SMART (Sustainable, Modular, Additively-manufactured, Robust, Tower-style) Urban Farming

Ang, Gedeon (School: Raffles Institution)

Global food security and sustainability issues, and rapid urbanization call for high-tech, space-efficient, sustainable urban farming technologies. In Singapore, only 3.9% of vegetables consumed are produced locally, and only 1% of land is allocated for agriculture. Nutrient film technique (NFT) hydroponics is practical, but current approaches are inadequate due to space and maintenance constraints. This project outlines the development of a novel design of tower-style NFT hydroponics that focuses on space efficiency, multifunctionality, intelligence, energy efficiency, and material efficiency. Complex internal and exterior geometry inspired by aircraft semi-monocoque fuselage, all with optimized dimensions are used. Optimization and analysis by finite element analysis (FEA) ensures the design is space efficient, material saving, and strong (safety factor>6 in all 3 loading conditions). Selective laser sintering (SLS), a laser powder bed fusion (LPBF) additive manufacturing (AM) process, is used to fabricate these complex geometries without support structures, with high isotropy; and with glass-bead filled polypropylene (PPGB), for its mechanical properties, waterproofness, and chemical resistance. This NFT hydroponics system is 3.3-9.8x more space efficient; and 3.4-4.7x more material efficient than existing ones. A more energy-efficient full-spectrum LED lighting solution is developed. A low-cost system monitors and maintains critical variables for the system's operation and alerts the user if manual intervention is needed. Modularity allows different plants to be grown together. Hence, this system can be practically installed into space-limited urban areas (e.g. homes, offices), and effectively aid in tackling global food security and sustainability challenges.