
Geo-Strata
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Energy
GEOTECHNICS
Will there be enough energy to sustain life in the future? 14
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Energy Geotechnology

Energy is required to sustain our lives. By the year 2040, the world population could reach 9 billion - a 30 percent increase from today's population. This increase, combined with growth in developing nations, could cause an 8.5 TW (one trillion watts) increase in power demand –50 percent more than today's consumption. To put these numbers in perspective, this additional demand would require that 300 large nuclear or coal-fired power plants be added every year. For reference, an average of 10 new reactors per year have come on line since the beginning of the nuclear era, and there is still no nuclear waste repository for commercial applications anywhere in the world.

Fossil fuels such as petroleum, coal and natural gas account for about 85 percent of the primary energy consumed worldwide. At current rates of consumption, fossil fuel reserves exceed several generations. However, there is increased concern that the rising CO_2 levels in the atmosphere are due to fossil fuel combustion and contribute to climate change. The U.S. emits 5.4 trillion tons of CO_2 every year – enough to fill a pool the size of Central Park one mile deep with liquid CO_2. The annual worldwide CO_2 emission is six times higher.

Clearly, the energy challenge is not about reserves, at least not in the short term. It is about the large anticipated increase in demand within the next generation, the current dependency on fossil fuels and climate implications, and the geographic mismatch between resources and demand. The situation is aggravated by the disparity in the short time scales for phenomena that affect national decisions (from a few weeks to a few years), to very long time scales for phenomena that affect energy infrastructure and the environment (up to 100,000 years, such as for the half-life of radioactive isotopes in high-level nuclear waste).

The geotechnical discipline is central to energy. Most energy sources are recovered from the earth (carbon, petroleum, gas, nuclear power, geothermal power). Energy infrastructure is built on or within the earth, including hydroelectric plants, foundations for offshore and onshore wind turbines and foundations for tidal systems. Some energy-related waste is buried underground, such as nuclear waste repositories and CO_2 geological storage, while other waste is stored in above-ground structures, such as impoundments for fly ash and coal refuse.

Great storage capacity can be built above and below ground using thermal capacitors, elevated reservoirs and compressed air storage. Geotechnical engineering could contribute to energy efficiency and/or conservation: there is lots of room for improvement when we consider that aggregate crushing operations are about 1 percent efficient and that ants dig tunnels with an energy efficiency 10,000 times higher than our tunnel boring machines.

Phenomena involved in energy geotechnology often relate to classical topics in our field. Hydraulic fracturing has gained great visibility as the media has associated "fracking" with unacceptable consequences: hydraulic fracturing is essentially a geotechnical process with geoenvironmental consequences. Of course, there are many other examples – fines migration and formation damage in oil and gas recovery are akin to filter criteria and clogging, while oil and gas recovery and CO_2 storage are essentially unsaturated soil mechanics and mixed fluid flow problems.

Further, hydrate-bearing sediments have many common features with frozen ground engineering, the analysis of geothermal piles must consider thermal consolidation, fly ash impoundments can experience static liquefaction, and reactive fluid transport following CO_2 injection and water acidification parallels karst formation. There are other phenomena that push our classical boundaries. Typically, they involve coupled hydro-thermo-chemo-bio-mechanical processes, such as the design of nuclear waste repositories, emergent phenomena such as various forms of localizations, and spatial variability inherent to large-scale field projects.

In the 1980s and 1990s, our community took decisive action to deal with geoenvironmental challenges. Those efforts have led to innovative engineering solutions – renewed emphasis on the sciences, including chemistry, biology and physics; updated educational programs; new policies and a reinvigorated industry. Once again, the geotechnical community has an exceptional opportunity to make a difference, this time by confronting the greatest challenge humanity has ever faced. Energy geotechnology problems are fascinating, and there are vast resources available to develop and implement unprecedented engineering solutions. Let's embrace the challenge!

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