

Development of a National Scale Digital Twin for Domestic Building Stock

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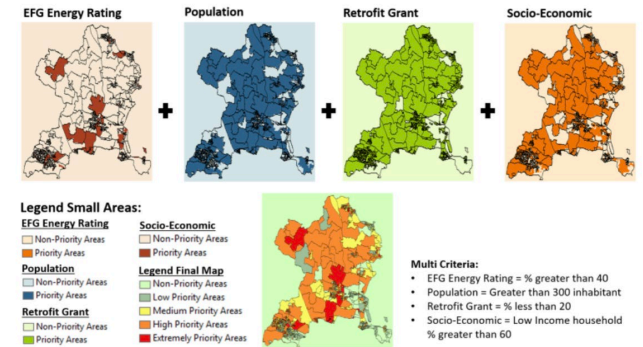
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Intelligent Data Harvesting for Multi-Scale Building Stock Classification and Energy Performance Prediction

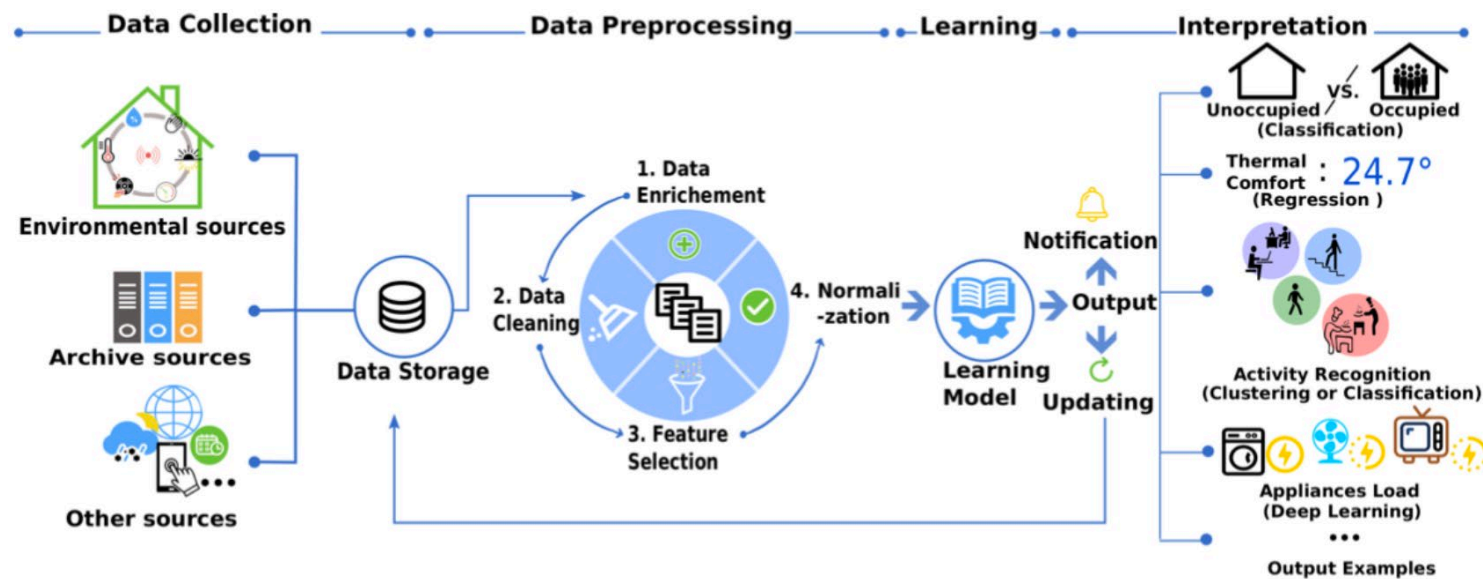


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Djenouri, Djamel & Laidi, Roufaida & Djenouri, Youcef & Balasingham, Ilangko. (2019). Machine Learning for Smart Building Applications: Review and Taxonomy. ACM Computing Surveys. 52. 10.1145/3311950.

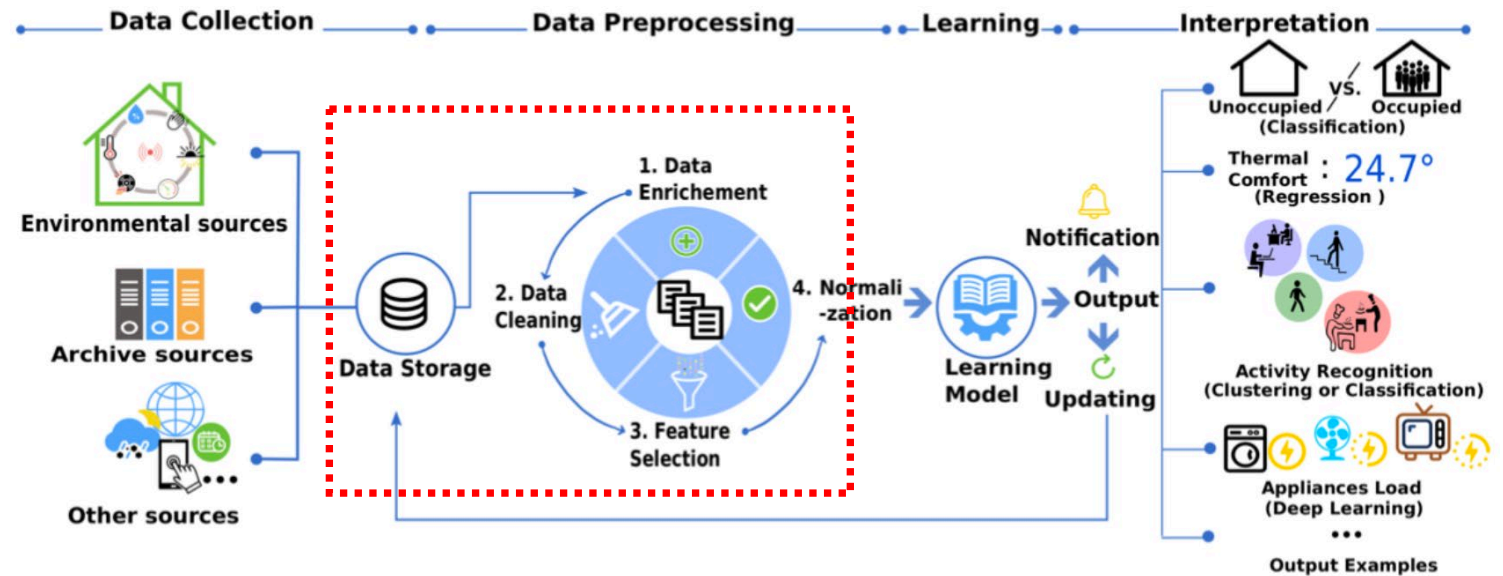


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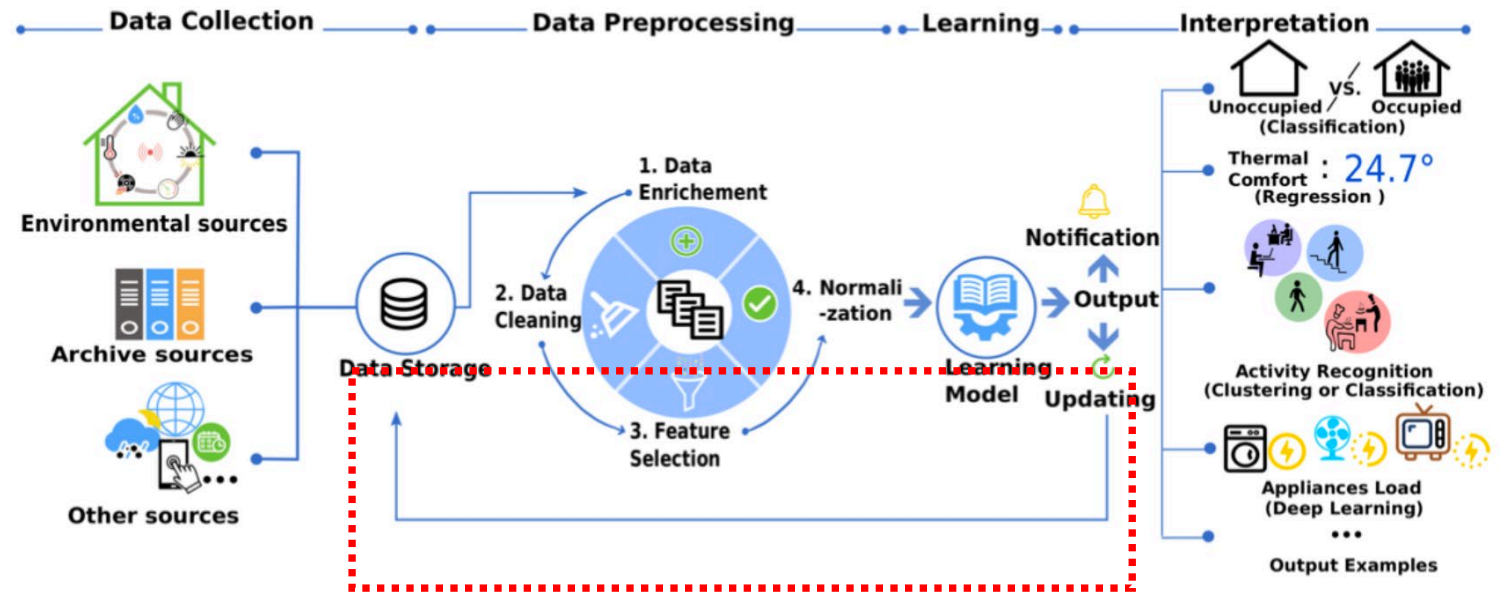


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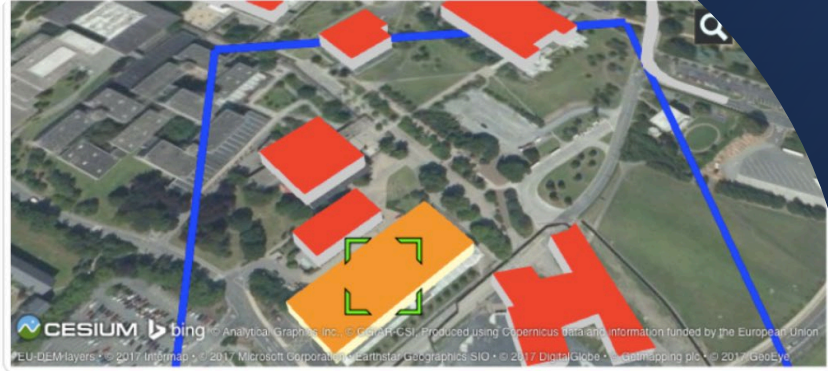
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Building Data provides deep insights but is **Large, Complex and Siloed**



The screenshot shows a web application interface for building data. At the top, a browser address bar displays "newtrend1.westeurope.cloudapp.azure.com". Below the browser, a 3D map of a building complex is shown. A blue line outlines a specific area, and a yellow building within that area is highlighted with a green bounding box. The map includes logos for Cesium and Bing, along with copyright information for Copernicus, Microsoft, and GeoEye.

District

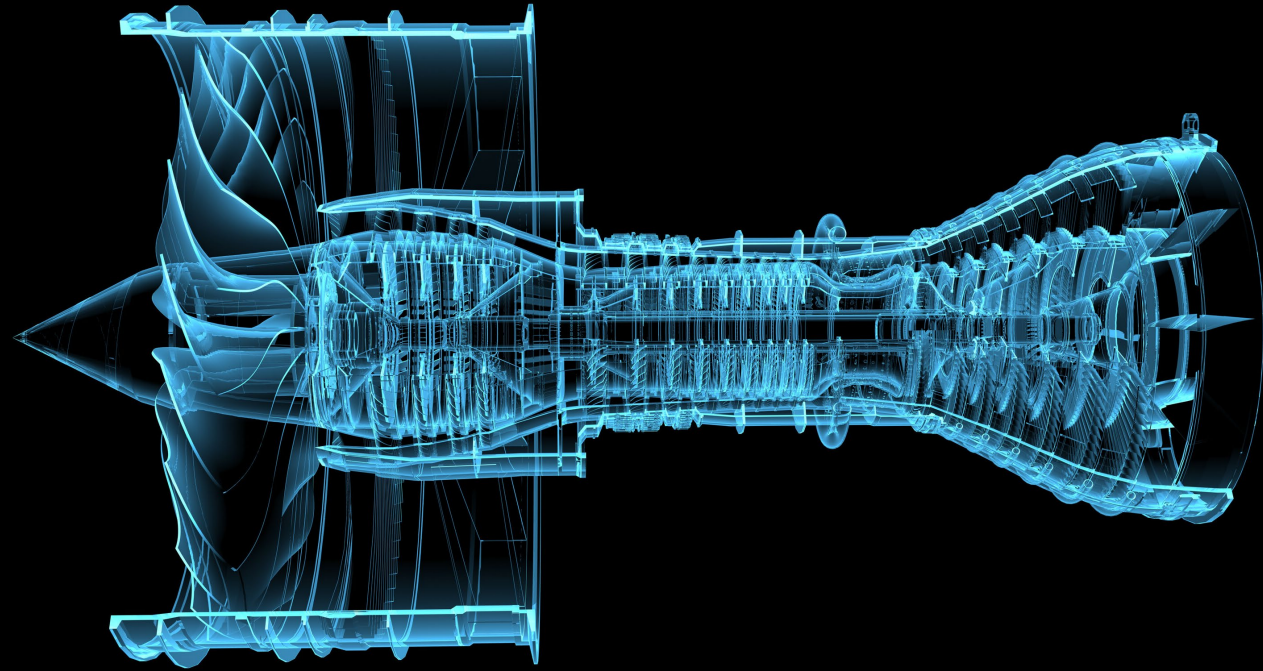
Upload Download Clear

Object

Upload Download Detail

ID:	BLDG_96a0077f-3529-45ae-bca3-20cc9bcd66ba
Name:	Building 2
Description:	Building 2 Description
	2017-01-31T19:33:18.624000Z

Defining a Digital Twin



- **Digital Twin and Digital Shadow**
- **Digital Twin is a Two-Way Cyber-Physical Model**
- **System State Represented by a Rich Data Model**
- **Learns and enables Learning**
- **Delivers deep insights**
- **Feedback**

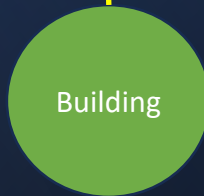
Defining a Knowledge Graph



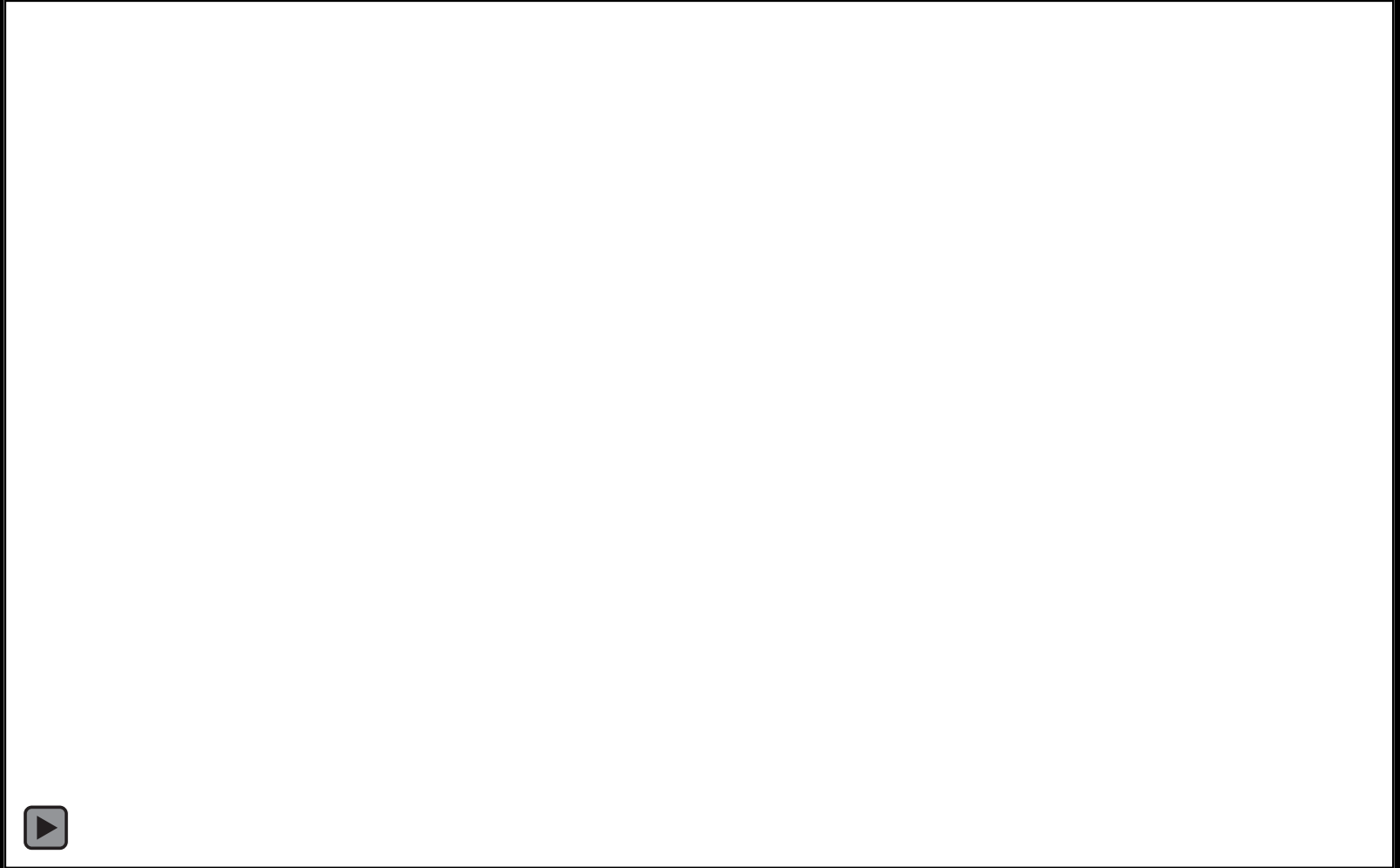
GeoDirectory (CSV)



EPC (CSV)



BIM (LBD)

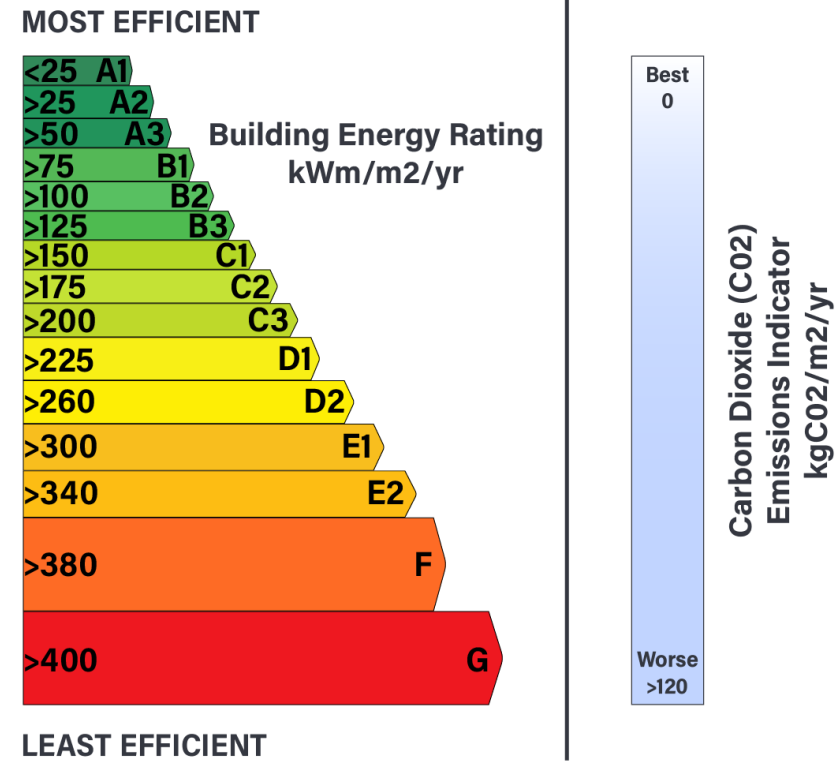


Diverse Data

BUILDINGS GEOGRAPHIC_FORMAT IRISH_GEOGRAPHIC_FORMAT OFFICIAL_POST_ADDRESS IRISH_OFFICIAL_POSTAL_ADDRESS BUILDING_ID ADDRESS_POINT_ID ADDRESS_REFERENCE PERSONAL_NAME ORGANISATION_NAME DEPARTMENT SUB_BUILDING_NAME BUILDING_NAME BUILDING_NUMBER BUILDING_GROUP_NAME THOROUGHFARE SECONDARY_THOROUGHFARE LOCALITY SECONDARY_LOCALITY PRINCIPAL_POST_TOWN COUNTY EIRCODE ADDR_LINE_1 ADDR_LINE_2 ADDR_LINE_3 ADDR_LINE_4 ADDR_LINE_5 ADDR_LINE_6 ADDR_LINE_7 ADDR_LINE_8 ADDR_LINE_9 ADDR_LINE_10	GEOGRAPHIC_FORMAT_CHANGES IRISH_GEOGRAPHIC_FORMAT_CHANGES BUILDING_ID ADDRESS_POINT_ID ADDRESS_REFERENCE NEW_ADDRESS OLD_ADDRESS CHANGE_TYPE COMMERCIAL_ADDRESS RESIDENTIAL_ADDRESS OLD_BUILDING_ID EIRCODE PRINCIPAL_POST_TOWN NACE_CODE GEOCODE_QUALITY IRISH_GRID ITM_GRID LATITUDE_LONGITUDE ORGANISATION_NAME DEPARTMENT SUB_BUILDING_NAME BUILDING_NAME BUILDING_NUMBER BUILDING_GROUP_NAME THOROUGHFARE SECONDARY_THOROUGHFARE LOCALITY SECONDARY_LOCALITY COUNTY TOWNLAND ELECTORAL_DIVISION	BUILDINGS BUILDING_ID GROUP_ID THORFARE_ID PRINCIPAL_POST_TOWN_ID DATA_SRC_ID CHANGED_DATE POSTAIM_PRESORT_61 POSTAIM_PRESORT_152 ED_ID NAME NO BUILDING_USE DERELICT VACANT INVALID UNDER_CONSTRUCTION RESIDENTIAL_DELIVERY_POINTS COMMERCIAL_DELIVERY_POINTS COUNTY_ID TLAND_ID EAST NORTH LOCALITY_ID SECONDARY_LOCALITY_ID VERIFIED ITM_EAST ITM_NORTH QUALITY_CONTROL PPZ_ID HOLIDAY_HOME DEMOLISHED CREATE_DATE BUILDING_TYPE_ID LATITUDE LONGITUDE BUILDING_NUMBER_NUMERIC BUILDING_NUMBER_ALPHA LA_ID VO_ID LOCALITY_POSTALLY_REQ SMALL_AREA_ID	THOROUGHFARES THORFARE_ID CHANGED_DATE THORFARE_NAME QUALIFIER MIN_X MIN_Y MAX_X MAX_Y ITM_MIN_X ITM_MIN_Y ITM_MAX_X ITM_MAX_Y NAME GEOGRAPHIC DESCRIPTOR SECONDARY_THORFARE_ID INVALID IRISH_NAME TOWN_ID IRISH_VERIFICATION	BUILDING_TYPES BUILDING_TYPE_ID NAME CODE	PRINCIPAL_POST_TOWNS PRINCIPAL_POST_TOWN_ID COUNTY_ID NAME IRISH_NAME IRISH_VERIFICATION
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					EIRCODE_LOOKUP BUILDING_ID ADDRESS_POINT_ID ADDRESS_REFERENCE ECAF_ID EIRCODE

GeoDirectory + EPC + web harvested text and imagery + weather

Diverse Data



GeoDirectory + EPC + web harvested text and imagery + weather

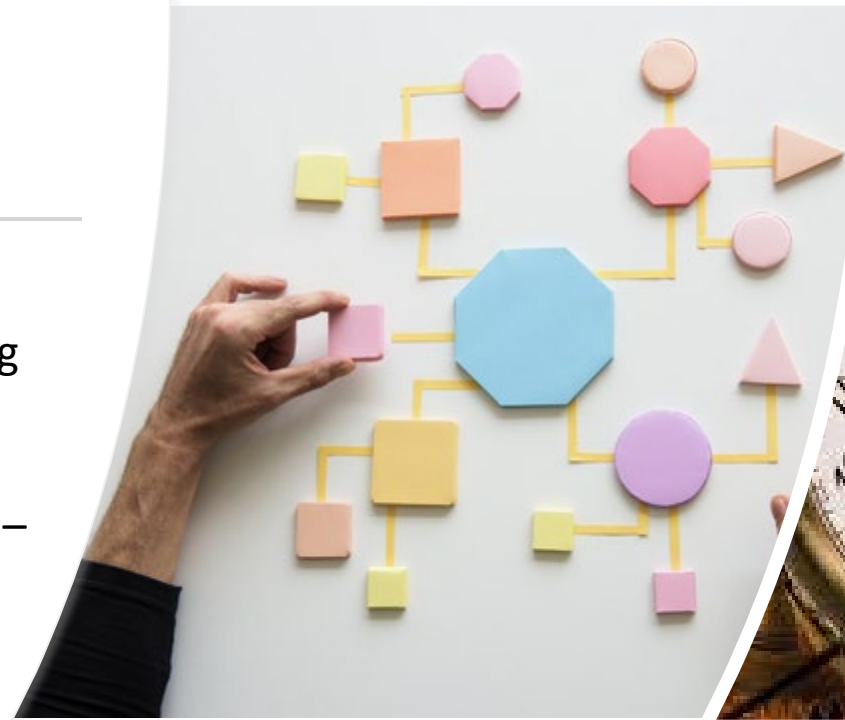
Diverse Data



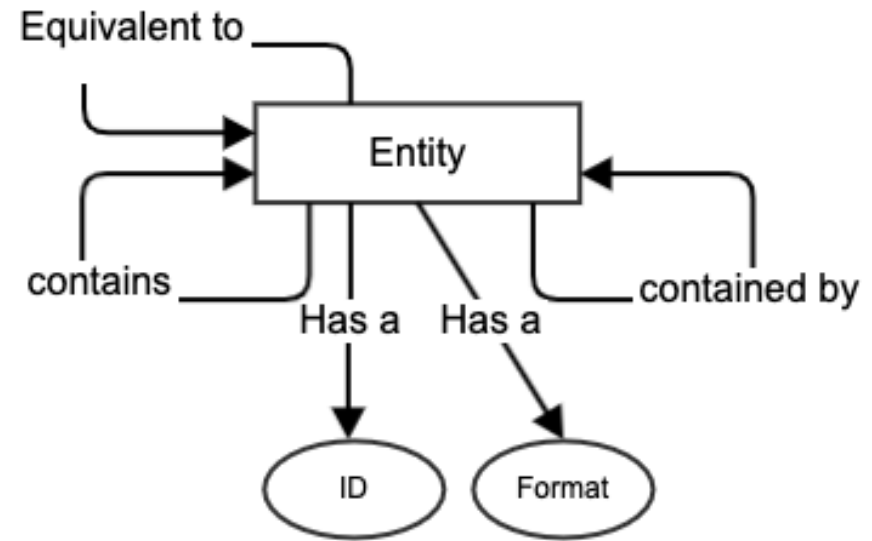
GeoDirectory – whole residential building stock with geographic contexts

Data Integration Framework - DDIM

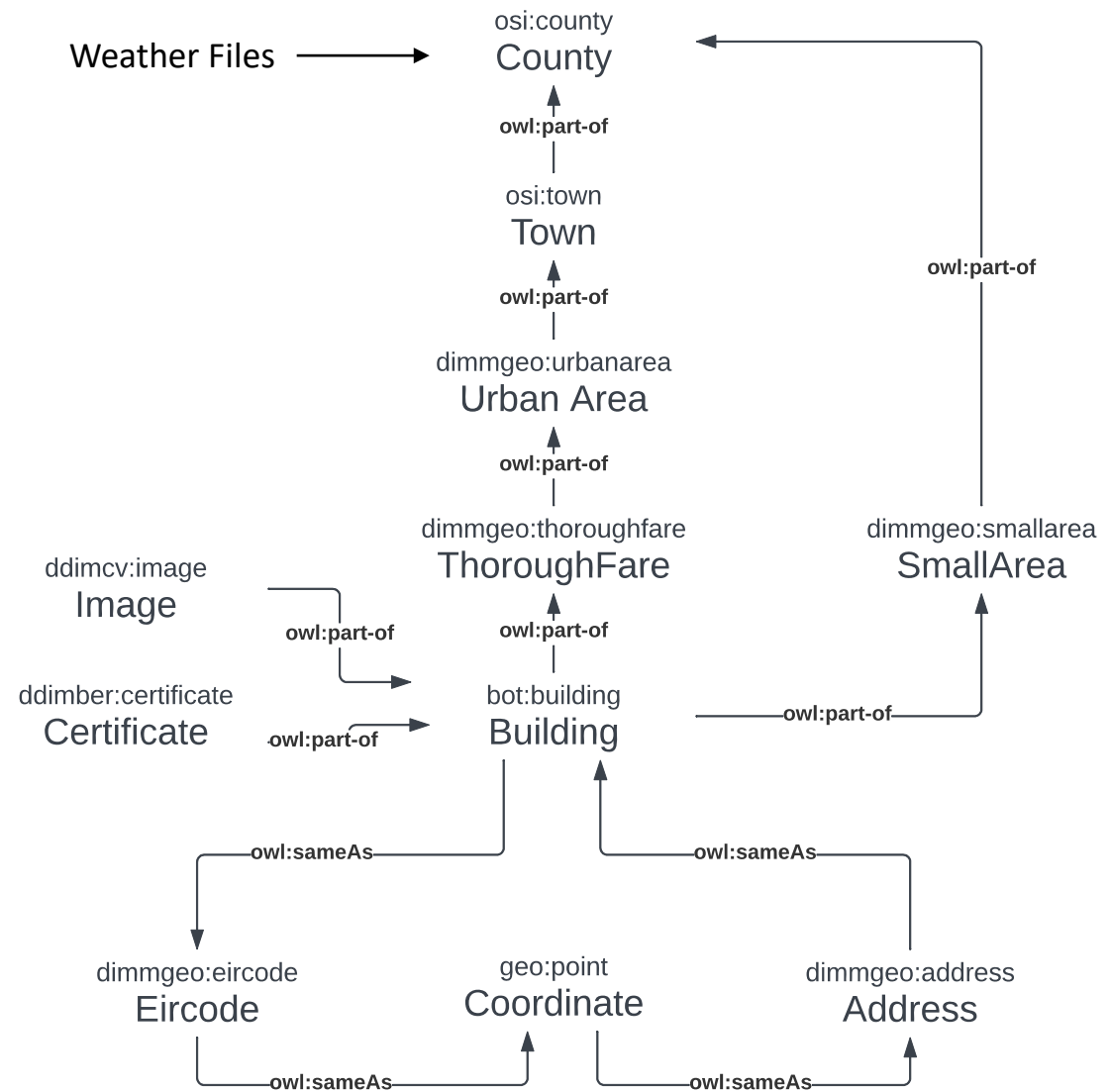
- DDIM is turnkey and form driven
- Serves to integrate information sources among project partners and enable knowledge discovery
- Data is integrated through a common context – this overcomes homogeneity
- Information provenance



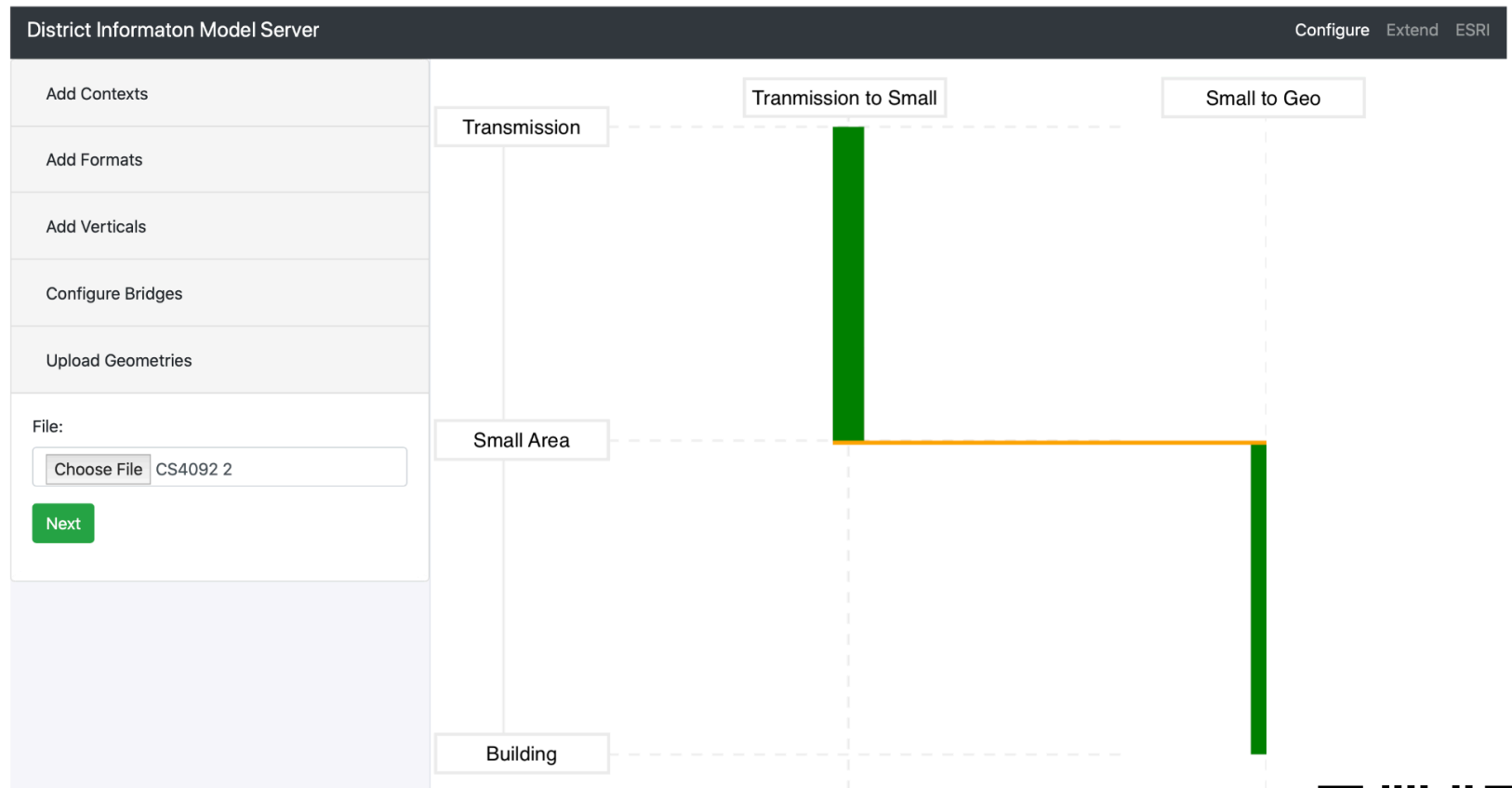
Data Integration Framework – An Ontology to define a Common Context



Applying the Common Context



Data Integration Framework - DDIM



- Implemented as a DjangoREST Server, Docker Deployed
- MySQL, Neo4J (with NeoSemantics)/GraphDB
- RESTful interface
- Graph Creation Steps:
 - Upload Information Sources
 - On upload extract source meta-data (for CSV, column headings)
 - Define relationships using forms
 - Script transforms data to set of entities and relationships in turtle format



The Need for Enrichment



- I Know this building quite well!
- In one database it is described as being built c.2007 and having 2 bedrooms – neither fact is correct
- I could examine data that has been fused from other databases and take an ensemble approach to determine the most accurate value. But the building doesn't have a BER (EPC) Certificate
- A different approach is required

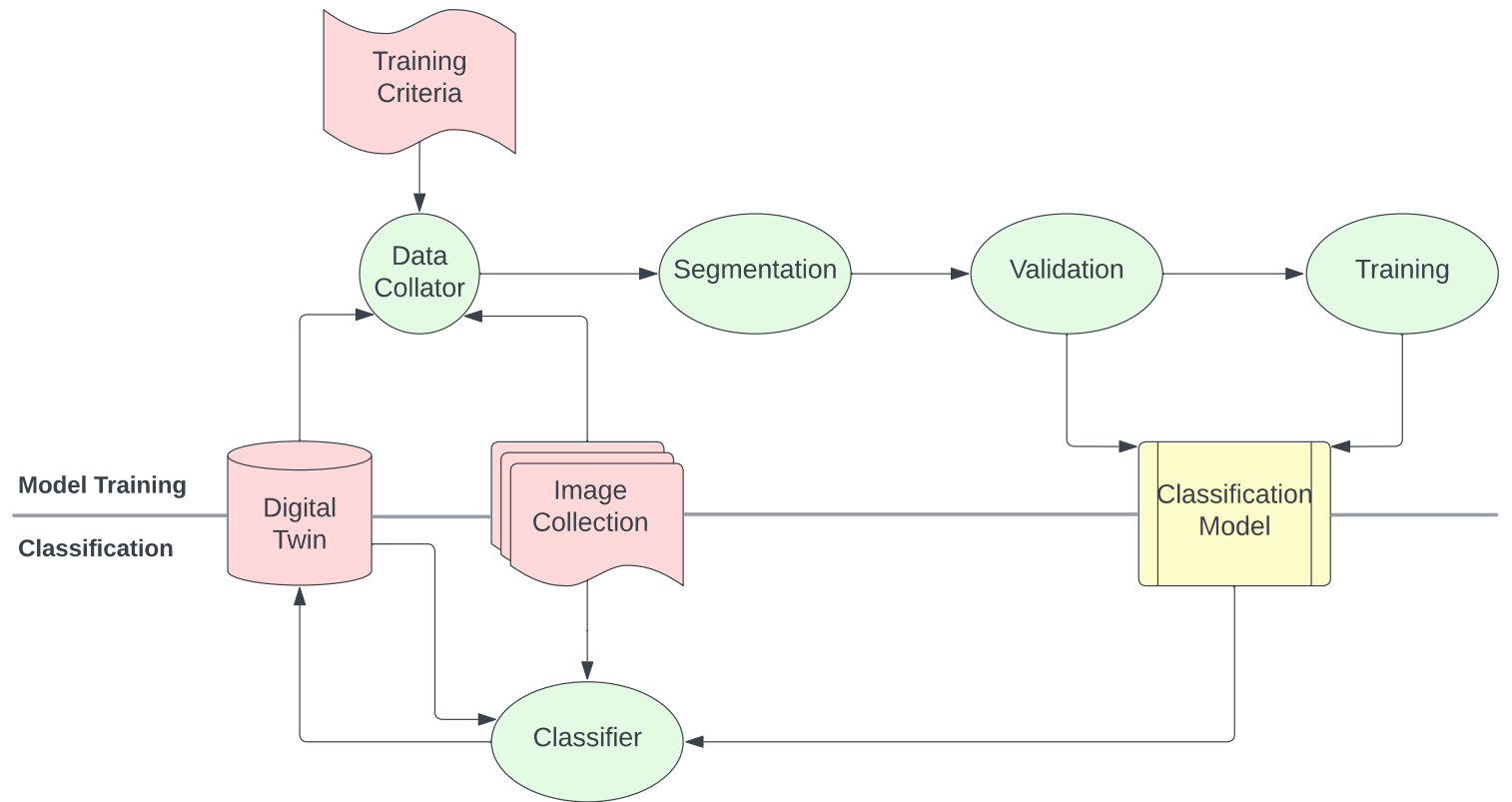
Enrichment Requirements

Number	Parameters	Unit
P1	Wall U-value	W/m^2K
P2	Window U-value	W/m^2K
P3	Floor U-value	W/m^2K
P4	Roof U-value	W/m^2K
P5	Door U-value	W/m^2K
P6	Orientation	North Axis {deg}
P7	Lighting density	W/m^2
P8	Occupancy	Person(s)
P9	Equipment density	W/m^2
P10	Heating setpoint	$^{\circ}C$
P11	Heating setback	$^{\circ}C$
P12	HVAC efficiency	%
P13	Renewables	boolean
P14	DHW	$l/m^2/day$
P15	ACH	Air changes per hour
P16	Window-to-wall ratio	%
P17	Heating factor	numeric
P18	Electricity factor	numeric

A data-driven approach to optimize urban scale energy retrofit decisions for residential buildings, Usman Ali et al.



An Enrichment Methodology Using Images



An Enrichment Example – Results and Issues

- This building is actually a poor example
 - The least accurate results are for standalone buildings in the countryside where building details are obscured by plants, are variable distances from the image source, have a wide variety of building designs
 - These types of buildings account for X percentage of Irish building stock
- Works best for suburban areas with large numbers of similar designs and site layouts



Thank You



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