Singapore and Denmark Lead Sustainable Cooling Innovation for Megacities Backed by US$9.4 Million from Grundfos Foundation

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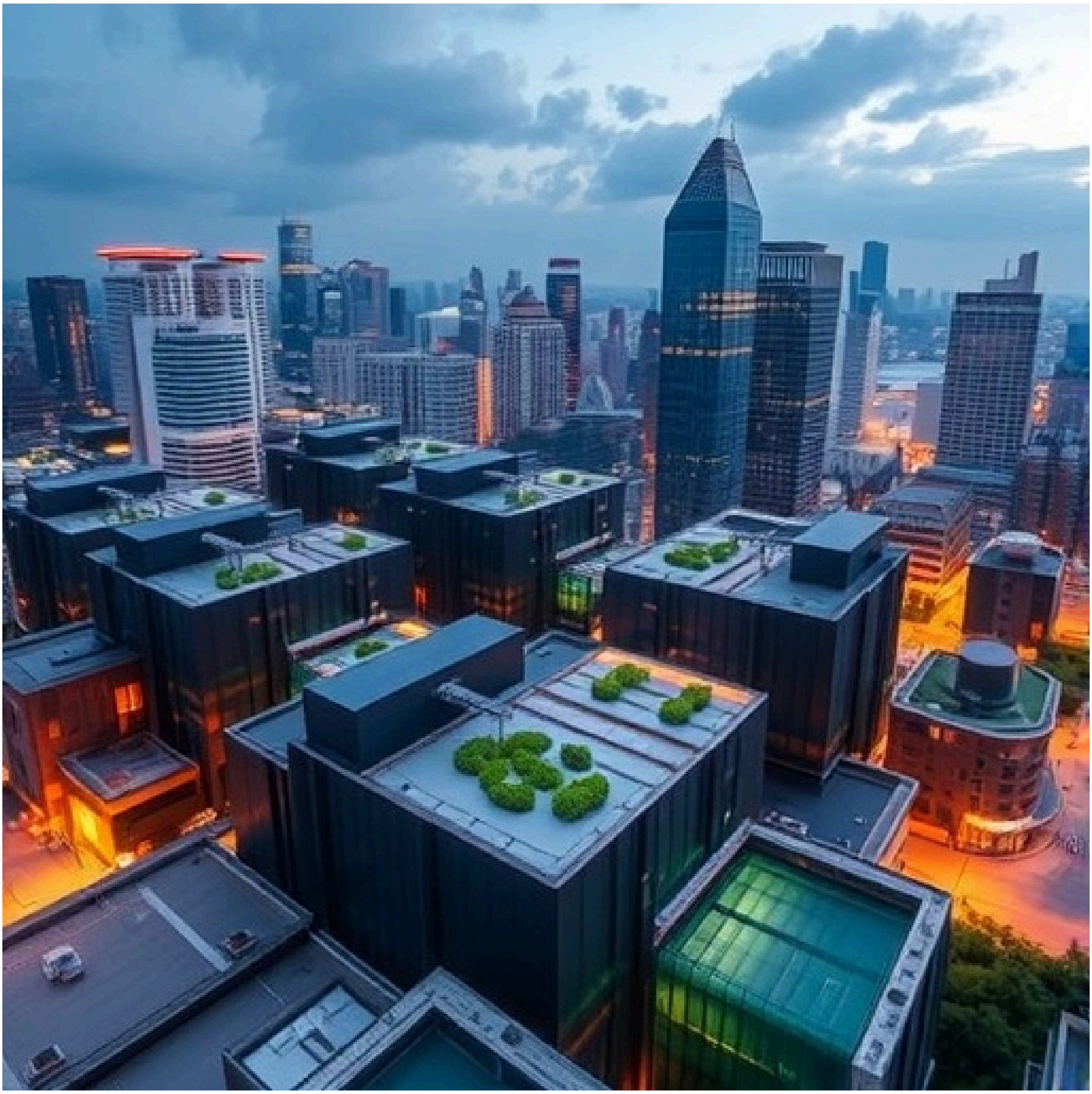

As global temperatures continue to rise and climate change accelerates, the demand for effective and sustainable cooling solutions in urban environments becomes increasingly urgent. Megacities, especially those located in tropical and subtropical regions, are facing unprecedented challenges in managing the growing need for cooling infrastructure. Traditional cooling systems, while essential for maintaining livable environments, often rely on energy-intensive processes that exacerbate carbon emissions, further fueling the very climate crises they seek to alleviate. Responding to this critical challenge, a groundbreaking international research initiative has been launched, bringing together world-leading experts from Nanyang Technological University (NTU Singapore), Aalborg University, and Aarhus University in Denmark.

This ambitious five-year project, underpinned by a significant investment of US$9.4 million from the Grundfos Foundation—the foundation's largest research grant to date—aims to revolutionize urban cooling by developing intelligent, water-based sustainable systems tailored for megacities. The initiative, titled Sustainable Water-based Cooling in Megacities (SWiM), leverages the complementary strengths of Danish and Singaporean urban infrastructure innovation. Through integrated research spanning engineering, artificial intelligence, and urban planning, SWiM seeks to break the entrenched cycle of high energy consumption and carbon emissions caused by conventional cooling technologies.

District cooling and heating technologies form the foundational expertise upon which this project builds. Denmark, a global pioneer in district heating systems, has long demonstrated the efficiency advantages of centralized thermal energy distribution. Facilities such as the Avedøre Power Station and the Amager Bakke waste-to-energy plant epitomize cutting-edge combined heat and power technologies, providing sustainable, large-scale thermal solutions. Meanwhile, Singapore has adeptly adapted these concepts into district cooling networks optimized for tropical urban conditions. The Marina Bay district's extensive underground chilled water pipeline system exemplifies this, significantly reducing carbon emissions citywide.

Despite these successes, current district cooling installations in megacities are typically limited in their geographical coverage and scalability. Business districts and housing estates can be served effectively, but extending these benefits to entire cities requires overcoming substantial technical challenges. The SWiM project directly addresses these barriers by focusing on scalable, modular cooling architectures enabled by advanced control systems. These systems are designed to respond dynamically to varying urban environments, demand fluctuations, and operational anomalies.

Central to the SWiM initiative is the development of autonomous control mechanisms that can ensure reliable, fault-tolerant operation without the need for constant expert supervision. This autonomy is critical for deployment in complex urban settings where human error, potential cyber-attacks, and equipment failures could otherwise compromise system integrity. Aarhus University's expertise in electrical and computer engineering drives this domain, utilizing digital twin technologies that model physical cooling infrastructure and support adaptive control strategies. Such digital replicas provide real-time operational insights, enabling predictive maintenance and optimal system adjustments.

Artificial intelligence plays a transformative role in the SWiM framework. By integrating machine learning algorithms, the system can monitor performance continuously, detect inefficiencies or faults early, and employ predictive analytics to prevent downtime. Notably, the project incorporates smart algorithms that balance the competing demands of cooling load, energy efficiency, and grid stability. This ensures that cooling systems contribute positively to the broader urban energy ecosystem rather than destabilizing it.

A distinctive aspect of this research is its focus on applicability under real-world conditions. SWiM's approach transcends laboratory testing by constructing physical testbeds at multiple scales — room, floor, and building levels — within Singapore's urban fabric. These physical environments will be complemented by comprehensive digital twin simulations, enabling scalable replication of system behavior across various city scenarios. Such rigorous validation is essential for transitioning innovations into practical, large-scale solutions that city planners and policymakers can adopt confidently.

The collaborative nature of SWiM, uniting Singaporean and Danish academic and industrial stakeholders, embodies a model for global scientific partnership. With Grundfos Foundation's funding strategically underpinning the initiative, industry knowledge will be deeply integrated into research outcomes to ensure feasibility and immediate applicability. This collaboration is particularly timely as both Singapore and Denmark pursue ambitious climate objectives—Singapore targeting net-zero emissions by 2050 and Denmark aiming for climate neutrality by 2045.

Professor Madhavi Srinivasan of NTU Singapore highlights the convergence of interdisciplinary expertise in this project, noting how the blend of sustainability science, engineering, and artificial intelligence can yield cutting-edge urban cooling solutions. Similarly, Professor Rafael Wisniewski of Aalborg University underscores the importance of developing systems that are not only theoretically sound but also resilient and user-friendly, capable of deployment without reliance on specialist intervention.

The envisioned integration of digital tools such as Building Information Models (BIM) with real-time monitoring systems promises unprecedented precision in managing energy flow and cooling demands. Professor Peter Gorm Larsen of Aarhus University elaborates on how digital twins will facilitate seamless transitions between operational states, ensuring that cooling resources are allocated efficiently under varying conditions.

SWiM's innovations aim to disrupt the current paradigm, making cooling systems vital components of sustainable urban infrastructure rather than significant contributors to environmental degradation. By combining low-energy water-based cooling methods with intelligent control architectures and comprehensive urban planning tools, the project charts a visionary pathway for megacities grappling with the twin crises of urban heat and climate change.

As urban populations continue to expand, particularly in tropical megacities, the stakes for sustainable cooling solutions have never been higher. SWiM represents a bold leap forward, promising to reduce city-wide energy consumption for cooling by up to 30 percent—a transformative achievement with profound implications for global carbon emissions and urban liveability.

In the coming years, the success of SWiM will be measured not only by technological milestones but also by its ability to influence policy, shape standards, and catalyze widespread adoption of sustainable cooling infrastructures worldwide. This initiative underscores the critical role of cross-border collaboration and innovation in addressing one of the defining environmental challenges of our time.

Subject of Research: Sustainable urban cooling systems for megacities involving water-based, intelligent district cooling technologies.

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