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research group of spatial information management and modeling rim

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VINGROUP VINHOMES

SUA SMART URBAN AREAS

FINAL CONFERENCE

Fachvorträge / Presentations / Bài Thuyết Trình

Vietnam National University (VNU)

Trường Đại học
Khoa Học Tự nhiên Hà Nội
19 Lê Thánh Tông

06.05.2025

VGBC STANDARD MEMBER

#**Green** Buildings #**Blue** Infrastructure #**Digital** Solutions
#**Ex**port **I**nitiative Environmental Protection

M² CEMM

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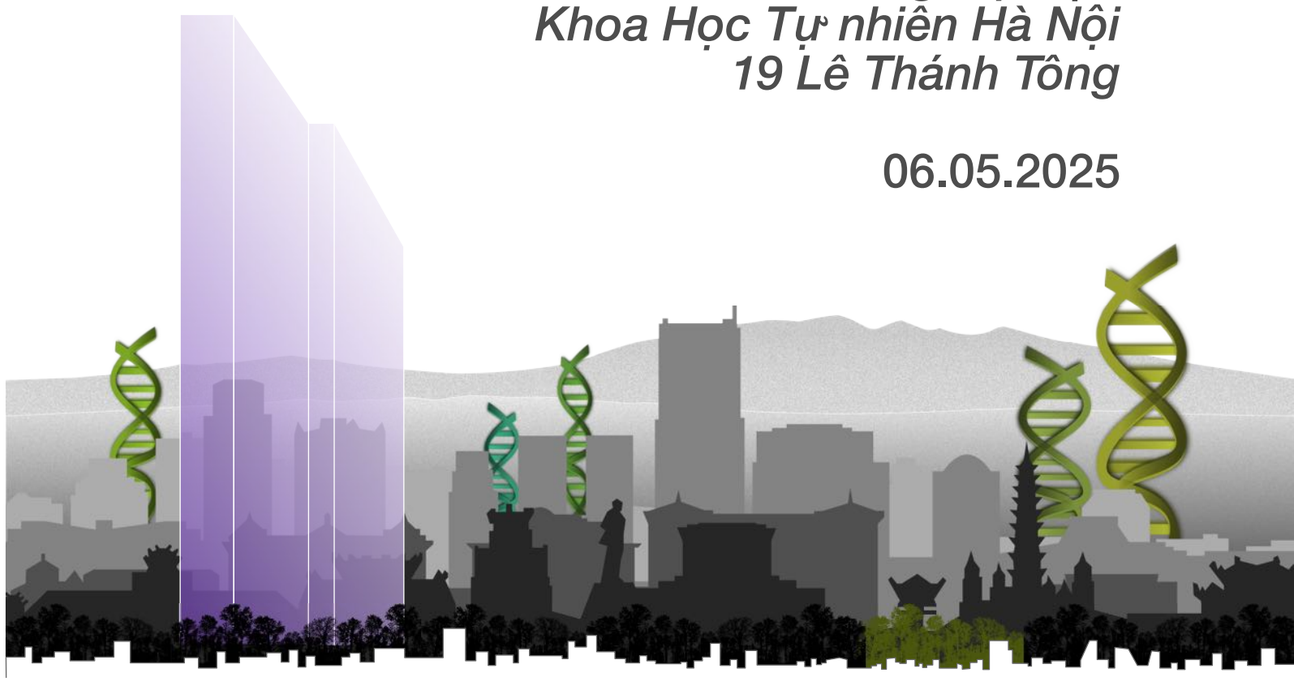

#**Green** Buildings #**Blue** Infrastructure #**Digital** Solutions
#**Ex**port **I**nitiative Environmental Protection

IMPRESSUM

HERAUSGEBER:
Fachgebiet Raumbezogene Informationsverarbeitung
und Modellbildung (RIM)
Technische Universität Dortmund
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44227 Dortmund
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Tobias Kuester-Campioni, Dr. Mathias Schaefer,
Sinan Karakus, Flemming Eismann, Sophie Girlich,
Prof. Dr. Nguyen Xuan Thinh

FINANZIERUNG:
Die folgende Vortragssammlung ist im Rahmen des
Forschungsprojekts **Smart-Urban-Areas (SUA)**
entstanden und wurde vom **Bundesministerium
für Umwelt, Naturschutz, nukleare Sicherheit
und Verbraucherschutz (BMUV)** gefördert
[Förderkennzeichen 67EXI5001A].

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Wel

come

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resses

TU Dortmund University
Germany

Prof. Dr. Nguyen Xuan Thinh

dortmund university

Dear Mr. Vu Quy Huy, Director of the Vietnam National Innovation Center,

Dear Dr. Pham Hong Quat, Director General of the National Agency for Technology Entrepreneurship and Commercialization Development, Ministry of Science and Technology,

Dear Dr. Nguyen Tuan Quang, Deputy Director General of the Department of Climate Change, Ministry of Agriculture and Environment,

Ladies and gentlemen,

Welcome and thank you all very much for attending the final conference of our BMUV project “Smart Urban Areas.” In addition to the directors of the three ministries, I would like to warmly welcome

- **Prof. Dr. Hoang Vinh Hung**, Director General of the Vietnam Institute for Urban and Rural Planning (VIUP),
- **Prof. Dr. Ha Thuc Vien**, Vice President of the Vietnamese-German University,
- **Prof. Dr. Nguyen Thanh Bang** and **Dr. Nguyen Tiep Tan**, Deputy Directors General of the Vietnam Academy for Water Resources,
- **Prof. Dr. Pham Ngoc Ngo**, VNU/HUS, founder of the first Faculty of Environmental Sciences at a university in Vietnam,
- **Dr. Le Thi Bich Thua**n, Deputy Director General of the Institute of Urban Research and Infrastructure Development, and from the German side
- **Prof. Dr. Dietwald Gruehn**, Dean of the Department of Spatial Planning at the TU Dortmund University and
- **Mr. Gero Boehmer**, Director for Government & Public Affairs of Wilo SE.

I would also like to extend a warm welcome to the numerous experts from Vietnamese academic institutions, politics, administration and business, as well as students from various universities in Hanoi.

Our sincere thanks go to the German Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (BMUV) for funding the project and to the project sponsor ZUG for the excellent support and supervision of the research project. We would like to thank our Vietnamese partner Vingroup/Vinhomes for their cooperation and for making Tonkin 2 in Vinhomes Smart City Hanoi a research building. Our sincere thanks go to the owners of the TestBed 1 and TestBed 2 buildings, Mr. Nguyen Huu Chung and Dr. Truong Chi Trung. As long-standing partners, the Research Center for Environmental Monitoring and Modeling (CEMM) of VNU/HUS and the Vietnam Academy for Water Resources have actively supported our project on site throughout its entire duration. We are very grateful for this fruitful collaboration. Last but not least, as project leader, I would like to thank everyone involved, especially Gero Boehmer, Tobias Kuester-Campioni, Dr. Mathias Schaefer, Sinan Karakus, Pham Nhat Anh, Anna Dumke, Flemming Eismann, Lea Maiwald, Sabrina Pilarczyk, Louisa Kegel, David Gisa, Jan Kanelias, Raphael Michaelis-Braun and Sophie Girlich for their tireless work and participation in various scopes and conducting phases to ensure the overall success of the project.

The participants' keen interest demonstrates how topical and urgent the question of how cities can be designed for the future in times of climate change, resource scarcity, and rapid growth. This is precisely where the SUA project comes in: It combines digital technologies, ecological innovations, and interdisciplinary urban planning into a holistic solution approach. As our project video clip shows, we – the project consortium – have built three research stations as demonstrations and remaining physical references of the BMUV-EXI program and equipped them with several technologies that were used for the first time in Vietnam, thus performing pioneering work in Vietnam. Be inspired by the project's results and test our VR application.

Thank you very much!

National Innovation Center (NIC)
Vietnam

Vu Quang Huy

Dear Prof. Dr. Nguyen Xuan Thinh, Director of Smart Urban Areas Project and distinguished delegates,

Ladies and gentlemen,

It is with great pleasure and honor that I join you today at the Final Conference of Smart Urban Areas (SUA)— a pivotal event that marks the culmination of three years of fruitful collaboration among the Government, the business sector, and leading academic institutions of Vietnam and the Federal Republic of Germany. With a financial commitment of nearly € 2 million from the Federal Ministry for Environment, Nature Conservation and Nuclear Safety (Germany - BMUV), alongside Wilo SE, the SUA Project stands as a compelling testament to the synergy between scientific research and practical implementation, it has significantly contributed to addressing pressing challenges such as rapid urbanization, climate change, and the imperative transition towards a carbon-neutral economy. As Director of the National Innovation Center (NIC), I take particular pride in the fact that this initiative traces its origins to the “Vietnam Innovation Network Connection Program” in 2018, a platform facilitated by the NIC. This program laid the groundwork for the collaboration between TU Dortmund University, Vingroup/Vinhomes, and Wilo SE, thereby fostering international knowledge exchange and cross-sectoral partnership.

Over the past three years, the Smart Urban Areas (SUA) Project has delivered pioneering and transformative outcomes. For the first time, a comprehensive digital twin system has been deployed to optimize building management processes — encompassing the use of Wilo’s high-efficiency pumps in irrigation systems, the integration of green infrastructure such as vegetated walls and rooftops, and the efficient collection and reuse of rainwater. A particularly noteworthy achievement is the green roof installed at the Tonkin 2 Tower in Vinhomes Smart City. Designed following the Akira Miyawaki method, this innovative feature has given rise to a “mezzanine forest,” significantly enhancing urban biodiversity. Within a mere eight months, the rooftop ecosystem has attracted native bird species to nest, exemplifying the ecological value of nature-based urban design. In addition, the project marks the first large-scale application of the DAVIS Instruments weather sensor system in tandem with a LoRaWAN network across a 40 - storey high-rise. This configuration has enabled the collection of critical data on building–microclimate interactions, offering new insights into sustainable urban living. As an integrated achievement, these outcomes not only embody technological advancement but also serve as practical and scalable models for sustainable urban development — with the potential for technology transfer in cities across the globe.

I would like to express my sincere appreciation for the creativity, commitment, and interdisciplinary collaboration demonstrated by the entire project team — from the distinguished scientists at TU Dortmund University, led by Prof. Dr. Nguyen Xuan Thinh and Research Center for Environmental Monitoring and Modeling (CEMM), to our esteemed corporate partners, Vingroup and Wilo SE. The achievements of the SUA Project have established a solid foundation for the development of smart urban areas in Vietnam, contributing meaningfully to the reduction of greenhouse gas emissions and the enhancement of energy efficiency. As a facilitator and connector of the national innovation ecosystem, the Vietnam National Innovation Center (NIC) is committed to support initiatives like SUA, fostering the replication of cutting-edge research, and in bridging scientists, industry stakeholders, and policy makers towards the collective goal of building a more sustainable, resilient, and inclusive innovation ecosystem.

I look forward to the continued efforts of the SUA project team in sharing its research findings, practical experiences, and expert evaluations. These resources will serve as valuable references, enabling related initiatives across Vietnam to learn from and build upon the project’s success. NIC remains committed to supporting the dissemination of this knowledge through dedicated networking platforms, capacity-building programs, and international collaboration, contributing to more sustainable, innovative, and livable cities

across the region.

The year 2025 also marks the 50th anniversary of the establishment of diplomatic relations between Vietnam and Germany (September 23, 1975 – September 23, 2025), a significant milestone that reaffirms the depth and strategic nature of our bilateral partnership. The SUA Project stands as a vivid example of this effective cooperation — contributing not only to scientific and technological advancement, but also to the shared vision of sustainable development between two nations. NIC will continue to serve as a vital bridge, facilitating the introduction of advanced technological solutions from Germany to Vietnam., further strengthen the national innovation ecosystem.

Once again, I would like to extend my heartfelt congratulations to the SUA project team for their remarkable and commendable achievements. I am confident that, with the continued support of the German Government, TU Dortmund University, esteemed enterprises such as Wilo and Vingroup, and the active engagement of the National Innovation Center (NIC), we will witness many more successful collaborative initiatives in the future, contribute to developing a modern, intelligent, and sustainable Vietnam.

I wish you all continued good health, fulfillment, and success in your life.

Thank you very much for your kind attention.

German Federal Ministry of Nature, Environment, Nuclear Safety and Consumer Protection (BMUV)
Germany

Nilgün Parker

Bundesministerium
für Umwelt, Naturschutz, nukleare Sicherheit
und Verbraucherschutz

UMWELTSCHUTZ
made in Germany

Dear General Director of the Vietnam Academy for Water Resources

Dear General and Deputy Director of Vingroup/Vinhomes

Ladies and Gentlemen,

It is my pleasure to welcome you also on behalf of the German Federal Ministry for the Environment and its project supporter “Zukunft – Umwelt – Gesellschaft (ZUG) gGmbH”. Even no representative is able to attend todays conference in person, the responsible Division in the Ministry would like to emphasize the importance of the various challenges of urbanization that the SUA project addresses.

Due to growing population and growing cities the demand for water and energy is rising substantially, making natural resources increasingly scarce and more expensive. Hence, nations depend more than ever on the ability to use water and energy more efficiently and in a more sustainable manner. Cities have to become more efficient, environmental-friendly and worth living bearing in mind, that also space is limited. Smart and sustainable solutions are required to meet the resulting demands without destroying the environment.

The Ministry’s division for Environment-related Promotion of Foreign Trade and Investment emphasizes that SUA is one of those projects that combines all the relevant topics of urban development. It addresses the issue of water management, climate and environmental protection by using the latest and most efficient technologies and by considering solutions in the field of digital twins, 3D simulations and augmented reality/virtual reality that allow a user-friendly illustration and experience of the solutions for the various stakeholders.

Sustainable, green and smart solutions are an important building block for the protection and preservation of our natural resources that in turn fosters economic prosperity, competitiveness and a higher standard of living. These goals can only be achieved if the necessary infrastructure and the legal, political and administrative framework are in place. To encourage cooperation in this area the German Ministry of the Environment has launched the Export Initiative Environmental Protection.

With SUA an innovative project was developed by a strong consortium. The consortium has conducted pioneering research with practical implementation in Vietnam and has established and commissioned three research stations. I would like to emphasize the novelty and uniqueness of the project results in Vietnam. The SUA project pursues a multidimensional approach to optimizing holistic system solutions in Vietnam for urban neighborhoods.

- *For the first time, green roofs and facades were installed in a building, with water supplied by a water treatment plant.*
- *For the first time, a next-generation smart pump was installed to monitor the irrigation system.*
- *For the first time, DAVIS Instruments weather stations and sensors were installed in Vietnam.*
- *For the first time, a LoRaWAN sensor network of this size was installed on a high-rise building.*
- *For the first time, the green roof was designed as a badger forest using Akira Miyawaki's method for brownfield regeneration to increase biodiversity. Natural bird settlement and nest building occurred after eight months.*

The SUA project bring out a best practice example that could be transferred to other cities and countries around the world.

The Ministry’s team of the Export Initiative Environmental Protection wishes you a fruitful discussion and successful conference.

TU Dortmund University
Germany

Prof. Dr. Dietwald Gruehn

dortmund university

Dear Dr. Nguyen Tuan Quang, Dear Vu Quoc Huy, Tran Minh Trung,
Ladies and Gentlemen,
Excellencies,
Dear colleagues and friends,

When I first arrived in Hanoi just a few days ago, I was struck by the vibrancy of this city – its dynamic growth, its energy, and its clear sense of direction. It quickly became clear to me that this is a place where tradition and innovation are deeply connected.

The Smart Urban Areas project serves as a prime example of how universities, industry leaders, and governments can work hand in hand to shape the future of our cities. This initiative has successfully integrated sustainable, smart technologies into urban spaces. It stands as a testament to the hard work and dedication of everyone involved.

On German-Vietnamese research cooperation

While the potential for German-Vietnamese research cooperation is still growing, projects like Smart Urban Areas mark an important milestone in fostering partnerships based on mutual respect and shared learning. In the last few days, I saw firsthand how Vietnam's academic landscape is rapidly evolving. For me, it is exciting to be here in Vietnam, witnessing how our collaboration is expanding.

What is fascinating about this particular collaboration on Smart Urban Areas is that it is a partnership of equals, where both sides contribute their expertise to tackle global challenges. Local partners from both Vietnam and Germany have been involved in every phase, ensuring that the solutions developed are not just imported, but tailored to the specific needs and context of Hanoi. This ensures that the results of the project will have a lasting impact, supported by both local knowledge and international experience.

I would like to sincerely thank everyone involved in this outstanding project – for your dedication, your vision, and your openness. Let us carry the spirit of this cooperation forward – into future initiatives, new partnerships, and our shared journey toward more livable and sustainable cities.

I wish this final conference many valuable insights – and all of us, fresh inspiration for what lies ahead.

Introduction

SUA Einleitung
SUA Introduction
Giới thiệu SUA

Digitale Zwillinge und intelligente Stadtgebiete im Kontext von Digitalisierung, grünem Wachstum und Anpassung an den Klimawandel in Vietnam
Digital Twins and Smart Urban Areas in the Context of Digitalization, Green Growth and Climate Change Adaptation in Vietnam
Bản sao số và khu đô thị thông minh trong bối cảnh số hóa, tăng trưởng xanh và thích ứng với biến đổi khí hậu tại Việt Nam

Prof. Dr. Nguyen Xuan Thinh

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Digital Twins and Smart Urban Areas in the Context of Digitalization, Green Growth and Climate Change Adaptation in Vietnam

SUA SMART URBAN AREAS

Final Conference of SUA Project

19 Le Thanh Tong, Hanoi

Prof. Dr. Nguyen Xuan Thinh, TU Dortmund University

Digital Twins and Smart Urban Areas
in the Context of Digitalization, Green Growth and Climate Change Adaptation in Vietnam

- **VN Population 101 Mio.**
- **Urbanization Rate 44,3%**
- **Construction industry growth rate 7-8%/year**
- **Pressures**: Infrastructure, heat stress, heavy rain, typhoon, floods

Data in 2024

2

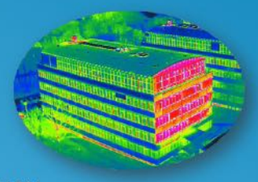
Traffic jams and congestion in Hanoi happen every day

3

System Solutions for Sustainable Urban Development

- **Digitalization, Digital Transformation, Digital Twins → Smart City**

TU Dortmund Main Building of Department



3D Model with LOD4

Laserscanning

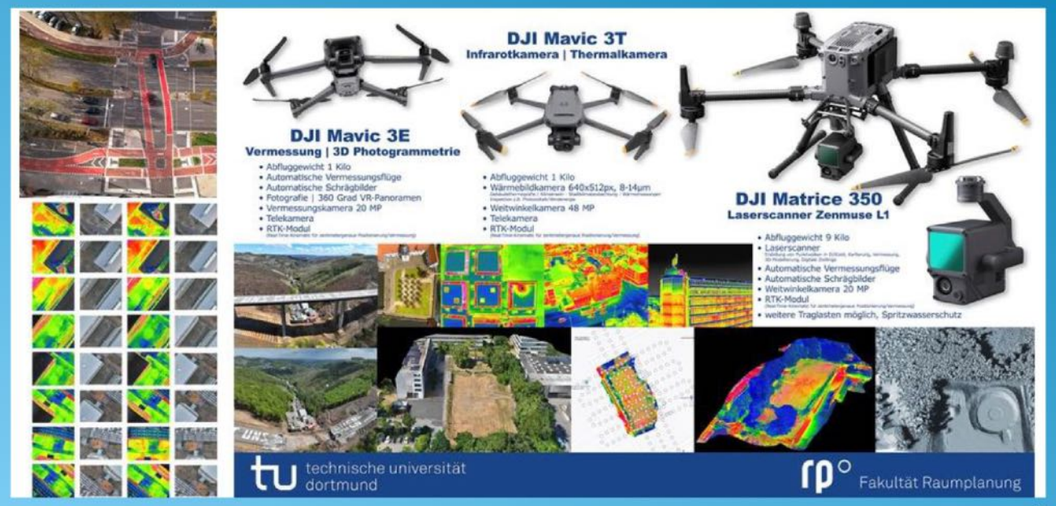
Thermal Images by using UAV

10/2022
Teaching Project

Vietnamese-German University Library

4

Three Drones of the Department of Spatial Planning, TU Dortmund



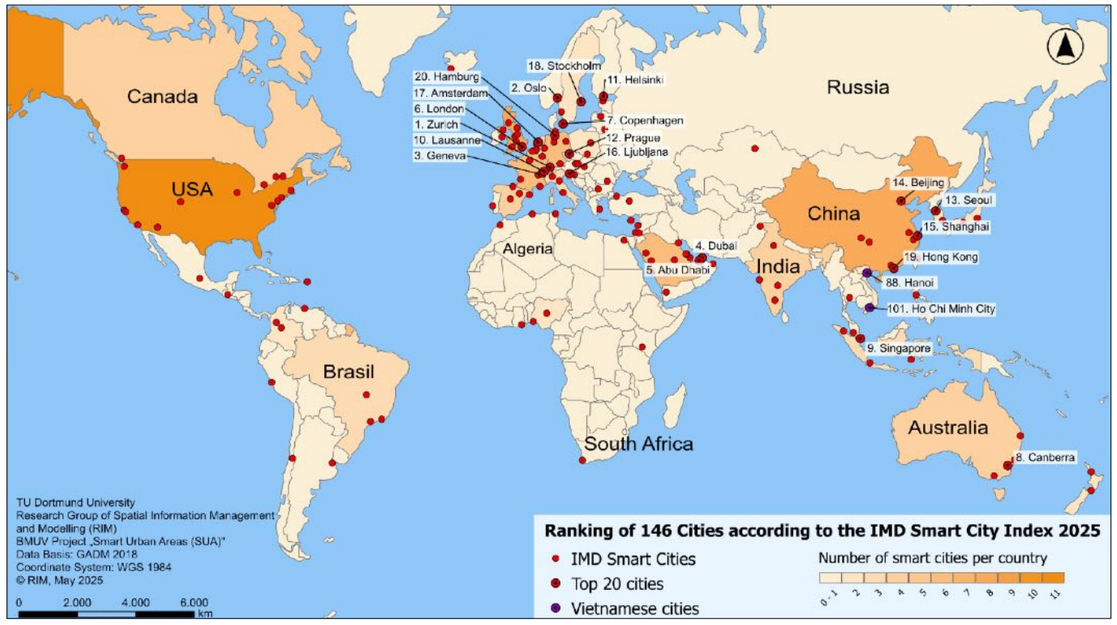
System Solution for Sustainable Urban Development

- Digitalization, Digital Transformation, Digital Twins → Smart City
- Technologies for Environmental and Climate Protection, e. g. Smart Pump Technology by Wilo SE
- Rainwater Management and Reuse of Grey Water
- Green Building and Grenning Measures

Digital twins as the basis for **smart cities**

Smart City is one Major Global Trend

- Many cities around the world are striving to become Smart Cities
- Technical, economic and social innovations are integrated to meet the challenges of demographic change, urbanization, climate change and resource scarcity
- National and international Smart City Indexes have used for years



Key Features of a Smart Urban Area

- **Internet of Things (IoT):** Devices and systems are networked to collect and analyze data in real time (e.g., smart street lighting, networked waste collection, traffic monitoring).
- **Broadband Internet:** High internet speeds are widely available to ensure connectivity and access to digital services.
- **5G networks:** For faster communication between devices and to support innovations in autonomous vehicles, smart homes, etc.

9

Key Features of a Smart Urban Area

- **Energy optimization:** The use of renewable energies, intelligent power grids (smart grids) and energy-efficient buildings.
- **Water management:** Technologies for monitoring and controlling water consumption, collecting and treating rainwater, or monitoring water quality.

10

Key Features of a Smart Urban Area

- **Green infrastructure:** more parks, sustainable architecture and the integration of nature into urban design.
- **Air and noise measurement:** Sensors to monitor air quality and implement measures to improve environmental conditions.

11

Key Features of a Smart Urban Area

- **Intelligent traffic management systems:** Sensors that monitor traffic in real time and control traffic flow to minimize congestion.
- **Public transport:** Connections and timetables are optimized, often through apps that provide real-time information.
- **Autonomous vehicles:** Self-driving vehicles and car-sharing services are becoming increasingly integrated.
- **Electromobility:** Promotion of electric vehicles and the provision of charging stations.

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Key Features of a Smart Urban Area

- **E-government:** Digital platforms enable citizens to handle their concerns online (e.g., applications, communication with the city administration).
- **Participation and data access:** Citizens can be involved in decision-making processes and have access to relevant urban data (e.g., through apps that display data on air quality or extreme weather).

13

Traffic jams and congestion in Hanoi happen every day

14

Key Features of a Smart Urban Area

- **Sensors and real-time data analysis & simulation:** These technologies enable continuous optimization of urban processes and services.
- **Big Data and AI:** By analyzing large amounts of data, urban problems such as traffic congestion, crime, or energy consumption become more predictable and solvable.

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Key Features of a Smart Urban Area

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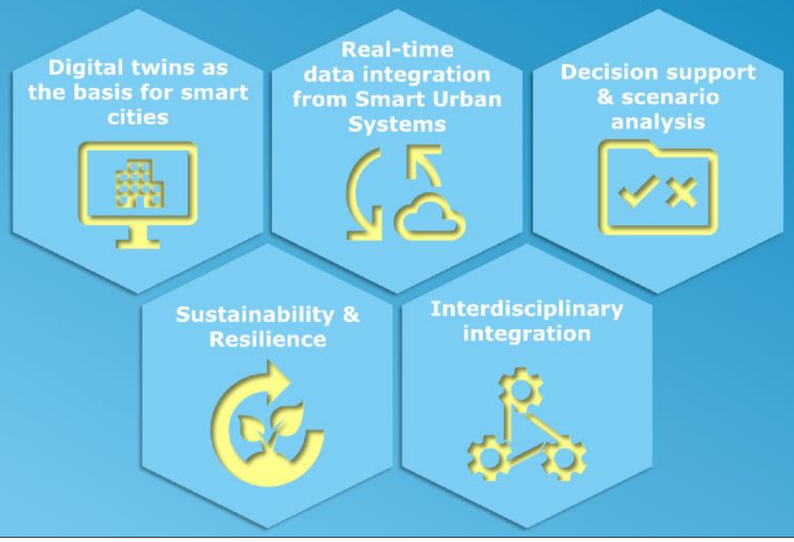
Key Relationships between Digital Twins and Smart Urban Areas



17

Key Relationships between Digital Twins and Smart Urban Areas

- **Digital twins of cities** represent the physical city virtually (e.g. buildings, streets, infrastructure).
- They make it possible to test **plans, changes and optimizations** virtually before they are implemented in the real world.
- This allows **smart solutions** to be planned and tested more efficiently (e.g. traffic flow, energy distribution, emergency management).

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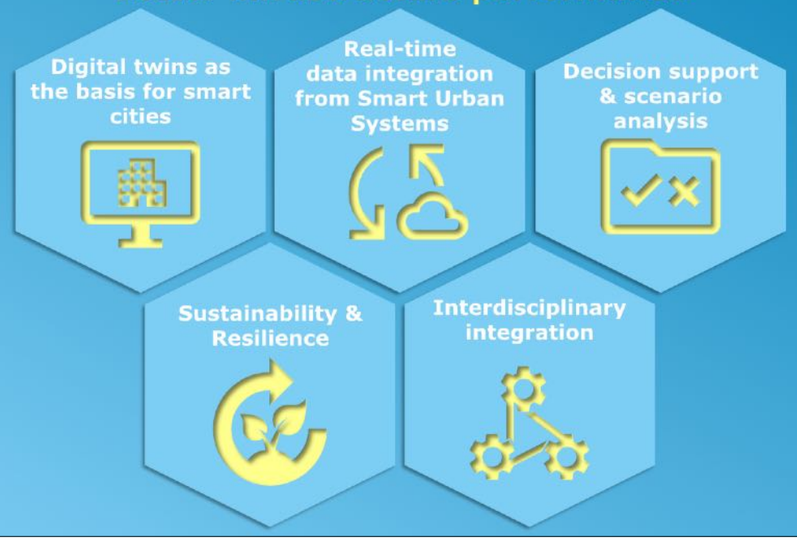
Key Relationships between Digital Twins and Smart Urban Areas

- The digital twin serves as **an integration platform** to bring together **interdisciplinary data** and **think in a networked manner**.
- Change the state management method, innovate the planning method and content according to the **integrated, multi-sectoral method**, end the situation where each sector plans for its own sector,

19

DT delivers public benefit value, better outcomes for people and better infrastructure performance



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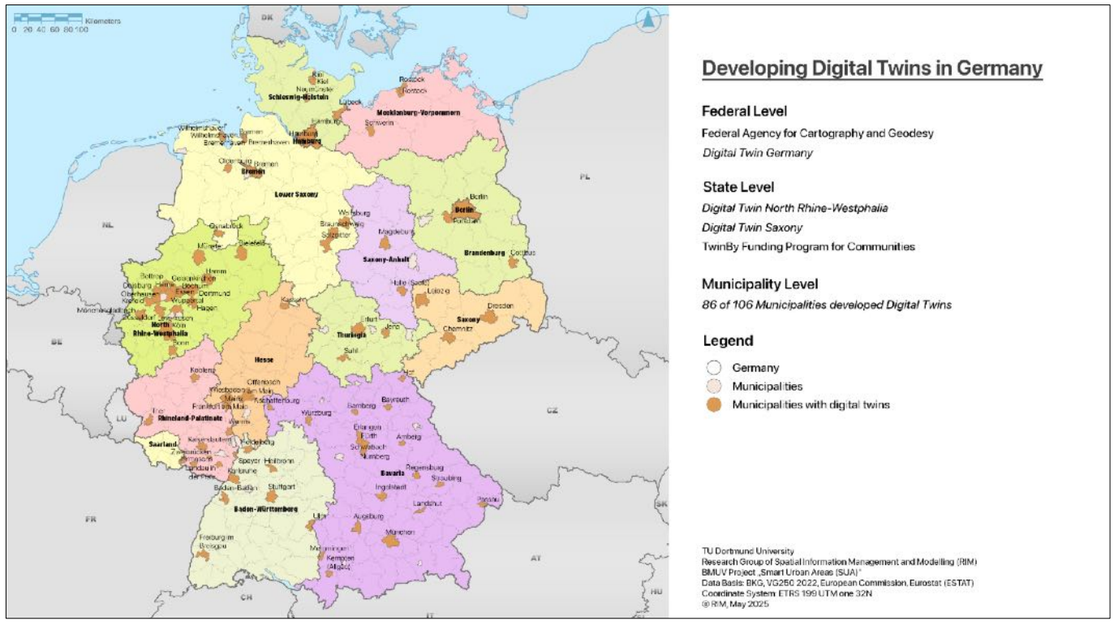
Kilometers
0 20 40 60 80 100
Developing Digital Twins in Germany
Federal Level
Federal Agency for Cartography and Geodesy
Digital Twin Germany
State Level
Digital Twin North Rhine-Westphalia
Digital Twin Saxony
TwinBy Funding Program for Communities
Municipality Level
86 of 106 Municipalities developed Digital Twins
Legend
Germany
Municipalities
Municipalities with digital twins
TU Dortmund University
Research Group of Spatial Information Management and Modelling (RIM)
BMUV Project „Smart Urban Areas (SUA)"
Data Basis: BKG, VG250 2022, European Commission, Eurostat (ESTAT)
Coordinate System: ETRS 1989 UTM zone 32N
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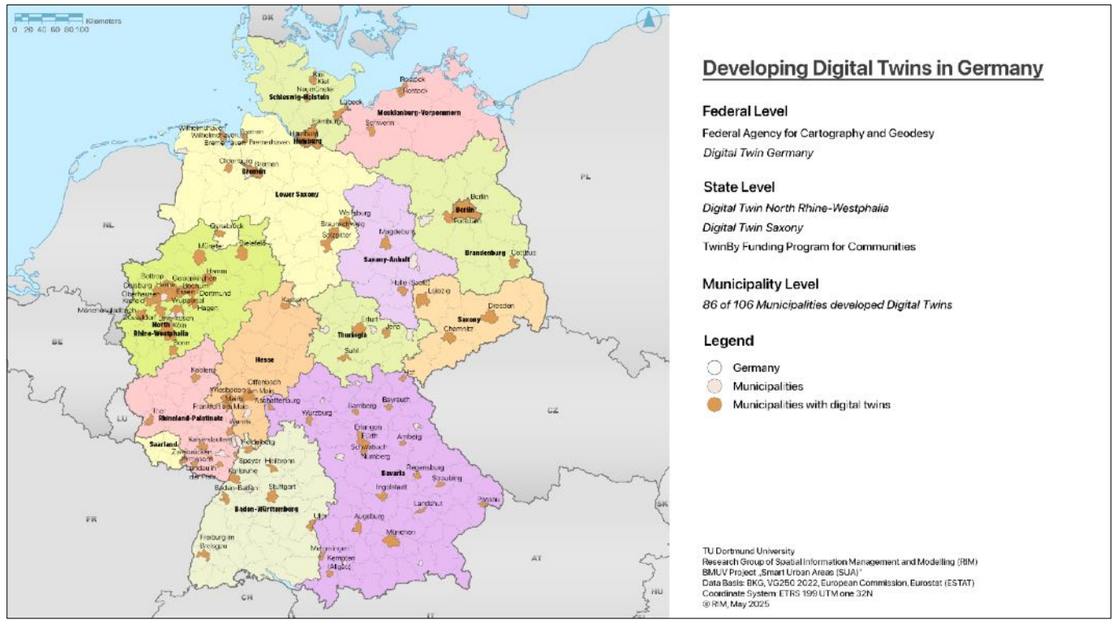
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Developing Digital Twins in Germany
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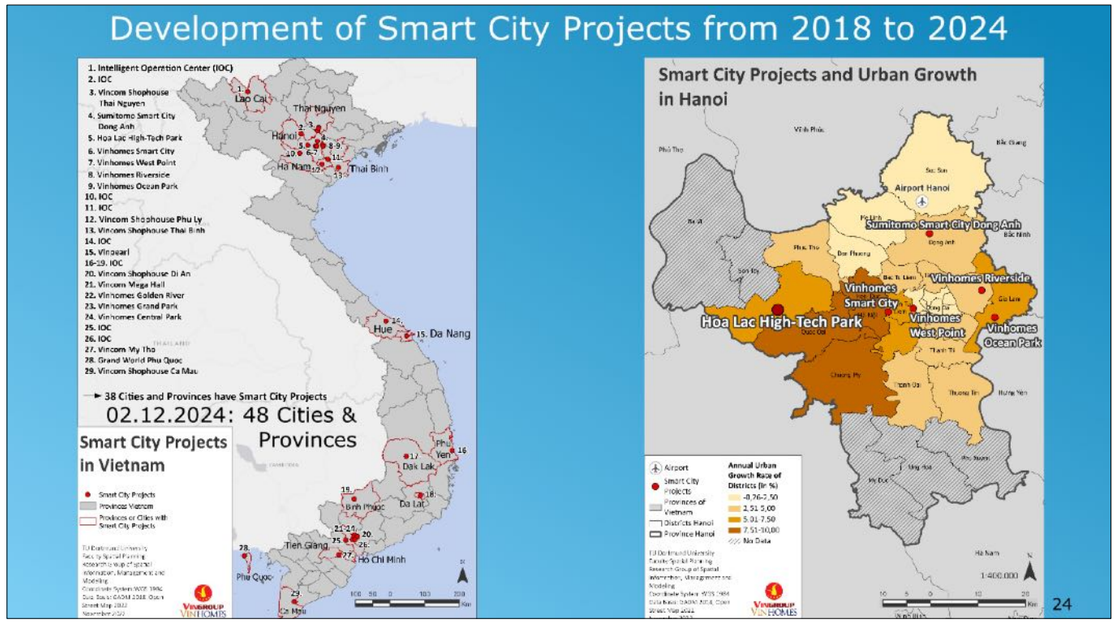
Development of Smart City Projects from 2018 to 2024
1. Intelligent Operation Center (IOC)
2. IOC
3. Vincom Shophouse Thai Nguyen
4. Sumitomo Smart City Dong Anh
5. Hoa Lac High-Tech Park
6. Vinhomes Smart City
7. Vinhomes West Point
8. Vinhomes Riverside
9. Vinhomes Ocean Park
10. IOC
11. IOC
12. Vincom Shophouse Phu Ly
13. Vincom Shophouse Thai Binh
14. IOC
15. Vinpearl
16-29. IOC
20. Vincom Shophouse Di An
21. Vincom Mega Mall
22. Vinhomes Golden River
23. Vinhomes Grand Park
24. Vinhomes Central Park
25. IOC
26. IOC
27. Vincom My Tho
28. Grand World Phu Quoc
29. Vincom Shophouse Ca Mau
38 Cities and Provinces have Smart City Projects
02.12.2024: 48 Cities & Provinces
Smart City Projects in Vietnam
Smart City Projects and Urban Growth in Hanoi
Airport Hanoi
Sumitomo Smart City Dong Anh
Vinhomes Riverside
Vinhomes Smart City
Hoa Lac High-Tech Park
Vinhomes West Point
Vinhomes Ocean Park
Hanoi
Hue
Da Nang
Dak Lak
Binh Phuoc
Tien Giang
Ho Chi Minh
Phu Quoc
Ca Mau
24

Da Nang

Smart City and Flood Management

Theme: Smart Urban Area + Climate Change Adaptation Da Nang is one of the most climate-vulnerable cities in Vietnam but also a frontrunner in smart city development.

Highlight:

- Da Nang implemented a *Smart City Monitoring Center* integrating traffic, water, and emergency data.
- The city uses *real-time flood monitoring systems* and GIS-based simulations to manage heavy rain events and typhoons.
- The potential for a **Digital Twin of Da Nang's drainage system**: simulate stormwater flows, run "what-if" flood scenarios, optimize response.

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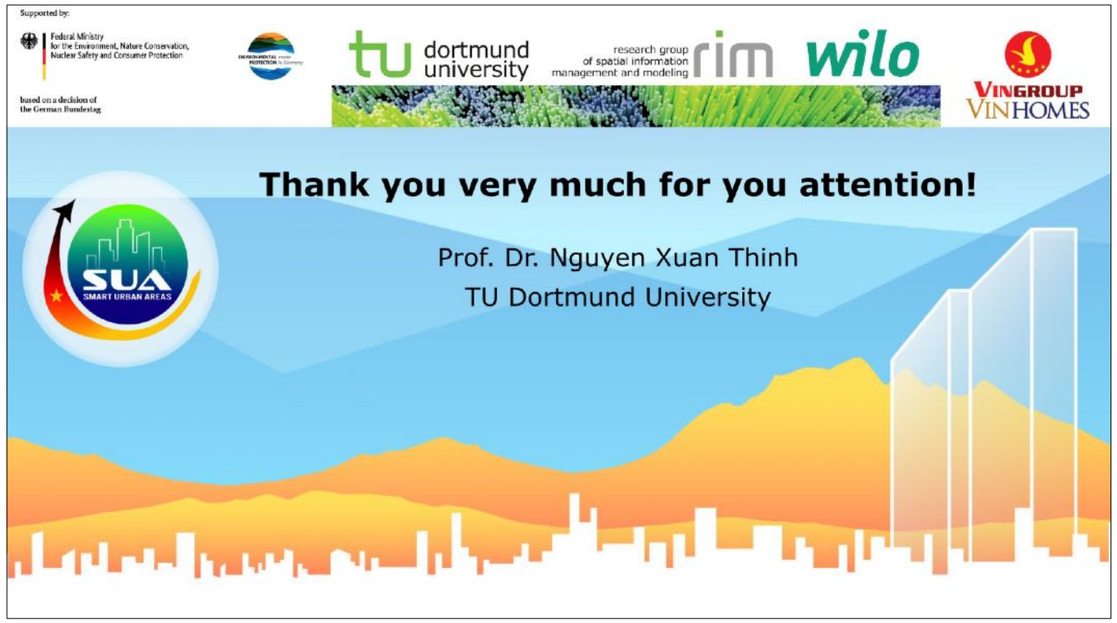
Roadmap for the Development of a Digital Twin of a City

TARGET DEFINITION & VISION	TECHNOLOGICAL IMPLEMENTATION	DATA STRATEGY & INFRASTRUCTURE	GOVERNANCE & COOPERATION	SCALING INTEGRATION	MONITORING, MAINTENANCE & PROGRESSION
• Strategic goals • Applications	• Data Sources • IoT-Strategy • Data Platform	• 3D-Modelling • Simulation • Visualization	• Responsibly	• Additional Fields • Connections to other Projects	• KPIs • Updates • Scalability

26

27



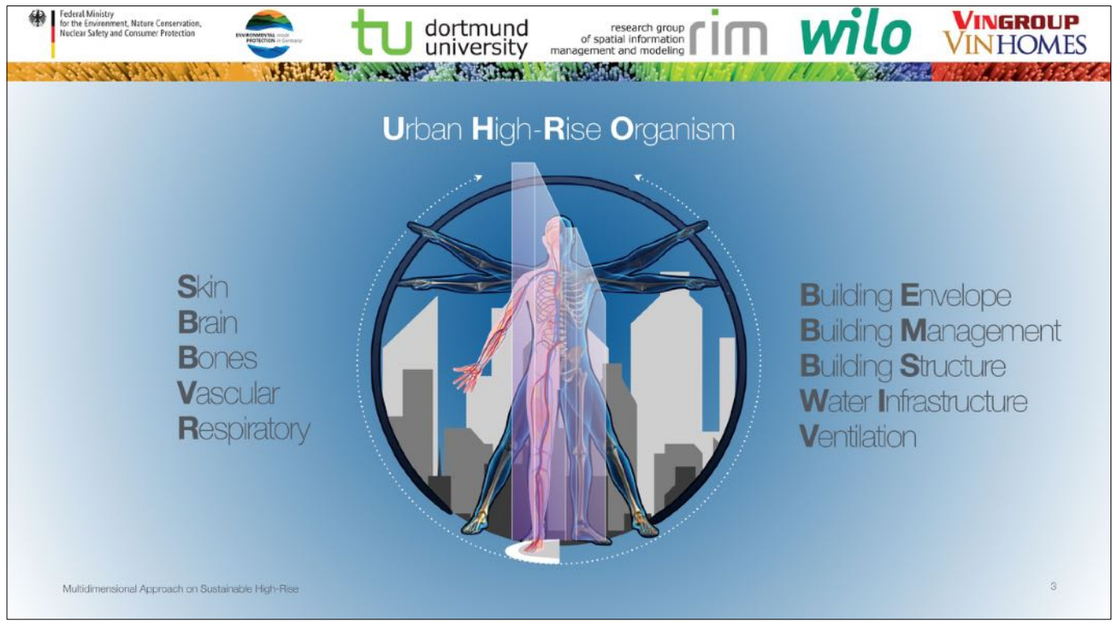
Pre
sen
tations

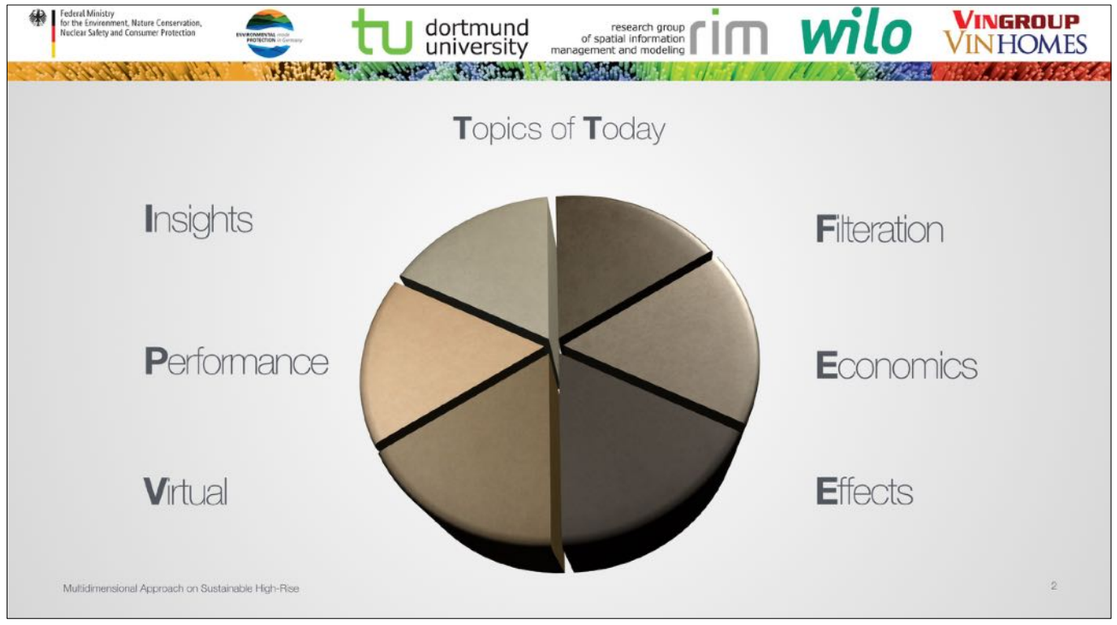
Fachvortrag 01
Presentation 01
Bài thuyết trình 01

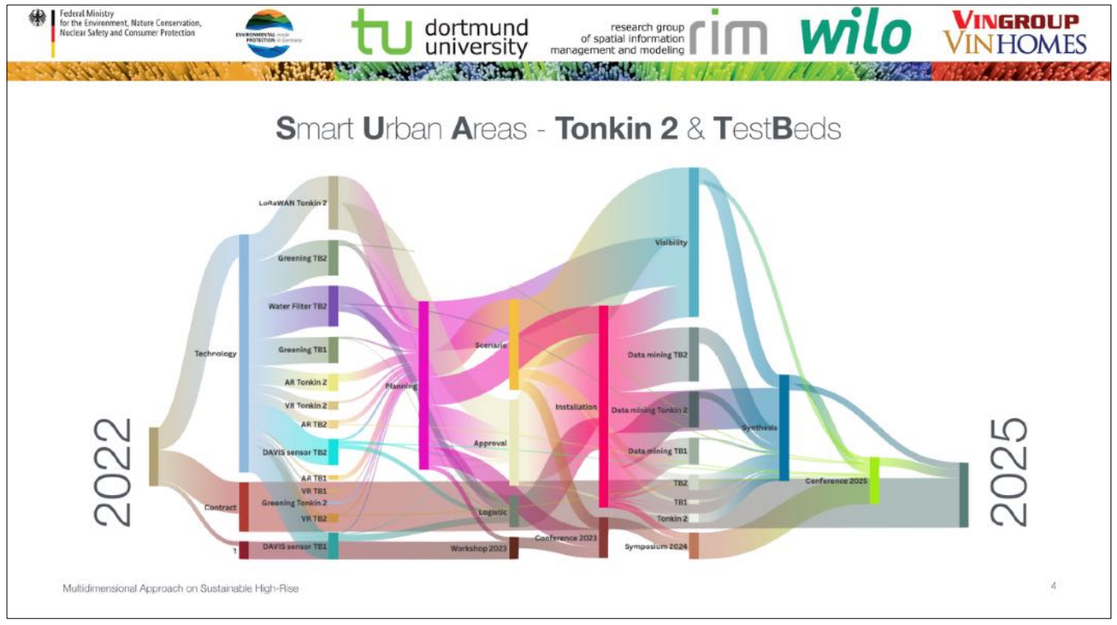
Mehrdimensionaler Ansatz für grüne Hochhäuser
Multidimensional Approach for Green High-Rise
Tiếp cận đa chiều cho nhà cao tầng xanh

Tobias Kuester-Campioni

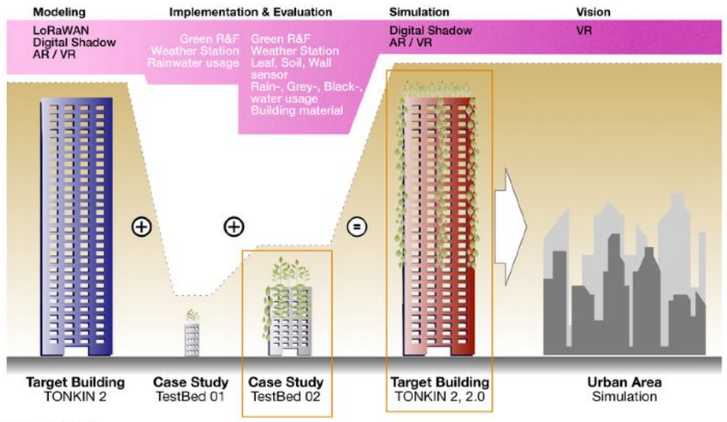

CO2
$
Multidimensional Approach of Sustainable High-Rise
Tobias Kuester-Campioni, 03.05.2023


Urban High-Rise Organism
Skin
Brain
Bones
Vascular
Respiratory
Building Envelope
Building Management
Building Structure
Water Infrastructure
Ventilation
Multidimensional Approach on Sustainable High-Rise
3


Topics of Today
Insights
Performance
Virtual
Filteration
Economics
Effects
Multidimensional Approach on Sustainable High-Rise
2


Smart Urban Areas - Tonkin 2 & TestBeds
2022
2025
LoRaWAN Tonkin 2
Greening TB2
Water Filter TB2
Greening TB1
AR Tonkin 2
VR Tonkin 2
AR TB2
DAVIS sensor TB2
AR TB1
VR TB1
Greening Tonkin 2
VR TB2
DAVIS sensor TB1
Technology
Contract
Planning
Scenario
Approval
Logistic
Workshop 2023
Installation
Conference 2023
Visibility
Data mining TB2
Data mining Tonkin 2
Data mining TB1
TB2
TB1
Tonkin 2
Symposium 2024
Synthesis
Conference 2025
Multidimensional Approach on Sustainable High-Rise
4

Downsizing & Rescaling

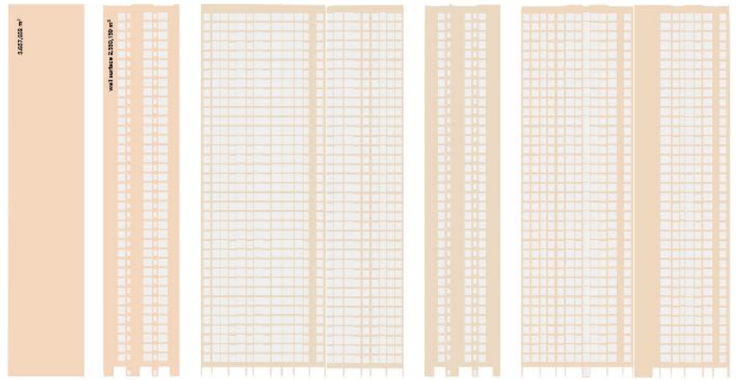


Impressions from **Tonkin 2**

of the **building envelope**

Wall to Window Ratio in % (WWR)

North - East - South - West



Wall to Window Ratio (WWR) in %

East
45% / 55%

High Solar Gain

North & South
75% / 25%

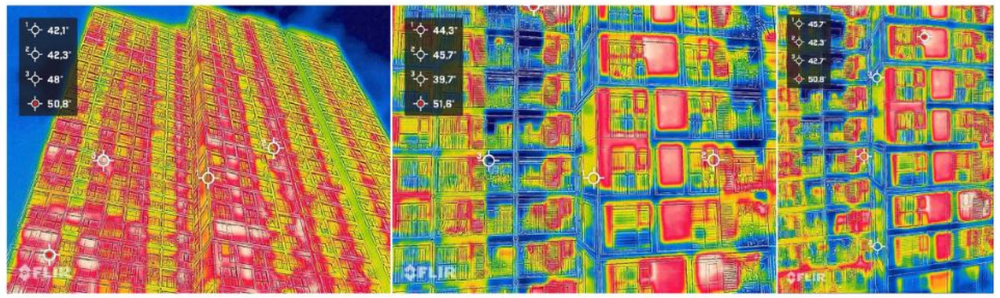
Low-Mid Solar Gain

West
50% / 50%

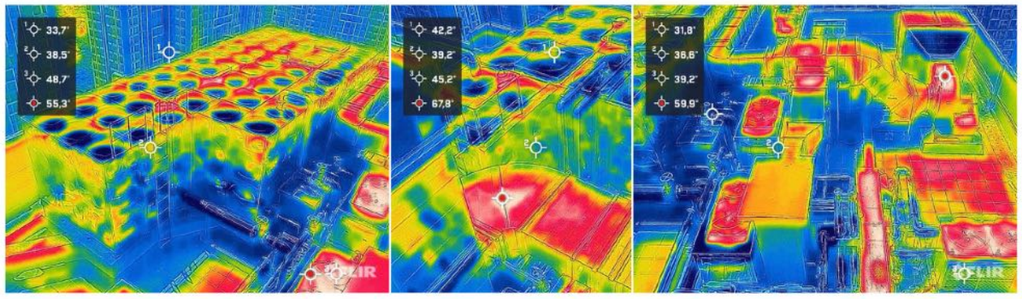
High Solar Gain

Thermal Imaging on **Tonkin 2**

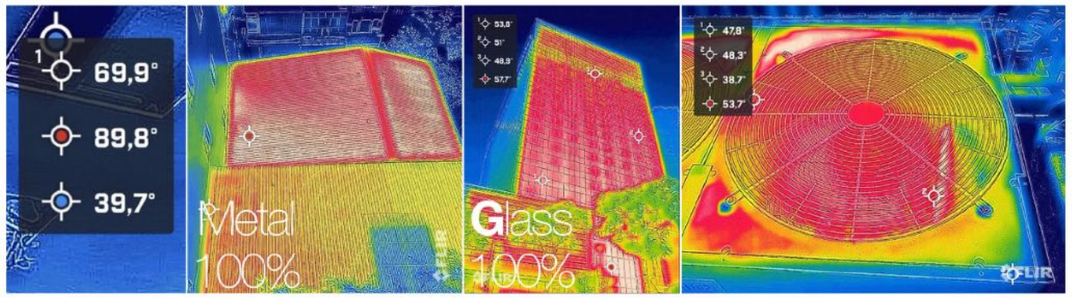
of the **building envelope**



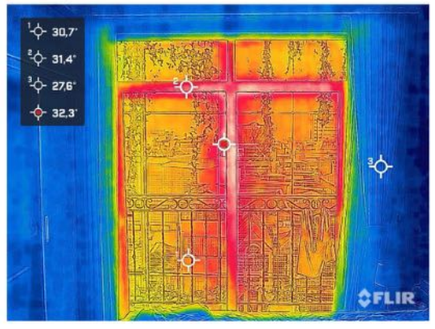
Thermal Imaging on **Tonkin 2 Roof Top**



Thermal Imaging in **Ha Noi**



Window Design **Tonkin 2** & **TB2**



2 pm, south facing side; Xingfa frame

Thermal Conductivity Wall (λ) 0.93 W/mK
Single-layer wall, 130-150 mm

Thermal Conductivity Window (λ) 0.78 W/mK
Double-layer tempered glass, 8,38 mm

Thermal Conductivity Alu Frame (λ) 200 W/mK
Uninsulated aluminium fram, 1,8 mm

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Impressions from **construction**

of the **building envelope**

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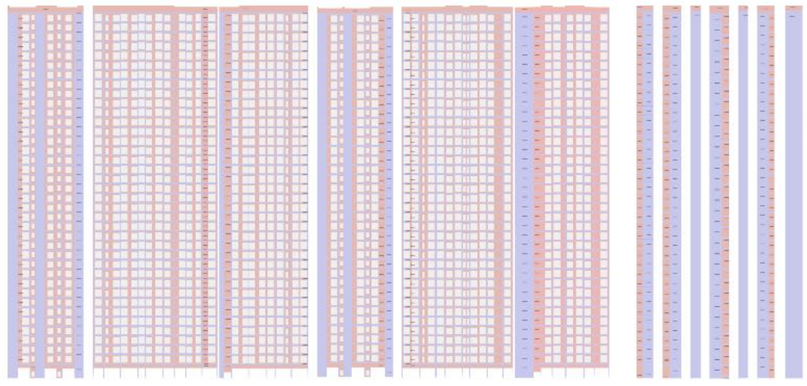
Brick to **C**oncrete **R**atio (BCR) in % on **Tonkin 2**

North - **E**ast - **S**outh - **W**est



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Brick to **C**oncrete **R**atio (BCR) in % on **E**levations

of the **building envelope**

North
38% / 62%

Low-**M**id **S**olar **G**ain

East
59% / 41%

High **S**olar **G**ain

South
41% / 59%

Mid **S**olar **G**ain

West
54% / 46%

High **S**olar **G**ain

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Brick to **C**oncrete **R**atio (BCR) in %

of the **building envelope**

BCR T2
44% / 56%

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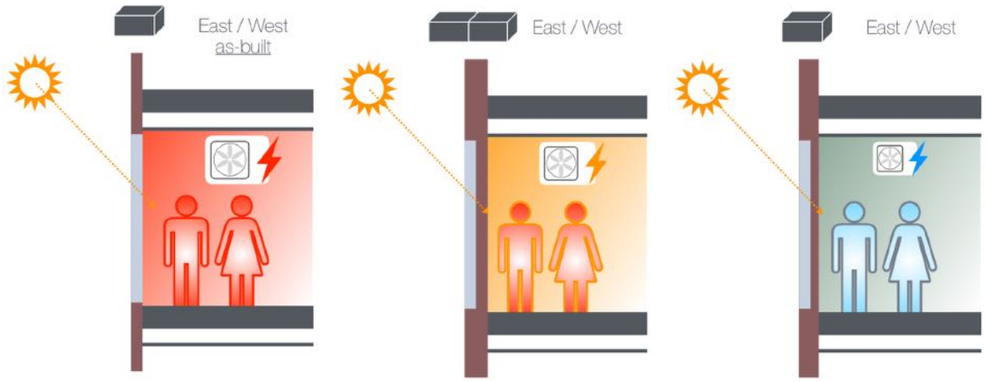
Solar Radiation & Air Conditioning

of the **building envelope**



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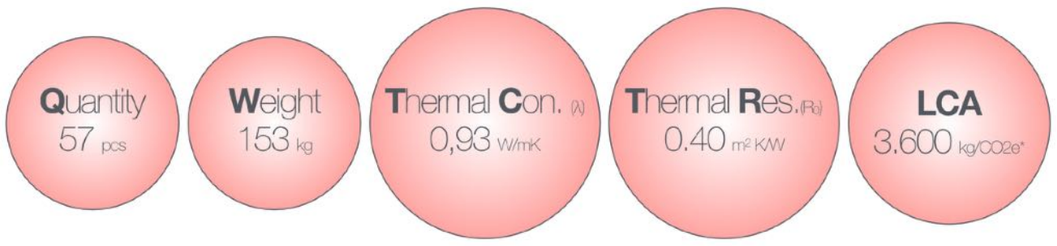
Brick Wall Conditions (BWC) on m^2

of the **building envelope**

one layer-*exterior* wall = **130 mm** = ***As built!***



*50 years

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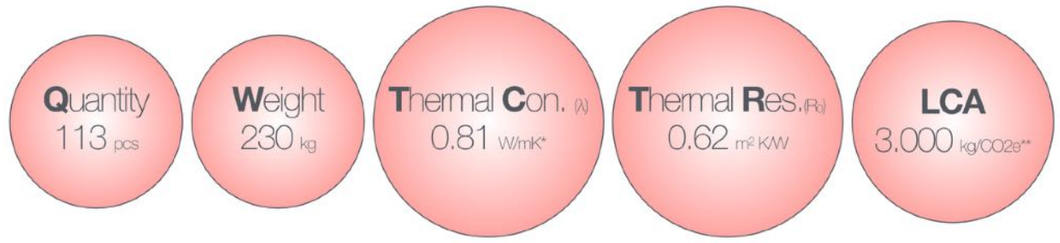
Brick Wall Conditions (BWC) on m^2

of the **building envelope**

two layer-exterior wall = **250 mm**



*QCVN 09:2017/BXD; **50 years

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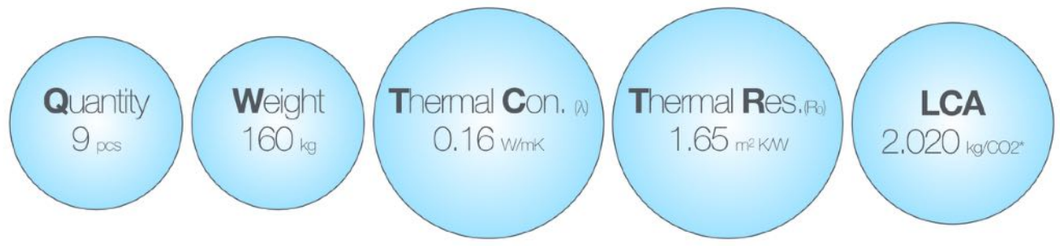
AAC Wall Conditions on m^2

of the **building envelope**

one layer-exterior wall = **206 mm**



*50 years

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Comparison Bricks vs. AAC on Tonkin 2

on **9.800 m²** plastered masonry on building envelope

	Stones	Weight	Cost	LCA		Time
Bricks	1.100.000 pcs	2.200 metric ton	160.000 USD	30.000.000 CO2e	75.000	40.000 Hrs
AAC	88.000 pcs	1.500 metric ton	122.000 USD	19.000.000 CO2e	60.000	5.000 Hrs

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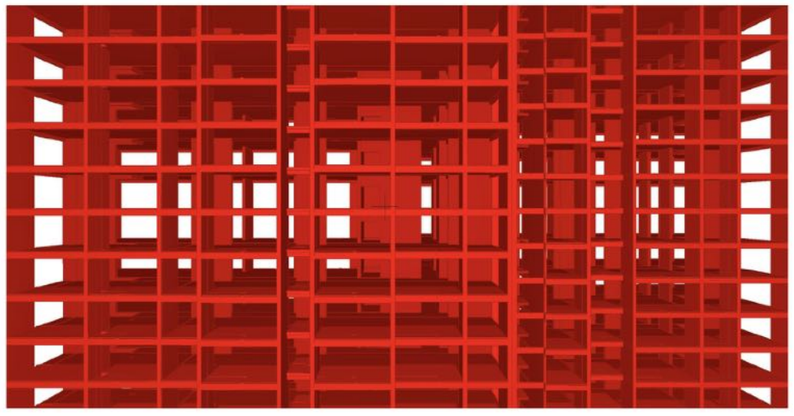
Construction Framework (CF) on Tonkin 2



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Concrete Slabs & Columns

Slab thickness = **200 mm**

Volume	Weight	CO2	LCA	
240.000 Cbm	600.000 mt	190.000 kg/CO2e	9.500.000 kg/CO2e*	20.000

*50 years

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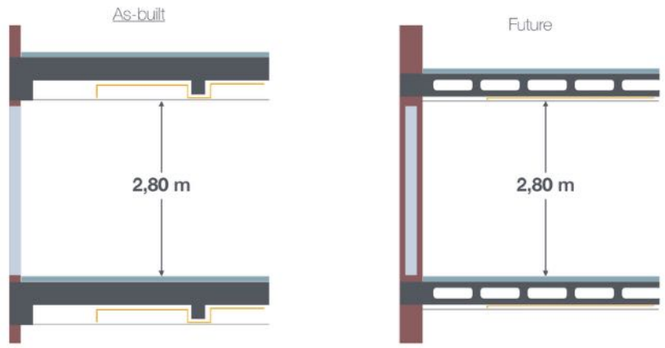
Potentials in Ressource Savings

Slab Section



Concrete Slabs Ressourcen Savings by 32%

Slab thickness = **200 mm + concrete beams!!!!**

Volume Fl.	Weight Bldg.	CO2	LCA	
56.800	136.000	43.500	2.250.000	12.000
m^3	mt	kg/CO2e	mt/CO2e*	

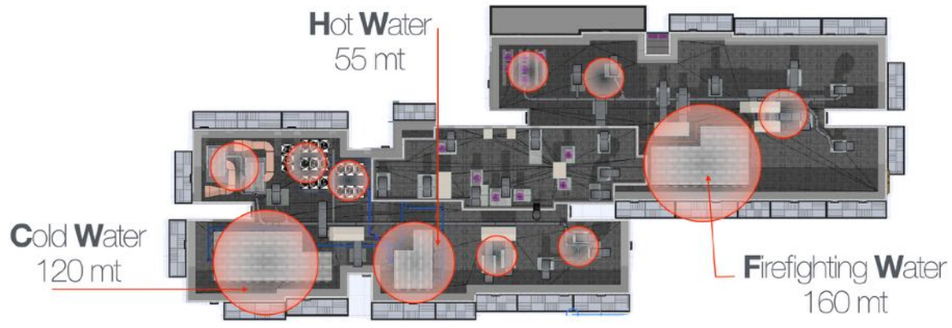
Every **10th Floor** = **+1 Floor**

*50 years

T2 vs. A380

500 mt technical equipment = loads on roof and facades

Vertical Loads on Roof by Technical Equipment



400 kg/m²

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Vertical Loads on Roof by Greening

250 kg/m²

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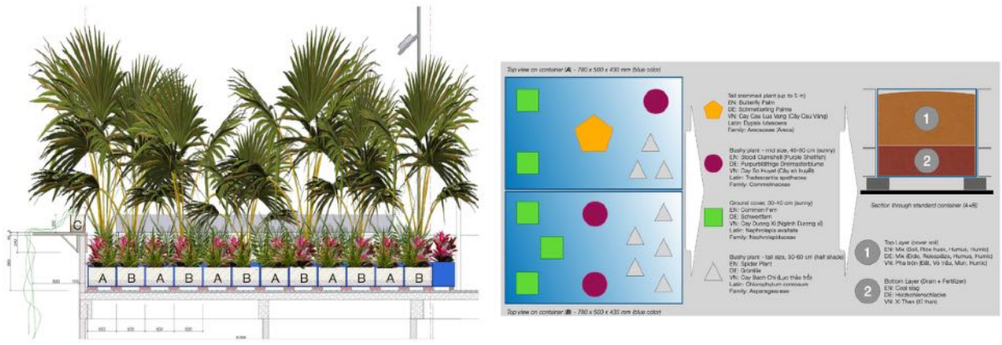
Greening Systems on TB 2



Mid Weight System = 250 kg/m²

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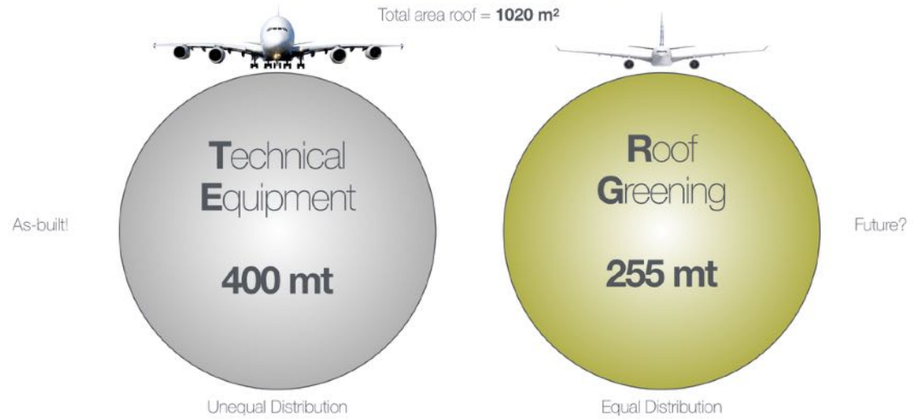
Vertical Loads Comparison

Total area roof = **1020 m²**



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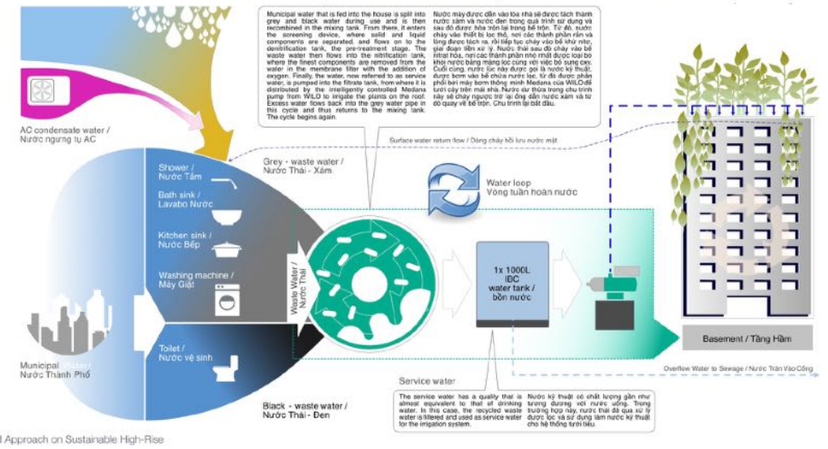
Water Loop - Circular System - TB2



Ressources Relocation

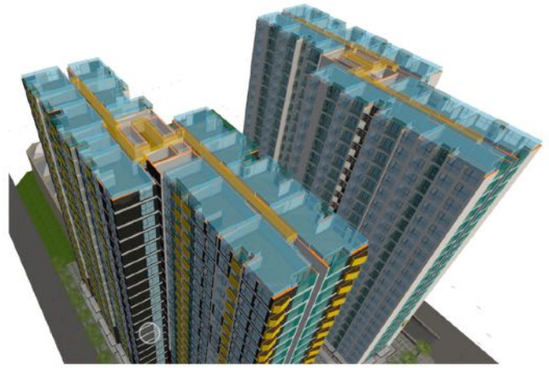
Top **F**loor

- **G**ravity **M**ove
- **L**ess **B**iased to
  - legionella bacteria
  - salmonellae
- **D**ecrease **L**oads
- **D**ecrease **B**eton & **S**teel
- **D**ecrease **P**umps & **P**iping
- **D**ecrease **CO2 E**missions

Basement

Waste Water Treatment Unit (WA-MBR-TB225) at **TB2**

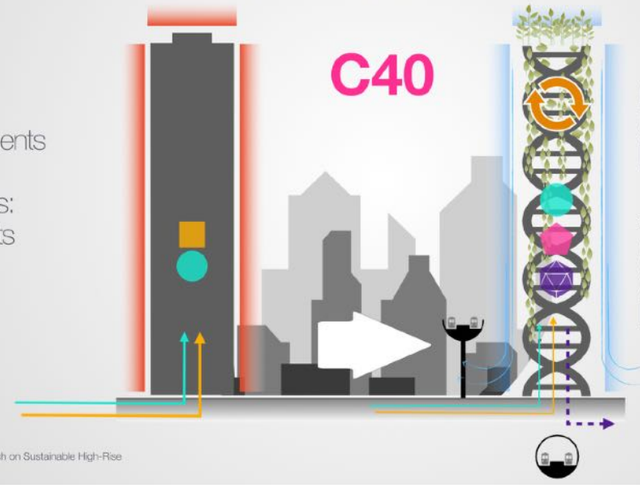
Augmented Reality on **Tonkin 2** & **TB2**



Ultimate **G**oal **H**anoi

Current
Urban
Developments

3 Methods:
Apartments
Office
Retail



Future
Urban
Developments

> Methods:
(**MUD**) **M**ixed-**U**se
(**TOD**) **T**ransit **O**riented
Development

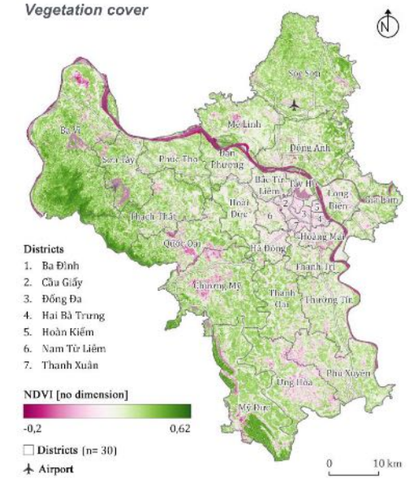
Fachvortrag 02
Presentation 02
Bài thuyết trình 02

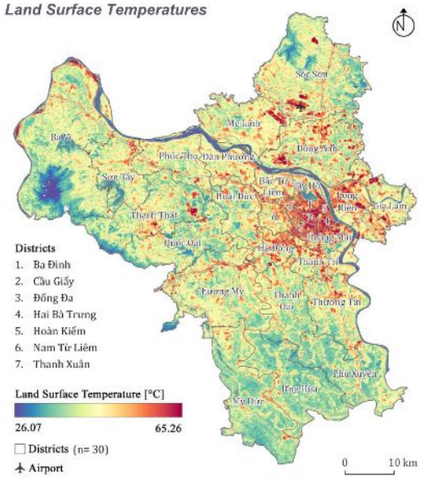
Thermisches Verhalten von Dach- und Fassadenbegrünungen unter sommerlichen Hitzewellenbedingungen in Hanoi, Vietnam
Thermal Performance of Roof and Facade Greening Under Summer-Time Heatwave Conditions in Hanoi, Vietnam
Hiệu suất Nhiệt của Mái và Mặt dựng Xanh trong Điều kiện Nắng nóng Mùa hè tại Hà Nội, Việt Nam

Mathias Schaefer

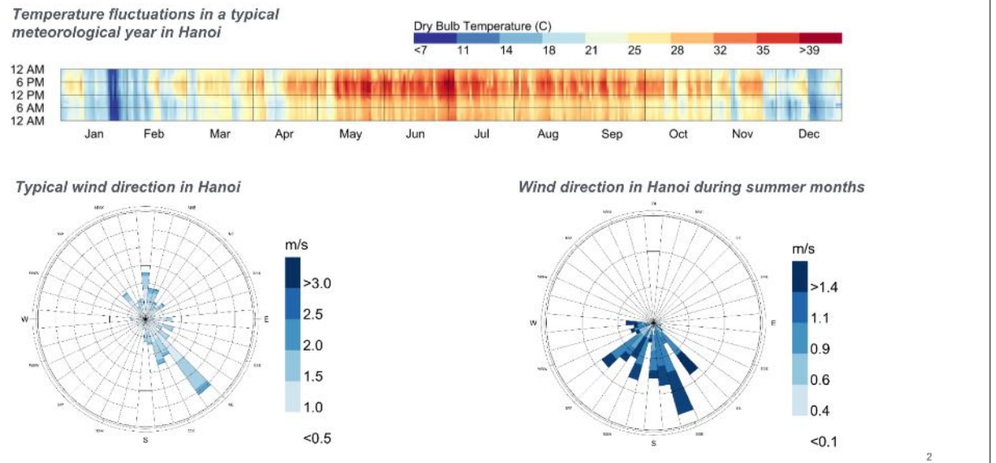
Thermal Performance of Roof and FacadeGreening Under Summer-Time Heatwave Conditions in Hanoi, Vietnam

Dr. Mathias Schaefer





3



2

4

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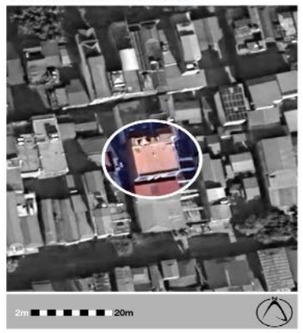
Location in Hai Ba Trung



TestBed_02 after installation

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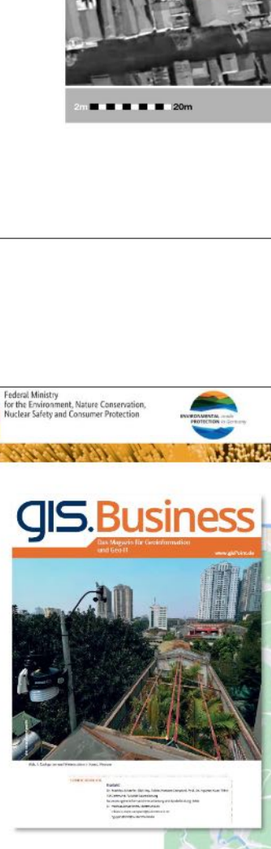

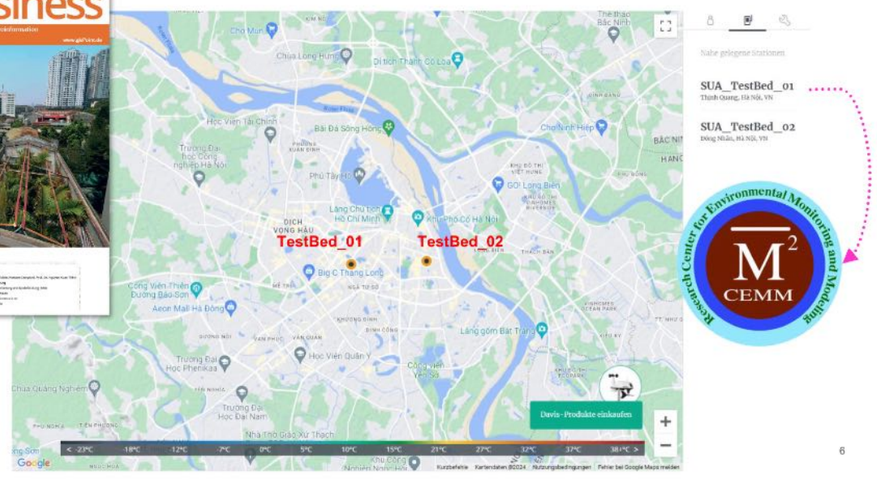

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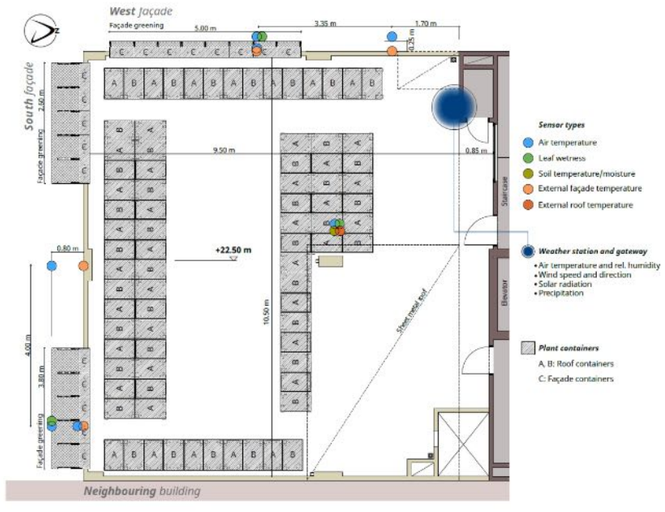
West façade



730 individual plants

22 sensors

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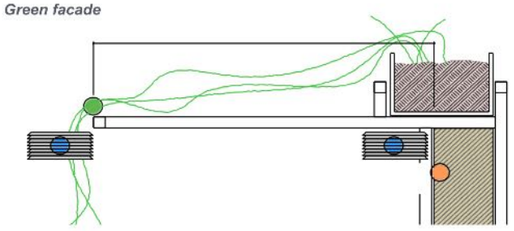
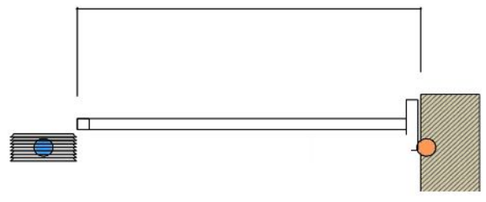
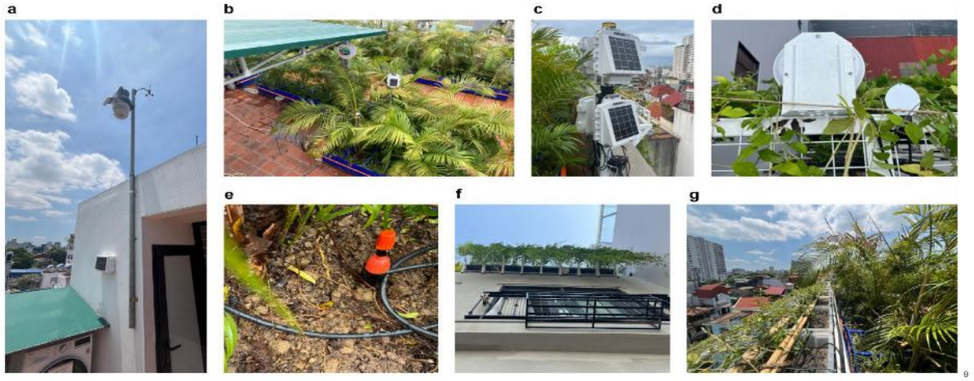
Green facade



Control facade





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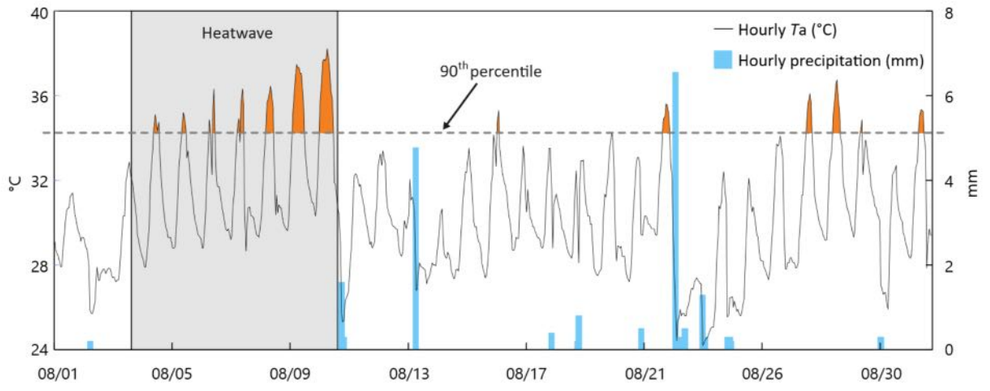
Defining „heatwave“



10

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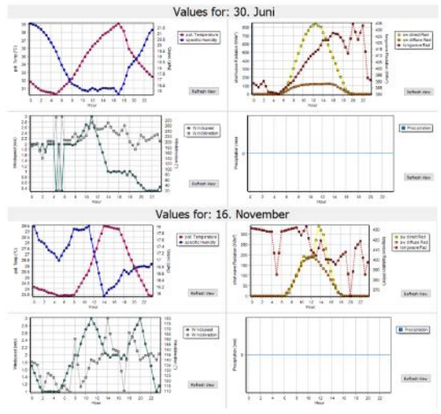
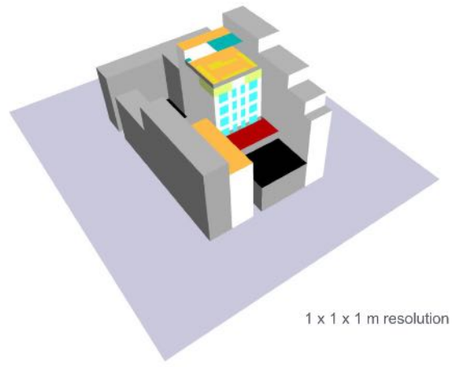
Forcing file with measured boundary conditions



Geometric model of TestBed_02



1 x 1 x 1 m resolution

11

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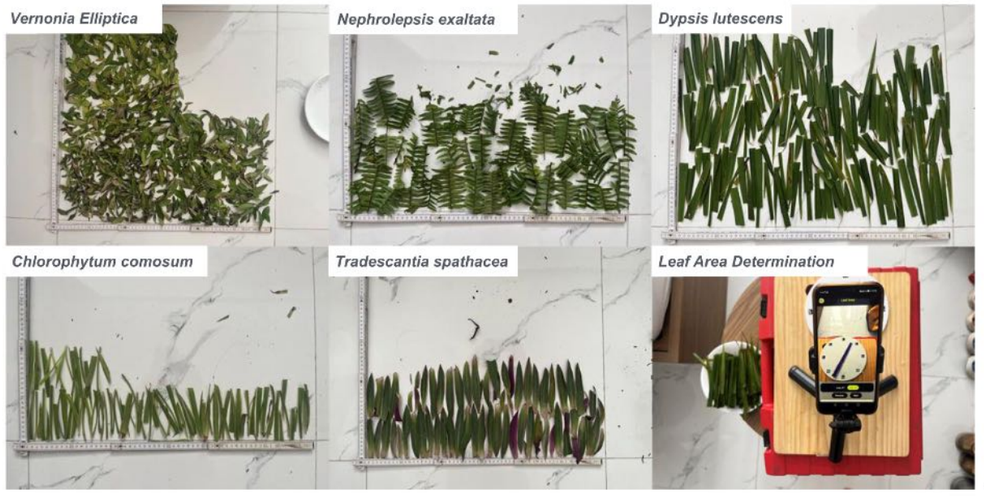
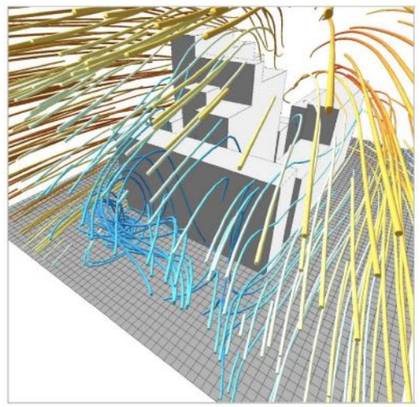
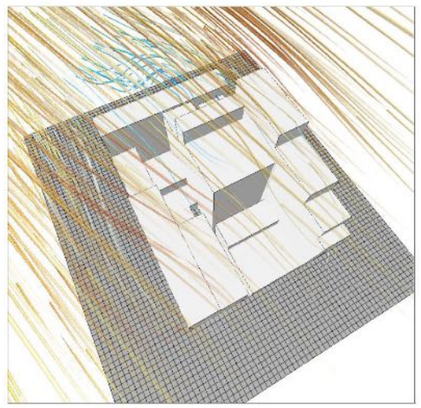


12

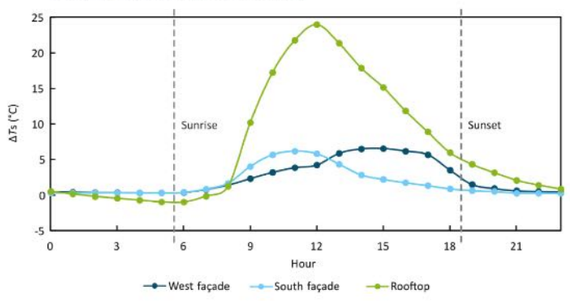
Wind field back view



Wind field top view

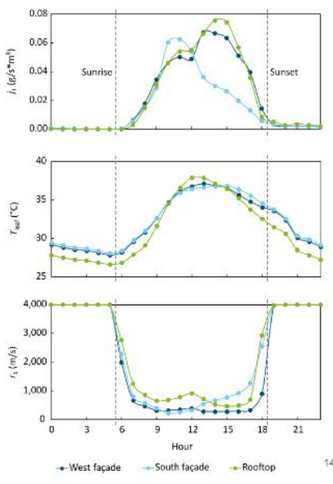


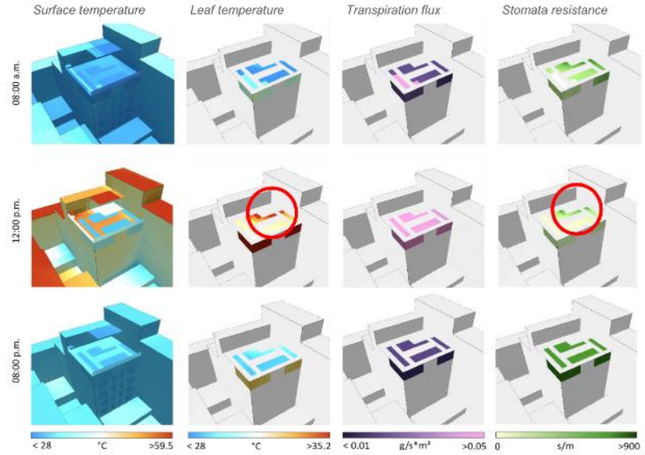
Surface temperature reduction (Ts)

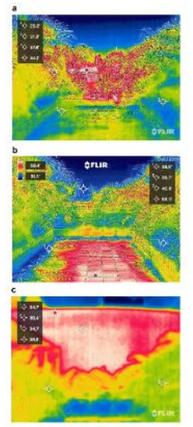


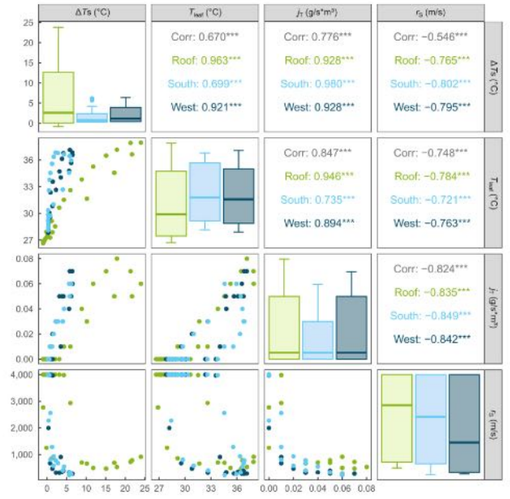
- Green roof provides the **greatest cooling effect (*Ts*) due to thermal insulation** by the substrate.
- Because of the horizontal leaf orientation, green roofs exhibit the highest leaf surface temperatures (*T*leaf).
- East and west façades contribute a tandem cooling effect in response to the shifting solar position.

Physiological plant parameters









TAKE-HOME MESSAGES

1. Green Infrastructure should be planned locally, but holistically.

2. Alternative solutions should always be considered.

3. Big data is the new primary sector.

STAY TUNED

Peer review status

Thermal Performance of Roof and Façade Greening Under Summer-Time Heatwave Conditions in Hanoi, Vietnam

- Reviews completed: 1
- Review invitations accepted: 2
- Review invitations sent: 2+

Under Review

Last review activity: 8th April 2025

Watch to learn what we're doing behind the scenes

Journal:
Urban Forestry & Urban Greening

Corresponding author:
Mathias Schaefer

Manuscript number:
UFUG-D-25-00146

BE PART OF OUR SURVEY

Dr. Mathias Schaefer

Fachvortrag 03
Presentation 03
Bài thuyết trình 03

Von der Realität zur Virtualität und zurück
From Actuality to Virtuality and Back
Hiện thực - Ảo - Trở lại

Sinan Karakus

From Actuality to Virtuality and Back

Exploringthe Application Potentialsand Key Challenges
of Digital Shadows and Virtual Reality in Sustainable

Speaker: M.Sc. Sinan Karakus, RIM TUDortmund

Motivation and Context

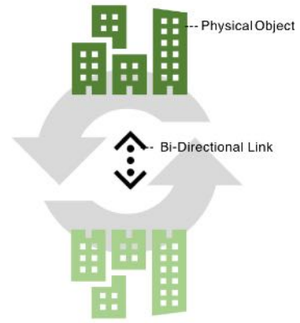
Environmental challenges: urban heat islands, air pollution, sealed surfaces

Goal: Reduction of heat stress and more efficient use of resources (energy and water)

The task of the Digital Shadow: Storage of weather data by the installed sensors + formatting for analysis and visualization

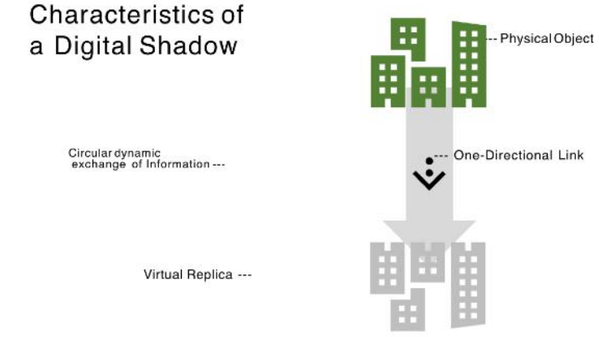
What is a Digital Twin?

Characteristics of
a Digital Twin



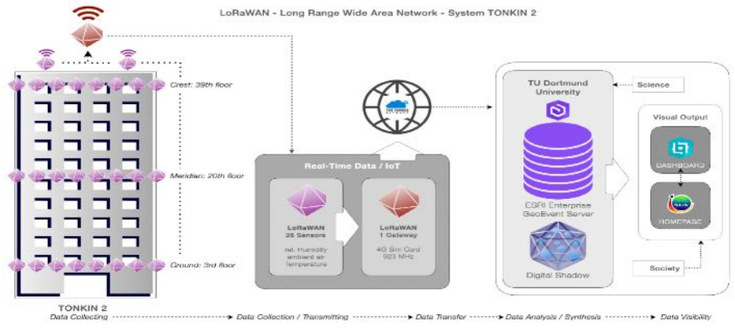
What is a Digital Shadow?

Characteristics of
a Digital Shadow

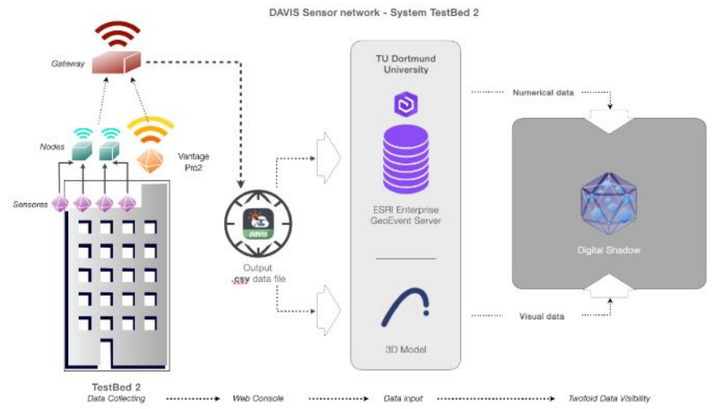


Why a Digital Shadow? More Lightweight and Retrospective!

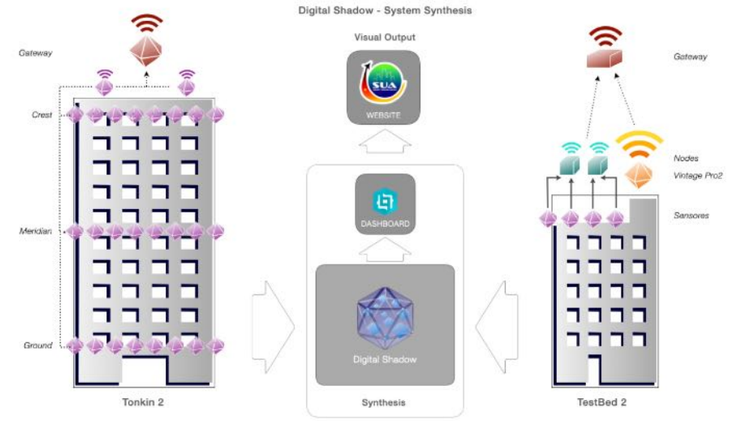
Application on TONKIN2



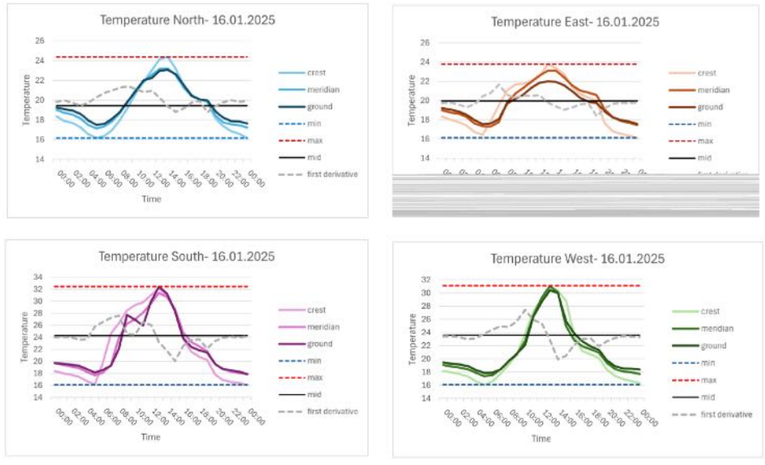
Application on Testbed 02



Data Visualization



Data Visualization



Identified Potentials of Digital Shadows

- ✓ Energy modeling & microclimate adaptation
- ✓ Scenario simulation before real-world construction
- ✓ Smart city planning & district-level analysis
- ✓ Collaboration: shared access for all stakeholders
- ✓ Ongoing optimization & extended building lifecycle

Key Challenges

- × Data integration: lack of standards across IoT, BIM, GIS
- × High initial costs: sensors, computing, modeling
- × Data privacy & security
- × Transmission issues: signal gaps, power/network dependence
- × Cultural & planning gaps
- × Regulatory hurdles

Conclusion & Outlook

Digital Shadows = effective tool for sustainable building monitoring

Must address technical, legal, cultural, and ethical issues for adoption!

Opportunity for the Global South: supports SDG 11 (Sustainable Cities & Communities)

Near endless upgrading potential = integration with VR and neighborhood-scale planning

Virtual Reality in Sustainable Urban Planning

Sub-topic of the SUA research project

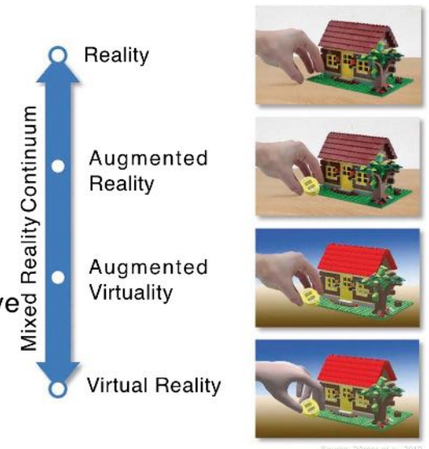
What is Virtual Reality (VR)

Virtual Reality (VR): "is the use of computer modeling and simulation that enables a person to interact with an artificial three-dimensional (3-D) visual or other sensory environment." (Henry E. Lowood; Encyclopedia Britannica)

VR vs. AR – What's the Difference?

Virtual Reality (VR):
Fully virtual environment
→ thus fullimmersive

Augmented Reality (AR):
Real-world enhancing
→ thus partially immersive



Source: Dörner et al., 2019

The Importance of Immersion

Immersion describes the degree to which a virtual world is perceived as spatially and sensorially real

Achieved through:

→ 360° visuals with depth (stereoscopic rendering)

→ Head tracking and real-time reaction to movement

→ Interactiveness

The Importance of Immersion

Why it matters in planning:

→ Enables planners, stakeholders & citizens to experience spatial qualities (e.g. enclosure, scale, atmosphere)

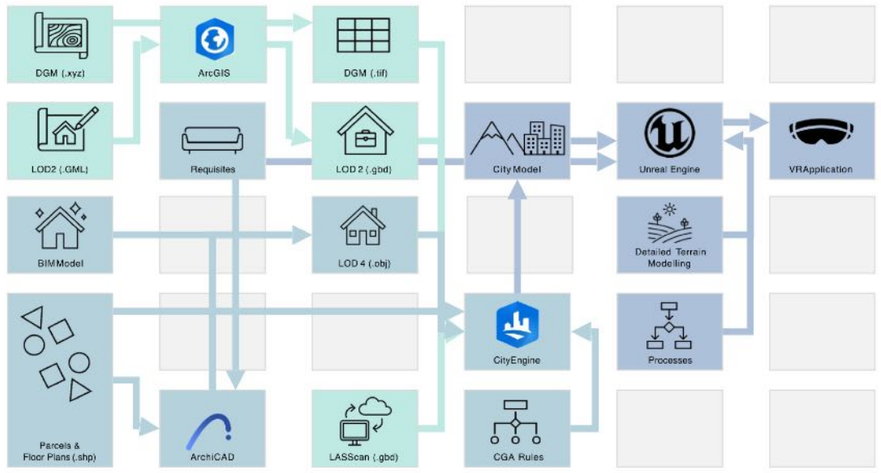
→ Supports emotional connection to future urban spaces

VR in Context of SUA

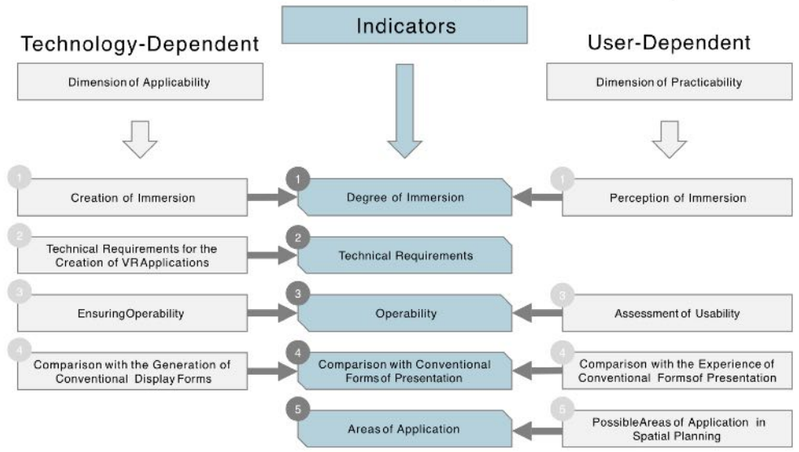
Goal: Improve spatial decision-making & stakeholder communication

The task of VR: Visualization of selected test environments in the context of SUA and certain potential future scenarios

Workflow



Indicators of Applicability



Benefits for Urban Planning

✓Visualize future developments from a pedestrian or drone view

✓Visualize urban heat, building heights, and shadows

✓Test mobility flows or zoning scenarios

✓Enhance participation: citizens "walk" through urban concepts before implementation

Challenges & Considerations

High hardware/software requirements

Data integration with existing GIS/BIM systems can be complex

Not all users can tolerate VR (motion sickness, etc.)

Conclusion & Outlook

VR has high potential for spatial planning: better visualization, better decisions

Key enabler for participation and interdisciplinary collaboration

Need for further standardization and simplification

SUA project as practical testbed for future planning tools!

Thank you very much for your attention!

Fachvortrag 04
Presentation 04
Bài thuyết trình 04

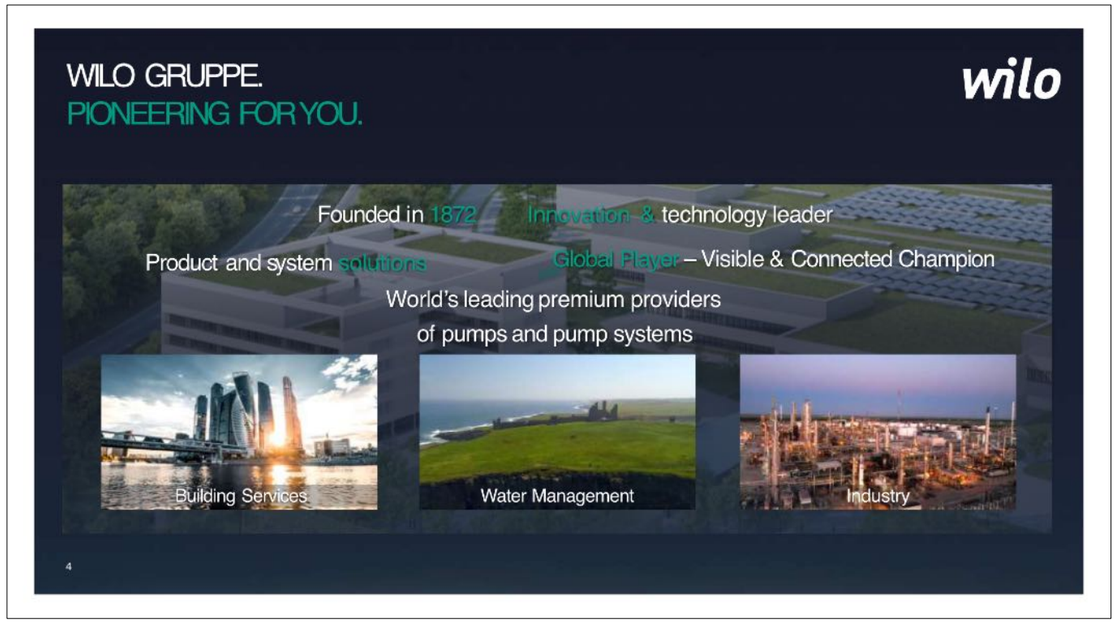
Intelligente Quartiere: Die Zukunft ist verbunden!
Smart Urban Areas: The Future is Connected!
Đô thị Thông minh: Tương lai Kết nối!

Gero Boehmer


Smart Urban Areas: The Future is connected!
Water Reuse in the urban context
Gero Böhmer, Director Government & Public Affairs, Wilo Group


Loving Traditions. Living Innovations.


DIGITAL TRANSFORMATION.
PRODUCTS & SERVICES.
1928 Pioneer Heating Pump Technology
1988 Pioneer Electronic Control
2001 Pioneer High-Efficency
2009 Pioneer System Technology
2018 Digital Pioneer & Solution Provider
2020 Beyond the Obvious
2022 150 years Wilo
DIGITAL PIONEER
Wilo-Web including Wilo-Select
Wilo-Rexa SOLIDQ with Nexos-Intelligence
Wilo-Stratos MAXO
Wilo-Assistent
WILO-SMART CONNECT Digital Customer Self-Services
33


WILO GRUPPE.
PIONEERING FOR YOU.
Founded in 1872
Innovation & technology leader
Product and system solutions
Global Player – Visible & Connected Champion
World's leading premium providers of pumps and pump systems
Building Services
Water Management
Industry
4

WILO HIGHLIGHTS.
TURNOVER 2024.

wilo

2.0 Billion EUR

5

PUMPS AMD SYSTEMS.
IN ALMOST ALL PERFORMANCE CLASSES.

BUILDING SERVICES

WATER MANAGEMENT

INDUSTRY

6

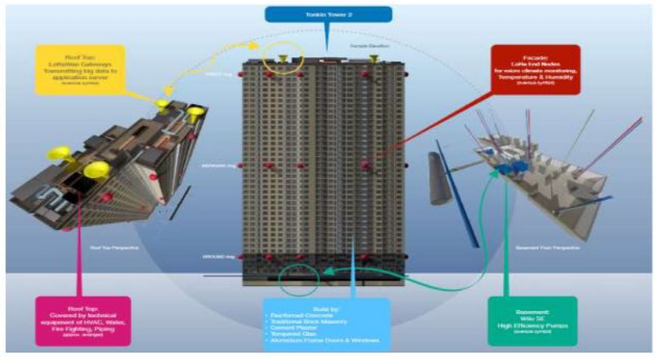
OUR MEGATRENDS.
WE LOOK 20 YEARS AHEAD.

wilo

7

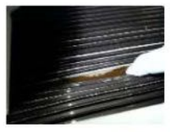
Tonkin Tower 2

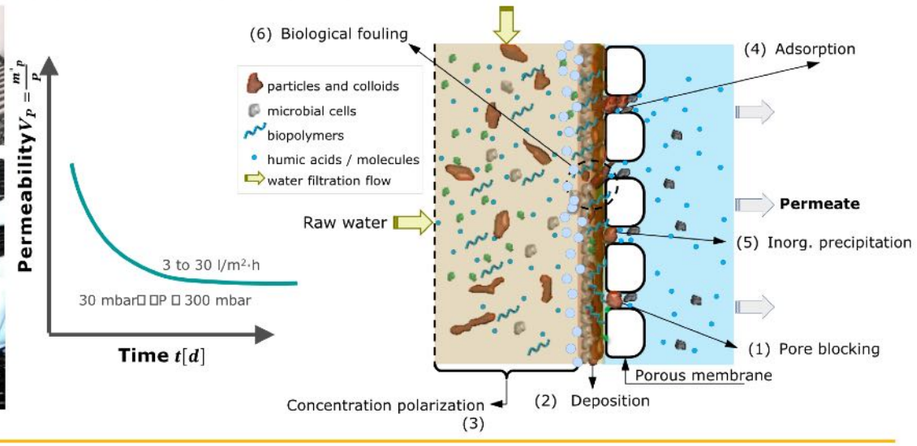
Facade:
LoRa End Notes for micro climate monitoring. Temperature & Humidity



SUA PROJECT.TestBed 1
HANOI, VIETNAM.

Membrane filtration via gravity driven membrane filtration - GDM or low-pressure ultrafiltration - ULPUF



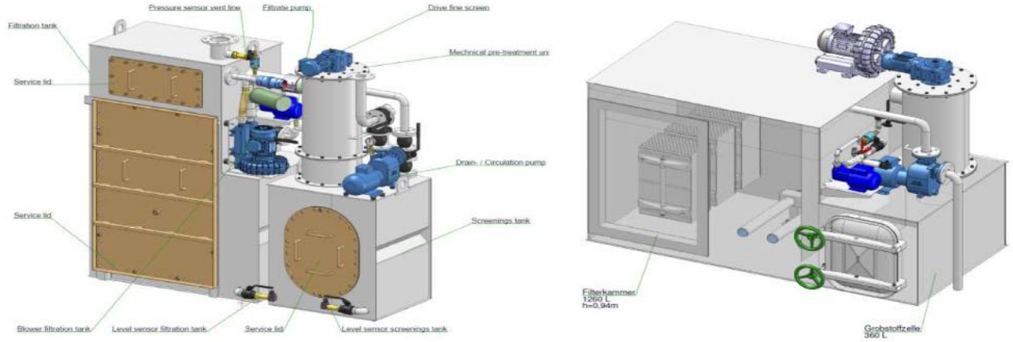


Filter Cube® FM mini-Cube;

application on greywater treatment

- **0,50 m²** to **25 m²** membrane area
- Modular arrangement – **stack and rack**
- High **flexibility** and **adaption** to load and flow variations
- Highest **package density** in class; **Efficient** water cleaning
- Long life time in **excess of 10 years**

Case study, treatment of wastewater: BMA15N, BMA15 --> ca. 3 to 5



Case study: wind park application offshore

Effluent Treatment - domestic wastewater

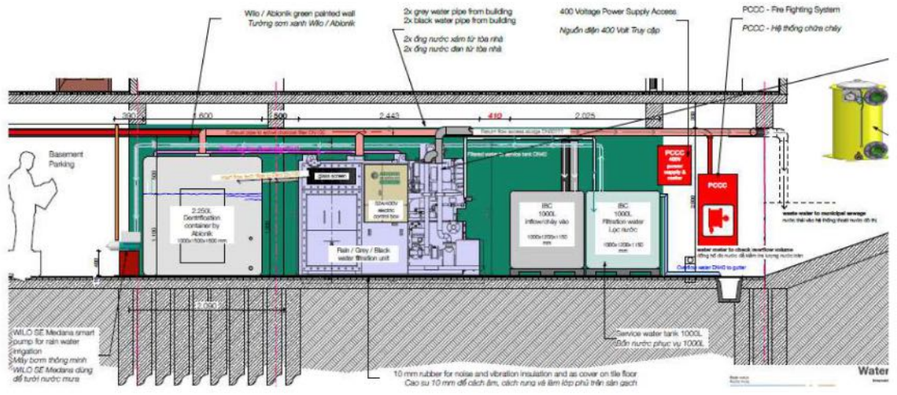
Wastewater treatment plant; MBR system; wind park

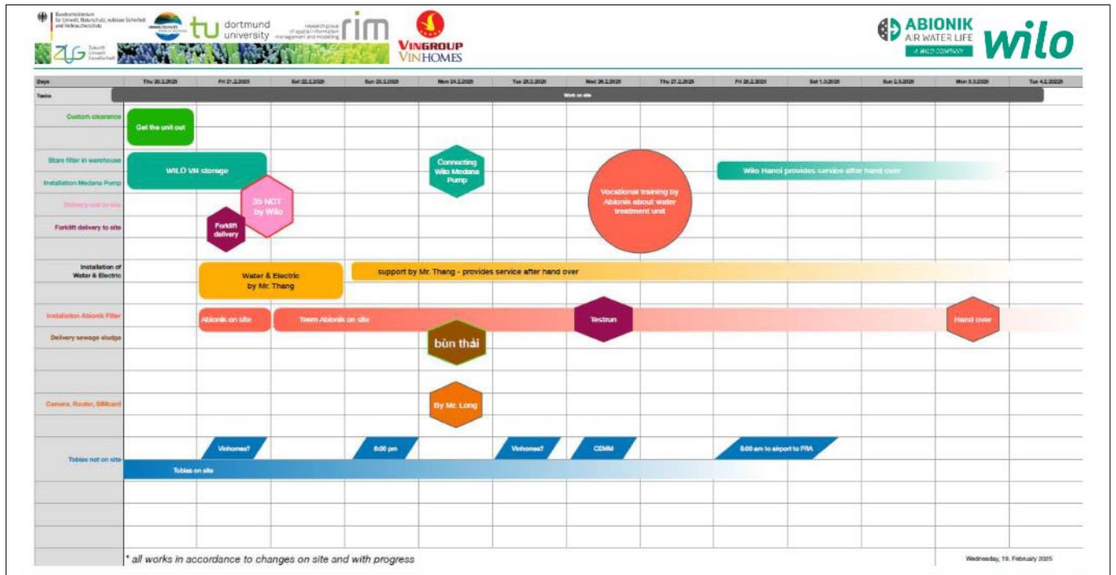
Case study: Antartica

Effluent Treatment - domestic wastewater

Wastewater treatment plant; MBR system;

Water Concept TestBed 2




Days
Tasks
Custom clearance
Get the unit out
Store filter in warehouse
WILO VN storage
Installation Medana Pump
Connecting Wilo Medana Pump
Vocational training by Abionik about water treatment unit
Wilo Hanoi provides service after hand over
DO NOT by Wilo
Forklift delivery
Forklift delivery to site
Installation of Water & Electric
Water & Electric by Mr. Thang
support by Mr. Thang - provides service after hand over
Installation Abionik Filter
Abionik on site
Team Abionik on site
Testrun
Hand over
Delivery sewage sludge
bùn thải
Camera, Router, SIMkard
By Mr. Long
Tobias not on site
Vinhomes?
8:00 pm
Vinhomes?
CEMM
5:00 am to airport to FRA
Tobias on site
* all works in accordance to changes on site and with progress
Wednesday, 19. February 2025
17 SBU Water Treatment
05.05.2025


wilo
SUSTAINABLE.
RELEVANT.
DIGITAL.


Water Realization TestBed 2
18 SBU Water Treatment
05.05.2025

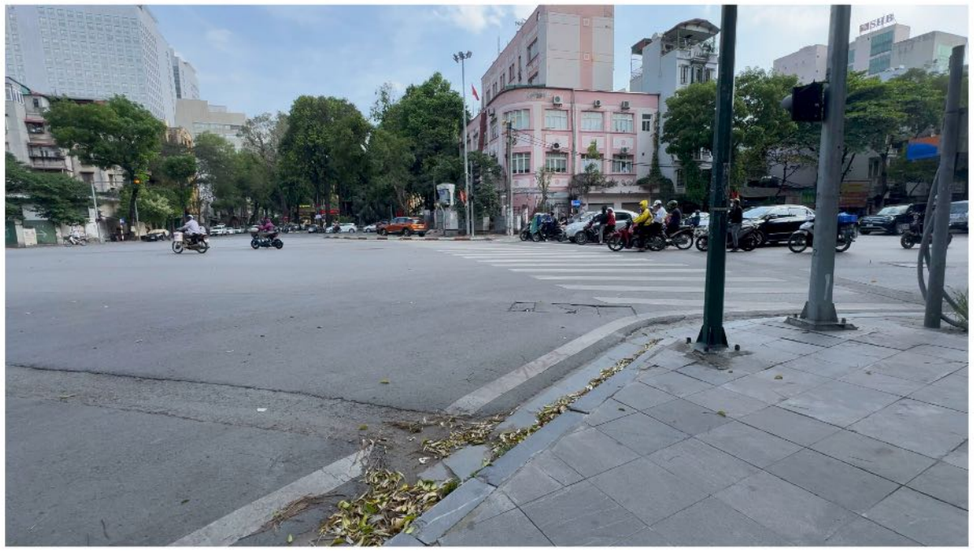
Fachvortrag 05
Presentation 05
Bài thuyết trình 05

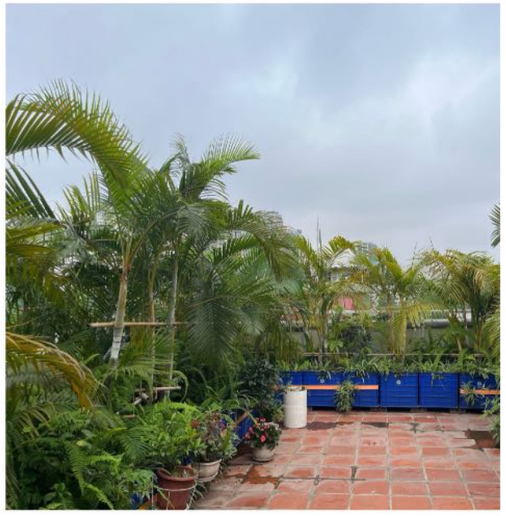
Ökonomische Faktoren in der Umsetzung von Grün auf Gebäuden
Economics for Implementing Green on Buildings
Nghiên cứu Kinh tế về Triển khai Xanh hóa Công trình

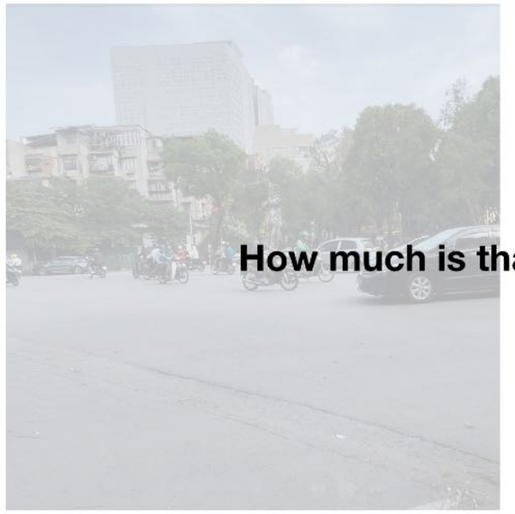
Sophie Girlich

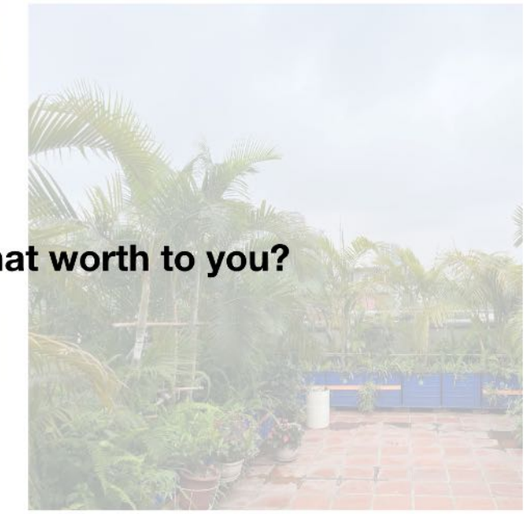
Economics for Implementing Green on Buildings

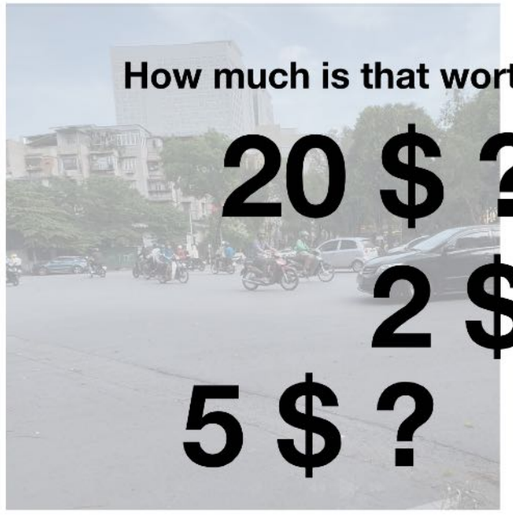
SUA - Economics // Sophie Ulrich



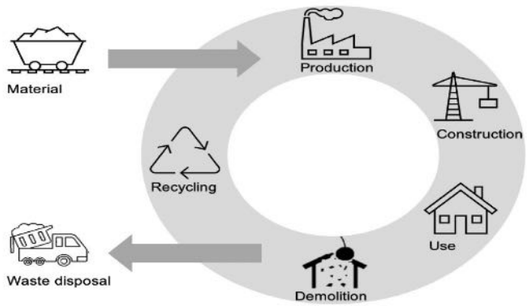



How much is that worth to you?



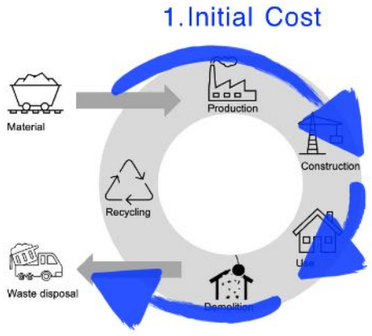

How much is that worth to you per month?
20 $?
10 $?
2 $?
5 $?
15 $?

Life Cycle Assessment



10

Life Cycle Costs



1. Initial Cost

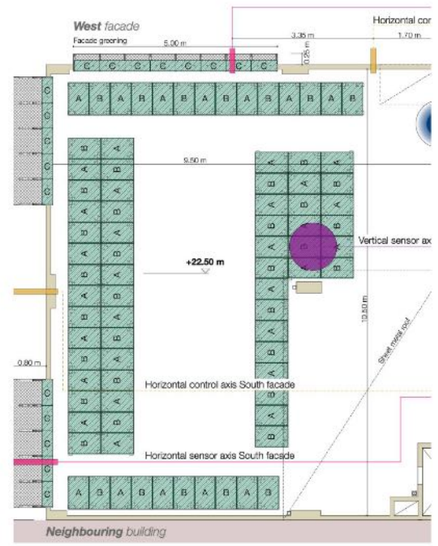
2. Recurring Cost
2.a Operating Cost
2.b Maintenance Cost

3. Disposal Cost

11

TestBed02

- Size: 73 m²
- Plants: 730
- Container A+B:80 pc
- Irrigation System



12

Life Cycle Costing

1.Initial Cost

- Planing
- Material
- Plants
- Logistics
- Irrigation system

→ 9,247 $

127$ per m² per year

13

Life Cycle Costing

2. Recurring Cost

2a Operating
- Water consumption
- Care of plants
- Cleaning

for 50 years

→ 70,145 $
19 $ per m² per year

14

Life Cycle Costing

2. Recurring Cost

2b Maintenance
- Irrigation System
- Roof

for 49 years

→ 23,814 $
7 $ per m² per year

15

Life Cycle Costing

3. Disposal Cost

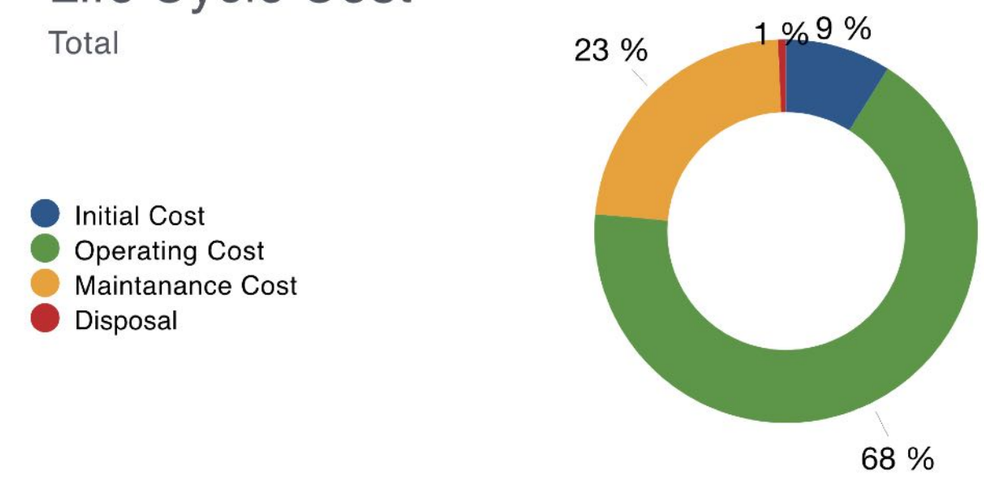
- Dismanteling

→ 405 $
0,11$ per m² per year

16

Life Cycle Cost

Total



17

Life Cycle Cost

1. Initial Cost	9,247 $
2. Recurring Cost	
a. Operating Cost	70,145 $
b. Maintenance Cost	23,814 $
3. Disposal Cost	405 $
Total	103,611 $
	1,419$ / m²

TONKIN 2

Roof & Facade

Roof:
- 680 m²

→ 965,144 $

Facade
- East, West
- 4 Levels

→ 449,093 $

Total

→ 1,414,237 $

21

TONKIN 2

Roof & Facade

Total	→	1,414,237 $
+ 20%	→	1,697,084 $

22

Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection

dortmund university

research group of spatial information management and modeling rim

wilo

VINGROUP VINHOMES

Thank you for your attention

SJA : Economics // Sophie Girlich

23

Fachvortrag 06
Presentation 06
Bài thuyết trình 06

Kühleffekte an Tonkin 2 und TestBed 2 durch Begrünung

Cooling Effect on Tonkin 2 and TestBed 2 through Greening

Hiệu quả Làm mát trên Tonkin 2 và Test Bed 2 thông qua Xanh hóa

Flemming Eismann

Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection

dortmund university

research group of spatial information management and modeling rim

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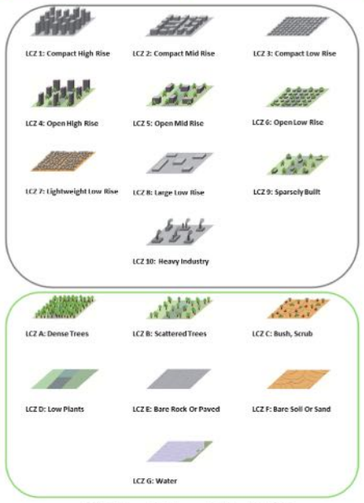
VINGROUP VINHOMES

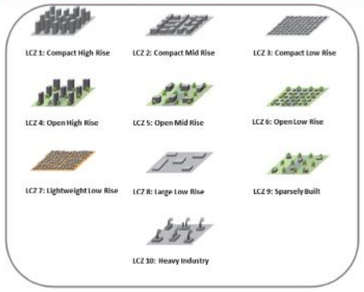
Cooling Effect on Tonkin 2 and Test Bed 02 through Greening

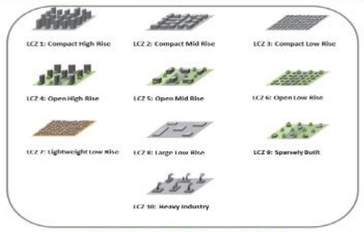
Flemming Eismann
TU Dortmund University

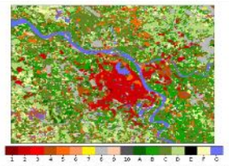
"What cooling effect can identical building greening achieve in two different local climate zones?"



LCZ classification, own illustration according to Stewart & Oke (2012)

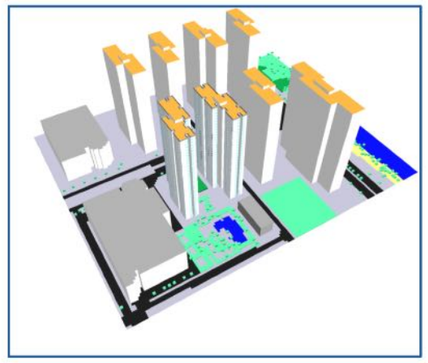


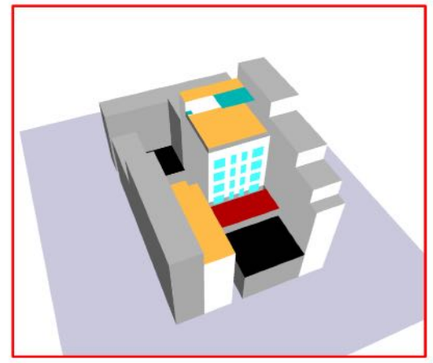


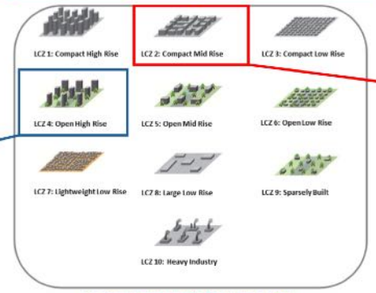


Eismann, Flemming (2025): WUDAPT Level 0 training data for Hanoi (Vietnam, Socialist Republic of) submitted to the LCZ-Generator

Microclimatic Simulations ENVI-met

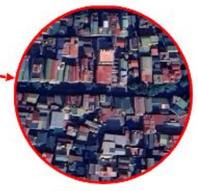






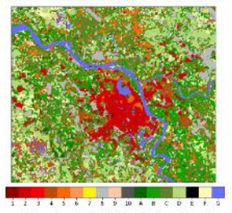
Tonkin 2

- Buildings of 9 floors or more
- Larger open spaces between buildings
- More space for vegetation



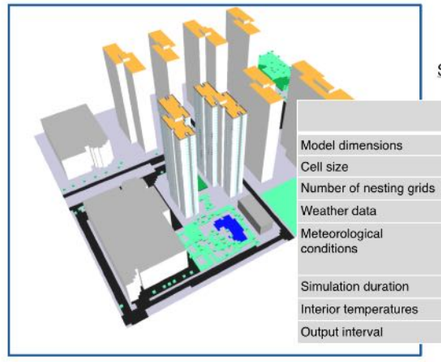
Test Bed 02

- High building density
- 3 to 9 floors
- High level of sealing, little space for vegetation
- Accumulation of heat



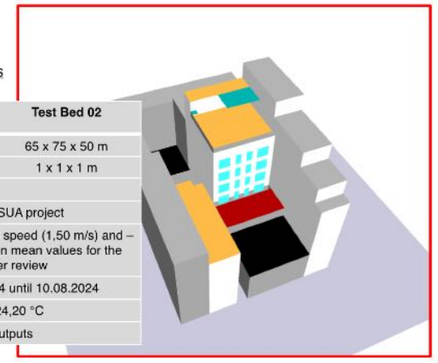
Eismann, Flemming (2025): WUDAPT Level 0 training data for Hanoi (Vietnam, Socialist Republic of) submitted to the LCZ-Generator

Microclimatic Simulations ENVI-met

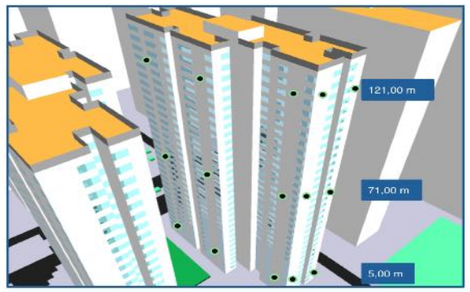


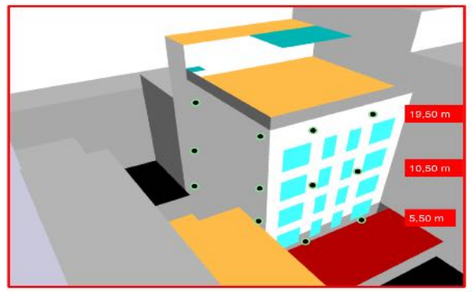
Simulation of Scenarios

	Tonkin 2	Test Bed 02
Model dimensions	140 x 111 x 100 m	65 x 75 x 50 m
Cell size	3 x 3 x 2 m	1 x 1 x 1 m
Number of nesting grids	14	
Weather data	Measured by SUA project	
Meteorological conditions	Full forcing, Constant wind speed (1,50 m/s) and – direction (156°), based on mean values for the period under review	
Simulation duration	72 h from 08.08.2024 until 10.08.2024	
Interior temperatures	Constant 24,20 °C	
Output interval	Hourly outputs	

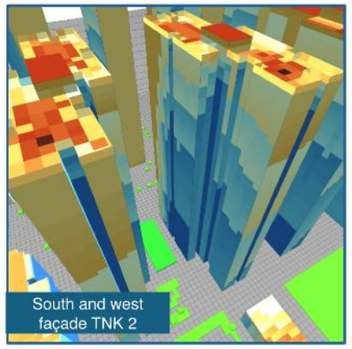


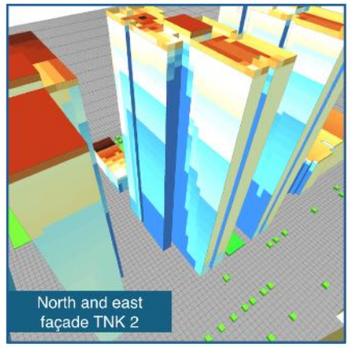
Measurement points

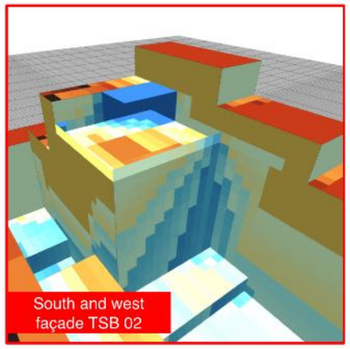




Influence of shading







0 h 1 h 3 h 4 h 5 h 6 h 8 h 9 h 10 h 12 h

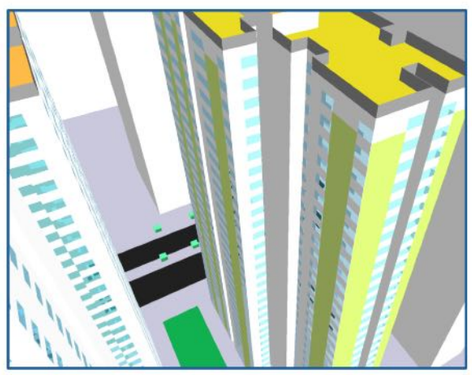
Building Greening of Test Bed 02

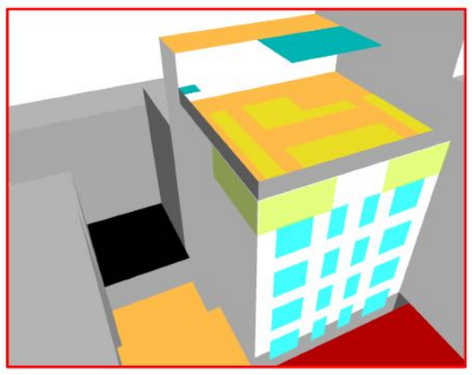
- Hanging plants
- 15 cm plant thickness
- No substrate
- LAI 0,92

- Potted plants
- 30 cm substrate layer
- 180 cm plant thickness
- LAI 2,40

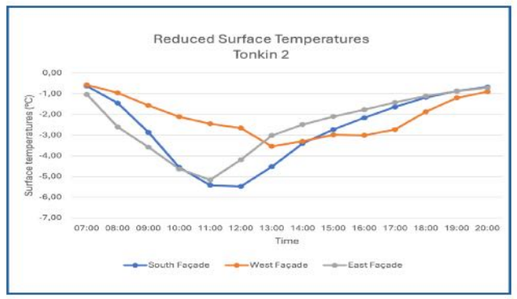
Pictures taken by SUA

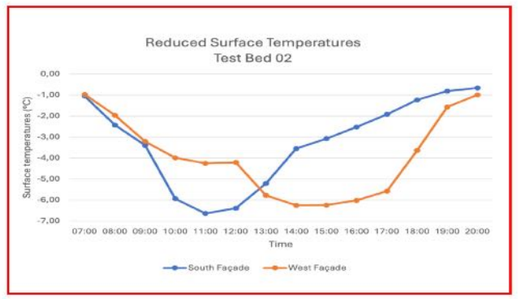
Greened ENVI-met models



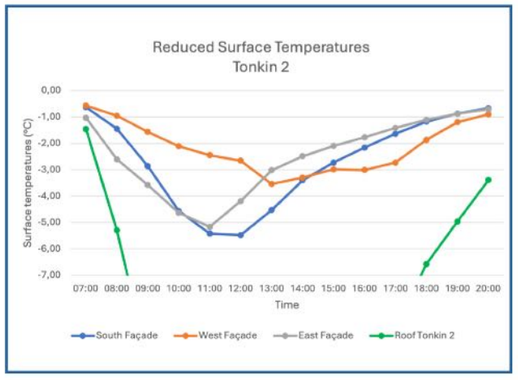


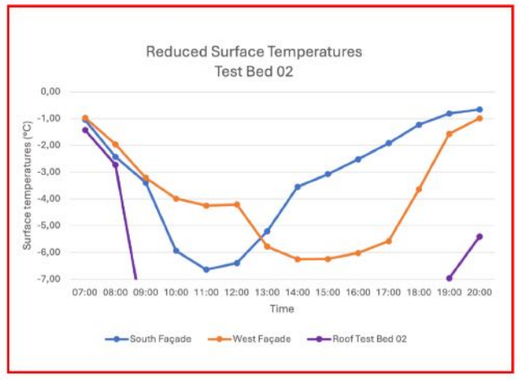
Reduced surface temperatures



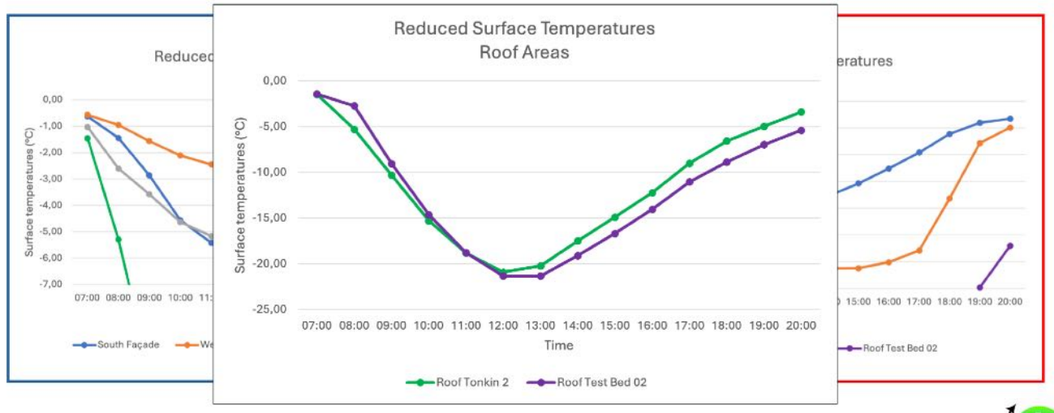


Reduced surface temperatures

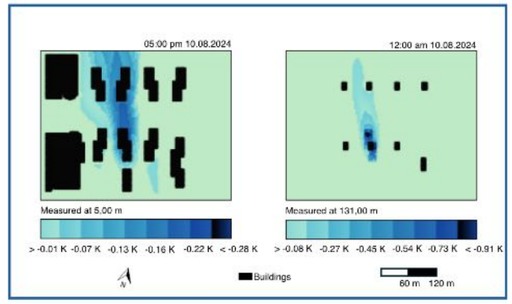


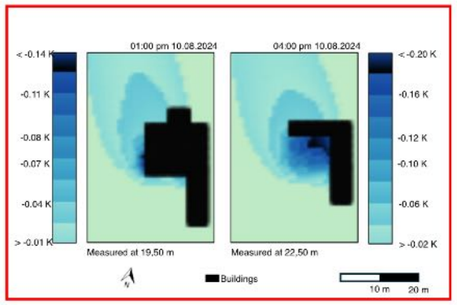


Reduced surface temperatures

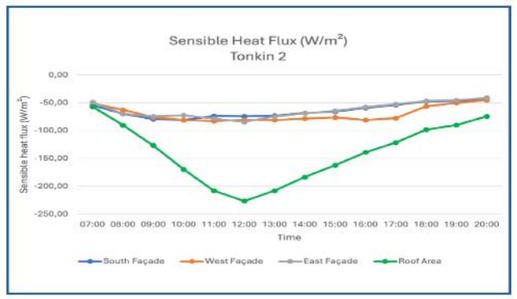


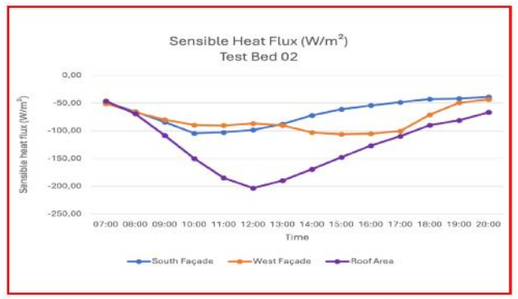
Reduced potential air temperature





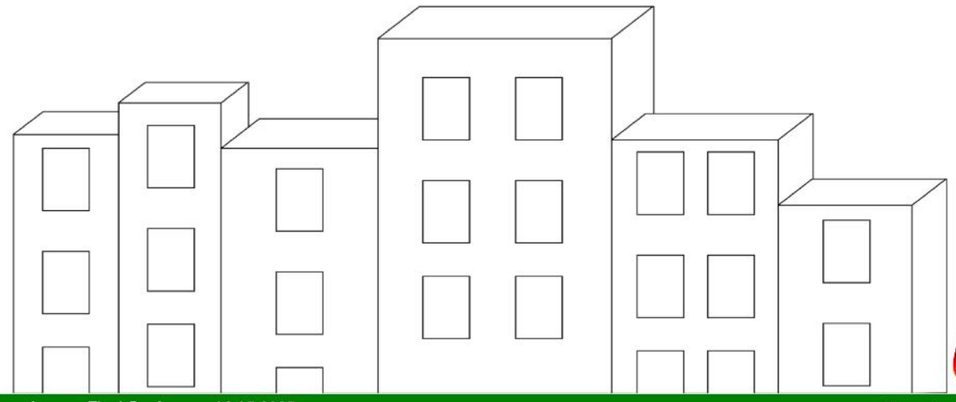
Sensible Heat Flux

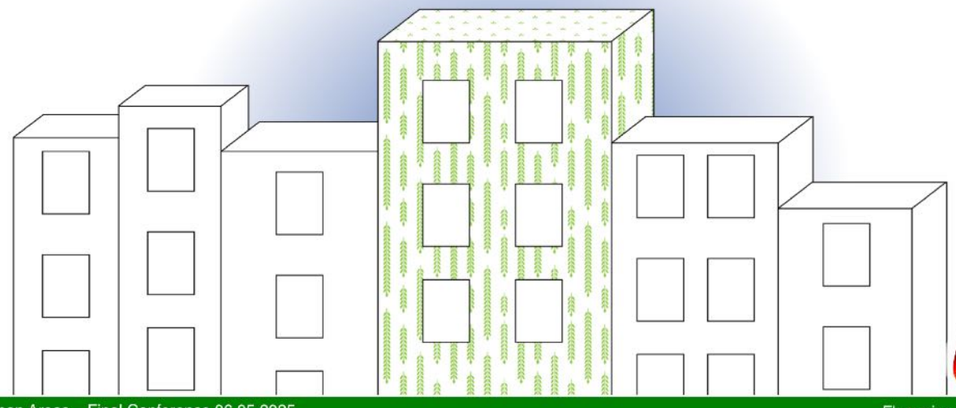


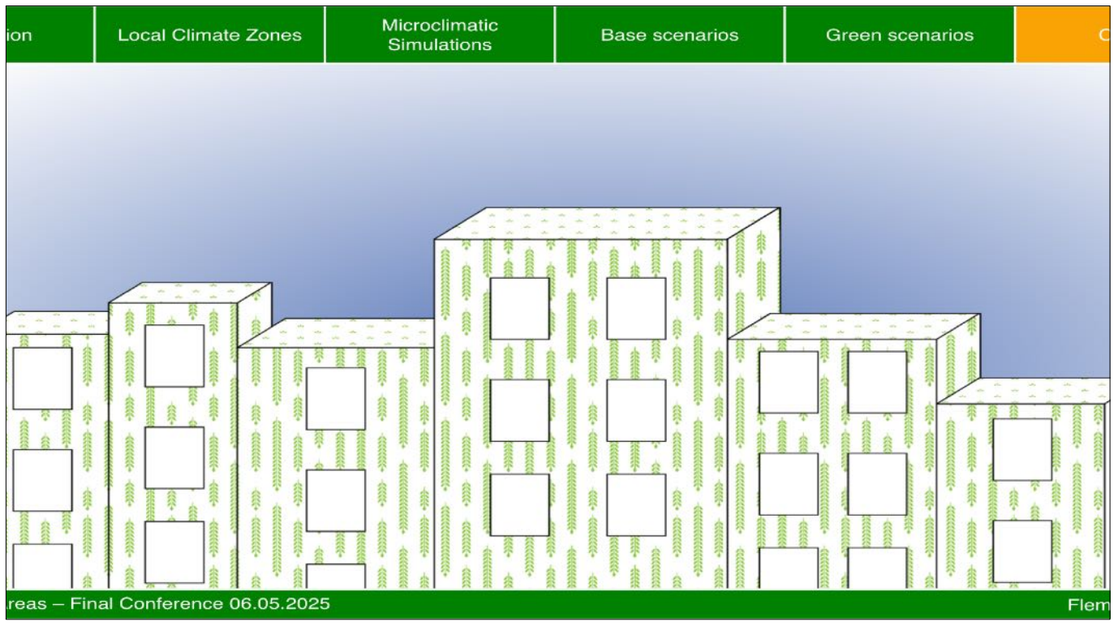


Conclusion

1. The presented building greening offers a huge cooling potential in both local climate zones
2. The greatest influences can be observed in the surface temperatures
3. Differences in the effectiveness of the building greening can be explained by the larger area covered with greenery and by influences of shading







Thank you very much for your attention!

Conclusion

SUA Zusammenfassung
SUA Conclusion
Kết luận của SUA

Vision urbaner Entwicklung in ein nachhaltige Süd-Ost-Asien
VISION into sustainable urban development in South East Asia
TẦM NHÌN vào phát triển đô thị bền vững ở Đông Nam Á

Prof. Dr. Nguyen Xuan Thinh

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VISION into sustainable urban development in Southeast Asia

Final Conference of SUA Project

19 Le Thanh Tong, Hanoi

SUA SMART URBAN AREAS

Prof. Dr. Nguyen Xuan Thinh, TU Dortmund University

Digital Twins for a Sustainable Southeast Asia (SEA)

- Imagine **Hanoi** 2050 - thriving - net zero where smog, traffic jam, heat wave are predicted before it happens.
- Imagine **Jakarta** in 2035 - not sinking, but thriving - where flooding is predicted before it happens, and informal settlements are connected to clean water and energy grids

- This isn't sci-fi. It's possible, with the right tools and mindset.

2

Problem & Opportunity – Urban Growth vs Urban Risk

- **Challenges** in Southeast Asia **cities**: Rapid urbanization, informal settlements, climate risk, infrastructure strain.
- **Unique** Southeast Asia **context**: Diversity of economies, data gaps, governance complexities.
- Pivot: But the very complexity of our cities makes them **perfect candidates for transformation**.

3

Vision – Cities that Learn, Adapt, and Care

- **Our vision:** *Southeast Asian cities as resilient, inclusive, and smart – powered by digital twins that are human-centered, adaptive, and regionally grounded.*
- **Localization of smart city tech**: Digital twins must be designed not just for buildings but for barangays, kampungs, and entire ecosystems.

- **Examples**: Flood modeling in Bangkok, informal housing monitoring in Manila, energy optimization in Singapore.

4

Digital Twin – More Than a 3D Model

5

Call to Action – Let's Build It Together

- **Governments** to adopt open standards and invest in urban data infrastructure.
- **Academia & researchers** to drive local digital twin innovations.
- **Private sector** to co-develop tools that prioritize social equity and resilience.
- **Communities** to be co-designers, not just data points.

6

Call to Action – Let's Build It Together

Southeast Asian cities that are not only smart, but wise. Not only efficient, but equitable. Cities that learn, adapt, and care.

This means:

- **Inclusive infrastructure** that serves all citizens.
- **Planning tools** that simulate multiple futures, not just one.
- **Governance** that listens to data - and people.

Digital twins can help us get there - but only if we make them context-aware, locally driven, and people-centered.

7

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Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection
based on a decision of the German Bundestag

Thank you very much for you attention!

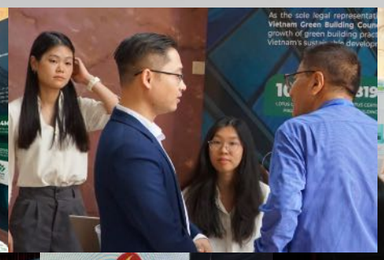
Prof. Dr. Nguyen Xuan Thinh
TU Dortmund University

Impressionen

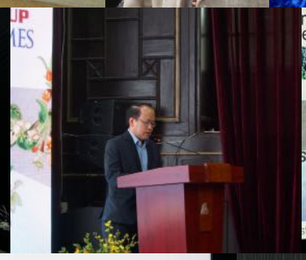



Smart Urban Areas (SUA)
Final Conference
6th May 2025
Welcome!







Smart Urban Areas (SUA)
Final Conference
6th

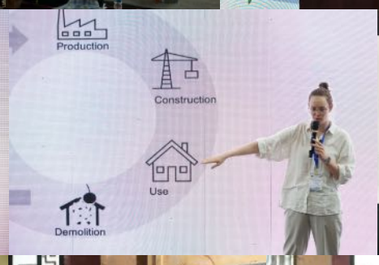




Thermal Performance of Roof and Facade Greening Under
Summer-Time Heatwave Conditions in Hanoi, Vietnam
Dr. Mathias Schaefer

& microclimate adaptation
on before real-world construction

wilo
Loving Traditions. Living Innovations.


Production
Construction
Use
Demolition

Cooling Effect on Tonkin 2 and
Test Bed 02 through Greening







NGU TUONG VIEN
LANDSCAPE
SMART GREENING



SUA
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Credits

Mit der tatkräftigen Unterstützung der folgenden Mitarbeiter konnte das Symposium erfolgreich umgesetzt werden:

With the active support of the following employees, the symposium was successfully implemented:

Với sự hỗ trợ tích cực từ các nhân viên sau đây, hội thảo đã được tổ chức thành công:

Anna Dumke
Nhat Anh Pham
Jan Kanelias
Raphael Michaelis-Braun
Lea Maiwald
Flemming Eismann
Jonathan Meurer

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Special thanks for the on-site support go to:
Xin trân trọng cảm ơn sự hỗ trợ tại chỗ của:

Center for Environmental Modeling and Monitoring (CEMM)

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SUA welcomes you!