Eco-economic Evolution, Sustainable Development and Public Policy Options for Tibet of China

An Emergy Evaluation of Tibet

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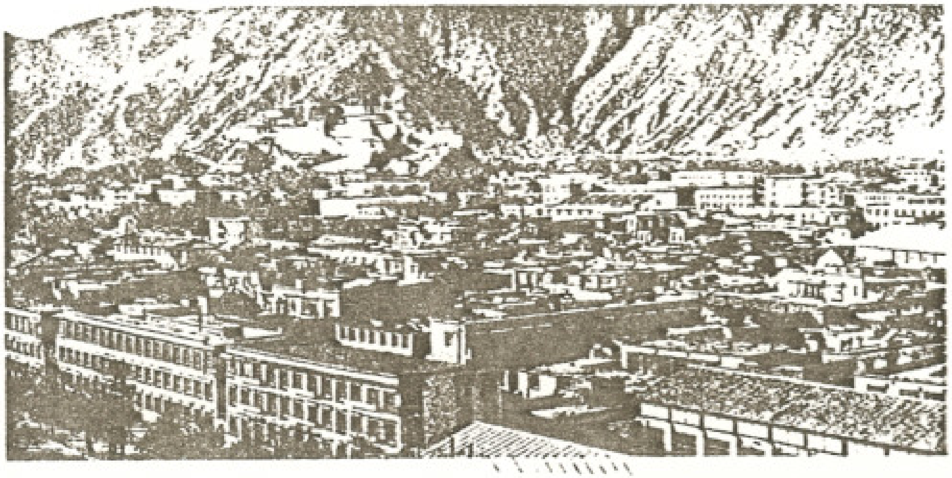

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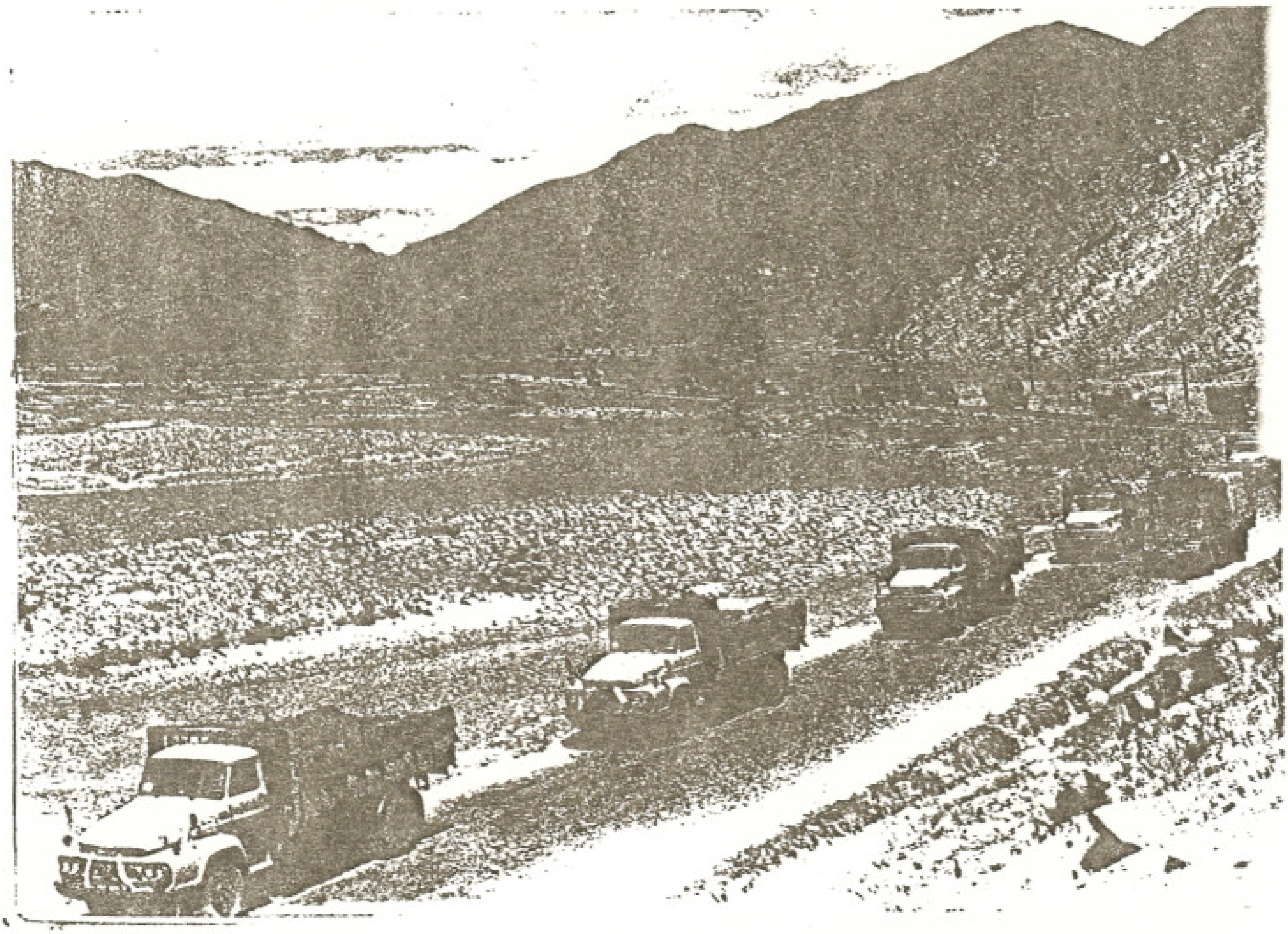
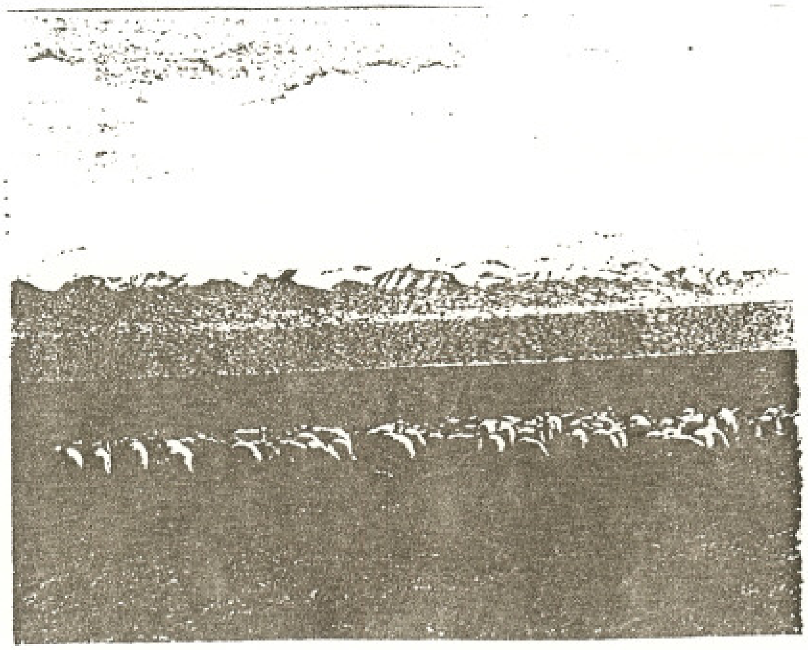
Overview of Lhasa,Capital of Tibet, the top building is Podala Palace



The busy Qinghai-Tibet highway. Most oil are imported through this highway from Golmund of Qinghai by Army in Tibet. Part of the oil is imported through pipeline from Golmund to Tibet.The train has reached Golmund where many materials are transferred to Tibet by truck.



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The grassland of North Tibet

The crop(Qingke), the main grain of Tibetans. Many agriculture technicians were imported to Tibet, which increased the creative emergy in Tibet

The People's Liberation Army in Tibet. Many important engineering project were built by Army in Tibet. They built 70% of Tibetan highway, 4 airports, 1200 kilometer oil import pipeline, 149 power plants and many state farms and factories.

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Yan Maochao* and H. T. Odum#

Abstract

As economies and ecological support systems become more interdependent, new disciplines are needed to "bridge the gap" of understanding between societies and nature. It is now clear that neither ecology nor economics alone can address the problems of our global commons. New measures of wealth, of value, of contributions and production are needed that acknowledge the "natural capital" and "ecosystem services" provided from healthy environments.

A new interface is now being recognized called"ecological economics". It is an ambitious and necessary attempt to understand the affairs of humanity and nature as a single, interdependent system. New tools are being invested to measure wealth, services and production fairly and equitably. In this report we use systems analysis approach to study the combined ecological-economic system of Tibet. We use an alternative measure of value, based on real contributions to system performance, termed EMERGY, spelled with an "M". It is a concept which quantifies"energy memory" in products and process. It is an accounting unit of total contributions, direct and indirect, used in generation of a product or service. It is a concept derived from understanding whole systems, their interactions and interdependence, and the resources driving and maintaining them.

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This broader approach will help us to investigate Tibetan resources utilization and potentialities and exchange. Emergy analysis allows comparison and incorporation of environmental costs and benefits with variables of traditional economic costs and benefits to provide a more comprehensive perspective for public policy directives. Through this researches, we think:

1)China has made a great effort in making Tibet develop from a closed regional system to a more and more opened regional system that are very important to the sustainable development of Tibet.

2)The increase of economic development and population increases has a close relationship with the total emergy storage and use in transportation. Education in modern science and technology increased the shared emergy of Tibetans to modern science and technology and stimulated the process of matching material and energy imports from outside with local resources.

3)There is great potential to develop hydropower and geothermal reserves that may stimulate not only economic development but also the better use of environment.

4)The better trained population can increase the empower of Tibet eco-economic system. Future development needs all kinds of talent exchanges with the outside system to develop education.

5)Compared with the Tibet economic system, Taiwan economic system is much more competitive. GNP and emergy use are very useful functions for comparing the competitiviblity of different ecological economic systems.

Key words: Emergy; eco-economic evolution; sustainable development

1. Introduction

Tibet--the name alone conjures up visions of mystery and fantasy, visions of spirituality, exotic and mysticism. On the face of it this cloud of mystery was not surprising. Because of its geographical isolation and lack of roads and modern communication networks for so many years, just like many mountain areas of China, Tibet escaped, for most part, the development opportunities in the world during the 18th, 19th centuries, and almost half century of 20th.

In 1950 Tibet was a primitive land with a feudal social structure and pre-industrial economy when it was a land of three great lack(fuel, communication, people) and of three abundances (poverty, oppression, belief in the supernatural). The estimated social background structure for the people were: nobility 5%; clergy 15%; herdsmen(nomads) 20%; serfs 60%. Those serfs were tied to the masters, they received the right to work the land in exchange for taxes and corvee labor. So powerless were they that they required permission to enter a monastery and even to marry. If two serfs of different lords married, male offspring reverted to the father's lord, while female offspring went to the mother's. Permission to leave the estate--even for the briefest period--for such matters as family visits etc. required the consent of the lord. Such consent was not readily given and usually come only after all the feudal obligations had been successfully completed.

Since Tibet was returned to the big family of motherland of China in 1951, Tibetan people under the leadership of Chinese Central Government began to survey the land, restructure the local governing organs, establish a network of transportation and communication facilities, and develop many kinds of industries. Great changes occurred through more than 40 year's development.

In order to understand its eco-economic evolution, resource utilization and potentialities and make recommendations for a sustainable future for Tibet, systems analysis was made of the economy of Tibet, its resources base of environmental flows, imports and exports. Several selected problems such as education, transportation within Tibet were also analyzed.

2. Overview of Tibet and its position in China

Tibet lies between 78-103 degrees east longitude and 27-39 degrees north latitude, thus place north of the subcontinent of India and South of the deserts and mountains of central Asia. Tibet is a stunning place, Predominantly a plateau, averaging 46500m. above sea-level, the elevation structure of Tibetan earth surface are listed in Tab.1.

Tab.1 The elevation structure of Tibet earth surface

Elevation (meter)	Percentage of total area(%)
Above 5500	19.7
5000--5500	25.9
4500--5000	32.1
4000--4500	8.4
3500--4000	6.0
3000--3500	2.4
2500--3000	1.2
Below 2500	4.3

Its landscape includes not only snow-covered mountains but also glaciers and green forests, grassland and salt lakes. It is surrounded by mountains: the Kunlun range in the north, the Hengduan in the east, the Himalayas in the south and Pamirs and Karakorum in the west. Those great mountains are the source of many of Asia's major rivers: the Tsangpo, which meanders first east and then south to become the Brahmaputra('son of Brahma'); the Mekong, which flows into Burma and Laos; the Salween ,which flows into Sichuan and Yunnan Provinces of China; the Sutlei into Pakistan; and the Indus flowing west into Ladakh. Because these great mountains and great rivers, there are great reserves of hydropower, about 17569.0 E+8 KWh/yr., which are 29.7% of China's total reserves. Because the great Tibet plateau, the hydropower reserves in Tibet, Sichuan and Yunnan are about 67% of China's hydropower reserves.

Tibet is a Autonomous Region of China, it includes 7 prefectures, 74 counties, 30 towns and 7570 villages, the total population in 1989 is 2159 thousands(Tab.2). Lhasa city is the capital of Tibet.

Tab.2 The administrative district of Tibet and its population

Prefecture	County	Town	Village	Land area (km^2)	% of total area	Pop. (E+2 Persons)	% of Population. Distribution
Lhasa	8	4	762	29052	2.37	3573	16.55
Linzhi	7	2	603	75802	6.17	1282	5.94
Changdo	11	9	1604	157100	12.79	4921	22.79
Shannan	12	2	899	118546	9.65	2817	13.05
Xigaze	18	10	1715	176000	14.33	5442	25.20
Nachu	11	2	1487	380000	30.93	2960	13.71
Ali	7	1	340	305000	24.83	596	2.76
Total(7)	74	30	7570	1228400	100	21591	100

There are rich resources in Tibet and some of its resources may play very important role in Tibet and China's sustainable development(Tab.3)

Tab.3 Population and resources of Tibet and China in 1989

Item	Tibet	China	Tibet/China(%)
1.Population (million persons)	2.16	1100	0.20
Population density (persons/km2)	1.76	115	1.53
2.Land (E+4 km2)	122.84	960.00	12.80
Arable land (E+4 ha)	22.27	9933.33	0.22
3.Forest (E+4ha)	632.00	12465	5.07
Forest coverage(%)	5.14	12.98	39.60
Wood storage(E+8m³)	14.36	105.72	13.58
4. Grassland(E+8 ha)	8293.3	31908	25.99
Explorable area (E+8 ha)	5580.7	22434	24.88
4.Hydrology			
1) Runoff in rivers (E+8m³/yr)	3959	26144	15.14
2)Lakes number(>1km²)	778	2305	33.75
3)Lakes area(km2)	25111	71787	34.98
4)Lakes water storage (E+8m³)	3472	7088	48.98
5)Water storage (E+8m³/yr)	4482.0	28124.4	15.94
6)Hydropower reserves (E+8KW.h/yr)	17569.00	59221.80	29.67
Explorable reserves (E+8kw.h/yr)	3300.48	19233.04	17.16
Developed hydropower (E+8kw.h/yr)	1.64	863.57	0.19
7.Mine & ore reserves			
Iron ore(E+8 ton)	3.23	497.31	0.65
NaCl reserves(E8 ton)	1.40	1241.0	0.11
Coal reserves(E+8 ton)	0.46	7276.11	0.01
Geothermal energy reserves(E+12 J/yr)	47535	111058	42.80
8.Average rainfall (mm/yr)	475	630	75.40

The total output value of agriculture and industries of Tibet was 2.92E+8 $ in 1989 which is just 0.07% of China's. There are not much ore in Tibet, until now, no petroleum and natural gas reserves being found, but its wood storage is 13.58% of China's, hydropower reserves is 29.7% of China's, yearly water storage is about 4482E+8m3/yr, which is 15.9% of China's; there are 778 lakes in Tibet, is 33.8% of total China's lakes, and its water storage about 3472E+8m3/yr, which is 48.98% of total water storage of Chinese lake; Tibet is very rich in geothermal energy, geothermal energy yield per year is about 47535E+12 J/yr, which is 42% of that of China. The land area of Tibet is 12.86% of China's. According to some experiment in Jiangzhi county of Tibet, the grain yield could reach 14250kg/ha which is highest unit yield in China. If the production environment could be changed, there are great potential to increase grain yield in Tibet and make a great progress in developing animal husbandry and industries.

Tibet play an very important military and strategic role to China's sustainable development. The length of the border line between Tibet and other countries are more than 3800 kilometer, in the past, it was a natural defense which kept China from other countries' invasion and aggression. With modern science and technology have enough ability to overcome those obstacles. Military armies with modern weapons from other countries controlling Tibet could be severe menace to inland China. Weapons of war such as missiles, aircraft etc which are still developing will have great empower in high plateau areas. Especially, Tibet plateau is very high and almost all the time its sky is clear, whereas, inland China is much lower with cloudy weather. The weapons delivered from high to low areas may have empower advantage. If Tibet were controlled by other countries' armies, China would have to establish a military defense and monitoring system at the foot of the high plateau, requiring much emergy from China. Defense spending would increase country's overhead costs. With relatively less defense expense, it easier for other countries to compete. The cost to the Chinese economy will be an unnecessarily large loss of emergy consumption, of raw resources, increases in taxes, loss of competitiveness, and an overall decline in the standard of living. This situation would make China lose competitive abilities and an international sphere of influence that are important to China's trading and sustainable development. Therefore, in the future, Tibet may become more and more important to China's military defense and sustainable development. This is a great feedback or return to the supports and aids provided by Chinese government.

3. The eco-economic system of Tibet

Ecology dominates the existence of the nomadic pastoralist of Tibet and prescribes the manners of living and the patterns of eco-economic systems to some extent. Tibetan have learned to survive in an extremely unfavorable environment. From topography and climate, two fundamental aspects of the Tibetan plateau, all secondary ecological influence derive. Topography is wholly causal, which lifted the Tibet plateau to heights which gives rise to its sobriquet "roof of the world", climate, however, results from topography, the characteristics of continental land mass, hemispheric wind patterns. The climate gives livestock distinctive characteristics, determines the materials used, and styles of shelter and clothing. It influences the manner in which fires are built, hearths are made, and food is cooked.

The open systems is much better and more competitive than the closed systems. The former has a close relationship with other region or systems to exchange materials, energy, goods, and talented persons. Through international or interstate exchange, a country or region can get outside resources to remedy its defect and make up for the shortages in its resources. Material and energy exchanges increase the operational efficiency of system. The total empower is increased by adding fuels to the local empower. This principle can be used to explain the evolution of Tibet since 1949. Since then, Chinese government had made a great efforts to develop transportation, education and science and technology and improve the exchanges with outside in Tibet, a macroscopic overview of Tibet is given in Figs.1 to 5.

Fig.1 and 2 shows the great efforts in transportation and education. Before 1949, there were no highway and automobile and only 2 schools in Tibet, through 40 year's efforts, the roads to Kathmandu, Nepal, Yunnan Province, Sichuan Province, Qinghai Province, and more remote areas of the region were constructed and the total highway grid numbered 90 with an aggregate length of about 22000 km, reaching into all the counties and prefectures, crossing 757 bridges and 10 ferries along the way(Fig.1).

Fig. 1 Highway and automobile development in Tibet

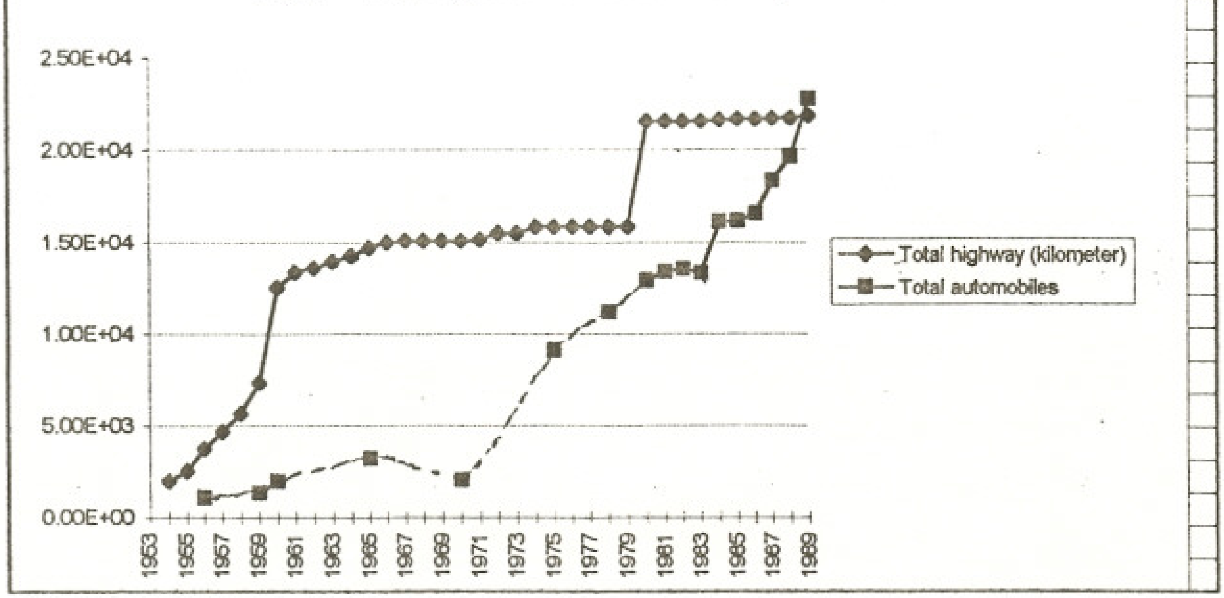
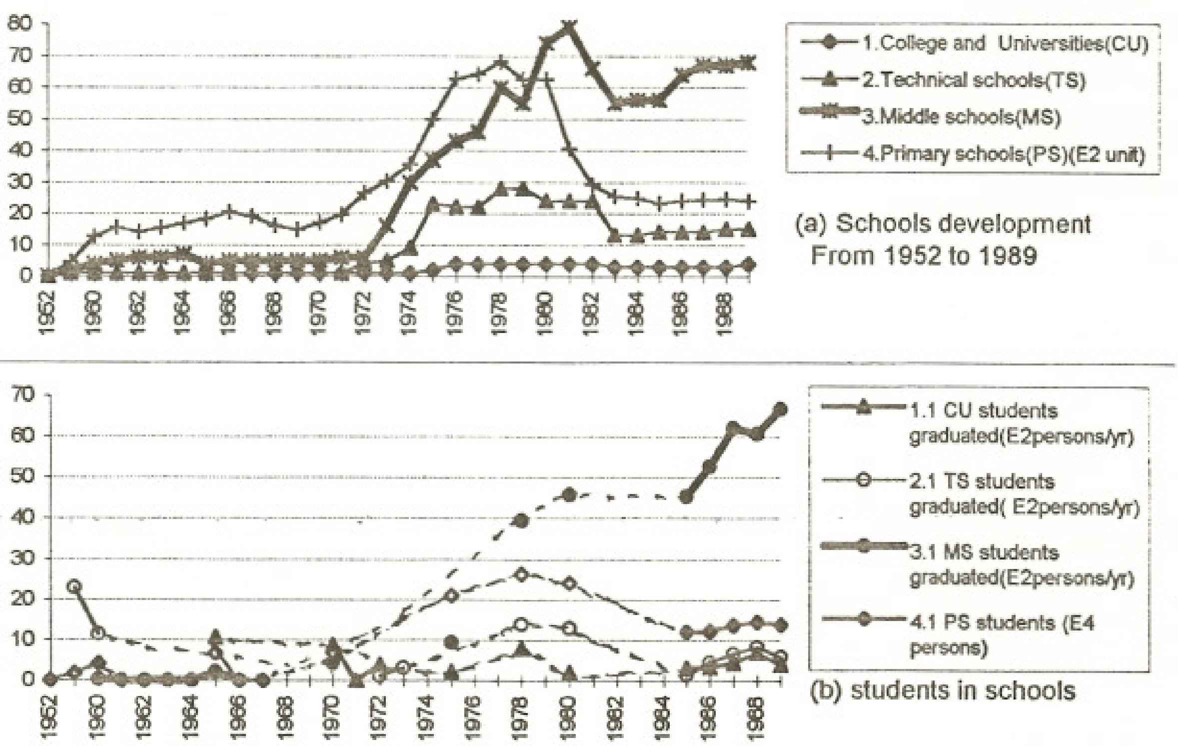


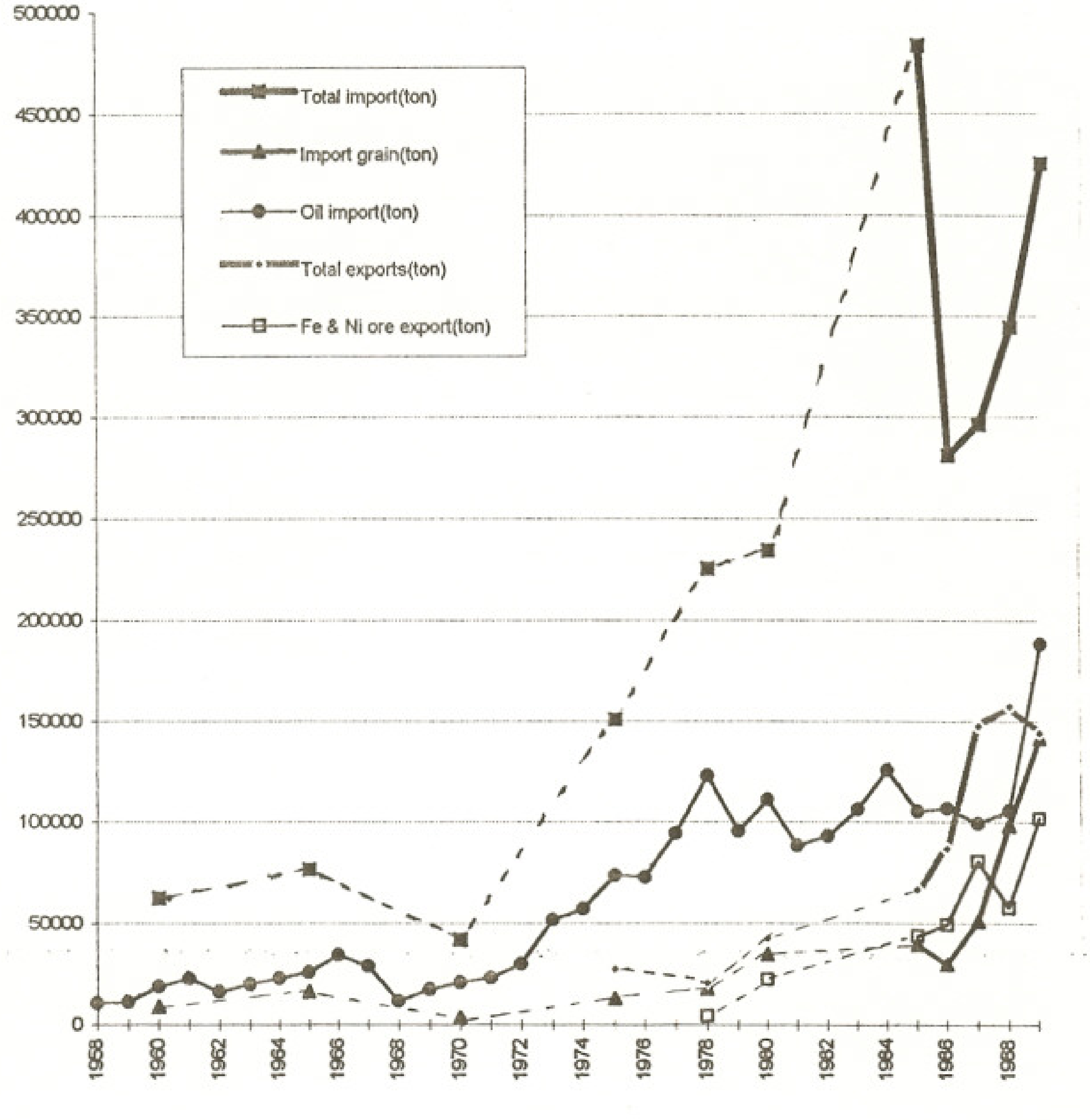
Fig.2 Education development in Tibet



There were only two formal schools in Tibet before 1949, after 1959 a high priority was set on the development of education, Fig.2 illustrates the gains for Tibet. Despite impressive gains, some problems and difficulties remain. In the urban areas, only 80% of eligible children attend schools; while in the rural areas only 30% or less.

Fig.3 shows the trend of material imports and exports from 1958 to 1989. Oil is main imports, a very important energy source for development of Tibetan industry.

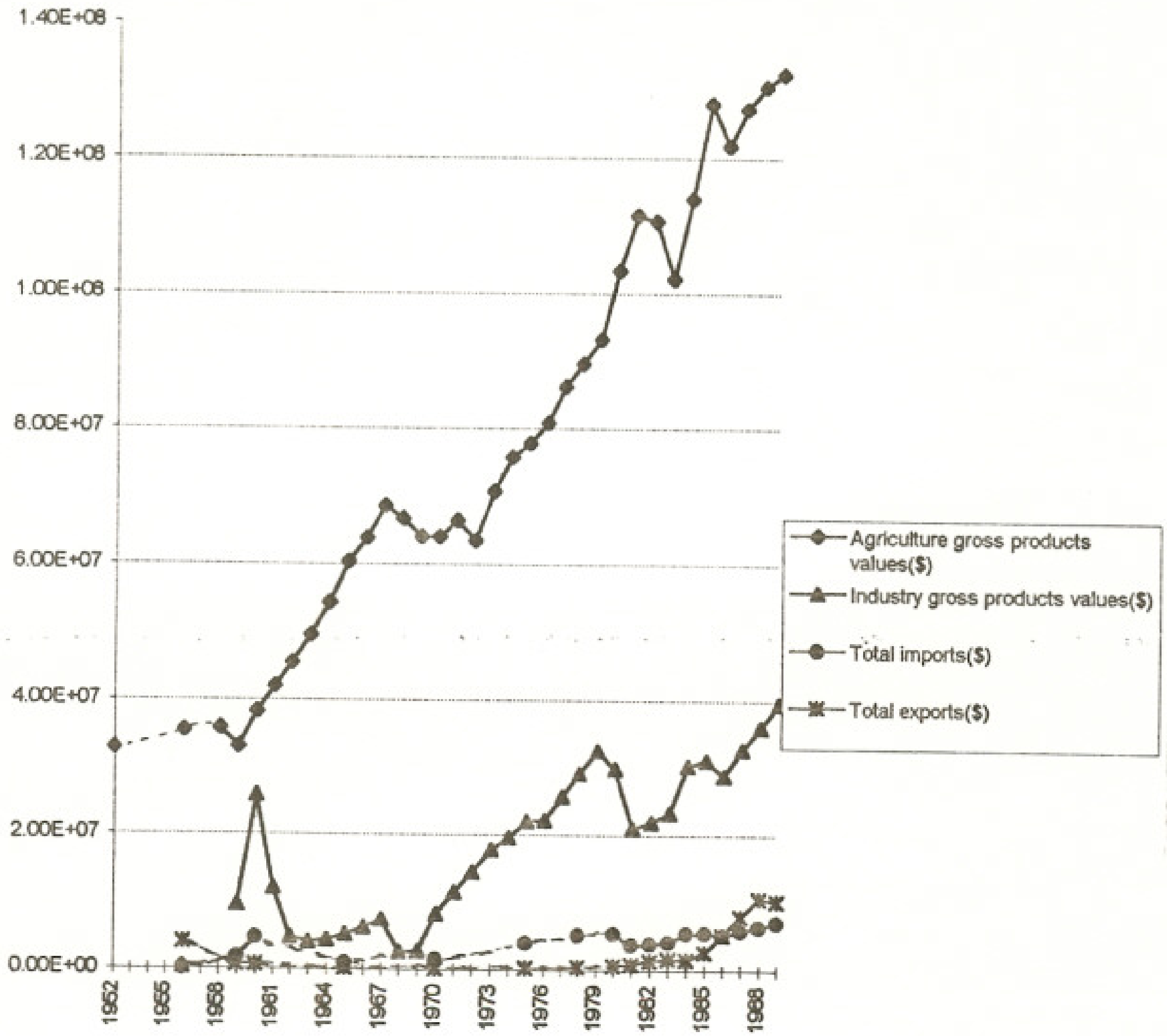
Fig. 3 Material exchanges in Tibet



Due to the shortage of energy and the constraints of transportation and science etc used in industry, industrial development expanded at a much slower rate. The output increased much slowly too. The road to industrialization is very uneven(Fig.4). By 1964, there were only 67 industrial enterprises (cement, tanneries, lumber mills, motorshops) established in Tibet and they were only small and medium-sized. In 1989, there were 268 industrial enterprises. Of those only 4 were medium-size; others were small size), 21% of those enterprises were in deficit.

Material exchanges with outside had a great increase which stimulated the development of agriculture and industries(Fig.3 and 4).

Fig.4 Development of agriculture and industries,export and import in Tibet from 1952 to 1989



Compared with what was before 1949, Tibet economy had great development. Health care improved much stimulating the increases of population after 1949(Fig.5). According to related historic population data, Tibetan population before 1949 had been oscillating around 1 million. The maximum population recorded in history were about 7 million 1200 years ago when Tibet was relatively flourishing. The local king had made great efforts to spread its territory and to control surrounding areas. Before liberation, Tibet was not a healthy place. Venereal disease was estimated to affect 90% of population, and smallpox afflict about one-third of population (including 13th Dalai Lama in 1900, and 7000 in Lhasa in 1927). Cataracts, leprosy (especially in Amdo and Kham) and gastro-intestinal diseases were chronic..

As shown by Fig.4 and Fig5, the agriculture and industry development apparently increased faster than the population between 1952 and 1989, and some people left countryside to find new job opportunities in the city or town, but the roads to transfer people to city or town for industrialization is very uneven, Fig.5 shows that the non-agricultural population increased very slowly in Tibet.

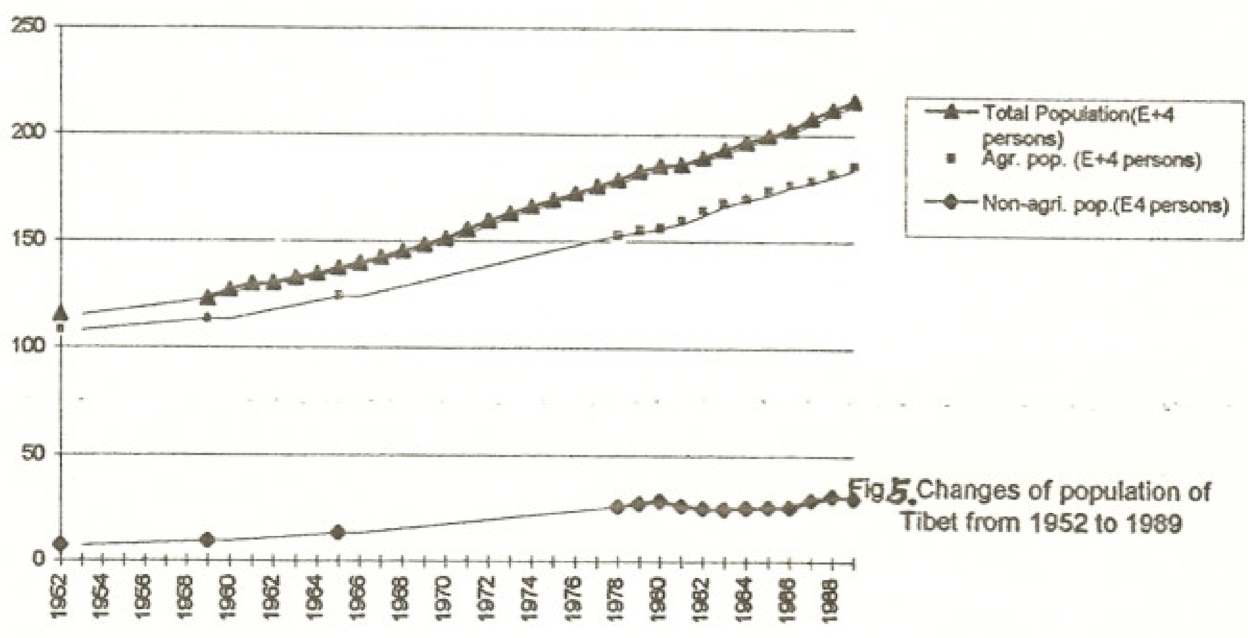


Fig.5. Changes of population of Tibet from 1952 to 1989

4.Emergy analysis of Tibet

An emergy system diagram of Tibet is given in Fig.6 for overview. Here environmental energies are diagrammed on the left-hand side of the diagram with high-quality energy flows and storage diagrammed at the right, concluding with cities as information processors whose action affect lower level production processes.

A detailed analysis for Tibet is given in Tables 4 to 6. A summary of the main emergy flows is given in Tables 7 to 8 and diagrammed in Fig.7. The emergy basis of the national or regional economy is considered in perspective of economic and environmental emergy contributions, self-sufficiency and trade. Indices of fuel use, renewable and purchased emergy use, import-export ratios are also presented in Table 7 and 8, to lend insight to the Tibet's emergy support basis. Their meaning is better discussed in section 6.

Total emergy use(U) for Tibet in 1989 was estimated at 2.45E+23sej/yr. The total annual emergy use by a nation or region measures its annual wealth. By dividing the annual Tibet emergy use by the GDP of Tibet in 1989, the solar emergy/money ratio was 6.26E+14 sej/$. This ratio is similar to other underdeveloped countries in the world.

The renewable environmental sources(R) are identified as rainfall and earth cycle. They account for 97.37% of total emergy use.The total emergy from independent sources supporting nature and economy of Tibet is calculated as the sum of free, renewable and mined, non-renewable environmental resources and the contribution of imported emergy that is used(usefully transformed) within Tibet.

Internal use of stored minerals and other geologic materials(N1) accounts for just about 0.08% of Tibet's annual emergy use. Almost all extracted minerals are used for exports and their processing within Tibet is negligible.

Among total imports of goods(G1), fuels(F1), associated human services,tourism and central government aids, central government direct aids constituted the 51.20% of the total emergy imports supporting Tibetan economy. The emergy in imported fuels(F1) and material goods(G1) represents about 0.56% of Tibet's annual total emergy use.

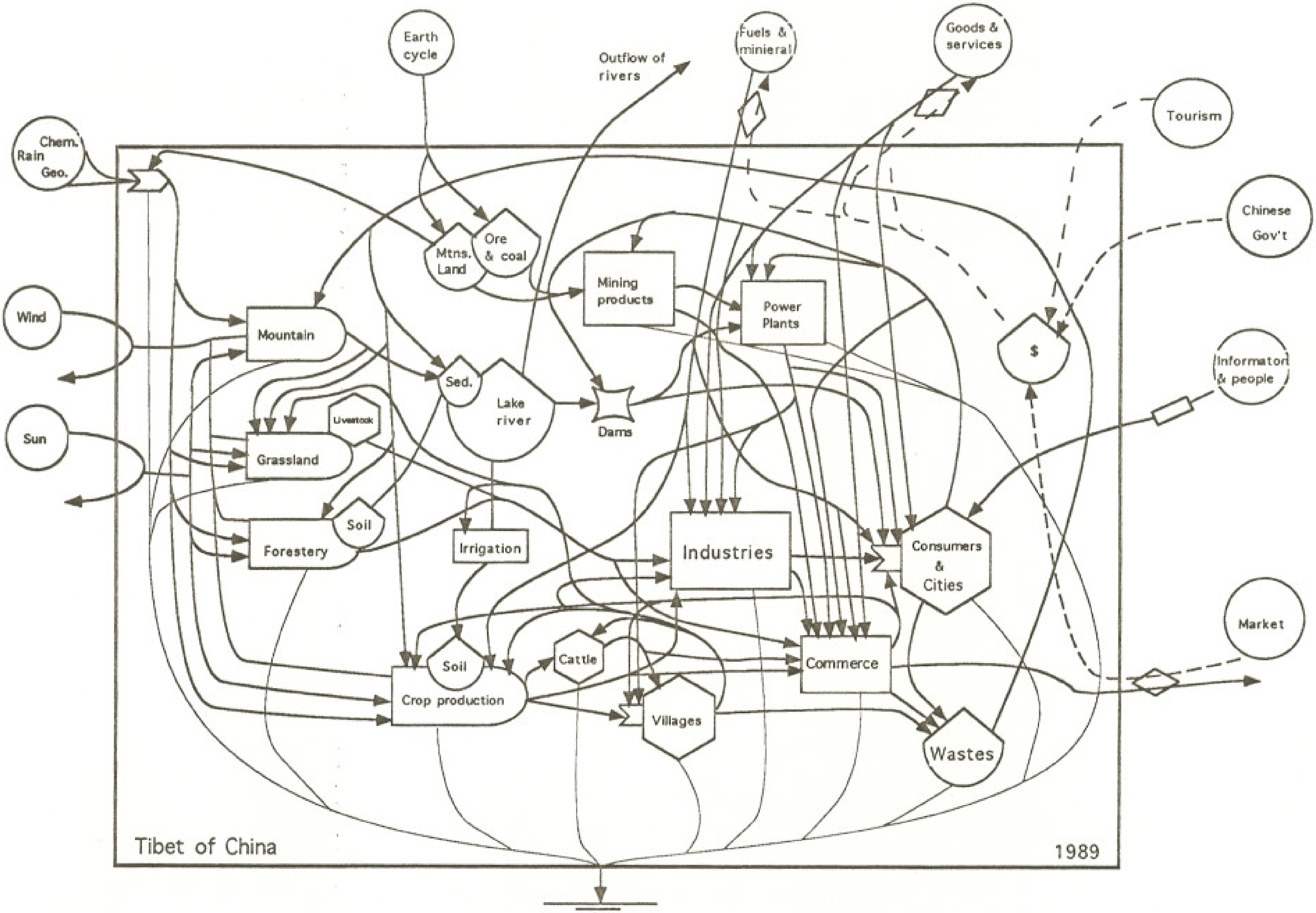


Fig.6 Emergy diagram of Tibet , 1989

Tab.4 The emergy evaluation of main resources flows in Tibet eco-economic system in 1989

Item	Raw data (J,g,or $)	Transformity (sej/unit)	Solar emergy (sej)	Mareconomic value(E8 US$)
Renewable resources				
1.Solar energy, J	6.36E+21	1	6.36E+21	7.34
2.Rain chaemical potential, J	1.30E+18	18200	2.37E+22	27.29
3.Rain geopotential energy, J	1.25E+19	10488	1.31E+23	151.21
4.Wind kinetic energy, J	1.16E+21	1496	1.74E+24	2001.57
5.Earth cycle, J (steady uplift balanced by erosion)	3.69E+18	29000	1.07E+23	123.43
Indigenous renewable products				
6.Hydropower, J	9.90E+14	2.00E+05	1.98E+20	0.23
7.Wood products, J	2.41E+18	34900	8.41E+22	97.01
8.Crop production, J	8.51E+15	154637	1.32E+21	1.52
A. Grain products, J	7.83E+15	147524	1.16E+21	1.33
1)Rice, J	4.28E+13	35900	1.54E+18	0.0018
2)Wheat, J	1.85E+15	68000	1.26E+20	0.15
3)Qingke(like wheat), J	4.73E+15	68000	3.22E+20	0.37
4)Beans, J	9.98E+14	690000	6.89E+20	0.79
5)Corn & other grain, J	2.14E+14	85178	1.82E+19	0.02
B.Other crops products, J	6.75E+14	2.37E+05	1.60E+20	0.18
6)Vegetable oil, J	2.14E+14	690000	1.48E+20	0.17
7)Vegetables, J	3.52E+14	27000	9.50E+18	0.01
8)Fresh feeding crops, J	1.09E+14	27000	2.94E+18	0.003
9.Fruit(apples etc), J	1.17E+13	530000	6.20E+18	0.01
10.Livestock, J	1.45E+15	2815310	4.08E+21	4.71
1)Meat, J	4.15E+14	2.00E+06	8.30E+20	0.96
2)Milk, J	4.15E+14	2.00E+06	8.30E+20	0.96
3)Eggs, J	6.50E+12	2.00E+06	1.30E+19	0.01
4)Wool, J	4.93E+14	4.40E+06	2.17E+21	2.50
5)Leather and other livestock prod. J	1.20E+14	2.00E+06	2.40E+20	0.28
11.Fisheries, J	7.05E+11	2.00E+06	1.41E+18	0.00163
Non-renewable sources mined or used within Tibet				
12.Coal , J	1.47E+14	3.98E+04	5.85E+18	0.01
13.Electricity(using coal), J	2.73E+09	2.00E+05	5.46E+14	0.00
14.Ni &Fe ore, g	8.7E+10	8.55E+08	7.44E+19	0.09
15.Gold, g	10394	4.40E+14	4.57E+18	0.01
16. Salt, g	1.00E+09	1.00E+09	1.00E+18	0.00
17.Other ore(B &Mg), g	1.84E+10	1.00E+09	1.84E+19	0.02
18. Loss of topsoil, J	3.97E+16	62500	2.48E+21	2.86

Tab.5 Emergy evalution of commodities trade for Tibet,1989

tem	Raw units	Transformity (sej/unit)	Solar emergy (sej)	Macroeconomic value(E4 US$)
Import and outside sources				
1.Oil	7.88E+15 J/yr	5.30E+04	4.18E+20	4817.07
2.Grain	3.90E+15 J/yr	1.48E+05	5.75E+20	6636.05
3.Vegetable oil	1.30E+14 J/yr	6.90E+05	8.97E+19	1034.60
4. Wood	3.46E+14 J/yr	3.49E+04	1.21E+19	139.28
5.Mech.&transport equip.	4.72E+09 g/yr	1.25E+10	5.90E+19	680.51
6.Steel	3.61E+10 g/yr	4.65E+09	1.68E+20	1936.16
7.Copper	5.60E+07 g/yr	6.80E+10	3.81E+18	43.92
8.Aluminum	2.00E+07 g/yr	1.63E+10	3.26E+17	3.76
9.Lead	5.60E+07 g/yr	1.25E+10	7.00E+17	8.07
10.Zinic	4.20E+07 g/yr	1.25E+10	5.25E+17	6.06
11.Cement	3.32E+07 g/yr	1.00E+09	3.32E+16	0.38
12.Chemicals	2.92E+07 g/yr	3.80E+08	1.11E+16	0.13
13.Fertilizer	1.35E+10 g/yr	4.88E+09	6.59E+19	759.88
1)Nitrogen,N	5.31E+09 g/yr	4.62E+09	2.45E+19	282.96
2)Phosphate.P_2O_5	1.87E+09 g/yr	6.88E+09	1.29E+19	148.39
3)Potassium, K_2o	2.52E+08 g/yr	2.96E+09	7.46E+17	8.60
4)Mutifertilizer	6.03E+09 g/yr	4.60E+09	2.77E+19	319.93
14.Aids from central govern.	2.21E+08 $/yr	8.67E+12	1.92E+21	22100.00
14. Other imports & service	5.01E+07 $/yr	8.67E+12	4.34E+20	5010.00
15.tourism	1.80E+06 $/yr	2.50E+12	4.50E+18	51.90
Export			3.22E+20	3714.67
1.Wood	3.68E+14 J/yr	3.49E+04	1.28E+19	148.13
2.Wool	4.95E+13 J/yr	4.40E+06	2.18E+20	2512.11
3.Medical products	3.23E+06 g/yr	2.07E+11	6.69E+17	7.71
4.Nickle and iron ore	5.00E+09 g/yr	1.00E+09	5.00E+18	57.67
5.Oil	1.49E+13 J/yr	5.30E+04	7.90E+17	9.1084
6.Goods	8.68E+05 $/yr	1.45E+13	1.26E+19	144.95
7.Other exports and service	5.00E+06 $/yr	1.45E+13	7.24E+19	834.98

Footnote: The item 1 to 5 in export products earned 1.63E+7$, and the emergy value of those product is is 2.37E20 sej, so the emergy/$ ratio is 1.45E+13 sej/$. Other goods and exports and service use this emergy/$ ratio to evaluate emergy values.

Tab6 Money flows and wastes flows for Tibet,1989

Item	Resources flows	Transiformity	Solar emergy(Sej)	Macrovalue (E8 US$)
Money flows				
1.GDP(1989)	3.90E+08 $/yr	8.67E+12	3.38E+21	3.90
2.Goods imports(exc. 3 to 5)	1.16E+08 $/yr	8.67E+12	1.00E+21	1.16
3.Tourism imports	1.80E+06 $/yr	2.50E+12	4.50E+18	0.01
4.Central govern. aid	2.21E+08 $/yr	8.67E+12	1.92E+21	2.21
5.Other imports & services	5.01E+07 $/yr	8.67E+12	4.34E+20	0.50
6.Goods expts(exec. 7 below)	1.70E+07 $/yr	1.45E+13	2.46E+20	0.28
7. Service & other exports	5.00E+06 $/yr	1.45E+13	7.24E+19	0.08
Wastes flows			1.24E+20	0.143
8.Liquid wastes	9.7E+12 J/yr	665714	6.46E+18	0.007
9.Industries solid wastes	6.541E+13 J/yr	1800000	1.18E+20	0.136

Tab.7 Summary of major solar emergy flows and market economic monetary flows for Tibet, 1989

Variable	Item	Solar emergy (sej/yr)	Market vale (US$,1989)	Em./$ ratio (sej/$)
R	Renewable sources[1]	2.38E+23		
N	Nonrenewable sources within Tibet	2.92E+21		
	No Dispered rural sources[2]	2.48E+21		
	N1 Concentrated use[3]	1.98E+20		
	N2 Export of unprocessed raw materials[4]	2.37E+20		
F1	Imported fuels & fertilzers	4.84E+20	5.61E+07	
G1	Imported goods(exc. fuel & ferti.)	9.09E+20	5.98E+07	
IMP	Total imports(including tourism and servicce and aids)	3.75E+21	3.89E+08	
F2	Exported fuels	7.90E+17	1.03E+05	
M2	Exported minerals	5.00E+18	6.13E+05	
G2	Agriculture products and medical raw products	2.31E+20	1.54E+07	
EXP	Total exports(including other goods and service)	3.22E+20	2.70E+07	
X	Gross Domestic Product, 1989(5.6YMB/US$)		3.90E+08	
P2	China solar emergy/$ index[5]			8.67E+12
P1	Tibet solar emergy/$ index			6.26E+14

Fotenote to Tab. above:

1)Solar emergy contributions from rainfall, and earth cycle. Other renewable sources are accounted in this summation---since they are coupled, global flows, their solar transformities share global solar emergy flux.

2)Net topsoil loss.

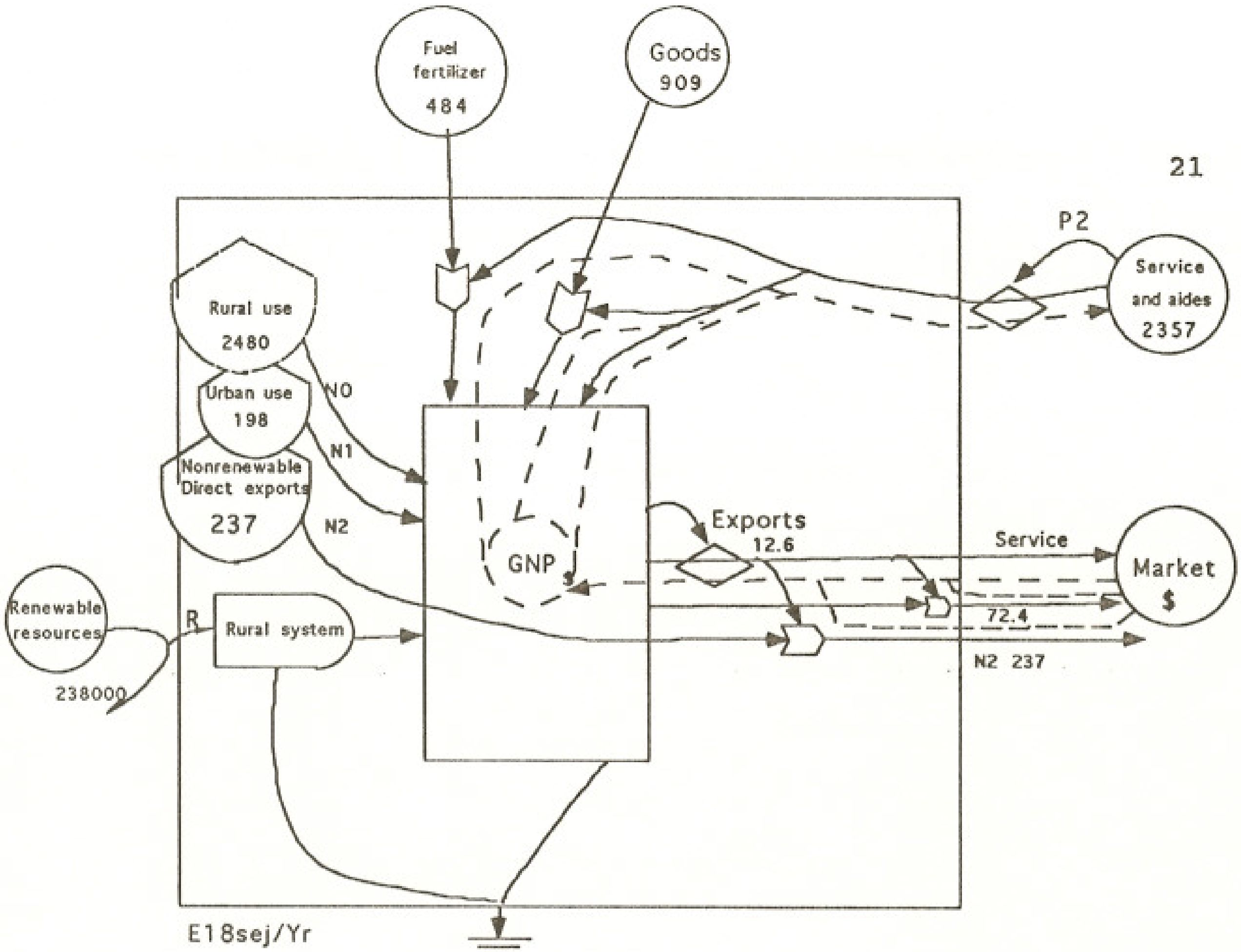
3)Electricity generation.

4)Mined minerals and wood, wool and medical raw products.

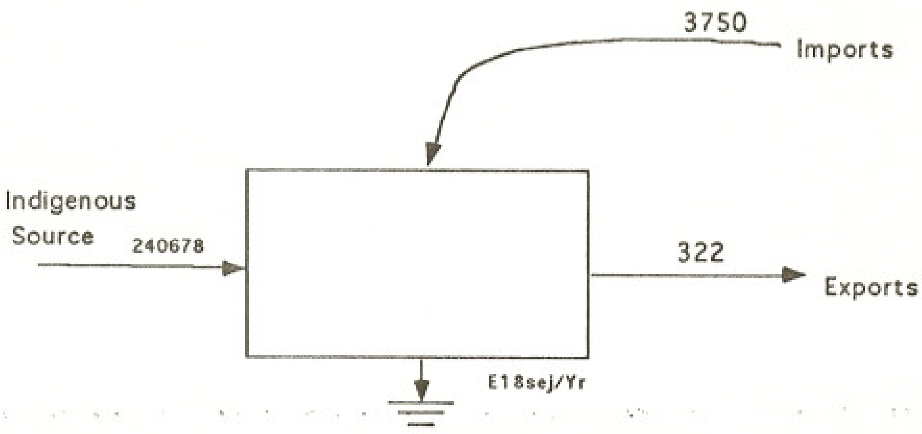
5)From Odum and S. Lan, 1990.

Tab.8 Emergy indices for overview of Tibet, 1989

Item	Name of index	Expression	Quantity or ratio(unit)
1	Renewable emergy flow	R	2.38E+23 sej/yr
2	Nonrenewable sources from Tibet	N	2.92E+21 sej/yr
3	Flow of imported emergy	IMP	3.75E+21 sej/yr
4	Total emergy inflows	R+N+IMP	2.45E+23 sej/yr
5	Total emergy used, U	No+N1+R+IMP	2.45E+23 sej/yr
6	Total exported emergy	EXP	3.22E+20 sej/yr
7	Fraction of emergy used derived from home sources	(No+N1+R)/U	98.47%
8	Imported minus exports	IMP-EXP	3.43E+21 sej/yr
9	Ratio of exports to imports	EXP/IMP	8.59%
10	Fraction used, locally renewable	R/U	97.37%
11	Fraction of use purchased	IMP/U	1.53%
12	Fraction of use that is free	(R+No)/U	98.39%
13	Concentrated/renewable ratio	N1/R	0.08%
14	Emergy investment ratio(emergy import/environment)	IMP/(R+N)	0.02
15	Emergy use per unit area	U/area	1.99E+11 sej/m^2
16	Emergy use per person	U/population	1.13E+17 sej/person
17	Carrying capacity at same living standard using renewable resources	(R/U)population	210.32 E4 persons
18	Developed carrying capacity at same living standard	8(R/U)(populati.)	1682.58 E4 persons
19	Ratio of electricity to use	Electricity/U	0.08%
20	Electricity use per person	Electricity/pop.	9.17E+13 sej/person
21	Fuel & fertilizer use per person	F/population	2.24E+14 sej/person
22	Ratio of emergy use to GDP	P1=U/GDP	6.26E+14 sej/$
23	Fractiont of wastes to renewable sources emergy	W/R	0.00052
24	Fraction of wastes to total emergy used	W/U	0.00051
25	Fraction of wastes to GDP	W/GDP	3.18E+11
26	Emergy investment ratio	U/R	1.03



(a)



(b)

Fig 7 Sumary of Emergy Flows of Tibet in 1989

Including use of internal storage of minerals and free environmental contribution, 98.5% of the emergy utilized annually by Tibet is derived from home sources, while 1.5% of Tibetan emergy use comes from purchased goods, fuel, services and tourism from outside. The ratio of import emergy to export emergy is 11.64, import emergy is much more than its exports emergy, Fig.8 shows Tibetan exchange with main economy of China and its adjacent countries.

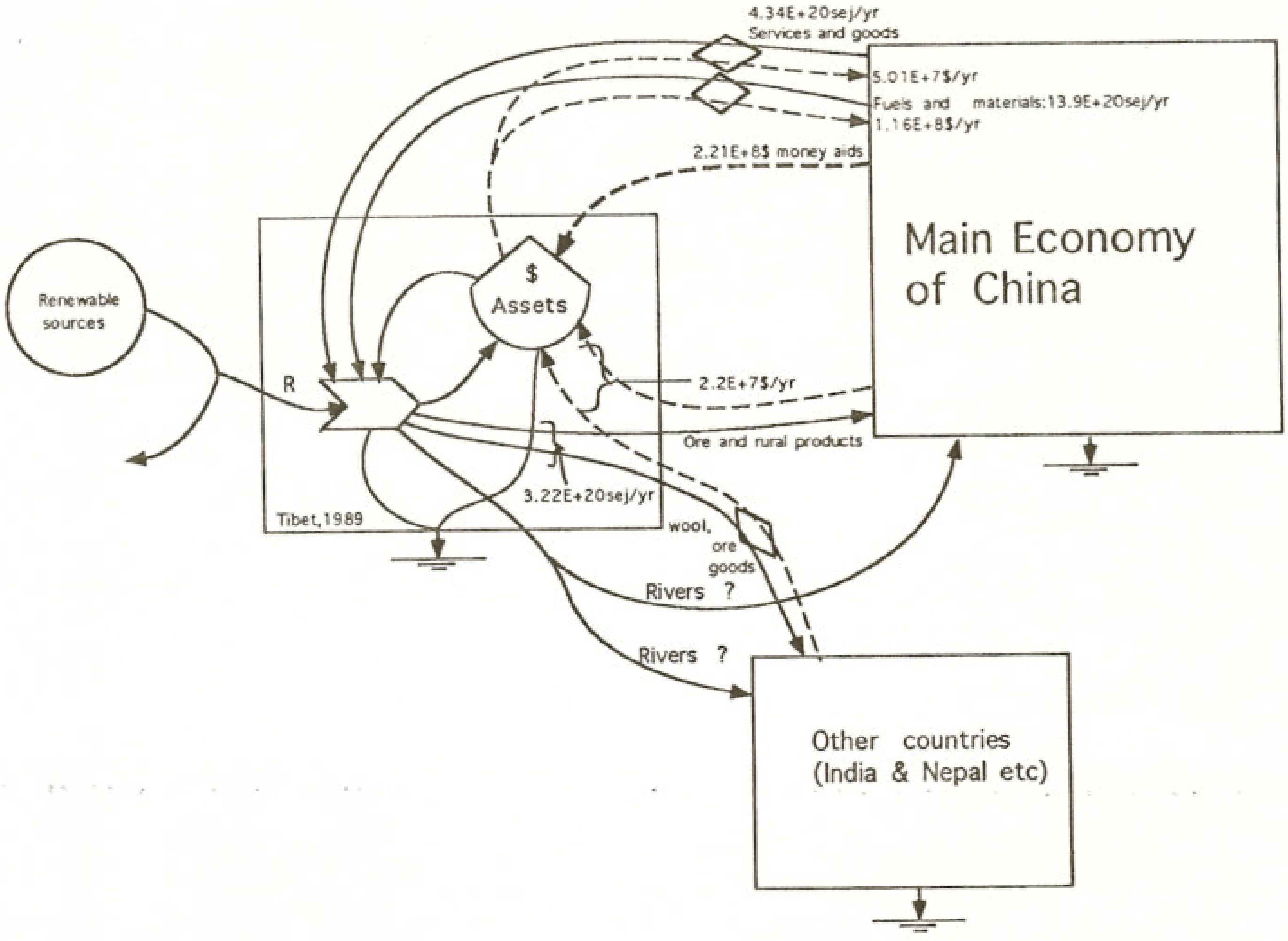


Fig.8 Exchanges with main economy of China and adjacent countries

5. Emergy evaluation of indigenous resources reserves

Tibet has large resources reserves, some resources such as hydropower reserves and geothermal energy reserves are very important to in China. The macrovalue of these renewable reserves is 1245.17E+8$/yr, which is almost 320 times great than the current GDP of 3.9E+8US$. The macrovalue of non-renewable resources(ore) and wood reserves is 3854.63E+8US$,which is almost 1000 time greater than the current GDP of Tibet. At present the transportation is difficult, and some ore deposit is deep, so the net yield would be less. Some economic assets, particularly infrastructure have long use times(Table 9).

Tab.9 Emergy evaluation of resource reserves of Tibet, 1989

Type of energy	Storage	Transformity (sej/unit)	Solar emergy(sej)	Macrovalue(E+8$)
A: Ore and wood reserves			3.34E+24	3854.63
1.Coal reserves	1.943E+17 J	39800	7.73E+21	8.92
2. Iron ore	3.23E+14 g	8.55E+08	2.76E+23	318.53
3. Nickle and Iron ore	4.405E+12 g	1.00E+09	4.41E+21	5.08
4.Copper(ore)	1.158E+15 g	1.00E+09	1.16E+24	1335.64
5.Boron ore(B_2O_3)	1.238E+12 g	1.00E+09	1.24E+21	1.43
6.Peat	1.749E+17 J	19000	3.32E+21	3.83
7.Gypsum	1.22E+15 g	1.00E+09	1.22E+24	1407.15
8.Graphite ore	2.437E+12 g	1.00E+09	2.44E+21	2.81
9. Salt	1.4E+14 g	1.00E+09	1.40E+23	161.48
10.Wood biomass	1.51E+19 J	34900	5.29E+23	609.76
B: Renewable resources reserves			1.08E+24	1245.17
11.Water reserves	1.793E+18 J/yr	41068	7.36E+22	84.92
12.Geothermal energy reserve:	4.75E+16 J/yr	6100	2.90E+20	0.33
13.Hydropower reserves	6.325E+18 J/yr	159000	1.01E+24	1159.92
C: Other reserves			2.14E+24	2472.19
14.Economic assets($)	7.8E+09 $	8.67E+12	6.76E+22	78.00
15.Population(person-years)	6.70E+07 per-yr,	3.1E16sej/py	2.08E+24	2394.19

6. Indices based on emergy

Results from emergy analysis clearly display their potential if the area under study is compared with other different nations or region. In this way one can evaluate the position of the country or area in the world's hierarchy of nations. Emergy indices can be used to compare the technological and financial development, resources use (environmental impact and conversion efficiency), long-term sustainablity for the system as a whole, and equity in trade with other countries.

Emergy use to an area or country and emergy use per person suggest a measure of standard of life in a country more effectively than just fuel use per person. Here standard of life should be intended as availability of resources and goods, availability of real stuff. It cannot be considered a measure of quality of life in the social sense(less crime, more happiness, higher level of culture etc). Very often the two effects are linked and it is not easy to have the latter(quality of life) without the former(availability of goods). Emergy-use index takes into account the different quality of inputs joules and also includes renewable as well as non-renewable environmental resources, usually neglected in energy balances. These indices allow a more complete evaluation of country's real standard of living and make it easier to compare developed and developing countries; in fact, these latter are very often supported by large inputs of environmental emergy. Annual emergy use per person in Tibet was 113.43E15sej, it was much higher than many countries(Table 10). It shows there exist great potential to develop in the future.

Table 10 Emergy use, population and per capita emergy use for Tibet and other selected countries[a]

Nation or Region	Emergy uesd (E+20sej/yr)	Population (E+6 persons)	Emergy per capita (E15 sej/person/yr)
Tibet(A part of China)	**2450**	**2.16**	**113.43**
Australia	8850	15	59.00
Sweden	4110	8.5	48.35
Papua New Guinea	1216	3.5	34.74
USA	66400	227	29.25
Netherlands	3702	14	26.44
New Zealand	791	3.1	25.52
Liberia	465	1.3	35.77
Italy	12650	57.51	22.00
Soviet Union	43150	260	16.60
Brazil	17820	121	14.73
Dominica	7	0.08	8.75
West Germany	8027	62	12.95
Japan	15300	121	12.64
Switzerland	733	6.37	11.51
Ecuador	1029	9.6	10.72
Taiwan(A part of China)	2137	20.16	10.60
Poland	3305	34.5	9.58
China	71900	1100	6.54
Spain	2090	134	1.56
World	202400	5250	3.86
Thailand	1590	50	3.18
India	6750	630	1.07

a) Data for countries are based on revised national analyses from Odum and Odum(1983), excep papua New Guinea(Doherty et al.,1992), Thailand(Brown and McClanahan,1992),Sweden(Doherty et al.,1991), Taiwan(Huang and Odum,1991), Ecuador(Odum and Arding,1991), and Italy(S.Ulgiati and Odum et al.,1994)

The environmental loading ratio is the ratio of purchased and non-renewable indigenous emergy to free environmental emergy. It is like the "load" on an electric circuit. A large ratio suggests a high technological level in emergy use as well as a high level of environmental stress. The ratio of economic component(emergy use other than free renewable) to environmental component is just 0.03 to 1 for Tibet(Table 11). This ratio is much lower than many countries in the world.

Table 11 Environmental and economic components of annual emergy use for Tibet and other selected countries of World[a]

Nation or Region	Environ. component (E+20sej/yr) A	Economic component (E+20sej/yr) B	Environmental loading ratio B/A
West Germany	193	8027.0	41.59
Poland	159	3145.6	19.78
Netherlands	219	3483.0	15.90
Italy	1207.62	11442.1	9.47
Taiwan(A part of China)	213	1924.0	9.03
Switzerland	86.8	646.0	7.44
Spain	255	1835.0	7.20
USA	8240	58160.0	7.06
Sweden	511	3597.0	7.04
Dominica	1.8	4.8	2.67
World	94000	108000.0	1.15
Thailand	779	811.0	1.04
India	3340	3410.0	1.02
Soviet Union	9110	9110.0	1.00
Australia	4590	3960.0	0.86
New Zealand	438	353.0	0.81
Brazil	10100	7600.0	0.75
Ecuador	891	483.0	0.54
Tibet(A part of China)	**2380.0**	**64.3**	**0.03**
Papua New Guinea	1052	163.0	0.15
Liberia	427	38.0	0.09

a) See footnote in Table 10.

The emergy/money ratio is the ratio of the total emergy used by the country from all sources divided by the gross national product(GNP) for that year. It includes emergy used in renewable environmental resources as well as non-renewable environmental resources used up, such as fuel reserves and organic matter in soil. It also includes the emergy content of imported resources, goods and services. Rural countries or regions have a higher emergy/dollar ratio because more of their economy involves direct use of environmental resources not paid for. Developed countries, even when driven by large inputs of solar emergy, usually show a low emergy/dollar ratio(Table 12), signaling of a fast money circulation(large value of GNP). These countries are generally favored in buying resources from outside, because emergy embodied in money paid for is less than emergy purchased. Tibet is a landlocked area, the money and material circulation is slow, so its emergy/dollars ratio is very high.

Table 12 Emergy use, Gross National Products(or GDP) and Emergy/GNP indices for Tibet and other selected countries of the world [a]

Nation or Region	Total emergy (E+20sej/yr)	GNP or GDP (E+9US$/yr)	Emergy use/GNP(or GDP) (E12 sej.US$)
Tibet(A part of China)	**2450**	**0.39**	628.21
Papua New Guinea	1216	2.6	46.77
Liberia	465	1.34	34.70
Dominica	7	0.08	8.75
Ecuador	964	11.10	8.68
China	71900	376.00	19.12
Brazil	17820	214.00	8.33
India	6750	106.00	6.37
Australia	8850	139.00	6.37
World	202400	5000.00	4.05
Thailand	1509	43.10	3.50
Soviet Union	43150	1300.00	3.32
New Zealand	791	26.00	3.04
Sweden	4110	160.00	2.57
USA	66400	2600.00	2.55
Netherlands	3702	16.60	22.30
Janpan	15300	715.00	2.14
Spain	2090	139.00	1.50
Italy	12650	865.83	1.46
Taiwan(A part of China)	2137	158.00	1.35
West Germany	8027	715.00	1.12
Switzerland	733	102.00	0.72

a) See footnote in Table 10.

The emergy exchange ratio is the ratio of emergy received for emergy delivered in a trade or sales transaction. The area receiving the larger emergy receives the larger value and has its economy stimulated more. Raw products such as minerals, rural products from agriculture, fisheries and forestry, all tend to have high emergy exchange ratios when sold at market prices. This is a result of money being paid for human services and not for the extensive work of nature that went into these products. The existence of emergy-attracting countries is underlined in Table 13. Many technologically and financially developed countries are not emergy self-sufficient(see table 13, % of emergy from within) and show an emergy import much higher than the export. It contributes very much to the economy of the importing country, which will use more resources and will successfully compete with other countries. Tibet shows a 99% self-sufficiency; it has an import/export ratio more than 21.67, Tibet is a exception because main economy of China give much higher supports and aides to Tibet.

Table 13 Emergy self-sufficiency and trade balance for Tibet and other selected countries of the world[a]

Nation or Region	% emergy from within	Emergy import/export
Tibet(A part of China)	**99**	**21.67**
Netherlands	23	4.3
Janpan	31	4.20
Switzerland	19	3.20
West Germany	23	2.60
Italy	38	2.53
Spain	24	2.30
USA	77	2.20
Taiwan(A part of China)	29	1.56
India	88	1.45
Sweden	46	1.30
Brazil	91	0.98
Dominica	69	0.84
New Zealand	60	0.76
Poland	66	0.65
Thailand	70	0.54
Australia	92	0.39
China	98	0.28
Soviet Union	97	0.23
Ecuador	94	0.20
Liberia	92	0.15
Papua New Guinnea	96	0.09

a) See footnote in Table 10.

The empower density, i.e. the emergy flow per unit time and unit are(with the units solar emjoules per m2 per unit time), is a measure of spatial concentration of emergy flow within a process or system. A high empower density can be found in countries where emergy use is large if compared to available area(Table 14).It suggests a spatial hierarchy, where very industrialized countries or areas(cities, industrial regions in a nation) are in the top positions, followed by areas characterized by less concentrated or rural economies. This index is not always directly proportional to population density. A high empower density eventually suggests land to be a limiting factor for the future economic growth of the country.

Table 14 Population density and empower density for Tibet and other selected countries of the world

Nation or Region	Area ($E+10m^2$)	Population density ($people/km^2$)	Empower density ($E11\ sej/m^2/yr$)
Netherlands	4	378.00	100.00
Italy	30.1	191.05	42.03
Janpan	37.2	325.00	41.09
Taiwan(A part of China)	3.6	560.00	37.24
West Germany	24.9	247.00	32.30
Switzerland	4.1	154.00	17.70
Poland	31.2	110.00	10.60
Sweden	41.1	20.70	10.00
Dominica	0.08	107.00	8.80
Mainland China	953.6	115.00	7.54
USA	940	24.20	7.00
Liberia	11.1	16.10	4.10
Ecudor	28	34.00	3.40
Spain	50.5	68.50	3.12
Papua New Guinea	46.2	7.60	2.63
Thailand	74	67.60	2.15
Brazil	918	13.20	2.08
India	329	192.00	2.05
Tibet(A part of China)	**123**	**1.76**	**1.99**
New Zealand	26.9	11.50	1.94
Soviet Union	2240	11.60	1.71
Australia	768	1.90	1.42
World	14900	35.23	1.36

a) See footnote in Table 10.

Table 15 shows the percent of emergy used that is electrical. Electricity is a very high-quality energy, that is usually used for interacting with low-quality inputs to feedback and stimulate the production process. Electricity can also support the manipulation and processing of information for modern era. According to its high transformity,it should be used where it can have commensurate effects, allowing maximum and optimum use of large amount of low-quality resources. Tibet is one of the richest area in hydropower reserves, but unfortunately, at present electricity use just 0.08%, it is much lower than many countries.

Table 15 Emergy self-sufficiency and trade balance for Tibet and other selected countries of the world [a]

Nation or Region	% Electrical
Switzerland	32.0
Janpan	26.1
Sweden	23.5
West Germany	22.4
Spain	22
Taiwan(A part of China)	20
USA	20
Soviet Union	19
Poland	18
New Zealand	15
Italy	14
World	13.2
Thailand	10.8
India	10
Netherlands	10
Brazil	8
Australia	6.8
China	4.3
Ecuador	3.2
Liberia	1
Papua New Guinea	0.8
Tibet(A part of China)	**0.08**
Dominica	<0.01

a) See footnote in Table 10.

7. Discuss on selected problems

7.1. Creative emergy, education system and shared emergy

Creative scientific jobs yield creative products the results of great emergy input. This kind of emergy storage is creative emergy. Creative emergy is specially used to measure emergy content of the creative knowledge and technologies.Without these, there would be no modern era and advanced industrialized society. Shared emergy is the master to creative knowledge and skill which contain a great deal of emergy input, i.e creative emergy. Because shared emergy is the master by copying creative emergy, shared emergy has almost same effects as creative emergy to social production process. For example, famous USA inventor Edison had the knowledge and skill to make the light bulb. The skill was the result of Edison's material, energy, time and educational input. The sum emergy of all these inputs was the creative emergy of bulb making skill, when other people master this skill, the amount of his shared emergy is equal to the amount of creative emergy and has same effects on the bulb making process. Education is a transformation system which can transform and amplify creative emergy thousands and even billions times into shared emergy which gave great stimulation to social production. Japan has a high efficient education system which transformed and amplified thousands of creative emergy invented by many countries to shared emergy in Japan to stimulate its economic development. The production process of creative emergy needs much time and very high energy input, but the master and studying process to creative emergy just needs a little energy and time which is much lower than production process of creative emergy. Taiwan and Japan benefit greatly from education and transformation systems which absorbed thousands of technologies from the world and saved much energy inputs and time.

Here we want to introduce other concepts related to creative emergy: amplifying coefficient of creative emergy; areas of amplifying distribution; span of influence of creative emergy.

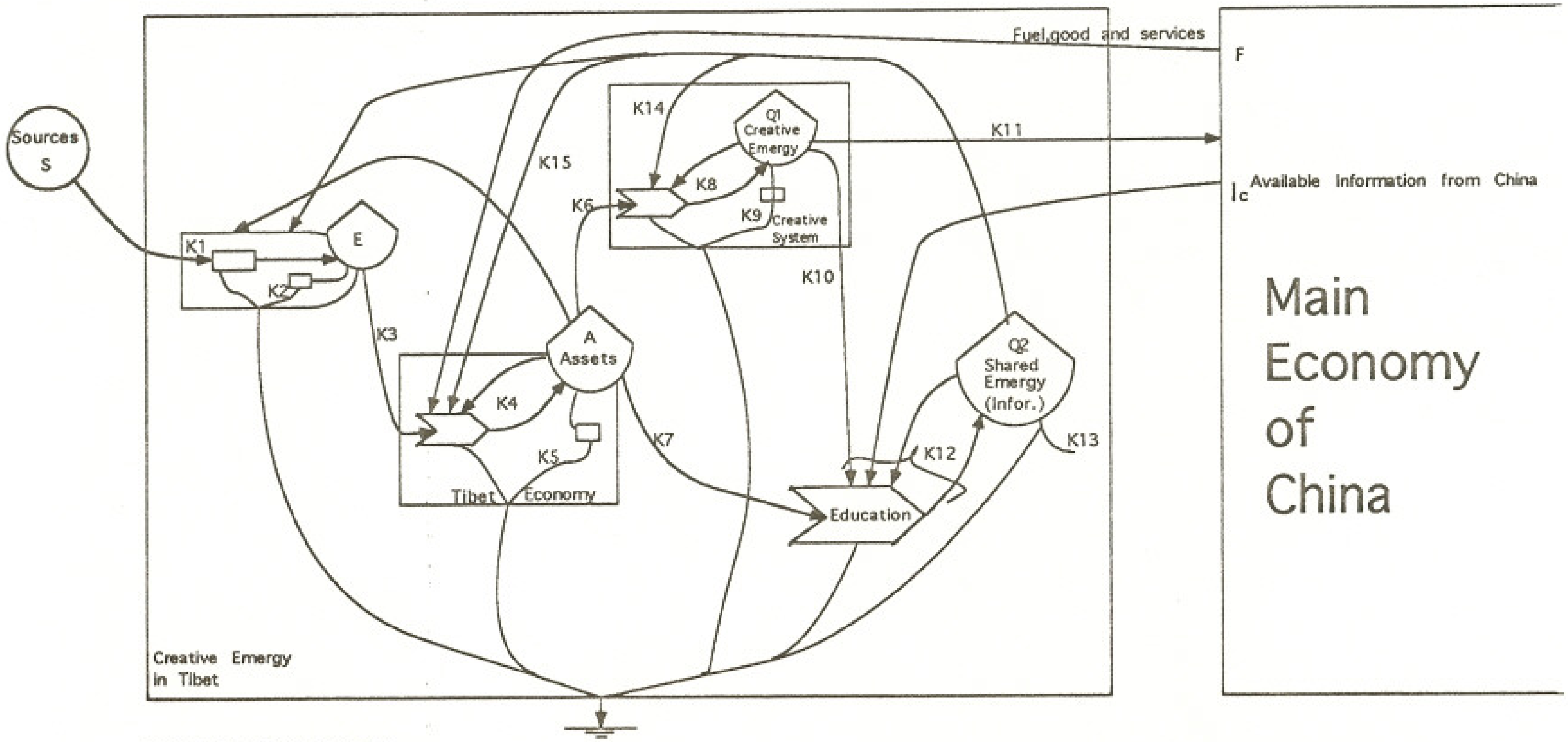
Amplifying coefficient of creative emergy is the ratio of shared emergy to creative emergy. Practical creative emergy has larger amplifying coefficient. Certainly, if people want to keep an invention secret, or a country has an inefficient transformation system, amplifying coefficient of creative is often lower. The ratio can be used to discuss the result of scientific research, the efficiency of education etc.

Amplifying area of distribution is the area of influence of creative emergy. Some agriculture technologies have limited influences area, so these areas with special environment should create its own technological system.

Influence span of creative emergy is the duration of influence of a creative emergy. With the high speed development of science and technology, some new advanced technology often replaces the older tradition, so that the span of influence of some creative emergy is often very short. Fundamental science and technology(theory and methodology) usually have a very long span of influence.

Tibet was once an isolated, closed system with only two formal schools before 1949. Without an education system there was little possibility to improve its citizen's knowledge of alternative forms of society ,and modern science and technology. There was no way to transform, amplify and share creative emergy so as to improve the efficiency of economic production. Especially, Tibet environment is very different from many area in the world and has special requirements. Sometimes its scientist need to discover creative technology with special characteristics. About the importance of education, there are some arguments.

Fig.9 suggests the relationship between Tibet economy and its education system.



DE=k1*S-K2*E-K3*E*F*Q2*A

DA=K4*E*F*Q2*A-K5*A-K6*A*Q1*Q2-K7*A*Q1*Q2*Ic

DQ1=K8*A*Q2*Q1-K9*Q1-K10*A*Q1*Q2-K11*Q1

DQ2=K12*A*Q1*Ic*Q2-K13*Q2-K14*A*Q1*Q2-K15*E*F*Q2*A

Fig.9 The relationship among creative emergy, shared emergy and the education system in Tibet

7.2 GNP and emergy use possibility function comparison

7.2.1 Trends of GNP and increase in emergy use(economic component, U-R) over time

Different economic systems have different inner structures, and the trends of GNP and emergy use(U-R) are very different. Fig.10 shows these trends for Tibet and Taiwan separately.

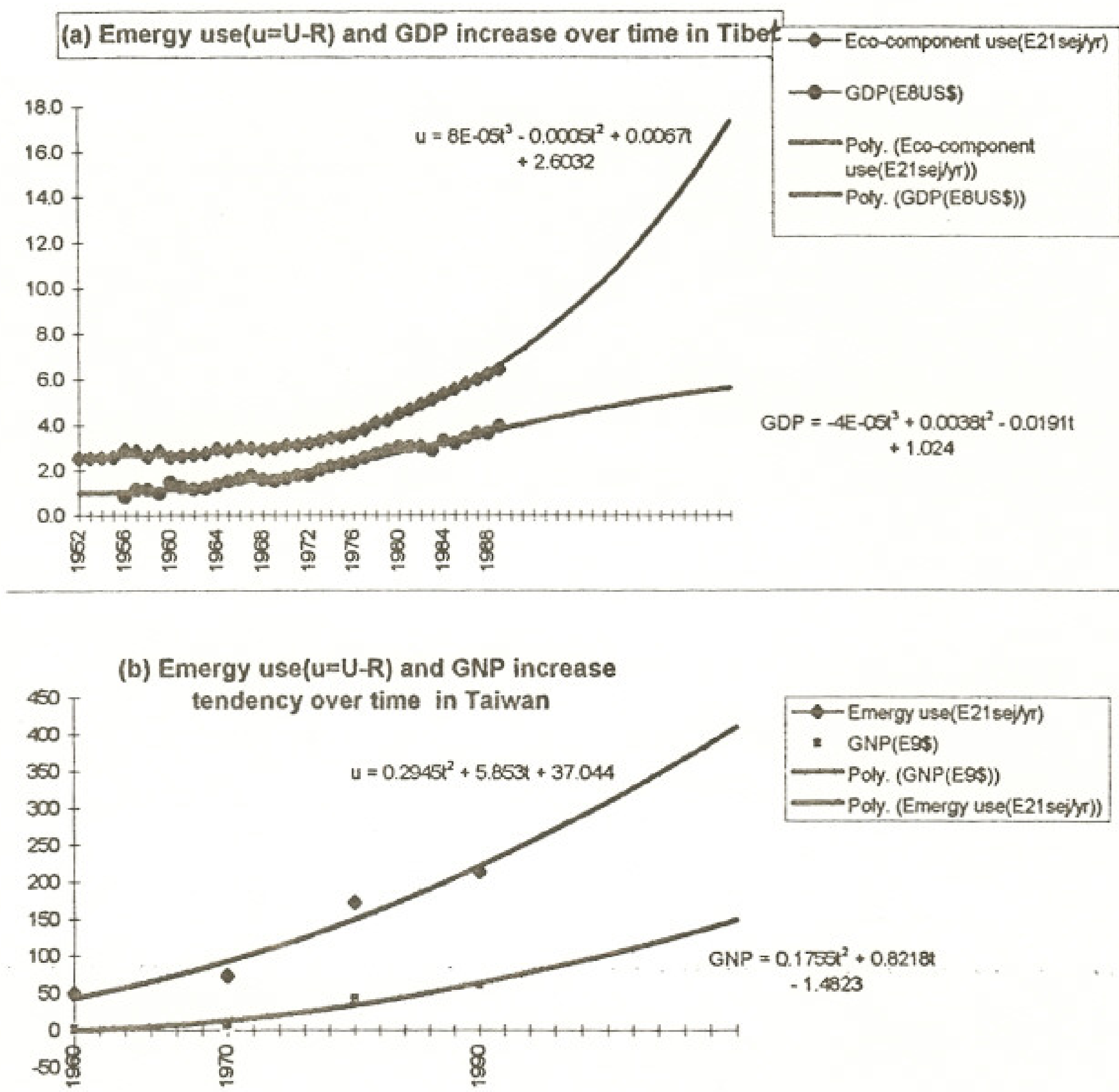


Fig.10 The increase tendency of GNP and emergy use in different economy system

7.2.2 GNP and emergy use(economic component, U-R) possibility function

Total emergy use(U) includes all kinds of input contribute to economic increase. Here we try to establish the function between GNP or GDP and emergy use(economic component, U-R) to find the relationship between GNP or GDP and emergy use(U-R, abbreviated to "u" in Fig.11) in different economic system. Fig.11 shows the GNP and emergy use "u" possibility function in Tibet and compares with Taiwan. From those curves,we can find: with the increase of emergy use, GNP increase in Taiwan is much faster than that in Tibet. This shows that Taiwan economic system is much more competitive than that of Tibet.

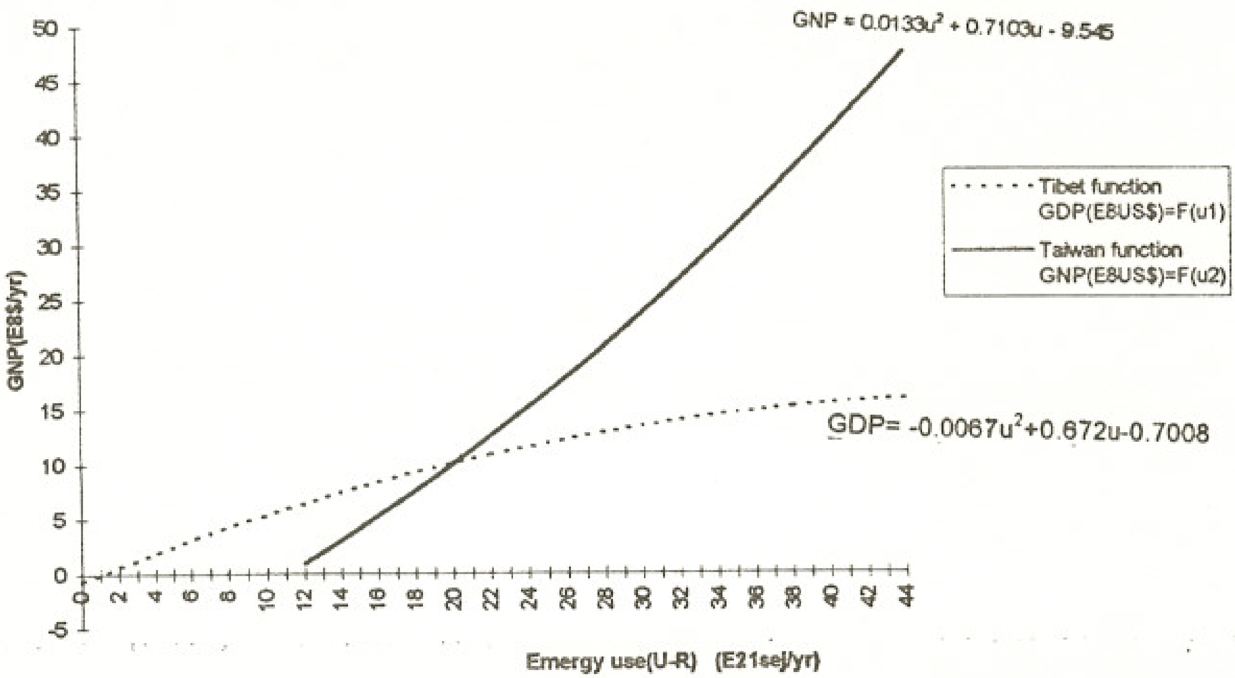


Fig.11 GNP and emergy use(U-R, abb."u") possibility function between Taiwan and Tibet

7.2 Transportation in Tibet

In order to stimulate the development of the Tibetan economy and find the alternatives forms of social structure in Tibet, Chinese government had to overcome formidable obstacles and difficulties in road construction. The first artery(Sichuan to Lhasa) stretched over fourteen mountain passes, for a distances of 2400 km and took 4 years and 9 months to complete. At the end of 1954, 2100km long Qinghai-Tibet highway was opened for traffic. The third 1200km long road from Xinjiang province through the Aksai-Chin area was completed in Oct.,1957. About 22,000km of roads have been built so far, using the average unit cost(30000$/km)of Qing-Tibet and Sichuan-Tibet roads, the total value of these highway should be 6.6E+8 US$. The emergy storage should be about 5.7E+21sej/yr. It is about 8.5% of Tibetan total economic assets.

Economically the roads succeeded in cutting the price of some essential goods. The roads allowed one truck to transport, in two days, the same quantity of goods previously carried by sixty yaks in twelve days, so when first two roads opened, the price of many goods dropped, the price of tea dropped by two-thirds in two years.

Although many roads have been established, they are still insufficient to stimulate much industrialization in Tibet. With a lack of supplies in Tibet, fuels and materials had to be imported from outside Tibet. When materials reach Tibet, the net emergy yield ratio is very low. Maybe this is the main reason for its uneven industrial development. At present, at least 15% of industrial enterprises are in deficit.

At present, Tibet is the only Province in China without a railway, but the railway web has reached a point at the Golmund in Qinghai Province, still 1000 km. from Lhasa. If Chinese railroad web reaches Tibet, this area can be brought into the industrial age. However the obstacles may be much more formidable than highway-building. It may be some time before railways spread into Tibet.

8. Concluding remarks and policy suggestions

Chinese government has already made a great efforts to improve Tibetan transportation, education and the social economic system as a foundation for further development, Tibet has made great progress in every aspect, but compared with other countries and regions, Tibet is not very competitive. Some resources with great potential in Tibet still haven't been developed. The following are policy suggestions:

8.1. Make Good Use of Hydropower Reserve and Geothermal Energy

An important constraint to its economic development is lack of enough high quality energy in Tibet such as electric power. Tibet is very rich in hydropower reserves and geothermal energy. Both are renewable resources. Best use of these resources may increase economic vitality in Tibet.

8.2. Revise Economic Structure and Improve the Use of Available Emergy

According to the comparison of GNP and emergy use with Taiwan, Tibet is much less competitive than Taiwan, Tibet generates more real wealth per dollar, Tibet is less developed than Taiwan. Tibet is a rural society and its exports are mainly agriculture products. In the future, Tibet might adjust its economic structure with more professional education and skilled workers. In the past, many skilled works left Tibet for India and Nepal and other countries, Tibet should make good policy to attract these skilled workers back to Tibet. Tibet should export less raw products and more finished products using electric power.

8.3. Encourage Tourism

Tibet culture and environment is very attractive to the world. Tourism in Tibet should develop rapidly. Industrial development should be connected to its indigenous resources before decision-making.

In 1980, there are 1,059 tourists to Tibet , in 1987 43,500 persons, but in 1989 just 3,603 persons when Tibet society was not unstable. Social and political stability is very important to its tourism and prosperity. Tibet should arrange for increasing airline service for its tourism development too. The net emergy yield ratio for tourism in Tibet may be higher than for many industrial project in Tibet and many area in China and even in the world. An emergy analysis for its industrial choice and decision-making is needed. In the past many industrial enterprise collapsed because too much of its raw materials were imported from distant market. Before railroads reach Tibet, its industrial choice must mainly depend on indigenous resources.

8.4. Encourage Increase of Educated Population

The developed carrying capacity of population is 16.8 million persons, the current population is much lower than 16.8 million. In order to stimulate Tibetan economic development, moderate immigration of better trained, talented population from outside Tibet is necessary and acceptable. The carrying capacity for the same living standard as developed countries in Tibet is 16.8 millions persons. If its living standard increases to three times as much as that of present, its developed carrying capacity would be 5.6 million persons. 1000 years ago, the present area of Tibet had ever experienced a prosperous time when its total population was more than 7 million, the future prosperity of Tibet requires a moderate population increase and immigration.

8.5. Encourage Investments from Inland China and Other Countries. Import Technology and Talented Scientists to Improve Existing Industrial Enterprise.

The empower density in Tibet is 1.99E+11 sej/m2/yr, a little higher than Australia(1.42E+11 sej/m2/yr), the average level of the world(1.36E+11 sej/m2/yr), according to the current rate of investment speed, more than 100 years will be required for the empower density in Tibet to reach the current level of China and Taiwan, so Tibetan development has a long way to go. However there are political differences regarding an open policy, some are afraid to accept population from outside Tibet.

8.6. Improve Education Links Between Tibet and outside Universities

Education system should have good exchange with Institutes and Universities both in Tibet, inland China, and other countries. Amplify much more creative emergy into shared emergy for its economic development and social progress. Creative emergy has very high transformity, it may save much more time and energy to import information than to create it directly. Good education and transformation systems can amplify creative emergy thousands of times(Fig.9). Creative information is a special emergy and real wealth for social development. Tibet should make great efforts to reform and reinforce its education and transformation system.

8. 7 Researches is Needed on the following Questions for Better Policy Choice

Evaluations of the spatial distribution of resources is needed from North Tibet to South Tibet. Generally, resources availability and potential is much better in south Tibet especially southeast Tibet than in the other areas. For example, in Linzhi prefecture of southeast Tibet, the rainfall is 900 to 2300mm; forest coverage is about 34.5%, and some ancient cypress trees are more than 2000 years old with diameters of 20 meters. Although its land area is just 6.17% of Tibet, its hydropower reserves is 33% of Tibet's, with much of its hydropower easy to exploit. The Yalutsangpu river fall down 2300 meter from Paixiang of MiLing county(2800 meter above sea level) to Xiyuang of Meituo county(500 meter above sea level). If a 10 kilometer tunnel is constructed for water flow through mountains to a power plant, the hydropower capacity would be 40 million Kw. It would be the most powerful hydropower plant in the world, with power 14.7 times of Guozhou Dam hydropower plant on Yangtze river(the largest hydropower plant now in China). In order to make wise policy, the following questions need further researches:

.What is the spatial distribution of forests and their production-potential based on emergy analysis and minimodel simulation

.What should be the energy development strategy in different region of Tibet based on emergy analysis

According to Dr Odum's researches, the global net emergy yield ratio of imported oil is often 6, but Tibet is so far from the market, much emergy is required for transportation , and the ratio would be less. The net emergy yield ratio for hydropower is 20, geothermal energy 13, wind energy 0.25, solar technology 0.2. Since there are some difference in emergy yield ratio, in different area it is necessary to do emergy analysis for a better project choice and right energy development strategy.

.Based on emergy analysis, what areas are best for developing crops in Tibet?

There has been wasted efforts spreading agriculture to areas not suitable for crop and grain planting.

.What is the sequence of developments to be expected after development of hydropower reserves, what does simulation of energy systems models predict?

Because of the lack of electricity, many factories in cities can't operate well, and it is necessary now to use manure and crop stalks for cooking, etc. Development of hydropower reserves could return great values both to the economic system and to nature. A series of chain-reactions may be expected in the eco-economic system.

.What are the alternative uses of water, hydropower reserves, and wetlands in Tibet for further development.

Annex1: Footnotes to Tab.4-Tab.9

Tab.4. The energy calculation of main resources flows in Tibet eco-economic system in 1989

Renewable resources

1.Solar energy	
Land area=	1.228E+12 m^2
Insolation=	165 kcal/cm2/yr
Albedo=	25%
Solar energy=	(land area)(avg.insolation)(1-albedo)(E4cm2/m2)(4186j/kcal)=
	6.36E+21 J/yr
2.Rain chaemical potential	
Land area=	1.228E+12 m^2
Rain(average)=	0.475 m
Evapotransp.rate	45%
Energy=	(area)(evbapotranspired rainfall)(water density)(Gibbs free energy)=
	1.297E+18 J/yr
3.Rain geopotential energy	
Land area=	1.228E+12 m^2
Rain(average)=	0.475 m
Average elevation=	4650 m
Runoff rate=	47% of total rainfall
Energy=	(area)(runoff rate)(avg.elevation)(water density)(gravity)=
	1.25E+19 J/yr
4.Wind kinetic energy	
Avg. wind energy density=	30 watt/m2(?)
Land area=	1.228E+12 m^2
Energy=	(land area)(Avg. wind energy density)*365*24*3600=
	1.162E+21 J/yr
5.Earth cycle(steady uplift balanced by erosion)	
Heat flow per area=	3.00E+06 J/m2/yr
Land area=	1.228E+12 m^2
Energy=	(land area)(Heat flow per area)=
	3.685E+18 J/yr
Indigenous renewable products	
6.Hydropower	2.20E+08 Kw.h/Yr
Energy content per kwh=	3.60E+06 J/kwh
Energy=	7.909E+14 J/yr
(total electric generation)=	2.75E+08 Kwh/yr
Energy=	9.90E+14 J/yr
7.Wood products=	1.60E+08 ton
Energy=	(1.6E8kg)(1000kg/ton)(1000g/kg)(3.60kcal/g)(4186J/kcal)=
	2.411E+18 J/yr
8.Crop production	8.51E+15 J/yr
I.Grain products	5.50E+08 kg/yr
1)Rice	3.10E+06 kg/yr

Energy= (3.3E+3kcal/kg)(3.1E+6kg/yr)(4186j/kcal)
= 4.278E+13 J/yr

2)Wheat 1.34E+08 kg/yr
Energy= (3.3E+3kcal/kg)(3.1E+6kg/yr)(4186j/kcal)
= 1.852E+15 J/yr

3)Qingke(like wheat) 3.42E+08 kg/yr
Energy= (3.3E+3kcal/kg)(3.43E+8kg/yr)(4186j/kcal)
= 4.729E+15 J/yr

4)Beans 5.39E+07 kg/yr
Energy= (1.85E+7J/kg)(539E+7kg/yr)
= 9.978E+14 J/yr

5)Corn & other grain 1.70E+07 kg
Energy= (3.0E+3kcal/kg)(1.7E+7kg/yr)(4186j/kcal)
= 2.139E+14 J/yr

II.Other crops products
6)Vegetable oil 8.37E+06 kg/yr
Energy= (6.10E+3kcal/kg)(8.37E+6kg/yr)(4186J/kcal)
= 2.137E+14 J/yr

7)Vegetables 8.39E+07 kg/yr
Energy= (4.19E+6J/kg)(8.39E+7kg/yr)
= 3.517E+14 J/yr

8)Fresh feeding crops 2.61E+07
Energy= (4.19E+6J/kg)(2.61E+7kg/yr)
= 1.093E+14 J/yr

9.Fruit(apples etc) 5.10E+06 kg/yr
Energy= (5.50E+2kcal/kg)(5.1E+6kg/yr)(4186J/kcal)
= 1.174E+13 J/yr

10.Livestock 1.84E+15 J/yr
1)Meat 9.02E+07 kg/yr
Energy=(total production)(0.22 organic)(1000g/kg)(5.0kcal/g)(4186J/kcal)
= 4.15E+14 J/yr

2)Milk 1.75E+08 kg/yr
Energy=(total production)(0.22 organic)(1000g/kg)(5.0kcal/g)(4186J/kcal)
= 8.04E+14 J/yr

3)Eggs 1.41E+06 kg/yr
Energy=(total production)(0.22 organic)(1000g/kg)(5.0kcal/g)(4186J/kcal)
= 6.50E+12 J/yr
4)Wool 2.35E+07 kg/yr
Energy=(total production)(1000g/kg)(5.0kcal/g)(4186J/kcal)
= 4.93E+14 J/yr

5)Leather and other livestock prod. 2.61E+07 kg/yr
Energy=(total production)(0.22 organic)(1000g/kg)(5.0kcal/g)(4186J/kcal)
= 1.20E+14 J/yr

10.Fisheries 153000 kg/yr
Energy=(total production)(0.22 organic)(1000g/kg)(5.0kcal/g)(4186J/kcal)
= 7.05E+11 J/yr

Non-renewable sources mined or used within Tibet
11.Coal= 5500 ton
Energy= (5000 ton)(7E6kcal/ton)(4186 J/kcal)
= 1.465E+14 J/yr

12.Electricity(using coal) 757 Kwh/yr
Energy= 2.73E+09 J/yr
=

13.Ni &Fe ore= 87047 ton
= 8.70E+10 g

14.Gold= 10394 g

15. Salt= 1000 ton
= 1.00E+09 g

16.Other ore(B &Mg) 18407 ton
= 1.841E+10 g

17. Loss of topsoil
(area with mature vegetation are assumed to have little net gain or loss of topsoil)
Farmed area(Cultivated +grassland)= 4.74E+11 m2
Erosion rate= 200 g/m2/yr
%organic in soil= 2.00%
Energy content per g organic= 5 kcal/g
Energy of net loss= 3.97E+16 J/yr

Tab 9 Emergy evaluation of resource reserves of Tibet, 1989

Type of energy	Storage	Transformity (sej/unit)	Solar emergy(sej)	Macrovalue(E+8$)
1.Coal reserves	4.64E+06 ton			
Energy =(total imports)(1E+7kcal/t)(4186J/kcal)=	1.943E+17 J	39800	7.73354E+21	8.92
2. Iron ore	3.23E+08 ton			
=	3.23E+14 g	8.55E+08	2.76165E+23	318.53
3. Nickle and Iron ore	4.41E+06 ton			
=	4.405E+12 g	1.00E+09	4.405E+21	5.08
4.Copper(ore)	1.16E+09 ton			
=	1.158E+15 g	1.00E+09	1.158E+24	1335.64
5.Boron ore(B_2O_3)	1.24E+06 ton			
=	1.238E+12 g	1.00E+09	1.238E+21	1.43
6.Peat	8.14E+06 ton			
Energy=(8.14E+6ton)(1E6g/ton)(2.15E+4j/g)=	1.749E+17 J	19000	3.32396E+21	3.83
7.Gypsum	1.22E+09 ton			
=	1.22E+15 g	1.00E+09	1.22E+24	1407.15
8.Graphite ore	2.44E+06 ton			
=	2.437E+12 g	1.00E+09	2.437E+21	2.81
9. Salt	1.40E+08 ton			
=	1.4E+14 g	1.00E+09	1.4E+23	161.48
10.Wood biomass	1.01E+09 ton=			
(1.01E+C34)(1E+6g/ton)(3.6kcal/g)(4186J/kcal)=	1.51E+19 J	34900	5.29E+23	609.76
11.Water reserves	4.48E+11 ton/yr			
=	4.482E+17 g/yr			
Energy=	1.793E+18 J/yr	41068	7.36E+22	84.92
9.Geothermal energy reserves				
Total enenrgy=	4.75E+16 J/yr	6100	2.90E+20	0.33
10.Hydropower reserves=	1.76E+12 Kwh/Yr			
Energy content per kwh=	3.60E+06 J/kwh			
Energy=	6.325E+18 J/yr	159000	1.01E+24	1159.92

11.Economic assets($)	2.376E+09 $			
12.Population(person-years)	6.70E+07 per-yr	3.1E16se	2.08E+24	2394.19

Tab.6 Money flows and wastes flows for Tibet,1989

Item	Resources flows	Transiformity	Solar emergy(Sej)	Macrovalue US$
Money flows				
1.GDP(1989)	3.90E+08 $/yr			
2.Goods imports(exc. 3 to 5)	1.16E+08 $/yr			
3.Tourism imports	1.80E+06 $/yr			
4.Central govern. aid	2.21E+08 $/yr			
5.Other imports & services	5.01E+07 $/yr			
6.Goods expts(exec. 7 below)	1.70E+07 $/yr			
7. Service & other exports	5.00E+06 $/yr			
Wastes flows				
8.Liquid wastes	1.94E+06 ton/yr			
Energy=(1.94E+6ton/yr)(1E+6g/ton)(5J/g)=				
	9.7E+12 J/yr	665714	6.46E+18	0.01
9.Industries solid wastes	1.55E+04 ton/yr			
Energy=(1.94E+6ton/yr)(1E+6g/ton)(5J/g)=				
	6.541E+13 J/yr	1800000	1.18E+20	0.14

Tab 5.
Emergy evalution of commodities trade for Tibet,1989

Import and outside sources			
Total import	Quanity and its market value and energy		
1.Oil	188172 ton;	5.43E+07 $	
Energy=	(188172 t/yr)(1E+7kcal/t)(4186J/kcal)=		7.88E+15 J/yr
2.Grain	266419 ton;	2.38E+07 $	
Energy=	(266419t/yr)(1E6g/t)(3.5kcal/g)(4186J/kcal)=		3.90E+15 J/yr
3.Vegetable oil	5.08E+03 ton;	9.07E+06 $	
Energy=	(5.08E3t/yr)(1E3kg/t)(2.51E7J/kg)=		1.30E+14 J/yr
4. Wood	2.72E+04 m3=	2.18E+07 kg=	1.09E+06 $
Energy=	(2.18E11kg)(3800kcal/kg)(4186J/kcal)=		3.46E+14 J/yr
5.Mech.&transport equip.	4.72E+03 ton;	9.34E+06 $	
=	4.72E+09 g		
6.Steel	3.61E+04 ton		
=	3.61E+10 g		
7.Copper	5.60E+01 ton		
=	5.60E+07 g		
8.Aluminum	2.00E+01 ton		
=	2.00E+07 g		
9.Lead	5.60E+01 ton		
=	5.60E+07 g		
10.Zinic	4.20E+01 ton		
=	4.20E+07 g		
11.Cement	3.32E+08 ton		
=	3.32E+14 g		
12.Chemicals	2.92E+02 ton		
=	2.92E+08 g		

The total market value from item 4 to 12 is 2688.93E4$.

13.Fertilizer	1.35E+04 ton;	1.76E+06 $
1)Nitrogen	5.31E+09 g	
2)Phosphate	1.87E+09 g	
3)Potassium	2.52E+08 g	
4)Mutifertilizer	6.03E+09 g	
14.Aids from central govern.	2.21E+08 $	
14. Other imports & service	5.01E+07 $	
15.tourism	1.80E+06 $	

Export		2.20E+07 $
1.Wood	2.44E+04 ton;	1.46E+06 $
	2.44E+10 g	
Energy=(2.44E10g)(3.6kcal/g)(4186J/kcal)=	3.68E+14 J/yr	
2.Wool	2.37E+03 ton	1.32E+07 $
	2.37E+09 g	
Energy=(2.37E9g)(5kcal/g)(4186J/kcal)=	4.95E+13 J/yr	
3.Medical products	3.23E+00 ton	7.63E+05 $
	3.23E+06 g	
4.Nickle and iron ore	5.00E+03 ton	6.13E+05 $
	5.00E+09 g	
5.Oil	3.57E+02 ton	1.03E+05 $
Energy=(3.57E2 ton)(1E7kcal/ton)(4186J/kcal)=	1.49E+13 J/yr	
6.Goods		8.68E+05 $
7. Other exports and service		5.00E+06 $

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