# Emergy evaluation of the environment and economy of Hong Kong*

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**Abstract**—— An environment-economy systems analysis of Hong Kong has been carried out using a new measure emergy for evaluating its environmental resource basis and economy as well as its international economic relations for recommending a sustainable development. Emergy is the total energy of one kind required directly and indirectly to form a resource, product or service. It provides a common basis for measurement of the value of environment and economy.

A preliminary analysis of emergy contributions supporting the system of Hong Kong is presented in this paper.

**Keywords**: emergy; solar transformity; environmental resource; Hong Kong.


# 1 Introduction

One of the most important problems facing humanity today is the sound management and integration of human and natural processes. Neither economics nor ecology alone adequately addresses the problems the world society presently faces. It is becoming quite apparent that economic well being and ecologic stability depend upon developing an interface between eco-environment and economy. The interface of ecology and economics is most often found in the marketplace. Yet economic considerations often do not reflect ecologic realities, environmental impacts, or sustainability of natural resources and internationalship because these things are generally outside the realm of individual human preferences (Jansson, 1984; Braat, 1987).

A central issue for eco-environmental problems is to find a common denominator to analyse multidisciplinary data of environment and economy. Neither money nor energy can be a common denominator for measuring environment and economy. Money circulates only among people for their services, and the contribution of nature and environment is not paid for. Energy flows circulate between environment and economy. However, attempts to evaluate environmental and economic products or services in units of energy must recognize that all forms of energy do not accomplish equivalent amounts

of work (Odum, 1988). The "form" or "quality" of each type of energy is quite differ-ent.

Emergy, spelled with an "m", is a new measure that quantifies the energy previ-ously required to produce a given product or drive a given process. Emergy includes the energy of one type directly and indirectly used in the production of a r generate a prod-uct, whose units are solar emjoules (abbreviated "sej"). Transformity is the emergy per unit energy or material; solar transformity is the solar equivalent energy directly and in-directly required for a joule of product. A list of solar transformity for many types of en-ergy and commodities is derived from previous studies (Odum, 1988; 1991).

In this study, a new emergy analysis method is used to evaluate contributions of en-vironmental resources to economic wealth and the ability of different energy forms to contribute to the economy. The overall objective of this research is to integrate selected environmental and economic data from Hong Kong, and in particular to evaluate and compare the relationship of environmental and economic energies of Hong Kong.

## 2   Methodology and procedure

Emergy analysis provides an overview of the systems of humanity and nature (Odum, 1988). This is accomplished by first gathering relevant information including physical and economic statistics. Then, a detailed systems diagram is drawn as a way to gain an initial overview and organize data-gathering efforts, involving both natural envi-ronment and economy using energy language symbols (Odum, 1983; 1988). Second, emergy evaluation tables are set to facilitate calculations of main environmental and eco-nomic contributions of the system. The total emergy of each input to the system is cal-culated, this is done by calculating the energy value of each form or process in joule, multiplying it by the appropriate solar transformity value to get the solar emergy (solar emjoules). The term macroeconomic value refers to the total amount of dollar flow generated in the entire economy by a given amount of emergy input. Third, from the e-mergy evaluation tables, the emergy indices are calculated to compare systems, predict trends, suggest which will be efficient and successful. Fourth, an aggregated diagram is generated from the detailed diagrams and emergy calculated. Fifth, public environmen-tal and economic policy questions are considered using emergy evaluation, and indices to determine which alternatives generate most contribution to the unified economy of hu-manity and environment.

## 3   Results and discussion

3. 1 Emergy basis for the environment and economy of Hong Kong

An energy system diagram of Hong Kong is given in Fig. 1 for overview. The dia-gram includes the environment and the economy. Here environmental energies are dia

grammed on the left-hand side of the diagram with higher quality energy flows diagrammed on the right, concluding with human information processors whose actions affect lower level production processes.
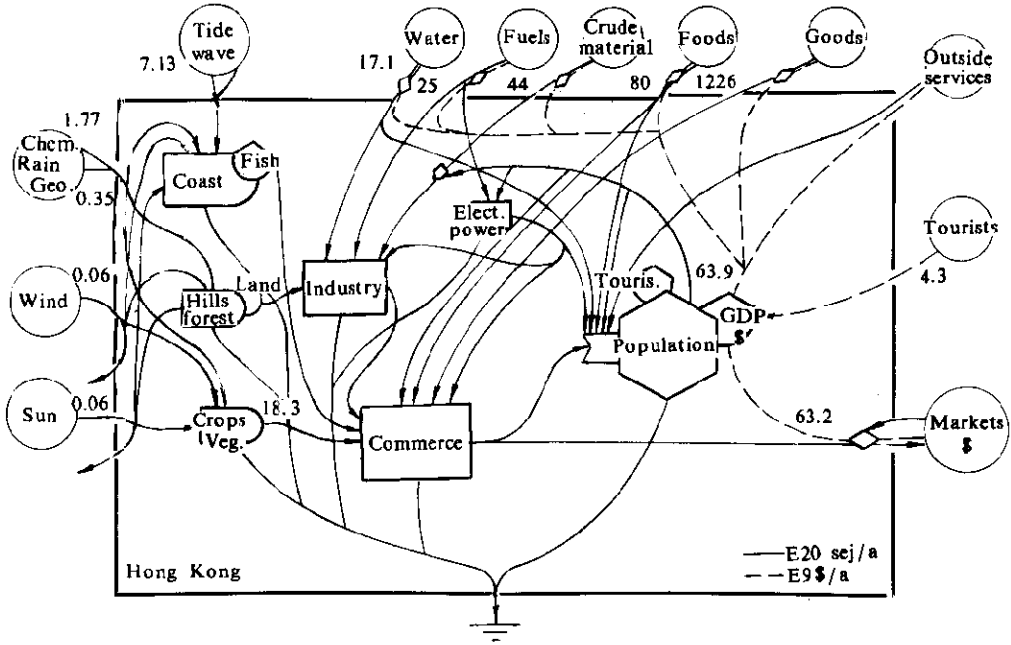


Fig. 1    Emergy diagram for environment and economy of Hong Kong
with flows evaluated in Table 1—2 for details

Emergy evaluation of environmental resources basis and economy of Hong Kong are presented in Table 1. This includes the main renewable sources (sunlight, rain, waves and tides), indigenous renewable products and import-export emergy. The nonrenewable resoruces of fuels, minerals and goods depend on imports, and re-exports is larger than domestic exports for Hong Kong.

In Table 2, emergy evaluation summary for import-export, industry, agriculture and tourism in Hong Kong is presented.

In these Tables, items are first calculated in units of actual energy or mass for Hong Kong during 1988. These annual amounts are then multiplied by appropriate solar transformities to measure the emergy contribution of each resource or market products. The total emergy from independent sources suporting environment and economy of Hong Kong is calculated as the sum of renewable and nonrenewable environmental resources and the contribution of import emergy that has been used within Hong Kong.

A summary of emergy analysis is given in Table 3 and diagrammed in Fig. 2.

Table 1    Emergy evaluation of annual environmental and
economic flows for Hong Kong in 1988

| Note | Item | Raw data. J or US $ | Trans- formity, sej/unit | Solar Emergy. E20 sej | Macroeconomic value*, E6 1988. US $ |
|---|---|---|---|---|---|
| Renewable sources: | | | | | |
| 1 | Sunlight (J) | 5. 84E+18 | 1 | 0. 06 | 2. 92 |
| 2 | Wind, kinetic (J) | 9. 72E+15 | 623 | 0. 06 | 3. 03 |
| 3 | Rain, geopotential (J) | 3. 89E+15 | 8888 | 0. 35 | 17. 29 |
| 4 | Rain, chemical (J) | 1. 15E+16 | 15444 | 1. 77 | 88. 49 |
| 5 | Tide (J) | 6. 78E+14 | 23564 | 0. 16 | 7. 99 |
| 6 | Waves (J) | 2. 75E+16 | 25889 | 7. 13 | 356. 45 |
| 7 | Earth cycle (J) | 3. 22E+15 | 29000 | 0. 93 | 46. 72 |
|  | Total (Item 4+6) | | | 8. 90 | 444. 95 |
| Indigenous renewable products: | | | | | |
| 8 | Agric. & Fishing (J) | | | 18. 29 | 914. 50 |
| Imports and outside sources: | | | | | |
| 9 | Water consumption (J) | 2. 58E+15 | 665714 | 17. 14 | 857. 11 |
| 10 | Mineral fuels ( $ ) | 1. 22E+09 | 2. 00E+12 | 24. 39 | 1219. 73 |
| 11 | Food & animals ( $ ) | 4. 01E+09 | 2. 00E+12 | 80. 21 | 4010. 63 |
| 12 | Crude materials ( $ ) | 2. 18E+09 | 2. 00E+12 | 43. 70 | 2184. 87 |
| 13 | Chemicals ( $ ) | 5. 73E+09 | 2. 00E+12 | 114. 51 | 5725. 51 |
| 14 | Basic manufac. ( $ ) | 1. 69E+10 | 2. 00E+12 | 337. 85 | 16892. 31 |
| 15 | Machin. & transp. ( $ ) | 1. 84E+10 | 2. 00E+12 | 368. 42 | 18421. 15 |
| 16 | Manufac. articles ( $ ) | 1. 41E+10 | 2. 00E+12 | 282. 08 | 14104. 23 |
|  | (Total imports) | | | 1268. 31 | 63415. 55 |
| Re-exports: | | | | | |
| 17 | Food & animals ( $ ) | 1. 43E+09 | 2. 00E+12 | 28. 50 | 1425. 11 |
| 18 | Crude materials ( $ ) | 1. 59E+09 | 2. 00E+12 | 31. 79 | 1589. 37 |
| 19 | Chemicals ( $ ) | 3. 16E+09 | 2. 00E+12 | 63. 14 | 3157. 08 |
| 20 | Basic manufac. ( $ ) | 7. 96E+09 | 2. 00E+12 | 159. 20 | 7960. 00 |
| 21 | Machin. & transp. ( $ ) | 9. 93E+09 | 2. 00E+12 | 198. 60 | 9930. 00 |
| 22 | Manufac. articles ( $ ) | 1. 04E+10 | 2. 00E+12 | 208. 00 | 10400. 00 |
|  | Total (incl. others) | | | 705. 71 | 35285. 71 |
| Domestic exports: | | | | | |
| 23 | Food & animals ( $ ) | 2. 58E+08 | 1. 02E+12 | 2. 63 | 131. 46 |
| 24 | Crude materials ( $ ) | 2. 83E+08 | 1. 02E+12 | 2. 88 | 143. 92 |
| 25 | Chemicals ( $ ) | 5. 39E+08 | 1. 02E+12 | 5. 49 | 274. 40 |
| 26 | Basic manufac. ( $ ) | 3. 31E+09 | 1. 02E+12 | 33. 71 | 1685. 27 |
| 27 | Machin. & transp. ( $ ) | 7. 06E+09 | 1. 02E+12 | 71. 87 | 3593. 30 |
| 28 | Manufac. articles ( $ ) | 1. 58E+10 | 1. 02E+12 | 160. 53 | 8026. 44 |
|  | Total (incl. others) | 2. 79E+10 | 1. 02E+12 | 283. 69 | 14184. 66 |
|  | (Total exports) | 6. 32E+10 | | 989. 41 | 49470. 37 |

* Solar emergy divided by 2. 0E+12 sej/ $ for world emergy/ $ ratio in 1988

**Table 2   Evaluation of exports and other flows of Hong Kong in 1988**

| Item | Raw data, J or US $ | Trans- formity, sej/unit | Solar emergy, E20 sej | Macroeconomic value, E6 1988. US $ |
|---|---|---|---|---|
| Agriculture & Fishing: | | | | |
|     Vegetables (J) | 2.20E+15 | 2.70E+04 | 0.60 | 29.76 |
|     Fresh fruit (J) | 3.37E+13 | 5.30E+05 | 0.18 | 8.94 |
|     Other crops (J) | 2.66E+13 | 5.30E+05 | 0.14 | 7.04 |
|     Flowers ( $ ) | 9.31E+06 | 1.39E+12 | 0.13 | 6.47 |
|     Fish total catch (J) | 8.62E+14 | 2.00E+06 | 17.25 | 862.29 |
|     Total | | | 18.29 | 914.50 |
| | | | | |
| Industry (29% GDP) | 1.59E+10 | 1.02E+12 | 161.51 | 8075.63 |
| | | | | |
| Tourism ( $ ) | 4.27E+09 | 2.00E+12 | 85.40 | 2171.47 |
| | | | | |
| External trade: | | | | |
|     Imports ( $ ) | 6.39E+10 | 2.00E+12 | 1268.97 | 63948.46 |
|     Total exports ( $ ) | 6.32E+10 | | 989.41 | 49470.37 |
|     Re-exports ( $ ) | 3.53E+10 | 2.00E+12 | 705.71 | 35285.71 |
|     Domestic exports ( $ ) | 2.79E+10 | 1.02E+12 | 283.69 | 14184.66 |
| | | | | |
| Dollar flows: | | | | |
|     DGP (US $) | 5.47E+10 | 1.02E+12 | 556.94 | 27847.00 |
|     Total revenue ( $ ) | 8.43E+09 | 1.02E+12 | 85.79 | 4289.54 |
|     Total expend. ( $ ) | 6.28E+09 | 1.02E+12 | 63.84 | 3192.20 |
|     Money supply ( $ ) | 1.14E+10 | 1.02E+12 | 115.86 | 5792.82 |
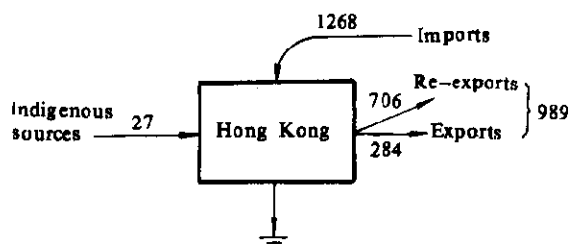


Fig. 2   Summary of emergy flows for Hong Kong in 1988

(units are in E20 solar emjoules)

Table 3   Summary of flows for Hong Kong in 1988, based on Table 1—2

| Letter | Item | Solar emergy, E20 sej/a | Dollar E9 US $ |
|--------|------|--------|--------|
| R | Renewable sources (waves, rain) | 8.90 | |
| N | Nonrenewable sources flow within HK | 0 | |
| F | Imported fuels and minerals | 24.39 | 1.22 |
| G | Imported goods | 1226.77 | 62.56 |
| I | Dollar paid for imports | | 63.91 |
| P2I | Emergy value of goods & services imports = (P2)(I) | 1268.31 | |
| I3 | Dollar paid for imports minus goods | | 0.13 |
| P2I3 | Imported services = (P2)(I3) | 2.59 | |
| T | Tourism import, money basis | 85.40 | 4.27 |
| RE | Dollar paid for re-exports | | 35.29 |
| ER | Emergy value of re-exports | 705.71 | |
| P1E | Emergy value of goods & serivces exports | 283.69 | |
| U | Total emergy used = R+N+F+G+P2I3 − ER | 556.94 | |
| X | Gross domestic product (GDP) | | 54.75 |
| P2 | World emergy/ $ ratio, used for imports * | 2.00E12sej/ $ | |
| P1 | Hong Kong emergy/ $ ratio = U/X used for Hong Kong and exports | 1.02E12sej/ $ | |

* Source: Odum, 1988, 1991.

Table 4   Emergy indices for Hong Kong in 1988 based on Table 1  3

| Name of index | Emergy or ratio | |
|---------------|--------|--------|
| Indigenous source | 27E20 | Scj |
| Import emergy | 1268E20 | Scj |
| Tourism import | 85.4E20 | scj |
| Exports emergy | 989E20 | scj |
| Import/export  ratio = (emergy received / emergy exported) | 1.37 | |
| Total emergy used within HK | 556.94E20 | scj |
| Emergy use per person (5.681E6 population) | 9.8E15 | scj / person |
| Economic / environmental ratio = (U-R)/R | 61.58 | |
| Ratio of emergy use to GDP, emergy/ $ | 1.02E12 | scj / $ |
| Emergy investment ratio = (total import emergy − reexport emergy)/indig. emergy | 20.8 | |

Indices of indigeous renewable sources, purchased emergy use, import-export ratios, emergy/ $ ratio and economy/environment ratio are presented in Table 4.

The renewable environmental sources (R) are identified as rain and wave. Wind, tide and sunlight are not added into the total renewable flow of emergy (Table 1) since

they are a part of the same coupled solar and earth based flows, it would be double counting to add the emergy of each.

Table 3 and Fig. 2 show the summary of emergy flows and use for Hong Kong. Most resources emergy for Hong Kong are from outside input, especially from China mainland where primary products and services are provided. It is apparent that Hong Kong's economy is based on outside resources and benefiting in purchasing emergy.

3. 2 Environmental resource emergy perspectives on economy of Hong Kong

The emergy basis of the economy is considered in perspective of economic and environmental emergy contributions, self-sufficiency and international trade.

Total emergy use for Hong Kong in 1988 is estimated at 556. 94 E20 sej/a, that measures its annual real wealth, including resources and products. By dividing the annual emergy use by the Gross Domestic Product (GDP) of Hong Kong in 1988, the solar emergy supporting its currency is calculated at 1. 02 E12 sej/US $. This emergy/money ratio, a measure of emergy buying power of Hong Kong's currency converted into international dollars for 1988, is very close to the value of other industrially developed countries in the world (USA 1. 7; Japan and Spain 1. 6; Italy 1. 44; Switzerland 0. 7), while developing or unindustrialized countries show higher ratios (Papua New Guinea 48. 0 E12; Liberia 34. 5 E12; Dominica 14. 9 E12; Ecuador, Brail and China 8. 7 E12), where a smaller GNP is supported by large environmental free emergy flows.

Imports of goods, primary products and fuels, associated human services and tourism constitute the largest of the emergy inflows supporting Hong Kong's economy. Most import emergy are used for re-exports, and others are used in domestic production and consumption for Hong Kong (Table 1,2).

The ratio of import emergy to export emergy for Hong Kong in 1988 is 1. 37 (Table 4), which means emergy inflows are more than outflows. That is similar with most developed countries or regions and different from developing countries (Japan 4. 2; Switzerland 3. 2; USA 2. 2; New Zealand 0. 7; Thailand 0. 5; China 0. 3; Ecuador 0. 2).

Emergy use per person, as a measure of standard of living, is 9. 8 E15 sej/person/a for Hong Kong in 1988. This standard is at a middle level compared with other countries or regions (USA 29 E15; Netherlands 26 E15; Japan 12. 6 E15; Ecuador 10. 7 E15; Taiwan 7. 5 E15; China 6. 5 E15; Thailand 3. 2 E15; India 1. 05 E15). There are two ways to increase the emergy per person: either increasing the flows of energy or controlling the population. It is necessary to control the population of Hong Kong, since that can decrease the pressure both on the environment and on the society.

Finally, the economy/environment ratio of Hong Kong is 61. 58 in 1988. Such high ratio suggests a fully developed economy and a higher level of environment stress in Hong Kong than many countries in the world (Switzerland 7. 4; USA 7. 1; Sweden 7. 0; Australia and Thailand 1. 1; Ecuador 0. 09) since Hong Kong is only a metropolitan city.

Hong Kong's low emergy/money and high economy/environment ratio indicates

that its economy depends on outside environmental resources and is not self-sufficient based on emergy; and its GDP is supported by purchasing emergy. The sustainable development of Hong Kong is limited especially by the natural resources factor. However, Hong Kong is full of vitality. It must be acknowledged that Hong Kong is currently benefiting in emergy wealth from import and export with China mainland and other countries. If emergy-rich raw materials, goods and services now being imported into Hong Kong are no longer available, or their cost rises to equal their emergy value, the economy of Hong Kong will be reduced, which means Hong Kong should continue to develop international trade and cooperation with China mainland and other countries in the world.

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