Semantic data exchange in BIM to BEM workflows using IFC and SQL-based mapping

9th AIEE Energy Symposium on Energy Security

Current and Future Challenges to Energy Security

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Context and research gaps

Growing energy footprint of buildings and stricter regulatory requirements highlight the lack of integrated design approaches between architecture and energy systems.

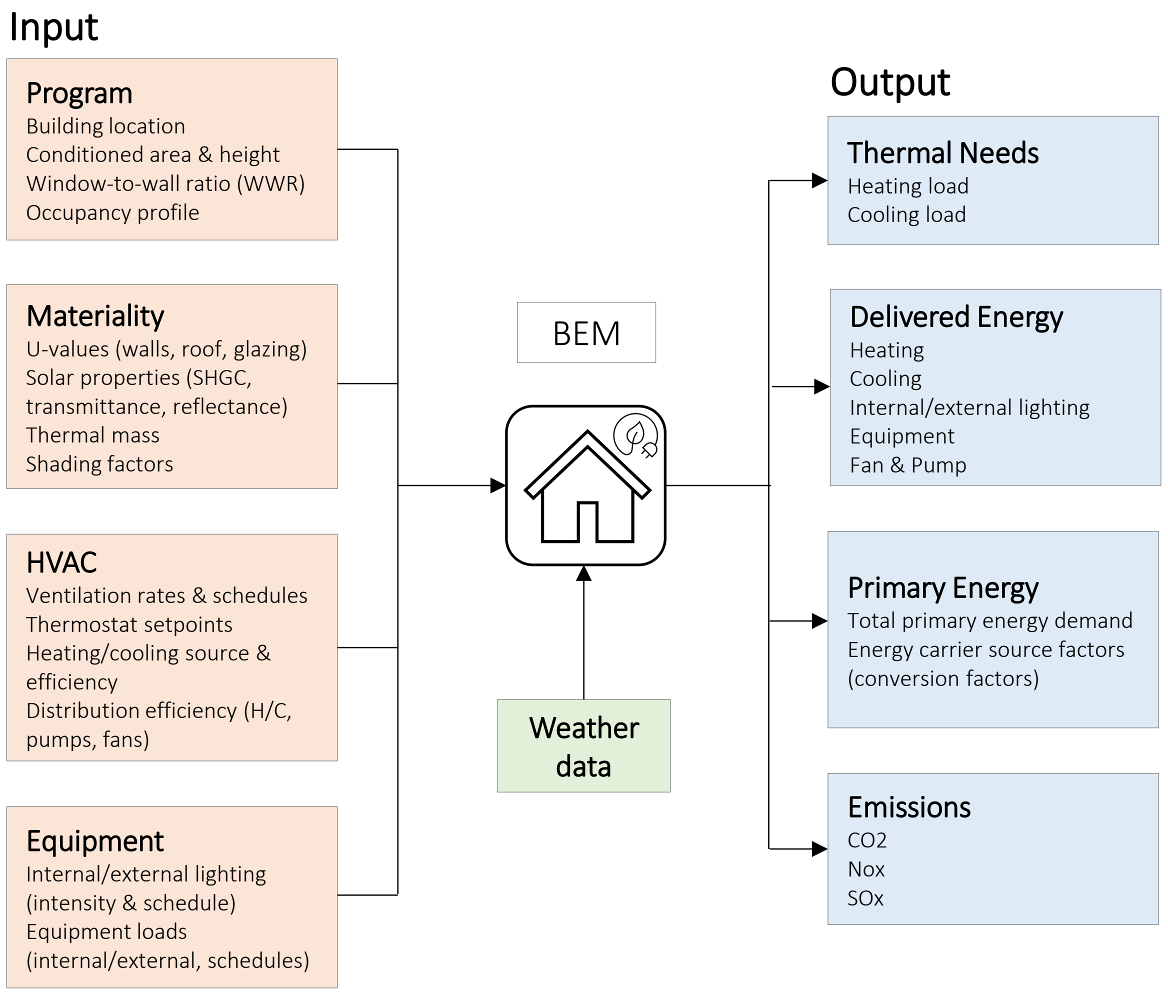
→ Integrating BIM and BEM enables the evaluation and optimization of energy performance during both the design stage and building operation.

Significant semantic and structural differences between BIM and BEM models hinder seamless information exchange and automation.

→ Adopting IFC as a common data standard can enhance interoperability, ensuring consistent and reliable information transfer between BIM and BEM environments.

Context and research gaps

BEM



A Building Energy Model (BEM) is a digital representation of a building energy-related features, used to simulate energy performance across systems.

The BEM can be partially generated from BIM models:

- BIM provides geometric and semantic data, such as zones, surfaces, materials properties;
- Not all BEM inputs come from BIM;
  - Additional data (schedules, setpoints, system specs) must be manually integrated or imported from external databases.

Many simulation tools support the import of IFC or gbXML files.

- However, data loss or incomplete mapping often occurs during import.

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Research objective

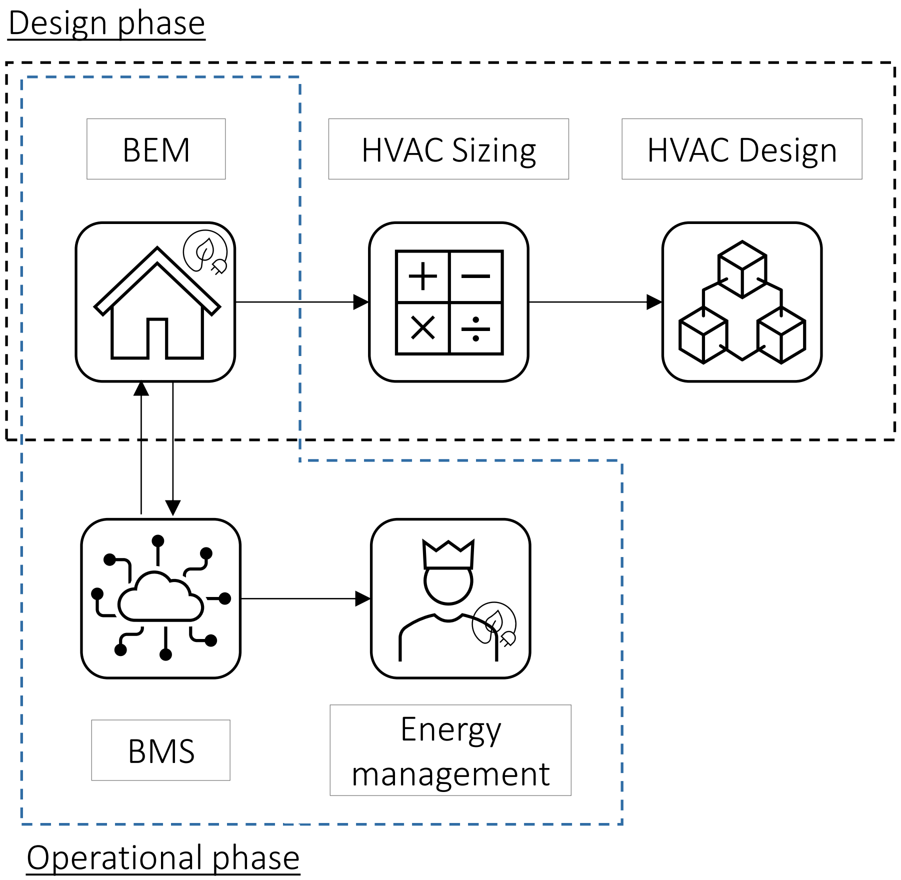
An optimized and interoperable workflow is essential to enable reliable energy simulations starting from BIM models.

- Simulation outputs support critical design activities such as **HVAC system sizing** and layout definition.
- In the Operation & Maintenance (O&M) phase, energy simulation also serves as a **validation tool to detect anomalies**, identify **inefficiencies**, and optimize HVAC system performance.

Therefore, establishing a consistent and streamlined workflow is fundamental to support both the design and operational stages of the building lifecycle.

PROCESS OPTIMIZATION

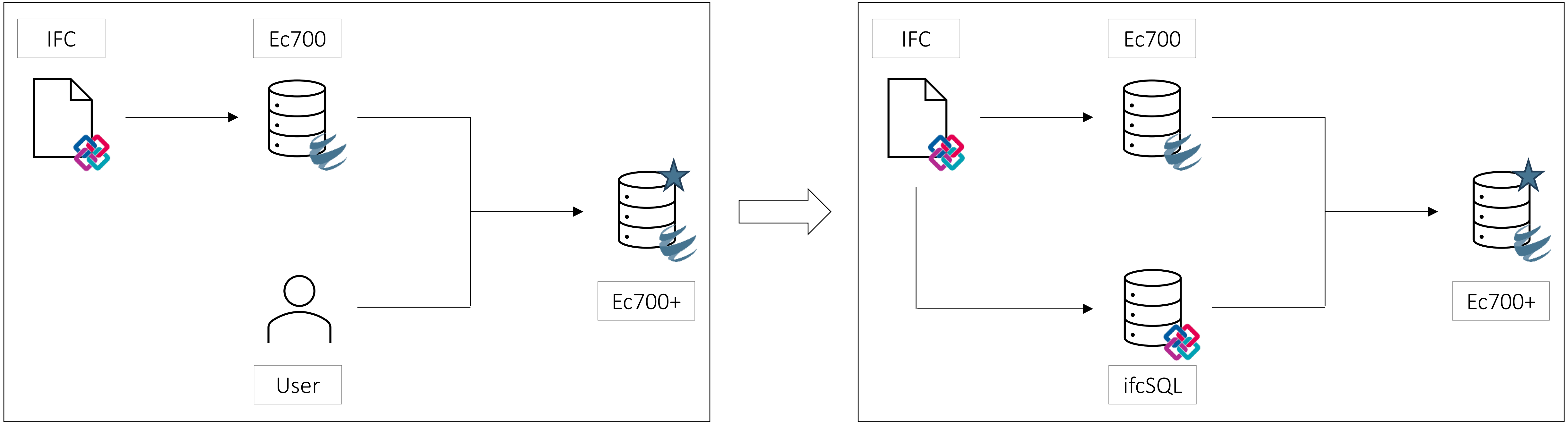
OPERATIONAL EFFICIENCY



Methodology

BIM to BEM workflow

Semantic data exchange in BIM to BEM workflows using IFC and SQL-based mapping



Conventional BIM to BEM workflow with manual data handling

Enhanced BIM to BEM workflow with semantic data exchange

Methodology

BIM to BEM workflow

Semantic data exchange in BIM to BEM workflows using IFC and SQL-based mapping

Ec700

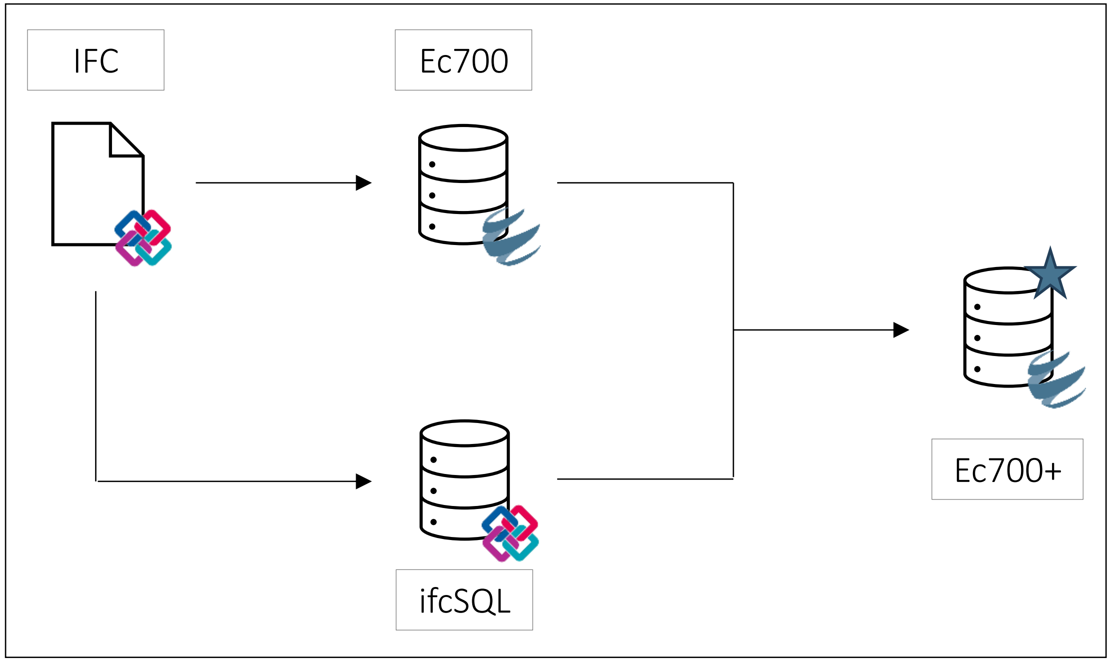
Relational databases in BEM:
- Calculations rely on relational DBs;
- Logical data structure enables mapping.

IFC

IFC as data source:
- IFC can include calculation input data;
- Depends on standard availability.

ifcSQL

IFC to SQL Translation
- Bock and Eder’s IFC-to-SQL method;
- Supports interoperability between BIM and BEM.



Enhanced BIM to BEM workflow with semantic data exchange

Methodology

BIM to BEM workflow

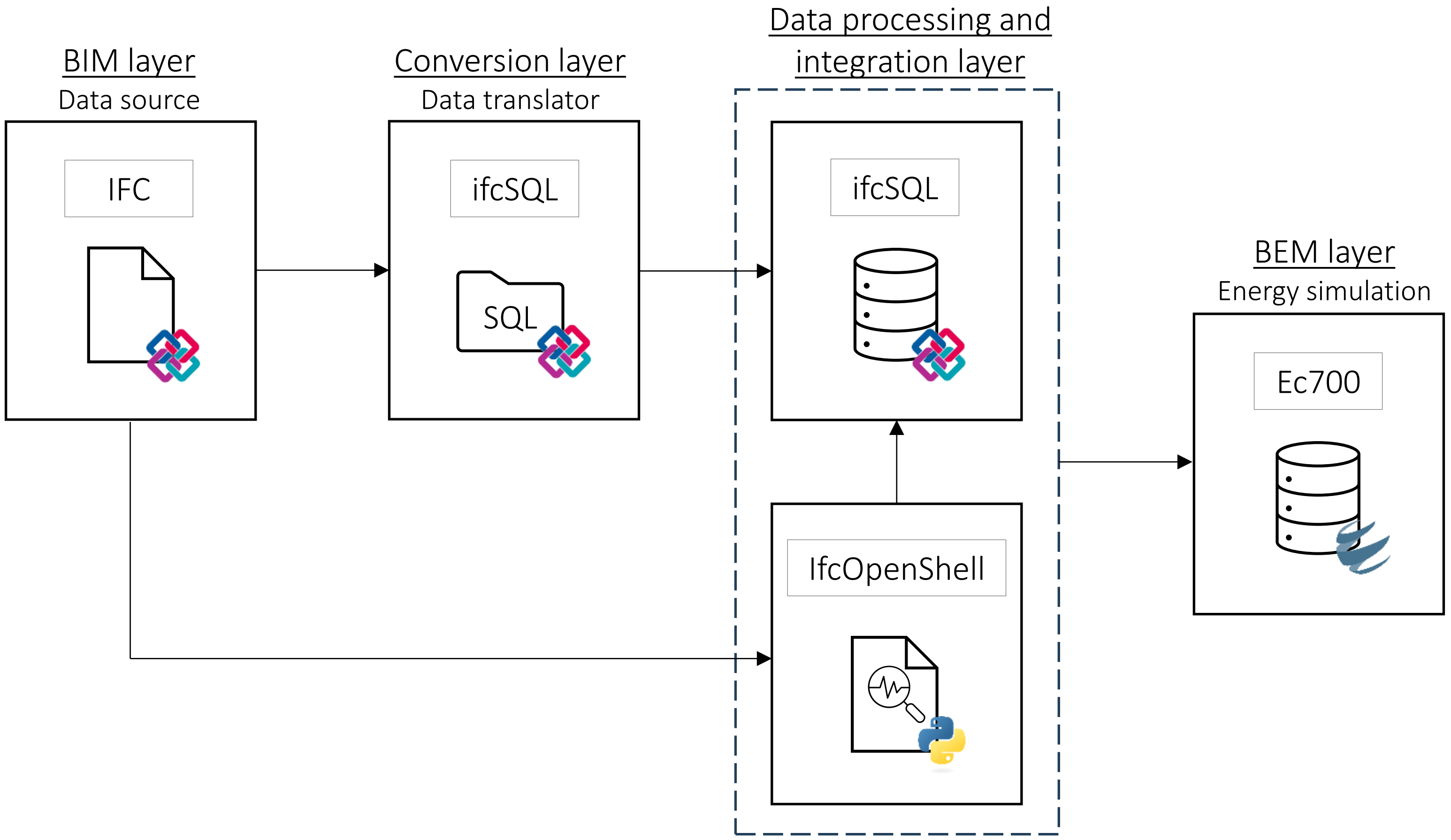
Framework modules

- BIM layer
Creation of the BIM model and IFC export

- Conversion layer
Translation of IFC into relational SQL structure

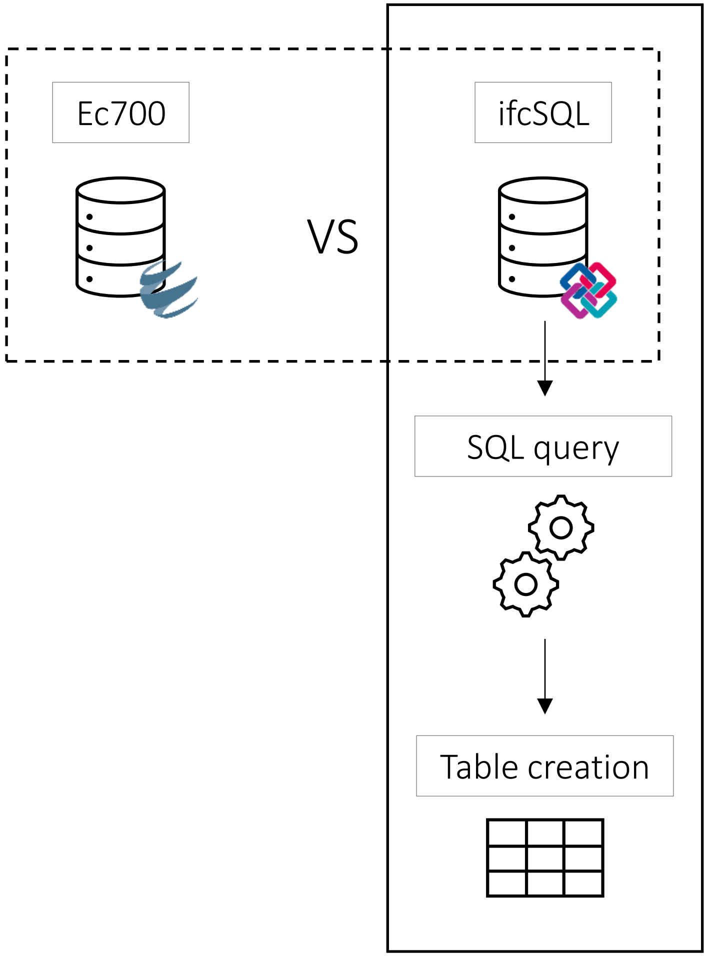
- Data processing and integration layer
Data reorganization, enrichment, and alignment to BEM schema

- BEM layer
Automatic import and data enrichment of the energy model



Methodology

BIM to BEM workflow



<u>Data processing and integration layer</u>

The procedure by Bock and Eder (2021) enables the translation of IFC files into SQL language. This makes it possible to:

- Organize the information according to the EdilClima tables;
- Transfer the information to the EdilClima software.

<u>Mapping between IFC and Edilclima database</u>

- Identify where each piece of information should be placed by consulting both the IFC standard and the Edilclima database structure.

<u>SQL queries in SSMS to extract IFC properties</u>

- Retrieve the required data from the translated IFC dataset.

<u>Creation of tables matching the EC structure</u>

- Build SQL tables with the same schema as those used in EdilClima.

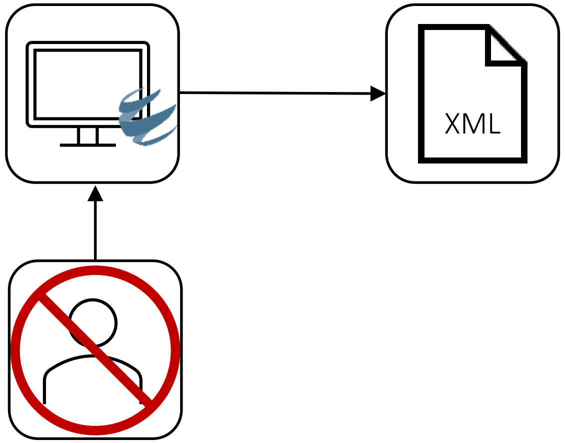
Methodology

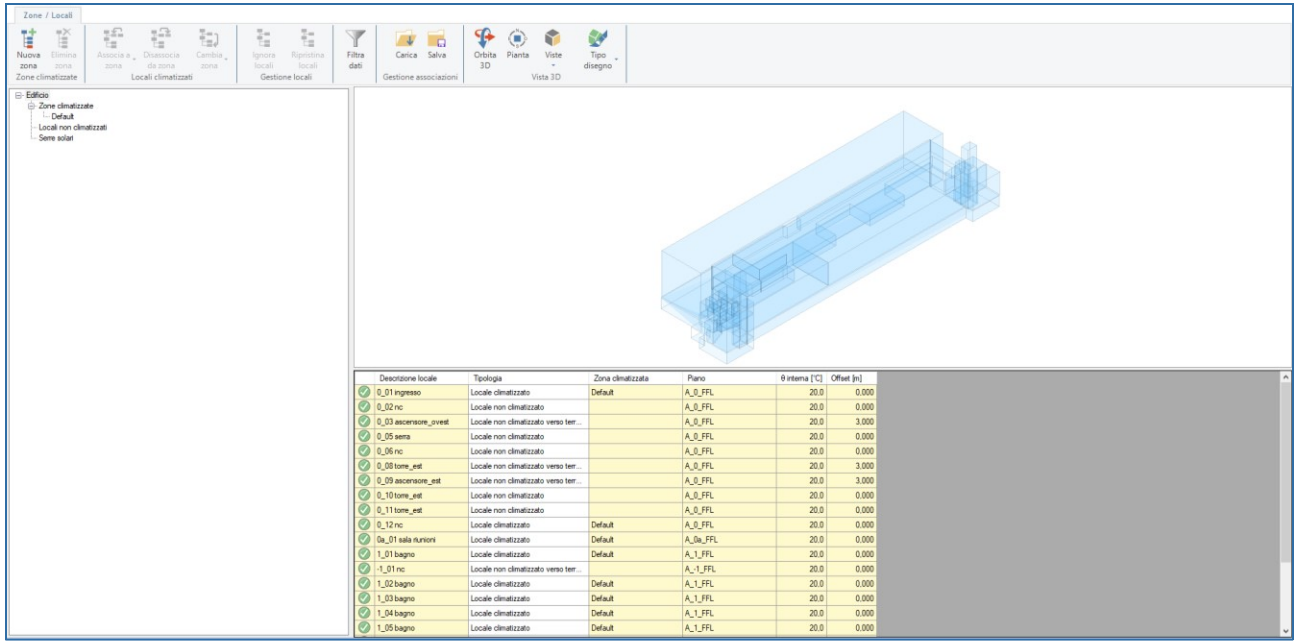
IfcSpace and IfcZone

When importing an IFC file, EdilClima requires the user to:

- Define the room type;
- Assign each conditioned room to a specific thermal zone.

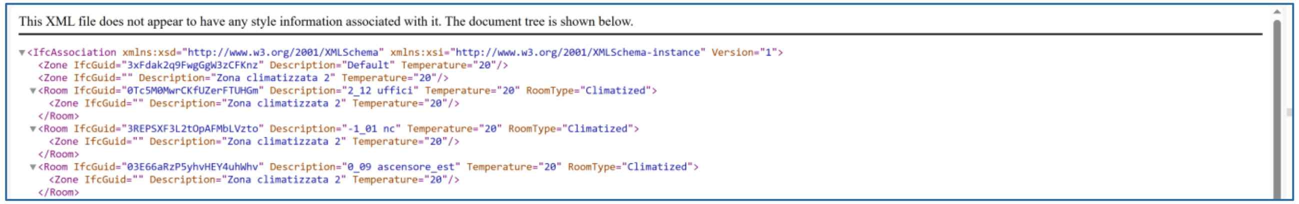
After defining the room-to-zone mapping, the software enables the creation of XML-based association files.





Descrizione locale	Tipologia	Zona climatizzata	Piano	θ interna [°C]	Offset [m]
0_01 ingresso	Locale climatizzato	Default	A_0_FFL	20,0	0,000
0_02 nc	Locale non climatizzato		A_0_FFL	20,0	0,000
0_03 ascensore_ovest	Locale non climatizzato verso terr...		A_0_FFL	20,0	3,000
0_05 serra	Locale non climatizzato		A_0_FFL	20,0	0,000
0_06 nc	Locale non climatizzato		A_0_FFL	20,0	0,000
0_08 torre_est	Locale non climatizzato verso terr...		A_0_FFL	20,0	3,000
0_09 ascensore_est	Locale non climatizzato verso terr...		A_0_FFL	20,0	3,000
0_10 torre_est	Locale non climatizzato		A_0_FFL	20,0	0,000
0_11 torre_est	Locale non climatizzato		A_0_FFL	20,0	0,000
0_12 nc	Locale climatizzato	Default	A_0_FFL	20,0	0,000
0a_01 sala riunioni	Locale climatizzato	Default	A_0a_FFL	20,0	0,000
1_01 bagno	Locale climatizzato	Default	A_1_FFL	20,0	0,000
-1_01 nc	Locale non climatizzato verso terr...		A_-1_FFL	20,0	0,000
1_02 bagno	Locale climatizzato	Default	A_1_FFL	20,0	0,000
1_03 bagno	Locale climatizzato	Default	A_1_FFL	20,0	0,000
1_04 bagno	Locale climatizzato	Default	A_1_FFL	20,0	0,000
1_05 bagno	Locale climatizzato	Default	A_1_FFL	20,0	0,000

Room-to-Zone Mapping Interface


This XML file does not appear to have any style information associated with it. The document tree is shown below.


```xml
<IfcAssociation xmlns:xsd="http://www.w3.org/2001/XMLSchema" xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" Version="1">
  <Zone IfcGuid="3xFdak2q9FwgGgW3zCFKnz" Description="Default" Temperature="20"/>
  <Zone IfcGuid="" Description="Zona climatizzata 2" Temperature="20"/>
  <Room IfcGuid="0Tc5M0MwrCKfUZerFTUHGm" Description="2_12 uffici" Temperature="20" RoomType="Climatized">
    <Zone IfcGuid="" Description="Zona climatizzata 2" Temperature="20"/>
  </Room>
  <Room IfcGuid="3REPSXF3L2tOpAFMbLVzto" Description="-1_01 nc" Temperature="20" RoomType="Climatized">
    <Zone IfcGuid="" Description="Zona climatizzata 2" Temperature="20"/>
  </Room>
  <Room IfcGuid="03E66aRzP5yhvHEY4uhWhv" Description="0_09 ascensore_est" Temperature="20" RoomType="Climatized">
    <Zone IfcGuid="" Description="Zona climatizzata 2" Temperature="20"/>
  </Room>
```


XML Output from EdilClima

Methodology

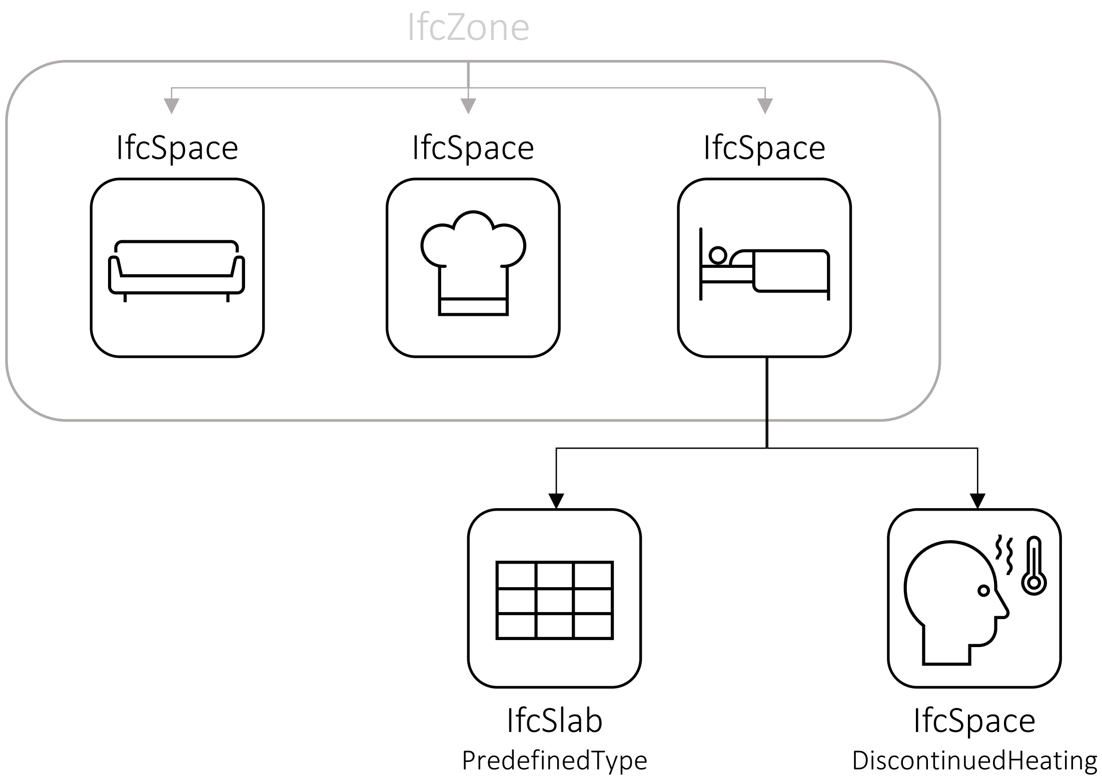
IfcSpace and IfcZone

In order to map the correspondence between room types used in EC700 and the IFC standard, the following matrix was developed:

EC RoomType	DH	S2	S3
Climatized			
NotClimatized			
UndergroundClimatized			
UndergroundNotClimatized			
SolarGreenHouse			
UndergroundSolarGreenHouse			

Where:

- DH stands for DiscontinuedHeating (a boolean parameter indicating the absence/presence of heating/cooling);
- S2 stands for IfcSlab – BaseSlab (slab on ground);
- S3 stands for IfcSlab – Floor (floor slab)



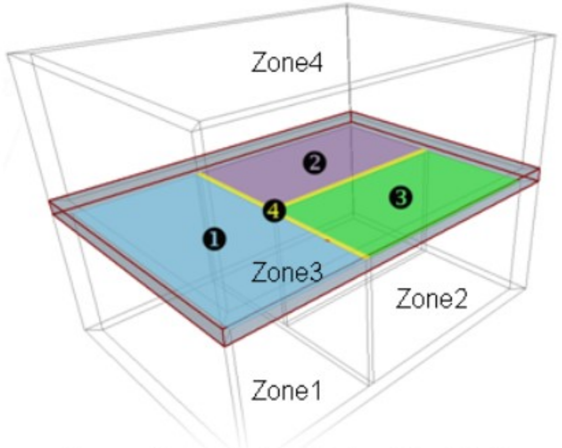
IfcSpace and IfcZone

IfcSpace and IfcZone

IFC → An IfcSlab can be shared by multiple IfcSpaces, depending on how it has been modelled within a BIM authoring software.

??? ↕ ???

BEM → Any building component is divided into several parts depending on the type of energy transmission.



Space Boundaries (defined by Slab):
1 - Slab part defined by Zone1
2 - Slab part defined by Zone3
3 - Slab part defined by Zone2
4 - Slab part without thermal convection

Methodology

IfcSpace and IfcZone

IfcSpace and IfcZone

IFC

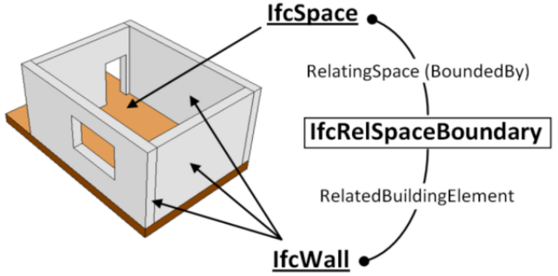
An IfcSlab can be shared by multiple IfcSpaces, depending on how it has been modelled within a BIM authoring software.

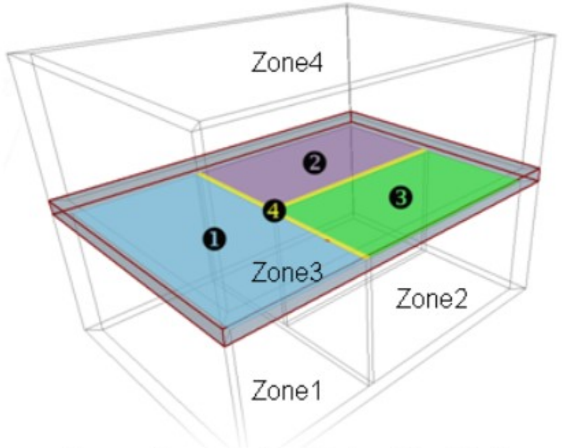
??? ???

BEM

Any building component is divided into several parts depending on the type of energy transmission.

IFC





Space Boundaries (defined by Slab):
1 - Slab part defined by Zone1
2 - Slab part defined by Zone3
3 - Slab part defined by Zone2
4 - Slab part without thermal convection

Research project

IfcSpace and IfcZone

The information extracted from the IFC file is used to generate two SQL tables (**Zone XML** and **Space XML**), which are then used to create the XML file associating rooms to zones.

	Zone_Gid	IfcGuid	Description	Temperature
1	109979	3xFdak2q9FwgGgW3zCFKnz	Default	20

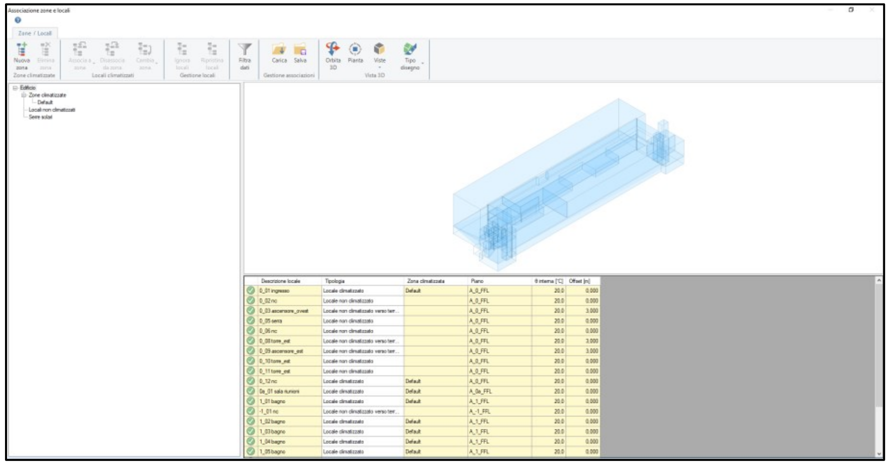
Zone XML table

```sql
CREATE TABLE SpaceXML (Space_Gid INT, Space_Guid NVARCHAR(MAX), Description NVARCHAR(MAX), Temperature INT, RoomType NVARCHAR(MAX), Zone_Guid NVARCHAR(MAX), Zone_Des
INSERT INTO SpaceXML (Space_Gid, Space_Guid, Description, Temperature, RoomType, Zone_Guid, Zone_Description, Zone_Temperature)
SELECT
    ss.Space_Gid,
    ss.Space_Guid,
    RTRIM(LTRIM(ss.Space_Name)) + ' ' + RTRIM(LTRIM(ss.Space_LongName)) AS Description, --Combino SpaceName con SpaceLongName
    20 AS Temperature,
    CASE
        WHEN MAX(CASE WHEN ss.Slab_Type = 2 THEN 1 ELSE 0 END) = 0 AND MAX(CAST(ss.Unheated AS INT)) = 0 THEN 'Climatized'
        WHEN MAX(CASE WHEN ss.Slab_Type = 2 THEN 1 ELSE 0 END) = 0 AND MAX(CAST(ss.Unheated AS INT)) = 1 THEN 'NotClimatized'
        WHEN MAX(CASE WHEN ss.Slab_Type = 2 THEN 1 ELSE 0 END) = 1 AND MAX(CAST(ss.Unheated AS INT)) = 0 THEN 'UndergroundClimatized'
        WHEN MAX(CASE WHEN ss.Slab_Type = 2 THEN 1 ELSE 0 END) = 1 AND MAX(CAST(ss.Unheated AS INT)) = 1 THEN 'UndergroundNotClimatized'
        ELSE 'Climatized'
    END AS RoomType,
    zx.IfcGuid,
    CASE
        WHEN MAX(CASE WHEN ss.Slab_Type = 2 THEN 1 ELSE 0 END) = 0 AND MAX(CAST(ss.Unheated AS INT)) = 1 THEN ''
        WHEN MAX(CASE WHEN ss.Slab_Type = 2 THEN 1 ELSE 0 END) = 1 AND MAX(CAST(ss.Unheated AS INT)) = 1 THEN ''
        ELSE zx.Description
    END AS Zone_Description,
    zx.Temperature
FROM @SpaceSlab ss
LEFT JOIN @RelGroup rg ON ss.Space_Gid = rg.Space_Gid
LEFT JOIN ZoneXML zx ON rg.Zone_Gid = zx.Zone_Gid
GROUP BY ss.Space_Gid, ss.Space_Guid, ss.Space_Name, ss.Space_LongName, zx.IfcGuid, zx.Description, zx.Temperature;
```

SQL query

	Space_Gid	Space_Guid	Description	Temperature	RoomType	Zone_Guid	Zone_Description	Zone_Temperature
1	174	0Tc5M0MwrCKfUZerFTUHGm	2_12 uffici	20	Climatized	3xFdak2q9FwgGgW3zCFKnz	Default	20
2	759	03E66aRzP5yhvHEY4uhWiU	0_01 ingresso	20	Climatized	3xFdak2q9FwgGgW3zCFKnz	Default	20
3	953	03E66aRzP5yhvHEY4uhWiJ	0_03 ascensore_ovest	20	UndergroundNotClimatized	3xFdak2q9FwgGgW3zCFKnz		20
4	1037	03E66aRzP5yhvHEY4uhWiN	0_02 nc	20	NotClimatized	3xFdak2q9FwgGgW3zCFKnz		20
5	1179	03E66aRzP5yhvHEY4uhWiF	0_05 serra	20	NotClimatized	3xFdak2q9FwgGgW3zCFKnz		20
6	1339	03E66aRzP5yhvHEY4uhWi3	0_06 nc	20	NotClimatized	3xFdak2q9FwgGgW3zCFKnz		20
7	1490	03E66aRzP5yhvHEY4uhWhx	0_08 torre_est	20	UndergroundNotClimatized	3xFdak2q9FwgGgW3zCFKnz		20
8	1583	03E66aRzP5yhvHEY4uhWhv	0_09 ascensore_est	20	UndergroundNotClimatized	3xFdak2q9FwgGgW3zCFKnz		20
9	1693	03E66aRzP5yhvHEY4uhWh$	0_10 torre_est	20	NotClimatized	3xFdak2q9FwgGgW3zCFKnz		20
10	1837	03E66aRzP5yhvHEY4uhWhz	0_11 torre_est	20	NotClimatized	3xFdak2q9FwgGgW3zCFKnz		20
11	2043	03E66aRzP5yhvHEY4uhWhn	0_12 nc	20	Climatized	3xFdak2q9FwgGgW3zCFKnz	Default	20
12	2197	03E66aRzP5yhvHEY4uhWXZ	0a_01 sala riunioni	20	Climatized	3xFdak2q9FwgGgW3zCFKnz	Default	20
13	2417	0A17tIFzjDPfgFYNAR0vSn	1_09 rip bagno	20	Climatized	3xFdak2q9FwgGgW3zCFKnz	Default	20
14	2556	0A17tIFzjDPfgFYNAR0vSC	1_01 bagno	20	Climatized	3xFdak2q9FwgGgW3zCFKnz	Default	20
15	2623	0A17tIFzjDPfgFYNAR0vS8	1_02 bagno	20	Climatized	3xFdak2q9FwgGgW3zCFKnz	Default	20
16	2748	0A17tIFzjDPfgFYNAR0vS6	1_03 bagno	20	Climatized	3xFdak2q9FwgGgW3zCFKnz	Default	20
17	2879	0A17tIFzjDPfgFYNAR0vS4	1_04 bagno	20	Climatized	3xFdak2q9FwgGgW3zCFKnz	Default	20
18	2946	0A17tIFzjDPfgFYNAR0vS2	1_05 bagno	20	Climatized	3xFdak2q9FwgGgW3zCFKnz	Default	20
19	3051	0A17tIFzjDPfgFYNAR0vS0	1_06 bagno	20	Climatized	3xFdak2q9FwgGgW3zCFKnz	Default	20
20	3145	0A17tIFzjDPfgFYNAR0vSU	1_07 bagno	20	Climatized	3xFdak2q9FwgGgW3zCFKnz	Default	20
21	3290	0A17tIFzjDPfgFYNAR0vSS	1_08 dis bagno	20	Climatized	3xFdak2q9FwgGgW3zCFKnz	Default	20
22	3529	0A17tIFzjDPfgFYNAR0vSO	1_10 disimpegno	20	Climatized	3xFdak2q9FwgGgW3zCFKnz	Default	20
23	3941	3REPSXF3L2tOpAFMbLVzto	-1_01 nc	20	UndergroundNotClimatized	3xFdak2q9FwgGgW3zCFKnz		20

Space XML table

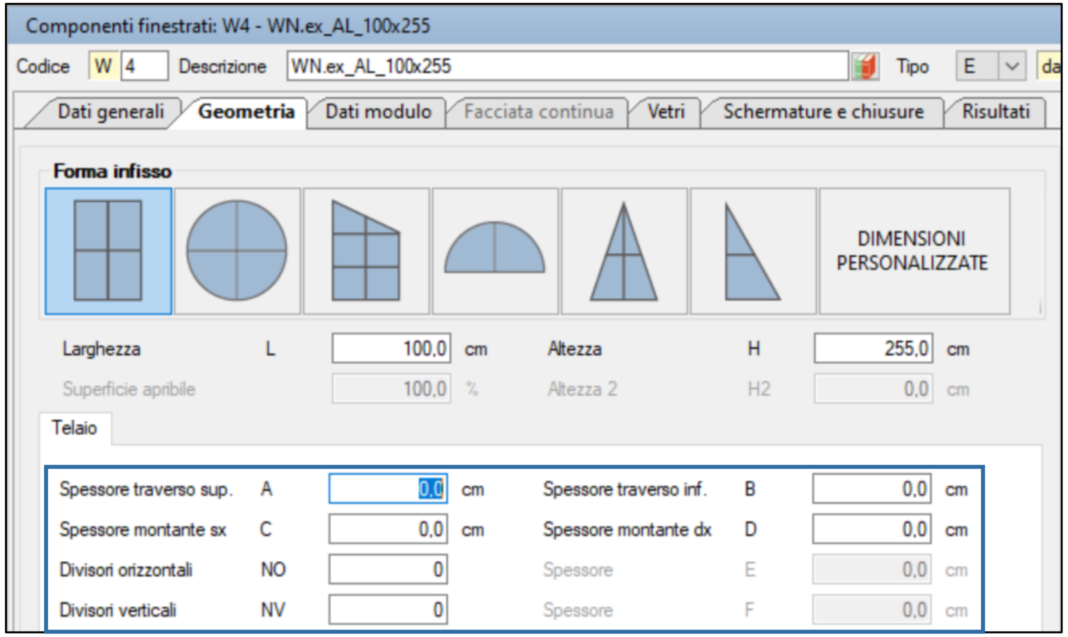


EC700 – Room-to-Zone Association

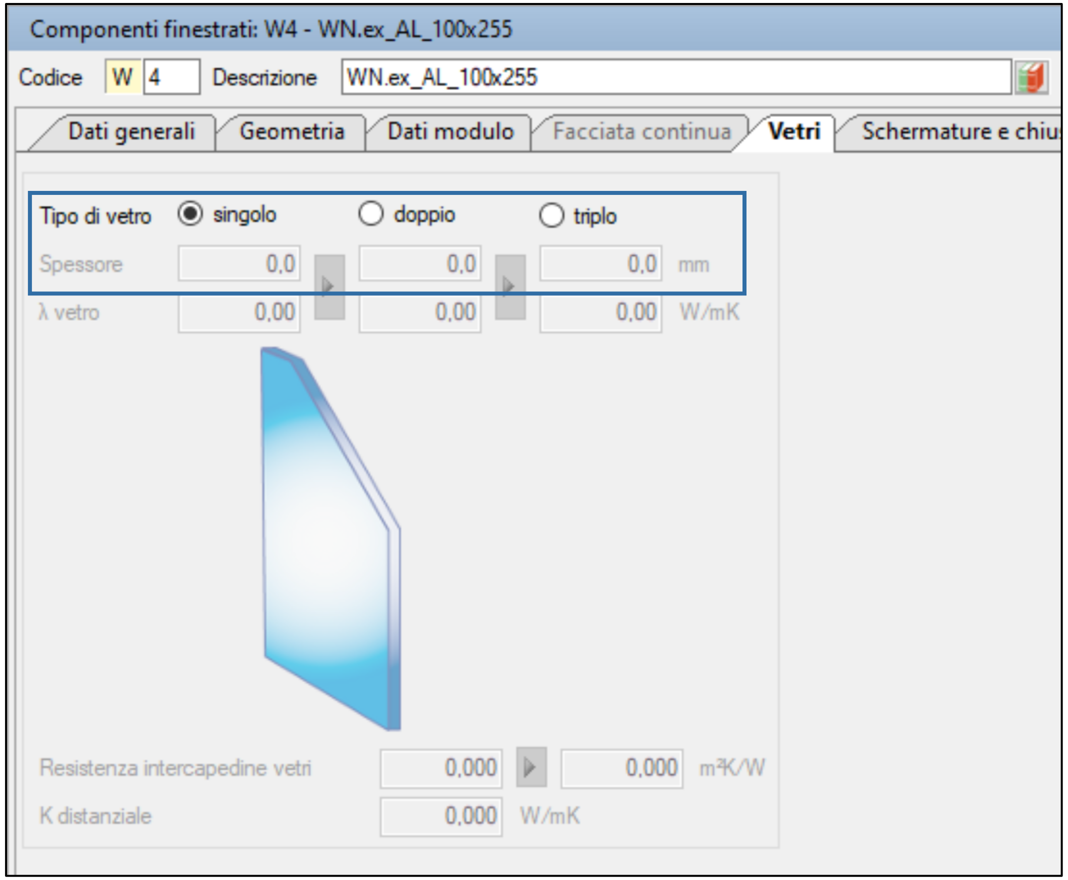
Methodology

IfcWindow

Importing the IFC file into the simulation environment does not transfer the **energy properties** of the **windows**.



EC User interface

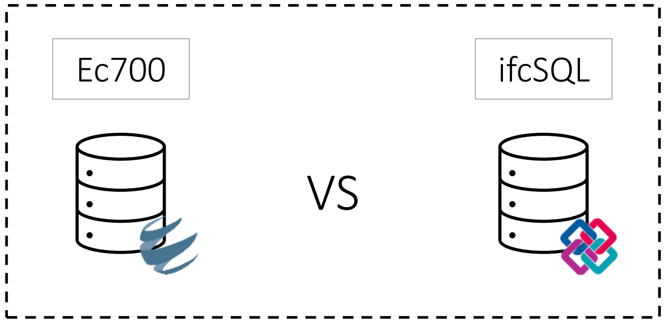


EC User interface

Methodology

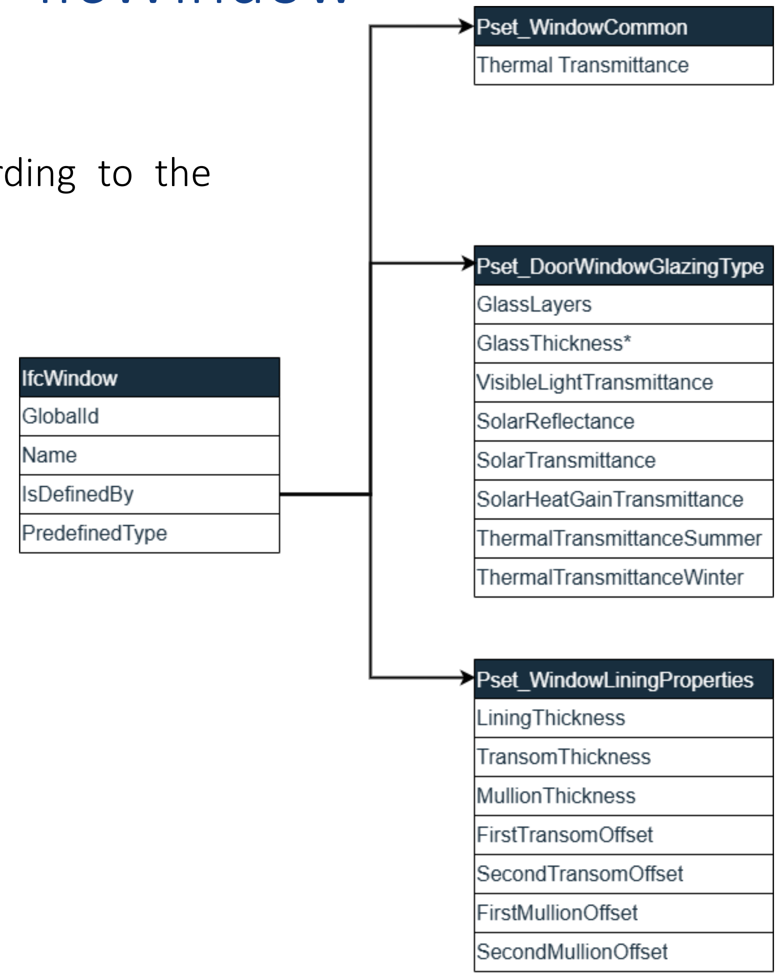
IfcWindow

The **mapping activity** enables the transfer of data according to the availability of the IFC standard.



The same procedure was applied to:

- **IfcSlab**;
- **IfcSpace**;
- **IfcZone**.



Methodology

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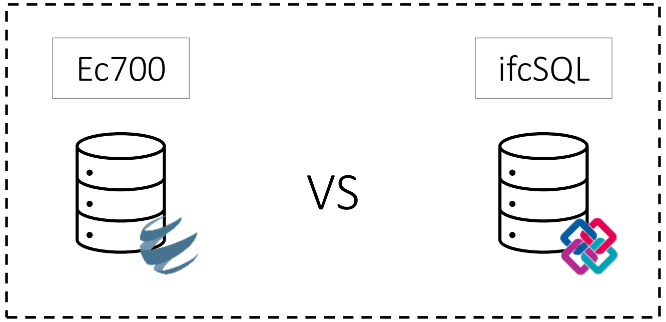
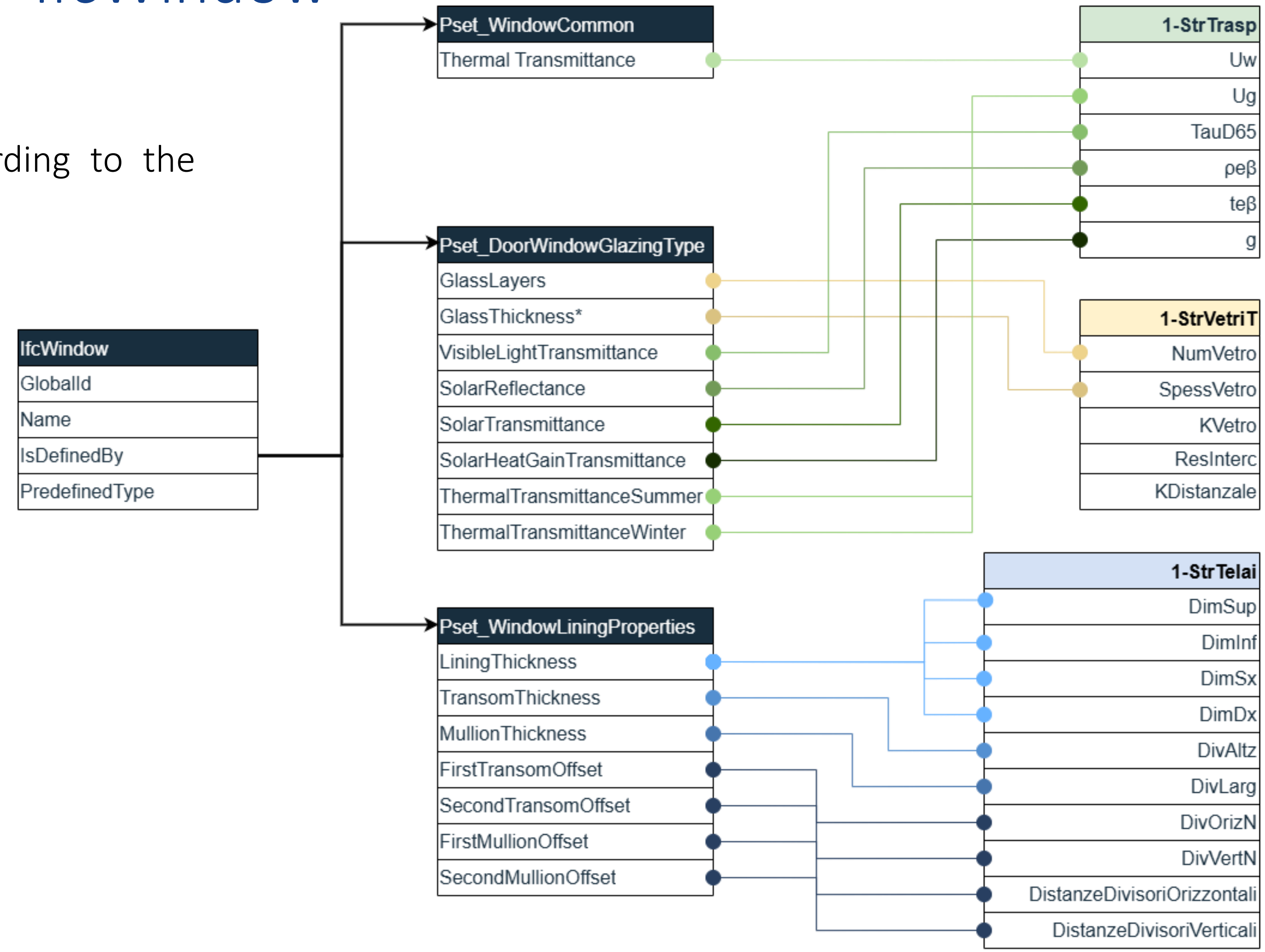




The same procedure was applied to:

- IfcSlab;
- IfcSpace;
- IfcZone.

Methodology

IfcWindow

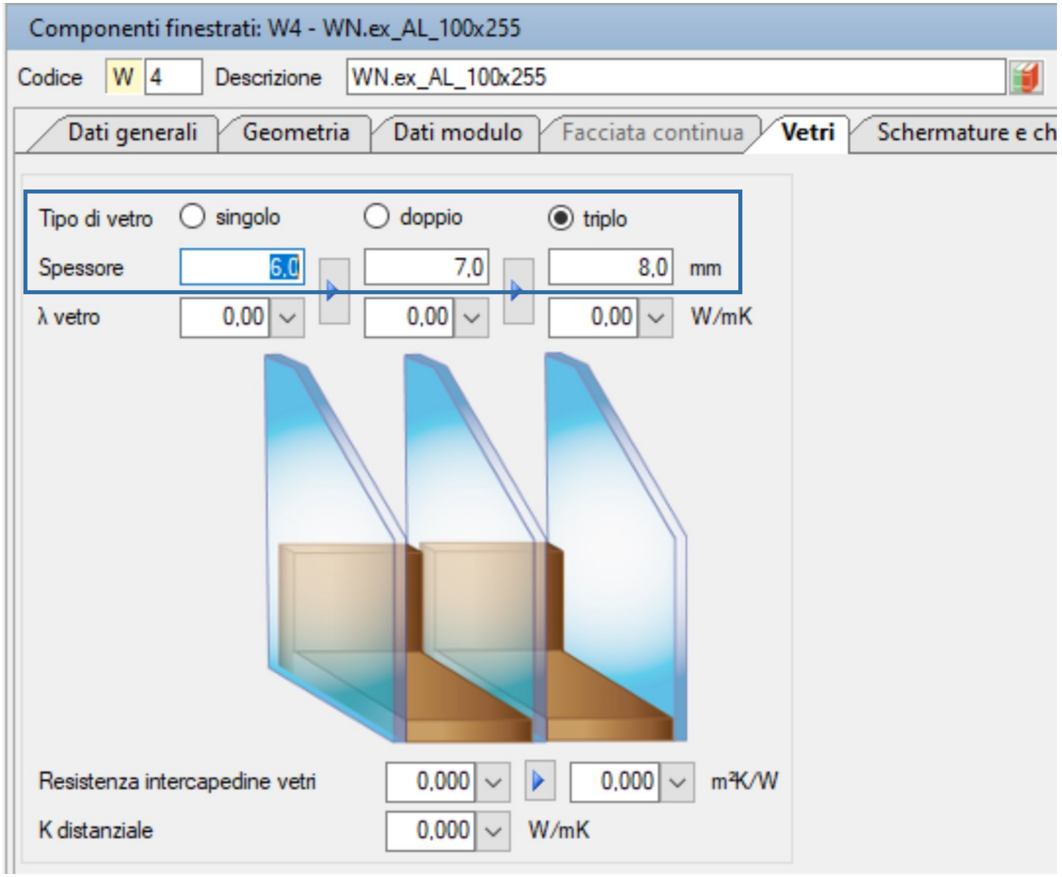
Data Integration - Window

Then, a verification is carried out between the data entered in the database and what is displayed in the user interface.

Tabella: 1-StrVetriT

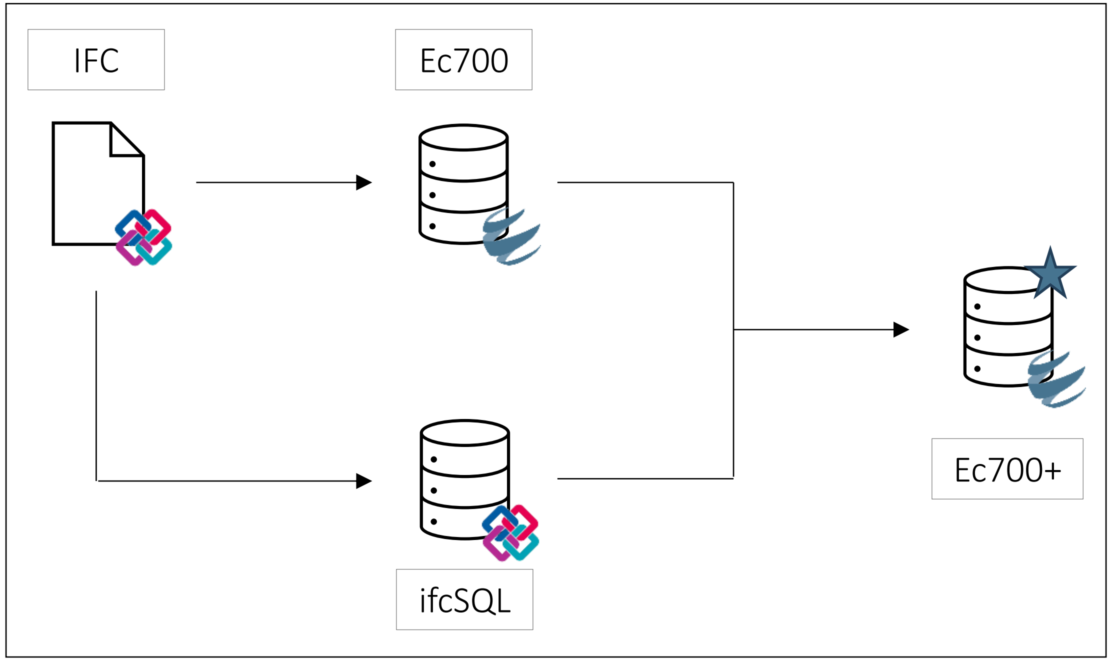
	Codice	NumTelaio	NumVetro	SpessVetro	KVetro	ResInterc	KDistanziale
	Filtro	Filtro	Filtro	Filtro	Filtro	Filtro	Filtro
1	1	1	1	5.0	0.0	0.0	NULL
2	2	1	1	6.0	0.0	0.0	NULL
3	3	1	1	6.0	0.0	0.0	NULL
4	4	1	1	6.0	0.0	0.0	NULL
5	4	1	2	7.0	NULL	NULL	NULL
6	4	1	3	8.0	NULL	NULL	NULL
7	3	1	2	8.0	NULL	NULL	NULL
8	1	1	2	6.0	NULL	NULL	NULL
9	1	1	3	7.0	NULL	NULL	NULL
10	2	1	2	7.0	NULL	NULL	NULL

1-StrVetriT table



EC User interface

Results



Enhanced BIM to BEM workflow with semantic data exchange

- **Enhanced interoperability**

Adoption of the IFC-based workflow ensures consistent and automated data exchange between BIM and BEM, overcoming fragmentation.

- **Process efficiency**

Automated information transfer reduces manual input, minimizes errors, and accelerates energy modelling and simulation phases.

- **Scalability and reusability**

The framework can be easily replicated across different projects and contexts, supporting the permanent integration of BIM–BEM workflows into design practices.

Limitation and future works

Limitations

The current IFC standard does not fully represent the energy domain.

The current methodology enables a unidirectional data flow from BIM to BEM.

Future works

Expansion of IFC data model to include additional energy-related entities and properties.

Extension of the workflow to enable bidirectional data exchange.

THANK YOU FOR YOUR ATTENTION

Any questions?

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