Renewable and Sustainable Energy Reviews 14 (2010) 1172–1186

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

Energy production, consumption, policies and recent developments in Turkey

E. Toklu, M.S. Güney, M. Işık, O. Comaklı, K. Kaygusuz *

Department of Mechanical Engineering, Bayburt University, 69000 Bayburt, Turkey

ARTICLE INFO

Article history:
Received 18 November 2009
Accepted 2 December 2009

Keywords:
Sustainable development
Energy sources
Renewable energy
Greenhouse gases

ABSTRACT

Many factors to be appropriately addressed in moving towards energy sustainability in Turkey are examined. These include harnessing sustainable energy sources, utilizing sustainable energy carriers, increasing efficiency, reducing environmental impact and improving socioeconomic acceptability. The latter factor includes community involvement and social acceptability, economic affordability and equity, lifestyles, land use and aesthetics. On the other hand, Turkey, with its young population and growing energy demand per person, its fast growing urbanization, and its economic development, has been one of the fast growing power markets of the world for the last two decades. Turkey is heavily dependent on expensive imported energy resources that place a big burden on the economy and air pollution is becoming a great environmental concern in the country. In this regard, renewable energy resources appear to be the one of the most efficient and effective solutions for clean and sustainable energy development in Turkey. Turkey's geographical location has several advantages for extensive use of most of these renewable energy sources. This article presents a review of the potential and utilization of the energy sources in Turkey.

Contents

1. Introduction

Energy sustainability is becoming a global necessity, given the pervasive use energy resources globally, the impacts on the environment of energy processes and their reach beyond local to regional and global domains, and the increasing globalization of the world's economy. Energy is directly linked to the broader concept of sustainability and affects most of civilization. That is particularly evident since energy resources drive much if not most of the world's economic activity such as industry, transportation, residential, and commercial. Also, energy resources, whether carbon-based or renewable, are obtained from the environment, and wastes from energy processes are typically released to the environment. Finally, the services provided by energy allow for

* Corresponding author. Tel.: +90 458 2111153; fax: +90 458 2111128.
E-mail address: kamilk@bayburt.edu.tr (K. Kaygusuz).

1364-0321/$ – see front matter © 2009 Elsevier Ltd. All rights reserved.
doi:10.1016/j.rser.2009.12.006

good living standards, and often support social stability as well as cultural and social development. Given the intimate ties between energy and the key components of sustainable development, the attainment of energy sustainability is being increasingly recognized as a critical aspect of achieving sustainable development [1].

Energy sustainability is taken here not just to be concerned with sustainable energy sources, but rather to be much more comprehensive [1]. That is, energy sustainability is taken to involve the sustainable use of energy in the overall energy system. This system includes processes and technologies for the harvesting of energy sources, their conversion to useful energy forms, energy transport and storage, and the utilization of energy to provide energy services such as operating communications systems, lighting buildings and warming people in winter. Thus, energy sustainability goes beyond the search for sustainable energy sources, and implies sustainable energy systems, i.e., systems that use sustainable energy resources, and that process, store, transport and utilize those resources sustainably [1–4].

Sustainable development is increasingly becoming a goal to which countries aspire. Overall sustainability has been defined in many ways, and is often considered to have three distinct components: environmental, economic and social [1,2]. These three factors when considered separately usually pull society in different directions (e.g., economic sustainability may be achieved at the expense of environmental and social sustainability). Overall sustainable development in general requires the simultaneous achievement of environmental, economic and social sustainability. Achieving this balance is challenging, and energy factors into each component [1–4].

Energy is used in almost all facets of living and in all countries, and makes possible the existence of ecosystems, human civilizations and life itself. Different regions and societies adapt to their environments and determine their own energy resources and energy uses. The standards of life achieved in countries are often a function of energy-related factors. On the other hand, energy can exist in many forms, and can be converted from one form to another with energy conversion technologies. We use energy carriers, produced from energy sources, in all aspects of living [4].

Some points on energy carriers are worth noting. First, they are closely related to endeavours of people and societies, representing the direct energy forms used to deliver needed or desired energy services. Thus, energy carriers influence living standards and are related to technological development [3]. Also, the difference between energy carriers and sources is important. Energy carriers can exist in a variety of forms and can be converted from one form to another, while energy sources are the original resource from which an energy carrier is produced [4]. Confusion sometimes results between energy sources and carriers because some energy sources are also energy carriers. Hydrogen for example is not an energy source, but rather an energy carrier that can be produced from a wide range of resources using various energy conversion processes. Nevertheless, hydrogen is often erroneously referred to as an energy source, especially in discussions of its potential future role as a chemical energy carrier to replace fossil fuels [3,4].

2. Energy for sustainable development

Sustainable development was defined by the 1987 Brundtland Report of the World Commission on Environment and Development [2] as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." This definition implies that actions of present societies should not threaten cultures or living standards for societies [2]. Other definitions and descriptions have been presented. The degree to which sustainable development can be achieved by countries varies, since countries differ according to such characteristics as size, wealth, living standards, culture, and political and administrative systems. Wealth and advanced technology may make it easier for developed countries to strive for sustainable development, but this is not always the case. The basic motivations and desires of societies, countries, cultures and people to advance appear to be inherent, and these aspirations often require increasing energy use and often yield correspondingly increasing emissions [1–4].

In some ways, the concept of energy sustainability is simply the application of the general definitions of sustainability to energy. In other ways, energy sustainability is more complex and involved [1]. Energy sustainability involves the provision of energy services in a sustainable manner, which in turn necessitates that energy services be provided for all people in ways that, now and in the future, are sufficient to provide basic necessities, affordable, not detrimental to the environment, and acceptable to communities and people. Universal agreement on a definition of energy sustainability has not yet been achieved, but various definitions and descriptions have been presented [2]. Linkages between energy sustainability and factors such as efficiency and economic growth have been investigated [4].

The connection between energy, the environment and sustainable development is worth highlighting [3]. Energy supply and use are related to climate change as well as such environmental concerns as air pollution, ozone depletion, forest destruction, and emissions of radioactive substances [4]. These issues must be addressed if society is to develop while maintaining a healthy and clean environment, especially since the future will be negatively impacted if people and societies continue to degrade the environment. A society seeking sustainable development ideally must utilize only energy resources which cause no environmental impact. However, since all energy resources lead to some environmental impact, improved efficiency and environmental stewardship can help overcome many of the concerns regarding the limitations imposed on sustainable development by environmental emissions and their negative impacts [1].

3. Turkey's energy situation

3.1. Share of the energy sector

Turkey is situated at the meeting point of three continents (Asia, Europe and Africa) and stands as a bridge between Asia and Europe. The country is located in southeastern Europe and southwestern Asia. Its size is 779,452 km^2. Turkey's population was about 73 million in 2007 [10]. Because of social and economic development of the country, the demand for energy is growing rapidly. The main indigenous energy resources are hydro, mainly in the eastern part of the country, and lignite [5]. Turkey has no big oil and gas reserves. Almost all oil and gas is imported, as is high quality coal. Turkey also has a large potential for renewable energies. In Turkey, electricity is produced by thermal power plants (TPPs), consuming coal, lignite, gas, fuel oil and geothermal energy, and hydropower plants (HPPs) [5–8].

Table 1 depicts the historical and projected relationship between population, economic output and energy demand. Several relationships are worth highlighting. First, the population projections signal the slowing down of population growth. At the same time the gross national product (GNP) is expected to nearly double every 10 years. A similar relationship between population, per capita energy demand and total energy demand is projected. The implication of these figures is that energy intensity of the Turkish economy will substantially improve over time, going from 81 Mtoe/GNP/capita in 1973 to 40 Mtoe/GNP/capita in 2000 to 33 Mtoe/GNP/capita in 2020 [10]. The main energy resources of