Energy Cost Benefit Approach to Evaluating Power Plant Alternatives

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A vital economy requires good use of free resources of the environment, effective utilization of energy resources, and elimination of unnecessary wasteful expenditures of money and thus energy. Our economy is intertwined with that of nature with part of our basis for life supplied by energy flows of the environment acting to produce winds, rains, tides, the seashore-building waves, the vegetation that filters, cleans, and restores soils etc. We rarely evaluate or are aware of these very large energy supports from nature that come mainly from the sun's action in keeping air, water and other materials of the biosphere circulating. The rest of our energy basis is from fuels that we buy with money and for this basis we are kept painfully aware by payment of the money that we must earn. The two kinds of energy are shown in Fig. 1.

Because of the close intertwining of the several kinds of energies that support our economy (some natural, and some paid for), we can hurt our economy and make it uncompetitive with loss of incomes, increased taxes, etc., if we make decisions that waste energy. We waste energy if we interfere unnecessarily with the free flow of energies of the environmental areas. We waste energy if we build technology that is not necessary. We waste energy if we try to add a new industry, if that new industry interferes with more of the old natural energy support to the economy that the new industry contributes. We waste energy if we try to invest our accumulated resources in new enterprises if there are no new resources that will be tapped by the new enterprise. In other words new enterprises will fail if energy costs are in excess of the energy returns that ultimately develops from the investment.

Energy Cost Benefit Idea for Decision Making

In the previous paragraph we suggest that the correct way to make an economy most vital, most prosperous, and continuing to be competitive with other areas or other plans that might have been developed is to maximize the energy income and minimize the energy waste. To calculate the total energy available we need to add the two kinds of energy shown in Figure 1: (1) the natural energies , and the (2) bought energies. The bought energies depend on the regions overall income of money which can go back out to buy fuels and goods and services that are in turn based on energy flows elsewhere. The amount of energy that income buys depends on world prices, and these prices are going up because of the increased energy cost of getting energy as we have to dig and drill deeper and deeper into the ground and further offshore.

If a decision needs to be made that involves a new enterprise such as a power plant, it should be made so as to maximize the energy that can be developed and minimize the waste. One may measure the energy change in free contributions from the environment and from the new activity with its various alternative means of operation. The combination that provides the maximum energy benefit and least energy cost is the one that contributes most to the economy of both man and nature. Remember that man's economy is so intimately interwoven with nature that a stress on the environment's productivity ultimately is a drain on man's money economy as well.

Thus we have evolved the energy cost-benefit analysis as a new procedure for tabulating the annual energy contributions and losses associated with proposals so as to recommend which plans are best. The method puts economics and environment in perspective using the common denominator of energy as the basis since energy can be a measure of all useful work upon which the systems depend.

Measurements are made of the energy flow into work from all natural or bought contributions directly and indirectly and calculated in units of Calories (Kilocalories) which is the same unit one sees in TV advertisements about diet. Work of man, machines, winds, etc. can be measured in Calories.

Energy Concentration Factors Towards Useful Work

There is one critical detail about making energy comparisons that is new and makes the energy cost-benefit procedure different from some efforts in this direction made earlier. Different forms of energy are in different concentrations. A flow of gasoline is a very concentrated flow of energy, 36,000 Calories or more in a gallon in a form that can cause very effective work of machines. A flow of sunlight, however, is a very dilute flow of energy with one thousand trillionth of a calorie in a gallon of space through which light is passing. When energy has done its work it ends up in dispersed heat without sharp differences in temperature. Such dispersed heat is really the random motions of the molecules, and man has no way to get further work out of calories that have been degraded into the dispersed heat version. One can only hook heat engines to heat sources when there are great differences in temperature as between the hot boiler of a steam power plant and the cool outside. Thus a Calorie of energy is not a measure of the ability to do work unless one also indicates what kind of energy form it is in. If it is in a concentrated form like gasoline it can do much work per calorie; if it is dilute energy like sunlight, it can do only a little energy per calorie because it uses energy in being concentrated. It can do no work if it is already in dispersed heat form.

Thus there are conversion factors to show the relative work abilities of each type of energy. In one procedure we convert all energies to FOSSIL FUEL WORK EQUIVALENTS. A Calorie of sunlight for example, seems to have a work contributing ability to our economy of around 1/2000th of a calorie of coal or oil. Most people are already familiar with the fact that it takes about 4 calories of coal to generate one calorie of electrical energy. Electrical energy is a high quality, high concentrated form of energy and thus costs more energy to develop and can generate more work per calorie in processes. Electrical energy can do things that lower energy forms cannot.

Summarizing the procedure, one may make an energy cost-benefit calculation by calculating the annual flows of energy involved in a proposed enterprise, the changes in energy flows of the environment represent all these in fossil fuel work equivalents using the conversion factors between various forms of energy and fossil fuels. Then one adds up the pluses and minuses associated with the questions being considered and recommends the one with the highest ratio of energy benefits to energy costs. This procedure gives due credit to the environment, whereas the traditional money cost-benefit method gives no credit to environmental contributions, or to the energy resource changes involved. Consider next an example, the question of a cooling tower versus environmental cooling.

Cooling Tower Question

In several places in Florida cooling towers are being considered in comparison to the alternative of flowing marine or fresh waters through the plant for cooling, a process that initially changes the aquatic ecosystems causing them to develop a different kind of ecosystem one in balance with the plant's operation. There are many studies going on throughout the United States by Federal, state, local agencies and by power authorities to measure the stresses that develop during the transition from old ecosystem to the new one. A very open question is the relative value of the old ecosystems compared to systems adapting to heat flows. When the temperature differences are small there may be positive effects on the ecosystems. If temperature effects were very large (larger than allowed by various permitting agencies) normal life would not prosper in these ecosystems. Many questions such as the action of power plants on aquatic plankton are involved. The plant acts somewhat like a giant oyster in filtering and recycling some of the aquatic planktonic life. The main question is whether the artificial giant oyster (the power plant's action) is similar, stressing, or energy enriching. Studies in progress are probably able to show what percent of the original ecosystem's biological productive energy budget in driving the food chains that support fish etc. has been increased or decreased. The question we address in this article is not that one, but the evaluating of the environmental impact as compared to the other energy inpacts on the combined economy of both man and nature together.

Energy Cost Benefit Table

Given in Table 1 in very simplified version is the kind of calculation we are attempting to make with the energy cost-benefit procedure for annual impact of a cooling tower compared to an environmental area. Just for sake of a sample calculation without reference to any particular plant suppose tha annual running cost of a cooling tower in dollars including amortizing the cost of construction, repair, operation, maintenance, etc. is 5 million dollars in 1974 dollars. If about 30,000 Calories of work (fossil fuel equivalent) are done throughout our economy for every dollar that circulates, then the cooling tower puts a cost load on our economy of 150 billion kilocalories of fossil fuel equivalents per year. This is a waste to whatever extent that it is a greater energy cost than an alternative. Suppose the alternative cooling were to completely inhibit the biological production of one square mile of estuary (2.58 million square meters). This may be 10 times what is actually being observed. In this, we regard as inhibited the biological community production based on the interplay of sunlight incoming at 4000 Calories per square meter per day. Multiplying this by 365 days and 2.58 million square meters in a square mile one has the annual contribution of solar based economy upon which the estuarine life is based. (For this calculation we left out tides and winds although these are included in the real analyses we are doing in real examples). Suppose the fossil fuel equivalents of the solar based food chain is 1/2000th of this. The result is 1.89 billion kilocalories per year, a much smaller value than the cooling tower. In this example the cooling tower turns out to be a waste and should not be built. So far preliminary calculations at Anclote and Crystal River suggest that cooling towers are wasteful there also. Final report on the detailed calculations on the system at Crystal River are due this Fall.

Many government recommendations are being made now about power plants, barge canals, draining swamps, choices of water use, etc. that are made by political judgements of boards and individuals under pressures without objective comparison of environmental values and money values. Many of these may be wrong; sometimes a development adds net energy; sometimes it decreases net energy. The energy cost benefit analysis method is now sufficiently accurate to substitute for judgements which are made without substance. Some of the concentration factors will need tightening up for greater accuracy. The public and the judicial system will have to learn the manner by which the greater good is measured by total work. We may even need a State and Federal constitutional amendment that says that no man has the right to reduce the net energy resource of the public or his neighbors, since this affects the public good and ability to survive.

Table 1.

Sample of an Energy Cost-Benefit Calculation for Two Power Plant Cooling Alternatives. Annual Work in Kilocalories of Fossil Fuel Work Equivalents.

	Cooling Tower	Estuarine Cooling
Special Energy Cost	$- 150. \times 10^9$	0
Environmental Energy Disruption	0	$- 1.9 \times 10^9$

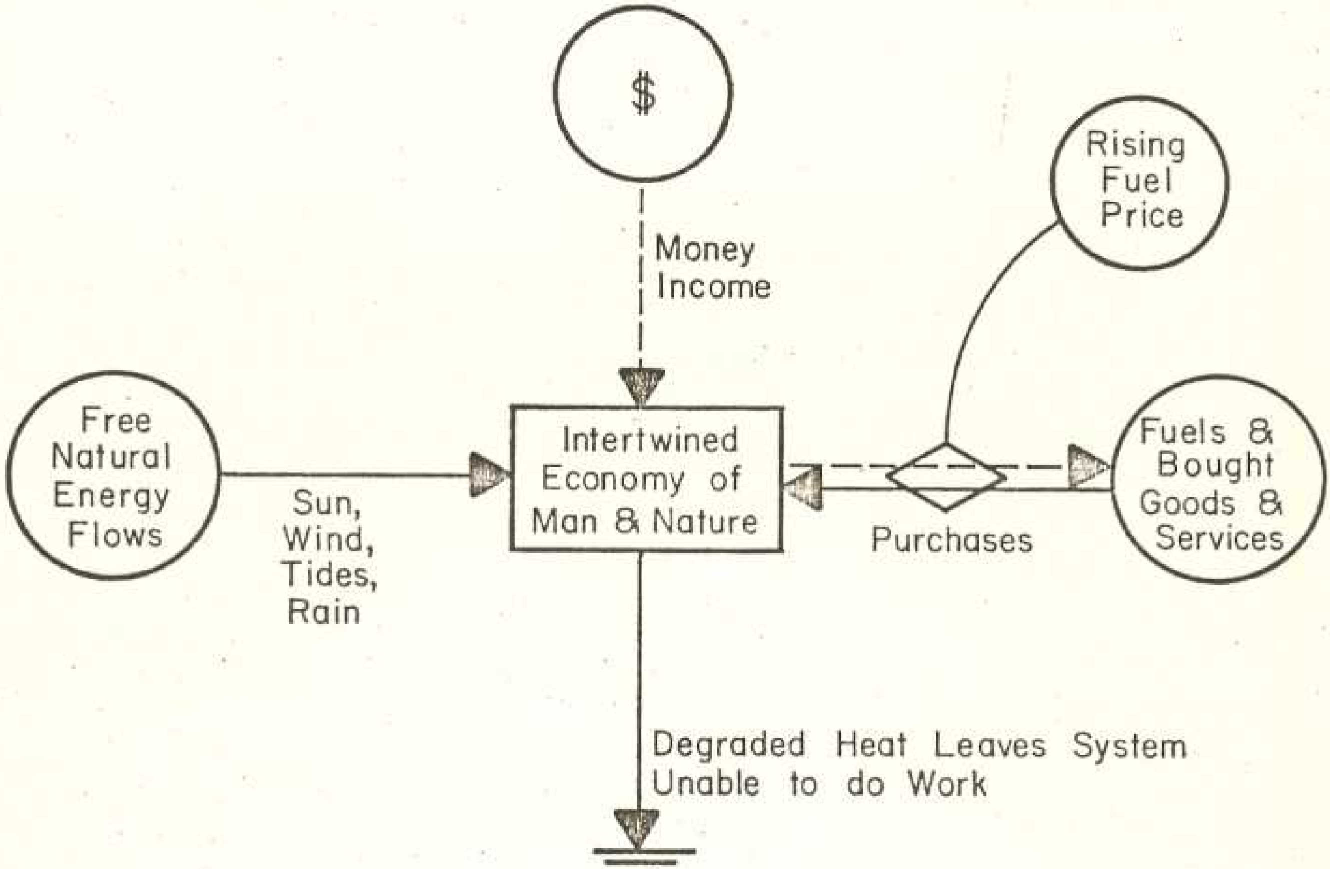

Fig. 1. Diagram showing two main kinds of energy that support the intertwined economy of man and nature: Natural free flows and purchased fuels and goods and services based on fuels.