Harnessing the Earth, the atom and the leaf

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With the world's energy needs growing rapidly, can zero-carbon energy options be scaled up enough to make a significant difference? How much of a dent can these alternatives make in the world's total energy usage over the next half-century? As the MIT Energy Initiative approaches its fifth anniversary next month, this five-part series takes a broad overview of the likely scalable energy candidates.

Beyond wind and solar power, a variety of carbon-free sources of energy — notably biofuels, geothermal energy and advanced nuclear power — are seen as possible ways of meeting rising global demand.

But many of these may be difficult to scale up enough to make a major contribution, at least within the next couple of decades. And a full accounting of costs may show that some of these technologies are not realistic contributors toward reducing emissions — at least, not without new technological breakthroughs.

Biofuels have been an especially controversial and complex subject for analysts. Different studies have come to radically different conclusions, ranging from some suggesting the potential for significant reductions in greenhouse gas emissions to others showing a possible net increase in emissions through increased use of biofuels.

For example, a 2009 study from MIT's Joint Program on the Science and Policy of Global Change found that a major global push to replace fossil fuels with biofuels, advocated by many as a way to counter greenhouse gas emissions and climate change, could actually have the opposite effect. Without strict regulations, that study found, the push to grow plants for biofuels could lead to the clearing of forestland. But forests effectively absorb carbon from the air, so the net effect of such clearing would be an increase in greenhouse gases entering the atmosphere, instead of a decrease.

Another recent MIT study, by researcher James Hileman of MIT's Department of Aeronautics and Astronautics, found that replacing fossil fuels with biofuels for aviation could have either positive or negative effects — depending on which crops were used as feedstock, where these were located, and how the fuels were processed and transported.

Key to biofuel's success is the development of some sort of agriculture that wouldn't take away land otherwise used to grow food crops. There are at least two broad areas being studied: using microbes, perhaps biologically engineered ones, to break down plant material so biofuels can be produced from agricultural waste; or using microscopic organisms such as algae to convert sunlight directly into molecules that can be made into fuel. Both are active areas of research.

For the former, one problem is that traditional processes to break down cellulose use high temperatures. “You really want these conversions to go on at low temperature, otherwise you lose a lot of energy to heat up” the material, says Ron Prinn, the TEPCO Professor of Atmospheric Science and co-director of the MIT Joint Program on the Science and Policy of Global Change. But, he adds: “Given the ingenuity of bioengineers, these conversion problems will be solved.”

Tapping the Earth

Geothermal energy has huge theoretical potential: The Earth continuously puts out some 44 terawatts (trillions of watts) of heat, which is three times humanity’s current energy use.

The most promising technology for tapping geothermal energy for large-scale energy production is so-called hot dry rock technology (also called engineered geothermal), in which deep rock is fractured, and water is pumped down into a deep well, through the fractured rock, then back up an adjacent well after heating up. This heated water can then be used to generate steam to drive a turbine. A 2006 MIT study led by professor emeritus Jefferson Tester, now at Cornell University, found potential to generate 0.5 terawatts of electricity this way in the United States by 2050. And a new study by researchers at Southern Methodist University, released this week, found that just using presently available technology, there is a potential for 3 terawatts of geothermal electricity in the United States.

In principle, this power source could be tapped anywhere on Earth. As you drill deeper, the temperature rises steadily; by going deep enough it’s possible to reach temperatures sufficient to drive generating turbines.

Some places have high temperatures much closer to the surface than others, meaning this energy could be harnessed more easily.

Using this method, “there are thousands of years’ worth of energy available,” says Professor of Physics Washington Taylor. “But you have to drill deeply,” which can be expensive using present-day drilling methods, he says.

“There’s a lot of energy there, but we don’t quite have the technology” to harness it cost-effectively, he says. Less-expensive ways of drilling deep into the Earth could help to make geothermal energy cost effective.Advanced nuclear

Most analysts agree nuclear power provides substantial long-term potential for low-carbon power. But a broad interdisciplinary study published this year by the MIT Energy Initiative concluded that its near-term potential — that is, in the first half of this century — is limited. For the second half of the century, the study concluded, nuclear power’s role could be significant, as new designs prove themselves both technically and economically.

The biggest factors limiting the growth of nuclear power in the near term are financial and regulatory uncertainties, which result in high interest rates for the upfront capital needed for construction. Concerns also abound about nuclear proliferation and the risks of radioactive materials — some of which could be made into nuclear weapons — falling into the hands of terrorists or rogue governments.

And, while nuclear power is often thought of as zero-emissions, Prinn points out that “it has an energy cost — there’s a huge amount of construction with a huge amount of concrete,” which is a significant source of greenhouse gases.

A bewildering variety of other sources of energy have been discussed. Some, such as fusion power — harnessing the process that powers the sun itself — require significant technological breakthroughs, but could conceivably pay dividends in the very long term.

Others have inherent limits that will, for the foreseeable future, make them much smaller contributors to energy production. For example, the power of waves and tides is a potential energy source, with the world's oceans producing a total of 3.75 terawatts of tidal power. But, practically speaking, the most that could ever be captured for human use is far less than one terawatt, Taylor says.

With any energy source, it's crucial to examine, in great detail, the total process required to harness their power. "Every one of these has an energy or environmental cost," Prinn says. "Nevertheless, this should not deter their consideration. It should instead spur the research needed to minimize these costs."

More information: *Tomorrow: A megawatt saved is better than a megawatt made, and there are plenty of ways to save energy without sacrifice.*

Part 1. www.physorg.com/news/2011-10-dent.html
Part 2. www.physorg.com/news/2011-10-p … ons-electricity.html
Part 3. www.physorg.com/news/2011-10-v … ar-energy-earth.html

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