organization can be a non-standing organ within NDRC with NDRC as the leading department and the relevant departments playing a supporting role. The urgent issues presently for this organization could be to accelerate the establishment and development of a demonstration city and a demonstration project.

The establishment of a special organization can help to gain a better understanding of the CGP system, and can integrate resources from different field to overcome the obstacles in CGP implementation.

A potential significance of this leading organization can be that this combination of different department and industry can break through the industrial partition, especially between the power industry and the petro-chemical industry. It should be noted that the environmental cost and GHG problem must be taken into consideration of the external cost of current mainstream power technology. Without industrial partition, this special organization can concentrate on the research and development of CGP technology from an overall perspective, based on the fact that CGP technology has incomparable advantages whether from an economic or a sustainable development perspective

6.2.2 Try and gain support from the provincial government

The central and the local government of the host city are regarded as key factors; however, the provincial level government can be of the same importance regarding local protectionism. In the same province in China, the relationship between governments in different cities can be seen as a kind of competitiveness, as the assessment of the government officials is based on the comparison of the economic and societal condition. Thus, an official in one city may feel some reluctance towards the large consumption of a product produced by another city. In this case, the role of provincial government can be crucial. Generally speaking, from a provincial perspective, the implementation of CGP technology may bring about huge benefits, so the provincial official can view this positively. But the central government still needs to bring incentives to the provincial and regional governments in order to push them to be more active in this process, e.g. fiscal subsidy or tax reduction, or adjust the official assessment system.

6.2.3 Encourage the participation of energy magnates in CGP technology implementation

As illustrated in previous sections, the dominating status of energy magnates especially in the downstream market makes it valuable to gain their support. One possible method is to set up

[69] General Administration of Quality Supervision, Inspection and Quarantine of the People's Republic of China

[70] SERC (2006).

a cooperative relationship with them through a business manner (e.g. establish business project together with SINOPEC), or sell stock share to them to establish common benefit to both sides. Compared to importing petroleum from abroad, the substitute fuel produced from the CGP system can be attractive to these energy companies as well. In fact, these energy magnates can be the best investor in CGP technology project, as they have the petro-chemical industry background and the competitive advantage in the downstream phase.

6.2.4 Constitute an implementation plan and specify the responsibilities of each organization and the target for each phase

Because the CGP system involves a comprehensive practical situation, without a clear plan from the national level the implementation can arouse disorder, which may increase the obstacles to its implementation. Hence, a clear plan from the central government level is needed to direct the overall process through specifying the organization responsible, the targets for each step of development, and the approaches needed.

The plan and the approaches should be planned carefully and discussed by experts from different field before it is carried into action

6.2.5 Set up an overall programme for pipeline infrastructure construction and management at both regional and national levels, and in both the upstream and downstream phases

Because the construction cost of the infrastructure for fuel supply and usage is huge and hard to be reduced in the foreseeable future, it is reasonable to consider the perspective of implementation of substitute fuel in the downstream field, i.e. to take the usage of CGP product into consideration in long term pipeline development plans, and to make CGP development comply with the energy plan as a whole. This can avoid the incorrect location of resources and funds, and help to reduce blocks for the use of a cleaner fuel in the future.

6.2.6 Decrease the profits of conventional coal combustion power plants

According to the documents of NDFC, the on-grid price of power from a CCC plant without a desulphurization equipment was reduced to RMB0.015[71] lower per KWh.[72] Even though, the external cost is not considered properly, hence the development speed of CCC power plant is still fast these days.

A power plant in construction now will be in use for at least the following twenty years, causing huge environmental and societal damages, and will not be replaced within a long time because of the high withdrawal cost. Furthermore, these newly planned CCC plants can influence the fate of the CGP project, as they will be occupying the market in the future. So more rigorous requirements should be put into practice and more cost should be reduced from the on-grid price of power from a CCC plant.

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[71] The currency used in China, around 0.19cent in US$.

[72] Document no.688 (2005) of National Development and Reform Commission. Resource: ICBC document?

6.2.7 Accelerate the participation of the motor car industry

For the motor industry, applying themselves to motor improvement to make it suitable for a cleaner fuel such as DME would be a strategic decision for these motor producers to obtain some competitive advantage in the market. Besides, this can greatly reduce the huge risks caused by stringent exhaust regulation they are likely to face in the near future. What the government can do to stimulate the motor industry to go ahead includes the following.

- Apply fiscal subsidy on the technical alteration.
- Technical support.
- Update and improve the industrial policy to encourage more investment in approaches to reduce downstream pollution.
- Reduce tax on the sales of motor vehicles using substitute fuel.

6.2.8 Try and gain support from the public and NGOs

The end-user decides the size of the final market for substitute fuel. The implementation of CGP technology cannot be achieved without achieving a large number of end-users. Besides, the recognition of the public of the potential environmental benefit and the damage caused by the current technology can bring about great power to overcome the obstacles in the process.

One weak part in CGP implementation at present may be the lack of participation of public organizations. The public is much concerned by air pollution though less people know the role that CGP technology could play to improve the air condition. In fact, given its huge environmental benefit, this technology can obtain the support of public, especially environmental NGOs in China, whose influence has been increasing rapidly in recent years. There will be no greater driving force to push forward the implementation. Plus the special background of the NGO can play a unique role which can not be replaced by the other stakeholders, e.g. in public education, breaking the department partition, and bringing pressures on government. So the involvement of the public can certainly be significant. This involvement can be accelerated through the following approaches by relevant organization or industry.

- Educate the public through the media about the negative impact of current technology.
- Illustrate the huge external benefit of CGP tech to the public.
- Organize discussion, lectures and other actions with local communities, NGOs and other stakeholders.
- Provide more material to NGOs interested, or
- Accelerate to the establishment of NGO with different industrial background focused on CGP implementation.

6.3 Conclusion

Though the CGP project has proved to have an excellent financial performance, the characteristics of China's economy (i.e. in the process of transition to market economy) determines that the implementation of CGP requires more approaches other than the invisible hand of the market to achieve a better resource allocation.

The establishment of a large-scale demonstration project, especially a demonstration city, can be a break-through for CGP implementation, for only under a large-scale business implementation situation can the possible solution for the obstacles be evaluated and improved. And the driving force of government, together with the CGP project operator, can be the key factor for the success of a demonstration city.

To achieve the implementation of CGP technology, on the one hand, favoured circumstance for CGP implementation need to be created (e.g. to obtain the support of downstream distributors, the public and local communities, and another point is the cooperation with motor industry for the technical improvement of motor to achieve a better emission); on the other hand, the development of conventional coal combustion power plants needs to be controlled by taking the external cost into the consideration of the plant cost.

The implementation of CGP system is a comprehensive system, which requires government, industry and experts alike to break through the industrial partition, and constitute the development programme from an overall perspective to direct the process.

7 Final conclusions

The main findings are presented in line with the research questions stated in the first Chapter.

How would a business bank evaluate the economic feasibility of coal gasification-based polygeneration (CGP) projects in China? At present time, what could be the obstacles for a polygeneration project to meet the requirement of the project loan assessment system of a business bank?

CGP project can be the perfect business project appealing to the bank's funds, given its high internal rate of return and the huge potential market. However, the bank would refuse to provide a loan to such a project proposed in this paper because the uncertainties and obstacles in the project implementation can cause rather high risk in the current situation. From a bank's perspective, the main weak part for the business feasibility of the CGP project can be the uncertainties in market access and that the optimum technology is not specified or confirmed through large-scale demonstration implementation. .

It should be noted that the research shows these weak parts are mainly caused by temporary obstacles in today's China. The success of a small-scale project both in the production phase and in the downstream phase shows that the technical issue cannot be a vital drawback for CGP technology. Furthermore, the advantages of DME make it incomparably suited to be a strategic product to meet the huge energy demand in China, without China becoming overly dependent on imports.

Compared to the conventional coal combustion technology and other options, how to evaluate the role of CGP technology in China's energy sector from a society perspective?

The implementation of CGP technology can ensure energy safety on the basis of a full use of the abundant coal reserves; and the energy security challenge caused by huge demand for transportation and household cooking fuel can be partly mitigated without overly depending on imports. At the same time, the severe air pollution can be dramatically reduced; and the capture and treatment of carbon dioxide can be facilitated in the process.

For the evaluation of external benefit and external cost, the author finds that the CGP system can dramatically decrease the latter, while the former can be simultaneously maintained and enlarged. Compared to other potential substitute technology such as hydropower or wind power, CGP undoubtedly has an incomparable advantage.

Based on the above, plus the high profit making ability of CGP, which is the basis for the business promotion of CGP, we can draw this conclusion: CGP technology can potentially be the strategic technology in the energy sector of China.

How to accelerate the implementation process of CGP technology?

The establishment and development of a large-scale demonstration project, especially the establishment of a demonstration city, can be a break-through.

The main significance of the establishment of a demonstration city is that it can help solve the obstacles in the implementation process, and more importantly provide a clear illustration of the feasibility of CGP technology. The public, local government and energy companies can recognize the huge societal and economic benefits, and can then be appealed to take part in the promotion process. It should be noted that without the support of a demonstration city the CGP demonstration project in production phase cannot be pushed forward.

Moreover, a successful demonstration city can bring about even more profound effectiveness. As a potentially strategic technology, the implementation of CGP technology must be based on stringent evaluation and feasibility analysis. The establishment of a demonstration city can provide the central government with essential data and information from different angles, including product storage, transportation, treatment, usage, management, environmental benefit and business feasibility. Since both the societal and economic benefit can be huge, the success of a demonstration city can make the decision makers lose their apprehension, and take more measures to accelerate the implementation.

The role of government is the key factor in the establishment and development process of a CGP demonstration city

The host government can obtain the support of the central government once the city is chosen to be the demonstration city. The composition force of different levels of government, together with the promotion of the CGP project operator, can overcome the potential obstacles illustrated above. This may trigger the leap in CGP technology implementation as almost all the main stakeholders, including the public, energy distributors, and government, can obtain benefit from it. Furthermore, the success of the demonstration city can result in the confirmation of a national technical standard, the technical maturity in large-scale business implementation, the optimum utilization of existed infrastructure, public preference, business feasibility and financial perspective, and the societal and environmental benefits. Based on this, industry, business and government can go further.

Other recommendations are as follows:

- Set up special leading organization.
- Try for the support from provincial government.
- Encourage the participation of energy magnates in CGP technology implementation.
- Set up fuel usage infrastructure programming both at the regional and national levels.
- Decrease the profit of conventional coal combustion power plant.
- Try for support from the public and NGOs.
- Stimulate the participation of motor car industry.

The CGP technology can be one of the most suitable technologies in the energy sector, and much economic and external benefit can be achieved with the diffusion of CGP technology. However, much effort is still needed to create better circumstance for the evaluation and implementation of CGP technology.

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Abbreviations

CCC	Conventional coal combustion
CCICED	China Council for International Coorperation on Environment and Development
CFB	Circulating fluid bed
CGP	Coal gasification-based polygeneration
CHP	Combined heat and power
CNPC	China National Petroleum Corporation
DME	Dimethyl ether
FGD	Flue gas desulphurization
FIRR	Financial internal rate of return
FYP	Five-year-plan
GHG	Greenhouse gas
GW	Gigawatt
ICBC	Industrial and Commercial Bank of China
IGCC	Integrated gasified combined cycle
IEI	International Energy Initiative
IPM	Investment profit margin IPM
Kt	Kiloton
KW	Kilowatt
LHV	Low heat value
Mt	Megaton
MW	Megawatt
NDRC	National Development and Reform Committee
NGOs	Non-Government Organizations
NPV	Net present value
NSB	National Bureau of Statistics of China
O&M	Operation and maintenance
PLAS	Project loan assessment system
SINOPEC	China Petroleum & Chemical Corporation
SO_2	Sulphur dioxide
SEPA	State Environmental Protection Agency
TFEST	Task Force on Energy Strategies and Technologies
TEC	Equivalent ton of coal
USC	Ultrasupercritical plant

Appendix List of personal interviews by telephone or by email

Bao Jianxin, an employee in charge of business loan in ICBC Dezhou Branch, feedback about the project loan requirement, 05 June 2006, 16 June 2006 by email and telephone (jx1266@126.com +13336268628).

Eric D. Larson, researcher at the Princeton Environmental Institute, Princeton University, USA, feedback about the data of economic analysis on CGP system, 12 June 2006, 24 July 2006 (elarson@Princeton.EDU).

Ji Wei, engineer of Dongyue Energy Co., feedback about the CGP development in China and in Japan, 27, 30 of July, and 7, 10 of August, by email and by telephone (+13793800925).

Ji Tao, employee in charge of project management in ICBC project assessment, feedback about PLAS and calculation of project financial index, on 15, 20, 22, 24, 29 of July, by email and by telephone (jitao_dz@sd.icbc.com.cn).

Li Zhe manager in the loan management department of ICBC Dezhou Branch, feedback about policy on polygeneration project and project loan regulation by email on 7, 12, 13 of June respectively (lz-dte@tsinghua.edu.cn).

Zheng Hongtao, a researcher of polygeneration and employee in SINOPEC, collecting information about the policy and development of CGP in China, by email and by telephone on 20, 25 of July (zhenght@cnooc.com.cn +84521895).

Ren Tingjin, researcher on CGP system of Tsinghua University, collecting information on CGP development and on obstacles in CGP implementation, by email on 20, 25 of June, 2006 (rentj@tsinghua.edu.cn).

Wu Yingxue, financial employee of Yankuang Group in Zaozhuang city, collecting financial information about CGP demonstration project, 20, 25 of July and 13 August, by email and by telephone (Yingxuewu1973@yahoo.com.cn, +6322368075).

Li Zheng, professor at Tsinghua University, collecting information and views on CGP technical and economic perspective, on 7, 10 of June by email (lz-dte@tsinghua.edu.cn).