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ENTREPRENEURIAL ACTUARIES SECTION

Entrepreneurial Actuaries Section Leadership

William Ely, Editor

Sustainable Production of Food for Growing World Population

by Oz Ben-Ami

Entry for Society of Actuaries Entrepreneurial Actuaries Section 2010 Papers Competition

Executive Summary

Over the last few centuries, the global population has grown at an unprecedented rate. The major causes are decreasing mortality rates, advancing technology, and better access to healthcare, food, and water. In 1800, economist Thomas Malthus warned that this growth was unsustainable due to inherent resource limitations of the planet. He predicted that the growth could only last until a certain population capacity was reached, at which point the population would be checked by famine, war, disease and slower reproduction induced by poverty. Recent research shows that after a period of unconstrained growth we are nearing the food producing capacity of arable lands. This, combined with uneven distribution of resources and drought, is causing an impending world food crisis.

I will analyze the expected food shortage in terms of the inherent resources of land, energy, water and labor. I propose a system of combined solar-powered desalination and irrigation agriculture in drylands as both a scalable model for long-term population sustainability and a profitable investment in the short term.

Background

The main constraint on human population in the foreseeable future is cultivable land for food agriculture. Though only an estimated 38 percent of the potential arable land (for rain-fed cultivation) in the world is currently in use for agriculture, most of the remaining land is not readily available. Some of the land is forest, which provides necessary assimilation of carbon dioxide and other valuable services. The rest of the arable land is either occupied by human settlement, or savannas and

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other grasslands, which not only form large ecosystems for diverse and often unique wildlife, but are also utilized as pasture for the production of livestock (WSR 39-40). Most of the remaining land is made of desert or polar ice. Therefore, existing arable land cannot be relied on to supply a growing population.

This lack of land can be demonstrated by another approach. It has been estimated that sustainable rain-fed agriculture on all cultivable lands can support a maximum of about 10-20 billion people worldwide. Superficially, this seems to remove the threat of overpopulation in the foreseeable future as the population is not projected to exceed these amounts in the next century. However, the need for forests and pastureland, and the difficulty of implementing sustainable high-yield agriculture globally, implies that the total capacity in practice may be significantly lower than the above estimate. Additionally, the uneven distribution of both cultivable land and population, as well as the economic constraint of uneven wealth distribution, mean that a significant portion of the population will continue to face food insecurity.

Proposed Solution

To summarize, conventional rain-fed cultivation of arable land must be supplemented by other means. I will demonstrate that the most sustainable solution is use of the desert. The desert has two important advantages: it provides cheap land with little current utility, and it provides abundant amounts of solar energy. However, the main challenge of cultivating the desert is the necessary creation of artificial freshwater. However, this paper proposes a profitable and sustainable model for farming of the desert, using irrigation with water provided by desalination, which is in turn power by solar energy.

Though desalination and solar power generation have in the past been considered uneconomic processes that cannot compete with traditional power and freshwater sources recent technological advances have caused their prices to decrease sufficiently to allow their use. Their advantages are further utilized in the desert environment.

A small prototype of a comprehensive sustainable desert farming solution would have the following components:

- 10,000 m^3/day desalination plant using reverse osmosis technology
- 2MW Concentrated Solar Power plant
- 600 hectare farm plot
- Residential and commercial center for workers and others

Description of the Food Creation Process

Energy from the sun will be converted by the CSP plant to electrical power, at a rate of 2MW. This electrical power will be used to directly power an adjacent desalination plant that has a capacity of 10,000 m^3/day. The water from the desalination plant will be directed using drip irrigation to a plot of land. A water-efficient crop will be harvested by workers living on-site and sold for a profit.

Detailed Cost Analysis

Based on recent similar projects, the power plant will be built using an estimated initial capital cost of about $9 million for installation and associated costs. Ongoing maintenance will require a team of at most three full-time employees or a part-time equivalent. The desalination plant will cost around $12 million for a capacity of 10,000m^3/day, again based on recent market research. Currently available technologies use approximately 4kWH/m^3, so the plant will need a constant energy input of about 1.5-2 MW at maximum capacity. Ongoing desalination costs, other than electricity, are expected to be around $600,000 annually. Using stock values from the UN's Food and Agriculture Organization, 1 m^3 of irrigation water can produce, for example, 4-7 kg of potatoes, 8-10 kg onion, or 5-8kg of watermelon. For simplicity, it will be assumed that the entire plot is planted with watermelon year-round, or that irrigation rotates between different land plots in different seasons. Watermelon is highly suitable for the hot, dry climate of the desert because of its tolerance for high temperatures and low water needs. Using a low value of 25 tons/hectare for annual watermelon yield, 600 hectares of land would produce 15,000 tons annually, using 3,000,000 m^3 of water, or about 8,000 m^3/day. According to FAO data, average trade price (total value traded/total volume traded) of watermelon worldwide in 2006 was $393/ton, up from a 10-year average of $313/ton. Using a conservative estimate of $300/ton yields an annual revenue of $4.5 million. Labor intensity of the agriculture is assumed to be approximately 0.5 workers/hectare, as is typical for the region. The costs for labor, at about $2000/person/year, add up to about $600,000/year. Other agricultural costs, including fertilizers, are estimated at $300,000/year.

Using values of $23 million for the original investment (including $2 million for efficient interfaces between the components and other miscellaneous costs), $3.0 million for annual profit, and 25 years for the economic lifetime of the project, the internal rate of return is calculated to be 12.3 percent. This value is calculated using current prices and technology and a fully resource-sustainable process. In practice, profitability can be further improved by initially relying partially on non-renewable energy and water resources, and gradually phasing in greater use of solar power and desalination as their prices become relatively lower.

Scalability

By design, this model can easily be implemented on a much higher scale: the only technical inputs are land, seawater, and solar power, which are almost unlimited, and labor, which is inexpensive in the region.

Look to the Future

Over the next few decades, the inherent trends which make this model profitable will increase. Technological costs for both solar power and desalination are decreasing exponentially, while greater population growth and evolving diets will spur an ever-growing demand for food. Technologies currently in development include nano-filters that would drastically reduce the cost of Reverse Osmosis desalination, as well as innovative ways to build cheaper solar power plants. In addition, research is being done on generation of nitrogen fertilizer, which is currently synthesized using natural gas, using electrolysis to provide hydrogen. This would remove yet another dependency on diminishing fossil fuel reserves. In the long term, this general model can be used to effectively cultivate the resources of the desert, and even allow permanent de-desertification and large-scale settlement.

Necessary Research and Alternatives

Although this model is expected to be profitable, there is much room for improvement. Ongoing research is needed to correctly choose the best crops for the desert environment, considering water efficiency and global market demand in a particular year. In addition, there will likely be considerable cost-saving potential in more efficient integration of different components of the desalination plant and solar power. For example, by using thermal desalination, solar heat could be used directly in desalination without the intermediary conversion to electricity. Also, different systems should be evaluated for effective utilization of labor. Instead of simply offering jobs, the company could offer land for sale or lease, or perhaps for free in exchange for a set share of the revenue, and present potential farmers with an opportunity to become independent and succeed on their own. Other revenue opportunities include selling power, water, and commercial real estate to other parties. The relative profitability of such opportunities will have to be considered in more detail, but the diverse options for future revenue ensure future profitability in a variety of possible markets.

References

German Aerospace Center (DLR), Institute of Technical Thermodynamics Section Systems Analysis and Technology Assessment. November 2007. *AQUA-CSP Study: Concentrating Solar Power for Seawater Desalination*, Final Report http://www.dlr.de/tt/aqua-csp

U.S. Department of Energy, Energy Efficiency and Renewable Energy, *2008 Solar Technologies Market Report* Nrel.gov/applying_technologies/pdfs/2008_solar_market_report.pdf

United Nations Food and Agriculture Administration, FAOSTAT database, http://faostat.fao.org/

United Nations Food and Agriculture Administration. Rome, 2000. *World Soil Resources Report* ftp://ftp.fao.org/agl/agll/docs/wsr.pdf

Eswaran, H., F. Beinroth, and P. Reich. 1999. Global land resources and population supporting capacity. Am. J. Alternative Agric. 14:129-136. Accessed online on August 28, 2010 at http://soils.usda.gov/use/worldsoils/papers/pop-support-paper.html

United Nations Food and Agriculture Administration, Land and Water Development Division, Water Resources, Development and Management Service. Rome, 2004. *Water desalination for agricultural applications*. ftp://ftp.fao.org/agl/aglw/docs/lwdp5_e.pdf

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