

Turkey's Energy Profile and R&D Activities at TÜBİTAK Marmara Research Center

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1. Introduction

Turkey is geographically located between energy producing countries of its region with more than 75% of the world's proven oil and gas reserves and the well-developed European energy consumer markets. This privileged natural position provides Turkey with both opportunities and responsibilities in terms of energy security.

Turkey's demand for energy has been increasing due to economic and population growth. Turkey's installed capacity has exceeded 93 GW (August 2020), which represents a threefold increase in 15 years. Having said that, Turkey is heavily dependent on energy import. So Turkey, not only to overcome energy-dependency, but also to meet environmental concerns for sustainable development, sets the following goals in its energy policy;

- 1) Diversification of supply routes and sources for imported oil and natural gas
- 2) Increasing the ratio of local and **renewable energy** in our energy mix
- 3) Increasing energy efficiency
- 4) Adding nuclear to our energy mix.

Turkey has a substantial amount of renewable energy potential, and the utilization of this potential has been increasing over the last decade. Renewables account for the half of the total installed capacity while hydro-power is the leading renewable source with 32% share (August 2020), followed by wind (8.6%) and solar (6.8%) power.

Turkey, as being a founding member of the International Renewable Energy Agency (IRENA), has made it a priority to increase the share of renewable sources further in the country's total installed power. This will run in parallel to the government's commitment to energy efficiency, whereby it is enacting laws that set principles for saving energy, at both individual and corporate levels, as well as providing incentives to energy efficiency investments. Moreover, Turkey's Development Plan (2019-2023) not only set strategies for biomass and waste utilization but also includes the support for R&D projects on clean coal technologies.

R&D activities of Turkey on energy is being performed by dedicated research groups of several public/private universities and institutes while Energy Institute (EI) of TÜBİTAK Marmara Research Center is a leading entity in the development of "applied energy technologies" with its large infrastructure and human potential. EI develops know-how into practical applications of advanced and innovative energy and transportation technologies. It forms a bridge between fundamental research and industrial applications.

EI cooperates with national and international institutions on science and technology projects, constantly develops its infrastructure and capabilities since 1980s.

2. R&D activities related to clean energy technology

Energy Institute's research activities includes areas such as Clean Coal and Biomass Technologies, Fuel Cell and Energy Storage Technologies and Power Systems and Renewable Energy Technologies. Among these activities, Clean Coal and Biomass, Fuel Cell and Renewable Energy (solar & hydro) are the ones especially contributes to the development of clean energy technology in Turkey. Project activities under these areas are funded by national and international sources.

In Materials Institute we are enrolling the industry by applied and pilot scale research on

photovoltaic solar energy through national goals. For that, the institute utilizes distinctive deposition systems and equipments for the fabrication, development and characterization of crystalline and thin film silicon photovoltaics and TCO coatings, pilot scale photovoltaic module development line, small scale back contacted module development line. Large electrical and meteorological data logged from outdoor test bed enables us for the development of whether forecast models in different time base in performance estimation of a photovoltaic installation. We are also involved in economic feasibility, design, installation and performance optimization of a solar power plant where we conduct projects on solar power stations, BIPV and floating photovoltaic applications.

One of the other Institute of MRC is “Environment and Cleaner Production Institute (ECPI)”. ECPI has taken over the responsibility of being the National Cleaner Production Centre for Turkey. To this end, training and coordination programs are planned to organize for individual and institutional capacity development of those serving industrial sectors, and to prepare and disseminate sectorial best available technologies and references for stakeholder introduction to current cleaner production technologies. ECPI also coordinate the network of expert institutions and external experts for risk assessment, life cycle assessment, eco-design and energy efficiency.

One of the laboratory of ECPI is Energy Efficiency Measurement. There is an infrastructure in place for measuring energy efficiency, one of the most important components of cleaner production audits. In this scope, the institute measures combustion efficiency, point temperature, and flows. It determines flue gas emissions, thermal losses, electrical energy consumption, thermal imaging. Energy and cleaner production audits are still being carried out by ECPI FOR Trakya Development Agency in private sector companies.

For details: <http://www.temizuretimmerkezi.org/eng/active-audits>

3. Specific research activities in renewable energies, next generation energy management system with batteries, hydrogen, CCUS, and related technologies

Our research teams on biomass and coal conversion technologies carry out lab and pilot studies on the development of coal gasification, pyrolysis, syngas cleaning, coal to liquid, bio-hydrogen etc. technologies. One of the flagship projects, in this sense, is TRIJEN, which aims to produce more efficient and clean liquid fuels from coal and biomass. The pilot scale liquid fuel production plant has been successfully established in Soma and another related project of pre-design of commercial plant has been started. Another significant project, Tunçbilek Methanol production, includes the study of entrained flow coal gasification and synthesis of methanol. In another project namely Hydrogen Production via Gasification of Biomass, the aim is to develop a process at pilot scale for hydrogen production through gasification of biomass as a renewable energy source.

Within the scope of “Advanced Coal Conversion Technologies Excellence Center” project, a research center will be established in the field of coal-to-SNG conversion technologies.

The Institute started CCUS activities in 2010 within the scope of the "Liquid Fuel Production from Biomass and Coal Mixtures - TRIGEN" Project for “Turkish Coal Enterprises”. Initially, a laboratory-sized CO₂ capture system designed, tested and optimized. This design successfully was scaled-up and installed successfully as a pilot system. The pilot CO₂ capture system is still actively working as a part of TRIGEN project demonstration system. Additionally, another pilot scale CO₂ capture system was designed for “Turkish Coal Enterprises” "Tunçbilek Methanol

Production" project. For simultaneous carbon dioxide and H₂S removal lab-scale test unit was designed and constructed in terms of "Advanced Coal Conversion Technologies Excellence Center" project. Not only the capture but also utilization of CO₂ are aimed and studied currently in the institute. Our main intention is developing and improving catalysts/electro catalysts and catalytic/electro catalytic processes utilizing renewable energy sources for the CO₂ utilization. The institute is interested in conversion of CO₂ to carbon monoxide, methanol, methane, liquid fuels and organic acids via chemical and electrochemical routes. The institute also interested in mineral processes for CO₂ utilization.

In terms of oxy-combustion studies, 30 kWth atmospheric CFB oxy combustion with flue gas recycle and 30 kWth pressurized BFB oxy combustion systems were designed, constructed and operated successfully.

We also develop clean coal combustion technologies. In this respect, within MILTES Project, a 22 MWe environmentally-friendly thermal power plant was designed based on CFBC technology. On the other hand, MILKAS Project aimed to develop a flue gas desulphurization system for thermal power plants, where the design was completed. A waste heat utilization Project (TSAD) investigated the methods to benefit from thermal power plant surplus heats and district heating.

In the framework of fuel cell technologies; hydrogen production from sodium borohydride and natural gas are being conducted in addition to development of fuel cell stack and system sub-components, fuel cell system integration, power conditioning

In the framework of fuel cell technologies; studies on hydrogen production from sodium borohydride and natural gas are being performed. Moreover, fuel cell stacks and system sub-components are developed including fuel cell system integration, power conditioning and control, fuel cell component and stack tests, stationary and portable applications and transportation and intelligence applications. Sodium Borohydride Vehicle and Fuel Cell Based Micro-cogeneration System are among the successful projects.

At the renewable energy side, Solar Power and Hydroelectric Power Plants are main research areas. The institute has an expertise on photovoltaic inverter development and command & control systems for photovoltaic solar power plants. Energy Institute is taking part in the Development of Photovoltaic Solar Power Plant Technologies (MILGES) Project which aims design/manufacturing and installation of photovoltaic power plant equipment with 80% local technology (for solar cells with 18% efficiency, solar panels, solar central inverters with 1 MVA capacity, a plant automation system, a solar power plant with 10MW capacity) in order to meet national needs.

As for hydropower research, the focus is on control, protection, excitation and synchronization systems as well as speed regulator and generator designs. With the National Design and Manufacturing of Hydroelectric Power Plant Components (MILHES) Project, the Institute has worked on the design/manufacture and installation of newly developed products (vertical francis turbine, 11 MVA synchronous generator, speed governor, excitation system, power plant automation and prot. system, auxilliary systems) utilizing national engineering and material resources. The manufactured items are successfully installed and commissioned at Kepez-1 HEPP.

The institute also works on wind power monitoring and forecasting systems.

Some of the related projects conducted by Energy Institute:

- Hydroelectric Power Plant Rehabilitation Projects (nearly 10 hydro-power plants) (2012-2024)
- Fuel Cell Based Micro-Cogeneration System / Site Application (2 KWe) (2016-2022)
- Advanced Coal Conversion Technologies Excellence Center (2016-2021)
- TUBITAK 1007 Program -National Design and Manufacturing of Hydroelectric Power

- Plant Components (2015-2021)
- TUBITAK 1003 Program - Hydrogen Production (via Gasification) from Biomass (2017-2020)
- TUBITAK 1007 Program -Development of Photovoltaic Solar Power Plant Technologies (2015-2020)
- Methanol Production in Tunçbilek (2013-2020)
- TUBITAK 1007 Program -Liquid Fuel Production from Coal and Biomass Blends (TRİJEN) (2009-2020)
- Development of a National Flue Gas Desulphurization System for Thermal Power Plants (MİLKAS) (2014-2018)
- Development of a Monitoring and Forecasting System for Wind Power in Turkey (2012-2018)
- Development and Localization of Thermal Power Plant Technologies (MİLTES) (2013-2017)
- Sodium Borohydride Fuel Cell Based Range Extender for Electric Vehicles (2014-2016)
- Research and Development of Methods to Benefit from Thermal Power Plant Surplus Heats and District Heating (TSAD) (2006-2013)
- Sodium Borohydride Fuel Cell Vehicle (2009-2012)
- Fuel Cell Based Micro-Cogeneration System (5 KWe/30 KWth) (2006-2010)

4. International collaboration

4-1 International alliance/networking development

Under the coordination of TUBITAK Presidency, there are many bilateral cooperation agreements signed with various countries at intergovernmental or inter-institutional level in the field of science and technology. Within the framework of these agreements, joint research projects are supported and monitored and financial support is provided for joint scientific meetings, expert exchanges, study visits and similar activities. The programs are two types: permanent applications and calls for projects. Many of these programs support project proposals on clean energy research and development studies. Energy Institute conducted several projects within the framework of these programs.

International collaboration is performed through multilateral research programs, the most significant of which is EU programs. Energy Institute has performed several co-studies within FP6-7 and HORIZON2020 calls.

Energy Institute extends its collaboration network to non-EU countries as well. Within the scope of a recent HORIZON2020 call on bio-energy, Energy Institute and several EU countries formed a consortium along with Japan (National Institute of Advanced Industrial Science and Technology – AIST) and India (Indian Institute of Technology - IIT) and submitted a proposal.

There are also MoUs signed between TUBITAK Marmara Research Center and research centers abroad which is reflected as partnership in especially clean coal projects of Energy Institute. Additionally, a partnership with King Abdulaziz City for Science and Technology (KACST)-Saudi Arabia is established in the fields of Solar Inverter Systems and Power Quality Analyzers.

On the other hand Energy Institute is officially a member of below international organizations:

- EERA AIBSL- European Energy Research Alliance
 - EERA Bioenergy
 - EERA Smart Grids
 - EERA Wind Energy

- EERA Hydrogen & Fuel Cell
- IEA-International Energy Agency
 - IEA HEV-ExCo & Annex 1: Hybrid and Electric Vehicle Technologies and Programmes Executive Committee and Annex I Information Exchange
- N.ERGHY -Fuel Cell and Hydrogen Joint Technology Initiative (FCH JTI)
- EUREC- The Association of European Renewable Energy Research Centers

4-2 International joint R&D activities

Joint R&D activities of Energy Institute are mostly within EU Framework programme or bilateral cooperation programmes coordinated by TUBITAK Presidency.

The followings are International joint research projects with institutes taking part in RD20.

- 2534 BMBF /Germany – TÜBİTAK / Turkey Collaboration Project -2+2 Joint Research Programme Project: “1 kWe fuel processing system integrated with an advanced high temperature fuel cell stack for UPS application”
- (H2020) - 5TOI_4EWAS Quintuple Helix Approach to Targeted Open Innovation In Energy, Water, Agriculture in the South Mediterranean Neighborhood (2016 – 2019)
- (H2020) - BIOMASUD PLUS Developing the Sustainable Market of Residential and Commercial Mediterranean Solid Biofuels) (2016-2018)
- (7th FP) - CITYFiED-RepliCable and InnovaTive Future Efficient Districts and cities (2014-2019)
- (7th FP) - IRPWind- Integrated Research Programme on Wind Energy (2014-2018)
- (7th FP) - ELECTRA - European Liaison on Electricity Committed Towards long-term Research Activities for Smart Grids
- (7th FP) - ETRERA 2020 Empowering Trans-Mediterranean Renewable Energy Research Alliance for Europe 2020 Challenges (2013-2016)
- (6th FP) - MCFC-CONTEX Effects of CONTaminants in biogenous fuels on MCFC catalyst and stack compo-nent degradation and lifetime and EXtraction strategies (2010-2014)
- (6th FP) - TYGRE High Added Value Materials From Waste Tyre Gasification Residues (2009-2013)
- (6th FP) - E2PHEST2US -Enhanced Energy Production of Heat And Electricity By a Combined Solar Thermionic-Thermoelectric Unit System
- (6th FP) - MC-WAP Molten-Carbonate Fuel Cells For Water Borne Applications (2006-2011)
- (6th FP) - TERMISOL New Low Emissivity and Long-lasting Paints for Cost Effective Solar Collectors (2006-2010)
- (6th FP) - EU-DEEP The Birth of A European Distributed Energy Partnership That Will Help The Large-Scale Implementation of Distributed Energy Resources in Europe (2003-2009)
- (6th FP) - NATURAL-HY Preparing for the hydrogen economy by using the existing natural gas system as a catalyst (2004-2009)
- (6th FP) - CASES (6th FP) Cost Assessment Sustainable Energy Systems (2006-2008)
- (6th FP) - HYPROSTORE Improving of the S&T Research Capacity of TUBITAK MRC IE in the Fields of Hydrogen Technologies (2005-2008)
- (6th FP) - BIGPOWER Improving of the S&T Research Capacity of TUBITAK MRC IE in the Fields of Integrated Biomass Gasification with Power Technologies (2005-2008)
- (6th FP) - NETBIOCOF (6th FP) Integrated European Network For Biomass Co-Firing

- (2005-2007)
- H2020 - Assessment of Novel Technology for Phosphorus Removal, Recycling & Re-use from Domestic Wastewaters (2015-2016)
 - (EU) - ZERO BRINE - Re-designing the value and supply chain of water and minerals: a circular economy approach for the recovery of resources from saline impaired effluent (brine) generated by process industries (2017-2021)
 - (7th FP) Preparation of ITO Free Transparent Conductive Electrode via Layer-By-Layer Deposition of Carbon Nanotubes and Its Application for Solar Cells (2012-2016)
 - (7th FP) Cost-Reduction Through Material Optimization And Higher Energy Output Of Solar Photovoltaic Modules - A Collaboration Between Europe's Leading Pv R&D Institutes And Universities (CHEETAH) (2014-2018)
 - 2522 NRDI/ Hungary-TUBITAK/ Turkey Collaboration Project- Development of High CO-Tolerant Anode Electrocatalysts for Reformate-Fed PEM Fuel Cells

5. Future perspectives (beyond 2030)

Turkey sets its energy policy in a way both to overcome energy-dependency and to diminish diverse environmental effects in power production. Renewable energy technologies are fully supported for wider expansion in the country. Marmara Research Center Energy Institute is developing strategies and projects to apply above technologies to the benefit of the country. Integration of hydrogen production technologies with renewable energy is in the future scope of Energy Institute. Fuel cell technologies will be promoted through out the country as zero-emmission transportation technology. Development of clean coal, biomass/waste utilization, biofuel/biohydrogen production, CO₂ conversion technologies along with further dissemination of renewable plants are planned and seeking funding, collaboration partners. However, these technologies are, as well-known, challenged with both low maturity and readiness levels and cost competition with conventional technologies. That's why international collaboration is essential for advancement, cost-competiveness and commercial acceptance of these technologies.

Asc.Prof.Dr. Murat MAKARACI



Dr. Murat Makaracı was born in Zonguldak, Turkey, 1970. He got his BSc degree in Mechanical Engineering, Middle East Technical University, Ankara, 1992. For a brief period he was with Ministry of Energy and Natural Resources. He won scholarship to pursue graduate degrees in USA. He received his MSc degree in Mechanical Engineering on the title of Vehicle-Barrier Interactions In Crash Tests from Pennsylvania State University, USA, 1995. He got PhD degree in Mechanical Engineering from Mechanical, Aeronautical & Nuclear Engineering Department, Rensselaer Polytechnic Institute, NY, 2001. In the mean time he worked in Teaching Assistant and Research Assistant positions During doctoral studies he implemented finite Element, implicit backward Euler time integration of the Viscoplasticity Theory for high homologous temperatures. Simultaneously, he also worked for General Electric Corporate Research and Development (CRD) projects for increasing gas turbine performances and testing and analysis. He has been a faculty member for Kocaeli University, Mechanical Engineering Department, Kocaeli, Turkey since 1993. He served as Deputy Director of Graduate School of Natural Sciences (2006). He was cofounder of graduate programs for Automotive Engineering, Mechatronics Engineering and Biomedical Engineering. He was a pioneering consultant to University Rector for Technology Transfer Mechanism 2007-2008. He was appointed as a member to newly established Technology Transfer Committee of Higher Education Council of Turkey. He has been serving as Vice President for Marmara Research Center (MRC) of TUBITAK (Scientific and Technological Research Council of Turkey) since 2014. He is responsible for Strategy and Technology Development; Business Development and Industrialization and Corporate Development. During his stay, he founded Patent Support Unit and Technology Development Units. He has been serving as head of Commercialization and Licensing Committee. He was a part of commercialization of new Technologies of over 40 products to 25 companies. Under his leadership, TUBITAK MRC began to serve Tests and Analysis now for 44 countries in 5 continents. He is a member of national and international Professional associations and serve as a referee for several journals and projects. He taught course in International Hoca Ahmed Yesevi Turkish-Kazakhstan University. He represents TUBITAK MRC in WAITRO (World Association of Industrial, Technological and Research Organization) and COMSATS (Commission on Science and Technology for Sustainable Development in the South) and International Atomic Energy Agency (IAEA). He took part in design and manufacturing of first domestic National Wind Turbine project. He has been actively supporting research in Molten Salt Reactor amongst 4th Generation Nuclear Power Plants. Beside his educational and professional duties, he assumed presidency for Critical and Analytical Thinking (CAT) Platform and hosted 2 International CAT Symposiums in Turkey. He is married with two children.