IN SEARCH OF STEADY STATE

Written in 1978
Scanned & OCR conversion and edited in 2018

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INTRODUCTION

In 1978 a small group of students at the Auckland Architectural School made an undergraduate thesis study of Low Energy Settlement Patterns in New Zealand under the supervision of Associate Professor Cameron McClean. Each student concentrated on a particular aspect of human settlements while, at the same time, participating in a group 'think tank'. Some areas of study led to conventional conclusions while others – in particular Leslie Matthew's chosen topic of agriculture, a key factor – led to a group consensus that existing spatial patterns of settlements in New Zealand would ultimately need to change with the advent of a diminishing supply of easily accessible high-grade energy. My own sub-thesis, In Search of Steady State, concentrated on the overriding context of low energy settlement patterns in New Zealand.

In 1979 I published a summary of my sub-thesis as a short communication in the international journal Urban Ecology. In this summary article titled Ekistics and Energetics: A Sustainable Future Planning Approach, I advocated the integration of the two separate disciplines of Energetics and Ekistics to enable an orderly transition from growth to steady state settlements.

Energetics, as promoted by Howard Odum of Florida University, uses circuit language to describe energy flows. Studies of the energy flow patterns in existing human populations and settlements are needed so that the mechanism of growth to steady state is better understood and appropriate measures can be taken to alleviate the transition period. By tracing energy flows, the embodied energy content of goods and services can be reduced as a result of a better understanding of how and where energy is used. Net energy analysis of alternative methods of generating energy can show whether a particular method is feasible or not. By using energetics, comparisons of different methods are enabled at a comprehensive level which does not ignore intangibles or externalities. This applies especially to technologies such as nuclear fission, solar cells, and bio-fuels.

Ekistics is a taxonomic and methodological system developed by Constantinos Doxiadis for examining the highly complex organisation of human settlements. In any complex field of study there needs to be a systematic form of classification. Although this is a process of reductionism, the science of Ekistics is the study of the relationships of the parts.

I included in my short communication a summary of my sub-thesis in table form which compares the attributes of growth versus steady state settlements. This table, or matrix, shows the direction of change required to achieve long term steady state when all high grade energy resources such as oil, coal, gas, and shale would be too expensive to further extract from the ground. In my short communication I promoted use of this Growth and Steady State Settlement Matrix (GSSS Matrix) by planners to construct a parallel and internally consistent planning strategy matrix to assist guiding a transition from growth to steady state.

It is now almost 40 years ago that I created this GSSS Matrix. I was an undergraduate at the time in my final year of studies towards a degree in Architecture. My background and time available back then was too limited to do full justice to an in-depth study of steady state settlements. I had relied heavily on research that had been carried out by others in disparate disciplines and my contribution was in creating a reasonably comprehensive summary of that research.

A number of categories and attributes in my 1978 GSSS Matrix need to be revised, corrected, and updated. These items are highlighted in red. Modifications include rewording and regrouping of attributes under better worded categories. Additional categories that address economics, politics, and banking also need to be included.

In this 2018 edited version of my 1978 sub-thesis I used Abby FineReader 12 to scan and OCR convert the hardcopy of my sub-thesis into a word document. I then corrected spelling and formatting errors. The only changes I have made to the text are a number of additional Settlement Attribute categories against existing attributes in the Summary of the Principles of Steady State table. Diagrams and tables within the text and the Appendices on New Zealand data are not included in this 2018 edited version. These can be viewed by downloading the scanned version of my sub-thesis from my website:

www.insearchofsteadystate.org/downloads/InSeachOfSteadyState-1978.pdf

When I wrote this sub-thesis in 1978, time was of the essence. I therefore relied heavily on using long quotations in order to retain the scope of my sub-thesis. These quotations are highlighted in red in this 2018 edited version.

IN SEARCH OF STEADY STATE

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1978

Thesis submitted as partial requirement for BArch

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SYNOPSIS

IN SEARCH OF STEADY STATE

This thesis was initially a study of "low energy" settlements in New Zealand. By putting on mental blinkers and making "gross assumptions that whatever was not investigated would not upset the overall conclusions made a string of pearls approach plausible. But what the study required was a holistic approach. An examination of the meaning of a "low energy" settlement reveals that such a settlement is a "steady state" settlement. But just exactly what is "steady state"? This thesis has developed into the study of the context of a low energy future. The accelerating energy interrelated problems that beset mankind are outlined. Through the use of Energetics, the study of energy flows through ecosystems, an understanding is made of the growth and climax phase of ecosystems and why human settlements also either adopt steady state or decline. An exploratory study is made of the spatial, organisational, and economic factors which together influence the various patterns of steady state. The principles of steady state, alas ,cannot be simply summed up as "Zero population growth, zero economic growth". This thesis does not pretend to answer all the questions that the reader may raise. But it does put forward the important issue that the context of a low energy future is steady state. And very little about steady state has been researched. The open-ended question of "what is steady state" continues.

" Questions I am asking, Answers I am seeking,
Is seeking the Truth Living, or is Living the Truth,
Because these two Paths I can see,
. . . ."

To Pam, Debby and Mark, and their children . . . . . .

Acknowledgements

To Associate Professor Cam McClean who initiated this type of study and without whose encouragement I would have been tempted to "prune" down many times the scope of this thesis.

To fellow students and the staff of the Auckland Architectural School,

My special gratitude goes to Richard Newbold Adams, Ludwig von Bertalanffy, Walter Christaller, Herman Daly, Constantinos Doxiadis, Paul and Anne Ehrlich, Nicholas Georgescu-Roegen, John Holdren, Howard and Elisabeth Odum, William Ophuls, A.C. Pigou, and many others too numerous to name, without whose research this thesis would not have been possible

CHAPTER 1

THE PROBLEM

"The point is not to see who may be the more correct, but to see the areas which will be particularly vital in the future and also to note some of the profound moral, ethical, and human questions which will be raised." - Sir George Thomson

INTRODUCTION - FUTURE FORECASTING

Before the reader starts turning the following pages let there be no misunderstanding between us. The purpose of this thesis is to present a future forecast of what steady state means for mankind. In any forecast the predictions are laced with the value judgements and assumptions of the forecaster. Some of the following areas may be, as yet, unfamiliar to the reader. Nonetheless, this is the time where I bear a responsibility to be as frank as I can and list all my own assumptions and value judgements which relate to the following pages and to outline the purpose of this thesis.

1. A forecast can be a prediction or a plan. We plan those events subject to our control and predict those that are not. This thesis is a forecast. I am certain, (and the following pages will support each of my convictions) that mankind will not prove the exception to the laws of thermodynamics and as part of an open ecosystem, will be subject to the same laws of growth. Eventually when our high grade energy resources are depleted or are too expensive to further extract from the ground, mankind will either live in a homeostatic, steady state, symbiotic relationship within his closed ecosystem of Earth, or else he, like others before him, will face extinction I make the assumption that mankind will continue to survive. I do not wish to be foolhardy, and make rash predictions. Instead I will attempt' to predict the future we are able to have rather than the future we would desire to have. The following diagram will illustrate my point.

Figure 1-1 Growth to Steady state (refer to scanned version)

We are now on the rapid growth part of the logistic curve and possibly near the hump of the transition period. Why the hump? Mankind unlike other organisms within our ecosystem has been able to tap high grade energy resources and the momentum of the growth made possible creates this transition period where there will be a decline before steady state is reached. I have chosen to investigate the steady state part of the growth curve. This could be at point T1, T2, or Tn in time. This is an assumption in itself that point Tn will be similar to point T1 which I will continue to outline.

2. At point Tn in time our high grade energy resources such as oil, coal, and gas will be depleted. The only other sources of energy will be solar based energy such as hydro-electricity, phytomass (plant tissue) burning, wind power, and solar concentrators. Of course we have nuclear fission energy and solar photo cells. This thesis is concerned with long term steady state and there are strong practical reasons why nuclear energy is excluded. (see section on The Problem - Alternative Energy Sources). I also have a strong personal value judgement against the use of nuclear fission as an energy source on ethical grounds that we bear a responsibility to future generations of mankind not to endanger their existence and leave them a heritage they will have to guard for centuries. This thesis is also concerned only with technology that we have fully developed now. We need to be cold hearted realists and irresponsible optimists have no place in this field. Nor am I taking the stance of the pessimist as we must also be open to new ideas. Due to our diminishing capital for further investment in large scale developments, I am disregarding the far off possibility of fusion energy. Should our level of technology improve then the implications of this is that the carrying capacity and the consumer level of life can both increase.

3. Steady state for mankind means zero population growth. If we were to adopt a policy of ZPG now we would not be able to attain ZPG for a number of generations due to the momentum of population growth, in spite of the low growth we have now in some countries. This gives some indication of the earliest period that we can attain steady state in New Zealand.

4. This undergraduate thesis will be looking at the direction of change required to achieve steady state rather than at magnitude I realize that in the short space of time that has been available many areas will not be covered. I will do my best to 'cover those that are the most important. This in itself will reflect my own priorities. You, as the reader have a duty to point out the areas where I, through lack of experience or understanding, have made false assumptions. This type of study is too important' for one to withhold criticism. On one point I rest assured - that regardless of criticism and discussion we will have steady state or become extinct, irrespective of our present world view of what steady state means.

Because we have much to cover and because the social and environmental problems that mankind faces are well documented I will make direct quotations to give an outline of these problems. If you, the reader are well versed in this field, suggest that you skim over the remainder of the chapter for any new information and commence in Chapter 2 where an introduction to energetics is made. I make no apologies that this, a thesis for a. Bachelor of Architecture degree covers a diverse range of topics not normally explored. I believe that the training an architect receives offers him an advantage over many other disciplines to encompass the full complexities which directly or indirectly influence future settlements and indeed the survival of mankind itself.

In the Appendices section at the back of this thesis is presented' some statistical information on New Zealand. As you read through the thesis you may wish to refer to the Appendices to assure yourself that New Zealand is not a unique land of Utopia which is excluded from the findings in this thesis. (From time to time direct reference to New Zealand will be made and where reference to the Appendices is recommended this will be indicated in the same way as other references). A recommended reading list also included at the end of the Appendices.

THE PROBLEM - REDUCTIONISM

> "We have been trained to think, or have accepted as common sense that what goes on around us can be understood as some set of simple causal sequences in which, for instance a causes b and b causes c, then c causes d, and so on. This is only good enough when a causes b but has very little effect on anything else, and similarly the overwhelmingly most important effect on b is to cause c. Many of our own individual actions still have this character. That is really because they are in some ways relatively feeble compared to the whole mass of things and processes of which they are a part. The change which has occurred, or is occurring now, is that the effect of human societies on their surroundings is now so powerful that it is no longer adequate to concentrate on the primary effects and neglect all the secondary influences." C.H. Waddington, "Tools for Thought", St Albans, Paladin, 1977, pxi.

> "There is, perhaps, a deep-lying reason why our mental representation of the universe always mirrors only certain aspects or perspectives of reality. Our thinking, at least in occidental but possibly in any human language, is essentially in terms of opposites. As Heraclitus has it, we are thinking in terms of warm and cold, black and white, day and night, life and death, being and becoming." Ludwig von Bertalanffy, "General System Theory", New York, George Brazilier, 1968, p247.

"Since the time of Galileo and Newton, modern science has been dominated by the ideal of explanation by reduction to the smallest isolable component's behaviour in causal terms. Phenomena, however complex, were sought to yield isolated causal relation, and the sum of these were believed to constitute an explanation of the phenomena themselves. Thus two-variable linear causal interaction emerged as the principal mode of scientific explanation, applying to the primitive components of a given complex of events. Explanation in these terms presupposed atomism and mechanism as a general world view. But where contemporary science progressed to the rigorous observation, experimental testing and interpretation ... such explanations no longer functioned. Complex phenomena proved to be more than the simple sum of the properties of isolated causal chains, or of the properties of their components taken separately." "The Relevance of General Systems Theory", Editor E. Laszlo, New York, George Brazilier, 1972, p5.

THE PROBLEM - EXPONENTIAL GROWTH

There is the well-known story of the farmer who noticed a waterlily on his pond which doubled in size every day. To start with, the water-lily covered only a small area of the pond and the farmer said “to hell with it”. Eventually it got quite large and covered a sizeable area. The farmer said to himself that he would take care of the water-lily when it grew to cover half the pond. And it did. And the following day the water-lily choked up the entire pond.

There is also the story of the peasant who, when asked by the Sultan what gift he desired in return for saving the life of his daughter, replied that all he desired was to be paid in grains of wheat - with one condition. On the first day he should be paid one grain of wheat and for each day hence until all the squares on the Sultan's chess board had been marked off for each day, he should receive double the number of grains of the previous day. The puzzled Sultan agreed to these terms. How soon did the Sultan request the peasant to choose an alternative gift?

"Given steady exponential growth, the absolute size of the stock of any resource has very little effect on the time it takes to exhaust the resource.

Given already high absolute demand on a particular resource, the rate of growth in demand thereafter has almost no effect on the time it takes to exhaust the resource.

The time for concern about the potential exhaustion of a resource comes when no more than about 10% of the total has been used up." William Ophuls, "Ecology and the Politics of Scarcity'', San Francisco, Freeman, 1977. p65.

THE PROBLEM - ENERGY

"Analysis of the depletion of conventional stock limited energy resources is itself a complicated enterprise. Much confusion is sometimes engendered in this connection by failure to distinguish clearly between reserves and resources. The term 'reserves' generally refers to materials whose location is known (proved reserves) or inferred from strong geologic evidence (probable reserves) and which can be extracted with known technology under present economic conditions (that is, at costs such that the material could be sold at or near prevailing prices). The "resources" of a substance includes the reserves and, in addition, material whose location and quantity are less well established or which cannot be extracted under prevailing technological and economic conditions. The tern "ultimate recoverable resources" describes an estimate of how much material will ever be found and extracted (implicitly including an assessment of how much effective technology will ever become and how much civilization will ever be willing to pay for the material). Such estimates are necessarily very crude. ...

Probably the least sophisticated approach to the analysis of depletion is to estimate the lifetime of the supply by dividing present proved reserves by the present rate of consumption. This approach is the origin of the often-heard statements to the effect that, 'We have X years' worth of petroleum left'. The method errs because consumption is not likely to stay constant and because proved reserves often bear little relation to ultimately recoverable resources. ...A somewhat more instructive way to assess the lifetime of a fuel is to divide available estimates of the ultimately recoverable resources by a level of consumption several times the present one (on the assumption that consumption will level off before too long) or a level of consumption continuing to grow as it has in the recent past. A shortcoming if a constant consumption is assumed is the sensitivity of the result to highly uncertain estimates of the resource and of the equilibrium level of consumption; if continuous growth is assumed, the result is not so sensitive to errors in the resource estimate, but is very sensitive to the growth rate chosen.

The most realistic approach seems to be the one devised by geologist M. King Hubbert. He notes that the production cycle for any stock-limited resource is likely to be characterised by several phases: first, increasingly rapid growth in the rate of exploitation as demands rises, production becomes more efficient, and costs per unit of material fall; then a levelling-off of production as the resource becomes scarcer and starts to rise in price; and finally a continuous decline in the rate of exploitation as increasing scarcity and declining quality proceed more rapidly than can be compensated for by improving technology, and as substitutes are brought fully to bear." P.R. & A.H. Ehrlich and J.P. Holdren, "Ecoscience: Population, Resources, Environment", San Francisco, Freeman, 1977, pp400-1.

Photocopy of Hubbert Curve (refer to scanned version)

"The future of oil supply is uncertain. The cases considered in this analysis show differing years and different levels of peak production, with dissimilar levels of production in the year 2000. However one conclusion is very clear: potential oil demand in the year 2000 is unlikely to be satisfied by crude oil production from conventional sources. …The end of the era of growth in oil production is probably at the most only 15 years away. However, there may be a decade or so of more or less constant oil production after 1990 in which consumers will have to make the adjustments necessary to face a decline in oil supply." "Energy: Global Prospects 1985-2000", Report of the Workshop on Alternative Energy Strategies. Project Director Carroll L. Wilson New York, McGraw-Hill, 1977, p145.

Energy Conservation and Efficiency

"… what are the prospects for using energy with greater efficiency and therefore reducing demand significantly? In fact, very large savings, possibly as much as 25 or 35 percent of consumption, could be made without major technological breakthroughs or drastic changes in life-style. Already, for example, the increased cost of energy has lead businesses to engage in energy cost accounting, and substantial economies (15 to 30 percent) have been made by some plants. However, once the easy targets, like sheer waste, have been dealt with, it will become progressively harder to make further economies without either technological breakthroughs or major social changes..... In fact, any gains in efficiency are likely to be counterbalanced by another form of diminishing returns - declining net energy yields. Energy is always needed to produce energy. The trend towards declining net energy yield is (therefore) already in evidence, and it is certain to become more pronounced in the decades to come. ...there can be little doubt that the process of energy production must become more energy (and capital) intensive and that most calculations of reserves, because they do not take into account the increasing amounts of energy needed to turn the reserves into useful forms of supply, grossly overstates the actual quantity of net energy available to us in the future. …" William Ophuls, "Energy and the Politics of Scarcity", San Francisco, Freeman, 1977, pp111-5.

Firewood

"Dwindling reserves, of petroleum and artful tampering with its distribution are the stuff of which headlines are made. Yet for more than one third of the world's people, the real energy crisis is a daily scramble to find wood they need to cook dinner. Their search for wood, once a simple chore and now, as forests recede, a day's labour in some places, has been strangely neglected by diplomats, economists, and the media. But the firewood crisis will be making news - one way or another - for the rest of the century." Erik P. Eckholm, "The Other Energy Crisis: Firewood" in "Worldwatch Paper 1", Washington, Worldwatch Institute, 1975, p5.

See Appendices pp194-203

THE PROBLEM - UNEQUAL DISTRIBUTION OF RESOURCES

"Every recent scientific analysis of the food-production problem shows in fact, if not in the overlaid political interpretations, that people go hungry not because the world cannot produce enough to feed them, but because they are too poor to afford it. To claim that many people go hungry and cold in the world because there is not enough adequate food and fuel has no more basis than the claim that some people in the United States are poor because there is not enough wealth to go around. The basic fault that gives rise to these calamitous problems is the unequal distribution of wealth - between rich countries and poor ones and, within each country, between rich people and poor people. Their origins will not be found in the earth's ecosystem or in the present state of its available resources." Barry Commoner, "The Poverty of Power", New York, Bantam, 1977, pp218-9.

"By 1972, people in Developed countries on the average consumed directly, or indirectly, four times as much food per person as people in the Lower Developed countries." United Nations Statistical Yearbook.

Table of Gross national product and population, 1973 (percentages). (refer to scanned version)

Based on World Bank Atlas, 1975; Population, per Capita Product, and Growth Rates in "Reshaping the International Order" Jan Tinbergen: Co-ordinator London, Hutchinson, 1977, p12.

"Let us define as 'rich' all populations in countries with an average fuel consumption - in 1966 - of more than one metric ton of coal equivalent (abbreviated: c.e.) (using United Nations figures throughout):

Table 1 (1966) (refer to scanned version)

If the 'rich' population grow at the rate of 1.25 per cent and the poor at 2.6 per cent a year, world population will grow to about 6,900 million by 2000 A.D.... If, at the same time, the fuel consumption per head of the 'rich' population grows by 2.25 per cent, while that of the 'poor' grows by 4.5 per cent a year, the following figures will emerge for the year 2000 A.D.

Table 2 (2000)

...These figures are not, of course, predictions: they are what may be called exploratory calculations. ... It is clear that the 'rich' are in the process of stripping the world of its once- for-all endowment of relatively cheap and simple fuels." E.F. Schumacher, "Small is Beautiful" London, Abacus, 1977, pp20-1.

Transportation and Equity

"Past a certain threshold of energy consumption, the transportation industry dictates the configuration of social space. Motorways expand, driving wedges between neighbours and removing fields beyond the distance a farmer can walk. ...Past a certain threshold of energy consumption for the fastest passenger, a worldwide class structure of speed capitalists is created. The exchange value of time becomes dominant, and this is reflected in language: time is spent, saved, invested, wasted and employed. As societies put price tags on time, equity and vehicular speed correlate inversely. High speed capitalises a few people's time at an enormous rate but, paradoxically, it does this at a high cost in time for us all. Beyond a critical speed, no one can save time without forcing another to lose it. ...Beyond a certain velocity, passengers become consumers of other people's time, and accelerating vehicles becomes the means for effecting a net transfer of life-time. The degree of transfer is measured in quanta of speed. This time-grab despoils those who are left behind, and since they are the majority, it raises ethical issues of a more general nature than kidney dialysis or organ transplants. ...The need for unequal privilege in an industrial society is generally advocated by means of an argument with two sides. The hypocrisy of this argument is clearly portrayed by acceleration. Privilege is accepted as the necessary precondition to improve the lot of a growing total population, or it is advertised as the instrument for raising the standards of a deprived minority. In the long run, accelerating transportation does neither. It only creates a universal demand for motorised conveyance, and puts previously unimaginable distances between the various layers of privilege. Beyond a certain point, more energy means less equity." Ivan D. Illich, "Energy and Equity", London, Calder & Boyers, p1974, pp35-45.

THE PROBLEM - CAPITAL

GNP Indicator

"… GNP is a poor measure of the quality of life. On the one hand it aggregates so many wildly diverse things into one number that the number does not say very much. At the same time it excludes from consideration such a broad assortment of factors that … the quality of our lives can diminish as GNP swells. Robert Kennedy spoke movingly of the shortfalls of such GNP accounting: For the gross national product includes air pollution and advertising for cigarettes, and ambulances to clear our high-ways of carnage. It counts special locks for our doors and jails for the people who break them. The gross national product includes the destruction of the redwoods and the death of Lake Superior. It grows with the growth of napalm and missiles and nuclear warheads, and it even includes research on the dissemination of bubonic plague. The gross national product swells with equipment for the police to put down riots in our cities; and though it is not diminished by the damage these riots do, still it goes up as slums are rebuilt on their ashes. It includes Whitman's rifle and Speck's knife, and the broadcasting of television programs which glorify violence to sell goods to our children." Denis Hayes, "Energy: The Case for Conservation" in "Worldwatch Paper 4", Washington, Worldwatch Institute, 1976, p51.

Capital and Space-Colonization

"Most technologists would deny any pretension to replacing nature. Yet there are abundant examples of failure to count the financial cost of technological schemes. One is found in the assertion, which has unfortunately begun to achieve some currency, that the way out of man's ecological bind here on earth lies in space. ...It is abundantly clear that whatever the ultimate potential for founding extra-terrestrial colonies or whatever the ultimate cosmic destiny of the human race, space offers no escape from the limits to growth on this planet. To rocket into space just one day's world population growth (approximately 200,000 people) would be a major undertaking (assuming 100 persons per shuttle flight, 2,000 flights would be necessary). This alone would generate colossal environmental problems - enormous quantities of energy for fuel, pollution of the atmosphere (especially the vulnerable stratosphere) by toxic exhaust gases, and so on - and trying to keep pace with population growth would be out of the question. Moreover the expense would be staggering. According to the latest NASA estimates, it would require $160 to lift each pound of pay load into orbit with the space shuttle now being developed; it would therefore cost $20,000 per 125 pound person or about $4 billion for those 200,000 persons (exclusive of space-colonization or other life-support costs, which would be substantial). Thus keeping pace with the world's population growth for just one year would require a sum exceeding the U.S. gross national product. It is apparent that even highly developed and routinised space travel is not likely to involve large-scale movement of people and materials from earth, at least not in any foreseeable future." William Ophul, "Ecology and the Politics of Scarcity", San Francisco, Freeman, 1977, p122.

THE PROBLEM - ALTERNATIVE ENERGY SOURCES

Nuclear Reactor Hazards

Radiological hazards arising from the nuclear reactors can be divided into three categories:
1. routine and accidental radiation doses to workers in nuclear
power plants;
2. radiation doses to members of the public resulting from routine emissions of radioactivity from reactors in normal operation;
3. radiation doses to members of the public from accidents or sabotage at reactors. ... there are at least four modes of potential failure modes (in no implied order of likelihood): 1. human error and/or mechanical failure internal to an installation; 2. human error and/or mechanical failure external to the installation (such as a plane crash); 3. natural catastrophe (earthquake, tornado, tsunami);
4. malicious human activity (war, sabotage, terrorism). Reactor systems themselves are extraordinarily complex, and neither the probabilities of component failure nor the possible failure modes of the systems are known with sufficient assurance to permit a meaningful calculation of a catastrophic event of Category 1, listed above. Although there has been no major accident to date (in loss of human life) at a commercial power reactor, there have been enough serious malfunctions to confound the calculators of such probabilities. ... As of mid-1975, there had been little more than 1,000 reactor years of power-reactor experience worldwide. Therefore, on the basis of experience alone, no one can be sure that the probability of a catastrophic accident is not as high as 1/1000 per reactor-year (although so high a figure seems unlikely). P.R. & A.H. Ehrlich and J.P. Holdren, "Ecoscience: Population, Resources, Environment", San Francisco, Freeman, 1977, pp442-7.

An Accident

"At noon on March 22, 1975, both units 1 and 2 of the Browns Ferry plant in Alabama were operating at full power, delivering over 2,100 megawatts of electricity to the Tennessee Valley Authority (TVA). Just below the plant's control room, an electrician and an inspector were trying to seal air leaks in the cable-spreader room, where the electrical cables that control the two reactors are separated and routed through tunnels to the reactor buildings. They were using strips of spongy foam rubber to seal the leaks. They were also using candles to determine whether or not the leaks had been successfully plugged, by observing how the flame was affected by the escaping air. The electrical inspector put the candle too close to the foam rubber, and it burst into flame. The resulting fire disabled a large number of engineered safety features at the plant, including the entire emergency core cooling system (ECCS) on Unit 1, and almost resulted in a meltdown accident." David Dinsmore Comey, "The Incident at Browns Ferry" in "The Silent Bomb", Editor Peter Faulkner San Francisco, Vintage Books, 1977, p 3.

Effects of Radiation

"If a major accident occurs, enormous amounts of radioactive fission products will be released into the atmosphere. A large number of people will be exposed directly to massive doses of radiation. What will happen to them?

- No one would survive a whole body dose of greater than about 600 rem unless they received good supportive therapy; even then their chance of surviving would not be large. .
- A dose of 300-350 rem will be deadly in half the cases, although good medical treatment might extend this to 500 rem.
- A dose of 200 rem or more received in a single brief exposure will be fatal in some cases. ... The important question is, how does the level go before we can declare unequivocally that no genetic damage will occur? In 1960, James F. Crow, professor of genetics at the University of Wisconsin School of Medicine and president of the Genetics Society of America, provided the chilling answer: Geneticists are convinced that there is no threshold for radiation-induced mutations: that is, there is no dose so low that it produces no mutations at all. Each dose, however small, that reaches the germ cells between conception and reproduction carries a risk to future generations proportional to the dose."

Richard Curtis and Elizabeth Hogan, "What You Don't Know Will Kill You", in "The Silent Bomb", pp64-70.

Nuclear Power and Energy Demand

"Assume, as the technology optimists want us to, that in one hundred years all primary energy will be nuclear. ...In order to produce the world's energy in one hundred years ... we will merely have to build, in each and every year between now and then, four reactors per week! And that figure does not take into account the lifespan of nuclear reactors. If our future nuclear reactors last an average of thirty years, we eventually shall have to build about two reactors per day simply to replace those that have worn out." M. Mesarovic and E. Pestel, "Mankind at the Turning Point", New York, New American Library, 19745, p132.

Breeder Reactors

"Breeder reactors are arranged so that some of the initial nuclear reaction produces secondary nuclear reactions that create additional radioactive fuels. The radioactive reaction of one kind of fuel causes a second type to become radioactive and capable of reacting to make more heat. Because the reaction generates some new kind of fuel while using the first fuel, it is called a breeder reaction. There are some breeder-reactor pilot (test) plants in operation, but how much net energy they will generate is not yet clear. One uncertainty is the costs (high in terms of both money and energy) that will be necessary for long-term storage of radioactive wastes. The breeder processes involve a very poisonous element, plutonium. Because plutonium is so toxic, special care must be exercised in the operation itself, in disposing of wastes, and preparing for possible accidents." H.T. & E.C. Odum, "Energy Basis for Man and Nature", New York, McGraw-Hill, 1976, p183.

Disposal of Nuclear Reactor Waste

“No international agreement has yet been reached on waste disposal. … High level wastes continue to be dumped into the sea, while quantities of so-called 'intermediate' and 'low-level' wastes are discharged into rivers or directly into the ground. An AEC report observes laconically that the liquid wastes ‘work their way slowly into the ground water, leaving all or part (sic!) of their radioactivity held either chemically or physically in the soil'. The most massive wastes are, of course, the nuclear reactors themselves after they have become unserviceable. There is a lot of discussion on the trivial economic question of whether they will last twenty, twenty-five, or thirty years. No-one discusses the humanly vital point that they cannot be dismantled and cannot be shifted, but have to be left standing where they are, probably for centuries, perhaps for thousands of years, an active menace to all life, silently leaking radioactivity into air, water and soil." E.F. Schumacher, "Small is Beautiful", London, Abacus, 1973, pp113-4.

"Current reactor technology is extraordinarily inefficient. Although alternative technologies exist (for example, Canada's CANDU reactors), the so-called light-water reactors now predominately used to generate power burn only naturally fissionable uranium 235 which constitutes only a tiny fraction of naturally occurring uranium (composed largely of uranium 238). The uranium 235 must be concentrated by laborious and highly energy-intensive techniques before it can be used for reactor fuel. Although minable uranium ore has not yet run out, proven reserves (especially. of domestic uranium) will hardly last until 1985 if nuclear generation grows as rapidly as projected. ...Current light-water reactors are also relatively inefficient energy converters, transforming only about 30 percent of their fuel into electricity (as against 40 percent achieved by the most efficient fossil-fuel plants). The rest of the potential energy in the uranium 235 is turned into waste heat." William Ophuls, "Ecology and the Politics of Scarcity", San Francisco, Freeman, Page 25 1977, pp90-1.

THE PROBLEM - POLLUTION

"What we have to face is not an occasional dose of poison which has accidently got into some article of food, but a persistent and continuous poisoning of the whole human environment." - Rachel Carson, "Silent Spring", Harmondsworth, Penguin, 1965, front cover quotation.

Climate

"The impact of the world's four billion people on climate can already be measured locally where ever population density is great. Even more worrisome, local changes may also be triggering shifts in global climatic patterns and trends. Unfortunately, the impact of man's activities on the world's weather is not fully understood. A growing population generates increasing amounts of carbon dioxide, airborne dust, and thermal pollution. It fuels an expanding demand for food that may soon be the justification for attempts by hard-pressed countries to tamper with their climate. These unforeseen and often abrupt climatic changes add yet another element of uncertainty to an already uncertain future." Lester R. Brown, Patricia L. McGrath, Bruce Stokes, "Twenty-Two Dimensions of the Population Problem" in "Worldwatch Paper 5", Washington, Worldwatch Institute, 1976, p37.

"There are half a million man-made chemicals in use today, yet we cannot predict the behaviour or properties of the greater part of them (either singly or in combination) once they are released into the environment. We know, however, that the combined effects of pollution and habitat destruction menace the survival of no fewer than 280 mammal, 350 bird, and 20,000 plant species. To those who regret these losses but greet them with the comment that the survival of Homo sapiens is surely more important than that of an eagle or a primrose, we repeat that Homo sapiens himself depends on the 'continued resilience of those ecological networks of which eagles and primroses are integral parts." Editors of *The Ecologist*, "A Blueprint for Survival", Penguin, 1977, pp20-1.

THE PROBLEM - FOOD

"During periods of expanding energy, technological agriculture, and modern medicine, the world as a whole produced enough food and at the same time expanded populations. By the 1970's there was doubt that food production could be expanded much more. Agriculture is now based mainly on fossil fuels, and fossil-fuel energy is being rapidly depleted and becoming harder to get. Also, many of the methods of stimulating agricultures have been used, and now yields increase less for each effort to stimulate them. When countries with too many people for their own food supplies have experienced famines, the rest of the world has sent its surpluses, preventing the terrible episodes of starvation and disease that accompanied famine. No really strong force has compelled any country to limit population or to change its culture to avoid famine. By the 1970's the world food pools existed only in the industrialized agricultural nations, and these pools have begun to disappear as costs of fossil fuels rise. Any further growth of population is sure to bring worse food shortages and more famines." H.T & E.C. Odum, "Energy Basis for Man and Nature", New York, McGraw-Hill, 1976, pp207-8.

"If systems of food production, processing, and distribution worldwide were "modernised" to the same degree as in the U.S. and the U.K., the equivalent of 40 percent of the world's commercial fuel consumption in 1972 would be required to feed Earth's 4 billion people today." Gerald Leach, "Energy and Food Production", in Food Policy, Vol 1, no 1, pp62-73.

"… there have been some danger signals that we would be foolish to ignore. One is the disappearance of the world food reserve between 1972 and 1974. The planet's grain reserves could not now feed people for more than a fortnight, whereas, in the last ten to fifteen years, we have never had a reserve that could last less than 80 to 90 days. This is a very large cut in one of the resource bases that, until recently, we thought to be adequate." Barbara Ward, RIBA Journal, Dec. 1974, p13.

"Three-fourths or more of the food in an Asian's diet comes directly from grain - 135 to 180 kilograms per year. An affluent American accounts for the consumption of nearly a ton of grain per year, but 80 percent of it is first fed to animals. Because Americans are feeding higher on the food chain, most or the food is lost to human nutrition." Lappe, F.M., "Diet for a small Planet", New York, Ballantine, 1975, p138.

"If energy accounting rather than financial accounting is used to evaluate the efficiency of food-production systems, a surprising fact emerges. The books are not balancing for the more advanced agricultural systems, which are running up an energy deficit. As the geographic distance from producer to consumer lengthens, as the degree of processing increases, and as energy is substituted for labor and land, the deficit increases accordingly." Lester R. Brown, "By Bread Alone", New York, Praeger, 1974, p106.

"Energy is another factor which dominates the whole field of agriculture. While fuel supplies were cheap and abundant, we were slow to appreciate that agriculture in the developed countries is highly energy-intensive. The increasing cost of fossil fuels and the growing awareness that these resources are finite have prompted many studies of the economics of food production expressed in terms of energy rather than money. How many calories does it cost to put a calorie of food on the table? In simple human societies which obtain their food without fossil food subsidies, a typical ratio of food calories gained to fuel calories invested is around 10. In advanced technological societies some analyses have given a ratio of calorie output to calorie input of 0.1. Of course these figures in isolation give an over-simplified view of agriculture, and I would not advocate on the strength of them that we revert to a peasant economy to increase productivity. But I do believe that simple comparisons of this nature do illustrate quite dramatically the very great dependence of our agriculture economy on energy: not simply on its cost but on its availability. It seems inevitable that a growing scarcity of the fossil fuels needed to power machinery on the farm, to produce fertilisers and pesticides, and to process and transport agricultural products must have profound long-term effects on production." Hon. L.W. Gandar, Minister of Science & Technology in his Opening Address to symposium on the management of dynamic systems in New Zealand agriculture, "Management of Dynamic systems in New Zealand Agriculture", Wellington, Science Information Division DSIR, 1977, p10.

"Hearing talk of food shortages and future production constraints, some scientists calculate reassuringly that with present-day technology put to work on all potentially arable lands, planet earth could feed fifteen, twenty, or even forty billion inhabitants. But rarely does the real world of human events intrude upon theoretical computations wearing such a gaunt face as it does in the case of food. ...Even as capital and energy consideration hamper the realization of hypothetic agricultural potential, every ton of fertile topsoil unnecessarily washed away, every hectare claimed by desert sands, every reservoir filled with silt further drains world productivity and spells higher costs for future gains in output. ...Losses of productive capacity due to environmental stress must also be considered in the context of the reckless, inadequately measured takeover of current and potential farmlands by urban sprawl and other competing uses, a myopic activity occurring in both rich and poor countries. ...Land losses to non-agricultural uses join the losses to environmental deterioration to reduce the ability of our planet to produce food." Erik P. Eckholm, "Losing Ground: Environmental stress and world food prospects", New York, Norton, 1976, pp181-2.

Food and the Oceans

"For the past years much public attention has been paid to the degradation of the environment. Whilst much of this concern has centred on essentially local issues, there is a growing awareness that the processes involved are global in scale. The biggest, most significant changes are probably those which have occurred in the vast expanses of the world's oceans and seas, yet it is these changes which have received the least attention. ... So far no marine biologist has contradicted the assertion that the seas are in decline. On the contrary, more and more are coming to express serious concern as they receive worse and worse evidence. Little of this concern has leaked through to the media and thereby expressed itself as a solid body of opinion; nonetheless decision-makers the world over have spent the last two years getting increasingly concerned, and hardly a week goes by without an international conference being held on some aspect of the marine environment. ...As well as increasing the quantities of naturally occurring elements, we are further upsetting the stability of the chemical composition of the seas by introducing entirely new substances into them. ...Whatever the details, there can be no disputing that marine life is a critically important element of the cyclic processes which occur on the surface of our planet and that to disrupt it seriously is to disrupt the cycles equally seriously. It can be seen that any threat to the world ocean and the life within it is also a major threat to the immediate and log-term survival of man. It could well be that the decline of the marine ecosystem is the most critical environmental threat facing mankind." Colin Moorcraft, "Must the Seas Die?", Melbourne, Sun Books, 1972, pp14-27.

Food and Water

"In the final quarter of this century, the lack of fresh water rather than of land may be the principal constraint on efforts to expand world food output. ...With water becoming increasingly scarce, man will have to pay more attention to the efficiency with which crops, particularly cereals, use water. ...The efficiency with which it is used will increasingly determine the adequacy of food supplies in the future. Lester Brown, "By Bread Alone", New York, Praeger, 1974, pp92-104.

Implications of Severe Malnutrition in Children

"The serious malnutrition prevalent in our overpopulated world causes incalculable suffering, waste of human life, and loss of human productivity. Malnourishment, especially protein deficiency, inhibits the development of protective antibodies and lowers resistance to diseases, thus contributing to higher death rates and loss of productivity in less developed countries. But even more alarming is the growing body of evidence that malnutrition in infants and young children may have essentially permanent effects. It has been known for a long time that severe undernourishment during the years of growth and development will result in a certain amount of dwarfing and delayed physical maturity, even if the deficiency is temporary and a normal diet is later restored. What is far more ominous is the evidence that malnourishment before birth and during the first two or three years afterwards may result in permanent impairment of the brain." P.R. & A.H. Ehrlich, "Ecoscience: Population, Resources, Environment" San Francisco, Freeman, 1997, p309.

Table Infant Mortality Rates (refer to scanned version)

United Nations, Demographic Yearbook, 1973, in above "Ecoscience", p309.

THE PROBLEM - POPULATION

"While you are reading these words, four people, most of them children, will die of starvation and twenty four more babies will have been born." Paul R. Ehrlich, "The Population Bomb" London, Pan/Ballantine, 1971, front cover quotation.

Table Doubling Times of the human population (refer to scanned version)

Ehrlich, P.R. & A.H. Ehrlich & J.P. Holdren Ehrlich, "Ecoscience: Population, Resources, Environment" San Francisco, Freeman, 1977, p183.

Age Composition

"One of the most significant features of age composition of a population is the proportion of people who are economically productive to those who are dependent on them. The proportion of dependents in Lower Developed Countries is generally much higher than in the Developed Countries, primarily because such a large fraction of the population is under 15 years of age. Thus the ratio of dependents to the total population is higher in the poor countries and lower in the rich countries, although the ratio is somewhat misleading because of the greater utilization of child labour in LDC's. This unfortunate dependency ratio is an additional burden to the LDC's as they struggle for economic development." P.R. & A.H Ehrlich and J.P. Holdren, "Ecoscience: Population, Resources, Environment", San Francisco, Freeman, 1977, p205.

THE PROBLEM - URBAN GROWTH

"Modern urbanisation, as we all know, is a very recent thing. ...I think there is plenty of historical evidence that important cities have tended to grow and grow until they could grow no further. ....They lived off their surroundings, and as they became bigger they had to be provisioned from ever more extended surroundings; and as distances had to be extended, transport could no longer cope. The bottleneck was transport, and the bottleneck of transport was energy. In the future, the tune will be called by fuel supplies, and not primarily by our likes and dislikes. ...the fact remains that high-density living patterns can be sustained only by high density fuels." Fritz Schumacher, Urban Impasse Lecture to 1974 RIBA Conference, Durham. AD/9/74, p548.

Urban Growth Conflict

"The problem of population is not simply one of expanding numbers. ... By the year 2000, for the first time in human history rather more people will be living in urban than in rural areas. Previously in our experience of rapid urbanisation, rural populations have diminished as city populations have grown. Both types of populations will grow. However formidable the movement of migrants to the cities - and it is already vast enough to make the biggest cities grow at two or three times the overall rate of population increase - by the end of the century there will be millions more people both in the countryside and in the towns." Barbara Ward, RIBA Journal, Dec., 1974, p13.

"Unless man quickly learns to control the rate of change in his personal affairs as well as in society at large, we are doomed to a massive adaptational breakdown." Alvin Toffler, "Future Shock", London, Pan, 1970.

Housing

"Providing decent living quarters for rapidly increasing population seems dishearteningly difficult today. Housing requires space, building materials, capital, and energy for fabrication. As a result of the swelling demand for houses, the land, lumber, cement, and fuel required have risen beyond the financial means of many of the world's four billion people. The expectation that a growing share of each nation's people would be able to enjoy a home of their own has now been dimmed considerably by the impact of rapid population growth and associated material scarcity. Lester R. Brown, Patricia L. McGrath, and Bruce Stokes, "Twenty-two Dimensions of the Population Problem", in "Worldwatch Paper 5", Washington, Worldwatch Institute, 1976, p32.

THE PROBLEM - THE TRADEGY OF THE COMMONS

"It has been known since ancient times that resources held or used in common tend to be abused. ...However the dynamic underlying such abuse was first suggested by a little-known Malthusian of the early 19th century, William Forrester Lloyd ... who wondered why the cattle on a common pasture were 'so puny and stunted' and the common itself 'bare-worn'. He found that such an outcome was inevitable. Men seeking gain naturally desire to increase the size of their herds. Since the commons is finite, the day must come when the total number of cattle reaches the carrying capacity; the addition of more cattle will cause the pasture to deteriorate and eventually destroy the resource on which the herdsmen depend. Yet, even knowing this to be the case, it is still in the rational self-interest of each herdsman to keep adding animals to his herd. Each reasons that his personal gain from adding animals outweighs his proportionate share, of the damage done to the commons, for the damage is done to the commons as a whole and is thus partitioned among all the users. Worse, even if he is inclined to self-restraint, an individual herdsman justifiably fears that others may not be. They will increase their herds and gain thereby, while he will have to suffer equally the resulting damage. Competitive overexploitation of the commons is the inevitable result." William Ophuls, "Ecology and the Politics of Scarcity" San Francisco, Freeman, 1977, pp145 -6.

**** 2018 comment: See the book "Governing the Commons: The Evolution of Institutions for Collective Action" by Elinor Ostrum 2015.

THE PROBLEM – HUMANKIND'S INHUMANITY

"Normal men have killed perhaps 100,000,000 of their fellow normal men in the last fifty years." - R.D. Laing

"It is becoming more and more obvious, that it is not microbes, not cancer, not starvation, but man himself who is mankind's greatest danger." - Carl Jung

"Inequality and injustice within countries are only matched by inequality and injustice between countries. These are the two obscenities of world development. And they are obviously linked." - Louis Emmerji

"Today even the survival of humanity is a Utopian hope." - Norman O. Brown

"It seems clear that the first major penalty man will have to pay for his rapid consumption of the earth's non-renewable resources will be that of having to live in a world where his thoughts and actions are ever more strongly limited, where social organisations has become all pervasive, complex, and inflexible, and where the state completely dominates the actions of the individual." - Harrison Brown

"The very feature which distinguishes man becomes the feature which damns him." - Konrad Lorenz

"Science may have found a cure for most evils; but it has found no remedy for the worst of them all - the apathy of human beings." - Helen Keller

CHAPTER 3

ENERGETICS: AN INTRODUCTION TO THE PRINCIPLES

"No one is going to repeal the second law of thermodynamics, not even the democrats." Kenneth Boulding, 1970.

AN INTRODUCTION TO ENERGETICS

Energetics is the study of the energy transformations which occur within ecosystems. Energy is involved in all the functions of life and physical Systems, being used in the growth and maintenance of the system. The study of energy inputs, distributions and uses represents a logical and useful entry point into ecological studies of human populations, since energy is one of the few common denominators that cuts across all levels of environmental and human considerations. Further, there appears to be an immediate advantage in using a single, imported variable such as energy as a vehicle for cross-disciplinary integration.

Energy flows in ecosystems have been studied for many years by biologists; however energetics as a discipline in its own right began in the early 1970's When Howard Odum (1971) in his book "Environment, Power and Society" pointed out that "industrial man no longer eats potatoes made from solar energy; now he eats potatoes partly made, of oil". Roy Rappaport (1971) in his Scientific American article "Energy in an Agricultural Society" found in his study of the Tsembaga Tribe in New Guinea that for every kilocalories of energy put in as labour, the output was about 16 kilocalories. Since then with the awareness of the energy crisis many other people have entered the field of energetics and in August 1974 the first workshop on energy analysis was held to discuss the need for consensus on conventions and recommendations for further work.

Energetics (or eco-energetics) is one of four approaches to energy analysis. The other approaches are:-

a) Input-Output Analysis
b) Process Analysis
c) Second Law Efficiency

Energetics, which has been promoted by Howard Odum of Florida University, is a development of ecological energy studies of natural systems. Energetics uses Circuit language to describe energy flows. There are differences between energetics and, input - output or process analysis. Energetics places a value on all forms of energy and converts them into energy equivalents. Also, the energy requirements of labour inputs are included as well. One criticism of energetics is that the method is unnecessarily complex. After reading into the other methods of energy analysis I personally feel that energetics is the most appropriate method for investigating the relationships between energy, social organisation, and settlement patterns.

The following is a summary of the areas where energetics provides analysis, insight, and application. The list is by no means comprehensive.

Energy Conservation by Analysing Energy Content

By tracing energy flows potential for savings is gained by a better understanding of how and where energy is used. The energy content of goods and services can be reduced by using alternative methods and energy sources at previous high energy entry points in the energy content flow.

Alternative Energy Sources and New Technology

A net energy analysis of alternative methods of generating energy can show whether a particular method is feasible or not and enables comparisons of different methods at a comprehensive level which does not ignore “intangibles". This also applies to new technology.

Economic Analysis

Energetics can be used as a means by which physical variables can be injected into economic theory, and enables a better understanding of the relationship between energy use and GNP. By using energy as a measure the contribution of nature can be accounted for and allows cost - benefit analysis to be made on a less arbitrary basis.

The two main criticisms that economists have against the encroachment of energy analysis into their field are:

a) The price mechanism takes into, account energy and other resource factors, and is a better tool for allocation and decision making.

b) No credit is given for capital and no allowance is made for improvements in technology.

Both these criticisms and others are answered within this text and the reader is left to draw his own conclusions.

Social Organisation

It is known that the organisation patterns of human beings is interrelated with the flow of energy and technological developments and yet little is known of the full significance of energy flow variables as they act on the entire system. There is an urgent need for studies of energy flow patterns in existing populations so that the mechanism of growth to steady state is better understood and the appropriate measures can be taken to alleviate the transition period. (1, 5,6,7,8)

ENERGY, THE ENERGY LAWS, AND ENERGY FLOW

"Energy is the ultimate resource and, at the same time, the ultimate pollutant. The solar energy continuously intercepted by earth drives the geophysical and ecological machinery that make the planet’s surface habitable by human beings. The remarkable growth of the human population and the development of civilizations are attributable largely to the singular progress of our species in learning to harness natural. flows and accumulations of energy and turn them to human ends. Human beings have learned to tame fire for warmth and light and protection; to organise (and later subsidise) photosynthesis in agriculture thus allowing people to specialize and thereby promote the growth of cities; to tap the energy of wind and running water for transportation and mechanical work; and to unlock the concentrated energy of coal and oil for extracting, concentrating, transporting, and applying the many other resources upon which society depends.

Yet no means of harnessing energy- and no means of applying it - is completely free of adverse environmental impacts. The impacts manifest themselves at all stages of energy - processing, from exploration to disposal of final wastes. Many of these impacts can be significantly controlled, at some expense in money and in energy itself. But, in consequence of the fundamental characteristics of energy and matter, reflected in the laws of thermodynamics, the impact can never be averted entirely. All the energy people use ends up in the environment as heat; and energy, unlike other physical resources, cannot be recycled.

It is the dichotomy between energy's roles as ultimate resource and ultimate pollutant that generates the deepest of several dilemmas that make up the "energy problem". (3, p p391-2)

The Energy Laws

All forms of energy are inter-convertible, and when conversions occur they do so according to rigorous laws of exchange. These are the laws of thermodynamics. The First Law of Thermodynamics is also known as the Law of Conservation of Energy.

LAW I

"Energy may be transformed from one form into another, but energy is neither created nor destroyed."'

The Second Law of Thermodynamics May appear equally simple to understand but however, this law is very deceptive as there are many far reaching implications which-connect back to this law.

LAW II

"All physical processes, natural and technological, proceed in such a way that the availability of the energy involved decreases."

This law may be restated in many ways depending upon the application and context.

1. The entropy of the Universe is increasing. 2. In spontaneous processes, concentrations tend to disperse, structure tends to disappear, and order becomes disorder. 3. In any transformation of energy, some of the energy is degraded. 4. The availability of a given quantity of energy can only be used once; that is, the property of convertibility into useful work cannot be "recycled.” (1, 2,3,5,6)

".. .The laws of thermodynamics explain why we need a continual input of energy to maintain ourselves, why we must eat much more than a pound of food in order to gain a pound of weight, and why the total energy flow through plants will always be much greater than that through plant-eaters, which in turn will always be much greater than that through flesh-eaters. They also make it clear that all the energy used on the face of the Earth, whether of solar or nuclear origin, will ultimately be degraded to heat... .” (3, p35)

The Second Law of Thermodynamics tells us that structure is breaking down, matter is becoming less organised and energy more uniformly diffused. And yet in ecosystems matter becomes more highly organised and energy more concentrated.

This process is not a reversal of the Second Law. Living organisms do not reverse the universal process; rather, if anything, they hasten it. Their very life depends on a continuing conversion of energy from higher forms to entropy. Or, in other words, life feeds on negative entropy. Entropy of the total system still increases thus still following the Second Law."

Energy Flow

The study of energy flow, or energetics, is based on the first and second laws of Thermodynamics. In energetics we are concerned with the change of one energy form to another. In the human cultural system energy flows also carry information however this aspect which involves communication theory does not concern us at this stage. The different types of energy flow can be grouped in the following way.

“1. Flow as transport and storage of matter: this first usage of flow refers to materials moving through an ecosystem. The differentiation between transportation and storage is merely a time - space separation where storage represents a zero Change in space.

2. Flow as transduction and radiation of energy: this refers to the movement of energy in space, such as in solar and thermal radiation, evaporation, convection and conduction.

3. Flow as conversion from one state to another: this usage refers to the change that occurs in time when there is energy conversion or change in the state of energy. Examples are - the. burning of fuel; photosynthesis; and water becoming steam.

4. Flow as energy cost of triggering energy release: this occurs when energy of one system is applied to the environment of the second so that the second must seek a new equilibrium, thereby changing the state of the second system. Or, it includes the energy costs of input in the in the productive process." (1, pp115-8)

To help us visualize the laws and flows of energy within ecosystems, symbols and diagrams are used to introduce the idea of an ecosystem as a combination of interacting parts.

DEFINITION OF ENERGY SYMBOLS

The following symbols are those used in eco-energetics, a technique used by Howard Odum and his team at the University of Florida in discussing energy, economics and the environment. The function of each symbol may be familiar to those who have studied electronics or systems analysis.

"**Energy Source**
The circle indicates a source of energy from outside the system under consideration. It may be a steadily flowing source like a river. It may be a large source with a constant pressure, available to as many connections as necessary - like the source of domestic electric power, which is large enough to supply an enormous number of appliances. It may be a source that varies, as solar energy does from day to night. We can add words to the diagram to describe what kind of energy is being considered and how it is being delivered.” (6, p20)

Figure 2-1 (Refer to scanned version)

“Energy Storage Tank
This symbol indicates a storage of some kind of energy within the system. The symbol could indicate energy stored in an elevated water tank, in an oil tank, in the manufactured structures of a building, in a library (information), or in any way that makes it ordered and valuable.” (6, p21)

Figure 2-2 (Refer to scanned version)

“Heat Sink
The arrow pointing downward, seemingly into the ground, symbolizes the loss of degraded energy - that is, energy which cannot do any more work - from the system. The pathway of degraded energy flowing out includes heat energy that is degraded as a by-product of work and is also the dispersal energy of depreciation. Concentrations of matter are energy storages. Energy is lost if the concentration is spread apart: this is depreciation. Depreciation of an automobile is the loss of energy as it rusts, becomes worn, and gradually falls apart. Heat sinks are required on all storage-tank symbols and all interaction symbols.” (6, p21)

Figure 2-3 (Refer to scanned version)

“Interaction

The pointed block is used to show to show the interaction of two or more types of energy required for a process. In the example of the farm, sunlight interacts with water, soil, bought machinery, and stored structure: all these are required for the interaction that produces food.” (6, p21)

Figure 2-4 (Refer to scanned version)

“Money Transaction

The diamond-shaped symbol indicates the flow of money in one direction to pay for the flow of energy or energy-containing materials in the reverse direction.” (6, pp21-22)

Figure 2-5 (Refer to scanned version)

“Production

This symbol has one blunt end and one rounded end. It indicates the processes, interactions, storages, etc., involved in producing high-quality energy from a dilute source like sunlight. It is used for producer subsystems such as plants. The symbol can be used with or without interior details.” (6, p22)

Figure 2-6 (Refer to scanned version)

“Self-interaction

The double-input block is used for any process which flows according to the amount of self-interaction. For example, when people cooperate to produce a building, the total effect is not only their separate efforts but that which arises from their interactions. Human activity is especially effective when there are good 'cooperative interactions. The double input is a faster action than a flow without interaction. However, the self-interaction symbol indicates thatr000rvoo of energy are being used more quickly. As long as the source of energy is large, the special acceleration efforts, although costing more drain from the storage, may accelerate more than they drain and thus result in faster growth. If, however, the source of energy is not large, such pathways lose their growth effect, becoming only fast drains.” (6, p70)

Figure 2-7 (Refer to scanned version)

Self-maintaining Unit

The hexagon symbol here represents a self-maintaining unit where there are storage and feedback interactions to interact with the incoming energy. Examples are organisms, towns, and humanity. (6)

Figure 2-8 (Refer to scanned version)

Self-maintaining Unit with two energy sources

Where more than one type of energy interacts as input to an energy consuming unit, it is sometimes useful to show the interaction symbol coming out of the consumer hexagon without showing the interior detail.” (6)

Figure 2-9 (Refer to scanned version)

Example 1

Figure 2- 10 (6, p50) (Refer to scanned version)

Example 2

Figure 2-11 (6, p40) (Refer to scanned version)

AVAILABILITY AND SECOND LAW EFFICIENCY

All forms of energy ultimately degrade into heat energy. Energy can thus be defined as the ability to generate heat. A convenient measure of energy in eco-energetics is the calorie which is the unit of energy used in connection with nutrition.

The calorie is defined as the quantity of heat required to raise the temperature of 1 gram of water through 1 Celsius degree. NOTE: 1 kilocalorie = 1 Calorie

Different forms of energy differ in their ability to do useful work. A Calorie of dispersed heat cannot do any work. Sunlight must first be concentrated to be able to do useful work. However, different kinds of energy are not equally convertible into useful work. It takes energy to concentrate energy. Some energy must be degraded in order to concentrate what is left. (see figure below)

Figure 2-12 Scale of Energy Quality. (6, p32) (Refer to scanned version)

The figure above gives the scale of quality of energy and some of the conversion factors for going from one form of energy to another. These factors include the energy cost of any machinery that the conversion process may require 6.

The degree of convertibility of energy - stored work - into applied work is often called availability. Energy in forms having high availability is called high grade energy. Low grade energy is the energy which only a small fraction can be converted to applied work. An example of high grade energy is the energy stored in fossil fuels and electricity. Sunlight is an example of low grade energy. Thermal energy is a special case. The greater the difference between the heat source and its environment, the greater is the availability. The hot core in a nuclear reactor is energy of high availability while that of a domestic radiator s of low availability or low grade energy. 2, 3.

The following diagram shows that human activity is involved with the conversion of low grade energy to high grade energy. This high grade energy has greater availability to do useful work.

Figure 2-13 Energy Conversion (6, p77) (Refer to scanned version)

High grade energy interacts with the incoming main flow of low grade energy and net energy is produced. High grade energy is wasted if it is not used to "amplify" the flow of further high grade energy such as the waste involved in using high grade energy for heating purposes. (6)

Figure 2-14 Comparison of the use of high grade energy. (6, p78) (Refer to scanned version)

Table of Energy Equivalents

The following table gives the energy costs of transforming one type of energy into another. The table makes it possible to express all different kinds of energy as equivalents of fossil This table takes into account the efficiency of conversion of one form of energy into another. The table gives the avail- fuels. ability of energy in terms of Fossil Fuel Equivalents or FFEs. 6.

Table 2-1. Energy Equivalents. (6, p79) (Refer to scanned version)

Second Law Efficiency

We are concerned with how efficiently energy is used in transport, industry, agriculture and many other processes. By using energy in efficient ways, not only do we use less of our non-renewable resources, but also less energy ends up in the environment as low grade heat.

The First Law efficiency is the ratio of the amount of energy delivered to perform a task to the amount of energy that must be applied to achieve this task. This First Law approach is concerned only with the efficiency of one particular method of performing the task and disregards alternative methods which may perform the same task with less energy consumption.

The Second Law efficiency, on the other hand, is the ratio of the minimum amount of available work needed to perform a task to the actual amount of available work used to perform this task.

An outcome of the Second Law is that all forms of energy, ultimately degrades into dispersed heat energy. There is no process whose sole result is the complete transformation of energy into. another form of energy which is of higher grade than heat. This is why it is impossible to drive a steamship across the ocean by extracting heat from the ocean or why the "perpetual motion machine" does not exist. In other words, there are some fixed limits to technological innovation, placed there by fundamental laws of nature. The Second Law efficiency approach focuses on. the task at hand and gives a measure of how much improvement in performance is theoretically attainable. 2, 3, 6.

The following is an example of 'how misleading use of the First • Law efficiency can be. In considering the task of heating a house an ordinary furnace gives a First Law efficiency of 67 per cent. Application of the Second Law efficiency shows that when compared to the most efficient possible heat pump the furnace in question has an efficiency of about 4.7 percent.

"In 1974, when a study group of the American Physical Society investigated the second - law efficiencies of the U.S. energy system, the figures obtained were industrial processes, 25 percent; space heating and cooling, 6 percent; transportation, 10 percent; and electricity generation, 30 percent...." (3, p399)

The above figures show that there is a great deal of theoretical potential for improving efficiency of energy use before the upper limits are reached.

See Appendices p216

NET ENERGY

All processes aimed at producing high grade energy in the form of fuel, goods, and services involve the use of high grade energy. In the previous section low grade energy of the sun was shown to be upgraded by the interaction of this incoming flow of low-grade energy With feedback loops of high-grade energy. In tapping high-grade energy resources such as oil, coal, and gas, high grade energy in the form of machinery, fuel for this machinery, and the expertise and labour of the personnel is used. For each unit of energy extracted there is an energy cost involved in doing so. Whether or not the extraction of high-grade energy resources results in net energy depends upon the energy cost of extraction. In some cases the production of high-grade energy involves heavy subsidies of high grade energy. An example of this is the oil subsidy in agriculture to produce larger crops.

Figure 2-15 Oil subsidy in agriculture (6, p87) (Refer to scanned version)

In the past further energy inputs in the form of fertilizers, pesticides, and machinery yielded diminishing crops but because the cost of energy had been small compared to the price received for the crop yield, it was profitable to continue using cheap energy even though this was an inefficient way of doing so. Higher yields allowed less land to be used and as a result sunlight was used less and less. while' fossil fuels were used more and more. Farmers aware of this energy - crop yield relationship have tried using less energy in their farming. Crop yield has been less but so has costs so that they are able to continue farming by doing so more efficiently.

The so called Green Revolution was due to the breeding of new strains of grain and the hidden subsidy of crop yield by fossil fuel8. In considering the carrying capacity of farmland the above relationship shows that as population grows and energy resources diminish food production falls. We have lived in an age where energy has subsidised growth and the time for paying the true costs may occur within our -generation.

Likewise, it is of urgent priority to determine whether other energy-transforming activities generate net energy. Figure 2 - 16 shows an example of a rich energy source with net energy, and Figure 2 - 17 shows allow energy source which does not yield net energy. This analysis of net energy applies to the generation of electricity from photocells. Photocells do not produce net energy. However, in certain circumstances such as communication satellites, the energy costs of alternatives may be much greater than that of the photocell.

In the case of generation of electricity from nuclear power stations it has not yet been shown whether they produce net energy. There is a high technological energy cost in using a high temperature nuclear core which is mismatched to the task of converting water into steam to drive the turbines. There is a high technological energy cost in making the nuclear fission process safe to an acceptable level. There is a high depreciation factor which makes the building of a new nuclear station at high capital cost necessary —the previous plant cannot be re-equipped due to the radioactivity. But most importantly the energy cost of storing the radioactive waste by-products for long periods of time need to be included as well. Without even considering the ethical issues of whether nuclear power should be used or not the generation of electricity by nuclear fission processes are certain to be excluded from future use. Capital intensive energy production processes will have to give way to processes that have higher energy yield ratio that is the ratio of energy yielded to energy fed back from high grade sources, with both terms expressed in fossil-fuel equivalents.

Figure 2 – 16 Example of rich energy source with net energy (6, p82) (Refer to scanned version)

(a) Energy flows are Calories of heat equivalents per day.

(b) Fossil-fuel equivalents.

(c) To test for net energy of source 1, substitute feedback of outflow oil for source 2.

Figure 2 – 17 Example of poor energy source-no net yield. (6, p83)

(a) Energy flows are Calories of, heat equivalents per day.

(b) Fossil-fuel equivalents.

(c) To test for net energy of source 1, substitute feedback of outflow oil for source 2.

In closing this introduction to net energy, consider the situation of the United States buying oil from the Arabs. (See Figure 2-18)

"In 1974, 1 barrel of oil from Arab sources cost $10. If $1 represents 25,000 calories in FFEs ...then paying $10 for 1 barrel of oil is equivalent to sending 250,000 FFE'S to the Arab countries in exchange for it. Since 1 barrel of oil yields about 1.6 million calories, the yield ratio is there- fore...about 6.4. This figure is high. With such a high return for energy invested, it easy to see why there has been a tendency for all the world to become dependent on these rich sources of oil, and to remain so even after the large increase in price of 1973..." (The energy yield ratio or ratio of energy yielded to energy input is useful for comparing alternative energy sources. When the value of the yield ratio is greater than 1, there is net energy)." 6, p85.

*This was the United States ratio of money (GNP) to energy used in 1974.

SUMMARY OF ENERGETICS PRINCIPLES

Energetics is the, study of the energy transformations which occur within ecosystems.

Energy is one of the few common denominators that cuts across all levels of environmental, human and biosocial considerations.

Energetics uses circuit language to describe energy flows. By tracing energy flows potential for savings is gained by a better understanding of 'how and where energy is used. A net energy analysis of alternative methods of generating energy can show whether a particular method is feasible or not. Energetics can also be used as a Means by which physical variables can be injected into economic theory, and enables a better understanding of the relationship between energy use and - GNP.

Organisation patterns of human beings is inter-related with the flow of energy and technological - developments. There is an urgent need for studies of energy flow patterns in existing populations so that the mechanism of growth to steady state is better understood and the appropriate measures can be taken to alleviate the transition period.

The remarkable growth of the human population and the development of civilizations are attributable largely to the singular progress of our species in learning to harness natural flows and accumulations of energy and turn them to human ends. All the energy people use ends up in the environment as heat; and energy, unlike other physical resources, cannot be recycled. It is the dichotomy between energy's roles as ultimate resource and ultimate pollutant that generates the deepest of several dilemmas that makes up the energy problem.

The First Law of Thermodynamics: "Energy may be transformed from one form into another but energy is neither created nor destroyed."

The Second Law of Thermodynamics: "All physical processes, natural and technological, proceed in such a way that the availability of the energy involved decreases."

The Second Law of Thermodynamics tells us that structure is breaking down, matter is becoming less organised and energy more uniformly diffused.

The study of energy flow, or energetics, is based on the First and Second Laws of Thermodynamics To help us visualize the laws and flows of energy within ecosystems, symbols and diagrams are used to introduce the idea of an ecosystem as a combination of interacting parts.

Different forms of energy differ in their ability to do useful work and are not equally convertible into useful work. The .degree of convertibility of energy - stored work - into applied work is often called availability. Energy in forms having high availability is called high grade energy.

High grade energy interacts with the incoming main flow of low grade energy to produce high grade energy. High grade energy is wasted if it is not used to "amplify" the flow of further high grade energy.

The Second Law efficiency is the ratio of the minimum amount of available work needed to perform a task to the actual amount of available work used to perform' this task. The Second Law efficiency approach focuses on the task at hand and gives a measure of how much improvement in performance is theoretically attainable.

All processes aimed at producing high grade energy in the form of fuel, goods and services involve the use of high grade energy. For each unit of energy extracted, from existing resources there is an energy cost involved in doing so. Whether or not the extraction of high - grade energy resources results in net energy depends upon the energy cost of extraction. The energy yield ratio or ratio of energy yielded to energy input is useful for comparing alternative energy sources. When the value of the yield is greater than 1, there is net energy.

REFERENCES

1. ADAMS, R.N. "Energy and Structure - A Theory of Social Power" London, University of Texas Press, 1975.

2. COMMONER, B. "The Poverty of Power" New York, Bantam, 1976.

3. EHRLICH, P.R., A.H. EHRLICH and J.P. HOLDREN "Ecoscience Population, Resources, Environment" San Francisco, W.H. Freeman & Co., 1977.

4. FAULKNER, P. Editor. "The Silent Bomb: A guide to the nuclear energy controversy" New York, Vintage Books, 1977.

5. ODUM, H.T. "Environment, Power, and Society" London, Wiley, 1971.

6. ODUM, H.T. and E.G. ODUM "Energy Basis for Man and Nature" New York, McGraw-Hill, 1976.

7. PEARSON, R.G. "Energy Analysis" ERDC Report No. 30, Auckland, 1976.

8. PHILLIPSON, J. "Ecological Energetics" London, Edward Arnold, 1966.

9. RAPPAPORT, R.A. "Pigs for the Ancestors: ritual in the ecology of a New Guinea people" New Haven, Yale University Press, 1968.

CHAPTER 3

ENERGETICS AND ECOLOGICAL SYSTEMS

"Nature never breaks her own laws." - Leonardo da Vinci

FLOWS OF ENERGY IN ECOLOGICAL SYSTEMS

"Ecology is that branch of science which deals with the relationship between living things and their physical environment together with all the other living organisms within it. Organisms and the physical environment in which they exist form what is termed an ecosystem. The ecologist interested in energetics is primarily concerned with the quantity of incident energy per unit area of the ecosystem and the efficiency with which this energy is converted by organisms into other forms." (4, p1)

"…Energy diagrams help us compare ecosystems and recognise equivalent roles in different systems. Some ecosystems are new, changing, or growing, and some are old and in a steady state". (3).

Producers and Consumers

All ecosystems are solar based and have some common characteristics that follow from the principles of energy. Within an ecosystem there are the food producers - plants that use sunlight to produce food, and the food consumers - both plants and animals that use this food. Both the producers and consumers maintain the ecosystem by recycling the by-products given off by the other. The below diagram shows a balanced ecosystem.

Figure 3-1 Balanced Ecosystem (3, p95) (Refer to scanned version)

Sunlight supports the photosynthetic process of the producers. Heat disperses into the atmosphere and oxygen is produced. The consumers use this oxygen and feed on the food of the producers giving off heat and carbon-dioxide as they do so. This carbon-dioxide plus sunlight forms the food of the producers with the producer —consumer interaction the processes of photosynthesis and respiration are complementary: One provides what the other needs. This complementary interaction is called symbiosis. (3, 4)

"....The production - respiration symbiosis may be diagrammed in various degrees of detail. ...The production process - photo- synthesis - is labelled "P"; the process of respiration by consumers is labelled "R". Sometimes we call this overall symbiotic process the "balance of P and R". ..." (3, p98)

The following diagram shows this P-R symbiosis. Chemical components are isolated to show how they cycle in the P-R process. Each component contributes part of the energy requirement. The nutrients are shown coming out with the heat but going on separately to be cycled and reused.

Figure 3-2 Producer-consumer symbiosis (3, p100) (Refer to scanned version)

"There is a three - stage pathway through which solar energy passes in developing storages of organic matter. First, sunlight develops organic matter in plant tissues; second, the organic matter goes into a dead form such as wood and forest litter; third, some of the organic matter is processed to become the organic matter in the bodies of consumers, such as in the tissues of insects eating the wood. The three stages constitute a chain of food proc000ing in which some energy is lost at each stage. The quality of some of the energy is upgraded at each stage ..." (3, p99)

A plant may be eaten by one animal which in turn is eaten by another, and so on. Most ecological systems develop food chains with at least five stages. A food chain is linear and follows the following generalized form:-

Plant - Herbivore - Carnivore

However, in nature, the food and feeding relationships of plants and animals are rarely in the form of a simple linear food drain, but instead interconnects with a large number of other food chains to form a food web. This web can become extremely complex and the discovery and description of a food web in any given habitat is an enormous task. This is why tampering with a food web can have some unexpected and undesirable effects.

It has been found that "animals at the base of a food chain are relatively abundant while those at the other end are relatively few in number, and there is a progressive decrease in between the two extremes." In comparing the population of other carnivores and herbivores with that of man it is clear that man does not have the same symbiotic relationship within the ecosystem. The reason why is because man has been able to tap the resources of energy and utilise this energy to sustain a larger population than that of other similar sized animals. Other parts of the ecosystem may not be able to tap external sources of energy other than sunlight but they too have inflows and outflows of mineral nutrients. (1, 2, 4)

The following diagram is representative of a typical ecosystem, with inflows of both organic matter and mineral nutrients so that both photosynthesis and respiration are stimulated to higher levels than they would reach without the inflows.

Figure 3-3 Steady state inflow and outflow of nutrients (3, p104) (Refer to scanned version)

GROWTH AND UNLIMITED ENERGY SOURCE

Whether a system can continue to grow or not depends upon whether the system can tap a source of energy that can maintain further growth. During the period of growth when the storage of structure, reserves of energy, population, information and order are expanding, the inflows of energy into the system exceeds the outflows. With a large energy source such as a rich oil well the users can tap whatever amounts of energy they can pump. On the other hand with a limited energy source the energy users must divide up the limited flow. (See Figure below)

Figure 3-4 Comparison of energy sources (3, p47) (Refer to scanned version)

The maximum - power principle explains why certain energy systems survive others and may be stated as follows:-

"Those systems that survive in the competition among alternative choices are those that develop more power inflow and use it best to meet the needs of survival." They do this by:

(1) Developing storages of high - quality energy.
(2) Feeding back work from the storage to increase inflows.
(3) Recycling materials as needed.
(4) Organising control mechanisms that keep the system adapted and stable.
(5) Setting up exchanges with other systems to supply special energy needs. ....". (3, pp40-41)

The following diagram demonstrates these ideas.

Figure 3-5 Energy feedback loop (3,p41) (Refer to scanned version)

The more energy that is pumped into the storage C, the more is fed back to A. This energy - pumping feedback stimulates inflow from the source of energy, E. The steeply rising graph of growth produced by this feedback acceleration with a large source of energy is sometimes called 'Malthusian growth". As long as the source is larger enough to maintain a constant force in spite of a greater drain of energy, the pumping will increase faster and faster until natural limits are reached. (3)

Super - Accelerated Growth

In the past 100 years growth in the more developed countries has been at a faster rate than the Malthusian exponential curve. This has been due to the universal conviction that growth and expansion was a positive value. The profit motive, the protestant work ethic, and the capitalist system enabled a unified effort in bringing together various resources for the maximum rate of growth. By their co-operation a self-interaction process, enabled super - accelerated growth. (See diagram below)

Figure 3-6 Super-accelerated growth. (3, p69) (Refer to scanned version)

Growth is faster with self-interaction pumping than with ordinary Malthusian feedback pumping. The A+B curve is the super-accelerated growth made possible.

The system that is able to accelerate its growth faster than another system is able, to capture the energy source flows from the other system. The system which has super - accelerated growth survives at the expense of the other. (1, 2, 3) (See diagram below).

Figure 3-7 Competitive exclusion (3, p71) (Refer to scanned version)

GROWTH AND LIMITED ENERGY SOURCE

A limited energy source is where the source itself controls the energy flow. An example is the sunlight falling upon earth. The extent of the process photosynthesis depends upon this incoming flow of energy. Once this incoming energy has been used to the fullest growth either declines - a situation in which outflows exceeds inflows and storages are decreasing - or the system maintains a steady state where the inflows of energy just keep up with depreciation and losses. (See diagram below)

Figure 3-8. Limited growth, (3, p68) (Refer to scanned version)
Example a - Economic growth on large newly discovered oil reserves.
Example b - Economic growth on solar energy.

The following diagram shows the mechanics of decline. An example would be termites feeding off a log until the energy source is completely eaten away.

Figure 3-9. Mechanics of decline. (3, p72) (Refer to scanned version)
Growth of quantity (Q) accelerates at first until the source (T) begins to run out. Then the quantity of stored order (Q) gradually declines, as depreciation (D) and outflow of feedback (F) exceed production (P).

Most systems are able to tap a steady source of energy and during their period of rapid growth they have been able to tap a temporary energy source as well. The following diagram shows a surge of growth and then a return to steady state. (3)

HOMEOSTASIS

All ecosystems have developmental stages corresponding to that of an organism - birth, early rapid growth, and maturity. Each developmental stage brings the ecosystem closer to steady state - that is a state of homeostasis in which there is a dynamic equilibrium interaction between the ecosystem and its physical environment.

Succession is a natural process where organisms within the same ecosystem succeed one another by maximising their energy inflow, until a highly stable climax ecosystem develops. During this succession stage energy and nutrients are being added to the ecosystem so that the net ecosystem production is high. The ratio of gross production P to respiration R is greater than 1, and the food chains of the ecosystem are linear.

As the ecosystem approaches climax the P/R ratio approaches 1, the net ecosystem production approaches 0, and the food chains of the ecosystem tend to be woven into food webs. A climax ecosystem is stable and in a condition of internal self-regulation where feed-back mechanisms enables the ecosystem to return to equilibrium following any stress of change in climate, energy and nutrient resources.

There is a relationship between diversity or complexity and the stability of an ecosystem. Increasing the complexity of an ecosystem may or may not increase the stability of the system. The development of a high degree of diversity can favour the collection of energy and provides flexibility in cases where there are changes in the relative availability of energy resources. On the other hand, the energy required for organising diversity is large and can be either an aid or a drain on energy. During the succession stage there is a low diversity of species, but a high level of diversity of special 'adaptations within the species. At climax there tends to be a high level of species diversity. A careful evaluation of an ecosystem should be made before a change in diversity is considered and effected. Man is basically a grazer where he either feeds off grain directly himself, or indirectly through the animals he breeds.

Agriculture is an attempt to increase the P/R ratio for human consumption by preventing the natural process of succession, and decreasing diversity. Man has been able to crop a high yield from an unstable agricultural ecosystem by feeding in energy in the form of fertilizer, weeding, and insecticides. Monoculture systems of growing crops, building dams, roads, and different types of pollution threaten the homeostasis of ecosystems. An eco-energetic approach should be used to determine whether instabilities will occur in ecosystems so that appropriate changes to original plans of development can be made - in other words the eco-energetic approach allows an environmental impact assessment of proposed developments. (1, 2, 4, 5)

(A table showing comparisons between growth and climax ecosystems is included in the summary of this section).

CARRYING CAPACITY AND DEPENDENCE UPON SOLAR ENERGY

Carrying capacity is the maximum population that can be supported in a given environment. As has been discussed in previous sections, organisms and ecosystems have developmental stages where there is initially a period of slow growth, a period of rapid growth and a stable period of non-growth where there is a steady state climax. This also applies to the growth of the population of an organism within an ecosystem (see following diagram)

Figure 3-11 Carrying capacity (Refer to scanned version)

The limiting factor that prevents further population growth is the availability of nutrients. In climax ecosystems there are complex food webs where the cycles of nutrients are tightly interlinked. The carrying capacity of each organism in a given environment is limited by the stock of that requisite of life that is in shortest supply. The following simplified diagram shows the interdependence of the nutrient cycles.

Figure 3-12 Interdependence of Nutrient cycles. (1, p77) (Refer to scanned version)

Herbivores feed on plants, and carnivores feed on herbivores and fellow carnivores. As can be seen, the ultimate limiting factor of total biomass (combined carrying capacities of all organisms) in an ecosystem is the process of photosynthesis carried out by plants, algae, and certain bacteria.

The quantity of solar energy entering the atmosphere is in the order of 15.3 x 18^8 calories/m^2/year. Much of this energy is absorbed by the atmosphere, or reflected back to space by clouds. The actual quantity of solar energy available to plants ranges from 2.5 - 6.0 x 10^8 calories/m^2/year depending upon the geographic location. However much of this available energy is not used in the process of photosynthesis. As much as 95 to 99 percent of this available energy is lost from the plants in the form of sensible heat and heat of evaporation. The remaining 1 to 5 percent of energy is used in photosynthesis and is transformed into the chemical energy of plant tissues (phytomass). Even then not all this energy is continuously available to herbivores as this energy represents the Gross Primary Production (GPP) of the plant. The Net Primary production, (NPP) which is continuously available to herbivores is the sum of the Gross Primary Production less the respiration (R) of the plant. The ratio of respiration to gross production can range from 0.20 to 0.75, depending upon the type of plant. The following diagram shows an example of the available Net Primary Production available to herbivores. (4)

Figure 3-13 Net production (4, p6) (Refer to scanned version)

The photosynthetic efficiency of plants which is the ratio of Net Primary Production to the amount of solar energy received while the plant is in leaf ranges from 1 to 5%. A plant with high photosynthetic efficiency may not necessarily produce more phytomass (plant tissue) per unit time than a plant with a low photosynthetic efficiency. The latter plant may have a higher productivity factor as plants have a different ground coverage percentage and not all plants carry out photosynthesis during the entire year. Over one year an average Net Primary Production is approximately 0.25% of the incident solar energy for land plants though under favourable conditions this may reach 2% over the growing season. Because of these intervening complexities it is more useful to consider productivity rather than photosynthetic efficiency as a comparison indicator of different plants. (1, 4)

Herbivores feed on the available Net Primary Production; on an average they convert approximately 10 percent of their food intake to growth. Thee individual gross growth efficiency, Calories of growth/Calories consumed, varies from 6 to 37 percent among the species and a high gross growth efficiency indicates an efficient assimilation of food energy for growth with little being voided as faeces or used in respiration. The gross growth efficiency of an organism reduces as the organism grows larger. Another growth factor is the Net growth efficiency, Calories of growth/Calories, assimilated where a high net growth efficiency indicates that a relatively small amount of the assimilated energy is lost as heat of respiration and that the remainder is used for growth. Tissue growth efficiencies tend to decrease as one goes up the trophic level food chain. Herbivores, in building up their body tissues, dissipate a large proportion of the phytomass energy they consume. The efficiency of energy transfer between trophic levels which is known as Linderman's efficiency

Calories consumed by predator/Calories consumed by prey is approximately 10%

accounts for why the total phytomass of plants is greater than the biomass of herbivores which is greater than the biomass of carnivores. The biomass pyramid shows this relationship. (4)

Figure 3-14 Biomass pyramid (1, p134) (Refer to scanned version)

Although the biomass of bacteria and fungi accounts for only 0.58 percent of the community biomass, the following energy flow pyramid shows that they account for approximately 17 percent of the energy flow because, in general, smaller organisms have a higher metabolic rate and reproduce more rapidly than larger ones. (1)

Figure 3-15 Energy flow pyramid (1, p134) (Refer to scanned version)

The Net Community Production (NCP) available to man as a food and energy source is that share of the Net Primary Production or net phytomass he shares alongside with other herbivores. Man also feeds on biomass and that available to him is what I have termed Net Community Secondary Production (NCSP). Man is concerned with maximising his food and energy resources by maximising the NPP/GPP, NCP/GPP and NCSP/GPP ratios. If man wishes to maximise his food and energy resources he should remain exclusively a herbivore and feed directly off plants and use phytomass as fuel alongside with hydro-electricity and other solar based energy sources. In doing so He would be sharing the available net phytomass alongside other herbivores. This raises the question of whether he should attempt to succeed other herbivores.

It is improbable that man will succeed bacteria and insects by taking over their share of the net phytomass available. However man has caused birds and animals to become extinct at a faster rate than normally occurs within nature. Assume that man does monopolise a larger share of the phytomass available. Would he be able to return to the soil the necessary nutrient cycle? For man to attempt a monoculture of his own species would be to upset the balance of nutrient and energy cycles resulting in succession of man himself by the lower order species. Mankind needs to live in harmony with animals, insects, birds, fish, bacteria, and plants in order for himself to survive. In striking a balance between food consumption and energy consumption from phytomass together with other forms of solar energy collection we need to understand more fully the patterns of energy flow within ecosystems and in particular our own energy flows and their effect on the environment.

SUMMARY TABLE OF ENERGETICS AND ECOLOGICAL SYSTEMS

	Ecosystem Attribute	Growth Stage	Climax
		Energetics	
1	Gross production/respiration (P/R) ratio	Greater than 1	Approaches 1
2	Net production (yield)	High	Low
4	Biomass supported/unit energy flow (B/E ratio)	Low	High
4	Food chains	Linear	Weblike
		Structure	
5	Species diversity	Low	High
6	Stratification and spatial heterogeneity (patter diversity)	Poorly organised	Well organised
		Life History	
7	Life cycles	Short and simple	Long and complex
		Nutrient and Energy Cycling	
8	Mineral and energy cycles	Open	Closed
9	Nutrient and energy exchange rate	Rapid	Slow
		Selection Pressure	
10	Growth form	For rapid growth	For feedback control
11	Production	Quantity	Quality
		Overall Homeostasis	
12	Internal symbiosis	Underdeveloped	Developed
13	Recycling	Unimportant	Important
14	Stability (resistance to external stress)	Poor	Good
15	Entropy	High	Low
16	Information	Low	High

REFERENCES

1. EHRLICH, P.R.., A.H. EHRLICH and J.P. HOLDREN "Ecoscience: Population, Resources, Environment" San Francisco, W.H. Freeman & Co., 1977.

2. ODUM, E.P. "Fundamentals of Ecology" Philadelphia, W.B. Saunders, 1971.

3. ODUM, H.T. and E.C. ODUM "Energy Basis for Man and Nature" New York, McGraw-Hill, 1976.

4. PHILLIPSON, J. "Ecological Energetics" London, Edward Arnold, 1966.

5. TROOST, C.J. "Homeostasis" article "Environmental Education; A Sourcebook" Edited by C.J. Troost and H. Altman. New York, John Wiley, 1972.

CHAPTER 4

SETTLEMENTS – THE ECOSYSTEM OF MAN

"We must understand the process of irrational growth, decay, decline and death of the human settlement and its parts. Only when we understand the natural process can we adjust ourselves to every occasion and realize the specific requirements of all or part of the settlement we are dealing with." Constantinos Doxiadis 1968.

EKISTICS - THE STUDY OF HUMAN SETTLEMENTS

After many years of research into human settlements, Constantinos Doxiadis finally produced in 1968 an outstanding contribution to this field - namely the book - "Ekistics: An Introduction to the Science of Human Settlements". His methodological approach has been widely accepted as being a powerful tool for examining the highly complex, social, organic, and biological nature of human settlements. It is my belief that the use of Energetics within the framework of Ekistics will prove a formidable combination in the study of settlements in the future. In any highly complex field of study there needs to be a systematic form of classification. Although this is a process of reductionism, the science of Ekistics is the study of relationships of the parts. Doxiadis has chosen to classify human settlements in the following way:

by Ekistic units
by Ekistic elements
by Ekistic functions
by Ekistic evolutionary forces
by factors and processes in accordance with the requirements of the particular study.

These areas of classification will now be looked at in more detail.

Ekistic Units

This classification takes into account the different scales of settlements, by which is meant either distinctly separate settlements or relatively homogeneous parts of settlements. Such a division of scale is based upon the Ekistic logarithmic scale which is based upon the population occupying the distinct settlement or homogeneous part of the settlement. There are 15 Ekistic units:

Unit Number	Ekistic Unit	Population
1	Man	1
2	Room	2
3	Dwelling	4
4	Dwelling group	40
5	Small neighbourhood	250
6	Neighbourhood	1,500T
7	Small town	9,000
8	Town	50,000
9	Large city	300,000
10	Metropolis	3,000,000
11	Conurbation	14,000,000
12	Megalopolis	100,000,000
13	Urban region	700,000,000
14	Urbanised continent	5,000,000,00
15	Ecumenopolis	30,000,000,000

Ekistic Elements

Human settlements can be subdivided into five elements.

Nature
Man.
Society
Shells
Networks

Nature provides the foundation upon which the settlement is created and the frame within which it can function.

Man himself is constantly adopting and changing to the forces of nature.

Society comprises all those aspects that are commonly dealt with by sociologists, economists, and administrators.

Shells, or the built environment, come within the traditional domain of architects and the engineering profession.

Networks are the transportation and communications systems of man.

In Table 4-1 each element is further subdivided into sub-elements. The number of asterisks after each element indicates the extent and degree that the particular element is investigated in this thesis. i.e. concentration on Man-Nature-Network interactions.

Table 4-1 Ekistic elements (1, p35) (see scanned version)

These five basic elements, nature, man, society, shells, and networks, together form a system. An Ekistic grid of Ekistic Units and Ekistic Elements can now be made to show the extent of study of the relationships. (See Table 4-2).

Table 4-2 Ekistic grid coverage of study (see scanned version)

Doxiadis has made the value judgement that the system exists to make man happy and, safe and has ordered the five elements into a pentagon of goals.

Figure 4-1 Pentagon of elements (1, p318) (see scanned version)

My value judgement in this thesis is that man should continue to survive by communing with nature.

The five elements of human settlements can be combined in twenty-eight ways and their relationships studied.

Figure 4-2 Relationship of elements (1, p23) (see scanned version)

This thesis does not cover the whole spectrum of relationships as will be shown in the final matrix of relationship interactions. The thesis does study the relationships by using energetics as a tool. Energetics and communications theory is not investigate as this is a highly involved and complex field in its own right.

Ekistic Functions

This is a classification on of settlements in terms of the functions the Ekistic unit serves. In classifying a settlement as being industrial or commercial, it is better to talk in terms of the percentage of different functions carried out within that Ekistic Unit. At a smaller scale or Ekistic Unit the function is the activity carried out within that space - an example is sleeping and eating.

In building up a relationship matrix I have considered the following function categories:-

Natural open spaces
Agricultural
Transportation
Commercial
Industrial
City Services
Public Recreation
Residential

Ekistic Evolutionary Forces

This classification is based upon a macro-scale of history where settlements are classified as being nomadic, agricultural, urban, urban-industrial, and industrial. This takes into account the flow of time. The following time dimensions are included on the relationship matrix.

PAST
10,000 years
1,000 years
100 years
One generation
5 year

PRESENT

FUTURE
5 years
One generation
100 years

Factors and Disciplines

This classification relates to the factors which contribute to the creation, maintenance, operation and function of human settlements.

In the relationship matrix each of the following aspects are included:-

Economic
Social
Political
Technological
Cultural.

(1, pp31-41, 109-116).

Table 4-3 shows the relationship matrix which may apply for a settlement.

Table 4-3 Relationship Matrix (1) (see scanned version)

The relationships which this thesis is investigating are marked. It can be seen that this thesis is by no means comprehensive, especially in view of the condensed and often skimpy nature of this thesis in the effort to cover the essential interrelated areas of study. To argue that one should stick with one's own specialty area is the line of thinking that has led to the fragmentation of knowledge. Where I have made errors or gross assumptions bear with me and should these errors completely alter the nature of this thesis then this should be pointed put. Otherwise it is expected that the author himself will refine and examine in more detail those aspects which - escaped his attention first time around and correct only those aspects which catch his eye. It is my opinion that more people should cross disciplines to prevent the artificiality of the field labelling that we have now. Doxiadis has this comment to make:-

"It may be argued that such a body of knowledge would be better acquired by concentrating separately on each one of the elements Nature, Man, Society, Shells, and Networks. I believe that such an approach to the solution of the problems of human settlements would be completely wrong. In a way, this is what is happening today. There are attempts in each of the fields concerned with each of these elements, at forming theories related to each.

These theories are not always of equal value; and even if one of them has great value it is not sufficient to guide the development of entire human settlements. The failure to merge theories into a system has contributed to two situations: It has led to the development of a separate approach for every element and the real issue of interest has been treated by these fields only as a side issue. For example, physical geography, concerned with Nature, has not concentrated on relating Nature to human settlements as a whole.

The disciplines concerned with these elements have tended to develop particular approaches toward the entire human settlement. For example, the approach of the anthropologist is different from that of the planner, which in turn is different from that of the engineer, the architect, etc.

It is exactly this which must be avoided in the future. What we need - and this is the only way of achieving the best results is a unified approach to the entire problem of human settlements. Only a balanced knowledge of all elements and their interactions in the formation of settlements can lead to a successful theory. Only then can we branch out into more specific fields." (1, p284)

Once the general principles of steady state have been established the implications for settlements can be generated onto an Ekistic Relationship Matrix and the matrix can be used as both a check list and as a catalyst for further implications. I envisage such a matrix as being in the form of proposals, policies, and objectives in the present tense and past tense to assist with the freeing and loosening of "future' thinking". The matrix would be supported by the principles of steady state, the principles of settlement patterns and by-statistical and research data for the region being considered. The matrix would be of loose fit form where implications could be modified and added to. The task of a think tank would be to refine the matrix of relationships so that dichotomies and conflicts of settlement requirements were eliminated or alleviated.

IN SEARCH OF STEADY STATE SETTLEMENT PATTERNS

In our search for the principles of steady state settlement patterns we shall trace the development of human settlements from the dawn of civilisation up until the industrial revolution. By looking at settlements of ages past and gone we are able to develop a better understanding and insight as to the main factors which interact to influence the patterns of human settlements. A brief look at the communes of China today is also made. These settlements are unique in a world of industrial settlements based on non-renewable energy and they offer an alternative perspective for us to consider.

Pre-Agricultural Settlements

Man appeared in his present form of Homo sapiens less than half a million years ago. For many thousands of years man lived as a predatory animal. Hunting, fishing, cannibalism, and the gathering of wild fruit and vegetables remained his only mode of sustenance. Indeed, man has lived as a primitive hunter and gatherer for all but 1 percent of his known existence and this period may be the only time that man has ever lived a long term steady state way of life.

Much of man's time and energy was spent in search of food. He relied mainly on good luck together with whatever hunting skills he had developed. Starvation was a constant threat and this, together with the hazards of the hunt and the wilds, made for a short life and a violent death. Although fertility rates were high, the population was held in check so that there was virtually zero population growth for many thousands of years. Mankind was struggling to survive.

Stone tools were used about 500,000 years ago. Fire was mastered about 450 - 350,000 B.C. and this enabled man to add previously inedible plants to his diet. New skills and innovations helped increase man's food collecting efficiency, but his use of exosomatic capital was still at a very low level and the only energy that he had command over was that muscular energy stored within his own body.

This energy was sustained by the solar energy converters of the plants and animals that he fed on. Resource and energy consumption was minimal. The ecosystem provided man with his needs and the system rejuvenated itself every spring.

Early hunting and gathering societies adapted to the seasonal patterns of nature and lived a nomadic life migrating from one area to another. The density of the populations varied with climatic changes and with the disappearance of game. It is thought that densities never exceeded much more than 1 person per square kilometre. While man was a hunter-gatherer his settlements were small and temporary because food collection productivity was low and each band of hunter - gatherers required immense hunting territories. They lived in small family groups and settled in natural shelters such as caves. Only rarely did they make huts and if so, these may have consisted of tents made out of skins. There were no transportation or communication lines between these family tribes. The settlements themselves were of the lowest order consisting of a nucleus in the form of shells and several paths leading into the open. (1, pp200-201; 2, p112-113; 3, pp17, 38-40, 77; 4, pp33-35)

Figure 4-3 Pre-Agricultural settlements. (1, p201) (see scanned version)

Agricultural Settlements

The transition from hunting and gathering to agricultural food production was a gradual process. Many thousands of years passed before agriculture, which had been an undeveloped secondary source of sustenance, became the primary source of production. This transition took place .in the New World. In the Near East, cultivation and domestication of animals developed after 10,000 B.0 During the Neolithic period of 7000-5500 D.C. farming and stock breeding was well established.

Initial agricultural production was based on shifting agriculture. Plots were cut or burned back, the crops were planted by hard labour and later reaped, and then the tribes moved to another area while the original plot revitalised itself. This type of shifting agriculture is still to be found in the tropics where control of weeds is difficult and new plots are burned back each year. Later on irrigation, 3 field crop rotation, and the use of domesticated animals in agriculture were used. The dog and the sheep were the first animals to be domesticated. Dairy farming was in progress in 3000 B.C. and the horse was domesticated in India about 2500 B.C. The domestication of the bull and the horse gave man a completely new supply of mechanical energy. Before the industrial revolution in the 1800's, 80-85% of the total energy used by man came from plants, animals and human labour. The energy' consumption per capita was in the order of 10-15 kilocalories per day*, this comprising mainly of food and energy for warmth. * Approximately 15-23 Mega joules/capita/year.

Mankind has spent thousands of years improving early Neolithic technology., Linen was being produced in 4500 B.C., the loom was in use in 4000 B.C. and cotton fabrics were being manufactured in 2500 B.C. Iron ore was being smelted in 300 B.C. while sailing boats were being put to the seas. By 1400 B.G. iron ore was being smelted and worked on a large scale. The discovery of the wheel and harnessing techniques saw the wheeled vehicle in Sumeria about 300 B.C. The introduction of horseshoes in Austria about 400 B.C. enabled equestrian labour to be used more extensively. Tools such as the hammer, saw, wedge tongs, lever, and pulley were in use long before the birth of Christ. Water power was used in 100 B.C. A vertical axis windmill was collecting wind energy in Persia about 700 A.D. and by 1300 A.D. clothing production was powered by the water wheel.

The capital stocks of the agricultural settlements were much more extensive than that of the hunter - gatherers. Including the settlements themselves which we shall discuss in more detail the capital stocks comprised of stocks of seeds, fertilizers, ploughs and other implements, draught animals and herds of cattle, silos, mills, boats and wagons. In early settlements annual production was almost totally consumed each year. There was little food surplus. Highly fluctuating death rates was an indicator of an inadequate control of the environment. A critical minimum level of capital formation was required before a full transition to agricultural production could be achieved as productivity increased there were qualitative as well as quantitative changes. Clustering into settlements allowed specialization and better use of available resources. This also required social and organisational changes. Early cities had a similar technology base of

1) Wheat, barley and cereal crops
2) A bronze industry
3) Wheeled vehicles
4) A nucleus concentration of organisational power.

Trade allowed greater specialization but still the major proportion of production was involved in agriculture, textile manufacture and building. Agricultural settlements provided for the basic need of food, clothing, and shelter.

The crude birth rate of the agricultural settlements ranged from 35-55 births per 1000 people. The growth rate ranged from 0.5 to 1.0 percent. This growth rate was due to a lower death rate an effect of the agricultural revolution. At the eve of the agricultural revolution in 10,000 B.C. it is estimated that the total world population ranged from 2 - 20 million people. At the eve of the industrial revolution in 1750 the world population ranged from 650 - 850 million people. Plague, famine, and war took their toll on population growth; however population growth did take place. As the world population grew the doubling time of 1500 years in 8000 B.C. reduced to 200 years by 1650 A.D.

About 8000 B.C. the first permanent settlements developed and the village became the dominant pattern. Neolithic Jericho occupied 10 acres, Jarmo - 3 acres, and Catal Hujuk - 32 acres. Until the industrial revolution, towns of 100,000 people were rare. In Europe towns of 5 - 20,000 people were considered large. The first towns were initially mere organs of a more complex agricultural world and were nothing more than collecting centres of agricultural rents. Increased productivity and surplus rents enabled the population to be supported in the towns. This enabled specialization and secondary production. The towns developed into places of secondary and tertiary production as well as being a market place for exchange of goods. Even though towns and cities developed in their own right their populations were greatly outnumbered by the surrounding rural population and nomadic bands.

During this period the stocks of exosomatic capital also grew. Agricultural settlements are not examples of steady state settlements but rather examples of the growth phase of settlements. Within the context of newly adopted agricultural technology and increasing efficiency, the limits of the carrying capacity on earth were a long way in the future. There are striking differences between the growth of agricultural settlements as compared to our industrial settlements. Many believe that the carrying capacity of earth has already been reached and it is clear that populations cannot continue to expand indefinitely. The energy consumption per capita of the agricultural settlements remained more or less constant while agricultural technology and secondary technology grew more efficient. In our industrial settlements energy consumption per capita has been increasing. We have higher yields in agriculture but these have been due to the increasing energy input of non-renewable energy resources. True energy efficiency in our primary production has been decreasing. Although agricultural settlements are not true examples Gf steady state, they do allow us a glimpse of the patterns necessary to sustain steady state. Population growth and improvements in technology have been sufficiently gradual processes to allow us to examine the stationary state requirements of settlements.

(3, pp18-26, 40-51, 64-66, 98-101; 5, pp9-17; 6, pp139-142; 7, pp181-186.)

It has been mentioned that human settlements can be classified in terms of Ekistic elements - Nature, Man, Society, Shells, and Networks. Within this classification, the main emphasis of this thesis is on man's interactions with nature and the corresponding networks required to sustain a steady state settlement pattern. Networks reflect the spatial system of man's movements or the kinetic field of man. Human settlements also reflect the patterns of energy production and consumption. In agricultural settlements the texture of energy production is homogeneous while by far the largest proportion of energy consumption is concentrated within the nucleus of the settlement. The networks of the settlement enable energy flow from the extremities of the settlement to the nucleus.

Early agricultural settlements were non-permanent so that the daily movements of the inhabitants did not lead to any permanent pattern of kinetic fields. This situation changed when man created permanent settlements. These settlements are usually divided into rural and urban settlements, however both contained different percentages of farmers and urban dwellers. The average maximum time-distance for the farmer to walk to his fields was about 1 hour or 5 kilometres while the average maximum time - distance for the urban dweller to reach urban functions on foot was about 10 minutes or 1 kilometre. These kinetic fields formed cells for farming or urban functions with the urban cell forming a nucleus at the centre of the rural cell. Agricultural settlements tended to have an optimum radius of between 1 or 2 and 5 kilometres which allowed for the formation of a nucleus of several hundred people depending upon climatic and cultivation factors. This type of settlement, known as the village, predominated at the beginning of the agricultural revolution.

Agricultural settlements were seldom planned and developed in the same way as natural plant systems where the networks lead to one nucleus without any ring connections. These settlements later developed higher levels of organisation as the following diagram shows.

Figure 4-4. Levels of organisation (1, p115) (see scanned version)

Minor settlements had one nodal point and when the population grew above a few thousand, the one nodal point tended to be elongated along a main axis or split into more additional nodes. The radial pattern of networks allowed one node to be easily serviced. When the scale of the settlement's nucleus grew beyond a certain size requiring more than one node there was a tendency for the nucleus of the settlement to develop an orthogonal form. Most agricultural settlements were based on a radial system which later developed into an orthogonal nucleus' system.

Figure 4 -5 Radial-Orthogonal form. (2, p114) (see scanned version)

As the villages multiplied and individually reached an optimum size, they gradually covered the available arable land until the boundaries of their circular kinetic fields met. As soon as their daily kinetic fields made contact interactions between neighbouring villages began, and this lead to lines of network connections between them. These networks gradually strengthened the functions of the 'more central settlements and they acquired a greater percentage of non-farming activities. These settlements developed into urban settlements and cities.

(1, pp151-6, 200-218; 2, pp1112-118; 13, pp1-32)

Figure 4-6 Development of settlements (1, p206) (see scanned version)

The Communes of China

This short thesis cannot do full justice to the study of settlements in China. With the help of direct quotes from Professor Keith Buchanan of Victoria University, Wellington, Wilfred Burchett and Rewi Alley, and Han Suyin who all write with the experience of having visited and lived in China, I hope to indicate the more relevant factors akin to this study from the wealth of information the above authors have provided.

"One of the most striking features of contemporary China is the massive mobilisation of human muscle and human skills. To transform their land, to create, if we may lapse into Western concepts and ways of speaking, a 'new Heaven on Earth' - and for the Chinese this means a condition where no one hungers, where the physical or mental potential of no child is wasted, where each and every citizen may expand to the full his or her capacity for selflessness dedication and solidarity in the service of mankind. This mobilisation, this 'turning of labour into capital to use the fashionable phrase, must be seen as a specifically Chinese attempt to solve the major problems of our century - and that is not the protecting or perfecting of the living level of those who dwell within the handful of affluent societies which dominate the globe, but the creating of 'a more humane world' for the two thirds or so of humanity which exist in degrading and increasingly impoverished subhuman conditions. Like the remainder of this great submerged mass of humanity the Chinese confronted the problem of development lacking the capital and the capital equipment on which the progress of the affluent nations has rested; they had little but the muscle and ingenuity of their people with which - and the phrase is used here both in the literal and metaphorical sense - to create a new world." (9, pp2-3)

"Of all the leaps into the future that Mao's China has made, the formation of People's Communes in 1958 was one of the most decisive. Within four months of the formation of the first People's Commune, all of China's more than half a billion farmers were organised without any interference in production... This radical transformation between the harvesting season of one year and the planting season of the next could not have taken place unless the farmers wanted it. There is no force in China that could have imposed it on the peasantry, and not even the prodigious prestige of Mao Tse-Tung could have brought it about by administrative measures from above." (11, pp15-16)

"The new units of organisation which had become the norm by 1957, grouped together an average of 168 households as against 32 in the lower form of co-operation; each, of these consisted of some five original co-operatives which constituted sub units or brigades By 1957 the greater part of China's rural population had been organised into some 740,000 advanced co- operatives. By late 1958 the co-operatives had been merged into 26,000 communes. The average commune thus consists of some six to seven advanced co-operatives; its population was of the order of 20,000 people, as compared with somewhat under 3000 in the average advanced co-operative..... The experience of the next two or three years demonstrated that some of these were too large for successful operation; many were in consequence subdivided to give units of a more manageable size. By 1966 the total (number of communes) had risen from 26,000 to approximately 78000. Where environmental conditions are more favourable as in the double-cropping rice regions of the South or the loessial of the plains of Hojeh the commune remains a large unit, at least in terms of population; thus in terms of population; thus the average population of a commune in Kwangtung is over 30,000, as against an average for China as a whole of between 7000 and 8000." (9, pp121, 124, 130)

"At each of the three levels of commune organisation, the team, the brigade and the commune itself, management is elected by assemblies of the total membership at each level. The basic unit - the team - is a work-group specializing in one or another of the activities of the commune - field work, pig raising, machine maintenance, tractor driving, and so on. The brigade carried out tasks beyond the capacity of individual teams - small irrigation and flood control works benefit the team under the brigade. It also manages rice mills, food processing plants and machine maintenance stations and looks after primary schools and small clinics. ...At the top of the pyramid is the commune revolutionary committee. On the economic side it handles tasks beyond the capacity of the brigade... they must spend a minimum of sixty days a year working as ordinary commune members - an insurance against them developing into bureaucrats." (11, pp26-7)

"The overwhelming majority of Chinese - over 600 million out of the 750 million usually considered, to be the present total population - live in the People's Communes. Although the communes have a certain degree of autonomy, they become increasingly important links in the total state structure. They pay an annual grain quota to the state and through the county organisations in which they are integrated they have the contacts necessary to complete each year's production plan in accordance with the overall state plan. But in a way they are something like 50,000 states within a state." (11, p33)

“Each commune has its own veterinarian stations, agricultural research stations, 'cultural groups, libraries, and hospitals and clinics. All have primary schools and many also middle schools. Trucks, tractors, barges, boats, fishing equipment, small railways, repair shops, building and carpentry shops, flour mills, extra industrial or handicraft workshops are found in every commune. Factories, canning plants, cement works, brick kilns, small steel furnaces, fertilizer plants, insecticide stations are being developed in the decentralization and overall industrialization process.“ (10, p63)

“The fact that secondary and technical educational facilities are inside the communes solves the acute problem of the drift from rural to the cities ... Secondary school graduates, on the communes as elsewhere, go to work for two or three years before going on to higher education .. By the time a student goes off to university, his or her roots will have been sunk deep in the soil of the community and the specialities chosen are almost certainly those needed 'back on the farms. ..." (11, p40)

“On the majority of communes each family has the right to a small individual parcel of land; in the aggregate these individual parcels represent between 3 percent and 7 percent of the total cultivated area of the commune. They are usually devoted to production of vegetables needed by the household; some will include a fruit tree or some vines, others may be devoted to grain product ion. The role of this private sector is especially important in the field of livestock production. Most of the poultry production

...is in the hands of individual peasant families and a sizeable proportion of the pig-rearing is carried on by the private sector." (9, p131)

"Communes near Peking.

Population 56,000 comprising 22,500 households, of which 9000 are peasant households. Labour force 12,900. Crop area 16000 acres. Some basic crops (wheat, sweet potatoes, groundnuts) but main emphasis on vegetable production (tomatoes, cucumbers, peppers, cabbages, etc.), partly under glass. Fourteen tractors, with workshop for maintenance work and agricultural tools factory." (9 p168)

"Communes in Kansu

Population 18,000, consisting of 3000 households. Area approximately 4.500 acres (including some hill - land) most of which is now irrigated. Emphasis on production of vegetables and fruit, with some wheat and maize. Livestock includes 670 horses, donkeys or mules, 4000 pigs, 3000 sheep, 110 dairy cows (an innovation; it was hoped to quadruple the number in 1959), 20,000 poultry and 70 hives of bees. Small area of fish - ponds. Some 50 tons of sulphate of ammonia or bone meal were used (i.e. about 15-20 lb per acre) in addition to organic manures. Five tractors and one lorry. Commune runs twelve primary schools, one middle school and a veterinary school." (9, pp167-8)

“The socio-economic logic behind the settlement pattern of traditional China has been brilliantly analysed by G.W. Skinner*. The self-contained world of the Chinese peasant is, Skinner argues, based not on the village but on the marketing community. This is the population within a 'standard marketing area' which, in brood terms, is the area within walking distance (3.4-6.1 kilometres) of a market town. His analysis of agricultural China shows that 'in the modal case, marketing areas are just over 50 sq. kilometres in size, market towns are less than 8 kilometres apart, and maximum walking distance to town is approximately 4.5 kilometres. The average (mean) population of the standard marketing community is somewhat over 7,000... The model developed by Skinner shows that each marketing area contains eighteen villages; his analysis of actual marketing areas in various parts of China shows that conditions approximate closely to this model with a range of 17.9 to 21.4 villages per market area... The marketing area and the standard market town are in turn tied into a network of what Skinner terms 'higher level central places'. There results an approximately hexagonal pattern of Market towns and higher level market towns". (9, p263-4)

* G. William Skinner "Marketing and Social Structure in Rural China” in Journal of Asian Studies Vol.XXIV (November 1964-August 1965)

See Figure 4-8 for a diagrammatic form of a typical marketing area.

Figure 4-8 Abstraction of marketing area (9, p264) (see scanned version)

"Since 1960 the Chinese have released few 'hard' statistics on any branch of economic production. ...We are confronted with what is nowadays a common enough feature of the political scene - a credibility gap, a continually widening discrepancy between the analyses of the 'China - watchers' and the picture which emerges from Chinese press releases and from the observations and judgements of those who have recently visited the country." (9, p242-3)

Paul Bairoch in a recent study of agricultural productivity in the Third World had this to say.

"In Asia the outstanding phenomenon is ... the progress achieved by China since 1950, a contrast with the regression or stagnation of most of the countries of Asia. Even on the basis of Western estimates the annual increase in productivity has been 2.7 per cent per annum between 1946 - '50 and 1960 - 64; the index of productivity (measured in millions of net calories per male worker per year) has risen from 3.7 to 5.1. At this level China has passed the threshold of vulnerability to famine. (This Bairoch places at a productivity level of 4.9 units) It is even possible that the (actual level of the harvest lies between the estimate based on Western data and that based on official announcements. From this it can be postulated that the index of productivity lay, towards 1964, above 6. This would permit the country to embark on the process of industrialisation since at this level of productivity it becomes possible to draw off a significant proportion of the agricultural labour force." (p9, pp192-193)

"Agricultural development in recent years has been based on the principles set out in the 'Eight-Point Charter for Agriculture'; they are: deep ploughing and soil improvement, heavy fertilisation , water conservancy, seed selection, close planting, plant protect- ion, field management, and repair of tools • Of (these) technical developments some, such as the use of improved higher yielding seed strains on 70 per cent of the crop area, brought an immediate increase of yield without additional labour. Others, such as heavy manuring, close-planting and close tending of each plant, involved an intensification of labour output per area. ...Meanwhile, mechanisation is still on a small scale. Many of the communes in North China possess tractors and simple equipment such as irrigation pumps and improved implements, is beginning to lighten the burden of peasant toil. The long term objective of the Chinese is to mechanise all the land that can be ploughed or irrigated by machine by 1969. By mid-1966, however, mechanised farming was practiced on only 10 percent of the cultivated land and the demands of agriculture for various types of equipment are obviously going to exert a strong pressure on industry. Heavy use of artificial fertilisers has scarcely begun. Some 10 million tons were used in 1966 and of this between 8 and 9 million tons were produced in China. This has been supplemented by massive quantities of fertilisers produced by 'native —style' plants on the commune." (9, pp205-7)

"Planning in industry follows some of the basic principles of that in agriculture. Each years plan is primarily based on the previous year's production and the details are decided on the factory floor. Apart from five categories of industry which are run by the counties, communes and brigades to serve agriculture directly (small mines for coal, iron ore and other minerals; small iron and steel plants; small cement works and hydro-electric power plants; small fertilizer plants; and small machine shops producing farm implements, various types of spare parts and the machines to make them) all the rest of industry is integrated into the state plan. Obviously overall freedom to choose what to produce cannot be the same in a state factory as in a commune because its roles are different. A major task of the collectively owned communes is to produce all it can to supply the daily needs of its members in foodstuffs and the tools and services necessary for that.

Surplus production is a welcome contribution to support those who are not direct food producers. The publicly owned factories are not producing goods for the use of those that produce them but for society as a whole. Thus the initative of what to produce lies at a higher level,' but how to produce and in what quantities remains basically an initiative of the workers in the various plants." (11, pp198-9)

"The general lines of development of the transport industry can be summarised briefly. Two main features may be stressed; first, the increasing importance of the modern sector, secondly, the continuing role of the traditional forms of transport. The former is represented by the network of railways and motorable roads, by the steamships plying coastal and inland waters and the airways; the traditional sector is represented by human and animal carriers, by push carts and other vehicles and by junks and sampans. ...One of the most dominant features of the last two decades has been the extension of the railway system into the formerly inaccessible areas of China's Western and South-western interior. ...By 1963 the Chinese railway system had some 52,000 kilometres of trackage ... Expressed in terms of kilometres of operating railways per 1000 sq. kilometres the density was highest in the Northeast with a density of 13 kilometres, almost double the figure for the Eastern and Central regions; for the Northwest it was 1.5 and for the Southwest 1. ... the rapid overall increase in the importance of the railways is suggested by three sets of data: between 1949 and 1963 the volume of freight carried by the railways .increased tenfold (55.89 M. net. tons to 611.13 M.), the volume of freight traffic measured in billion ton/Km., increased sixteen fold, and the number of passengers carried increased fivefold. These figures indicate the beginning, on a decisive scale, of integration of the various regions and peoples of China into a coherent national economy. China had almost 70,000 kilometres of all-weather roads open to traffic in this total almost doubled, to 131,000 by 1953 and increased further to approximately 200,000 kilometres by 1960. … supplementing this developing national network of roads are the local roads built by the-commune for purely local needs; no estimate of the aggregate length of these is available but in all areas visited by the writer they formed a close - meshed network, acting as vital links between the team, the brigade and the commune and the rest of China, ...The various largescale water conservancy schemes contribute also to the expansion of the network of internal waterways; to take a single example, in North Anhivei a carefully planned system of drainage canals is providing also almost 80,000 miles of waterways navigable to small steamers and junks, linking together all the townships and communes in the area." (9, pp252-60)

"China has long been the classic textbook example of over-population; its total population today approaches, if it has not already passed, 700 million and is increasing at the rate of some 15-20 million a year. This massive increase is moreover, regarded by many in China as an asset rather than as a burden ... Ma Yin-Chu's 'New Population Theory' (1959) stressed that uncontrolled population growth might well delay China's attainment of a true Communist society and the apparent shifts in official attitudes to birth control suggest some official uncertainty as to the consequence of such growth." (11, pp278-9)

Ecumenopolis

Ecumenopolis was the name coined by Constantinos for his envisaged global city of the future. This global settlement has been included in the search for steady state because many other people also envisage such a global city. Doxiadis himself provides the reasons why Ecumenopolis will never eventuate:

"Changes in man's daily kinetic fields are ... the clearest expression of his need for and experience of a better way of life under existing conditions. ... A study of the maximum time spent upon his daily movements show that, as a hunter, movement occupied many hours each day; as a farmer, he decreased his travelling time to 2 hours a day; as an urbanised citizen to half-an-hour. This seems to be man's optimum because he held to it for thousands of years ... It appears that the percentage of all available energy used for all types of movement and transportation of people and goods started at a high level: it was about 20% for the organised hunter, and dropped to about 12.5% for both farmers and urban dwellers before the era of mechanical means of transportation. From then on it began to grow until it is now 20% for the whole world and 25% for the United States. Man has always endeavoured to create an optimum type of settlement, corresponding to the time and energy available to him. ... as greater total energy became available to him, man increased the percentage spent upon movement and transportation in order to create a world economy. ..." (2, pp120-122)

Doxiadis continues his prediction of the future with these words:-

"We can therefore expect a ninth phase in the evolution of human settlements with settlements growing in terms of people, in which a minimum amount of time and an increasing amount of energy is spent upon movement; also a tenth phase in which we will find a stable population on the earth and ameliorated movements that will tend to reduce time even more and thus make it possible to achieve more contacts to all points at a minimum expenditure of the total energy available, even though the actual amount will be very much greater than at present. ..." (2, p122)

When Doxiadis published his earlier works on Ecumenopolis he was unaware of the urgency of the energy supply problem, the dependence of food productivity, exosomatic capital growth, and carrying capacity on energy. His forecast of the global city, Ecumenopolis, was based on the world's population levelling out at 30 billion people in 200 year's time. This is 7-8 times the present world population. Doxiadis also spoke of total energy consumption being much greater than it is now. Ecumenopolis was envisaged as being the Utopian city where the consumer level of life is at a level that many people aspire to have now. It is doubtful whether Doxiadis was aware of the principles of steady state otherwise his forecast would have taken account of the harsh reality that we cannot expect continued growth and then have our icing as well. (1, pp215-220, 450-60; 2, pp123-4)

SETTLEMENTS AND THE LAWS OF ECOSYSTEMS

I have made the statement that settlements form the ecosystem of man. In the summary of the previous chapter a list was made of the growth and climax stage attributes of ecological systems. This chapter has traced the development of human settlements and certain patterns emerge. There are strong similarities between the patterns of development of ecosystems and human settlements. In other words settlement development is organic. Although Doxiadis did not make a specific study of the climax phase of settlement development his theory of settlement development in terms of statistical laws show the similarity. The Ekistic theory of Doxiadis is based on:

existing settlements
extinct settlements
critical interpretation of the phenomena of these settlements
theoretical models the validity of which has been checked but
with existing settlements.
tests and experiments carried out in existing settlements.

The following statistical laws come from the book written by Doxiadis in 1968 - "Ekistics: An Introduction to the Science of Human Settlements". Only those laws that I have considered to be the most relevant have been listed.

"LAWS OF DEVELOPMENT

CREATION

LAW 1 A human settlement is created in order to satisfy certain needs expressed by different forces, needs of both its inhabitants and of others. ...

LAW 4 The satisfaction of the inhabitant6 cannot be ensured unless all their needs - economic, social, political, technological and cultural - are largely satisfied...

LAW 7 The development and renewal of human settlements is a continuous process. If it stops, conditions leading to death are created; but how long the actual death will take depends on many factors •

LAW 10 The values created within a settlement, in addition to the initial needs leading to its creation, act as a secondary force contributing to its speedier development, or, in case of depression, they slow down or even arrest and reverse its decline.

LAW 12 The per capita cost of a settlement increases (other conditions, such as income, being equal) in proportion to the services provided by it and the number of inhabitants.

LAW 13 Time is a factor necessary for the development of settlements. As such it is inherent in settlements and is physically expressed in them •

EXTINCTION

LAW 15 The gradual death of a settlement begins when the settlement no longer serves and satisfies some of the basic needs of its inhabitants or of society in general…

LAW 17 In the death process of a settlement its elements do not die simultaneously. The .same holds true for the values that it represents. As a consequence, the settlement as a whole has much greater chances of surviving and developing through renewal even if some of its elements are dying.

LAW 19 The death process of a settlement is complete when every reason for its life has ceased to exist, or when the facilities it provided have been Made in a location which can be approached more easily, or which can provide them to a higher degree.

LAWS OF INTERNAL BALANCE

LAW 21 The elements in each part of a settlement tend toward balance...

LAW 22 The balance among the elements of a settlement is dynamic. ...

LAW 23 The balance of the elements is expressed in a different way in each phase of the creation and evolution of a settlement,

LAW 25 The most important balance of all the elements in space is that of human scale, which is fully controlled by man through his body and senses. ...

LAWS OF PHYSICAL CHARACTERISTICS

LOCATION.

LAW 26 The geographic location of a settlement depends upon the needs it must serve for itself and for the Ekistic system to which it belongs.

SIZE

LAW 28 The population size of a settlement depends upon its role in servicing certain needs for its inhabitants and for its Ekistic system.

LAW 29 The physical size of a settlement depends upon its population, its needs, its role within the Ekistic system and its topographic location.

FUNCTIONS

LAW 30 The functions depend upon the geographic and topographic location, the population size and the Ekistic role of the settlement.

LAW 31 The role of a settlement in the Ekistic system depends on its function, its geographic location and its population size.

STRUCTURE

LAW 33 The basic cell of human settlements is an Ekistic unit which is the physical expression of a community. This unit should function without being fragmented in any way, for if it is, the settlement will not perform its role properly.

LAW 34 All communities, and therefore, all Ekistic units tend to be connected to each other in a hierarchical manner. ...

LAW 35 The fact that all communities tend to be connected in a hierarchical manner does not mean that this connection is an exclusive one. Many other connections at the same level or at different ones are equally possible, but for organisational purposes the connections are hierarchical. ..

LAW 37 The type of services and the satisfaction provided by every Ekistic unit, community and function of a higher order to those of a lower order depend upon a time distance and cost – distance ... (or energy cost distance)*

LAW 38 The overall physical texture of a human settlement depends upon its basic Ekistic units. ...

LAW 39 The texture of human settlements changes as its dimensions change...

FORM

LAW 40 The main force which shapes human settlements physically is the tendency towards a close interrelationship of all its parts.

LAW 44 The form of a settlement is determined by a comblnation of the central, linear and undetermined forces in adjustment to the landscape and in accordance with its positive and negative characteristics...

LAW 45 A settlement grows in the areas of greatest attraction and least resistance...

LAW 47 Another force which exercises an influence on the form of a settlement is the tendency towards an orderly pattern.

LAW 50 The right form for a human settlement is that which best expresses all the static positions and dynamic movements of Man, animals and machines within its space.

LAW 52 The densities in a settlement or in any of its parts depend upon the forces which are exercised upon it. ...

LAW 54 The satisfaction derived from the services provided by the Ekistic unit to the inhabitants greatly depends upon the proper density of the settlement. ..." (1, pp 288-316) * my own inclusion

A steady state settlement would need to meet the above requirements. When generating the implications of steady state upon the settlement patterns the above would need to be taken into consideration.

I see the process of understanding steady state as being cyclic rather than linear. Much of the spade-work for developing a steady state central place theory is contained within this thesis. However I feel it is wise to investigate the other aspects of steady state which also influence the spatial patterns of settlements. For those who wish to jump the gun, the steady state central place is based on Christaller's k = 4 hexagonal central place system. Although there is much controversy about central place theory, much of this is dispelled when Central place theory is considered within the context of steady state rather than continued growth. Woldenberg's research supports the k = 4 concept of steady state .central place. With a change in perspective, many of the methods used in analytical geography can be used to develop the network patterns required in steady state settlements. (see bibliography Ch 4) The attributes which are similar to those found in ecosystems are listed in the summary.

SUMMARY OF SETTLEMENTS – THE ECOSYSTEM OF MAN

Settlement as Ecosystem

	Settlement Attribute	**Growth Settlement**	**Steady State Settlement**
1	Energy inflow/energy outflow	Greater than 1	Approaches 1
2	Net production (Investment over and above maintenance)	High	Approaches 0
3	Population supported/unit energy inflow	Low	High
4	Life support system	Linear	Weblike
5	Occupational diversity	Low	High
6	Stratification and spatial heterogeneity	Poorly organised	Well organised
7	Energy Stock cycle	Open	Closed
8	Energy Flow cycle	Open	Open
9	Energy inflow rate	Rapid	Slow
10	Growth form	For rapid growth	For feedback control
11	Production	Quantity	Quality
12	Internal symbiosis	Underdeveloped	Developed
13	Recycling	Unimportant	Important
14	Stability (resistance to external stress)	Poor	Good
15	Entropy	High	Low
16	Information Feedback	Low	High

The development of technology, social organisation and the tapping of high grade energy stock sources have allowed the centralisation of settlement spatial patterns where the urban population percentage has increased. This trend will be reversed in steady state settlement. The implications of decentralisation will be investigated more fully in the following chapter.

REFERENCES

1. DOXIADIS, Constantinos A. "Ekistics: An Introduction to the Science of Human Settlements" London, Hutchinson, 1968.

2. DOXIADIS, Constantinos A. "Man's Movements and his Settlements" in "Man, the Environment, and Human Ecology" Editor A.S. Boughey New York, Macmillan, 1973.

3. CIPOLLA, C.M. "The Economic History of World Population" Harmondsworth, Penguin Books, 1970.

4. WELLS, H.G. "A Short History of the World" Harmondsworth, Penguin Books, 1976.

5. DAVIS, Kingsley "Introduction: The First Cities: How and Why Did They Arise?" in "Cities: Their Origin, Growth and Human Impact" Readings from Scientific' American. San Francisco, Freeman, 1973.

6. ODUM, H.T. and E.C. ODUM "Energy Basis for Man and Nature" New York, McGraw-Hill, 1976.

7. EHRLICH, P.R., A.H. EHRLICH and J.P. HOLDREN "Ecoscience: Population, Resources, Environment" San Francisco, Freeman, 1977.

8. DOXIADIS, Constantinos A. "The Two-Headed Eagle: From the past to the future of human settlements" Athens, Lyaceth Press, 1972.

9. BUCHANAN, Keith "The Transformation of the Chinese Earth" London, Bell and Sons, 1970.

10. SUYIN, Han "China in the Year 2001" Harmondsworth, Penguin, 1970.

11. BURCHETT. W. and R. ALLEY "China: The Quality of Life" Harmondsworth, Penguin, 1976.

BIBLIOGRAPHY

WOLDENBERG, Michael J. "Energy Flow and Spatial Order, with Special Reference to Mixed Hexagonal Central Place Hierarchies" in "Geography and the Properties of Surfaces" series Paper No 8, Harvard University, Cambridge, Mast., 1968.

HAGGETT, P. and R.J. CHORLEY "Network Analysis in Geography" London, Edward Arnold, 1969.

HAGGETT, Peter "Locational Analysis in Human Geography" London, Edward Arnold, 1965. ODUM, H.T. and L.R. PETERSON "Relationship of Energy and Complexity in Planning" AD/10/72 Pp624-9.

ALEXANDER, Christopher et alia "A Pattern Language" New York, Oxford University Press, 1977.

CHAPTER 5

THE PRINCIPLES OF STEADY STATE

"The ecological constraints on population and technological growth will inevitably lead to social and economic systems different from the ones in which we live today. In order to survive, mankind will have to develop what might be called steady state. The steady state formula is so different from the philosophy of endless quantitative growth, which has so far dominated Western civilization, that it may cause widespread public alarm." Rene Dubos, 1969.

INTRODUCTION

We have been introduced to some of the many problems that beset mankind and threaten our survival. By using Energetics to study the flow of energy within ecosystems, we have been able to unravel the interrelated factors that characterise an ecosystem in its growth stage as compared to climax. It has been shown why continued growth within a closed system cannot be sustained and that an ecosystem either develops a mature, climax, steady state phase of growth or else declines. The term "a closed system" is not strictly correct in that energy in the form of solar radiation enters our ecosystem from outside our closed system, Earth. Over a period of time there is a balance between incoming energy in the form of solar radiation and outgoing energy in the form of long wave heat radiation into outer space. The limits to growth for all ecosystems on Earth is the rate that solar energy enters and leaves our system, and the size of the energy net that each ecosystem can utilise to capture this incoming energy without succeeding other ecosystems necessary for its own survival.

In previous pages I have stated that mankind and his settlements form an ecosystem and, as such, are subject to the same laws of nature that apply to other ecosystems.

I realise that this view of mankind as being on the same level as the animal kingdom may be unacceptable to some. If the heated "discussions" on steady state that I have had while writing this thesis are any indication, then much of what follows will be objectionable to many as well. This thesis is concerned with settlement patterns under a steady state economy and ostensibly is a solution to the energy crisis. However, before continuing, I wish to make this point. We do not face an energy crisis. Man continually comes across limits in every sphere of life. The depletion of easily accessible high grade energy is but one of many limits. A crisis develops when man does not accept his limits. We do not face an energy crisis - we face a values crisis. The real problem that mankind faces in the near future is the transition from growth to steady state and the attendant teething pains of accepting a value system change which is necessary to enable this transition to be without strife and grief. In reading and assessing the following pages one should be aware that one's own value system is the product of a value system, commonly held by most for many generations. A growth philosophy may have been useful to a certain extent during the growth stage of human civilization but we are now approaching our limits to growth. Each and every one of us needs.to re-examine their own value system within the context of the change which is to follow and be prepared for initial value system pre-judgement and dichotomies during this internal transition period.

In the summer of 1970, Professor Jay Forrester of MIT presented a global computer model to the Club of Rome conference in Cambridge, Massachusetts. This global model which took into account over 100 factors including population, agricultural production, natural resources, industrial production, and pollution, enabled the analysis of the behaviour and relationships of these factors. An international team under the direction of Professor Dennis Meadows was set up to examine these five basic factors that determine and ultimately limit growth on our planet.

Many different model runs were made based on different inputs of the physical aspects of man's behaviour. In all model runs capital and population growth were allowed to continue until they reached some "natural limits". The results of their study were published in the book "The Limits to Growth".

When population and capital growth were allowed to find their own level there was no policy that avoided the scenario of an exponential growth of population and capital, followed by collapse. An example of one world collapse model is given.

Figure 5 -1 World with "Unlimited" Resources (see scanned version)

"The problem of resource depletion in the world model system is eliminated by two assumptions: first, that "unlimited" nuclear power will double the resource reserves that can be exploited and second, that nuclear energy will make extensive programs of recycling and substitution possible. If these changes are the only ones introduced in the system, growth is stopped by rising pollution..." (1, p132)

Some policies delayed collapse but the collapse scenario by the year 2100 and earlier were common to all model runs.

In the process of seeking the requirements for global equilibrium constraints on population and capital growth were each tested separately. It was found that the collapse scenario also applied for these conditions. When simultaneous constraints on population and capital growth were tested it was found that global equilibrium was achieved. The minimum requirements for steady state were defined as being:

"1. The capital plant and the population are constant in size. The birth rate equals the death rate and the capital investment rate equals the depreciation rate.
2. All input and output rates - births, deaths, investment, and depreciation - are kept to a minimum.
3. The levels of capital and population and the ratio of the two are set in accordance with the values of the society. They may be deliberately revised and slowly adjusted as the advance of technology creates new options." (1, pp 173-4)

The above minimum requirements for steady state in a human ecosystem are equivalent to the conditions for climax in other ecosystems. Life of any form basically feeds on low entropy. Our entire economic system is in itself the feeding on low entropy in the form of highly ordered structure such as buildings, transport networks, and machinery. Steady state is not a unique requirement for mankind's survival alone and nor is the concept and philosophy of a steady state economy a new and recent catch cry. Plato had this to say in 322 B.C.

"Most persons think that a state in order to be happy ought to be large; but even if they are right, they have no idea of what is a large and what a small state...To the size of states there is a limit, as there is to other things, plants, animals, implements; for none of these retain their natural power when too large or too small, but they either wholly lose their nature, or are spoiled."

The "Middle Way" in finding the "Right livelihood" is one of the requirements of the Buddha's Noble Eightfold Path. In fact the tenet of growth values is found mainly in Western cultures and the Eastern philosophy has much to offer with their view of man being a part of nature rather than boing the favoured ones. 2.

John Stuart Mill wrote the following words in the 1850-70s:-

"If the earth must lose that great portion of its pleasantness which it owes to things that the unlimited increase of wealth and population would extirpate from it, for the mere purpose of enabling it to support a larger, but not better or a happier population. I sincerely hope, for the sake of posterity, that they will be content to be stationary, long before necessity compels them to it". (3, p751)

"It is scarcely necessary to remark that a stationary condition of capital and population implies no stationary state of human improvement. There would be as much scope as ever for all kinds of mental culture, and moral and social progress; as much room for improving the art of living and much more likelihood of its being improved". (3, p754)

In more recent times John Maynard Keynes, the economist who played the most dominant role in directing our economy out of the 1930's depression by his economic growth prescriptions believed that the age of growth was only a temporary one and that in the meantime "foul is useful and fair is not" until we had passed through the growth phase, "the tunnel of economic necessity". (4)

In 1973 a year after "The Limits to Growth" was published thirteen essayists associated with the Science Policy Research Unit of the University of Sussex published "Thinking about the Future: A Critique of The Limits to Growth". This book represented the severest of criticism levelled against the "Limits to Growth". The team, co-ordinated by Marie Jahoda, Professor of Social Psychology at. Sussex, pointed out the same limitations of such a study which the Limits to Growth team had also pointed out.

The main criticisms were as follows:

1. There is insufficient data available to construct a satisfactory world model.
2. The MIT team concentrated on physical limits to growth and omitted to take into account changes in values. (The world model MIT used was not interactive).
3. That there are strong simplistic technocratic tendencies inherent in Forrester's approach.

The general nature of criticism was on points of methodology which the MIT team themselves had pointed out. Some criticisms were on points of accuracy. The general conclusion of the Sussex team was that forecasts of the world's future are very sensitive to a few key assumptions, and suggests that the assumptions made at MIT may be unduly pessimistic. Marie Jahoda concluded

"The major weakness of the world dynamics models is that they illustrate the pessimistic consequences of exponential growth in a. finite world without taking account of politics, social structure, and human needs and wants. The introduction of an extra variable - man - into thinking about the world and its future may entirely change the structure of the debate which these models have so far limited to physical properties." (5, p209)

This is a very valid criticism to "The Limits to Growth" but, however, the main finding of the MIT team - that unless population and capital growth are constrained, further growth would eventually lead to collapse - was unsuccessfully challenged.

1976 heralded in the publication of the second report to The Club of Rome - "Mankind at the Turning Point". Mihajlo Mesarovic and Edward Pestel headed the research team that also used a world dynamics model with the following major structural characteristics:

"1. The world system is represented in terms of interdependent subsystems, termed regions. This is essential to account for the variety of political, economic, and cultural patterns prevailing within the world system.
2. The regional development systems' are represented in terms of a complete set of descriptions of all essential processes which determine their evolutionary, i.e.; physical, ecological, technological, economic, social, etc.
3. Account is taken of the apparent capability possessed by the world development system to adapt and change." (6, p36)

(The computer model used about 100,000 relationships as compared to a few hundred in other world models.)

The following conclusions were made:-

"1. A world consciousness must be developed through which every individual realises his role as a member of the world community........
2. A new ethic in the use of material resources must be developed which will result in a style of life compatible with the oncoming age of scarcity. This will require a new technology of production based on minimal use of resources and longevity of products rather than production processes based on maximal throughput.
3. An attitude toward nature must be developed based on harmony rather than conquest.
4. If the human species is to survive, man must develop a sense of identification with future generations, and be ready to trade benefits to the next generations for the benefits to himself. If each generation aims at maximum good for itself, Homo Sapiens is as good as doomed." (6, p147)

In outlining "The Limits to Growth" and "Mankind at the Turning Point", in no way am I basing the need for steady state on these two reports to The Club of Rome alone. I am of the school of General Systems Theory where GST is a perspective philosophy and not a discipline in terms of structuring and partitioning of knowledge. (GST has the unity of nature as a fundamental philosophical credo, holism is the accepted methodology, and humanism as a task and responsibility.) When I accept steady state I base this on the total evidence. Liken the acceptance of steady state to the intellectual knowledge that eventually everyone passes away. Although man has the gift of pre-knowledge of death based on past and present evidence, many do not wish to accept death as a part of life and they block it from their minds. Death is essentially an easy concept to grasp and a difficult one to accept. Likewise is the concept of steady state. I put forward that, because so many people associate growth with life, the acceptance of steady state as being a part of the life of an ecosystem, including man, will come no easier than acceptance of death as a part of life and yet the evidence for both is all around us.

Before the industrial revolution we fed on the abundant source of low entropy in the form of solar radiation, but because of the low availability of this source we had not developed the technological means of fully tapping this source. The industrial revolution, made possible by the tapping of energy sources of high availability, has brought with it mixed blessings. Now that we are rapidly approaching the limits to further growth, the technological skills that we have been able to fully develop during this period of growth can assist us through the transition period and into the steady state phase of human civilization. The following pages will explore the implications of steady state. I may not be able to provide the right answers but in the attempt I hope to at least raise some of the relevant questions.

STEADY STATE ECONOMICS

"The man who holds that every human right is secondary to his profit must now give Way to the advocate of human welfare." - Theodore Roosevelt

All forms of life, and also our economic system of capital formation, are open systems in that both maintain a state of high order and organisation by feeding on a source of negative entropy - solar energy - which comes from outside the global ecosystem. Life feeds on the flow of energy from outside and also on stocks of energy from within the global ecosystem. The stocks of energy available to man are the net phytomass and biomass of other forms of life which is a self - maintaining stock, and the stocks of mineral resources which, over time, become depleted. Man uses the flow of solar energy and the self- maintaining stock of energy to produce exosomatic capital extensions of man's body in the form of dwellings, tools and energy converters - from the non - renewable stock of resources. This exosomatic capital depreciates over time due to the laws of entropy unless further energy flow and stock are used to maintain this capital. Therefore both endosomatic capital formation - life - and exosomatic capital formation - the economic system supporting human life - are open systems, and as such, are both subject to the same steady state laws of open systems. 8, pp277-8; 9, pp141-4.

Investment and Depreciation

Because the term "flow" is reserved for solar energy, let us use the terms "inflow", "outflow" and "throughput" to describe the movement of energy flow and stock passing through our economic system. Consider the following diagram.

Figure 5-2 Energy Flow and Stock (see scanned version)

The formation of (exosomatic) capital stock depends upon the inflow of the combination of energy flow and stock "triggered" by mankind and the outflow by the way of depreciation and wastes.

In case (a) the inflow is greater than the outflow as has been during the period of the industrial revolution. The capital stock increases with time.

In case (b) the inflow is less than the outflow. The economic system is suffering a decline where depreciation is greater than investment in maintenance.

In case (c) the inflow and outflow are equal - we have a dynamic equilibrium called steady state. "Staying the same is simply a special case of changing". Steady state is a state of stability. 0 In our economic system, as compared to .ecosystems, we do not have automatic feedback systems which regulate stability. Instead, to sustain a stable steady state we need to regulate our economic system ourselves.

In steady state there is a direct relationship between the size of our total capital stock and the magnitude of inflow and outflow. An inflow of capital investment into maintenance is required to balance the outflow of depreciation. The proportion of inflow that is available for offsetting depreciation limits the size of the total capital stock that we are able to maintain. It is in our interests to have capital stock which has a low depreciation factor. In other words, by producing capital goods that have high durability and which also have a high recycling efficiency potential, we are able to maintain a larger total capital stock for the same inflow investment, or we are able to maintain the same capital stock for a smaller inflow. By using capital stock, such as transport systems, which are more energy efficient than the systems we use at the moment and by re-proportioning inflow we are able to maintain a larger capital stock or we are able to use the same capital stock for a smaller energy inflow.

The main point I wish to get across is that although steady state means a constant level of capital stock (with some fluctuations) in the form of dwellings, transport systems, machinery, and goods and services, the control of the outflow of energy in the form of depreciation and waste influence the ultimate level of capital stock as much as does the inflow. As man learns to harness solar energy, the flow rate of solar energy and the size of the solar "net" will ultimately set a limit to the possible inflow of energy into our economic system maximising energy use efficiency, recycling, and producing goods of long durability with high recycling efficiency potential will all help to maintain an economic system at a higher level than otherwise possible. This would be the case of more - with less. The actual level is a moral decision. Even steady state cannot make more ample that which is scarce. Let S represent the stock of low entropy resources on earth, and R the average annual amount of depletion. The theoretical maximum number of years until the non-renewable stock S is depleted is S/R years. The greater R is the smaller is the time period for mankind to find alternatives. Both the population and our consumption rate set the pace of depletion of resources which may well represent the life support system of future generations. We have a responsibility to attain steady state as soon as possible. The actual level of steady state is a responsibility further in the future.

So far in our discussions of steady state we have discussed the implication of maintaining our capital stock. One question comes to mind. How do we create new capital stock when there is no surplus capital for investment? Within the context of steady state, the answer lies within the question. When the steady state economy is in balance new capital stock implies the replacement of old capital stock. If old capital stock is found to be deficient in that it uses energy inefficiently, requires high maintenance, or to put it into today's terms - is not competitive - then capital investment is diverted into new capital stock and the old capital stock is allowed to depreciate and is recycled.

A steady state economy allows for replacement of existing capital stock but unless the population is prepared to temporally forgo their consumption level of life, steady state does not allow for large scale capital investments into new projects. It is of high priority that we set up the necessary low maintenance capital stock now and this especially applies to alternative energy production. At the moment we consume certain goods and services which are unnecessary, waste, energy needlessly, and we invest unwisely in projects that rely on a growth economy. By re-examining our consumption and investment patterns - by monitoring and controlling inflow and outflow - we can redistribute investments into the type of capital stock that can be easily maintained in steady state. Some of the investments required may mean that we may need to allow certain existing stock to depreciate and also to accept a lower consumer level now. This would allow the necessary capital stock to be fully established by the time our fossil fuels are depleted to the level where it is prohibitive to rely on a fossil fuel based economy any longer.

(8, pp277-8; 9, pp120-154; 10, pp8-18; 11, p138, pp140-41; 12, pp45-6; 13, pp13-19)

ZERO POPULATION GROWTH

The study of changes in population size - population dynamics - is basically the keeping track of births, deaths, and net migration within a given population. The birth rate (b) is the ratio of births per total population for that year and is given in terms of births per 1000 people. A high present day birth rate is in the order of 50 births per 1000. The prehistoric birth rate is thought to have been around 40 to 50 births per 1000. The death rate (d) is also given in terms of deaths per 1000 population. There is no upper limit on the death rate as war and pestilence both take their toll. However, because we are all mortal, there is a lower limit. With our present day way of life with sound nutrition and medical care a low death rate is in the order of 5 deaths per 1000. A low death rate implies that the average life expectancy of the population is lengthened from about 40 years (death rate 23 per 1000) to about 70 years.

Population growth is an input - output process just like the capital investment and depreciation process in our economic system. The growth rate (r), which is the sum of (b-d), put into a percentage, describes the rate of natural increase or effects of input over output. The following diagram shows an example of a low growth and a high growth population.

Figure 5-3 Population growth (see scanned version)

Pre-agricultural society is an example of a low growth population. The average high death rate would have been only fractionally less than the average high birth rate. India today is an example of a high growth population where births exceed deaths by a large margin. Let us see the implications of a high rate of natural increase. Any quantity which undergoes a constant annual percentage increase is growing at an exponential rate. One way of describing exponential growth is to consider the time period for the population to double. The following table shows the doubling times of the human population.

Table 5-1. Doubling times of the Human Population. (14, p182) (see scanned version)

The doubling time is approximately the growth rate percentage divided into 70. If our present global population continues to increase at its present rate of 2% per year, then our population will increase from about 4 to 8 billion people in the year 2100. As has been pointed out, this would result in starvation for millions unless we adopt a zero population growth policy now and maintain a steady state population in the future.

The following diagram shows the age composition profile of Mexico and Sweden.

Figure 5-4 Age Composition. (14, p203) (see scanned version)

The triangular shaped population profile of Mexico is characteristic of those countries which have a high birth rate and a declining death rate. It is a sad fact of life that the underdeveloped countries have the advantages of modern age medicine to reduce their death rate. However each child born has the prospect of facing a life at subsistence level. Sweden is typical of a country with a low birth rate and death rate. Fertility drops with prosperity. This is a social phenomenon. Infant mortality is low so there is no need to over reproduce as insurance towards being taken care of in old age. The tendency for nuclear families elsewhere also encourages smaller families. A further burden of a high birth rate and a lower death rate is that the proportion of dependents to those who are economically productive is higher in the undeveloped countries as the following diagram shows.

Figure 5-5 Dependency Ratio (14, p204) (see scanned version)

Children in underdeveloped countries are required to work before they receive an adequate education which is a necessity to enable a higher technological society to develop.

Our input - output model is a simplified way of showing the dynamics of our population growth. Births and deaths both act as positive and negative feedback processes respectively as the following diagram shows

Figure 5-6 Feedback processes. (see scanned version)

All self-regulating systems use negative feedback processes to counteract the positive feedback processes which would otherwise drive the system towards self-destruction. This includes nature where ecosystems are prevented from exceeding the carrying capacity via the negative feedback process of succession. In the past, mankind has regulated his populations through the practice of infanticide, war, and the out-casting of the elderly. If mankind wishes to extend his longevity, and to die a natural and peaceful death, then he has no choice but to regulate his own birth cycle so that the number of births does not exceed the number of deaths.

To achieve Zero Population Growth (ZPG), we need to change our reproductive behaviour. As we decrease our birth rate, the age composition of our population will also change. Population will continue to grow as females entering the child-bearing age rank will produce children at a faster rate than those leaving the child bearing age rank but after a period of one average life time, the age composition profile would re-stabilise. The following diagram shows the age profile pyramid for India changing in shape to a stable ZPG age composition profile.

Figure 5-7 Change in Age Composition to ZPG (14, p220) (see scanned version)

The birth rate that we have used so far does not compensate for this change in age composition so a better indicator of birth trends is the general fertility rate - the number of births per 1000 women between the ages of 15 to 44 years of age. A more meaningful fertility indicator is the average completed family size or total fertility. At the replacement fertility level, each family on an average would comprise of 2.11 children in our society with our present death rate. The extra 0.11 child compensates for the children who do not survive to reproduction age, and for those women who do not have children by virtue of choice or infertility. The changes in this total fertility indicator for New Zealand are shown later on.

There are two ways of achieving ZPG. One way is to periodically reduce our fertility rate well below replacement level. This would produce undesired effects on the age composition structure within a population and would produce fluctuating population growth and decline in the future. The other method is to reduce the fertility rate down to replacement level and hold it there. Population growth would slow down to zero and the age composition would stabilise over one life time. To maintain ZPG a stable age composition is necessary, as well as a replacement fertility rate. If a retirement age of 65 is maintained then the increase in the elderly dependents would be balanced out by the decrease in child' dependents. A large part of our budget is spent on education and old age pensions. The elderly could be encouraged to help look after the young in the same way as they do in extended families. There would be little change in the labour force proportion of the population.

When the age composition distribution of a population is changing, it is extremely difficult to make population projections. The following diagram shows the global population projections on their path to ZPG. The graph shows the urgent need for a global ZPG policy now.

Demographer Nathan Keyfitz has calculated that if the lower developed countries were to achieve a replacement fertility rate overnight, then their population would continue to increase until it stabilised at about 1.6 times its present size. If the replacement fertility rate took 30 years to achieve then the final population would be 2.5 times the present size. Much depends upon how long it takes for a ZPG policy to be put into effect. The developed countries do not face the same increase on their way to ZPG because their total fertility rate is closer to the replacement level. In our case, we in New Zealand could expect a 50% increase in population on our way to ZPG.

(14, pp98-114, 181-4, 202-222, 966)

Figure 5-8 ZPG Population Projection (11, p221) (see scanned version)

ZPG in New Zealand

The population of New Zealand at the last census in 1976 was 3.13 million people. Figure 5,-10 shows the population from 1920 until the last census. Including net inward migration which accounts for one third of the population increase from 1971 to 1976, the average percentage rate of increase was 1.8. As we are interested in the natural population trends, let us look at the total fertility rate.

Figure 5-9 Total Fertility Rate (14, p216) (see scanned version)

The average family size is decreasing after the post war baby boom and in 1974 the total fertility rate was 2.23 children. The Net Reproductive Rate (NRR) is another way .of estimating the rate of increase. The NRR is the ratio of the number of women in one generation to that in the next and is calculated by applying the age-specific birth and death rates of the population at a given time to a hypothetical group of 1,000 new-born female babies, determining how many live female babies those females themselves produce, and dividing that number by 1,000.

Figure 5-10 Population of New Zealand (18, p5) (see scanned version)

An NRR of 1.0 indicates zero population growth and an NRR of 1.x indicates that the population is tending to increase by x percent per generation of approximately 25 to 30 years. (14, p210)

The following table shows the slowing down of population growth in New Zealand.

Table 5-2 Net Reproduction Rate in N.Z. (19, p89) (see scanned version)

Although our fertility rates are decreasing, we still have some way to go before we achieve replacement fertility.

Population projections have been made for New Zealand on the basis of continued growth at our present rate of increase and also with differing net annual immigration rates. (19, p51). With no further net immigration and an upper limit of 15,000 people per year, population projections for New Zealand range from 4.0 to 4.5 million people by the year 2000. If New Zealand were to put a ZPG policy into effect now, our natural population (excluding immigration) would stabilise at about 4.7 million people by the year 2080. (14, p966.) This raises the following question: do we need to adopt a ZPG policy right now when we do not have the same pressing need to do so as other over-populated countries do?

Whether we adopt a ZPG policy now is a value judgement. V could adopt a life-boat ethic with respect to the rest of the world and delay ZPG until it becomes necessary for us to do so. The findings of "Mankind at the turning Point" indicate that we either help each other to attain steady state or else we all eventually face the same fate of over-population, starvation, or global war. Whether we have an urgent need to adopt a ZPG policy now depends upon the carrying capacity of New Zealand. This carrying capacity ultimately depends upon the available renewable energy per capita.

Any excess carrying capacity represents our willingness to share our energy sources while maintaining a consumer level of life that is acceptable to us. A limited energy source implies that we should limit our population to enable a larger excess or surplus of energy stock and flow. The question is then whether we share this surplus or consume it ourselves. As the next section will show, our future economy will be based on distribution rather than production. We have the choice of sharing our energy sources with the generations of continued population growth in New Zealand, or adopting a ZPG policy now and assisting less fortunate countries to attain a steady state economy so that they can become self-sufficient. Each potential birth over and above replacement level in New Zealand represents the deprivation of another human being of the necessities for survival. One may argue that such aid would be but a wasted gesture. This would be so if those countries were not also adopting a ZPG policy. What is needed is global trust, co-operation, and humanity. A Zero Population Policy does not mean deprivation for us, or our children's children. By not limiting our population now we are sounding the death knell not only for those less fortunate in other parts of the world, but also for our own future generations to come. (6, pp97-100, 143-7)

See Appendices pp189-193.

PRODUCTION AND DISTRIBUTION

Although many writers are aware of the basic economic principles for steady state, there have been few books written in depth on this vital subject. Georgescu-Roegen's book "The Entropy Law and the Economic Process" covers more aspects of steady state than do other books, but is complex and difficult to follow and understand. A search in the Auckland University library uncovered Professor Pigou's excellent study "The Economics of Stationary States" which was published in 1935. It is of interest that the last person to have borrowed this book did so in 1936 and my name is the third on the library card. Professor Pigou wrote his book more or less as an academic exercise:-

"The actual economic world, as everybody knows, is always undergoing highly complex forms of movement. ...A full discussion of positive economics would, of course, seek to comprehend the functioning of the maximum principle in this ever-changing concrete actuality. But the problem is too complex for direct frontal attack. ...in our imagined stationary state no less than in the actual world, the, maximum principle is at work; and the fact that the environing conditions are moderately simple enables us to grasp its significance with sureness and precision. This is my excuse, if excuse be needed, for publishing a book of this character. The analysis worked out in this book cannot by itself make any large contribution to the study of real life. It provides a taking-off place, but little more; a first stage only, which needs extensive supplement. The building is much more than the foundation. But, none the less, to take pains over the foundation is not to waste time." (10, pp4-5,261)

I do not profess to be an economist, and this thesis is not the time and place to write in depth on steady state economics. I strongly recommend that those who wish to follow up steady state economics in depth, to read the above two books and the other references which supports this section.

Our economic system of today is based on a few fundamental economic ideas:

"1. The central idea of economics is the scarcity concept, namely, that every society faces a conflict between unlimited' wants and limited resources.

2. Out of the scarcity concept a family of ideas emerge. Because of scarcity, man has tried to develop methods to produce more in less time, or more with less material and in shorter time. Various types of specialization were discovered in order to overcome the conflict between unlimited wants and limited resources. We specialize geographically, occupationally, and technologically. The third family of ideas grows out of specialization.

3. Because of specialization, we are interdependent; interdependence necessitates a. monetary system. The fourth idea emerges from the first, scarcity, and from interdependence.

4. Men had to discover an allocating mechanism and this is the market, where through the interactions of buyers and sellers price changes occur. Prices, determine the pattern of production, the method of production, income distribution and the level of spending and saving, which in turn, decide the level of total, economic activity. The fifth family of ideas grows out of the fact that the economic system is a part of political society.

5. The market decision is modified by public policies, carried out by the government, to assure welfare objectives. The welfare objectives are determined...through the political interaction of people which generates thousands of welfare objectives which...have (been) reduced to five: our attempts to accelerate growth, to promote stability, to assure economic security, to promote economic freedom, and to promote economic and justice." (20, pp24-26)

These ideas are shown in chart form in Figure 5-11.

Figure 5-11 Fundamental Ideas of Economics (20, p?) (see scanned version)

The concept of steady state economics are basically the same as those of growth economics outlined above - with one major difference. The primary foundation concept in both steady state economics and growth economics is the concept of scarcity. The key difference between steady state and growth economics is that steady state accepts scarcity as being the foundation concept upon which to build a family of ideas. Growth economics does not fully accept scarcity and the conflict of scarcity and promotion of growth is continued up through the framework of ideas. (16)

Throughout this thesis I have carefully avoided using the term "quality of life" and have instead used the term "consumer level of life." The quality of life has a different meaning for different people. Some may value leisure time, others the freedom to travel, a circle of close friends, status in the community, or the ownership of material possessions. The quality of life is a value judgement. A high consumer level of life does not imply a high quality of life and nor does a high quality of life imply a high consumer level of life. The quality of life is a part of our internal world, and is reflected in our culture and social organisation. There is no denying that the structure of our settlements, economic system, and political system can restrict the potential quality Of life. The consumer level of life is concerned more directly with economics - production and consumption - and the remainder of this section is concerned with these two aspects of economics. (21, 22)

Production Output as Maintenance

In Figure 5-6 was shown the inflow of energy flow (renewable solar energy), energy stock (non-renewable resources) and births into a settlement and the outflow of energy in the form of depreciation, wastes, and deaths. (Energy flow can be regarded as income and energy stock as capital. During our present petroleum based economy we are consuming our capital stocks and are not making full use of the available income in the form of solar energy) Within the settlement there is exosomatic capital stock (machinery, energy converters, buildings, urban structure) and endosomatic capital (the population of people including the labour force). The inflows of energy flow and energy stock maintain both the exosomatic and endosomatic capital stock. The maintenance of the Exosomatic Capital Stock requires that the labour force directs and "triggers" the inflow of energy flow and stock. The Endosomatic Capital Stock replaces itself through the birth death cycle process, and consumption by people can be regarded as maintenance of this Endosomatic Capital Stock. It can be seen that our true income is ultimately the energy flow of solar energy and this is limited by the size of the "net" that we use to capture this energy. It can also be seen that existence of life depends upon the use of energy stock which, over time, becomes depleted. As Georgescu-Roegen pointed, but in my own words, "it is not economic to exist".

To summarise so far we have:

Energy Flow (renewable income)
Energy Stock (non-renewable capital stock)

which maintains

Exosomatic Capital Stock.

The interaction of energy flow, energy stock, Exosomatic. Capital and Endosomatic Capital in the form of labour produces goods and services

which maintains

Endosomatic Capital Stock

The groups can be further subdivided. Let us do so and examine each factor in more detail.

Energy Flow is renewable solar energy sources which can be in the form' of solar radiation for photosynthesis, solar heat, for solar concentrators, winds, waves, and hydro. For all intents and purposes geothermal can be included. Phytomass can be also included so long as the use allows this to be a self-maintaining energy source.

Energy Stock is the natural non-renewable resources on our planet. This includes air, water, minerals, metals, oil, coal, gas, and nutrients for plants. Some of these are involved in complex cycles of life and in the cycle are reprocessed back to their original unpolluted form. Some energy stock such as oil, coal, and gas, once used are gone for ever. Other forms of energy stock such as minerals and metals can be recycled at an energy cost so that the rate of depletion is retarded.

Exosomatic Capital Stock: This group can be divided into two groups - Fixed Exosomatic Capital Stock and Liquid Exosomatic Capital Stock - or Fixed Capital and Liquid Capital for short.

As has been stated before, our only true income is that of Energy Flow. Steady State is the final phase of ecosystem development. In steady state the Fixed Capital Stocks are already established and the Liquid Capital maintains these stocks and also the Endosomatic Capital Stock of the population. For the moment, I prefer to continue to describe steady state economics as having a no Real Income factor and all outputs of production are for maintaining the Fixed Exosomatic Capital Stock, the Endosomatic - Capital Stock, and, by recycling, maintaining the Energy Stock as far as is energetically possible.

The Fixed Exosomatic Capital Stock can be further subdivided into Fixed Productive Capital Stock and what I term "Fixed Supportive Capital Stock".

Fixed Productive Capital includes

(a) Energy Converters such as wind generators, hydro-electricity dams, solar collectors and plants and animals. Energy Flow is fed into these energy converters and net high availability energy is the result. (Note man is also an energy converter.)
(b) Machinery and Tools which together with high grade energy from the energy converters and the energy "triggering" of man combine to form a Productive Energy Slave.
(c) Production Buildings.
(d) Transport Vehicles and Networks.
(e) Supportive production organisations which will be discussed under Endosomatic Capital.

All these factors of Fixed Productive Capital are involved in the production process to produce Liquid Capital - part of which is fed back to offset the depreciation of this group of fixed capital.

Fixed Supportive Capital, includes the housing, urban structure, public buildings etc. which do not contribute directly to production. This group of fixed capital requires to be maintained and that part of Liquid Capital used to offset depreciation could be said to be consumption and part of what is known as Real Income. (A diagram will tie up all of these ideas)

Endosomatic Capital Stock is the population of the settlements. This capital stock needs to be maintained with Food, Clothing, and Shelter. Some of these basic requirements come directly from Liquid Capital and some indirectly through the maintenance of Fixed Supportive Capital Stock. This group of maintenance factors could be regarded as Primary Consumption and part of Real Income.

The labour force section of Endosomatic Capital represents an input into production (agricultural or industrial). Production requires a trained labour force. Education can be regarded as a maintenance factor of production and indeed any service which contributes to production or indirectly enhances production can be regarded as a maintenance factor of production. This immediately suggests that the rearing of children is a maintenance factor of production and not a factor of consumption.

In the nuclear family the parents bear the major proportion of the financial burden on rearing children and the person who said that two can live as cheaply as one had obviously never tried doing so on one wage and a family to provide for. Motherhood has not been regarded as a maintenance cost of production and in our unenlightened age we have a sophisticated form of slavery where responsible parents provide the inflow to the labour force largely at their own cost. The pressure of doing so has resulted in many mothers going to work to help provide for the family- I believe this is a major cause of many of our social ills that we have today. Production is for the care and maintenance of people and not the other way around. Steady state suggests that society should carry the full cost of child nearing. This may mean paying a wage to mothers or a new form of extended family.

Before outlining the process of production and the energy implications, let me make quite clear the difference between production and that of Direct Consumption or Indirect Consumption through the maintenance of Fixed Supportive Capital Stock. By production, I mean physical production of a product at the door of the production unit. The finished product has an added energy input as compared to the product or material before entering the production unit. Note that I do not include transportation to the Market Place as being a factor of production. I do this for good reasons. This definition rules out regarding the added energy cost of middlemen, transportation and market place transactions as being factors of production when upon consideration they are factors which facilitate consumption.(I expect others to disagree but the middle-Man argument is a difficult one to get around to enable a better definition of true physical production.)

All factors which enhance production, such as child-care, education, and medical care come under Production Maintenance. Food, clothing, and shelter are Primary Consumption Maintenance Factors while all other services, private transportation, private money transactions and Fixed Capital Stock Maintenance come under Secondary Consumption Maintenance.

In summary we have the inflows of Energy Stock and Energy Flow combining in the production process to generate Liquid Capital which provides for the following:-

a) Energy Stock Maintenance through recycling/replacement *
b) Production Maintenance (including energy use)
c) Primary Consumption Maintenance
d) Secondary Consumption Maintenance

* Footnote: This recycling aspect of maintenance will be defined and discussed in more detail later on.

In steady state all Capital Stocks require to be maintained. This applies for the physical stock of Liquid Capital as well. Under Liquid Capital Stock Maintenance we can conveniently include the energy costs of transportation to the Market Place, storage and depreciation, and Market Place transactions. We can regard this maintenance factor as the energy cost of maintaining the flow of Liquid Capital through the Market Place and by doing so, thus facilitating Primary and Secondary Consumption Maintenance. This also includes non7 productive services. So we add:

e) Liquid Capital Stock Maintenance

Figure 5-12 Maintenance Output of Liquid Capital

I have previously stated that I prefer to regard Energy Flow as our only true Real Income and that in steady state all outputs of production are maintenance factors. Professor Pigou outlines the role of maintenance and concludes (10, pp19-26):

"Indeed, if the matter were pressed to the last analysis and food regarded as a mere means of restoring exhausted energies, far and away the greater part of gross output would be absorbed in this way and real incomings would stand a tiny remnant. There can be no question of a definition along these lines."

Pigou continues to give a definition of Real Income as being

" ... those goods and services that are normally bought with money, the only important thing not so bought that is included being the services rendered by houses and lands that are occupied by their owners ...It follows that some substantial elements of wealth - stocks of useful things - are not factors of production."

In 1935 Professor Pigou's approach was along conventional monetary economic lines and as he himself said "...the analysis worked out in this book cannot by itself make any large contribution to the study of real life."

My approach to steady state is along ecological, energy, economic lines or "econergetic" lines. Steady State in ecological systems, including human settlements, is concerned with maintenance and these are the terms of reference that I have used to describe Steady State. There are also other advantages in this approach. Steady State in nature is not concerned with ownership.

Professor Pigou states "Factors of production... may, of course, be owned in a variety of ways. This is quite immaterial to the definition of them."

I agree. By defining the output of production as maintaining the steady state settlement the political implications of the ownership of production and distribution of output are avoided and this section can concentrate on the "econergetic" processes of steady state

Liquid Capital Stock and Money Flow

Professor Odum has this to say about the cycle of money:-

"Money passing through a human economy is an example of a cycle' driven by and dependent upon the steady inflow of energy. The money, cycle however, turns in the opposite direction from the usual cycles of matter ... because it helps account for services given and value received, it facilitates the system of material flows and the receipt and processing of energy. Energy stored in a financial system is in the form of information, money and social agreements. These have to be maintained at some cost of potential energy, but they make the overall systems of cycles run better..." (7, p51-2)

Professor Pigou has the following to say about the flow of money. Remember that his definition of Income is equivalent to my definition of Liquid Capital Maintenance and Primary and Secondary Consumption Maintenance:-

"...in a stationary state there are no capital transactions - only income transactions. Money …is a permanent stock. ... There is not a stream of new money flowing into the lake of being from nothingness at one end and out again into nothingness at the other, as the stream of real income does. On the contrary, the same money that flows out of the lake returns again and again into it. Money is always entering along with the real income that enters, and always going out along with the same real income that goes out. But whereas real income, after passing through the lake, disappears for ever, money repeats its journey again and again in endless succession. There is an annual flow of money income paid out to the providers of real income for their services and fixed stock of money. In stationary conditions the annual flow and the stock are both constant, and there is, therefore, between them a constant numerical relation. The annual income of the community is such and such a multiple of its fixed money stock." (10 pp 72-3)

These transactions of the consumption component of Liquid Capital and money take place in a perfect market. The price of each commodity reflects the energy input of production. Scarcity is reflected by a high energy cost of collection. Professor Pigou has the following to add:-

"A market ... is theoretically perfect when all traders have a perfect knowledge of the conditions of supply and demand and the consequent ratio of exchange. ...in a-stationary state ignorance may properly be conceived as smoothed away. Hence the markets with which we have here are all perfect..." (10, p76)

Earlier on I said that a steady state economy allows for the replacement of existing capital stock but that unless the population is prepared to temporarily forgo their consumption level of life, steady state does not allow for large scale capital investments into new projects. Assume that the settlement has invested in more energy converters. Professor Odum has the following to say about increased energy inflow in a steady state settlement:-

"If inflowing energy is enough to cause production to increase, the amount of stored assets increases, the feedback action of the assets pumps in more production, and the money circulating represents more true work being done. In this situation more money can be put into circulation without changing the amount of work a dollar buys." (7, p 156)

Now comes the question of interest. Professor Odum continues:-

"Investment can be arranged by borrowing money; money available from loans is called capital. ...The supply of capital that one can add to stimulate production should depend upon the expansion of production and assets with new energy. Extra capital is not available if there has been no previous expansion in production and assets. Investment in new production will not be successful unless new energy is available. Transfer of money from an old to a new activity allows the purchase of initial goods and services from old assets to start assets. If new energy is successfully drawn in, there will be enough new assets to create new money that can be paid back by the borrower; as interest for the use of money." (7, p156-7)

Professor Odum states that:-

"Money will not be loaned unless interest is paid for its use. Interest is really an attempt to add new money." (7, p157)

He continues to explain that inflation occurs when interest paid for new money (a loan) is not accompanied by an equivalent increase in true work (productivity). (7, p157)

If one considers that there are two components to interest rates - inflationary interest and real rate of interest - many people lend money at a negative real interest rate. The following quote from Professor Pigou gives an excellent account of this process interest. In steady state there is no inflation so the rate of interest Professor Pigou talks about is the real rate of interest:-

"When there is a stock of capital, this stock yields a return which is capable of being expressed as a rate of interest. In the fluctuating conditions of real life, where the values of different commodities relatively to one another are continually varying, the analysis of this concept involves considerable difficulty, but in a stationary state, where relative values are, ex hypothesis, constant, there is no difficulty. The rate of interest is necessarily one and the same, no matter what commodity is in terms of which it is expressed. Let us conceive it as expressed in money. If then we take the money cost of the marginal unit of any section of capital and divide it into the money value of the difference made to the total annual product of that section by this marginal unit, the result is the annual rate of interest per unit. If we ...(ear-mark) to capital that share of the total value of product which is obtained by multiplying quantity of capital by the value of its marginal yield, then this annual rate of interest per unit is also equal in a stationary state to the total money cost of any section of capital divided into its annual earnings. The rate of interest per cent is, of course, the rate of interest per unit multiplied by 100: and, equally of course, for equilibrium in a stationary state, this rate of interest is the same on all sections of capital. On this basis it is easy to show that the quantity of...capital stock needed to satisfy the conditions of a stationary state... is such quantity that the rate of interest per given time interval is equal to the rate at which (we) discount future satisfactions. The proof is as follows. Let the rate of interest as defined above, and also at the, rate at which (we) discount future satisfactions, be, say, 5 per cent. In these conditions, if (we) neither invest nor dis-invest, since, the state being stationary, (we) reckon to have the same income for consumption a year ahead that (we) have now, (we) will also discount goods a year hence at 5 per cent. There is, therefore, equilibrium. But, if (we) invest anything, (we) must withdraw income from present consumption, and must, therefore, reckon next year's income for consumption as larger than this year's: which entails that the marginal desiredness to (us) of goods then is smaller than that of goods now. It follows that (we) will discount goods a year hence at more than 5 per cent. But by investing (we) can only get 5 per cent. Therefore (we) will not invest. By precisely an analogous argument it can be shown that (we) will not dis-invest. It follows that the stock of capital will be held constant. Constancy, in short, is achieved, provided only that the objective rate of interest, as defined above, is equal to (our) rate of discounting future satisfactions; and no further condition is required. <u>This conclusion, it will be noticed, runs counter to the opinion, which has sometimes been entertained that in a stationary state the rate of interest must necessarily be nil.</u> It is necessary to a stationary state that the capital stock shall stand at such a level that the rate of interest is equal to (our) rate of discounting future satisfactions. If that rate is nil, then the rate of interest must also be nil. But that rate need not be nil. So far as a priori considerations go, it may be anything whatever, 50 per cent per annum or even minus 50 per cent per annum. What it is in actuality is brute fact depending on (our) mental make-up." (10, pp53-55) (My underlining)

The remainder of this thesis continues in energy cost terms. (At a fixed level of energy production there is a constant dollar to energy ratio).

Energy Costs of Maintaining Capital Stocks

Dr Schumacher in his book "Small is Beautiful" has written of his concern of the high capital cost of machinery to the labour input ratio in the production process. He writes the following:

"If methods and machines are to be cheap enough to be generally accessible, this means that their cost must stand in some definable relationship to the levels of incomes in the society which they are to be used. I have myself come to the conclusion that the upper limit for the average amount of capital investment per work place is probably given by the annual earnings of an able and ambitious industrial worker. ...The second requirement is suitability for small-scale application. Small-scale operations, no matter how numerous, are always less likely to be harmful to the natural environment than large scale ones, simply because their individual force is small in relation to the recuperative forces of nature. The third requirement is perhaps the most important of all - that methods and equipment should be such as to leave ample room for human creativity." (2, pp 28-9)

There is much of which Dr Schumacher has written that I agree with. In recommending for a lower capital to labour ratio there is an inference that future settlement should strive for a lower technological based society and this need not be so. In steady state there is an energy cost of maintaining capital stocks. Some capital stock use large quantities of energy such as machine and transport systems. In conventional economic terms these capital stocks have a large capital input. In steady state it is the maintenance factor we are concerned with and capital stack that use energy can be looked at separately. In a mature, climax ecosystem information via chemical feedback processed enables the system to maintain homeostasis. Likewise our steady state, settlements require a highly developed feedback network. In the hunter - gatherers phase of development word of mouth communication may have been sufficient. The society that we have now is more complex and in advocating steady state I am not asking for a return to the hunter gatherer phase if this is not necessary.

To maintain our present level of social development we require sophisticated communication networks especially if our spatial patterns require to be more decentralised because of transportation energy costs. It is only our growth philosophy that creates unnecessary obsolescence. Much of our present hardware and software can continue to be used at a low energy cost of maintenance. By using a sophisticated communications and information network the energy costs of education and training can also be reduced. But the primary purpose of a communications network will be for feedback via information to enable a stable steady state economy and social organisation.

A production process that uses large quantities of high grade energy produces exosomatic capital stock that is said to have a high energy input content. An energy analysis of all the processes involved in the production of capital stock can quantify the energy contribution so that comparisons can be made between capital stock that does the same job. More importantly, an input-output analysis of the entire economy can pinpoint the areas where there is a large energy drain.

Capital stock of high production energy cost content may be a better proposition than that of an alternative with a low energy cost of production but which has a high energy cost of maintenance in use and a high energy cost of recycling/replacement.

The process of recycling/replacement requires some explanation. When a material or resource is scarce there is an energy cost in collecting a certain amount of that material from the store of Energy Stock external to the settlement. For reasons which will become clear, let us regard the energy cost of collection as also including the energy costs of processing that material to a suitable stage for production of capital stock. (There is an energy cost in smelting iron ore ready for further manufacturing processes). The material is now within the settlement. The same material processed into capital stock should at the end of its life-time when maintenance in use costs are rising beyond the stage when it is econergetic to continue maintenance - be recycled to the stage where the marginal energy cost of doing so matches the marginal energy cost of replacement (collection and processing to some recycled stage) of the marginal unit of material from the external Energy Stock Source.

By using this criterion for recycling/replacement materials which have a low energy cost of recycling as compared to replacement, will be fully recycled and other materials will be recycled to the stage where it is equal energy costly to replace the Energy Stocks within the settlement by drawing upon the reserves of Energy Stock from outside the settlement. Materials which have a high recycling energy cost will tend not to be used unless they are abundant and have a low energy cost of collection and processing.

Although a part of Liquid Capital has been set aside to maintain Energy Stock, this external stock can never be maintained in the true sense of the word. This recycling/replacement portion of Liquid Capital ensures that the Fixed Exosomatic Capital Stock of the settlement is maintained for the lowest energy cost. By separating recycling/replacement energy costs from maintenance during use, the separate accounting allows a clearer picture to be seen so that the settlement does not unwittingly draw upon external Energy Stock reserves when recycling is a more viable proposition. So Energy Stock Maintenance is the minimum energy cost of maintaining the inflow of Energy Stock which enables the Fixed Exosomatic Capital Stock to be maintained over a period of time.

I define the Net Maintenance Energy Cost (NMEC) to be that average power required to maintain capital stock within the settlement over time. This includes the high grade energy costs of production, the NMEC proportion of the Fixed Productive Capital Stock used in the production process, the energy costs of maintenance during use, and the energy costs of recycling/ replacement. The NMEC proportion of production processes further removed from the last process become less significant upon each addition unless there is a large energy drain in the chain of production processes. The energy analysis is made over a suitable standard time-period so that at least one recycle/replacement is included. In considering which of two capital stocks one should use or continue to maintain then naturally one chooses the capital stock with the lower NMEC and this will be in energy units per unit of time or the average power required to maintain that capita] stock within the settlement.

Consumption, or direct and indirect maintenance of Endosomatic Capital Stock, can now be defined as the maintenance of fixed capital and flow of liquid capital that does not share its NMEC with any other form of Exosomatic Capital Stock. By adding up all the NMEC's of fixed and liquid capital stock that maintains man (food, clothing, shelter, all other forms of Fixed Supportive Capital Stock including use of high grade, energy, and Liquid Capital Maintenance), one is summing up the total average power required to maintain the entire settlement. The average power required to maintain the settlement comes from the energy converters, including the energy conversion process of agriculture and is the total initial energy output from the energy converters. (Some energy converters require a loopback of energy to sustain the energy conversion process. Net Energy may be regarded as a negative NMEC after all other NMECs of production are included.)

Energy Stock Maintenance is the only maintenance factor which increases in energy cost over time while maintaining the same inflow of Energy Stock. With regards to Energy Flow, the planet Earth is an open system but is a closed system with regards to Energy Stock. Entropy on Earth is increasing. Disorder increases. Products during use deteriorate and some of the Energy Stock contained in the product is scattered and lost. No recycling process is 100% efficient so that further Energy Stock is lost to the settlement. As the settlement draws upon Energy Stock to maintain its Exosomatic Capital Stock these reserves become scarcer and the energy cost of collection rise.

The settlement could try to offset the rising energy costs of maintaining the inflow of Capital Stock by investing in more energy converters. This will require using more reserves of Energy Stock which in turn aggravates the initial problem. There will come a stage where the last additional energy converter is unable to produce Net Energy due to the increased energy costs of recycling and replacement. This limit does not take into account that there is a limit to the Real Income of Energy Flow that can be used by man without upsetting the balance and stability, of the ecosystem. Within this limit, more high-grade energy conversion for the settlement means less food production. Then there comes the factor of redistribution of the work force...

The rising energy costs of maintaining the inflow of Energy Stock will make it energy cost prohibitive to continue using those resources which are scarce and not durable or which have a high energy cost of recycling unless these resources play a decisive role in the technology of the settlement. Even resources which can, themselves, contribute to their own energy cost of collection and processing - oil, coal, and gas - will reach a stage where it is energy cost prohibitive to continue using them as an energy fuel because the collection does not produce Net Energy. At this stage there would still be reserves of oil, coal, and gas in the ground. Can one legitimately include these reserves in the estimates of high grade energy stocks available for man's use? If these resources were required for more useful purposes where there were no lower energy cost alternative, then other energy converters could subsidise the energy cost of collection and processing.

Consider the following NMEC comparison decision of whether to use timber or concrete for building purposes. Timber is also an energy source and the question arises whether we should use the timber for direct energy conversion or as a material for building purposes. The energy costs of recycling/replacement of concrete would be low because concrete is plentiful and the maintenance in use factor would also be small because concrete is durable. The NMEC for concrete would be low compared to many other alternative building materials. The energy costs of recycling/replacing timber would be negative because the timber would be able to release energy over 'and above the energy cost of fertilising and growing another tree. NMEC can also be applied to energy converters The energy costs of growing fuel in the case of energy farming, of collecting the fuel for the energy converter,. maintaining the energy converter including recycling/replacement, processing and releasing the energy contained within the fuel, transporting the high grade energy to the user end, and the energy cost of reducing the pollution effects of using that particular energy fuel are all positive energy costs. The energy released is a negative energy cost. The energy conversion process produces Net Energy if the Net Maintenance Energy Cost of the process is negative.

In deciding whether timber should be used for building purposes rather than concrete depends upon the difference in the NMEC of using the timber for, building purposes first and the NMEC of the timber used directly 'as an energy fuel compared to the NMEC of using concrete. To complicate the problem one would need to determine the optimum time period to discontinue maintenance and recycle or replace.

Very often the energy costs of maintaining a settlement can be reduced by recycling organic matter which contribute a negative energy cost to the settlement. Bio-recycling processes are often more efficient and less energy costly than artificial recycling processes. Looking far away into the future, the main sources' of high grade energy will come from bios-energy converters. Fixed Capital Stock will be based on the most abundant of materials, and more use will be made of materials that originate from a bio-source that can replace itself, at a low NMEC. A larger part of the Liquid Capital for maintenance will be devoted to recycling and replacing the remaining forms of Capital Stock that rely on Energy Stock reserves. Whether man returns to the hunter gatherer stage of development will depend upon whether man is able to develop his bio-engineering skills to a' highly sophisticated level.

(7, pp75-92,165-91; 29, pp58-62; 30; 32)

The Production Process

Professor Pigou defines the inputs of production as the following

"It is customary to divide the factors of production into three broad groups: income - yielding human agents; income - yielding gifts of nature; grouped under the name land; and income yielding equipment, both material and immaterial (in the form of organisation), made by man and grouped together under the name capital. Under each of these broad heads there are, of course, innumerable sub-groups - an indefinite number of birds of labour, kinds of land, and kinds of equipment. For some purposes the distinction between particular sub-groups in a given main group is more important than the distinction between the main groups themselves." (10, pp214- 25). (My underlining)

To enable us to trace the energy implications through the agricultural and industrial' process the following have been defined as being the sub-group inputs into the production unit.

a) Energy Flow
b) Energy Stock
c) Energy Converters
d) Machinery and Tools
e) Production Buildings
f) Transport Vehicles and Networks
g) Supportive Production Organisations
h) Trained Labour Force.

The only income factor is Energy Flow. Energy Stock is capital stock which needs to be converted into useful liquid capital. All the other factors represent an investment in capital stock which ultimately came from Energy Flow and Energy Stock. Professor Pigou states "If the analysis were pushed back far enough in time capital instruments would all be found to originate in labour, land..." (10, p26)

The development of human settlements provides an outline of the capital formation and the importance of energy converters in this process. For those who are keen to follow up this aspect Fred Cottrell's book "Energy and Society" gives an absorbing account of the role of energy, and energy converters in society.

The following diagrams help to explain the process of production. Remember that in steady state all fixed Capital Stock are already established and that steady state is, concerned with maintenance and not new capital formation unless Capital Stocks are allowed to depreciate or new energy sources can be tapped. To simplify the diagrams the energy factor of transport is not shown in all diagrams.

Figure 5-13 is a flow chart of an energy converter. Low availability Energy Flow is fed into the energy converter and high availability energy flows out. Part of this high grade energy is fed back into the energy converter to assist the energy conversion process. The balance of the output does not represent true net energy. The energy inputs into the maintenance of the energy converter and the energy transportation system plus the energy input into transporting this energy are all factors which may determine whether the energy conversion process does in fact produce net energy at the user end. This has definite spatial implication for certain energy conversion processes such as energy farming. It is now clear why an econergetic approach is necessary to determine which capital stock we should continue to maintain in steady state.

Figure 5-13 Energy Converter (see scanned version)

Figure 5-14 shows the industrial production process. The energy costs of transportation are not shown. High grade energy from the energy converters combine with the machinery to produce an Energy Slave which processes the inflow of Energy Stock. In the production process there is an output of waste Energy Stock which is recycled back into the production process via a Recycling Plant. Pollution is also recycled or reduced by a Pollution Plant or bio-process means. Part of the physical output or Liquid Capital of the production process is used for these two processes. In any production process there is an energy loss in the form of waste heat. Part of this energy may be recycled back through the energy converter or used s for home heating purposes. The balance of the Liquid Capital output maintains all productive supporting Fixed Capital Stock and maintains the Endosomatic Capital Stock of the populations of the Settlements. Part of the total Liquid Capital output will be high grade energy. (Energy converters are part of the production process). Figure 5 -15 shows the same process for the agricultural sector. The agricultural sector requires an input maintenance factor of Liquid Capital. The agricultural and industrial sectors mutually co-exist for the benefit of each other.

Figure 5-14 Industrial Production Process (see scanned version)

Figure 5-15 Agricultural Production Process (see scanned version)

When mankind settles for a certain level of steady state, high grade energy production is limited and is balanced against food production. The Consumer level of life (Liquid Capital Maintenance, and Primary and Secondary Consumption Maintenance per capita) is determined by the organisation of Endosomatic and Exosomatic Capital Stock, and the distribution of high grade energy through: the structure of the settlement. Spatial and labour organisation also have an effect on the potential consumer level of life. The settlement may choose not to optimise these factors as they affect the life style of the settlement. By not optimising the potential consumer level of life the efficiency of energy use in production is a consumer decision and is a factor of consumption. The spatial and social organisation of both production and consumption are closely interrelated. Although a settlement may choose not to optimise every factor which influences production, there is no room for gross inefficiencies of energy use. Figure 5-16 shows a model of energy throughput in a steady state settlement. The following is a list of the energy processes that we are concerned with:-

a) Conversion of Energy Flow to high grade energy. This includes food production.
b) Energy Stock conversion to other forms. This includes production, depreciation, and pollution.
c) Energy involved in the use of Exosomatic Capital Stock. This includes transport, machinery.
d) Human energy in triggering energy release or providing labour.

Liquid Capital is the physical production output of food, high grade energy, and liquid Exosomatic Capital Stock. Because energy conversion is part of the production process the initial high grade energy output is a part of the physical production output of Liquid Capital. Figure 5-13 shows the loopback of high grade energy which sustains the energy conversion process and the transportation of energy. Figure 5-12 shows the loop- back of Production Maintenance into Production as including the high grade energy used in production.

Figure 5-16 Model of Energy Throughput (see scanned version)

To demonstrate the flows of energy throughput, Figure 5 -16 shows the loopbacks of high grade energy for energy conversion and production as a combined but separate flow from Production Maintenance. By tracing the high grade energy component of Liquid Capital we are able to pinpoint the areas not already covered where inefficient use of energy in production can prove an energy drain to the settlement. The Model of Energy Throughput shows the following inflows and outflows:-

1. Energy Flow
2. Energy Stock
3. Liquid Capital
4. Production Maintenance
5. Energy Stock Maintenance
6. High Grade Energy into Production
7. Liquid Capital Maintenance
8. Primary Consumption Maintenance

9. Secondary Consumption Maintenance
10. Labour Contribution to Production (direct and supportive)
11. Labour Contribution to Consumption (services)

Spatial and social organisation also influence the energy costs of the above factors.

At a fixed level of steady state there is a constant inflow of births, Energy Flow, and Energy Stock which equal the outflows of deaths, the low grade energy of heat, and wastes which cannot be econergetically recycled. The Model of Energy throughput shows that although a settlement may have a fixed level of steady state in terms of fixed inflows and outflows, this does not necessarily imply that there are no internal changes. So long as the inflow of births, Energy Flow and Energy Stock are held constant the remainder of the system will be in a dynamic equilibrium.

The total average power use per capita, like GNP per capita, is not an indicator of the consumer level of life within such a figure there is no indication of the distribution or efficiency of energy use. At a fixed level of steady state the settlement has reached a technology plateau.

All energy transformation processes are carried out at an optimum efficiency level. The constant inflow of Energy Flow and Energy Stock results in a constant production output of Liquid Capital. The flow-back of Energy Stock Maintenance remains a fixed ratio of Liquid Capital over a short period of time. (This ratio increases over time unless the level of technology improves). Liquid Capital is thus generated by a balance of the High Grade Energy and Production Maintenance flow-back into Production. Part of the High Grade Energy flow-back is the loopback which sustains the energy production process. This portion remains a fixed ratio of Liquid Capital at a fixed level of steady state.

The balance of High Grade Energy flow-back into Production is variable depending upon the Labour Contribution. While we have been drawing heavily upon energy from Energy Stock reserves this Labour Contribution has been insignificant in energy terms and the main role has been to act-as a "trigger" for the release of a much larger flow of energy. If and when we achieve steady state the Total Average Power per capita will be much less than it is now unless the population is allowed to decrease over a period of time. The Labour Contribution to Production in the meantime would be a much more important contribution than it is now. I agree with Dr Schumacher that the Capital to Labour ratio in production should be reduced in those areas where man and tool can combine more efficiently in energy terms than can man and machine. In steady state increased production is no longer necessary or desirable. Machines have a high NMEC because the production of one machine relies on the production of a chain of machines. The machines then use large quantities of scarce high grade energy, dehumanise the role of the machine operator, and do not allow the creativity of labour to participate in production. By matching man and tool, the consumption proportion of Liquid Capital can be increased. Without any prior knowledge of steady state this statement may seem a paradox.

To illustrate why a change in the Capital to Labour ratio is required I will quote from one of the few comprehensive energy analyses of production. I strongly recommend that those who have an interest and involvement in the energy field to read Gerald Leach's book "Energy and Food Production". His type of research needs to be made in all major areas of production. Until this is done we are working very much in the dark in planning ways to alleviate the transition from growth to steady state.

"In 1968 UK agriculture consumed in total some 378 MGJ of energy.... For this investment, among others, it delivered 130 MGT of food or enough to feed half the population and 1.16 million t of protein for human consumption. Its Energy Ratio was thus 0.34 while it took 326 MJ or 7.6 kg oil equivalent to produce 1 kg of crude protein ...Yet these energy inputs for primary food production are only a minor fraction of the total needed to produce, process, transport, package, and sell food in the UK and to import all the animal feedstuffs and human food that cannot be, or are not grown domestically • ... What then are the efficiencies of the whole system? With an input of 1300 MGJ, the UK food supply system had in 1968 an output of only 260 MGJ approximately ... With these figures the overall Energy Ratio is 0.26, so that 5 units of fuel are needed to supply each dietary unit of energy." 29, pp25, 31.

“Nor, it must be said, is the system very efficient in terms of manpower use. UK agriculture, employing 413,000 in 1972 ...is highly labour efficient. Each of these farm workers feeds some 66 people on a food energy basis But if one counts up all the direct and indirect labour employed in the food system from farm to shop ... each person in food-related employment in the UK or abroad feeds 'only' 13 to 14 people. …Putting this another way, it takes about 4 million workers to supply 261 MGJ of food energy, giving an output of about 30-35 MJ per man-hr. ...this performance is little better than that for pre-industrial subsistence farmers." (29, pp 31-2)

Figure 5-17 shows an example of the energy inputs used in producing a loaf of bread. Just under 20% of the total energy input is used in growing the wheat, while the remainder - bar 3% - is used in processing, packaging and transport.

Figure 5-17 Energy Analysis Example (29, p29) (see scanned version)

The above examples of the primary production process are an apt illustration for the need to reduce the Capital to Labour ratio in Production when high grade energy becomes scarce. It also shows that when production uses "cheap" energy, little thought is given to the distribution of energy inputs. What is disturbing is that the example given is but one of many production processes that uses capital and labour energy inefficiently. In suggesting that there should be a more direct use of human labour to production task at hand I do not foresee a brutish and sweaty existence for the inhabitants of a steady state settlement. The Labour Contribution to Production can be increased by decreasing the Labour Contribution to Consumption (all non-productive services which facilitate consumption). When the available energy per capita is limited, human labour would be too valuable not to use in direct and supportive production. The tertiary sector of the economy would be distributed into Primary and Secondary Production.

Centralisation has created a spatial differentiation between the place of work and home together with a distinction between work and leisure. By worshipping consumption we still continue to work a 40 hour week in spite of the use of machines which are supposed to be our Energy Slaves doing our work for us. When our leisure time becomes limited we allow others' to perform services for us that we would otherwise have time to do for ourselves. As well as each steady state settlement being more self-sufficient in energy and primary production, each family would also be more self-sufficient. There would be an overlap of leisure and work as well as a spatial overlap of work and home. Groups of families would combine to become a neighbourhood production unit selling their products directly to the other inhabitants of the settlement. Each settlement would specialize in certain products and trade with other settlements. When specialisation of human labour and physical products are not concentrated the networks of settlements have a greater stability and resilience to external stress and change.

See Appendices pp204-212

Organisation

Adam Smith (1723 - 1790) has often been called the father of economics. In his "Wealth of Nations" he postulated the theory of laissez - faire, examined value, the division of labour, the process of production, free trade, institutional development, natural liberty, the function of government and the role of capital. He rejected the theory of the Physiocrats that land alone is the basis of wealth. His concept of laissez - faire was that self-interested participants in a competitive market place will be unwittingly led to promote the common good by the "invisible hand" of the market. Steady state economist, Herman Daly has more aptly described the "invisible hand" as being the "invisible foot" of the market place. The Tragedy of the Commons is the result of the "invisible hand" in a closed system. It was John Maynard Keynes who said that "Ideas shape the course of history" and John Galbraith who pointed that the lives of men can be ruled by the ideas of some defunct economist. The division of labour concept was described by Adam Smith by pointing out that by a pin maker dividing the labour operations of each stage with other pin-makers the combined production unit could produce more pins than the combined individual efforts of each pin-maker doing the whole operation himself. (33)

Allow me to continue with the example of pin making. As each worker performed their own particular task they would increase their efficiency as they became more conversant with their task. If the workers were asked to exchange tasks, output would fall because each worker had specialized in his original task. Let us now consider the task of carrying heavy boxes to the door of the factory. One worker by himself would find this task difficult and tiring. Two workers would find the task easier and both together would be able to perform the task more quickly with less effort than two workers by themselves. Now consider the sale of these pins. The factory has running costs which is included in the price of the pins. By producing more pins the running costs can be shared among more pins so that the price of each pin can be reduced which encourages the sale of more pins. Two small factories, by merging may be able to produce more pins at a lower running cost per pin. All these processes of specialisation, division of labour, co-operative sharing of work and economy of scale is geared towards greater output at less cost per article. But there is an underlying assumption that production should and is able to grow in output. This has been possible during the growth phase of the industrial revolution when high grade energy stock was relatively inexpensive to collect and use. This cannot continue.

The energy implications of specialization, division of labour, economy of scale, centralisation versus decentralisation, and social power present a complex but highly interesting study. The spatial implications of steady state settlement patterns are tightly interwoven into this aspect of energy and organisation. One book which explains many of the above factors of organisation if Richard Newbold Adam's "Energy and Structure". Early in the second chapter I stated that "It is known that the organisational patterns of human beings are interrelated with the flow of energy... Communication theory has much to offer in this area. During my literature survey for this thesis I came across a number of articles involving the use of Entropy Theory and Spatial Analysis (23, 24, 25, 26). I am sure that, in time, a general theory which involves energy flow, communication theory and spatial' organisation aspects of entropy will be developed.

The following is a simplified explanation of the interaction between energy flow into a steady state settlement and the organisation of the settlement. By organisation I refer to the combination of spatial organisation, social organisation and distribution of energy flow via liquid capital within the settlement. By energy flow I mean the original high grade energy flow out of the energy converters of the settlement including the feedback high grade energy. This enables comparisons with different levels of steady state. Let us consider a constant consumer level of life C 1 which is made possible by different levels of energy inflow per capita and different levels of organisation. Figure 5-18 describes the curve C1.

Figure 5-18 Organisation and Constant Consumer Level (see scanned version)

A low level of organisation will maintain the consumer level of life C1 but only at a higher energy inflow/capita cost. This may be due to a combination of an inefficient distribution of liquid capital maintaining inefficient machines, high depreciation capital stock, energy converters with low net energy, high transportation costs and inefficient labour organisation.

Higher levels of organisation have higher energy costs. The elements of organisation cannot be separated as they all interact upon each other. We all know that over-organised labour can be most inefficient and we have heard of Parkinson's Law pertaining to this. The type of transportation system used reflects social organisation patterns and is also closely related to labour organisation. Over-centralisation creates high transport costs. There is no denying that organisational structure and energy flow are closely related. There is a balance where the consumer level of life C1 can be maintained at a minimum energy inflow per capita cost. This may require a sub-optimisation of some factors of organisation to achieve an overall optimisation. (The two key concepts of steady state are the acceptance of scarcity and distribution rather than production to achieve a higher level of steady state.)

Our next task is to look at different levels of steady state. Consider the curves A, B, C, D and E in Figure 5-19. Each point further away from the origin along these curves represents a higher consumer level of life and these curves pass through the optimised energy inflow per capita point for each consumer level of life.

Figure 5-19 Organisation and changing Consumer Levels (see scanned version)

Which curve best represents a progression to higher consumer levels of steady state? We can immediately eliminate Curve E because a higher consumption of energy cannot be achieved without a higher energy inflow. Next to be eliminated is curve A because the management of a higher energy inflow requires a higher level of organisation. This leaves Curves B, C and D. We can eliminate Curve D because higher levels of organisation require high energy inflows, not diminishing energy inflows. This leaves us with curves B and C. As organisation increases more and more "noise" in the system is created which requires higher levels of energy inflow to maintain that increasing level of organisation. We are left with Curve B. There are two limits to the ultimate consumer level of steady state that we can achieve. One is the limits of energy inflow and the depletion of energy stocks. The other is the limits of man himself in being able to create and live in a complex world of a high level of organisation. There is a balance between simplicity in life, complexity in life, quality of life and consumer level of life. These issues are but some of those that will be debated in the future.

Figure 5-20 Organisation and different Consumer Levels (see scanned version)

This brings us around to the question of the optimal size of the work force in a steady state settlement. The work force represents 55 - 60% of the total population. The size of the work force sets a limit upon the number of production units in the settlements. The number of production units has a relation- ship with the stability, diversity and total output of the settlement. In a steady state settlement there will be fluctuations in climate, production, consumption, and population. A larger number of production units offer greater resilience to external changes and stress - a greater adaptational ability. Also a larger number of production units can be of mutual advantage where separately they produce less but with mutual trade the total production of the settlement is increased.

For the moment, assume that the carrying capacity of the settlement is many times greater than that required. Now start adding production units to the settlement. Each production unit has, by itself, a fixed output but when interacting with the other production units the total output of the settlement is greater. There will come a stage when, because of spatial energy costs, an additional production unit does not raise the total settlement output by more than its individual output. This is the time for a new agglomeration of production units to be set up to form another settlement*. What we are discussing is centralisation versus decentralisation. The pattern of Energy Flow income is diffuse and not centralised like Energy Stock. The patterns of steady state settlements will reflect this decentralisation of energy collection. As well as the spatial energy costs involved in centralising consumption of Energy Flow when production is decentralised, there are energy costs of centralising social organisation. The degree of centralisation depends upon the available energy per capita.

* Footnote: Decentralisation should occur at the point of diminishing returns rather than at this “bare minimum” stage of over-centralisation.

In real life we have a finite carrying capacity. Settlements can choose to have a larger population with a lower consumer level of life or a smaller population with a higher' consumer level of life. The total size of the population would be that when the last additional worker to the work force can maintain himself and his proportion of dependents at an original predetermined consumer level of life. Decentralisation should occur at the point of diminishing returns rather than at this "bare minimum" stage .of over-centralisation. Unless the settlement is perpetually striving for a higher consumer level of life the ultimate carrying capacity may never be reached. The closer to the carrying capacity limit that man reaches the less stable is the total ecosystem including the human settlement sub-system. Constant maximisation in all areas of life can lead to strife, grief, and destruction. The middle way or distribution rather than production is the philosophy of steady state.

In previous pages I have outlined why New Zealand should adopt Steady state which would result in a natural ZPG population in the order, of 4.7 million people by the year 2080 with a work force of approximately 2.7 million people. New Zealand has one of the lowest population densities per square kilometre in the world (2 persons per square kilometres as compared to 200p/km2 (14, pp 960-3) and unlike other countries with low population densities a large proportion of the country can be used for agricultural purposes. The following table comes from the New Zealand report to the United Nations Preparatory Committee for the 1972 Conference on the Human Environment.

Table 5-3 New Zealand Land Use (27, p7) (see scanned version)

If New Zealand relied on its present hydro-electricity and geothermal energy supply - New Zealand's only form of Energy Flow at the moment - and did not invest in any further steady state energy converters the available energy per capita for the steady state population would be 13.6 gigajoules per capita per year. (28). This is in the order of energy per capita that China and Brazil use today including their Energy Stock sources. New Zealand has a head start over many nations. But there is no room for complacency. The lowest energy consumption per capita in New Zealand this century was during the depression years of the 1930's. The energy consumption per capita then was 50 Gigajoules per capita per year. Even allowing for inefficient use of energy back then it can be seen that there is a large difference between energy consumption per capita back in the 1930's and that energy supply which can be expected in the year 2080 if we do not invest in steady state energy converters. But one may say that I am conveniently forgetting our present supply of coal, natural gas, and surely we can rely petroleum for a while longer. My reply is that these Energy Stock sources are urgently required not for consumption (New Zealand's present Primary Energy Consumption including that of Energy Stock is 117 Gigajoules per capita per year), but for investment in 'steady state converters and Fixed Capital Stock. When we adopt ZPG, population will continue to grow from 3.2 to 4.7 million people. In the meantime Energy Stock sources pf oil, coal and gas will become more scarce and the energy costs of collecting this high grade energy will eventually make it prohibitive to continue doing so. We will never be able to use all the energy reserves of oil, coal, and gas because of the energy cost factor of collection.

New Zealand has one of the highest potential carrying capacity surplus ratios in the world. Provided that New Zealand adopts Steady State and takes the course of action of investing heavily in the capital stock necessary to sustain steady state. New Zealand may be able to play a large role in assisting with over population problems in other countries. So we are not discussing whether New Zealand should allow its natural population to grow to allow a greater work force but instead we should be asking the following questions:-

1) What consumer level of life should we adopt?
2) What is the carrying capacity of New Zealand at this consumer level of life?
3) What is the optimum organisational size of sub-settlements?

The answers to these questions are all interrelated and require much further study than that presented here. I know that some economists advocate a larger work force for New Zealand. The simple statement that a larger work force in New Zealand implies an improved industrial - agricultural based economy has within that statement many assumptions that require analysis and any statement of what natural population New Zealand should settle for requires far more than a few cursory paragraphs of explanation based on previous growth economic principles.

OMEGA

SUMMARY OF PRINCIPLES OF STEADY STATE

2018 Note: Items highlighted in red need to be reconsidered, reworded, corrected, or revised.

Settlement Attribute		Growth Settlement	Steady State Settlement
Economic Philosophy			
1	Primary Concept	Scarcity	Scarcity
2	Attitude to Scarcity	Conflict	Acceptance
3	Purpose of Production	Consumption	Maintenance
4	Emphasis on Production	Productivity	Distribution
5	Timescale Horizon	Narrow	Wide
6	Incentive for Work	Income for consumption	Satisfaction
7	Attitude to Work	Necessary evil	Part of Life
8	Work and Leisure	Differentiated	Little difference
9	Place of Man in Ecosystem	Domination	Participatory
Population			
10	Doubling Time	36 Years (NZ)	No doubling time
11	Percentage Growth Rate	2.0 % (NZ)	0 %
12	Age Composition Profile	Triangular	Cylindrical
13	Dependency Ratio	High	Low
14	Total Fertility	2.23 (New Zealand)	Approx. 2.11
15	Time to Re-stabilise	70 years	Already stable
16	Net Reproduction Rate	1.221 (NZ)	1.000
17	Family Structure	Nuclear family	Extended family
18	Urbanisation	High (80%)	Low (20-40 %?)
Capital Stock			
19	Durability	Low	High
20	Net Maintenance Energy Cost	High	Low
21	Recycling	Not accounted for	Important
22	Creation of New Capital Stock	Investment from profit (increase in energy use)	Allow old stock to depreciate or forgo consumption
Energy Production			
23	Source	Energy stock	Energy flow
24	Quantity	Abundant	Scarce
25	Limits of Production	Depletion and net energy decrease	Technological and energy/food balance
26	Permanence of Source	Non-renewable	Renewable
27	Source Pollution	High Pollution	Low Pollution
28	Pattern of Energy Flow	Increasing then decline	Constant level
Consumption			
29	Pattern per Capita	Increasing per capita	Constant per capita
30	Goods and Services Consumption	Unnecessary consumption	Necessary consumption
31	Tertiary Sector	High dependence of large tertiary sector	Small tertiary sector – self sufficiency
32	Distribution of Consumption	Unequal distribution	Equal distribution
33	Wastage	High wastage	Low wastage

Production			
34	Pollution	Heavy pollution	Light or no pollution
35	Energy Efficiency	Low energy efficiency	High energy efficiency
36	Energy Consumption	High energy consumption	Low energy consumption
37	Technological Accidents	Frequent and serious	Infrequent and insignificant
38	Type of Processes	Complicated and out of control	Comprehensible and under control
39	Impact on other Life Forms	Destruction of other life forms	Partial dependence of on other life forms
40	Risk of Processes	Ecologically dangerous	Ecologically adapted
Agriculture			
41	Type of Agricultural System	Monoculture	Diversity
42	Type of Industry	Specialised industry	Food industry involves everyone
43	Production Factors Intensity	Energy and capital intensive	Labour intensive
44	Use of Fertilisers	Artificial fertilisers	Natural recycled fertilisers
45	Use of Animals	Animals used primarily as food source	Animals used as resource and mechanical energy value
46	Food value of animals	Animals used for carbohydrates value	Animals used for protein value
47	Control of Pests	Dangerous pesticides used	Ecological techniques used
Organisation of Production			
48	Degree of Centralisation	Centralised	Decentralised
49	Dependency	Interdependence of production units	Self-sufficient production units
50	Scale of production units	Large production units	Small production units
51	Specialisation	High specialisation	Low specialisation
52	Practice of Science and Technology	Science and technology practised by specialist elite	Science and technology practiced by all
53	Production Factor Intensity	Capital and energy intensive	Labour intensive
54	Emphasis on Production	Mass production	Emphasis on artisanship
55	Unemployment Level	High unemployment due to unprofitability of labour	No unemployment. Concept of work non-existent. No profit in economy – maintenance only
Money Flow			
56	Inflation	Inflation as net energy of energy stocks approaches zero	No inflation. Dollar to energy ration remains constant
57	Interest rates	Interest rates include inflation	Interest rate does not have an inflation component
58	Profit	Production produces profit over and above maintenance. Accumulation of capital has positive feedback.	Production produces liquid capital for maintenance only
59	Control of Production	Production output is controlled by owner of capital and land	Production is controlled by owners of labour and land.

REFERENCES

MEADOWS, D.H., D.L. MEADOWS, J. RANDERS, and W.W. BEHRENS "The Limits to Growth", London, Earth Island Ltd., 1972.

2. SCHUMACHER, E.F., "Small is Beautiful", London, Sphere Books Ltd., 1977.

3. MILL, John Stuart "Principles of Political Economy", Editor W.J. Ashley, New York, Sentry, 1965.

4. KEYNES, John Maynard, "Economic Possibilities for our Grandchildren" in "Economic Growth vs. the Environment". Editor W.A. Johnson and J. Hardesty Belmont California, Wadsworth, 1971.

5. COLE, H.S.D., C. FREEMAN, M. JAHODA, and K.L.R. PAVITT, "Thinking about the Future; A Critique of The Limits to Growth", London, Chatto and Windus Ltd., 1973.

6. MESAROVIC, M. and E. PESTEL, "Mankind at the Turning Point", New York, New American Library Inc., 1976.

7. ODUM, H.T. and E.C. ODUM "Energy Basis for Man and Nature", New York, McGraw-Hill, 1976.

8. GEORGESCU-ROEGEN, Nicholas, "The Entropy Law and Economic Process", Cambridge, Harvard University Press, 1971.

9. BERTALANFFY, Ludwig von "General System Theory", New York, George Brazilier, 1968.

10. PIGOU, A.G., "The Economics of Stationary States", London, Macmillan, 1935.

11. GEORGESCU-ROEGEN, N., "Bio-Economic Aspects of Entropy" in "Entropy and Information in Science and Philosophy", Editors L. Kubat and J. Zeman, New York, Amsterdam - Oxford, 1975.

12. GEORGESCU-ROEGEN, N., "The Entropy Law and the Economic Problem" in "Toward a Steady-State Economy", Editor H.E. Daly, San Francisco, Freeman & Co., 1973.

13. DALY, H.E., "Introduction" in "Toward a Steady-State Economy", San Francisco, Freeman & Coy, 1973.

14. EHRLICH, P.R. A.H. EHRLICH and J.P. HOLDREN, "Ecoscience: Population, Resources, Environment" San Francisco, Freeman & Coy., 1977.

15. COTTREL, F., "Energy and Society: The Relation between Energy, Social Change, and Economic Development", New York, McGraw-Hill, 1955.

16. OPHULS, W., "Ecology and the Politics of Scarcity: Prologue to a Political Theory of The Steady State", San Francisco, Freeman, 1977.

17. ADAMS, Richard Newbold, "Energy and Structure: A Theory of Social Power", London, University of Texas Press, 1975.

NEW ZEALAND DEPARTMENT OF STATISTICS, "1976 Census of Population and Dwellings Vol 1 A", Wellington, Government Printers, 1977.

19. NEW ZEALAND DEPARTMENT OF STATISTICS "New Zealand Official Year Book 1976", Wellington, Government Printers, 1976.

20. SENESH, Lawrence, "Organising a Curriculum around Social Science Concepts" in "Concepts and Structure in the New Social Science Curricula" Editor I. Morrissett, New York, Holt, Rinehart & Winston, 1967.

21. "Philosophy and Environmental Crisis", Editor William T. Blackstone, Athens, University of Georgia Press, 1974.

22. "Environment and Society: A Book of Readings on Environmental Policy, Attitudes, and Values."

Editors R.T. Roelofs, J.N. Crowley, D.L. Hardesty, Englewood Cliffs, Prentice-Hall, 197^+

25. SHEPPARD, Eric S., "Entropy in Geography: An Information Theoretic Approach to Bayesian Inference and Spatial Analysis" in Discussion Paper No, 18 Toronto, University of Toronto, 1975.

24 LEE, Russel, "Entropy Models in Spatial Analysis" in Discussion Paper No. 15, Toronto, University of Toronto, 1974.

25. BATTY, Michael, "Urban Density and Entropy Functions", Reading, University of Reading, 1975.

26. WILSON, A.G., "Entropy in Urban and Regional Modelling", London, Pion Ltd., 1970.

27. "The New Zealand Environment", National Report to the United Nations Preparatory Committee For the 1972 Conference on the Human Environment, Prepared by the Town and Country Planning Division of the Ministry of Works, New Zealand.

28. MINISTRY OF ENERGY, "Goals and Guidelines: An Energy Strategy for New Zealand" Wellington, Government Printers, 1978.

29. LEACH, Gerald, "Energy and Food Production", Guildford, IPC Science and Technology Press, 1976.

30. PEARSON, R.G., "Energy Analysis", ERDC Report No. 30, Auckland, 1976.

31. "Energy Flow in Human Communities", Proceedings of a Workshop in New York, 1974, Sponsored by the Human Adaptability Coordinating Office and the Committee on the Biological Bases of Social Behaviour, Editors P.L. Jamison, S.M. Friedman University Park, Pennsylvania, 1974.

32. YEANG, Ken, "Energetics of the Built Environment", AD/7/74 pp4Zj.6-ij.51.

RECOMMENDED READING LIST

The most time consuming aspect in writing this thesis (apart from wife trying to decipher my writing) was the searching, reading, and sifting of relevant information. I soon found that the majority of books published before 1970 were not written 1 with a full awareness of the complexities of the energy problem and many before and after represented a reductionist view of the problems that we face. Time is limited for those who wish to pursue a more comprehensive study of steady state. For this reason the following reading list is offered which provides a solid foundation for a thorough understanding of why we need steady state. As far as I am aware, the truly comprehensive text on steady state settlements has yet to be written. (This thesis is an exploratory study). I am sure that many others have much to offer in this field, especially geographers whose training gives them an advantage over other disciplines. Perhaps you can contribute to rectifying this "gap” in our knowledge. The main requirement is a perspective change.

(Random order)

WILLIAM OPHULS, "Ecology and the Politics of Scarcity", San Francisco, Freeman, 1977.

C. H. WADDINGTON "Tools for Thought", St Albans, Paladin, 1977.

"Towards a Steady-State Economy", Editor Herman E. Daly, San Francisco, Freeman, 1973.

PAUL R. EHRLICH. ANNE H. EHRLICH. JOHN P. HOLDREN "Ecoscience: Population, Resources, Environment", San Francisco, Freeman, 1977.

FRED COTTRELL "Energy and Society", New York, McGraw-Hill, 1955.

DONELLA H. MEADOWS, DENNIS L. MEADOWS, JORGEN RANDERS, WILLIAM W. BEHRENS III "The Limits to Growth", London, Earth Island, 1972.

HOWARD T. ODUM and ELISABETH C. ODUM, "Energy Basis for Man and Nature", New York, McGraw-Hill, 1976.

LUDWIG von BERTALANFFY, "General System Theory", New York, George Brazilier, 1968.

KEITH BUCHANAN, "The Transformation of the Chinese Earth", London, Bell & Sons, 1970.

AMORY B. LOVINS, "Soft Energy Paths", Harmondsworth, Penguin, 1977.

BARRY COMMONER, "The Poverty of Power", New York, Bantam, 1977.

MIHAJLO MESAROVIC and EDUARD PESTEL, "Mankind at the Turning Point", New York, New American Library, 1976.

RICHARD NEWBOLD ADAMS, "Energy and Structure: A Theory of Social Power", London, University of Texas Press, 1975.

CONSTANTINOS A. DOXIADIS, "Ekistics: An Introduction to the Science of Human Settlements" London, Hutchinson, 1968.