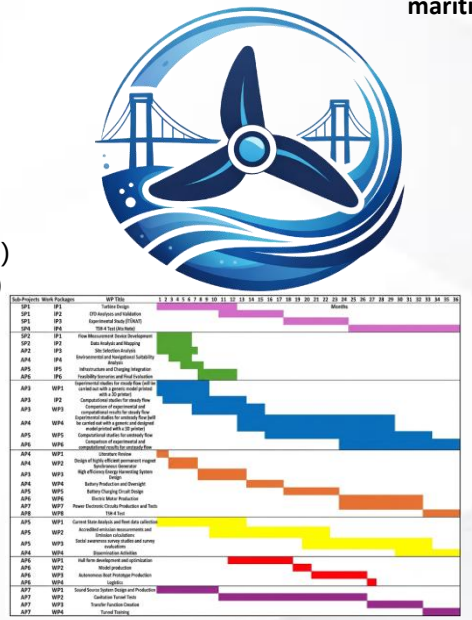
BOSHEP – Electrical Energy Generation from Bosphorus Currents Using a Turbine: Towards Electrification of Maritime Transport in Istanbul

Platform Program Manager – Department: Naval Architecture and Marine Engineering
Total budget: 7,499,956 TL
Duration: 36 months
TRL: 4
Participating Departments: Naval Architecture and Ocean Engineering, Space Engineering, Electrical Engineering, Aeronautical Engineering

This project aims to design and implement, at TRL-4, a low-noise and environmentally friendly current turbine suited to the unique current structure of the Bosphorus and capable of supporting the electrification of maritime transport. In the first stage, the goal is to provide a feasible energy solution for scheduled urban maritime transport. Shaped within the framework of seven sub-projects, the project's original value lies in its unique concept, which—through a Bosphorus-specific turbine design, its power, cavitation and noise characteristics, hydroelastic analysis and energy integration—will make a measurable contribution to the electrification of maritime transport.

Project team:

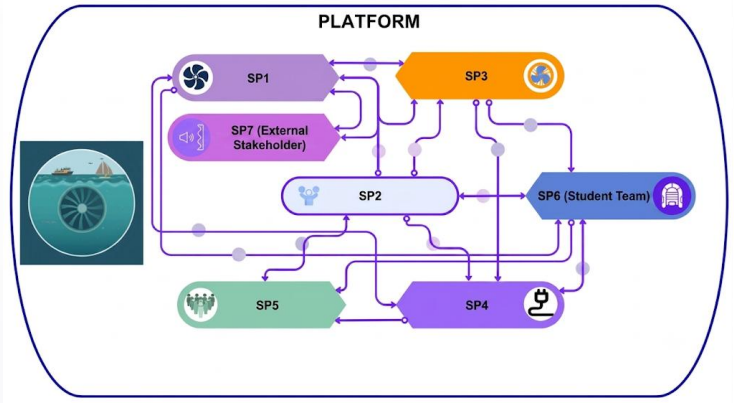
- **Prof. Dr. Uğur Oral ÜNAL (GEM)**
- Prof. Dr. Emin Korkut (GEM)
- Prof. Dr. Şakir Bal (GEM)
- Prof. Dr. Ali Can Takinacı (GEM)
- Prof. Dr. Devrim Bülent Danışman (GEM)
- Prof. Dr. Nuriye Leman Okşan Çetiner Yıldırım (UZB)
- Assoc. Prof. Dr. Şafak Nur Ertürk Bozkurtoğlu (DEN)
- Assoc. Prof. Dr. Ceren Bilgin Güney (DEN)
- Assoc. Prof. Dr. Gökhan Tansel Tayyar (GEM)
- Assoc. Prof. Dr. Derya Ahmet Kocabaş (ELK)
- Assoc. Prof. Dr. Seher Eken (UZB)
- Asst. Prof. Dr. Burcu Erbaş Öz (DEN)
- Dr. Murat Durmaz (GEM)
- Dr. Tuncay Akal (SUASİS)
- Gürkan Beyoğlu (SUASİS)



Laboratories where the project will be carried out:

- Sub-project 1 (SP1) – Design of a High-Efficiency Turbine for Energy Generation from Bosphorus Currents
- Sub-project 2 (SP2) – Site Selection and Applicability Feasibility Analysis for Installing a Current Turbine in the Bosphorus
- Sub-project 3 (SP3) – Hydrodynamic Investigations and Hydroelastic Analyses of Underwater Turbines under Unsteady Flow Effects
- Sub-project 4 (SP4) – Energy Harvesting and Storage from Strait Currents and Design of a Marine Vehicle Charging Station
- Sub-project 5 (SP5) – Emission-Focused Environmental Impact Analysis of the Transition to Electric Vessels for Sustainable Maritime Transport in Istanbul
- Sub-project 6 (SP6) – Autonomous Turbine Maintenance and Monitoring Vessel (İTÜ Autonomous Team)
- Sub-project 7 (SP7) – Development of an Acoustic Transfer Function to Improve Measurement Accuracy and Precision in the Cavitation Tunnel

Supporting companies:



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TRİSONİK ARAŞTIRMA LABORATUARI

ELECTRICAL MACHINERY LABORATORY

BOSHEP – Electrical Energy Generation from Bosphorus Currents Using a Turbine: Towards Electrification of Maritime Transport in Istanbul

This platform offers a holistic and feasible engineering approach that combines clean energy generation under conditions specific to the Bosphorus with experimental validation and urban electrification.

Keywords: Bosphorus, Current Turbine, Clean Energy, Turbine Cavitation, Hydroacoustic Noise, Pressure Pores, Hydroelastic Behavior, Unsteady Flows, Turbine–Generator Integration, Electrification

Original Value and Strategic Contribution:

- Addressing the hydrodynamic–acoustic–structural constraints specific to the Bosphorus within a single design–validation–integration chain
- Joint evaluation of cavitation, hydroacoustic noise and hydroelastic behavior
- Integrating clean energy generation and the electrification of maritime transport on a single platform
- Direct contribution to reducing CO_2 / NO_x / SO_x / PM emissions and to urban air and noise quality
- Alignment with the 2050 net-zero target, the 12th Development Plan, the Green Deal, the Paris Agreement, the UN Sustainable Development Goals (7, 9, 11, 13, 14) and the IMO / IEC 62600 frameworks
- Know-how, patent/utility model and export potential for domestic blade, generator, power electronics and control components

Aim and Scope:

- Joint assessment of site selection, current potential, navigation, ecology and cable–charging integration using Geographic Information Systems and multi-criteria decision analysis
- Optimization of the turbine blade geometry taking hydrodynamic, cavitation and hydroelastic effects into account
- Reduction of cavitation and hydroacoustic noise through pressure-pore technology
- Integrated design and validation of the turbine–generator–power electronics–charging interface
- System validation at TRL-4 through cavitation tunnel, towing tank and free-surface water channel experiments
- Demonstrating, in measurable terms, the electrification of maritime transport and the associated emission reduction

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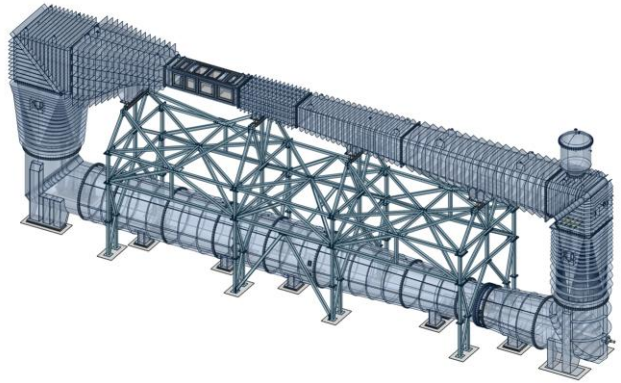
ELECTRICAL MACHINERY LABORATORY

SUASIS SINCE 2005

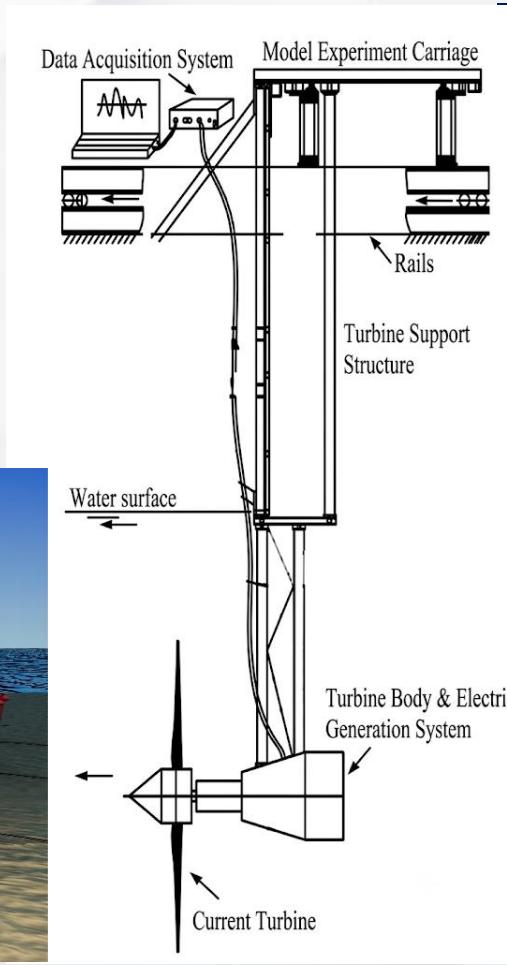
SP1 – Design of a High-Efficiency Turbine for Energy Generation from Bosphorus Currents

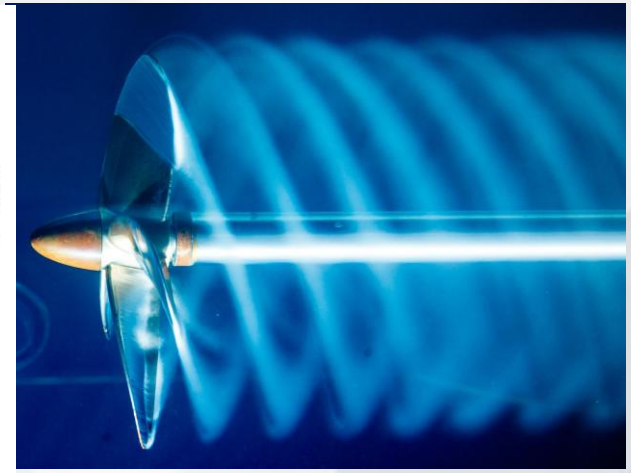


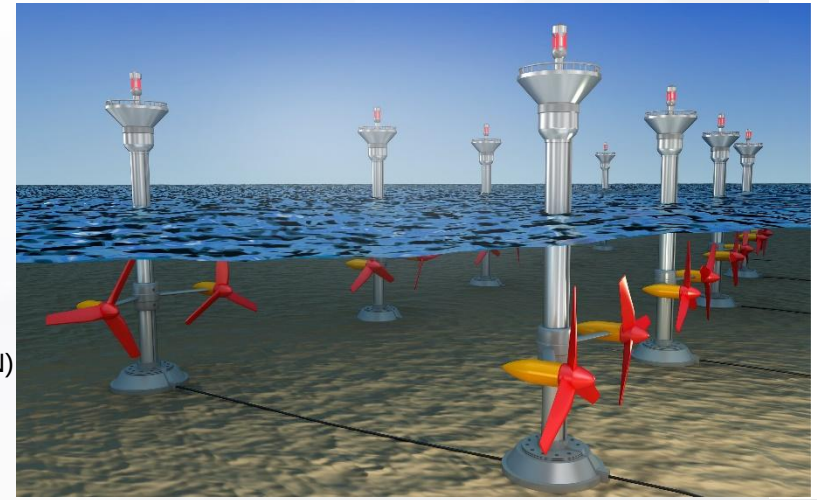
The aim of the sub-project is to determine the optimum turbine geometric characteristics in accordance with the incoming current speed and uniformity specific to the Bosphorus; to experimentally test the turbine model at İTÜKAT in terms of performance, cavitation and noise characteristics; to reduce cavitation and hydroacoustic noise by applying pressure pores to the turbine blades if cavitation is observed under operating conditions; and to demonstrate the generation of electrical energy from the turbine by testing the designed turbine under model conditions at the Ata Nutku Ship Model Testing Laboratory in accordance with TRL-4.

Sub-project 1 Final Outputs:

- ❑ A high-efficiency, low-noise turbine model tailored to the current conditions of the Bosphorus,
- ❑ A design methodology supported by CFD and experimental validation,
- ❑ Open-water performance, cavitation and hydroacoustic noise measurements in the İTÜ Cavitation Tunnel (İTÜKAT),
- ❑ Electricity generation and charging tests with turbine–generator integration at the Ata Nutku Ship Model Testing Laboratory,
- ❑ Patent or utility model application







Sub-project 1 (SP1) team:

- **Prof. Dr. Uğur Oral ÜNAL (GEM)**
- Prof. Dr. Emin KORKUT (GEM)
- Prof. Dr. Şakir BAL (GEM)
- Prof. Dr. Ali Can TAKINACI (GEM)
- Prof. Dr. Devrim Bülent DANIŞMAN (GEM)
- Asst. Prof. Burcu ERBAŞ ÖZ (DEN)
- Asst. Prof. Deniz BAYRAKTAR BURAL (DEN)
- Res. Asst. Selahattin ÖZSAYAN (GEM)
- Res. Asst. İsmail Kahraman
- Res. Asst. Feyza ERTARHANACI (GEM)
- Res. Asst. Mehmet DELIKAN (GEM)
- Res. Asst. Tunahan ŞIK (GEM)

SP2 – Site Selection and Applicability Feasibility Analysis for Installing a Current Turbine in the Bosphorus

Sub-project 2 (SP2) team:

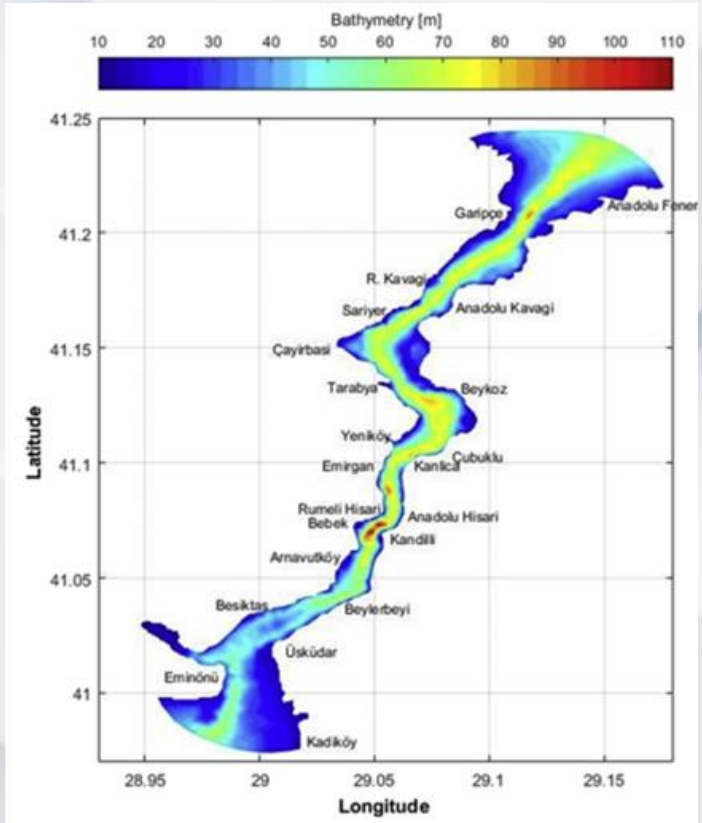
- **Assoc. Prof. Dr. Şafak Nur Ertürk Bozkurtoğlu (DEN)**
- **Prof. Dr. Devrim Bülent Danışman (GEM)**
- Assoc. Prof. Dr. Gökhan Tansel Tayyar (GEM)
- Res. Asst. Yağmur Kopuz (DEN)

Aim:

The aim of the sub-project is to carry out site selection, environmental and navigational suitability, infrastructure connection and overall applicability analyses for the model-scale current turbine planned to be installed in the Bosphorus. By providing decision support on the potential application of the model-scale turbine in the Strait, this sub-project will form a strong basis for the main project in terms of environmental sustainability and technical applicability. The outputs obtained will contribute to the experimental testing and integration processes of the main project.

WP	MONTHS											
	1	2	3	4	5	6	7	8	9	10	11	12
WP1												
WP2												
WP3												
WP4												
WP5												
WP6												

Work Package (WP)	Work Package Title	Main Activities
WP1	Current Measurement Device Development and Field Measurements	· Sensor and measurement system design · Hardware and software development · Calibration and laboratory tests · Preliminary field trials · Field measurements at potential sites
WP2	Data Analysis and Mapping	· Analysis of the acquired data using MATLAB or GIS-based software · Creation of depth-based current profiles, current direction maps and velocity distribution charts. · Analysis of current continuity and mean velocity, particularly in areas with potential for energy generation
WP3	Technical Site Selection Analysis	· Collection of bathymetric maps and seabed data · Ship traffic density analysis (AIS data) · Determination of technically suitable turbine locations, taking ship traffic and morphological structure into account
WP4	Environmental and Navigational Suitability Analysis	· Preliminary impact analysis on the marine ecosystem · Maritime traffic safety and risk assessment · Examination of official/regulatory constraints · Coordination with the Social Impact Project (SP5)
WP5	Infrastructure and Charging Integration	· Analysis of proximity to shore, cabling distances and infrastructure compatibility · Identification of suitable coastal areas for integrating the generated electricity into charging stations · Technical coordination meetings with the Faculty of Electrical Engineering (SP4)
WP6	Applicability Scenario and Final Evaluation	· Development of alternative siting scenarios · Technical, environmental and structural suitability analysis · SWOT / advantage–disadvantage assessment · Determining the applicability level via Multi-Criteria Decision Analysis · Preparation of the final recommendation · Reporting of the results



SP3 – Hydrodynamic Investigations and Hydroelastic Analyses of Underwater Turbines under Unsteady Flow Effects

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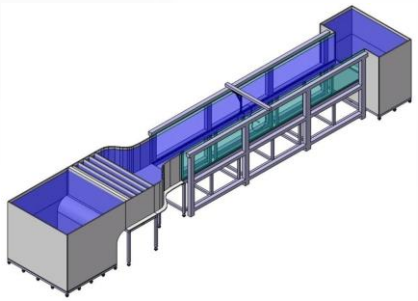
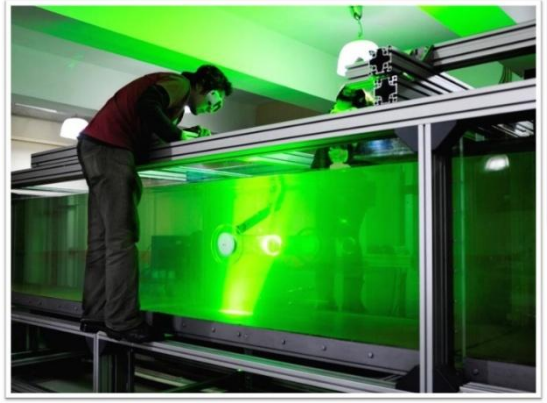
TRİSONİK ARAŞTIRMA LABORATUARI

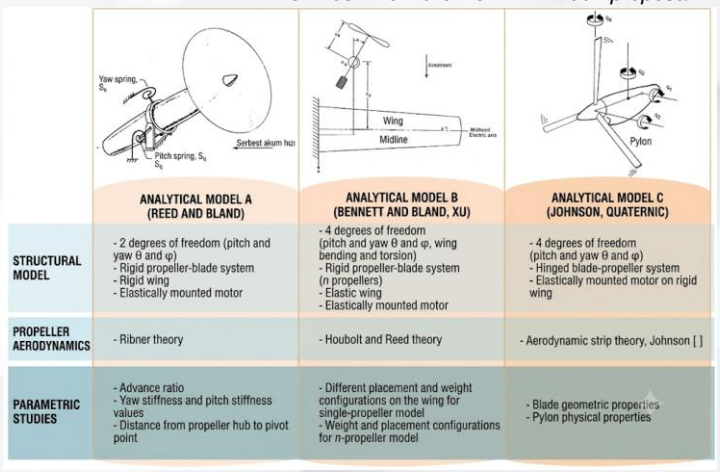
TRISONIC RESEARCH LABORATORY
WATER CHANNEL

The main aim of the sub-project is to investigate, through experimental and numerical methods, the fluid–structure interaction and performance behavior—under unsteady flow effects—of current turbines operating in the complex hydrodynamic conditions of the Bosphorus, and thereby to develop modeling methods for reliable, efficient and economical turbine designs. Because of counter-directional currents, geometric irregularities, tanker passages and turbine wake interactions, the Bosphorus has a highly complex flow structure. These conditions will lead to time-dependent fluctuations in turbine performance, structural vibrations and efficiency losses. The sub-project aims to systematically investigate and model these effects.

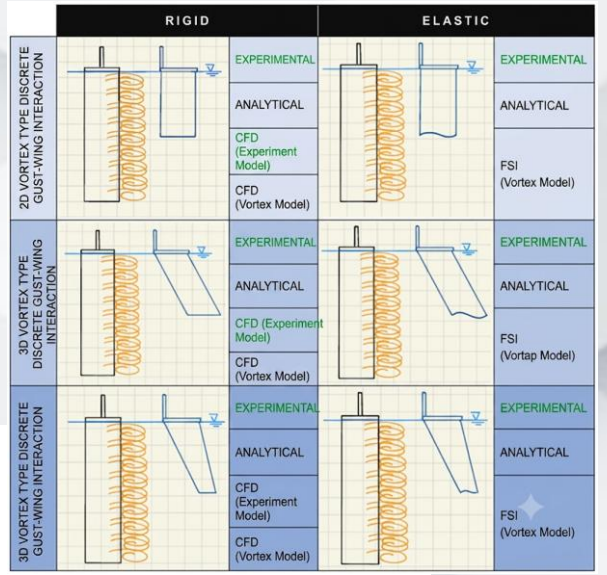




223M205 From the TÜBİTAK-1001 proposal



125M674 From the TÜBİTAK-1001 proposal



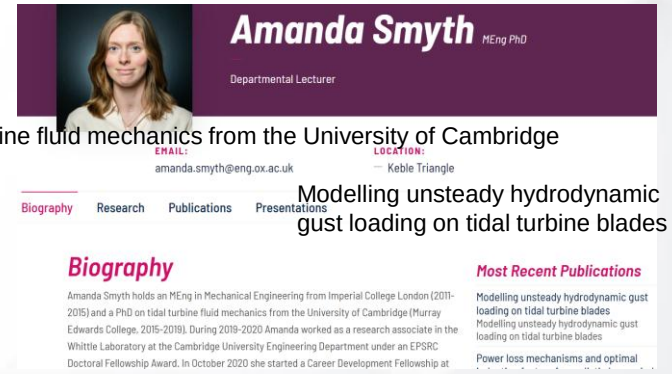
Project team:

- **Prof. Dr. N. L. Okşan Çetiner Yıldırım** (UZB)
- Assoc. Prof. Dr. Seher Eken (UZB)
- Asst. Prof. Murat SARITAŞ (UCM)
- Res. Asst. Orhan HIZALAN (UCM)
- TÜBİTAK 1001 Undergraduate Scholars

223M205 “Investigation of the Roll Instability Behavior of Propeller-Driven Aircraft via Analytical and Numerical Approaches”

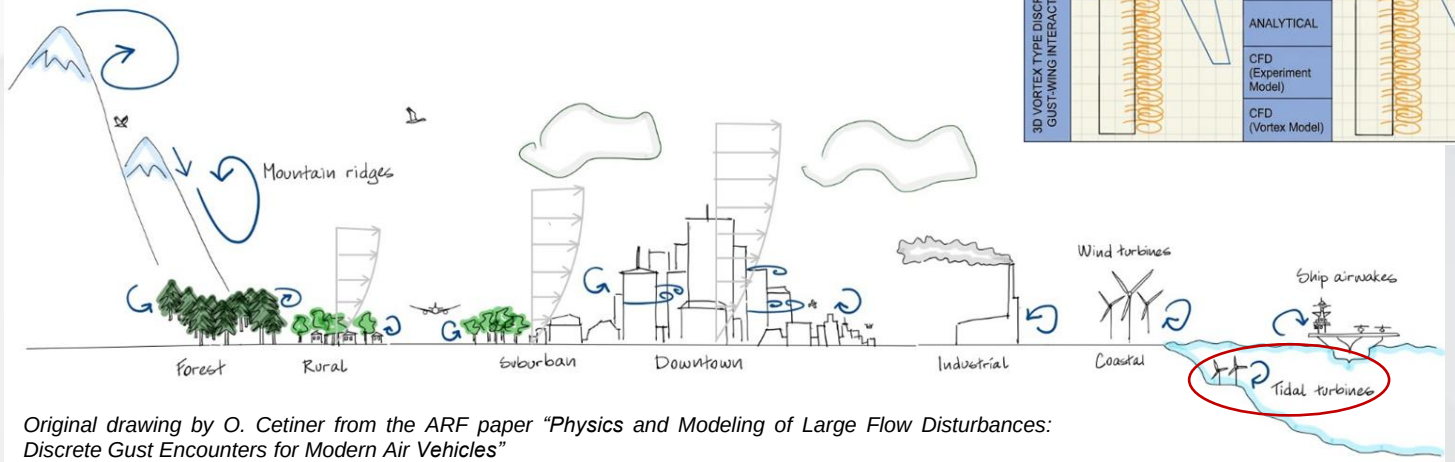
125M674 “Fluid–Structure Interaction on Three-Dimensional Rigid and Elastic Wings under a Large-Scale Discrete-Vortex-Type Gust Effect”

Advisor:



PhD on tidal turbine fluid mechanics from the University of Cambridge

Modelling unsteady hydrodynamic gust loading on tidal turbine blades



Original drawing by O. Cetiner from the ARF paper “Physics and Modeling of Large Flow Disturbances: Discrete Gust Encounters for Modern Air Vehicles”

SP4 – Electrical Energy Harvesting and Storage from Strait Currents and Design of a Marine Vehicle Charging Station

İTÜ ELECTRICAL MACHINERY LABORATORY

It aims to design, manufacture and experimentally validate a laboratory-scale preliminary prototype—of approximately 500 W—of an integrated system for generating electrical energy from Bosphorus currents. The project targets converting subsurface flow energy into electrical energy via a turbine–generator–power electronics–battery–DC-DC converter chain, storing it, and delivering it as constant-voltage charging energy suitable for marine vehicles. The resulting prototype will be used as a validation platform for determining the design and control criteria of the full-scale system.

Project team:

- **Assoc. Prof. Dr. Derya Ahmet Kocabaş**
- Res. Asst. Güven Onur
- Res. Asst. Selçuk İnanç
- Res. Asst. Ali Metehan Gürer

Undergraduate Level

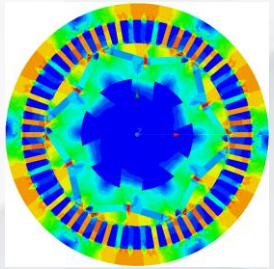
- Istanbul Technical University Electric Vehicle Team
- ITU AS Autonomous Vessel Team

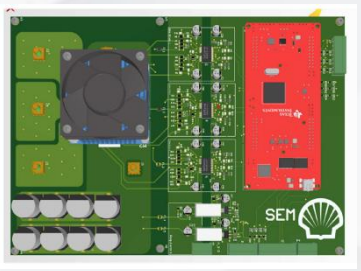
Supporting Companies

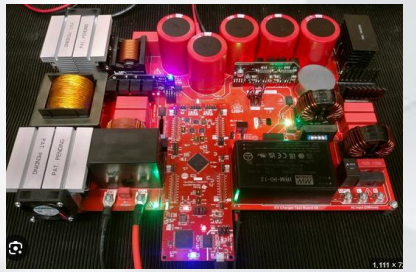
WAT

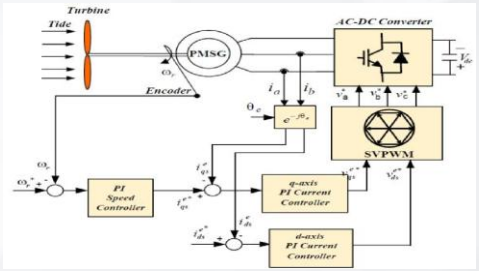
Original Value

- Experimentally realizing—as a single, integrated energy-conversion chain—a turbine coupled with a permanent-magnet synchronous generator suited to the low-speed, high-torque current characteristics of the Bosphorus, together with a MOSFET-based active rectifier, modular 48 V Li-ion battery storage and a 96 V constant-output charging line.
- Being an engineering platform unmatched in Türkiye—validated at laboratory scale and directly providing data for full-scale applications—that converts the variable mechanical power obtained from the current into a stable energy infrastructure capable of directly serving the electric propulsion systems of marine vehicles









SP5 – Emission-Focused Environmental Impact Analysis of the Transition to Electric Vessels for Sustainable Maritime Transport in Istanbul (Social Impact Sub-project)

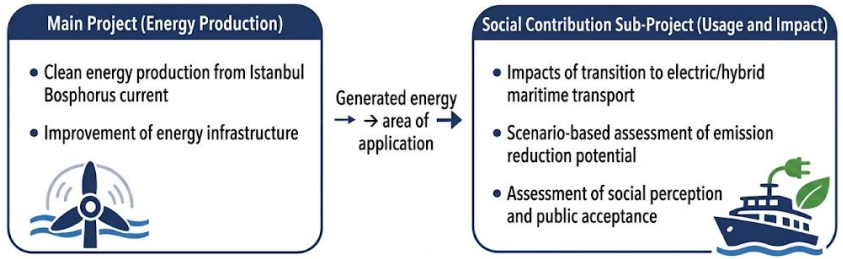
This project is one of the first holistic studies to address, within a single framework, the environmental and social impacts of the transition to electrification in Istanbul's local maritime transport.

While the main project focuses on clean energy generation, this social-contribution sub-project makes visible the use of the generated electricity in maritime transport and the environmental and social benefits it creates; in this respect, the two projects complement each other.

SP5 Project team:

- **Asst. Prof. Dr. Burcu Erbaş Öz (DEN)**
- Assoc. Prof. Dr. Ceren Bilgin Güney (DEN)
- Assoc. Prof. Dr. Gökhan Tansel Tayyar (GEM)
- Dr. Murat Durmaz (GEM)
- Two M.Sc. Students

Platform Project – Connection Between Main Project and Social Contribution



The two projects complement each other: energy infrastructure + making benefits visible on an urban scale

Months	Work Package / Activity	Responsibilities
1–12	**WP1** - Current Status Analysis - Literature review, collection of fleet data - Selection of sample vessel types - Creation of emission inventory for the diesel fleet (Tier 1)	Principal Investigator Researchers + Researchers + Grant Holders
10–22	**WP2** - Accredited emission measurements (At least 5 vessels) - Emission calculations (Tier 2)	Principal Investigator + Researchers + Grant Holders
20–32	**WP3** - Social awareness survey studies and evaluation of surveys	Principal Investigator + Researchers + Grant Holders
30–36	**WP4 (Broad Impact & Awareness)** - Preparation of social media content (video, infographic) - Workshop directed towards high school students - Pavlication of public awareness outputs	Principal Investigator + Researchers + Grant Holders

Work Packages	WP Title	1	2	3	4	5	6	9	10	11	12	13	14	15	16	17	18	20	22	23	27	28	30	31	32	33	34	35	36
WP1	Current Status Analysis and fleet data collection	■	■	■	■	■	■	■	■	■	■																		
WP2	Accredited emission measurements and Emission calculations								■	■	■	■	■	■	■	■	■	■	■										
WP3	Social awareness survey studies and evaluation of surveys																	■	■	■	■	■	■	■	■	■			
WP4	Dissemination and Impact Activities																									■	■	■	■

Technical and Environmental Assessment

- Determining the emission profile of Istanbul's inner-line maritime transport fleet
- Diesel emission calculations and measurement-based assessments using representative sample vessels
- Establishing the emission-reduction potential for electric (and/or hybrid) fleet scenarios
- Quantitative assessment of the air-quality and environmental effects of electrification

Social Impact and Stakeholder Engagement

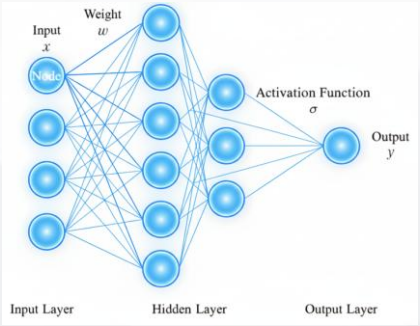
- Survey-based assessment of social perception, awareness and public acceptance regarding electrification
- Determining social-contribution indicators through passengers, industry stakeholders and young participants
- Sharing project outputs through NGOs for information and dissemination purposes
- Making emission and electrification scenarios visible at the urban scale by engaging with the Istanbul Metropolitan Municipality and Şehir Hatları A.Ş.
- Project outputs providing technical input to local-government decision-support processes

SP6 – Design of an Autonomous Vessel for Turbine Maintenance and Upkeep for Electrical Energy Generation from Bosphorus Currents

The uninterrupted execution of regular maintenance and upkeep activities is critically important for the sustainable operation of underwater turbines. This project aims to design a dedicated, fully autonomous vessel and to develop a prototype for carrying out turbine maintenance and upkeep activities.

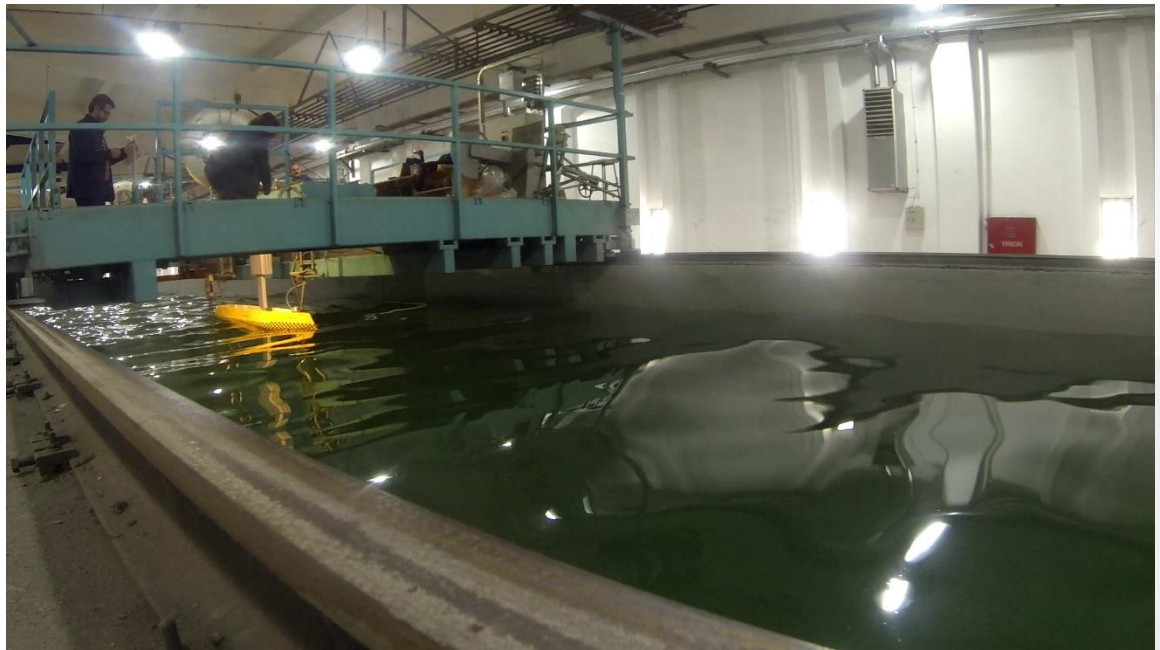
Work to be carried out within the project:

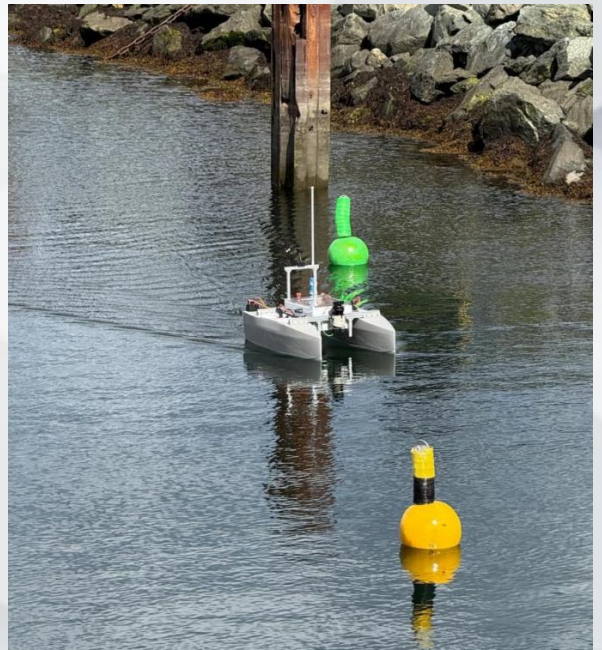
- Determining the mission profile and operating conditions
- Determining the main dimensions and hull form for the autonomous vessel
- Optimizing the hull form for the best hydrodynamic performance using AI-based tools
- Model experiments to validate the computational analyses performed on the resulting form
- Autonomous prototype development activities; the İTÜ Autonomous Systems Team (ituautobee) will actively take part
- Field tests: will be conducted at the İTÜ Pond.



Project team:

- **Prof. Dr. Devrim Bülent DANIŞMAN (GEM)**
- Prof. Dr. Ali Can Takinacı (GEM)
- Assoc. Prof. Dr. Gökhan Tansel Tayyar (GEM)
- Res. Asst. Feyza Ertarhanacı (GEM)
- Res. Asst. Duygu Ünlü (GEM)
- ITU Autobee Autonomous Vessel Team

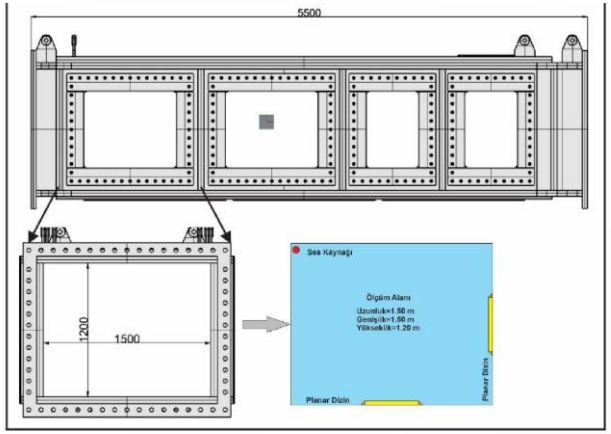




SP7 – Development of an Acoustic Transfer Function to Improve Measurement Accuracy and Precision in the Cavitation Tunnel

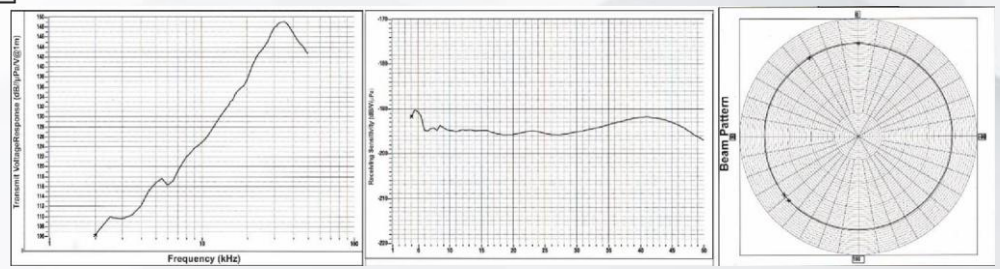
Project team:

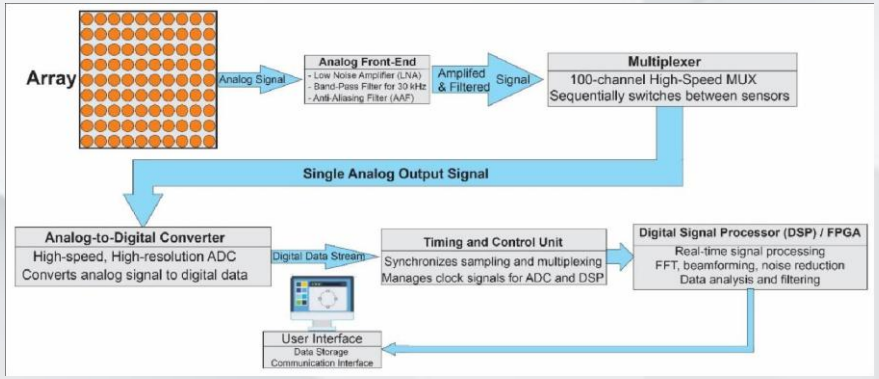
- **Prof. Dr. Emin Korkut (GEM)**
- Dr. Tuncay Akal (SUASİS)
- Gürkan Beyoğlu (SUASİS)



It will enable the noise characteristics measured in cavitation tunnels to be discretized correctly and the resulting data to be used for more accurate prediction of prototype or full-scale water-turbine characteristics. In the design of water-turbine blades, the knowledge obtained from the sub-project will allow a more efficient system to be designed while, through a quieter system, minimizing the impact on the marine ecosystem and marine life and improving the quality of life of marine organisms. To this end;

- The noise to be measured using the ITC 1032—an omnidirectional sound source (transducer)—will be compared with a noise spectrum calibrated in the laboratory environment. For frequencies below 5 kHz, measurements will be carried out at sea or at the İTÜ Pond, as well as at the facility developed by SUASİS for underwater acoustic measurements and calibration.
- By developing a planar hydrophone-array system for acoustic holography with a directional sound source, more precise acoustic measurements will be possible in the cavitation tunnel.
- An acoustic transfer function will thus be developed.





BOSHEP – Electrical Energy Generation from Bosphorus Currents Using a Turbine: Towards Electrification of Maritime Transport in Istanbul

SUSTAINABILITY OF THE PROJECT AND ITS INSTITUTIONAL BROAD IMPACT

Starting from the Bosphorus, the platform project aims to establish a sustainable and institutionalizable research ecosystem oriented toward decarbonization and clean-energy transformation in the maritime sector.

Long-Term Sustainability Approach

- The platform project has been conceived as the starting step of a long-term, scalable and applicable R&D line that is not limited to the project's duration.
- Sustainability is addressed through the dimensions of national policy alignment, public–industry collaborations, integration into international funding and institutional capacity building.

Institutional Broad Impact and Future Vision

- Evolution of the process that began with TÜBİTAK-supported projects into national applied projects and internationally funded studies
- In the medium to long term, establishing a national applied R&D center in the field of clean energy generation from the seas and the electrification of maritime transport
- Development of a permanent interdisciplinary research ecosystem and human resources within İTÜ

Scalability and Application Potential

- *Transforming the solutions developed specifically for the Bosphorus into scalable engineering approaches for the Dardanelles, the Sea of Marmara, the Black Sea and the Aegean–Mediterranean coasts*
- *Potential to support ports, scheduled ferries, coastal charging infrastructure and, in selected regions, the main electricity grid*
- *An output structure that can evolve into applied R&D projects together with the Ministry of Transport and Infrastructure and relevant public institutions*

Outputs: Patent/utility model. Each sub-project is expected to produce at least one Q1/Q2 journal article and one national or international conference paper. Across the platform, at least six research articles (three of them in top-10% journals) are planned. One workshop will be held each year during the platform, and a comprehensive final workshop will be organized at its closing.

UÇAK VE UZAY BİLİMLERİ FAKÜLTESİ TRİSONİK ARAŞTIRMA LABORATUARI

ELECTRICAL MACHINERY LABORATORY