Clean Energy Technologies Journal
Web page info: https://cetj.yildiz.edu.tr
DOI: 10.14744/cetj.2024.0002

CLEAN ENERGY TECHNOLOGIES JOURNAL

Technical Note

Sustainable energy research at Clean Energy Technologies Institute: An overview

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ARTICLE INFO

Article history
Received: 21 February 2025
Accepted: 21 February 2025

Key words:
Clean energy; Sustainability, Research; Innovation; Commercialisation.

ABSTRACT

Yildiz Technical University (YTU) Clean Energy Technologies (CET) Institute has started operations in 2022 with the aim to pioneer in advancing clean energy technologies through research and development. Integrating aspects of research, innovation, education and commercialisation it aspires to become leading research centre in Türkiye for innovative energy solutions and support decision makers in developing key energy policies for a sustainable society. Bringing together pioneering research leaders, the Institute has organised in eight research groups that correspond to different thematic areas in the energy sector. Being designed to train future energy and sustainability leaders with the appropriate skills and knowledge, two postgraduate degree programmes (at Master and PhD levels) in the field of Advanced Energy Technologies are offered to graduates from a broad range of disciplines and have a strong interest in clean energy technologies. In the long term, the Institute hopes to address regional and global challenges in the clean energy technologies and develop sustainable solutions in the sector with the help of a strong connection between scientists, industrial and research partners and policy makers.

Cite this article as: Kanturk Figen A, Balcioglu G. Sustainable energy research at Clean Energy Technologies Institute: An overview. Clean Energy Technol 2024;2(1):8-13.

INTRODUCTION

Energy is at the corner store of modern society, linking to social welfare and economic growth. However, many primary sources are not sustainable [1]. The existing fuel mix contributes to numerous environmental issues, such as global climate change, acid rain, freshwater consumption, air pollution, and radioactive waste, all of which also threading the social welfare and socio-economic activities [2-3]. To be sustainable, today's energy industry requires not only a shift from carbon-intensive systems to less environmentally destructive ones based on renewable sources and greener practices but also corresponding changes

Highlights

- Clean Energy Technologies Institute aims to be a leading energy and sustainability-focused research centre integrating aspects of research, innovation, education and commercialisation.
- The Institute provides a high-quality multidisciplinary research environment to tackle global and regional challenges in clean energy technologies through research and teaching,
- Subject areas covered a wide array of topics such as energy storage technologies, energy logistics, policies and strategies, hydrogen and alternative fuel technologies, economic, social impact and sustainability.

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in governance, institutional frameworks, legal regulations, public attitudes, and consumption habits [4-5].

However, the question how to replace conventional technologies by renewables brings other important questions that need to be answered: What are alternative energy technologies to fossil resources? What does the future hold for them? What do they mean in terms environmental, economic, and social sustainability? Which technologies and systems are more efficient to achieve low emissions and environmental benefits while ensuring economic growth and social welfare? How these technologies be improved through new developments in related areas, such as material science, chemistry, and physics? [5-6].

CLEAN ENERGY TECHNOLOGIES INSTITUTE

Since its founding in 2022, Yildiz Technical University (YTU) Clean Energy Technologies (CET) Institute [7] has made answering such questions its business as a multi-disciplinary energy ecosystem focusing on its activity areas including "Research, Innovation, Education, Commercialization and Service" (Fig.1a). Being located at the centre of Istanbul, CET Institute is a world class research centre established with the aim to pioneer in advancing clean energy technologies through research and development of state-of-the art technologies and to translate results of research activities to actionable knowledge that can support public policies and research innovation and commercialization studies and thereby increase CET's impact on economy and the society (Fig.1b). It will also help provide insights to policymakers in the implementation of the European Green Deal and develop strategies for the achievement of net zero target of Türkiye by 2053 [8].

Bringing together a multidisciplinary group of researchers, educators and industrial partners, the CET Institute is uniquely placed to provide technical, social and cultural solutions based on clean energy technologies to contribute sustainable energy, environment and industry through different type of projects sponsored by YTU and other national and international organisations. These solutions will contribute to decarbonization and reduction of global warming while training researchers and students to be leaders in renewable energy-focused research and provide innovative solutions in topics where science and technology matters.

The vision of the YTU CET Institute is to be one of the World's Excellence Centres in the field of clean energy technologies. In line with the Institute's vision, the missions are;

- To create a world-class research cluster,
- To primarily consider research, innovation and technology development,
- To work with local partners for sustainable development of Türkiye, and
- To conduct cutting-edge research for current problems and future technologies and their development.

In this purpose the objectives that leads to this mission and vision can be defined as;

- To excel in research, development and innovation,
- To play a key role in technology development and transfer,
- To develop partnerships with industry, government agencies, and other institutions,
- To advance knowledge,
- To educate and train people, students, researchers, scientists etc.,
- To serve local community for solving their problems, and
- To organize local and international events to disseminate new developments.

Based at the YTU Davutpasa Campus, the CET Institute offers a unique multidisciplinary research environment through its taught and research programmes in Advanced

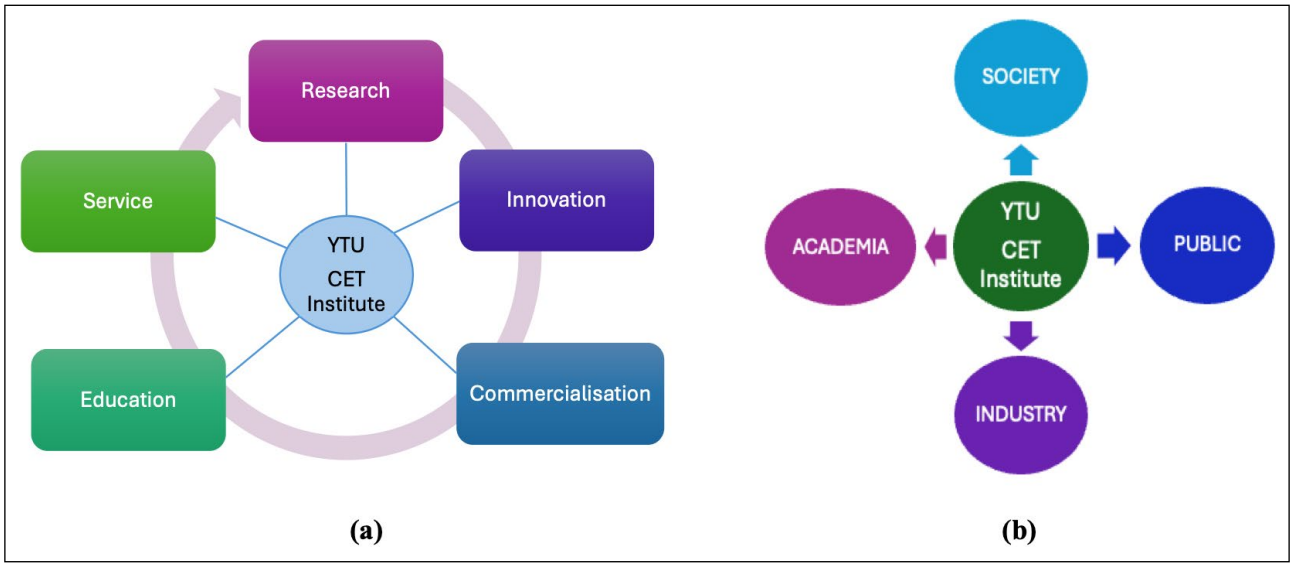

Figure 1. The CET Institute's activities **(a)** and stakeholders **(b).**

Energy Technologies not only to train highly employable graduates with knowledge and skills in their chosen field but also to meet the increasing demand for skilled workers and leaders needed to deliver the clean energy transition. Master and PhD programmes are respectively run over 24 months and 48 months (at least), with two semesters of taught courses followed by a research project leading to a research thesis. Applicants with a background in energy issues or a strong interest in topics that falls within Institute's research themes, can develop their research skills and acquire in-depth technical knowledge balanced with practical experience at state-of-the art research facilities and laboratories including Hydrogen Research Centre, and Battery Research and Testing Centre, Energy Efficiency Centre and Clean Combustion Research Centre. To provide students with a comprehensive understanding of what clean energy technologies, these programmes cover a wide array of topics. Though the programme is grounded in engineering, students can benefit from the programme's multidiscipline design, with courses considering the environmental, societal, economic and policy aspects of the energy industry and thereby giving new career opportunities in the broad field of clean energy technologies. The professional development of researchers is also supported by workshops, publications and internal and external seminars. Promoting open-access publication, Clean Energy Technologies Journal hosted by YTU provides an opportunity to disseminate project's research outputs and CET's impact to a wider community after a thorough peer-review process. In line with the mission to translate knowledge into added value, YTU Yildiz Technopark also supports researchers and academics to commercialise the outcomes of research on subjects such as patents, license agreements, technology transfer, helping explore start-up business idea and providing funding opportunities.

Today, the CET Institute with the core scientific staff and increasing number of post-graduate students and researchers every year investigates the regional and global challenges in clean energy technologies ranging from improving efficiency of different technologies to understanding their sustainability implications. CETs scientists represent every branch of energy science and technology as well as other fields where interdisciplinary research is necessary to put these technolo-

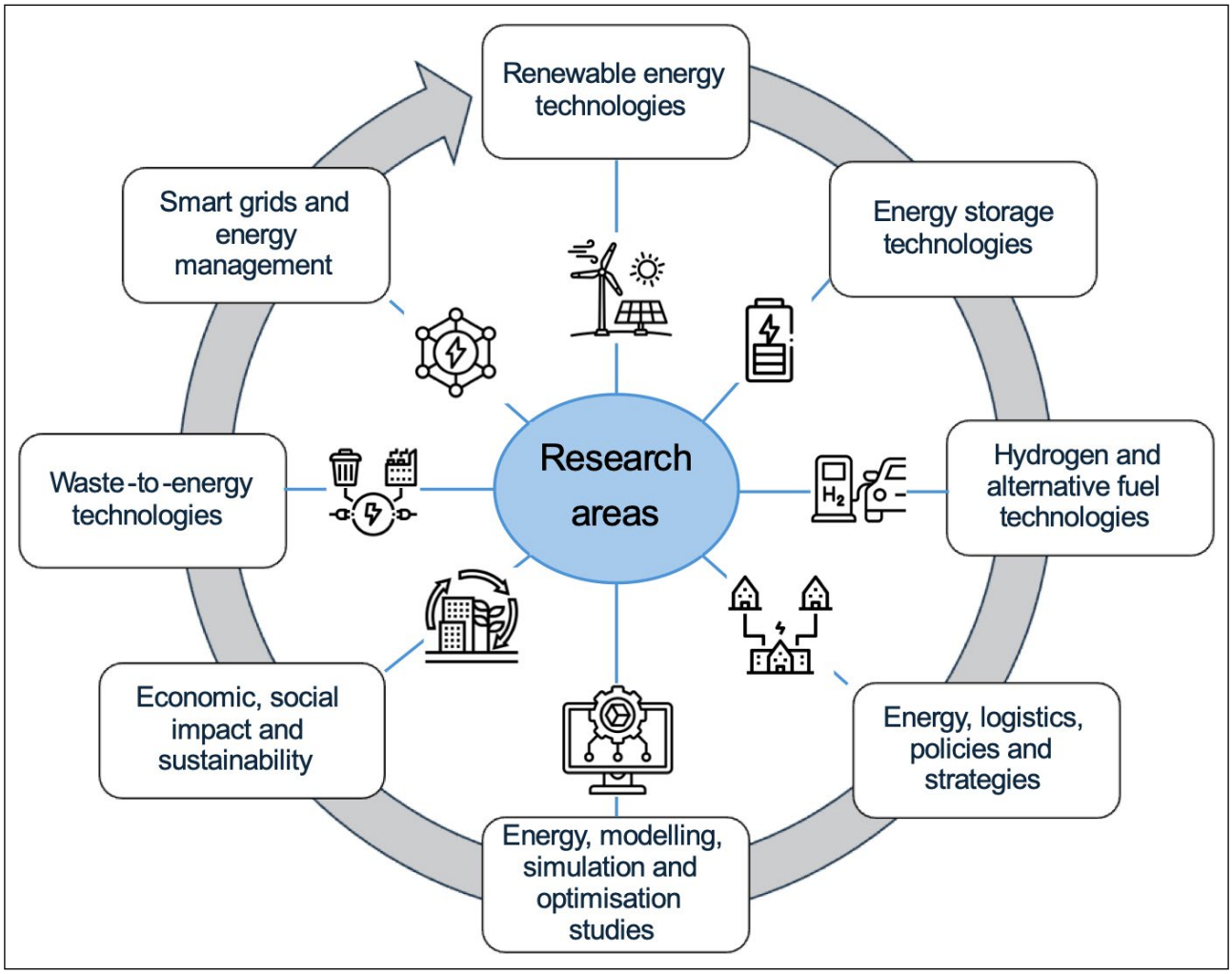

Figure 2. Main research areas in the CET Institute.

gies into action, such as economy and policy research. Prof. Dr. Aysel Kanturk Figen, who is also a board member of the National Hydrogen Association, is assigned as the director of the CET Institute. Many other scientists and collaborators at universities and research centres around the world also take part in the advisory board of the CET Institute, including National Hydrogen Association's chair Prof. Dr. Ibrahim Dincer from Ontario Tech University / Yildiz Technical University, Prof. Dr. Neven Duić from University of Zagreb, Prof. Dr. Feridun Hamdullahpur from University of Waterloo, Prof. Dr. Bruce Logan from Penn State University, Prof. Dr. Mihri Özkan from University of California-Riverside, Prof. Dr. Seeram Ramakrishna from National University of Singapore, Prof. Dr. S. Ravi P. Silva from University of Surrey, Prof. Dr. Benjamin K. Sovacool from University of Sussex, Prof. Dr. Peter Strasser from Technische Universität Berlin, Olcay Unver from Arizona State University and Zafer Ure from Phase Change Material Products Limited.

MAIN RESEARCH AREAS

The centre's research is organised around eight scientific divisions, each representing critical components of energy research, though not limited to them (Fig. 2). Within this scope, smart grid and energy management, waste-to-energy, energy storage technologies, energy logistics, policies and strategies, hydrogen and alternative fuel technologies, modelling, simulation and optimization of energy systems, renewable energy technologies, economic, social impact and sustainability are the main topics that researchers at CET Institute focus on.

A short description of each research group and areas of work are provided in the following sub-sections.

The Smart Grid and Energy Management Research Group

Smart Grid and Energy Management Research Group aims to provide innovative solutions to the complex problems of electric power system operation from different stakeholders' perspectives. The mentioned innovative solutions include artificial intelligence and optimization-based decision-making mechanisms as well as planning tools for production, transmission, distribution and consumption centres together with technoeconomic players. Last but not the least, multi-energy solutions including the simultaneous operation of different energy types' infrastructures are also within the scope of this research group.

The Waste-to-Energy Research Group

The Waste-to-Energy Research Group is dedicated to developing biological, chemical, and bio-electrochemical bioenergy production technologies from various waste streams to offer low-cost and environmentally sustainable solutions for waste management, recycling, and recovery.

The research group has been centred on academic research projects carried out with different industries to include wastes in a circular economy model and observe the life cycle assessment of processes. It focuses on building up new technologies for sustainable waste management, environmentally friendly energy production and storage.

The Energy Storage Technologies Research Group

The Energy Storage Technologies Research Group aims to cover all important aspects of energy storage technologies, in particular novel energy storage technologies. The Energy Storage working group is focusing on the theory and applications of mechanical, electrochemical, chemical, electrical, and thermal energy storage systems. In addition, different aspects of energy storage technologies in electrified transportation, off-grid systems, portable electronic system, and grid-scale electrical storage are considered. Demand and management of intermittency in large-scale low-carbon power generation with energy storage systems are other topics to be considered within the work carried out by researchers in this group. Another indispensable research subject in the group is Vehicle-to-grid, energy storage integrated with buildings, and multi-purpose and hybrid storage systems. Furthermore, life cycle costs, life cycle assessment, the safety of energy storage systems and their economic, policy, and regulatory aspects, and market introduction concepts will be studied.

The Energy Logistics, Policies and Strategies Research Group

The Energy Logistics, Policies and Strategies Research Group (ELPS) aims to analyze and discuss the related policies and strategies of energy based on clean and renewable energy alternatives. Additionally, the group aims to analyse future energy perspectives of countries to obtain a road map for energy management. The ELPS group also concentrates on design the most ideal logistics strategy for energy management. The group also investigates how to determine the best network design for logistic with respect to right locations, methods, tools and transport strategies between destinations for all of the energy types.

The Hydrogen and Alternative Fuel Technologies Research Group

The Hydrogen and Alternative Fuel Technologies Research Group pioneers research and development in energy strategy solutions based on hydrogen and alternative fuels. The formulation of solutions to the CO2-free energy systems links to the hydrogen-related industries necessitating to address the challenges in technological trends and creating alternative pathways for realization. We have been focused on different aspects of key research areas, propose new projects in cooperation, and launch new activities.

Especially, balancing the electrical power consumption has a significant effect in the perspective of investments and carbon free energy production as it has peaks and valleys due to its own characteristics. In another word the storage

of the excessive energy due to the intermittent energy production of renewable energy sources and using this energy in the peak times where the load demand is generally supplied by the fossil fuels provides new opportunities not only for decreasing environmental burdens but also for reducing the investment cost of energy plants. Hydrogen energy with its high energy density and potability is a prominent key solution technology for the near future in this area. Hydrogen generation, storage, transportation, certification, and injecting hydrogen to natural gas etc. are the research topics studied by the experts of this research group. R&D studies for green hydrogen production, hydrogen vehicles, fuel cells and the auxiliary equipment for hydrogen storage and technologies are the priorities of this research group.

The Modelling, Simulation and Optimization of Energy Systems Research Group

Modelling, Simulation and Optimization of Energy Systems Research Group focuses on the classical and advanced Modelling, Simulation and Optimization Technics (theoretical, statistical, and Artificial Neural Network (ANN) models) to develop better Energy Systems by using Art and Science as Tools.

The group focuses on cross disciplinary research in energy system modelling, simulation and optimization to improve understanding of the energy processes, to optimize process and operating conditions, to design a control strategy for the energy process, to simulate a model to optimize system performance or to make predictions about a real system, and to study the characteristics of a real-life or fictional system by manipulating variables that cannot be controlled in a real system.

The Renewable Energy Technologies Research Group

The Renewable Energy Technologies Research Group (RETRG) contributes to the research and development of new renewable energy technologies that are cost-effective, stable, sustainable and environmentally friendly, as well as improving existing renewable technologies in innovative ways, by developing new materials and concepts for reducing carbon footprint. In addition to energy production with renewable technologies, energy saving is also within the area of interest. We envision new scientific projects based on the energy systems of the sustainable future. On the other hand, the group participates in social responsibility activities/projects to raise awareness about the benefits of energy saving, understanding of global warming and its serious consequences.

The Economic, Social Impact and Sustainability Research Group

The Economic, Social Impact and Sustainability Research Group measures the economic impacts of both developed and planned clean energy technologies and evaluate their possible societal impacts. It also examines the relation between those technologies and the sustainability goals, especially the United Nations Sustainability Goals. In addition, it helps to develop economic and social impact analyses of projects that are led by other research groups.

CONCLUSION

With all the mentioned specialties, young and dynamic CET Institute serves as a research ecosystem which consist of research groups including interdisciplinary national and international experts, strong industrial relationships, and solution partnerships. The Institute aims to finance its own R&D investments with the help of stakeholder system, sustainable solution partnerships for sustainable energy. For this purpose, the institute has a mission to convert technology to an economic outcome with the rule of science to technology and technology to product. The widely open doors for national and international project partnerships and considering socio-cultural part of the technology is set apart the CET Institute and transform it to a next generation R&D ecosystem.

This article is prepared as part of the special issue on "Clean Energy Technologies Institute". In the following section of this journal, readers can find out more about core three research facilities at the CET Institute (Energy Efficiency Centre, Hydrogen Research Centre and Battery Testing and Research Centre), including their areas of research, current projects and recent publications.

AUTHORSHIP CONTRIBUTIONS

Authors equally contributed to this work

DATA AVAILABILITY STATEMENT

The authors confirm that the data that supports the findings of this study are available within the article. Raw data that support the finding of this study are available from the corresponding author, upon reasonable request.

CONFLICT OF INTEREST

The author declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

ETHICS

There are no ethical issues with the publication of this manuscript.

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