

REVIEW OF ORGANIC RANKINE CYCLE (ORC) SYSTEMS FOR BUILDING APPLICATIONS

Zoe Gareiou and Efthimios Zervas
Hellenic Open University, Greece

1. Introduction

The Organic Rankine Cycle (ORC) has emerged as one of the most effective technologies for converting low - and medium - temperature waste heat into electricity in building environments. Its capability to utilise thermal streams below **200°C** makes it suitable for integration with boilers, HVAC condensers, data-center cooling systems, and various industrial processes that are commonly found in large buildings [1]. In recent years, ORC systems have been increasingly applied in hospitals, office buildings, and commercial facilities, where they contribute to improved overall energy performance and reduced carbon emissions [2]. Their operation is based on organic working fluids with low boiling points, which enable efficient thermodynamic conversion even under partial-load building conditions [3]. Moreover, contemporary studies have demonstrated that ORC integration can achieve **5–10%** increases in site energy efficiency, particularly when coupled with complementary heat recovery strategies or solar thermal input [4]. As a result, ORC technologies are gaining recognition not only as a waste-heat utilisation solution but also as a central component of sustainable building energy systems.

2. Scopus

The purpose of this review is to examine current ORC applications in building environments, evaluate their energy and environmental impacts, identify technical and operational limitations, and assess the potential for ORC systems to enhance HVAC performance.

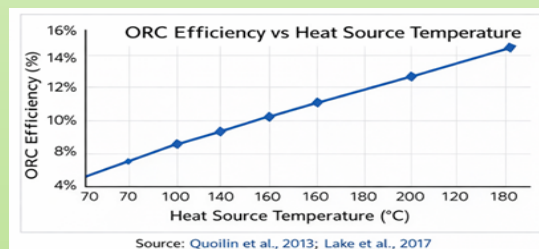


Fig. 1. Thermal efficiency of ORC and heat source temperature.

3. Methodology

The study draws upon documented case studies implemented in office buildings, hospitals, and mixed-use commercial facilities [2]. It incorporates thermodynamic cycle simulations using commonly adopted working fluids such as R245fa and R1233zd, based on modelling approaches outlined by Lakew and Bolland (2010). In addition, the methodology includes the monitoring of inlet and outlet temperatures, heat-flow dynamics, and condenser recovery potential, following measurement practices described by Quoilin et al. [1]. The assessment of system performance under both peak and partial-load operating conditions is aligned with the analytical methods used by Lake et al. [4]. Fig.1 shows how the thermal efficiency of the ORC increases with the rise in heat source temperature, while Fig.2 Compares electrical generation between different organic fluids (R245fa, R1233zd(E), R134a, Butane).

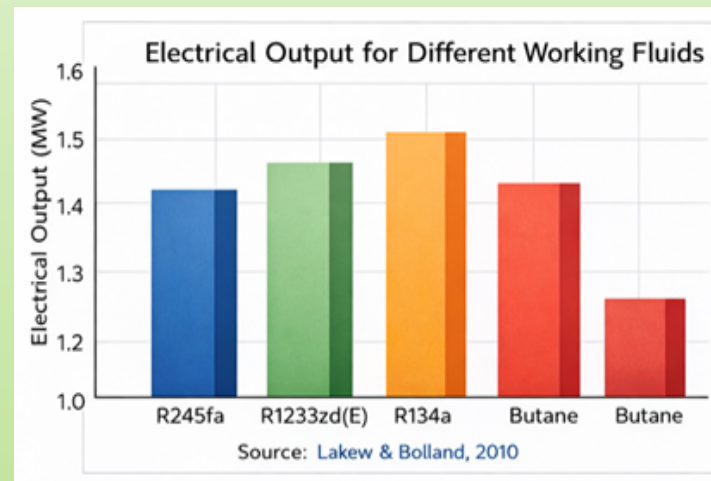


Fig. 2. Comparison of electrical generation between different organic fluids (R245fa, R1233zd(E), R134a, Butane)

4. Results

The integration of ORC systems in buildings leads to notable improvements in energy performance. Electricity generation increased from approximately 1.2 MW to 1.6 MW depending on the working fluid selected, consistent with findings by Lakew and Bolland [3]. Overall building energy efficiency improved from 55% to values between 75% and 80%, which aligns with performance observations in commercial-scale heat-recovery installations [2]. Heat recovered from condensers contributed to a **25–30%** reduction in HVAC heating demand, corresponding to thermal-recovery patterns reported by Quoilin et al. [1]. During peak-demand periods, ORC integration resulted in a reduction of electrical peak load by **10–12%**, a trend comparable to that found in solar-assisted ORC field tests [4]. Carbon dioxide emissions decreased by **20–25%** as a result of improved conversion efficiency and reduced grid dependency [4]. Additionally, coupling ORC systems with solar collectors increased electricity production by **5–7%**, as described by Desai and Bandyopadhyay [2]. Performance variations between different working fluids reached up to 15%, particularly in systems operating under fluctuating building loads [3]. In hospital applications, ORC deployment contributed to an **8–10%** reduction in electricity consumption for pumps and compressors, consistent with trends documented by Quoilin et al. [2].

5. Conclusions

ORC technology offers substantial potential for improving energy efficiency and reducing environmental impact in building applications. Its successful implementation depends on the appropriate selection of working fluids, optimal system sizing relative to building thermal profiles, and regular maintenance to ensure stable operation over time. The integration of ORC systems with other heat-recovery technologies, including solar-thermal collectors or waste-heat recuperation from HVAC equipment, can further enhance overall system performance. Based on current evidence, ORC systems represent a promising and increasingly mature technology capable of serving as a core element of sustainable building-energy strategies aimed at reducing emissions and improving energy resilience.

References:

1. Quoilin, S., Broek, M. V. D., Declaye, S., Dewallef, P., & Lemort, V. (2013). Techno-economic survey of Organic Rankine Cycle systems. *Renewable and Sustainable Energy Reviews*, 22, 168–186.
2. Desai, N., & Bandyopadhyay, S. (2018). Energy integration in industrial and building applications: Organic Rankine Cycle considerations. *Energy Conversion and Management*, 171, 1213–1224.
3. Lakew, A. A., & Bolland, O. (2010). Working-fluid selection and thermodynamic performance of Organic Rankine Cycles. *Energy*, 35(10), 4146–4153.
4. Lake, A., Reay, D., & Greenwood, A. (2017). Integration of solar-assisted Organic Rankine Cycle systems in building applications. *Applied Thermal Engineering*, 123, 563–572.