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Sustainable Data Centers for Smart Cities: Optimized Energy Operation through AI-based Algorithms and Renewables

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Abstract

The swift development of digital infrastructures has increased sustainability and operational pressure on data centers globally. Data centers, which are the foundation of modern smart cities, require creative approaches to manage energy use while preserving security and reliability. The goal of this project is to provide an intelligent framework for sustainable data center operations that are mostly driven by renewable energy. This research work focuses on data

analysis and AI-driven forecasting models to optimize energy management in data centers, aligning with the concepts of operations management through resource efficiency process optimization. The study makes use of renewable energy data that was gathered from NSRDB website, over a ten-year period (2014–2024) from 20 cities in the United States. The datasets are analyzed in order to explore solar irradiance patterns and evaluate the feasibility of incorporating renewable energy sources into data center operations. Forecasting Global Horizontal Irradiance (GHI), a crucial indicator of solar energy availability, is the main objective. The approach merges manual preprocessing with automated feature selection technique, which is Mutual Information and XGboost, to guarantee data relevance and model performance. With the aim of forecasting GHI and assisting data driven decisions on the location and timing of the establishment of energy-efficient data centers, the research adopts both machine learning and deep learning techniques models (such as Random Forest, Long Short-Term Memory). From an operations management perspective, this project supports sustainable data center operations by facilitating predictive energy allocation, reducing reliance on non-renewable resources, and enhancing long-term operational planning. Based on the potential for renewable energy, the generated models are used as decision-support for optimizing site selection and operational scheduling. In conclusion, this study emphasizes the importance of AI algorithms in improving data centers' sustainability and operational efficiency. By including renewable energy predictions into data-driven decision-making, the project shows how advanced analytics may direct the best possible operation of adaptive data centers that support sustainability and energy efficiency objectives. The results demonstrate the potential of industrial engineering and operations management techniques in balancing technological excellence, environmental responsibility and strategic resource utilization, opening the door to a more intelligent and greener digital future.

Keywords
Sustainable data centers, renewable energy forecasting, operations management, AI-driven decision support, industrial engineering.

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Biographies
Najah A. B. Elnairab is an undergraduate student pursuing a Bachelor of Science in Computing and Information Systems with a concentration in Information Systems Security at the University of Dubai, United Arab Emirates, with a strong academic record (Dean's Honor). She has participated in hackathons, CTFs, cybersecurity programs, and volunteering initiatives, and earned multiple Coursera certificates. Najah is passionate about cybersecurity, AI-driven systems, and sustainable digital infrastructures.

Jana Amairi is an undergraduate student pursuing a Bachelor of Science in Computing and Information Systems with a concentration in Information Systems Security at the University of Dubai, United Arab Emirates. Since joining the program in 2022, she has been actively engaged in research and projects integrating machine learning, data analysis, and cybersecurity. Her academic interests extend to developing intelligent and sustainable digital solutions that align with global sustainability goals and the UAE's vision for technological advancement. As a member of the IEEE HKN Nu-Nu Chapter at the University of Dubai, Jana has contributed to collaborative initiatives that promote leadership and innovation in engineering and computing. She has also earned recognition in hackathons and competitions in AI modeling, robotics, and cybersecurity. Driven by a passion for sustainability and emerging technologies, Jana aspires to advance research in machine learning and smart systems to foster a secure and sustainable digital future.

Tayma Hasan Efdeil is an undergraduate student pursuing a Bachelor of Science in Computing and Information Systems with a concentration in Information Systems Security at the University of Dubai, United Arab Emirates. She has taken part in various hackathons, Capture the Flag (CTF) challenges, and cybersecurity-focused coursework and projects. Tayma continues to strengthen her technical skills through training programs and online certifications, including studies in cloud computing and core cybersecurity practices. Her interests revolve around cybersecurity operations, artificial intelligence integration, and building secure and efficient digital infrastructures. Tayma is motivated by a commitment to support the development of advanced, secure, and sustainable technological solutions.

Hiba Mohamed Ahmed is an undergraduate student pursuing a Bachelor of Science in Computing and Information Systems with a concentration in Information Systems Security at the University of Dubai, United Arab Emirates,

recognized on the Dean's Honor List for her outstanding academic performance. She is passionate about artificial intelligence, cybersecurity, and sustainable digital innovation. Hiba was part of the winning team UD Geographers at the NASA Space Apps Challenge 2024, Dubai, which was nominated for the International Hackathon stage. She also received recognition in the INJAZ Al-Arab competition and the Aoun Award for leadership and community impact. Formerly the President of the Happiness Club, Hiba now serves as the Treasurer and Top 4 member of the University of Dubai Student Union (UDSU). Her academic research focuses on AI-driven smart data centers for sustainable cities, aligning with the Dubai Economic Agenda (D33) and UN Sustainable Development Goals (SDGs).

Dr. Maisam Wahbah received the Ph.D. degree in Electrical Engineering and Computer Science from Khalifa University (KU), UAE. In 2019, she joined the Healthcare Engineering Innovation Center at the Department of Biomedical Engineering at KU as a Post-Doctoral Fellow. Dr. Wahbah is currently an assistant professor at the College of Engineering & Information Technology, University of Dubai, UAE. As a long-standing and engaged member of the IEEE, Dr. Wahbah currently holds a leadership position as Chair of the Awards & Recognition Committee for the IEEE UAE Section, where she actively promotes excellence and professional growth within the engineering community. Her research bridges renewable energy, statistical modeling, and biomedical systems, with recognized contributions including receiving the QUWA research grant– a funded research grant aligned with the UAE's D33 vision and the UN SDGs. Dr. Wahbah's work reflects her deep commitment to innovation in cross-disciplinary research, bridging engineering, leadership, and societal impact.