Reflections/The decarbonization of the global economy

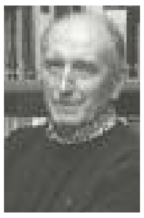
Proof of facts

An assessment of the prospects for a low carbon future, considering both the economic powers and the countries of the developing world, in particular those of Asia and Africa

by VACLAV SMIL

The only proper way to assess the decarbonization prospects of the modern energy supply is to do so on a global scale, as the emissions of CO_2, CH_4 and N_2O from fossil fuel combustion contribute to rising tropospheric temperatures regardless of their sources or national origins. Such realistic assessments—taking into consideration many national peculiarities, economic and technical imperatives and environmental concerns—differ from wishful scenarios that disregard these things.

Affluent countries in general, and the EU in particular, are vocal about the perils of global climate change and are willing to mandate and subsidize new "green" solutions in order to accelerate the decarbonization of their energy systems. Germany calls for a 50 percent cut by 2050, Sweden aims at completely eliminating all fossil fuels. In contrast, the main preoccupation of the low-income countries of Asia and Africa, whose annual per capita energy use is an order of magnitude smaller than in Europe, is continued economic growth energized by any domestically available resources, be it coal in India, crude oil in Angola or newly discovered natural gas in Mozambique. Their efforts will, inevitably, increase national CO_2 (and also CH_4) emissions for decades to come. And then there is China, always a unique player—the world's largest population, the world's largest energy consumer and the world's largest emitter of greenhouse gases—which promises to reduce the carbon intensity of its economy but will see emissions continue to rise before peaking sometime during the late 2020s. The following key elements should be thus kept in mind as we look ahead. →



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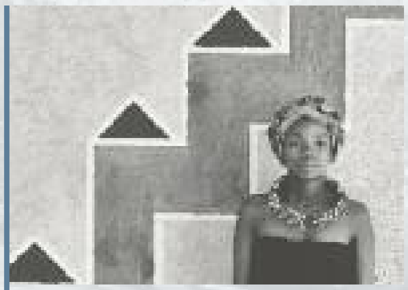
Decarbonization

There is nothing new about trelative decarbonization of economies. A combination of rising energy conversion efficiencies, greater reliance on natural gas (particularly as it replaces much more carbon-intensive coal), and higher shares of renewables (wind and solar) in electricity generation has been reducing carbon emissions per unit of economic product. Some countries have shown impressively rates of reduction but on the global level this has been a very slow process, with the carbon content of the world's primary energy supply declining from about 25 kilograms per gigajoule in 1900 to less than 19 kilograms per gigajoule in 2010, a 25 percent drop in 110 years that translates to an average decarbonization rate of only about 0.2 percent per year.

A comparison of different countries

Absolute decarbonization is a recent phenomenon that has been restricted to affluent countries, especially those with stagnating economies and populations. Until the 1980s, all major economies were emitting more carbon. Many EU countries (and also the U.S.) have seen their emissions either stagnating or declining during the past generation, while the totals for modernizing countries, be they India and Indonesia, Brazil and Egypt, or China and Bangladesh, have been rising, in some cases quite steeply. Germany's carbon emissions from fossil fuel combustion declined by about 25 percent between 1990 and 2015 but Brazilian emissions, in contrast, more than doubled, and Chinese emissions nearly quadrupled. Global emissions rose by almost 60 percent during the same period.



Africa and the future

More than half of the world's population increase between 2015 and 2050 will take place in Africa, where average per capita energy use is a small fraction of the rate in affluent countries. Even in hydrocarbon-rich Nigeria, the annual rate is merely 6 gigajoules per capita (less than 150 kg of oil) compared to the average of more than 150 gigajoules (more than 3.5 tons of oil) for leading EU economies, and in most sub-Saharan countries the consumption of modern energies is only a few gigajoules per capita. In order to develop their economies all of those rapidly growing countries will require badly needed infrastructural and agricultural investment and hence large amounts of fossil fuels to produce steel, cement, farm machinery and fertilizers and to fuel their trucks and tractors.

"Carbon neutral" industry

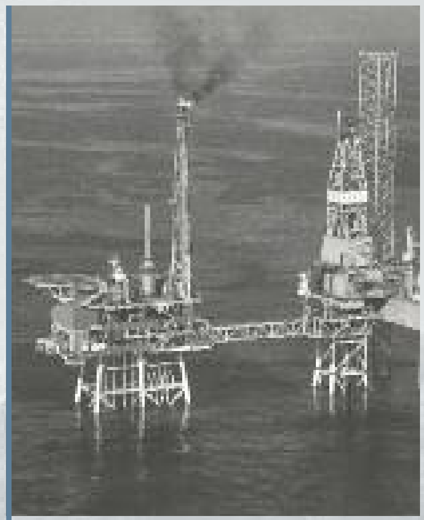
In many countries, significant shares of electricity now produced from fossil fuels can be replaced by renewables, but solar and wind electricity will do little or nothing to secure energy for several key industrial processes whose mass-scale output defines modern civilization. Steel production rests mostly on the smelting of iron from iron ore, a process that now requires about one billion tons of coal to produce metallurgical coke. No carbon-free process is ready to be deployed on a mass commercial scale, and none looks to be able to fill the need anytime soon. The synthesis of plastics and ammonia (the first step to all nitrogenous fertilizers) requires large volumes of liquid and gaseous (above all methane and ethane) feedstocks. Again, there are no alternative carbon-free commercial process to synthesize plastics and ammonia that could be deployed soon on mass scales.

Mass transportation

Renewable electricity generation will also have a limited impact on three key forms of mass transportation: trucking, shipping and flying. While it is not unrealistic to foresee large shares of passenger cars running on electricity or eventually relying on hydrogen-based fuel cells, trucking, marine shipments (both bulk carriers and container vessels) and flying (now consuming about 65 percent of the global supply of fuels refined from crude oil) will rely on high energy-density fuels for decades to come as, yet again, no mass-scale alternatives are on any practical engineering horizon.

Biofuel opportunities

The only possible alternative for these key transportation uses are modern biofuels, but their output amounts to a small fraction of overall demand and scaling up of their production faces serious economic and environmental limits. Only a few land-rich countries could replicate U.S. or Brazilian reliance on ethanol (the U.S. now diverts a third of its corn crop, the world's largest, to make ethanol), but its production may, or may not, reduce overall carbon emissions. Similar limits apply to biodiesel derived from oil crops. The only possible mass-scale alternative is fuels derived from ligno-cellulosic biomass that is not digestible by humans and that comes from logging and crop residues whose exploitation does not compete with food and food needs and does not require additional nutrient-rich land. The world's first cellulosic ethanol plant opened in Iowa in 2015 and will produce about 100 million liters a year, while the world's demand for liquid transportation fuels is about 25,000 times higher than that. Clearly, even if the costs of cellulosic ethanol prove to be acceptable, a very long scaling-up task lies ahead before cellulosic ethanol could supply a large share of transportation fuels, leaving out the need for a practical substitute for diesel fuel.



Fossil fuels

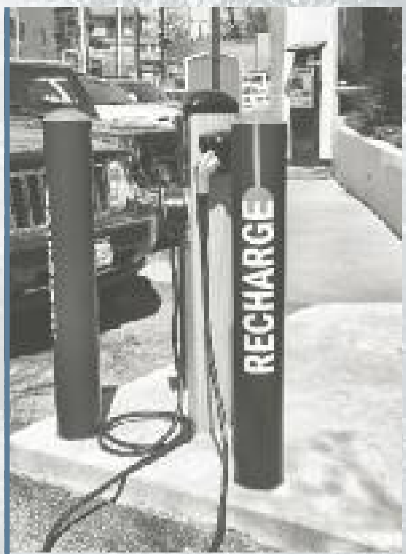
Even after more than two decades of promoting and subsidizing new renewables (wind, solar and modern biofuels), their overall contribution to the global primary energy supply remains minuscule. European media love to point out that on one sunny day half of Germany's electricity during one noon hour came from photovoltaics or that on a windy day Denmark got all of its electricity from wind. But these are fleeting, localized achievements that have, so far, done little to change the fundamental nature of global primary energy supply. In 1990, 90 percent of the world's commercial primary energy came from fossil fuels, with hydro and nuclear energy delivering nearly all of the rest. In 2015, a generation later, fossil fuels still supplied about 86 percent of all commercial primary energy, with hydro energy contributing nearly 7 percent and nuclear energy more than 3 percent, while the combination of wind turbines, photovoltaics and modern biofuel provided less than 3 percent of the total.

Non-carbon energies require a lot of fossil fuels

The term non-carbon energies is actually a misnomer, as all such conversion techniques require large inputs of raw materials that we now produce only by using large amounts of fossil fuels. Construction of hydro stations and nuclear power plants needs large amounts of concrete and reinforcing and structural steel, as do wind turbine farms. For example, I have calculated that if wind-generated electricity were to supply 25 percent of the global electricity demand by the year 2030, the requisite number of large (5 MW) wind turbines would need an equivalent of more than 600 million tons of coal to produce steel for foundations, towers and nacelles (but not for high-voltage transmission towers), and an equivalent of nearly 100 million tons of crude oil to make large plastic blades.

We need a multi-generational effort

Mandates and subsidies can accelerate the adoption of non-carbon (or, more accurately) low-carbon energy conversions, but we are a predominantly fossil-fueled civilization and will remain so for decades to come. The world's economies and populations now depend on annual extraction of more than 11 billion tons of fossil fuels, amounting to about 470 exajoules of energy used at the rate of 15 terawatt. Substantially reducing our dependence on this enormous, deeply embedded system (the world's most extensive and the most expensive infrastructure worth more than $20 trillion) cannot be done—regardless of the desirability of such a shift -– in a matter of few decades; it will be a multi-generational effort. A new energy system must emerge gradually and should develop organically: such complex transformations cannot be rigidly planned according to government targets and quotas because their eventual progress, composition and performance cannot be fully envisaged decades before it take place.



Shift the energy basis

This slow market penetration is as expected because global energy transitions are inherently protracted affairs: a small country can shift its energy basis fairly quickly, but on the global level it takes many decades before a new energy source claim a significant market share. I have shown that after coal reached 5 percent of the global energy supply (when it began displacing wood) it took another 35 years for it to provide 25 percent of total consumption; oil took 40 years to go from 5 percent to 25 percent, and it was 55 years before natural gas rose from 5 percent of the world's energy to 25 percent— and new renewables are yet to reach the 5 percent mark.