Study on evaluation of circular economy system of energy and heavy chemical industry park based on energy value theory

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Abstract. Circular economy system of energy and heavy chemical industry park is usually assessed by efficiency, economy and environmental impact indicators. Few studies have focused on the integrity and comprehensiveness of system operation. Based on energy value theory, we develop four indices, namely, energy yield ratio, environmental loading ratio, energy index of sustainable development and energy conversion ratio. These indices are then applied to comprehensively evaluate circular economy systems with different media and capacity. An empirical analysis is conducted to the circular economy system of Energy and Heavy Chemical Industry Park in Jinjie of Yulin City at different development phases (initial phase, 1st phase and 2nd phase). The results show that as the system is being constantly improved and updated, the overall performance increases, and the capacity of the system for sustainable development increases dramatically. In the meantime, the energy investment ratio has been rising, though the environmental loading ratio is relatively high. It is necessary to increase the ecological efficiency of the system by expanding and enriching the ecological chain of the system.

1. Introduction

Energy value theory is founded by American ecologist Odum in the late 1980s on the basis of energy ecology, system ecology, ecological engineering and economic ecology [1]. It is a theory that deals with energy flow, transmission and conversion in an ecosystem or compound ecosystem. Energy value theory uses emergy as a measure of energy, which provides a link between different energies in energy analysis. Starting from a system standpoint, energy value theory calculates embodied energy, i.e., energy memory, which is the sum of all the energy required to produce any goods or services. Providing a measure of donor value rather than market value of the goods or services, the energy value theory has become one of the most effective tools for evaluating the value and operation of system resources [2]. This theory was introduced into China in the 1990s and has been applied fruitfully in many fields since then. Industrial economic system is among the major research topics of energy value theory, which can be used to evaluate the operating status of an industrial economic system as an ecosystem and to guide industrial optimization; moreover, energy value theory offers an evaluation of the real value embodied in an industrial system. Yang *et al* conducted an analysis on environmental and economic input and sustainability of a cassava chip production system for ethanol fuel manufacturing [3]. Mu *et al* studied mixed waste management and environmental impact of polyethylene production [4]. Lou *et al* conducted energy value analysis of a coal-fired power generation system and constructed a new indicator system [5]. Ju *et al* performed a comprehensive

evaluation of the energy carrying capacity of an electric furnace [6].

2. Energy value theory and analytical approach

Energy is a new concept and measure in the field of energy analysis. According to Odum (1978), energy is defined as an amount of energy flowing through an ecological chain or stored in another form of energy. Energy is in essence embodied energy. Any form of energy comes from the solar energy; different energies can be measured in terms of solar energy [7].

Energy value analysis converts different energies in the ecosystem or ecological-economic system into amounts of solar energy so that they can be compared and analyzed. On this basis, different types of ecological flows in the system are investigated, including energy & material flow, currency flow, population flow and information flow. A set of energy indices have been constructed to quantify the structural and functional features as well as the eco-economical benefits of the system. A quantitative analysis usually consists of four steps: plotting energy system diagram, developing energy analysis table, constructing energy comprehensive structure diagram of the system (during computing), and design and computing of indices. Energy system diagram is an illustration of the main constituents in the system and their interactions. Energy analysis table converts indices with different dimensions using conversion ratio of solar energy. Dimension unification is important for computing, comparison and analysis of different indices. Energy comprehensive structure diagram of the system depicts the path and intensity of energy flowing in a system; it is a refinement and decomposition of the energy system diagram. Design and computing of evaluation indices are generally based on the contents to be assessed.

2.1. Plotting the energy system diagram

Energy system diagram is plotted using energy symbol language. Figure 1 is a simplified version of the energy analysis diagram of a green integrated manufacturing system [8]. External input of the system consists of three parts: renewable resources (R), non-renewable resources (N) and external investment (F). Depending on purposes, external investment is further divided into five parts: F1 is the investment of raw materials required for goods manufacturing; F2 is the investment for compensating for the environmental loss during the production process, such as sewage treatment plant; F3 is the investment for improving production process and workflow and developing green manufacturing technology; F1 is the investment for resourceful utilization of wastes; F5 is the investment for reutilization of surplus energy in the production process; for example, the heat energy produced by the power plant can be used for heating purposes for local residents. Effective output of a system comprises product Y and wastes W discharged to the environment. Product Y1 is the product manufactured by the enterprise; Y2 is the product generated in the resourceful utilization of wastes; Y3 is the product generated in the reutilization of surplus energy. Sustainable development indices for energy analysis are constructed based on the computing of input, output and feedback energy flow of the system.
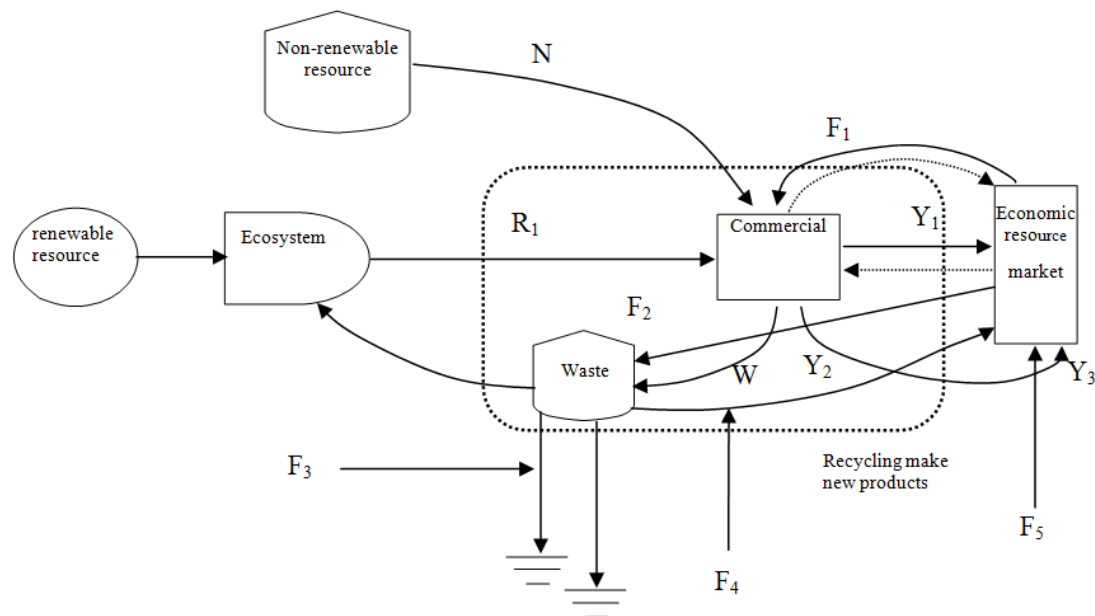
Figure 1. Energy system diagram.

2.2. Developing emergy analysis table

Energy, material and economic flows are computed for the system. Using different emergy conversion ratios, ecological or ecological flow in different units (J, G or $) is converted into the unit of emergy (sej). The emergy analysis table is constructed and its role in and contribution to the system is evaluated. The energy conversion rate is shown in Table 1.

Table 1. Solar energy conversion ratios of some major energies.

Solar energy conversion ratios of energies (sej/J)	
Solar energy	1
Wind-driven	623
Organic matters	4420
Potential energy of rain	8888
Chemical energy of rain	15423
Potential energy of river	23564
Chemical energy of river	41 000
Mechanical energy of waves and tides	17000-29 000
Fuels	18 000-58 000
Food, fruits & vegetables, grains, native products	24 000-200 000
High-protein food	1 000000-4 000000
Human labor	80000-5000000000
Information	10000-10000000000000

Data source: Odun, 1988, 1996 units (sej/J)

2.3. Design of evaluation indices [9]

- Net emergy yield ratio (EYR) is the system output energy to economic feedback (input) energy.

$$EYR=Y/F \qquad (1)$$

EYS is an index of productivity of a system. It is a measure of the economic contribution made by

system output as well as the system's utilization efficiency of energy. The higher the EYR, the higher the output energy under a certain economic energy input, that is, the higher the production efficiency of a system. High EYR usually indicates strong economic competitiveness of a system and serves as the basis for sustainable development of a system.

- Energy investment ratio (EIR) is the ratio of the feedback energy of an economy to the energy input from the environment.

$$EIR = F/(N+R) \qquad (2)$$

EIR reflects the competitiveness of an economy under certain conditions. This index measures the degree of intensity of economic development and the environmental bearing capacity on economic activities. The market competitiveness of products generated in this system is evaluated on this basis.

- Environmental loading ratio (ELR) is the ratio of the total input energy of non-renewable energy of a system to the total input energy of renewable energy.

$$ELR = (F+N)/R \qquad (3)$$

A larger ELR represents highly intensive emergy utilization in an economic system, which, however, exerts a great pressure on the environmental system. ELR is considered a prewarning index of an economic system. If the system has a high ELR over a long period of time, it will undergo irreversible functional decline or loss. In light of emergy analysis, intensive emergy input from the environment and excess exploitation of non-renewable resources are the major reasons underlying environmental deterioration.

- Energy index of sustainable development (EISD) is the ratio of EYR to ELR

$$EISD = EYR/ELR \qquad (4)$$

EISD not only considers the socio-economic benefits of a system that is consistent with the development goal of the system, but also the negative impact of environmental pollution on system development. It reflects the socio-economic benefits of a system under unit environmental pressure. The higher the EISD, the higher the socio-economic benefits under unit environmental pressure and the better the sustainable development performance of the system.

- Energy conversion ratio [10]

Energy conversion ratio is an important concept derived from food chain in ecosystem and thermodynamic principle. It is a measure of energy quality difference between different energies and closely related to the energy level of a system.

3. Case study

Based on emergy theory and analysis, the circular economy system of Energy and Heavy Chemical Industry Park in Jinjie of Yulin City (hereafter referred to as the Industry Park) is studied in three different phases. The overall performance and development state of the system are analyzed from two perspectives, horizontal and longitudinal. The findings will shed new light on the ecological reconstruction of the Industry Park.

3.1. An overview of the Industry Park and circular economy system
Energy and Heavy Chemical Industry Park in Jinjie is an important part of the energy and heavy chemical base of northern Shaanxi, covering an area of 16 km^2. The Industry Park is rich in coal, quartz sand, and natural gas. The Industry Park is located in the hinterland of Loess Plateau of northern Shaanxi Province and the wind-sandy grass shoal area in the Mu Us Desert transition zone. It belongs to semi-arid continental climate with an annual precipitation of about 441.2 mm and potential evaporation of 2111.2 mm. Its unique topographic and climate features lead to high ecological vulnerability.

The Industry Park is typical of the heavy chemical industrial-ecological manufacturing system in

China's coal-rich regions. A systemic analysis of the Industry Park is of high theoretical and practical importance. As to the industrial orientation, the Industry Park mainly relies on local coal, calcium carbide, limestone and quartz sand, as well as the abundant crude salt in the surrounding region. The pillar industries of the Industry Park are transformation from coal to electricity, coal chemistry, and salt chemistry. It aims to develop a cluster network of ecological industry chain. After the initial phase, 1st phase and 2nd phase of development, the Industry Park has already formed a well-functioning circular economy system, as illustrated in figure 2 below.
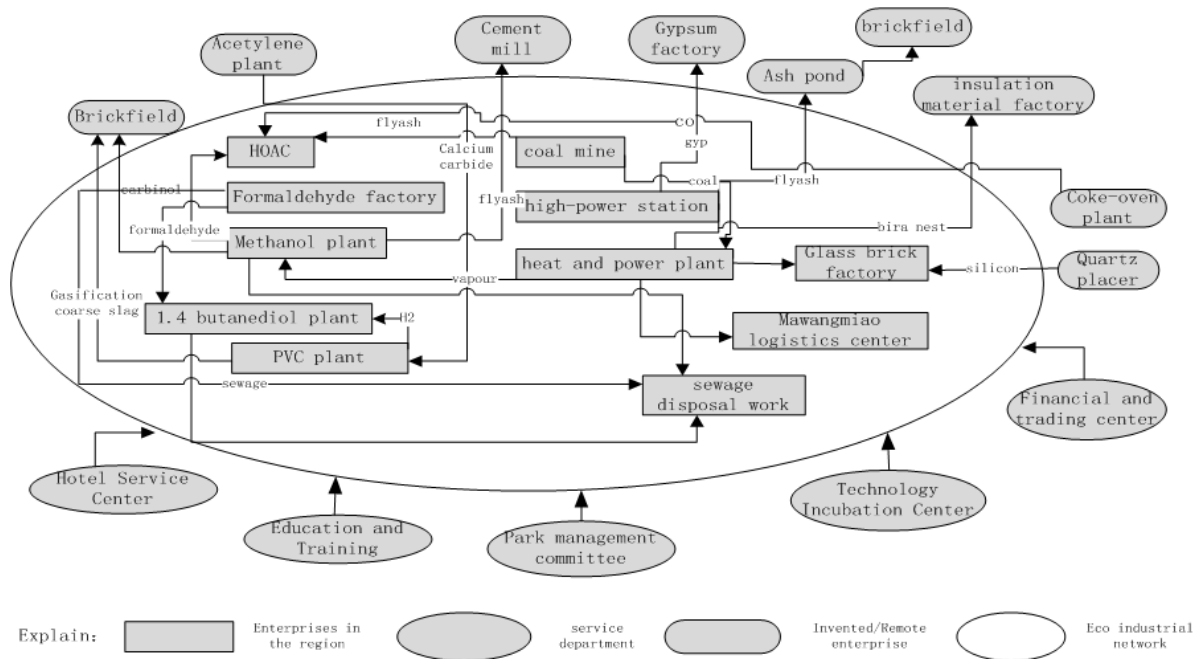

Figure 2. Eco industrial network of Industrial Park.

As seen from the figure, the core enterprises, affiliated enterprises and remote virtual enterprises are linked by material, energy, water and information flows. They together constitute a system based on circular use of materials and water, energy cascade use and information sharing. This mode of circular economy ensures high-efficiency circular use of resources throughout the entire production process and has already changed traditional linear resources-products-wastes mode. Instead a sustainable recycling mode of resources-products-wastes-resources-products has been established.

3.2. Energy index computing

Based on material, energy and information flows of the circular economy system of the Industry Park, the energy analysis table is developed (see the appendix). Energy indices are computed for different development phases using energy analysis method, as shown in table 2. The overall performance of the circular economy system is compared between different phases, as shown in table 3.

Table 2. Longitudinal comparison of emergy indices of the green integrated manufacturing system of the Industry Park.

Index	PEYR	PEIR	PELR	PESI
Development phase				
Independent operation of the enterprise	3.64	0.403	0.56	6.5
First phase	4.36	0.392	0.526	8.28
Circular development phase	5.51	0.387	0.515	10.7

Table 3. Horizontal comparison of emergy indices of the green integrated manufacturing system of the Industry Park.

Source of index Index	Jinjie EHCIC-GIMS system	Industrial clusterof Shuozhou thermal power plant	Average level of five provinces in northwestern China in 2005	Co-production of ammonium phosphate-cement of Shandong Lubei Enterprise
PEYR	5.51	3.14		5.83
PEIR	0.387	0.47	0.495	
PELR	0.515		0.508	

3.3. Result analysis

Longitudinal comparison shows that at the three development phases, EYR increases from 3.64 to 4.36, by 19.8%, and then from 4.36 to 5.51, by 26.4%. EIR decreases from 0.403 to 0.392 by 4%, and then from 0.392 to 0.387 by 1.3%. ELR decreases from 0.56 to 0.53 by 5.3%, and then from 0.53 to 0.51 by 3.8%. ESI increases from 6.5 to 8.28 by 27.4%, and then from 8.28 to 10.7 by 29.2%. The above results indicate that from the initial phase to the 1st and 2nd phase, the production efficiency has been increasing substantially. Ecological efficiency has been also improved, but only to a limited extent. Enterprise competency also increases by a small margin. The system's capacity for sustainable development has been enhanced gradually over the years.

Horizontal comparison reveals that EIR of the Industry Park is 0.387, as opposed to 0.495, the average level of the five provinces of northwestern China. EIR of the Industry Park is lower than the average level by 28%. ELR of the Industry Park is 0.515, as opposed to 0.508, the average level of the five provinces of northwestern China. ELR of the Industry Park is higher than the average level by 0.01%. The Industry Park does excellently in EIR, which indicates high performance of the system. However, ELR of the Industry Park is above the average level, but still acceptable. The Industry Park cluster is faced with high environmental pressure and needs to step up the efforts in increasing ecological efficiency. Compared with the ecological industry cluster of Shuozhou Thermal Power Plant, the Industry Park outperforms in terms of resources utilization rate and overall benefits. However, the Industry Park has much room for improvement compared with co-production of ammonium phosphate-cement of Shandong Lubei Enterprise.

3.4. Discussion

In light of the results of emergy analysis, the Industry Park should strengthen their work in the following two aspects:

- Intensify technological integrity, extend product line and expand integration façade. The Industry Park should adhere to the production of fine chemical products and high-added-value products; enhance the degree of coupling within the industrial chain network, optimize production process, increase the technical content of products, strengthen the industrial chain, stabilize the industrial network, and improve and perfect system structure and function. Compared with the average level of the five provinces in northwestern China, the Industry Park outperforms in terms of EIR, which indicates high system performance. However, the Industry Park has a higher ELR, indicating considerable environmental pressure of the industrial cluster of the Industry Park and the need for increasing ecological efficiency of the system.
- Strengthen the work of system integration, evolution and upgrading. First of all, introduce enterprises that have a complementary effect to the industrial chain into the network and continue restructuring and updating the manufacturing processes of the existing enterprises.

Secondly, strictly formulate and implement the requirements for enterprise entry, maintain and perfect system structure, and increase system flexibility. Thirdly, reinforce investment in local public environmental infrastructures, such as sewage treatment plant, three-wastes recycling and trading market, so as to enhance the self-purification capacity. Fourthly, develop solar and wind power plants by utilizing local solar and wind energy resources, so as to reduce environmental load.

4. Conclusion

A scientific evaluation of circular economy system of an energy and heavy chemical industry park can inform reasonable construction and performance improvement of the circular economy system. It also provides technical support and roadmap for constructing a local circular economy system. In this study we take a multidisciplinary approach based on system theory to enrich the theory of circular economy. Finally, a case study is performed to Energy and Heavy Chemical Industry Park in Jinjie in northern Shaanxi Province. The implementation of circular economy theory on the meso- and microscopic scales is examined. The findings provide theoretical guidance and roadmap for the sustainable development of energy and heavy chemical industry.

Appendix

Energy analysis table of Jin-jie Industrial Park

	Item Number		Project Name	basic data	Energy conversion rate	Energy (sej)
A	energy	Put in	coal	9.65E+12g/a	4.00E+04 sej/J	1.61E+22
			Fresh water	1.56E+13g/a	6.64E+05 sej/g	1.00E+19
			Air	11.52E+11g/a	5.16E+07 sej/g	5.94E+19
			limestone	2E+10g/a	1.00E+09 sej/	2.00E+19
			Investment	1.78E+9$	3.46E+12 sej/$	6.16 E+21
		output	Electricity	6.75E+16j/a	1.60E+05 sej/J	1.08E+22
			Fly ash	9.30E+11g/a	8.30E+08 sej/g	7.72E+20
			Slag	1.19E+11g/a	8.30E+08 sej/g	9.88E+19
			Heat	5.21E+12J/a	6100 sej/j	3.19E+16
			plaster	5E+10g/a	1.00E+09 sej/g	5.00E+19
B	Methanol	Put in	coal	9.2E+11g/a	4.00E+04 sej/J	3.68E+16
			oxygen	8.53E+11g/a	1.59E+09 sej/g	1.36E+21
			Caustic soda	3.03E+9g/a	6.94E+09 sej/g	2.10E+19
			Fresh water	4.32E+11g/a	6.64E+05 sej/g	2.87E+17
			steam	107.71E+10j/a	6100 sej/j	6.57E+15
			Electricity	2.16E+14j/a	1.60E+05 sej/J	3.46E+19
			Investment	1.22E+8$	3.46E+12 sej/$	4.22E+20
		output	Methanol	6.0E+11g/a	2.78E+09 sej/g	1.67E+21
			Gasification slag	1.323E+11g/a	8.30E+08 sej/g	1.99E+20
C	formaldehyde	Put in	Methanol	1.6928 E+11g/a	2.78E+09 sej/g	4.71E+20
			Process water	1.348E+11g/a	6.64E+05 sej/g	8.51E+16
			Electricity	1.37E+14j/a	1.60E+05 sej/J	2.18E+19
			steam	37.014E+10j/a	6100 sej/j	2.26E+15
			Investment	0.11041E+8$	3.46E+12 sej/$	3.82E+19
		output	formaldehyde	1.8E+11g/a	3.705E+09 sej/g	6.67E+20

D	polyformaldehyde	Put in	formaldehyde	5E+10g/a	3.705E+09 sej/g	1.11E+20
			Ethylene oxide	4.8E+8g/a	3.1E+10 sej/g	1.49E+19
			benzene	1.566E+9g/a	1.59E+10 sej/g	2.49E+19
			Process water	2.72E+11g/a	6.64E+05 sej/g	6.71E+16
			steam	13.7904E+10j/a	6100 sej/j	8.36E+14
			Electricity	0.8064E+14j/a	1.60E+05 sej/J	1.29E+19
			Investment	0.12915E+8$	3.46E+12 sej/$	6.65E+19
		output	polyformaldehyde	2E+10g/a	3.18E+10 sej/g	6.36E+20
E	Paraformaldehyde	Put in	Methanol	6E+10g/a	3.705E+09 sej/g	2.22E+20
			steam	12.24E+10j/a	6100 sej/j	7.47E+14
			Cooling water	2.8E+12g/a	6.64E+05 sej/g	1.86E+18
			Electricity	0.144 E+14j/a	1.60E+05 sej/J	2.30E+18
			Investment	0.0338E+8$	3.46E+12 sej/$	1.17E+19
		output	Paraformaldehyde	2 E+10g/a	9.93E+09 sej/g	1.99E+20
F	acetic acid	Put in	Carbon monoxide	1.24 E+11g/a	0.6E+09 sej/g	7.44E+19
			Methanol	1.35 E+11g/a	2.78E+09 sej/g	3.75E+20
			oxygen	8 E+10g/a	1.59E+09 sej/g	1.27E+20
			steam	85.68E+10j/a	6100 sej/j	5.23E+15
			Electricity	0.21E+14j/a	1.60E+05 sej/J	3.23E+18
			Investment	0.8159E+8$	3.46E+12 sej/$	2.82E+20
		output	acetic acid	2.5 E+11g/a	8.94E+09sej/g	2.24E+21
G	acetic anhydride	Put in	acetic acid	1.0 E+11g/a	8.94E+09sej/g	8.49E+20
			water	1.04 E+12g/a	6.64E+05 sej/g	6.91E+17
			Electricity	1.296 E+14j/a	1.60E+05 sej/J	2.07E+19
			steam	9.792E+10j/a	6100 sej/j	5.97E+14
			Investment	0.024E+8$	3.46E+12 sej/$	8.33E+18
		output	acetic anhydride	8 E+10g/a	1.39E+10 sej/g	1.11E+21
H	Two vinegar tablets	Put in	acetic acid	3.51 E+10g/a	8.94E+09 sej/g	3.14E+20
			Wood pulp	3.155 E+10g/a	1.59E+10 sej/g	5.02E+15
			steam	163.2E+10j/a	6100 sej/j	1.00E+16
			Electricity	1.206 E+14j/a	1.60E+05 sej/J	1.93E+19
			Fresh water	1 E+12g/a	6.64E+05 sej/g	6.64E+17
			Investment	0.5813E+8$	3.46E+12 sej/$	2.01E+20
		output	Two vinegar tablets	5 E+10g/a	2.38E+10 sej/g	1.19E+21
I	1.4 butanediol	Put in	Acetylene	7.93 E+9g/a	1.16E+10 sej/g	9.20E+19
			Methanol	1.85 E+10g/a	2.78E+09 sej/g	5.14E+19
			Fuel gas	8.1 E+9g/a	4.80E+04sej/J	3.89E+14
			Fresh water	3.2 E+11g/a	6.64E+05 sej/g	2.14E+17
			steam	35.7E+10j/a	6100 sej/j	2.18E+15
			Electricity	0.37 E+14j/a	1.60E+05 sej/J	5.86E+18
			Nitrogen	1.01 E+9g/a	0.4E+09 sej/g	4.03E+17

			Electricity	0.1618E+8$	3.46E+12 sej/$	5.60E+19
		output	1.4 butanediol	2.5 E+10g/a	1.01E+10 sej/g	2.53E+20
J	Tetrahydrofuran	Put in	1.4 butanediol	2.54 E+10g/a	1.01E+10 sej/g	2.53E+20
			BHT	7.4 E+6g/a	3.77E+10 sej/g	2.79E+17
			steam	8.53536E+10j/a	6100 sej/j	5.21E+14
			Electricity	8.0E+11j/a	1.60E+05 sej/J	1.27E+17
			Nitrogen	31.37 E+7g/a	0.4E+09 sej/g	1.26E+17
			Investment	0.0128E+8$	3.46E+12 sej/$	4.43E+18
		output	Tetrahydrofuran	2 E+10g/ a	2.49E+10 sej/g	4.98E+20
K	Polytetrahydrofuran	Put in	Tetrahydrofuran	1.62 E+10g/a	2.49E+10 sej/g	4.03E+20
			Magnesium oxide	2.7 E+8g/a	2.98E+10 sej/g	8.05E+18
			BHT	9 E+6g/a	3.77E+10 sej/g	3.39E+17
			Process water	4.31 E+10g/a	6.64E+05 sej/g	2.86E+16
			Electricity	0.2 E+14j/a	1.60E+05 sej/J	3.07E+18
			steam	19.0332E+10j/a	6100 sej/j	1.17E+15
			Nitrogen	6.6 E+8g/a	0.4E+09 sej/g	2.64E+17
			Investment	0.0337E+8$	3.46E+12 sej/$	1.17E+19
		output	Polytetrahydrofuran	1.5 E+10g/a	5.26E+10 sej/g	7.89E+20
L	Salt Chemical Industry					
L1	Liquid alkali	Put in	crude salt	6.72 E+11g/a	1.0E+09 sej/g	6.72E+20
			Sodium carbonate	6.56 E+9g/a	3.57E+09 sej/g	2.34E+19
			Caustic soda	2.06 E+10g/a	6.94E+09 sej/g	1.43E+20
			Sodium polyacrylate	4 E+6g/a	4.37E+10 sej/g	1.75E+17
			BHT	9.6 E+7g/a	3.77E+10 sej/g	3.62E+18
			Pure water	8.8 E+11g/a	6.64E+05 sej/g	5.84E+17
			Sulfite	3.04 E+8g/a	3.97E+09 sej/g	1.21E+18
			sulfuric acid	7.2 E+9g/a	6.64E+08 sej/g	4.78E+18
			fresh water	3.2 E+12g/a	6.64E+05 sej/g	2.12E+18
			steam	128.112E+10j/a	6100 sej/j	7.81E+15
			DC	3.2+15/a	1.60E+05 sej/J	5.09E+20
			Power	1.5+15/a	1.60E+05 sej/J	2.47E+20
			Nitrogen	1.5+9/a	0.4E+09 sej/g	6.03E+17
			Investment	0.7017E+8$	3.46E+12 sej/$	2.43E+20
		output	Liquid alkali	4 E+11g/a	6.94E+09 sej/g	2.78E+21
			Liquid alkali	8.3 E+9g/a	8.88E+09 sej/g	7.37E+19
			hydrogen	3.1 E+9g/a	4E+07 sej/g	1.24E+17
			Hydrogen chloride	2.7 E+11g/a	3.61E+09 sej/g	9.75E+20
L2	PVC	Put in	Hydrogen chloride	2.7 E+11g/a	3.61E+09 sej/g	9.75E+20
			Acetylene	1.772 E+11g/a	1.16E+10 sej/g	2.06E+21
			NaOH	1.76 E+6g/a	1.0E+10 sej/g	1.76E+16
			fresh water	2 E+13g/a	6.64E+05 sej/g	1.33E+19
			Electricity	6.9E+14j/a	1.60E+05 sej/J	1.11E+20

			steam	163.2E+10j/a	6100 sej/j	1.00E+16
			Nitrogen	1.4+9/a	0.4E+09 sej/g	5.63E+18
			Investment	0.0171E+8$	3.46E+12 sej/$	5.92E+18
		output	Calcium carbide	123E+10g/a	7.67E+08sej/g	9.43E+20
			PVC	4 E+11g/a	2.89E+10 sej/g	1.16E+22
L3	CPVC	Put in	PVC	1.1+11g/a	2.89E+10 sej/g	3.18E+21
			Liquid alkali	6.65 E+10 g/a	8.88E+09 sej/g	5.91E+20
			fresh water	8.4 E+12g/a	6.64E+05 sej/g	5.58E+18
			steam	57.12E+10j/a	6100 sej/j	3.48E+15
			Electricity	0.67E+14j/a	1.60E+05 sej/J	1.06E+19
			Investment	0.1499E+8$	3.46E+12 sej/$	5.46E+19
		output	CPVC	1.4 E+11g/a	6.95E+10 sej/g	9.31E+21
L4	Dimethyl ether	Put in	Methanol	3 E+11g/a	2.78E+09 sej/g	8.34E+20
			steam	122.4E+10j/a	6100 sej/j	7.47E+15
			Electricity	0.0828 E+14j/a	1.60E+05 sej/J	1.32E+18
			Investment	0.2587E+8$	3.46E+12 sej/$	8.95E+19
		output	Dimethyl ether	2 E+11g/a	1.11E+10 sej/g	2.22E+21
L5	Vinyl acetate	Put in	Acetylene	4.95 E+10g/a	1.16E+10 sej/g	5.69E+20
			acetic acid	1.08E+11g/a	8.94E+09 sej/g	9.67E+20
			Electricity	1.08 E+14j/a	1.60E+05 sej/J	1.73E+19
			steam	85.68E+10j/a	6100 sej/j	5.23E+15
			Investment	0.4080E+8$	3.46E+12 sej/$	1.41E+20
		output	Vinyl acetate	1.5 E+11g/a	2.1E+10 sej/g	3.15E+21
M	Polyvinyl acetate	Put in	Vinyl acetate	3 E+10g/a	2.1E+10 sej/g	6.30E+20
			Dibutyl ester	3.2 E+9g/a	2.07E+10 sej/g	6.62E+19
			fresh water	3.47 E+11g/a	6.64E+05 sej/g	2.30E+17
			Electricity	0.072 E+14j/a	1.60E+05 sej/J	1.15E+18
			Nitrogen	6.3+8g/a	0.4E+09 sej/g	2.51E+17
			steam	20.4E+10j/a	6100 sej/j	1.22E+15
			Investment	0.4972E+8$	3.46E+12 sej/$	1.72E+20
		output	Polyvinyl acetate	1 E+11g/a	3.167E+10 sej/g	3.17E+21
N	Polyvinyl alcohol	Put in	Acetylene	2.31 E+10g/a	1.16E+10 sej/g	2.68E+20
			acetic acid	1.67 E+10g/a	8.94E+09 sej/g	1.49E+20
			Methanol	7 E+9g/a	2.78E+09 sej/g	1.95E+19
			Caustic soda	9E+8g/a	1.0E+10 sej/g	9.00E+18
			Electricity	3.3 E+14j/a	1.60E+05 sej/J	5.28E+19
			steam	384.54E+10j/a	6100 sej/j	2.35E+16
			Investment	0.2538E+8$	3.46E+12 sej/$	8.78E+19
		output	Polyvinyl alcohol	5 E+10g/a	2.27*=E+10 sej/g	1.14E+21
O	Methane chloride	Put in	Methanol	0.75E+10g/a	2.78E+09 sej/g	2.09E+19
			Liquid Chlorine	3.38E+10g/a	8.88E+09 sej/g	3.00E+20
			Investment	0.1276E+8$	3.46E+12 sej/$	4.41E+19
		output	Methane chloride	4E+10g/a	2.5E+10 sej/g	1.00E+21

P	glass	Put in	Quartz sand	1.83E+10g/a	1.20E+08sej/g	2.20E+18
			soda ash	0.61E+10g/a	2.55E+09sej/g	1.56E+19
			Calcite	0.41E+10g/a	1.0E+09sej/g	4.10E+18
			Aluminum hydroxide	0.064E+10g/a	4.42E+09sej/g	2.83E+18
			coal	1.8E+10g/a	4.00E+04sej/J	7.20E+14
			Liquefied gas	0.11E+10g/a	4.80E+04sej/J	5.28E+13
			Electricity	0.2592E+14j/a	1.60E+05sej/J	4.15E+18
			water	14.4E+10g/a	6.64E+05 sej/g	9.56E+16
			Investment	2.3 E+7$	3.46E+12 sej/$	7.9 E+19
		output	glass brick	3.024E+10g/a	5.45E+09sej/g	1.65E+20
Q	Building materials					
Q1	Insulation Materials	Put in	cinder	11.9E+10g/a	8.30E+08 sej/g	9.88E+19
		output	Insulation Materials	11.9E+10g/a	2.52E+09sej/g	3.00E+20
Q2	cement	Put in	Calcium carbide	20E+10g/a	7.67E+08sej/g	1.53E+20
		output	cement	60E+10g/a	3.30E+10sej/g	1.98E+22
Q3	cement	Put in	Fly ash	10E+10g/a	8.30E+08 sej/g	8.30E+19
		output	cement	30E+10g/a	3.30E+10sej/g	9.39E+21

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