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The Optimization of the Food-Energy-Water Nexus Framework of Urban Farms with Renewable Energy and Micro Supply Chains

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Abstract

Designing a food-energy-water (FEW) nexus framework is critical for the development of future sustainable cities, as well as addressing global concerns of increased demand for natural resources (food, energy and, water). A case study consisting of seven Urban Farms in South Florida is established, with the main objective of providing fresh produce to the local community. Each Urban Farm belongs to a community-scale microgrid system that generates electricity from renewable sources (solar, wind, biomass), and provides electricity to the urban farm and surrounding community buildings. Additionally, a micro-supply chain is established among the seven farms to increase food availability for the local community, combating food deserts and reducing food waste. Following the establishment of a FEW nexus framework, a mathematical programming model is introduced to design and optimize the parameters within the framework. Data inputs used for the model are obtained from the results of a previously developed agent-based model (ABM). The objective of the mathematical programming model is to address the supply and demand balance within the FEW network, and depending on the supply-demand trend, will optimally match supply and demand over time, using indicators such as cost and carbon footprints. In addition, solving the model identifies optimal capacities for renewable energy sources (solar, wind, biomass), as well as the scheduling of the unit commitment and micro supply chain. The results will provide valuable insight into the design of a FEW nexus framework, as well as the interactions that occur between food, energy, and water systems, and allows for the analysis of different policy scenarios and their implications. Once solved, the model provided results for a period of 264 hours, determining optimal operational decisions for power production, electricity for irrigation, and consumption of water that is needed for a combined heat and power (CHP) unit, and for irrigation of crops. The results of the micro supply chain led to the transport of 78,657kg between four farms, and the remaining food waste was converted into biomass energy. The optimal capacities of renewable energy technologies were found, solar with a total capacity of 4,400 kW, and wind with a total capacity of 7,000 kW. The optimal capacity of battery storage systems at each microgrid belonging to each urban farm was found, and this was based on electricity demands, as well as electricity generation capacities. The results of the mathematical programming model led to the optimal design of an urban FEW framework, determining the optimal capacities of renewable energy technologies, battery storage systems, and optimal operation conditions of the FEW nexus.

Keywords
Optimization, Food-Energy-Water Nexus, Urban Farms, Food Supply Chain, Renewable Energy.

Biographies
Dr. Marwen Elkamel is a Post Doctoral Fellow at the Department of Industrial Engineering & Management Systems at the University of Central Florida. He obtained a Bachelor degree with distinction in Economics with a minor in Management Studies from the University of Waterloo, Ontario, Canada and a Master of Science degree in

Management (Business Analytics track) from the University of Central Florida. He received his Ph.D. in Industrial Engineering from the University of Central Florida in 2023. Before starting his PhD, he worked as a data analyst for WeCare tlc. During his undergraduate studies, he served as a Research Assistant at the Waterloo Institute for Sustainable Energy (WISE). He was involved in two different projects that encompassed the acquisition and summary of data and preparation of computer programs to simulate processes and to make appropriate conclusions. During his PhD studies, he has been preparing machine learning models for electricity consumption with the consideration of socio-economic factors. He was also involved in a project that dealt with power resources scheduling and planning. He is currently focusing on modeling and optimizing the Urban Food-Energy-Water Nexus in order to find more efficient ways to supply water, energy and food and manage natural resources that can aid in sustainable energy development and improved water and food security. He is a member of IEOM, IFORMS, and the Institute of Industrial & Systems Engineering. He has published several journal and conference papers in the areas of modeling, simulation, optimization, and big data analytics.

Dr. Luis Rabelo is a Professor of Industrial Engineering & Management Systems at the University of Central Florida. He was the NASA EPSCoR Agency Project Manager (2009-2011). He received dual degrees in Electrical and Mechanical Engineering from the Technological University of Panama and Master's degrees from the Florida Institute of Technology in Electrical Engineering (1987) and the University of Missouri-Rolla in Engineering Management (1988). He received a Ph.D. in Engineering Management from the University of Missouri-Rolla in 1990, where he also did Post-Doctoral work in Nuclear Engineering in 1990-1991. In addition, he holds a dual MS degree in Systems Engineering & Management from the Massachusetts Institute of Technology (MIT). He has over 300 publications, three international patents being utilized in the Aerospace Industry, and graduated 35 Master and 24 Doctoral students as advisor and co-advisor. He has consulted with NASA, NSF, ONR, NIST, Lockheed Martin Corporation, Boeing, Tyco, and others. His experience includes Ohio University, BF Goodrich Aerospace, Honeywell Laboratories, the National Institute of Standards and Technology, NASA, and MIT. He has received many awards among them ONE NASA in 2006, the Alumni of the Year of the Technological University of Panama in 2008, Fulbright Scholar in 2008, Two NASA Group Achievement Awards, the Emerald Literati Network Awards for Excellence 2007, the 2004 Arch T. Colwell Merit Award from the Society of Automotive Engineers (SAE), the 23rd Annual Hispanic Engineer National Achievement Awards Corporation (HENAAC) Education Award Winner in STEM in 2011, the Engineer Educator of the year 2011 by the US Engineer's Council, and the 2013 International Joseph McFarland Award from SAE.