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Findings of IEA Annex 81 ‘Data-Driven Smart Buildings’

Dr. Stephen White
IEA Annex 81 Operating Agent

What makes a building ‘smart’?

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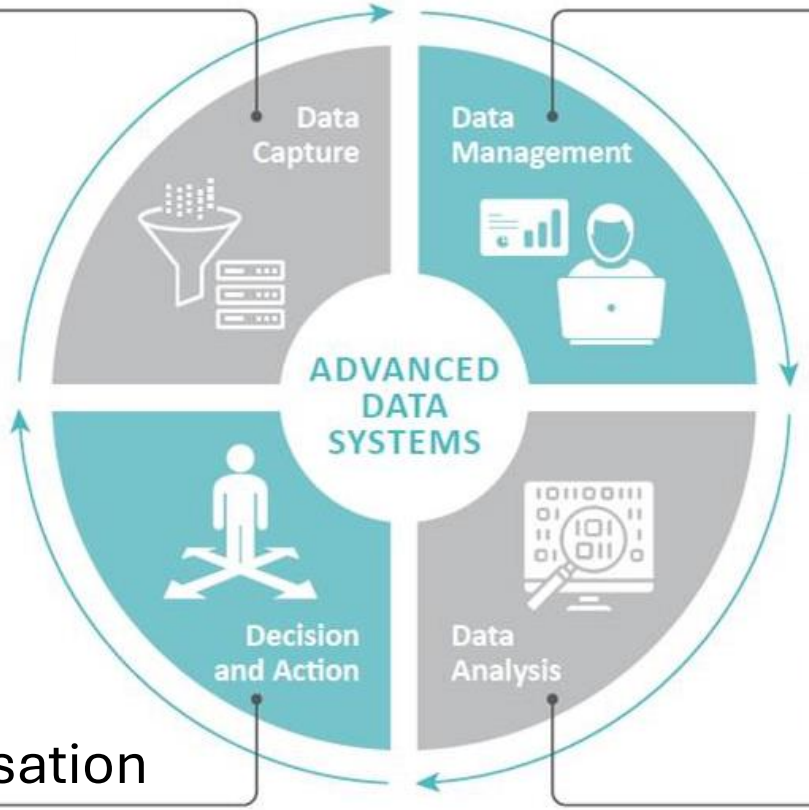
- Energy meter
- IoT sensors and devices
- Connected BMS
- Mobile devices



- Access controls
- Data federation
  - Standard data structures

- Dispatch instructions
- Automated settlement
- Human interfaces & visualisation

- Data mining
- AI/ML

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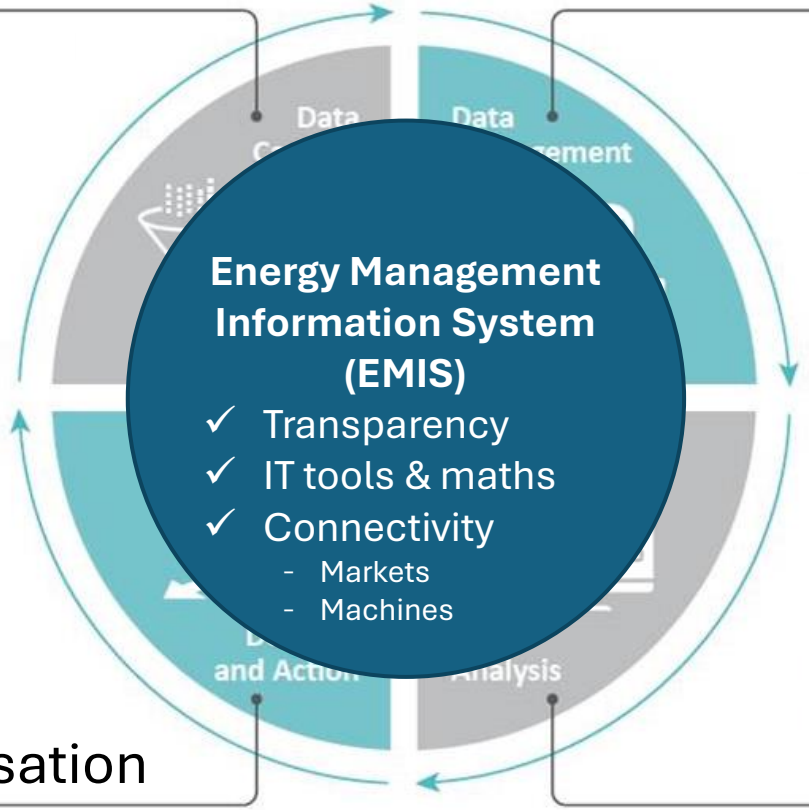

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“Platform” for managing multi-stakeholder interactions

Scaling AI

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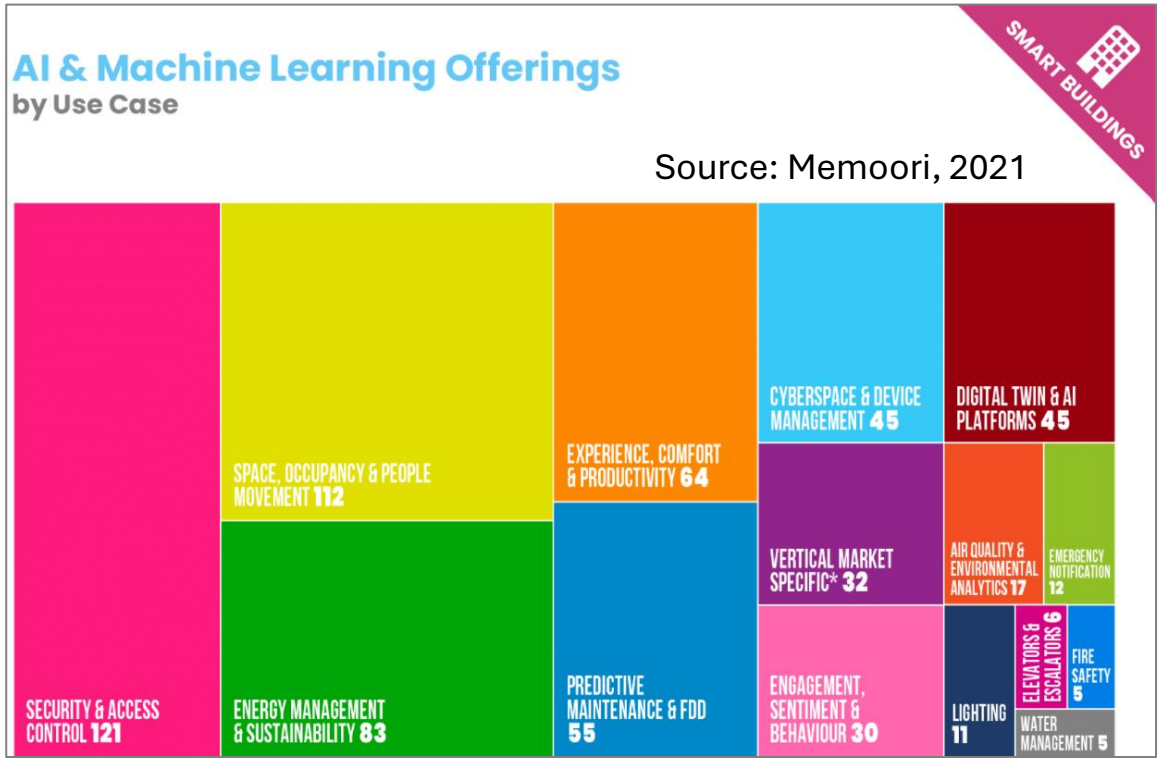

What creates scalability???

1. Use of data-driven algorithms (*Machine-Learning: numerical trial-and-error Vs physical rules-based*)
   - Automated logic instead of labour-intensive human logic
   - New value by identifying unexpected patterns

2. IT industry data infrastructure/ practices
   - Machine to machine connectivity
   - FAIR data management

↳ **Self-service deployment**

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Subtask A:
Data Sharing and Data Platforms

Cloud-Based Data Management?

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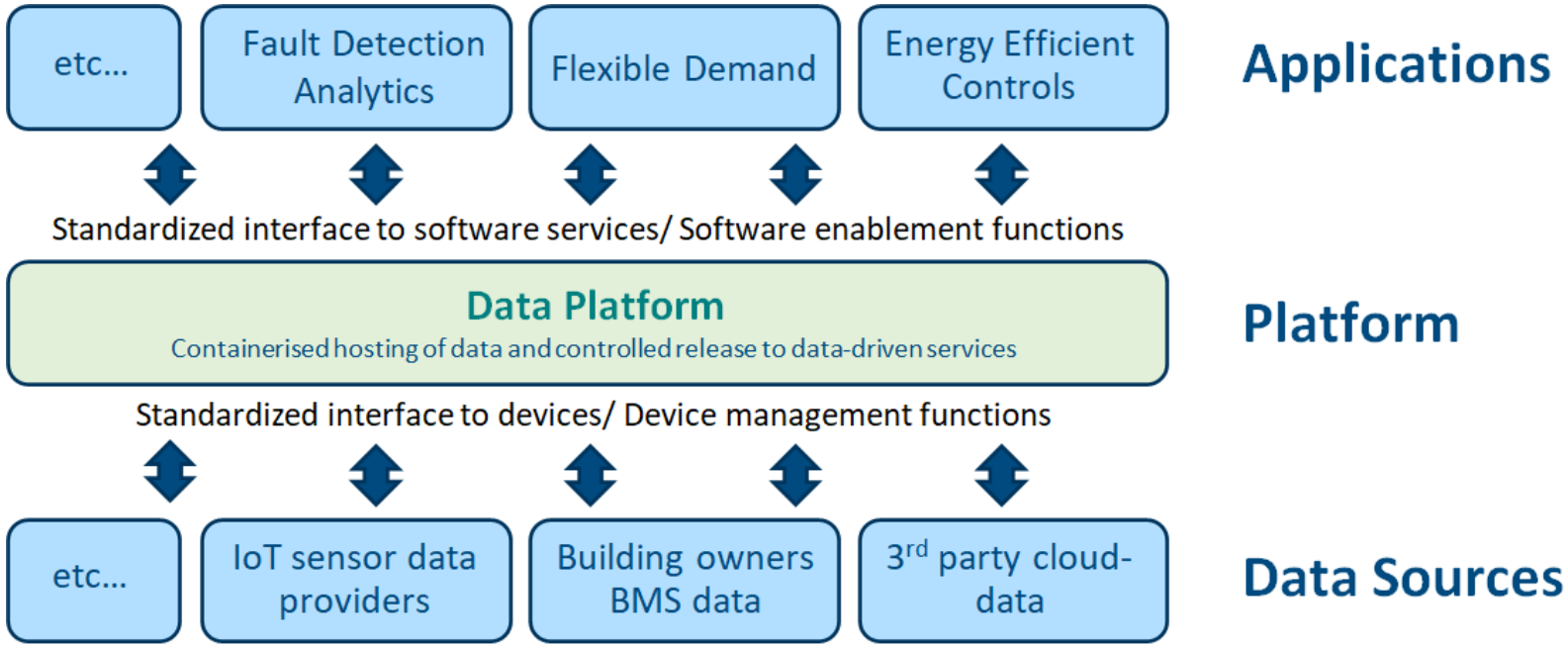
- ✓ Remote access to services.
- ✓ Scalable resources and access to specialist data management skills.
- ✓ Consolidation with 3rd party data.



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Theme 2: Establish 'digital ready' certification

"when you talk about analytics, it's all about data management, right? - Data quality, data management."
SaaS Platform Provider

"I mean, it's not a secret that in anything data driven 80% of the effort is in the data part"
SaaS Platform Provider

"Standards on data modelling/ acquisition would be very helpful"
Controls Contractor

"I think for me it all comes back down to the data structures. How fast it can go will be related to how interoperable and structured in standard are the different assets".
SaaS Platform Provider

"the next challenge is ultimately standardisation"
SaaS Platform Provider

"We have to convince them with lot of certifications. We have to spend so much of our budget qualifying for the cyber security so that our product is qualified"
Hardware Supplier

"How do we get consistent data and how consistent does the data need to be. At the moment, everyone's got data and different bits and pieces [of data but] it's not associated with a clear taxonomy or labelling piece"
Consultant

"A digital ready audit for the customer. There's no point putting analytics on the table if a customer's not digitally ready."
SaaS Platform Provider

"[Facilities Management is] like going into a library and someone's got in there before you and messed it all up, and they've swapped all the books around and you spend a day trying to find something which should be categorized properly"
Facilities Manager

"regulatory measures might be like specifically implementing smart metering properly and that gets the infrastructure in place to collect the data appropriately"
Consultant

"The ability to get like that, bronze, silver and gold kind of data cost effectively is critical and it might be about how that again is in their specification clauses - examples that you can kind of write out so it's easy to embed them in your future contracts."
Consultant

"What will it do to my building and how do I evaluate that? So it's kind of the quality assurance of AI piece that needs to be understood."
Consultant

"A clearly defined cloud infrastructure that is NIST compliant helps the owner or operator to overcome their fears"
Hardware Supplier

"If we had a plaque that says «you are digitized», at a standard level, silver level, etc... If something like this exists, then I can come into that building and provide my services very, very, very quickly."
SaaS Platform Provider

"It's better to focus on what the minimum pieces are for the minimum viable product?" ... "how do we transfer that digital information across at each stage and what should actually be required in that".
Consultant

"Buildings need to have at least certain level of digital maturity (accessibility for example)"
Building Owner

"I'm always against anything that's trying to standardize ... because it usually has the attitude that it's one answer, and that answer fits everything... we know that's not the case".
Consultant

The FAIR Data Principles

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Box 2 | The FAIR Guiding Principles

To be Findable:
F1. (meta)data are assigned a globally unique and persistent identifier
F2. data are described with rich metadata (defined by R1 below)
F3. metadata clearly and explicitly include the identifier of the data it describes
F4. (meta)data are registered or indexed in a searchable resource

To be Accessible:
A1. (meta)data are retrievable by their identifier using a standardized communications protocol
A1.1 the protocol is open, free, and universally implementable
A1.2 the protocol allows for an authentication and authorization procedure, where necessary
A2. metadata are accessible, even when the data are no longer available

To be Interoperable:
I1. (meta)data use a formal, accessible, shared, and broadly applicable language for knowledge representation.
I2. (meta)data use vocabularies that follow FAIR principles
I3. (meta)data include qualified references to other (meta)data

To be Reusable:
R1. meta(data) are richly described with a plurality of accurate and relevant attributes
R1.1. (meta)data are released with a clear and accessible data usage license
R1.2. (meta)data are associated with detailed provenance
R1.3. (meta)data meet domain-relevant community standards

Wilkinson et al, 2016 '"The FAIR Guiding Principles for Scientific Data Management and Stewardship", Scientific Data, 3:160018'

Meta-Data Management for ‘machine readability’

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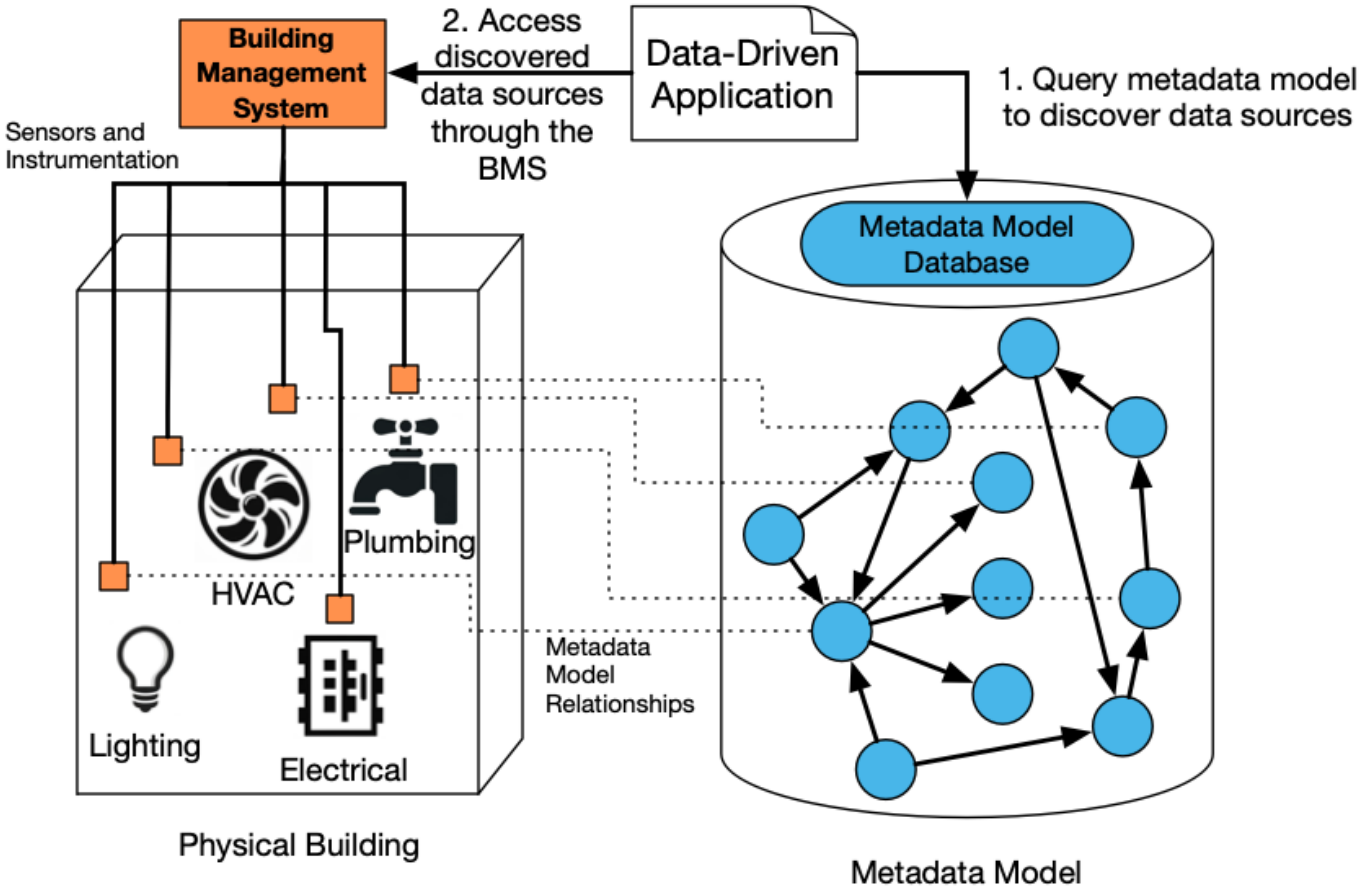

Meta-data ***schema***

- Ontologies

Meta-data ***model***

Semantic Sufficiency

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4.1 VAV Terminal Unit—Cooling Only

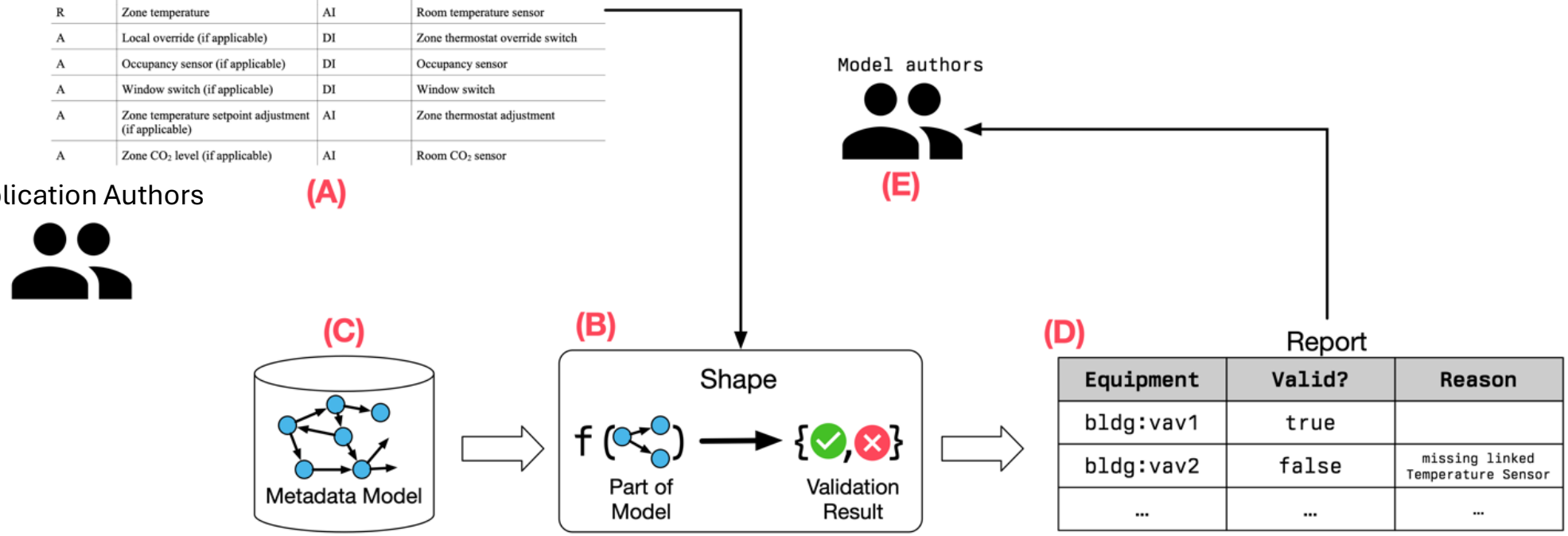
Required?	Description	Type	Device
R	VAV box damper position	AO OR two DOs	Modulating actuator OR Floating actuator
R	Discharge airflow	AI	Differential pressure (DP) transducer connected to flow sensor
R	Zone temperature	AI	Room temperature sensor
A	Local override (if applicable)	DI	Zone thermostat override switch
A	Occupancy sensor (if applicable)	DI	Occupancy sensor
A	Window switch (if applicable)	DI	Window switch
A	Zone temperature setpoint adjustment (if applicable)	AI	Zone thermostat adjustment
A	Zone CO_2 level (if applicable)	AI	Room CO_2 sensor

Application Authors

(A)

Model authors

(E)



Data Platform Features

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- Building onboarding and connecting to data-source
  - Building registration wizards
  - Device communication protocols
  - Data source discovery and authentication
- Data storage and retrieval
  - Data cleaning
  - Time series data storage
  - Meta-data structured storage
  - Data access permissioning system
  - Data download
- Data utilisation and user support
  - Basic visualisations and alerts
  - Compute resources and output results sharing
  - Application market-place and access to 3rd party data

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Subtask B: Model Predictive Control

Digital twin for control

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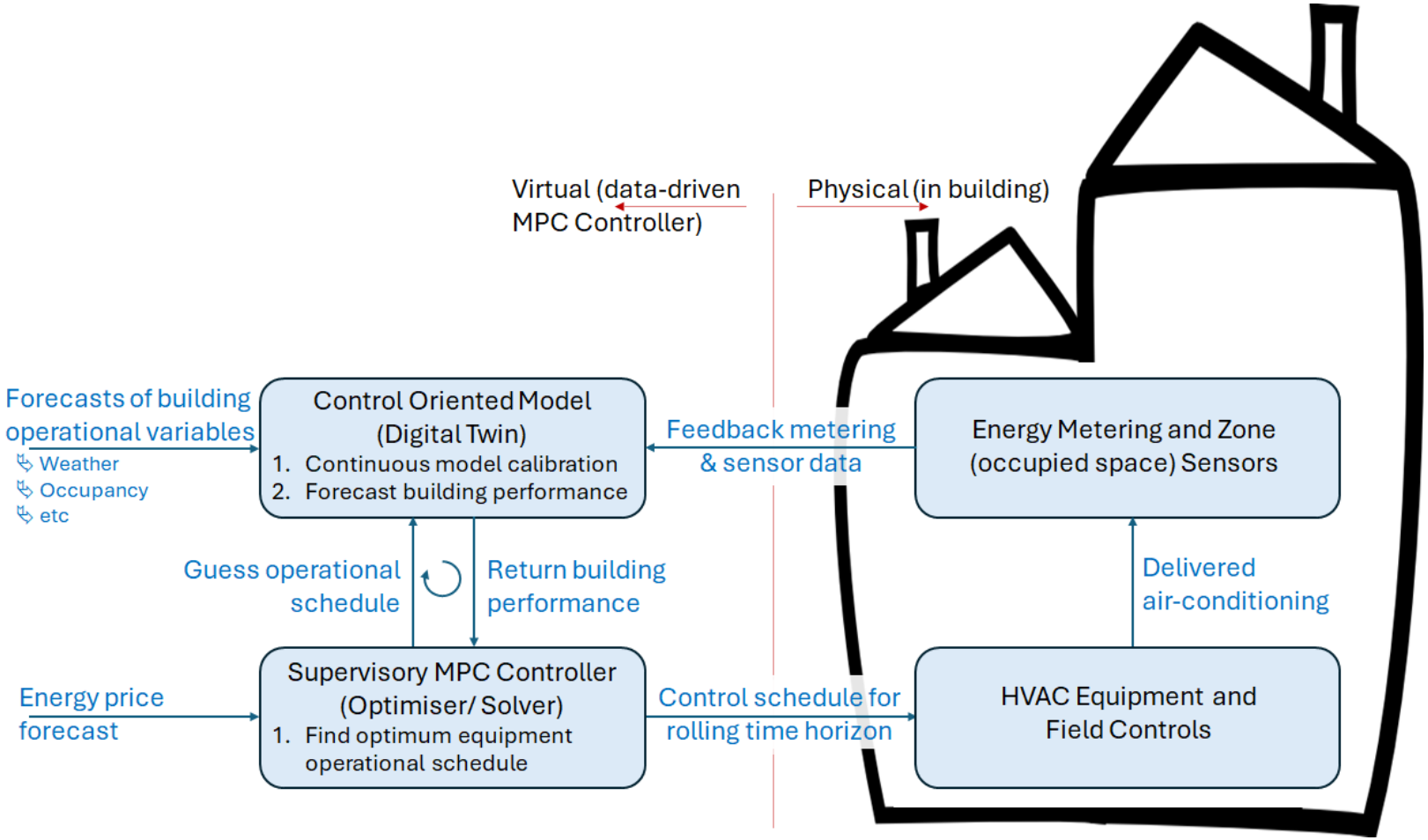
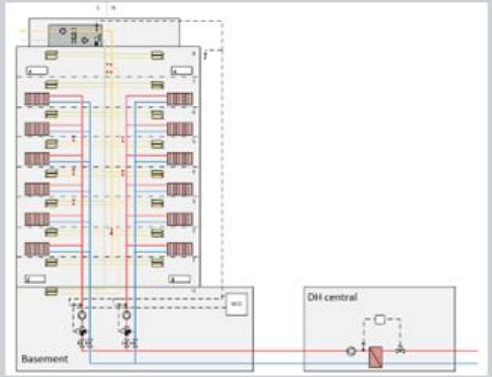


Multi-criteria optimisation

- Kh thermal discomfort
- Cost
- Emissions

Six exemplar datasets

1. Office Building (Oslo, Norway)	2. ZEB Living Lab (Trondheim, Norway)	3. FlexHouse (Copenhagen, Denmark)
		
• 8 floors, total area 3,800 m^2 (40,880 ft^2) • AHU with a rotating heat recovery wheel • District heating	• Testing facility, NTNU • 100 m2 (1100 ft2) • Space heating: floor heating, central radiator, air ventilation	• Experimental facility, DTU campus • Several zones instrumented independently

https://data.mendeley.com/datasets/xztfbtsgys/3

4. Varennes Library (Varennes, Canada)	5. FLEXLAB (Berkeley, California)	6. Office space / Research Techno Plaza (NTU, Singapore)
		
• 2100 m^2 (23100 ft^2) • 110 kWp of PV panels on the roof • 10 ground-source heat pumps	• Experimental facility, Berkeley • 3.64 kW PV system • Electric battery storage system	• Living lab, NTU • Testbed office with a floor area of 46 m^2 • VAV system

Common Exercise Studies

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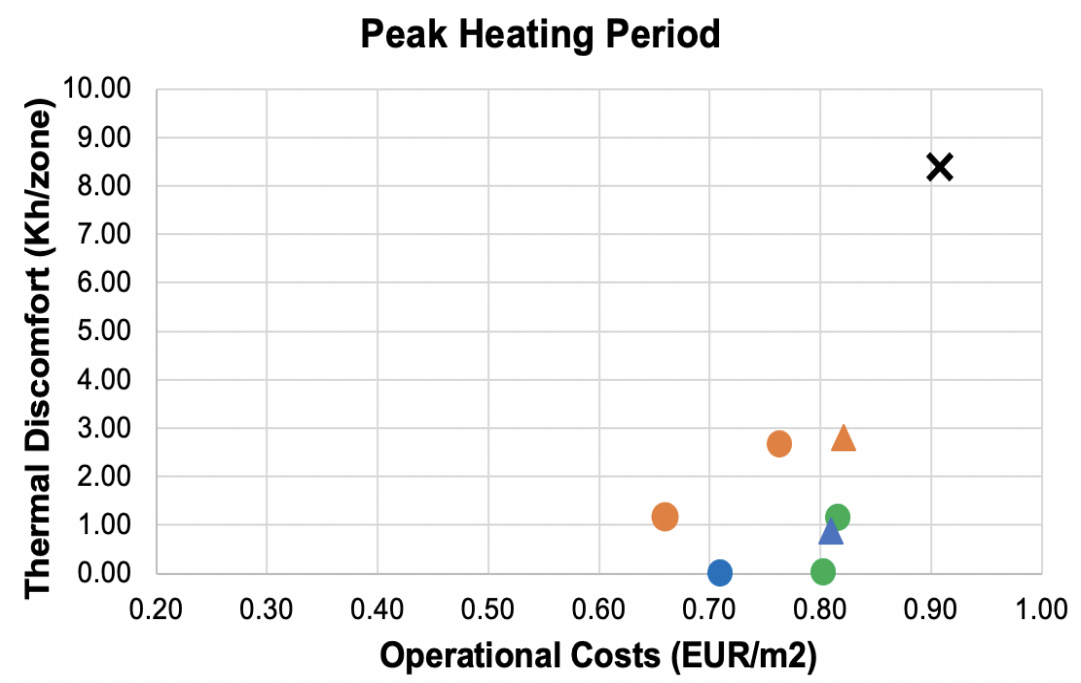
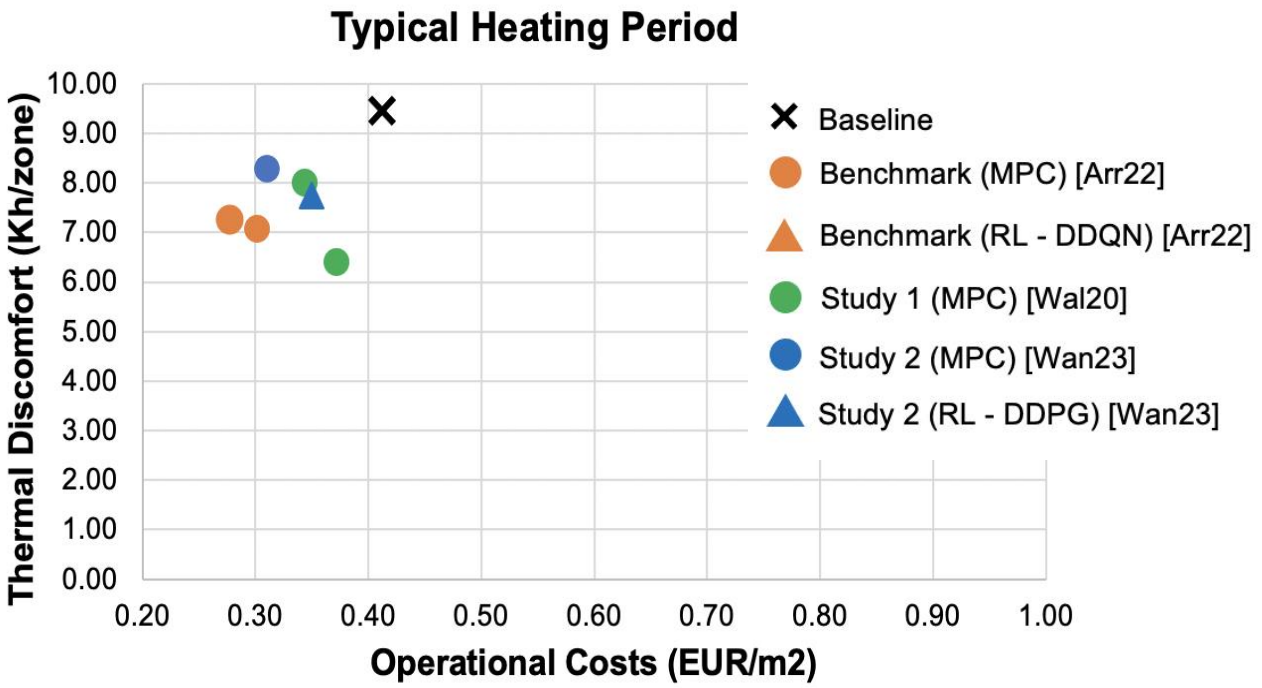
bestest_heat_pump_hydronic test case





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Subtask C: Applications and Services

- KPIs for Benchmarking
- Fault Detection and Diagnosis
- Building to Grid

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Subtask D:
Case Studies and Roadmap

Case Studies and Website

https://datasmartbuildings.org/

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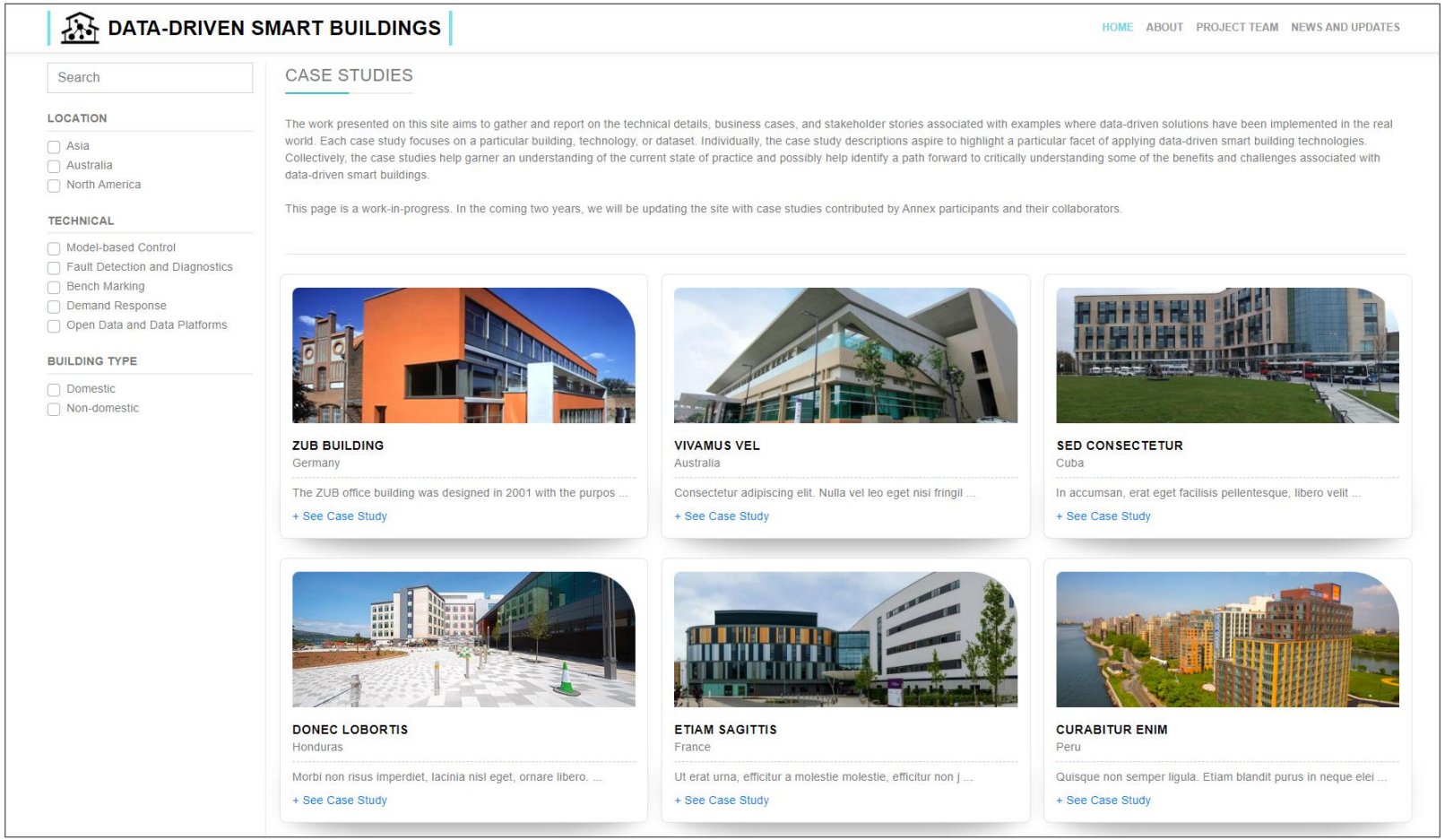
Lessons Learnt

- Data quality and management
- Technology specification and implementation,
- Stakeholder engagement,
- Governance, compliance, and legal oversight



Policy Roadmap Themes

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- **Theme 1: Provide Information** – to reduce complexity and information asymmetry for buyers.
- **Theme 2: Establish 'digital ready' certification** – to standardise solutions and recognise achievement.
- **Theme 3: Lead by example** – to provide a cohort of early adopters that catalyse the market.
- **Theme 4: Support researchers and innovators** – to catalyse a wider range of product offerings and industry maturity, and provide independent validation of the benefits of digitalisation.
- **Theme 5: Incentivise EMIS technology** – to improve the return on investment from the technology.
- **Theme 6: Reduce data sharing risk** – to improve certainty and manage possible compliance issues.
- **Theme 7: Build workforce skills and capacity** – to be able to deliver the services at scale.
- **Theme 8: Integrate buildings into the electricity system** – to prioritise the clean energy transition.

Defining and incentivising data infrastructure

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Current Industry

Bundled service for each Application

IT Infrastructure & Connectivity

Combined with

Single Application/ Solution

Barriers for each App
(mainly linked to IT infrastructure)

- ? Product confusion
- ? Interoperability
- ? Trust/ commercial capture
- ? Cybersecurity
- ? Data quality
- ? Complexity/ risk
- ? Cost (or cost uncertainty)

Desired Future Industry

Separated IT infrastructure and software Apps

Step 1

IT Infrastructure & Connectivity

'Digital Ready'

Step 2

Multiple Analytics, Advanced Controls, and Renewables Integration Applications

'Digital Ready' Outcomes

- Reduce product confusion
- Ensure interoperability
- Create trust
- Require cybersecurity
- Enable data quality
  - *Simpler*
  - *Lower cost*
  - *More certainty*

Resulting Proposals

- NCC J9D3 'Facilities for energy monitoring'
- VEU 'Foundational EMIS' Activity

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Thank You

Dr. Stephen White

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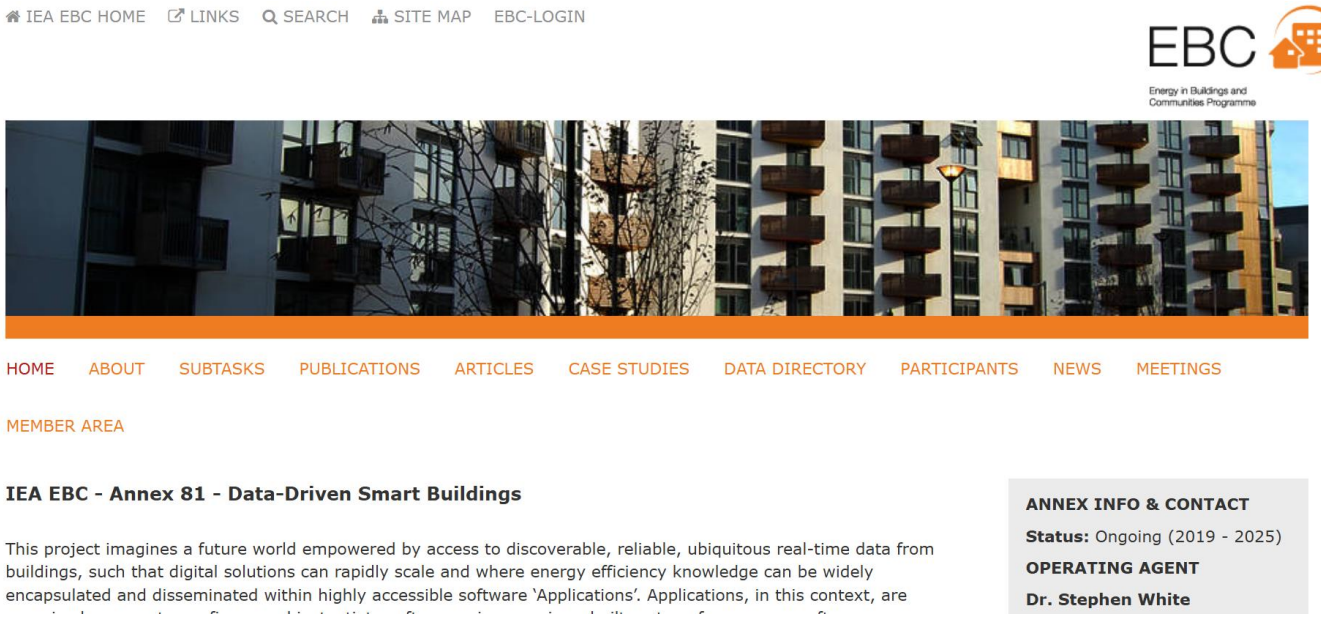

https://annex81.iea-ebc.org/

Resources

https://annex81.iea-ebc.org/

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- **IEA Annex 81 ‘Subtask A report’ on digital infrastructure for data-driven smart buildings**
- **IEA Annex 81 ‘Subtask B report’ on model predictive control**
- **IEA Annex 81 ‘Subtask C report’ on data-driven smart building software applications**
- **Report ‘Data-Driven Smart Buildings State of the Art’**
- **Report ‘A survey of metadata schemas for Data-Driven Smart Buildings’**
- **Report ‘A Data-Sharing Guideline for Buildings and HVAC Systems’**
- **Report ‘Opportunities for Government Leadership on Data-Driven Smart Buildings’**
- **Report ‘A Guide on Data Platforms for Data-Driven Smart Buildings”**
- **Building Data Directory**
- **FDD Dataset Repository**
- **MPC Dataset Repository**
- **Building to Grid Dataset Repository**
- **BOPTEST Framework**
- **Energy-Flexibility-KPIs software tool**
- **Data-Driven Smart Buildings Case-Study Repository**