

# SPECO: A Novel Multiparametric Methane Forecasting and Mitigation System Using Quantum Long Short-Term Memory and Sonophotoelectrochemical Oxidation

Sami, Shanza (School: West High School)

Anthropogenic methane ( $\text{CH}_4$ ) emissions cause roughly 700,000 premature deaths annually; moreover,  $\text{CH}_4$  is difficult to monitor and predict. Existing methods lack the predictive accuracy and real-time response necessary for effective mitigation, due to high predictive error (Khan et al., 2024). Further, few innovations currently exist to effectively reduce ambient  $\text{CH}_4$ . The goal of this study is to enhance  $\text{CH}_4$  forecasting and mitigation efforts through SPECO, a multiparametric, dual-stage system using a Quantum Long Short-term Memory (QLSTM) neural network for accurate  $\text{CH}_4$  hotspot prediction and sonophotoelectrochemical oxidation (SPECO) for  $\text{CH}_4$  oxidation. The QLSTM neural networks were trained on 6 spatiotemporal datasets extracted from Google Earth Engine and the Emissions Database for Global Atmospheric Research, forecasting  $\text{CH}_4$  concentrations with hyperparameter tuning. QLSTM showed a 17.37% reduction in Root Mean Squared Error (RMSE) compared to the classical LSTM baseline. The SPECO was optimized using ANSYS multiphysics software, undergoing three phases of testing: laminar flow testing using Computational Fluid Dynamics (CFD) simulations, chemical optimization using Molecular Dynamics Simulation (MDS), and vibroacoustics simulations. A physical oxidation chamber prototype was engineered using an ultrasonic transducer, yielding a 40% decrease in  $\text{CH}_4$  as frequency increased. The novel introduction of ultrasonic cavitation was shown to enhance  $\text{CH}_4$  oxidation by increasing reactivity through uniform propagation – an emerging solution for future space energy. The multiparametric SPECO resulted in syngas and  $\text{H}_2$  products used for recurrent energy feedstock, supported by computational validation. SPECO is a promising dual-stage system to identify and reduce  $\text{CH}_4$  emissions.

**Awards Won:**

