On the Decision Making for Energy Resources Selection in China

Project of ETM 530
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January, 2009

Abstract

Energy is important to human existence, economic development and society progress, which is also related to safety of a country and sustainable development of society economy. China is a rapidly developing country, in which the decision making about energy selection is critical. This paper discusses the alternatives of energy resources of coal, petroleum, natural gas, nuclear energy and renewable energy resources of China. The research makes a decision model for the selection of energy resources for China in the future by the method of Hierarchical Decision Modeling (HDM) by Dundar F. Kocaoglu. The result of the research indicates that rankings of energy resources are that renewable energy ranks the 1st, coal ranks the 2nd, nuclear energy ranks the 3rd, natural gas ranks the 4th and petroleum ranks the last.The sensitivity analysis reflects that the most critical criterion in the energy selection is current energy infrastructure.

1. Introduction

China is facing a complex situation in the problem of energy resources selection. On the one hand, China possesses the rapidest economic growth in the past 30 years of the world with an average of about 10% annually. On the other hand, China can't avoid the problems about growth in energy consumption and pollution. Chinese government has set a target of reducing energy consumption per unit of GDP by 20 percent and major pollutant emissions by 10 percent from the 2005 levels by 2010, in a bid to protect environment and insure a sustainable development. However, the country still faces great difficulties in fulfilling the commitment, and the situation remains arduous.

This paper discusses the alternatives of energy resources in China as coal, petroleum, natural gas, nuclear energy and clean energy resources. Hierarchical decision models (HDM) with sensitivity analysis[1] is a good method for rating and selection of energy resources. HDM is developed by Dundar Kocaoglu in 1976, which is based on the same basic concept of AHP(Saaty, 1980) but using different pairwise comparison scales and judgment quantification techniques. This paper discusses the problem of energy resources evaluation based on the awareness of

Chinese people to the decision making criteria of the energy resources. Therefore, we can give a subjective rating for each energy resource alternatives and make sensitivity analysis based on China's energy situation

2. Literature Review

2.1. Dissertation on HDM Sensitivity Analysis by Hongyi Chen

In Hongyi's paper[Error! Bookmark not defined.], a comprehensive algorithm is developed to analyze the sensitivity of hierarchical decision models (HDM), including the analytic hierarchy process and its variants, to single and multiple changes in the local contribution matrices at any level of the decision hierarchy.

By using HDM sensitivity analysis, we can see what is the tolerance for the weight of each decision factor for not changing the rank order of different energy resources. We will also know that if we hope the rank order of the energy evaluation to be changed how will the awareness and preference of Chinese people change.

The research will employ the HDM SA method to analyze how the rating for energy resources selection changes with the changing of the weights of criteria of Chinese people for energy resources selection.

2.2. The Saaty/Gholamnezhad Model

The selection of energy resources is widely concerned by the countries of the world. Saaty and Gholamnedzah[2] had used the HDM model for evaluation of different energy sources. Saaty and Gholamnedzah suggested the following model for evaluation of energy sources in 1982 as shown in Fig.1. We will use the same concept by tuning the Saaty/Gholmenezdah model to develop an energy model for China. The sensitivity analysis method is a powerful tool for further analysis of the dynamic situations of China's energy resources.

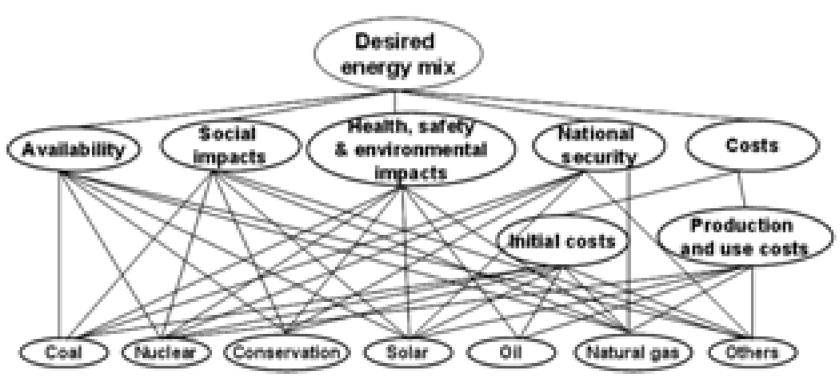


Figure 1 The Hierarchical Decision Model of Saaty/Gholmenezdah for Energy Resources

2.3. The Chinese Government Program on Energy Savings and Emission Elimination

The Central Government of China published a notice about comprehensive working program on energy saving and emission elimination on June 3rd of 2007[3]. This program pointed out ,"the energy consumption for the GDP of every 10,000 RMB will be reduced from 122 million tce to less than 100 million tce, which means about 20% reduction. The Water Consumption/Value Added of Industry will be decreased by 30%. The main polluting emission will be decreased by 10%, which means that the emission of SO_2 will be eliminated from 25.49 million tons of 2005 to 22.95 million tons of 2010, the Chemical Oxygen Demand of will be eliminated from 14.14 tons to 12.73 tons. The treatment rate of domestic sewage won't be less than 70%. comprehensive utilization rate of industrial solid wastes will be above 60%."

The issue of the notice has actually changed the preference in the evaluation of different energy resources for China. It put more weight to the factors of environment impact.

2.4. Yushi Shen's Doctoral Dissertation – The Research on the Strategy Model of Chinese Energy Development

Yuzhi Shen's doctoral dissertation makes research on the regularity of energy in China on the basis of background and theory research. His research forecasts consumption volume of energy and analyses several elements related to energy production and consumption structure and makes some policy suggestions of energy development of China.

It analyses energy storage, production and consumption features of China systematically. Coal plays a leading role in the energy consumption structure of China, about 67%. Petroleum below 25%, natural gas 2.7%, hydroelectric 5.6%，nuclear electric 0.6%, which has obvious differences compared with energy consumption structure of the world.

The research was conducted in 2004, so it hasn't fully considered the factors of energy saving and emission elimination. It mainly focused on the forecast of China's energy selection. But it hasn't been focused on the subjective rating of the energy resources.

2.5. The Current Energy Resources Production Structure of China

According to the National Bureau of Statistics of China the energy production structure of China in from 1978 to 2006 is shown in Table 1, the change of energy production structure from 1978 to 2006 is shown as Fig. 1[4]. From 1978 to 2006, the proportion of coal energy production increased by 9%, the oil energy proportion decreased by 50%, the natural gas energy proportion increased by 21% and the proportion of nuclear/hydro/wind energy increased by 155% from 1978 to 2006. The reason of the change in the energy structure is because China has abundant coal, but is relatively meager in petroleum and natural gas. China is also trying to improve the portion of renewable energy resources and nuclear energy.

Table1 The Energy Production Gross and the Structure of China from 1978 to 2006

Year	Energy Gross Production 10 thousands tce	Percentage of the Gross Energy (%)			
		Coal	Oil	Natural Gas	Hydro Nuclear Wind Energy
1978	627.70	70.3	23.7	2.9	3.1
1980	637.35	69.4	23.8	3.0	3.8
1985	855.46	72.8	20.9	2.0	4.3
1990	1039.22	74.2	19.0	2.0	4.8
1991	1048.44	74.1	19.2	2.0	4.7
1992	1072.56	74.3	18.9	2.0	4.8
1993	1110.59	74.0	18.7	2.0	5.3
1994	1187.29	74.6	17.6	1.9	5.9
1995	1290.34	75.3	16.6	1.9	6.2
1996	1326.16	75.2	17.0	2.0	5.8
1997	1324.10	74.1	17.3	2.1	6.5
1998	1242.50	71.9	18.5	2.5	7.1
1999	1259.35	72.6	18.2	2.7	6.6
2000	1289.78	72.0	18.1	2.8	7.2
2001	1374.45	71.8	17.0	2.9	8.2
2002	1438.10	72.3	16.6	3.0	8.1
2003	1638.42	75.1	14.8	2.8	7.3
2004	1873.41	76.0	13.4	2.9	7.7
2005	2058.76	76.5	12.6	3.2	7.7
2006	2210.56	76.7	11.9	3.5	7.9

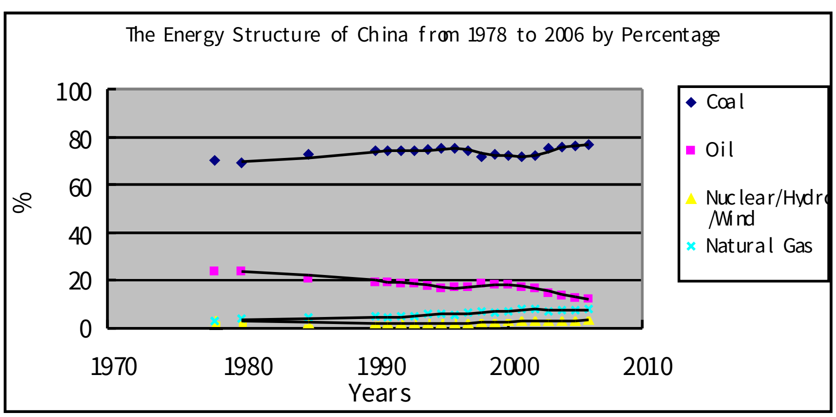


Figure -1 The Energy Gross and the Structure of China from 1978 to 2006

3. Problems

With *Comprehensive Working Program on Energy Saving and Emission Elimination* issue by the Statement Department of China, China must reconsider the problem of energy resource selection. Which energy types should China invest in for gaining the best utility? The rating for every energy type will be a critical issue. HDM method give us a powerful tool for rating different types of energy resources. In order to select the energy resource properly, we have to solve the following problems.

- What candidate energy resources are to be evaluated in China?
- What are the factors to be considered in the decision making process of energy resource selection?
- What are the weights for each influencing factor according to the value view of Chinese decision makers?
- How does each energy resource type act in the different aspects of influencing factors?
- What are the rank order for different energy resource types?
- How does the value of weights of different influential factors change if the rank order of the types of energy resources change?
- How will the rank order change if the influencing factors such as cost, availability, etc. change?

4. Energy Resources Alternatives of China

The Saaty/Gholamnezhad model has seven kinds of energy resources for evaluation, which are coal, nuclear power, conservation, solar energy, oil, natural gas, other resources. While, we hope to set the options according to the reality of China.

The *Comprehensive Working Program on Energy Saving and Emission Elimination*[3] issued by the Statement Department of China has listed the conservation as a major step in the coming years. It is also difficult to compare conservation to the other energy resources because they don’t have the same attributes. So we decide to exclude conservation as a candidate option for us to make decision.

The musthave qualification for the candidate options include:

- We should include the main kinds of applicable resources in China.
- The energy resource is technological practical for exploitation and utilization.
- We can get the data for comparison by research, otherwise the comparison is lacking of the basis of being authentic.

Now the main energy resources in China are coal, petroleum, natural gas, nuclear energy resources and renewable energy resources. Among the renewable energies, hydro and wind electricity has the potential to be used in large scale, biomass/biofuel energy, solar energy, tide energy and geothermal energy are also used, but the portions of those energies are very small. China also have oil shale and tar sands reserves, but they haven’t become practical to be utilized in large scale in the recent years in China. So we choose only five mainstream energy resource options to be evaluated, which include coal, petroleum, natural gas, nuclear energy and renewable energy.

5. The Criteria for Energy Resources Selection of China

We choose six criteria for the selection of five types of energy resource alternatives in China as show in figure 2. The six criteria are:

- Availability
- Current energy infrastructure
- Price
- Safety
- Social impacts

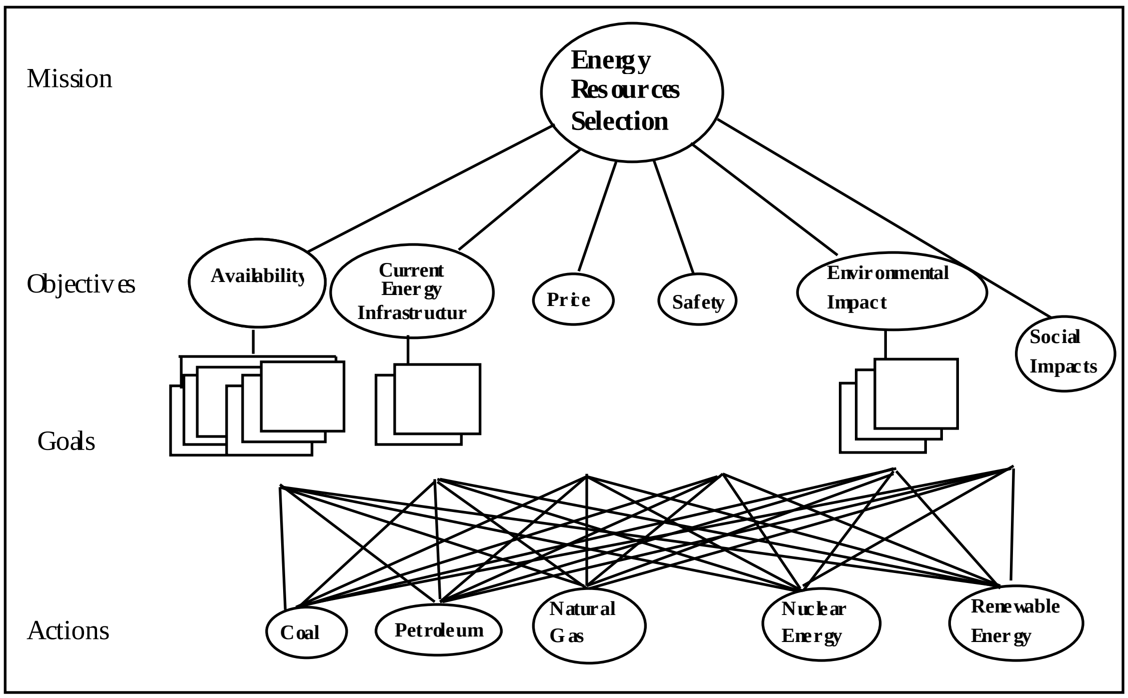


Figure 2 The Criteria for Energy Resources Selection of China

5.1 Availability

The most important factor for energy resource selection is the availability. Energy resource supply must be sustainable and persistent as the interruption of energy supply can cause great loss to the economic development and the living situation of people. The nonrenewable resources such as coal, petroleum, natural gas and uranium is limited. They will run out in a period of time. While, the renewable resources will be renewed by the nature and last forever.

For a specific type of energy resource, availability means that it is suitable and ready for use. We can explain availability with the exploitable reserves of the energy resource, the proved reserves of the energy resources and the readiness of technologies for the exploitation of it. If we import the energy resource, we need to take a estimate of sources of goods. An energy resource is more available when there are more sources of goods and we have better bargain power when purchasing it. The times of the world production to the domestic production can be regarded as an indicator for the easiness of importing energy resources. The decision making is also influenced greatly by the present annual production structure of different types of energy resources because the facilities to produce energy resources and methods to utilize the different energies need to change if the structure of energy resources change and thus will bring great cost to the economy.

The renewable energy resources can be replenished by new growth naturally as sunlight, wind, rain, tides and geothermal heat. Non-renewable energy resource is in contrast with fossil energy which can't be renewed naturally, such as coal, oil, natural gas, etc.. Climate change concerns coupled with the fear of energy crisis are driving people to the research to exploit and use renewable energy resources.

We depict the sub-factors for the most important influential factor as figure 3:

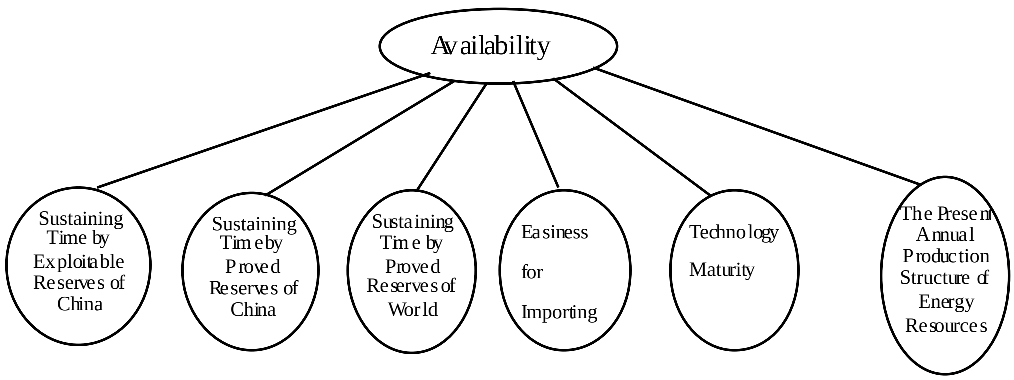


Figure 3 The Sub-factors for the Availability

We tried our best to find the information for the sub-factors depicted in figure 1,which are shown in the table-2, to table-7:

The annual energy consumption is about 2.65 billion tce (ton of standard coal equivalent) in 2007, among which the annual electricity consumption is about 3.2632 trillion kilowatt hours[6].

5.1.1 The Sustaining Time of China's Energy Resource by Exploitable Reserve

Table-2 The Sustaining Time of China's Energy Resource by Exploitable Reserve

	Exploitable Reserve	Annual consumption	Consumption percentage	Sustaining time
Coal	114.5 billion tonnes[5] (2000 est.)	2.58 billion tonnes[6] (2007 est.)	70.1%	44.39 years
Petroleum	2.043 billion tonnes[7] (2006 est.)	0.34 billion tonnes[6] (2007 est.)	20.6%	6.01years
Natural Gas	3.1 Trillion Cubic meters[8] (2007 est.)	67.3 billion cubic meters[6] (2007 est.)	2.94%	46.06 years
Nuclear Energy Resources	64,000 tonnes[9] (1997 est.)	1500 ton[10]	0.72%	77.58 years
Renewable	The hydrogen electricity is about 0.39 trillion kilowatts hours			For ever

Energy Resources	in 2006. The wind electricity is about 3.8 billion kilowatts hours in 2006. The hydro and wind electricity account for 12.07% of the annual electricity consumption and 6% of the total energy consumption.	

Note: 1.The annual production of world's uranium can only satisfy 55% demand of the fuel of nuclear reactors. The lacking part of the fuel is made up from the second time uranium including the recycling of spent fuel, the uranium stocks and conversion of highly enriched uranium within the nuclear weapons. 2.According to the *Development Report of Renewable Energy Resource of China*, the hydrogen electricity production in China is about 0.39 trillion kilowatts hours in 2006, China will develop the hydro electricity plants to exploit nearly all the hydro power within the territory of China before 2030. The annual provision of electricity by hydrogen energy will reach about 1.5 trillion kilowatts till then[14]. The wind electricity production in China is about 3.8 billion kilowatts hours in 2006. China will develop the installed capacity of wind power plant to 40 million kilowatts which will provide as much as 80 billion kilowatts hours of annual production in 2020. If the wind energy within China 's territory are all exploited in the future, the electricity provided by wind can reach 2 trillion kilowatts hours.[11] That means if the hydrogen and wind energies are fully utilized, it can provide all the annual electricity demand of China. The biomass energy is made from the crop haulm, forestry surplus, oil plants, domestic garbage and other organic waste. As estimated, the exploitable biomass energy can provide as much as 0.5 billion tce, which is 18.9% of the total energy consumption.[14]

5.1.2 The Sustaining Time of China's Energy Resource by Proved Reserve

Table-3 The Sustaining Time of China's Energy Resource by Proved Reserve

	Proved Reserve	Annual consumption	Consumption percentage	Sustaining time
Coal	1002.5 billion tonnes[12] (1996 est.)	2.58 billion tonnes[6] (2007 est.)	70.1%	388.56 years
Petroleum	18.14 billion tonnes[13] (2007 est.)	0.34 billion tonnes[6] (2007 est.)	20.6%	53.35years
Natural Gas	4.7 Trillion Cubic meters[8] (2007 est.)	67.3 billion cubic meters[6] (2007 est.)	2.94%	69.84 years
Nuclear Energy Resources	Abundant	1500 ton	0.72%	1000 year (unlimited)
Renewable Energy Resources	The hydro and wind energy can provide 3.5 trillion kilowatts hours annually at most, which can cover all the electricity consumption of China. The biomass can provide as much as 0.5 billion tce annually, which account for 18.9% of the total annual energy consumption.[14]			For ever

Note:

1. Atomic energy resources are mainly uranium and thorium. China is lack of uranium and is after the top 10 countries which process the most uranium mine of the world. The uranium of China is insuffcient for the development of unclear energy industry. While China does have

plenty of thorium as a replacement of uranium and is listed as the second country of the world which process the most of thorium mine after India. The proved reserve of uranium and thorium can provide as 20 times of energy as the sum of energy provided by the fossil fuel of coal, oil and natural gas. So we can just assume that the sustaining year of the atomic energy resource can be 1000 years or more[15]. But the present unclear power plants in China are designed to process uranium. The technologies to generate electricity by thorium is still developing.

5.1.3 The Sustaining Time of the World's Energy Resource by Proved Reserve

Table-4 The Sustaining Time of the World's Energy Resource by Proved Reserve

	Proved Reserve	Annual consumption	Consumption percentage	Sustaining time
Coal	909.06 billion tonnes [16] (2006 est.)	3.09 billion tones [17] (2006 est.)	28.41%	294.20 years
oil	1,208.2 billion barrels [18] (2006 est.)	28.51 billion barrels [19] (2007 est.)	35.76%	42.38 years
Natural Gas	181.46 trillion Cubic meters(1st, Jan, 2008[20])	2.85 trillion cubic meters[21]	23.67%	63.67 years
Nuclear Energy Resources	16200000 tonnes[22]	69110 tonnes[22]	5.84%	234 years
Renewable Energy Resources				For ever

Note:

1.As estimated by IAEA-NEA, the conventional uranium reserve is about 16200000 tonnes, which can last for 234 years according to the present consumption. The uranium reserve reasonably assured as of 1/1/2007 which costs less than US$130 per kilogram is about 3338300 tonnes, with which the nuclear reactors of the world can only last for 48.3 years. The annual production of world's uranium is about 41279 tonnes in 2007.

5.1.4 Easiness for Importing Energy resources

Table-5 Easiness for Importing Energy resources—Times of World's Production of China's Production of 2006:

	China's Production	World's Production	World/China
Coal	1,212.3 million tonnes oil equivalent [23] （2007 est.）	3,079.7 million tonnes oil equivalent[23] （2007 est.）	2.54
Oil	183.7 million tonnes[23] （2007 est.）	3,914.1 million tonnes[23] （2007 est.）	21.31
Natural Gas	58,553 million cubic metres[23] （2007 est.）	2,865,297 million cubic metres[23] （2007	48.96

		est.)	
Nuclear Energy Resources	712 tonnes[24] (2008 est.)	41279 tonnes[24] (2008 est.)	57.98
Renewable Energy Resources	It is impractical to import renewable energy from other country at present.		0

5.1.5 Technology Maturity

Table-6 Maturity in Technologies to Exploit Different Types of Energy in China

Energy Types	Technologies Development Status
Coal Energy	Mature
Oil Energy	Mature
Natural Gas Energy	Mature
Nuclear Energy Resources	Practical but still developing
Renewable Energy Resources	Some of the technologies are mature(such as hydro and wind energy), while others are still in the beginning or developing stages (such as biomass energy).

5.1.6 Annual Production Structure

Table-7 The Production Structure of Different Types of Energy Resources of China in 2007[25]

Energy Types	Annual Production Percentages
Coal Energy Petroleum Energy	76.4% 11.3%
Natural Gas Energy	3.9%
Nuclear Energy	0.72%
Renewable Energy	7.68%

5.2 Current Energy Infrastructure

We should also consider the consumption as an important factor because the production should match the demand of each type of energy in reality. The sub-factors for the Energy Consumption Structure is depicted as figure 4.

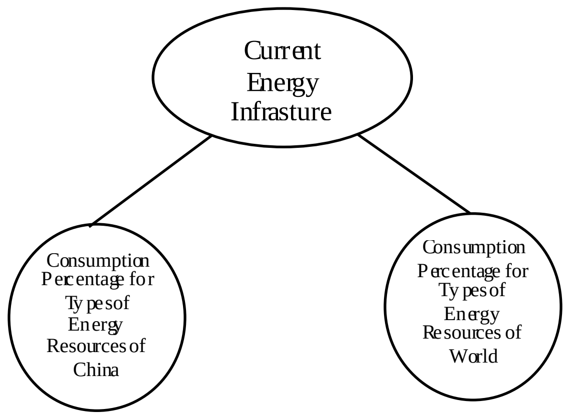


Figure 4 The Sub-factors for the Energy Consumption Structure

The consumption of various types of energy is not only decided by the production but also by the way we live and the industries we run which is path dependence. The facilities built in the past are agree with the present energy consumption structure. If we change the structure of energy types, the facilities should be changed together which make the shifting very different. It is essential to consider the present consumption percentage as an important factor for us while making decision. We can indicate the importance of different types of energies by Consumption Percentage for Types of Energy Resources of China and World as shown table-8 and table-9.

Table-8 Consumption Percentage for Types of Energy Resources of China[26] (2006)

	Consumption of 2006	Percentage of total energy consumption
Coal	1,191.3 million tonnes oil equivalent	70.17%
Petroleum Natural Gas	349.8 million tones 50.0 million tonnes oil equivalent	20.60% 2.94%
Nuclear Energy Resources	12.3 million tonnes oil equivalent	0.72%
Renewable Energy Resources	94.3 million tonnes oil equivalent	5.57%
Total	1,697.8 million tonnes oil equivalent	

Table-9 Consumption Percentage for Types of Energy Resources of World[26] (2006)

	Production of 2006	Percentage of total energy consumption
Coal	3,090.1 million tonnes oil equivalent	28.41%
Petroleum	3,889.8 million tonnes	35.76%
Natural Gas	2,574.9 million tonnes oil equivalent	23.67%
Nuclear Energy Resources	635.5 million tonnes oil equivalent	5.84%
Renewable Energy Resources	688.1 million tonnes oil equivalent	6.33%

Total	10,878.5million tonnes oil equivalent	

5.3 Price

Gholamnezhad and Satty used cost as an influencing factor for the selection of energy resources, which means the expenditure of money, time and labor paid for raw material acquisition, production, transportation, storage, etc. of the energy generated by the type of energy resource. "Two types of expenditures involved in the provision of energy are the initial costs of exploration and early development of resources, and those of production, distribution, and utilization."[A. H. Gholamnezhad and T. L. Satty][27]

We use prices as substitutes of costs of energy resources. Because the prices are not only decided by the costs when we exploit and utilize energy resources, they also reflect the supply and demand situation in the market, in other words, they reflects the scarcity of the energy resources. Moreover, it's also easier to get the information about prices of coal, oil and natural gas in market rather than the costs of them, thus make the research practical.

Table10 The Prices of Energy Resources

<table>
<tr><th></th><th colspan="3">Description</th></tr>
<tr><td>Coal</td><td colspan="3">The price of the composite price of commodity coal is about RMB￥422.85/tonne.[28]</td></tr>
<tr><td>Petroleum</td><td colspan="3">Because the price of crude oil fuctuated largely in the past years, we decided to adopt the average price of the past four years (2005, 2006, 2007, 2008), which is about $69.99/bbl.[29] The price fluctuated from 17.76 to 123.88 since 1946 according to the comparable prices of 2008.</td></tr>
<tr><td>Natural Gas</td><td colspan="3">In the first three months of 2008, the average price of the natural gas of China National Petroleum is about $3.15/thousand cubic feet. [30]</td></tr>
<tr><td>Nuclear Energy Resources</td><td colspan="3">The nuclear electricity is in the same level as the coal electricity or a little bit lower than coal electricity. The benchmarking price of coal electricity in China is about RMB ￥0.42/kwh, while the price of the nuclear electricity of Qinshan is about RMB ￥0.393/kwh.[31]</td></tr>
<tr><td rowspan="5">Renewable Energy Resources</td><td colspan="3">The prices of renewable energy resources are decreasing and they are now very competitive to the coal electricity.[14]</td></tr>
<tr><td>Hydro Electricity</td><td>3.8 billion kwh in 2006</td><td>RMB￥0.25/ kwh[32]</td></tr>
<tr><td>Wind Electricity</td><td>0.39 trillion kwh in 2006</td><td>RMB ￥0.52/kwh[33]</td></tr>
<tr><td>Solar Electricity</td><td>Very small</td><td>RMB￥2.1-3.5/ kwh[14]</td></tr>
<tr><td>Biomass/Biofuel</td><td>Very small</td><td>RMB￥0.56-0.84/ kwh[14]</td></tr>
</table>

In order to make the information explicit, we try to calculate the cost per kilowatt hour as

Table 11 The Prices of Energy Resources Compared with Coal

	Price of Heat	Price of electricity	Price Comparison (Times of Coal)
Coal	RMB￥0.0727/kwh	RMB￥0.42/kwh	1
Petroleum	RMB￥0.2841/kwh		3.90
Natural Gas	RMB￥0.0721/kwh		1

Nuclear Energy Resources	RMB￥0.393/kwh	0.94
Renewable Energy Resources	RMB￥0.285/kwh	0.68

5.4 Safety

Safety concerned with the energy resources means the freedom from the occurrence of risks of injury, danger or loss caused by the energy resources and the confidence of being safe with the energy resources. Energy production has impact to the safety of environments and the inhabitants. For instance the emission of waste air, waste water and the nuclear waste are harmful to the inhabitants' health. Some energy source can cause irreversible disasters to the environment such as nuclear leak. Energy Education Australia Inc. has done a detailed research to the possible large scale different kinds of energy systems as shown in table-12.

Table-12 Possible Large Scale Disasters of Energy System[34]

Energy System	Possible Large Scale Disasters	
Coal	Mine accidents, landslides, sudden subsidence in urban areas, depletion and contamination of water resources in arid regions.	
Petroleum	Massive spills on water from tanker accidents and offshore well blowouts, massive spills on land from pipeline breaks, refinery fires.	
Natural Gas	Pipeline explosions, liquefied natural gas (LNG) tanker explosions	
Nuclear Energy Resources	Release of radioactive material from meltdown of reactor core, sabotage.	
Renewable Energy Resources	Generally the disasters caused by renewable resources are relatively slight.	
	Hydro Electricity	Dam breaks
	Wind Electricity	None
	Solar Energy	None
	Biomass and Biofuels	None
	Geothermal Energy	Depletion and contamination of water resources in arid regions
	Tidal Energy	None

5.5 Environment Impact

Energy generation has various negative impacts to environment as figure 5:

- Air pollution: atmosphere is a major concern of China. The main polluting emission refers to the emission of SO_2. While, emission of CO_2 is another concern because the greenhouse effect is caused by the emission of CO_2. The burning of coal, oil and natural gas all produce the air pollutant.
- Water pollution: Energy generation can also cause water pollution by drainage of the waste water into the natural water bodies.

- Land disruption: Mining of coal, oil, natural gas can disrupt the green land because of subsidence, surface mining, proposal of used materials, etc..

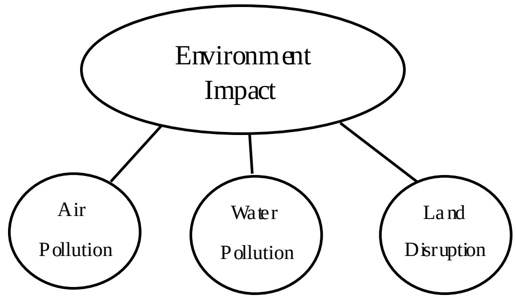


Figure 5 The Sub-factors for the Energy Consumption Structure

Table-13 Environment Impact of Energy System[34]

<table>
<tr><th>Energy System</th><th>Air Pollution</th><th colspan="2">Water Pollution</th><th>Land Disruption</th></tr>
<tr><td>Coal</td><td>Sulphur dioxide, inhalable particulates, nitrogen oxides, global climate change from carbon dioxide, radioactive emissions.</td><td colspan="2">Acid mine drainage, acid rain, dissolved solids from washing coal, excess heat.</td><td>Underground and strip mining, subsidence, slag disposal, erosion.</td></tr>
<tr><td>Petroleum</td><td>Suphfur Dioxide, nitrogen oxides and hydrocarbons, global climate change from carbon dioxide.</td><td colspan="2">Oil spills from blowouts, tanker accidents, pipeline ruptures.</td><td>Subsidence, estuary pollution</td></tr>
<tr><td>Natural Gas</td><td>Global climate change from carbon dioxide.</td><td colspan="2">Excess heat</td><td>Subsidence</td></tr>
<tr><td>Nuclear Energy Resources</td><td>Radioactive emissions</td><td colspan="2">Radioactive mine wastes, excess heat, radio effluents.</td><td>Open pit and underground mining, storage of radioactive wastes.</td></tr>
<tr><td rowspan="3">Renewable Energy Resources</td><td colspan="4">Generally the environment impact caused by renewable resources are relatively slight.</td></tr>
<tr><td></td><td>Air</td><td>Water</td><td>Land</td></tr>
<tr><td>Hydro Electricity</td><td>Negligible</td><td>Disruption of aquatic ecosystems</td><td>Flooding in areas to form lake(s), ecosystem disruption, loss of wildlife and human habitat, disruption of estuary into which river flows.</td></tr>
</table>

	Wind Electricity	Negligible except for some noise and aesthetic degradation. Possible local or regional climate changes.	Negligible	Negligible
	Solar Energy	Negligible except for moderate amount air pollution from materials (cement, steel, glass) needed to male collectors.	Negligible	Requires land for large farms of solar collectors, disruption of desert ecosystems.
	Biomass/Biofuels	Particulates and hydrocarbons, global climate change from carbon dioxide. Global climate change from carbon dioxide.	Large use of land, soil erosion, soil salinity and waterlogging from irrigation, ecosystem simplification, loss of wildlife habitats	Large use of land, soil erosion, loss of habitat for wildlife.
	Geothermal Energy	Hydrogen sulphide and ammonia, global climate change from carbon dioxide, radioactive materials, noise, local climate change, odor.	Dissolved solids (salinity), runoff, excess heat.	Subsidence
	Tidal Energy	Negligible	Estuary disruption	Negligible

5.6 Social Impact

Social impact plays an important role in energy development. Since energy as an industry is a great opportunity to impact social and economic change, we will be carrying out social impact assessment as part of energy resources selection. The energy industry's scale is large in China. Development of different energy section has different power of influence. We can define the industry scale according to the employees and contribution to GDP of each sections of the energy industry in China. If any section of the industry changes, there will be impact to the employment and GDP concerned with that section. The sub-factors of social impact are listed as below and are shown as figure 6.

- Industrial Added Value: The contribution of the industries concerned with various energy resources to China's GDP. We can use the industrial added value to indicate the contribution of kinds of energy resources to China's GDP shown in table 15.
- Employment: The numbers of employees of the industries concerned with various energy resources. We can use table 17 to assist the rating of different energy resources.
- Price Fluctuation: The price of the energy resource is determined by many factors, including the cost and the monopoly situation of the resource. Sometimes the political and economics situation have great impact to the price of energy resource. If the price fluctuates largely, it can be dangerous and harmful to the steady development of China's economy. The price fluctuation is shown in table 18.
- Others: The selection of different energy resource has many side effects. The development of different energy resources will have side effects. For example, the nuclear reactor will make the real estate around it depreciate. Some of the other social impacts are shown in table 19.

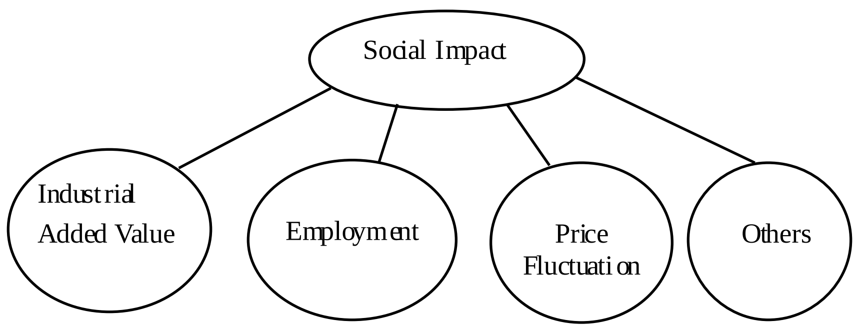


Figure 6 The Sub-factors for Social Impact of Energy Resources

5.6.1 Industrial Added Value

Table 14 The Percentages of the Industrial Added Value of Energy Resource Sectors in China (2006) [35]

Mining and Washing of Coal	3.90%
Extraction of Petroleum and Natural Gas	6.60%
Processing of Petroleum ,Coking ,Processing of Nucleus Fuel	2.50%
Production and Supply of Electric Power and Heat Power	7.60%
Production and Distribution of Gas	0.20%
Total	20.80%

We adjusted the numbers in the table above roughly according to the proportion of energy consumptions of China and got table 15, which is more practical in assisting decision making.

Table 15 The Adjusted Percentages of the Industrial Added Value of Energy Resource Industry in China (2006)

Energy System	Industrial Added Value Percentage
Coal	11.71%
Petroleum	6.61%
Natural Gas	1.14%
Nuclear Energy Resources	0.90%
Renewable Energy Resources	0.60%

Total	20.96%

5.6.2 Employment

Table 16 The Employee Numbers of Energy Resource Sectors in China (2006)[35]

Energy Resource Sectors	Employee Numbers (in thousand persons)
Mining and Washing of Coal	3574
Extraction of Petroleum and Natural Gas	879
Processing of Petroleum, Coking, Processing of Nucleus Fuel	542
Production and Supply of Electric Power and Heat Power	2292
Production and Distribution of Gas	163
Total	7450

We adjusted the numbers in the table above roughly according to the proportion of energy consumptions of China and got table 17, which is more practical in assisting decision making.

Table 17 The Adjusted Employee numbers of Energy Resource Systems of China (2006)

Energy System	Employee Numbers (in thousand persons)
Coal	5858
Petroleum	950
Natural Gas	288
Nuclear Energy Resources	202
Renewable Energy Resources	180
Total	7478

5.6.3 Price Fluctuation

Table 18 Price Fluctuation of Energy Resources

Energy System	Price Fluctuation
Coal	Rising steadily every year
Petroleum	Fluctuating largely with the international oil price. The domestic oil can account for 47% of the consumption and 53% of the oil is relying on the import.[36]
Natural Gas	China will reportedly raise natural gas prices within the year in an effort to ensure healthier profits for the sector.[37]
Nuclear Energy Resources	The price of nuclear electricity is going to decrease in the future with the development of nuclear energy technologies.
Renewable Energy Resources	The price of hydro and wind electricity is going to decrease in the future with the development of renewable energy technologies.

5.6.4 Other Social Impact

Table 19 Other Social Impact of Energy Resources

Energy System	Other Social Impact
Coal	
Petroleum	
Natural Gas	

Nuclear Energy Resources	Causing the depreciation of land and real estates around the nuclear reactor.
Renewable Energy Resources	Causing the change of ecology around the dam of hydro electric plant. Boosting the R&D of renewable energy technology and manufacturing industry.

6. The Survey and the Result

We designed a survey questionnaire as shown in appendix 2 and 12 Chinese experts filled out the questionnaire, we got the weights of the decision making criteria and sub-criteria and the rating for the five energy alternatives by pairwise comparison. The comparison of weights of the criteria are shown in figure 6. We calculated the rating results according to the pairwise comparison given by the experts as shown in table 20.

The comparison of energy alternatives to each criterion are shown in figure 7. The comparison of energy alternatives as a whole to the selection are shown in figure 8.

From the comparison in detail, we can see that the renewable energy is valued by Chinese people as the first rank, much better than coal, nuclear energy, natural gas and petroleum because renewable energy get the highest value in availability, price, environmental impacts. While the proportion of renewable energy in the current energy infrastructure is still very low and the social impacts of renewable energy is also relatively low because the industrial size is relatively smaller.

The second rank goes to coal. Coal has the top ranks in current energy infrastructure and social impacts. It also does well in availability and price. But the weakness of coal lies in the safety and the environmental impacts.

The third rank goes to nuclear energy. Nuclear energy gets the second rank in availability, price, environmental impacts. But its proportion in the current energy infrastructure is very small. People worry about the safety of nuclear energy and the social impacts of nuclear energy also make it inferior in the positioning of the selection.

The forth rank goes to natural gas. Natural gas ranks as third in availability, price, current energy infrastructure, safety and environmental impacts, but ranks as 4th in social impacts.

The last rank goes to petroleum. Though petroleum has the second rank in current energy infrastructure and safety, its shortage in availability and expensive price make it drop to the last rank. Its ranks in environmental and social impacts are also gloomy.

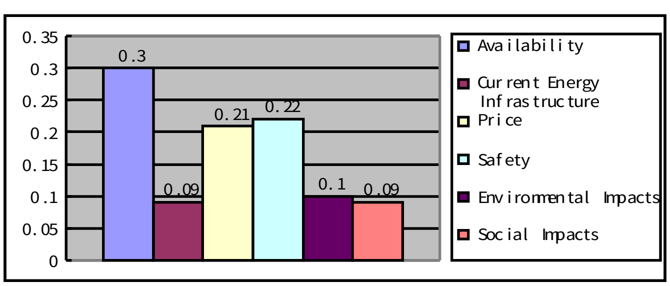


Figure 6 The Weights of the Criteria in Energy Resources Selection of China

Table 20 Calculation of the Rating Results According to the Pairwise Comparison about Selection of Energy Resources of China

Criteria&Weights	Sub-criteria	Weights in Sub-criteria	Weights in mission	Coal	Petroleum	Natural Gas	Nuclear Energy	Renewable Energy
Availability 0.3	Sustaining Time by Exploitable Reserves of China	0.19	0.057	0.05	0.01	0.05	0.07	0.82
	Sustaining Time by Prooved Reserves of China	0.22	0.066	0.11	0.04	0.04	0.29	0.52
	Sustaining Time by Prooved Reserves of world	0.18	0.054	0.15	0.03	0.04	0.15	0.64
	Easiness for Importing	0.14	0.042	0.04	0.21	0.34	0.4	0
	Technology Maturity	0.14	0.042	0.29	0.26	0.23	0.13	0.09
	The Present Annual Production Structure of Energy Resources	0.12	0.036	0.5	0.18	0.12	0.07	0.13
Current Energy Infrastructure 0.09	Consumption Percentage for Types of Energy Resources of China	0.42	0.0378	0.52	0.21	0.14	0.06	0.06
	Consumption Percentage for Types of Energy Resources of World	0.58	0.0522	0.25	0.33	0.23	0.11	0.08
Price 0.21		1	0.21	0.21	0.06	0.2	0.23	0.31
Safety 0.22		1	0.22	0.15	0.18	0.18	0.15	0.35
Environmental Impacts 0.1	Air Pollution	0.38	0.038	0.09	0.1	0.14	0.24	0.44
	Water Pollution	0.38	0.038	0.09	0.08	0.21	0.16	0.45
	Land Disruption	0.24	0.024	0.13	0.14	0.2	0.14	0.4
Social Impacts 0.09	Industrial Added Value	0.23	0.0207	0.44	0.22	0.13	0.13	0.08
	Employment	0.25	0.0225	0.52	0.17	0.13	0.09	0.09
	Price Fluctuation	0.36	0.0324	0.22	0.11	0.15	0.24	0.28
	Others	0.16	0.0144	0.19	0.16	0.14	0.21	0.31
Final Rating Value				0.200508	0.132861	0.1654	0.179396	0.333261
Ranks				2	5	4	3	1

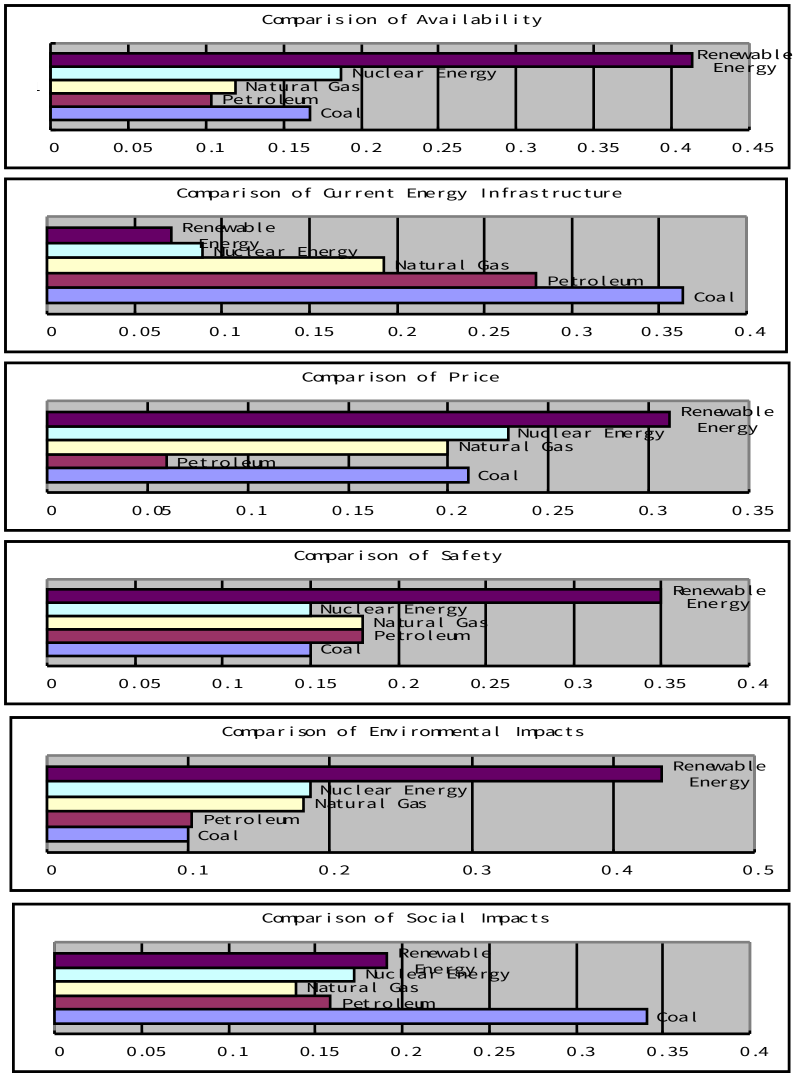


Figure 7 The Comparison of Energy Alternatives to Each Criterion

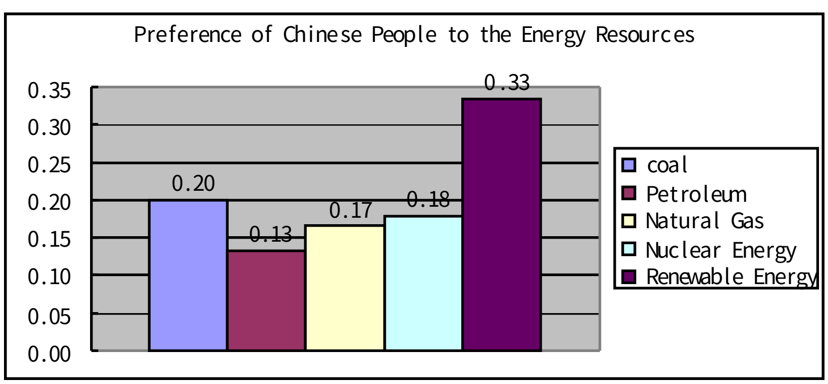


Figure 8 The Result of the Comparison of Energy Resources Alternatives of China

7. Sensitivity Analysis of Objective's Weights

In our project, we did the sensitivity analysis on the criterion level, which is the objective level. We used the sensitivity analysis algorithm for hierarchical decision models mentioned in Hongyi Chen and Dundar F. Kocaoglu 's study[Error! Bookmark not defined.]. Tolerance is defined as the allowable range in which a contribution value can vary without changing the rank order of decision alternatives. In order to determine the tolerance, the allowable ranges of perturbations are always calculated first. In our result, we find out the tolerances of contributions of influencing factors to the mission that will tolerate the current energy selection rankings to remain the same.

Before we start the sensitivity analysis algorithm, there are some symbols to be defined.

Ol: The l th objective, $l = 1,2...L$

In our project, the objectives are Availability, Current Energy Infrastructure, Price, Safety, Environmental Impacts, Social Impacts.

Ai: The i th action, $i = 1,2...I$

Here the actions are Coal, Petroleum, Natural Gas, Nuclear Energy, Renewable Energy.

a_{il}: Contribution of the i th action to the l th objective

a_i: Contribution of the i th action to the mission

r: The rank of i. A_r ranks higher than A_{r+n}, indicating $a_r \geq a_{r+n}$

o_l: Contribution of the l th objective to the mission

Let's denote the perturbation induced on one of the o_l 's (o_{l*} is used to differentiate it from other o_l) as ε_{l*} and $-o_{l*} < \varepsilon_{l*} < \sum_{l=1, l \neq l*}^{L} o_l$.

The original ranking order of A_r and A_{r+n} will not reverse if

$$\varepsilon_{l*} \leq \frac{C_0}{C_{l*}} \ \left(\text{if } \frac{C_0}{C_{l*}} > 0\right) \qquad \text{or} \qquad \varepsilon_{l*} \geq \frac{C_0}{C_{l*}} \left(\text{if } \frac{C_0}{C_{l*}} < 0\right)$$

where $$C_{l*} = a_{r+n,l} - a_{rl*} - \sum_{l=1, l \neq l*}^{L} a_{r+n,l} \times \frac{o_l}{\sum_{l=1, l \neq l*}^{L} o_l} + \sum_{l=1, l \neq l*}^{L} a_{rl} \times \frac{o_l}{\sum_{l=1, l \neq l*}^{L} o_l}$$

and $C_0 = a_r - a_{r+n}$.

The original ranking of all Ai's will remain unchanged if the above condition is satisfied for n=1, and r=1,2,3,4 in our project. The top choice will remain the same to choice if the above condition is satisfied for r=1 and n=1,2,3,4 in our project.[38]

We first list the known condition figures by table 21 and table 22 as follow.

Table21. Ranking and Contributions of the Alternative Energy Resources To the Mission

	Coal	Petroleum	Natural Gas	Nuclear Energy	Renewable Energy
Value	0.2005	0.1328	0.1654	0.1793	0.3332
Ranks	2	5	4	3	1

Table22. Contribution Matrix of Alternative Energy Resources to the Criteria

Energy Alternatives (Ranks)	Coal (2)	Petroleum (5)	Natural Gas (4)	Nuclear Energy (3)	Renewable Energy (1)
Availability	0.17	0.10	0.12	0.19	0.41
Current Energy Infrastructure	0.36	0.28	0.19	0.09	0.07
Price	0.21	0.06	0.2	0.23	0.31
Safety	0.15	0.18	0.18	0.15	0.35
Environmental Impacts	0.10	0.10	0.18	0.19	0.43
Social Impacts	0.34	0.16	0.14	0.17	0.19

Based on the definition $-o_{l*} \text{ p } \varepsilon_{l*} \text{ p } \sum_{l=1, l\neq l*}^{L} o_l$, we can see that $-0.3 \text{ p } \varepsilon_1 \text{ p } 0.7$.

$$C_0 = a_1 - a_2 = 0.3332 - 0.2005 = 0.1327$$

$$\sum_{l=2}^{6} o_l = 0.09 + 0.21 + 0.22 + 0.1 + 0.09 = 0.7$$

$$C_1 = a_{2,1} - a_{11} - \sum_{l=2}^{6} a_{2,1} \times \frac{o_l}{\sum_{l=2}^{6} o_l} + \sum_{l=2}^{6} a_{11} \times \frac{o_l}{\sum_{l=2}^{5} o_l}$$

$$\begin{aligned}
&= 0.17 - 0.41(0.36*0.09/0.7 + 0.21*0.21/0.7 + 0.15*0.22/0.7 + 0.1*0.1/0.7 + 0.34*0.09/0.7) \\
&+ (0.07*0.09/0.7 + 0.31*0.21/0.7 + 0.35*0.22/0.7 + 0.43*0.1/0.7 + 0.19*0.09/0.7) \\
&= -0.156
\end{aligned}$$

$$\frac{C_0}{C_1} = \frac{0.1327}{-0.156} = -0.85$$

We can get that $\varepsilon_1 \geq -0.85$

Repeating the same steps for $n = 1$ and, $r = 2,3 \ldots 5$ we get the following allowable range of ε_1.

$-0.3 \text{ p } \varepsilon_1 \text{ p } 0.7$, $\varepsilon_1 \geq -0.85$, $\varepsilon_1 \leq 0.372$, $\varepsilon_1 \geq -0.1782$ and $\varepsilon_1 \leq 1.68$.

We find out the intersection of the above sets and get the perturbation of the weight of "availability" as follow.

$$-0.1782 \le \varepsilon_1 \le 0.372$$

The allowable range of the perturbation on O_l is denoted as $[\delta_{1l}, \delta_{2l}]$, and the tolerance of oℓ is defined as $[\delta_{1l} + o_l, \delta_{2l} + o_l]$ [38]. From the calculations above, we can get to the result that the tolerance of O_l, which is "availability", to keep the current ranking of all the alternatives in energy resource selection is [0.1218, 0.672]. After repeating the same steps for each objective, we put all the results in table 23 and we describe the meaning of the result in table 24.

Table 23 Sensitivity Analysis on the Weights of Criteria of Mission to the Ranks of Energy Alternatives

	Availability	Current Energy Infrastructure	Price	Safety	Environmental Impacts	Social Impacts
Perturbations	[-0.1782, 0.372]	[-0.077, 0.1096]	[-0.21, 0.4]	[-0.22, 0.238]	[-0.1, 0.1729]	[-0.09, 0.43]
Tolerance	[0.1218, 0.672]	[0.013, 0.1996]	[0,0.61]	[0, 0.458]	[0, 0.2729]	[0, 0.52]
Sensitivity Coefficient	1.82	5.36	1.64	2.18	3.66	1.92
Criticality to Current Ranking	5	1	6	3	2	4

Table 24 Explanation of the Results of Sensitivity Analysis

Criteria	Tolerance of the Weights	Description
Availability	[0.116,0.661]	When the weight of availability is less than 0.116 natural gas will surpass nuclear energy to become the 3rd instead of the 4th. When the weight of availability is more than 0.661, nuclear energy will surpass coal to become the 2nd instead of the 3rd. When the weight of availability changes within the range from 0.116 to 0.661， the ranks of the energy alternatives remain the same.
Current Energy Infrastructure	[0.015,0.197]	When the weight of current energy infrastructure is less than 0.015, nuclear energy will surpass coal to become the 2nd instead of the 3rd. When the weight of current energy infrastructure is more than 0.197, natural gas will surpass nuclear energy to become the 3rd instead of the 4th. When the weight of current energy infrastructure changes within the range from 0.015 to 0.197， the ranks of the energy alternatives remain the same.
Price	[0,0.615]	When the weight of price is more than 0.615, nuclear energy will surpass coal to become the 2nd instead of the 3rd. When the weight of price changes within the range from 0 to 0.615，the ranks of the energy alternatives remain the same.
Safety	[0,0.531]	When the weight of safety is more than 0.531, natural gas will surpass nuclear energy to become the 3rd instead of the 4th. When the weight of safety changes within the range from 0 to 0.531， the ranks of the

		energy alternatives remain the same.
Environmental Impacts	[0,0.277]	When the weights of environmental impacts are more than 0.277, nuclear energy will surpass coal to become the 2nd instead of the 3rd. When the weights of environmental impacts change within the range from 0 to 0.277， the ranks of the energy alternatives remain the same.
Social Impacts	[0,0.518]	When the weights of social impacts are more than 0.518, coal will surpass renewable energy gas to become the 1st instead of the 2nd. When the weights of social impacts change within the range from 0 to 0.518， the ranks of the energy alternatives remain the same.

8. Conclusion and Recommendation

This research about energy selection of China disclosed that Chinese people have realized that renewable energy will become the most desirable energy resource in the future. Coal will be a major energy resource in China because its abundant reserve in China. China should deploy the clean coal technology to eliminate the environmental impacts brought by coal production and consumption. Nuclear energy will be developed in China because its economic and clean features. While, since china is lack of uranium, the new technology using thorium as the nuclear fuel, which is rich in China, should be developed. Petroleum is the last in the preference of Chinese people. The consumption of petroleum and natural gas will relay on the import more and more in the future. If the new technology doesn't emerge in the recent years, China will face tough situations with the lack of petroleum. So the R&D of the technologies for the substitute of petroleum will become a hot field.

The preference of Chinese people also reflect that the contrast between the ideal and the reality. The sensitivity analysis reflect that the most critical criterion in the energy selection is current energy infrastructure. Now it mostly influences the attitude of Chinese people to nuclear energy. The present energy production and consumption infrastructure need to be changed in the future because the lack of fossil fuels and the negative environmental impacts of them. The energy preference of Chinese people can't be realized unless the energy technologies and energy infrastructure make big progress.

9. Discussion about the Decision Making Concerning the Availability of Energy Alternatives

In the research we have found out the exploitable and proved reserves of China and the proved reserve of the world about coal, petroleum, natural gas, nuclear fuels and renewable energy resources. Assuming that the consumption remains the same in the future we calculated sustaining time of the five energy alternatives mentioned. We use the sustaining time of exploitable and proved reserves to represent the availability of the energy alternatives.

While time passes, the reserves of the fossil fuels decrease but the reserves of renewable energy resources remain the same. What will be the decision of the Chinese people faced with the decrease of the fossil fuels in 10 or 20 years? We consider the problem by assuming that only the availability of the energy resources changes with time while the other parts of the model used in the research remain the same.

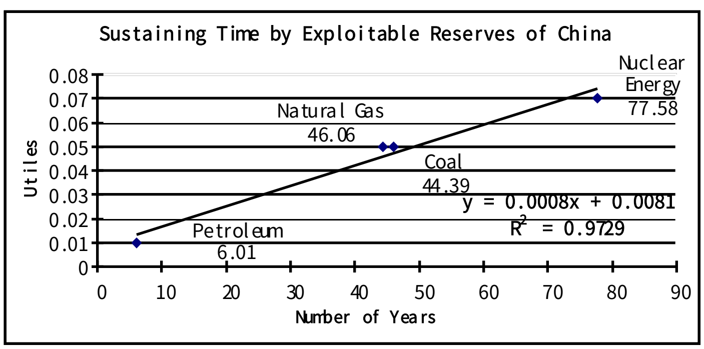
In the part 6 of the paper we have calculated the relative utility value of the sustaining time of coal, petroleum, natural gas, nuclear energy and renewable energy by exploitable reserves and proved reserves of China and proved reserves of world using the survey questionnaire which was filled by 12 experts and pairwise comparison.

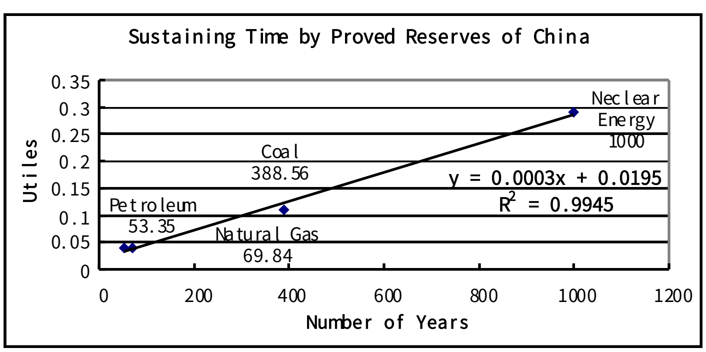
Since we already have the relative utility value for the sustaining years, we can infer the utility of sustaining years in the future by calculation. If we get the relative value for the utility of availability of different energy resources after 10 or 20 years and then we change the figures concerned in Tab. 20 to calculate the results, we will know about the preference of energy resource alternatives of Chinese people in 10 or 20 years.

Table 25 The Sustaining Time and the Utility Value (UV)

		Coal	Petroleum	Natural Gas	Nuclear Energy	Renewa-ble
Sustaining Time by Exploitable Reserves of China	Years	44.39	6.01	46.06	77.58	Infinite
	UV	0.05	0.01	0.05	0.07	0.82
Sustaining Time by Proved Reserves of China	Years	388.56	53.35	69.84	1000	Infinite
	UV	0.11	0.04	0.04	0.29	0.52
Sustaining Time by Proved Reserves of world	Years	294.2	42.38	63.67	234	Infinite
	UV	0.15	0.03	0.04	0.15	0.64

We combine the result from the pairwise comparison and the sustaining years of the energy alternatives into Tab. 25 and depict the actual data into a xy scatter chart. Then by using linear regression, simply adding the liner trend line, we formalize a liner equation between the four energy alternatives including coal, petroleum, natural gas and nuclear energy. Renewable energy was not included in the calculation due to its infinite usage nature.





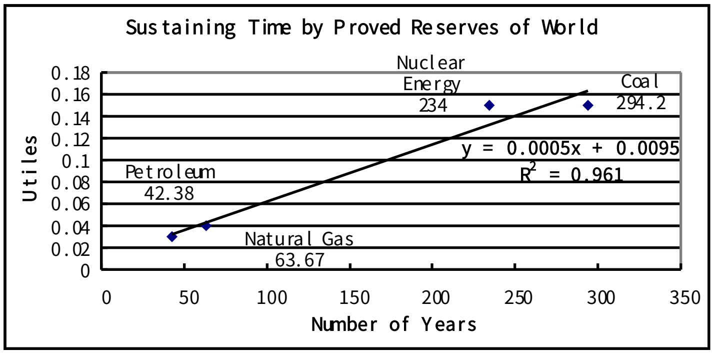


Figure 9 The Linear Regressions between Utility Value and Sustaining Time

Then we can calculate the utility for the availability of the 5 energy alternatives of 5, 10 and 20 years later according to the 3 regression equation. While, the utility value of the renewable energy resource remains the same because the availability of renewable energy resources remain as infinite. We list the normalized utility value of the availability in Tab. 26.

If we use the normalized utility value of the sustaining time as substitutes to the utility in original model as Tab. 20, then we get the comparison results showing the preference of Chinese people to the 5 energy alternatives of 10, 20 and 50 years later, as shown in Tab. 27. From the results we can see that though the preference for renewable energy resource goes up slightly and the preference for natural gas goes down slightly, the results won't change dramatically within 50 years.

Table 26 The Sustaining Time and the Utility Value (UV) of 10, 20, 50 Years Later

The sustaining time, utility value & normalized utility value of 10 years later						
		Coal	Petroleum	Natural Gas	Nuclear Energy	Renewa-ble
Sustaining Time by Exploitable Reserves of China	Years	34.39	0	36.06	67.58	Infinite
	UV	0.04	0.01	0.04	0.06	0.82
	NUV	0.04	0.01	0.04	0.06	0.85
Sustaining Time by Proved Reserves of China	Years	378.56	43.35	59.84	990	Infinite
	UV	0.13	0.03	0.04	0.32	0.52
	NUV	0.13	0.03	0.04	0.30	0.50
Sustaining Time by Proved Reserves of world	Years	284.2	32.38	53.67	224	Infinite
	UV	0.15	0.03	0.04	0.12	0.64
	NUV	0.16	0.03	0.04	0.13	0.65
The sustaining time, utility value & normalized utility value of 20 years later						
		Coal	Petroleum	Natural Gas	Nuclear Energy	Renewa-ble
Sustaining Time by Exploitable Reserves of China	Years	24.39	0	26.06	57.58	Infinite
	UV	0.03	0.01	0.03	0.05	0.82
	NUV	0.03	0.01	0.03	0.06	0.87
Sustaining Time by Proved Reserves of China	Years	368.56	33.35	49.84	980	Infinite
	UV	0.13	0.03	0.03	0.31	0.52
	NUV	0.13	0.03	0.03	0.31	0.51
Sustaining Time by Proved Reserves of world	Years	274.2	22.38	43.67	214	Infinite
	UV	0.15	0.02	0.03	0.12	0.64
	NUV	0.15	0.02	0.03	0.12	0.67
The sustaining time, utility value & normalized utility value of 50 years later						
		Coal	Petroleum	Natural Gas	Nuclear Energy	Renewa-ble
Sustaining Time by Exploitable Reserves of China	Years	0	0	0	27.58	Infinite
	UV	0.01	0.01	0.01	0.03	0.82
	NUV	0.01	0.01	0.01	0.03	0.94
Sustaining Time by Proved Reserves of China	Years	338.56	3.35	19.84	950	Infinite
	UV	0.12	0.02	0.03	0.30	0.52
	NUV	0.12	0.02	0.03	0.31	0.52
Sustaining Time by Proved Reserves of world	Years	244.2	0	13.67	184.00	Infinite
	UV	0.13	0.01	0.02	0.10	0.64
	NUV	0.15	0.01	0.02	0.11	0.71

Table 27 The Comparison Results of 10, 20, 50 Years Later

	Coal	Petroleum	Natural Gas	Nuclear Energy	Renewable
Present	0.20	0.13	0.17	0.18	0.33
10 years later	0.20	0.13	0.16	0.18	0.33
20 years later	0.20	0.13	0.16	0.18	0.34
50 years later	0.20	0.13	0.16	0.18	0.34

10. Discussion about the Price Fluctuation of the Petroleum

The petroleum price is fluctuating largely in the recent decades. We depict scatter diagram of the average comparable prices from 1946 to 2008 based on the price of 2008 as shown in Fig. 10. The lowest average price is $15.52/bbl which happened in 1998, the highest price is $99.65/bbl which occurred in 2008. Because the price of petroleum fluctuates so largely, we hope to find out the how the preference of the energy resources change with the price of petroleum fluctuating.

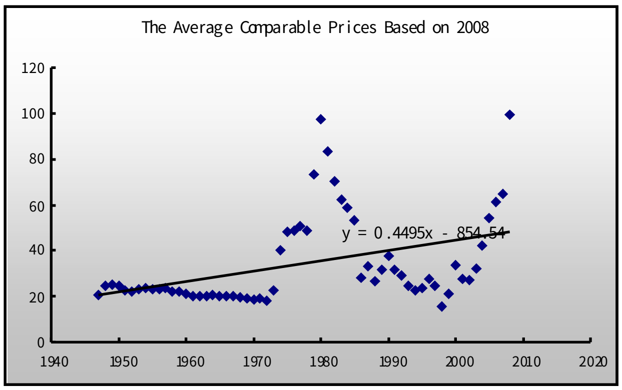


Figure 10 The Fluctuation of Petroleum Price from 1946 to 2008

We can calculate that 1bbl petroleum provide 1699.82kwh heat. If we calculate the price by the heat value in per kilowatt hour and assume that the exchange rate between US Dollar and RMB Yuan is at 6.9 RMB¥ for 1 US$, we will get the Tab. 28 and Tab. 29.

Table 28 The Calculation Table for Petroleum Price

The Description	Price of $US	Price of RMB¥	Price (per kilowatt hour)
Average (2005~2008)	$69.99/bbl	RMB¥ 482.931/ bbl	RMB¥ 0.2841/kwh
Upper Limit	$99.65/bbl	RMB¥ 687.585/bbl	RMB¥ 0.4045/kwh
Lower Limit	$15.52/bbl	RMB¥ 107.088/ bbl	RMB¥ 0.0630/kwh

Table 29 The Prices of Energy Resources Compared with Coal

	Price of Heat	Price of electricity	Price Comparison (Times of Coal)
Coal	RMB¥0.0727/kwh	RMB¥0.42/kwh	1
Petroleum	RMB¥0.2841/kwh [0.0630, 0.4045]		3.91 [0.87, 5.56]
Natural Gas	RMB¥0.0721/kwh		1
Nuclear Energy		RMB¥0.393/kwh	0.94
Renewable Energy		RMB¥0.285/kwh	0.68

Assuming that the utility of cost is strictly in reverse ratio with the cost itself, if we fix the prices of coal, natural gas, nuclear energy, renewable energy and only change the price of petroleum, we can get the relative utility value for the 5 energy alternatives. We replace the utility value for prices in Tab. 20. and get the results represented in Tab. 30. and Tab. 31.

Table 30 The Comparison Results at Lower Limit of the Price of Petroleum

	Time of Coal's Price	Relative Utility Value
Coal	1	0.18
Petroleum	0.87	0.20
Natural Gas	1	0.18
Nuclear Energy	0.94	0.19
Renewable Energy	0.68	0.26

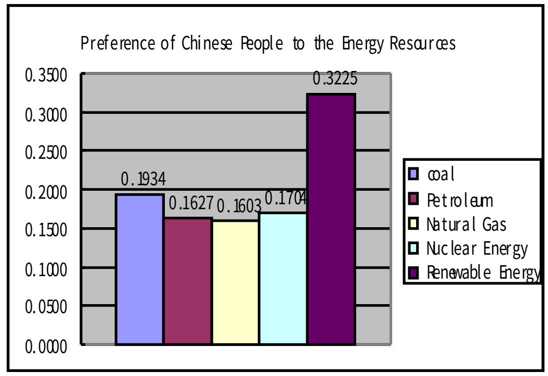
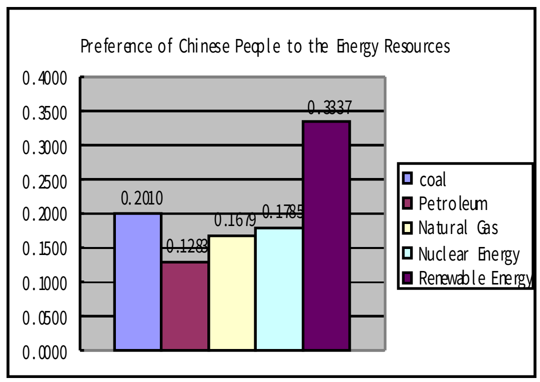


Table 31 The Comparison Results at Upper Limit of the Price of Petroleum

	Time of Coal's Price	Relative Utility Value
Coal	1	0.21
Petroleum	5.56	0.04
Natural Gas	1	0.21
Nuclear Energy	0.94	0.23
Renewable Energy	0.68	0.31



In order to describe the influence brought by the fluctuation of petroleum price we found the division of price lies in \$16.53, which means that the rank of petroleum in the preference of Chinese people will rise to the 4th when its price is lower than \$16.53/bbl and the rank of petroleum will remain as the 5th when the price is higher than \$16.53/bbl.

Appendix 1

The International Comparison of the Exploitable Reserves of the Main Energy Resources in 2000

	Population (million)	Coal		Petroleum		Natural Gas	
		Gross (billion tons)	Per capita (tons)	Gross (billion tons)	Per capita (tons)	Gross (Trillion Cubic meters)	Per capita (Cubic meters)
China	1275.31	114.500	89.80	3.30	2.60	1.37	1074.00
USA	281.42	246.643	876.40	3.70	13.10	4.74	16843.00
OECD	1120.04	447.100	399.20	11.20	10.00	13.43	11991.00
World	6057.00	984.211	162.50	142.10	23.50	150.19	24796.00
China/World	21.05%	11.63%	55.26%	2.32%	11.06%	0.91%	4.33%

Source: 1.2000 年主要能源指标的国际比较〔J〕. 能源工程.2003 年第 4 期。

2. Yushi Shen, The Research on the Strategy Model of Chinese Energy Development, doctoral dissertation of Liaoning Technical University. 2004, p3~30.

Appendix 2

Survey Questionnaire

On the Decision Making for Energy Resources Selection in China

02/20/2009

For Project of ETM530 Course

Engineering & Technology Management Department

Portland State University

Instructor: Dr. Dundar F. Kocaoglu

Project Team: Fei Huang, Jiting Yang, Lifeng Liu, Jingyang Zhang, Luqi Huang, Bing Wang

Your Name:____________________

Note: This questionnaire is for the project of "On the Decision Making for Energy Resources Selection in China**".** For the details about the project please check the assistant information given together with the questionnaire.

Level of confidence (Circle the appropriate number):

5: Very high 4: High 3: Medium 2: Low 1: Very Low

Objective: **Selection of Energy for China**

Criteria for selection an energy alternative:

1.Availability
2. Current Energy Infrastructure
3. Price
4. Safety
5. Environmental Impacts
6. Social Impacts

Please allocate a total of 100 points to the table 1, representing your perceived percent about how many times the relative importance of one criterion is in comparison to the other criterion for selection of energy alternatives for China. For example, if you believe that criterion 1(availability) is twice as important as criterion 3 (price), allocate 67 points to (1) and 33 points to (3) in the pair 1 vs. 3. Do not use "0" to your pairwise comparisons. If you believe that one element is completely irrelevant in comparison to the other element of a pair, allocate 1 and 99 respectively.

Table 1

1		Vs.		2
1		Vs.		3
1		Vs.		4
1		Vs.		5
1		Vs.		6
2		Vs.		3
2		Vs.		4
2		Vs.		5
2		Vs.		6
3		Vs.		4
3		Vs.		5
3		Vs.		6
4		Vs.		5
4		Vs.		6
5		Vs.		6

The Results:

Inconsistency Measure:

Level of confidence (Circle the appropriate number):

5: Very high 4: High 3: Medium 2: Low 1: Very Low

Criterion: **Availability**

Sub-criteria:

1. Sustaining Time by Exploitable Reserves of China
2. Sustaining Time by Proved Reserves of China
3. Sustaining Time by Proved Reserves of World
4. Easiness for Importing
5. Technology Maturity
6. The Present Annual Production Structure of Energy Resources

Please allocate a total of 100 points to the table 2, representing your perceived percent about how many times the relative importance of one sub-criterion is in comparison to the other sub-criterion for the availability of energy alternatives for China. For example, if you believe that sub-criterion 1 (sustaining time by exploitable reserve of China) is twice as important as criterion 3 (sustaining time by proved reserves of world), allocate 67 points to (1) and 33 points to (3) in the pair 1 vs. 3. Do not use "0" to your pairwise comparisons. If you believe that one element is completely irrelevant in comparison to the other element of a pair, allocate 1 and 99 respectively.

Table 2

1		Vs.		2
1		Vs.		3
1		Vs.		4
1		Vs.		5
1		Vs.		6
2		Vs.		3
2		Vs.		4
2		Vs.		5
2		Vs.		6
3		Vs.		4
3		Vs.		5
3		Vs.		6
4		Vs.		5
4		Vs.		6
5		Vs.		6

The Results:
Inconsistency Measure:

Level of confidence (Circle the appropriate number):

5: Very high 4: High 3: Medium 2: Low 1: Very Low

Criterion: **Current Energy Infrastructure**

Sub-criteria:

1. Consumption Percentage for Types of Energy Resources of China
2. Consumption Percentage for Types of Energy Resources of World

Please allocate a total of 100 points to the table 3, representing your perceived percent about how many times the relative importance of one sub-criterion is in comparison to the other sub-criterion for the current energy infrastructure of energy alternatives for China. For example, if you believe that sub-criterion 1(consumption percentage for types of energy resources of china) is twice as important as criterion 2 (consumption percentage for types of energy resources of world), allocate 67 points to (1) and 33 points to (2) in the pair 1 vs. 3. Do not use "0" to your pairwise comparisons. If you believe that one element is completely irrelevant in comparison to the other element of a pair, allocate 1 and 99 respectively.

Table 3

1		Vs.		2

The Results:
Inconsistency Measure:

Level of confidence (Circle the appropriate number):

5: Very high 4: High 3: Medium 2: Low 1: Very Low

Criterion: **Environment Impacts**

Sub-criteria:

1. Air Pollution

2. Water Pollution

3. Land Disruption

Please allocate a total of 100 points to the table 4, representing your perceived percent about how many times the relative importance of one sub-criterion is in comparison to the other sub-criterion for the current energy infrastructure of energy alternatives for China. For example, if you believe that sub-criterion 1(consumption percentage for types of energy resources of china) is twice as important as criterion 2 (consumption percentage for types of energy resources of world), allocate 67 points to (1) and 33 points to (2) in the pair 1 vs. 3. Do not use "0" to your pairwise comparisons. If you believe that one element is completely irrelevant in comparison to the other element of a pair, allocate 1 and 99 respectively.

Table 4

1		Vs.		2
1		Vs.		3
2		Vs.		3

The Results:

Inconsistency Measure:

Level of confidence (Circle the appropriate number):

5: Very high 4: High 3: Medium 2: Low 1: Very Low

Criterion: **Social Impacts**

Sub-criteria:

1. Industrial Added Value

2. Employment

3. Price Fluctuation

4.Others

Please allocate a total of 100 points to the table 5, representing your perceived percent about how many times the relative importance of one sub-criterion is in comparison to the other sub-criterion for the social impacts of energy alternatives for China. For example, if you believe that sub-criterion 1 (industrial added value) is twice as important as criterion 3 (price fluctuation), allocate 67 points to (1) and 33 points to (3) in the pair 1 vs. 3. Do not use "0" to your pairwise comparisons. If you believe that one element is completely irrelevant in comparison to the other element of a pair, allocate 1 and 99 respectively.

Table 5

1		Vs.		2
1		Vs.		3
1		Vs.		4
2		Vs.		3
2		Vs.		4
3		Vs.		4

The Results:

Inconsistency Measure:

Level of confidence (Circle the appropriate number):

5: Very high 4: High 3: Medium 2: Low 1: Very Low

Sub-criterion: **Sustaining Time by Exploitable Reserves of China**
(According to the table given in the questionnaire assistant information)

Energy Alternatives:

1. **Coal**
2. **Petroleum**
3. **Natural Gas**
4. **Nuclear Energy Resources**
5. **Renewable Energy Resources**

Please allocate a total of 100 points to the table 6, representing your perceived percent about how many times the relative utility of one energy alternative is in comparison to the other energy alternative for the sub-criterion of "sustaining time by exploitable reserves of china" in China. The longer the sustaining time is, the more percentage should be given. For example, if you believe that energy alternative 1(coal) is twice as better as energy alternative 3 (natural gas), allocate 67 points to (1) and 33 points to (3) in the pair 1 vs. 3. Do not use "0" to your pairwise comparisons. If you believe that one element is completely irrelevant in comparison to the other element of a pair, allocate 1 and 99 respectively.

Table 6

1		Vs.		2
1		Vs.		3
1		Vs.		4
1		Vs.		5
2		Vs.		3
2		Vs.		4
2		Vs.		5
3		Vs.		4
3		Vs.		5
4		Vs.		5

The Results:

Inconsistency Measure:

Level of confidence (Circle the appropriate number):

5: Very high 4: High 3: Medium 2: Low 1: Very Low

Sub-criterion: **Sustaining Time by Proved Reserves of China**
(According to the table given in the questionnaire assistant information)

Energy alternatives:

1. **Coal**
2. **Petroleum**
3. **Natural Gas**
4. **Nuclear Energy Resources**
5. **Renewable Energy Resources**

Please allocate a total of 100 points to the table 7, representing your perceived percent about how many times the relative utility of one energy alternative is in comparison to the other energy alternative for the sub-criterion of "sustaining time by proved reserves of china" in China. **The longer the sustaining time is, the more percentage should be given.** For example, if you believe that energy alternative 1(coal) is twice as better as energy alternative 3 (natural gas), allocate 67 points to (1) and 33 points to (3) in the pair 1 vs. 3. Do not use "0" to your pairwise comparisons. If you believe that one element is completely irrelevant in comparison to the other element of a pair, allocate 1 and 99 respectively.

Table 7

1		Vs.		2
1		Vs.		3
1		Vs.		4
1		Vs.		5
2		Vs.		3
2		Vs.		4
2		Vs.		5
3		Vs.		4
3		Vs.		5
4		Vs.		5

The Results:

Inconsistency Measure:

Level of confidence (Circle the appropriate number):

5: Very high 4: High 3: Medium 2: Low 1: Very Low

Sub-criterion: **Sustaining Time by Proved Reserves of World**
(According to the table given in the questionnaire assistant information)

Energy alternatives:

1. **Coal**
2. **Petroleum**
3. **Natural Gas**
4. **Nuclear Energy Resources**
5. **Renewable Energy Resources**

Please allocate a total of 100 points to the table 8, representing your perceived percent about how many times the relative utility of one energy alternative is in comparison to the other energy alternative for the sub-criterion of "sustaining time by proved reserves of world**"** in China. **The longer the sustaining time is, the more percentage should be given.** For example, if you believe that energy alternative 1(coal) is twice as better as energy alternative 3 (natural gas), allocate 67 points to (1) and 33 points to (3) in the pair 1 vs. 3. Do not use "0" to your pairwise comparisons. If you believe that one element is completely irrelevant in comparison to the other element of a pair, allocate 1 and 99 respectively.

Table 8

1		Vs.		2
1		Vs.		3
1		Vs.		4
1		Vs.		5
2		Vs.		3
2		Vs.		4
2		Vs.		5
3		Vs.		4
3		Vs.		5
4		Vs.		5

The Results:

Inconsistency Measure:

Level of confidence (Circle the appropriate number):

5: Very high 4: High 3: Medium 2: Low 1: Very Low

Sub-criterion: **Easiness for Importing**

(According to the table given in the questionnaire assistant information)

Energy alternatives:

1. **Coal**
2. **Petroleum**
3. **Natural Gas**
4. **Nuclear Energy Resources**
5. **Renewable Energy Resources**

Please allocate a total of 100 points to the table 9, representing your perceived percent about how many times the relative utility of one energy alternative is in comparison to the other energy alternative for the sub-criterion of "easiness for importing**"** in China. **The bigger the times of world's production of China's production is, the more percentage should be given.** For example, if you believe that energy alternative 1(coal) is twice as much as energy alternative 3 (natural gas), allocate 67 points to (1) and 33 points to (3) in the pair 1 vs. 3. Do not use "0" to your pairwise comparisons. If you believe that one element is completely irrelevant in comparison to the other element of a pair, allocate 1 and 99 respectively.

Table 9

1		Vs.		2
1		Vs.		3
1		Vs.		4
1		Vs.		5
2		Vs.		3
2		Vs.		4
2		Vs.		5
3		Vs.		4
3		Vs.		5
4		Vs.		5

The Results:

Inconsistency Measure:

Level of confidence (Circle the appropriate number):

5: Very high   4: High   3: Medium   2: Low   1: Very Low

Sub-criterion: **Technology Maturity**
(According to the table given in the questionnaire assistant information)

Energy alternatives:

1. **Coal**
2. **Petroleum**
3. **Natural Gas**
4. **Nuclear Energy Resources**
5. **Renewable Energy Resources**

Please allocate a total of 100 points to the table 10, representing your perceived percent about how many times the relative utility of one energy alternative is in comparison to the other energy alternative for the sub-criterion of "technology maturity**"** in China. **The more mature the technology is, the more percentage should be given.** For example, if you believe that energy alternative 1 (coal) is twice as much as energy alternative 3 (natural gas), allocate 67 points to (1) and 33 points to (3) in the pair 1 vs. 3. Do not use "0" to your pairwise comparisons. If you believe that one element is completely irrelevant in comparison to the other element of a pair, allocate 1 and 99 respectively.

Table 10

1		Vs.		2
1		Vs.		3
1		Vs.		4
1		Vs.		5
2		Vs.		3
2		Vs.		4
2		Vs.		5
3		Vs.		4
3		Vs.		5
4		Vs.		5

The Results:

Inconsistency Measure:

Level of confidence (Circle the appropriate number):

5: Very high 4: High 3: Medium 2: Low 1: Very Low

Sub-criterion: **The Present Annual Production Structure of Energy Resources (According to the table given in the questionnaire assistant information)**

Energy alternatives:

1. **Coal**
2. **Petroleum**
3. **Natural Gas**
4. **Nuclear Energy Resources**
5. **Renewable Energy Resources**

Please allocate a total of 100 points to the table 11, representing your perceived percent about how many times the relative utility of one energy alternative is in comparison to the other energy alternative for the sub-criterion of "**the present annual production structure of energy resources"** in China. **The bigger the production percentage of one energy alternative is, the bigger percentage should be given to this energy alternative.** For example, if you believe that the production percentage of energy alternative 1(coal) is twice as much as that of energy alternative 3 (natural gas), allocate 67 points to (1) and 33 points to (3) in the pair 1 vs. 3. Do not use "0" to your pairwise comparisons. If you believe that one element is completely irrelevant in comparison to the other element of a pair, allocate 1 and 99 respectively.

Table 11

1		Vs.		2
1		Vs.		3
1		Vs.		4
1		Vs.		5
2		Vs.		3
2		Vs.		4
2		Vs.		5
3		Vs.		4
3		Vs.		5
4		Vs.		5

The Results:

Inconsistency Measure:

Level of confidence (Circle the appropriate number):

5: Very high 4: High 3: Medium 2: Low 1: Very Low

Sub-criterion: **Consumption Percentage for Types of Energy Resources of China (According to the table given in the questionnaire assistant information)**

Energy alternatives:

1. **Coal**
2. **Petroleum**
3. **Natural Gas**
4. **Nuclear Energy Resources**
5. **Renewable Energy Resources**

Please allocate a total of 100 points to the table 12, representing your perceived percent about how many times the relative utility of one energy alternative is in comparison to the other energy alternative for the sub-criterion of "**consumption percentage for types of energy resources of China"**. **The bigger the consumption percentage of one energy alternative is, the bigger percentage should be given to this energy alternative.** For example, if you believe that the consumption percentage of energy alternative 1 (coal) is twice as much as that of energy alternative 3 (natural gas), allocate 67 points to (1) and 33 points to (3) in the pair 1 vs. 3. Do not use "0" to your pairwise comparisons. If you believe that one element is completely irrelevant in comparison to the other element of a pair, allocate 1 and 99 respectively.

Table 12

1		Vs.		2
1		Vs.		3
1		Vs.		4
1		Vs.		5
2		Vs.		3
2		Vs.		4
2		Vs.		5
3		Vs.		4
3		Vs.		5
4		Vs.		5

The Results:

Inconsistency Measure:

Level of confidence (Circle the appropriate number):

5: Very high 4: High 3: Medium 2: Low 1: Very Low

Sub-criterion: **Consumption Percentage for Types of Energy Resources of World (According to the table given in the questionnaire assistant information)**

Energy alternatives:

1. **Coal**
2. **Petroleum**
3. **Natural Gas**
4. **Nuclear Energy Resources**
5. **Renewable Energy Resources**

Please allocate a total of 100 points to the table 13, representing your perceived percent about how many times the relative utility of one energy alternative is in comparison to the other energy alternative for the sub-criterion of "consumption percentage for types of energy resources of world". **The bigger the consumption percentage of one energy alternative is, the bigger percentage should be given to this energy alternative.** For example, if you believe that the consumption percentage of energy alternative 1 (coal) is twice as much as that of energy alternative 3 (natural gas), allocate 67 points to (1) and 33 points to (3) in the pair 1 vs. 3. Do not use "0" to your pairwise comparisons. If you believe that one element is completely irrelevant in comparison to the other element of a pair, allocate 1 and 99 respectively.

Table 13

1		Vs.		2
1		Vs.		3
1		Vs.		4
1		Vs.		5
2		Vs.		3
2		Vs.		4
2		Vs.		5
3		Vs.		4
3		Vs.		5
4		Vs.		5

The Results:

Inconsistency Measure:

Level of confidence (Circle the appropriate number):

5: Very high 4: High 3: Medium 2: Low 1: Very Low

Sub-criterion: **Price**
(According to the table given in the questionnaire assistant information)

Energy alternatives:

1. **Coal**
2. **Petroleum**
3. **Natural Gas**
4. **Nuclear Energy Resources**
5. **Renewable Energy Resources**

Please allocate a total of 100 points to the table 14, representing your perceived percent about how many times the relative utility of one energy alternative is in comparison to the other energy alternative for the sub-criterion of "price". **The lower the price of one energy alternative is, the bigger percentage should be given to this energy alternative.** For example, if you believe that the price of energy alternative 1(coal) is half of the price of energy alternative 3 (natural gas), allocate 67 points to (1) and 33 points to (3) in the pair 1 vs. 3. Do not use "0" to your pairwise comparisons. If you believe that one element is completely irrelevant in comparison to the other element of a pair, allocate 1 and 99 respectively.

Table 14

1		Vs.		2
1		Vs.		3
1		Vs.		4
1		Vs.		5
2		Vs.		3
2		Vs.		4
2		Vs.		5
3		Vs.		4
3		Vs.		5
4		Vs.		5

The Results:

Inconsistency Measure:

Level of confidence (Circle the appropriate number):

5: Very high 4: High 3: Medium 2: Low 1: Very Low

Sub-criterion: **Safety**
(According to the table given in the questionnaire assistant information)

Energy alternatives:

1. **Coal**
2. **Petroleum**
3. **Natural Gas**
4. **Nuclear Energy Resources**
5. **Renewable Energy Resources**

Please allocate a total of 100 points to the table 15, representing your perceived percent about how many times the relative utility of one energy alternative is in comparison to the other energy alternative for the sub-criterion of "safety**". The safer one energy alternative is, the bigger percentage should be given to this energy alternative.** For example, if you believe that energy alternative 1(coal) is as twice safe as energy alternative 3 (natural gas), allocate 67 points to (1) and 33 points to (3) in the pair 1 vs. 3. Do not use "0" to your pairwise comparisons. If you believe that one element is completely irrelevant in comparison to the other element of a pair, allocate 1 and 99 respectively.

Table 15

1		Vs.		2
1		Vs.		3
1		Vs.		4
1		Vs.		5
2		Vs.		3
2		Vs.		4
2		Vs.		5
3		Vs.		4
3		Vs.		5
4		Vs.		5

The Results:

Inconsistency Measure:

Level of confidence (Circle the appropriate number):

5: Very high 4: High 3: Medium 2: Low 1: Very Low

Sub-criterion: **Air Pollution**
(According to the table given in the questionnaire assistant information)

Energy alternatives:

1. **Coal**
2. **Petroleum**
3. **Natural Gas**
4. **Nuclear Energy Resources**
5. **Renewable Energy Resources**

Please allocate a total of 100 points to the table 16, representing your perceived percent about how many times the relative utility of one energy alternative is in comparison to the other energy alternative for the sub-criterion of "air pollution**"**. **The lighter the air pollution of one energy alternative is, the bigger percentage should be given to this energy alternative.** For example, if you believe that the air pollution of energy alternative 1(coal) is only half of that of energy alternative 3 (natural gas), allocate 67 points to (1) and 33 points to (3) in the pair 1 vs. 3. Do not use " 0" to your pairwise comparisons. If you believe that one element is completely irrelevant in comparison to the other element of a pair, allocate 1 and 99 respectively.

Table 16

1		Vs.		2
1		Vs.		3
1		Vs.		4
1		Vs.		5
2		Vs.		3
2		Vs.		4
2		Vs.		5
3		Vs.		4
3		Vs.		5
4		Vs.		5

The Results:

Inconsistency Measure:

Level of confidence (Circle the appropriate number):

5: Very high 4: High 3: Medium 2: Low 1: Very Low

Sub-criterion: **Water Pollution**

Energy alternatives:

1. **Coal**
2. **Petroleum**
3. **Natural Gas**
4. **Nuclear Energy Resources**
5. **Renewable Energy Resources**

Please allocate a total of 100 points to the table 17, representing your perceived percent about how many times the relative utility of one energy alternative is in comparison to the other energy alternative for the sub-criterion of "water pollution". **The lighter the water pollution of one energy alternative is, the bigger percentage should be given to this energy alternative.** For example, if you believe that the water pollution of energy alternative 1(coal) is only half of that of energy alternative 3 (natural gas), allocate 67 points to (1) and 33 points to (3) in the pair 1 vs. 3. Do not use "0" to your pairwise comparisons. If you believe that one element is completely irrelevant in comparison to the other element of a pair, allocate 1 and 99 respectively.

Table 17

1		Vs.		2
1		Vs.		3
1		Vs.		4
1		Vs.		5
2		Vs.		3
2		Vs.		4
2		Vs.		5
3		Vs.		4
3		Vs.		5
4		Vs.		5

The Results:

Inconsistency Measure:

Level of confidence (Circle the appropriate number):

5: Very high 4: High 3: Medium 2: Low 1: Very Low

Sub-criterion: **Land Disruption**

(According to the table given in the questionnaire assistant information)

Energy alternatives:

1. **Coal**
2. **Petroleum**
3. **Natural Gas**
4. **Nuclear Energy Resources**
5. **Renewable Energy Resources**

Please allocate a total of 100 points to the table 18, representing your perceived percent about how many times the relative utility of one energy alternative is in comparison to the other energy alternative for the sub-criterion of "land disruption". **The lighter the land disruption of one energy alternative is, the bigger percentage should be given to this energy alternative.** For example, if you believe that the land disruption of energy alternative 1(coal) is only half of that of energy alternative 3 (natural gas), allocate 67 points to (1) and 33 points to (3) in the pair 1 vs. 3. Do not use "0" to your pairwise comparisons. If you believe that one element is completely irrelevant in comparison to the other element of a pair, allocate 1 and 99 respectively.

Table 18

1		Vs.		2
1		Vs.		3
1		Vs.		4
1		Vs.		5
2		Vs.		3
2		Vs.		4
2		Vs.		5
3		Vs.		4
3		Vs.		5
4		Vs.		5

The Results:

Inconsistency Measure:

Level of confidence (Circle the appropriate number):

5: Very high 4: High 3: Medium 2: Low 1: Very Low

Sub-criterion: **Industrial Added Value**

(According to the table given in the questionnaire assistant information)

Energy alternatives:

1. **Coal**
2. **Petroleum**
3. **Natural Gas**
4. **Nuclear Energy Resources**
5. **Renewable Energy Resources**

Please allocate a total of 100 points to the table 19, representing your perceived percent about how many times the relative utility of one energy alternative is in comparison to the other energy alternative for the sub-criterion of "industrial added value". **The more the industrial added value of one energy alternative is, the bigger percentage should be given to this energy alternative.** For example, if you believe that the industrial added value of energy alternative 1(coal) is as twice as that of energy alternative 3 (natural gas), allocate 67 points to (1) and 33 points to (3) in the pair 1 vs. 3. Do not use "0" to your pairwise comparisons. If you believe that one element is completely irrelevant in comparison to the other element of a pair, allocate 1 and 99 respectively.

Table 19

1		Vs.		2
1		Vs.		3
1		Vs.		4
1		Vs.		5
2		Vs.		3
2		Vs.		4
2		Vs.		5
3		Vs.		4
3		Vs.		5
4		Vs.		5

The Results:

Inconsistency Measure:

Level of confidence (Circle the appropriate number):

5: Very high 4: High 3: Medium 2: Low 1: Very Low

Sub-criterion: **Employment**

(According to the table given in the questionnaire assistant information)

Energy alternatives:

1. **Coal**
2. **Petroleum**
3. **Natural Gas**
4. **Nuclear Energy Resources**
5. **Renewable Energy Resources**

Please allocate a total of 100 points to the table 20, representing your perceived percent about how many times the relative utility of one energy alternative is in comparison to the other energy alternative for the sub-criterion of "employment". **The more the employees of one energy alternative is, the bigger percentage should be given to this energy alternative.** For example, if you believe that the employees of energy alternative 1(coal) is as twice as that of energy alternative 3 (natural gas), allocate 67 points to (1) and 33 points to (3) in the pair 1 vs. 3. Do not use "0" to your pairwise comparisons. If you believe that one element is completely irrelevant in comparison to the other element of a pair, allocate 1 and 99 respectively.

Table 20

1		Vs.		2
1		Vs.		3
1		Vs.		4
1		Vs.		5
2		Vs.		3
2		Vs.		4
2		Vs.		5
3		Vs.		4
3		Vs.		5
4		Vs.		5

The Results:

Inconsistency Measure:

Level of confidence (Circle the appropriate number):

5: Very high 4: High 3: Medium 2: Low 1: Very Low

Sub-criterion: **Price Fluctuation**

(According to the table given in the questionnaire assistant information)

Energy alternatives:

1. **Coal**
2. **Petroleum**
3. **Natural Gas**
4. **Nuclear Energy Resources**
5. **Renewable Energy Resources**

Please allocate a total of 100 points to the table 21, representing your perceived percent about how many times the relative utility of one energy alternative is in comparison to the other energy alternative for the sub-criterion of "price fluctuation". **The less largely the fluctuation of the price of one energy alternative is, the bigger percentage should be given to this energy alternative.** For example, if you believe that the price of energy alternative 1 (coal) fluctuates as half largely as that of energy alternative 3 (natural gas), allocate **67** points to (1) and **33** points to (3) in the pair 1 vs. 3. Do not use "0" to your pairwise comparisons. If you believe that one element is completely irrelevant in comparison to the other element of a pair, allocate 1 and 99 respectively.

Table 21

1		Vs.		2
1		Vs.		3
1		Vs.		4
1		Vs.		5
2		Vs.		3
2		Vs.		4
2		Vs.		5
3		Vs.		4
3		Vs.		5
4		Vs.		5

The Results:

Inconsistency Measure:

Level of confidence (Circle the appropriate number):

5: Very high　4: High　3: Medium　2: Low　1: Very Low

Sub-criterion: **Others**

(According to the table given in the questionnaire assistant information)

Energy alternatives:

1. **Coal**
2. **Petroleum**
3. **Natural Gas**
4. **Nuclear Energy Resources**
5. **Renewable Energy Resources**

Please allocate a total of 100 points to the table 22, representing your perceived percent about how many times the relative utility of one energy alternative is in comparison to the other energy alternative for the sub-criterion of "other social impacts**"**. **The better the other social impacts of one energy alternative are, the bigger percentage should be given to this energy alternative.** For example, if you believe that the other social impacts of energy alternative 1(coal) are as twice good as that of energy alternative 3 (natural gas), allocate **67** points to (1) and **33** points to (3) in the pair 1 vs. 3. Do not use "0" to your pairwise comparisons. If you believe that one element is completely irrelevant in comparison to the other element of a pair, allocate 1 and 99 respectively.

Table 22

1		Vs.		2
1		Vs.		3
1		Vs.		4
1		Vs.		5
2		Vs.		3
2		Vs.		4
2		Vs.		5
3		Vs.		4
3		Vs.		5
4		Vs.		5

The Results:

Inconsistency Measure:

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