INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI
SHORT ABSTRACT OF THESIS

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Programme of Study	:	Ph.D.

Thesis Title: Optimization of Renewable Energy Systems

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Thesis Submitted to the Department/ Center	:	Yes
Date of completion of Thesis Viva-Voce Exam:	:	16-08-2024
Key words for description of Thesis Work	:	Renewable energy; Biorefinery supply chain; Multi-unit strategy; Exergetic optimization; Metaheuristic techniques; MILP;

SHORT ABSTRACT

The transition to carbon-neutral energy sources like solar, wind, biofuels etc., reduces dependence on fossil fuels. Biofuels offer a practical alternative, while solar energy is popular for its low cost and abundance. This thesis explores optimization methodologies for developing renewable energy systems, focusing on biorefinery supply chains and solar energy systems, ensuring technical and economic feasibility. The biofuel supply chain requires complex, multi-stage optimization, particularly in biorefinery capacity planning, where design constraints limit economic processing options leading to suboptimal results. MILP models can optimize supply chain decisions; however, they are computationally intensive. Metaheuristic methods provide near-optimal solutions but face challenges with feasibility due to complex mass balance constraints.

The difficulty in solving biorefinery supply chain networks with metaheuristic techniques arises from numerous equality constraints. In order to address this, a novel framework is proposed, optimizing the metaheuristic approach to handle these constraints and search for optimal solutions efficiently. The framework was evaluated in a case study using various metaheuristic techniques to minimize the total life cycle cost, consistently identifying feasible solutions and demonstrating its robustness. The framework is extended to a multi-unit strategy to address processing capacity limitations in biorefineries, which incorporates a heuristic mechanism for capacity planning by deploying multiple units of the selected technology within the capacity range. The performance analysis using various metaheuristic techniques demonstrated a reduction in total lifecycle cost compared to the single-unit strategy. The performance analysis employing various metaheuristic techniques revealed a 1.64% reduction in total lifecycle cost when utilizing a multi-unit framework compared to the single-unit scenario.

The benefits of the multi-unit strategy are further demonstrated on a distributed multi-unit MILP supply chain model for biorefineries. The efficacy of the proposed model is demonstrated using the total life cycle analysis approach with linear approximations for the capital cost calculations. The optimal solution of the multi-unit MILP model has a reduced total life cycle cost of 1.25% compared to the single-unit model. This thesis also explored the effectiveness of the multi-unit strategy on the periodic assessment of the biorefineries as they are prone to seasonal variabilities. A multi-objective multi-unit MILP framework that adopts a multi-period distributed biorefinery supply chain network is proposed by considering maximization of profit and maximization of social impact as the conflicting objectives. The multi-objective multi-unit model improved the profit by 4.73% and generated 78 additional jobs in the analysis performed over 12 months compared to the single-unit strategy.

The thesis also explores solar energy-based systems and proposes efficient optimization strategies, focusing on solar air and water heating technologies, addressing the literature gap regarding problem formulation, decision variables, and constraints. In this direction, an exergetic optimization framework is proposed for flat plate solar air collectors and solved using metaheuristic techniques to maximize exergy efficiency. Additionally, a multiobjective solar water collector model is proposed to maximize exergy efficiency while minimizing the absorber plate area. The proposed strategies eliminate thermodynamically infeasible solutions by imposing constraints on operating conditions. The research highlights the potential of these optimization techniques in enhancing the efficiency and sustainability of renewable energy systems, encouraging their broader adoption in large-scale applications.