A Few words with Vaclav Smil …

"The fortunes of nations," Vaclav Smil writes in his 2008 book *Global Catastrophes and Trends: The Next Fifty Years*, "are not determined primarily by strategic designs or economic performance but by the magnitude and efficiency of their energy conversions."

We are now in the midst of just such a grand transition from fossil fuels to renewable and alternative energy sources. This evolution, Smil observes, is "the most fundamental future shift in the global economy. It is not, as one might think, further globalization but rather the coming epochal energy transition," which Smil discusses here in the context of nuclear power.

Smil's abiding focus is in the deep structures that have shaped history and that drive future trends. Born in 1943 in what is now the Czech Republic, Smil is Distinguished Professor in the Faculty of Environment at the University of Manitoba, where he has taught since 1972. The first non-American to receive the American Association for the Advancement of Science Award for Public Understanding of Science and Technology, Smil has published 32 books on energy, the environment, the history of technology, and global risk assessment and most of the recent ones have been reviewed by Bill Gates on his website. His next book, *(Not) Made In USA,* (MIT Press), is an assessment of the rise and fall of American manufacturing.

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Smil has given briefings and testified on wide-ranging risk and energy issues at the White House, the US House of Representatives, and the US State Department. He is a regular consultant to agencies and associations including the World Bank, the Rockefeller Foundation, the CIA, and the Department of Defense. In 2010 Smil was named by *Foreign Policy* as one of the Top 100 Global Thinkers.

Let's talk about nuclear power. You've written that "no rational long-range energy plan of any major modern economy should exclude the nuclear option. The debate shouldn't be about whether to proceed but about how to proceed."

I'll tell you why I say it. It's here. It's a fundamental part of the energy mix, embedded into the baseload supply of electricity People don't realize this. In the US nuclear power provides 20 percent of the power generation. In Canada, nuclear's share of electricity generation is 30 percent. In Japan 30 percent. This is a huge percentage. People think about France, which generates 75 percent of its electricity via nuclear power, but no, think about others also—Belgium, 50 percent rate, for instance.

The typical Western countries are 20 to 40 percent. This is not two or four percent. It's a base load, it's factual, it's embedded. And nuclear can deliver the power at a large scale—one gigawatt, two gigawatts, three gigawatts. The biggest nuclear power plant in Japan provides 10 gigawatts of electricity. So it has this potential for scale already built in. It can deliver power to the emerging mega-cities of the world. So why don't we use third or fourth generation nuclear? Why not do that? Because otherwise [if we do not] we are cutting 30, 40 percent of our juice, and this is not an option. Nuclear power fits the scale that's needed.

The IEA projects electricity demand to grow most rapidly in non-OECD countries like China, which is projected to triple its demand by 2035 to 9,594 terawatt-hours in 2035—or 27 percent of all the electricity generated on the planet.[1] And that of course doesn't include the rest of Asia. In other words, world demand for electricity will grow at a scale that is staggering.

Exactly. You put one nuclear power plant and it could serve a megalopolis and it could do that reliably for 30 years. These plants are up and running all the time. They are very efficient, with load factors [a percentage measure of efficiency over time] of 95 percent, many of them. We do not have any other large-scale generation of electricity as reliable—I'm not saying as economical, because economics have been a barrier. But if you are practical, you cannot say you can do without it.

You visit and lecture at Tokyo University regularly and have written extensively about Japan and China. You said you were writing about the Fukushima accident. It seems like the nuclear industry would be extremely sensitive to that kind of fatal discontinuity. What's the impact? Is this "game over" for the nuclear sector?

No. I've been corresponding with many, many people who are extremely knowledgeable about nuclear design, and it appears that this was very largely preventable, actually. They butchered the first day, basically. Fukushima, as you know, is a problem that is now about one-tenth of Chernobyl in terms of total radioactivity released into the environment. So it's a serious thing, but if they would have taken the right steps in the first day, the radiation released could have been one-tenth of what was actually released, one-tenth, so it could have been only like one percent of Chernobyl. So it would have been a "disaster" but very much more manageable. This was a natural catastrophe, but still it was largely human error that caused its extent.

And these were old plants. Fukushima is 40 years old. It and other plants like it will have to be replaced. Japan will build some new nuclear power plants. There may be some delay and they may build fewer of them then planned. But this is not the end of nuclear power for Japan What alternative do the Japanese have, after all? To import more coal? Or to import more liquefied natural gas to generate electricity?

What effect will Fukushima have on the nuclear industry in China?

This is just a postponement for the nuclear industry, which will continue to grow. Two years from now, it will be business as usual. Again, like Japan, the Chinese have no choice because of the mind-boggling demand statistics you mentioned. Imagine in 2000—I think it was three years altogether if not four—I think 2004, '05, '06—each of these years

Getting [to a world without fossil fuel] will be expensive and require considerable patience. Coming energy transitions will unfold, as the past ones have done, across decades, not years.

1 Under the IEA's "New Policies Scenario," which takes into account planned energy-security and climate policy commitments, world electricity generation is expected to grow to 35,336 terawatt-hours by 2035. China's electricity generation is projected to grow from 3,495 terawatt-hours in 2008 to 9,594 terawatt-hours in 2035. Nuclear's share of that will rise from 2 percent (68 terawatts) to 9 percent (895 terawatts). The IEA projects US generation to be 5,169 terawatt-hours by 2035, according to Marco Baroni, senior analyst at the IEA. By comparison, the total electricity generation for the United States in 2009 was 3,949 terawatt-hours, according to the EIA.

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the Chinese built more coal-fired electricity capacity than the total electricity-generating capacity of Germany or France for the same period. And practically all of it in coal. So there's that option. Again, the Chinese need to build something on the order of 60 gigawatts of electricity capacity every year. So, yes— they'll be building nuclear.

You're obviously not against renewal energy, but why are some of the leading renewable alternative energy pathways insufficient to address the world's need for energy?

To attack this in the simplest way, you would point to the singular problem of scale—the sheer scale of the world population that will soon be aspiring to a middle-class way of life and to levels of consumption and consumer activity that are made possible by electricity [That breaks down to] seven billion people of whom one billion are filthy rich compared to the rest, another billion already are getting there, and the rest want to be there eventually. All of them, quite reasonably, want what we have [in terms of quality of life and comfort], and what we have is made possible, to a large extent, by electricity. This—the scale of human aspiration, and the energy required to provide it—is the thing that somehow most of advocates of so-called green technologies do not want to look at. And much of this has to do with where people will be living. A couple of years ago, we passed a great milestone in human history. Half of the people live now in cities. And not just in cities, they live increasingly in mega-cities.

A typical city in Asia has one to two million people. China before long will have dozens of cities with five, eight million people. How do you run a city like that on a wind turbine or a photovoltaic cell? How do you run modern mega-cities where most of the population would be housed in high-tower structures, how do you run them on renewable energy sources?

You're a realist about the pace of large-scale energy transitions, and this one—the transition from fossil-fuel based energy to alternative and renewable energy—will take place over generations, and not, as some proponents have claimed, over a single decade. Why is that?

By the late 1890s, when combustion of coal (and a bit of oil) surpassed the burning of wood, charcoal, and straw, each of the two resource categories supplied annually an equivalent of about half a billion tons of oil. If during the coming decades we sought to replace worldwide only 50 percent of all fossil fuels with renewable energies, we would have to displace fossil energies equivalent to about 4.5 billion tons of oil, a task equal to creating an almost entirely new industry whose energy output would surpass that of the entire world oil industry that took more than a century to build.

Al Gore proposes to replace the two nonrenewable forms of generation in the United States—fossil fuel and nuclear—which now amount to about 900 gigawatts of installed capacity and took nearly 60 years to build, but this poses some spectacular challenges. America's wind turbines and solar photovoltaics now add up to less than four percent of the total electricity generating capacity of more than 1,000 gigawatts. Even if all the transmission lines were in place, which they are not, because of significantly lower load (capacity) factors of renewables (typically no more than 25% compared to 75% for fossil and more than 90% for nuclear stations) the country would have to build more than 2,500 gigawatts of new wind and solar capacity to replace today's thermal (coal, gas, nuclear) generation—and under no imaginable scenario this could be done in a decade.

In addition, this would mean, of course, writing off, in a decade, the entire fossil-fuel and nuclear-generation industry, an enterprise whose power plants alone have replacement value of at least $1.5 trillion. Another $2.5 trillion would be spent to build the new replacement capacity and the requsite high-voltage lines. Where will deeply indebted and financially precarious America get $2.5 trillion to invest in this new infrastructure within a decade?

But you've written favorably about solar—and some have argued that committing a large enough area to solar could actually achieve the kind of replacement of fossil fuel generation that many seek.

Right. Put enough solar panels in a little square somewhere the size of Arizona and you can power the country, but then you have to build high voltage transmission lines from that little square to everywhere in US — and still to find what to do after the sun sets, not a trivial challenge given that we have no practical way to store electricity on gigawatt scale. Trillions of dollars will need to be spent on financing to rebuild the infrastructure to support that. It's an infrastructural problem. People live in big cities so you have to bring the juice to them on a scale which is amazing.

You build the one nuclear power plant—like them or hate them—and one plant easily equals 2,000 megawatts. You build one big wind turbine, it's two megawatts or three megawatts. So again, you have to build thousands of wind turbines to equal one nuclear plant.

Then there are the many unforeseen risks. We don't know how long these things last, say after 20 years when solar and wind are installed in millions of units and have accumulated the working lifetime of hundreds of millions of hours. Do we have any experience with giant solar panels working for 20 years? Do we have any experience with giant off-shore wind farms working reliably for 20 years?

What will happen to a wind turbine farm if a massive ice storm comes, as it sometimes does in parts of the northern US, and literally grows a thick coating of ice on every surface out there?

You've seen these recent tornadoes outbreaks in the [US] south—170 tornadoes touching within a few hours over six states. What will happen to these mega-wind farms in Oklahoma or Texas when they'll be touched by mega tornadoes? That's a rare event, but it happens again and again.

These are just some of the reasons why energy transitions in large economies and on a global scale are inherently protracted affairs. A world without fossil fuel combustion is highly desirable, and, to be optimistic, our collective determination, commitment, and persistence could accelerate its arrival. But getting there will be expensive and will require considerable patience. Coming energy transitions will unfold, as the past ones have done, across decades, not years. ■