WORLD POPULATION AND ENERGY GROWTH:
IMPACT ON THE CARIBBEAN AND THE
ROLES OF ENERGY EFFICIENCY IMPROVEMENTS
AND RENEWABLE ENERGIES

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by

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INTRODUCTION.

The world's population in 1995 was estimated as 5.7 billion people, and its rate of growth as 1.6% per year. The population in 2100, projected by the World Bank (1994) is estimated to be 10 to 12 billion, increasing at only 0.2% per year. A study of the fertility of women, throughout the world, shows a snapshot rate for 1992 decreasing systematically with increasing annual commercial energy use per capita (Goldemberg, 1995). An analysis of historical data of the related population growth versus annual per capita commercial energy use (United Nations, 1965, 1975, 1977, 1987, and 1994), shows a similar dynamic trend over the last 30 years. The majority of transitional countries i.e., those whose population growth rate is decreasing but is not at the low or zero level of developed countries, show a population growth rate following a simple pattern of decrease as the annual per capita commercial energy use increases. This dynamic change is shown in Figure 1, for countries which have much of the world's population. It appears from this picture that the per capita annual energy use is a good surrogate measure for all of those factors that influence population growth - the emancipation of women, the standard of living, education, etc.

In a separate paper (Sheffield, 1997), a discussion is given of the consequences of these trends on future energy demand, if they continue to hold as the world's population follows the World Bank's kind of growth trajectory. The growth rates of the various countries may be characterized in terms of the annual, per capita, commercial energy use (E) and another factor, described as cultural effects (Ec). This factor allows for the fact that there is spread in growth rates for the different countries at any given per capita energy use. Ec is the intercept of a simple formula, which characterizes the typical trends, on the zero growth rate axis:

\[
\text{Growth (\%)} = \frac{(E_c - E)}{(1.6 \times E^{0.38})}, \text{ for } E \leq E_c
\]

Where E and Ec are in tonnes of oil equivalent per capita per year (toe/cap.a).

As can be seen from Figure 1, most of the transitional countries fit within the boundaries set by \(E_c = 2.0\) to \(3.25\) toe/cap.a.
This paper describes, briefly, the consequences for the world and the Caribbean of a continuation of these trends as the world's population continues to grow.

THE ROLE OF ENERGY EFFICIENCY

Today, the world uses about 9,000 Mtoe/a of energy, including about 1,000 Mtoe/a of biomass energy; i.e., about 1.5 toe/cap.a on average. However, this average comes from a developed world use of some 6,000 Mtoe/a for a population of about 1.3 billion people, and a rest of the world use of about 4.7 Mtoe/a for a population approaching 4.5 billion people, or 0.67 toe/cap.a.

It is generally assumed that the developed world population will increase relatively little by 2100 and, absent any other changes, if standards of living continue to rise, i.e., higher energy use per capita, its energy use might rise to say around 8,000 Mtoe/a. However, to meet the World Bank's projections, assuming growth-energy trends continue the per capita energy use in the rest of the world will need to be in the range of 2.0 to 3.25 toe/cap.a (say 2.5 toe/cap.a on average). With the rest of the world's population of 8.7 to 10.7 billion people this implies an energy use of 22,000 to 27,000 Mtoe/a. The world's total energy use would be in the range of 30,000 to 35,000 Mtoe/a.

Ameliorating this potential increase will be energy efficiency improvements in both energy production and end-use since, presumably, it is the energy used productively that counts not that wasted. Recent studies, show that energy efficiency improvements, from improved technology and systems, averaging around a factor of two are quite possible. If the developed world were to use energy efficiency improvements to constrain energy use, while increasing standard of living, it might continue to use 6,000 Mtoe/a. Similarly, if the rest of the world achieved a factor of two improvement in the average efficiency of energy production and use, it might achieve its goals with 11,000 to 14,000 Mtoe/a. Thus the World Bank's estimate of a stable population of 10 to 12 billion people might be accompanied by improved standards of living across the world and an energy use of around 17,000 to 20,000 Mtoe/a.

THE ROLE OF FOSSIL FUEL

Fossil fuels are presently abundant and relatively cheap, see Table 1. They offer a way for developing countries to raise their per capita energy use and achieve the social and economic conditions, which are associated with low population growth rates.
Table 1. Proven plus Projected Fossil Reserves.

<table>
<thead>
<tr>
<th>Region</th>
<th>Oil +NGL Mtoe</th>
<th>Gas Conventional</th>
<th>Oil Shale +bitumen (a)</th>
<th>Coal (b) Mtc</th>
</tr>
</thead>
<tbody>
<tr>
<td>N. Amer</td>
<td>8,670</td>
<td>8,430</td>
<td>(243,820)</td>
<td>847,600</td>
</tr>
<tr>
<td>L. Amer</td>
<td>56,620</td>
<td>15,810</td>
<td>(32,950)</td>
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<td>Eur. OECD</td>
<td>4,120</td>
<td>6,690</td>
<td>(1,920)</td>
<td>297,210</td>
</tr>
<tr>
<td>FSU + CEE</td>
<td>8,300</td>
<td>49,010</td>
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<td>2,989,520</td>
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<td>Pac. OECD</td>
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<tr>
<td>Total</td>
<td>212,000</td>
<td>136,240</td>
<td>(563,650)</td>
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(a). The amounts of oil shale and bitumen listed are the total proven and projected reserves. The recoverable percentage today is typically around 10%. Improvements in technology are expected to increase the recovery rates and lower the costs.

(b). All of the "coal" (bituminous, sub-bituminous, and lignite) is treated as if it has a calorific value similar to bituminous coal - 29.3 GJ/tonne. This is optimistic, and may be taken as reflecting a hope that more is found or recoverable than in these estimates.

(c). Large amounts of unconventional gas - 450,000 Mtoe are projected to exist. Additional occurrences of fossil fuels, not known to be recoverable, 12,000,000 to 25,000,000 Mtoe.

However, while there is an abundance of fossil energy, it is both finite and unevenly distributed. It is sensible for each country, even those presently endowed with fossil resources, to prepare for a future when indigenous, alternative energy sources will increase in importance. This lesson is clear from the consequences of previous oil shocks. For example, in the United States, between 1973 and 1987, the price of oil increased about $30 US per barrel on average over the underlying price trend (1993$). The incremental cost of oil to the U.S. during this period was about $1,000 billion (1993 $) (Greene, 1996). The conditions that held in 1973 and contributed to the vulnerability of a shock still hold today: OPEC's share of
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the market is ≥ 35%; there are limited world oil stocks, about 57 days (44 days in 1973); there remains low elasticity in the use of oil in most countries. For example, if oil prices went up by $U.S. 200 per tonne, it would cost Barbados an extra $U.S. 58 million to sustain oil imports for a year.

Research and Development (R&D) of energy technologies and systems should be viewed as an insurance against the potential costs of oil shocks, and other external costs such as environmental and health effects associated with the poor use of energy.

CONSEQUENCES OF A LIMITED PER CAPITA ENERGY GROWTH

On the assumption that the trends in population growth versus annual per capita commercial energy use continue, consider the following two cases. Case 1: The energy use is raised rapidly to the level (E_C) at which the growth rate is zero. Case 2: The annual per capita energy use (E) and population growth rate are constant.

Example: E = 0.5 toe/cap.a. and E_C = 2.5 toe/cap.a. The initial population is 1 billion people. Use the formula above.

After about 163 years the integrated energy use is the same, but
- in Case 1, the population remains at 1.0 billion while,
- in case 2 it rises to 14 billion!

While neither scenario is particularly realistic, the cases serve to illustrate the point that it is important to use the present period of low price, easily transportable fuel to get the population growth rate down in every sector of the world.

THOUGHTS FOR THE CARIBBEAN NATIONS

Caribbean nations are following the same trends in population growth as the rest of the world, see Figure 2. Most Caribbean nations are heavily dependent on imported oil; Trinidad and Tobago being the notable exception. Energy efficiency improvements, demand side management, integrated resource planning will be crucial to a sustainable future, robust against fossil energy disruptions (e.g., Hill, 1994).

Renewable energies are an indigenous resource, a protection against fluctuating fossil energy prices, convenient for distributed applications, and environmentally attractive.
Solar energy seems to be the most widespread and largest opportunity though, presently, unit cost can be an issue. (At the conference, Oliver Headley and his colleagues described a number of innovative applications for today, see the proceedings).

Wind power can also play an important role.

However, for both of these renewable energy sources, an effective storage system is important to maximizing their use. Energy storage systems include:
- Thermal systems,
  - chilled water, ice or eutectic salt, and
  - brick, concrete, or freeze-melt materials.
- Mechanical systems,
  - flywheels (45 Wh/kg),
  - pressurized hydraulic fluids (2 Wh/kg),
  - compressed air storage + fuel to heat the air prior to passing it through a turbine.
- Electromechanical,
  - lead-acid (44 Wh/kg),
  - sodium-sulfur (150 Wh/kg),
  - zinc-bromine (70-80 Wh/kg),
  - zinc-air (220 Wh/kg).
- Hydrogen for fuel cells.
- Superconducting magnetic energy storage - tends to be expensive.

Sustainable biomass residues, municipal waste, and animal wastes are valuable energy resources.

Biomass energy crops might be viable in Guyana and Surinam. Hydropower (Jamaica) and geothermal energy (St Lucia) are available in some countries.

Past and projected costs of energy for a number of these systems are shown in Figure 3.

STATISTICS FOR SOME CARIBBEAN NATIONS

The populations, population densities, annual commercial energy consumption, and potential, per capita, per year solar energy for given assumptions, for the members of the Caribbean Academy of Sciences (CAS) are shown in Table 2.
Table 2. Statistics for Caribbean countries of the CAS.

<table>
<thead>
<tr>
<th>Country</th>
<th>Pop (M) 1991</th>
<th>Pop km²</th>
<th>Births-Deaths %</th>
<th>toe/cap.a 1991</th>
<th>toe/cap.a (0.1%) solar elec (a)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barbados</td>
<td>0.255</td>
<td>593</td>
<td>0.68 1989</td>
<td>1.13</td>
<td>0.08 (0.23)</td>
</tr>
<tr>
<td>Guadeloupe</td>
<td>0.345</td>
<td>202</td>
<td>1.16 1986</td>
<td>0.88</td>
<td>0.22 (0.67)</td>
</tr>
<tr>
<td>Guyana</td>
<td>0.800</td>
<td>4</td>
<td>1.91 1985-90</td>
<td>0.35</td>
<td>11.3</td>
</tr>
<tr>
<td>Jamaica</td>
<td>2.366</td>
<td>215</td>
<td>1.94 1984</td>
<td>0.59</td>
<td>0.21 (0.63)</td>
</tr>
<tr>
<td>St Lucia</td>
<td>0.153</td>
<td>246</td>
<td>1.58 1989</td>
<td>0.41</td>
<td>0.18 (0.55)</td>
</tr>
<tr>
<td>Surinam</td>
<td>0.429</td>
<td>3</td>
<td>2.45 1986</td>
<td>1.32</td>
<td>15.0</td>
</tr>
<tr>
<td>Trinidad and Tobago</td>
<td>1.253</td>
<td>244</td>
<td>1.39 1989</td>
<td>6.08</td>
<td>0.18 (0.55)</td>
</tr>
</tbody>
</table>

(a). Average sunlight is in the range 250 - 300 W/m².  
PV efficiencies in the range 15 -25% are expected at a "reasonable" price.  
Solar electric power at around 60 Wₑ/m² should be possible.  
The numbers in this column are the potential solar electric power per capita per year, if 0.1% of the land were covered with solar collectors.  
Note that, for example, the replacement fossil energy could be 3 times larger (figures in parentheses).  

It can be seen that Guyana and Surinam have more than enough area to meet energy needs through solar energy. Even for the higher population density, island nations solar can play a major role for the conditions discussed.

POTENTIAL ENERGY EFFICIENCY IMPROVEMENTS

Examples of opportunities, e.g., see Hill, 1994, are:
• Replacing retiring equipment with more efficient equipment:
  - lighting, refrigeration, cooling, stoves, motors, etc,
  - transportation;
• improved construction and retrofit of buildings;
• Use of solar heating;
• Improved electricity and water production,
  - low flow faucets and shower heads;
• Cogeneration;
• Electrical load management.

SUMMARY

Historical trends for transitional countries, including some in the Caribbean, show a correlation between population growth rate and the annual per capita commercial energy use - a surrogate measure of the many factors that influence population growth.

If the trends continue to hold, an increase in per capita energy will be important to stabilizing populations of the transitional countries.

Energy efficiency improvements will be crucial to facilitating the transition. Many opportunities exist for the more effective use of energy - cogeneration, coproduction of water and energy, and the use of more efficient equipment.

While, today, fossil energy is relatively cheap and available, all countries with a high percentage of imported energy are vulnerable to disruptions (oil shocks).

The use of alternative (indigenous) sources of energy, when they make economic sense, will provide protection against disruptive external events. For the Caribbean, solar power, wind power, and the use of biomass residues (energy crops in countries with a low population density) make long-term sense. Hydropower and geothermal power are important resources for some countries.

For intermittent energy sources, storage of one kind or another is essential to maximizing their usefulness. Generally, R&D into providing advances and solutions relevant to Caribbean Nations should be a high priority for the area. Such R&D should be regarded as an insurance policy against the potential cost of oil shocks, and environmental and health effects associated with the poor use of energy.
REFERENCES


J.Sheffield, Population Growth and the Role of Energy Use Per Capita. Accepted by the Journal of Technological Forecasting and Social Change, April, 1997.


Figure 1. Population growth rate versus annual energy per capita and trend curves for the period 1965 to 1995.
Figure 2. Population growth rate versus annual energy per capita for the period 1970 to 1990.
Figure 3. Past and projected energy costs for a number of renewables.