complex since it involves issues of end-use energy requirements, resource-use trade-offs (including water and land), and material scarcity.

Similarly, it is often assumed that alternative energy will seamlessly substitute for the oil, gas, or coal it is designed to supplant—but this is rarely the case. Integration of alternatives into our current energy system will require enormous investment in both new equipment and new infrastructure—along with the resource consumption required for their manufacture—at a time when capital to make such investments has become harder to secure. This raises the question of the suitability of moving toward an alternative energy future with an assumption that the structure of our current large-scale, centralized energy system should be maintained. Since alternative energy resources vary greatly by location, it may be necessary to consider different forms of energy for different localities.

It is not possible to single out one metric by which to assess the promise of a particular alternative energy form. The issue is complex and multifaceted, and its discussion is complicated by political biases, ignorance of basic science, and a lack of appreciation of the magnitude of the problem. Many factors come into play, of which nine are discussed here.

1. SCALABILITY AND TIMING

For the promise of an alternative energy source to be achieved, it must be supplied in the time frame needed, in the volume needed, and at a reasonable cost. Many alternatives have been successfully demonstrated at the small scale (algae-based diesel, cellulosic ethanol, biobutanol, thin-film solar) but demonstration scale does not provide an indication of the potential for large-scale production. Similarly, because alternative energy relies on engineering and construction of equipment and manufacturing processes for its production, output grows in a stepwise function only as new capacity comes online, which in turn is reliant on timely procurement of the input energy and other required input materials. This difference between "production" of alternative energy and "extraction" of fossil fuels can result in marked constraints on the ability to increase the production of an alternative energy source as it is needed.

For example, the tar sands of Canada (although often excluded as an "alternative" energy, tar sands are subject to the same constraints because the production of oil from the tar-sands deposits is essentially a mining and manufacturing operation) have already achieved a fully commercial scale of production, and because of the immense reserves indicated in Alberta, tar sands are looked to be a backstop to declining conventional crude oil production. In 2008, production of oil from the tar sands reached 1.2 million barrels per day (bpd), less than 2 percent of global production of conventional crude oil. By 2020, the Canadian Association of Petroleum Producers projects that production will increase by 2.1 million bpd to a total of 3.3 million bpd.[1] But the International Energy Agency (IEA) estimates that the global decline rate from conventional-oil fields is 6.4 percent, or about 4.8 million bpd per year.[2] Thus by 2020, the new oil coming from tar-sands production will not even make up half of what is being lost from ongoing depletion of existing conventional-oil fields. Even with a "crash" production program, it is estimated that tar-sands production in 2020 could not exceed 4.0 million bpd, an increase still less than the annual rate of conventional crude oil depletion.[3]

Scale also matters in comparing projected production of an alternative energy form against expected demand growth. In 2007, the U.S. Energy Policy Act established a target for the production of ethanol in 2022 at 36 billion gallons, of which 15 billion gallons were to be sourced from corn and the remainder from cellulosic sources. In terms of gasoline equivalency, this target is equal to 890,000 bpd of additional supply. In 2008, however, the U.S. Department of Energy, in its *Annual Energy Outlook*, forecast demand for gasoline would grow by 930,000 bpd by 2022,[4] more than offsetting projected supply growth from ethanol and leaving gross oil dependency unchanged.

This lack of the kind of scalability needed given the magnitude and time frame of conventional-oil depletion and in the face of continued demand growth is found as well in other biofuels, coal-to-liquids, and alternative liquids for transportation. Also of concern is the difficulty of scaling up alternative energy quickly enough to meet greenhouse gas emissions targets.