AIVC April Workshop

Marc Delghust
co-lead ST5
IEA-EBC Annex 86

Series of four webinars
organised in collaboration with
IEA-EBC Annex 86 ‘Energy efficient IAQ management’

April 1,	Building ventilation: How does it affect SARS-CoV-2 transmission?	
April 8,	IAQ and ventilation Metrics	
April 13,	**Big data, IAQ and ventilation**	**- part 1**
April 21,	Big data, IAQ and ventilation	- part 2

Register at www.aivc.org

EBC
Energy in Buildings and Communities Programme

IEA-EBC Annex 86

Energy Efficient IAQ Management in residential buildings

EBC Annex 86

Energy in Buildings and Communities Programme

Scope and Goals

Provide a framework to improve energy efficiency of IAQ management for

residential buildings

both new construction and refurbishment

To select metrics to assess energy performance and indoor environmental quality of an IAQ management strategy and study their aggregation
To improve the acceptability, control, installation quality and long-term reliability of IAQ management strategies by proposing specific metrics for these quality issues
To set up a coherent rating method for IAQ management strategy that takes into account the selected metrics
To identify or further develop the tools that will be needed to assist designers and managers of buildings in assessing the performance of an IAQ management strategy using the rating method
To gather existing or provide new standardized input data for the rating method
To study the potential use of smart materials as (an integral part of) an IAQ management strategy
To develop specific IAQ management solutions for retrofitting existing buildings
To benefit from recent advances in sensor technology and cloud-based data storage to systematically improve the quality of the implemented IAQ management strategies, ensure their operation and improve the quality of the rating method as well as the input data
To improve the availability of these data sources by exploring use cases for their providers
To disseminate about each of the above findings.

EBC Annex 86

Energy in Buildings and Communities Programme

Partners

42 institutes from 24 countries

Active participation by companies encouraged!

List of annex participants per country:
Australia: CSIRO
Austria: University of Innsbruck
Belgium: UGent, KUL, BBRI, University of Antwerp
Brazil: Pontfical Catholic University of Parana
Canada: NRC
Chile: PUC
China: Nanjing University, BUCE and Tsinghua University
Denmark: DTU and Aalborg University Copenhagen
Finland: Aalto University
France: La Rochelle University, ENS PSL, CEREMA, Université de Lille, UPJV and CETIAT
Germany: TH Rosenheim
Ireland: NUIG
Italy: EURAC research center
New Zealand: BRANZ
Netherlands: Technical University of Eindhoven, BBA/TUDelft and Zehnder
Norway: Oslo Metropolitan University and SINTEFF
Portugal: University of Coimbra, Polytechnic Institute of Viseu and University of Porto
Singapore: National University of Singapore
Spain: Eduardo Torroja Institute for Constructon Sciences – CSIC
Sweden: Chalmers University and KTH
Switzerland: ETH
Turkey: TTMD
United Kingdom: University of Strathclyde, Lancaster University and University of Nottingham
USA: Syracuse University, UMD, UTexas and LBL

EBC Annex 86

Energy in Buildings and Communities Programme

Workplan

6 Subtasks

ST 1 and 2: methodology

ST 3 and 4: application to technology

ST 5: new opportunities through IoT

ST 6: dissemination and management

Subtask 1 Metrics and development of an IAQ management strategy rating method

This subtask is devoted to the development of a general rating method for the benchmarking of the performance of IAQ management systems. In addition to relevant metrics, a set of appropriate tools, consistent modeling assumptions and monitoring protocols are also proposed.

Subtask 2 Source characterization and typical exposure in residential buildings

This ST creates consistent input values for the assessment method developed in ST 1 and control strategies in ST 4. It starts from information available in literature, adding new experimental results where needed and reviewing and developing models (empirical, semi-empirical or physical models) for characterizing relevant residential sources.

Subtask 3 Smart materials as an IAQ management strategy

This ST identifies opportunities to use the building structure and (bio-based) building materials (focussing on hemp concrete) and the novel functional materials inside it to actively/passively manage the IAQ, for example, through active paint, wallboards, textiles coated with advanced sorbents or hemp concrete, and quantifies their potential based on the assessment framework developed in ST 1.

Subtask 4 Ensuring performance of smart ventilation

This subtask focuses on practical conditions that assure reliable, cost effective and robust implementation of smart ventilation. This includes both installation and operation. A poor performance of smart ventilation systems can not only lead to waste of energy and aggravated IAQ. It can also create a bad reputation of smart ventilation among relevant stakeholders - designers, installers as well as occupants. This, in the end, can lead to adoption of more primitive, less efficient (in terms of energy use) and less effective (in terms of IAQ) forms of IAQ management. The subtask defines a smart ventilation according to the AIVC

Subtask 5 Energy savings and IAQ: improvements and validation through cloud data and IoT connected devices

This subtask is exploring the potential of the new generation of IoT connected devices (both standalone and embedded in eg. AHU's) for smart IAQ management. What can we learn from big data? Can we benchmark system energy and IAQ performance based on this data? How can we make sure that the data is available and can be accessed? Can we update what we think we know about what happens in dwellings based on what we see in big data rollouts? What are the best protocols and ontologies? How to create viable services out of the data/business plans? How can we integrate data with smart grids?

Subtask 6 Dissemination, management and interaction

The final subtask assures the close alignment of the activities within the annex and the interaction with the AIVC. This subtask includes the outreach of the annex, eg. by managing the dedicated section of the IEA EBC webpage. It uses the different platforms that the AIVC provides to interact with the broader target audience. This task will also ensure the continuation of the link with (the results from) other ongoing and ended annexes, especially annex 68.

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EBC Annex 86

Energy in Buildings and Communities Programme

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Annex 86 ▸ ST 5

Energy savings and IAQ: improvements and validation through cloud data and IoT connected devices

- **Smartness**
  (e.g. smart ventilation incl. continuous commissioning & optimization, use of remote data, ST4)
- **Knowledge & data-sets**
  (e.g. for defining metrics (ST1), typical exposures (ST2)

applications

real-time & delayed, on-line & off-line, new business cases?

challenges

- real-life, uncontrolled environments (cause/effect?)
- data quality: often limited number and lower cost sensors
- GDPR
- IT
- …

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April 21,	Big data, IAQ and ventilation	- part 2	(industry)

Register at www.aivc.org

Big data, IAQ and ventilation – part 1

webinar
2021.04.13

Wouter Borsboom
TNO
The Netherlands

Benjamin Hanoune
University of Lille
France

Pieter Pauwels
TU Eindhoven
The Netherlands

Webinar management

Maria Kapsalaki
(INIVE, BE)

Valérie Leprince
(INIVE, BE)

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Big data, IAQ and ventilation – part 1

webinar
2021.04.13

Objectives:
To address

- **the applications** of IoT devices and big data in IAQ and ventilation and
- discuss **the possibilities** they provide **for research**.

To set the starting stage for subtask 5 of IEA-EBC Annex 86

17:00 | Introduction
Marc Delghust – Ghent University, Belgium

17:10 | Improving IAQ with BIM based Predictive Twins
Wouter Borsboom – TNO, Netherlands
17:30 | Online personal IAQ monitoring,
Benjamin Hanoune – University of Lille, France
17:50 | Brains for buildings: where to find all the relevant smart building data?
Pieter Pauwels – Eindhoven University of Technology, Netherlands

18:10 | Questions and Answers
18:30 | Closing & End of webinar

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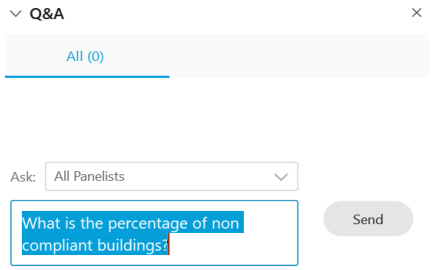
webinar
2020.04.13

How to ask questions during the webinar

Note: Please DO NOT use the chat box to ask your questions!

Locate the **Q&A box**

Select **All Panelists** | Type your question | Click on Send



webinar
2020.04.13

NOTES:

- The webinar will be **recorded and published** at www.aivc.org in a few days, along with the presentation slides.
- After the end of the webinar you will be redirected to our **post event survey**. Your feedback is valuable so take some minutes of your time to fill it in.

Organized by: www.aivc.org **Facilitated by** INIVE

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Q&A

?

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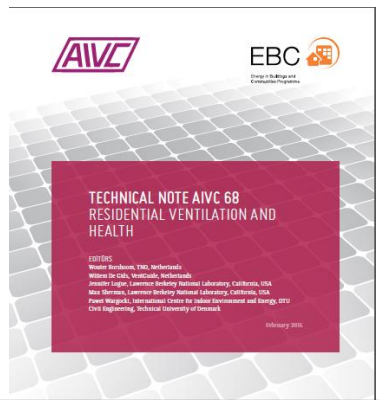
1

WOUTER BORSBOOM

Wouter Borsboom
Senior Business Consultant TNO

Energy Built Environment, Monitoring and assestment of dwellings and offices, energy, ventilation and health, Country representative IEA-ANNEX V: AIVC.org, Board Member INIVE.org, BDTA.

TNO (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/uuid:ba8043dd-1dfc-4469-bfeb-53006de6e88a

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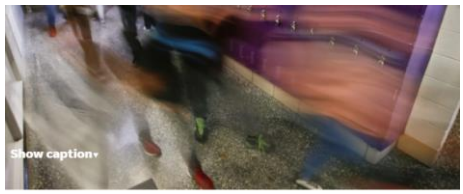
2

THERE IS A CLEAR NEED TO ASSESS INDOOR AIR QUALITY



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 critical 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.

3

DIFFERENT PROTOCOLS TO ASSESS IAQ

BINNENKLIMAAT LABEL

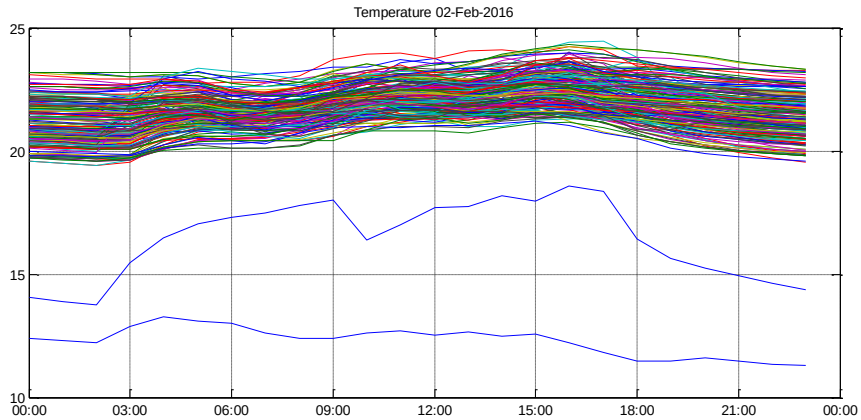
Example of a Dutch IAQ requirement, which parameters to use, how to measure, where to measure.
www.pvegezondekantoren.nl

Theme	Survey	Continious 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

4

BUILDINGS PROVIDE TONS OF DATA, BUT DO WE HAVE INFORMATION TO IMPROVE IAQ ?

WHAT CAN BIM AND PREDICTIVE TWINS MEAN?



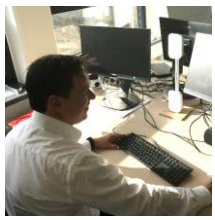
600 room temperatures, which one to choose?

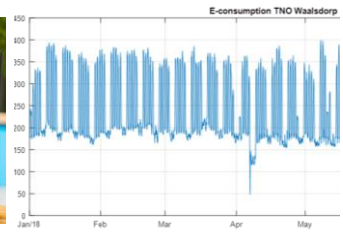
Wouter Borsboom, Ruud van der Linden, TNO, 2021

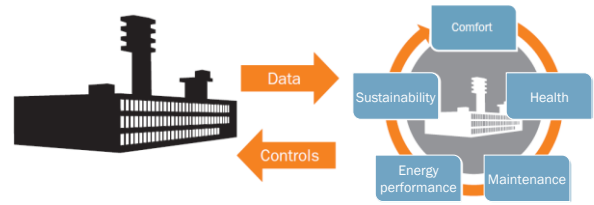
TNO innovation for life

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

Wouter Borsboom, Ruud van der Linden, TNO, 2021

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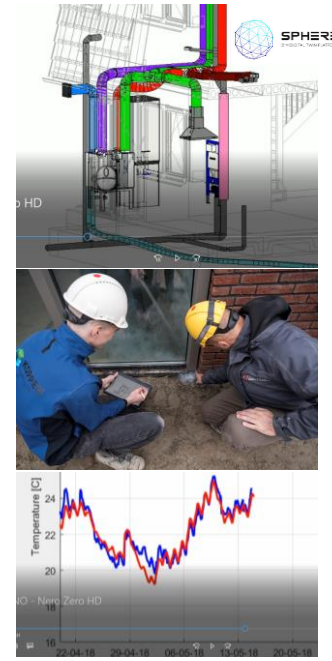
BIM 2 PREDICTIVE TWIN

- 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.



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

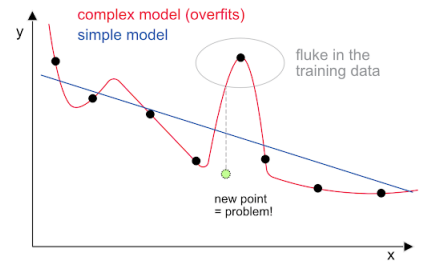
Wouter Borsboom, Ruud van der LInden TNO, 2021

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



Wouter Borsboom, Ruud van der Linden, TNO, 2021

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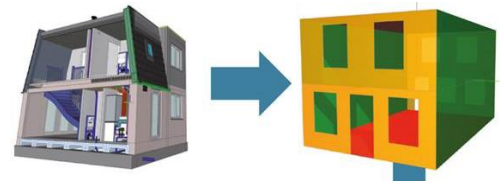
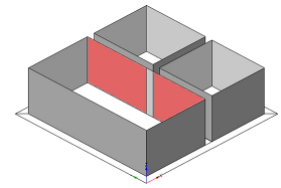
EXAMPLE BIM 2 PREDICTIVE TWIN: BIM 2 BEM CHALLENGES

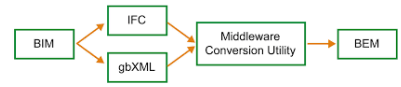
- BIM models not made for simulation models
- Decisions have to be made for zoning, and also for space boundaries.
- Inconsistencies especially on the space boundaries can give issues for building model.
- Different standards: IFC, gbXML, IDF.



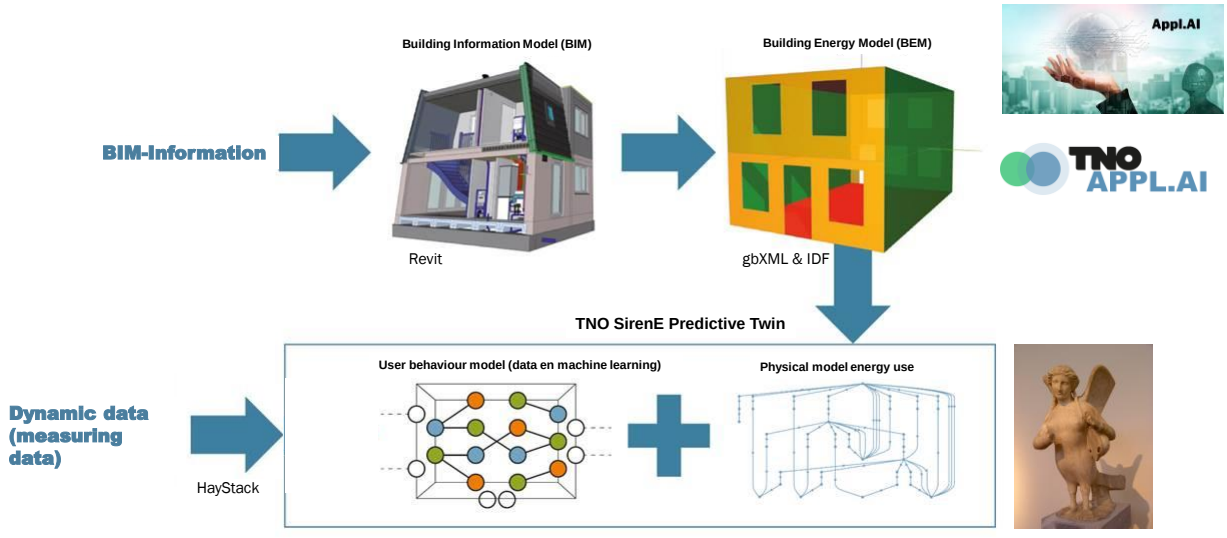
8-zone BIM model | 2-zone BEM model



Space boundaries issues



BIM 2 PREDICTIVE TWIN FOR IAQ AND ENERGY USE



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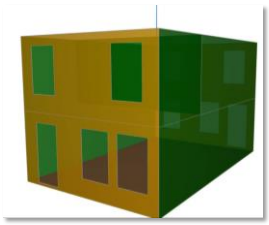
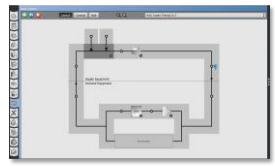
BIM INFORMATION: EXAMPLE OF GBXML 2 MODEL

gbXML data container standard 6.1 & IDF file

File import / data selection

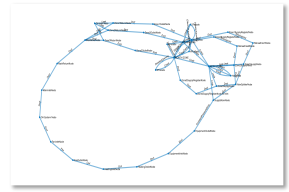


Dwelling: two zone gbXML model

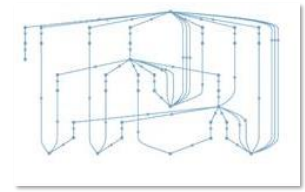


IDF HVAC model

SirenE: Generation of a general struct containing all information needed for building simulation



TNO AirMaps ventilation model



TNO Heat transfer model

Wouter Borsboom, Ruud van der Linden, TNO, 2021

syn.ikia

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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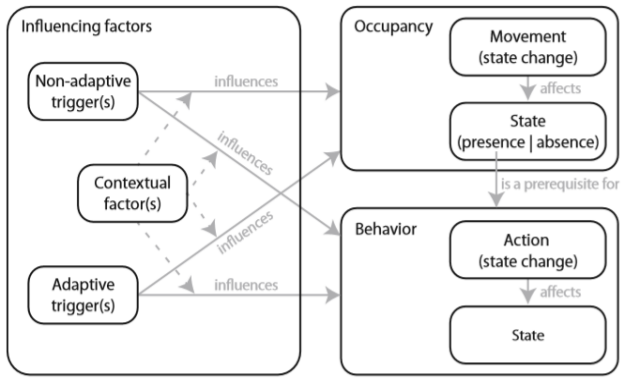
OCCUPANT MODEL , WORK IN PROGRESS



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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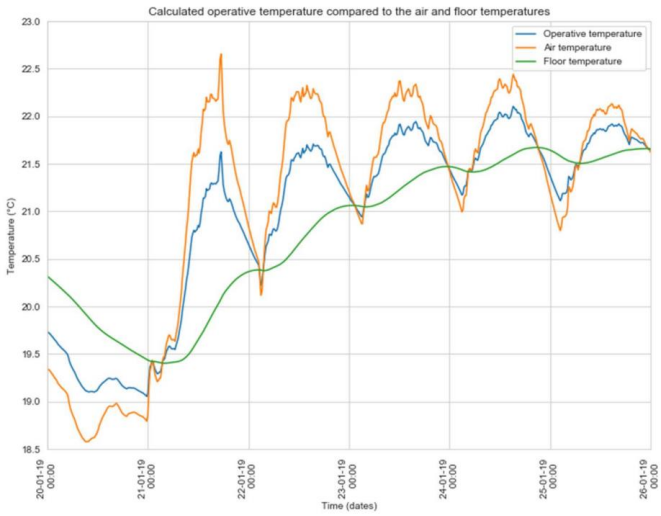
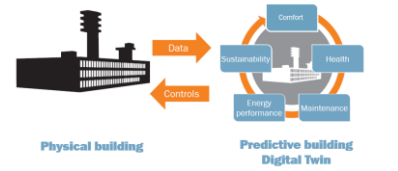
EXAMPLE: PREDICTIVE TWIN TO ESTIMATE FLOOR TEMPERATURE



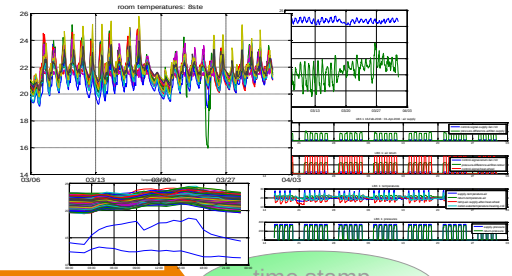


TKI Officecomfort

13

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

"Data Tsunami"



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

time stamp database(s)

Data consistency

Data ≠ Information

Wouter Borsboom, Ruud van der Linden, TNO, 2021

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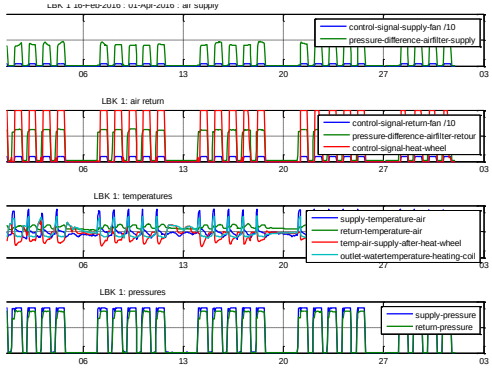
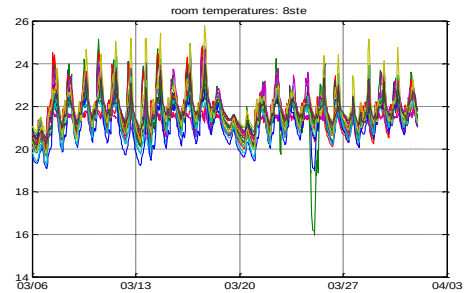
14

DATA ISSUES

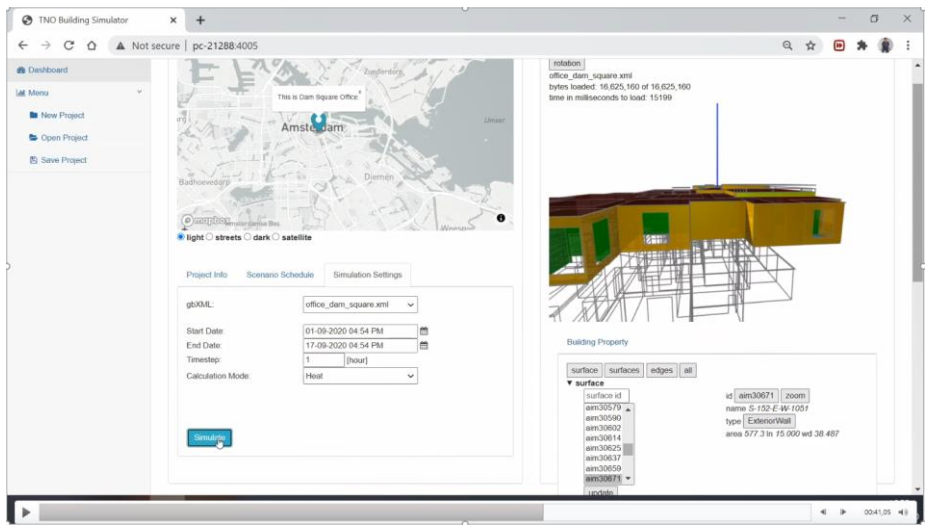


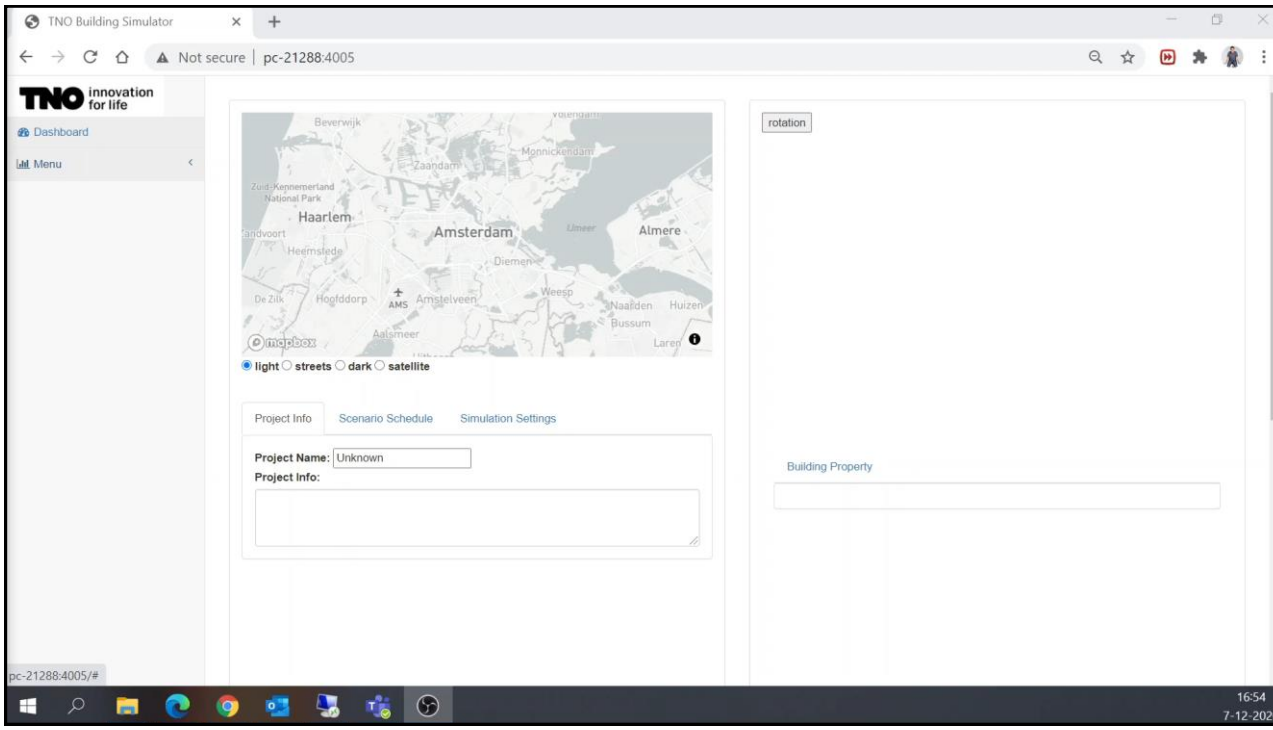
Lots of parameters in the AHU, but will it give me insight?



An outlyer or a problem?

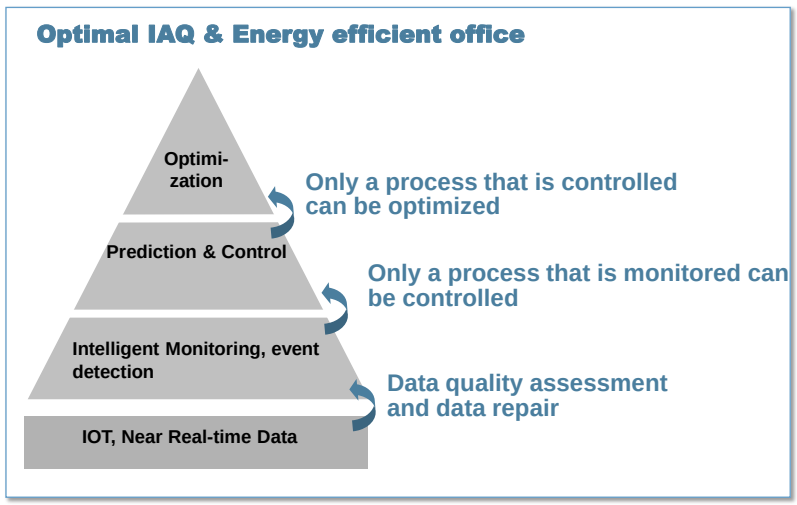
DEMONSTRATION USE CASE GUI SCALABLE MODELS





17

WHAT IS NEEDED?

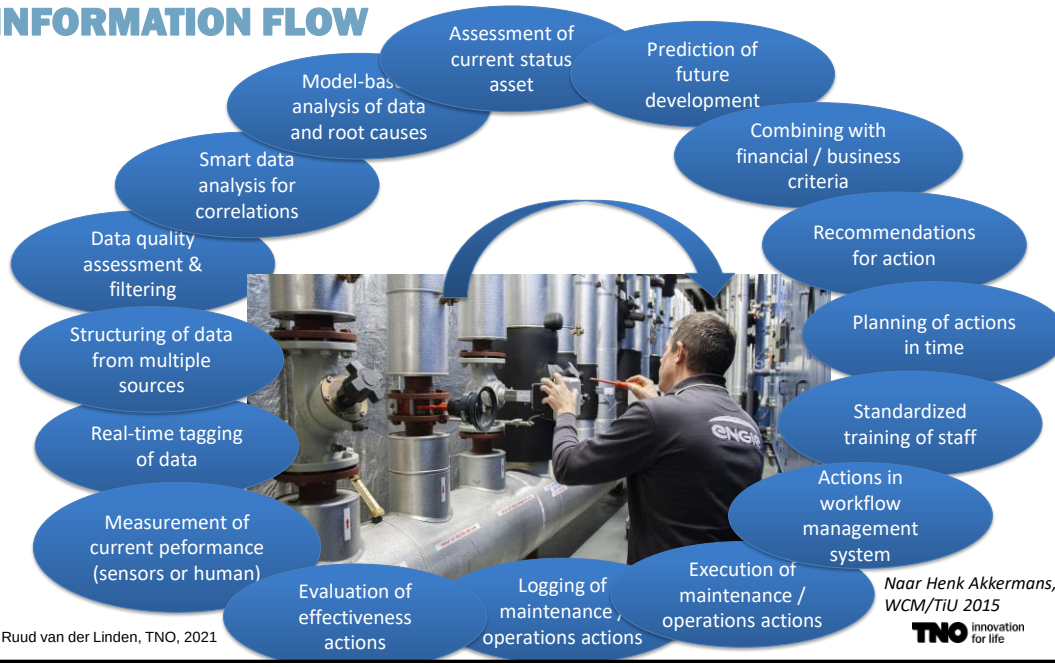


Wouter Borsboom, Ruud van der Linden, TNO, 2021

TNO innovation for life

18

DATA INFORMATION FLOW



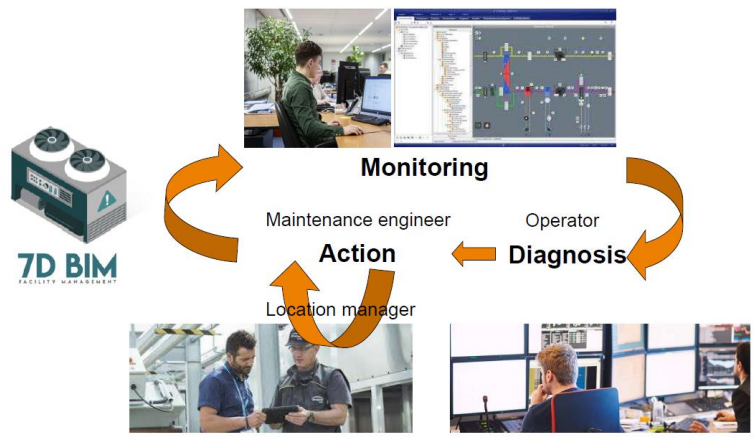
Naar Henk Akkermans, WCM/TiU 2015

Wouter Borsboom, Ruud van der Linden, TNO, 2021

TNO innovation for life

19

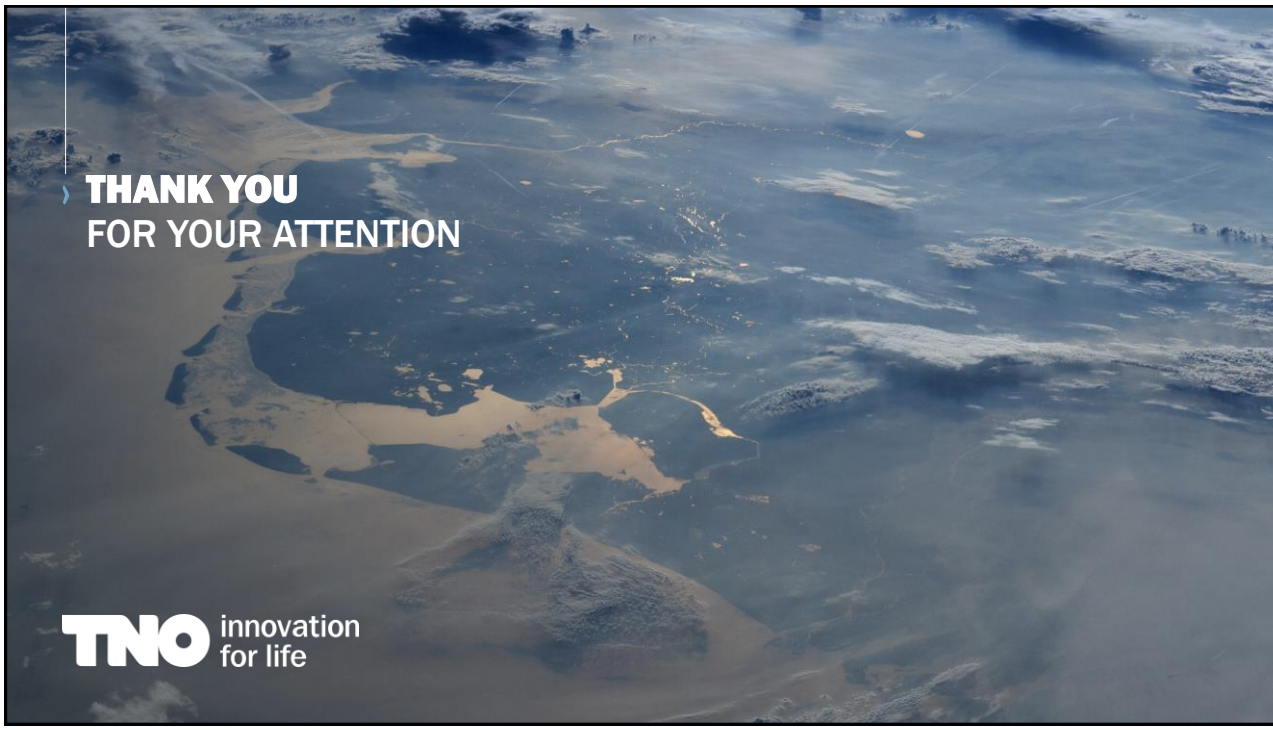
MANY STAKEHOLDERS INVOLVED,



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

TNO innovation for life

20


THANK YOU
FOR YOUR ATTENTION
TNO innovation for life

Online personal IAQ monitoring – personal exposure to indoor air pollutants.

B. Hanoune

benjamin.hanoune@univ-lille.fr

1

Apolline
AIR POLLUTION AND INDIVIDUAL EXPOSURE

https://www.apolline.science

- Development of small-size, **low-cost, pollutant monitoring system** adapted to indoor and outdoor environments
- U Lille campus-wide sensor network, can be deployed in other environments
- Research objectives : to understand the **drivers of the dynamics of pollution inside buildings** (U Lille and other environments), and to **quantify the exposure of people**
- **Educational and awareness tool** for students, staff, academics and general public

2

Strategies to monitor personal IAP exposure

- 69% in a home
- 2% in a bar/restaurant
- 5% in a vehicle
- 11% in an outdoor/indoor location
- 5% in an office/factory
- 8% outdoors

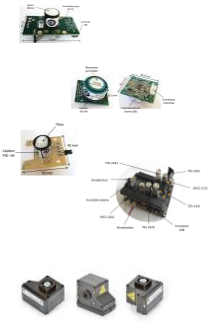
Strategy #1 : Personal sensors
- Size, weight, autonomy, communications are critical factors
- Few sensors inside the device
- Access to indoor and outdoor personal exposure

Strategy #2 : Fixed indoor air sensors
- Electrical plug and ethernet available
- Sensor box can be somewhat large
- Access to room/building air concentration, not exposure

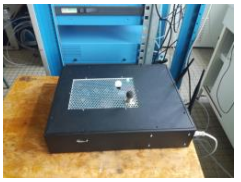
3

From sensors to data

Individual sensors



Sensing node

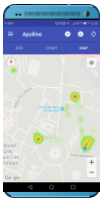


Communication protocol

Server (storage infrastructure)

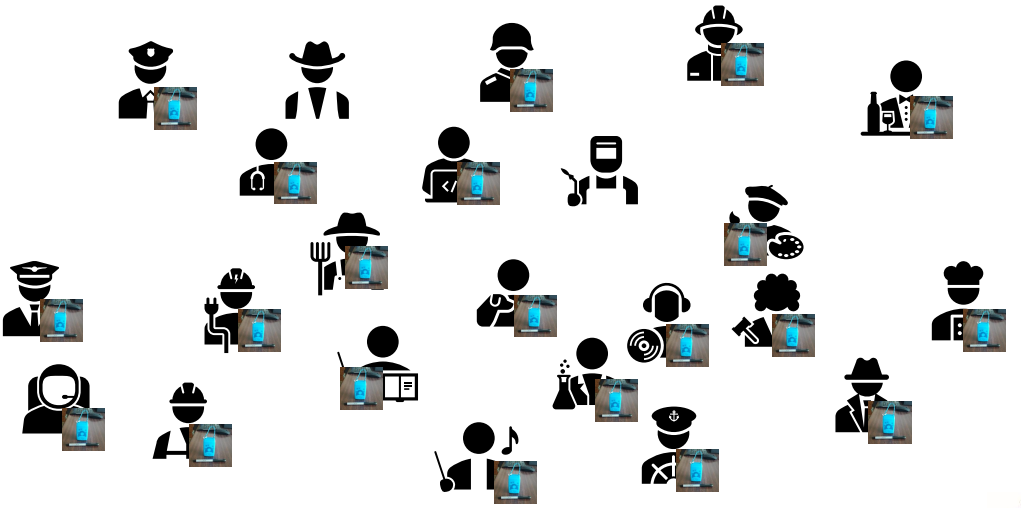
apisense

Delayed or real-time web-based display



4

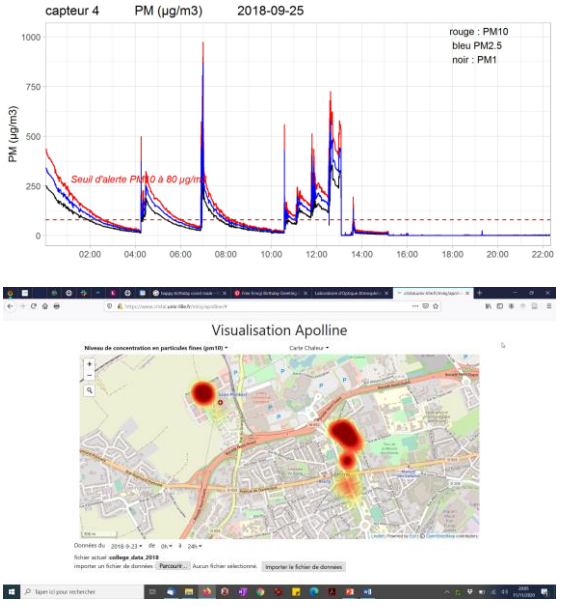
« Wearable sensors » strategy



Do we really want to have sensors on everyone ? (would be great also, but…)

5

24 hours with a sensor

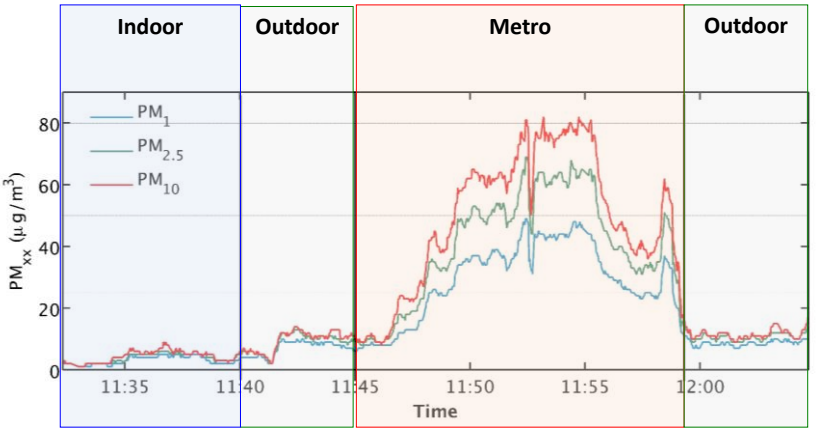


Challenges :

- Discrimination indoor/outdoor : jumps in T, RH, number of satellites…
- Metrology of sensors (changes in T, RH, speed)
- Data transfer
- Autonomy
- Time and space variability
- Inter-individual variability
- Are the sensor people-proof ?

6

Apolline in the subway

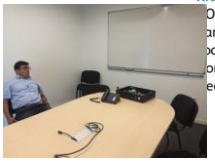


Indoor concentrations ~ 5 µg/m3
Outdoor concentrations ~ 10 µg/m3

PM_{10} Subway concentrations up to 80 µg/m3
PM_1 Subway concentrations up to 50 µg/m3

7

« Fixed sensors » strategy



edrooms
ust and dust mites, bacteria and viruses, pet dander, VOCs from ersonal care products

athroom
Mould and mildew, acteria, VOCs and ther chemicals from leaning products

Kitchen
O, NO_2 and articulates from gas ookers/stoves, VOCs om household eaning products

Attic
Man-made mineral fibres, asbestos, formaldehyde, dust

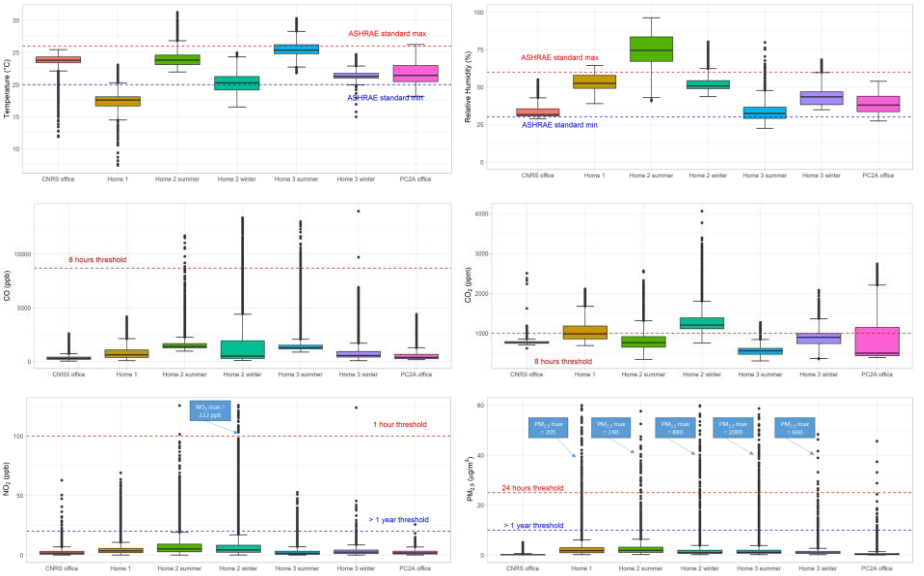
Living areas
Radon from soil/bedrock, CO and NO_2 from fires and wood-burning stoves, VOCs and formaldehyde from carpets, paints, glues, furniture and air fresheners, tobacco smoke, pet dander

Garage
CO from car exhaust, mould an VOCs fro paints an pesticides herbicides

Do we really want to have sensors in every room of every building ? (would be great, but…)

8

What inter-dwellings variability ?



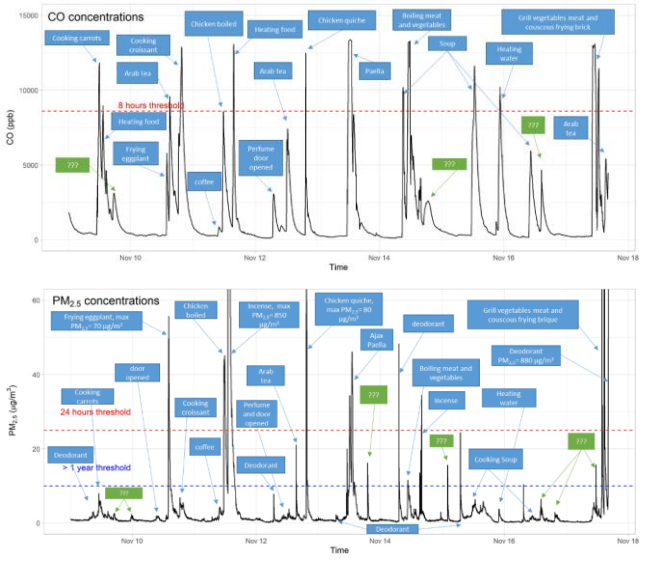
All investigated environments behave similarly.

Main difference is T and RH, driven by behavior, not by pollution sources.

The « statistical » outliers correspond to pollution episodes driven by activities.

9

Identification of patterns associated to activities



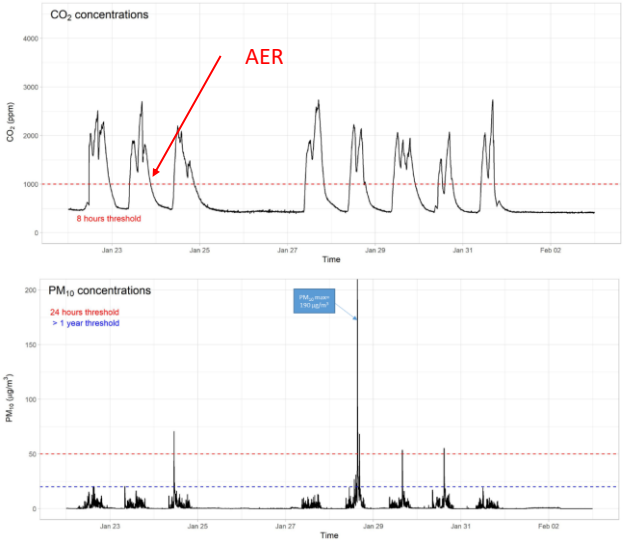
Self-reported activities : cooking (various methods), some cleaning.

Some events detected but not reported.

« Chemical signature » of activities. Need to construct a database for such signatures.

10

Sensors and ventilation



Students in their office at the University

CO2 as a proxy to trigger ventilation only when necessary.

11

From sensors to usable information

Sensing node

Server (storage infrastructure)

apisense

Can we / should we analyze the data before transmission ?

- **Partial information**
- **Computation power**
- **Less transmissions**
- **Energy efficiency**

Data analysis : ongoing work, and the key to putting sensors everywhere

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Take home messages

- Wearable and fixed sensors allow to monitor or evaluate personal exposure.
- Provided you can fix all technical issues : sensor response, size, weight, autonomy, cost, communication protocols, storage infrastructure…
- Not that much low cost, if you consider putting sensors everywhere, framework infrastructure, calibration and operation, environmental cost
- For exposure, recommandation for a network of wearable sensors / fixed sensors / reference monitoring stations
- Issue #1 : make sure what the goal is : exposure characterization, building-related pollution, activity-related pollution, building management, alerting system…
- Issue #2 : what are we looking for ? Environmental parameters, particles, (speciated) gases, exposure duration, pre-identified events, unexpected events…
- Issue #3 : how and when to analyze ? Delayed/real-time. Server/on-board sensor. Time-series, classification, artificial intelligence…

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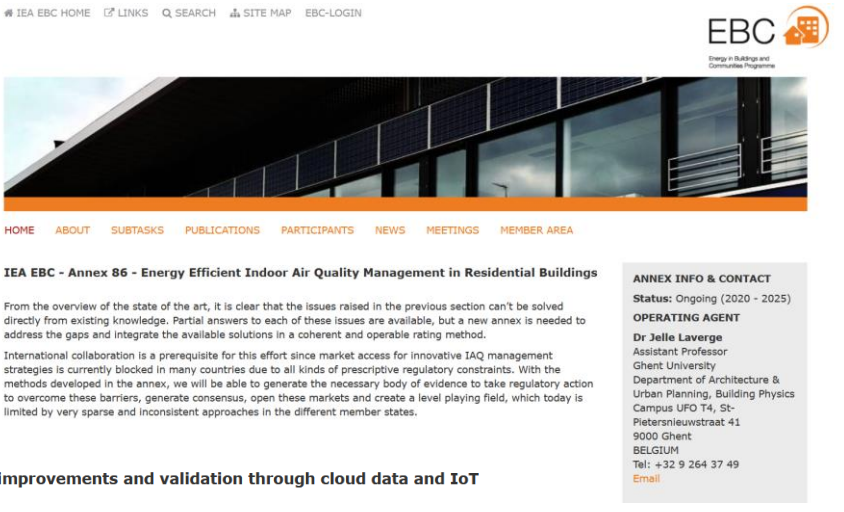
https://annex86.iea-ebc.org/



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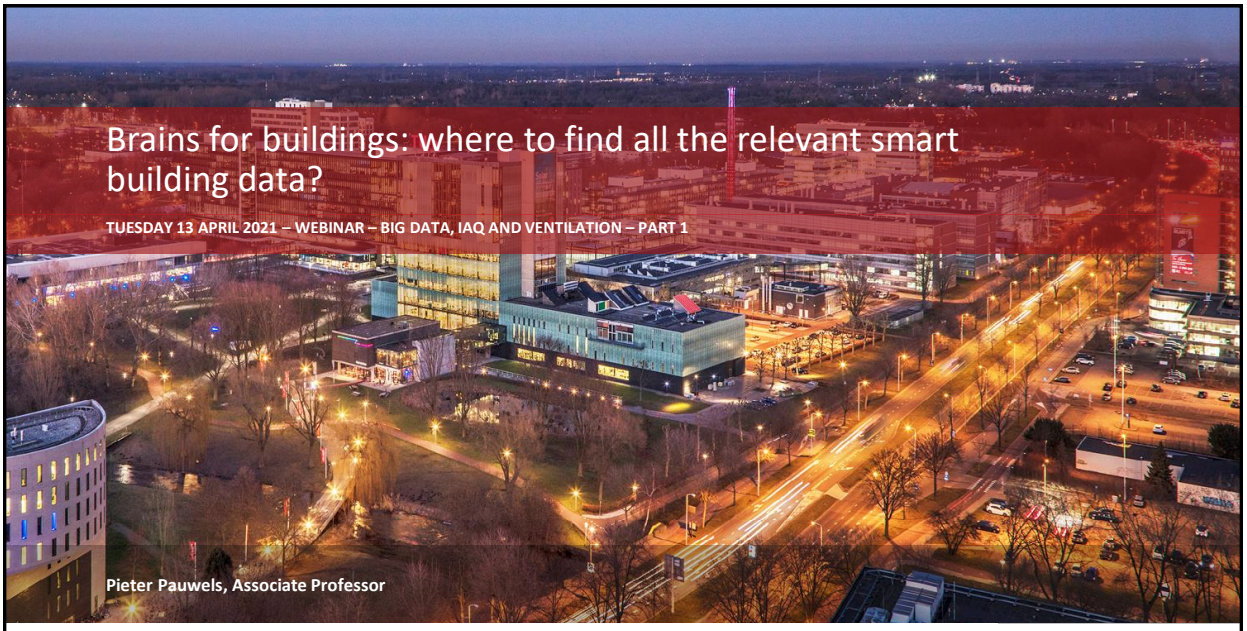
Thanks to :

- the participants in the studies
- the U Lille APOLLINE team that designed and implemented the sensors network infrastructure
- the APOLLINE funding partners : CLIMIBIO, IREPSE, CaPPA, Rincent Air, I-SITE ULNE
- the AIVC Webinar organizers
- the audience



Department of the Built Environment, Information Systems in the Built Environment

TU/e EINDHOVEN UNIVERSITY OF TECHNOLOGY

1

Who am I?

GHENT UNIVERSITY

W3C®

buildingSMART

Associate Professor TU Eindhoven (2019)

Assistant Professor Ghent University (2016-2019)

Postdoc Ghent University (2014-2016)

Postdoc University of Amsterdam (2012-2014)

Master & PhD in Civil Engineering – Architecture @Ghent University (2008, 2012)

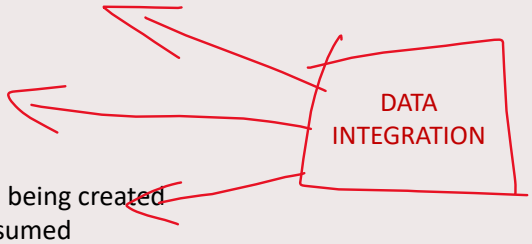
2

Presentation Outline

1. Brains 4 Buildings: why?
2. Building Data Semantics: BIM, IFC, LBD, BRICK, etc.
3. System Integration for scalability and feasibility

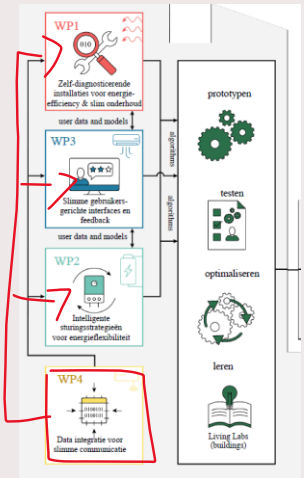
End aims and user stories

- Fault detection (improved building management systems – BMSs)
  - understanding what goes wrong in a system
  - predicting when faults occur and having clues about the why
  - live detection
- User-centered systems
  - comfort levels per individual user
  - learning from user interaction
- Flexible Energy (interfaces):
  - consumption of energy where it is being created
  - creation of energy where it is consumed
  - load balance in the local and regional grid, including the appliances used



5

Data Integration for Smart Buildings



To enable making our buildings smarter, advanced data integration is needed (among several other matters):

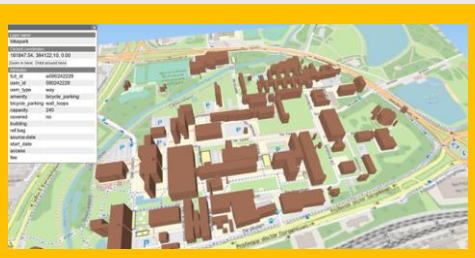
- Ensure **data connectivity** between applications
- Ensure security, **ethical use and privacy of data**
- **Standardise** data sets and approaches
- Aim for **system integration at API level**, between individual systems of diverse manufacturers

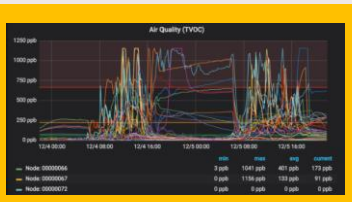
6

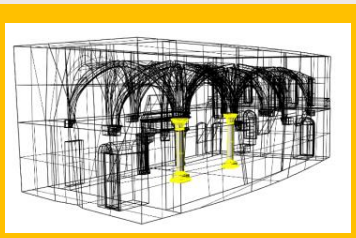
Presentation Outline

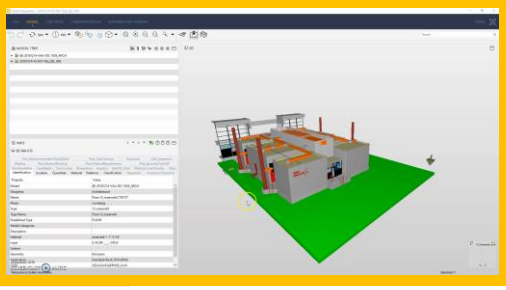
1. Brains 4 Buildings: why?
2. Building Data Semantics: BIM, IFC, LBD, BRICK, etc.
3. System Integration for scalability and feasibility

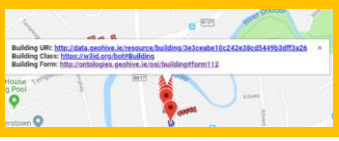
All sorts of data available …





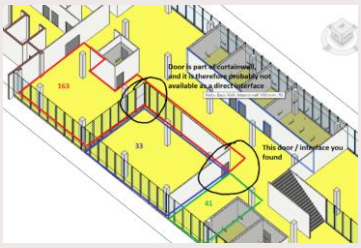


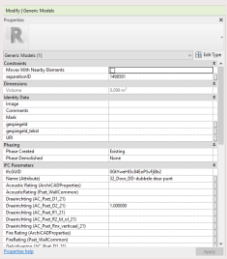


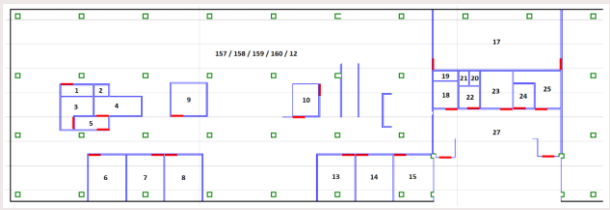


BIM Data

BIM data: Revit, modelling guidelines, agreements, 3D modelling, and IFC

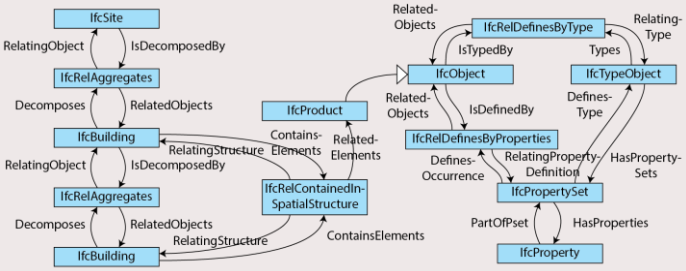


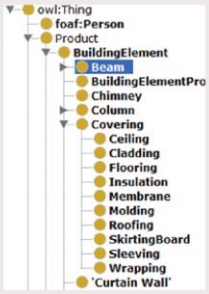


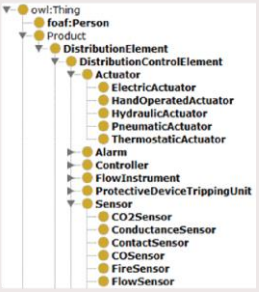


Data in the Industry Foundation Classes (IFC)

- Overall building shape and topology easy
- Classification of elements possible, but not many classes => extension with bSDD classes and properties possible
- Difficult (not impossible) to include sensor data (timeseries data)
- Availability in STEP, XML, RDF, and JSON







W3C Linked Building Data

Emergence of W3C LBD Community Group: Mission Statement

Bring together experts in the area of Building Information Modeling (BIM) and Web of Data technologies to:

1. define existing and future use cases and requirements for Linked Data based applications across the life cycle of buildings.
2. discuss best practices for publishing building data on the Web propose ontology models to describe:
    1. Buildings and building elements (topology, associate values to properties)
    2. Products and product properties
3. discuss how they can be used together with other specifications:
    1. existing standards (IFC, GeoSPARQL, Semantic Sensor Network, ...)
    2. separate initiatives (schema.org, Haystack, BRICK, ...)

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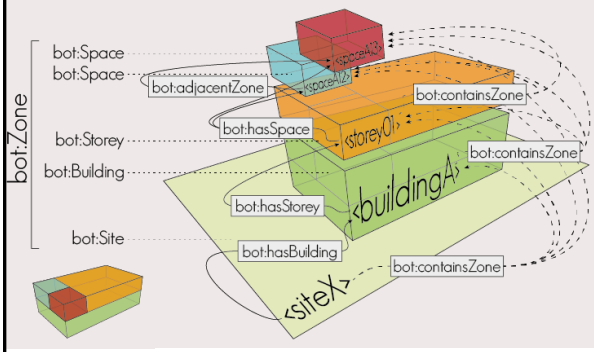
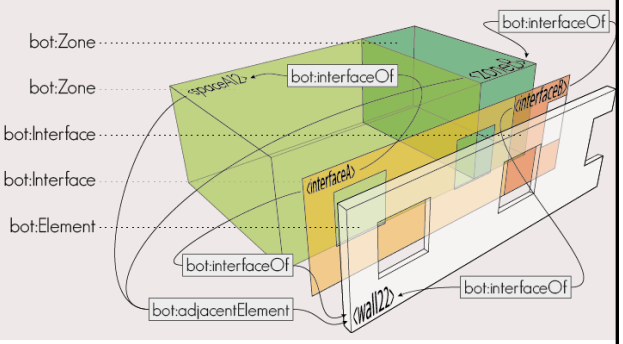
Scope of BOT: just the start, allowing to extend

- Limited set of classes
- Extensible and easy to combine with other ontologies and data sets
- Comprehensible





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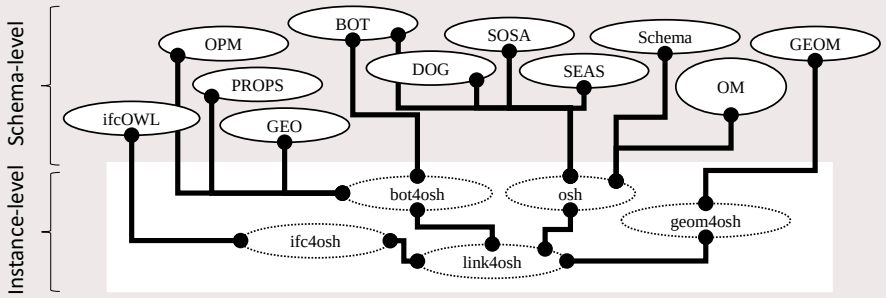
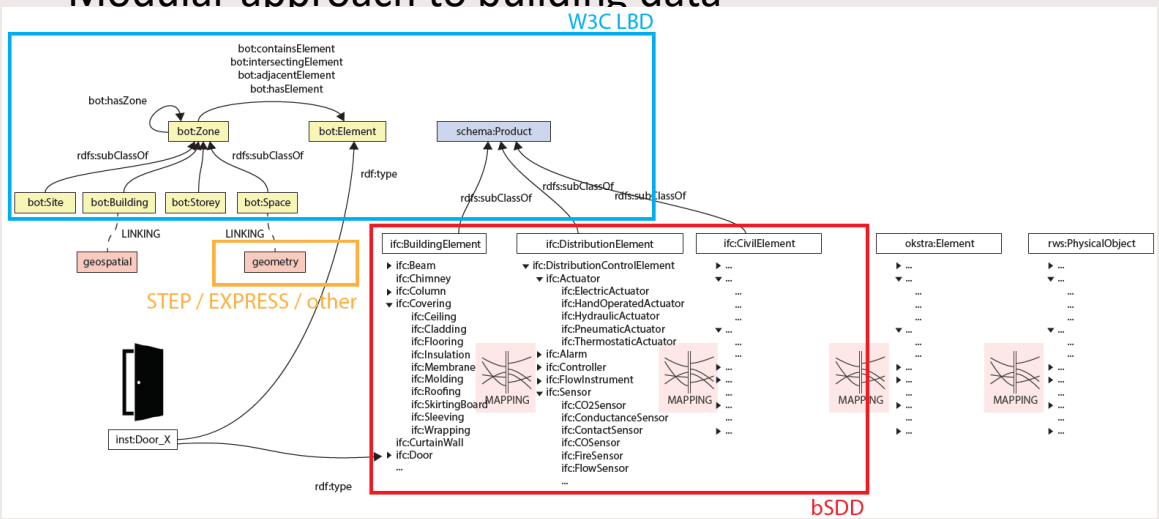
Modular ontology modelling advocated by LBD group



- Implemented using Semantic Web Technologies -> Web-scale, queryable
- Reuse of existing ontologies -> Modular
- Linking at instance level -> Multi-model method

Sample dataset available at:
https://github.com/TechnicalBuildingSystems/OpenSmartHomeData

Modular approach to building data



Reference ontologies

BOT	https://w3id.org/bot#
BEO	https://pi.pauwel.be/voc/buildingelement/
MEP	https://pi.pauwel.be/voc/distributionelement/
OMG	https://w3id.org/omg#
FOG	https://w3id.org/fog#
BPO	https://www.w3id.org/bpo#
OPM	https://www.w3id.org/opm#

Revit to LBD exporter: on demand
IFC to LBD converter: on demand

BRICK, HTO, SAREF, and REC

BRICK, HTO, SAREF, REC, etc.

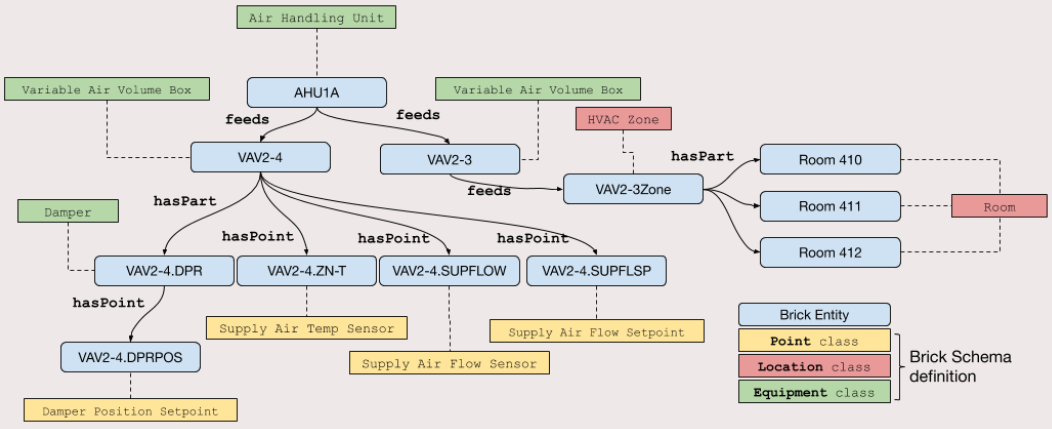
- Developments are rather disconnected from any BIM- or building-related area
- Focus on systems, incl. operation and control
- Focus on the sensor Point and Equipment types

- Beware of biased overview tables

Modeling Support	Brick	Project Haystack	IFC	BOT	SAREF
HVAC Systems	yes	yes	yes	no	no
Lighting Systems	yes	partial	yes	no	no
Electrical Systems	yes	yes	yes	no	no
Spatial Information	yes	no	yes	yes	no
Sensor Systems	yes	yes	generic	no	yes
Control Relationships	yes	no	generic	no	no
Operational Relationships	yes	no	generic	no	no
Formal Definitions	yes	no	yes	yes	yes

https://brickschema.org/

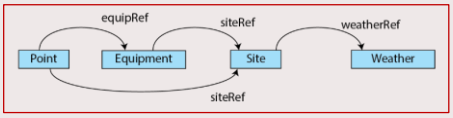
BRICK - A uniform metadata schema for buildings



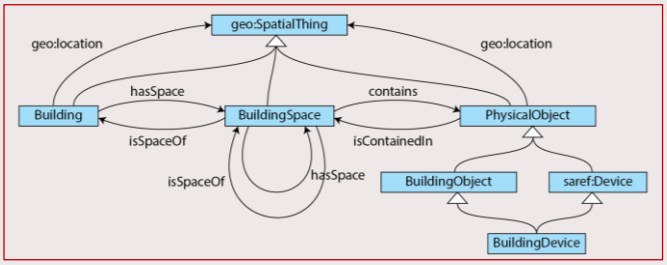
https://brickschema.org/

BRICK, HTO, SAREF, REC, etc.

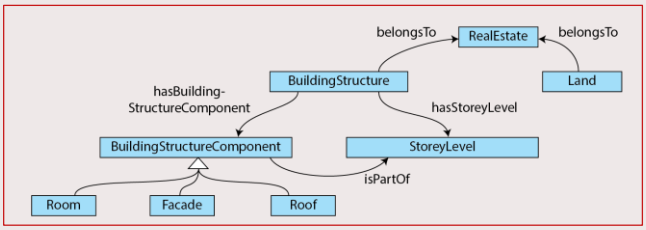
BRICK



SAREF4BLDG



Real Estate Core



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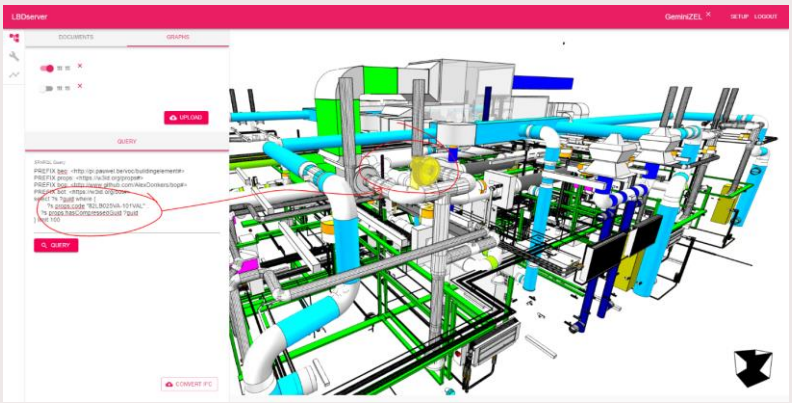
In short

Nothing that cannot be included in a modular linked building data (LBD) cloud.



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Presentation Outline

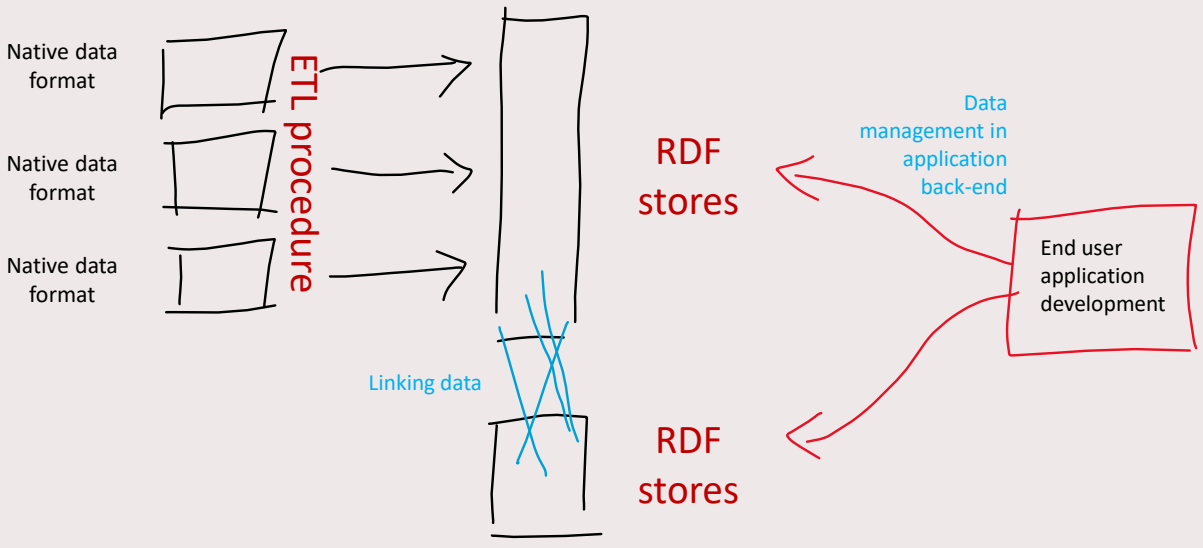
1. Brains 4 Buildings: why?
2. Building Data Semantics: BIM, IFC, LBD, BRICK, etc.
3. System Integration for scalability and feasibility

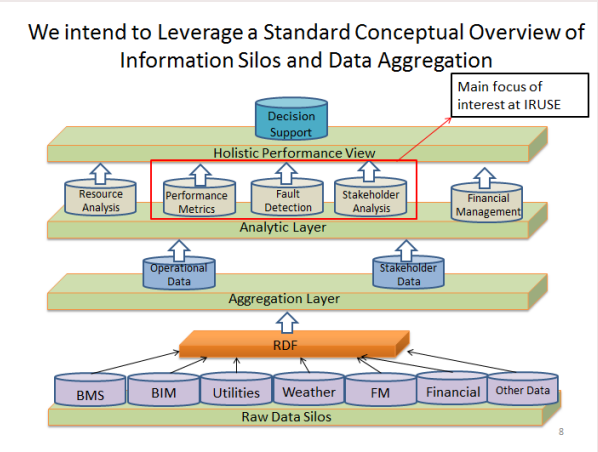
Mapping all into RDF

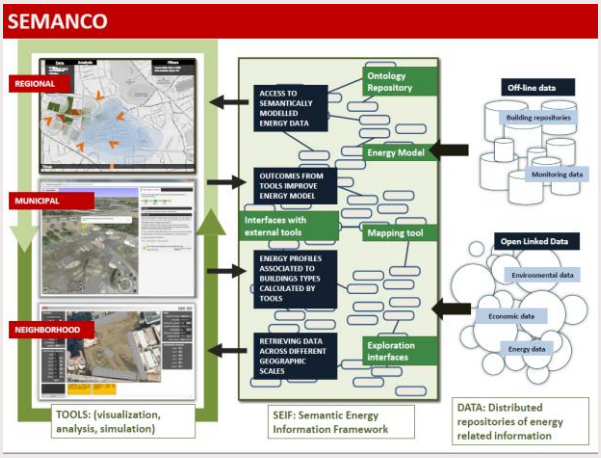
Available options for integration for software

OPTION 1: Transform all into semantic graphs (e.g. R2RML or custom data transformers) and do data integration

- Plus: all in same format
- Plus: inference possible
- Minus: unfit storage
- Minus: disconnect from origin
- Minus: no ML algorithms nor procedural code possible
- Minus: how to handle privacy and security (trust?)

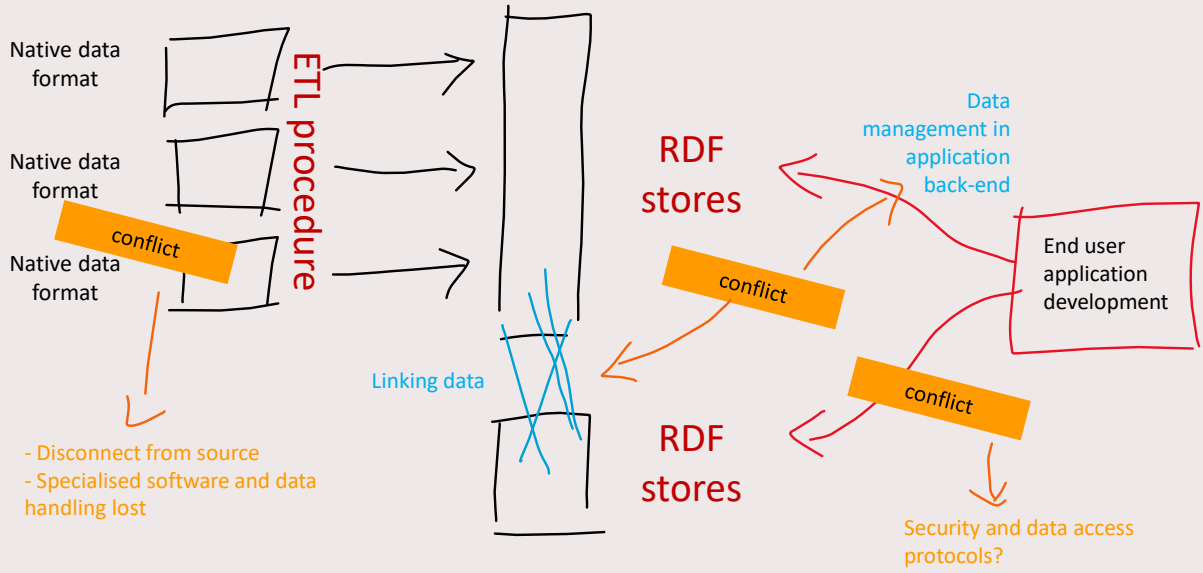






Gonçal Costa, Alvaro Sicilia, Leandro Madrazo. Energy efficiency of buildings. 1st Intl. Workshop on Linked Data in Architecture and Construction. Ghent, BE, 2012.

James O'Donnell, Edward Corry, Edward Curry, Marcus Keane. Building and using multi-domain data. 1st Intl. Workshop on Linked Data in Architecture and Construction. Ghent, BE, 2012.

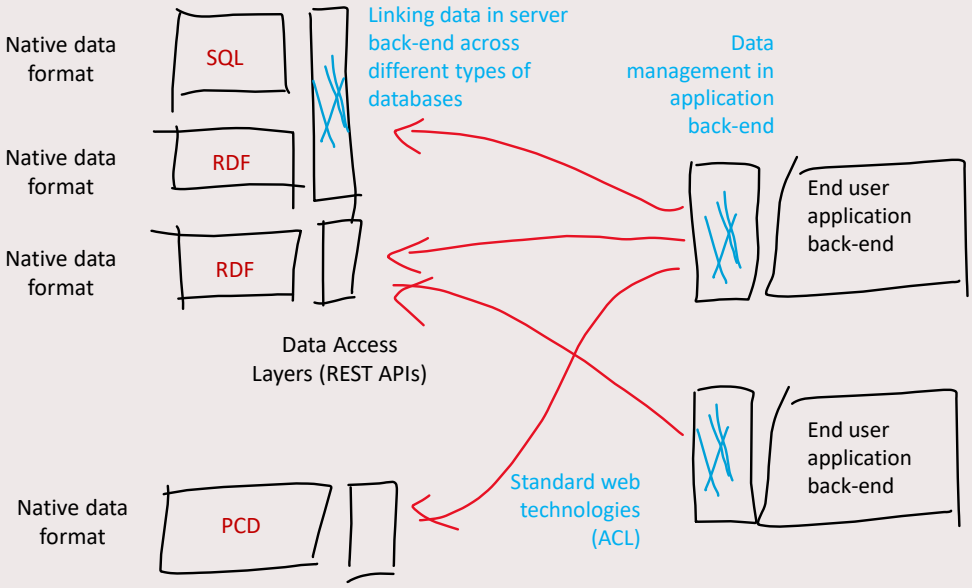


Maintaining specialized data stores and deploying web technologies

Available options for integration in trustworthy manner

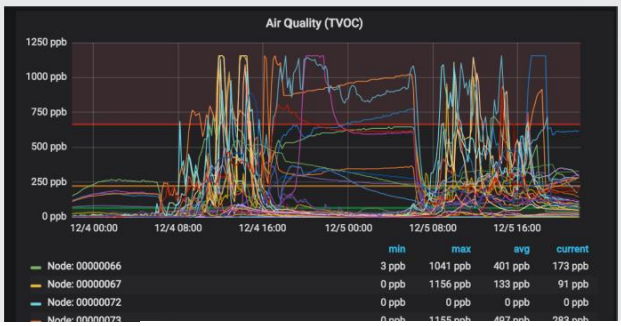
OPTION 2: Store all in well-fit data stores (KV stores, graphDBs, relational DBs, timeseries stores, etc.) and perform data integration (also) on a system and API level (system integration)

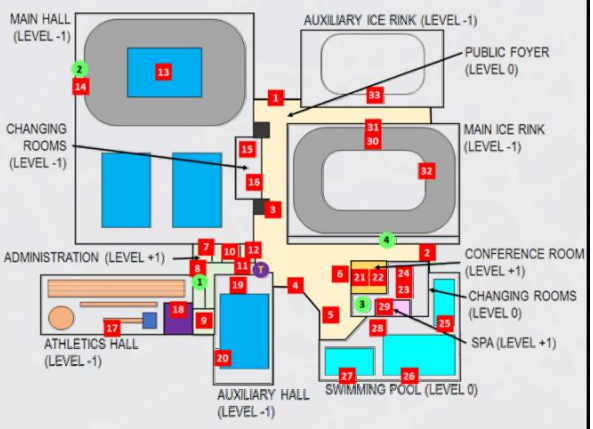
- Plus: apt data storage
- Plus: data stays at source -> web-based connections needed
- Plus: ML algorithms and procedural algorithms not blocked
- Plus: Privacy and security can be easily handled at the gates of APIs and DBs.
- Minus: multitude of systems requires lots of diverse software and expertise



SENSOR DATA EXAMPLE: GIGANTIUM IOT LIVING LAB AALBORG

- 35 sensor nodes monitoring Temperature (°C), Relative Humidity (%), Air Pressure (hPa), Indoor Air Quality (Total Volatile Organic Compounds ((TVOC), ppb) and CO2 (ppm)), illuminance (lux) and motion
- Data storage in SQL database
- Data monitoring and visualization in Grafana





Source: Rodriguez et al. (2018)

Grafana

SEMANTIC GRAPH ENRICHED WITH PERFORMANCE PATTERNS AND WEB REFERENCE TO SENSOR DATA

```
inst:room_16
        rdf:type bot:Space ;
        gig:hasSensorNode inst:sensorNode_0000014 ;
        gig:spaceType "Cafe" ;
        rdfs:label "Cafe" .

inst:sensorNode_00000014
        rdf:type gig:SensorNode ;
        rdfs:label "00000014" ;
        gig:observation "Indoor climate" ;
        gig:purpose "Thermal comfort in the lobby during big events when there is a gathering of a lot of people." ;
        sosa:hosts inst:sensor_00000014_1, inst:sensor_00000014_2, inst:sensor_00000014_3, inst:sensor_00000014_4, inst:sensor_00000014_5,
inst:sensor_00000014_6 ;
        gig:placement "Placed on a column in the cafe without direct sunlight." .

inst:sensor_00000014_1 ;
        rdf:type sosa:Sensor ;
        sosa:madeObservation inst:observation_1 ;
        sosa:observes inst:obsProperty_1 ;
        rdfs:label "00000014_1" .

inst:result_1 rdf:type sosa:Result ;
        rdfs:label "Result of observation of Relative Humidity";
        gig:values "https://gigantium.dk/Gigantium2018instances?orgId=1&datastream=true" .
```

Petrova, E., Pauwels, P., Svidt, K., Jensen, R.L. (2018) From patterns to evidence: Enhancing sustainable building design with pattern recognition and information retrieval approaches. Proceedings of the 12th ECPPM conference, pp. 391-399.

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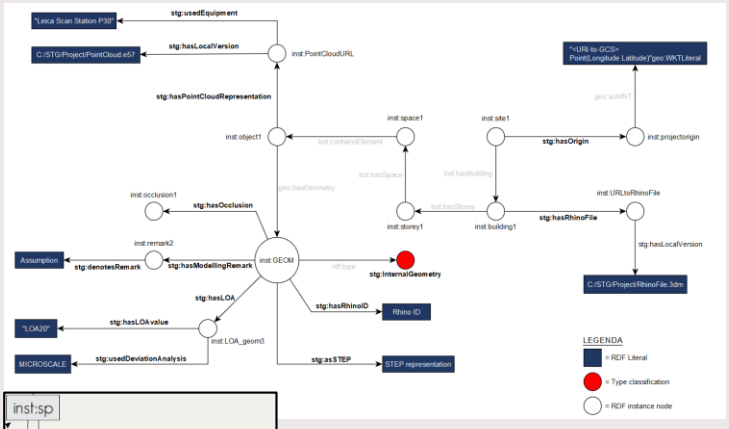
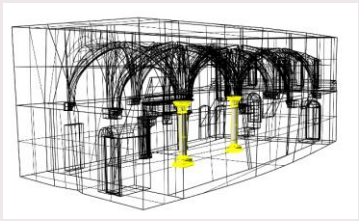
Abox linking to point cloud data and geometry





Jeroen Werbrouck et al., Scan-to-graph: Semantic enrichment of existing building geometry, Automation in Construction, 119 (2020). https://doi.org/10.1016/j.autcon.2020.103286.

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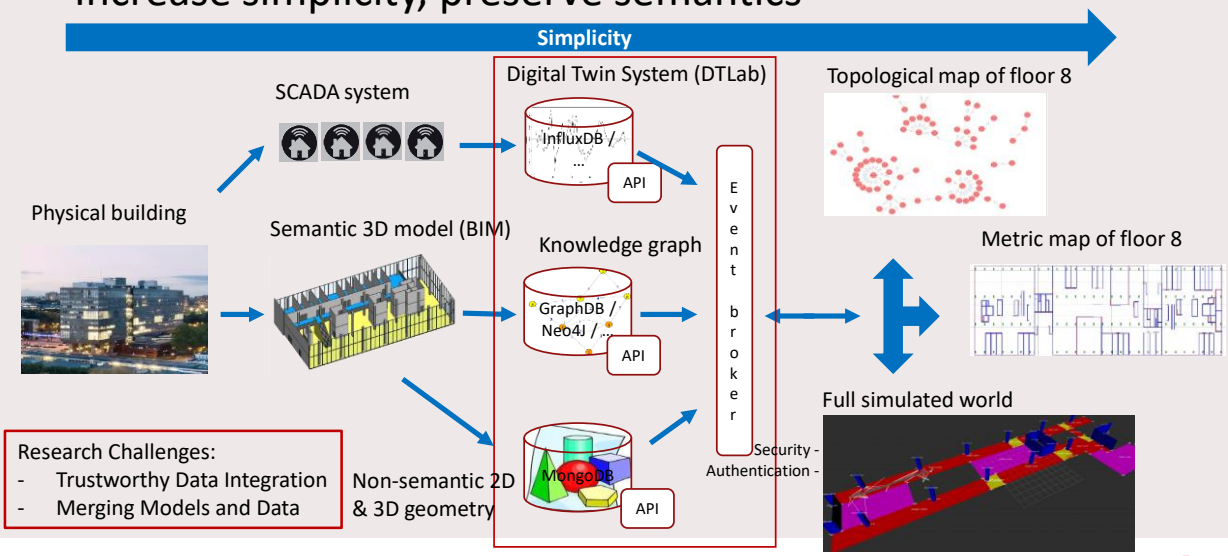
Increase simplicity, preserve semantics



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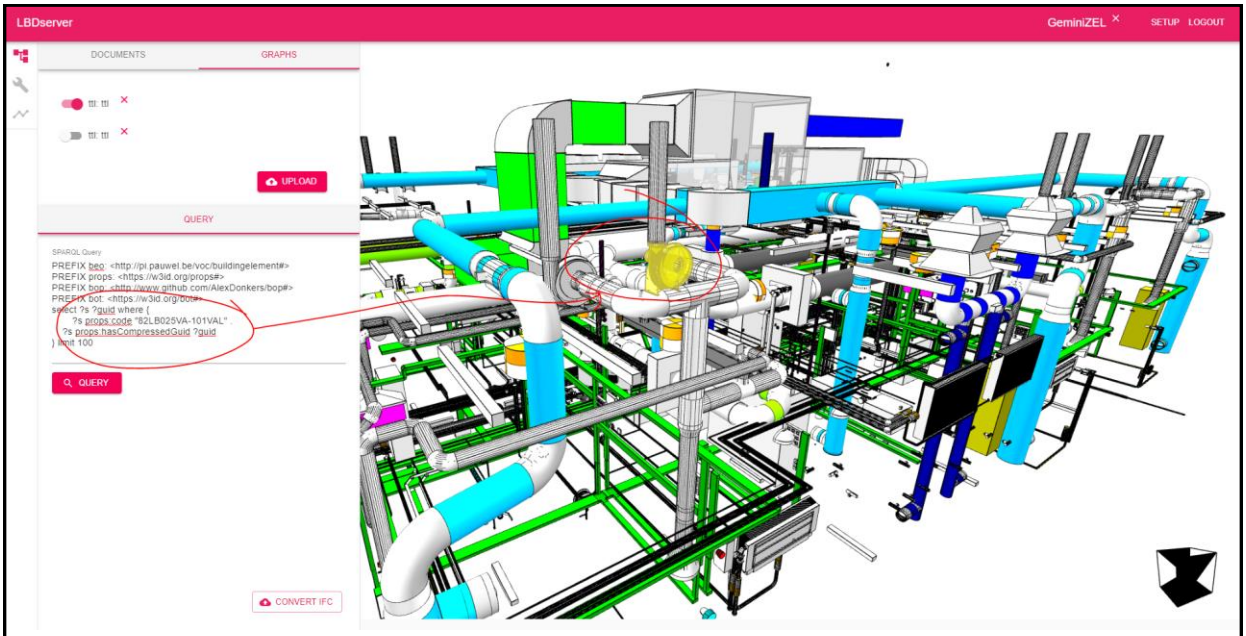

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Presentation Outline

1. Brains 4 Buildings: why?
2. Building Data Semantics: BIM, IFC, LBD, BRICK, etc.
3. System Integration for scalability and feasibility