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Diversification and localization of energy systems for sustainable development and energy security

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Abstract

The dominance of a single-energy system inevitably leads to excessive burden on, and eventually weakening, a particular aspect of the environment, and can cause environmental fatigue and failure (permanent damage) or even catastrophe if dominated for too long; thus it inevitably poses the health and environmental risk. This is the case for our currently fossil-fuel-based energy systems. In fact, each energy system, including renewables and alternative fuels, has its own unique adverse impact on the environment, as dictated by the second law of thermodynamics. A truly sustainable development may be achieved with the diversification and localization of energy sources and systems if the adverse impact of each energy system is sufficiently small and well within the tolerance limit of the environment. Energy diversification and localization would also provide a security for the energy supply and distribution as well for the energy consumers—a specifically important issue in the wake of blackout (electric power failure) in the Northeastern states to the Midwest of the United States and part of Canada on August 14, 2003. The idea of diversified energy systems for the good of humanity and environment is similar to many analogies in other fields, such as bio-diversity is the best means to prevent the spread and damage of diseases and pests, and diversified investment is the best strategy to guarantee the overall best investment return. It is concluded that the diversification and localization of energy systems is the best future energy systems that would be environmentally compatible, and allow for sustainable development as well as energy security for both supply and distribution to the energy consumers.

Keywords: Energy diversification; Energy localization; Sustainable development; Energy and environment; Energy security

> The economic and technological triumphs of the past few years have not solved as many problems as we thought they would, and, in fact, have brought us new problems we did not foresee.
> (Henry Ford II)

1. Introduction

Worldwide energy consumption has been increasing rapidly (IEA, 2003), in fact almost exponentially, since the industrial revolution; and this increasing trend of energy consumption has been accelerated by the improvement of the quality of life, that almost directly relates to the amount of energy consumption; by the industrialization of the developing nations; and by the increase of population in the world. At present, the absolute majority of energy requirement worldwide is met by the combustion of fossil fuels (IEA, 2003) (i.e., coal, petroleum oils, natural gas, etc.), which have become an essential and integral part of modern civilization, being increasingly relied upon since the industrial revolution. Only a very small proportion from the nuclear and hydro powers, and even a much smaller portion from the renewable energy sources, such as solar, wind, geothermal, tidal wave, and so on, provides the rest of the energy demand.

This almost exclusive reliance on the combustion of fossil fuels has resulted in enormous amount of harmful

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pollutant emissions to our environment, has caused severe degradation of local and global environment, and has exposed the world population, from humans to animals and from plants to any form of lives on earth, to the hazards and risks created by the extensive use of fossil fuels. For example, air pollution resulted from the pollutant emissions poses a severe threat to the health of millions of population living in many of the world's urban areas. In 1998, over 113 million people in the United States were estimated living in areas not meeting US National Air Quality Standards (Chalk et al., 2000). Combustion of fossil fuels continues to contribute significantly to the increase in the atmospheric carbon dioxide concentrations, thus intensifying the prospect of global warming and threatening the very existence of our civilization and mankind on the planet earth. In addition to the health and environmental concerns, a steady depletion of the world's limited fossil fuel reserves also calls for alternative primary energy sources, and new energy technologies for energy conversion and power generation, which are more energy efficient than the conventional combustion engine with minimal or no pollutant emissions, and also compatible with renewable energy sources or carries for sustainable development. Many studies have pointed to the hydrogen economy as the perfect solution to our present dilemma arising from the dominance of fossil fuels based energy systems (Adamson, 2004; Barreto et al., 2003), and fuel cell has been identified as the promising and potential energy technology, which meets all of the above requirements for energy security, economic growth, and environmental sustainability.

Is hydrogen-based energy system a perfect solution to our plight or another "Pandora Box" waiting to be opened? In this study, energy systems and their inevitable negative impacts on the environment are examined, and the much-awaited hydrogen based energy system is analyzed. Historic lessons learned and analogy with other fields will be made. We conclude that the best approach to the issue of energy, environment and sustainable development is the diversification and localization of energy systems, which is also the best approach to the security of energy. In the following sections, we will first describe the energy systems and their impacts on the environment, and then the idea of diversification and localization of energy sources and systems will be developed as the only sensible and practically feasible solution to the goal of sustainable development and energy security.

2. Energy systems and their impacts on environment

Consumption of energy (or useful energy or exergy, to be thermodynamically correct) has become the daily necessity in modern civilization for the comfort and convenience of humanity, and the amount of energy consumption has served as the indicator for the standard of living and the degree of industrialization. It has long been recognized that associated with this excessive daily energy consumption is the adverse impact on the environment we live in, resulting in the deterioration of the local and global environment. However, utilization of energy from different sources tends to have different kinds and different degrees of impact on the environment. For example, the severe impact of energy use from fossil fuels has been well known for decades, while the energy from renewable sources may be considered to have minimal or neutral impact on the environment, so long as the amount of their usage remains low. Therefore, it is useful to look into the composition of energy systems and their impacts on environment.

An energy system may be considered as composed of five interconnected components as shown in Fig. 1 (Scott, 1995). It includes the raw energy resources that are available in nature (such as coal, sunlight, wind, etc.), and that are harnessed and processed/refined to a form or forms convenient for distribution, storage and utilization of energy (that we call transformer technologies in Fig. 1). Such convenient forms of energy are often called energy carriers, or energy currencies, such as gasoline, diesel and hydrogen. The extraction and processing of energy resources and the production of energy carriers form the traditional energy sector of the industry. The technologies that deliver the services needed by individuals and society as a whole (or the service technologies) and the energy services needed for the convenience and comfort of humans make up the remaining part of the energy system. It is noticed that human needs (or energy services) dictate the energy system and its evolution—the insatiable human desire is the constant source of the driving power for the improvement and evolution of energy systems. Typically, the energy services needed and the energy resources available in nature (energy sources) remain fixed, unchanged over time, whereas what's changing is the technologies for the extraction of energy from the natural resources (transformer technologies), the carriers of energy and the technologies that provide the energy services needed (service technologies). Numerous examples are given in Fig. 1 for each of the five components in an energy system.

To consider an energy system and its inevitable negative impact on the environment, let us take transportation as the energy service for an example. Traveling from one place to another historically had been met by using animal powers, say horses or horsepowers, before the arrival of combustion engines. The technology that provided the services needed was horse-drawn wagons (the service technology); and the energy currency (or the energy carrier) was hays, that