Peak Oil, the Rise of China and India, and the Global Energy Crisis

MINQI LI
Department of Economics, University of Utah, Salt Lake City, USA

ABSTRACT  Should current trends continue, China and India are widely expected to play leading roles in the world economy in the twenty-first century. However, the economic rise of China and India coincides with the decline of fossil fuels. There is growing consensus that the world’s total oil production is likely to reach its peak in the near future and, to alleviate global warming, it is necessary to dramatically reduce the use of all forms of fossil fuels. This article discusses the interactions between the economic rise of China and India and the global energy crisis. Several scenarios that range from the failure of the Chinese and the Indian national development projects to global environmental catastrophes are discussed.

KEY WORDS: China, India, peak oil, global energy crisis, world economy

The spectacular growth of the Chinese and the Indian economies is transforming the world at an unprecedented pace. Under current trends, it is suggested that China is set to become the world’s largest and India the third largest economy by 2020. Some predict that after centuries of Western domination, now it is just a matter of time before Asia recovers its historical leadership over the world economy, with China and India at its centre (Arrighi and Silver, 1999; Arrighi et al., 2003).

The rise of Western industrial capitalism under the British and American hegemony coincided with (and one may say, depended upon) the enormous expansion of energy consumption, especially the consumption of fossil fuels (oil, gas and coal). Today fossil fuels account for 80% of the world’s total primary energy supply. However, there is growing consensus that the world’s total oil production is likely to reach its peak in the near future and experience an irreversible decline thereafter. Further, the greenhouse gas emissions from human activities (primarily from the use of fossil fuels) contribute to global warming with potentially catastrophic consequences. To prevent or alleviate these, it is necessary to dramatically reduce the use of fossil fuels.

In this context, a serious question may be raised: does the world have enough energy and other resources to accommodate China’s and India’s search for material

Correspondence Address: Minqi Li, Department of Economics, University of Utah, 1645 E. Campus Center, Salt Lake City, UT 84112, USA. Email: minqi.li@economics.utah.edu

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abundance, with their enormous population? To the extent that this cannot be accomplished easily, what could be the implications for China and India, and for the rest of the world?

This article discusses the interactions between the economic rise of China and India and the global energy crisis that is likely to take place in the coming half-century. The next section discusses the changing relative positions of China and India in the world economy and the potential implications for world energy consumption. The third section discusses the coming peak of the global oil production, impact of global warming and the prospect of alternative energy sources. The fourth section evaluates the likely prospect of world energy supply in the coming half-century and argues that there will be great difficulty for the world to meet the projected energy demand. The shortage of liquid and gaseous fuels could become a binding constraint on the future world economy. The fifth section discusses the implications of China’s and India’s economic rise for the global energy crisis. Several possible scenarios are considered. The last section concludes the article.

**China and India in the World Economy: History and Future**

Figure 1 presents the historical and projected shares of world GDP of the world’s major economies: China, India, the “Euro 4” (the four largest Western European countries – the UK, France, Germany and Italy) and the USA, over the period 1820-2020.¹ Until the early nineteenth century, China and India were the two largest economies in the world, accounting for more than one-third of the world GDP. The two countries, however, experienced sustained declines in relative economic positions over the following 150 years. Western Europe dominated the world economy through the nineteenth and early twentieth centuries. After World War II, the USA

![Graph](image-url)
achieved undisputed world economic hegemony. Since then the US share in the world GDP has declined. Nevertheless, the USA remains the world’s largest economy. However, if the current trend continues, China will soon overtake the USA to become the world’s largest economy. By 2020, China and India combined will again account for more than one-third of world GDP, restoring their historical positions.

Such a development would certainly lead to major transformations in the world economy and geopolitics. There is one area in which the economic rise of China and India is set to bring about fundamental changes that has not been discussed extensively so far. That is, how would the rise of China and India affect the consumption and distribution of world resources, especially the energy resources? The current pattern of world energy consumption is highly uneven. The high-income countries, with 18% of the world population, account for 49% of the world’s total primary energy consumption and 60% of electricity consumption. China and India together, with 37% of the world’s population, account for only 19% of the world’s total primary energy consumption and 16% of the electricity consumption.2

According to the footprint analysis, the current rate of energy and resources consumption in high-income countries is already unsustainable. It takes 8.5 hectares of productive land to provide food, water and energy settlement area for an average person living in a rich country. Yet the world’s productive land per person is about 1.2 hectares (Trainer, 2005: ch. 10). To stabilise the global climate, the world’s emissions of greenhouse gases need to fall to about one tonne of carbon dioxide equivalent per person. But the current emissions in high-income countries stand at about 11 tonnes of carbon dioxide equivalent per person (in the USA it is about 20 tonnes per person).

This raises a serious question. How much energy and other resources are left available for the development of the rest of the world? Can the world generate a sufficiently large energy supply in the coming decades to accommodate the rise of China and India? Figure 2 presents the actual and projected shares of world energy consumption of the world’s major economies.3

Under the current trend, China and India together will account for about one quarter of the world’s total primary energy consumption by 2020 (this would still be less than their share of the world population). If the energy consumption in the USA, China and India all grow at their current trends, then by 2050 the total energy consumption in these three countries would reach nine times the US energy consumption in 2004 or 11 times the US energy consumption in 1990 (the reference year for the Kyoto Protocol). Will the world have enough energy resources to support ten more Americas?

There is no doubt that the Chinese and Indian people have every right to development, understood as the fulfillment of their basic needs as well as their desires for a decent life. Further, it would not be unreasonable for one to argue that the existing pattern of resources distribution in the world is historically and morally unjustified. Nevertheless, to the extent that the existing world economy is already on an ecologically unsustainable path, it cannot be denied that the attempt to replicate the existing pattern of consumption of the high-income countries among nearly two-fifths of the world population would make it even less sustainable.
Peak Oil, Global Warming and Limits to Energy Supply

Peak Oil

The current world economy depends on fossil fuels for 80% of its total energy supply. Oil accounts for 34% of the world’s total primary energy supply, coal accounts for 25%, natural gas for 21% and nuclear energy for 6.5%. Among the renewable energies, biomass and waste (wood, other biomass, animal products, municipal waste and industrial waste) account for 10.6%. Hydro-electricity accounts for 2.2% and all others (solar, wind, geothermal, tide and wave) for a mere 0.4%.

In terms of the world’s total final energy consumption, oil accounts for 42%, gas accounts for 16%, coal accounts for 8%, biomass and waste account for 14% and electricity and others account for 20%. Thus, oil is currently the single most important source of energy, accounting for more than two-fifths of the world’s total primary energy supply and two-fifths of the world’s total final energy consumption.

According to Campbell (2005a; 2005b), global oil discovery peaked back in the mid-1960s. Since 1980, new discovery has been less than depletion for every year and the gap has tended to grow. Global production of all oil liquids (including conventional oil as well as heavy oil, deep-water oil, polar oil, gas liquids, etc.) is expected to peak around 2010. By 2050, the total oil production is expected to fall by about 70% from the peak level.4

Trainer (2006a) counted a total of 61 estimates of the world’s total conventional oil resources and concluded that there is a considerable agreement on a figure under two trillion barrels. As the world’s total oil production so far has been about one trillion barrels and the peak production is likely to occur when about half of the total oil resource has been depleted, these estimates suggest that the world oil production peak is likely to occur in a few years.5

Figure 2. Share of world energy consumption, actual and projected (1960-2020)
Until recently, governments and businesses have tended to pay little attention to the peak oil argument. However, the idea is now gaining acceptance among mainstream institutions. The International Energy Agency (IEA) recently pointed out that the oil fields on which Europe and the USA have come to depend, including Russia, USA, Mexico and Norway, would peak in the next five to seven years. According to IEA, the world is on a course that will lead it "from crisis to crisis" unless governments act immediately to save energy and invest in nuclear and biofuels. IEA calls for a total investment of $US20 trillion in energy infrastructure from now to 2030 to stave off energy crisis (Financial Times, 8 November 2006).

Figure 3 presents the actual and projected total world oil production from 1960 to 2100. Projections of world oil production for 2005-2100 are based on data from ASPO (2006).\(^6\)

**Natural Gas and Coal**

Much (although not all) natural gas production is linked closely to oil production. The peak of the world natural gas production is likely to occur not long after the peak of the world oil production. Because of the physical features of natural gas, it has a depletion pattern different from oil. Campbell (2005a: 29-55; 2005b: 210-16) expects the world natural gas production to keep rising until 2025 and then stay on a high plateau before declining sharply after 2045.

Among the fossil fuels, coal is relatively abundant. The world's total identified coal resource is said to be 35 trillion tonnes (Cui, 2006: 16). Much of it, however, may never be recovered due to declining net energy returns (the net energy output that can be produced for each unit of energy input) and environmental constraints (Heinberg, 2003: 129-32). The world's economically recoverable coal is estimated to be about 750 billion tonnes of coal equivalent. At the current rate of production, it is

![Figure 3. World oil production (million barrels per day), actual and projected (1960-2100)](image-url)
sufficient to last more than 200 years (Boyle et al., 2003: 167). Trainer (2006a) used a high estimate of the world's potentially recoverable coal, at two trillion tonnes of coal equivalent. At the current rate of production, this would be sufficient to last more than 600 years.

However, with economic growth, coal could be depleted much faster. If coal consumption grows at 2% a year, then the world's total recoverable coal would be completely depleted before the end of this century (based on the lower estimate) or by the mid-twenty-second century (based on the higher estimate).

**Global Warming and Limits to Fossil Fuels**

The use of fossil fuels releases large amounts of greenhouse gases that have contributed to global warming. The potentially catastrophic consequences arising from global warming have been discussed widely, including rising sea levels, flood, drought, heat waves, spread of human and crop diseases, decline of food production and a possibility of triggering the next ice age (Kunstler, 2005: 147-66; Lovelock, 2006; Mobbs, 2005: 57-72).

A recent British government report written by a group of economists led by Nicholas Stern argued that if no action is taken to combat global warming, the global economy could shrink by between 5% and 20% over the next two centuries (reported in Financial Times, 31 October 2006). The potential human and ecological costs, however, could turn out to be much greater and the losses may be irremediable.

The Intergovernmental Panel on Climate Change estimated that to stabilise the concentration of carbon dioxide equivalent in the atmosphere at twice the pre-industrial level it is necessary to cut global annual emissions of carbon dioxide equivalent to 8-12 billions tonnes by 2100. The current global emissions from fossil fuels stand at 27 billion tonnes. This suggests that the global use of fossil fuels needs to be cut by at least 55-70% by the end of the century. However, some argue that even such a reduction may not be sufficient to prevent global catastrophes (Goldsmith, 2005; Trainer, 2005: ch. 1).

**Limits to Nuclear Energy**

With the coming decline of fossil fuels, nuclear and renewable energies must play growing roles in meeting the world energy demand.

The generation of nuclear electricity uses uranium, which is a finite resource. The World Energy Council estimated the world's potentially recoverable high-grade uranium (including proven reserves, estimated additional resources and speculative resources) to be 10.7 million tonnes (WEC, 2001). The world's current rate of high-grade uranium consumption is about 65,000 tonnes a year. Thus, at the current rate of consumption, the world's recoverable high-grade uranium could last about 160 years. However, if consumption grows at 2% a year, it can only last 70 years.

Although there have been no major nuclear accidents since the Chernobyl accident in 1986, if nuclear energy is used on a large scale, then some human failure will be inevitable, and any nuclear accident could lead to catastrophic consequences. Nuclear reactors produce large quantities of radioactive waste that have hazardous
effects lasting hundreds of thousands of years and there is no good long-term solution to the problem of nuclear waste storage (Mobbs, 2005: 96-101; Trainer, 2005: ch. 9).

**Limits to Renewable Energies**

Renewable energies generally have much less serious environmental problems than fossil fuels or nuclear energy. Renewable energies cannot be exhausted. However, within any given period of time, only a finite amount of renewable energies can be harvested. Unlike fossil fuels or nuclear energy, renewable energies have much lower intensity in terms of volume or weight. Energy production from renewable sources often requires large areas of land. The requirements of land impose physical limits to how much renewable energy can be made available. Moreover, renewable energies are characterised by intermittency and variability, which make them unreliable as the principal source of energy. Because of these problems, renewable energies are generally more expensive than fossil fuels. 

Table 1 presents estimates of electricity prices (costs) from different energy sources in the UK. The estimates suggest that while wind power seems to be able to deliver electricity at a cost comparable to conventional electricity, other renewable energies are more expensive by between 50% and ten times.

Prices or unit costs data can be confusing or misleading sometimes, as it is not always clear whether prices or costs are subsidised or not and what items are included. Trainer (2005; 2006b) made direct estimates of capital costs of wind and solar power based on Australian prices (see Table 2). Trainer’s estimates suggest that

<table>
<thead>
<tr>
<th>Energy source</th>
<th>Price or cost (pence per kilo-watt hour)</th>
<th>As percentage of conventional electricity</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional electricity</td>
<td>2.7&lt;sup&gt;a&lt;/sup&gt;</td>
<td>100</td>
<td>Boyle (2004: 141)</td>
</tr>
<tr>
<td>Nuclear</td>
<td>6.25&lt;sup&gt;b&lt;/sup&gt;</td>
<td>231</td>
<td>Boyle et al. (2003: 442-5)</td>
</tr>
<tr>
<td>Biomass</td>
<td>≈4&lt;sup&gt;c&lt;/sup&gt;</td>
<td>148</td>
<td>Boyle (2004: 143)</td>
</tr>
<tr>
<td>Wind</td>
<td>≈3&lt;sup&gt;d&lt;/sup&gt;</td>
<td>111</td>
<td>Boyle (2004: 280)</td>
</tr>
<tr>
<td>Solar thermal</td>
<td>8.5&lt;sup&gt;e&lt;/sup&gt;</td>
<td>315</td>
<td>Boyle (2004: 61)</td>
</tr>
<tr>
<td>Solar photovoltaic</td>
<td>30&lt;sup&gt;f&lt;/sup&gt;</td>
<td>1111</td>
<td>Boyle (2004: 93)</td>
</tr>
<tr>
<td>Tidal barrage</td>
<td>≈5</td>
<td>185</td>
<td>Boyle (2004: 218-23)</td>
</tr>
<tr>
<td>Wave</td>
<td>≈5</td>
<td>185</td>
<td>Boyle (2004: 332-3)</td>
</tr>
<tr>
<td>Geothermal</td>
<td>≈4&lt;sup&gt;g&lt;/sup&gt;</td>
<td>148</td>
<td>Boyle (2004: 376)</td>
</tr>
</tbody>
</table>

<sup>a</sup>Price for large industrial users.
<sup>b</sup>Cost for private producers using pressurised water reactors.
<sup>c</sup>Cost of electricity from energy crops.
<sup>d</sup>Capital cost of wind turbines (estimated at 66% of total wind electricity cost) ranges between £600 and £1000. £800 is used and the operating life assumed to be 40,000 hours.
<sup>e</sup>Cost for the SEGS plants. However, the SEGS plants use natural gas to generate up to 25% of their electricity production (Hayden, 2004: 187-91).
<sup>f</sup>The "best case" scenario for the bulk-purchased household systems.
<sup>g</sup>Costs are in the region of 5-9 US cents per kilowatt-hour.
wind power is about 20% more expensive than a coal-fired power plant. Solar power costs range from 3 to 35 times those for coal-fired power. If solar power is used on a large scale, then given the intermittency and variability problems, storage would be necessary to deliver a reasonably reliable electricity output. Taking into account storage, the cost of solar power is likely to range from 6 to 35 times that of coal-fired power.\textsuperscript{8}

How expensive is too expensive? Table 3 illustrates energy costs in term of equivalent oil and electricity prices and implied shares of energy spending in GDP. If the entire world energy supply is provided in the form of oil, then the world's total energy spending would cost only 4% of world GDP. By comparison, electricity is much more expensive. If the entire world energy supply is provided in the form of conventional electricity (primarily generated from coal) then the total energy spending would cost 12% of world GDP. It is equivalent to an oil price of $US79 per barrel. In 1980, in the middle of the second oil crisis, the oil price in real 2000 dollars was $66 per barrel.

<table>
<thead>
<tr>
<th>Energy source</th>
<th>With or without storage capacity</th>
<th>Capital cost</th>
<th>As multiples of coal-fired plant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal-fired plant\textsuperscript{a}</td>
<td>No</td>
<td>3.7</td>
<td>1</td>
</tr>
<tr>
<td>Wind</td>
<td>No</td>
<td>4.5</td>
<td>1.2</td>
</tr>
<tr>
<td>Solar thermal (summer)</td>
<td>No</td>
<td>11.2</td>
<td>3</td>
</tr>
<tr>
<td>Solar thermal (winter)</td>
<td>No</td>
<td>56</td>
<td>15</td>
</tr>
<tr>
<td>Solar PV plant (winter)</td>
<td>No</td>
<td>68</td>
<td>18</td>
</tr>
<tr>
<td>Solar PV plant (winter)</td>
<td>Yes</td>
<td>130.6</td>
<td>35</td>
</tr>
</tbody>
</table>

\textsuperscript{a}Cost includes fuel for lifetime.


<table>
<thead>
<tr>
<th>Energy input</th>
<th>Equivalent oil price ($ per barrel)</th>
<th>Equivalent electricity price ($ per kWh)</th>
<th>Share of energy spending in world GDP (%)\textsuperscript{a}</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oil</td>
<td>30\textsuperscript{b}</td>
<td>0.02</td>
<td>4</td>
</tr>
<tr>
<td>Conventional electricity</td>
<td>79</td>
<td>0.05\textsuperscript{c}</td>
<td>12</td>
</tr>
<tr>
<td>200% of conventional electricity</td>
<td>159</td>
<td>0.10</td>
<td>23</td>
</tr>
<tr>
<td>300% of conventional electricity</td>
<td>238</td>
<td>0.15</td>
<td>35</td>
</tr>
<tr>
<td>500% of conventional electricity</td>
<td>397</td>
<td>0.25</td>
<td>58</td>
</tr>
<tr>
<td>1000% of conventional electricity</td>
<td>793</td>
<td>0.50</td>
<td>116</td>
</tr>
</tbody>
</table>

\textsuperscript{a}Energy intensity is assumed to be 0.2 tonne of oil equivalent per thousand dollars.

\textsuperscript{b}The world average crude oil price in 2000 was $28.5 per barrel. 1 tonne of oil equivalent equals 7.33 barrels of oil.

\textsuperscript{c}US electricity price for large industrial users in 2000 was 4.6 cents per kilowatt-hour. 1 tonne of oil equivalent equals 11,630 kilowatt-hours.
The world’s total gross saving (total world income in excess of private and public consumption, or the part of world income that can be used for capital investment) is about 20-25% of world GDP and net saving (gross saving less depreciation) is likely to be in the range of 10-15% of world GDP. If the entire world energy supply is provided by an energy input that costs twice as much as conventional electricity, then the implied energy spending would be 23% of GDP, that is, nearly a quarter of world economic activities would have to be committed directly or indirectly to energy supply. Such a severe burden could force society to sacrifice other essential goods or services in order to divert resources into energy supply. If one takes into account plausible future cost reductions, then any energy input that costs more than three times as much as conventional electricity would certainly be prohibitively expensive. Thus, financial considerations seem to rule out the large-scale applications of solar thermal and solar photovoltaic power plants in the foreseeable future.9

Table 4 presents estimates of the physical potential of various renewable energies for the world and selected countries.10 It seems that in the three large economies (China, USA and UK), the potential of renewable energies is not large. In China and the UK, all forms of renewable energies have a practical potential to supply about 20% of the present energy demand. In the USA, the total potential from biomass and onshore wind power amounts to about 12% of the present energy demand.

By contrast, Australia seems to have a large biomass potential. However, this is somewhat misleading, as the figure refers to the primary energy supply, or the gross energy embodied in the biomass. To be useful, however, biomass needs to be

<table>
<thead>
<tr>
<th>Table 4. Renewable energy potentials (measured in million tonnes of oil equivalent)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Hydro</strong></td>
</tr>
<tr>
<td>Hydro</td>
</tr>
<tr>
<td>Biomass (fuel crops)</td>
</tr>
<tr>
<td>Wind (onshore)</td>
</tr>
<tr>
<td>Wind (offshore)</td>
</tr>
<tr>
<td>Solar</td>
</tr>
<tr>
<td>Tide</td>
</tr>
<tr>
<td>Wave</td>
</tr>
<tr>
<td>Geothermal</td>
</tr>
<tr>
<td>Other biomass</td>
</tr>
<tr>
<td>Total</td>
</tr>
<tr>
<td>2004 TPES</td>
</tr>
<tr>
<td>Total/2004 TPES (%)</td>
</tr>
</tbody>
</table>

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10Boyle (2004: 144; 379; 390), practicable potentials. Hydro is for small hydro only.
12Estimated to meet 20% of world electricity demand by 2050.
13Built-in or “rooftop” solar photovoltaic only.
15Trainer (2006b).
16Assume 100-year resource life.
17TPES: total primary energy supply.
converted to liquid fuels or electricity. If biomass is used to make liquid fuels (such as ethanol or methanol), the net energy output available for final consumption is about one-quarter of the original energy content of the biomass input. At best, less than half of Australia’s present demand for oil and gas may be replaced with biomass (Trainer, 2005: ch. 5). World-wide, biomass may have a potential to replace about 20% of the world’s present oil consumption and this assumes that 600 million hectares, or 40% of the world’s total arable land, is used to grow energy crops. Given the constraints of land and water resources, and the very low net energy returns, the actual levels of biomass production in the coming decades most likely will fall below this potential.

Given the intermittent and variable nature of wind power, there would be great difficulty in using wind as a primary source of electricity or energy supply. When wind contributes to a very small proportion of the total electricity production, the problem is insignificant. However, as wind contribution rises, it starts to create an “integration” problem. It is commonly assumed that in good wind regions wind has a “penetration” potential of meeting 25% of electricity demand. But Trainer (2005: ch. 4) believes this is optimistic.

Boyle (2004: 285) cited an estimate that assumes wind power would generate 20% of the world’s electricity by 2020. By this estimate, the wind power potential by 2020 would be 5,177 trillion watt-hours or 445 million tonnes of oil equivalent. Suppose world electricity consumption rises by 2% a year from 2020 to 2050 and wind meets 20% of world electricity demand by 2050, then the potential primary energy supply from wind by 2050 would be 806 million tonnes of oil equivalent, about 7% of the world’s present primary energy supply.

The UK has a relatively large offshore wind potential. But for Western Europe as a whole, the offshore potential is estimated to be half of the onshore potential (Boyle, 2004: 285). Trainer (2005: ch. 4) cited an estimate that puts the US offshore wind potential at one-seventh of the onshore potential. Offshore wind potential, even if it were large, would not overcome the intermittency and variability problems and would be subject to the same penetration limit as the onshore wind.

Tide, wave and geothermal are unlikely to make a large world-wide contribution (Hayden, 2004: 209-12; Heinberg, 2003: 151-4; Trainer, 2006b). The potential for hydropower is also limited, especially in advanced capitalist countries. Hydropower also has environmental problems (Boyle, 2004: 177-82; 190-1; Heinberg, 2003: 149-50; Kunstler, 2005: 119-21).

Global Energy Crisis — Can Hydrogen, Coal or Nuclear Come to the Rescue?

Based on the above discussions, it is possible to derive a reasonable projection of the potential world energy supply in the coming half-century which takes into account the coming peak of world oil and natural gas production, the requirements to alleviate global warming and the potentials and limitations of nuclear and renewable energies.

World oil production is assumed to peak in 2010 and decline to about 30% of the peak level by 2050. World natural gas production is assumed to keep rising until 2025, and then stay constant until 2045. By 2050, world natural gas production is assumed to fall by 20% from the peak level.
World coal production is assumed to keep rising until 2030 and decline thereafter. By 2050, the total use of fossil fuels is assumed to fall by 20% from the 2004 level. At this rate, by the end of this century, the total reduction of fossil fuels would be about 40%. This would be less than the 55-70% reduction required to stabilise the carbon dioxide concentration at twice the pre-industrial level. That is, to alleviate global warming, the use of fossil fuels might need to fall by a greater amount than is assumed here.

Nuclear energy is limited by the finite resource of uranium as well as safety and environmental concerns. Nevertheless, in the current projection, nuclear electricity production is assumed to rise steadily so that by 2050 the world’s total nuclear electricity production is projected to be 58% greater than the 2004 level.

The World Energy Council projects six possible scenarios of world energy supply. By 2050 the total primary energy supply from renewable sources is projected to range from 4400 million to 7500 million tonnes of oil equivalent (Boyle, 2004: 423-4). The most optimistic estimate amounts to twice as much as the total potential from biomass and wind power presented in Table 4.

If the World Energy Council's most optimistic estimate of the renewable energy potential is used, then the world’s total primary energy supply is projected to grow from 11,059 million tonnes of oil equivalent in 2004 to 16,484 million tonnes by 2030 before falling to 15,697 million tonnes by 2050. Renewable energies would account for 48% of the total primary energy supply by 2050. Figure 4 presents the projected energy supply from different sources from 2005 to 2050 (see Appendix for detailed assumptions regarding world energy supply projection).

Between 2004 and 2050, the world’s total primary energy supply is projected to grow at an annual rate of 0.76%. By contrast, between 1973 and 2004, the world’s total primary energy supply grew at an annual rate of 2.0%.

![Figure 4. Projected world energy supply (2005-20, million tonnes of oil equivalent)](image-url)
The US Energy Information Administration (EIA) projects three alternative scenarios of world energy demand from 2003 to 2030 (EIA, 2006b). Under the high growth scenario, the reference case scenario and the low growth scenario, the world energy consumption is expected to grow by 2.6%, 2% and 1.5% a year, respectively. If these growth rates are applied to the entire period from 2004 to 2050, then by 2050, there will be a gap between the world energy demand and supply that amounts to 56%, 43% and 28% of the projected demand respectively.

The Problem of Liquid and Gaseous Fuels

The above projections focus on the overall energy supply and demand and have ignored the problem of fuel structure, which is a topic in itself. However, for the world economy to function and grow, it is necessary to meet not only the overall energy demand but also the specific demand for each fuel type.

Nuclear, wind, solar, geothermal, tide and wave can be used only to generate electricity. However, electricity accounts for only 16% of the world’s final energy consumption. By contrast, liquid fuels (oil) and gaseous fuels (gas) account for 42% and 16% of the world’s final energy consumption, respectively. Liquid and gaseous fuels are the major energy sources for the world’s transportation, industry and agriculture, and provide indispensable inputs for the chemical industries (Heinberg, 2003: 137; 2006: 4-7; Kunstler, 2005: 123-31, 145).

According to the EIA’s reference case projection, the world’s oil consumption is expected to grow at an annual rate of 1.4% and natural gas consumption at an annual rate of 2.4% in the coming decades. At these rates, the world’s total liquid and gaseous fuel consumption would reach 14,072 million tonnes of oil equivalent by 2050. However, given the depletion pattern of oil and natural gas, the total energy production from oil and natural gas is projected to fall from the current 6105 million tonnes of oil equivalent to 3539 million tonnes, creating an unmet demand gap of 75% or 10,533 million tonnes of oil equivalent.

Biomass is the only renewable energy source that can be used to directly produce liquid or gaseous fuels in the form of ethanol or methanol. Table 4 suggests that biomass has a world-wide potential to provide a primary energy supply of 2866 million tonnes of oil equivalent (assuming using 40% of the world's cropland). If about one-quarter of the gross biomass energy input is converted into fuel for final consumption, then the total potential world liquid and gaseous fuel supply from biomass would be about 720 million tonnes of oil equivalent. Thus, by 2050, oil, natural gas and biomass would potentially provide a fuel supply of 4260 million tonnes, leaving an unmet demand gap of 9810 million tonnes.

Although, in some cases, liquid and gaseous fuels may be replaced by electricity with relative ease (such as replacing fossil fuel-powered trains with electric trains in railway transportation), in many areas of the modern economy oil and gas are indispensable, such as inter-continental transportation, modern chemical industries, fuel supply for heavy equipment in industry and agriculture, modern agriculture based on the large-scale use of fertilisers and pesticides, and the entire industries and lifestyle based on private cars. Thus, if the problem of liquid and gaseous fuels cannot be addressed effectively, then the shortage of liquid and gaseous fuels could become a binding constraint on the future world economy.
How About Hydrogen?

It is often assumed that electricity generated from renewable sources may be used to produce hydrogen fuel cells, which could in turn serve as the primary substitute for liquid or gaseous fuels in the future world economy (Hawken et al., 2000; Stipp, 2001). However, some recent studies suggest that the physical nature of hydrogen largely rules out the possibility of a large-scale hydrogen economy (Heinberg, 2003: 146-9; Kunstler, 2005: 110-16; Trainer, 2005: ch. 6).

Hydrogen is very light. A very large volume of hydrogen is needed to carry a given amount of energy and it easily leaks through joints, valves and seals. All of these make it very expensive to transport and store hydrogen and the overall energy returns end up being very low. A 40-tonne truck is able to carry an amount of hydrogen that is only equivalent to less than 300 kilograms of petrol or less than three tonnes of petrol if hydrogen is liquefied (but there would be a large energy loss in liquefaction). The storage tank must be heavy and expensive and could weigh as much as 115 times the hydrogen stored. Taking into account all of the energy losses that would occur in the conversion from electricity to hydrogen and then back into electricity, liquefying or pumping, transportation and storage, only 10-20% of the electricity generated ends up as useful energy for final consumption.

Moreover, the production of hydrogen fuel cells uses scarce materials such as platinum. The large-scale use of fuel cells therefore may be limited by the availability of the scarce materials.

How About Coal?

Coal may be converted into oil or gas through chemical processes. It is reported that China is currently investing $6 billion in production facilities that will have the capacity to make 14 million barrels of oil a year (Heinberg, 2006: 29). Coal costs about $50 a tonne and the conversion from coal to oil results in an energy loss of 40% (thus, one tonne of coal may be converted into just under three barrels of oil). Assuming a plant life of 20 years, then the total production cost of converting coal into oil is about $38 a barrel. Given the current world oil prices, this is not particularly expensive.

However, coal is the dirtiest of fossil fuels. If coal is mined and used on a massive scale to replace oil and natural gas, the emissions of greenhouse gases and other pollution would get out of control. The world would be on the path towards environmental catastrophe.

Pollution problems may be somewhat alleviated if so-called “clean coal” and carbon sequestration technologies are used to remove some of the pollution elements when coal is being processed. However, these technologies involve higher capital costs and reduce overall energy efficiency. They would not help to address the emissions generated by transportation vehicles, industrial and agricultural equipment (unattached to large-scale facilities) and residential homes (Boyle et al., 2003: 48, 577-83; The Economist, 2-8 December 2006 (Technology Quarterly Section): 30-2).

In Figure 4, world coal production is projected to be 3522 million tonnes of oil equivalent or 5283 million tonnes of coal equivalent by 2050. If coal is used to meet
the projected unmet demand for liquid and gaseous fuels, a 40% energy loss ratio must be assumed. Thus, to generate liquid and gaseous fuels in the amount of 9810 million tonnes of oil equivalent, each year there must be an extra consumption of coal in the amount of 24,525 million tonnes of coal equivalent. Thus, the total consumption of coal would be 29,808 million tonnes a year. At this rate, the world’s total economically recoverable coal would be depleted in 25 years.\(^{11}\)

**How About Nuclear Energy?**

In Figure 4, the world’s primary energy supply from nuclear energy is projected to rise from 719 million tonnes of oil equivalent in 2004 to 1136 million tonnes in 2050. The world’s high-grade uranium resources have a thermal equivalent of about 118 billion tonnes of oil equivalent. If the world nuclear electricity production stays at the projected 2050 level, all of the high-grade uranium resources would be depleted in the early twenty-second century.

The gap between the projected world energy demand under the EIA’s low growth scenario and the projected world energy supply amounts to 6342 million tonnes of oil equivalent by 2050. If starting with 2050, this gap is to be filled with nuclear energy, then the world’s remaining uranium resources would last only about ten years.

Some claim that if low-grade and more expensive uranium ores are used, the recoverable uranium could amount to 100 million tonnes (or about 1.1 trillion tonnes of oil equivalent). However, with low-grade ores, it could take so much energy to mine and process uranium that the net energy return could become negative (Boyle et al., 2003: 450-4).

A few countries (USA, UK, France, Japan and Russia) have experimented with breeder reactors that use plutonium (which can be used to make nuclear weapons). With breeder reactors, the lifetime of uranium resource could be extended by 50-60 times. However, the breeder reactors have much more serious safety and security problems than the conventional reactors. Plutonium is regarded as the most poisonous material known on Earth. With an accident, it could explode like an atomic bomb. Liquid sodium, the coolant used by breeder reactors, explodes on contact with air or water. Because of these problems, breeder reactors are expensive to build and maintain and are susceptible to long shutdowns. The French Super Phoenix reactor, the world’s largest breeder reactor, operated for less than one year during its ten years of service before it was closed (Boyle et al., 2003: 454-5; Heinberg, 2003: 134; Trainer, 2005: ch. 9).

Nuclear fusion is another proposed technology that could potentially provide a very large energy supply. Nuclear fusion is the reaction that takes place in the Sun and has been achieved by human beings in the form of hydrogen bombs. To use it for economic purposes, however, the reaction has to be controlled. To initiate a fusion reaction, a temperature of more than 100 million°C has to be reached and no known materials are capable of containing such temperatures. So far scientists have attempted to confine the reaction through different processes. But each process requires more energy than the reaction itself generates and has succeeded in sustaining the reaction for no more than a fraction of a second (Heinberg, 2003: 160).

The European Union, the USA, China, India, Japan, South Korea and Russia recently signed an agreement to launch an experimental nuclear fusion reactor
(about one-sixth the size of a regular power station) that would cost 10 billion Euros. The researchers hope that by 2045 they could start generating commercial electricity from nuclear fusion reactors (Financial Times, 22 November 2006).

The currently proposed nuclear fusion technology uses lithium, which is a limited resource. Trainer (2006a) suggested that it would yield about as much energy as remains in fossil fuels (about three trillion tonnes of coal equivalent).

Current nuclear electricity is generally uncompetitive compared with conventional electricity without huge government subsidies. If low-grade uranium ores are used or if breeder reactors and fusion reactors are used on a large scale, nuclear electricity is likely to cost many times more than conventional electricity and could be prohibitively expensive. In any case, nuclear energy can be used only to generate electricity and cannot help to make up the shortage of liquid and gaseous fuels.

China, India and the Global Energy Crisis

At best, using rather optimistic assumptions regarding the potential of renewable energies, the world would have to live with a dramatic slow down in the expansion of world energy supply in the coming half-century. Between 1960 and 2004, the world energy efficiency (measured as dollars of GDP in purchasing power parity per tonne of oil equivalent of primary energy consumption) improved at an average annual rate of 0.8% a year. After the first oil crisis, efficiency improvement accelerated. Between 1973 and 2004, the world energy efficiency improved at an average annual rate of 1.3% a year. Figure 5 presents the implications for world economic growth in the coming half-century, based on the projected world energy supply and the assumption that world energy efficiency improves at 1.5% a year between 2005 and 2050, in comparison with the actual world economic growth rates between 1950 and 2005.12

During the second half of the twentieth century, world economic growth rates fell below 2% on only three occasions, in the mid-1970s, the early 1980s and the early 1990s. These were regarded widely as periods of world economic recession. Figure 5 suggests that after the world oil production reaches the peak in 2010, world economic growth rates are likely to fall below 3% a year, comparable to the growth rates during the 1980s and the 1990s, widely considered as a period of economic stagnation. After 2030, when world coal production has to be cut in order to alleviate global warming, world economic growth rates would fall further to recession levels (below 1.5% a year). In effect, the world economy would suffer a prolonged depression.

Could efficiency improvement lead to somewhat higher growth rates? Although the world economy has experienced substantial improvement in energy efficiency over the past few decades, the scope for efficiency improvement is not unlimited. In the first place, improvement in energy efficiency is subject to the limit of physical laws. To the extent all economic activities involve certain physical and chemical transformations, there is a minimum amount of energy as is required by physical laws for these transformations to take place.

Investment in energy efficiency is also subject to the law of diminishing returns. While initially relatively large efficiency improvement may be accomplished with little or no economic and energy costs, overtime it may require increasingly greater
financial and energy investments to accomplish a given amount of efficiency improvement (Heinberg, 2003: 160-4). Stern and Cleveland (2004) argued that the observed improvement in energy efficiency in advanced capitalist countries to a large extent reflects the shift from fuels of poorer quality to fuels of higher quality. They suggested that prospects for further large improvement in efficiency in the future may be limited.

Some suggest that in advanced capitalist countries, energy use may be cut by a factor of four without affecting living standards (Lovins and Weisacher, 1997). But Trainer (2006b) points out that most of their arguments and examples suggest 50-75% reductions and believes that 50% reductions may be plausible.

The world economic growth rates projected in Figure 5 have already assumed substantial improvement in energy efficiency in the coming decades. The annual improvement rate of 1.5% is faster than the historical rates. At this rate, by 2050, world energy efficiency would approximately double from today's level. In fact, such an assumption could be too optimistic. Renewable energies generally have lower net energy returns than fossil fuels (Heinberg, 2003: 152-3). Further, the conversion from coal or biomass into liquid and gaseous fuels or the conversion from electricity into hydrogen would involve huge energy losses. All of these suggest that after the peak of the world oil and natural gas production, world energy efficiency could very well deteriorate rather than improve.

What are the implications of the coming global energy crisis for the economic rise of China and India, and vice versa? Several scenarios may be considered. Under the first scenario, suppose China and India maintain their growth momentum through the first half of the twenty-first century so that by 2050 the two countries reach per capita resources consumption levels comparable to those in today's high-income countries.

![Figure 5. World economic growth, actual and projected (1950-2150)](image-url)
EIA (2006b) projected that under its reference case scenario, China’s energy consumption would grow at 4.2% a year and India’s would grow at 3.2% a year in the coming decades. Applying these growth rates to the period 2004-50, by 2050 China’s energy consumption would increase by 6.6 times and India’s would increase by 4.3 times. If China were to have a population of 1.4 billion by 2050, China’s per capita energy consumption would be 7.6 tonnes of oil equivalent. This would still be less than the present US per capita energy consumption. If India were to have a population of 1.7 billion by 2050, India’s per capita consumption would be 1.4 tonnes of oil equivalent. This would still be less than the present world average per capita energy consumption.

Under these assumptions, by 2050 China and India together would have a total energy consumption of 13,119 million tonnes of oil equivalent, or 84% of the projected world energy supply. If India by then were to have the same per capita energy consumption as today’s high-income countries (4.7 tonnes of oil equivalent), then China and India together would have a total energy consumption of 18,670 million tonnes of oil equivalent, about 20% greater than the projected world energy supply, leaving no energy for the rest of the world. Obviously, there is no chance for this scenario to actually materialise.

Under the second scenario, suppose by 2050, the combined share of China and India in the world energy consumption increases from today’s 19% to 35%, roughly the same as their projected share in the world population. This would result in a much more equal distribution of the world energy resources among the world population.

Under this scenario, the total energy consumption of China and India would grow at an average annual rate of 2.1%, implying an average economic growth rate of 3.6% (assuming efficiency improvement rate of 1.5%). Such a low growth rate would be barely acceptable for China and India and it is unclear whether such a growth rate would be high enough to accommodate the various social tensions that have been unleashed by the transformation processes that have taken place in China and India in recent years. For the rest of the world, however, the average annual growth rate of energy consumption would be reduced to less than 0.3%, or virtual stagnation. This would clearly represent prolonged economic difficulties (if not disaster) for the rest of the world.

Both the first and the second scenario assume that the rise of China and India will take place, in the sense that their relative weights in the world economy will increase dramatically in the coming decades. Is it conceivable that the existing high-income countries might use their remaining advantages in technology, military power and ideology to secure a more favourable distribution of world energy resources for themselves?

Under the third scenario, energy consumption in high-income countries is assumed to grow by 1% a year between 2004 and 2050, securing a satisfactory economic growth rate for them. As a result, the energy consumption of high-income countries would increase by nearly 60%, to 8,705 million tonnes of oil equivalent. However, given the projected world energy supply, the rest of the world (including China and India) would have to be content with an average annual growth rate of energy consumption of 0.5% (or a total increase of energy consumption of about 25% between 2004 and 2050). Such a scenario would
be considered to be the failure of Chinese and Indian national development projects.\textsuperscript{13}

Could the projected world energy supply be increased dramatically to accommodate the rise of China and India without sacrificing national development projects in the rest of the world? The projected world energy supply adopts the most optimistic estimate regarding the potential energy supply from renewable sources. It has been argued that the world's high-grade uranium resource cannot support nuclear electricity production on a much larger scale for long. Nuclear fusion is not yet on the horizon. Low-grade uranium resources or breeder reactors could be prohibitively expensive and would involve much worse environmental and safety problems. More realistically, coal production might be expanded massively without much technical difficulty.

Under the fourth (and last) scenario, suppose world energy consumption grows at 2\% a year between 2004 and 2050 so that, by 2050, total world primary energy consumption reaches 27,500 million tonnes of oil equivalent. Energy supply from oil, natural gas, nuclear electricity and renewable sources would follow the same pattern as assumed in the previous section. However, world coal production would be increased greatly to make sure the projected world energy demand is met by supply.

Under this scenario, by 2050, the world would have used up about two-thirds of the total economically recoverable coal and the remaining recoverable coal would last only ten years if world coal consumption keeps growing by 2\% a year. The world's total consumption of fossil fuels would more than double and reach 18,863 million tonnes of oil equivalent, of which coal would account for 81\%. The march towards global environmental catastrophe would be unstoppable.

Limits to Growth and the Future of China and India

Since the nineteenth century, Western countries (Western Europe, North America, Australia, New Zealand, later joined by Japan) have opened up a huge gap with the rest of the world in terms of income, wealth, industrial production, technology and military power. In terms of per capita GDP, the gap between the USA and China, and between the USA and India, increased from about 2: 1 in 1820 to about 20: 1 in 1973 (Maddison, 2003b: 262). However, since the 1980s and the 1990s, China and India have experienced a spectacular economic revival. It appears that after two centuries of Western domination, the world is moving back towards Asian leadership, with China and India again playing the most prominent role. There is also hope that under the new Asian leadership, the world economy could become much more equal in income and wealth distribution (Arrighi and Silver, 1999: 286-9).

Arguably, fossil fuels (coal in the nineteenth century and oil in the twentieth century) have been the material basis of industrial capitalism and Western hegemonies. However, China and India arrive on the world economic stage as the world is entering the declining phase of fossil fuels. The discussions in the previous section suggest that China, India and the rest of the world are confronted with some very difficult and unpleasant choices. Moreover, as discussed earlier, the shortage of liquid and gaseous fuels could turn out to be the binding constraint on the future world economy. In that case, the possible prospects for China, India and the rest of the world would be far worse.
The global energy crisis is only one among many resource and environmental constraints that will set limits to future world economic growth. According to the footprint analysis, the world as a whole is already beyond sustainable limits (Meadows et al., 2006: xiii-xv). Current world agriculture depends heavily on fossil fuels and irrigation. In many parts of the world (including North China and India), aquifers are being depleted at alarming rates. With the decline of fossil fuels, depletion of aquifers, soil erosion and global warming, the world could suffer from dramatic declines in food production in the coming years (Brown, 2003: 23-58; Goldsmith, 2005). In fact, the world per capita grain production peaked in 1984 and has tended to decline since then (Earth Policy Institute, 2006). A recent study concluded that by 2048 the world stocks of all fish species will have collapsed to less than 10% of their peak levels, making fishing impossible (Financial Times, 3 November 2006). If all of the world population was to have the same per capita resource consumption as high-income countries, then the potentially recoverable resources for about one-third of the 36 basic mineral items will have been exhausted before 2050 (Trainer, 2006a).

Assuming that the world population will be 9 billion by 2050, then based on the projected world energy supply, the world’s per capita energy consumption will be no higher than its present level by 2050. If it turns out that there is not much scope for the further expansion of the world’s material consumption, a serious moral and political question is raised. How should the world’s limited material resources and wealth be distributed among the world’s population and between different geographical areas? How can a more equal distribution be accomplished? If it can no longer be accomplished through “upward convergence,” that is, by enlarging the club of “developed countries,” does it have to take place through “downward convergence?” How would such a downward convergence be operated and managed, and which parts of the world would have to bear the cost of adjustment?

How should limited energy and other resources be distributed within each country? In China, India and many countries, there have been sharp increases in economic and social inequality. Until now the majority that have been left behind have at least acquiesced in the hope that at some point in the future they or their children would eventually become part of the “middle class” and have a share in the material comforts. However, if it becomes apparent that such a hope will never materialise, would the majority continue to tolerate the existing inequality and inequity? If not, how could the contradiction be resolved? Will the resolution of this contradiction involve some forms of social explosion, revolution or collapse?

Finally, no matter how these contradictions are to be resolved, the emerging social structure would have to be one that is capable of meeting the population’s basic needs, as well as compatible with ecological sustainability. The sustainability requirement most likely would imply low levels of per capita consumption of material resources. It is beyond the purpose of this article to elaborate on the requirements of such a social structure.

However, to meet the population’s basic needs with low levels of material consumption would require a very high degree of economic and social equality. Moreover, for the high degree of equality to be sustained, some form of social and democratic control over the basic means of production seem to be necessary.
Probably there is not a single society in today’s world that match the social and ecological sustainability requirements proposed here. But Cuba, the only country in the former socialist camp that is still committed to socialist goals, might be close. Cuba has managed to maintain probably the best basic health care and education programs in the Third World despite its economic difficulties. It has also had some success in developing an ecological agriculture. In this respect, the success of India’s Kerala State and Maoist China in meeting the population’s basic needs also provide useful lessons.¹⁵

Notes

¹ Data for world GDP and the GDP of selected countries for the period 1975-2005 are from World Bank Group (2006). The GDP series are extended back to 1829 using data from Maddison (2003a). For the post-2005 period, countries are assumed to grow at the same rate as their respective average annual growth rate between 1995 and 2005.
² The world energy statistics cited in this article, unless stated otherwise, are from IEA (2006).
³ Data for the primary energy consumption of the world and selected countries are from World Bank Group (2006). For the post-2004 period, it is assumed that the annual energy consumption of each country grows at the same rate as the average annual growth rate of energy consumption between 1994 and 2004.
⁴ For complete discussions of peak oil estimates, see Campbell (2005a; 2005b). For mathematical models that apply the Hubbert’s method to the global situation, which correctly predicted peak oil production in the USA, see Korpela (2005). For general discussions of peak oil theories and the critiques, see Heinberg (2003; 2004), Kunster (2005) and Mobbs (2005). The Association for the Study of Peak Oil and Gas Ireland (ASPO Ireland) publishes monthly newsletters (http://www.peakoil.ie), which provide updated oil and gas production profiles and estimated dates of peak production.
⁵ The US Geological Survey (USGS, 2006) put forward a very optimistic but widely cited “mean estimate” of potentially recoverable conventional oil resources at about 3.5 trillion barrels. Campbell (2005c) has criticised the USGS estimate. The December 2006 Newsletter of ASPO Ireland carries an article showing that the actual trajectory of world oil discovery is on a path that would fall below the USGS low estimate of about 2.5 trillion barrels (ASPO, 2006).
⁶ World oil production data from 1960 to 2005 are from EIA (2006a). Projected world oil production for 2010, 2015, 2020 and 2050 are from ASPO (2006). After 2050, the world oil production is assumed to fall at the same annual rate as during 2020-50, about 3% a year. Gas liquids are excluded from the oil production figures.
⁸ The ratios of solar and wind power cost relative to coal-fired power cost used in this paper are somewhat smaller than suggested by Trainer. Trainer’s ratios are based on an estimate of coal-fired power plant capital and fuel cost at $A2.8 billion (Trainer, 2005: ch. 2). But, later, Trainer (2006b) suggested a higher estimate at $A3.7 billion. This paper uses the higher estimate.
⁹ It is often claimed that the prices of solar photovoltaic cells have fallen rapidly in the past, suggesting that they could keep falling in the future. However, evidence from the last few years suggests that photovoltaic cell prices have stabilised (see Hayden, 2004: 197-203; Meadows et al., 2006: 98). Further, in the case of solar thermal and photovoltaic plants, the cost mainly has to do with the “balance of system” cost or the cost of plant construction, which is unlikely to be affected by technological progress.
¹⁰ The definitions of physical potentials of various renewable energies are not necessarily consistent across literature. But the estimates of potentials presented in Table 4 correspond roughly to the concept of “practical potential,” defined as the annual energy that can be extracted from the available energy resource using current or near future technologies, subject to practical exclusion factors (such as land committed to prior use or difficulties in using or distributing energies). It should be emphasised that in many cases future technological advances are subject to the limits of physical laws. For alternative definitions of renewable energy resources, see Boyle (2004: 389).
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11 Vaux (2005) calculated that if coal is used to replace the declining oil supplies, then the world’s total coal reserves would be depleted by 2062, 2071 or 2080 if world energy consumption grows at 3.1%, 2.2% or 1.5% a year, respectively. Vaux ignored the energy loss that would result from the conversion of coal into oil.


13 By the standard of the twentieth century, “failure” of development does not have to involve absolute declines in the levels of economic output. For example, Latin America is considered widely to have “failed” in development in the 1980s and the 1990s. Yet, between 1979 and 2000, the total GDP of Latin America increased by nearly 70% (with an average annual growth rate of 2.5%).

14 On the social and environmental costs of China’s economic growth, see Wen (2005).

15 For discussions on Cuba’s social and ecological achievements and the Kerala experience, see Heinberg (2004: 104-108). For the achievements of Maoist China in basic health care and education, see Li and Zhu (2004). Some people might argue that the European social democracy represents the best hope for social equity and ecological sustainability. But this author would contend that the success of social democracy depends on high levels of material consumption and in fact, to some extent, depends on the economic and environmental exploitation of the Third World. At best, it is not obvious that European-style social democracy could work effectively under Third World conditions. There is a further problem with social democracy. As the experience over the past several decades has suggested, so long as there is economic and political dominance by the capitalist class, there is a strong tendency for social democracy to degenerate into neoliberalism, which is neither equitable nor sustainable.

References


Appendix: Projecting the World Energy Supply 2004-50

In 2004, the world's primary energy supply from oil, natural gas, coal, nuclear electricity and renewable energies (biomass and waste, hydro and others) is 3793, 2311, 2776, 719, and 1460 million tonnes, respectively.

The projections of world oil production from 2005 to 2050 are from ASPO (2006). The world natural gas production is assumed to grow by 1% a year between 2004 and 2025, stay constant between 2025 and 2045, and fall to 80% of the 2045 level by 2050. This is based on Campbell's (2005b: 209-16) estimate.

EIA (2006b) projected that under the reference case scenario, world coal production is expected to grow by 2.5% a year between 2003 and 2030 and world nuclear electricity production is expected to grow by 1% a year between 2003 and 2030. In the current projection, world coal production is assumed to grow by 2.5% a year until 2030 and then fall by 2% a year between 2030 and 2050 to control for global warming. World nuclear electricity production is assumed to grow by 1% a year between 2004 and 2050.

The World Energy Council projects six different scenarios of world energy supply from 2000 to 2050 (including three high-growth scenarios, one middle-growth scenario and two ecologically-driven scenarios). The six scenarios for energy supply from renewable sources in 2050 are as follows: 5500, 5750, 7500, 4400, 5460 and 5180 million tonnes of oil equivalent. All of these scenarios assume a sustained increase in natural gas production and only a moderate decline in oil production, thus failing to take into account the coming peak of the world oil and natural gas production (Boyle, 2004: 424).

In the current projection, total energy production from all renewable sources is assumed to grow by 131 million tonnes of oil equivalent each year between 2004 and 2050, so that the total primary energy supply from renewable sources by 2050 would be 7500 million tonnes, corresponding to the World Energy Council's most optimistic estimate.