3

ENERGETICS

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

INTRODUCTION TO ENERGETICS

Energy is involved in the transformation of all physical systems, including the growth and maintenance of different forms of life. Energetics is the study of these energy transformations in ecosystems. Human settlements also form ecosystems through which energy and materials flow. The organisational patterns of human settlements are interrelated with these flows of energy and materials, and an understanding of the flows within human settlements are essential to enable better planning for a transition from growth to steady state.

Energy flows in ecosystems have been studied for many years by biologists. For example, in a study of the Tsembaga Tribe in New Guinea, Roy Rappaport (1968) estimated that for every kilocalorie of energy put in as labour to produce food resulted in an output of about 16 kilocalories. The discipline of Ecological Energetics was documented by John Phillipson (1966) in his book of the same title. Energetics, as promoted by Howard Odum of Florida University, is a development of ecological energy studies of natural systems. In his book *Environment, Power, and Society* Howard Odum (1971) pointed out that "industrial man no longer eats potatoes made from solar energy; now he eats potatoes partly made of oil".

In 1973 the OPEC oil embargo resulted in sharp increases in the price of oil throughout the world. For example, the nominal price of regular grade petrol at the pump in New Zealand increased from 12.3 cents per litre in 1974 to 26.1 cents per litre in 1976 (NZ Parliamentary Library, 2000). The OPEC oil embargo prompted many countries to undertake Government funded research on energy. The New Zealand Energy Research and Development Corporation (NZERDC) was established in 1974 and 309 research publications on issues of energy were published between 1974 to 1988 (CBPR****).

In August 1974 the International Federation of Institutes for Advanced Study (IFIAS) held the first workshop on Energy Analysis to discuss the need for consensus on conventions and recommendations for further work (IFIAS, 1974). IFIAS categorised the four main approaches to the research field of Energy Analysis as follows:

a) Input-output Analysis

b) Process Analysis

c) Second Law Efficiency

d) Energetics (Ecological Energetics or Eco-Energetics)

There are major differences between Energetics and Input-Output Analysis or Process Analysis. Energetics places a value on all forms of energy and converts them into energy equivalents. The energy requirements of labour inputs are also included. One criticism of Energetics is that the method is unnecessarily complex (IFIAS, 1974). Different methods of Energy Analysis can provide the same results, but a major advantage of Energetics is its use of circuit language diagrams to describe energy flows. Use of such diagrams enables easier understanding of the energy flows of systems to the extent that the same diagramming approach is used within modern day dynamic simulation modelling software such as AnyLogic, Stella, and Vensim etc. The symbols used in diagrams might differ, but the end result of ease of understanding is the same. I have chosen to adopt the symbols used by Energetics when explaining the role of energy which flows through human settlements. Before doing so, we need to examine the laws of energy.

THE LAWS OF ENERGY

All forms of energy are inter-convertible and when conversions occur, they do so according to rigorous laws of exchange. The concepts of classical thermodynamics were derived and defined as the results of experiments in which macroscopic visible-to-the-eye properties of classical thermodynamics such as temperature, pressure, and volume could be measured directly. The principles and laws of classical thermodynamics were formalised by Clausius (1867) who based his work on the earlier writings of Rumford, Mayer, Joule, and Carnot.

Work and heat

In thermodynamics, a sub-field of physics, the words 'energy' and 'work' have precise definitions with meanings which differ from colloquial use of these words.

Energy is defined as 'the ability to do work on other bodies or as 'stored work'.

Work is said to be done on a system if that system experiences a displacement as the result of a force parallel to, and in the same direction as that force. It is meaningless to talk of 'work in a system' or 'work of a system'. Work depends on the particular process by which a system is taken from a reference state to a second state. A result of mechanical work on, or by, a system can be a change in kinetic energy, a change in potential energy of the system as in the case of compressing a spring, or dissipation into heat as in the case of boring out the centre of a cannon.

Heat is defined as that energy which is transferred between a system and its surroundings solely by virtue of a temperature difference. An early 19th century theory incorrectly regarded heat as a liquid called 'caloric'. It is incorrect to refer to 'heat in a body' because heat is not a substance. Heat is energy in transit.

The unit of heat energy is the calorie which is defined as that amount of heat whose absorption by 1 gm of water at constant atmospheric pressure is accompanied by a temperature rise from 14.5 to 15.5 °C. Calories with a capital 'C' is a unit which is used by nutritionists to describe the energy stored in food and one Calorie is equal to one kilocalorie (1,000 calories) with a small 'c'.

The mechanical equivalent of heat is the joule where 4.185 joules is the amount of mechanical work required to effect the same change in state as that produced by the absorption of one calorie of heat. The units of Calories, calories, and joules are all units of heat energy, and each unit can be converted from one unit to another using a conversion factor.

One watt (W) is a unit of power as opposed to energy, being the rate of one joule of energy flow per second. One kilowatt (1 kW) being 1,000 watts is a more appropriate unit to describe electricity consumption. One kilowatt hour (kWh) is a unit which describes the electrical energy consumption by a household or firm at the rate of one kilowatt over one hour. This energy consumption can be converted to joules by multiplying the unit of power (watts) by the unit of time (seconds):

One kilowatt hour = 1,000 watts x 60 minutes x 60 seconds = 3,600,000 joules (3.6×10^6 joules) or 3.6 megajoules (3.6 MJ)

First Law of Thermodynamics - Conservation of Energy

The First Law of Thermodynamics is also known as the Law of Conservation of Energy and can be stated as:

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

The First Law of Thermodynamics rules out any possibility of a perpetual motion machine of the first kind – a machine that will put out more energy in the form of work than is absorbed in the form of heat. Many attempts have been made to construct a perpetual motion machine and have failed.

Second Law of Thermodynamics

For a heat engine to be 100% thermally efficient, the engine is required to reject no heat to a reservoir. This requirement has proved to be a physical impossibility. The energy of heat comprises the internal energy of random molecular motion as opposed to the ordered kinetic motion of mechanical work. It is not feasible to completely convert the random molecular motion of heat to ordered molecular motion of mechanical work because the motions of each individual molecule would need to be fully controlled. Furthermore, part of the portion of heat that can be converted into mechanical work dissipates to the heat form of energy due to the unavoidable friction present in all machines. The degree of convertibility of energy - stored work - into applied work is often called availability. The Second Law of Thermodynamics can be stated as:

> *All physical processes proceed in such a way that the availability of the energy involved decreases.*

The Second Law of Thermodynamics is not deduced from the First Law of Thermodynamics, but stands as a separate law of nature. The First Law of Thermodynamics denies the possibility of creating or destroying energy, but does not preclude the possibility of running a power station that extracts heat from the atmosphere. The Second Law of Thermodynamics denies any possibility of perpetual motion of the second kind whereby a machine utilizes the internal energy of one, and only one, heat reservoir.

The Second Law of Thermodynamics may appear equally simple to understand as the First Law of Thermodynamics, but the Second Law of Thermodynamics is very deceptive (Andrews, 1980) and there are many far reaching implications which connect back to this law. An outcome of the Second Law of Thermodynamics is that all forms of energy ultimately degrade 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.

Entropy

In a low entropy system the energy is free in the sense that it is available for producing mechanical work, whereas in a high entropy system the energy is said to be bound. Lord Kelvin first developed the principle of the degradation of energy which states because all natural processes dissipate energy to heat, energy is continually becoming unavailable for work. Within the isolated system of the Universe there is a continuous and irrevocable degradation of free into bound energy.

The change in entropy for reversible and irreversible processes is formalized by the Second Law of Thermodynamics, the law of entropy, which states:

When all systems taking part in a process are included, the entropy S of the total system either remains constant or increases.

In mathematical terms:

$$\Delta S \text{ (universe)} \geq 0.$$

An open system may exchange both energy and matter with the outside, whereas a closed system exchanges only energy and not matter with the outside. Although the entropy of an isolated system remains either constant or increases, the entropy of open sub-systems may decrease. Life forms are an example of low entropy systems which, in order to retain the form of low entropy, need to continually take in energy and matter in the form of food and consume more than one unit of food in order to gain one unit in weight. During periods of increase in size and numbers, the entropy of living organisms decreases while the entropy of the combined system, which includes their life support systems, simultaneously increases. Contrary to being a violation to the law of entropy, life forms comprise systems that hasten the increase of entropy in the universe (Schrödinger, 1967, pp. 73-7).

Entropy as a measure of order and disorder

There are many different forms and interpretations of the law of entropy that incorporate the statistical mechanics concept of entropy as comprising a measure of order and disorder. In developing the kinetic theory of gases, Maxwell (1871) set up a model depicting the molecules of a gas as bounding in all directions and velocities off each other and the walls of a perfectly elastic container. Along with Boltzmann (1877), he developed an equation which showed that the distribution of molecular velocities of a gas at a particular temperature comprised a few molecules moving very slowly or very quickly with the larger percentages moving at intermediate velocities. A rise in temperature causes the average velocity of the molecules to rise – an increase in the kinetic energy of the molecules – while a drop in temperature caused the average velocity to fall. Mechanical work, as opposed to the haphazard motions of individual molecules against intermolecular forces, involves the orderly motion of molecules. Whenever mechanical work is dissipated into heat, the temperature of the system rises and the disorderly motion of molecules increases.

The kinetic theory of gases pictures temperature and heat as involving molecular movement and an interpretation of the Second Law of Thermodynamics as being a tendency for nature to proceed from a state of order to disorder thus providing a qualitative and supplementary understanding of the laws of classical thermodynamic.

The Law of Entropy can be stated as:

In spontaneous processes, concentrations tend to disperse, structure tends to disappear, and order becomes disorder.

There is a degree of similarity between statistical mechanics and quantum theory. Both theories have an explanatory and predictive value relating to microscopic phenomena and utilise the theory of probability. However, by making use of probability theory, statistical mechanics allows the possibility of water being able to spontaneously separate into a hotter and colder region. Human experience denies this possibility. According to statistical mechanics, even though this possibility is very small and may not occur within the time frame of any human experience, the possibility nonetheless exists.

Shannon and Weaver (1949) also used the theory of probability in the development of information theory in response to a study of how to most efficiently transmit a signal of information through telephone lines subject to noise interference. Shannon used the term 'entropy' to describe the measure of the 'amount' of information in the transmission of a signal perhaps on the basis of similarity in mathematical form to Boltzmann's equation for thermodynamic entropy. The information theory use of the term ‘entropy’ would seem to be metaphorical rather than a relationship of process because entropy is a measure of order and disorder in statistical mechanics, whereas the meaning of a message is irrelevant. The concept of entropy has also been utilised to define the arrow of time as being in the same direction as followed by all natural processes due to dictates of the Second Law of Thermodynamics (Coveney & Highfield, 1990).

Georgescu-Roegen (1971) regards Boltzmann's statistical approach to entropy opens the door to vacuous interpretations of what entropy means and that statistical mechanics is logically flawed by being underpinned by classical mechanics which denies qualitative change in the universe. The position adopted by Georgescu-Roegen is that entropy is neither reducible to locomotion nor to probability nor any subjective element. According to Georgescu-Roegen (1971, p. 9):

> “The entropic phenomenon of a piece of coal burning irrevocably into ashes is neither a flow of probability from a lower to a higher value, nor an increase in the onlooker's ignorance, nor man's illusion of temporal succession.”

The law of entropy was derived as a physics of the economic use of heat in an engine and not from the principles of classical mechanics that reduces all phenomena to reversible locomotion. As Georgescu-Roegen (1971, p. xiii) emphasises:

> “...the discovery of the Entropy Law brought the downfall of the mechanistic dogma of classical physics which held that everything which happens in any phenomenal domain whatsoever consists of locomotion alone and, hence, there is no irrevocable change in nature.”

The First Law of Thermodynamics does not contradict the laws of mechanics, but the Second Law of Thermodynamics, the law of entropy, is in direct contradiction with the laws of classical mechanics in that the law of entropy introduces the element of an irrevocable qualitative change when systems undergo any process.

ENERGY FLOWS

The study of energy flows within ecosystems, 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 human cultural systems, energy flows also carry information. This aspect does not concern us at this stage.

The different types of energy flow can be categorised in the following way. (Adams, 1975, p. 115-8)

- Flow as transport and storage of matter: The flow of materials moving through an ecosystem, including storage.
- Flow as transduction and radiation of energy: Solar and thermal radiation, evaporation, convection and conduction.
- Flow as conversion from one state to another: Examples include burning of fuel, photosynthesis, and water becoming steam.
- Flow as an energy cost of triggering energy release: For example, the energy of one system (human action) applied to the environment of a second system which releases greater energy (energy production).

To help us visualise 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. The following symbols are used by Howard Odum

(1983) and his team at the University of Florida when discussing energy, economics, and the environment. The function of each symbol might be familiar to those who have studied electronics or dynamic systems analysis.

My preference for making use of Energetics to help explain the role of energy in human settlements is not without some qualifications. I do not endorse Energetics' encroachment into economics. Howard and Elizabeth Odum (1976, pp. 49-59**) claimed that Energetics can be used as a means by which physical variables can be injected into economic theory thus enabling a better understanding of the relationship between energy use and GDP. The discipline of Energetics makes this connection by showing a reverse flow of money in its circuit diagrams in exchange for energy. This representation of money flows is overly simplistic and does not represent a realistic model of our financial and banking systems. Yes, there is a reverse flow of money involved with each flow of energy, but the primary purpose and benefits of making use of Energetics is in establishing the energy flows and their magnitudes within a human settlement. Representations of money flows can be safely ignored. I have therefore excluded money flows in the following diagrams. A more serious critique of Energetics' Energy Theory of Value is contained in the Notes section at the end of this chapter.

Energy Source Symbol
The flow of energy from an energy source might be steady and constant such as that from a hydroelectric dam or intermittent such as that from windmill or solar panels.

Figure 3-1

Energy Storage Tank Symbol
An energy storage tank is a stock of energy such as fossil fuels in the ground, petrol in the tank of a car, the embodied energy stored in a building, or the repository of information. All concentrations of matter are storages of energy.

Figure 3-2

Heat Sink Symbol
A heat sink symbolised as an arrow pointing down into the ground represents the loss of degraded energy from a system and the depreciation and degradation of that system as the material of the system becomes dispersed. All energy storage tanks have a heat sink.

Figure 3-3
Interaction Symbol
All processes involve the interaction of two or more types of energy and matter. All interactions have a heat sink.

Figure 3-4

Production Symbol
The production symbol represents the processes, interactions, and storages involved in photosynthesis whereby high-quality energy is produced from diffuse solar energy.

Figure 3-5

Self-interaction symbol

This symbol represents processes where self-interaction takes which results in a faster action that would otherwise take place. An example is where the interaction of a group of people building a house results in a quicker build than possible each person simultaneously working alone without any interaction.

Figure 3-6

Self-maintaining Unit Symbol
This symbol represents a system that maintains itself by using storage tanks and interactions to make use of inflowing energy and materials. Examples include an organism, or a town and city.

Figure 3-7

Self-maintaining Unit with two energy sources symbol
This symbol is useful to represent a self-maintaining unit which uses more than one type of energy.

Figure 3-8

Example 1 ***Note: add explanation

Figure 3-9

Example 2 ***Note: add explanation

Figure 3-10

THE GRADING OF AN ENERGY SOURCE * Note: editing needed**

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.

Figure 3-11 Scale of Energy Quality

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 is of low availability or low-grade energy.

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 3-12 Energy Conversion

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.

Figure 3-13 Comparison of the use of high-grade energy.

The grading of an energy source can be classified in terms of the energy level of the source – a measure of its energy intensity in terms of energy per unit mass – and its energy grade that is a measure of energy quality. A high energy level system has the characteristics of high temperature, pressure, or enthalpy (heat of combustion).

The energy grade of a source can be separated into either work forms or heat forms of energy. Work forms of energy include mechanical work, electrical energy, waterpower, wind power, and the kinetic energy of a jet stream. Because work can be completely transformed into heat – the reverse transformation of heat cannot completely transform heat into work due to the Second Law of Thermodynamics – work forms of energy are given a higher classification than heat forms. This distinction becomes less significant with high temperature sources of energy.

Heat forms of energy – heat from fusion/fission, heat from combustion, and heat from friction – are graded in descending order according to the temperature of the source. The energy grade of a source serves to qualify the energy level. When two energy sources have the same level but different grades, the ordering of the lower grade source can be adjusted downwards to reflect a lower availability.

Table of Energy Equivalents * Note: add text – MWe, emergy? ,**

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 availability of energy in terms of Fossil Fuel Equivalents or FFEs. 6.

Table 3-1 Energy Equivalents.

FIRST AND SECOND LAW EFFICIENCIES

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.

When energy is transformed from one form to another, each transformation is accompanied by a degradation of energy due to the Second Law of Thermodynamics. The efficiency of energy conversion is the ratio of the desired output energy, or work, to the necessary input energy, a ratio that can range from about 5% for an incandescent light bulb.

The first and second law efficiencies are measures of the efficiency in carrying out a specific task such as heating or lighting a building or providing a transportation network.

The first law efficiency is the ratio of the energy delivered by the process in the form and location necessary to achieve that task to the amount of energy supplied to the process. The first law efficiency can be used as a measure of energy conservation in carrying out a task, but in doing so the quality of energy conserved is not taken into account. There no differentiation between energy losses caused by imperfections in the energy conversion process and energy losses due to the Second Law of Thermodynamics cannot be avoided even by perfect technology. These factors are included in the second law efficiency.

The second law efficiency is the ratio of the <u>minimum</u> amount of available energy required to carry out a task to the <u>actual</u> amount of available energy used. The second law efficiency is a measure of how much the performance of a task falls short of what is theoretically possible, and can be used as a measure of the conservation of free, or available energy in carrying out a task.

An examination of the task of heating a house provides an illustration of the difference between first and second laws efficiencies. In an example provided by Ehrlich et al. (1977), a standard furnace is able to deliver 1 unit of energy for heating a house for every 1.5 units of energy extracted from its fuel. The first law efficiency is

$$\frac{1 \text{ unit of heat}}{1.5 \text{ units supplied}} = 67\ \%.$$

By using the most efficient Carnot heat pump where the Coefficient of Performance (COP) is solely dependent on the temperature difference inside and outside the house, the minimum amount of available work required to deliver 1 unit of heat is 0.07 units. The available work in a chemical fuel is approximately equal to its heat of combustion or enthalpy. The available work used by the furnace remains at 1.5 units. The second law efficiency is

$$\frac{0.07 \text{ units minimum available work}}{1.5 \text{ units available work of furnace}} = 4.7\,\%.$$

The second law efficiency is based on comparing actual processes with idealistic processes that do not necessarily include a realistic time frame. There is a trade-off between efficiency and power. An infinitesimally slow reversible process may be carried out with maximum efficiency, but with a penalty of a power output approaching zero. A very rapid process, on the other hand, approaches a maximum power input but at zero efficiency and zero power output. Life forms and the activities of humankind require energy processes to be carried out at an intermediate range of rates that fall well short of the maximum second law efficiency. Odum & Pinkerton (1955) proposed that natural systems tend to operate at an efficiency that produces a maximum power output, but Peet & Baines (1986) caution that although the maximum power principle represents deduction from a wide range of empirical observations, its universality has yet to be proved or generally accepted.

Moore (1981) recommends the following guidelines to ensure that the conservation of free or available energy is maximised when energy is supplied in a converted form in order to carry out a task.

- Firstly, there should be a minimum number of energy conversion steps. Each unnecessary energy conversion step involves an unnecessary loss in free energy because there is a severe penalty in transforming the energy of heat into mechanical work.
- Secondly, heat should be converted into work at the highest possible temperature and should be undertaken only once.
- Thirdly, the direction of any series of energy conversion processes should proceed from those with maximum conversion efficiencies to those with a lower efficiency of conversion.
- Fourthly, energy should ideally be stored in work reservoirs such as compressed air, mechanical springs, and pressurised liquids because such devices provide the potential for minimal energy storage loss.

NET ENERGY * Note: editing needed**

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. **** Insert Energy Returned on Energy Invested (EROI) greater than 1.

Figure 3-14 Oil subsidy in agriculture

In the past further energy inputs in the form of fertilisers, 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 fuels. 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. The time for paying the true costs will occur within the 21st century.

Likewise, it is of urgent priority to determine whether other energy-transforming activities generate net energy. Figure 3-15 shows an example of a rich energy source with net energy.

Figure 3-15 Example of rich energy source with net energy

(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 3-16 shows allow energy source which does not yield net energy. This analysis of net energy applies to the generation of electricity from photovoltaic cells. Photovoltaic cells do not produce net energy. *** Update. However, in certain circumstances such as communication satellites, the energy costs of alternatives may be much greater than that of the photocell.

Figure 3-16 Example of poor energy source-no net yield

(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 the case of generation of electricity from nuclear power stations it has not yet been shown whether they produce net energy. ****check

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. *** Update

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.

CRITICISM OF ENERGY ANALYSIS BY ECONOMISTS

Economists have two main criticisms against the encroachment of Energy Analysis into their field as follows:

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

b) Energy Analysis gives no credit for capital and no allowance is made for improvements in technology.

The first criticism is easily disposed of. A process might be technically feasible, but not necessarily viable. Net Energy Analysis compares different methods of energy generation at a comprehensive level by including externalities that are overlooked or ignored by conventional financial accounting methods. By doing so, Energy Analysis of alternative methods of generating energy can show whether a particular method is not only feasible, but also viable by being truly sustainable in the long term without the need for ongoing energy subsidies of fossil fuels. This applies especially to the technologies of nuclear fission, photovoltaics, wind turbines, battery storage, and bio-fuels.

With regards to the best allocation and decision-making of our finite resources of fossil fuels, the price mechanism has clearly failed. ***Add further comment.

*** Note: Address second criticism - Energy Analysis and Economics both needed.

SUMMARY *** Note: Rearrange order, check for completeness & edit

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.

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.

Energetics based on the First and Second Laws of Thermodynamics helps 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.

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

The entropy of the Universe is increasing.

In spontaneous processes, concentrations tend to disperse, structure tends to disappear, and order becomes disorder. The lower the entropy, the greater the order.

Low entropy energy has greater availability to undertake work.

In any transformation of energy, some of the energy is degraded.

The availability of a given quantity of energy can be used only once; that is the property of convertibility into useful work cannot be recycled.

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

Living organisms in ecosystems becomes more highly organised and energy becomes more concentrated. This process, however, is not a reversal of the Second Law. Living organisms do not reverse the universal process, if anything they hasten it.

Their very life depends on a continuing conversion of energy from higher forms to entropy. Put in another way, life feeds on negative entropy. Entropy of the total system still increases thus still following the Second Law.

All forms of life need a continual input of energy for growth and maintenance.

It always takes more than one kilogram of food to gain an increase of one kilogram of weight.

The flow of energy through plants is greater than the flow of energy through plant eaters which in turn is greater than the flow of energy through carnivores.

Regardless of origin, all forms of energy ultimately degrade to heat.

NOTES

Energetics and Energy Theory of Value

The discipline of Energetics makes a serious encroachment upon that of economics. Howard and Elizabeth Odum (1976, p. 58) claimed that energy, and not money, is the best measure of value. A number of their followers have subsequently claimed that the monetary contribution of nature can be accounted for by using energy as a measure which enables cost-benefit analyses to be made on a less arbitrary basis. For example, Robert Costanza (1980), whose 1979 PhD was supervised by Howard Odum, claimed that an energy theory of value could be created where "market-determined dollar values and embodied energy values are proportional for all but the primary energy sectors". Nicholas Georgescu-Roegen, the author of the book *The Entropy Law and the Economic Process* published in 1971 which established him as the "grandfather" of Steady State Economics, soundly debunked this claim (Georgescu-Roegen, 1982b**). According to Silvana de Gleria (1999), Robert Costanza has many years later failed to address Georgescu-Roegen's criticisms. Kozo Mayumi (2018) further explains why such a claim is a "theoretical absurdity". Nonetheless, some proponents of Energetics still use money flows in their circuit diagrams and estimate the financial benefits of ecological systems based on an energy theory of value. Steve Keen (2019), an economist who is well versed in the role and importance of energy in the economy with a recent publication, *A Note in the Role of Energy in Production accepted for publication in 2019,* has demonstrated that realistic models of flows of money in an economy must include the role of private banks and reserve banks which create money and debt (Keen, ***). Steve Keen makes use of the dynamic simulation software called Minsky which includes a Godfrey Table. *** etc etc,

Emergy * Note: Add text**

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RECOMMENDED READING *** Note: add recommended publications

***** **POSSIBLE INSERTS**

"The non-substitution theorem implies that under very strict assumptions the value of a good or service is given by the total amount of a non-producible production factor (such as labour) in its production. There are four crucial and narrow assumptions: there is only one primary non-producible production factor; (this one primary factor is used in the production of every intermediate and all final goods and services; all production processes are subject to constant returns to scale; and there is no joint production. If we apply the non-substitution theorem to energy as primary non-producible production factor, it is clear that the energy theory of value is totally unrealistic and unrealisable." (*Thermodynamics: Relevance, implications, misuse and ways forward*, Kozo Torasan Mayumi, 2018)