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Energy, society and science: The fifty-year scenario

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ABSTRACT

A vibrant, interactive, and rapidly advancing global society needs an adequate, low cost, predictable and diverse supply of energy; a stable climate; and an international market for energy that mediates across countries, regions, and energy carriers. The science discoveries needed to achieve these energy and societal outcomes are analyzed.

1. Introduction

The next fifty years will witness historic transitions in energy and society. Sustainable energy technologies such as wind, solar, biofuels, carbon sequestration, and electric vehicles are growing in our energy profile [1]. The old paradigm of a few technologically and economically advanced countries dominating the global stage is giving way to the growing aspirations and greater participation of developing countries in world affairs, driven by their desire to secure the societal benefits of economic growth and advanced technology. Increased globalization driven by widespread education, communication, trade, and exchange of people and ideas provides the means for developing countries to achieve their economic and technological aspirations. It is increasingly recognized that a high standard of living is a dynamic benefit: continuous and significant advances in science, technology, innovation, and competitiveness are critical to achieving and maintaining a high quality of life.

2. Energy and society in fifty years

Energy is a basic human need, like food, shelter and mobility, pervading all aspects of our personal, professional, civic and international lives. Access to energy enables or limits human aspirations, as reflected in the correlation of energy consumption with the human development index [2]. The societal benefits of technology, including modern energy-efficient residential and commercial buildings, farm-raised crops and animals, medical diagnosis and care, transportation by car, truck and air, communication of knowledge, information and ideas by electronic media and the rapid exchange of goods and

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services; all represent energy embodied in the materials and systems of society's infrastructure and expended in its operations.

To thrive and advance in the era of globalization, society must meet three basic energy challenges: adequate supply, stable climate and a transparent international energy market. These three challenges are outlined below.

2.1. First priority: adequate, low cost predictable energy supply

A scarcity of energy due to short supply or high cost limits the aspirations of society by restricting the technology that can be deployed and operated, the commercial trade that can be carried out and the cultural advances that can be achieved. Society responds not only to the quantity and cost of energy, but also to the reliability and predictability of its supply. With the notable exceptions of the decade starting in 1974 and recent history since 2003, oil prices have been relatively stable since 1880 [3,4]. This stability and predictability enhances energy security by promoting strategic long term planning by households, governments, businesses and societal institutions, encouraging them to implement the most strategically efficient and effective energy sources and operational technologies as they become available. The cost-benefit analysis of a given innovation or strategic trajectory can be evaluated over the long term with confidence and used to guide decision-making. In contrast, the recent price for oil has been volatile, with sharp increases and decreases driven by geopolitical events, financial crises and economic uncertainty. Volatility encourages short term tactical planning and reluctance to commit to innovative new technologies, business plans and strategic trajectories whose long-term economic viability cannot be established.

2.2. Second priority: climate stability

Climate stability [5] is a requirement for a vibrant, interactive and rapidly advancing global society. The evidence that climate change is occurring is overwhelming, reflected in increasing surface temperatures, rising sea levels, decreasing Arctic snow and ice cover, migration of species, shifts in plant hardiness zones and many other indicators [6–8]. Disruption of stable climate threatens many of the underlying foundations of global society, including agriculture and food production, commerce, coastal access to oceans, energy production, human health and ecosystem stability. The human and economic cost of climate disruption is high. The discretionary resources in developed and developing countries that remain after basic needs of food, shelter and health have been met are limited. These discretionary resources are the reserve that enables the forward progress of society through discovery of new phenomena, the development of new knowledge, implementation of innovative technology and adoption of new societal and cultural institutions that deliver greater service, higher standards of living and increased quality of life. These same reserves must cover the cost of unplanned natural events such as climate change. The high human and economic cost of climate disruption impedes or stalls technological and social progress of developed and developing countries toward higher levels of health, education, income, economic growth and environmental quality.

2.3. Third priority: international energy market

A vibrant, interactive and rapidly advancing global society requires an international market in energy that mediates across countries, regions and carriers of energy. Such a market enables countries to make informed energy and climate decisions that reflect their individual needs for energy and economic growth consistent with their national aspirations. An international market in energy would embody the economic principles of supply and demand, equality of access, and orderly processing of transactions by a transparent procedure. Such markets have proven their value in directing limited resources to the most effective uses, in providing a level playing field for competing players and in raising the long-term fortunes of all players. An international market in energy, like all markets, would inevitably be subject to mutually agreed restrictions, for example, to curb manipulation or reduce volatility. An international energy market provides choices among interchangeable energy carriers, eliminates exclusive two party contracts based on the geopolitical dominance of one the players, and promotes predictability based on transparent transaction procedures. In such a market players can better predict the outcomes of their own strategic plans and the impact of changing global energy conditions.

The international oil market is a good example of an international market for energy [9]. It mediates across the 31 varieties of crude oil, setting a price for each based on quality that allows substitution of one variety for another in an orderly and obvious way. The oil market responds to global shifts in supply and demand, and not to the whims of individual buyers or sellers unless they control a large enough market share to shift the global balance. In the best fifty-year global scenario, similar international markets would mediate not only oil but all forms of energy including gas [10], coal, biofuels, solar chemical fuels, uranium, hydrogen and electricity. Furthermore, these energy carriers would be fungible, so that a shortage in oil supplies could be compensated, for example, by increased use of gas or nuclear electricity. Establishing such a market requires not only social, economic and political institutions, but also science and technology breakthroughs to allow technical interchangeability among the energy carriers such as chemical fuels, electricity, heat and light. Interchangeability among these carriers now exists, as in combustion of chemical fuel to rotate a turbine driving a generator that produces electricity or in electricity heating a filament that emits incandescent light. Science breakthroughs are required to raise the efficiency of the interchanges among energy carriers, and to create new conversion routes, that, for example, eliminate heat