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ENERGY USE AND ITS EFFECTS ON THE GLOBAL ENVIRONMENT: AN EXAMINATION FROM THE HISTORY OF TECHNOLOGY*

TAKESHI MUROTA

Abstract

This paper is intended to be a brief survey of global environmental problems from the historical viewpoint of resource-technology dynamics. Emphases are upon the coal-steam engine relationship, the transition from organic to inorganic agriculture, and the fragile structure of the petroleum-nuclear civilization. Towards the end of the paper, some proposals for environmental betterment are presented in the context of Japan.

Introduction

Over eons the many forms of terrestrial life, one of which is the human being appeared later, have passed from one generation to the next, but now our watery planet and scene of life, the earth, is undergoing a number of abnormal changes. Although one could think of various reasons, the major cause is the intemperate use of underground resources. The massive consumption of coal and petroleum especially have brought about a modern type of environmental destruction that differs from what we know as ancient forms of destruction such as the depletion of forests and the desertification that ancient civilizations prompted.[1] While the concentration of atmospheric carbon dioxide was fairly stable at about 275 ppm prior to the industrial revolution that began in England, Wales and Scotland (Great Britain in sum), it has risen steadily since that time and recently attained about 350 ppm, which shows that the intemperate use of fossil fuels is no longer limited to local pollution, but has now even modified the composition of the earth's atmosphere.[2]

Needless to day, even before the industrial revolution people were producing carbon dioxide by burning firewood, but since forests absorbed that as one of the substances used in plant growth it presented no essential problem at all. Humans also generated wastes, but soil and water bacteria broke these down into inorganic substances and waste heat. The former was then taken in by plants in the process of photosynthesis, while the latter

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[1] For detail, see Carter and Dale (1955).

[2] See, for example, Intergovernmental Panel on Climatic Change (1990).

was mainly absorbed by water, and in a quite competent manner discarded into space through the tropospheric water cycle. In other words, as long as people avoided the sort of excessive logging that would overstep the limits of the water and carbon cycles, it was possible to maintain exuberant life activities. It was the invention of the steam engine that occasioned a fundamental change in this situation, and the subsequent invention of the internal combustion engine opened the way for the creation of today's environmental problems. This paper will thus consider global environmental problems principally in terms of their history, particularly in terms of their technological history.

I. *The Human Encounter with Coal and Petroleum*

"So we went together out of the west gate of the city and went three or four li west to a rocky mountain called Chin-shan. There is coal all over the mountain, and all the people from prefectures near and far come to get it to burn. For cooking meals it has a great amount of heat. We saw where the rocks of the cliff had been scorched to coal, and people told us that it had been burned by lightning. . . . "[3]

This was the scene witnessed by Ennin (Jikaku Daishi, 794–864) near Taiyuanfu during his travels in China during the first half of the ninth century.

Quite some time after that, in the thirteenth century, the Venetian merchant Marco Polo (1254–1324) traveled in China. He also made detailed observations of coal and wrote the following.

"It is a fact that all over the country of Cathay there is a kind of black stones existing in beds in the mountains, which they dig out and burn like firewood. If you supply the fire with them at night, and see that they are well kindled, you will find them still alight in the morning, and they make such capital fuel that no other is used throughout the country. It is true that they have plenty of wood also, but they do not burn it, because those stones burn better and cost less."

"Moreover with that cast number of people, and the number of hot-baths that they maintain—for every one has such a bath at least three times a week, and in winter if possible every day, whilst every nobleman and man of wealth has a private bath for his own use—the wood would not suffice for that purpose."[4]

Such observations allow one to surmise that from quite early times coal had been used on an everyday basis in several regions of China for cooking and other uses. Judging by the way in which Ennin and Marco Polo made special mention of coal, they mush have perceived this as a very extraordinary thing, and thus had probably not seen anything like it in Japan or Europe.

This is not to say, however, that coal had not at all been used in Europe. We hear that coal cinders have been discovered from Old Stone Age archaeological diggings in Czechoslovakia, and we also know that coal was used as a fuel for cremation in England beginning in about the first century. In Japan there is a story in the legend about Empress Jingu who, during a military expedition to Kyushu, got her robes wet while crossing

[3] This quotation is from Reischauer (1955) based on Ennin (around 847).
[4] Quoted from Yule (1875), Book I, p. 48.

a river near present-day Tagawa in Fukuoka Prefecture, and the local people dried them over a coal fire.

In consideration of fuel quality, however, coal is dirtier than firewood and charcoal, and tends to pollute the atmosphere. For this reason England's King Edward I prohibited the use of coal in 1306, and it is said that some offenders were punished by death.

Now let us consider the relationship between people and crude oil. Stories from long ago include that of Noah and the ark in the Bible's Old Testament. God had decided to cause a great flood, but wanted to save the righteous Noah, to whom he said, "Make yourself an ark of gopher wood; make rooms in the ark, and cover it inside and out with pitch."[5] The pitch spoken of here is interpreted to mean crude oil; people knew that crude oil functioned as a preservative. In Japan the earliest recorded reference to the human encounter with crude oil is in the *Nihon Shoki.* There is a passage which says that in the seventh year of Emperor Tenchi's reign, in autumn, the seventh month of A.D. 668, "Again, the province of Koshi presented to the Emperor burning earth and burning water."[6] It is thought that the burning earth here is natural asphalt, that the burning water is crude oil, and that the province of Echigo (Niigata Prefecture) presented these to the imperial court. Meanwhile Marco Polo, who had seen the heavy use of coal in China, observed crude petroleum in the region corresponding to the present Baku oil fields.

"The country is bounded on the south by a kingdom called Mosul, the people of which are Jacobite and Nestorian Christians, of whom I shall have more to tell you presently. On the north it is bounded by the Land of Georgians of whom also I shall speak. On the confines toward Georgiania there is a fountain from which oil springs in greater abundance, insomuch that a hundred shiploads might be taken from it at one time. This oil is not good to use with food, but 'tis good to burn, and is also used to anoint camels that have the mange. People come from vast distances to fetch it, for in all countries round about they have no other oil."[7]

As we can see from this general survey, the use of coal and crude petroleum has a history that can be traced quite far back, but their use was probably limited to the places where they were found and their immediate peripheries, and they were used principally in place of firewood as a way of obtaining heat. Crude oil, however, was also used as a medicine. While coal was regarded highly for its high thermal yield, people were also aware that it polluted the atmosphere, and efforts were made to restrict its use. If the use of coal and oil had been kept within these bounds, their use would not have resulted in global-scale environmental destruction. It was when these underground energy sources were used not just to produce heat, but when their heat was converted to motive power through certain technologies, that they constituted the cause for environmental destruction. Let us continue by examining this matter.

II. *The Expanded Self-Reproduction of Coal via the Steam Engine*

Since the time of ancient Greek civilization people have known that it is convenient

[5] Genesis 6:14.
[6] Quoted from Aston (1972), Vol. 2, p. 289.
[7] Yule (1875), Book I, p. 428.

to use water as a medium in converting heat to work or motive force. About the first century A.D. Heron (?–?), who was active in Alexandria, Egypt, linked the production of steam by heating water to a certain type of work: He used steam as the controlling mechanism when "automatically" opening and closing the doors of an altar used for religious purposes.[8] Additionally, in Italy and other countries during the Middle Ages much research was apparently conducted on devices that converted heat to work by way of water.

But we must turn to seventeenth century France and Great Britain for practical work applications. Since the French aristocracy liked to put fountains in the ponds of their gardens, French engineers noted that if one produces steam by heating water and then allows it to cool and condense back to liquid form, a pressure differential will arise between the inside and outside of a closed space, and they devised mechanisms that used this principle to raise water from low to high places. This was a fountain that combined the pump and siphon phenomena. In contemporary Britain as well there was increasing interest in steam-powered pumps, although there was not necessarily a clearly defined purpose.

Incidentally, in England and Wales at that time there was growing demand for the coal that lay buried in huge reserves there. The oldest presently known production of burned bricks was about 2000 B.C. in Mesopotamia, but in certain areas of Europe in the thirteenth and fourteenth centuries brick architecture began to spread, and it started in England around the fifteenth century, having come via the Netherlands. Bricks were baked not only with wood, but with coal as well, and the demand of coal grew, although this was not the only reason. This made for an entirely new set of circumstances in which the former prohibition against coal use disappeared. Until that time people could not burn coal indoors because of the soot and smoke, but the creation of brick fireplaces privoded good ventilation, making the indoor use of coal possible. So we see that coal-fired bricks were used to build fireplaces, which in turn made it possible to burn coal indoors, and this multiplication effect helped to make coal heavily used.

In this way an increasing amount of coal was mined, which meant that coal mine shafts around the country grew deeper day by day, and this resulted in more groundwater in the shafts. Although a small amount of groundwater could be drained by human or animal power, the amount increased until it exceeded this threshold, and the coal industry, which had been in its ascendency, started showing signs of decline.

At this time there appeared a number of engineers who looked for possible ways to drain coal mines other than by using human, animal, water, or wind power, and their efforts came to focus on the use of steam to raise water. It was Thomas Savery (c. 1650–1715) who had the most trailblazing idea of all. While low-grade coal waste was ordinarily burned near the shaft openings of coal mines because of its loose structure, for which it was considered to have almost no value, Savery developed a well-articulated design in which this coal would be used to produce steam by burning it under a vessel of water (a boiler); the power for mine drainage would be obtained through the steam condensation process, and by means of this he would build a machine making it possible to mine high-quality coal. In 1698 he took out a patent on this kind of machine and produced a working model, but he never practicalized it. This was because it was structured so that not only did the hot steam come into contact with the cold vessel, but the cooling wate ralso did, there-by making

[8] For a detailed account, see Takada (1990).

the device's heat loss too great. In contrast to this design, a French engineer who exiled to England, Denis Papin (1647-c. 1712), in 1699 proposed a piston that separated the steam and water, but he was unable to actually make such a device.

It was Thomas Newcomen (1663–1727) who overcame the limitations that had stymied Savery and Papin by making the boiler for generating steam, the piston/cylindes system, and the pump into three completely discrete units. He brought the steam to the cylinder via a pipe, and to cool the steam he injected water from a separate sump into the cylinder. His first practical unit was built at Dudley Castle in Staffordshire in 1712.

However, since Savery had already obtained a patent on a thermal-powered machine to raise water, Newcomen could not take it upon himself to sell the above-described engine. He therefore initiated procedures to join with Savery and set up a joint company. His engine was a large structure resembling a tower. Apparently the materials were copper for the boiler and brass for the cylinder, and while the machine used a great deal of wood, there was not much iron in it. The engine worked successfully and became acclaimed throughout all of Great Britain. Such machines were installed at coal mines and other mines all around the land and were useful in draining groundwater. In time it became common at mines throughout continental Europe.

Incidentally, the magnitude of work obtained in relation to the amount of heat consumed is called thermal efficiency, and the efficiency of the Newcomen engine was incredibly low by today's standards: even less than 1 percent. One cause of this low efficiency was that the water injected into the cylinder cooled it, making for a large heat loss just as before. It was the son of a Scottish ship carpenter, James Watt (1736–1819), a manufacturing engineer for precision machinery, who rectified this problem. Watt, who had obtained a laboratory at Glasgow University, was interested in the small Newcomen engine that the university had for educational purposes. The engine was apparently defective, and had never even once worked correctly. In trying to repair it, Watt noticed the aforementioned heat loss, and hit upon the idea of locating the cooling process for steam condensation outside the cylinder. In 1769 he developed a separate condensing unit (steam condenser), which made the thermal efficiency four times greater than formerly.[9] Then in 1781 he developed a mechanism that converted the piston's reciprocating motion to rotational motion, which changed the machine from one that formerly could be used only for pumping up water to an engine for general application.

On the basis of this work England's Richard Trevithic (1771–1833) and George Stephenson (1781–1848) practicalized the steam locomotive, while America's Robert Fulton (1765–1815) practicalized the steamship. As a result, burning a small amount of coal to power a steam engine made it possible to mine large amounts and transport the coal to distant places. In other words, coal had begun its expanded self-reproduction, which became the driving force for the industrial revolution.

[9] Conceptual framework of the heat efficiency improvement is given, for example in Cardwell (1971).

III. *From Steel Production with Coke to the Coal Gas Internal Combustion Engine*

While coal had been formerly conceived only as a source of heat, it acquired a new significance as a motive force through the technology of the steam engine. But what about crude oil, which had likewise been long used as a source of heat in a number of places throughout the world? I would like to consider this matter next, but we first turn our attention to the technology of iron manufacture, in what may seem to be a digression.

The iron-making industry consumed huge amounts of charcoal as a reductant. Additionally, the reduction of iron ore required high temperatures, but to achieve these temperatures it was not enough to just burn charcoal: only by supplying the fire with a strong air flow was it possible to obtain high-quality iron. For this purpose waterwheel-powered rotary blowers spread throughout the European countries beginning in about the fifteenth century. Meanwhile, there were attempts especially in England to use coal as a reductant instead of charcoal, whose overuse would result in deforestation, and in the 1660s Dud Dudley (1599–1684) succeeded in this by determining that it would be possible to make iron sufficiently good for practical application by using coke whose impurities—which weaken iron—had been removed by dry distillation.[10]

However, Dudley's coke-made iron, which was a watershed in the history of iron manufacture, was short-lived because no one directly carried on with Dudley's work. The reason for this is thought to be that although the trend toward deforestation in England was already evident, it was not yet a definitively serious problem in the mid-seventeenth century. Moreover, the early dry distillation technology did not yield such high-quality coke, and thus no doubt good-quality iron could still be obtained only by using charcoal. It was Abraham Darby I (1677–1717) who around 1709 first began the full-fledged manufacture of iron with coke. His son Abraham Darby II carried on with this work, and other entrepreneurs also began entering this field, for which reason the amount of coke-produced coal in England quickly approached that of charcol-produced iron. Since people were aware that supplying oxygen with the rotary blower was more effective than with the formerly used bellows, they were going the roundabout way of using water pumped up with the Newcomen engine to turn a waterwheel; in time Watt's rotary steam engine came upon the scene, which made coal essential to the iron-making industry.

With the flourishing of coke production owing to the rise of coke-produced iron, there was an increasing amount of coal gas, a by-product, but the Scotch engineer William Murdock (1754–1839) succeeded in using coal gas as a fuel for street lamps around 1800, and German engineers developed gas lamps that could be used indoors as well, such as in homes and factories. While the steam engine was a kind of external combustion engine that burned its fuel outside the cylinder, the invention of the internal combustion engine, which burns its fuel inside the cylinder, came about as part of the process in which coal gas lamps spread the use of coal gas throughout Europe. It was in 1794, even before Murdock made his gas lamp successful, that England's Robert Street acquired a patent on a device that

[10] For a detailed account, see Jevons (1865).

burned a vaporous mixture of air and fuel inside a cylinder to obtain motive force. This was first practicalized by Samuel Brown, who in 1823 acquired a patent on a gas engine that was used for such things as opening and closing canal lock gates.[11]

Still, it was not until the mid-nineteenth century in continental Europe that the coal gas engine was put to real practical use. To begin with, the French mechanic Jean J.E. Lenoir (1822–1900) built, in Paris in 1860, a two-cycle, compressionless, electrically ignited engine. Since this engine ran smoothly despite its low thermal efficiency of 3 or 4 percent, it became quite common as a source of motive power in small factories. In Germany Nikolaus A. Otto (1832–1891) and Eugen Langen (1833–1895) achieved a thermal efficiency of 7 or 8 percent with a free piston engine in 1867. Otto's 1876 four-cycle engine achieved an efficiency of 14 percent and became the prototype for today's internal combustion engine.

IV. *The Road to Petrochemical Agriculture*

As the heat efficiency of the steam engine was being significantly improved, Thomas Robert Malthus (1766–1834) published the monumental work; *An Essay on the Principles of Population* in London. Beforehand, Adam Smith (1723–90) had described a happy world of landowners, capitalists, and workers together building a harmonious market economy based on the division of labor [see Smith (1776)]. In contrast to this, Malthus (1798) pictured a gloomy world in which the arithmetic increase in food production fell behind the geometric (exponential) increase in human population. Such a situation would, unlike Smith's view, reduce the per capita food supply down, cut the real wages of workers accordingly, and throw the economy into turmoil.

Europe's population had been generally stagnant throughout the Middle Ages. If it had started to incraese, it was suppressed by repeatedly spreading epidemics. Shortly before the industrial revolution, however, it actually started to increase. The Malthusian fear, then, appeared to be real. But the history of the nineteenth century Europe did not go along the rail of which Malthus had been afraid. One of the crucial reasons of this was the rise of agricultural productivity owing to the use of *guano* (birds' dung). To see this better, we have to undersatnd the ecology of Peru in the southern hemisphere.

Nutrients, organic as well as inorganic, flow down from the uplands, through the lowlands, and finally to deep ocean. If they accumulate in an ocean bed, the material cycle on the earth stop there. But the history tells us that there are some mechanisms which maintain the material cycle. In the case of the Peruvian coast, it works in the following way. The Peru Current is a cold ocean current, caused by the west-wind drift of the South Pacific Ocean. It travels northward from the Antarctic Sea towards the equator along the western coast of South American Continent. This current, alternatively called the Humboldt Current after Alexander von Humboldt (1769–1859) who first measured its temperatures, has two subcurrents: the Peru Oceanic Current and Peru Coastal Current. The former is cold, deep blue in color and poor in biological activities. The latter, colder than it, is green-blue and extraordinarily rich in planktons and other microbes.

[11] See Tomizuka (1978).

This coastal current is described by *Encyclopedia Americana* thus: "The cold flow is intensified by constant south-east trade winds and the Earth's rotation. Upwelling brings abundant nutrients close to the sun, allowing rich plankton growth. This growth makes the waters off Peru, Chile, and Equador one of the world's greatest fish grounds for anchovies and larger fish (tuna) that feed upon them." Such a vast number of fish in turn provide food for innumerable marine birds living on small islands and peninsulas off the Peruvian coast. Their excreta accumulate little by little in those areas. If the weather were rainy, such excreta would have been washed down into the ocean. But it is very dry on the coast in question. The progression of upwelling, plankton growth, fish, birds and dry weather produced *guano*, a natural fertilizer extremley rich in nitrogen and phosphate contents. It had been utilized in small amounts by local people since the pre-Inca period.

The European people had been almost unacquainted with this until Humboldt brought its sample back to Europe in 1804. An intensive chemical analysis was couducted. It was discovered that one ton of *guano* was equivalent to 30 tons of ordinary manure in terms of effectiveness as a fertilizer. Accordingly, its demand sharply rose and it became the main item of export for Peru. Jean-Baptiste Boussingault (1802–87), a French agricultural chemist, was one of those who were interested in this miraculous substance. He extensively studied the wide range of vegetable-fertilizer realtionships and demonstrated the exceptionally rich contents of *guano*.

For him and others, it was recognized as a renewable resources. But he realized the time element involved in the process of *guano* formation. He then wrote:

> " . . . . . . from the calculations of M. de Humboldt, the excrements of these birds in the course of three centuries, would not form a layer of guano of more than one third of an inch in thickness;—imagination stops short, startled, in presence of the vast lapse of time which must have been necessary to accumulate such beds of the substance as now exist, as lately existed in many places; for it is rapidly disappearing since it has become a subject of the commercial enterprise of mankind."[12]

According to Martinez-Aliez (1991), Peru exported 20 million tons of the substance mainly to Europe and partly to North America during the four decades from 1840 to 1880. In the history of Peru, this time period is called "the guano era." Its major importer was Great Britain. This saved the people there from the Malthusian nightmare, and in turn forced its quick exhaustion in Peru only with small funds for railway construction being left. In the meantime, the expanding trade of Chili nitrate reduced the relative weight of Peruvian *guano* to negligible proportions.

What we witness from this course of history is that the massive use of Peruvian *guano* and Chili nitrate fundamentally changed the pattern of European agriculture in such a way that it became depending on resources other than those of its farmland and surroundung forests, instead of depending on its own material cycle. This paved way for the worldwide petrochemical agriculture in the twentieth century. Artificial synthesis of ammonia has been a dream of European chemists since the eighteenth cent uryw ith a whole series of failures. But the breakthrough came with the work of the German chemist Fritz Haber (1868–1934) who, in 1907, invented a process of ammonia formation from hydrogen and nitrogen under high tem-

[12] Quoted from Boussingault (1845?), p. 290.

perature and high pressure. C. Bosch (1874–1940) joined him, and they succeeded in the industrial production of ammonia in 1913.

V. *The Expanded Self-Reproduction of Petroleum, and Environmental Destruction*

Looking back at the nineteenth-century Europe and the United States again, people were working on the extraction of kerosene from crude oil, and the use of kerosene as a substitute for whale oil in lamps, which brought about an increasing demand for crude oil. In response, a former American train conductor, Laurentine Drake (1819–1881), instead of just collecting crude oil that had seeped up to the surface naturally, succeeded in an attempt to bring oil up from underground.

There was a problem, however, in that producing kerosene from crude oil yielded the volatile by-product of gasoline, which could be easily ignited if there were a spark nearby. The contemporary situation was such that while people wanted kerosene, gasoline was troublesome. But in what would prove to solve this problem, Germany's Gottlieb Daimler (1834–1900) developed a four-cycle gasoline-powered internal combustion engine in 1883. This engine was a milestone for its realization of high speed, small size, and light weight; together with the gasoline-powered internal combustion engine developed soon afterwards by Karl F. Benz (1844–1929), such engines started becoming commonplace with a broad range of uses, which included powering automobiles. In addition to this Rudolf Diesel (1858–1913) successfully developed in 1897 a compression ignition engine that ran on heavy oil. This was later restructured into an engine that ran on more easily ignitible light oil, and began to find very widespread use. Meanwhile, in 1903 America's Wright brothers succeeded in building an airplane with a gasoline-powered engine.

It was in this way that the internal combustion engine, which was initially designed to burn coal gas, underwent a major transformation at the close of the nineteenth century, becoming an engine that could run on a variety of petroleum products. Thus, the realization of petroleum's expanded self-reproduction through the union of petroleum and the internal combistion engine made the twentieth century into an era that augments the union of coal and the steam engine since Savery and Newcomen. During the nineteenth century the world consumption of coal dwarfed that of oil, but since the advent of the twentieth century oil consumption has increased dramatically, with the combined consumption of oil and natural gas surpassing coal consumption in the early 1960s. A consideration of oil as a raw material instead of as a fuel shows that petrochemistry, which is founded upon coal chemistry, has created a large number of organic synthetic substances which, although durable, are not very amenable to the biodegrading action of the soil. The latter half of the twentieth century is the era of the plastic civilization as well as that of the automobile civilization.

One problem with this mass consumption of fossil fuels is that it increases the concentration of atmospheric carbon dioxide, and brings on global warning. It was the Swedish chemist August Ahrrenius (1859–1927) who in 1896 first quantitatively argued that carbon dioxide is related to atmospheric warming, but there were not very many people then who seriously considered this as a problem of global warming. It was not until the 1970s that this became a worldwide topic of discussion.

We also know that not only carbon dioxide, but also CFCs, methane, nitrous oxide, and other trace gases contribute to global warming. By contrast, there might also be some significance in recalling that until the 1960s some meteorologists were issuing warnings of global cooling. If we are now in the midst of a cooling trend, which is linked to the ice age cycle that in turn has no direct human causes, then since that will to some degree counteract the greenhouse effect, one might hold the view taht global warming does not present so great a worry. With respect to this matter one would like to hear the opinions of the experts who once saw cooling as problematic.

Still, the unrestrained use of coal and oil to the extent that we substantially increase the concentration of atmospheric carbon dioxide causes other kinds of environmental disruption that are more direct than global warming. First of all, coal and oil contain impusities such as sulfur; second, they produce oxides of atmospheric nitrogen when burned. For these reasons they produce huge quantities of SOx and NOx, and bring forth damage such as acid rain. During recent years in Japan quite acidic rain with a pH of about 4.5 has been frequently, and even rain with a pH of 2.9 or so is not a rarity. There is no guarantee that a mass forest die-off will not happen if such a situation should continue, and there is also concern about the adverse effects that will ensure over the long term when rain acidity is added to Japan's farmland, much of which is acidic to begin with.

Next we see that the organic chemical industry, whose foundation is petroleum products, has created many kinds of poisonous chlorine-based chemical compounds. Some representative examples of these are PCBs, dioxin, and trichloroethylene. Some of these chemical poisons seem present in only tiny quantities when spread out thinly in a certain area, but via the ecosystem's food chain become concentrated in the bodies of certain organisms. And even if such poisons are not of a concentration sufficient to kill directly, they may sometimes work in a way that causes the loss of immunity against certain communicable disease organisms, thereby engendering the serial deaths of many living things. It is said that the mass deaths of Arctic Ocean seals and Mediterranean dolphins in the latter half of the 1980s may in part have been caused by such indirect effects.

The petroleum civilization has also given birth to nuclear weapons and nuclear power stations as an outgrowth of the Manhattan Project [see Patterson (1976)], and the radioactive contamination that accompanied their development is now very extensive. The nuclear test sites in the United States, the areas surrounding the Semipalatinsk nuclear test site in the former Soviet union, and the islands of the south Pacific are still contaminated. The many accidents at the British reprocessing plant at Sellafield (formerly Windscale) have released vast amounts of plutonium 239 into the environment, which has contaminated the Irish Sea and spread to a large part of the North Sea. This plutonium contamination has even reached Greenland. The 1986 explosion of the nuclear fuel itself in the unit 4 reactor at Chernobyl in the former Soviet Union seriously contaminated the northwest portion of the Ukraineian Republic, the southern belt of the Byelorussian Republic, and the southwestern portion of the Russian Republic, and even now—six years after the accident—as many as 4 million people must continue willynilly to live in hazardous areas.

Some people are of the opinion that since nuclear power plants do not emit carbon dioxide they contribute to the betterment of the gloval enbironment, but here we must take frank notice of the fact that the very process of manufacturing nuclear fuel from uranium ore is predicated upon the consumption of petroleum and coal products. Japan depends almost entirely upon the United States for uranium enrichment, but the United States' enrichment plant is electricity-intensive in the extreme, and since this electric power comes from a coalfired generating plant dedicated to the uranium enrichment plant, it is ridiculous tospeak of environmental betterment.

Much has already been said about the ozone layer depletion by CFCs and halons, as well as the resulting increase in harmful ultraviolet radiation, so there is no need to discuss this again here. For details, one can refer to Roan (1990). There is just one thing, however, to which I want to call attention: Despite the fact that many countries have signed the Montreal Protocol, by virtue of which CFC production is being phased out, only about 10 percent of the CFCs already released into the atmosphere have reached the ozone layer, while the remaining 90 percent are now on the way up. We should therefore note taht the hazardous ultraviolet radition now reaching the earth's surface is just the beginning, with the worst yet to come.

VI. *Tropical Rainforest Destruction and Japan's Economic Power*

The diminishing forests in the tropics on the one hand, and the desertification of semiarid regions on the other, are critical elements making up global environmental problems. In considering this matter with reference to the relationship with Japan we must look at the economic mechanism operating between Japan and other countries.

Since Japan is an insular country it can use as much sea water as it wants for industrial cooling purposes as long as low quality is sufficient. And because Japan has a history as a country of forests and paddy agriculture, it is possible to obtain large amounts of fresh water from the surface or from groundwater not far beneath the surface for good-quality coolant and cleaning water. The use of cheap crude oil from the Near and Middle East countries under the conditions presented by this bonanza of water for coolant and cleaning has made it possible for postwar Japan to achieve rapid economic growth. Japan's industrialization and urbanization happened under the availability of cheap water and crude oil. The result was that Japan mass produced internationally competitive steel, automobiles, consumer electronics, semiconductors, and other products, exported them, and became a so-called economic power. The *yen* also appreciated greatly in conjunction with this.

However, bigger incomes meant that wage levels, commodity prices levels, and the like also climbed considerably, and the products of the farming and forestry industries, which work by a logic differing from that of the manufacturing industry, had to reflect the high income level by becoming relatively higher. This resulted in not only a rapid increase in imports of relatively cheap grains, but also those of forestry products. Japan's rate of lumber self-sufficiency at the end of the 1980s finally under went 30 percent. Notwithstanding Japan's 65 percent forest cover, which is quite uncommon in the world, the amount of imported wood used here is greater than that of domestically produced wood, and a fair amount of the imported wood is tropical.

This is not a simple matter of Japan's trading companies working through others to recklessly clearcut tropical forests throughout Southeast Asia, and it is likewise not a matter of the locals' traditional slash-and-burn agriculture devastating tropical forests. In many instances logging operations were not clearcuts, but selective logging done according to the loggers' own methods, but in order to log selectively they availed themselves of the petroleum civilization's capabilities to build logging roads. Such roads having appeared, some of the locals took the roads into the forest's interior and there carried on slash-and-burn agriculture, which they ordinarily would not have done so far into the mountains. The combination of these factors resulted in the same situation that would have occurred has vast areas been clearcut. Moreover, the Japanese had given no thought to how they would regenerate the forests on such land. Although governments were probably aware of the situation, they could not take the step of banning exports because exporting lumber to Japan meant they could earn foreign currency, and they put their countries' economic development first.

These circumstances continued, and in time an apparent crisis—the forests' inability to regenerate—visited large tracts of Southeast Asia's rainforests, which may be described as a great trove of the earth's life forms. It wasn't that the Japanese had used physical violence in an ongoing plunder of the forests, but that the economic might of the forested country, Japan—supported by plentiful domestic water supplies and cheap imported crude oil—had, under the modern system of world trade, impoverished the tropical forests of the Southeast Asian countries, which were in a relatively weak position.

I do not have space here to discuss the depletion of tropical forests in Brazil's Amazon River basin. One will be able to understand the basics of the problem by refering to Caufield (1986). This is the time to reevaluate the tradition of regenerative forestry in the pre-modern Japan as is described in detail in Totman (1989).

Conclusion

In addition to substantial reductions in the use of underground resources such as coal and petroleum, it will be essential to invigorate the water and carbon cycles for a fundamental solution of global environmental problems. It would be impossible, however, to cut coal and oil consumption to zero beginning tomorrow, which means that thoroughgoing energy conservation is important. For this purpose we find that cogeneration technology (combined heat and power—CHP) is already established, and depending on how we go about using this technology it will be possible to make considerable reductions over the duplicate expenditure of fossil fuels seen in conventional energy supply systems, which supply electric power and heat separately. While the discovery and improvement of the steam engine and the internal combustion engine contributed to expanding the consumption of energy sources at an accelerated pace, we must now create institutions (in Japan, for example, this would include revisions of the Electric Utility Industry Act, the Gas Utility Industry Act and the Heat Supply Industry Act) that lead in the direction of reducing consumption. Promotion of the use of renewable energy sources is also important. In this regard, one can learn much from many aspects of electricity privatisation in Great Britain as seen in Roberts (1990) and Elliott (1992). It will also be necessary to work, on changing Japan's system for transportation and shipping, which now gives precedence to motor vehicles, to one based on bicycles, railways, and water transport.

The only possible way to deal with the problems of chemical and radioactive poisons is to stop their production. Society will have to come up with ways to return poisons already manufactured and on the market to their producers.

Japan can perhaps redirect its economic capabilities toward the recovery of the tropical and other forests. Although tropical ecosystems are fragile, going about the effort in the right way would make forest regeneration possible. And in Japan, where temperate forests predominate, it is important to foster a perspective that sees forests as a renewable energy source as is asserted in Murota (1985). While using wood (and its derivatives) as fuel, Japan should plant forests that include broad-leafed trees.

HITOTSUBASHI UNIVERSITY

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