## SUPPLEMENTARY READING

### Text A Solar power from space

Two general concepts have been proposed for delivering solar power to Earth from space. In one, Peter Glaser of Arthur D. Little, Inc. (Cambridge, MA), proposed in 1968 that a huge satellite in geosynchronous orbit around Earth could dependably gather solar power in space. In the second concept, discussed here, solar power would be collected on the moon. In both ideas, many different beams of 12-cm wavelength microwaves would deliver power to receivers at sites located worldwide. Each receiver would supply commercial power to a given region. Such a receiver, called a rectenna, would consist of a large field of small rectifying antennas. A beam with a maximum intensity less than 20 % of noontime sunlight would deliver about 200 W to its local electric grid for every square mete rectenna area. Unlike sunlight, microwaves pass through rain, clouds, dust, and smoke. In both scenarios, power can be supplied to the rectenna at night.

The space-based technology poses little risk to human health. A person standing in the microwave beam we absorb about 2 % of the incident power and feel slightly warmer. Nonetheless, the general population would be restricted from the industrially zoned beam area, and workers could be easily shielded. Such a beam does not pose a hazard to insects or birds flying through it. Microwave intensity under and horizontally beyond the rectenna will be far less than is permitted for continuous exposure of the general population.

### Text B Lunar solar collector

Fortunately, in the Lunar Solar Power (LSP) System, an appropriate, natural satellite is available for commercial development. The surface of Earth’s moon receives 13,000 power. The LSP System uses 10 to 20 pairs of bases - one of each pair on the eastern edge and the other on the western edge of the moon, as seen from Earth - to collect on the order of 1 % of the solar power reaching the lunar surface. The collected sunlight is converted to many low-intensity beams of microwaves and directed to rectennas on Earth. Each rectenna converts the microwave power to electricity that is fed into the local electric grid. The system could easily deliver the 20 TW or more of electric power required by 10 billion people. Adequate knowledge of the moon and practical technologies has been available since the late 1970s to collect this power and beam it to Earth.

## Text C Hospitable environment

Unlike Earth, the surface of the moon is compatible with the construction of extremely large areas of thin solar collectors and their dependable operation over many decades. No oxygen, water, atmospheric chemicals, or life is present to attack and degrade thin solar collectors. No wind, rain, ice, fog, sleet, hail, driven dust, or volcanic ash will coat and mechanically degrade them. Moonquakes and meteor impacts produce only tens of nanometers of ground motion. Micrometeors erode thin solar collectors less than 1 mm every 1 million years.

The production machinery constructs the lunar power bases primarily from materials that are widely available on the moon. Bulk soil and separated soil fractions can be melted by concentrated sunlight and formed into thin glass sheets and fibers or sintered into rods, tubes, bricks, and more complex components. Silicon, aluminum, and iron can be chemically extracted from lunar soil for fabrication of solar cells. Trace elements can be brought from Earth for doping solar cells. It is estimated that a kilogram of materials transported from Earth to the moon would result in the delivery of 200 times as much electric energy to Earth as a kilogram of a solar-power satellite.

The LSP System is a reasonable alternative to supply Earth's needs for commercial energy without the undesirable characteristics of current options. The system collects sunlight on the moon's surface, converts it to usable energy, and beams the energy to receivers on Earth. The system can be built on the moon from lunar materials and operated on the moon and on Earth using existing technologies.

## Text D How much water in the world?

Water is absolutely decisive for human survival, and the Earth is called the Blue Planet precisely because most of it is covered by water: 71 percent of the Earth's surface is covered by water, and the total amount is estimated at the unfathomably large 13.6 billion cubic kilometers. Of all this water, oceans make up 97.2 percent and the polar ice contains 2.15 percent. Unfortunately seawater is too saline for direct human consumption, and while polar ice contains potable water it is hardly within easy reach. Consequently, humans are primarily dependent on the last 0.65 percent water, of which 0.62 percent is groundwater.

Fresh water in the groundwater often takes centuries or millennia to build up - it has been estimated that it would require 150 years to recharge all of the groundwater in the United States totally to a depth of 750 meters if it were all removed. Thus, thoughtlessly exploiting the groundwater could be compared to mining any other nonrenewable natural resource. But the constant movement of water through oceans, air, soil, rivers, and lakes in the socalled hydrological cycle continuously replenishes groundwater. The sun makes water from the oceans evaporate; the wind moves parts of the vapor as clouds over land, where the water is released as rain and snow. The precipitated water then either evaporates again, flows back into the sea through rivers and lakes, or finds its way into the groundwater.

Looking at global water consumption, it is important to distinguish between water withdrawal and water use. Water withdrawal is the amount of water physically removed, but this concept is less useful in a discussion of limits on the total amount of water, since much of the withdrawn water is later returned to the water cycle. In the EU and the US, about 46 percent of the withdrawn water is used merely as cooling water for power generation and is immediately released for further use downstream. Likewise, most industrial uses return 80-90 percent of the water, and even in irrigation 30-70 percent of the water runs back into lakes and rivers or percolates into aquifers, whence it can be reused. Thus, a more useful measure of water consumption is the amount of water this consumption causes to be irretrievably lost through evaporation or transpiration from plants. This is called water use.

Over the twentieth century, Earth's water use has grown from about 330 $km^3$ to about 2,100 $km^3$.

So, if the global use is less than 17 percent of the readily accessible and renewable water and the increased use has brought us more food, less starvation, more health and increased wealth, why do we worry?

## Text E The three central problems

There are three decisive problems. First, precipitation is by no means equally distributed all over the globe. This means that not all have equal access to water resources and that some countries have much less accessible water than the global average would seem to indicate. The question is whether water shortages are already severe in some places today. Second, there will be more and more people on Earth. Since precipitation levels will remain more or less constant this will mean fewer water resources for each person. The question is whether we will see more severe shortages in the future. Third, many countries receive a large part of their water resources from rivers; 261 river systems, draining just less than half of the planet's land area, are shared by two or more countries, and at least ten rivers flow through half a dozen or more countries. Most Middle Eastern countries share aquifers. This means that the water question also has an international perspective and - if cooperation breaks down - an international conflict potential.

Beyond these three problems there are two others issues, which are often articulated in connection with the water shortage problem, but which are really conceptually quite separate. One is the worry about water pollution, particularly of potable water. While it is of course important to avoid water pollution in part because pollution restricts the presently available amount of freshwater, it is not related to the problem of water shortage *per se*. Consequently, we will look at this problem in the chapter on potable water and pesticides.

The second issue is about the shortage of access to water in the Third World, a problem, that we have already looked at. This problem, while getting smaller, is still a major obstacle for global welfare. In discussing water shortage, reference to the lack of universal access to drinking water and sanitation is often thrown in for good measure, but of course this issue is entirely separate from the question of shortages. First, the cause is not lack of water (since human requirements constitute just 50-100 liters a day which any country but Kuwait can deliver) but rather a lack of investment in infrastructure. Second, the solution lies not in cutting back on existing consumption but actually in increasing future consumption.

Finally, we should just mention global warming and its connection to water use. Intuitively, we might be tempted to think that a warmer world would mean more evaporation, less water, more problems. But more evaporation also means more precipitation. Essentially, global climate models seem to change where water shortages appear (pushing some countries above or below the threshold) but the total changes are small (1-5 percent) and go both ways.

## Text F Not enough water?

Also, there’s a fundamental problem when you only look at the total water resources and yet try to answer whether there are sufficient supplies of water. The trouble is that we do not necessarily know haw and how wisely the water is used. Many countries get by just fine with very limited water resources because these resources are exploited very effectively. Israel is a prime example of efficient water use. It achieves a high degree of efficiency in its agriculture, partly because it uses the very efficient drip irrigation system to green the desert, and partly because it recycles hold wastewater for irrigation.

By far the largest part of all water is used for agriculture - globally, agriculture uses 69 percent, compared to 23 percent for industry and 8 percent for households. Consequently, the greatest gains in water use come from cutting down on agricultural use. Many of the countries with low water availability therefore compensate by importing a large amount of their grain.

Summing up, more than 96 percent of all nations have at present sufficient water, resources. On all continents, water accessibility has increased per person, and at the same time an ever higher proportion of people have gained access to clean drinking water and sanitation. While water accessibility has been getting better this is not to deny that there are still widespread shortages and limitations of basic services, such as access to clean drinking water, and that local and regional scarcities occur. But these problems are primarily related not to physical water scarcity but to a lack of proper water management and in end often to lack of money - money to desalt sea water or to increase cereal imports, thereby freeing up domestic water resources.

## Text G Will it get worse in the future?

The concerns for the water supply are very much concerns that the current problems will become worse over time. As world population grows, and as precipitation remains constant, there will be less water per person, and using Falkenmark's water stress criterion, there will, be more nations experiencing water scarcity.

The problem of water waste occurs because water in many places is not well priced. The great majority of the world's irrigation systems are based on an annual flat rate, and not on charges according to the amount of water I consumed. The obvious effect is that participants are not forced to consider whether all in all it pays to use the last liter of water when you have first paid to be in, water is free. So even if there is only very little private utility from the last liter of water, it is still used because it is free. This is yet another example of The Tragedy of the Commons, as we saw it described in the section on fisheries.

This is particularly a problem for the poor countries. The poorest countries use 90 percent of their water for irrigation compared to just 37 percent in the rich countries. Consequently, it will be necessary to redistribute water from agriculture to industry and households, and this will probably involve a minor decline in the potential agricultural production (i.e. a diminished increase in the actual production). The World Bank estimates that this reduction will be very limited and that water redistribution definitely will be profitable for the countries involved." Of course, this will mean increased imports of grain by the most water-stressed countries, but a study from the International Water Management Institute indicates that it should be possible to cover these extra imports by extra production in the water abundant countries, particularly the US.

At the same time there are also large advantages to be reaped by focusing on more efficient household water consumption.