Addendum to 'Meeting India's future needs of electricity through renewable energy sources'

In a recent article[1], the present author had attempted to answer the question: can renewable energy sources eventually supply India's electricity needs in the future? The estimates made indicated that after assuming a per capita electricity need of 2000 kWh/annum and a stabilized population of 1700 million by 2070, India would need 3400 TWh/yr. As opposed to this need, a systematic analysis of the information available on all the renewable energy sources indicated that the total potential is only around 1229 TWh/yr. Thus it was concluded that in the future as fossil fuels get exhausted, renewable energy sources alone would not suffice for meeting India's electrical energy needs.

A number of readers of *Current Science* have written to the author commenting on various aspects of the article. The comments have been concerned with estimating the future needs for electricity and the potential of some renewable sources for supplying electricity. No one has questioned the overall conclusion of the article. The purpose of this note is to take into account the useful comments received.

In the article[1], the pioneering studies of Goldemberg *et al.*[2,3] were used to suggest that the most viable option for India would be to eventually provide an annual per capita availability of around 2000 kWh in the future. It was felt that such a frugal use of energy would be the only way to ensure sustainable development. Most readers agree with the logic of this argument. However, it has been pointed out that it would be unrealistic to expect India to settle for such a low benchmark when in most western countries, the per capita availability is already greater than 10,000 kWh. It has been suggested that India should aim for providing about 5000 kWh per annum in the long run. Keeping this in mind, we will specify the future need for electricity over a range of values corresponding to a minimum of 2000 kWh and a maximum of 5000 kWh. It is generally accepted that the population will stabilize around 1700 million in about 50 or 60 years. Thus, the production of electricity would have to range from 3400 to 8500 TWh.

Two types of comments have been made with reference to the procedure adopted for calculating the electricity produced via the solar thermal and solar PV routes:

(1) It has been pointed out that instead of assuming that the solar power plants would be located on open, non-agricultural land, it would have been more appropriate to assume that they would be located on barren, uncultivated land. In India, the area of barren and uncultivated land is 194,000 sq. km. We will approximate this to be 200,000 sq. km. Other open, non-agricultural lands fall under the categories of: (i) area under nonagricultural use; (ii) permanent pasture and grazing land, and (iii) fallow land. These categories would normally not be available for setting up solar power stations.

(2) It has also been pointed out that a much larger percentage of barren, uncultivated land could probably be acquired for locating solar power than the 1% value used in ref. 1 with respect to open, nonagricultural land. The percentage could range from 5 to 20. Acquiring more than 20% would probably be impossible. Using values of 5%, 10% and 20% and following the earlier procedure, we obtain range of values for the generation capacity and for the annual electricity production by the solar thermal and PV routes together (Table 1).

From table 3 of ref. 1, it is seen that the potential of all renewable sources (excluding solar thermal and PV) is 791 TWh. Adding this number to the range estimated for the solar thermal and PV routes, the total potential of renewable energy sources comes out to be 1229 TWh with 5% land usage, 1667 TWh with 10% usage and 2543 TWh with 20% usage. This is a more promising picture from the renewable energy view-

Table 1. Variation of electricity produced via the solar thermal and PV routes with percentage of barren, uncultivated land acquired

Per cent of land acquired	5	10	20
Generation capacity (MW)	250,000	500,000	1,000,000
Annual electricity production (TWh)	438	876	1,752

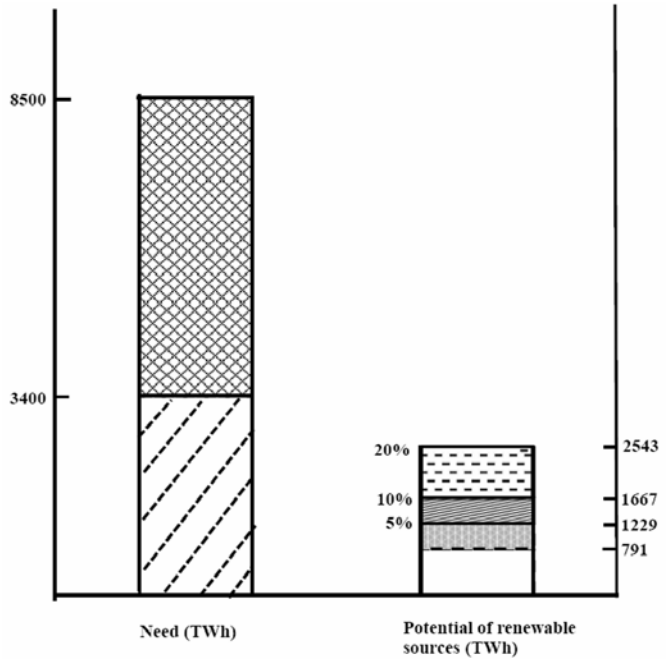

Figure 1. A comparison of the annual need for electricity and the available potential of renewable sources.

point. Nevertheless, there is still a significant shortfall compared to the minimum requirement of 3400 TWh. If the need is fixed at 8500 TWh, the short fall would be enormous. The situation is illustrated in Figure 1.

Thus, the overall conclusion remains the same as that in ref. (1). The future needs of electricity in India cannot be met from renewable energy sources alone, even if the electricity needs are kept to a minimum and the potential of renewable energy sources is fully exploited.

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S. P. SUKHATME

Department of Mechanical Engineering,
Indian Institute of Technology Bombay,
Powai,
Mumbai 400 076, India
e-mail: spsiitb@yahoo.co.uk

Mitigating pollution may help prevent violent conflicts

Decreased social security is a potential risk of climate change, which makes mitigating the effects increasingly urgent. Environmental change produced by climate change could strain societies vulnerable to conflict enough to induce violent outbreaks[1]. Recently, it has been proposed that reducing the emission of short-term climate changing pollutants (i.e. black carbon and methane) can slow down the effects of climate change[2], making these measures of interest.

Reducing the emission of black carbon and methane may slow down the rate of rising global temperature[2], which is an important component of reducing the risk of potential violent conflicts. Black carbon and methane, both potent climate-change inducers, are less-publicized pollutants that cycle quickly through the atmosphere. Measures taken to lower their emissions would prevent global temperatures from rising a critical 2°C above pre-industrial periods by 2050 and simultaneously increasing global crop production[2].

Research has shown that, historically, rapid changes in temperature are associated with violent conflicts. For example, there is a correlation between rising or falling of temperatures and the risk of wars[3,4]. Indeed, rising temperatures may also increase social tensions in the Middle East, increasing the risk of conflicts[5]. The reason why unstable global temperatures are associated with violence is unclear. However, one reason could be that unstable temperatures lower agricultural production, causing societies to fight over resources[3–5]. Therefore, increased crop yield due to mitigation of black carbon and methane could help ease the strain of rapidly changing temperatures.

Another potential danger that arises from increasing global temperatures is the possibility of flooding. Sea levels will rise rapidly over the next century[6], which is possibly due to climate change-induced melting of glaciers and ice caps[7]. Rising sea levels may increase flooding, which can cause violent conflict. An example is the flooding of New Orleans by Hurricane Katrina, where the natural disaster caused chaos by exploiting pre-existing social vulnerabilities[8]. How will flooding affect an area that is less financially and socially stable? In an impoverished megacity such as Lagos, it could destabilize the city and its surrounding region by creating an even more severe conflict[9]. Thus slowing down the effects of climate change via reduced black carbon and methane missions would likely reduce the risks of flooding, which would subsequently reduce the risk of violence in socially fragile coastal cities.

Climate change is intervening with the course of our future; executing means of slowing it down could help prevent violent conflicts. However, it must be stressed that climate change alone is unlikely to induce conflicts, though their causes are never one-dimensional. They arise from complex interactions between political, economic and environmental conditions. Still, decreased living conditions created by climate change will likely strain pre-existing social vulnerabilities within unstable impoverished regions. Thus, reducing the emissions of black carbon and methane could have great influence in preventing violence.

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ALVIN Y. CHAN

Department of Ecology and Evolutionary Biology,
University of California,
621 Young Drive South, Los Angeles,
CA 90095-1606, USA
e-mail: cyh@ucla.edu