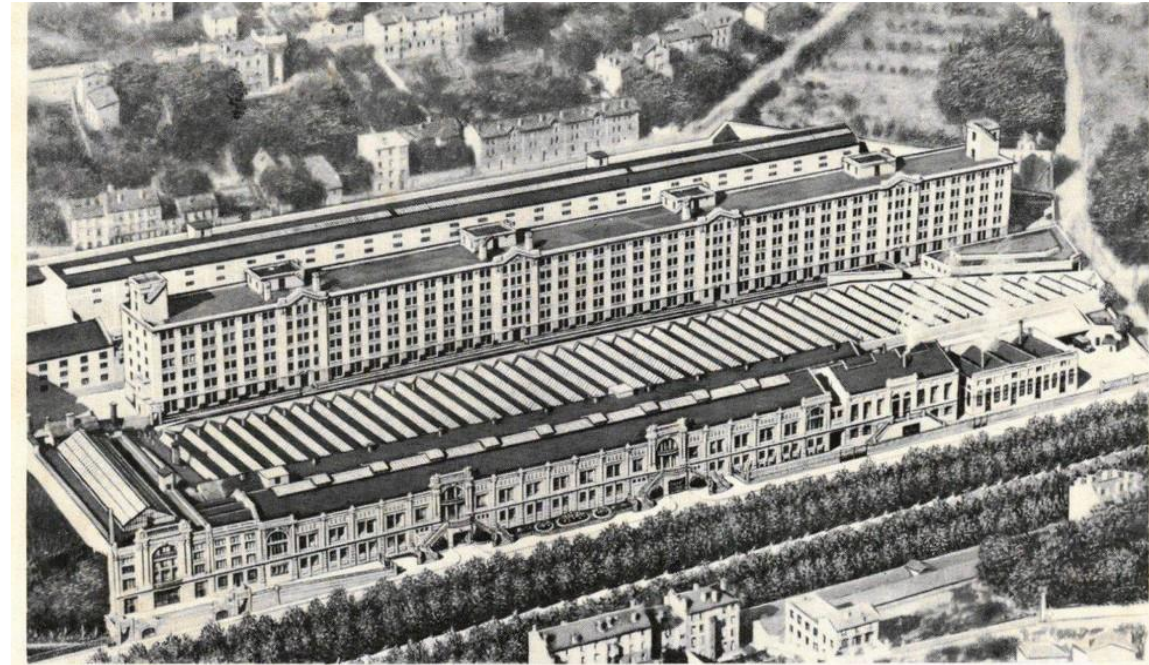# Modular Knowledge integration for Smart Building Digital Twins
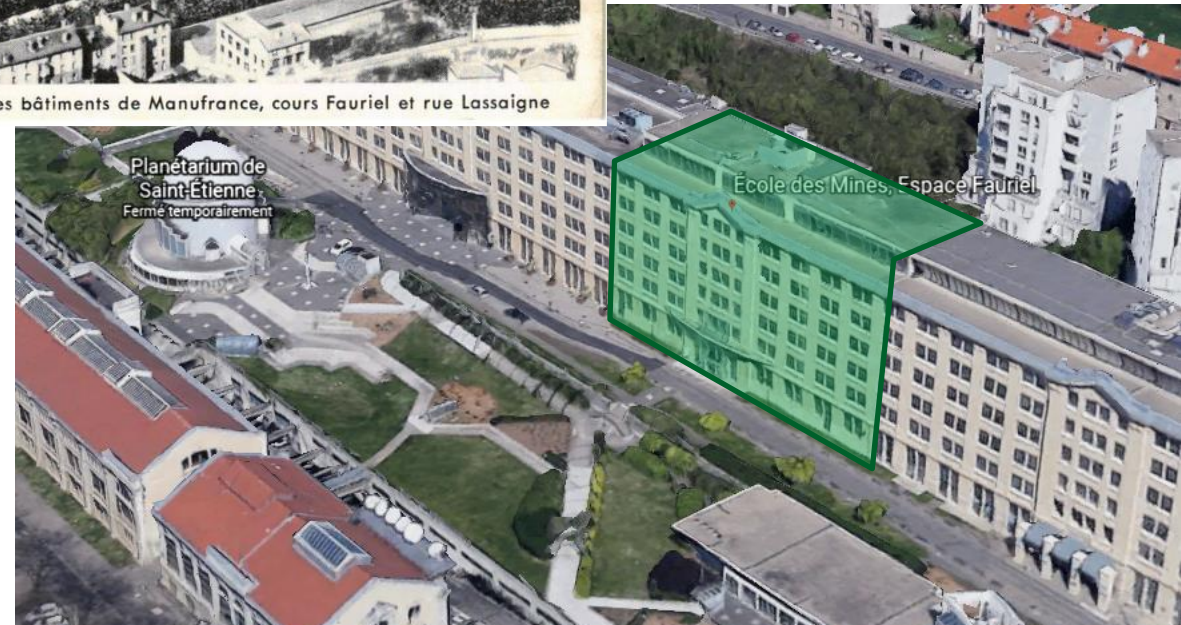
Isaac Fatokun, Arun Raveendran Nair Sheela, Thamer Mecharnia,
Maxime Lefrançois, Victor Charpenay, Fabien Badeig, and Antoine Zimmermann
Mines Saint-Étienne, Institut Mines Télécom

LDAC 2023

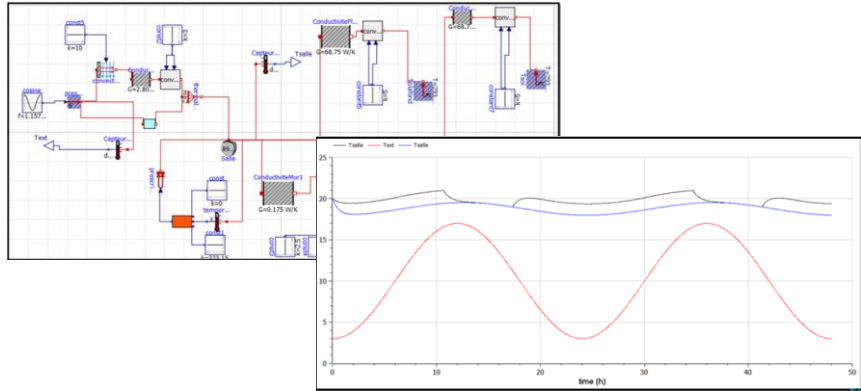# Espace Fauriel Building of Mines Saint-Étienne

SAINT-ÉTIENNE. Vue générale du groupe principal des bâtiments de Manufrance, cours Fauriel et rue Lassaigne

Built around 1920 by Manufrance, refurbished in 1994,
Part for Mines Saint-Étienne **8 storeys, 6720 m²**
Amphitheaters, classrooms, offices, meeting rooms,…
Average daily energy: winter 1,3MWh summer 0,5MWh
Building Management System EIB (now KNX)

Development of a Digital Twin for our building

DecisionTreeRegressor trained on real data and space and element properties to optimise when to start heating

KNX Building Management System + set of heterogeneous IoT devices: different protocols and properties

Thermal simulation parameters optimized to fit actual data

Deng, Mingyan, Carol C. Menassa and Vineet R. Kamat. "From BIM to digital twins: a systematic review of the evolution of intelligent building representations in the AEC-FM industry." *J. Inf. Technol. Constr.* 26 (2021): 58-83.

IFC model of our building, made openly available to the community https://ci.mines-stetienne.fr/EMSE_EF/

3

Development of a Digital Twin for our building

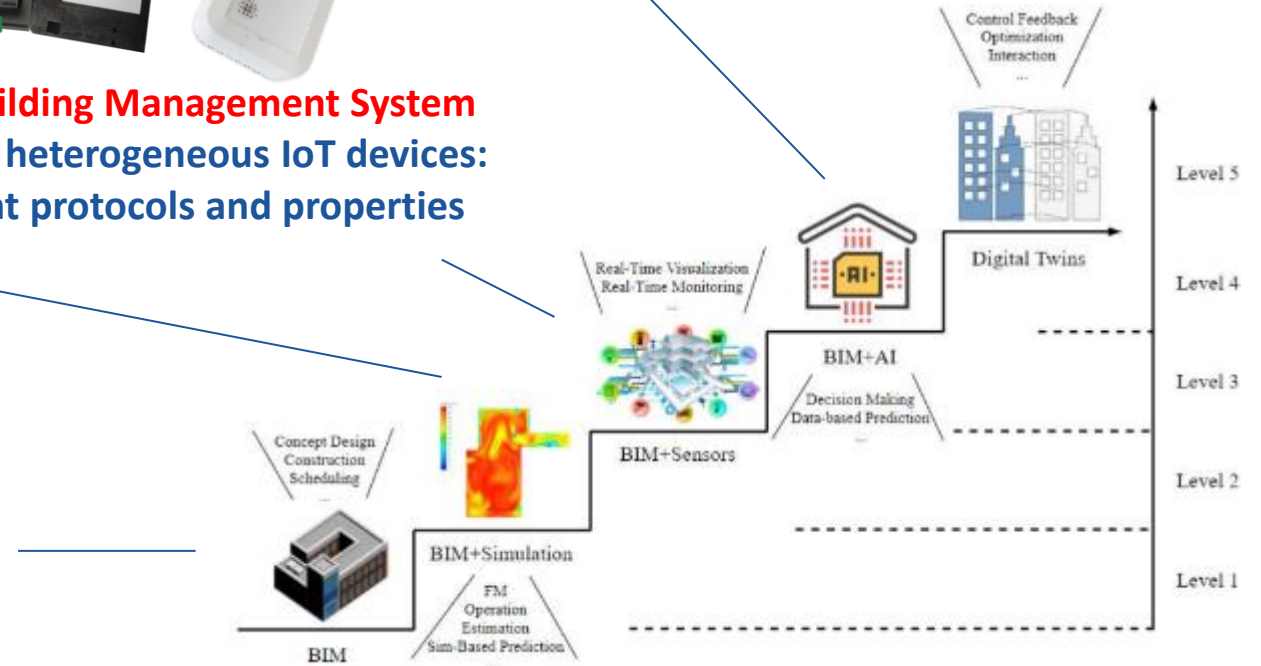**Thermal simulation parameters optimized to fit actual data**

KNX Building Management System + set of heterogeneous IoT devices: different protocols and properties

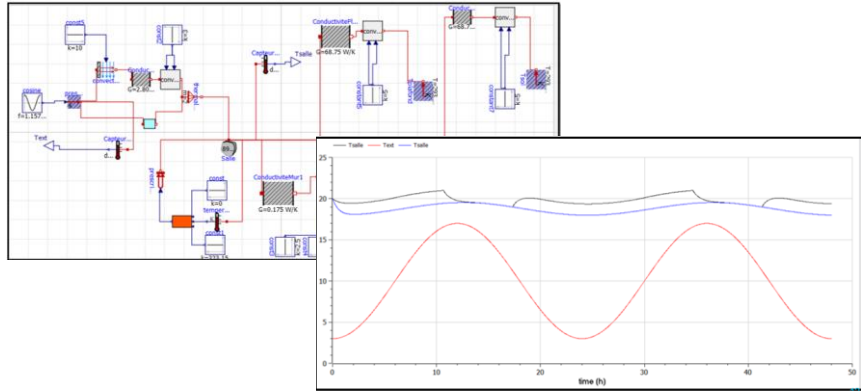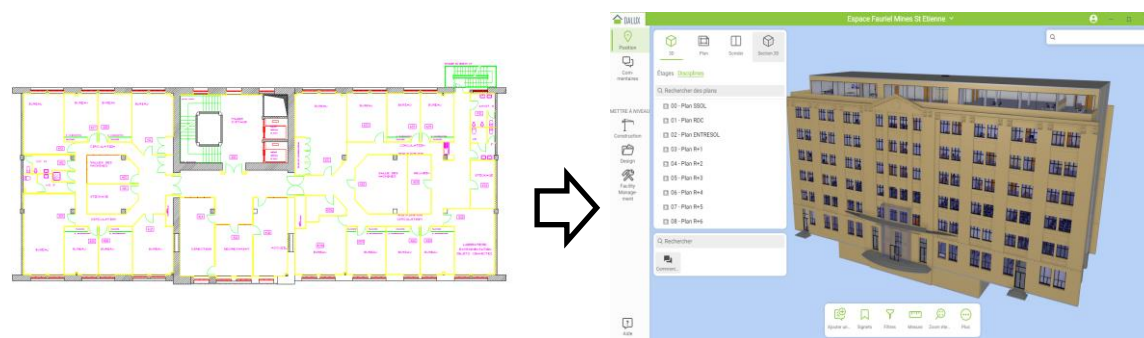**DecisionTreeRegressor trained on real data and space and element properties to optimise when to start heating**

Deng, Mingyan, Carol C. Menassa and Vineet R. Kamat. "From BIM to digital twins: a systematic review of the evolution of intelligent building representations in the AEC-FM industry." *J. Inf. Technol. Constr.* 26 (2021): 58-83.

IFC model of our building, made openly available to the community https://ci.mines-stetienne.fr/EMSE_EF/
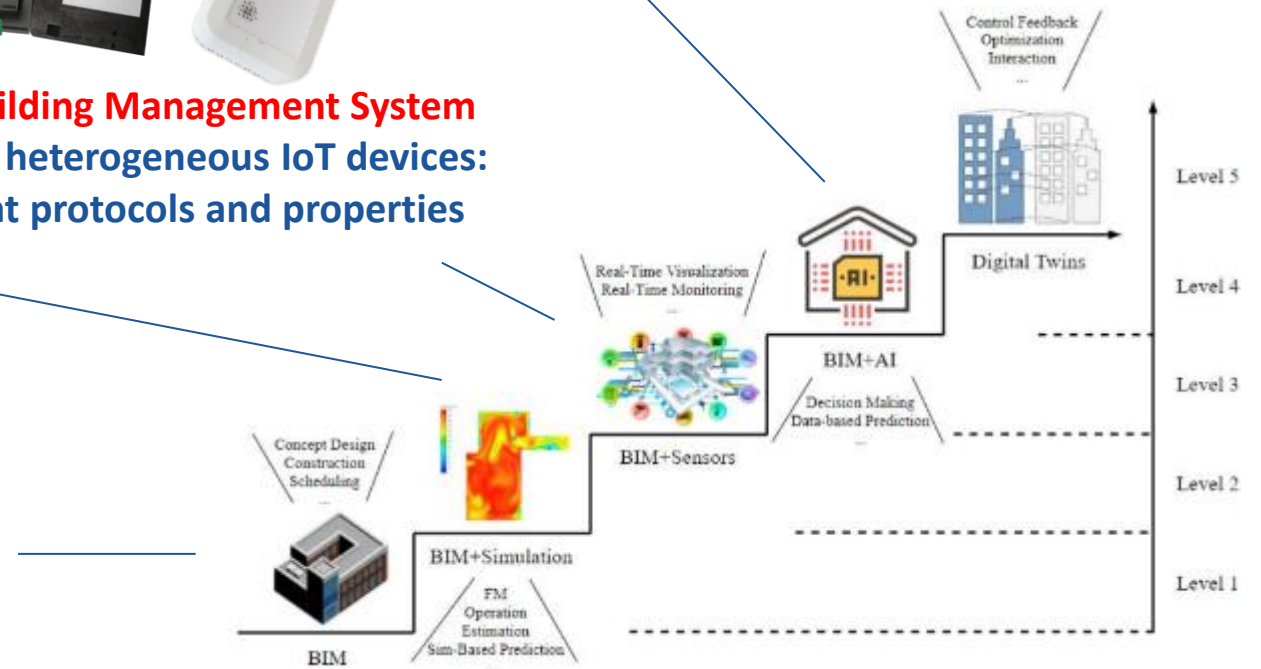
**+ make it FAIR !
knowledge graphs, code, sensor data**
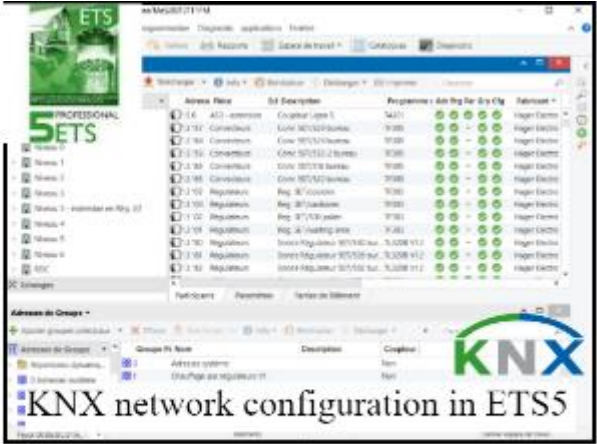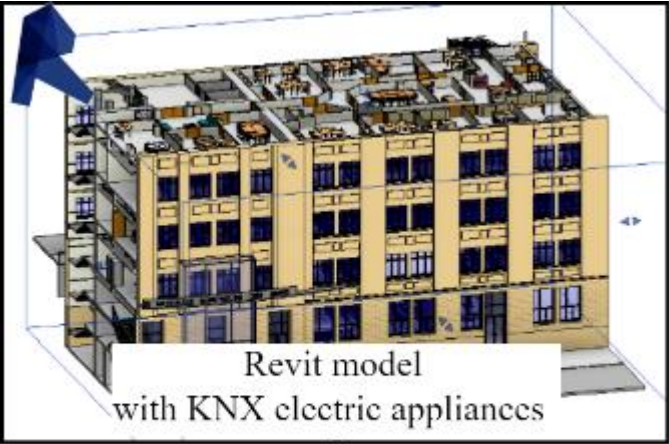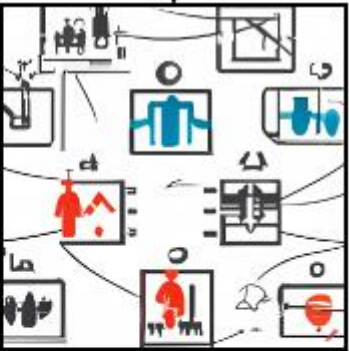
4

https://www.w3.org/DesignIssues/LinkedData.html
ADAPTED TO BUILDING DATA

1. Using URIs as names for building-related things such as: rooms, walls, products, elements, enable different parties to provide complementary descriptions of the same uniquely identified entities in different knowledge graphs.

2. Using HTTP URIs for these things enables the authority responsible for these URIs to provide reference information about this entity when one looks it up on the Web. For example, products in a catalogue, building appliances, or even the building itself.

3. Providing information using common standards (RDF, SPARQL) and common Knowledge Graph models enable semantic interoperability between data sources.

4. Include links to other URIs can help to discover more things, such as a link to the catalogue an appliance has been chosen from, or a link to the Web of Things Servient that enables it to interact with this appliance.

Revit model
with KNX electric appliances

Employee directory
of Mines Saint-Étienne

KNX network configuration in ETS5

KG_{BOT} https://ci.mines-stetienne.fr/emse/
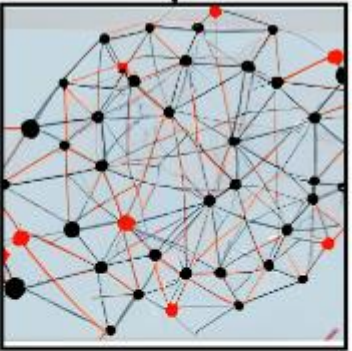
KG_{FOAF} << protected address >>

KG_{TD} https://ci.mines-stetienne.fr/knx/

links to

links to

links to

links to

links to
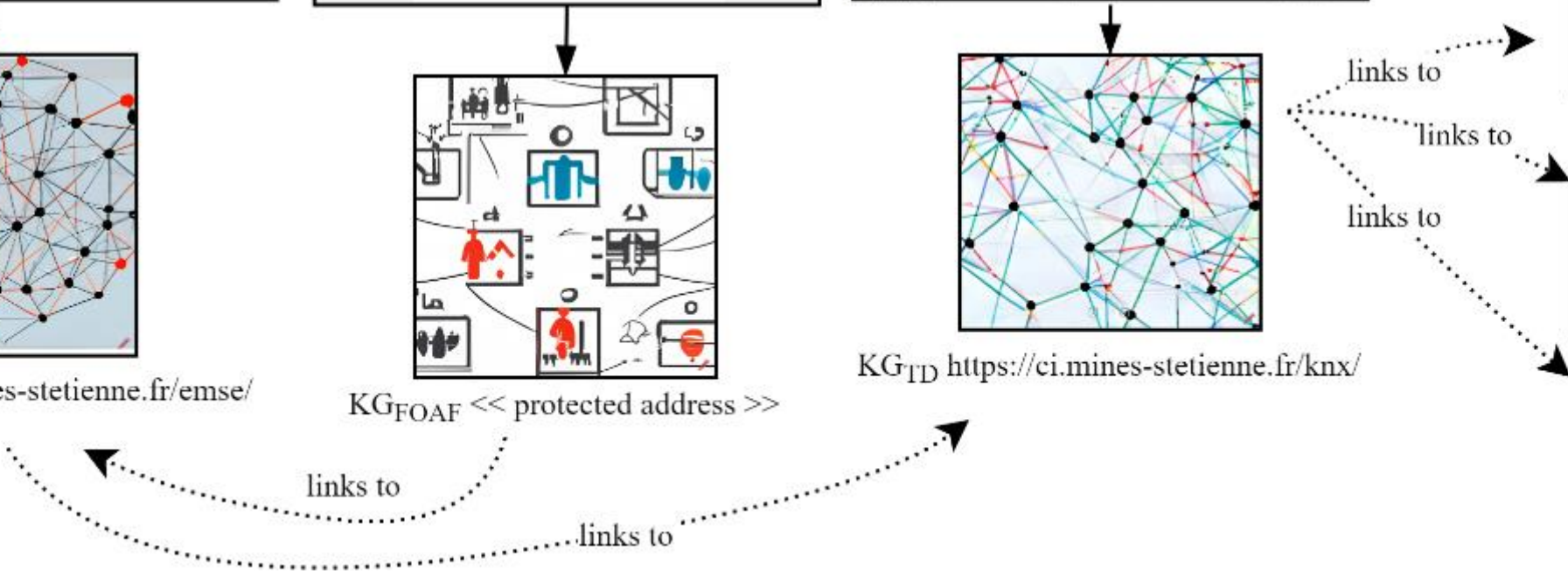
Preparation in Revit: add KNX devices and their addresses

https://ci.mines-stetienne.fr/EMSE_EF/

Revit to KG_{BOT} - https://ci.mines-stetienne.fr/emse/

Revit model
with KNX electric appliances
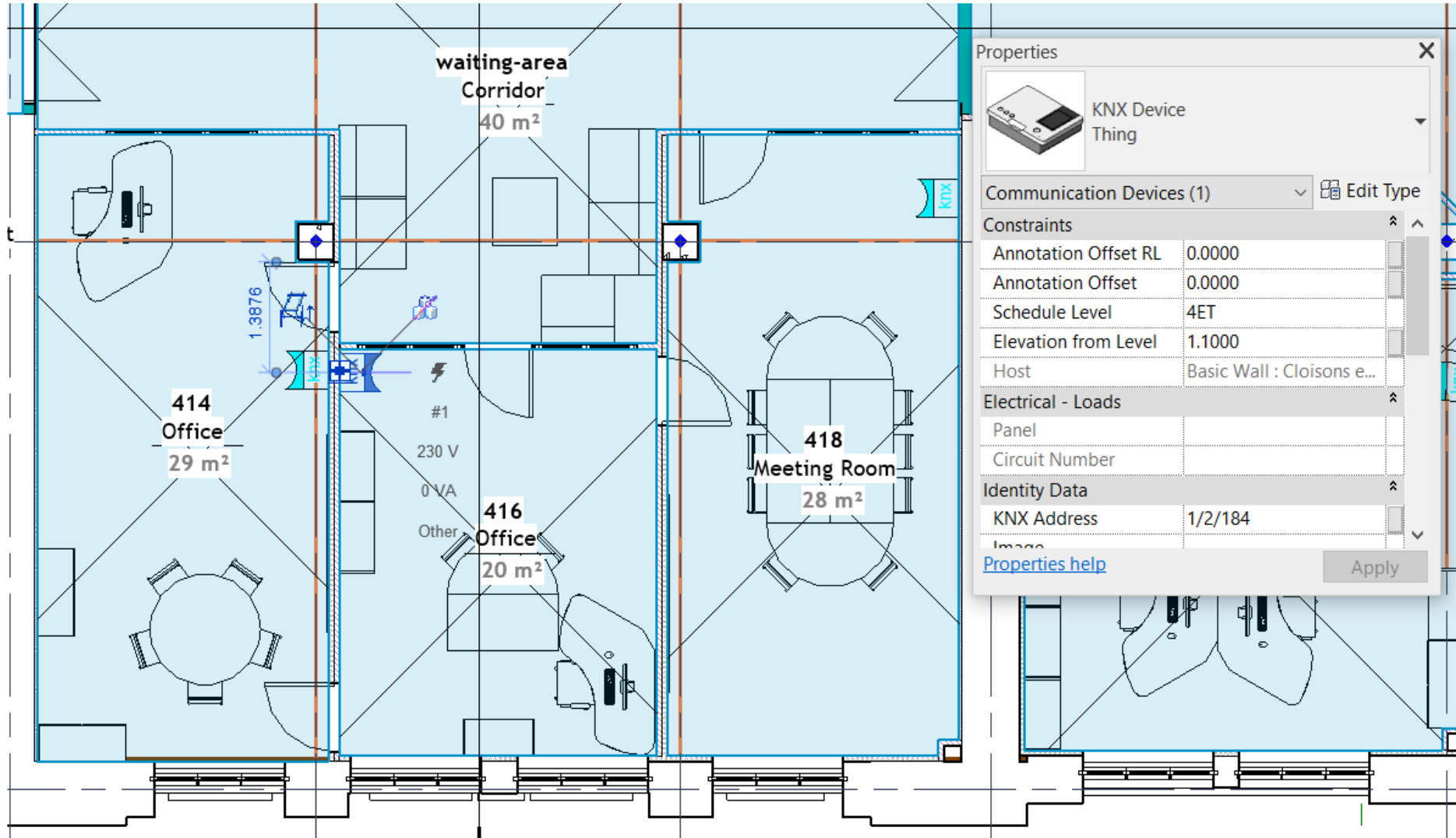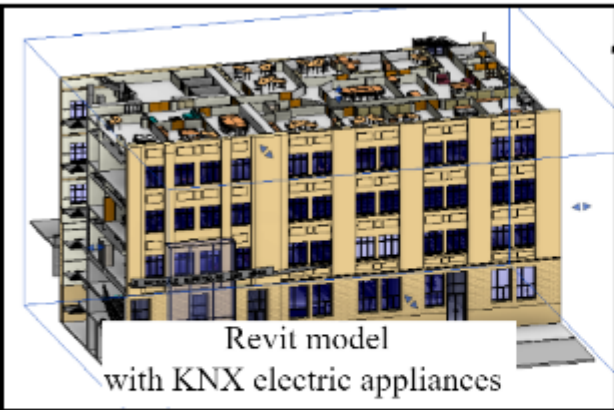
Export IFC from Revit: https://ci.mines-stetienne.fr/EMSE_EF/

IFC-to-LBD: 256k triples, unsatisfactory for our use case

1. Repare unicode: "\\X\\0D\\X\\0A" ->"\n", "\\X\\00E9\\X\\0A" -> "é", ...

2. Prune objects. delete "plate", "railing", "ramp", "roof", ... .129k triples

3. Transform RDF: set of SPARQL construct queries that select a subset of the triples and replace properties.. ex: props:objectTypeIfcObject_attribute_simple > rdfs:label ... 28.5k triples

4. Update IRIs: more natural IRI structure <{building}>, <{building}/{storey}>, <{building}/{storey}/{space}>, <{building}/{storey}/{space}/{knx_device_in_space}>.

5. Add schedules and Dynamo script results, that recover lost knowledge:
(i) in which space furnitures and devices are located,
(ii) which spaces windows and doors are adjacent to,
(iii) adjacency between spaces,
(iv) quantity values for properties were floored to the nearest integer, with no unit.
... 50 k triples

6. Explicit SOSA/SSN properties for features of interest temperature, CO_2, humidity, open/close state, ... 53 k triples

7. Serialize one graph per individual ... 4414 RDF graphs, 19.64 triples in average

Example: https://ci.mines-stetienne.fr/emse/fayol/4ET/416/   8
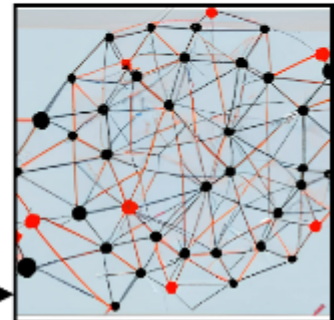
KG$_{FOAF}$ - Employees and their offices

Employee directory of Mines Saint-Étienne

Crawl employee data working in the Espace Fauriel building

<< *manual step* >>
Link employee to furniture

Serialize one graph per individual

ci.mines-stetienne.fr/foaf/b54952c3-e4a6-423d-b724-ed9392f6f2a1

```
@base <https://ci.mines-stetienne.fr/> .
@prefix rdfs: <http://www.w3.org/2000/01/rdf-schema#>.
@prefix foaf: <http://xmlns.com/foaf/0.1/>.
@prefix org: <http://www.w3.org/ns/org#>.
@prefix coswot: <https://w3id.org/coswot/>.

<foaf/b54952c3-e4a6-423d-b724-ed9392f6f2a1> a foaf:Document ;
  foaf:primaryTopic _:example .

_:example a foaf:Person ;
    foaf:name "Xxx Xxx" ;
    foaf:img <data:image/png;base64, /.....> ;
    foaf:phone <tel:+xxxxxxxxxxx> ;
    foaf:mbox <mailto:xxxxxxxxxxxxxxxx@emse.fr> ;
    org:memberOf <https://www.imt.fr/>, <https://mines-stetienne.fr/>, <foaf/fayol> ;
    coswot:worksAtDesk <emse/fayol/4ET/416/BureauD'Angle/1VMOlJ3knDeODu7af36LS_> .
```
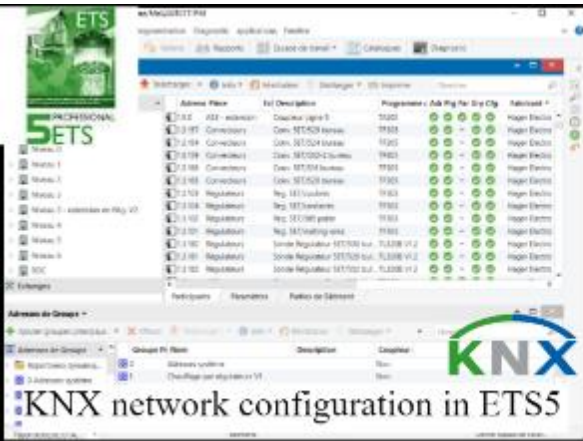
Example: https://ci.mines-stetienne.fr/foaf/b54952c3-e4a6-423d-b724-ed9392f6f2a1

KG_{TD} - KNX Configuration Linked to the BIM Model

KNX network configuration in ETS5

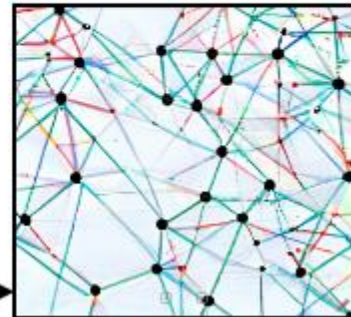1. Export .knxproj file ... 1MB zip archive.

2. Analyse XML project file

3. For each device, find and analyse hardware description in XML.
Generate TD Thing description for devices, their properties, and their communication objects

4. Generate property affordances for *group addresses*
For example group address 2/0/117 links Object O-12 of Device 1/2/185:
   the output command of a Hager TX320 room thermostat deployed in Office 423,
with Object O-140 of Device 1/2/171:
   one the controllable relays of a Hager TYA608C 8x16A Output module (heater in Office 423)

5. Generate forms for:
KNX (proposed knxip: IRI scheme and vocabulary)
MQTT (draft version of the w3c mqv vocabulary)
HTTP for historical data as CSV (http vocabulary)

6. Serialize one RDF graph per individual device and group address
(distribute 40.7 k triples into 1k graphs, 53 triples each on average)

Example in KG_{TD}: *https://ci.mines-stetienne.fr/knx/emse/fayol/1/2/184*
Example link from KG_{BOT}: *https://ci.mines-stetienne.fr/emse/fayol/4ET/416/device/1bDMdL0k55X8oOMH5VKzRL* 10

Demonstration Use Case: Comfort parameter monitoring

POV user:
1. Log in
2. Camera jumps at working desk
3. Click on device on the wall
4. View temperature

How-to:
- Just follow the links !

Demo:
https://territoire.emse.fr/databat
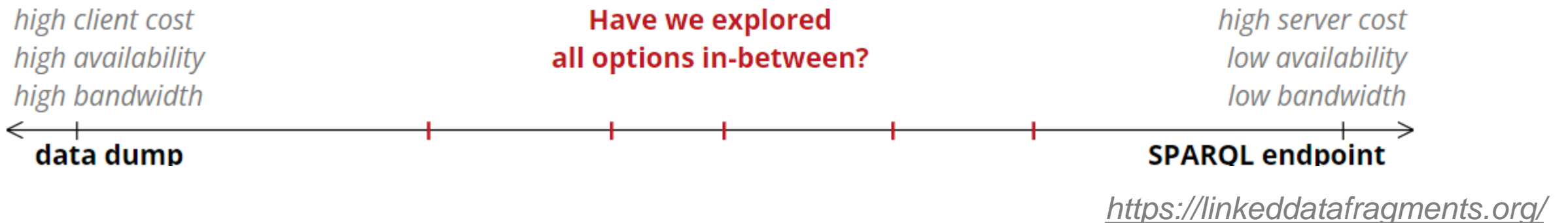
Conclusion and Discussion

➢ Integrate different source of information about the same building
➢ Not giant monolithic RDF graph about the building,
     ➢ but small, modular linked graph (Linked Building Data)
➢ Findable, Accessible, Interoperable, Reuseable: methodo, code, KGs, sensor data…

➢ One option on the Linked Data Fragments spectrum

high client cost   **Have we explored**   high server cost
high availability   **all options in-between?**   low availability
high bandwidth   low bandwidth

data dump   **SPARQL endpoint**

https://linkeddatafragments.org/

➢ applies to KGs what tilemaps apply to 2D or 3D game development …
    … LBD Knowledge Tiles ?