Hydropower  
versus  
Other Renewable Energy Sources


EMRE GOK AND ELCIN KENTEL
Renewables in Turkey

- Turkey is highly dependent on foreign fossil fuel sources → experiences many problems due to its increasing energy consumption.
- Renewable energy resources need to be developed to:
  - reduce vulnerability to disruptions in natural gas
  - maintain economic & sustainable development

Karakaya Dam – Euphrates River

http://tr.wikipedia.org/wiki/Karakaya_Baraj%C4%B1_ve_Hidroelektrik_Santrali
Energy Production to Consumption Ratio for Main Energy Sources from 1970-2011

Prepared by data obtained from ETKB (November, 2013)
Energy Production to Consumption Ratio for Domestic Energy Sources from 1970-2011

Prepared by data obtained from ETKB (November, 2013)
## Reserves & Electricity Generation from Renewables

<table>
<thead>
<tr>
<th>Renewable Energy Source</th>
<th>Potential ((10^9 \text{ kWh per year})^+)</th>
<th>Reserve 2011 (MW)**</th>
<th>Installed Capacity in 2011 (MW)*</th>
<th>Electricity Generation in 2011 (GWh/yr)*</th>
<th>Share in Total Electricity Generation in 2011 (%)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydropower</td>
<td>216</td>
<td>36603</td>
<td>17137.1</td>
<td>52.3</td>
<td>22.7</td>
</tr>
<tr>
<td>Solar Energy</td>
<td>380</td>
<td>not identified</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Wind Energy</td>
<td>150</td>
<td>48000</td>
<td>1728.7</td>
<td>4.7</td>
<td>2.1</td>
</tr>
<tr>
<td>Geothermal</td>
<td>9</td>
<td>600</td>
<td>114.2</td>
<td>0.7</td>
<td>0.3</td>
</tr>
</tbody>
</table>

* EUAS (2012)  
+ DSI (2013)  
** MENR (2012) (geothermal only for electricity)
Hydropower Capacity & Additions in 2013 – the World
Renewable Energy Planning for Electricity Consumption – MSc. study conducted by Emre Gök

🌟 Goal → prioritization of the development of renewable energy sources, namely hydropower, solar, wind, geothermal & biomass, to increase their contribution to electricity generation of Turkey using the Analytic Hierarchy Process

🌟 Renewable energy sources are compared with respect to selected criteria & sub-criteria by a group of experts who are mostly academics & professionals working in government offices.

Renewable Energy Planning for Electricity Consumption

🌞 Energy is central to sustainable development which affects economic, social, & environmental well-being for today & tomorrow.

🌞 The major renewable energy sources of Turkey are

.globally

- solar energy,
- biomass energy,
- geothermal energy,
- wind energy, &
- hydropower.

Energy & Environmental Goals

Renewable energy sources of Turkey are assessed using two main criteria:

**Energy Goals**

(i) maintaining security for electricity supply,
(ii) supplying electricity with low prices,
(iii) maintaining stability for electricity generation,
(iv) maintaining economic development.

**Environmental Goals**

(i) maintaining low carbon, SO\(_x\), and NO\(_x\) emission,
(ii) maintaining environmental sustainability,
(iii) minimum impact on public health,
(iv) maintaining social acceptability.
Energy Goals

1) Maintaining Energy Security

The Turkish energy sector is highly dependent on fossil fuels.

In 2011, 78.6% of Turkey’s energy demand was supplied through imports (WEC, 2012).

Thus, the electricity sector is vulnerable to the price fluctuations & exposed to security threats such as

- supply disruptions,
- associated economic, social, and health problems,
- international conflicts, & political disputes.
Energy Goals

2) Supplying Electricity with Low Prices

Electricity is an important economic input for
- residential,
- industrial,
- agricultural,
- transportation &
- other sectors

In order to maintain high living standards, & national competitiveness, electricity prices need to be low.
A common drawback of renewable energy sources is the unpredictable and intermittent output of electrical power.

- non-controllable variability,
- unpredictability, and
- dependency on sources that are location dependent
Energy Goals

4) Maintaining Economic Development

Renewable energy technologies contribute to economic development in many ways, especially through

- creating new job opportunities and
- supporting development of local economies.
Environmental Goals

1) Maintaining Low Carbon, SOx, NOx Emissions

Life-cycle GHG emissions of renewable energy sources are much lower than those of thermal sources such as lignite, natural gas and coal.

However life-cycle GHG emission among different renewable energy sources show variation as well; biomass & solar PV emissions are higher than those of hydro & wind.

<table>
<thead>
<tr>
<th>Power plant</th>
<th>Minimum</th>
<th>Mean</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lignite</td>
<td>800</td>
<td>1100</td>
<td>1700</td>
</tr>
<tr>
<td>Coal</td>
<td>760</td>
<td>1000</td>
<td>1280</td>
</tr>
<tr>
<td>Oil</td>
<td>520</td>
<td>780</td>
<td>1200</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>440</td>
<td>560</td>
<td>780</td>
</tr>
<tr>
<td>Nuclear</td>
<td>3</td>
<td>10</td>
<td>24</td>
</tr>
<tr>
<td>Hydro</td>
<td>1</td>
<td>10</td>
<td>34</td>
</tr>
<tr>
<td>Wind</td>
<td>8</td>
<td>14</td>
<td>30</td>
</tr>
<tr>
<td>Solar PV</td>
<td>43</td>
<td>56</td>
<td>73</td>
</tr>
<tr>
<td>Biomass</td>
<td>35</td>
<td>70</td>
<td>99</td>
</tr>
</tbody>
</table>
Environmental Goals

2 & 3) Maintaining Environmental Sustainability & Maintaining Social Acceptability

Protests at Rize

Reference: Dr. Oğuz Kurdoğlu's presentation at IMO Ankara on 23.06.2011
Environmental Goals

2 & 3) Maintaining Environmental Sustainability & Maintaining Social Acceptability
In Turkey, there is a legal requirement enforced by the Ministry of the Environment and Urbanization (formerly Ministry of Environment and Forestry) to complete an EIA study for HEPP projects with installed capacities of 25 MW or larger. Projects with installed capacities between 0.5 MW and 25 MW are subject to the Selection and Elimination Criteria. The owner prepares a “Project Presentation File” and the Ministry of Environment and Urbanization decides whether an EIA is required or not (MOEU, 2008). Currently, around 2000 SHPPs are planned throughout Turkey (Özalp et al., 2010). Although planning, construction and operation of these hydropower plants must be realized in accordance with the submitted project presentation files or EIA reports, currently appropriate auditing of these studies cannot be carried out by the government since the necessary organizational infrastructure is not fully established yet (Abay et al., 2010). This has resulted in many lawsuits and suspension of executions related with hydropower projects in Turkey. The Eastern Black Sea Region is among the problematic areas in terms of the development of small hydropower in Turkey.
Environmental Goals

4) Minimum Impact on Public Health

- The switch from fossil fuel electricity generation to electricity generation from renewables has the potential to deliver appreciable health benefits.
- But renewable energy sources may have some negative impacts on public well-being such as noise, visual impacts, & indirect health impacts of GHGs.
Method

To evaluate the major renewable energy sources of Turkey, a survey was prepared. The survey was conducted only with “experts”.

<table>
<thead>
<tr>
<th>Number of Experts</th>
<th>Employer</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>University</td>
</tr>
<tr>
<td>4</td>
<td>General Directorate of Renewable Energy (YEGM)</td>
</tr>
<tr>
<td>4</td>
<td>World Energy Council - Turkish National Committee (DEK-TMK)</td>
</tr>
<tr>
<td>2</td>
<td>Ministry of Energy and Natural Resources (ETKB)</td>
</tr>
<tr>
<td>1</td>
<td>Energy Market Regulatory Authority (EPDK)</td>
</tr>
<tr>
<td>1</td>
<td>Turkish Electricity Transmission Company (TEİAŞ)</td>
</tr>
<tr>
<td>1</td>
<td>General Directorate of Mineral Research and Exploration (MTA)</td>
</tr>
<tr>
<td>1</td>
<td>General Directorate of State Hydraulic Works (DSİ)</td>
</tr>
<tr>
<td>1</td>
<td>Ministry of Development</td>
</tr>
<tr>
<td>3</td>
<td>Private Sector</td>
</tr>
<tr>
<td>1</td>
<td>Editor of an Energy Journal</td>
</tr>
</tbody>
</table>
Method: AHP – Hierarchy Structure

Select a renewable energy source to increase its contribution to Turkey’s electricity generation.

Level 0
Objective

Level 1
Criteria

Energy Goals

Environmental Goals

Level 2
Sub-criteria

Maintaining Security for Electricity Supply

Supplying Electricity with Low Prices

Maintaining Stability for Electricity Generation

Maintaining Economic Development

Maintaining Low SO$_2$ and NO$_x$ Emissions

Maintaining Environmental Sustainability

Maintaining Social Acceptability

Maintaining Minimum Impact on Public Health

Level 3
Alternative

Results

☀ Energy Goals are ranked as more important than Environmental Goals by the experts.

☀ The main reason of this preference → energy is required for basic human needs such as lighting, cooking, health services, mobility and communication → Secure & stable electricity with low prices is necessary to meet economic development & improve human welfare & health.

☀ However development & improvement can be sustainable only if they are maintained without violating future generations’ ability to meet their needs.

☀ Attaining sustainable development requires eliminating those externalities that are responsible for natural resource depletion and environmental degradation (OECD, 2001).
Priorities of sub-criteria of Energy Goals

- Maintaining Security for Electricity Supply: 0.359
- Supplying Electricity with Low Prices: 0.183
- Maintaining Stability for Electricity Generation: 0.287
- Maintaining Economic Development: 0.171
Priorities of sub-criteria of Environmental Goals

- Maintaining Low Carbon, SOx and NOx Emission: 0.250
- Maintaining Environmental Sustainability: 0.252
- Minimum Impact on Public Health: 0.290
- Maintaining Social Acceptability: 0.208
Results

☀ Hydropower is selected as the most preferred renewable energy source followed by solar and wind energies to increase their contribution to electricity generation in Turkey.

☀ In terms of energy goals, hydropower performs best due to
  ☀ its untapped potential,
  ☀ providing electricity with low prices, and
  ☀ its potential for generating electricity in a stable manner in hydropower plants with reservoirs.
Results

However, in environmental aspects, performance of hydropower is not good:

- Forcing population displacement,
- Loss of cultural heritage assets,
- The large land requirement of hydropower plants with big reservoirs &
- Negative impacts of run-of-river hydropower plants on local people, nature & habitat.
Results

Both solar energy & wind energy performed very well for Environmental Goals. However, since their performances for Energy Goals are not as high as that of hydropower, they ranked second and third overall.

Stability for electricity generation is a critical problem both for solar energy and wind energy → Implementation of hybrid systems.

Solar energy performed the best for Environmental Goals. The main problem identified by the experts is the high cost associated with solar energy.
Turkey can annually generate approximately another 58,500 GWh electricity from hydropower.

Annual economically viable electricity generation from hydropower is estimated as 140,000 GWh.

Developing remaining hydropower potential will decrease Turkey's dependence on foreign energy sources.

Money saved through decreasing the utilization of foreign energy sources may be channelized into developing hydropower projects.

The need for the development of hydropower projects is obvious for Turkey; however this needs to be done in a wise and sustainable manner:

- HEP projects need to be audited by the related government agency.
- Planning of HEP projects need to be realized through an integrated basin management approach.
- Impacts of HEP projects on the environment and especially on aquatic life need to be investigated and adverse effects need to be minimized.
- Public and especially local people need to be informed about the HEP projects.
- Concerns of local community need to be listened and valued.

http://data.worldbank.org/indicator/EG.IMP.CONS.ZS/countries
# Production and Consumption of Electrical Energy in Turkey 2012-2013

<table>
<thead>
<tr>
<th></th>
<th>2012</th>
<th></th>
<th>2013</th>
<th></th>
<th>Increase</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>GWh</td>
<td>%</td>
<td>GWh</td>
<td>%</td>
<td>%</td>
</tr>
<tr>
<td>Thermal</td>
<td>174,871,7</td>
<td>73,0</td>
<td>171,812,5</td>
<td>71,6</td>
<td>-1,7</td>
</tr>
<tr>
<td>Hydraulic</td>
<td>57,865,0</td>
<td>24,2</td>
<td>59,420,5</td>
<td>24,8</td>
<td>2,7</td>
</tr>
<tr>
<td>Geo+Wind</td>
<td>6,760,1</td>
<td>2,8</td>
<td>8,921,0</td>
<td>3,7</td>
<td>32,0</td>
</tr>
<tr>
<td>GROSS PRODUCTION</td>
<td>239,496,8</td>
<td>100,0</td>
<td>240,154,0</td>
<td>100,0</td>
<td>0,3</td>
</tr>
<tr>
<td>IMPORTATION</td>
<td>5,826,7</td>
<td></td>
<td>7,429,4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>EXPORTATION</td>
<td>2,953,6</td>
<td></td>
<td>1,226,7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GROSS CONSUMPTION</td>
<td>242,369,9</td>
<td>1,0</td>
<td>246,356,6</td>
<td>1,6</td>
<td></td>
</tr>
</tbody>
</table>

## Breakdown of Electrical Energy Produced in Turkey by Primary Energy Resources 2012-2013

<table>
<thead>
<tr>
<th></th>
<th>2012</th>
<th></th>
<th>2013</th>
<th></th>
<th>Increase</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>GWh</td>
<td>%</td>
<td>GWh</td>
<td>%</td>
<td>%</td>
</tr>
<tr>
<td>Coal</td>
<td>68,013,1</td>
<td>28,4</td>
<td>63,786,1</td>
<td>26,6</td>
<td>-6,2</td>
</tr>
<tr>
<td>Liqued Fuels</td>
<td>1,638,6</td>
<td>0,7</td>
<td>1,738,8</td>
<td>0,7</td>
<td>6,1</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>104,505,5</td>
<td>43,6</td>
<td>105,116,3</td>
<td>43,8</td>
<td>0,6</td>
</tr>
<tr>
<td>Renewable + Waste + Waste heat*</td>
<td>714,5</td>
<td>0,3</td>
<td>1,171,2</td>
<td>0,5</td>
<td>63,9</td>
</tr>
<tr>
<td>Hydraulic</td>
<td>57,865,0</td>
<td>24,2</td>
<td>59,420,5</td>
<td>24,7</td>
<td>2,7</td>
</tr>
<tr>
<td>Geo+Wind</td>
<td>6,760,1</td>
<td>2,8</td>
<td>8,921,0</td>
<td>3,7</td>
<td>32,0</td>
</tr>
<tr>
<td>TOTAL</td>
<td>239,496,8</td>
<td>100,0</td>
<td>240,154,0</td>
<td>100,0</td>
<td>0,3</td>
</tr>
</tbody>
</table>

*Electricity via waste heat has been produced in 2013