FINAL CONFERENCE

“Green Cluster of Knowledge Institutions of Black Sea: A Roadmap on Renewable Energy Sources and Energy Efficiency for Research and Academic Institutions

July 23, 2012 - Taksim - İstanbul
Motivation

- World’s increasing energy demand is mainly provided by the fossil fuels

- Reserves decrease strictly

- Researchers have focused on alternative clean energy sources and how to set them for practical usage economically
Alternative energy sources

- Biomass Energy
- Wind Energy
- Solar Energy
- Geothermal Energy
- Hydroelectric Energy
Hydrogen

• *Hydrogen* is an energy carrier (like a battery), not a primary energy source (like coal).

• The feasibility of a *hydrogen economy* depends on issues of

  – energy sourcing,
  – including fossil fuel use,
  – climate change,
  – sustainable energy generation.
The hydrogen future

Current Energy Economy:
- Primarily based on hydrocarbons, small number of providers
- Central production
- Significant delivery distances
- Point, distributed, and mobile emissions

Future Hydrogen Electric Economy:
- Based on energy services, not energy sectors
- Central or distributed production
- Resource-flexible
- Potential for significant reduction in emissions
The outlook for future markets for hydrogen as a fuel can be governed by two economic scenarios:

1. Hydrogen production from conventional fossil sources

1. Hydrogen production from nonfossil (renewable) sources
A long-sought goal of energy research has been a method to produce hydrogen fuel economically by using nonfossil fuels such as sunlight, wind and hydropower as the primary energy source.

Although production of hydrogen by using renewable energy produced via the use of solar cells or wind turbines has been regarded as the cleanest and most desirable method, these processes do not supply enough hydrogen at the present stage.
Hydrogen must be derived from other energy sources.
Solar hydrogen production methods
Solar energy is the most abundant energy resource on earth. The solar energy that hits the earth’s surface in one hour is about the same as the amount consumed by all human activities in a year.
Solar PV Technology

• Direct conversion of sunlight into electricity in PV cells is one of the three main solar active technologies, while the other two technologies include concentrating solar power (CSP) and solar thermal collectors for heating and cooling (SHC).

• Solar PV technology is also used for \textit{hydrogen production}. 
Electrolysis Technology

• Water electrolysis has the potential to play a key role in a future energy model based on two energy carriers:
  – electricity and hydrogen.

• The global electrolysis reaction taking place is given in equation below.

\[ \text{H}_2\text{O} \rightarrow \text{H}_2 (g) + \frac{1}{2} \text{O}_2 (g) \]

• Since the renewable energy sources, mainly hydropower, wind, and photovoltaic, can be easily coupled with water electrolysis processes, producing clean and sustainable hydrogen.
Electrolysis Technology

• Currently, alkaline and polymer electrolyte membrane (PEM) electrolyzers are commercially available.

• Both are safe and reliable but only alkaline electrolyzers have a sufficiently large capacity to produce energy at significant rates.
Grid independent solar-hydrogen generation
Grid-assisted PV-hydrogen generation
PVs for grid-electricity and hydrogen generation
Integrated PV-hydrogen utility energy system
Grid independent integrated PV-hydrogen energy system
A Case Study – HYDEPARK Project

• “Development of Hydrogen Production, Conversion and Storage Technologies – HYDEPARK” project, which was supported by the State Planning Organization of Turkey (DPT), started on June 1st, 2005 and completed by the end of 2007. The HYDEPARK plant is located in Gebze Kocaeli - Türkiye.
Project partners

• TÜBİTAK Marmara Research Center (Project Coordinator)
• State Planning Organization of TÜRKİYE (Funding Council)
HYDEPARK Area
OBJECTIVES

• The main goal of this national project is to research hydrogen technologies and renewable energy applications.

• Solar and wind energy are utilized to obtain hydrogen energy via electrolysis. Hydrogen can either be used in fuel cell or stored for further use.

• The management of all work packages was carried by TÜBİTAK Marmara Research Center (MRC) Energy Institute (EI) with the support of the collaborators such as Ege University.

• Finally a renewable energy based hydrogen production and storage system was established and now it is in the demonstration phase.
SYSTEM COMPONENTS

Renewable Energy Systems

- WIND TURBINE
- SOLAR PANELS
- NATURAL GAS REFORMER
- BATTERIES
- PEM TYPE ELECTROLYZER
- H₂ STORAGE
- PEM FUEL CELL APPLICATION

METEOROLOGY STATION
The components of the power electronics and control unit
HYDROGEN PRODUCTION VIA ELECTROLYSIS

- A Proton Exchange Membrane (PEM) type electrolyser is used to produce hydrogen by utilizing the electricity generated by the wind turbine and the PV panels, which take place in the demonstration area.

- 1.05 Nm$^3$/h H$_2$ production rate
- max. 13.8 barg delivery pressure
- 99.9995% purity H$_2$
- **power consumption:**
  - 6.7 kWh/Nm$^3$ H$_2$ for optimal conditions and
  - 8.3 kWh/Nm$^3$ H$_2$ for end of life conditions
Hydrogen is fed to the compressor through a buffer tank with an inlet pressure of 7–10 bar. The single-stage hydrogen compressor has a triple diaphragm construction which isolates hydrogen from hydraulic oil.

- Flow capacity of 4 Nm³/h at maximum suction
- H₂ discharge pressure up to 103 bar
- The pressurised hydrogen leaving the compressor is cooled through a heat exchanger before sent to the cylinders for storage.
PHOTOVOLTAIC (PV) PANELS

• The photovoltaic system includes totally 145 PV panels and the total installed power is ~12 kWp in the standard conditions.
• 120 PV panels are CIS type thin film, total 9.6 kWp, ~ 10.5% efficiency
• 10 PV panels are multicrystalline type, produced by Ege University Solar Energy Institute, total 1.2 kWp, ~ 13% efficiency
• 15 PV panels are monocrystalline type, total ~ 1.1 kWp, ~ 14% efficiency.
WIND TURBINE

• The wind turbine power is 5 kWp which was produced by a national company in İzmir, Turkey.
• The wind generator is a permanent magnet and a three-phase synchronous machine. The nominal power of the generator is 5 kVA and the rated rpm is 375 (the wind speed is 13 m/s). The DC output voltage is 45-60 V DC.
All the generated electricity is stored in conventional stationary type lead acid batteries which were produced by a national company. The designed dc busbar voltage is set to be 48V. Therefore 2V dc cells are connected serially in number of 24, in order to achieve this voltage. The capacity of the desired battery is 1500Ah which is enough for standalone application for overnight period.
HYDROGEN STORAGE CYLINDERS

- Hydrogen is stored in high pressure cylinders in gas phase after pressurized by the compressor up to 103 bar.
- 12 cylinders in a stationary bundle
- 4 individual cylinders, ready to be carried to the laboratory in case of need
- Stored hydrogen in the cylinders can also be utilized in the fuel cell after regulating the pressure.
There are two PEM Fuel Cell modules in this demonstration park. All necessary auxiliary components (air compressor, cooling fan, humidity exchanger, purge valve, pressure regulator and microprocessor controller) are built into the system.

- air-cooled
- works at atmospheric pressure
- up to 1200 Watt of unregulated DC electrical power generation
Initially measurements of the reliable sources (the solar irradiation, module temperature and wind speed values) were used to calculate the system requirements. The average daily solar radiation energy and the load consumption energies were taken as the essential parameters for solar system sizing (The yearly total solar irradiation is ~ 1.6 MWh/m² in Gebze).
• Assuming that the **PV rated efficiency was 13.5%**, the **battery efficiency was 70%**, the mean **inverter efficiency was 90%**, the mean **charge controller efficiency was 90%**, the **efficiency of other components was 80%** and then the **total solar system efficiency was calculated to be ~ 6%** (Other efficiencies such as wind turbine, fuel cell, and hydrogen storage etc. are not included). By using these values, **the peak power of the PV generator was calculated to be ~ 12 kWp**.

• The operational parameters of the electrolyser can be monitored and stored by using its original PC program. Also it is possible to measure other system parameters and a PC system is set to view and save them. So efficiency of the individual systems and total system efficiency can be calculated and the system efficiency is found to be 9% according to the formula given below:

\[
\eta_{\text{system}} = \eta_{\text{PV}} \times \eta_{\text{PCU}} \times \eta_B \times \eta_o
\]

• where \( \eta_{\text{system}} \) = system efficiency, \( \eta_{\text{PV}} \) = PV efficiency (12.5%), \( \eta_{\text{PCU}} \) = power conditioning unit efficiency (96%), \( \eta_B \) = battery efficiency (75%), \( \eta_o \) = efficiency of others (98%)
For more information

• Assoc.Prof.Dr. Atilla ERSÖZ
  Atilla.Ersoz@tubitak.gov.tr

• Nilüfer İLHAN
  Nilufer.Ilhan@tubitak.gov.tr
Thanks for your attention

For more information

Assoc.Prof.Dr. Atilla ERSÖZ
Atilla.Ersoz@tubitak.gov.tr

Nilüfer İLHAN
Nilufer.ILhan@tubitak.gov.tr