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Energy and Minerals Galore, but Bugs with Everything

ENERGY WAS DRIVEN into glut by the very event which some people wrongly thought heralded a permanent energy shortage. There are several hundred possible ways of releasing energy from storage in matter. The most transportable in the second half of the twentieth century was the burning of the mineral slime called oil, and in the 1950s and 1960s this product was priced too cheaply. If oil gushed from your farm in Texas in 1955 you became a millionaire, but if it gushed from an Arabian desert the Arabs got far less than the Texans for it. This was partly because feudal Arab leaders were not especially keen on their people's simple life being made less feudal by too much money, and the fate which overtook the Shah of Iran once his people became richer suggests the leaders were possibly right.

The main consequence in the West of the underpricing of oil in the 1960s was that oil was wastefully used. Instead of just being burned in vehicles (for which it was the most economic fuel), oil was also consumed in electrical power stations (for which it was not), and in ridiculously fertilizer-intensive methods of agriculture. Non-insulated houses and unnecessarily heavy automobiles guzzled up this cheap fuel.

One afternoon during a late 1973 war against Western-supported Israel, the Arabs decided to punish the West by quintupling the asking price for their oil. Oil thus went instantly from being too cheap by more than half to being too expensive by nearly twice. The West reacted foolishly to this—initially by trying to keep the price to their own consumers down. The period of so-called "oil shortage" coincided with this foolishness. Once the higher price was fed through, demand proved elastic. In 1973–83 Japan cut its use of oil per unit of gross national product by 45 per cent; and other countries before 1973 had been using oil much more wastefully than Japan. In the United States the switch to capital-intensive nuclear power was delayed in 1975–85 by high eco-nuttery and high interest rates; but after 1985 both came down. Machines were miniaturized, methods of production made less energy-intensive, agricultural systems changed.

In the United States in the early 1980s nitrogen for use in fertilizers that supported grain production was costing America the energy-equivalent of 100 million barrels of oil a year. These fertilizers were not needed for plants such as lentils and soya beans which could fix their own nitrogen. If the genes controlling nitrogen fixation could be transplanted into cereal crops like wheat and rice, there would be huge savings in energy. This genetic engineering problem was complicated by the fact that nitrogen fixation is not carried out by leguminous plants themselves, but by Rhizobium bacteria to which they act as hosts. Rhizobia could not infect cereal crops because certain supporting systems which allowed the bacteria to live in the roots of legumes were missing from the roots of cereals. The problem was therefore not just to transplant the genes for nitrogen fixation from rhizobia to bacteria which routinely lived in the roots of cereal plants—though even this would have been difficult, as seventeen genes seem to be required to sustain the whole nitrogen-fixing biochemical system. The problem was to make cereals and rhizobia friends with each other.

After the early 1990s, with the aid of techniques giving high rates of cell transformation in living tissue, genetic engineers managed to manufacture strains of wheat whose root cells were hospitable to rhizobia and which were capable of exploiting the nitrogenous compounds the bacteria produced. The cereal plants which had been transformed into hosts for rhizobia had to divert some of their own productive capacity to feeding their new parasites and fuelling the reactions which produced the built-in fertilizer. Fields planted with the new strains thus produced less actual grain than fields planted with traditional strains and provided with artificial fertilizer. But, although less wheat was produced per hectare, it was produced substantially more cheaply. The U.S. wheat surplus began to decline as the new crops came into extensive use, but what was produced was produced more economically.

The oil companies also started to use genetic engineering to get oil. They turned to "microbial mining"; the use of microorganisms as agents to recover the energy of the petroleum locked up in oil shales and tar sands. There were several ways in which bacteria could be used in this exercise, either by producing substances that helped release the oil from its matrix (wetting agents or emulsifiers) or by taking the hydrocarbons into themselves. The latter proved immensely successful, and spread to the mining of many other minerals. Microbial mining therefore helped to banish the false fears of the 1970s that the world might also use up all its reserves of twenty or thirty other minerals and metals.

These fears had been pretty odd, because most of the metals concerned were not actually being used up at all. They were hammered into the shape of a motor car, and then re-used as scrap when the motor car wore out. The real minerals problem which existed until 2006 was political. If a company drilled a mine in some poor country and it was unprofitable, the company picked up the bill. If it dug a mine in a poor country and it was very profitable, the government of the poor country introduced retrospective taxation to steal the profit away. Companies were therefore emigrating to mine even in the Arctic in order to escape the demands of governments in the lush tropical parts of the earth. After 2006 the Centrobank system discriminated against the governments of poor countries which operated in this way. That alone might have returned many metals to glut. But, simultaneously, biotechnological advance made it possible to explore areas where minerals (including oil) had hitherto been difficult to dig out of the ground. Scientists called this "utilizing the fact that various naturally occurring organisms selectively take up particular elements from their environment." Ordinary folk called it "let the bugs do the mining. They won't belong to the National Union of Mineworkers."

Down the centuries the power of selective take-up by lower organisms had been exploited in a desultory way. Some seaweeds take up iodine from seawater and gradually build up such a concentration that it becomes easy to reclaim the iodine from the weed. Bacteria were known well before 1980 which took up cobalt, copper, zinc and many other metals from low-grade ores, and such micro-organisms were used as intermediaries in the processing of such ores. It was easier to let the microbes extract the metal from the ore and then to extract the metal from the microbes than it was to use chemical processes to extract the metals directly. Of particular commercial importance before 1980 was the microbial leaching of uranium ores.

So long as naturally occurring organisms had to be used, the potential of this kind of biological mining was limited. When it became possible to adapt bacteria more specifically for the jobs which had to be done, the business really took off across the world.

The micro-organisms developed by commercial genetic engineers for extracting metals from natural ores were also useful in reclaiming metals from corroded scrap. One of the main problems associated with the technological use of metals is their tendency to oxidize. Until the 1990s it had often been more energy-expensive to recover metals from their oxides—iron from rust, for instance—than from the common ores in which they naturally occur. Biotechnology changed that situation abruptly. The recycling of metals became a much more efficient business.

By the year 2010 the exploitation of oil shales and tar sands using "leach liquor" techniques was well under way. This involved facilitating a flow of liquid through the shale or sand (usually *in situ,* although material was occasionally extracted and transported to leaching quarries). The liquid supplied was a warmed-over "soup" of bacteria capable of feeding on the hydrocarbons in the shale or sand. Initially, this became a substrate allowing the bacteria to multiply; but, more recently, we have seen the development of bacterial species which store much of the materials in oil-vacuoles. Either way, the soup is processed as it is pumped out again, first to extract the enriched bacterial material and then to convert the biomass into useful liquid and solid fuels.

Exploitation of previously uneconomic coal reserves can be carried out in much the same way, but at present this is usually confined to the processing of slag, for reasons which have more to do with pollution control than energy supply. The main impact of biotechnology on the coal industry has been in the purification of easily accessible coal which was once difficult to use because the sulphur it contains is realized in toxic gases when it is burned. Sulphur-loving bacteria, developed by the enhancement of naturally-occurring species, are now used to purify coal and make it safe for burning. At one time environmentalists wailed that the addition of sulphur dioxide to the atmosphere (which ultimately returned to earth as sulphuric acid rain) was the single most dangerous health hazard created by the Industrial Revolution. The threat has now disappeared thanks to the ever-increasing use of biotechnology in sulphur control.

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The conquest of pollution has not been quite as complete as the conquest of the other scares. The most successful weapon in this battle has been the price and taxation system. If you pump sulphur dioxide into the air by burning dirty coal, you now, in most rich countries, pay the full price for the damage you inflict on the community by doing so; that gives you an incentive to clean the coal. The same happens if you release into the environment poison from heavy metals—particularly lead and mercury—which had hitherto been locked up in inert ores; and if you let loose organic wastes from the chemical industry.

Down to the 1980s most governments had not used tax systems against pollution, but had leapt erratically from full *laissez-faire* into lunatic bans. These bans blocked the roads to progress, and also spread misunderstanding of what pollution is. It means the release into the environment of compounds which are either toxic or nonbiodegradable or both. The resultant disruption of the ecosphere reflects the inability of local ecosystems to absorb and re-deploy the materials fed into it. Down to the 1980s the only way to tackle particular problems of this kind seemed to be to attempt to trap and isolate pollutants at source. When tax incentives were introduced, entrepreneurs found ingenious ways of trapping them, but they also soon found a better and broader method of pollution control. It has become increasingly convenient either to use biotechnological systems to inhibit production of the pollutant at source, or to use genetic engineering techniques to modify free-living species in such a way that they will mop up and render harmless various kinds of chemical effluents as they are released. Most potential pollutants can now be processed in this way, but that has bred the "second environmental scare."