EISKIG White Paper

Analysis and Expansion of Industrial Cooling Supply Systems for the Application of AI-Based Operational Optimization

EISKIG – Energy Intelligence System for Smart Cooling Systems in Industrial Buildings

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01 ABSTRACT

Demonstrated Impact of AI-Driven Cooling Optimization

The EISKIG research project analyzes and optimizes three industrial cooling systems using AI-based control models. The objective is to systematically identify efficiency potential and enable safe real-world implementation. In parallel, operational flexibility during live operations without disrupting production processes was ensured. A dedicated fallback mechanism was designed and validated.

This PDF is a summary of the white paper "Analyse und Erweiterung industrieller Kälteversorgungs-systeme zur Anwendung KI-gestützter Betriebs-optimierung. EISKIG – Energy Intelligence System für smarte Kältesysteme in Industriegebäuden" [1].

Figure 1: Cooling supply system at the project partner Merck

This mechanism continuously monitors system state, control signal plausibility, and communication integrity between the optimization platform and building management system. The system operates under boundary conditions defined in coordination with operational regulations. Manual override always remains available, ensuring supply security in safety-critical environments.

RESULTS ACROSS THE PROJECT

21% reduction

in electrical energy consumption in cooling system at Merck KGaA

≥20% reduction

in electrical energy consumption in cooling system at Equinix (Germany) GmbH

02 MOTIVATION

Industrial refrigeration systems are among the most energy-intensive subsystems in industrial production and building infrastructure. They ensure stable processes, product quality, and operational safety, yet often account for a substantial share of total electricity demand. Over time, many systems have been expanded or technically upgraded. However, control strategies are frequently based on system-level energy management and do not evolve at the same pace.

As a result, complex multi-component systems operate below their achievable efficiency levels due to suboptimal coordination between generation, distribution, and heat dissipation.

Figure 2: Operator monitoring and controlling

EISKIG: Bridging the gap between operation and efficiency

To address these challenges, the EISKIG research project was initiated. Its objectives are to:

- Systematically analyze industrial refrigeration systems
- Develop and validate AI-based control strategies

By combining industrial partners and research institutions, the project demonstrates how AI-supported supply optimization can improve energy performance without compromising process stability or supply security.

03 BARRIERS & COUNTERMEASURES

Static Control Strategies

Many refrigeration systems operate using fixed control setpoints that do not sufficiently adapt to dynamic load variations or changing environmental conditions. As a result, system operation may deviate from optimal efficiency conditions, leading to avoidable energy consumption.

Hidden Savings Potential

Although operators are aware of the high energy demand of cooling systems, the identification of the most inefficient subsystems and the quantification of their optimization potential is often limited by system complexity and insufficient transparency.

Complex Legacy Systems

Industrial plants have frequently been expanded or modernized over time without fundamentally revising the control architecture. This results in complex network structures with heterogeneous technologies, load profiles, and operational strategies.

Pump Inefficiencies

Pump groups are commonly operated outside their optimal efficiency range. In part-load operation, optimal operating points are not consistently maintained, reducing overall system performance.

However, this initial condition also represents a significant opportunity: since many systems are not yet optimized at the control level, AI-based methods can unlock efficiency potential without requiring major modifications to the physical infrastructure.

04 AI AS A SOLUTION

Optimization with the etaONE® platform from etalytics

The AI-based optimization platform etaONE® was deployed within the project. The solution is based on digital twins that represent the operational behavior of refrigeration systems. Using real-world measurement data, the platform continuously computes optimized control setpoints for pumps, cooling towers, chillers, and distribution components.

Multiple operating configurations are evaluated to identify the combination of volume flows, temperature levels, and operating states that maximize system efficiency. In contrast to conventional rule-based control strategies, which rely on isolated parameter adjustments, etaONE® considers the entire system and its component interactions.

How etaONE® works in practice

- Secure transfer of optimized setpoints to the building management system
- The multi-level optimizer enables a smooth transition.

Integration into existing building management systems is performed via the etaONE Gateway.
Fallback mechanisms continuously monitor connectivity, system stability, and control boundaries.
In case of deviations, the control function automatically reverts to conventional regulations, ensuring operational reliability.

05 APPLICATIONS AND USE CASES

Industrial refrigeration systems consist of multiple interconnected components. Their operation is influenced by variable loads, ambient conditions, redundancy requirements, and component-specific performance characteristics. Within the EISKIG project, three industrial cooling systems with differing topological and load structures were analyzed and optimized under real operating conditions.

Merck KGaA

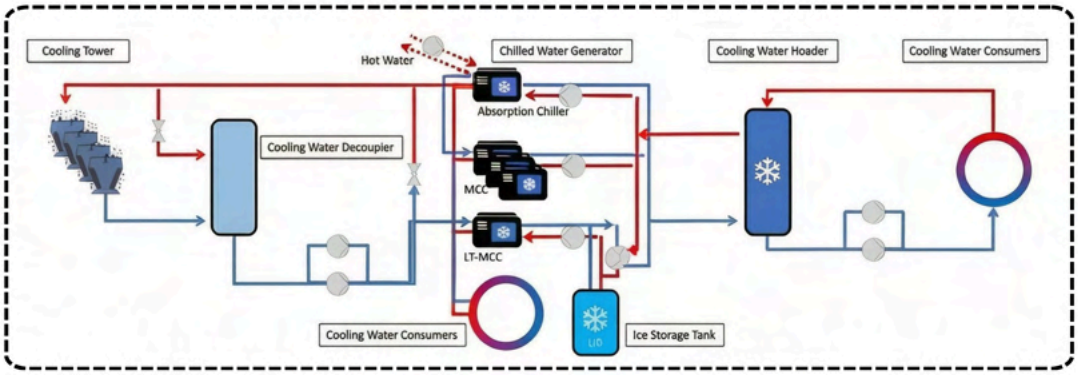


Figure 3: Network topologies of the industrial use case Merck KGaA

Bosch Rexroth AG

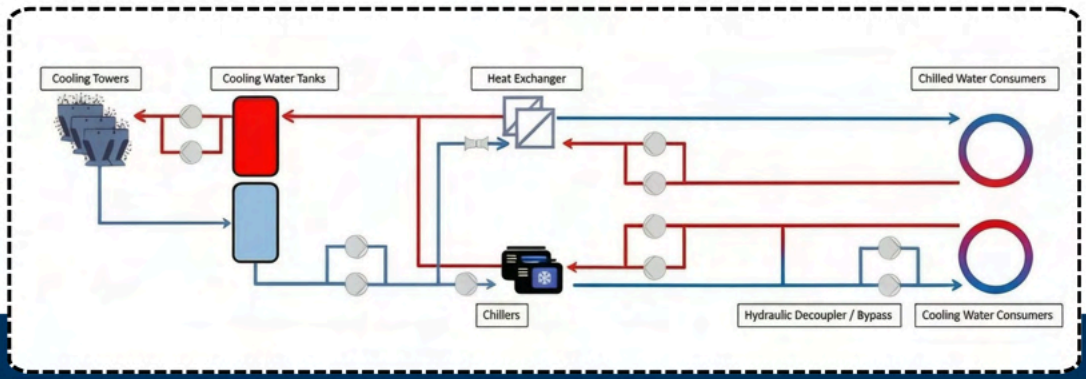


Figure 4: Network topologies of the industrial use case Bosch Rexroth AG

Equinix (Germany) GmbH

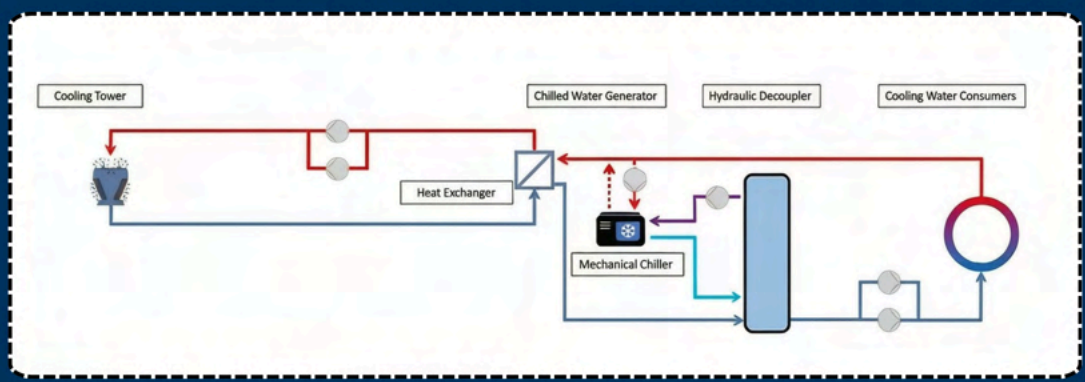


Figure 5: Network topologies of the industrial use case quinix (Germany)GmbH

Figures 3,4,5 Network topologies of the industrial use cases, Source: Lademann, T.; Weigold, M.; Petruschke, L.; Weber, T.; Helfert, M.; Elbæk, E.: Analyse und Erweiterung industrieller Kälteversorgungssysteme zur Anwendung KI-gestützter Betriebsoptimierung. EISKIG – Energy Intelligence System für smarte Kältesysteme in Industriegebäuden (Whitepaper). TU Darmstadt / etalytics GmbH / ETA-Solutions GmbH, 22.10.2025. Lizenz: CC BY 4.0. Available at: https://doi.org/10.26083/tuprints-00031434.

06 MERCK USE CASE

At the Merck site, >20M m^3/yr chilled water supports production and infrastructure units with varying demand profiles [2]. It is a a highly interconnected network with multiple generators, hydraulic switches, pump groups, and consumers [1].

Core Challenges

- Flow distribution at hydraulic switches caused internal circulation losses
- Pump groups operated outside efficient ranges, especially under partial load

Solution Identified and Implemented

Operational optimization focuses on pressure-based setpoints for pumps, cooling towers and chillers aligned with live system demand using AI. Control parameters were adjusted in real time based on system behavior, while respecting all operational limits and safety constraints (software-only, no retrofit).

RESULTS ACHIEVED

21% REDUCTION (3MO)

in electrical energy consumption in cooling system at Merck KGaA

UP TO 36% REDUCTION

in electrical energy consumption in pump group; cooling towers +5%

STABLE OPERATION

within defined temperature limits

07 EQUINIX USE CASE

The Equinix site operates a data center refrigeration system with strict requirements for availability, redundancy, and thermal stability. Cooling demand fluctuates with IT load and ambient conditions, while service levels must be always met.

Solution Identified and Implemented

Six refrigeration units were analyzed in parallel and dynamically adjusting different setpoints under real operating conditions. A key lever of the AI-optimized control strategy in this cooling system is to maximize the use of free cooling in combination with adiabatic cooling. The etaONE enables stable and energy-efficient operation and efficiency evaluated through real-time monitoring.

RESULTS ACHIEVED

≥ 20% REDUCTION

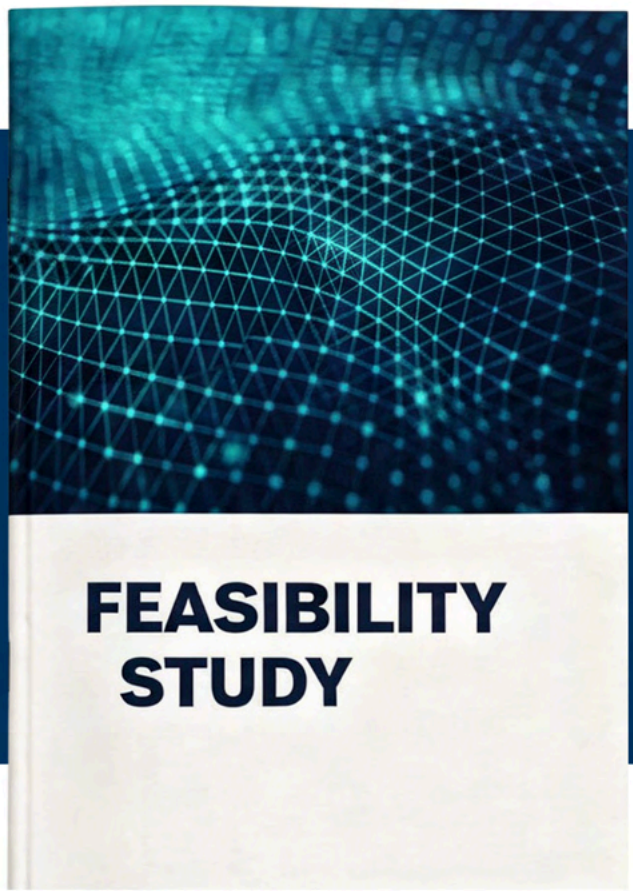
in electrical energy consumption in cooling system at Equinix (Germany) GmbH (observation period: ~4 months, Mar–Jun'25)

AI CONTROL ACTIVE

without impact on comfort or stability (76% AI Control Activity during the observation period)

08 VALIDATE YOUR POTENTIAL

If you want to understand what optimization could deliver in your own environment, you can start with a free feasibility study. This initial assessment reviews available data, identifies efficiency potential, and provides a fact-based estimate of possible savings, without obligation.



FREE FEASIBILITY STUDY

DETAILED EISKIG WHITE PAPER

If you want deeper insight into the methodology, system analysis, and detailed results, the full EISKIG white paper provides extended technical background and additional project findings.

Read the full EISKIG whitepaper on the TU Darmstadt website

Abbildung 6: Branchenerprobte Methode zur Bewertung von Energieeinsparungen (Quelle: etalytics GmbH)

Während der nächsten Phase der Inbetriebnahme der Betriebsoptimierung werden abwechselnd die konventionelle Regelung und die KI-optimierte Regelung aktiviert und die jeweils einhergehenden Energiebedarfe gemessen. So ist im Rahmen von sogenannten A-B-Tests ein direkter Vergleich der elektrischen Leistungsaufnahme möglich. In der Phase der autonomen Optimierung, d. h. bei dauerhafter Aktivität der KI-optimierten Regelung, erfolgt schließlich ein Vergleich der Energiebedarfe: Der Energiebedarf der KI-optimierten Regelung wird gemessen und die konventionelle Regelung wird simuliert. Dies ermöglicht einen dauerhaften Vergleich wie auch die Ermittlung der kumulierten Energieeinsparungen.

In den betrachteten Use-Cases bei Industriepartnern ergeben sich schließlich die nachfolgend geschilderten Einsparungen. Für das bei Merck KGaA betrachtete System ergeben sich im Vergleich zur konventionellen Regelung Einsparungen von bis zu 31 % im elektrischen Energiebedarf durch die autonome KI-optimierte Regelung. Insbesondere im Bereich der Pumpengruppe reduziert sich der Energiebedarf im betrachteten Zeitraum um bis zu 36 %, wenngleich der Energiebedarf der Kühltürme leicht um 5 % steigt. Dieser Effekt ist in Abbildung 7 im Verlauf der elektrischen Leistungsaufnahme sichtbar.

Abbildung 7: Elektrische Leistungsaufnahme der Pumpengruppe sowie der Kühltürme im Rahmen von Testfahrten zur Inbetriebnahme der KI-optimierten Regelung bei Merck KGaA

In einem weiteren Use Case wurde das bei Equinix (Germany) GmbH analysierte System optimiert, welches ebenfalls bereits in Kapitel 2 beschrieben wurde. In Abbildung 8 ist die Leistungsaufnahme und der EER des betrachteten Systems (insgesamt 6 Kälteerzeugungseinheiten) im Rahmen eines A-B-Tests zur Inbetriebnahme der KI-optimierten Regelung bei Equinix (Germany) GmbH dargestellt. In diesem mehrtägigen A-B-Test ergibt sich im Vergleich zur konventionellen Regelung eine Reduktion der elektrischen Leistungsaufnahme wie auch eine Verbesserung des EER. Wesentlicher Ansatzpunkt der KI-optimierten Regelung ist in diesem Kältesystem der optimierte Einsatz der Freikühlung in Kombination mit adiabatischer Kühlung.

Figure 6: Insights from the whitepaper, pages 17, Industry-proven method for evaluating energy savings [1].
Fgure 7: Insights from the whitepaper, pages 18, Electrical power consumption of the pump group and the cooling towers during test runs for the commissioning of the AI-optimized control system at Merck KGaA [1].

References

[1] Lademann, T.; Weigold, M.; Petruschke, L.; Weber, T.; Helfert, M.; Elbæk, E.: Analyse und Erweiterung industrieller Kälteversorgungssysteme zur Anwendung KI-gestützter Betriebsoptimierung. EISKIG – Energy Intelligence System für smarte Kältesysteme in Industriegebäuden (Whitepaper). TU Darmstadt / etalytics GmbH / ETA-Solutions GmbH, 22.10.2025. Lizenz: CC BY 4.0. Available at: https://doi.org/10.26083/tuprints-00031434.

[2] etalytics GmbH: Merck und etalytics realisieren 21 % Energieeinsparung bei industrieller Kühlung, 11 Feb 2026. Available at: https://etalytics.com/de/resources/blog/merck-und-etalytics-realisieren-energieeinsparung-bei-industrieller-kuehlung.