The Impact of Energy Use in Industrialised Countries upon Global Population Health

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Energy use, particularly the burning of fossil fuel, is a well established cause of local environmental pollution. Increasingly, it is causing wider ecological disruptions. We explore the relationships between energy use, particularly in Western countries, and its impact upon the health of human populations. To achieve global ecological sustainability, the prevailing consumption patterns of rich industrialised nations will have to be modified. Such changes should improve environmental conditions and hence the sustainability of health. [M&GS 1994;1:23-32]

Energy from inanimate sources is the basic currency of industrialised economic activity. Whereas solar energy, ❧ captured mostly by photosynthesis, has powered biological life over aeons of evolution, human cultural evolution has depended upon increasing supplementation of energy from nonbiochemical sources. Hence, although economic development can be measured by such indices as per capita consumption of materials (iron, wood, fertilizers, etc.), emission of waste products, or expenditure on goods and services (i.e., per capita Gross National Product [GNP]), energy use is a central and readily quantified component of economic activity: it reflects the intensity of industrial, agricultural, and transport activity, and, in broad terms (and with some notable exceptions), it is an indicator of GNP.

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Total global commercial energy use by humans has increased by around 100-fold since the onset of the industrial revolution [1]. Without radical changes in the efficiency of energy conversion (i.e., production) and in the end-use of electricity, worldwide energy use will undergo a further twofold to fourfold increase by the year 2030 [2,3]. Since most of this inanimate source of energy comes from fossil fuel that is external to the world's short-term energy and carbon budgets, global patterns of energy generation may impair the sustainability of various of Earth's natural systems. By jeopardising the life-support functions of those systems, this, in turn, would have great relevance to population health.

There is a self-apparent general association between per capita energy use and material consumption, comfort, and convenience. However, the relationship between energy use and level of population health is, almost certainly, complex, and largely indirect -- and it is therefore unlikely to be linear.

Figure I shows the cross-sectional relationship of national per capita energy consumption to life expectancy at birth for 127 countries, as listed in the World Bank's World Development Report 1993 [4]. At low levels of national energy consumption (<500 kg oil equivalent [KOE] per year), life expectancy rises in association with energy consumption. There is a less marked increase in life expectancy in the region of 500 to 2,000 KOE, while for countries with higher energy consumption (>2,000 KOE) there appears to be no relation. To explore this relationship further, for those same countries we have compared changes in energy consumption between 1984 and 1991 with proportional changes in life expectancy over the same interval. There was no association apparent for countries in the medium (500 to 2,000 KOE) and high (>2,000 KOE) energy use categories. Among the low-energy use countries, there was a weak positive relation between absolute change in energy use and percent change in life expectancy ($r = 0.17$).

These simple analyses indicate that, within countries, the causal link between energy use per se and mortality is generally weak. The association may be indirect, and, further, any mediating time-lag is of unknown duration. Not only might the association vary with the predominant forms of energy usage within a country, but the proportional allocation of energy use to health-influencing activities may change over time. These characteristics could all contribute to the scatter of points in Figure 1.

Further, energy use may be unevenly shared within a country. In this regard, energy use would resemble other economic indices, such as GNP, which refer to aggregate economic activity but give no information on the distribution of benefits. Although there are no data to test the hypothesis that the health benefit obtained from a unit of energy use varies with the intrapopulation spread of energy use, other evidence suggests that the healthiest distribution of intrapopulation wealth is that with the least inequality. Within the Organization for Economic Cooperation and Development (OECD) those countries with the most equal distributions of incomes tend to have the highest life expectancies [5]. Moreover, longitudinal data show consistent correlations at a national level between reductions in relative

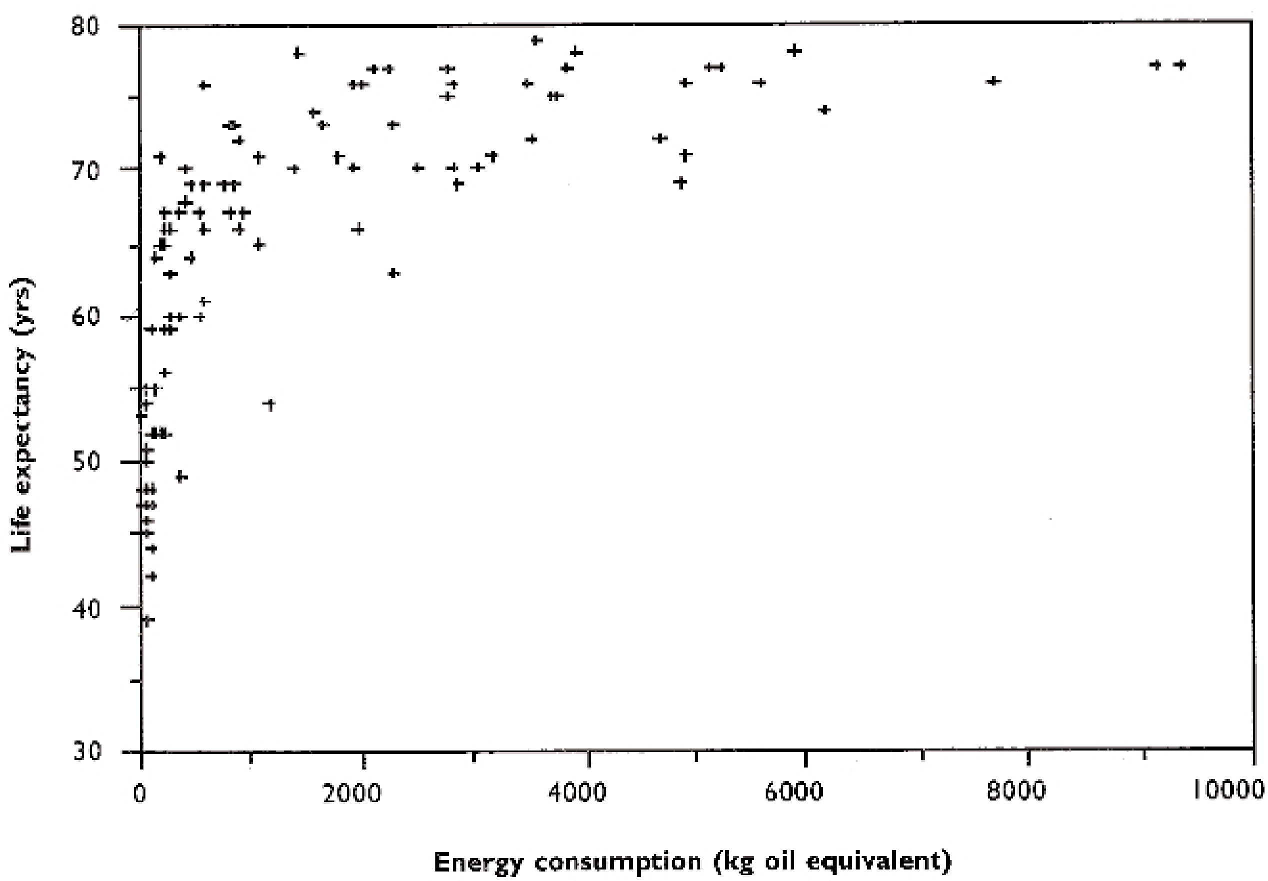

Figure I. National per capita energy consumption and life expectancy at birth, 1991 (Based on data from the World Bank [4]) poverty (i.e., the spread of incomes) and improvements in years of life expectancy.

Given these various complexities, it seems clear that there is no simple relationship between a country's level of energy consumption and its vital statistics. Indeed, as we will argue in this paper, the pattern of energy use in some parts of the world can, via several pathways, influence the health of populations elsewhere. Thus, it becomes important to use a supranational framework to examine the relationship of energy use to population health. A within-country analysis (such as has previously been attempted for Australia [6]) can only tell part of the story.

This paper, therefore, addresses the broader question: What, in qualitative terms, are the main types of consequences for population health of the world's current pattern of energy use? The analysis pays particular attention to the impact of energy use in rich countries upon the health of populations in poorer countries. The fact that increases in a country's energy consumption and in attendant material standards of living have, historically, been accompanied by substantial increases in life expectancy within that same country is not at issue here. Rather, the focus is on considering how that relationship may change in the future as global systems become overloaded, and on how health deficits may accrue to some populations as health benefits accrue to others.

The relevance of using a supranational framework can be illustrated by two examples. First, most of the accumulated anthropogenic greenhouse gases have come from the industrialised rich countries (the North), yet many of the anticipated adverse health consequences of climate change will affect vulnerable populations in the poor countries (the South). Second, if energy-conserving policies were introduced in the North -- such as a greater reliance on locally grown food to obviate food packaging, refrigeration, and long-distance transport -- these policies could impair both the economic well-being and the population health of food-exporting countries in the South.

The qualitatively distinctive characteristic of these international examples is, first, that adverse health impacts can occur in distant populations, and, second, that some of the anticipated impacts arise because worldwide levels of energy use are now, for the first time, pushing certain natural systems beyond their absorptive limits. Thus, consideration of the health impact of current patterns of energy use, particularly in the North, requires analysis in relation to the effects of the resultant localised environmental pollution, of the resultant regional or global ecological disruption, and -- more elusive -- of the underlying North-South economic relations.

North-South Differences in Energy Use, Living Standards, and Health

Currently, the rich countries (i.e., approximately one-fifth of the world's population) account for almost three-quarters of global energy use. Most of this energy comes from fossil fuel combustion, and in the rich countries about half of it is converted into electricity. The OECD countries consume 80 million barrels per day of oil equivalent (MBDOE) [2]. Eastern Europe and the former U.S.S.R. consume around 20 MBDOE. Each of those two total levels of consumption, after modest projected rises to 2010, is predicted to stabilise at current levels by 2020. Meanwhile, the consumption of commercial energy in developing countries is rising rapidly, and now accounts for almost one-third of the world total. Even on conservative estimates, the demand of developing countries for primary energy is likely to exceed 100 MBDOE by 2010 and perhaps 200 MBDOE by 2030 (Fig 2).

Developing countries are likely to be the major consumers of energy next century, predominantly because of their large, growing populations. In the 1980s, electricity generation rose by 60% in industrial countries and by over 110% in developing countries (equivalent to around 8% per year) [2]. Present indications are that many developing countries will strive not to moderate their energy use but rather to accelerate growth in this sector. For example, Indonesia plans to increase coal-powered electricity generation by a massive 15% per year over the next 10 years as it converts from an oil-exporting to an industrial-manufacturing economy. Neighbouring Malaysia plans a similar increase, to meet a surge in demand for power.

Comparison of national levels of standard of living, social well-being, and health is difficult, especially across the full, diverse range of countries. The GNP is conventionally used to compare the economic circum stances of countries; the average standard of living is thus assumed to reflect the per person production of goods and services. There are, however, well-recognised limitations of the GNP -- in particular, it does not include depreciation of natural-resource assets and the social and environmental costs of economic activity. These negative impacts are externalities, to which an ill-informed market assigns no exchange value. Hence, paradoxically, the Exxon-Valdez oil spill greatly boosted the Alaskan GNP because of the increased economic activity required to clean

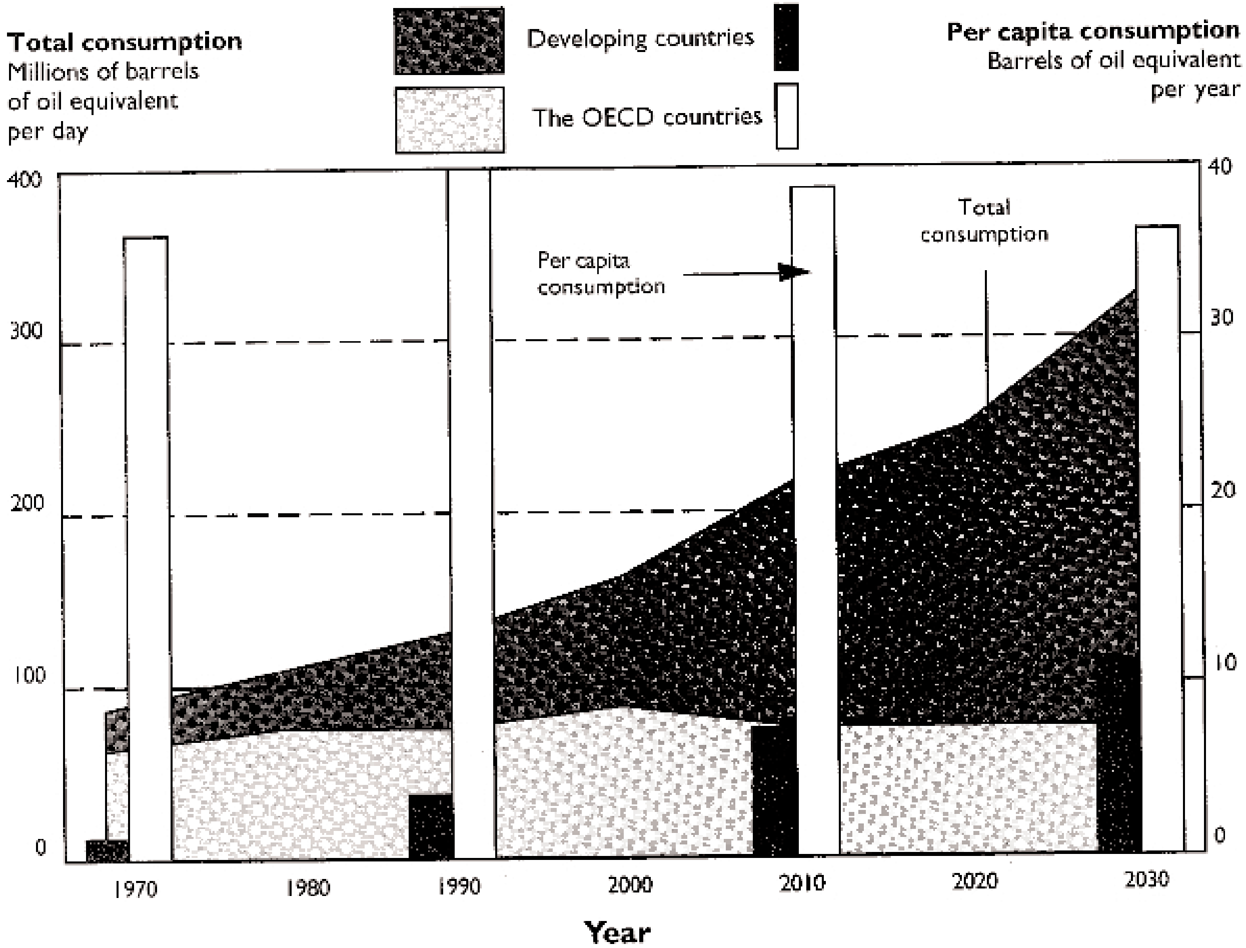

Figure 2. Energy consumption by country group 1970-2030 (energy efficient scenario). (Based on data from the World Bank [2])

up the fouled environment. Likewise, recent annual increases in the conventionally assessed monetary value of Indonesia's agricultural production would be almost halved if allowance were made for loss of forests and land degradation [7].

Increasingly, it is being recognized that GNP does not necessarily reflect human well-being [8,9]. The U.N.'s more recently formulated Human Development Index (HDI) encapsulates the chances that the citizens of a particular society have of achieving human development -- that is, a long life, a decent standard of living, and equal access to facilities such as education and health care [9]. Some societies with modest per capita income, such as Costa Rica and Jamaica, have actually achieved high HDI scores, while others, with high incomes and rapid economic growth, have failed to achieve commensurate levels of human development. Various oil-rich Gulf states, for example, score low because of their poor profiles of education (especially of females) and infant and child health. The U.S., near the top of the per capita GNP listing, is clearly lower on the HDI scale. Irrespective of the validity of the index, cross-sectional analyses of economic indices and population health cannot address impending global limits. Rather, they are framed in reference to prevailing theories of economic development, which posit that increases in national wealth (and in energy use) bring social development and, in turn, improved health. This assumes that economic growth can continue indefinitely and that each increment in production will bring commensurate material gains and improvements in health. However, this open system economic model is not applicable indefinitely to an essentially closed-system biosphere, since, at some level of aggregate consumption and waste generation, over loading of natural systems will occur.

The developed countries of the North are rich societies with much material welfare. As high-energy societies, they have a great dependency on electricity, mostly generated from nonrenewable sources (either fossil fuels or nuclear fission) and on petroleum-powered transport [1]. Their health status is generally high: infant mortality is low and life expectancy is long. Many countries of the South have widespread poverty, malnutrition, and high mortality from infectious diseases. This poor health status is aggravated by the consequences of rapid population growth and the often severe environmental problems of land degradation, exhaustion of natural resources, and uncontrolled local chemical pollution. Many of these countries are low-energy societies with small-scale economies whose main sources of inanimate energy are biofuels, especially wood [1,10]. In sub-Saharan Africa, around 80% of all energy used comes from fuelwood. In contrast to the rich North, the consequences of environmental damage caused by circumstances in the South are less often displaced to other places or to the longer-term future.

Approaches to Estimating Impacts on Global Population Health

All major changes in human culture and technology have caused changes in the profile of health and disease. Historically, environmental health problems have generally reflected the adverse effects of specific agents in the local environment. In early hunter-gatherer societies, vectorborne infections and physical injury were common environmental health hazards. After the advent of agriculture, local settled populations presented a new opportunity to microbes for person-to-person spread -- hence today's crowd infections (measles, influenza, etc.) [11]. The Industrial Revolution, with its new energy-intensive technologies, ushered in various serious local environmental health hazards. The period of wealth accumulation that followed in the North caused health profiles to alter further as diseases of affluence appeared -- especially heart disease, cancer, and diabetes -- reflecting lifestyles that deviate critically from formative evolutionary circumstances [1].

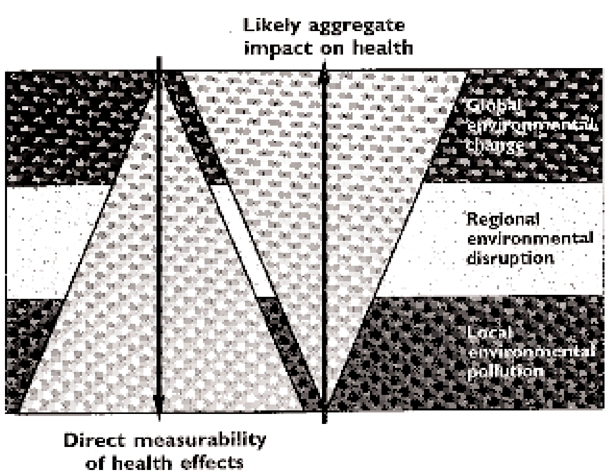

Figure 3. Reciprocity between the likely magnitude of levels of environmental health impact and their amenability to conventional scientific study.

Each biohistorical phase entailed an increase in population size and a rise in energy consumption. Today, per person energy consumption in the North is about 1,000 times higher than in the hunter-gatherer period [12]. Overall, today's human population uses about 1 million times more energy per day than it did at the dawn of agriculture. Today we are entering a new era in human history wherein both the earth's sources (e.g., supplies of soil, freshwater, fisheries, forests, genetic biodiversity, etc.) and sinks (e.g., atmospheric and oceanic absorption of carbon dioxide emissions) may become critically depleted [13]. The impairment of these essential life-support services would necessarily jeopardise human health in a more fundamental way than have the localised environmental risks for long encountered by human populations.

Health outcomes, however, are difficult to foresee with any certainty or quantitation. They encompass immediate and delayed effects, direct and indirect effects, and local and remote effects [14]. Fossil fuel combustion illustrates this complexity -- it includes direct effects of local air pollution, regional effects of acid rain, and global consequences of climate change [15]. Given this complexity and the potential scope of the phrase population health, we have not attempted to quantify the global impacts on health of energy use. Indeed, there is an inverse relationship between the ease with which health effects due to environmental disruption can be measured precisely (via conventional empirical research) and the likely overall relative magnitude of those health effects (Fig 3).

The impact of continued economic growth upon the world's environment and human well-being has been estimated by computer simulation models [13,15,16]. For example, Meadows and colleagues have developed the World3 model, to forecast future Earths in response to different combinations of five key variables: population, food, nonrenewable resources, industrial output and pollution [13]. That model predicts that, unless equilibrium policies are implemented, a crisis will eventually occur. (In fact, substantial reductions of energy use in the North could be made without affecting the material standard of living. In the assessment of Meadows and colleagues: "Western Europe and Japan, already the most energy-efficient economies of the world, could increase their efficiencies by factors of 2 to 4 with technologies already available or easily foreseeable within twenty years" [13].)

The World3 model can link economic, environmental, demographic, and other processes of the global level. However, it cannot analyze processes and outcomes at the regional level and cannot address regionally asynchronous events -- although a World4 model, with regional resolution, is now under development [16]. Nor does the World3 model encompass some important variables such as trading relation ships or social and cultural influences on health. Yet, as we argue in this paper, assessing the global health effect of energy usage in the North requires reference to a political and economic framework.

Health Effects of Energy Use

The harnessing of inanimate energy has enabled humans to extend control over the environment, thus facilitating food production, extending the hours of light, and enabling long-distance travel. However, some of the most serious ecological changes now occurring at regional and global levels are due to fossil fuel combustion, the chief source of inanimate energy in today's world [17]. This narrative encapsulates the central paradox of the energy debate: the comparison of past gains with impending hazards. Historically, the increase in humankind's ability to harness environmental energy sources, over many millennia, has conferred assorted advantages in survival and well-being. It has also potentiated population growth within each such energy-enriched environment. Today, however, the continued escalation of energy-use at a global level poses risks to human health via local environmental damage and by disruption of Earth's natural systems.

Of all commercial energy used in industrial countries, 85% comes from fossil fuels, 6% from hydropower, 5% from nuclear power and 4% from biomass and other minor sources; in developing countries, these figures are 58% fossil fuels, 6% hydropower, 1% nuclear energy, and 35% biomass [2]. The direct health effects of the three main energy generating technologies (nuclear, fossil fuel, and renewables), particularly the occupational health effects, have been widely studied by conventional epidemiological research [18,19,14].

The direct health risks associated with burning fossil fuels include the dangers of mining (especially injury, coal miners' pneumoconiosis, and lung cancer due to radon gas seeping into mines), and the small increases in cancer-incidence for workers in oil refineries and power plants. Coal mine disasters occur worldwide two to three times a year on aver age, killing hundreds of people. Severe accidents resulting from engineering failure occur around 104 times more frequently in coal mines than in nuclear plants [19].

The direct nonoccupational health effects of fossil fuel combustion are mostly due to air pollution that contributes to respiratory infections, bronchitis, asthma, and, perhaps, lung cancer. In its more extreme forms -- winter smog (sulphur dioxide and particulates) and summer smog (photochemical oxidants) -- this air pollution is a significant cause of increased mortality [2,15]. The Global Environmental Monitoring System (GEMS), operated jointly by WHO and other agencies within the U.N. system, covers many of the world's cities. From this database, WHO estimates that 625 million people are exposed to sulphur dioxide concentrations well above the safe level, while over a billion -- one-fifth of the world's population -- are exposed to unhealthy levels of particulate pollution [2,20]. Over half of the world's large cities, including overcrowded capitals in developing countries and many cities in the heavily industrialised parts of Eastern Europe, exceed the WHO standards for sulphur dioxide and for suspended particulates in air. These exposures pose risks to the respiratory health of the very old, the very young, people with asthma, and the chronically ill.

The main health risks to the general public from the nuclear power cycle arise from the transport of fuel and waste [19]. Occupationally, there are increased risks of lung cancer to uranium miners [21]. The possibility of catastrophic malfunction during operation of nuclear powerplants poses great potential risks for workers and the surrounding, even distant populations. Although most experts estimate (albeit less confidently following the Chernobyl disaster) that the probability of nuclear powerplant accident is low, it is widely conceded that the cumulative long-term health effects from the storage of nuclear waste-material from powerplants may be significant because of the large volumes of concentrated radioactive material involved.

The direct health effects associated with renewable energy sources occur mostly within the occupational setting. Accidents in the production and disposal of solar photovoltaic cells can release pollutants such as arsenic, cadmium, and silicon that may cause cancer in humans [19]. Hydroelectric dams flood land, nurture the aquatic vectors of infectious disease (e.g., schistosomiasis), and may cause drownings when they overtop or are breached.

For given scenarios, the impact on rates of death and major diseases can be estimated for most of these direct-acting effects [19]. However, it is difficult to quantify the various subclinical toxicological effects. Air pollution from fossil fuel burning, for instance, not only causes an increased incidence of respiratory diseases, but also diminishes lung function and adds to personal discomfort (e.g., eye problems).

Altogether more difficult is predicting the indirect health effects of energy production. For example, fossil fuel combustion accounts for a large proportion of acid rain and its associated regional environmental damage, and the summertime pollution of air by photochemical oxidants reduces crop yields at exposure levels below that which directly affects human health. These indirect processes entail some risks to human health. The potentially most serious and global environmental health consequence comes from the carbon dioxide emitted by fossil fuel combustion. Carbon dioxide is the most common of all anthropogenic greenhouse gases, ahead of methane and nitrous oxide; it currently accounts for most radiative forcing. Concentrations of carbon dioxide are now one-third higher than in preindustrial times, and are rising by 0.5% each year. On this trend, it is estimated that the earth could warm over the next century by 2° to 3°C [22,23]. Although scientific uncertainties still abound, such warming is anticipated to affect environment, ecosystems, and human health at the global level [24,25]. Although there would be both negative and positive effects on health, the former would almost certainly predominate and could include the following [15,26,27]:

* Increased morbidity and mortality because of more frequent extreme events -- particularly heat waves, fires, cyclones, and flooding).
* Changes in infectious disease epidemiology, particularly increases in the spread and activity of a variety of vectorborne diseases.
* Changes in agricultural productivity.
* Disruption of freshwater supply (and perhaps sanitation) because of sea level rise.
* Extensive population movements (ecological refugees) as a result of desertification and sea level rise.
* Social stresses and unemployment, with adverse health consequences, due to shifts in economic activity.

The Health Consequences of Inequalities Between North and South

Effects upon population health also result from the unequal North-South pattern of energy use and materials consumption and from the political and economic relations that underlie that pattern [28]. To the extent that the standard of living in the North depends on continued access to low-cost materials from the South and to a below-true-cost exploitation of the world's natural resources [29], then commensurate harm to aspects of population health in the South can be anticipated. Figure 4 provides a schematic overview of the relation between energy use in rich countries and global population health.

Many rich countries import much of their food from third world sources. There is continuing debate about the net effects of export-oriented food production on the nutritional status and health of third world populations, who may lack access to -- or (as displaced farmers) the ability to pay for -- good, cheap, local food. Relatedly, the diversion of agricultural land and the clearance of forest to create pasture for export-beef production -- especially Latin American countries exporting meat to the U.S. -- has various adverse environmental and social impacts [30]. The associated local transition of dietary preferences from plant to animal foods reduces the environmental efficiency of food-production and thus increases the environmental impact. More directly, the intensification and commercial control of agriculture in many poor countries, and the use of seasonal labor, have adversely affected the security and health of seasonal workers (especially women) [31]. Piecework has proliferated, reducing opportunities for workers to attend to their own and their children's health.

A second form of goods-flow from South to North involves production processes that entail occupation al hazards and that cause local environmental pollution. This problem is heightened by the tendency of multinational companies to relocate pollution-producing production facilities to countries with lower wage costs and lax environmental controls. These poor working conditions and lower environmental standards in the South pose risks to local population health, of which the Bhopal disaster in India was just the tip of a poorly defined iceberg.

More generally, the unequal terms of trade between North and South (pathway 2, Figure 4) nurture the continued poverty, overpopulation, lack of adequate health care facilities and large-scale ecological problems in the South. Unequal access to world markets, biased price-setting mechanisms, and failed development programs have all been part of a situation in which third world countries have been environmentally harmed by poorly controlled, often foreign owned, industries, while being asset-stripped of var-

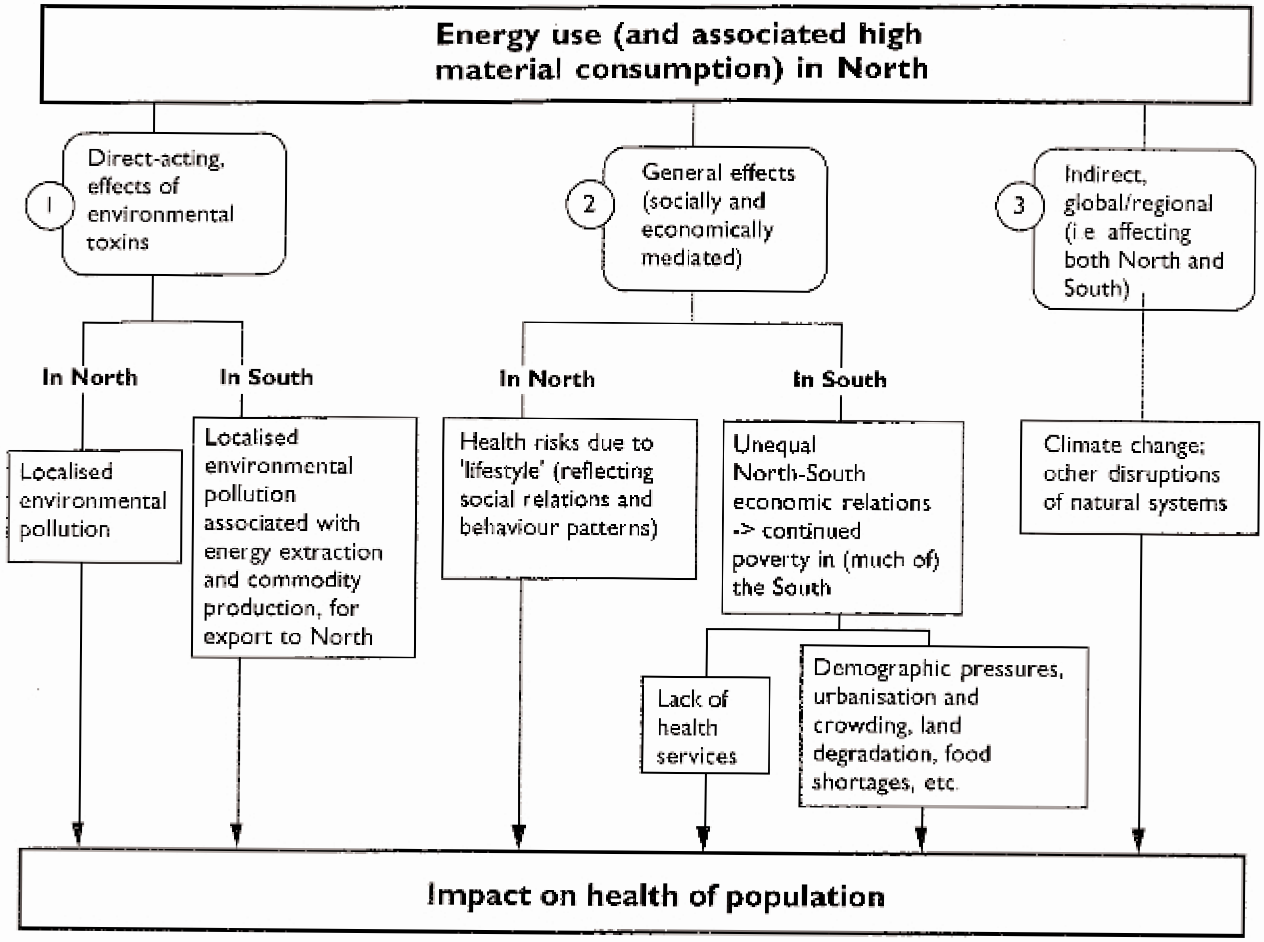

Figure 4. Schematic representation of major influences of energy use in the North upon global population health.

ious natural resources. The three key international instrumentalities set up after World War II to integrate the economic relations between developing and developed countries (IMF, World Bank and General Agreement on Tariffs and Trade [GATT]) continue to be dominated by Western free-market models and by policy decisions that tend to favor first world interests [261. This complex historically grounded situation, exacerbated by population pressures, causes circumstances that presumably impair population health in the South.

The third pathway by which patterns of energy use and materials consumption result in adverse health consequences on a global level is shown by arrow 3 in Figure 4. This is exemplified by the indirect health effects of climate change. The various poorer and more vulnerable Southern countries will probably be the most adversely affected by global environmental problems that arise predominantly from the energy intensive North. The Intergovernmental Panel on Climate Change has predicted that any increases in floods, storms, the spread of vectorborne infections and coastal inundation caused by global warming would have an impact first, and most severely, in geographically disadvantaged countries in the South (where impoverished rural communities cling to marginal, exposed land) [22,23]. Adverse regional consequences have been predicted for agricultural productivity (particularly in parts of Africa).

Future Scenarios

Historically, most commercial energy use has occurred within today's developed countries. Western countries have doubled their energy efficiency this century, but their aggregate energy use remains greater than that of the developing world. At the extreme, the per person consumption of energy in the U.S. is approximately 100 times higher than in sub-Saharan Africa. More generally, there is an aver age 10-fold difference in per person energy consumption between the rich and poor countries.

The U.N.'s World Commission on Environment and Development estimates that for the whole world to attain the U.S.'s level of per person energy consumption, a fivefold increase in global energy use would be required [32]. With existing technology, said the Commission, such an increase would not be ecologically sustainable. Yet, currently, it seems technically and politically infeasible that greenhouse gas emissions can be quickly and substantially reduced in the North. Further, it is morally questionable to expect that developing Southern nations will accept an imposed constraint upon their own material development [33].

However, if modern energy-efficient technologies were adopted (with the help of massive subsidies) in developing countries, then less than a doubling of their current energy consumption would enable their material standard of living to rise to something approaching recent levels in Western Europe. Indeed, it is argued that such energy efficiency is most feasible in countries in which a whole infrastructure still has to be built. It cannot readily be achieved in the present-day North -- at least for political reasons (including the influence of entrenched government subsidies to conventional energy producers). Hence, estimates of potential savings from energy efficiencies in rich countries are more conservative. [34].

More efficient energy generation and end-use technology, combined with clean technologies, would reduce direct environmental pollution and the associated health risks. However, in such a technologically modulated scenario, the North would continue to consume much the same amount of goods and food and perhaps more, as economic growth continues. Little would thus change in North-South relationships. Further, although technological advances that enhance the efficient combustion of fossil fuels and improved pollution abatement will buy time, they will not avert the eventual need for more radical sociopolitical change. The longer we defer addressing the essentially inelastic limits to growth, the more likely it is that in the future several of the limits discussed in this paper will confront society [13].

The political challenges are substantial. The North, historically and currently, has accrued much of its economic status and military power by exploiting the world's natural resources at a highly unsustainable rate. Within today's increasingly integrated world economy, the South has an immediate dependence upon selling assets and produce to the North, and therefore could not accommodate, without aid, a sudden change in the North's behaviour. Substantial transfers of wealth, resources, and ideas would therefore be needed from the North, to ensure the sustainable development of those countries. While this would require a reduced per capita consumption of energy and materials by the North, gains in energy efficiency and materials recycling may avert any significant reduction in material standard of living.

Conclusion

Sustained human population health, globally, requires a coordinated pattern of ecologically sustainable development -- as opposed to the current patchwork of local, apparently unsustainable, "growth" oriented activities. This will probably require the North to curtail its high-consumption energy-intensive lifestyle. In the South, a prerequisite for sustain able development is fertility control, which will require gains in the status and education of women and sensitive attention to cultural and religious barriers. Since, typically, there is resentment in the industrialising developing nations among political and industrial leaders when environmental scientists suggest that development must be constrained [35], the North should provide, soon, an example of a sustainable low-energy society -- while facilitating such transition in the South through transfers of wealth and technology. ❧

Acknowledgment

We have appreciated helpful suggestions from John Moss.

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