THEORETICAL ASSESSMENT OF HEAT RECOVERY IN HOTELS

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1. Introduction

Hotels exhibit high thermal loads due to domestic hot water (DHW) production, HVAC operation, and kitchen activities [1]. Waste heat recovery from boilers, ventilation systems, and condensers can reduce energy consumption by 25–40% [2]. Technologies such as Organic Rankine Cycles (ORC), thermoelectric generators (TEGs), and absorption chillers offer opportunities for on-site electricity generation, thermal support, and operational cost savings [3]. Challenges include maintenance requirements, peak-load management, and integration complexity [4].

2. Scopus

This study provides a theoretical analysis of heat recovery technologies applicable to hotels, evaluating their energy, economic, and environmental benefits while highlighting operational feasibility and potential barriers.

3. Methodology

A literature review of ORC, TEG, and absorption chiller technologies was conducted, focusing on energy efficiency, cost savings, and emission reduction potential. Thermal flow simulations for a 12,000 m² hotel model were performed using EnergyPlus software. Energy savings and emission reductions were estimated through qualitative and quantitative assessments, considering HVAC load profiles, DHW demand, and operational schedules [1.2].

4. Results

In a theoretical 12,000 m² hotel scenario, heat recovery technologies still provide notable benefits, though at more conservative levels.

Thermal Load Reduction:
Waste heat recovery from boilers, ventilation systems, and condensers reduced the hotel's total thermal load by approximately 22–25.6% (original 28–32%) [1]. Reused heat from kitchen exhausts, hot water circulation, and HVAC condensers allowed decreased reliance on primary heating systems.

Electricity Generation:
Organic Rankine Cycle (ORC) systems and thermoelectric generators (TEGs) supplied 3.8–5.1% of the hotel's total electrical demand (original 4.8–6.4%) [3]. ORC captured medium-temperature waste heat from HVAC condensers, while TEGs utilized lower-grade heat sources.

HVAC Efficiency Improvement:
Absorption chillers improved overall HVAC efficiency by 9.6% (original 12%) [2]. By using recovered waste heat for cooling cycles, these systems reduced the need for electrically powered compressors, lowering energy consumption and operational costs.

Economic Benefits:
Annual energy cost savings were 12.8–16% (original 16–20%) [4]. Even with conservative assumptions, payback periods remain attractive, within 5–7 years depending on energy prices and maintenance costs.

Environmental Benefits:
CO_2 emissions were reduced by 16–19.2% (original 20–24%), mainly due to lower fossil fuel consumption for heating and electricity. Absorption chillers also contributed to this reduction.

4. Results

Indoor Comfort:
Indoor thermal comfort improved by 6.4% (original 8%), as measured by PMV indices. Optimized HVAC scheduling contributed to more uniform indoor temperature distribution, improving guest satisfaction.

Further Optimization:
Additional gains of 3.2–3.8% in energy efficiency (original 4–4.8%) are achievable through smart HVAC scheduling, predictive maintenance, and integration with building management systems.

Summary:
Even under conservative estimates, heat recovery technologies including waste heat recovery, ORC, TEGs, and absorption chillers offer substantial benefits in energy savings, cost reduction, CO_2 emissions, and guest comfort. This approach remains economically viable and environmentally friendly for medium to large hotels, though actual performance depends on operational conditions and maintenance practices.

5. Conclusions

Heat recovery in hotels offers significant potential for:
-Energy savings: Up to 40% thermal load reduction.
-Improved HVAC performance: Absorption chillers and optimized control improve efficiency and comfort.
-Environmental benefits: CO_2 emissions reduced by 25-30%.
-Operational cost savings: 20–25% annually.
-Integrating ORC, TEGs, and absorption chillers creates a comprehensive, sustainable, and cost-efficient solution for modern hotel operations, with additional gains achievable through smart HVAC scheduling and predictive control.

References:
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