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Scopus Compendex and Geobase Elsevier,
Geo-Ref Information Services-USA, List B of Scientific
Journals, Poland, Directory of Research Journals

International Journal of Earth Sciences and Engineering

www.cafetinnova.org
ISSN 0974-5904, Volume 09, No. 05
October 2016, P.P.2200-2204

Chinese Clean Coal inversion Technologies with Life Cycle Assessment

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Abstract: China's coal consumed has caused inevitable environmental problem in the country. In the context of eco-economic, we put forward a full life cycle modeling and five clean coal inversion technologies. In this paper, a life cycle assessment (LCA) is employed for material consumption and environmental emission research. Incorporating up-to-date data, the study gives a brief economic discussion which covers the decision-making theory in this field and comes up with new technologies for the future.

Keywords: *Clean coal, Environmental impacts, Inversion, Life cycle assessment.*

1. Introduction

China is a vast country with a large number of energy produce and consumption, and is also one of only a handful of nations in today's world whose main energy-consuming is coal. Low-efficiency and unclean exploitable of coal as the most abundant energy resource produces bad environmental pollution. The right way for China to develop clean energy program now is exploiting the abundant coal-resource. As we all know, much more pollute materials are produced in the whole life cycle. Remarkable effective progress about reducing environmental pollution and improving the environmental and resource benefit of clean coal has been made. Enrico Benetto et al. [1] compared six scenarios in clean coal life cycle processes from an environmental point of view. Koornneef et al.'s [2] employed the methodology of life cycle assessment on a cradle to lay the foundation to research CO2 capture, transport and storage.

Life cycle assessment (LCA) is a system analysis methodology which ensures a sound evaluation and improvement upon environmental impact on the quality of every single part of coal emerge and conversion for its entire life cycle. Korre et al. and Nie et al. [3/4] introduced the dynamic LCA model and compared the life cycle environmental performance considering applying CO2 released, transit and injection course and sequestration technologies. Chen and Xu [5] introduced the key efficiency coal inversion technologies such as gasification technologies and liquefaction technologies.

It is important to estimate the emissions during fuel production and transportation. Having this theory in mind, Life Cycle Assessment (LCA) can help policy makers to make a comparison among CO2 capture and storage technologies with a life cycle sight. Lu and Zhang [6] employed a hybrid life-cycle assessment (LCA) to compare the eco-environment and economic influence of crop residue energy transform. Murat et al. [7] evaluated different algae co-firing in the whole life cycle process. Xiaoye et al. [8] presented a complete life cycle covering all upper reaches of the whole electricity life cycle pre-final consume including the integrated gasification combined cycle system. Thakur and Canter [9] employed a life-cycle assessment to evaluate and analyzed the ratios for per operation for power generation.

Coal inversion is a procedure to inverse coal into clean fuel or chemical materials by chemical methods mostly, which include coal vaporization, coal vaporization and fuel consume. Coal vaporization is to inverse coal into environment-friendly liquid fuel and chemical raw products in right conditions. Clean coal inversion technology will popular more and more in our country, so it is important to evaluate its advantage to environment in life cycle. By analyzing resource-consuming and the energy-exploitation in the entire system, we could understand what exactly the major environmental impacts are caused.

2. Research Scope

2.1 Introduce the technique and concept used

LCA is a sort of profiling mean, which is serived to analyze emissions, resources consumption, energy utilization and environmental influence factors, in the course from raw and semi-finished material to termination products. The life cycle includes raw material gathering and disposing, transiting, making use, servicing, and final dispose, which all induce environmental destruction. Comparing with traditional environmental assessment model, LCA takes all the life system into account, not just with the appraisal of products processing.

Clean coal Life Cycle Assessment includes coal exploitation, transit and inversion. On the base of LCA research outline, we analyzed the energy utilization and environment pollution and put forward the clean coal inversion technique with LCA. The main contents of the research are as follows: identifying and quantifying the run coal, preparation, transportation, inversion, dispose and releasing waste as well as contaminated emission related in the whole life cycle process. It makes, compares, and determines the advantage and disadvantage of the whole life cycle chain.

5 coal inversion routes are considered:

Route 1: run coal- coal preparation - liquefaction – use
Route 2: run coal- coal preparation – dry coal dynamic vaporization - liquefaction – use
Route 3: run coal- coal preparation - water coal slurry - water coal slurry vaporization – use
Route 4: run coal- coal preparation - dry coal dynamic vaporization - methanol - ME – use
Route 5: run coal- coal preparation -water coal slurry - water coal slurry vaporization - methanol -ME – use

2.2 System Margin

The purpose of this research is to figure out the share of clean coal dynamic inversion and conversion materials in China in the year of 2008, and all the data used in this study is according to the national average level. The coal inversion processes determine the system margin, containing coal mining, preparation, and selecting, transportation and inversion. As we lack of data as when new equipments and factory buildings were put into use and when they are to be out of use among China’s power plants. This factor is not taken into the consideration of the whole life cycle. 1Gj is also cited as the function unit.

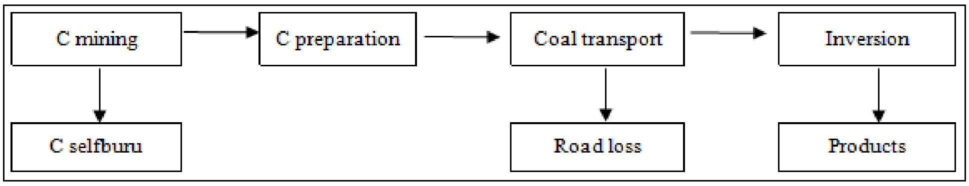

Figure1: *Life Cycle Margin of Clean Coal Inversion*

2.3 Data Source

The main data are mostly collected from China Statistical Yearbook [10], China Energy Statistical Yearbook [11], China Environment Yearbook [12] and China Transportation Yearbook [13] according to the national average level of coal exploitation and inversion technology. All technical data about inversion technology come from each firm’s reports.

3. Inventory analysis

3.1 life cycle inventory analysis

Table 1: *life cycle inventory analysis*

Definition	Energy consumed and emission
Exploitation and utilization	Consuming: coal and electricity, Emission: CH_4, coal gangue, water mining, destroy and occupy arable land
exploitation tools and mining equipments	Consuming: coal, steel, iron, electricity, aluminum, Emission: dust, waste water , CO_2, SO_2 , NO_X
tools and equipments: Energy consumption	Consuming: gasoline, electricity, diesel, Emission: SO_2 , CO_2, NO_X
Coal self-burning	Consuming: coal, Emission: SO_2, CO_2, NO_X , dust
Retirement of vehicle and equipment	Metal
Coal: preparation	Consuming: water, electricity, Emission: waste water, gangue
2.1 equipment manufacture	Consuming: steel, iron, Al, electricity, coal, Emission: dust, waste slag, SO_2 , CO_2,NO_X
2.2 equipment retirement	Metal
Coal: transportation	Consuming: gasoline, electricity, diesel, Emission: SO_2 , CO_2,NO_X

Table 1: *life cycle inventory analysis*

Definition	Resources consumed and emission
3.1 transportation tools manufacture	Consuming: electricity, coal, steel, iron, aluminum, Emission: dust, waste slag , SO_2 , CO_2,NO_X
3.2 road loss	Consuming: coal, Emission: solid waste and powder

3.3 transportation tools retirement	Metal and other solid material
Coal inversion	Consuming: electricity, coal, Emission: fume, water pollutes , SO_2 , H_2S,
4.1factoty house manufacture	Consuming: steel, aluminum, Emission: SO_2, CO_2, NO_X
4.2 equipment manufacture	Consuming: steel, iron, aluminum, electricity Emission: powder, waste slag , SO_2 , CO_2, NO_X
4.3 factory houses and	Metal and other solid material

3.2 Coal inversion technologies assessment

3 routes are discussed for the liquid goods.

Table 2: *1 Gj liquid goods*

Liquid products		Route 1	Route 2	Route 3
Input	Coal/t	9.614429E-02	1.17989E-01	9.998014E-02
	Water/t	2.076892E-01	4.060159E-0s1	3.553581E-01
	Electricity/G_j	1.745144E-02	9.532746E-02	1.240661E-01
	Fuel oil /kg	2.114138E-01	2.594486E-01	2.198485E-01
	Diesel /kg	5.370799E-01	6.591086E-01	5.585077E-01
	Gasoline /kg	7.368005E-01	9.042073E-01	7.661966E-01
Output	CO_2/kg	6.381472E+01	3.781607E+01	3.204414E+01
	SO_2/kg	2.165556E-01	1.668621E-01	1.441074E-01
	NO_X/kg	1.454811E-01	7.937507E-02	6.668371E-02
	CH_4/kg	5.621005E-01	6.89814E-01	5.845265E-01
	Gangue /kg	1.828053E-02	2.2434E-02	1.900986E-02
	Tailings /t	5.506253E-04	6.757316E-04	5.725935E-04
	Solid waste /t	1.125736E-02	1.381512E-02	1.170649E-02
	Fume /kg	1.653064E-02	6.515434E-03	5.520972E-03
	Powdered dust /kg	1.050192E-04	1.288803E-04	1.092091E-04
	Powdered coal ash /kg	1.775462E-04	2.17886E-04	1.846297E-04
	Cinder /kg	1.792869E-04	2.200222E-04	1.864398E-04
	Other solid waste /t	1.653064E-02	6.515434E-03	5.520972E-03
	Waste water /t	3.095737E-02	1.269611E-01	1.60939E-01
	H_2S/kg	0	9.199844E-04	8.907E-01(含CO)
	Fly ash /kg	0	3.021051E+00	0
	Waste catalyst /kg	0	9.160634E-02	3.604E-03
	Sludge /kg	0	5.3827E-01	7.26762E-01
	ash	0	1.31404E+01	1.635619E-02

Data source: calculated and sorted by the author.

The energy consumption is listed in Table 3

Table 3 *the energy consumption*

Liquid products	Route 1	Route 2	Route 3
Energy consumption /Gj	2.0467E+00	2.58570E+00	2.23430E+00
Efficiency /%	4.88600E+01	3.86700E+01	4.47600E+01

Data source: calculated and sorted by the author.

As is shown, the first route rank first in system efficiency and waste emissions, the second route has a lower efficiency, and a significantly higher emission of exhaust gas, floating dust, and waste materials, the third route lets out the least SO_2, CO_2 and NO_X, and its efficiency is between the first route and the second route.

Table 4: *1Gj of ME products*

Methyl ether products		Route 4	Route 5
input	Gangue /t	1.209174E-01	1.024616E-01
	Water /t	8.285684E-01	7.766535E-01
	Electricity /G_j	7.402042E-02	1.034724E-01
	Fuel oil /kg	2.658879E-01	2.253051E-01

	Diesel /kg	6.75467E-01	5.723696E-01
	Gasoline /kg	9.266487E-01	7.852132E-01
output	CO_2/kg	3.875462E+01	3.283946E+01
	SO_2/kg	2.270216E-01	2.037022E-01
	NO_X/kg	8.139002E-02	6.833877E-02
	CH_4/kg	7.069346E-01	5.990342E-01
	Gangue /t	2.299079E-02	1.948168E-02
	Tailings /t	6.925026E-04	5.868051E-04
	Solid waste /t	1.4158E-02	1.199705E-02
	Fume /kg	1.606372E-01	1.384349E-01
	Powdered dust /kg	6.677141E-03	2.21159E+00
	Powdered coal ash /kg	1.32079E-04	1.119196E-04
	Cinder /kg	2.232938E-04	1.892122E-04
	Other solid waste /kg	2.254829E-04	1.910672E-04
	Waste water /t	1.558987E-01	1.907199E-01
	H_2S/kg	1.228858E-04	9.118869E-01 (含CO)
	Fly ash /kg	6.716196E+00	1.589755E+00
	Waste catalyst /kg	7.211812E-03	6.76464E-03
	Sludge /kg	1.364205E+00	1.364205E+00
	ash	1.088737E+01	1.944294E-02

Data source: calculated and sorted by the author.

Table 5: *energy consumption of ME*

Methyl ether products	Route 4	Route 5
Energy consumption /Gj	1.558987E-01	1.907199E-01
Efficiency in whole life cycle /%	1.228858E-04	9.118869E-01 (含CO)

Data source: calculated and sorted by the author.

In making methanol, dry coal dynamic method consumes more energy than water coal pulp gasification method, except powdered dust, waste water and H_2S, its other waste emission is all more than the latter one's. If the problem of H_2S is well resolved, making methyl ether by water coal pulp technique is clearly better than dry coal powder technique.

5. Conclusions

Life cycle assessment system is popular in many fields and regarded as one potential analysis tool. As the biggest fuel consumption nation, developing clean coal inversion technologies, reducing pollutes emission not only contributing to improving Chinese eco-environment, but also improving global environment situation. We propose develop the clean coal inversion technologies and adopt life cycle assessment model to make serious analysis from initial run material exploitation to final waste handling in the whole process. This research sets out a theoretical and technological base for Chinese technological plan to push forward the clean coal dynamic inversion technologies, and helps policy-making in future energy strategy.

6. Acknowledgements

This paper was founded by the Project: Educational Research and Practice Which Orients to Software Engineering Master's Training Mode in Petrochemical Industry.

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