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Future Rx: Optimism, Preparation, Acceptance

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Lawrence M. Cathles (Professor, Cornell Univ.)

Future Rx: optimism, preparation, acceptance

Norman Beecher, Moderator,, offers:

This paper is 23 pages, so I have written a précis of it below. The original paper is available online at http://sp.lyellcollection.org/content/early/2013/10/18/SP393.6.full.pdf+html

Professor Cathles is a geologist with a long career in identifying and quantifying mineral resources. In this paper he takes the position that our earth can sustain a human population of 10.5 billion (the predicted peak population) at a standard of living equivalent to that in Europe at present for many centuries. His abstract for the paper follows.

"Abstract: The world contains the energy and mineral resources needed to sustain 10.5 billion (the level the world population is expected to reach in 2100) at a European standard of living for hundreds of centuries. Using physical and chemical principles to extrapolate from what we know, it is shown that the required resources are present, largely in the world's oceans. The environmental consequences of shifting to ocean supply will be positive, and a transition from fossil fuels to low carbon energy sources is provided by natural gas. The eventual steps required are big (thousands of nuclear reactors, country-size solar facilities in desert areas, large mining operations) and there are risks, but the risks are small compared with failing to meet the expectations of a growing world. The best course is to aim for success (all at European standard by 2113), accept and manage the risks of development, solving unforeseen problems as they arise, accept the transition to gas, and train and engage the best talents to prepare to tap the ocean's resources."

The paper then is a series of estimates of the various resources needed to sustain the population as proposed and then meticulous analysis to show how these resources are and will be available. I will present some examples from the paper. When the paper is quoted, the quotation is indicated by parentheses.

"At present things are very good. They have probably never been better in all of human history. As documented by Bjorn Lomborg (2001), we have never lived longer and we have never lived better. From 1200 to 1900 the life expectancy of males in England was about 40 years, but in the twentieth century it increased rapidly to almost 80. Mortality has decreased precipitously in this period as inoculations have controlled infectious diseases. As Lomborg states, population is increasing 'not because we are breeding like rabbits but because we are not dropping like flies'."

"Energy is the most essential resource."

"The world currently consumes 15 TW (terawatts or 1012 W) of power for all purposes (e.g. heat, transportation, electricity). Most of the power comes from hydrocarbon sources (Fig. 2). Meeting the challenge of supplying every human with the energy consumed by the average French or Australian person of 7 kW would require 50 TW for today's population

of 7 billion, and 75 TW in 2113 when the human population is forecast at 10.5 billion. Increasing from 15 to 75 TW over 100 years represents a compound growth rate of 1.6% per year, which is not very daunting.

Energy sources such as geothermal, biofuels, wind, ocean and local solar could, if developed to the maximum, produce only about half the energy requirements. BIG projects are needed in two areas, solar and nuclear.

"To supply solar power to a global population of 10.5 billion at 7 kW/person would require 30% of the non-polar desert area of the world (30% of 18.6 Å~ 106 km2 or c. 6% of land area of the Earth). "

The alternative to solar power is nuclear and meeting the energy requirements as above would require 22,272 nuclear plants each producing 3.3GW. Cathles points out that China is currently building nuclear plants at more than ten times the rate needed to achieve that number by the year 2100. However, Cathles recommends the construction of thorium reactors rather than uranium because the products of thorium reaction are not easily weaponized and there are other efficiencies of a thorium reactor. Furthermore the land reserves of thorium are much larger than those of uranium and there is enough to provide the required amount of thorium for world energy production for 20 centuries.

The metals and minerals needed for meeting the projected goal will need to be taken principally from the oceans because land resources are inadequate. For example, copper and zinc are available in massive sulfide deposits near the sub-ocean vents where hot seawater is discharged after heating by contact with the hotter earth interior.

Manganese nodules, a mineral looking much like coal deposited on large areas of the ocean floor, is another source and contains copper, nickel, cobalt and molybdenum. I managed a project at Kennecott Copper Corp to mine and extract these metals from such ore. We mapped an area of a few square miles at a depth of three miles in the Pacific ocean where there was enough ore to keep Kennecott Copper Corp. running at current rates for 900 years. We brought up many tons of this ore using a device like a vacuum cleaner in which the fluid was water instead of air. We developed a unique process for recovering he metals and produced them in a pilot plant built in Lexington, MA at a cost of about $2 million. 30 to 50 people were employed in Lexington for about six years and the same number at sea and in San Diego, from which port we operated a ship built for ocean mining about 2000 miles offshore. The project took about six years and cost about $58 million. It was successful and Kennecott would have gone into production except for the passage of the Law of the Sea by the United Nations that required that half the earnings of a project obtaining resources more than 200 mile offshore from the producing nation should be given to the United Nations to distribute to the poor nations of the earth. Further, there was a sudden crash in the price of nickel, which had monotonically increased for 25 years

Lithium is needed for batteries for electric automobiles. There is 1000 times as much lithium in the ocean as on land. Korea is at present constructing a pilot plant to recover this ocean lithium.

Rare earths and yttrium are needed for various electronic devices, such as cell phones. "John Kiser stated on a mining web site that was quoted in The Economist: 'The problem of [rare earth] supply is easily solved. It just takes three to five years and billions of dollars' ('Digging in', The Economist, 4 September 2010).

Fertilizers and soil are needed for food production. "Fertilization is a necessary part of sustainable agriculture. At the very least the nutrients that are removed when crops are harvested and shipped to market must be replaced. The main components that must be replaced are potash, nitrate and phosphate, which are needed for plant electrolytes, making chlorophyll, and constructing DNA respectively…. Potash is hugely abundant in evaporites and seawater. Nitrate can be obtained via the Haber–Bosch process from atmospheric N2. However, concerns have been expressed about phosphate..... Phosphate eroded from the continents is delivered to the oceans almost all as particulates which settle on the continental shelves at the rate of more than 30 x 10^{10} mol P a^{-1} (Payton & McLaughlin2007). At this rate, c. 9.3 x 10^6 are deposited in just 1 million years, and this would sustain 10.5 billion for 3735 centuries. Since sediments have been

depositing on the present-day shelves for hundreds of millions of years, this is a very low estimate of the phosphate present on the shelves."

"In conventional practice at least, crops require soil. Soil is probably the most threatened food related resource. In the last 40 years, 40% of the world's arable land has become unproductive as the result of soil erosion….. With energy available, it is hard to imagine that humanity would be impacted by diminishing soil cover. Hydroponic methods, even vertical agriculture in skyscraper towers (Despommier 2010), could be used. Nevertheless soil loss may be humanity's greatest future challenge, and the last thing we may want to be doing is taxing our soil resources further by cultivating biofuels ('A dysfunctional system may become more so', The Economist, 3 July 2010)."

Other ocean resources, such as salt, bromine and magnesium have been recovered by existing technology and are in more than adequate supply.

Cathles then discusses the transition from coal and other high carbon fossil fuels to non-carbon energy sources, such as solar or nuclear. He believes the most feasible transition method be to change to gas as energy fuel until about 2050 and then switch to non-carbon energy sources. This transition method is predicted to produce about one degree Centigrade in world temperature rise, not very dangerous.

He then discusses the way forward. The world must move to accomplish the BIG projects for nuclear or solar energy to make long term survival of the earth's population at a high standard of living for the long future possible. Various methods of encouraging this large transition are recommended.

Criticism of Cathles' paper

I asked Cathles for some criticism of his paper and he sent me the following. You may be able to find addition criticism via Google or other searches. Prof. Cathles himself commented on the criticism as follows:

"Needless to say my critics were critical—but what would one expect. The main opposition is the old Malthus argument that things cannot last, but that is countered by Lomborg's arguments that things have never been better, and the inventiveness of humans. End of the world predictions have always proved to be exaggerated, but that does not dampen enthusiasm for them."

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From: Martin Schoell <mschoell@gas-consult.com>
Sent: Thursday, November 21, 2013 2:10 PM
To: Lawrence M. Cathles
Larry, Finally you have some attention! You may quote in your interviews the infamous "Club of Rome" with several Noble Prize laureates predicting that mankind cannot support the population growth and will starve by the year 2000!! And regarding predicting any future: who predicted shale gas only 20 years ago?
Good cause, keep arguing! Martin

AN E&E PUBLISHING SERVICE ADAPTATION: **A tempest in academia over an optimist's plan to cope with climate change** (Wednesday, November 20, 2013) - Henry Gass, E&E reporter –

Lawrence Cathles wants you to stop worrying. The day-to-day discourse surrounding climate change may say differently. Whether it's stories on drought-stricken farmers or coastal communities retreating from rising seas, most climate news seems to focus on how doomed we are. The climate is warming, seas are rising and the planet's rapidly expanding population is living an unsustainable lifestyle. But Cathles thinks we have reasons to be hopeful. In an essay published in September by the Geological Society of London, the Cornell University geologist writes that the Earth has not only enough

resources to sustain humanity, but also enough to facilitate a transition to clean energy and sustain a population increase up to 10.5 billion by 2100. In his visions of the future, Cathles has a tendency to go first class. The 10.5 billion earthlings would each enjoy the current European standard of living. In short, this future includes harvesting resources from the oceans and using natural gas to bridge from fossil fuel resources to a combination of nuclear and renewable power. Ultimately, Cathles thinks Earth is in a much more secure position than we are often led to believe. "The issue is really what we do," he said in an interview. "We can talk ourselves out of a future if we want to."

Deep-sea mining potential

A central theme of Cathles' arguments is his opinion that humanity isn't sucking the planet dry of resources and isn't likely to do so for hundreds of centuries even as the population rises above 10 billion. We can count on the oceans, Cathles writes, for vast reserves of uranium, manganese, lithium and other minerals, as well as water than can be desalinated and used for drinking and irrigation. And while he concedes ocean-floor mining may be expensive at first, he said demand would soon make it feasible for extracting numerous resources. But it may not be that simple, according to Brian Skinner, a geophysicist at Yale University. "If you make a mistake in the sea, that mistake spreads very widely, very quickly," he warned. "I don't think that we would ever be drawing a very large amount of our resources from the sea," he added. But resources from the ocean may be necessary to achieve Cathles' vision of 10.5 billion people living, sustainably, at a European standard of living.

A huge buildout of nuclear energy

The world currently consumes about 15 terawatts of power each year for all purposes. Cathles estimates that, to achieve a European standard of living for 10.5 billion people, that number would increase to about 75 TW. That still only averages out to a growth rate of 1.6 percent per year from now until 2100, but even that much added capacity would require tremendous infrastructure development if the world is to transition completely off fossil fuels by 2100. Supplying that kind of power with solar panels would require concentrating panels in 30 percent of the nonpolar desert area of the world -- to power Europe, alone you'd need panels blanketing a desert twice the size of Poland. What's more, Cathles writes that solar and wind power will continue to run into distribution challenges, namely difficulty transmitting the power to remote areas. Alternatively, Cathles writes, 22,272 nuclear power stations could be built to generate 3.3 gigawatts each. With a larger population and a more urgent incentive, he writes, "the scale of construction is not daunting…. Never underestimate what large numbers of humans can do," he says in the essay.

There is more than enough uranium in the oceans to keep all these plants humming, he said, and proliferation could be avoided by using thorium to power the reactors, instead of uranium-238 which creates plutonium, a nuclear weapons material. The only obstacle would be the ongoing political hesitancy, in the wake of the Fukushima Daiichi disaster and proliferation concerns. Skinner said that with "sensible, careful site selection," many of the concerns with nuclear plants can be eliminated. Still, it might take some time for nuclear to regain its popularity. "It's not politically the most feasible option right now," Cathles said, "but down the line it could well be."

'Overselling' natural gas?

For the next few decades, Cathles recommends using natural gas to bridge from dirtier fossil fuels like coal and oil to clean, renewable energy. It's a popular theory, voiced by many high-profile policymakers including U.S. Energy Secretary Ernest Moniz (EnergyWire, March 5). Cathles writes that society, especially the West, should aim to transition from oil and coal to natural gas by 2050, then begin transitioning from natural gas to nuclear and renewable power. Critics question this approach because burning natural gas will still add carbon dioxide to the atmosphere, and once it runs out, there's no guarantee society won't just go back to burning dirtier fossil fuels. Raymond Pierrehumbert, a geophysicist at the University of Chicago, wrote in an email that Cathles "oversells gas as a bridge fuel….. Without strong policies on carbon, gas just

bridges a coal-powered past to a coal-powered future," he added. Cathles doesn't agree. Last year, he got into a fairly public argument with fellow Cornell professor Robert Howarth over the greenhouse gas emissions from hydraulic fracturing used to extract natural gas, and he maintains his position in this essay that natural gas has a much lighter carbon footprint than fossil fuels like coal. He also said the planet would stop burning natural gas by 2100 either because cleaner alternatives are ready or because there's no gas left. "It can't last too long, it can't last more than 100 years," he said, "but 100 years is significant."

All's well that ends well

Needless to say, Cathles still must contend with a chorus of skeptics beginning with one on his own campus. David Pimentel, a professor emeritus in entomology at Cornell, said he and Cathles have "about a 180-degree difference in views." Pimentel, as far back as 1994, has said Earth's sustainable population was as low as 2 billion. Pierrehumbert added that some assumptions in the essay are "wildly optimistic," particularly regarding the assumption that fossil fuel use will begin declining by 2050. "That is clearly possible, but I don't see the political system moving in the direction that is needed," Pierrehumbert said. But no one appears to disagree with Cathles' assessment that pessimism won't help things. Pierrehumbert said that "despair is not an option." He added: "Everybody is going to have to work as hard as possible to even have a chance of success, and that has to be done even if we consider the chances of success to be small." Cathles said universities need to play a bigger role in this regard by being motors for solving problems rather than raising problems, but he added that's not usually the best way to get funded.

Ultimately, with the world's population continuing to climb -- and 10.5 billion by 2100 looks more likely each year -- society will have to find some way to live sustainably sooner rather than later to avoid a climate change catastrophe, the scientists agreed. Some changes are already underway, such as sea-level rise and ocean acidification, but humanity still has time to adapt and expand the world population, fully power developing regions of the world, and not destroy the planet in the process.

"The human race is infinitely adaptable," said Skinner, before adding, "No, not 'infinitely.' Is 'exceptionally' adaptable."

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