SUSTAINABLE PLACES 2017 JUNE 28 – 30, 2017 MIDDLESBROUGH, UK

OptEEmAL

OPTIMISED ENERGY EFFICIENT DESIGN PLATFORM FOR REFURBISHMENT AT DISTRICT LEVEL

Sustainable Places 2017

28 June 2017, Middlesbrough, UK

Energy-related data integration using Semantic data models for energy efficient retrofitting projects

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FUNITEC, La Salle Architecture School, Ramon Llull University

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Optimised Energy Efficient Design Platform For Refurbishment At District Level

Challenges:

- Provide innovative **design tools**
- Renovation of **buildings as part of a global energy system**
- Support the **evaluation of retrofitting alternatives**
- Ensure **interoperability among tools**
- Solutions adapted to **collaborative multi-disciplinary work**

Optimised Energy Efficient Design Platform For Refurbishment At District Level

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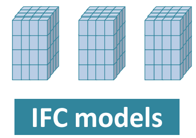
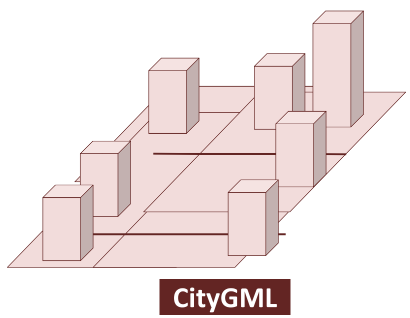
Energy-related data integration using Semantic data models

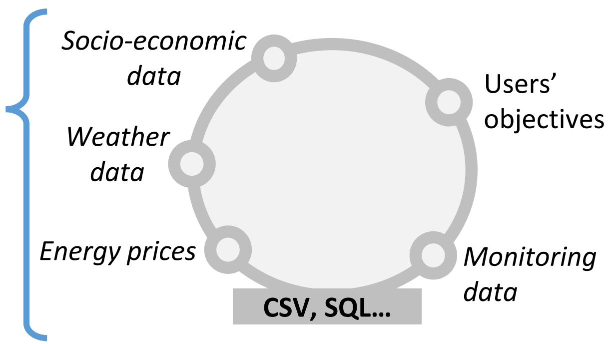
1 **BIM data**



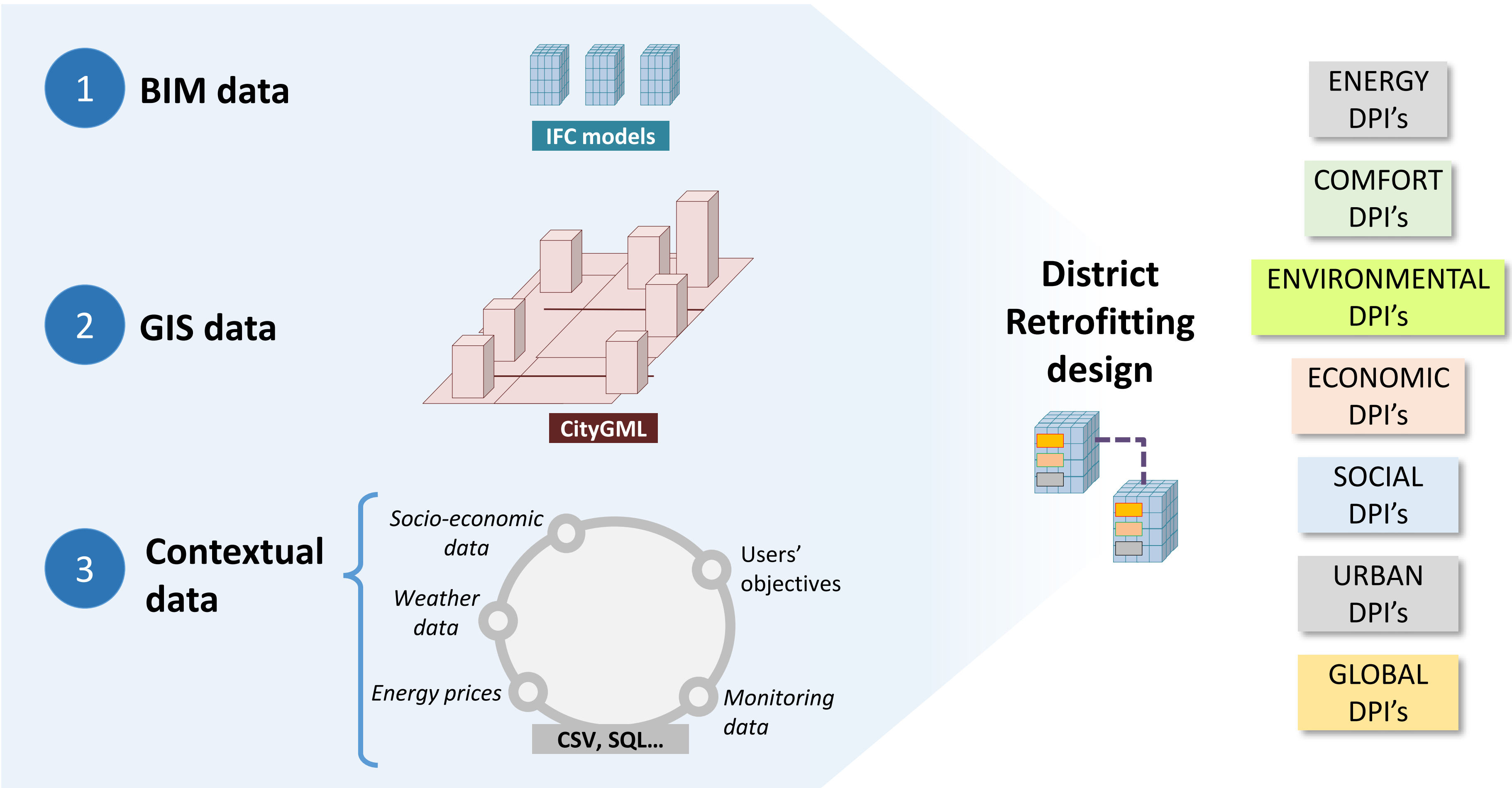
2 **GIS data**



3 **Contextual data**



Energy-related data integration using Semantic data models



Energy-related data integration using Semantic data models

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Input Data

1 **BIM data**
IFC models

2 **GIS data**
CityGML

3 **Contextual data**
CSV, SQL…

Multiple data models, domains, formats…

?

OptEEmAL Platform
A web-based platform for district energy-efficient retrofitting design

Automating data integration task to enable optimisation process **(>1000 simulations)**

Energy Plus

CitySim

NEST

…

Multiple tools, input formats…

District Retrofitting design

ENERGY DPI's

COMFORT DPI's

ENVIRONMENTAL DPI's

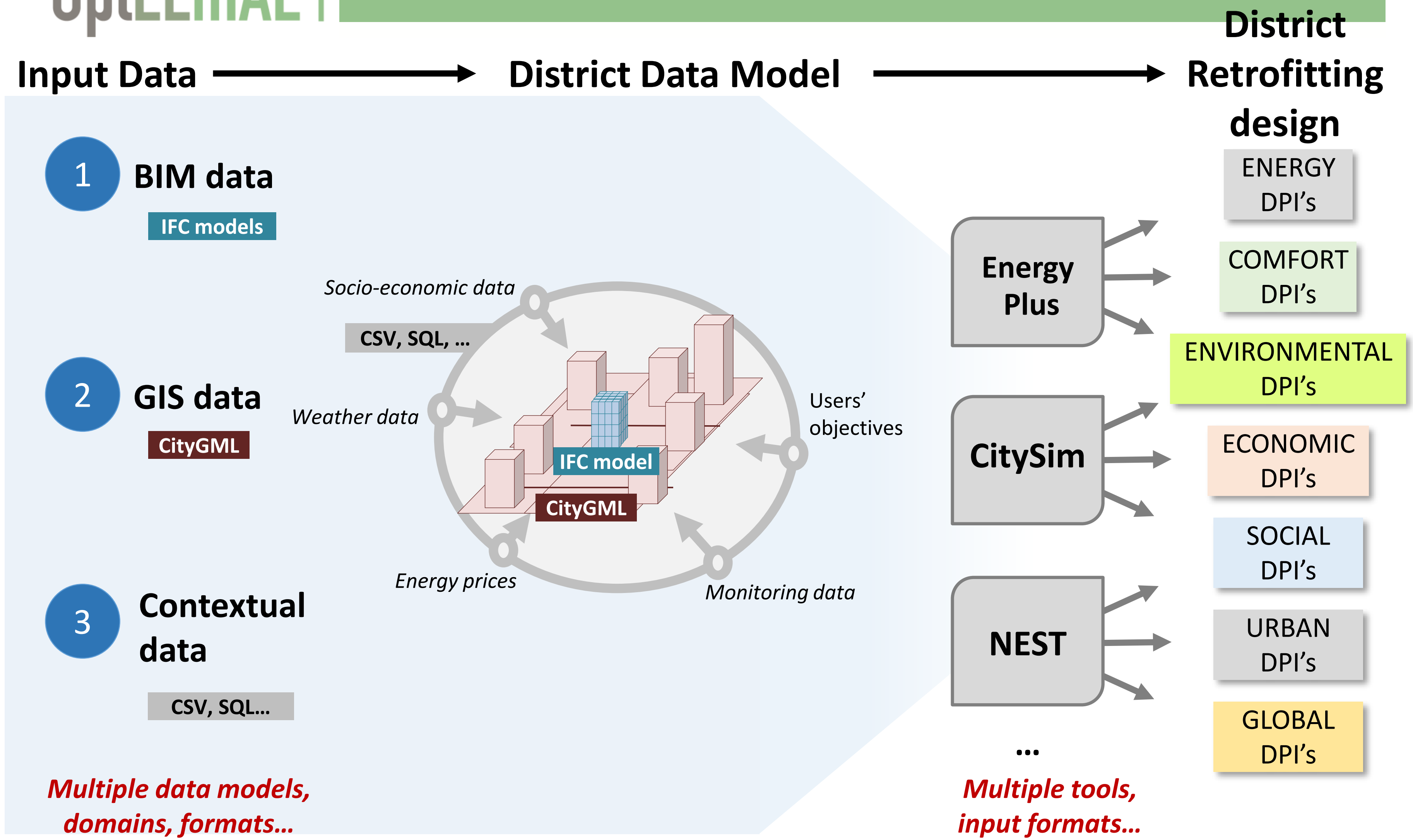
ECONOMIC DPI's

SOCIAL DPI's

URBAN DPI's

GLOBAL DPI's

Energy-related data integration using Semantic data models



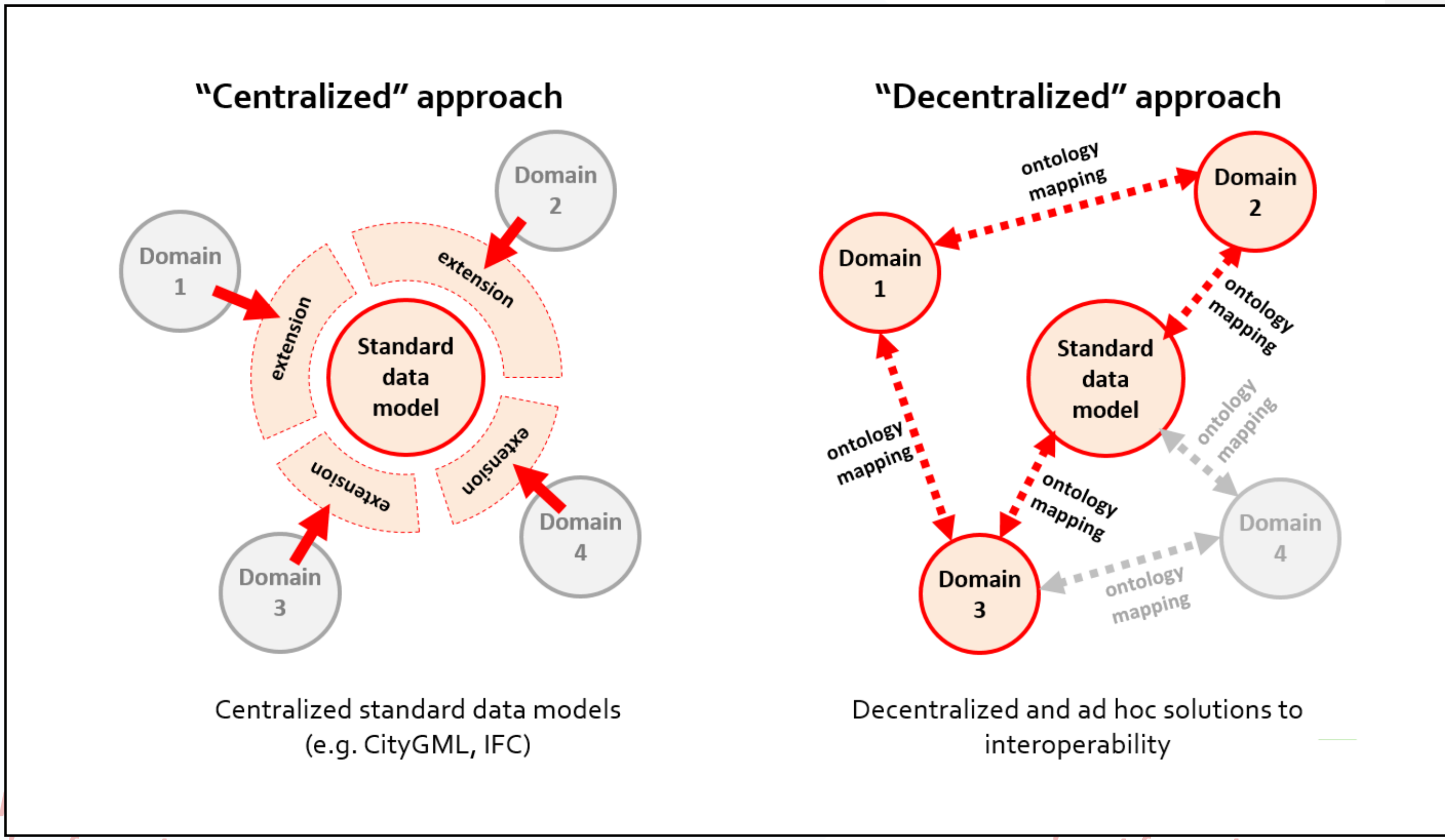
Energy-related data integration using Semantic data models

Input Data → District Data Model → District Retrofitting design

1

2

3



ERGY PI's

IFORT PI's

NMENTAL PI's

IOMIC PI's

CIAL PI's

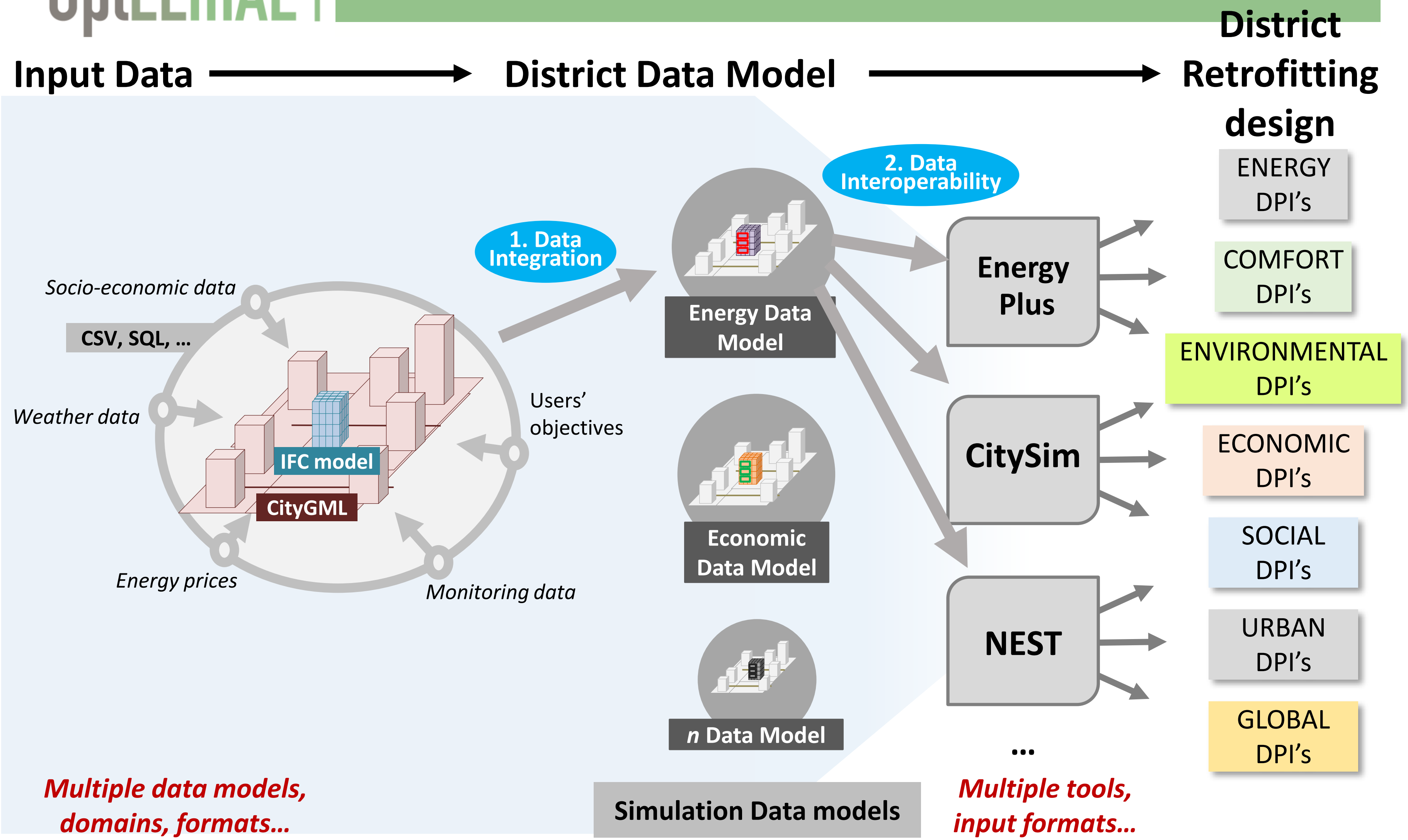
BAN PI's

OBAL PI's

Multipl... domains, formats...

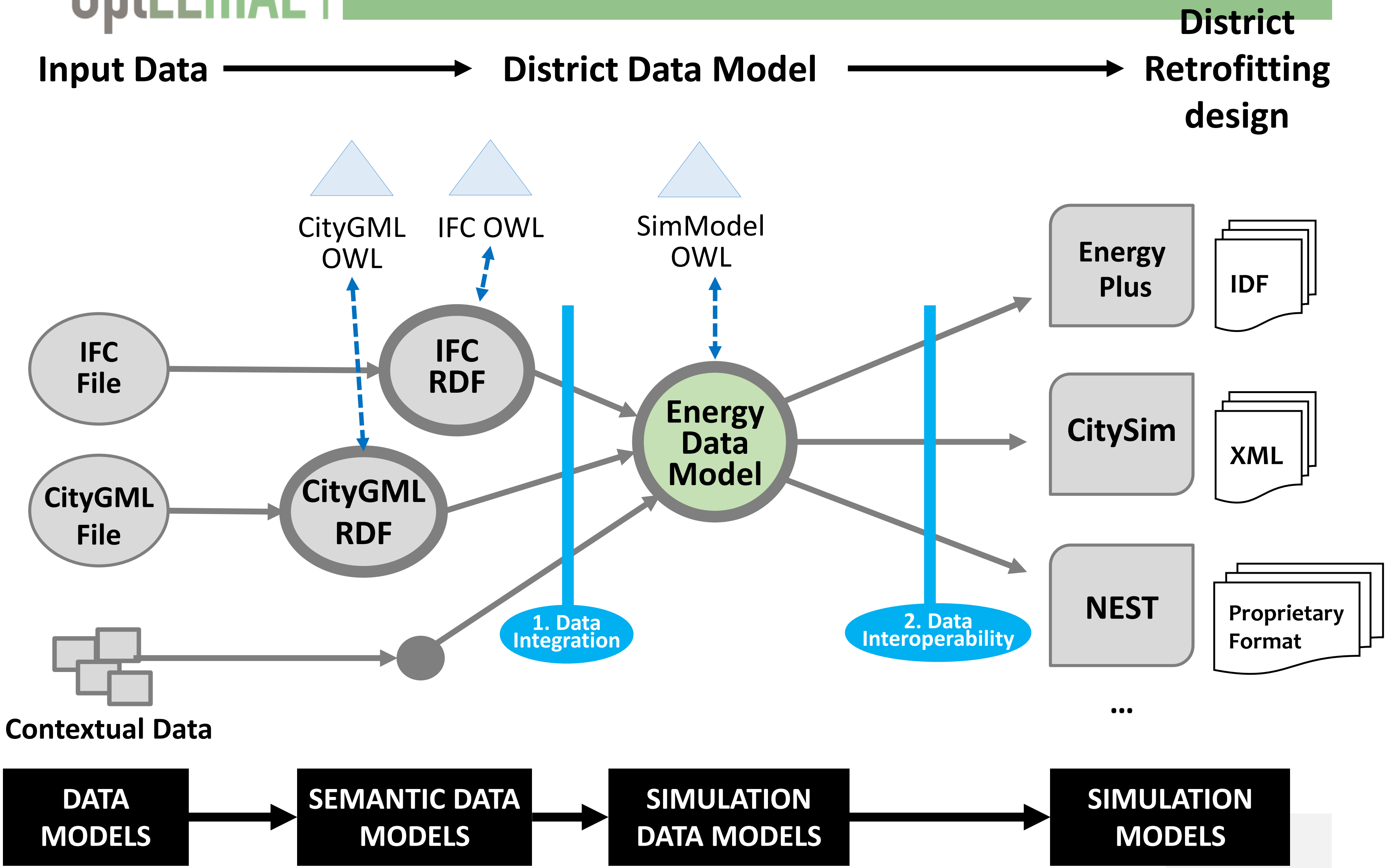
input formats...

Energy-related data integration using Semantic data models



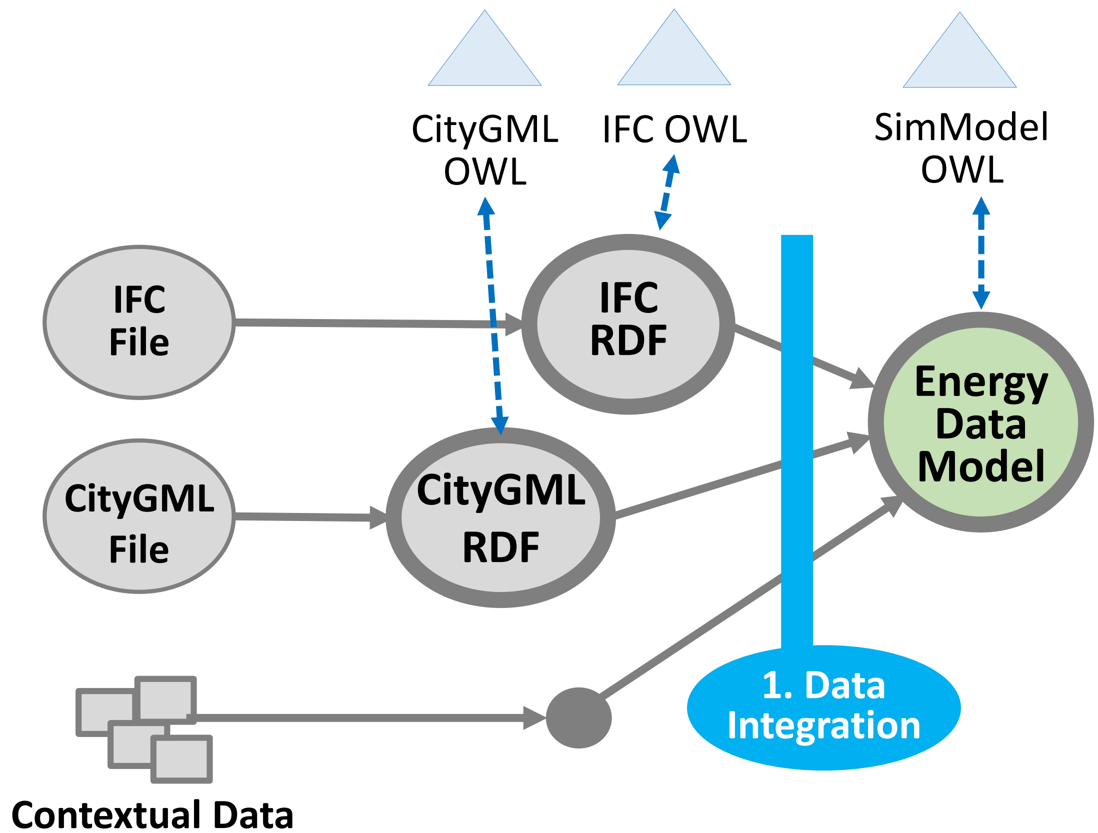
Semantic Web Technologies

Energy-related data integration using Semantic data models



Energy-related data integration using Semantic data models

Input Data → **District Data Model** → **District Retrofitting design**

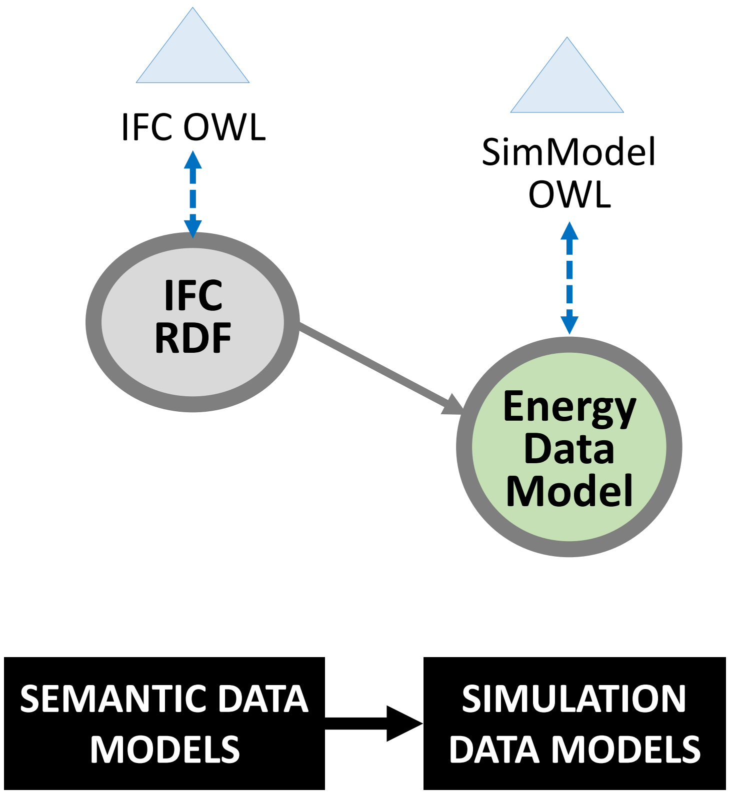


A) Finding relations (alignments) between CityGML OWL, ifcOWL and SimModelOWL
Ontology matching: ***LogMap, AML…***

B) Transforming RDF data according to the ontologies and their alignments. RDF-To-RDF via SPARQL constructs: ***SPARQL Constructs, R2R***

DATA MODELS → **SEMANTIC DATA MODELS** → **SIMULATION DATA MODELS** → **SIMULATION MODELS**

Energy-related data integration using Semantic data models

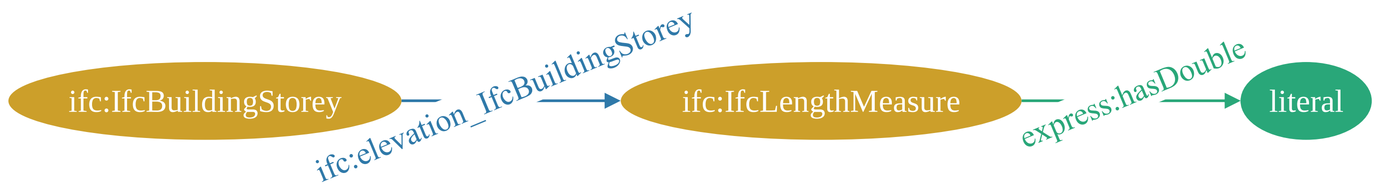


- Ontologies represent different domains (e.g,, Construction, Energy Simulations…)
- Ontologies have structural and semantic differences

Energy-related data integration using Semantic data models

SIMMODEL IFC RDF data

IFC RDF data



Structural and conceptual mismatches between models:

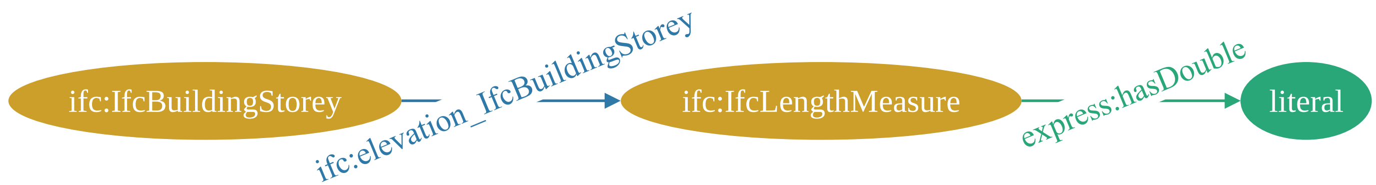
- **Different structures**

Energy-related data integration using Semantic data models

SIMMODEL IFC RDF data

inst:IfcBuildingStorey_941	rdf:type	sim:SimBuildingStory_BuildingStory_Default.
inst:ifcBuildingStorey_941	sim:BuildingStoryHeight	"2699.99999999993" .

IFC RDF data



inst:IfcBuildingStorey_941	rdf:type	ifc:IfcBuildingStorey .
inst:IfcBuildingStorey_941	ifc:elevation_IfcBuildingStorey	inst:IfcLengthMeasure_919 .
inst:IfcLengthMeasure_919	rdf:type	ifc:IfcLengthMeasure ;
inst:IfcLengthMeasure_919	express:hasDouble	"2.69999999999993".

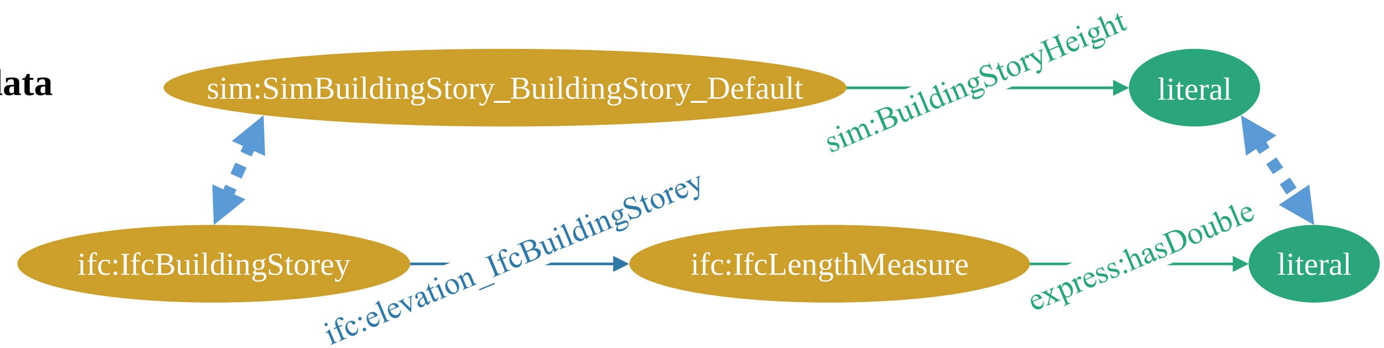
Structural and conceptual mismatches between models:

- **Different structures**
- **Different Units**

Energy-related data integration using Semantic data models

SIMMODEL IFC RDF data

IFC RDF data



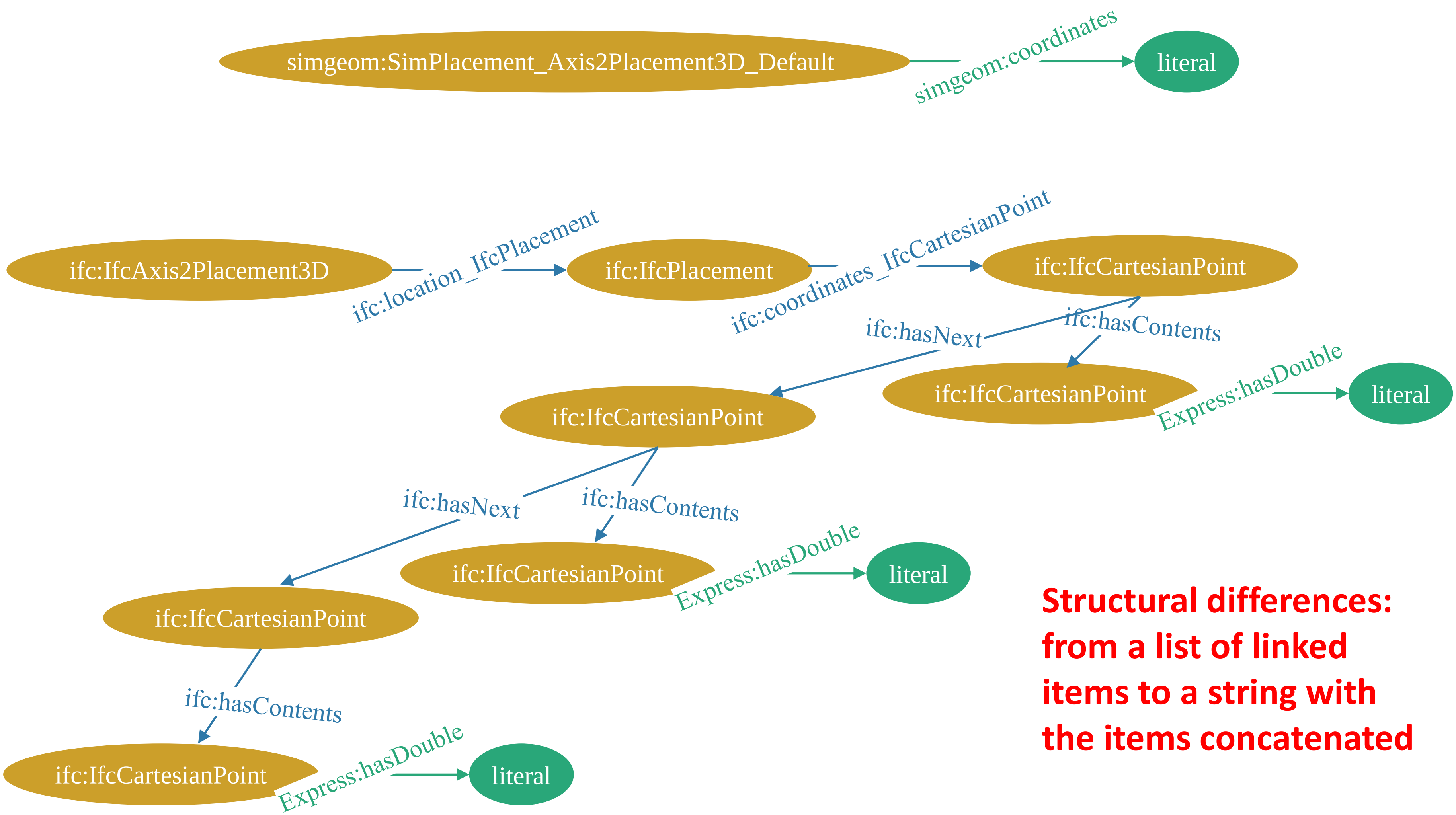

```
CONSTRUCT {
    ?storey rdf:type sim:SimBuildingStory_BuildingStory_Default ;
    ?storey sim:BuildingStoryHeight ?elevationInMM.
}
WHERE {
    ?storey rdf:type ifc:IfcBuildingStorey ;
    ?storey ifc:elevation_IfcBuildingStorey ?elevationStorey.
    ?elevationStorey express:hasDouble ?elevationInMts.
    BIND (?elevationInMts*1000 AS ?elevationInMM).
}
```

$\}$ SimModelOWL part

$\}$ ifcOWL part

$\}$ Data transformation (e.g, units)

Energy-related data integration using Semantic data models



Structural differences: from a list of linked items to a string with the items concatenated

Energy-related data integration using Semantic data models

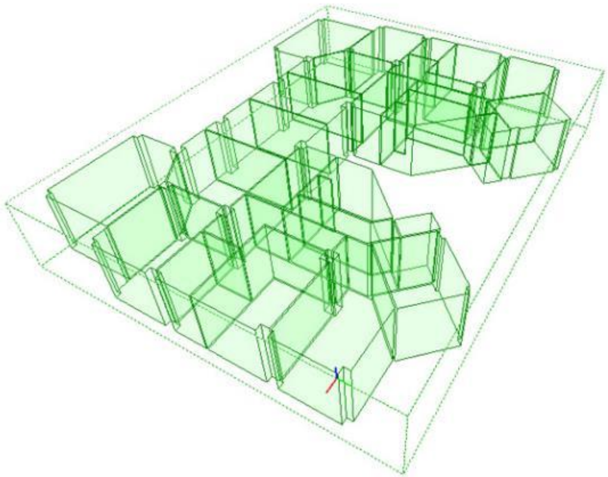

```
CONSTRUCT {
    ?placement rdf:type simgeom:SimPlacement_Axis2Placement3D_Default ;
        simgeom:coordinates ?coordinates .
}
WHERE {
    ?placement rdf:type ifc:IfcAxis2Placement3D .
        ?placement ifc:location_IfcPlacement [ ifc:coordinates_IfcCartesianPoint ?item1 ].
    ?item1 list:hasContents [ express:hasDouble ?point1 ];
        list:hasNext ?item2 .
    ?item2  list:hasContents [ express:hasDouble ?point2 ];
        list:hasNext [ list:hasContents [ express:hasDouble ?point3 ] ].

    BIND (concat (STR(?point1), ' ', STR(?point2), ' ', STR(?point3)) AS ?coordinates ) .
}
```

Structural differences: from a list of linked items to a string with the items concatenated

Energy-related data integration using Semantic data models

```
java -jar DataMapper.jar <input IFC file> <output SimModel file> <queries path>
```

	IFC - express	IFC CBIP-express
Building Storey	15	15
Slabs	48	48
Walls	675	675
Spaces	262	262
SpaceBoundaries	0	6332



```
OPTEEMAL - DataMapper (ETL2)
IFC input file:    UG1_Torre_Turina_18_BST.ttl
----------------------------------------------------------------------
Invoking the following sparql CONSTRUCTS (18):
Triples: 166   | 1527 ms | SimBuildingStory_BuildingStory_Default.rq
Triples: 29    | 35 ms   | SimBuilding_Building_Default.rq
Triples: 37993 | 446 ms  | SimGeomCurve_CompositeCurve_Default.rq
Triples: 18997 | 1424 ms | SimGeomCurve_Polyline_Default.rq
Triples: 94981 | 903 ms  | SimGeomSurface_BoundedSurface_CurveBoundedPlane.rq
Triples: 685   | 10 ms   | SimGeomVector_Vector_Direction.rq
Triples: 8     | 238 ms  | SimLocalPlacement_LocalPlacement_AbsolutePlacement.rq
Triples: 25361 | 4353 ms | SimLocalPlacement_LocalPlacement_RelativePlacement.rq
Triples: 84659 | 1461 ms | SimPlacement_Axis2Placement3D_Default.rq
Triples: 92134 | 1311 ms | SimPlacement_Axis2Placement3D_Default_optional.rq
Triples: 49    | 5463 ms | SimSlab_Floor_FloorOverEarth.rq
Triples: 203   | 5935 ms | SimSlab_Floor_InterzoneFloor.rq
Triples: 49    | 406 ms  | SimSlab_RoofSlab_RoofUnderAir.rq
Triples: 92277 | 1084 ms | SimSpaceBoundary_SecondLevel_SubTypeA.rq
Triples: 0     | 63 ms   | SimSpaceBoundary_SecondLevel_SubTypeB.rq
Triples: 4717  | 34 ms   | SimSpace_Occupied_Default.rq
Triples: 2887  | 86 ms   | SimWall_TypicalWall_ExteriorAboveGrade.rq
Triples: 5136  | 189 ms  | SimWall_TypicalWall_Interior.rq
----------------------------------------------------------------------
Storing test_002_Torre_Turina_sparql.ttl model with a total of 611818 triples
```

Only slabs and walls attached to a thermal space are processed

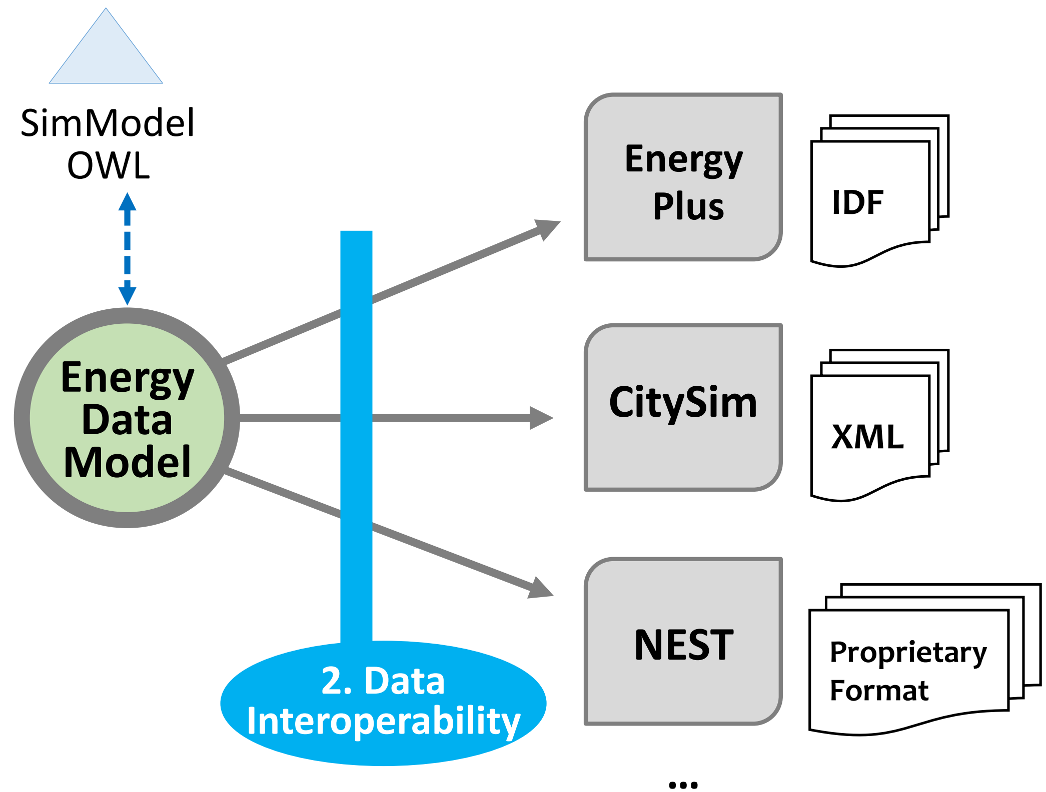
	IFC - express	IFC CBIP-express	SimModel - RDF
Building Storey	15	15	15
Slabs	48	48	**12**
Walls	675	675	**505**
Spaces	262	262	262
SpaceBoundaries	0	6332	6332

Energy-related data integration using Semantic data models

Input Data → **District Data Model** → **District Retrofitting design**

Ad hoc connectors between Energy Data Models and particular simulation models.

All particular data needed by Simulation models have been integrated in the Simulation Data Models.



SIMULATION DATA MODELS → **SIMULATION MODELS**

Example of a SPARQL query used in the simulation model generation process

```
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX simbldg: <http://www.lbl.gov/namespaces/Sim/BuildingModel#>
PREFIX simgeom: <http://www.lbl.gov/namespaces/Sim/ResourcesGeometry#>
PREFIX simres: <http://www.lbl.gov/namespaces/Sim/ResourcesGeneral#>

SELECT ?simSpace ?coordinates
WHERE
{
  ?simSpace rdf:type simres:SimSpaceBoundary_SecondLevel_SubTypeA .
  ?simSpace simres:relatingSpace ?SimSpace_Occupied_Default .
  ?simSpace simres:refId ?refId .
  FILTER regex(?refId, "58")
  ?SimSpace_Occupied_Default rdf:type simbldg:SimSpace_Occupied_Default .
  ?SimSpace_Occupied_Default simbldg:placement ?SimLocalPlacement_LocalPlacement_RelativePlacement .
  ?SimLocalPlacement_LocalPlacement_RelativePlacement simgeom:relativePlacement ?RelativePlacement .
  ?RelativePlacement rdf:type simgeom:SimPlacement_Axis2Placement3D_Default .
  ?RelativePlacement simgeom:coordinates ?coordinates .
}
```

Conclusions

- **Solve interoperability** issues between data models and simulations tools is a hard task

- **Mappings** and **transformation** rules help to overcome the structural and semantic heterogeneity

- Currently, we are **integrating** IFC, climate, Energy Conservation measures data to calculate the baseline scenario and the refurbished scenarios.

THANK YOU FOR YOUR ATTENTION!

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Ontologies

ifcOWL (Pauwels & Terkaj) - http://www.buildingsmart-tech.org/future/linked-data/ifcowl

- Is an ontology for IFC supported by BuildingSMART.
- Exploit the benefits of semantic web technologies in terms of data distribution, **extensibility of the data model, querying, and reasoning**,

CityGML Owl (Knowledge Engineering @ ISS UoG) - http://cui.unige.ch/isi/icle-wiki/ontologies

- A direct translation of the CityGML XMLSchema to OWL, manually tuned

SimModel OWL (Pauwels, Corry & O'Donnell, 2014) - http://www.lbl.gov/namespaces/Sim/

- It is a data model with a domain that **covers the domain of energy simulation** of the entire building.
- This is implemented as a data model (.XSD) that is **interoperable through XML.**
- Is "**geometrically compatible**" with **IFC** among other formats.