

▶ **IMPROVING IAQ WITH BIM BASED PREDICTIVE TWINS**  
**WOUTER BORSBOOM**

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INIVE.org, BDTA.

TNO ([www.tno.nl](http://www.tno.nl)) is an independent and not-for-profit organization. TNO connects people and knowledge to create innovations that boost the competitive strength of industry and the well-being of society in a sustainable way. This is our mission and it is what drives us, the over 3,400 professionals at TNO, in our work every day. We work in collaboration with partners and focus on nine domains.



Towards Networks of predictive twins in the Built Environment, Arjen Adriaanse, Wouter Borsboom, Rob Roef, 2021  
<https://repository.tudelft.nl/islandora/object/uuib:ba8043dd-1dfc-4469-bfeb-53006de6e88a>

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# THERE IS A CLEAR NEED TO ASSESS INDOOR AIR QUALITY



Show caption

**Kansas schools can fight COVID-19 with fresh air, but it's unclear how many even track ventilation**

Celia Llopis-Jepsen | Kansas News Service

After the pandemic hit, the largest school district in Kansas set to calculating how much outdoor air it should pull into its buildings.

Wichita Public Schools turned to the nation's top sources for expertise, then boosted ventilation and filtration in ways that scientists say dramatically cut the risk of inhaling COVID-19.

**Evidence that schools** — as well as operators of other buildings that bring people together — should take those steps has solidified, buoyed by scientific findings that the virus spreads primarily through particles in the air, not by lurking on doorknobs and table tops.

## CO2 Measurement Contributes to Better IAQ

Modern CO2 sensors help serve as indicators to create safer and healthier indoor environments

March 29, 2021

By Justin Walsh

In the throes of a global pandemic, assuring a clean, healthy environment for those who work in and visit commercial, industrial, and residential buildings remains a crucial priority for facility executives and facilities management professionals. Despite COVID-19 cases beginning to drop as more people become vaccinated, with warmer weather on the horizon, questions about indoor air quality (IAQ), HVAC systems, and their effect on the spread of COVID-19 remain top of mind.

In today's environment, building ventilation is fundamental to maintaining healthy, comfortable IAQ and decreasing risks to our health. From irritation of the eyes, nose, and throat; headaches, dizziness, and fatigue; to respiratory diseases, heart disease, and even cancer, both immediate and long-term health concerns are, in many cases, being directly linked to IAQ.



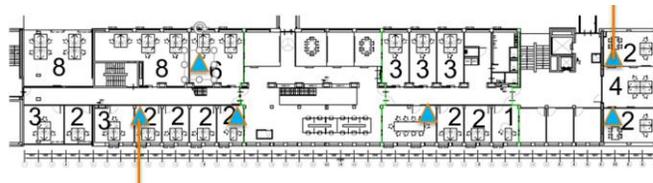
Beyond health, safety, and comfort, IAQ also has a significant impact on productivity and cognitive ability. Studies from 2016 and 2017 found that breathing better air led to significantly better decision-making performance among participants who were exposed to increased ventilation rates, lower levels of chemicals, and lower carbon dioxide. To that end, building owners are increasingly investing in advanced HVAC equipment and technologies in an effort to improve IAQ. Building safety is a crucial demand for an increasing number of tenants. Consequently, facilities management professionals who aim to attract and retain tenants in the future are going to have to demonstrate that their spaces are indeed safe in terms of IAQ.

# DIFFERENT PROTOCOLS TO ASSESS IAQ



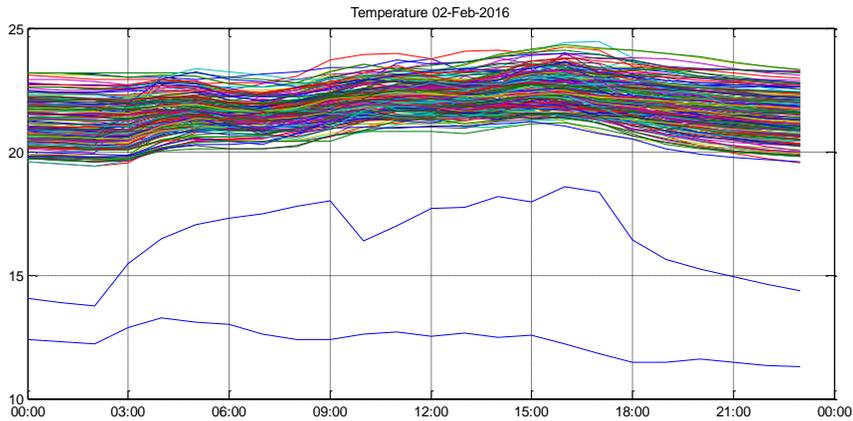
Example of a Dutch IAQ requirement, which parameters to use, how to measure, where to measure.

[www.pvegezondekantoren.nl](http://www.pvegezondekantoren.nl)



Theme	Survey	Continuous monitoring	Inspection	Total
Thermal	B	A	C	B
Noise	D	x	C	C
IAQ	C	B	B	B
Light	A	x	A	A
Total IEQ				C

## BUILDINGS PROVIDE TONS OF DATA, BUT DO WE HAVE INFORMATION TO IMPROVE IAQ ? WHAT CAN BIM AND PREDICTIVE TWINS MEAN?



600 room temperatures, which one to choose?

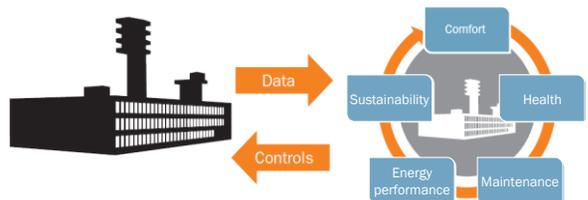
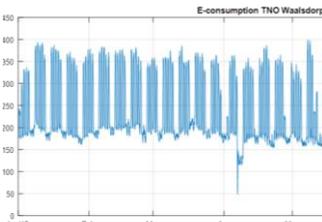
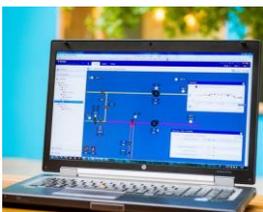
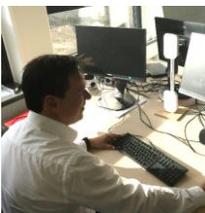
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## BUT HOW ARE DIGITAL SOLUTIONS REALLY GOING TO MAKE A DIFFERENCE TO THESE CHALLENGES?

Living lab TNO (NL)



Physical building

Predictive building Digital Twin

**Predictive twins** are predictive digital replicas of physical structures such as bridges, tunnels, homes and offices. With these twins, the future behaviour and use of structures and networks of structures can be predicted and influenced

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## BIM 2 PREDICTIVE TWIN

- › How can we use **BIM information to structure and analyze data** from building systems to check the current performance, detect events, predict, control and optimize?
- › How to make it operational in the form of **workflows in both design commissioning and operation?**
- › How to use it to improve IAQ, event detection, optimize building processes & commissioning?

Development of predictive twin methodologies and tools to meet these challenges for clients.



Wouter Borsboom, Ruud van der Linden TNO, 2021

This project has received funding from the European Union's H2020 programme under Grant Agreement No. 820805.

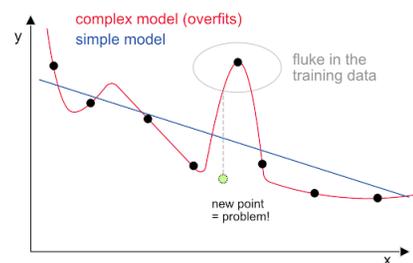
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## WHY USE BIM DATA, WE HAVE AI

- › **Measurement data:** generally a lot but usually **important factors unmeasured**
- › Many parameters in a data driven model with low quality data → **overfitting** -> poor estimation

### Advantages of using BIM in combination with physical models:

- › What you already know you **don't have to estimate**.
- › You can do with **less informative data** to calibrate the model
- › **Logical boundaries** on parameters in a physical model



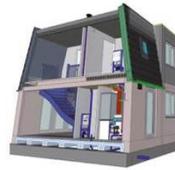
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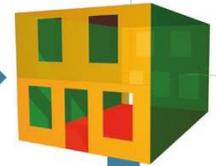
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## EXAMPLE BIM 2 PREDICTIVE TWIN: BIM 2 BEM CHALLENGES

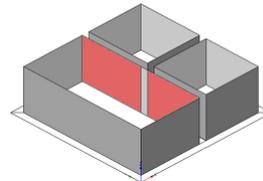
- › BIM models not made for simulation models
- › Decisions have to be made for zoning, and also for space boundaries.
- › Inconsistencies especially on the space boundaries can give issues for building model.
- › Different standards: IFC, gbXML, IDF.



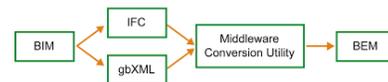
8-zone BIM model



2-zone BEM model



Space boundaries issues

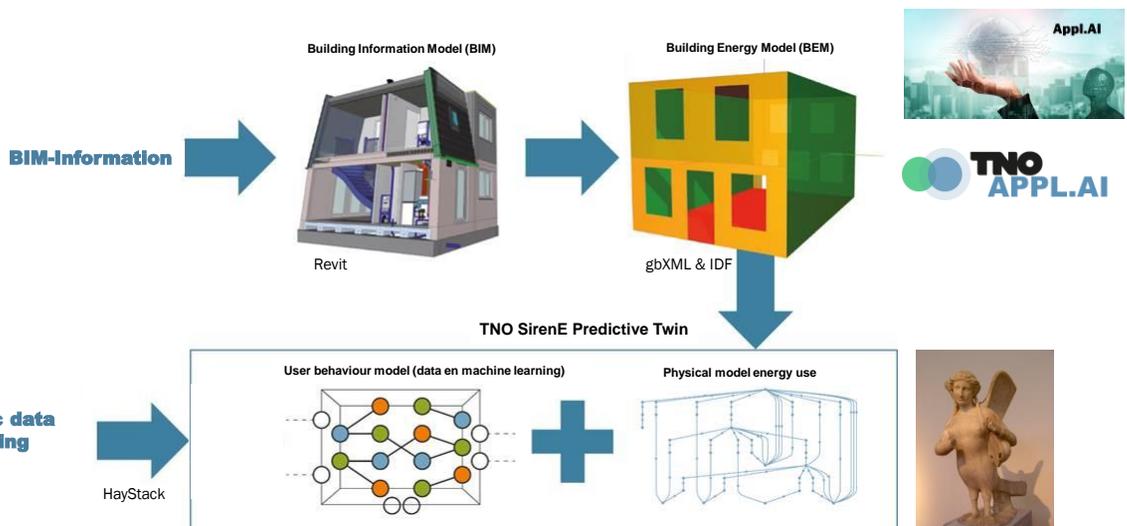


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## BIM 2 PREDICTIVE TWIN FOR IAQ AND ENERGY USE

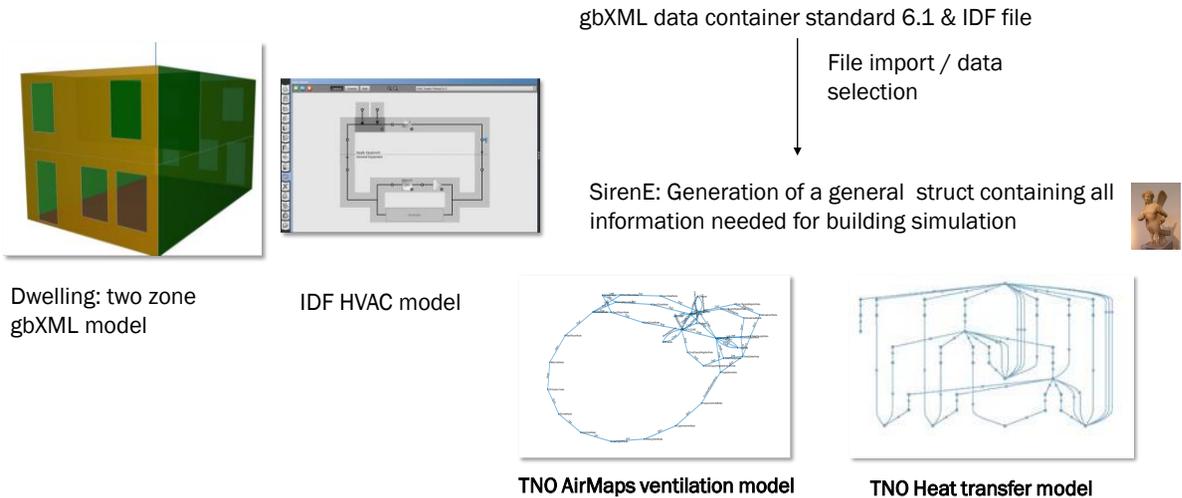


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## BIM INFORMATION: EXAMPLE OF GBXML 2 MODEL



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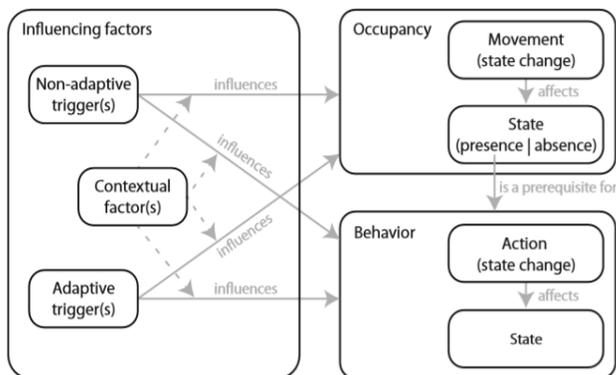


This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 869918



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## OCCUPANT MODEL , WORK IN PROGRESS



Schweiker, 2017

**Adaptive triggers:** environmental trigger (e.g. due to discomfort)

**Non-adaptive triggers:** intentional actions (e.g. showering)

**Contextual factors:** influence the magnitude of the triggers (e.g. occupants clothing)

Occupancy:  
- usually modeled with time profiles

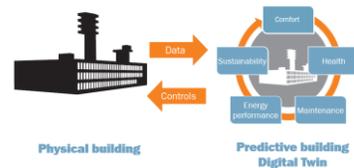
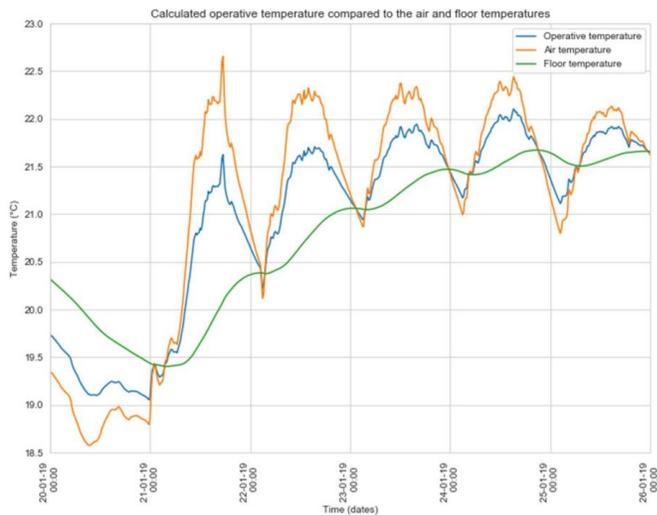
Behavior:  
- usually modelled with Markov chains,  
- TNO research on federated learning

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## EXAMPLE: PREDICTIVE TWIN TO ESTIMATE FLOOR TEMPERATURE



TKI Officecomfort

Stellenbosch University  
Netherlands

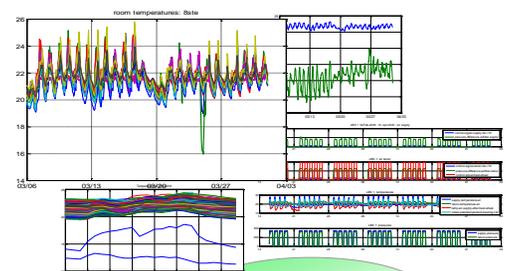
TKI URBAN ENERGY  
Energy City

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## DYNAMIC DATA FOR PREDICTIVE TWINS: DECISION MAKING NEEDS RELIABLE AND INFORMATIVE DATA



“Data Tsunami”



time stamp  
database(s)

### What is monitored?

- Data from Building Automation System: room thermostats, Air Handling Units, DID's, Coolers etc.
- Energy meters.
- IOT data
- Additional systems: (entry gates), sun shades, complaints etc.
- AIM: services, retrofitting

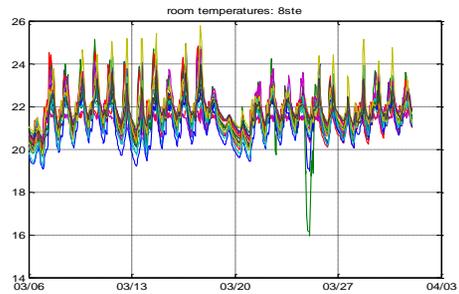
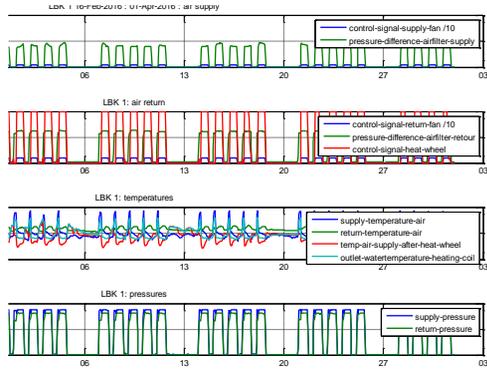
Data consistency  
Data ≠ Information

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## DATA ISSUES



An outlier or a problem?

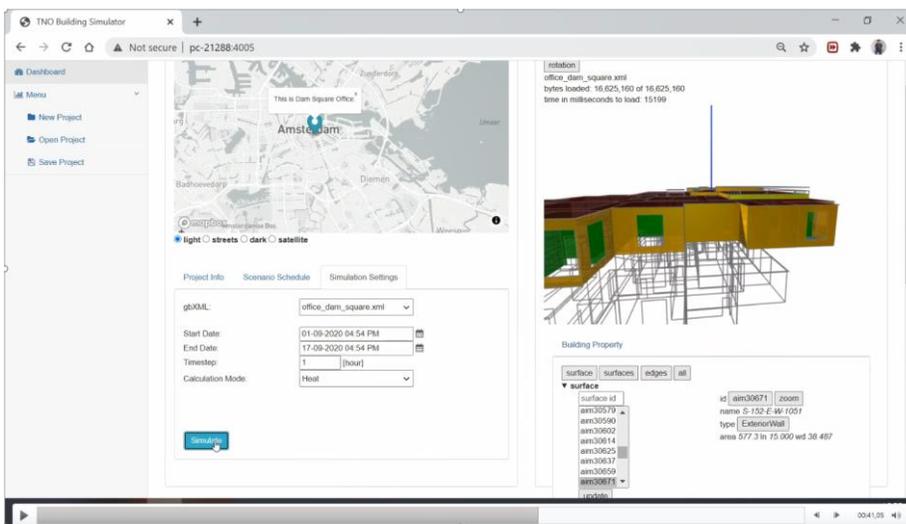
Lots of parameters in the AHU, but will it give me insight?

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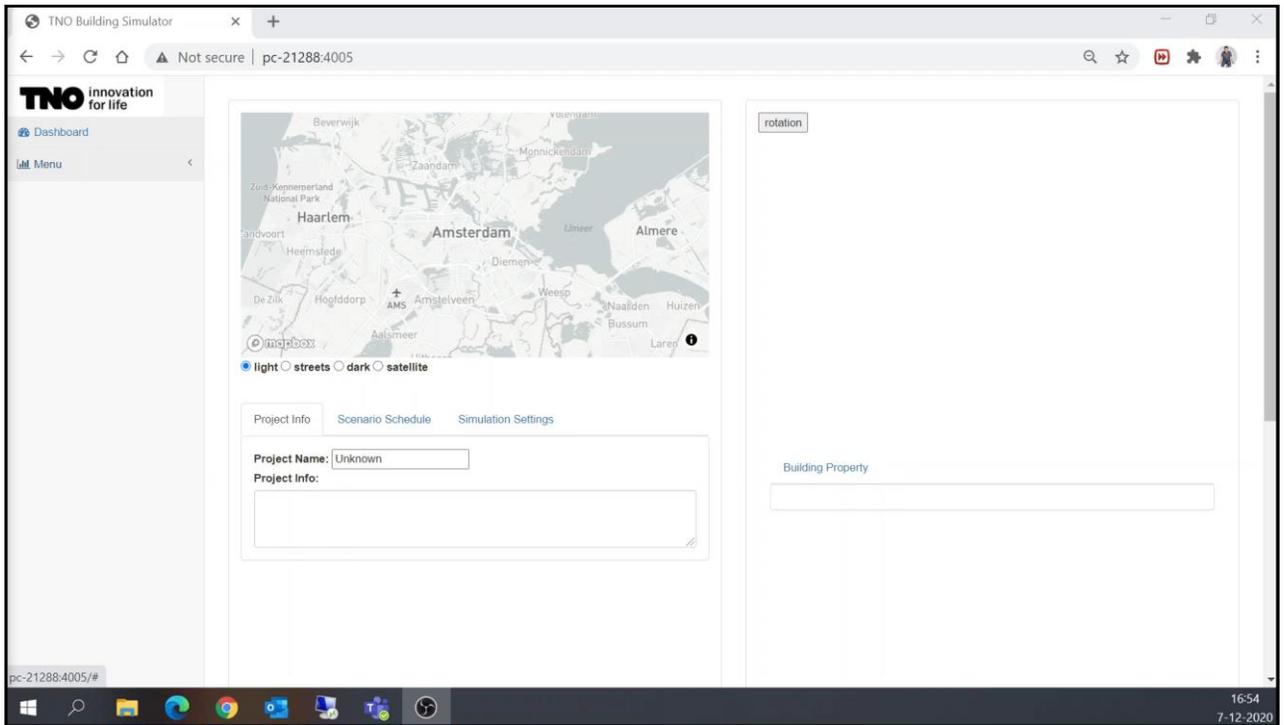
## DEMONSTRATION USE CASE GUI SCALABLE MODELS



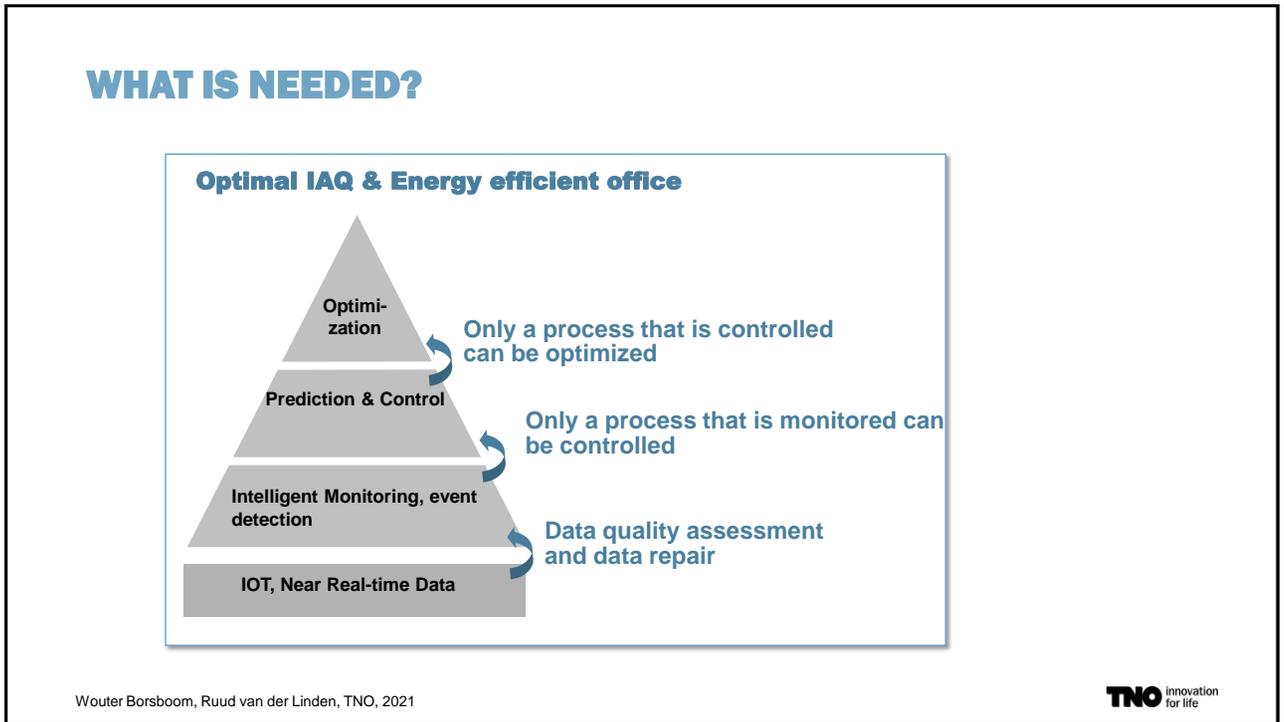
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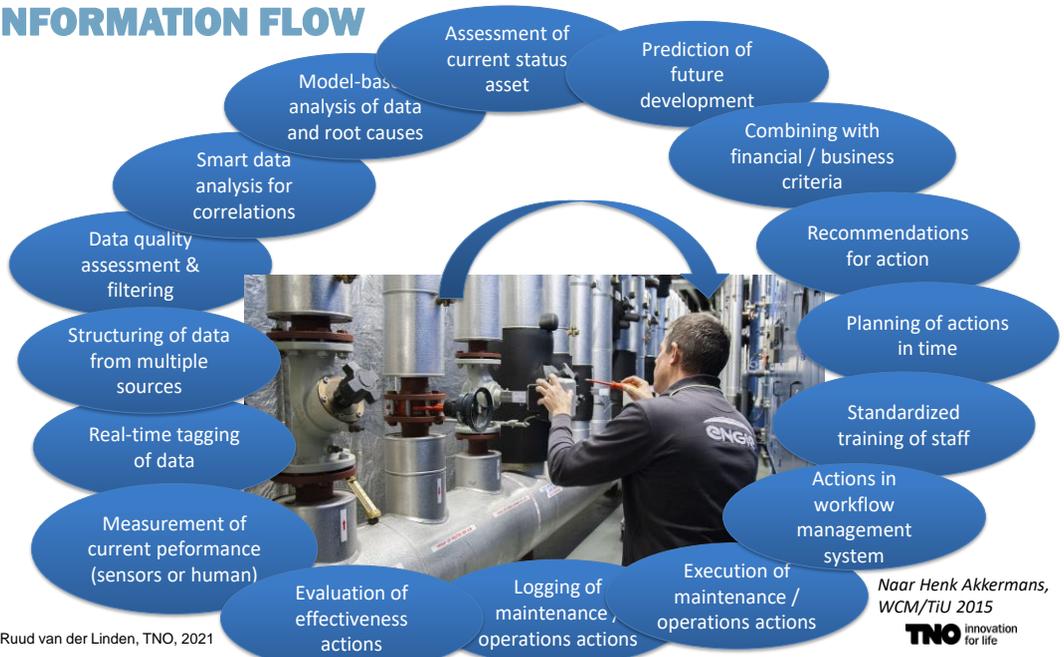


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## DATA INFORMATION FLOW



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## MANY STAKEHOLDERS INVOLVED,



**INTEGRATION WITH BIM IN OPERATION AND WORKFLOW ORGANIZATION IS CRUCIAL TO EFFECTIVELY IMPROVE IAQ**

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