Clean Energy Policies for Sustainable Development in Turkey

K. Kaygusuz

Department of Chemistry, Karadeniz Technical University, Trabzon, Turkey

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Abstract

Although energy has brought about significant changes in standards and life-styles, its generation, processing and consumption is also a source of both localized pollution and a major contributor to global climate change. In this context, at the international level, the challenges related to energy and climate change are at the very top of the agenda for action, and more than ever before, renewable energy is proving its potential as an important part of the solution. Turkey is energy importing country, which 70% of total energy consumption supplied by imported energy. Turkey is also generously endowed with renewable energy sources. There is an estimated yearly renewable energy potential of around 560 TWh from commercially exploitable sources such as hydropower, wind, biomass, geothermal and solar energy. This study shows that Turkey has enough renewable energy potential to dimishes the country’s energy dependency and greenhouse gases.

Keywords: Energy issues; Renewable energy; Sustainable development; Turkey

1. Introduction

Energy is essential to economic and social development and improved quality of life in all countries. Much of the world’s energy, however, is currently produced and consumed in ways that could not be sustained if technology were to remain constant and if overall quantities were to increase substantially. The need to control atmospheric emissions of greenhouse and other gases and substances will increasingly need to be based on efficiency in energy production, transmission, distribution and consumption in the country. Electricity supply infrastructures in many developing countries such as Turkey are being rapidly expanded as policymakers and investors around the world increasingly recognize electricity’s pivotal role in improving living standards and sustaining economic growth [1-3].

The warming of the global climate system as a result of increasing greenhouse gas (GHG) concentrations in the atmosphere has become a major concern worldwide. Climate change is manifest in higher average global temperatures, rising global mean sea levels, melting ice caps and an increased intensity and frequency of extreme weather events. Most scientific research suggests that the consequences of unabated climate change could be dramatic. It is virtually impossible to reasonably quantify the impact of unabated climate change in economic terms, as this involves a very long time horizon and highly subjective judgments. But because of the large risks and uncertainties, and the potential for severe economic repercussions, strong and early action to mitigate climate change is advocated. Looking at long-term climate change mitigation from this risk-management perspective is not primarily an economic issue but an ethical imperative [4-6].

There is a growing concern that long-run sustainable development may be compromised unless measures are taken to achieve balance between economic, environmental and social outcomes. Since the early 1980s, Turkish energy policy has concentrated on market liberalization in an effort to stimulate investment in response to increasing internal energy demand. This paper provides an overview of sustainable energy policies in Turkey.
2. Global Energy Consumption

Coal was the first fossil fuel to be used on an industrial scale, and it remains a major force in world energy and has indeed been the fastest growing worldwide in recent years. After centuries of mineral exploration, the location, size and characteristics of coal resources are well-established. Economically recoverable reserves are reported to exist in some 75 countries and the global total amount of coal at end-2008 of 860 billion tonnes was 1.6% higher than at end-2008. Table 1 shows world primary energy consumption [7, 8].

<table>
<thead>
<tr>
<th>Fuel</th>
<th>2000</th>
<th>2010</th>
<th>2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal</td>
<td>2295</td>
<td>3474</td>
<td>4908</td>
</tr>
<tr>
<td>Oil</td>
<td>3649</td>
<td>4113</td>
<td>5109</td>
</tr>
<tr>
<td>Gas</td>
<td>2088</td>
<td>2740</td>
<td>3670</td>
</tr>
<tr>
<td>Nuclear</td>
<td>675</td>
<td>719</td>
<td>901</td>
</tr>
<tr>
<td>Hydro</td>
<td>225</td>
<td>295</td>
<td>414</td>
</tr>
<tr>
<td>Bioenergy*</td>
<td>1045</td>
<td>1277</td>
<td>1662</td>
</tr>
<tr>
<td>Other renewables</td>
<td>55</td>
<td>112</td>
<td>350</td>
</tr>
<tr>
<td>Total</td>
<td>10304</td>
<td>12730</td>
<td>17014</td>
</tr>
</tbody>
</table>

*Includes traditional and modern biomass uses
Mtoe: Million tons of oil equivalent

Around 5.8 billion tons of hard coal and 953 million tons of brown coal were used worldwide in 2008 [8]. Since 2000, global coal consumption has grown faster than any other fuels. The five largest coal users such as China, USA, India, Japan and Russia account for around 72% of total global coal use [7]. On the other hand, the use of coal is expected to rise by over 60% by 2030, with developing countries accounting for around 97% of this increase. China and India alone will contribute 85% of the increase for demand in coal over this period. Most of this demand is in the power generation sector, where coal’s share in global electricity generation is set to increase from 41% today to 44% by 2030 [7-9].

proved reserves of oil, as assessed for the SER, continue to show a substantial supply base for the short-medium term [9]. The global level of proved recoverable reserves, based on information from World Energy Council Member Committees and supplementary sources, stood at 163 billion tons at end-2008, some 3 billion tons higher than at the end-2005 level. On the other hand, the Middle East remains the principal location of oil reserves, with 61% of the global total, followed by Africa with 11%, South America 10%, and Europe (including the whole of the Russian Federation) 8%, followed by Asia and North America each at around 5% [9]. At the present level of 185.5 trillion cubic meter (tcm), global gas reserves are equivalent to more than 54 years’ production at the 2008 rate.

The countries with the largest natural gas reserves are still the Russian Federation, the Islamic Republic of Iran and Qatar, but Turkmenistan has now overtaken Saudi Arabia to take fourth place in the global ranking list. At end-2008, the Middle East accounted for 41% of the world’s gas reserves, Europe (including the whole of the Russian Federation) for 27% and Asia for 15% [7-9].

There were 437 nuclear power reactors in operation at the beginning of 2010, with an aggregate generating capacity of 370 GW. Eleven construction starts were made in 2009, ten of them in Asia. A number of countries uprated existing plants by up to 20%, a highly effective way of bringing new capacity on-line [9]. During the first decade of the new millennium, annual electricity production from the global fleet of nuclear power plants ranged between 2 544 TWh and 2 661 TWh.
The 2009 production of 2,568 TWh translates into a market share of 14%, i.e., every seventh kilowatt-hour produced in the world was generated by nuclear power [9]. On the other hand, the 55 reactors under construction are in Asia (including the Middle East), as were 30 of the last 41 new reactors to have been connected to the grid. China’s target is 40 GWe of nuclear power capacity in 2020, compared to 8.4 GWe today [7-9].

Hydro-electric power is currently the largest of the perpetual or so-called Renewable energy resources. Hydro contributes to electricity generation in 160 countries and the least-cost way to increase hydro generating capacity is almost always to modernize and expand existing plants. Most of the hydro plant presently in operation will require modernization by 2030. While capacity expansions are generally made at existing hydro stations, there are sometimes opportunities for installing generators at nonhydro dams. There are 45,000 large dams in the world and the majority do not possess a hydro component.

Most hydropower projects were developed to provide base load to the power system, and this pattern will continue in developing countries. Currently, there are more than 127 GW of pumped storage throughout the world. Recent reporting in the technical press indicates that at least 15 projects are under construction in nine countries, and that these will add a further 8.8 GW of capacity. The power plants range in size from 150 to 1,353 MW. It is anticipated that the market for pumped storage will increase by 60% over the next four years [9].

Today, biomass supplies some 50 EJ globally, which represents about 10% of global annual primary energy consumption. This is mostly traditional biomass used for cooking and heating. There is significant potential to expand biomass use by tapping the large volumes of unused residues and wastes. Based on this diverse range of feedstocks, the technical potential for biomass is about 1,300 EJ/yr by 2030, although most biomass supply scenarios that take into account sustainability constraints indicate an annual potential of between 200 and 500 EJ.

Fuelwood consumers are of two very different types: in industrialised countries, the present-day wood user is likely to use a highly-efficient combustion appliance under strict regulations regarding emissions, whereas the typical developing-world consumer uses small, inefficient and highly-polluting fires and stoves. Indoor air pollution is a major health problem in less-developed countries [1-3, 8, 9]. The annual solar radiation reaching the earth is over 7,500 times the world’s annual primary energy consumption of 450 exajoules; it varies from place to place, with some parts of the earth receiving a much greater irradiance than the average annual level of 170 W/m². However, there is a useable solar resource in virtually all parts of the world, and economically attractive applications are not confined to the sunniest regions [7-9].

PV panels are solid-state and are therefore very rugged, with a long life. Currently, the commonest panels are based on crystalline and polycrystalline silicon solar cells. Their efficiency has gradually increased, while costs have declined. A major advantage of PV devices is that they can be installed as stand-alone systems, providing power ranging from microwatts to megawatts. In 2009, sales of PV modules for terrestrial applications exceeded 7,001 700 MWp. The global market has been growing at a phenomenal rate: an average of 47% per annum over the past five years [7-9].

Geothermal utilisation is commonly divided into two categories: electricity generation and direct use. Geothermal electricity are mostly major world economies, the six countries with the highest percentage share of geothermal in their power production are all relatively small, with three out of the top six being located in Central America, a part of the world rich in high-temperature geothermal resources.

At end-2008, approximately 10,700 MW of geothermal electricity generating capacity was installed, producing over 63,000 GWh/yr. Installed capacity for direct heat utilisation amounted to about 50,000 MWt, with an annual output of around 430,000 TJ (equivalent to about 120,000 GWh). The annual growth in energy output over the past five years has been 3.8% for electricity production and around 10% for direct use (including geothermal heat pumps). Energy produced by ground-source heat pumps alone has increased by 20% per annum over the same period. The low growth rate for electric power generation is primarily due to the low price for natural gas, the main competitor [9].

World wind energy capacity has been doubling about every three and a half years since 1990 as is doubtful whether any other energy technology is
growing, or has grown, at such a rate. Total capacity at the end of 2008 was over 120 GW and annual electricity generation around 227 TWh, roughly equal to Australia’s annual consumption. The United States, with about 25 GW, has the highest capacity but Denmark with over 3 GW, has the highest level per capita, and production there corresponds to about 20% of Danish electricity consumption [8]. Several commercial types of wind turbine now have ratings over 3 MW and diameters around 60-80 m; machines for the offshore market have outputs up to 6 MW and diameters up to 126 m. Machine sizes have increased for two reasons [9].

3. Energy Sources in Turkey

3.1. Energy Sources and Problems in Turkey
As a developing country and in conjunction with its fast growing economy and population Turkey’s energy consumption has increased rapidly between 1990 and 2007. While total primary energy consumption in 1990 was 50.47 million tons of oil equivalent (Mtoe), in 2007 it raised 107.78 Mtoe [10, 11]. On the other hand, total energy production in 1990 was 27.39 and 28.57 in 2007 (Tables 2, 3 and Figure 1).

![Figure 1. Primary energy production and consumption in Turkey](image_url)

<table>
<thead>
<tr>
<th>Energy Sources</th>
<th>2007</th>
<th>2010</th>
<th>2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal and Lignite</td>
<td>14.50</td>
<td>26.15</td>
<td>32.36</td>
</tr>
<tr>
<td>Oil</td>
<td>2.48</td>
<td>1.13</td>
<td>0.49</td>
</tr>
<tr>
<td>Gas</td>
<td>0.94</td>
<td>0.17</td>
<td>0.14</td>
</tr>
<tr>
<td>Nuclear</td>
<td>-</td>
<td>-</td>
<td>7.30</td>
</tr>
<tr>
<td>Hydropower</td>
<td>3.86</td>
<td>5.34</td>
<td>10.00</td>
</tr>
<tr>
<td>Geothermal</td>
<td>0.70</td>
<td>0.98</td>
<td>1.71</td>
</tr>
<tr>
<td>Wood and Biomass</td>
<td>5.27</td>
<td>5.12</td>
<td>4.96</td>
</tr>
<tr>
<td>Solar/Wind/Other</td>
<td>0.42</td>
<td>1.05</td>
<td>2.27</td>
</tr>
<tr>
<td>Total production</td>
<td>28.17</td>
<td>39.94</td>
<td>59.23</td>
</tr>
</tbody>
</table>
As it can be seen from Figure 1, Turkey is an energy importing country and dependent on the imported energy sources. Furthermore, this trend seems to be continuing in the future. Although it has a wide variety of energy sources, the quality and quantity of most of the sources are not sufficient to produce energy. Some of the energy sources in Turkey are hard coal, lignite, asphalt, oil, natural gas, hydropower, geothermal, wood, animal and plant wastes (biomass), solar and wind energy [10-13]. The proven reserves of lignite, the most abundant domestic energy source, is 7300 million ton and found in almost all of the country’s regions. Coal and lignite has the largest percentage in total energy production with its 51.5% share. After lignite, wood has the greatest share in total energy production with its 18.7% and oil accounts for 8.8%, 13.7% hydro and the final 7.3% includes animal wastes, solar, gas, geothermal electricity and geothermal heat [10-14]. Turkey’s various renewable energy sources represent its second largest energy source after coal [1-5]. Biomass and animal waste account 67.3 %, hydropower 29.5 %, geothermal 2 % and wind and solar account for 1.2 % each of total renewable energy production [3]. There are many rivers in Turkey, thus water sources are one of the most important energy sources. 18.5 % of electricity generation was provided by hydropower in 2007, and it increased to 26 % in 2020. Turkey’s largest hydroelectric power plant is the Atatürk Power Plant, which has the 6th largest capacity in the world, with the capacity of 2400 MW\(_e\) Karakaya with 1800 MW\(_e\) and Keban 1330 MW\(_e\). Thirty four hydro plants are under construction, and 329 more hydro power plants are projected [14-17]. The largest hydro power project in Turkey is the Southeastern Anatolia Project (GAP), which covers 74000 km\(^2\) of the country. Upon competition, GAP will have an installed capacity of 7476 MW 22% of Turkey’s total estimated economic potential [17-19]. Along with the economic growth and population increase, significant increases were observed both in primary energy and electricity consumption between 1975-2008 (see Figure 2). Consumption of primary energy reached 107.8 Mtoe as of the end of 2007 with an annual average increase of 2.9% while electricity consumption reached 169.3 billion kWh with an annual average increase of 4.6% during this period [12]. These increases are more evident in the period following 2003, since the impact of the 2001 economic crisis was alleviated, and the economy stabilized. During this term, primary energy and electricity utilization grew at an annual average rate of 5.4% and 6.3%, respectively [11-14]. Figure 3 shows electricity consumption by source in Turkey [12].

![Figure 2. The total power and gross electricity consumption in Turkey.](image-url)
4. Renewables in Turkey

Renewable energy supply in Turkey is dominated by hydropower and biomass [1-5], but environmental and scarcity-of-supply concerns have led to a decline in biomass use, mainly for residential heating. Total renewable energy supply declined from 1990 to 2007, due to a decrease in biomass supply [20, 21]. As a result, the composition of renewable energy supply has changed and wind power is beginning to claim market share. As a contributor of air pollution and deforestation, the share of biomass in the renewable energy share is expected to decrease with the expansion of other renewable energy sources. Table 4 shows yearly renewable energy potential in Turkey.

<table>
<thead>
<tr>
<th>Renewable energy</th>
<th>Technical</th>
<th>Economical</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solar electric (billion kWh)</td>
<td>6105</td>
<td>305</td>
</tr>
<tr>
<td>Solar thermal (Mtoe)</td>
<td>500</td>
<td>25</td>
</tr>
<tr>
<td>Hydroelectric (billion kWh)</td>
<td>240</td>
<td>130</td>
</tr>
<tr>
<td>Wind electric (billion kWh)</td>
<td>120</td>
<td>60</td>
</tr>
<tr>
<td>Geothermal electric (billion kWh)</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Geothermal heat (Mtoe)</td>
<td>7500</td>
<td>2850</td>
</tr>
<tr>
<td>Classic biomass (Mtoe)</td>
<td>10</td>
<td>8</td>
</tr>
<tr>
<td>Modern biomass (Mtoe)</td>
<td>40</td>
<td>25</td>
</tr>
</tbody>
</table>

Total gross hydropower potential and total energy production capacity of Turkey are nearly 60 GW and 120 TWh/yr, respectively and about 30% of the total gross potential may be economically exploitable. At present, only about 35% of the total hydroelectric power potential is in operation [15]. The national development plan aims to harvest all of the hydroelectric potential by 2020. The contribution of small hydroelectric plants to total electricity generation is estimated to be 6-8% [16]. On the other hand, the GAP is one of the largest power generating, irrigation, and development projects of its kind in the world, covering 3.0 million ha of agricultural land [19]. This is over 10% of the cultivable land in Turkey; the land to be irrigated is more than half of the presently irrigated are in Turkey. The GAP project on the Euphrates and Tigris Rivers encompasses 22 dams and 19 hydroelectric power plants. Once completed, 27 billion kWh of electricity will be generated and irrigating 1.7 million hectares [1-3, 18, 19].

Biomass is the major source of energy in rural Turkey [1-5]. Biomass potential includes wood, animal and plant wastes. Among the biomass energy sources, fuelwood seems to be the most...
interesting because its share of the total energy production of Turkey is high at 21%. The total biomass energy potential of Turkey is about 32 Mtoe [20, 21]. The amount of usable biomass potential of Turkey is approximately 17 Mtoe. The electrical production from usable biomass has a net impact of 5.4 billion USD in personal and corporate income and represents more than 160,000 jobs. There is a total 4 million ha of degraded coppice forests for energy forestry applications in Turkey. The improvement of degraded coppice forests is a very important activity, as important as forestation. Converting coppice forests into productive energy forests in order to meet continually-increasing fuel requirements in Turkey prevents the destruction of highly productive forests, thereby supplying more wood raw material for the forest industry, which at present operates with a low capacity. At the end of 2007, 643,247 ha of energy forest have been established [20].

Biogas systems are considered to be strong alternatives to the traditional stoves in rural Turkey [21]. The economic of biogas systems are compared with traditional heating systems fuelled by wood, coal and wood mixture, and dried animal waste in three different climatic regions in the country [1-3]. The technical data used in the analysis are based on the experimental results. Seven different comparisons are made between the biogas and traditional systems. The payback periods, cumulated life-cycle savings and the cost of biogas are calculated for a wide range using two unstable economic parameters, discount and inflation rates. The quality of the model and the assumptions are discussed. The results provide evidence of the economic viability of biogas systems over the traditional space heating systems of rural Turkey in many instances [10-13].

Turkey is one of the countries with significant potential in geothermal energy (at present seventh in the world) and there may exist about 2000 MW_e of geothermal energy usable for electrical power generation. Turkey’s total geothermal heating capacity is about 31,500 MW_th. At present, heating capacity in the country runs at 1240 MW_th equivalent to 150,000 households. These numbers can be heightened some seven-fold to 7,180 MW_th equal to 610,000 households through a proven and exhaustible potential in 2010. Turkey must target 1.1 million households equivalent 8,900 MW_th in 2020 [22-25].

The yearly average solar radiation is 3.6 kWh/m²·day and the total yearly radiation period is approximately 2640 hour, which is sufficient to provide adequate energy for solar thermal applications. In spite of this high potential, solar energy is not now widely used, except for flat-plate solar collectors. They are only used for domestic hot water production, mostly in the sunny coastal regions [28]. In 2007, country has about total 7.8 million m² solar collectors and it is predicted that total energy production is about 0.440 Mtoe in 2007. Although solar energy is the most important renewable energy source it has not yet become widely commercial even in nations with high solar potential such as Turkey [28]. The energy consumption for heating and cooling of buildings in Turkey was about 25 Mtoe for the year 2007 [12]. The average household in Turkey needs more that 60 % of its total energy consumption for space heating. The cooling demand in buildings increased rapidly in south region of the country at the summer season. The reason, beside general climatic and architectural boundary conditions, is an increase in the internal cooling load and high summer season. The reason, beside general climatic and architectural boundary conditions, is an increase in the internal cooling load and higher comfort requirements. These aspects show the huge potential in this field for the implementation of advanced thermal energy storage technologies in Turkey [10-13, 26-28].

There are a number of cities in Turkey with relatively high wind speeds. These have been classified into six wind regions, with a low of about 3.5 m/s and a high of 5 m/s at 10 m altitude, corresponding to a theoretical power production between 1000-3000 kWh/(m²·yr) . The most attractive sites are the Marmara Sea region, Mediterranean Coast, Agean Sea Coast, and the Anatolia inland. Capacity is likely to grow rapidly, as plans have been submitted for just under a further 600 MW of independent facilities. At start 2009, total installed wind energy capacity of Turkey is only 800 MW [28].

5. Air Pollution in Turkey

Greenhouse gas emissions from fuel combustion jumped 65% in the 1990s. In recent years, Turkey’s energy consumption increasing very fastly due to its economical development. The Turkish government is now in the process of developing a strategy to reduce the growth of greenhouse gases.
Turkey will have the obligation to implement measures and polices to mitigate greenhouse gas emissions but will not be required to meet a specific greenhouse gas emission target [29-33]. Turkey has achieved decoupling of SOx, NOx and CO emissions from economic growth. In 2006, estimated SO₂ emissions are 1.94 million tons, while GDP and fuel consumption increased by 26 and 23% respectively. Major contributors to SOx emissions continue to be power plants (66.3%) and industrial combustion (26.1%) [5]. On the other hand, NOx emissions, estimated at 1.2 million tons in 2006 [31, 32]. The major contributor to NOx emissions continued to be mobile sources. Power stations and industrial combustion accounted for 16.9 and 18.8% respectively (Table 5) [29-34].

<table>
<thead>
<tr>
<th>Source</th>
<th>SO₂</th>
<th>NOx</th>
<th>VOC</th>
<th>CO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power stations</td>
<td>1288.7</td>
<td>186.4</td>
<td>7.2</td>
<td>24.1</td>
</tr>
<tr>
<td>Industrial combustion</td>
<td>512.8</td>
<td>207.3</td>
<td>3.3</td>
<td>76.0</td>
</tr>
<tr>
<td>Non-industrial combustion</td>
<td>76.5</td>
<td>208.6</td>
<td>176.5</td>
<td>1464.5</td>
</tr>
<tr>
<td>Industrial processes</td>
<td>48.2</td>
<td>17.6</td>
<td>48.0</td>
<td>6.5</td>
</tr>
<tr>
<td>Mobile sources</td>
<td>22.0</td>
<td>454.0</td>
<td>123.7</td>
<td>1474.2</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>-</td>
<td>12.2</td>
<td>36.2</td>
<td>561.2</td>
</tr>
</tbody>
</table>

Carbon monoxide emissions amounted to 3.6 million tons in 2006 and mostly come from non-industrial (41%) and mobile (41%) sources (Table 6). On the other hand, volatile organic compound (VOC) emissions have increased slightly. Total emissions were estimated at 554 400 tons in 2004, with nonindustrial fixed sources contributing 31.5%, mobile sources 22.7% and solvents 28.4% of total VOC emissions [29-34].

<table>
<thead>
<tr>
<th>Years</th>
<th>CO₂</th>
<th>CH₄</th>
<th>N₂O</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990</td>
<td>139.6</td>
<td>29.2</td>
<td>1.3</td>
<td>170.1</td>
</tr>
<tr>
<td>1992</td>
<td>152.9</td>
<td>36.7</td>
<td>4.0</td>
<td>193.6</td>
</tr>
<tr>
<td>1994</td>
<td>159.1</td>
<td>39.2</td>
<td>2.2</td>
<td>200.5</td>
</tr>
<tr>
<td>1996</td>
<td>190.7</td>
<td>45.0</td>
<td>6.1</td>
<td>242.1</td>
</tr>
<tr>
<td>1998</td>
<td>202.7</td>
<td>47.7</td>
<td>5.6</td>
<td>256.6</td>
</tr>
<tr>
<td>2000</td>
<td>223.8</td>
<td>49.3</td>
<td>5.8</td>
<td>280.0</td>
</tr>
<tr>
<td>2002</td>
<td>216.4</td>
<td>46.9</td>
<td>5.4</td>
<td>270.6</td>
</tr>
<tr>
<td>2003</td>
<td>231.0</td>
<td>47.8</td>
<td>5.3</td>
<td>286.3</td>
</tr>
<tr>
<td>2004</td>
<td>241.9</td>
<td>46.3</td>
<td>5.5</td>
<td>296.6</td>
</tr>
<tr>
<td>2006</td>
<td>256.4</td>
<td>49.6</td>
<td>3.4</td>
<td>312.8</td>
</tr>
</tbody>
</table>

Between 1990 and 2006 total greenhouse gas (GHG) emissions increased by 84% from 170 Tg/CO₂eq in 1990 to 312.8 Tg/CO₂eq in 2005 (Table 6), in line with GDP growth [15]. The energy sector accounted for 77.3% of the total in 2006. The other contributing sectors are the waste sector (9.5%), industrial processes (8.1%) and agriculture (5.1%) [34]. On the other hand, CO₂ emissions account for 82.1% and CH₄ emissions for 15.8% of total GHG emissions. Most (92%) of total CO₂ emissions are from fossil fuel combustion [31-33].

6. Sustainable energy policies

The basic principle of Turkish energy policy, as set out in the 9th National Development Plan (2007-2013), was to ensure sufficient energy supply to meet the increasing demand, at the lowest cost possible. The 9th plan also introduced provisions for
minimizing negative environmental impacts, improving energy efficiency and increasing the share of renewable energy in energy consumption [14].

The government further reformed the regulatory framework to reduce pollution from energy production. In 2006, the new Regulation on Control of Air Pollution from Industrial Plants set standards for emissions of NOx, SO2, CO and PM from combustion plants. PM and CO standards were lowered for both solid and liquid fuel-fired power plants [31]. Some investments have already been made, especially to address the environmental impacts of the high sulphur content of domestic lignite. New lignite-fired power plants have been equipped with flue gas desulphurisation (FGD) technology to comply with regulations. Six of eleven pre-1986 lignite-fired plants have been retrofitted with electrostatic precipitators (ESP) to reduce particulate emissions. However, not all electrostatic precipitators are working at maximum efficiency. Construction of one power plant based on circulating fluidised bed technology has recently been completed. This first application of advanced coal technology in Turkey, designed to use low-quality lignite with high sulphur content, was followed by other plants [14, 33, 34].

In Turkey, renewables represent about 36.3% of total primary energy production. More than half of the renewables used in Turkey are combustible fuels and waste, the rest being mainly hydro, solar and geothermal. Turkey is richly endowed with hydro, wind and geothermal resources. Sectoral studies have indicated that small-scale is underdeveloped, with 140 plants in operation compared with 350 prospective development sites and a total potential production of 40 TWh of electricity per year. Turkey has the potential for up to 11,000 MW of wind power capacity, capable of generating about 45 TWh of electricity per year [3-5]. There is also large potential for geothermal and solar thermal applications in Turkey. Solar collectors are already a significant, market-driven business. The government expects the use of geothermal and solar energy to double between 2007 and 2020. The Geothermal Energy Law, enacted in 2007, aims to boost geothermal residential heating. The organic component of waste incineration is also considered a renewable option in the future, using appropriate technology to meet high health and environmental standards. On the other hand, commercial use of renewable energy has not developed rapidly. Financial assistance is being provided for the development of renewable energy projects. In 2007, USD 290 million was made available; by 2008, about half had already been committed to finance 24 projects with several other projects under preparation [12-14].

7. Conclusions

Renewable energy supply in Turkey is dominated by hydropower and biomass, but environmental and scarcity-of-supply concerns have led to a decline in biomass use, mainly for residential heating. As a contributor of air pollution and deforestation, the share of biomass in the renewable energy share is expected to decrease with the expansion of other renewable energy sources such as solar and wind. Turkey has substantial renewable energy sources such as hydropower, solar, biomass and wind power. There is also significant potential for wind power development. Renewables exception of large hydropower are widely dispersed compared with fossil fuels, which are concentrated at individual locations and require distribution. Hence, renewable energy must either be used in a distributed manner or concentrated to meet the higher energy demands of cities and industries.

References

[34] Kaygusuz, K. sustainable energy, environmental and agricultural policies in Turkey. Energy Conversion and Management 2010; 51: 1075-84.