A data management perspective on building material performance

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Introduction

Msc Julia Kaltenegger

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2019 - 2022 Master in Construction Management and Engineering - TUE (NL)

2018 - 2021 Master in Urban Systems and Real Estate Management - TUE (NL)

2017 - 2022 BIM Consultancy and coordination in practice – LRCZ (NL)

2013 - 2016 Architecture in practice

2012 - 2016 Bachelor in Architecture - TU Graz (AT)

2008 - 2012 Interior design and furniture construction - HTBLuVA Mödling (AT)

#EnergyTransition #MaterialPerformance #Renovation #BIM #LinkedData #Simulation
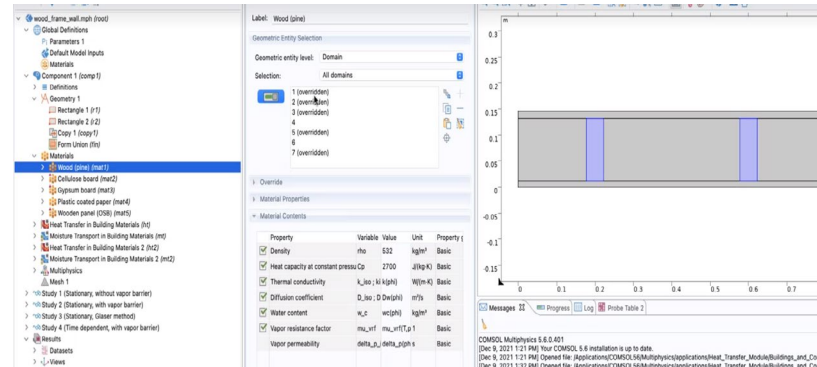
Background and Context

| Model performance	**Material modelling**	**Building performance simulation**
User Group	Material Scientist, Building Physicists, Manufacturers	Designer, Construction Engineers
Document	Measurement Physical, Hygric and Thermal Properties	Energy performance modelling
Tools	MATLAB, custom scripts, COMSOL Multiphysics.	DesignBuilder, EnergyPlus, openStudio, etc.
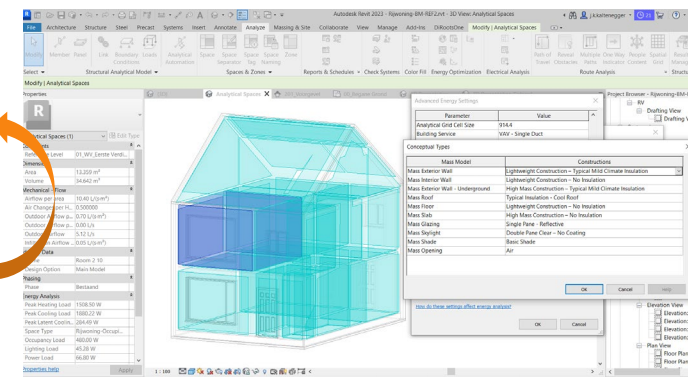
Lack of data reusability throughout multiple projects.
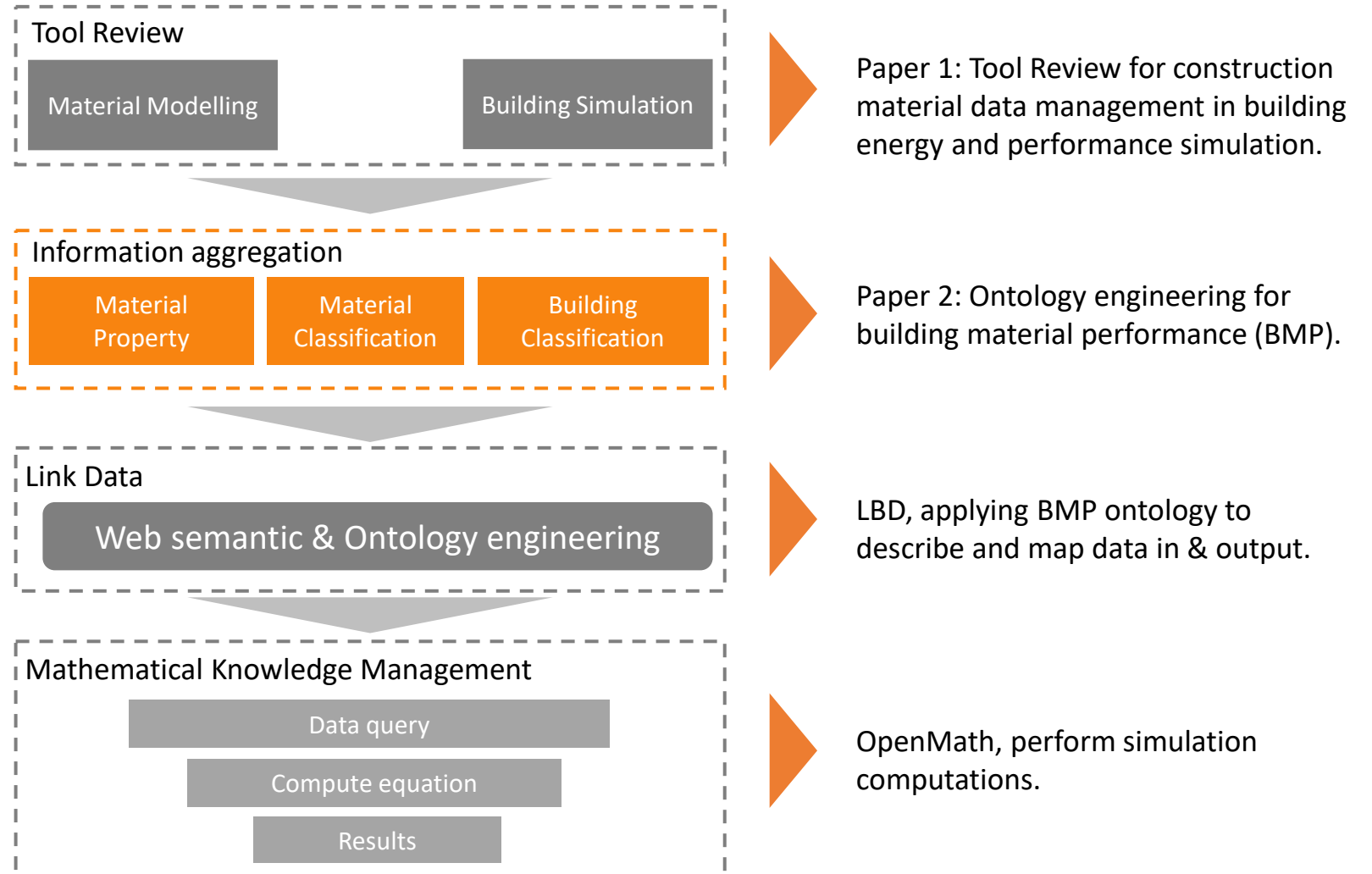Redundant data entry, for multiple use cases.

Problem Definition

Lack of scalability and data granularity between Building aggregation and material (property) classification
Lack of systematic building decomposition method (SBDM)
Data mapping (Simulation system model, Pre and post processing of data)
Lack of Interoperable data exchange

How to enabling building performance simulation that encompasses material modelling with Linked Building Data and Mathematical Knowledge Management?
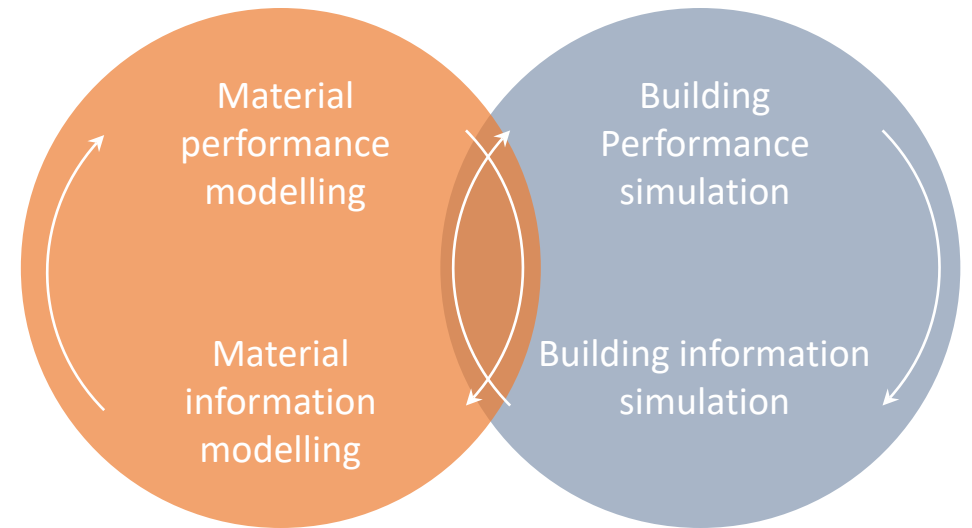
Solution Approach

Tool review {Material database}

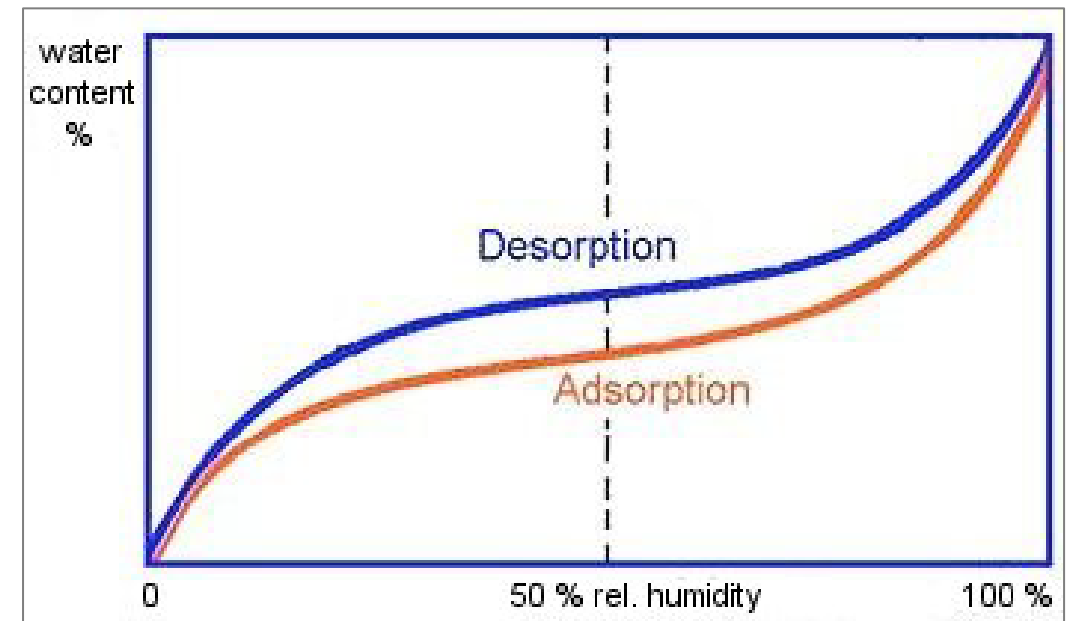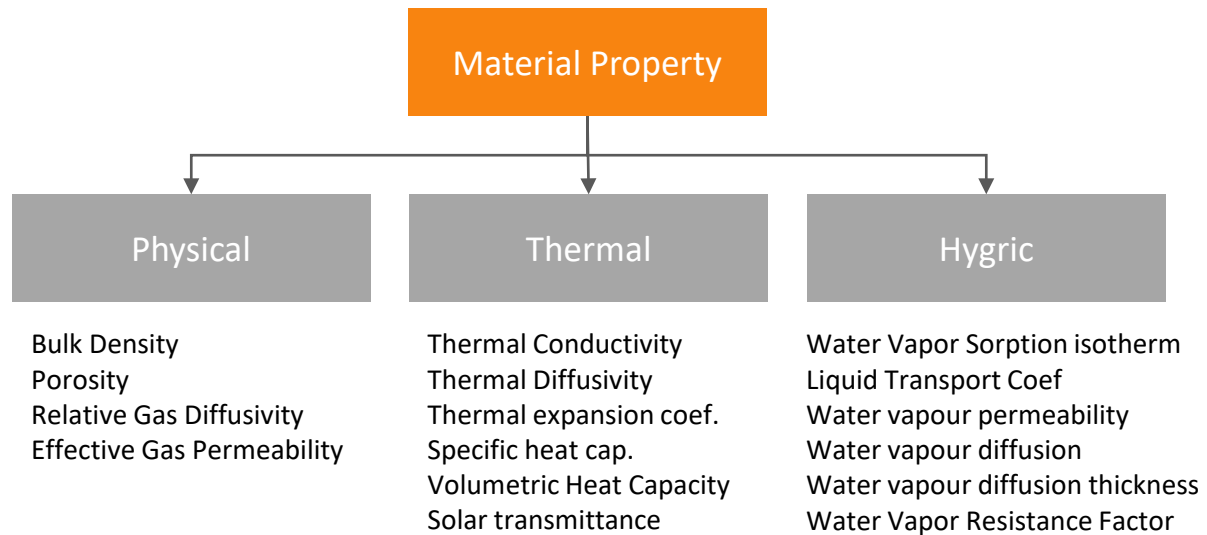| NAME	MATERIAL DB	MATERIAL CLASSIFICATION/INDICATORS	PROPERTY GROUP
U-Value Calculator	U-Value Calculator	Masonry, Concrete, Screed, Wool, Boards, Sheathing, Construction foils, Insulation boards, Loose-fill & SPF, Plaster render, Siding and Roofing, Timber.	Masonry, Concrete, Screed, Wool, Boards, Sheathing, Construction foils, Insulation boards, Loose-fill & SPF, Plaster render, Siding and Roofing, Timber.
VABI EPA, Element	VABI EPA, Element	Brickwork, Light Brick, Concrete, Reinforced concrete, Plaster, Screed, Felt, Cross section wood, Longitudinal section wood, Ply wood, Tiles, Rigid foam, Mineral Wool, Vapor barrier membrane, waterproofing vapor permeable membrane, Plaster reinforcement, Air.	Brickwork, Light Brick, Concrete, Reinforced concrete, Plaster, Screed, Felt, Cross section wood, Longitudinal section wood, Ply wood, Tiles, Rigid foam, Mineral Wool, Vapor barrier membrane, waterproofing vapor permeable membrane, Plaster reinforcement, Air.
BE18	BE18	n.a.	n.a.
Modelica	Modelica	Solid brick, Concrete, Cement, Wood, Gypsum, Lime, Lime Plaster, Sand-lime brick, Gypsum plaster,Mineral wool, Polysterol, PVC, Aluminium, Insulation, SuperInsulation.	Heat Transfer, Fluid Flow, Electrical, Translational, Rotational, Hygro Thermal,
Energy Plus	Energy Plus	Opaque Construction Elements (Material, Material NoMass, Material InfraredTransparent, Material AirGap, Material RoofVegetation); Material (Metal surface, Wood, Stone, Insulation board, Gypsum board, Fiberboard sheathing, Batt insulation, Brick, Lightweight concrete block, Concrete block, Heavyweight Concrete, Plywood, Laminated paperboard).*	Heat And Moisture Transfer, MoisturePenetrationDepth, Life Cycle Costing,
BSim	BSim	Building Materials (Brick and clay, Glazing units, Frames, Panels, Natural Stone, Precast elements, Metals, Wood, Organic Materials, Soil material, Inorganic material, Rubber and plastic, Glass material, Aggregates, Bituminous, Permeable materials, Metallics, Paints, Wood surface, Stone surface, Glass surface, Costing, PV materials)	Thermal, Phase Change Materials (PCM), Moisture
DesignBuilder	DesignBuilder	Brick and blockwork, Concretes, Asphalts, Boards, Sheets and Deckings, Carpets and floor coverings, Gases, Glass, Gravels, Insulating materials, Metals, Phase Change, Plaster, Plastics (solid), Rubber, Sands, Stones and Soils, Screeds and Renders, Sealant materials, Weather stripping and thermal breaks, Tile, Water, Wood.	Thermal Properties, Thermal Bulk Properties, Vapor Resistance, Moisture Transfer, Surface Properties, Radiance Daylight, Embodied Carbon, Phase Change Properties, Cost.
Simergy	Simergy	Opaque Material (No Mass, Infrared Transparent, Air Gap, Vegetation, Insulation Moveable); Glazing Material (Simple Glazing System, Glazing, GlazingRefractionExtinctionMethod, Gas, GasMixture, Shade, Blind, Screen, Complex Shade, Gap); EquivGlazingMaterial (Blind, Drape, Gap, Glazing, Screen, Shade)	Default extension of Material Property
COMSOL Multiphysics	COMSOL Multiphysics (version)	Brick, Concrete, Cellular concrete, Granite, Steel, Structural Steel, Cast iron, Wood pine, Gypsum, Glass wool, Cellulose, Lime silica brick, Plastic coated paper, Expanded polystyrene board (EPS), Extruded polystyrene board (XPS), Air, Aluminium, Glass.*	Acoustics Material Properties, Material Properties (Fatigue Module, Solid Mechanics Material Properties), etc.
ANSYS	GRANTA MI (version)	Ceramic, Wood, Composite, Metal, Plastic, Glass, Polymer, Bio-based Plastics, Polyester, Elastomers/Rubbers, Fluid gases.*	Structural, Thermal, Physical, Electrical, Magnetic, Room-temperature physical properties
WUFI (Wärme Und Feuchte Instationär)	Default library WUFI (Frauenhofer), verified DB from user (version)	Masonry bricks, Concrete and screeds, Natural stone, Wood, Montar and plaster, Exterior plaster, Insulating materials, Membranes, Air Layer.*	Basic Material Data (Hygric Extensions), Optional Data (Moisture Storage Function, Liquid Transport Coefficients, Heat Conductivity, Moisture-dependent, Diffusion Resistance Factor, Moisture dependent)
TRNSYS	TRNSYS standard component, TESS Libraries, TRNLIB Components, TRNAUS Components, Transsolr, (version)	Construction board-wall_board-WALL_BOARD; Insulation material - mineral_wool - MINEARL_WO; Wooden materials - spruce_pine - SPRUCE_PIN, Convering/seal amerials - poly-vinyl_chloride - PLYVINYL.*	n.a.

Information aggregation

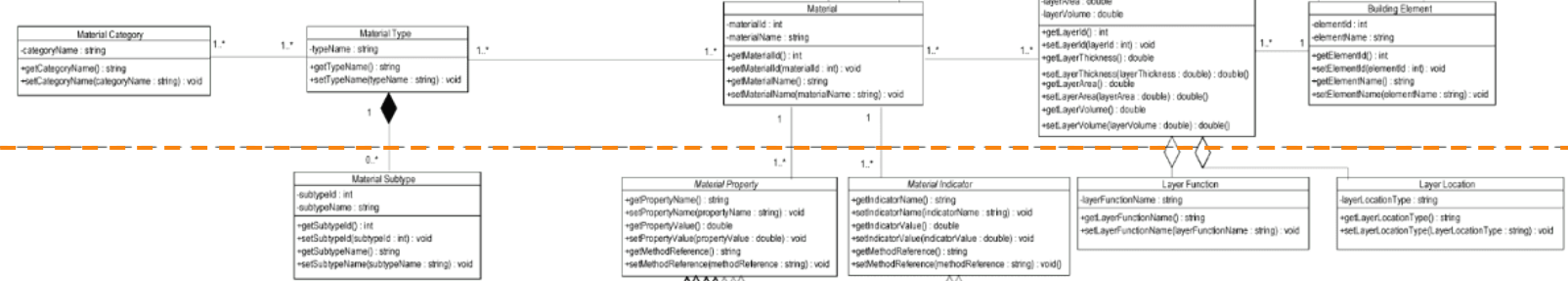Building aggregation and material classification
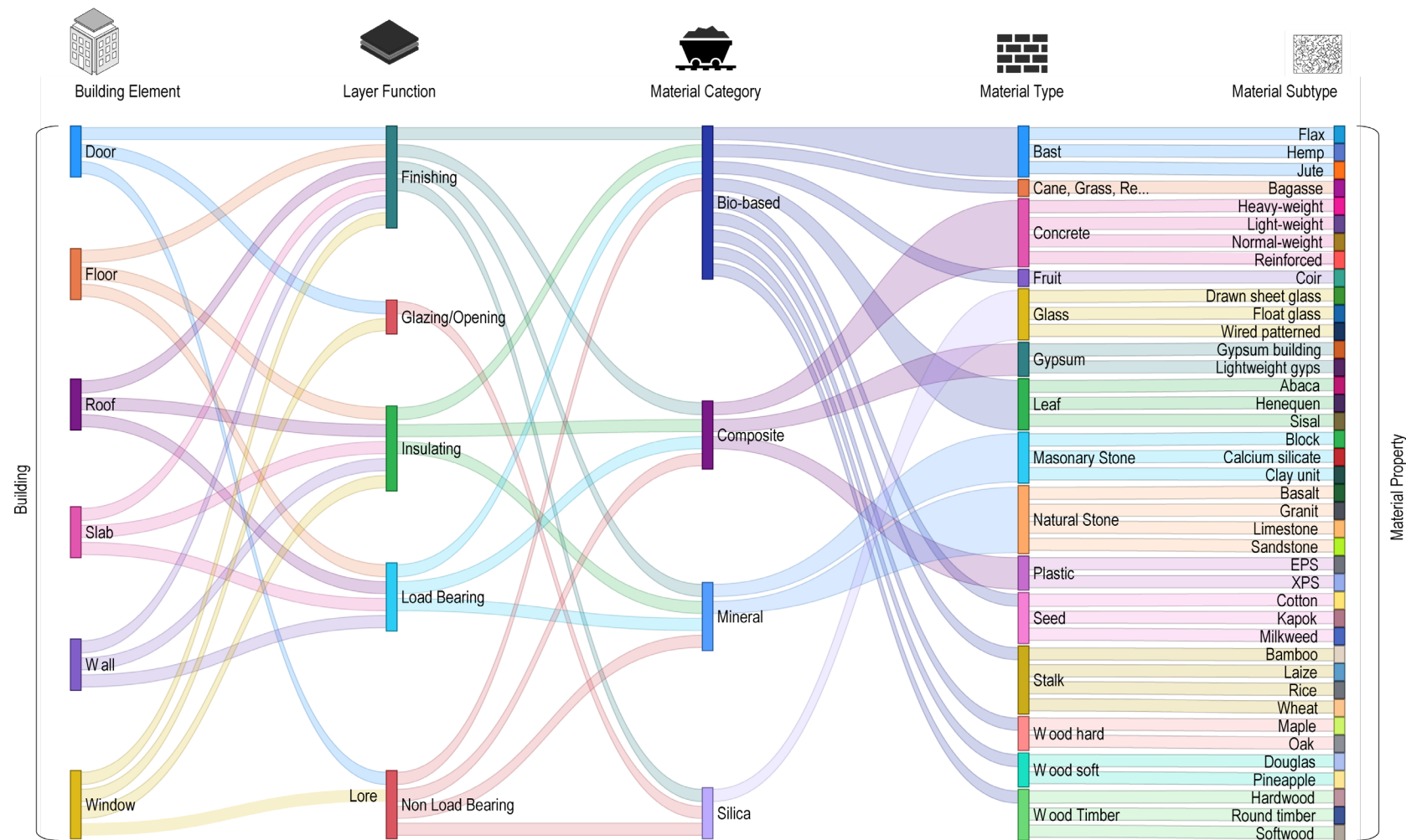
Material properties

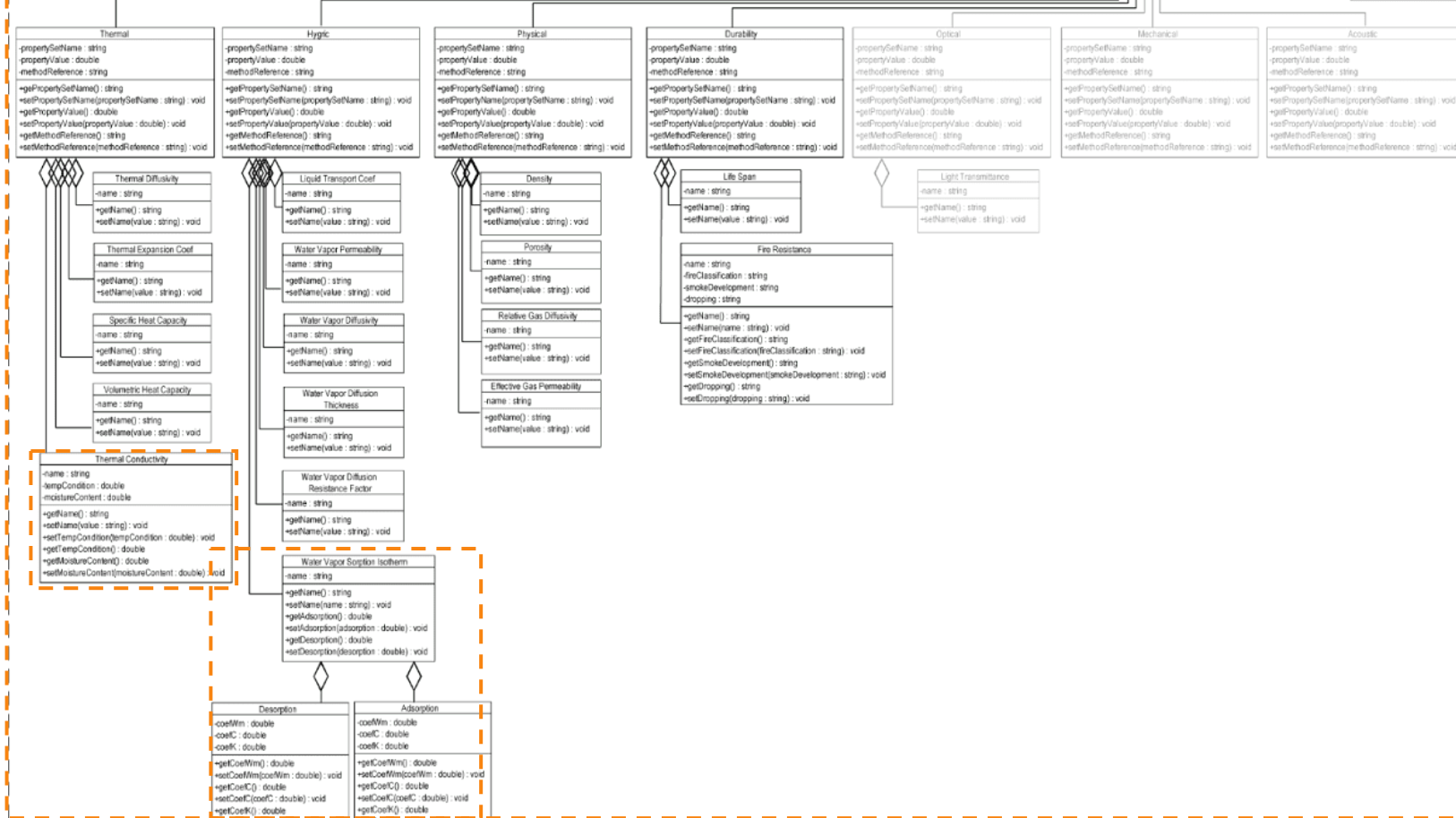In-depth analysis: Material physical properties and sustainable indicators

Material Property

Physical	Thermal	Hygric

Bulk Density
Porosity
Relative Gas Diffusivity
Effective Gas Permeability

Thermal Conductivity
Thermal Diffusivity
Thermal expansion coef.
Specific heat cap.
Volumetric Heat Capacity
Solar transmittance

Water Vapor Sorption isotherm
Liquid Transport Coef
Water vapour permeability
Water vapour diffusion
Water vapour diffusion thickness
Water Vapor Resistance Factor

UML – Class Diagram

Core Ontology {T-Box}

Ontology :BMP

Building Material Property
Ontology [:bmp]
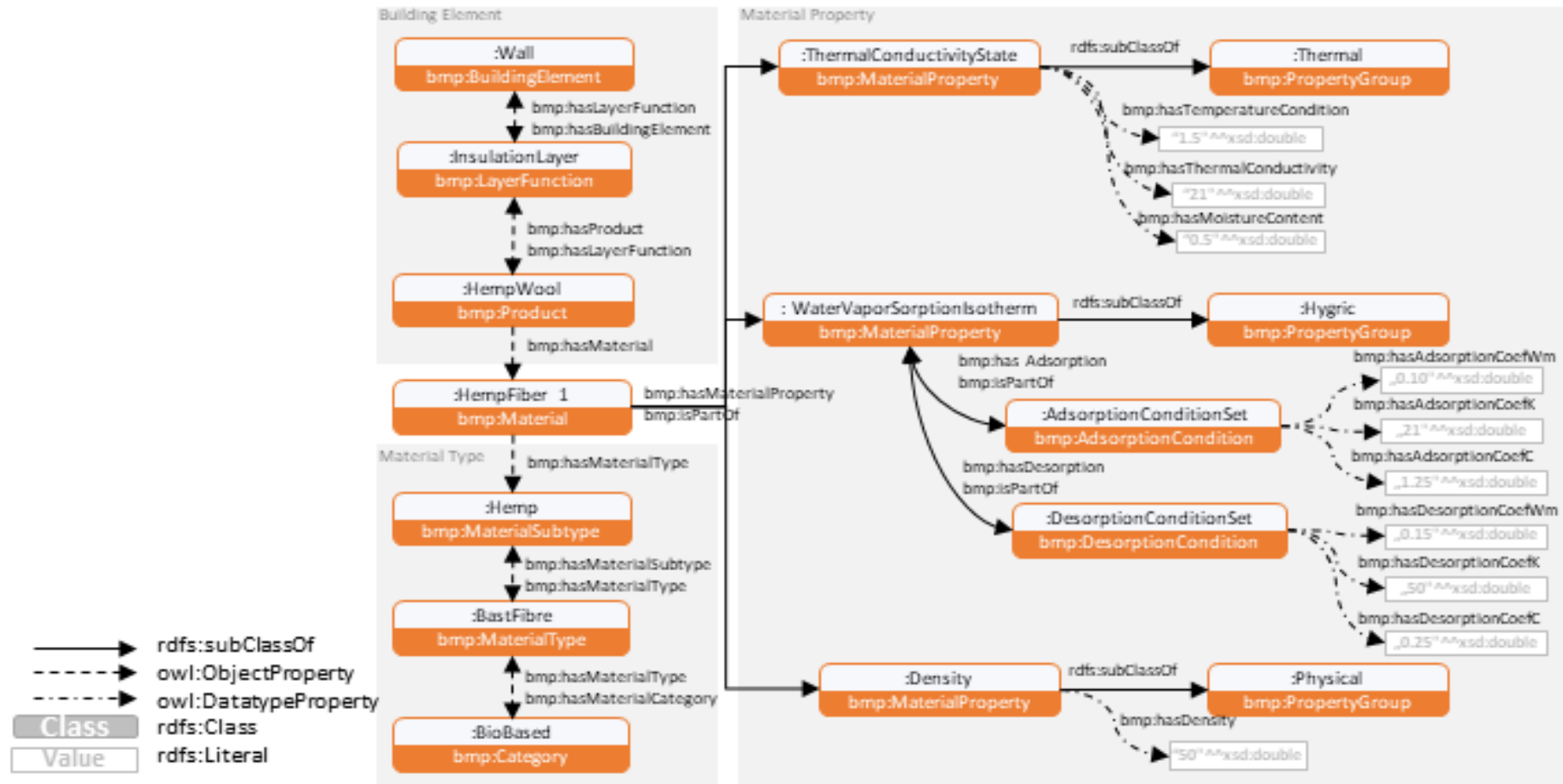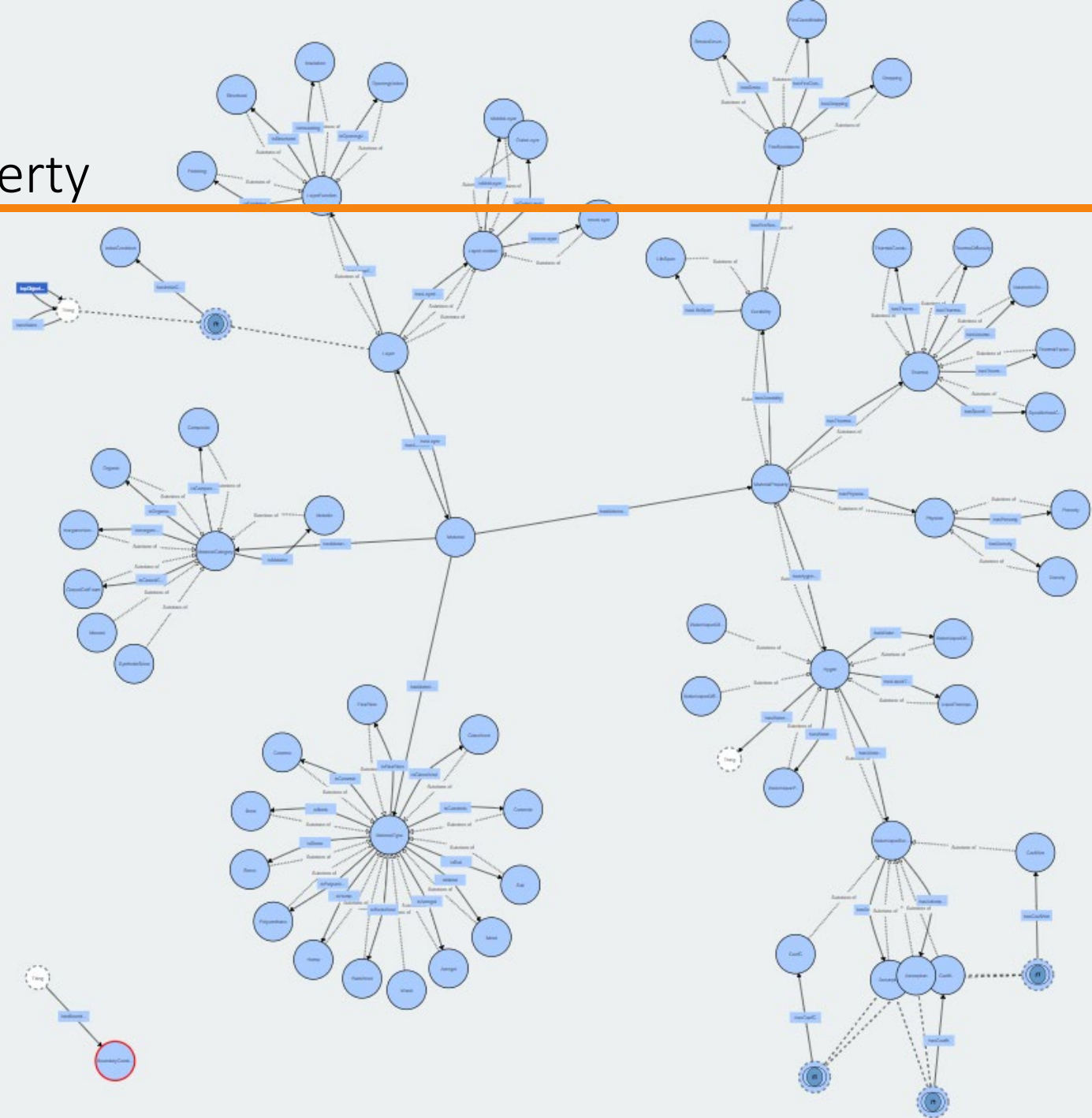
Use Case - Data retrieval

CQ1 *(Researcher wants to retrieve De- and Adsorption Condition (including three coefficients, Wm, K, C) of each measured material).*

```
SPARQL 1
PREFIX bmp: <https://w3id.org/bmp#>
SELECT *
WHERE {
        ?someMaterial bmp:hasMaterialType bmp:Hemp .
        ?someMaterial bmp:hasMaterialProperty ?property .
        ?property bmp:hasCondition ?condition .
        ?condition bmp:hasCoefficient ?coefficient .
        ?coefficient bmp:hasValue ?value .
    }
```

1	EXAMPLE:HempCreed001	EXAMPLE:HempCreed001_WVSIsotherm	EXAMPLE:HempCreed001_Adsorption	EXAMPLE:HempCreed001_Adsorption_Coefficient1	"21."
2	EXAMPLE:HempCreed001	EXAMPLE:HempCreed001_WVSIsotherm	EXAMPLE:HempCreed001_Adsorption	EXAMPLE:HempCreed001_Adsorption_Coefficient2	"23."
3	EXAMPLE:HempCreed001	EXAMPLE:HempCreed001_WVSIsotherm	EXAMPLE:HempCreed001_Adsorption	EXAMPLE:HempCreed001_Adsorption_Coefficient3	"25."
4	EXAMPLE:HempCreed001	EXAMPLE:HempCreed001_WVSIsotherm	EXAMPLE:HempCreed001_Desorption	EXAMPLE:HempCreed001_Desorption_Coefficient1	"24."
5	EXAMPLE:HempCreed001	EXAMPLE:HempCreed001_WVSIsotherm	EXAMPLE:HempCreed001_Desorption	EXAMPLE:HempCreed001_Desorption_Coefficient2	"26."
6	EXAMPLE:HempCreed001	EXAMPLE:HempCreed001_WVSIsotherm	EXAMPLE:HempCreed001_Desorption	EXAMPLE:HempCreed001_Desorption_Coefficient3	"26."

Use Case - Data retrieval

CQ2 *(Research wants to retrieve the dependent temperature and moisture values for thermal conductivity of each measure material)*

```
SPARQL 2
PREFIX bmp: <https://w3id.org/bmp#>
PREFIX EXAMPLE: <https://material.com#>
SELECT *

WHERE {
?someMaterial bmp:hasMaterialType bmp:Wood .
     ?someMaterial bmp:hasMaterialProperty ?property .
     ?property bmp:hasValue ?value .
               }
```
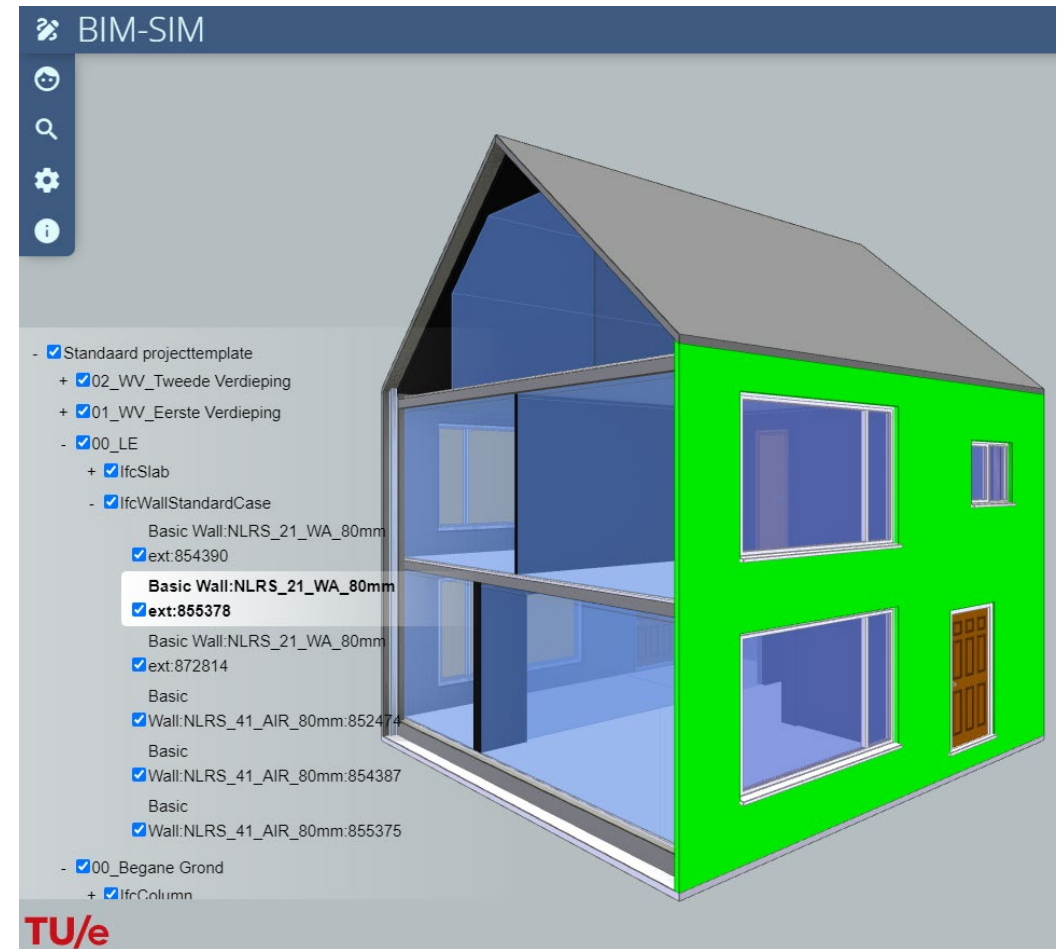
	someMaterial	property	value
1	EXAMPLE:Wood	EXAMPLE:WoodThermalConductivity	"2."
2	EXAMPLE:Wood2	EXAMPLE:Wood2ThermalConductivity	"4."

Use Case - Data integration

Material → **Building Element** → **Building Element Layer**

```
32  EXAMPLE:HempCrete001 a bmp:Material ;
33      bmp:hasMaterialCategory bmp:Bio-based%20 ;
34      bmp:hasMaterialType bmp:HempCrete ;
35      bmp:hasDensity "38"^^xsd:double ;
36      bmp:hasThermalConductivityState EXAMPLE:The
37      bmp:hasWaterVaporSorptionIsotherm EXAMPLE:W
38      bmp:hasSpecificHeatCapacity "1906"^^xsd:dou
39      bmp:hasVolumetricHeatCapacity "72.428"^^xsd
40      bmp:hasThermalDiffusivity "0.74971005688407
41      bmp:hasRelativeGasDiffusivity "456"^^xsd:dc
42
43  EXAMPLE:WaterVaporSorptionIsothermState_002 a
44      bmp:hasWaterVaporSorptionIsotherm "20"^^xs
45      bmp:hasAdsortpionWm "5.83"^^xsd:double ;
46      bmp:hasAdsortpionK "0.877"^^xsd:double ;
47      bmp:hasAdsortpionC "10.6"^^xsd:double ;
48      bmp:hasDesortpionWm "10.2"^^xsd:double ;
49      bmp:hasDesortpionK "0.738"^^xsd:double ;
50      bmp:hasDesortpionC "6.66"^^xsd:double .
51
52  EXAMPLE:ThermalConductivityState_002 a bmp:th
53      bmp:hasThermalConductivity "0.0543" ;
54      bmp:hasTemperatureCondition "21"^^xsd:doubl
55      bmp:hasMoistureCondition "60"^^xsd:double .
56
```

```
EXAMPLE:wall_31104
    a bot:Element ;
    a beo:Wall__STANDARD ;
    rdfs:label "Basic Wall:NLRS_42_WA_75mm:863010"^^xsd:string
    rdfs:comment ""^^xsd:string ;
    bot:hasGuid "03d162fd-fefd-42d3-84a2-bde414c91712"^^xsd:str
    props:hasCompressedGuid "03qMBz$lr2quIYlUGKoHSI"^^xsd:stri
    props:tag "863010"^^xsd:string ;
    props:roughness "304.8"^^xsd:double ;
    props:category "Walls"^^xsd:string ;
    props:reference "NLRS_42_WA_75mm"^^xsd:string ;
    props:description "stucwerk interieur, fijn, wit"^^xsd:stri
    props:reference "NLRS_42_WA_75mm"^^xsd:string ;
    props:loadBearing false ;
    props:isExternal false ;
    props:extendToStructure false ;
    props:reference "NLRS_42_WA_75mm"^^xsd:string ;
    props:thermalTransmittance "18.5333333333333"^^xsd:double ;
    props:roughness "304.8"^^xsd:double ;
    props:category "Walls"^^xsd:string ;
    props:reference "NLRS_42_WA_75mm"^^xsd:string ;
    props:description "stucwerk interieur, fijn, wit"^^xsd:stri
    props:reference "NLRS_42_WA_75mm"^^xsd:string ;
    props:isExternal false ;
    props:reference "NLRS_42_WA_75mm"^^xsd:string ;
    props:thermalTransmittance "18.5333333333333"^^xsd:double ;
    bmp:hasLayer EXAMPLE:layer_1 .
```

```
4
5  EXAMPLE:layer_1
6      a bmp:Layer ;
7      bmp:hasLayerFunction EXAMPLE:layerFunction_1 ;
8      bmp:hasLayerLocation EXAMPLE:layerLocation_1 ;
       bmp:hasMaterial EXAMPLE:ss ;
0      bmp:hasMaterial EXAMPLE:WoodFiber001 ;
1      bmp:hasMaterial EXAMPLE:LightBrick001 .
2
3  EXAMPLE:layer_2
       a bmp:Layer ;
5      bmp:hasLayerFunction EXAMPLE:layerFunction_1 ;
6      bmp:hasLayerLocation EXAMPLE:layerLocation_1 ;
7      bmp:hasMaterial EXAMPLE:WoodFiber001 .
8
9  EXAMPLE:layer_3
0      a bmp:Layer ;
1      bmp:hasLayerFunction EXAMPLE:layerFunction_1 ;
       bmp:hasLayerLocation EXAMPLE:layerLocation_1 ;
3      bmp:hasMaterial EXAMPLE:LightBrick001 .
4
5  EXAMPLE:layerFunction_1
6      a bmp:Insulation ;
7      a bmp:Finishing ;
8      a bmp:Structural .
9
```

Next Steps

- Semantic ontology integration and query data flow

- Mathematical knowledge Management

- Computation/Simulation integration

Questions?

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