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INSPIRE Harmonisation of existing Energy Performance Certificate datasets

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Energy Pilot

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Abstract

The European Union is giving more and more emphasis to its energy policies, whose strategy and actions are included in the Energy Union Package and the 2030 Framework for Climate and Energy. Buildings in which people live and work are responsible for an important portion of the energy consumption in Europe (approximately 40% of the primary energy consumption) and there are several policies and initiatives that are aiming at improving their energy performance.

In particular, the Energy Performance of Buildings Directive (Directive 2010/31/EU) contains requirements about systems of certification of the energy performance of buildings to be adopted by Member States. For example, energy performance certificates have to include the energy performance of a building and reference values such as minimum energy performance requirements in order to make it possible for owners or tenants of buildings to compare and assess their energy performance. Certificates have to be issued also for buildings where a total useful floor area over a certain threshold is occupied by a public authority and frequently visited by the public.

Moreover, these certificates contain location data related to energy consumption and energy efficiency, which are at the same time semantically rich and spatially detailed (at building level). Therefore, they contribute to improve considerably the data accuracy at local level, which is explicitly required by the energy efficiency policy instruments, aiming to overcome the current limitations of using top-down statistical approaches for energy efficiency assessments at local level.

In the policy context described above, the current lack of harmonisation of energy performance certificates at European level represents a barrier for different groups of stakeholders engaged in the energy policies lifecycle.

This report contains the results achieved by a pilot project, in which a methodology for the harmonisation of energy performance certificates was designed, developed and tested with a regional authority managing a certificates' register. Applying the same methodology to certificates' registers managed by other national/regional authorities will contribute to achieve the harmonisation of the certificates at European level.

The methodology is based on the INSPIRE Directive 2007/2/EC, establishing an infrastructure for spatial information in Europe to support Community environmental policies, and policies or activities which may have an impact on the environment, such as energy policies. In particular, the methodology used to extend the INSPIRE data models in thematic areas such as energy efficiency of buildings, can be re-used in other domains benefitting from data harmonisation according to common data models adopted at European level.

1 Introduction

This technical report describes the initial activities undertaken and the results achieved in the frame of the use case "INSPIRE Harmonisation of existing Energy Performance Certificate datasets", which is one of the use cases defined within the Energy Pilot project[1] of the European Union Location Framework (EULF) action.

The EULF[2] is led by the European Commission Joint Research Centre and is part of the Interoperability Solutions for Public Administrations (ISA) Programme[3], run by DG Informatics (DIGIT). The EULF is a framework of recommendations, guidance and actions to improve the way location information is used in all public services across Europe, targeting benefits for businesses, citizens and government in key policy areas, such as Transport and Energy, through a series of pilot projects to apply, evaluate and contribute to the EULF. The EULF builds on the spatial data infrastructure for Europe being implemented by INSPIRE [1].

Regarding the EULF Energy Pilot, a feasibility study on "Location Data for buildings Related Energy Efficiency Policies" [2] was concluded in 2015. The study made an initial analysis of the data flows relevant to the Energy Performance of Buildings Directive (EPBD) [3], the Energy Efficiency Directive (EED) [4] and the Covenant of Mayors initiative (CoM)[4], identified relevant INSPIRE data themes, and carried out an initial mapping exercise. Because of the variations in available data and the need to link data at different administrative levels, the study highlighted the need to properly combine data of a different nature (e.g. calculated vs. measured, static vs. dynamic), and of different geographical scales (e.g. urban vs. regional vs. national).

A pilot mobilisation phase started in late 2015, with an initial kick-off workshop held at JRC/Ispra from 24-26 November 2015 [5] with participants from BE, DE, DK, ES, EL, IT, SE, TR and UK. The pilot will involve a series of cities and regions to demonstrate how an integrated data approach can be established for planning, implementation, monitoring and reporting for the multiple policies and initiatives, considering energy performance of buildings, energy consumption of buildings and energy production at a local level. This will be done through:

- adoption of common structured data models (extending some INSPIRE core data models);
- use of common data access mechanisms (INSPIRE Network Services);
- re-use of (parts of) datasets for different planning, implementation, monitoring and reporting purposes;
- data access agreements to use the relevant data;
- development and application of relevant methodologies and models to fill data gaps;
- use of both centralised and distributed ICT infrastructures to access the data needed to fulfil planning, implementation, monitoring and reporting requirements.

The pilot is being implemented and tested through a series of use cases, involving different stakeholders (public authorities at local and regional level), businesses working in the energy sector and citizens (building owners).

This technical report describes the initial activities undertaken and the results achieved in the frame of the first use case "INSPIRE Harmonisation of existing Energy Performance Certificate datasets" (in the following, shortly "Use Case 1") and it is structured into six main sections:

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[1] https://joinup.ec.europa.eu/community/eulf/og_page/eulf-energy-pilot
[2] Information about the EULF, including links to publications and key events, can be found at http://ec.europa.eu/isa/actions/02-interoperability-architecture/2-13action_en.htm
[3] Information about ISA is available at http://ec.europa.eu/isa/ and at http://ec.europa.eu/isa/library/isa-work-programme/index_en.htm
[4] http://www.covenantofmayors.eu/index_en.html

- Section 1 - "Introduction", which provides the policy context for the activities carried-out and reported in this document, a definition of the problem addressed, a brief description of the partners involved and the specific objectives targeted;
- Section 2 – "Methodology", which contains detailed information about the different steps of the data harmonisation process, including the target data model extension of INSPIRE core data model of Buildings;
- Section 3 – "Expected benefits", which outlines the benefits expected from the re-use of the results achieved, by the partner involved in the use case, as well as by other interested parties in other geographical areas;
- Section 4 – "Sustainability", which outlines the main aspects to be considered to ensure the sustainability of the use case results;
- Section 5 – "Issues identified", which describes the issues encountered during the execution of the use case, distinguishing those of technical nature from those of organisational nature;
- Section 6 – "Conclusions and next steps", which identifies a number of steps to be made in order to further expand the use case in other geographical and/or organisational contexts.

1.1 The policy context

The EU is giving more and more emphasis to its energy policies, whose strategy and actions are included in the Energy Union Package[5] and the 2030 Framework for Climate and Energy[6].

In particular, buildings in which people live and work are responsible for an important portion of the energy consumption in Europe and there are several policies and initiatives that are aiming to improve their energy performance and to collect data of sufficient quality on the effect of energy efficiency policies on building stock across Europe.

More specifically, Article 11 of EPBD [2] states that "*Member States shall lay down the necessary measures to establish a system of certification of the energy performance of buildings. The energy performance certificate shall include the energy performance of a building and reference values such as minimum energy performance requirements in order to make it possible for owners or tenants of the building or building unit to compare and assess its energy performance. The energy performance certificate may include additional information such as the annual energy consumption for non-residential buildings and the percentage of energy from renewable sources in the total energy consumption.*" Other requirements and recommendations related to Energy Performance Certificates (EPC) of buildings are contained in other EPBD articles/clauses.

EPC datasets contain location data related to energy consumption and energy efficiency, which are at the same time semantically rich and spatially detailed (at building level). Therefore, they contribute to improve considerably the data accuracy at local level, which is explicitly required by the energy efficiency policy instruments, aiming to overcome the current limitations of using top-down statistical approaches for energy efficiency assessments at local level. In addition, used in combination with scale-up methodologies from building to district, city, regional up to national level (see ***Figure 1***), EPC datasets may represent a solid knowledge base to support the whole lifecycle of the energy policies, from planning to implementation, reporting and monitoring.

[5] https://ec.europa.eu/energy/en/publications/energy-union-package
[6] http://ec.europa.eu/clima/policies/strategies/2030/index_en.htm

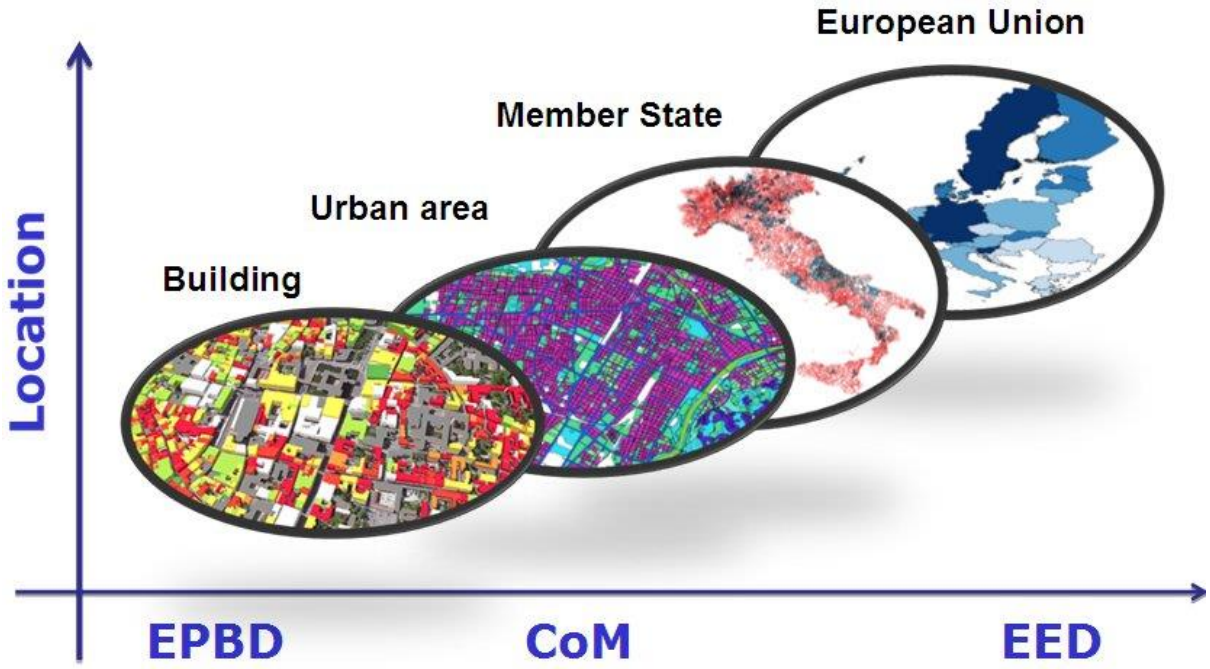


Figure 1 *– Location-enabled scale-up of energy efficiency methodologies*

1.2 Problem statement

In the policy context described above, it is important to highlight the need for harmonisation of EPC datasets at EU level.

This is also documented in the proceedings of the workshop held at JRC/Ispra from 24-26 November 2015 [5], during which invited speakers focused on the following key concepts:

- the importance of having a centralised EPC database at EU level in order to monitor the energy performance of buildings, given the impact of EPCs on the real estate market;
- EPCs are not equally defined in all the Member States, and there is the need to adopt a standardised approach across Europe, to facilitate independent control systems and provide a tool to map and monitor the EU building stock.

Lack of harmonisation of EPC datasets across Member States is also documented in the following reports:

- Energy Performance Certificates EPC across the EU. A mapping of national approaches 2014[7]
- Report on existing monitoring initiatives and database systems. From Databases to Retrofit Action: How European Countries are using Energy Performance Certificate (EPC) Database Systems[8]
- Report on best practice meeting in Brussels. Using Energy Performance Certificate databases - turning data into action.[9]

[7] http://bpie.eu/publication/energy-performance-certificates-across-the-eu/
[8] http://building-request.eu/sites/building-request.eu/files/d2.1_wp2_report_on_existing_monitoring_initiatives_and_databases_150901_aea.pdf
[9] http://building-request.eu/sites/building-request.eu/files/d2.2_wp2_report_on_european_best_practice_meeting_150227_public_aea.pdf

1.3 Partners

Starting from the need to have access to an EPC register providing source data to be harmonised, it was decided to identify an external partner playing the role of data provider and end user of the results, in order to maximise the level of engagement during the whole use case.

The partner identified was the Water Resources and Energy Agency of the Autonomous Province of Trento (IT), in brief APRIE, for the following main reasons:

- it is equivalent to an Italian regional authority (in virtue of the status of "autonomous province" of province of Trento) and therefore, according to the Italian transposition of EPBD which assigns to regional governments the power to adopt an EPC scheme, it well represents the fragmented EPC harmonisation at MS as well as at EU level;
- the Autonomous Province of Trento maintains and licenses as open data the cadastral data required to geo-reference the EPC source dataset before the harmonisation (more details are provided in the next section), and therefore the barriers to access data needed to execute the use case are lowered;
- it already started a process (not yet concluded) to license as open data the EPC dataset, lowering also in this case the barriers to access data needed to execute the use case;
- contacts with APRIE staff were already in place among JRC staff, facilitating therefore the administrative process to formalise a collaboration agreement with JRC for the execution of the use case.

Another potential partner identified was the Lombardy Region (IT), which operates an on-line EPC register and licenses as open data a huge EPC dataset. The main reason for preferring APRIE was due to the existence of IPR for Lombardy region related to the cadastral data required to geo-reference the EPC source dataset before the harmonisation. The consequent procedure to obtain permission to use the cadastral data was started, involving the Italian national tax agency who holds the IPR, but the duration of the procedure appeared immediately too long and therefore not compatible with the time schedule of the use case.

During the first energy pilot workshop of November 2015, the organisation operating the EPC register in Sweden was also identified as a possible partner. However, on closer reflection many privacy issues hindering the access to the source data to be harmonised were reported [5], therefore it was decided to opt for APRIE as the optimal first partner.

In the next phases, additional collaboration agreements can be established with the two potential partners already identified, i.e. Lombardy Region and the organisation operating the EPC register in Sweden, as well as with other partners that can be identified at a later stage, in order to test the re-usability of the use case results in other geographical and/or organisational contexts.

1.4 Objectives

The use case goal is to establish an accessible and interoperable common knowledge base for EPC datasets to support the different groups of stakeholders involved in energy efficiency policies, namely:

- the Government sector, e.g. energy policy makers at regional or local level, local authorities signatories of the CoM;
- the business sector, e.g. energy auditors and certifiers, companies working in the sector of energy renovation of buildings, ESCOs, utilities, banks;
- the consumer sector, e.g. citizens (building owners/tenants), citizens (willing to buy/rent a building).

More specifically, the use case objective is to define and implement a methodology to harmonise an EPC dataset, using a common target data model to be created extending

the INSPIRE core data model for Buildings. The need for such an extension was already highlighted in the energy pilot feasibility study [2].

Then, starting from the harmonised EPC dataset, another objective is to show its usability in a GIS environment or by third parties applications, to perform analyses and elaborations based on the information contained in the harmonised dataset, supporting different processes of the lifecycle of different energy policies.

It is worth mentioning that applying the same methodology described in this report to EPC registers managed by different national/regional authorities will allow to define a European common data model for EPCs, which is a pre-requisite for the harmonisation of EPCs at European level. This common data model will encompass the different existing EPC data structures currently used by different national/regional authorities managing heterogeneous EPC registers. Then, each authority can continue to use its own EPC data model and a simple data transformation process to the common target data model will allow to achieve EPC harmonisation at European level.

1.5 Target audience

The target audience for this document is represented by national/regional authorities managing EPC registers, European bodies supporting the implementation of energy efficiency policies, CoM signatories and INSPIRE thematic communities working on buildings and in general on core data model extensions.

2 Methodology

The methodology followed to execute the use case is shown in the following ***Table 1***, where a description of the use case, including its main steps, is provided. For the description of all the use cases of the EULF Energy Pilot, the template adopted for the description of use cases included in the INSPIRE Data Specifications was re-used.

Table 1 *– Use case 1 description*

Name	Use case 1 – INSPIRE Harmonisation of existing Energy Performance Certificate datasets and creation of a web application for accessing them

Primary user	• Government:
	  ○ Energy Policy makers at regional level
	  ○ Energy Policy makers at local level
	• Businesses:
	  ○ Energy auditors and certifiers
	  ○ Companies working in the sector of energy renovation of buildings
	  ○ ESCO
	  ○ Utilities
	• Consumers:
	  ○ Citizens (building/building unit owners/tenants)
	  ○ Citizens (willing to buy/rent a building/building unit)

Data provider	• Government:
	  ○ Public Authorities managing an EPC register
	• Consumers:
	  ○ Citizens (building/building unit owners)

Goal	To establish an accessible and interoperable common knowledge base for EPC datasets to support local government and private sector companies involved in energy efficiency policies.
Description	To harmonise existing EPC datasets according to INSPIRE and to create a user friendly web application to make them accessible and re-usable.
Documentation	• Energy Performance Certificates EPC across the EU. A mapping of national approaches 2014[10] • Report on existing monitoring initiatives and database systems. From Databases to Retrofit Action: How European Countries are using Energy Performance Certificate (EPC) Database Systems[11] • Report on best practice meeting in Brussels. Using Energy Performance Certificate databases - turning data into action.[12]

[10] http://bpie.eu/publication/energy-performance-certificates-across-the-eu/
[11] http://building-request.eu/sites/building-request.eu/files/d2.1_wp2_report_on_existing_monitoring_initiatives_and_databases_150901_aea.pdf
[12] http://building-request.eu/sites/building-request.eu/files/d2.2_wp2_report_on_european_best_practice_meeting_150227_public_aea.pdf

Pre-condition	• Availability of EPC georeferenced datasets to be harmonised according to INSPIRE. • Availability of datasets needed to georeference those EPC datasets that are not georeferenced.
Post-condition	• INSPIRE harmonised EPC datasets will be made accessible by means of INSPIRE Network Services (WMS + WFS), in order to be reused by any interested party for its own purposes. • INSPIRE harmonised EPC datasets will be made accessible to the interested users through a web application, which will enable easy visualisation/query of (part of) the datasets attributes.
Flow of Events – Basic Path (to georeference and harmonise the EPC dataset of Provincia Autonoma di Trento, IT) **See also *Figure 2***	
Step 1	To access/obtain from Autonomous Province of Trento (PAT) the EPC dataset to be georeferenced using cadastral open datasets
Step 2	To access the cadastral open datasets
Step 3	To define a methodology to georeference the EPC dataset using cadastral data
Step 4	To implement the methodology, obtaining a georeferenced EPC dataset.
Step 5	To create the target data model extending the INSPIRE core data model for Buildings
Step 6	To transform the georeferenced EPC dataset into the INSPIRE extended target data model
Step 7	To publish the transformed dataset by means of INSPIRE Network Services (WMS + WFS)
Step 8	To use the harmonised dataset into a GIS client desktop application
Step 9	To assess the possibility of applying the methodology (or enhance it) to other EPC datasets, managed by other organisations in other countries/regions

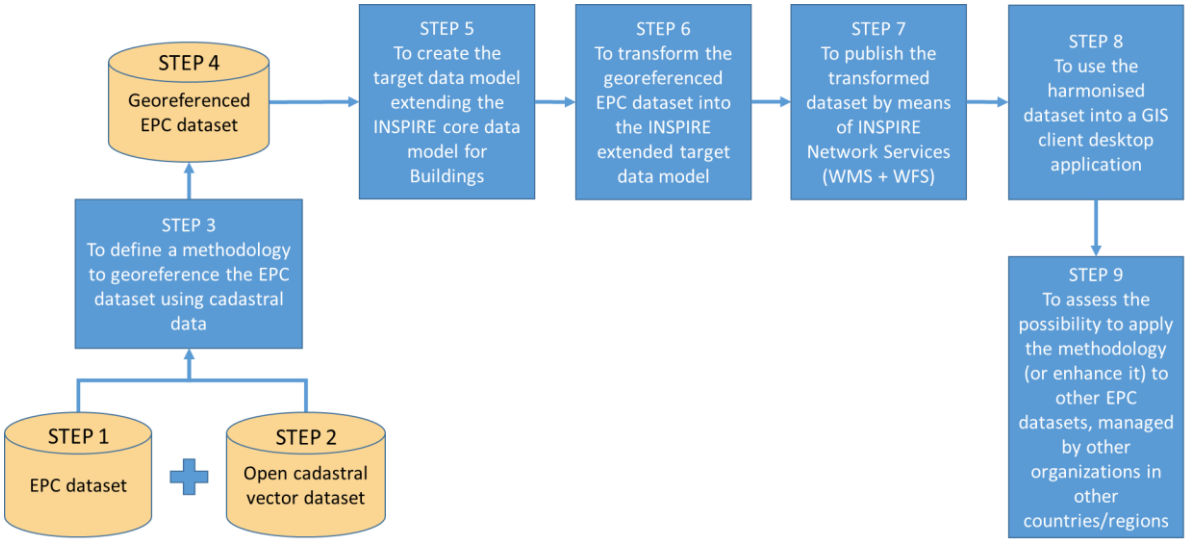


Figure 2 *– Use case steps*

In the following sub-sections a more detailed description of the steps of the methodology is provided.

2.1 Access to source data

The source data consist of two datasets:

1. the EPC dataset
2. the cadastral dataset

The EPC dataset, provided by APRIE in the form of an xml file, contains 1501 certificates extracted from the APRIE Oracle database selecting the records related to EPC of publicly owned buildings in the territory of Province Autonomous of Trento.

The cadastral dataset, accessible as open data, contains the geometries and parcel identifiers of both land parcels and built-up parcels, the latter coinciding with the building footprints, of the Autonomous Province of Trento. A zip file containing 447 shapefiles of all municipalities of the Province of Trento can be downloaded at http://dati.trentino.it/, while zip files containing the shapefile of each municipality can be downloaded at http://www.catasto.provincia.tn.it. For the demonstration purpose of the use case, the zip file related to the municipality of Trento, capital city of the Province, was downloaded.

2.2 Analysis and pre-processing of source data

This step had two objectives:

- to make a deep analysis and understanding of the semantically rich data model of the EPC source dataset, in order to properly address the next step consisting in the design of the INSPIRE extended target data model;
- to define a methodology to georeference the EPC dataset using the cadastral dataset, in order to add a geometry – consisting of the building footprints – to the EPC dataset, in which the only location-related information is provided by two character string attributes containing the building address and the cadastal parcel identifier, respectively.

Regarding the first objective, the data models of the two source datasets were deeply analysed. Their structure is shown in **Annex 1** – Source data model.

Regarding the second objective, it was decided to create two joins on-the-fly directly during the data transformation step using one of the functionalities of the transformation software:

- the first one, between the attribute 'parcelNumber' of the EPC dataset and the attribute 'NUM' of the cadastal dataset;
- the second one, between the attribute 'comuneCatastale' of the EPC dataset and the attribute 'CODCC' of the cadastal dataset.

Strictly related to this objective, there was the need to make some pre-processing of the cadastral source dataset, in order to prepare it for its use during the data transformation step. In particular, the following sub-steps were performed:

- filtering the parcels where a building is present (excluding the land parcels where no buildings are present), selecting only the 7.483 features having the value 'S' for the attribute 'FAB';
- removing the character "." present in some values (at the beginning) of the 'NUM' field.

2.3 INSPIRE core schemas extension

The deep analysis of the source data model of the EPC dataset led to the conclusion that the target data model to be created for the harmonisation process had to be an extension of the INSPIRE core data model for Buildings, which is one of the data themes belonging to the Annex III of the Directive and it is the most fit for purpose with respect to the data modelling requirements of the use case.

The definition of the extension approach required a prior analysis of the INSPIRE schemas currently available for the Buildings data theme.

2.3.1 The INSPIRE data model for Buildings

The INSPIRE Data Specification on Buildings [6] provides six different data models (or application schemas), covering different levels of detail from the semantic and geometric points of view (base vs. extended and 2D vs. 3D).

The relationships between the six application schemas are shown in ***Figure 3***, in which feature types are represented in blue, abstract application schemas are represented in green and instantiable application schemas are represented in red.

In ***Figure 4*** are schematised the dependencies between the six application schemas of theme Buildings.

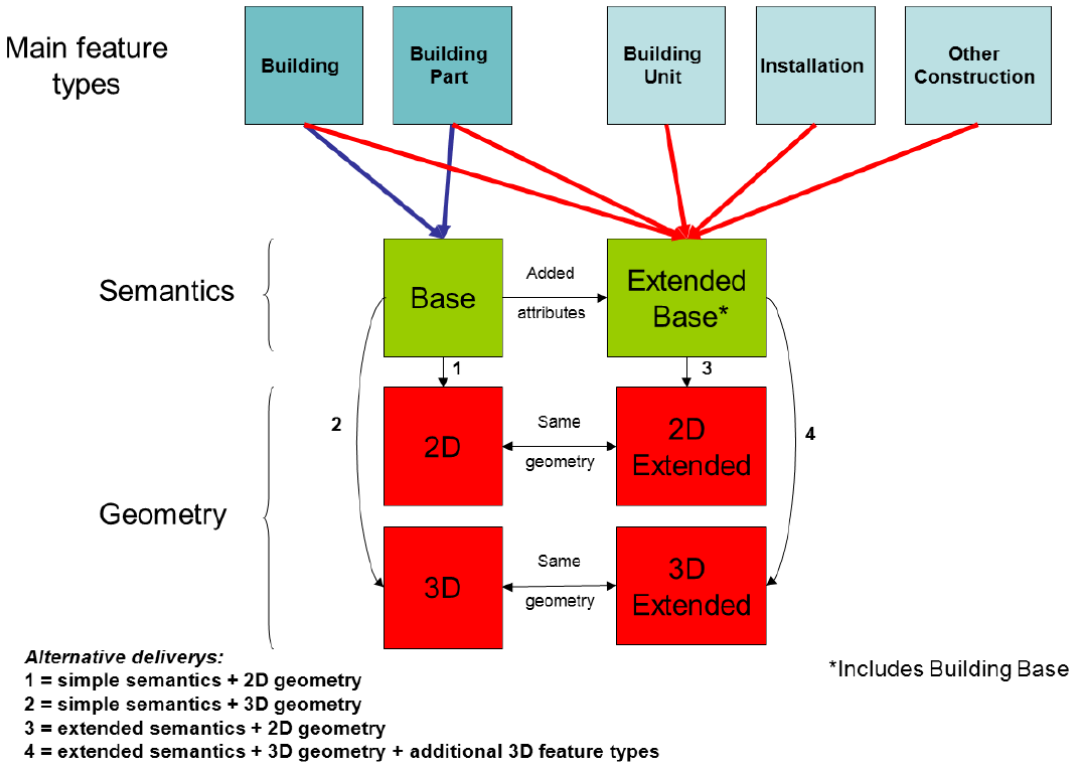


Figure 3 *– Content and structure of INSPIRE application schemas for Buildings theme*

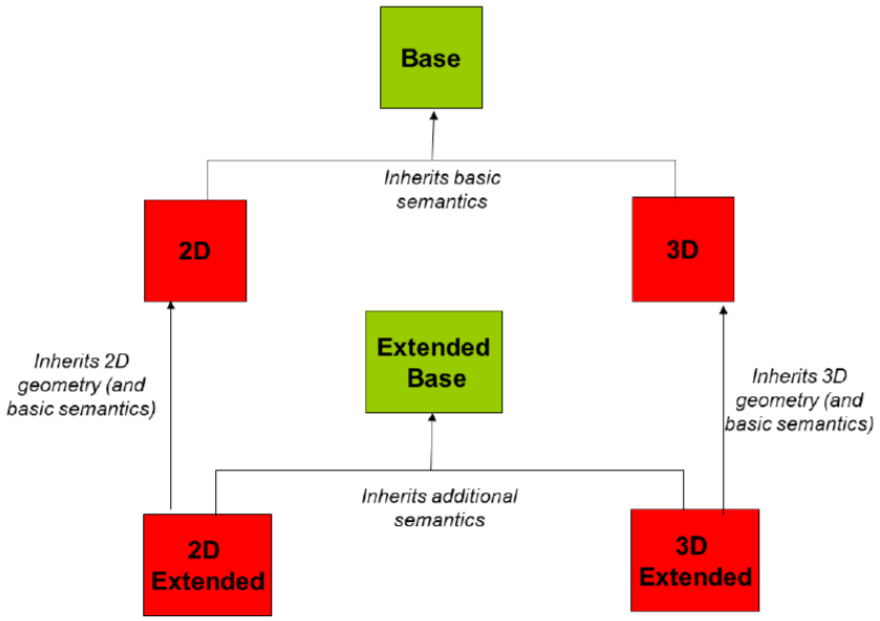


Figure 4 *– Dependencies between application schemas of theme Buildings*

It should be noted that various user requirements were collected by groups of experts in order to define these data models. As stated in the INSPIRE Data Specification on Buildings, "*… Because it seemed impossible to require data harmonisation at European level for all these requirements, the data specification on Buildings has defined some*

priority ...", as shown in the following ***Figure 5***, in which "*Feature types are represented in bright colours, whereas their properties are represented in clearer colours*".

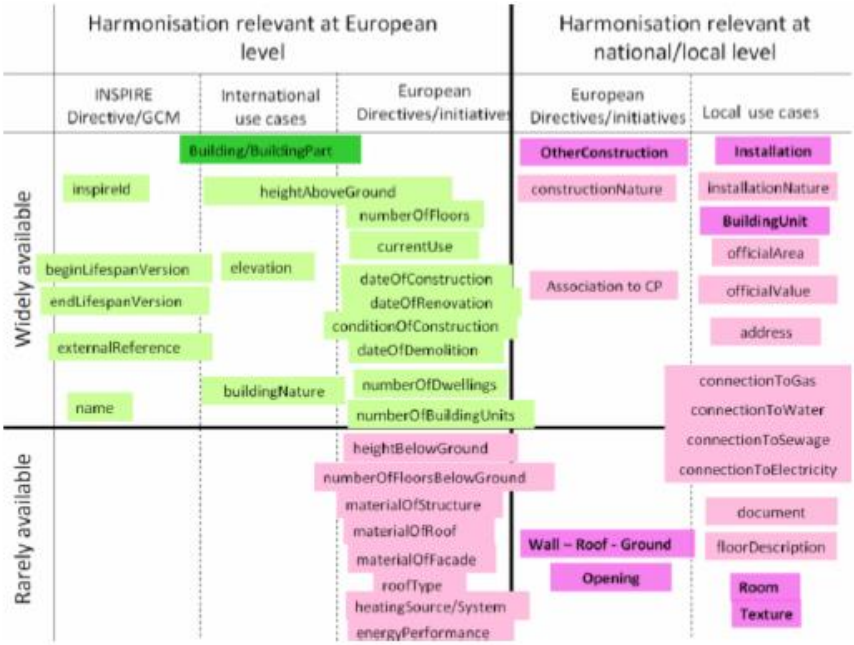


Figure 5 *- The hierarchy of semantics user requirements*

With reference to ***Figure 3*** and ***Figure 5***, as stated in the INSPIRE Data Specification on Buildings, "*… two kinds of semantic profiles are proposed in the data specification on Buildings:*

- ***normative*** *(i.e binding by law)* ***core profile****, based on the data widely used, widely available and whose harmonisation is required at European level, e.g. for homogeneous reporting on Environmental Directives;*
- ***informative*** *(i.e. not binding by law)* ***extended profile****, based on data that is widely required but whose harmonisation is not easily achievable at short term (e.g. data rarely available or data whose harmonisation may/should be done at national level).*

The common semantics used by all profiles has been described in a base application schema.

Core profile includes both basic topographic data (such as height, number of floors, nature of buildings, date of construction …) and coarse official data (such as current use, number of dwellings or of building units); the core profile aims to fulfil most user requirements, at least in a rough way. Core profile is based on the concepts shown in green in ***Figure 5****.*

Extended profile includes more detailed information about buildings and building related objects. Extended profile is based on the concepts shown in pink in ***Figure 5*** *…*".

In summary, the six application schemas of the Buildings theme shown in ***Figure 3*** and in ***Figure 4*** are listed and briefly described below:

- "***BuildingsBase****, describing the concepts that are common to all other Buildings application schemas; it contains mainly the core normative semantics of theme Buildings;*
- ***Buildings2D,*** *describing the 2D geometric representation of the spatial object types defined in Buildings Base application schema, namely buildings and building parts; it inherits from the common semantics of Buildings base*
- ***Buildings3D,*** *describing the 3D geometric representation of the spatial object types defined in Buildings Base application schema, namely buildings and building parts; it inherits from the common semantics of Buildings base*
- ***BuildingsExtendedBase,*** *describing the additional semantics that should be used to extend normative profiles, whatever the chosen geometric representation (2D or 3D) is.*
- ***BuildingsExtended2D,*** *describing the 2D geometric representation of the additional spatial object types (namely installations, other constructions, building units); it inherits both from the common semantics of <Buildings ExtendedBase> and of the 2D geometric representation of buildings and building parts.*
- ***BuildingsExtended3D,*** *describing both the 3D geometric representation of the additional spatial object types (namely installations, other constructions, building units) and the additional concepts that should be used to provide more detailed information about buildings and associated objects, when represented by 3D data (walls, roofs, openings, room, textures, …); it inherits both from the common semantics of <Buildings ExtendedBase> and of the 3D geometric representation of buildings and building parts."*

Considering that 2D geometries fit the use case data modelling requirements, then, looking at the semantic content of the BuildingExtended2D application schema, it is evident that it contains only few attributes of the EPC source data model. Therefore, a further extension of Buildings2D application schema was needed, in order to provide the target data motel with all the elements required to match those of the EPC source data model.

2.3.2 The data model extension approach

The generic approach to extend the INSPIRE data models for the theme Buildings is schematised in the following ***Figure 6*** [1], taking also into due consideration the informative content of Annex F "Example for an extension to an INSPIRE application schema" of the INSPIRE Generic Conceptual Model, which sets precise rules and conditions to ensure that the interoperability of harmonised data and services is not broken [7].

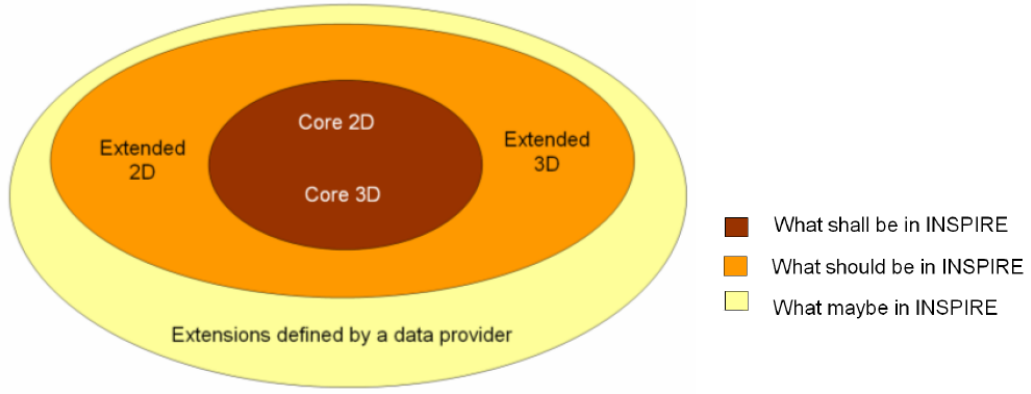


Figure 6 *– Modular approach for modelling Buildings theme*

Coherently with the approach schematised in ***Figure 6***, the first attempt to produce the target data model for this use case should consisted in further extending the INSPIRE BuildingExtended2D application schema.

However, it is to be noted that all the INSPIRE extended schemas, which are not binding-by-law, are still draft and, in addition, not always maintained, e.g. in terms of encoding issues. As an example, the double inheritance of the FeatureType Building, red-circled in ***Figure 7***, creates problems when the physical application schema has to be generated from the logical UML data model.

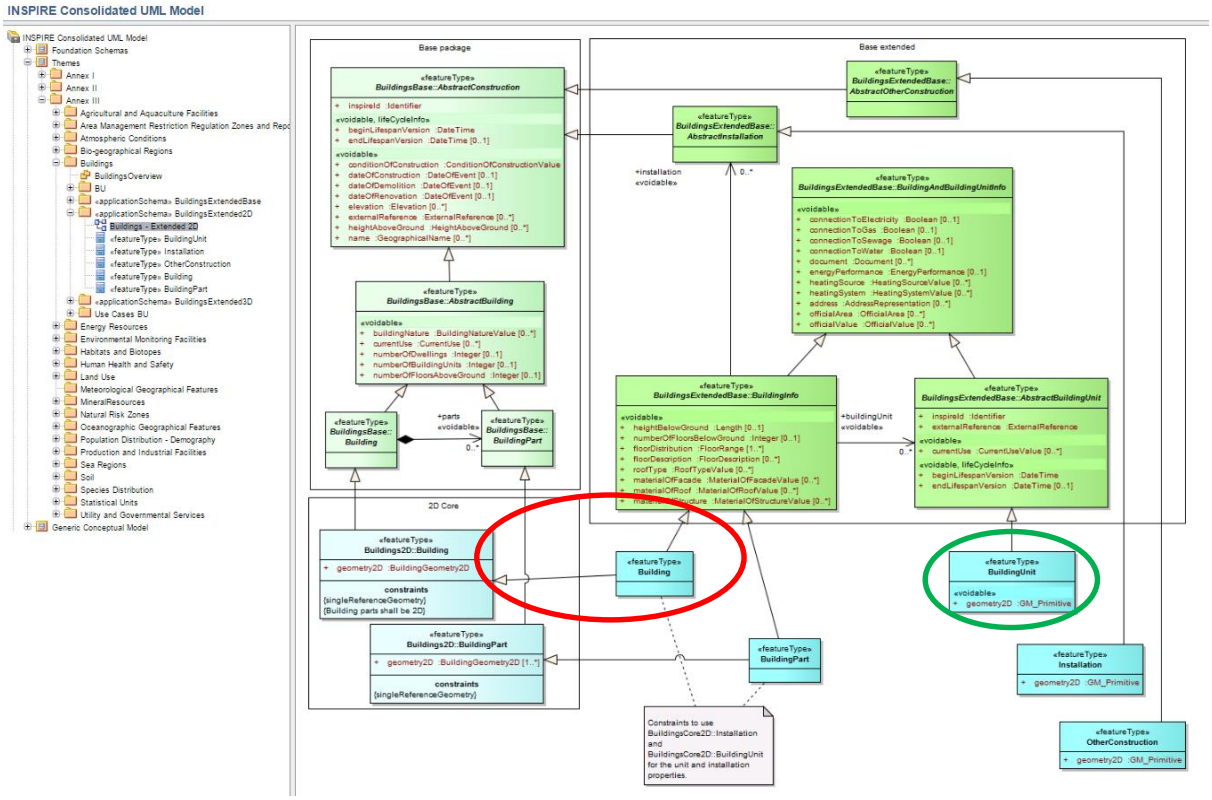


Figure 7 – *INSPIRE BuildingExtended2D data model in UML*

For this reason, it was decided to follow the approach schematised in ***Figure 8***, consisting in:

- extending the INSPIRE core and binding-by-law Buildings2D data model;
- including those additional classes and spatial objects of the BuildingsExtended2D draft data model matching the data modelling requirements of the use case;
- excluding those additional classes and spatial objects of the BuildingsExtended2D draft data model not matching the data modelling requirements of the use case;
- defining new classes and spatial objects needed to fully cover all the data modelling requirements of the use case;
- defining new associations between the classes.

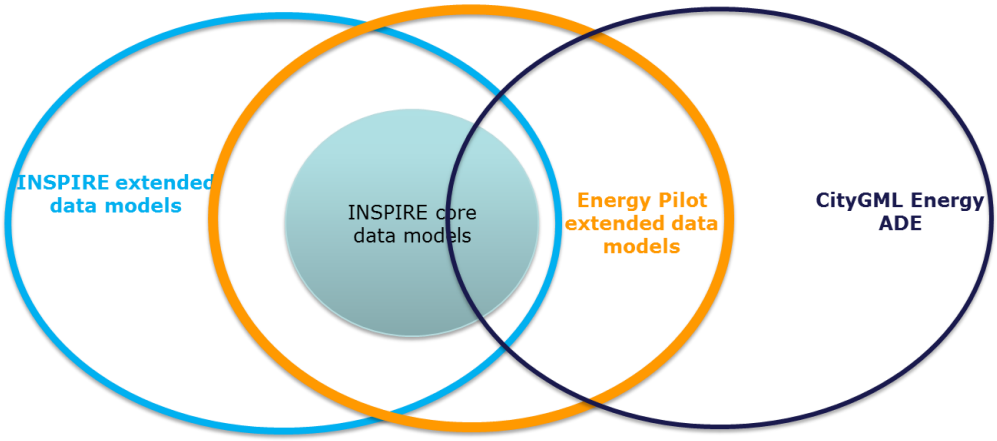


Figure 8 *– Approach followed to extend the INSPIRE core data model for Buildings*

In terms of classes and spatial objects defined in the BuildingsExtended2D schema and included in the use case target data model, it is worth to mention the BuildingUnit feature type, green-circled in ***Figure 7***, compared to Building and BuildingPart feature types defined in the INSPIRE core schemas (see ***Figure 7*** and ***Figure 9***).

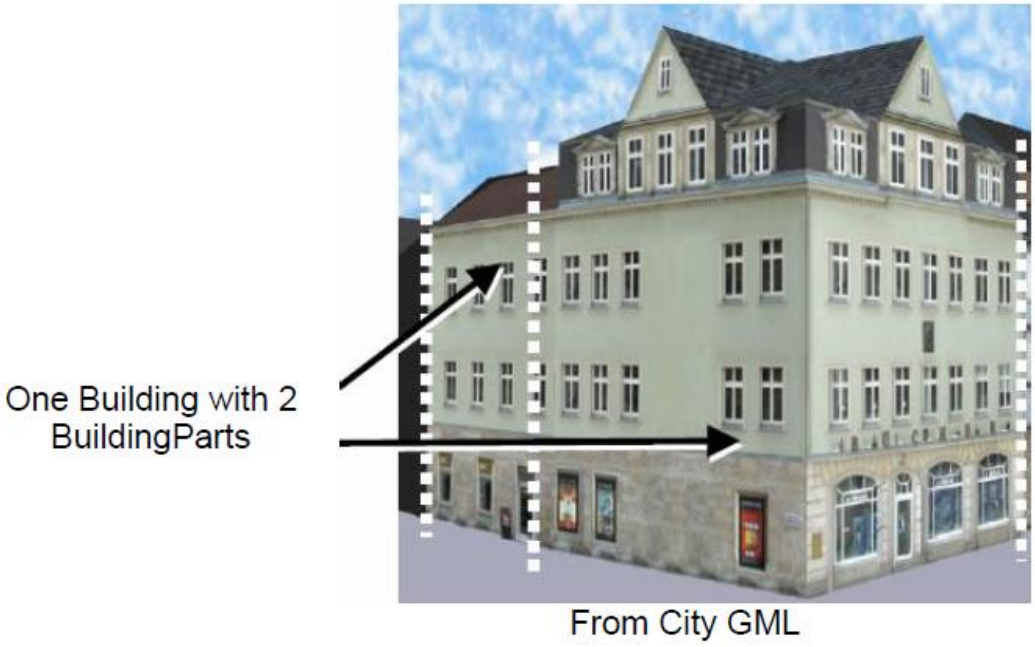


Figure 9 *– Relationship between Building and BuildingPart*

As described in [6], *"a BuildingUnit is a subdivision of Building with its own lockable access from the outside or from a common area (i.e. not from another BuildingUnit), which is atomic, functionally independent, and may be separately sold, rented out, inherited, etc. Building units are spatial objects aimed at subdividing buildings and/or building parts into smaller parts that are treated as seperate entities in daily life. A building unit is homogeneous, regarding management aspects. EXAMPLES: It may be e.g. an apartment in a condominium, a terraced house, or a shop inside a shopping arcade. NOTE 1: According to national regulations, a building unit may be a flat, a cellar, a garage or set of a flat, a cellar and a garage. NOTE 2: According to national regulation, a building that is one entity for daily life (typically, a single family house) may be considered as a Building composed of one BuildingUnit or as a Building composed of zero BuildingUnit."*

Despite that in most of the Energy policy instruments the lowest level of detail in location-related representations is constituted by spatial objects which can be modelled

by the Buildings or BuildingParts INSPIRE feature types, in the context of this use case the BuildingUnit concept is more relevant, because it is the spatial object referred to by an Energy Performance Certificate.

Regarding the data model extension approach, the two following projects/initiatives were also deeply analysed, in order to maximise the re-use of existing results already produced in the same field:

- the CityGML Energy ADE [13] initiative, which contributes considerably to the definition of a standard data model in the energy domain,
- the GeoSmartCity [14] EU project, which already performed energy-related data modelling work for buildings[15].

It should also be highlighted that the outcomes of a recent study defining a methodology for INSPIRE Data Specifications extensions, carried out by WeTransform[16], were taken into due consideration. In particular, the different patterns for INSPIRE extensions (a screenshot of the relevant web page is shown in ***Figure 10***) were duly analysed prior to design the different types of associations between the classes of the extended data model.

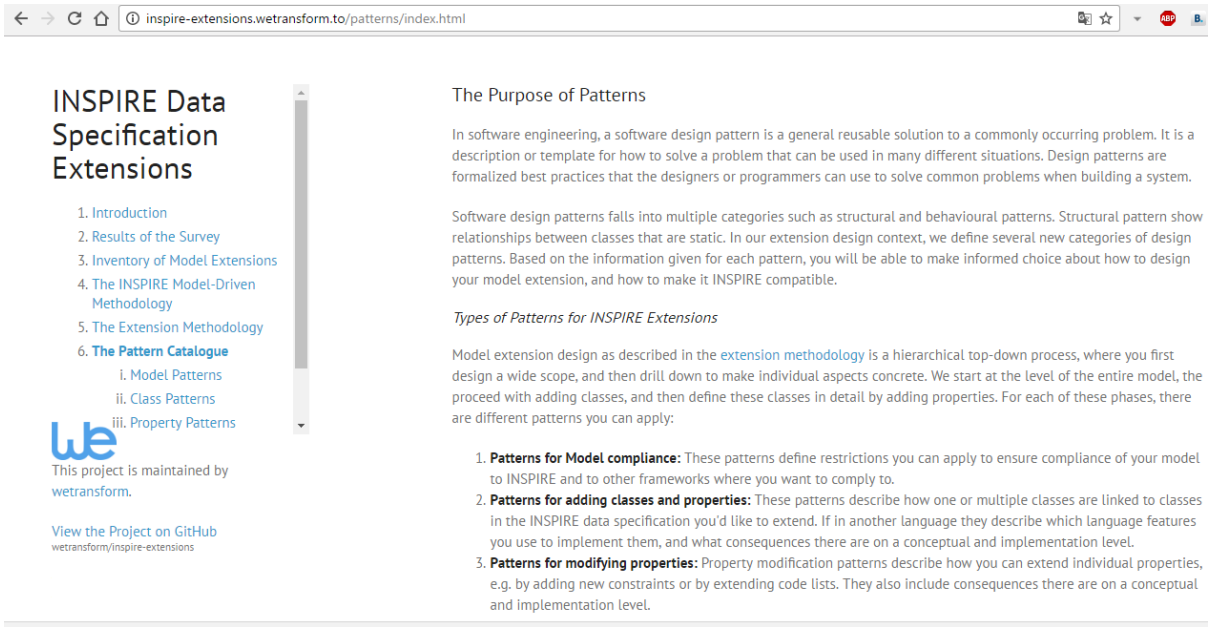


Figure 10 – *Methodology for INSPIRE core schemas extension*

2.3.3 The extended data model

The use case extended target data model was created following the data model extension approach described in the previous sections, by means of three main activities:

- the design of the conceptual model, using excel spreadsheets;
- the design of the logical model in UML, using Enterprise Architect software;
- the generation of the physical model, in the form of a gml application schema (xsd file), using Enterprise Architect software.

The conceptual model in excel format is shown in **Annex 2** – Conceptual target data model, whilst the overall logical model in UML is shown in ***Figure 11***, in which are

[13] http://en.wiki.energy.sig3d.org/index.php/Main_Page
[14] http://www.geosmartcity.eu/
[15] https://themes.jrc.ec.europa.eu/discussion/view/61352/extended-bu-data-model-for-energy-efficiency
[16] http://inspire-extensions.wetransform.to/index.html

separately identifiable the classes of the INSPIRE core2D schema, those included from the INSPIRE BuildingsExtended2D draft schema and the new classes.

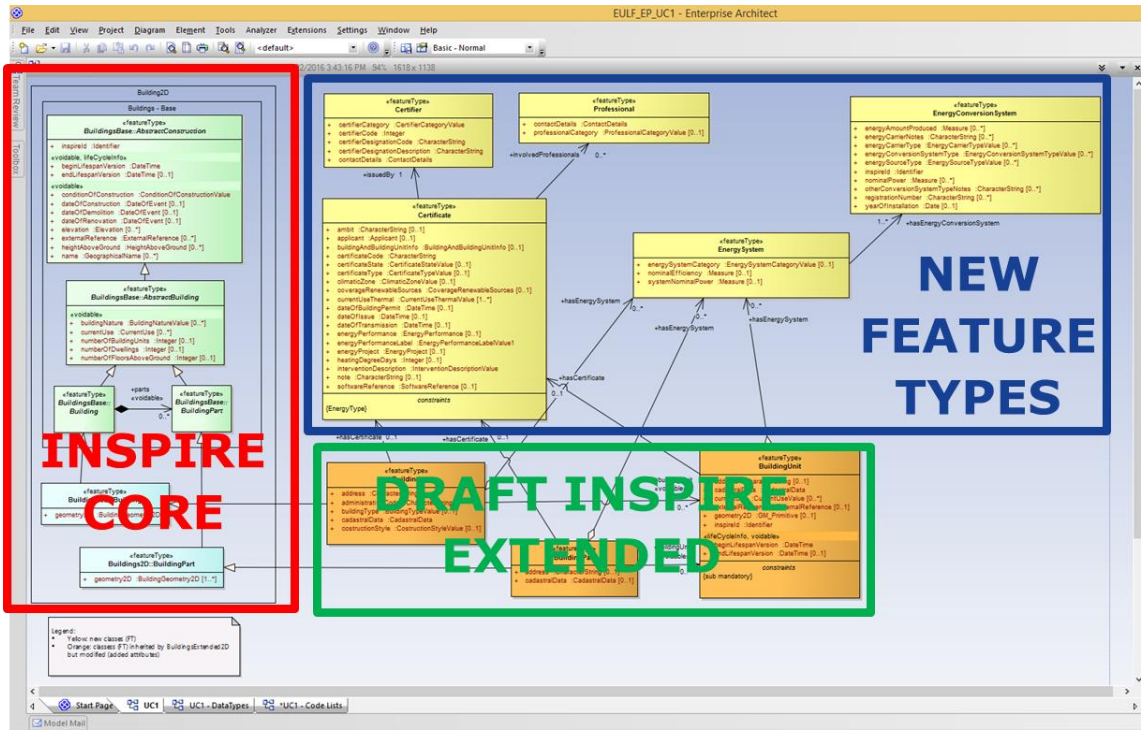


Figure 11 *– UML classes of the extended data model*

More details on specific aspects of the extended data model are provided in the following paragraphs.

Figure 12 shows the three feature types Building, BuildingPart and BuildingUnit taken from the INSPIRE BuildingsExtended2D draft schema and modified in order to match the data modelling requirements of the use case, whilst ***Figure 13*** shows the five new feature types defined for the Use Case extended schema.

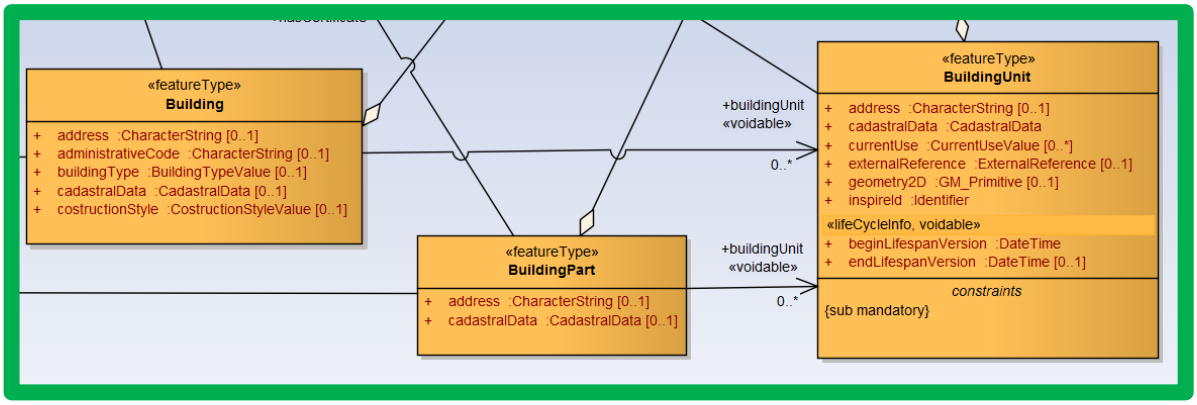


Figure 12 *– Modified feature types of INSPIRE BuildingsExtended2D draft schema*

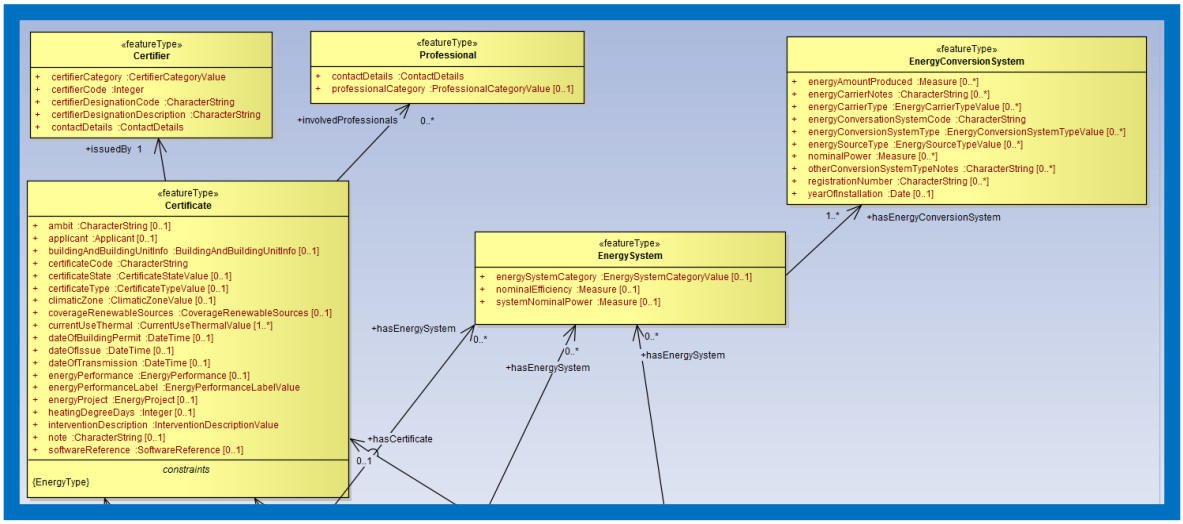


Figure 13 – *New feature types of Use Case extended data model*

Figure 14 shows in dark green the five feature types of the INSPIRE ExtendedBase draft schema and in cyan the five feature types of the INSPIRE Extended2D draft schema.

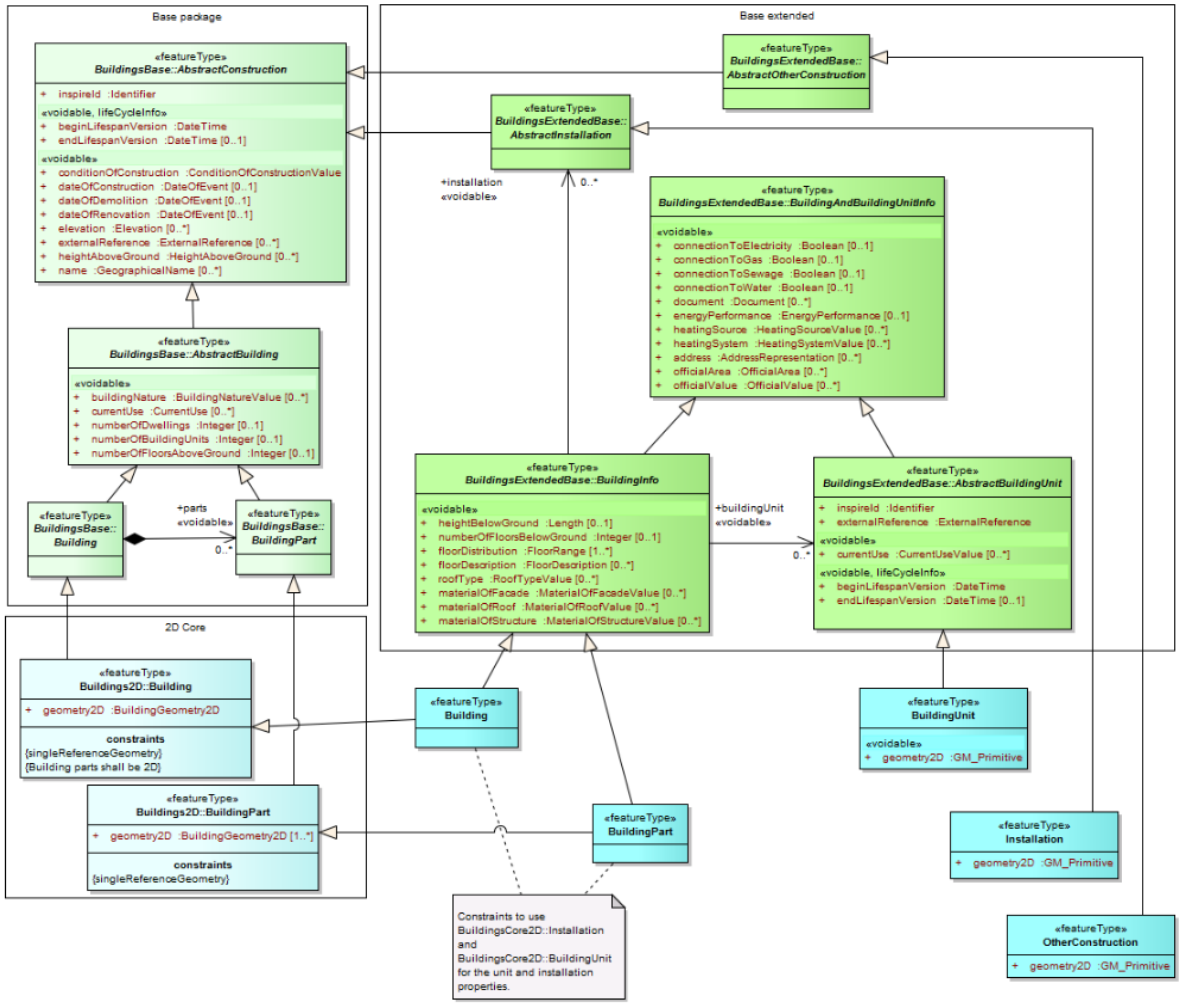


Figure 14 – *Feature types of INSPIRE Buildings Extended draft schemas*

Comparing the feature types described above and shown in ***Figure 14*** with those shown in ***Figure 12*** and in ***Figure 13***, it is evident that:

- the two feature types Installation and OtherConstruction of the INSPIRE Extended2D draft schema, as well as the two inherited abstract feature types of the INSPIRE ExtendedBase draft schema, were not included in the Use Case extended schema, because the EPC is related to a Building or to a BuildingPart or to a BuildingUnit and therefore the four feature types are not relevant to the use case;
- the feature type BuildingUnit of the INSPIRE Extended2D draft schema, which contains only the geometry, was modified in the use case extended data model, adding some attributes taken from the inherited abstract feature type of the INSPIRE ExtendedBase draft schema and adding also some new attributes;
- the two feature types Building and BuildingPart of the INSPIRE Extended2D draft schema, which inherit the corresponding feature types of the INSPIRE 2D Core schema (containing, in turn, the geometry) and the feature type BuildingInfo of the INSPIRE ExtendedBase draft schema, were modified in the use case extended data model, adding new attributes and modifying the type of relationship;
- the two feature types BuildingInfo and BuildingAndBuildingUnitInfo of the INSPIRE ExtendedBase draft schema were replaced by new feature types in the use case extended data model;
- the five new feature types shown in ***Figure 13*** (Certificate, EnergySystem, EnergyConversionSystem, Certifier, Professional) were defined in order to match the data modelling requirements of the use case, creating new attributes which, from a semantic point of view, are related to specific information contained in the EPC. Conversely, the new attributes created for the three feature types shown in ***Figure 12*** are related to more generic information which can be relevant also to applications outside the energy sector.

Regarding the relationships between classes:

- the double inheritance of the Building and BuildingPart feature types of the INSPIRE Extended2D draft schema was modified in the use case extended schema, maintaining the inheritance of the Building and BuildingPart feature types of the INSPIRE 2D Core schema and creating an association (with multiplicity 0..*) to the feature type BuildingUnit; this solution - to avoid the double inheritance and substitute one inheritance with one association - was adopted in order to overcome encoding problems in the generation of the xsd (gml application schema), re-using the same approach successfully adopted in the GeoSmartCity project;
- for the three feature types Building, BuildingPart and BuildingUnit an association (with multiplicity 0..1) was created to the feature type Certificate and an aggregation (with multiplicity 0..*) to the feature type EnergySystem;
- for the feature type Certificate an association (with multiplicity 1) was created to the feature type Certifier and an association (with multiplicity 0..*) to the feature type Professional;
- for the feature type EnergySystem an association (with multiplicity 1..*) was created to the feature type EnergyConversionSystem.

Regarding the more generic attributes of the feature types Building, BuildingPart and BuildingUnit shown in ***Figure 12***, they were designed in order to model the typical situation schematised in ***Figure 15***, in which a Building is made of 4 BuildingParts, with each BuildingPart having one or more addresses (same street, but different house numbers), and each BuildingPart containing one or more BuildingUnits, e.g. in different floors, or, in the same floor but with different apartment numbers.

Moreover, it is to be highlighted that the above mentioned three feature types and their attributes have to be able to model the opposite situation of a Building with no BuildingParts and only one BuildingUnit (single family house).

In this context, the data modelling requirements related to the attributes of the three feature types, derived from the EPC source dataset, as also shown in **Annex 1** – Source data model, can be summarised as follows:

- each EPC is referred to a single BuildingUnit;
- each BuildingUnit, apart from its address (which does not contain the apartment number) is characterised by a set of cadastral data which, according to Italian regulations applied to the cadaster of buildings, contains attributes like cadastral sheet, parcel number and sub (i.e. apartment number);
- for the purpose of the use case, which focuses on EPC of BuildingUnits, there is no need to elaborate a procedure aggregating at Building or BuildingPart level the Energy Performance Labels of multiple BuildingUnits.

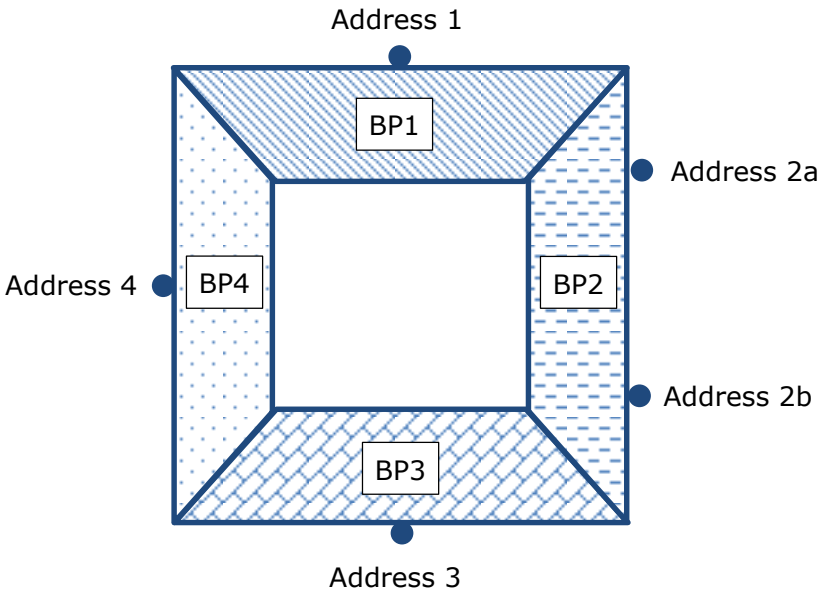


Figure 15 *– Relationship between Building, BuildingPart and BuildingUnit*

The data modelling solution adopted consisted in adding the attributes address and cadastralData to the three feature types, as shown in ***Figure 12***, whilst the whole set of attributes of the complex data type CadastralData are shown in ***Figure 16***

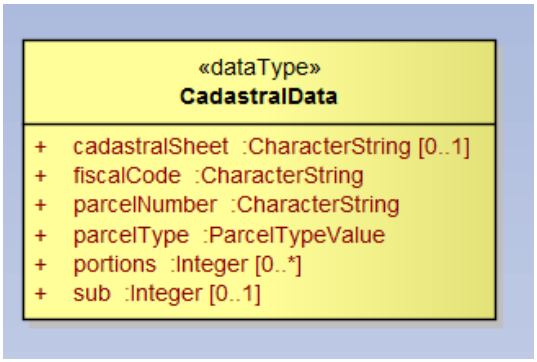


Figure 16 *– Complex data type CadastralData*

Figure 17 shows an overall view of all the data types used in the extended data model, differentiating the data types of the INSPIRE BuildingBase core schema in the red box

from the new data types in the blue box, whilst ***Figure 18*** shows only the new data types.

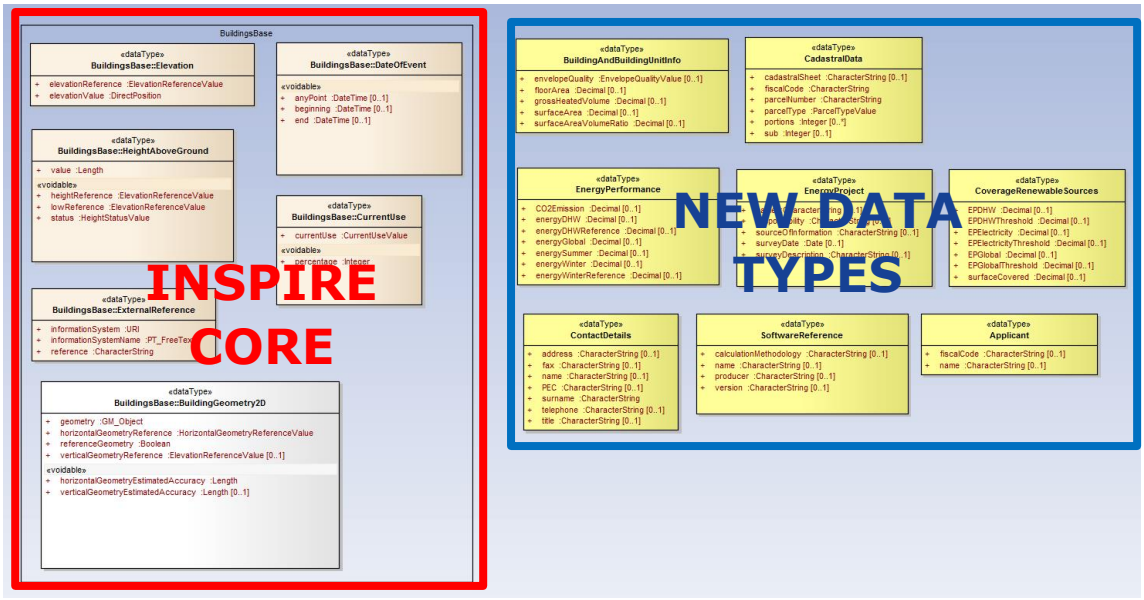


Figure 17 *–Data types of the extended data model*

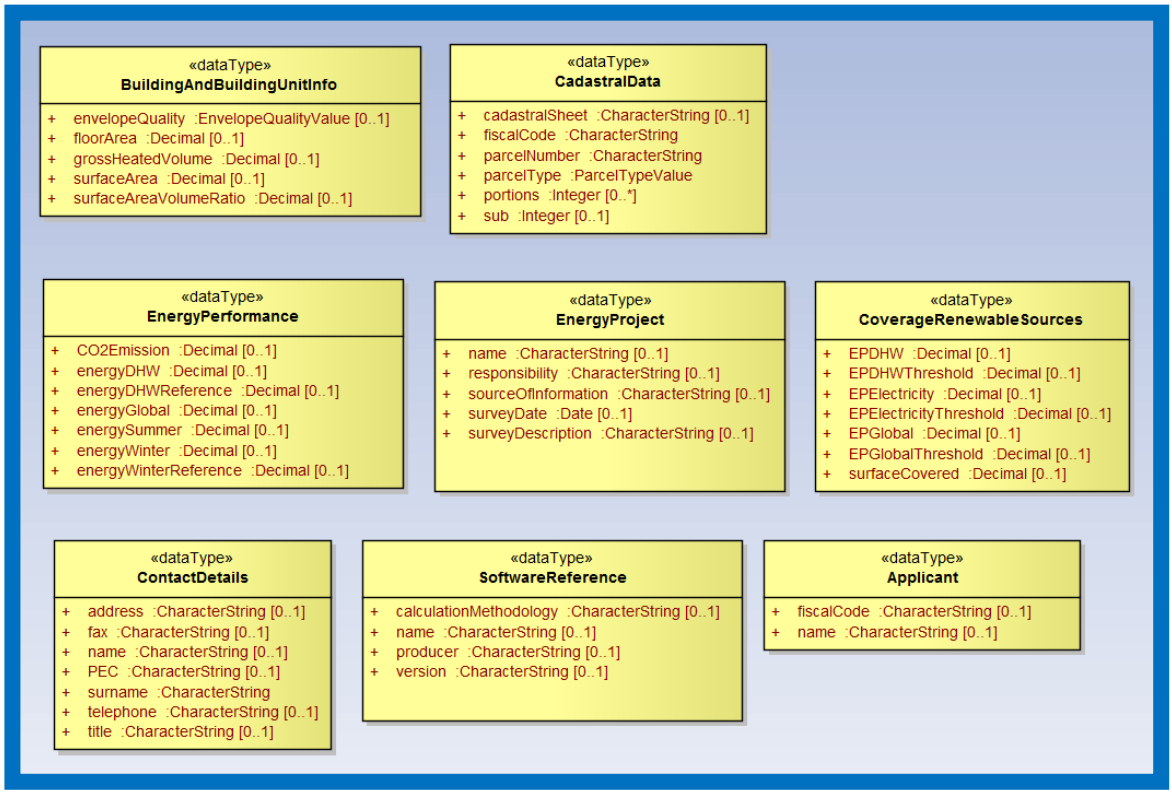


Figure 18 – New *data types*

It is to be highlighted that the data type BuildingAndBuildingUnitInfo was defined as a new data type, shown in ***Figure 19***, whilst it is defined as a feature type, but with different attributes, in the INSPIRE ExtendedBase draft schema.

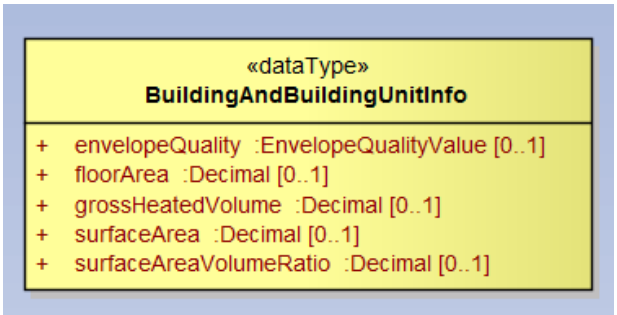


Figure 19 – *BuildingAndBuildingUnitInfo data type*

Regarding the code lists[17], the extension of existing code lists as well as the definition of new code lists is one of the most typical data modelling requirements to be fulfilled when extending an INSPIRE core data model.

In the present case, the code lists-related data modelling requirements were to define sixteen new code lists, without the need to extend any of the code lists already defined in the INSPIRE BuildingBase core schema, shown in ***Figure 20***.

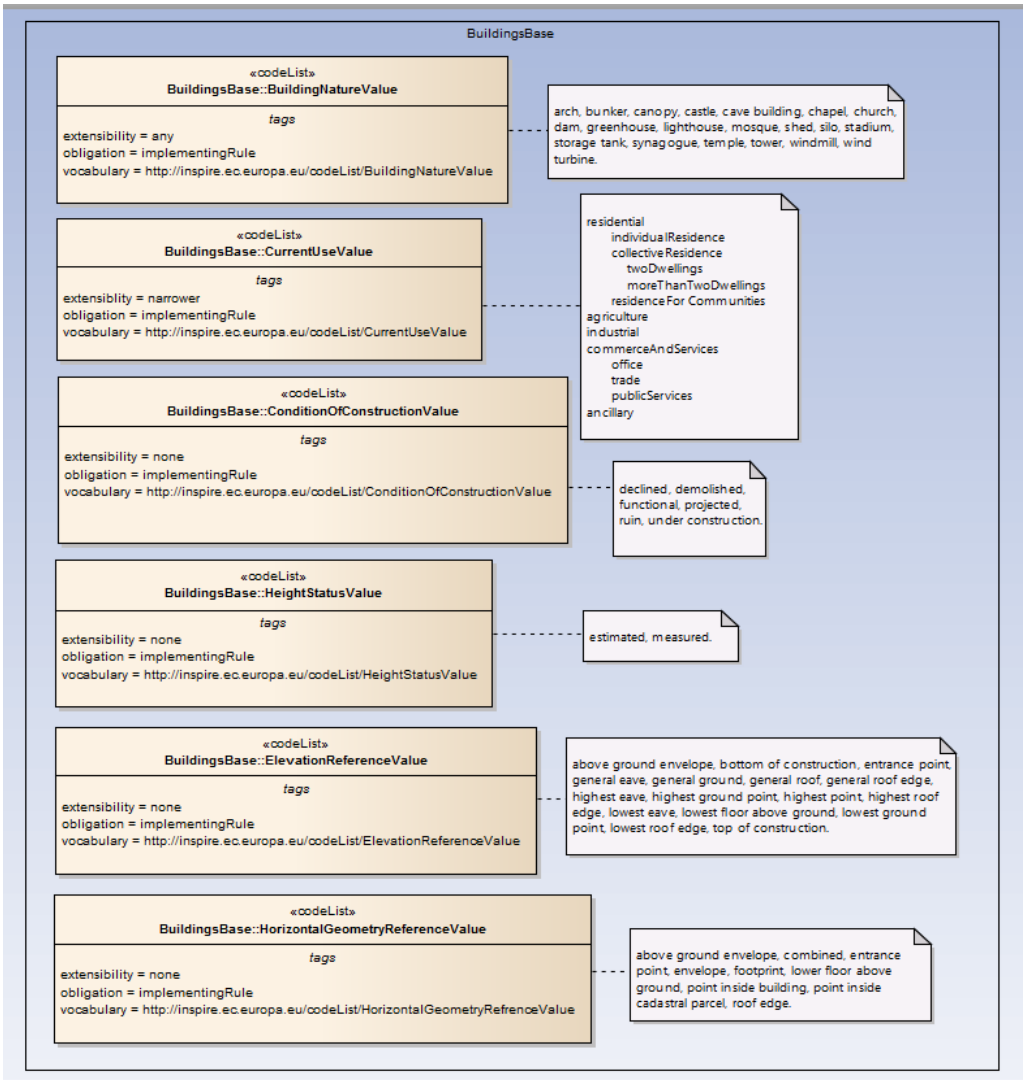


Figure 20 – *Code lists of the INSPIRE BuildingBase core schema*

[17] http://inspire.ec.europa.eu/glossary/CodeList

Figure 21 and ***Figure 22*** show the new sixteen code lists, as defined in the UML extended model.

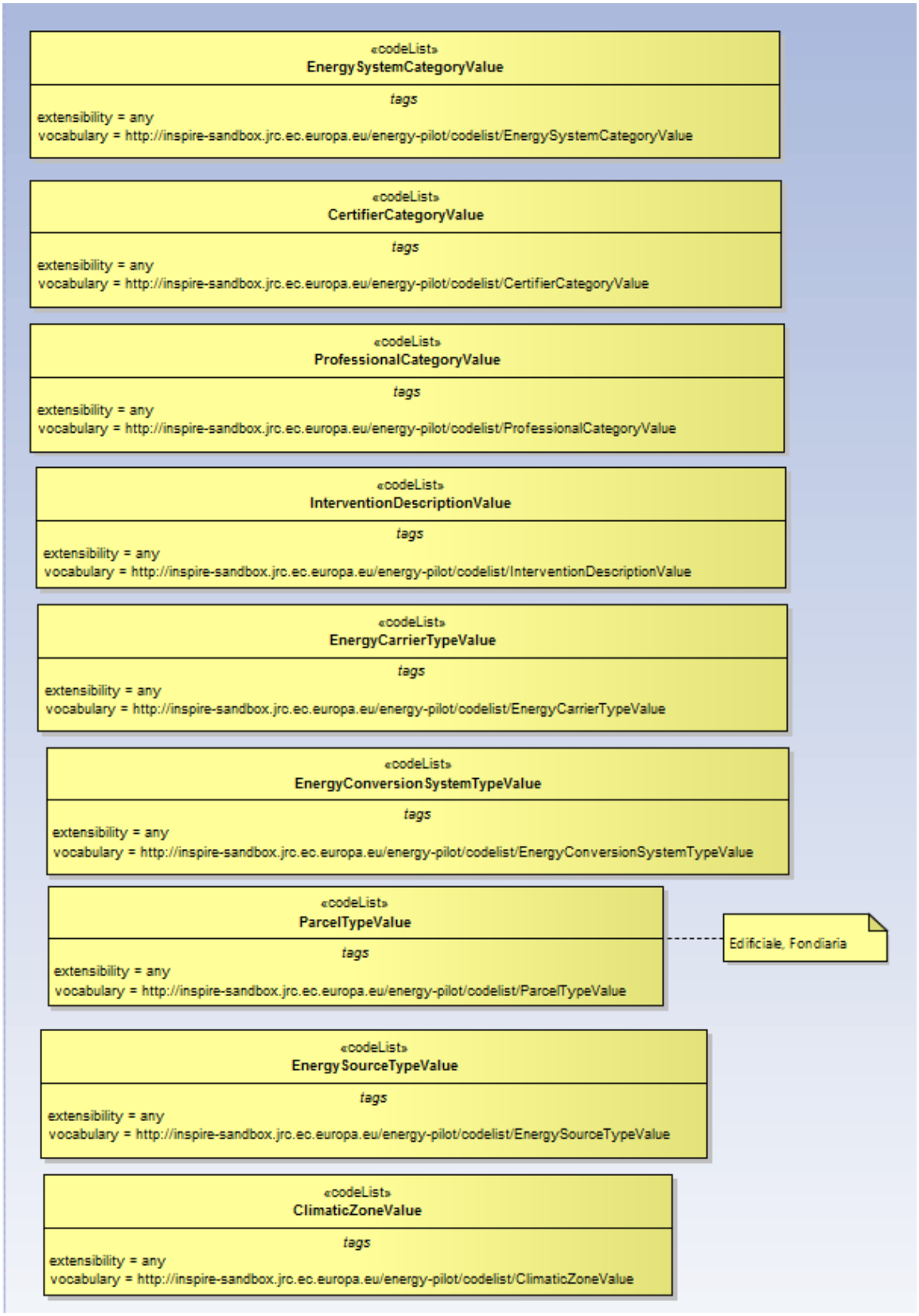


Figure 21 – *New code lists (1)*

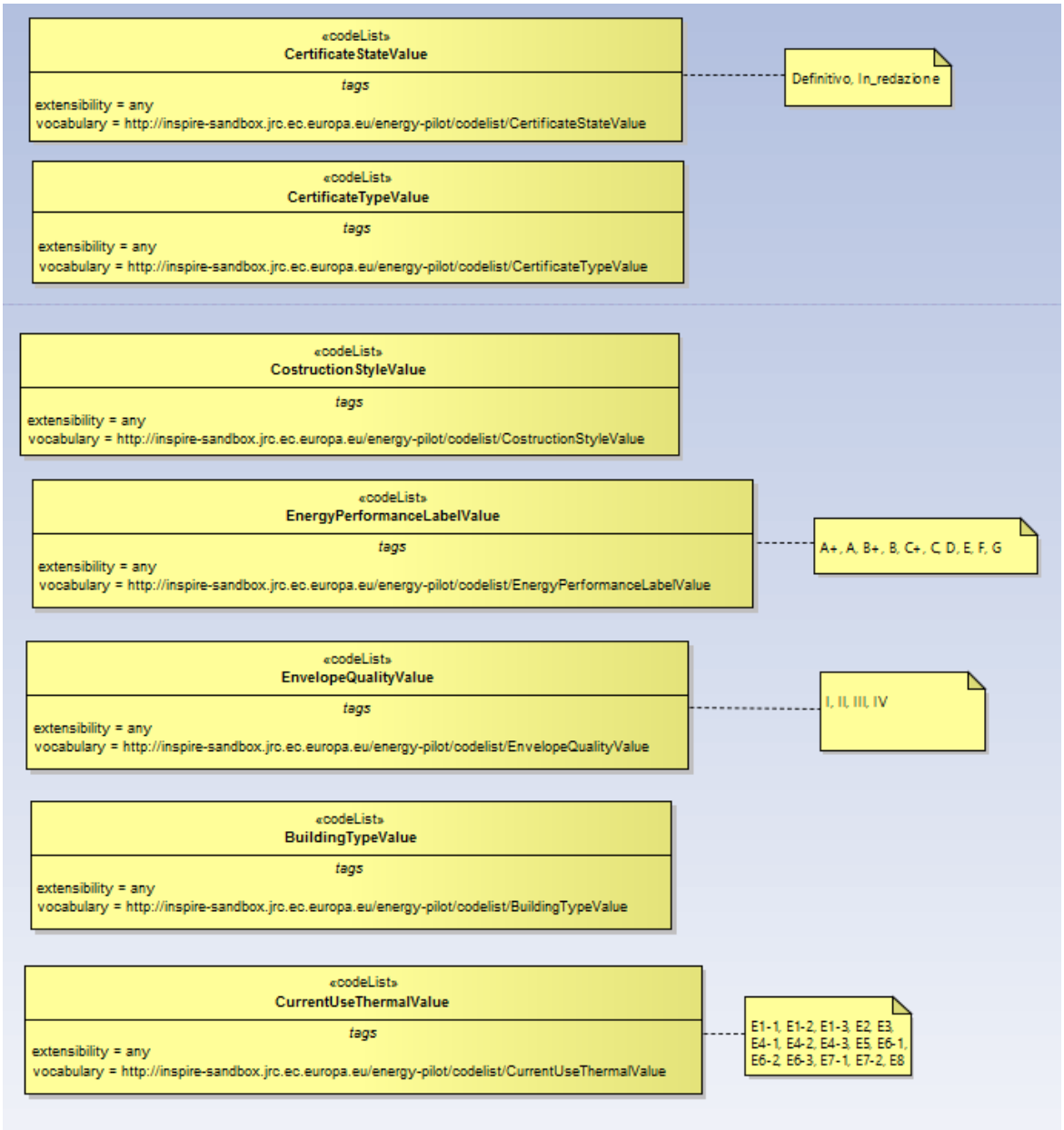


Figure 22 *– New code lists (2)*

Finally, regarding the re-use of CityGML Energy ADE elements, in **Annex 2** – Conceptual target data model are shown in green background the attributes of the use case extended data model taken as-is from CityGML Energy ADE modules.

2.4 Re3gistry implementation

Regarding the encoding of code lists, it is worth recapping the INSPIRE normative and informative context relevant to the data model extension performed for the use case:

- point 3 of article 6 of IR 1253/1013 [9], requiring that values and definitions of new code lists shall be made available in a register;
- section 9.4.5.3 "External code lists" of INSPIRE Generic Conceptual Model [7], recommending that, "*ideally, an externally managed code list should meet the following requirements:*
    - *it should be managed by a competent international organisation.*
    - *it should be well maintained, i.e. all its values must remain available forever, even if they have been deprecated, retired or superseded.*

    - *the code list and each of its values should be identifiable through a persistent URI6 in the „http" scheme.*
    - *the code list should be available in HTML plus at least one of the following machine-readable representations:*
        - *GML dictionary*
        - *SKOS;"*
- section G.9 "Use of code lists – referencing vs. download" of INSPIRE Generic Conceptual Model [7], recommending that:
    - *"code lists will be published online and should be referenceable by http URI;*
    - *each value should also be uniquely referenceable by http URI;*
    - *human readable representations of code lists will be published in HTML (or other form);*
    - *machine readable forms of the code list will be published in SKOS, GML (or other form);*
    - *any new code lists is implemented with URI identifiers at the outset to promote reuse and minimise costs and change at a later stage."*
- recommendation 5 for externally governed code lists, contained in section 5.2.4.4 "Governance" of INSPIRE Data Specification on Buildings [6].

In order to physically implement the requirements and recommendations mentioned above, it was decided to re-use the Re3gsitry[18][19] software, which is an open source solution to help managing and sharing 'reference codes', developed at JRC in the framework of the Are3NA[20] (A Reusable INSPIRE Reference Platform) action of the ISA (Interoperability Solutions for European Public Administrations) Programme. The Re3gistry web page on the ISA website is shown in ***Figure 23***. It is to be highlighted that the INSPIRE registry[21], containing code lists as well as several other registers, was developed using the Re3gistry software.

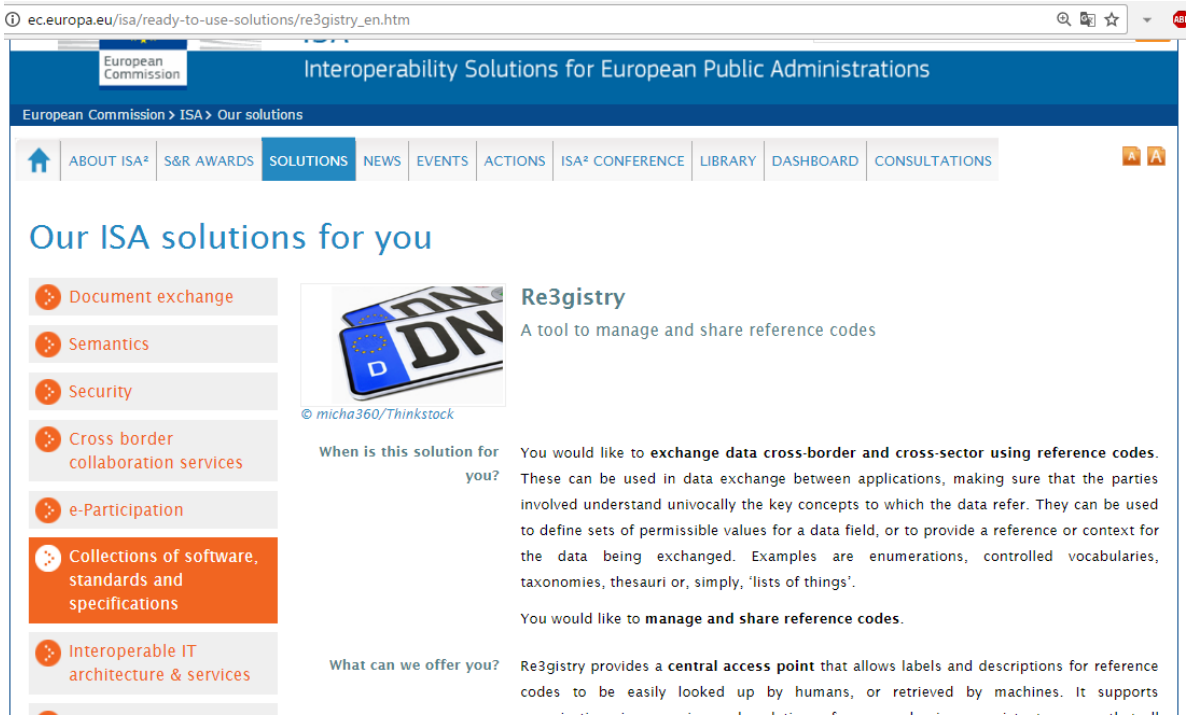


Figure 23 *– Re3gistry web page on ISA website*

[18] https://joinup.ec.europa.eu/software/re3gistry/description
[19] http://ec.europa.eu/isa/ready-to-use-solutions/re3gistry_en.htm
[20] http://ec.europa.eu/isa/actions/01-trusted-information-exchange/1-17action_en.htm
[21] http://inspire.ec.europa.eu/registry

With the help of the INSPIRE Re3gistry team, an instance of the Re3gsitry software was implemented in order to create the EULF Energy Pilot registry, containing the code list and the application schema registers. The registry is accessible at http://inspire-sandbox.jrc.ec.europa.eu/registry and a screenshot of the code list register is shown in ***Figure 24***).

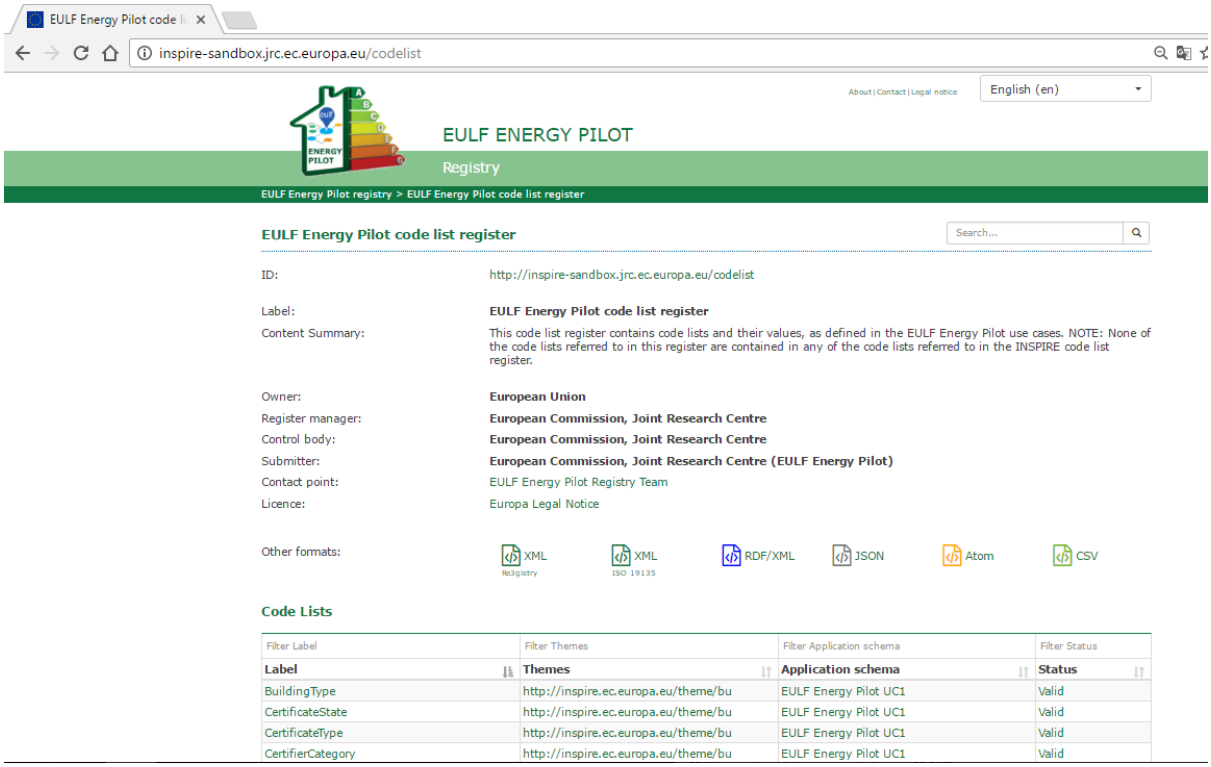


Figure 24 *– Screenshot of the Re3gsitry instance created for the EULF Energy Pilot*

The code list register was implemented following the standard procedure recommended by the INSPIRE Re3gistry team, based on the import of two CSV files containing, in the required syntax, the information related to the sixteen code lists and their values, respectively.

In terms of multilingualism, the current implementation contains two languages, English and Italian:

- LocalId of code list names (corresponding to <CodeListName> in the pattern http://inspire-sandbox.jrc.ec.europa.eu/codelist/<CodeListName>/<value> used to make code lists and code lists values uniquely referenceable by http URI) are provided in English;
- labels and definitions of code list names are provided both in English and Italian;
- LocalId and labels of code list values are currently provided only in Italian (due to time constraints);
- descriptive text of code lists and code list values is currently missing (due to time constraints);
- currently missing English version of LocalId and labels of code list values, as well as descriptive text of code lists and code list values in both languages, will be provided at a later stage.

2.5 Data transformation

The first activity performed to execute the step 6 of the methodology schematised in ***Figure 2*** consisted in the creation of the mapping table, using an excel spreadsheet which shows the correspondence between the elements of the source data model and

those of the target data model. The entire content of the mapping table provided in **Annex 3** – Mapping table.

After having filled-in the mapping table, the second activity consisted of the physical transformation of the source dataset described in section 2.1, from its source data model shown in **Annex 1** – Source data model to the target data model described in section 2.3.3.

For this activity, one of the most popular tansformation software within the INSPIRE community was used, i.e. hale studio open source[22] (version 2.9.4).

A screenshot of the transformation is shown in ***Figure 25***.

It is to be highlighted that, in order to georeference the EPC dataset using the cadastral dataset, it was decided to create two joins on-the-fly directly during the data transformation step using one of the hale studio functionalities:

- the first one, between the attribute 'parcelNumber' of the EPC dataset and the attribute 'NUM' of the cadastal dataset;
- the second one, between the attribute 'comuneCatastale' of the EPC dataset and the attribute 'CODCC' of the cadastal dataset.

In this way, it was possible to add a geometry – consisting of the building footprints – to the EPC dataset, in which the only location-related information is provided by two character string attributes containing the building address and the cadastal parcel identifier, respectively.

The transformation process was concluded by exporting the harmonised gml file.

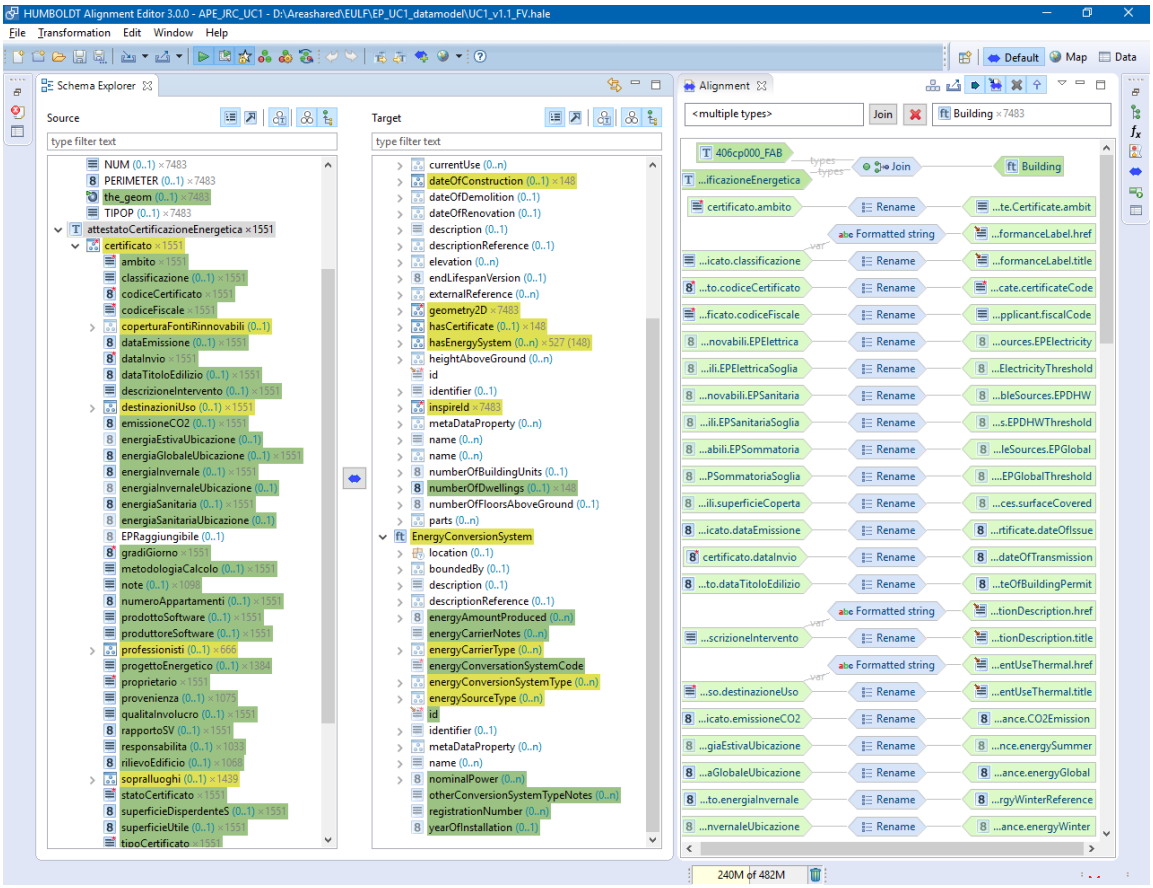


Figure 25 – *Screenshot of the data transformation made with hale studio*

[22] https://www.wetransform.to/products/halestudio/

2.6 Data validation

Even though hale studio performs an on-the-fly schema validation during the transformation, which greatly supports the solution of transformation issues encountered even at a single instance level, a final schema validation was made on the exported gml file, using the software oXygen XML Editor[23] (version 14.0).

Two screenshots of the harmonised dataset validation are shown in ***Figure 26*** and in ***Figure 27***, showing different details of the gml encoding: the first one showing the encoding of the schema locations and of one geometry, with the second one showing the encoding of some of the attributes of the extended target data model.

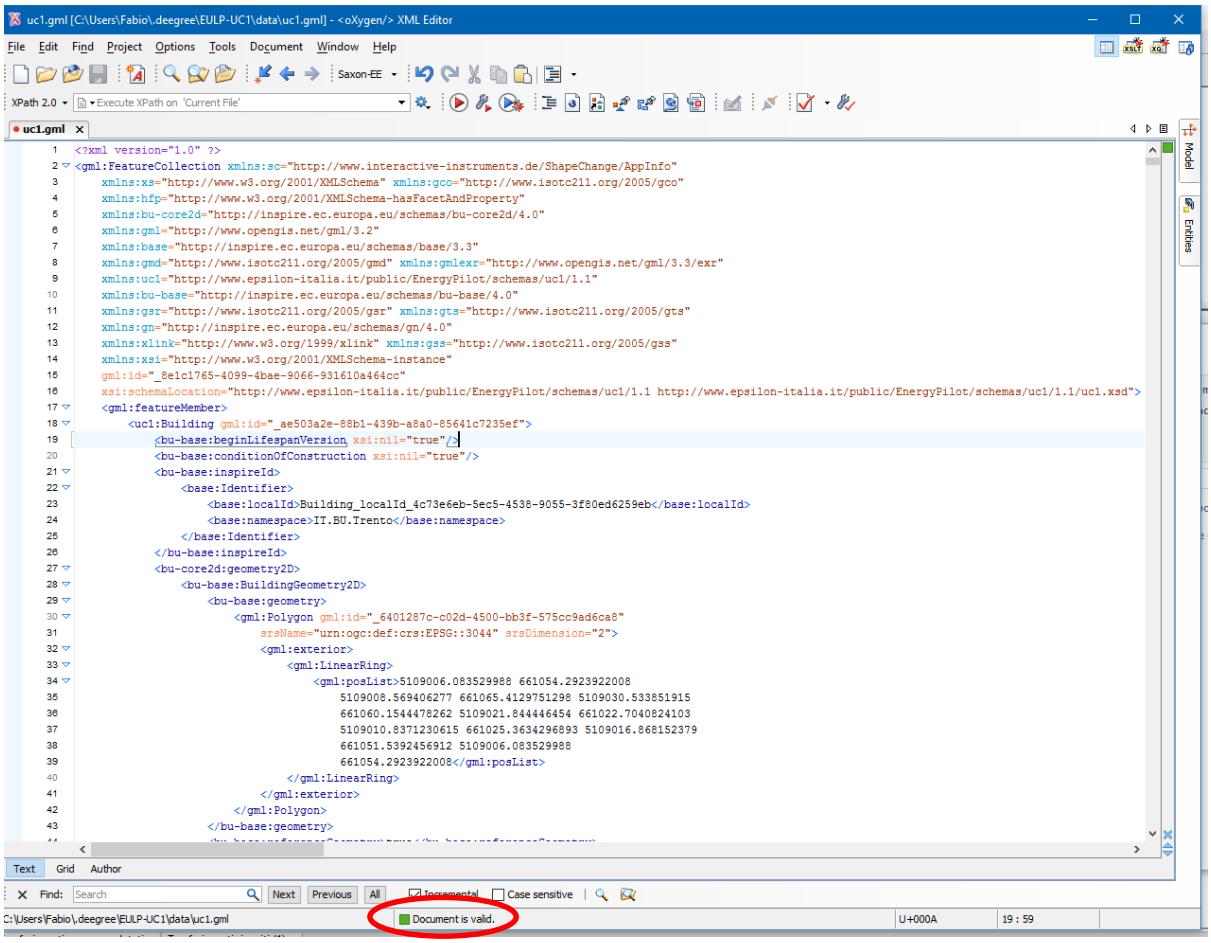


Figure 26 – *Screenshot of the harmonised dataset validation with Oxygen, showing the encoding of the schema locations and of one geometry*

[23] https://www.oxygenxml.com/

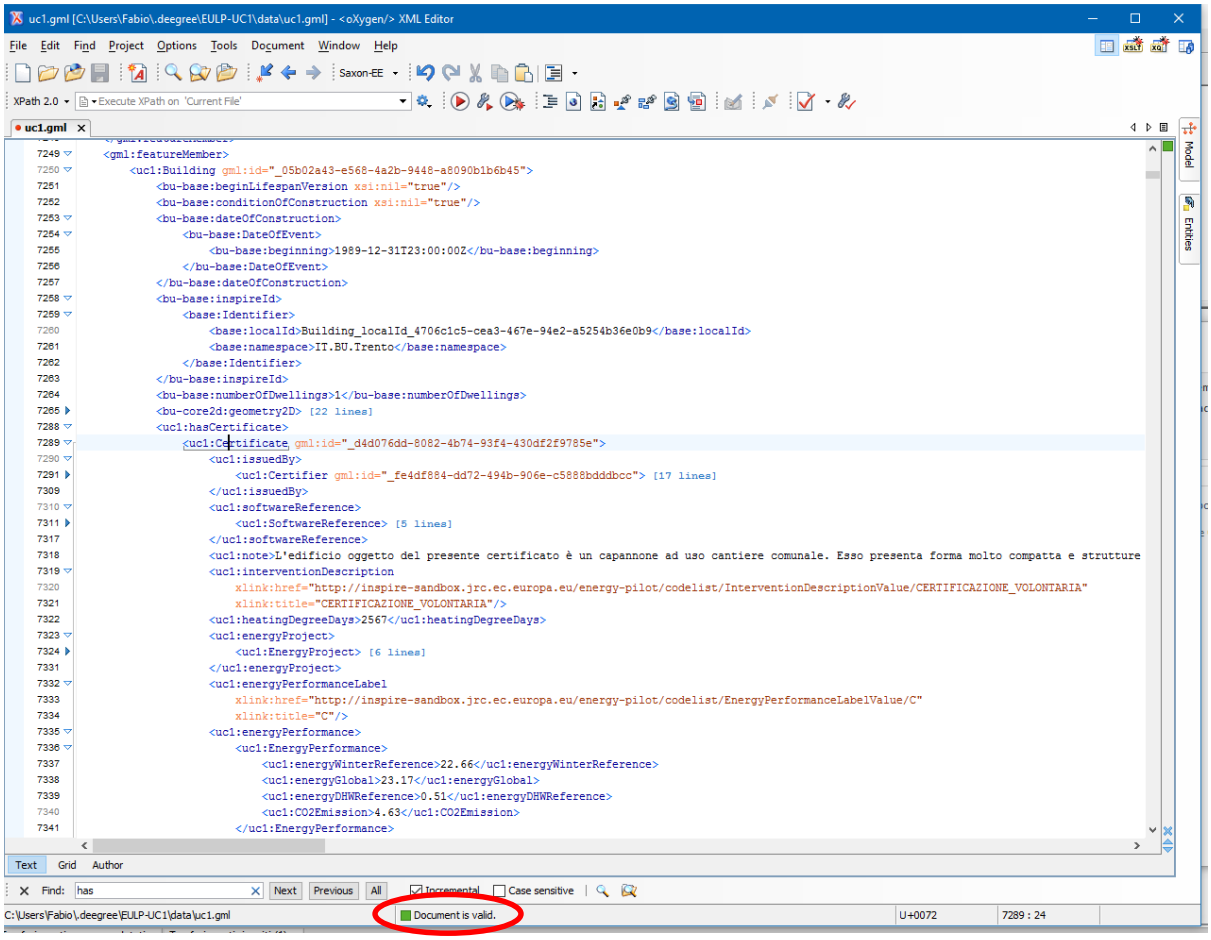


Figure 27 *– Screenshot of the harmonised dataset validation with Oxygen, showing the encoding of some of the attributes of the extended target data model*

2.7 Data publication

The last step of any INSPIRE data harmonisation process consists in the publication of the valid transformed dataset by means of an INSPIRE view and/or download service.

For this use case, a WFS 2.0 direct access download service was deployed, using the open source software degree (installed on localhost), and in particular its memory feature store option, which enables a straightforward WFS setting publishing a gml file.

Two screenshots of the harmonised dataset WFS GetFeature response are shown in ***Figure 28*** and in ***Figure 29***, showing different details of the gml encoding: the first one showing the encoding of the schema locations and of one geometry, with the second one showing the encoding of some of the attributes of the extended target data model.

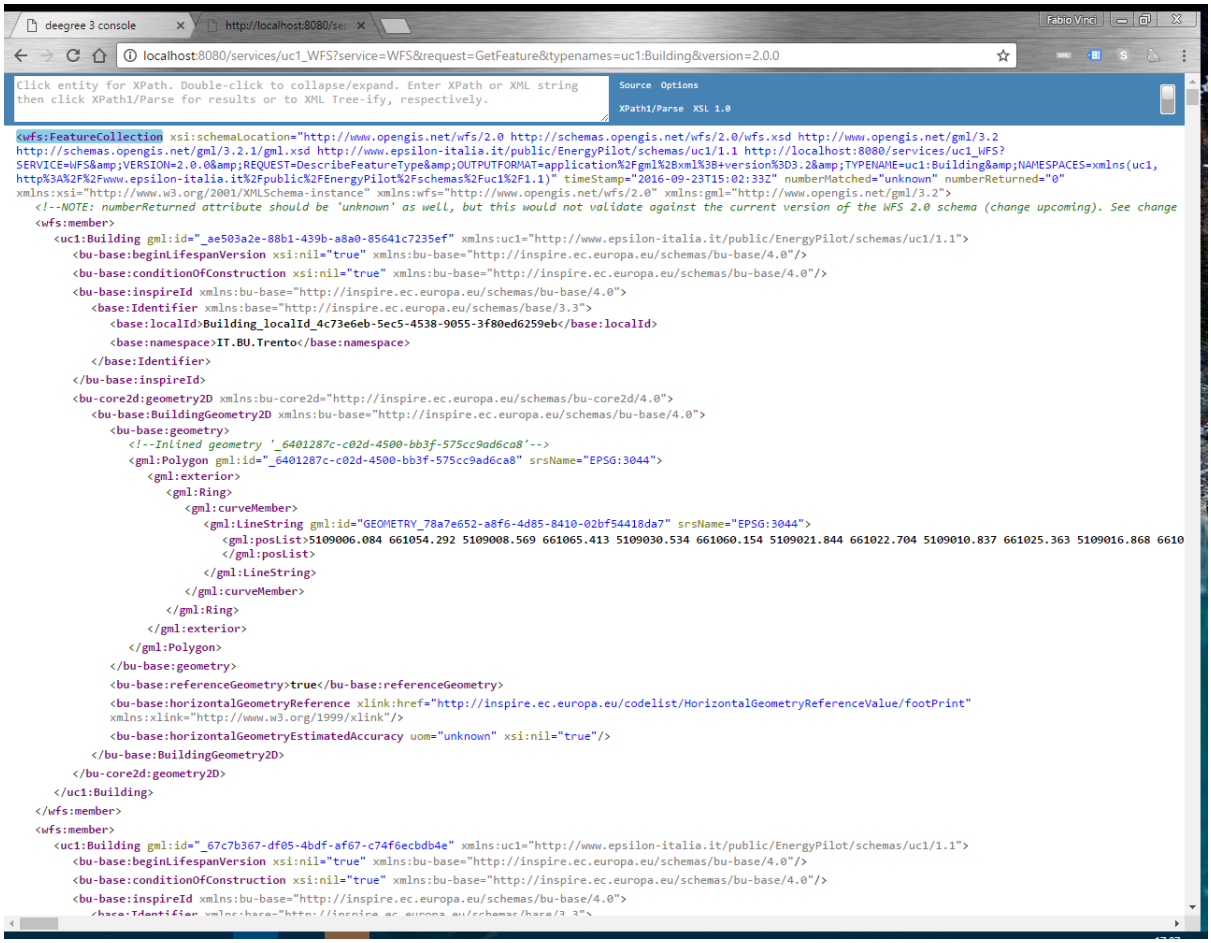


Figure 28 *– Screenshot of the harmonised dataset WFS GetFeature response, showing the encoding of the schema locations and of one geometry*

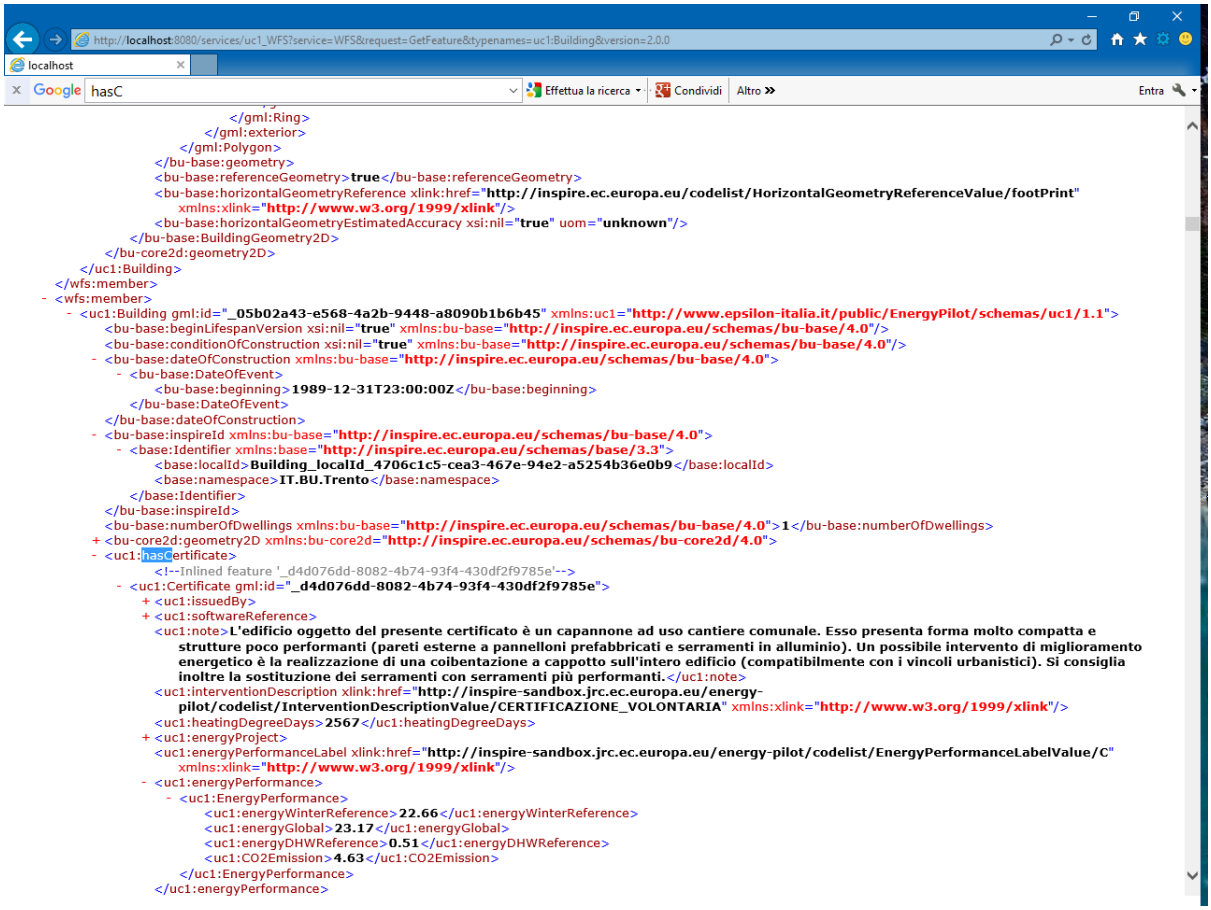


Figure 29 *– Screenshot of the harmonised dataset WFS GetFeature response, showing the encoding of some of the attributes of the extended target data model*

2.8 Data use

Apart from any maintenance operation, the successful publication of a WFS direct access download service should represent the last step of a data harmonisation process, as seen from a data provider perspective.

Regarding the beneficial usability of the harmonised data by different categories of users, which should represent the ultimate goal of any data harmonisation process, the following figures show screenshots taken from a GIS client environment (QGIS desktop), able to consume data served by a WFS 2.0.

Figure 30 shows a sample of buildings having one or more building units with an EPC, thematised according to their energy performance labels, whose values in the target data model are encoded in the EnergyPerformanceLabel code list[24].

In this particular case, from the legend in the left side of the map shown in ***Figure 30*** and from the information about the source data provided in section 2.1, it can be deduced that:

- the cadastral source dataset of the Municipality of Trento contains 7.483 buildings;
- the join between these 7.483 buildings and the dataset containing the 1.501 EPCs of public buildings in the whole territory of the Province of Trento, returns 137 public buildings (or building units) located in of the Municipality of Trento and having an EPC;

[24] http://inspire-sandbox.jrc.ec.europa.eu/codelist/EnergyPerformanceLabelValue

- the statistical distribution of the energy performance labels of these 137 buildings (or building units) is shown in legend of the map shown in ***Figure 30***;
- for 7.335 buildings located in the Municipality of Trento (out of the 7.483), the join did not produce any result, i.e. they do not represent public buildings having an EPC;
- the apparently missing 11 buildings, representing the difference between 7.483 total joining buildings and 7.472 total joined buildings (the latter consisting of the sum of 7.335 + 137), may be due to cases where one EPC covers more than one building. A deeper analysis is out of the scope of the use case.

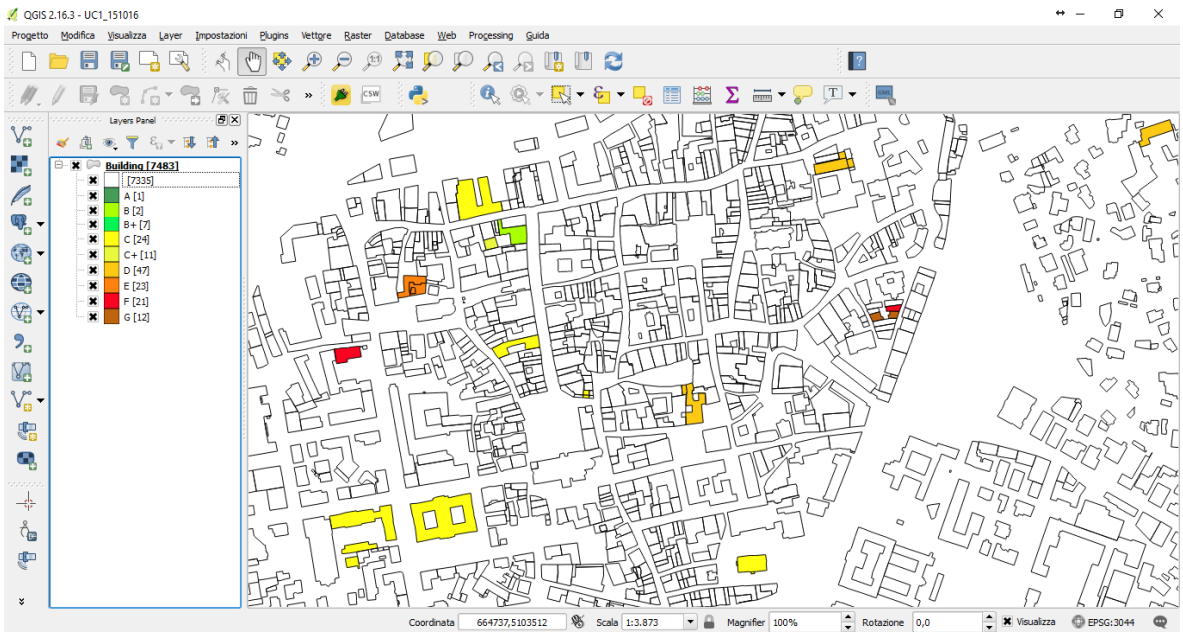


Figure 30 *– Screenshot of a sample of harmonised data accessed in a GIS client desktop environment (1)*

Figure 31 shows a more detailed view of the thematised layer shown in ***Figure 30***, overlaid to aerial Bing Maps.

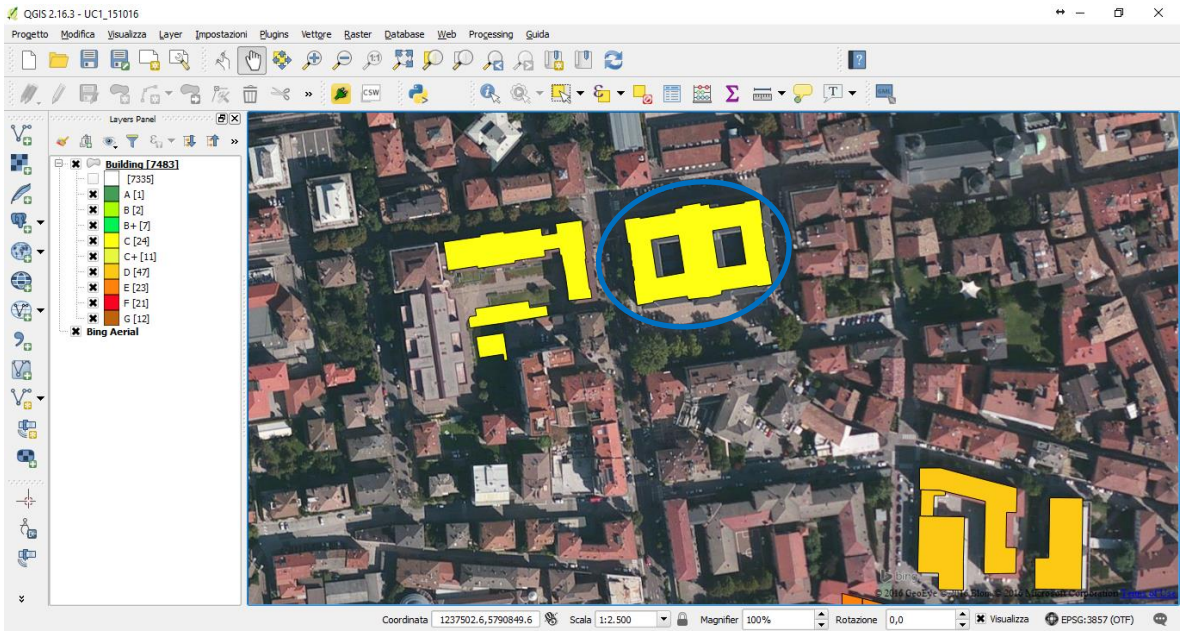
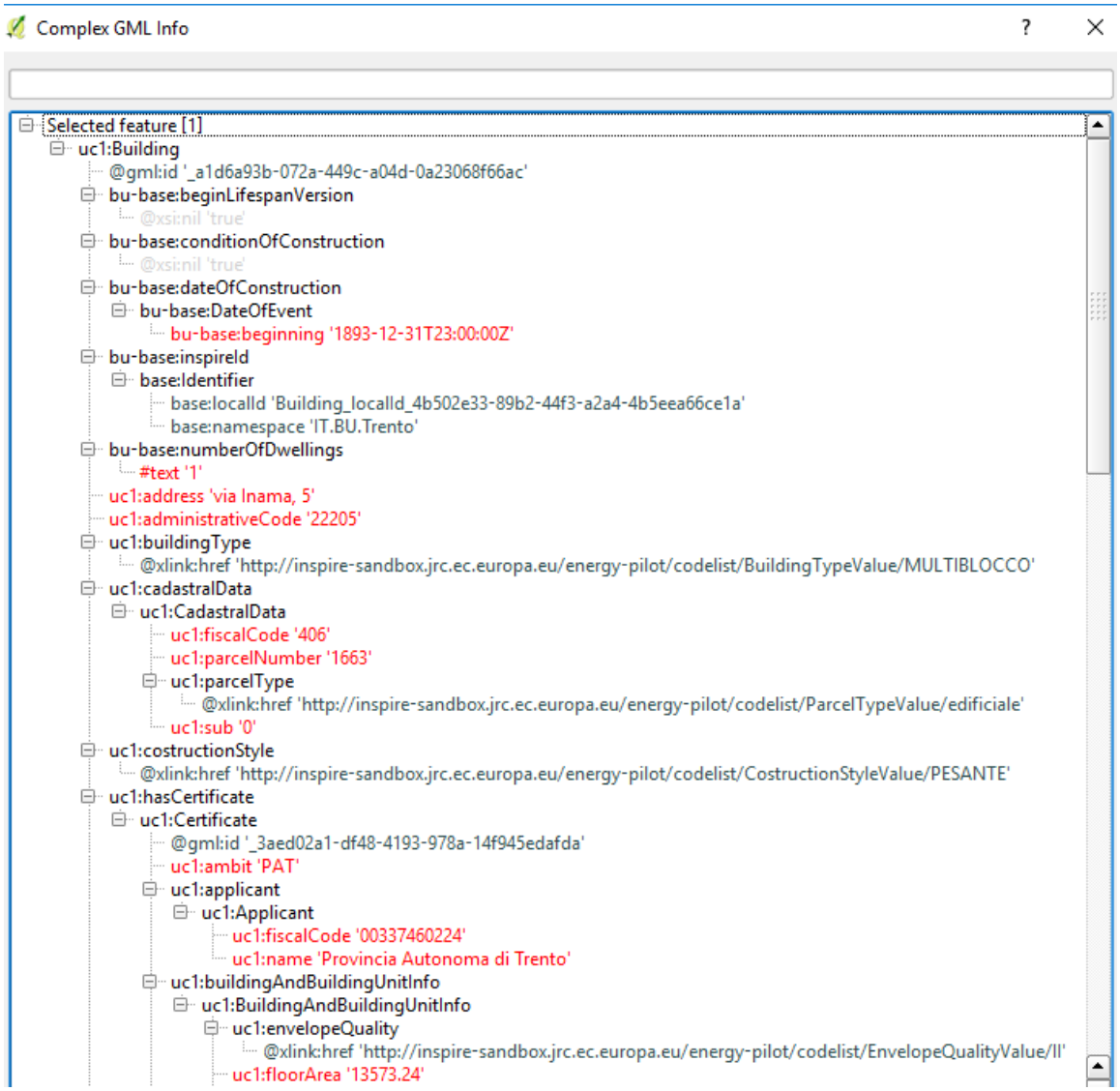


Figure 31 *– Screenshot of a sample of harmonised data accessed in a GIS client desktop environment (2)*

Figure 32 shows screenshots of the attributes of the blue-circled feature in ***Figure 31***, generated using the QGIS plugin Complex GML Info.

In addition to the thematisation based on the energy performance label shown in the previous figures, it is possible to make other thematisations related to other attributes, as well as simple or advanced elaborations based on harmonised data attributes used as terms in operations available in a GIS environment. Furthermore, data usability may be enhanced by means of GIS based analyses combining the EPC harmonised dataset with other datasets related to other spatial objects, e.g. town planning zones, population distribution, energy distribution networks.

It's important to highlight that the harmonised data, once published as a direct access download service, can be used in disparate ways, e.g. in a GIS environment using the functionalities of GIS desktop clients, as well as in ad-hoc developed web applications.



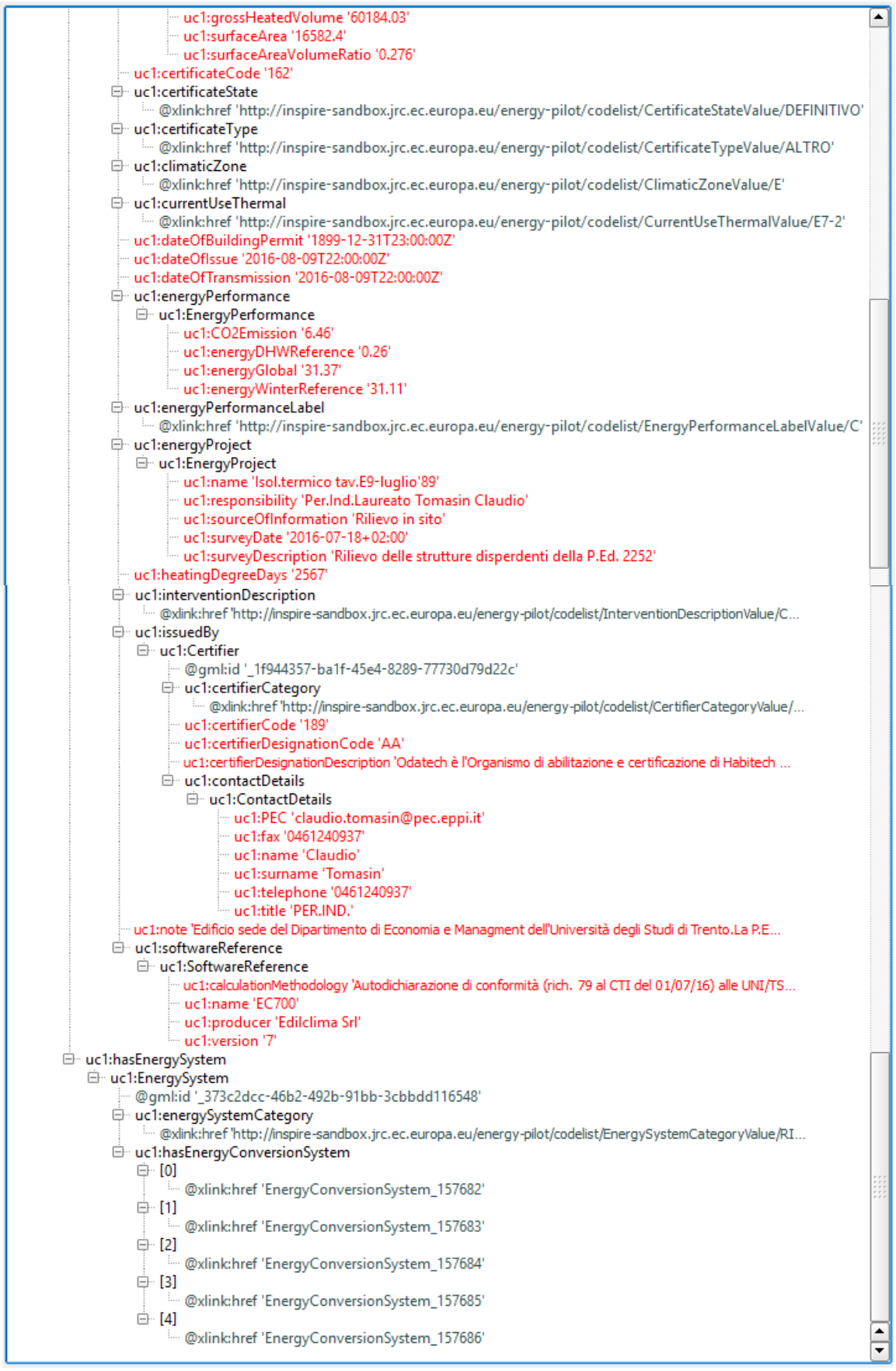


Figure 32 *– Screenshot of the attributes of the blue-circled feature in* ***Figure 31***

3 Expected benefits

In section 1.4 three different groups of stakeholders involved in energy efficiency policies were identified: the government sector, the business sector and the consumers sector. Accessing harmonised EPC datasets will produce different benefits for each of them:

- Government sector:
  - energy policy makers at regional or local level can take decisions in a more efficient and effective way, because they can be supported by geospatial information contained in the EPC datasets which is complete, accurate, readily available and easily accessible;
  - organisations responsible for the maintenance of EPC registers can save time required to ensure updating of and accessibility to the registers by the end users, because the data harmonisation workflows may speed-up the insertion of new EPC records in the registers as well as the usability of EPC data;
  - local authorities which are CoM signatories can be supported during the compilation of their Baseline Emission Inventories, because they could validate their emissions on the building sector, based on detailed and accurate geospatial information contained in the EPC datasets;
  - energy policy makers at national and EU level can be supported by geospatial information contained in the EPC datasets which is harmonised and interoperable across countries and regions;
- business sector:
  - private players working in the sector of buildings renovation to improve the buildings energy performance, as well as energy auditors, can increase their competitiveness, because they can perform marketing analyses and strategies (e.g. identifying potential customers in a specific geographical area, interested to acquire their services) based on harmonised and interoperable geospatial information contained in the EPC datasets and related to buildings potentially needing their intervention;
- consumers sector:
  - citizens willing to buy/rent a building can be supported by the availability of detailed geospatial information contained in the EPC datasets and related to the energy performance of the building they are willing to buy/rent.

As a concrete example of multiple benefits simultaneously achievable by all the stakeholder groups above described, it is worth mentioning the case of an Italian regional authority, which published a tender [25], restricted to small municipalities, providing funds to renovate their building stock. It is evident that the availability of a harmonised EPC datasets would facilitate the whole process, from an easier identification of buildings with low energy performance by the tendering regional authority as well as by the municipalities acting as intermediate direct beneficiaries, to business sector as intermediate indirect beneficiaries, to citizens as final beneficiaries.

[25] http://www.cened.it/bando_piccoli_comuni

4 Issues identified

Several issues of different nature were identified.

Organisational issues

The long time needed to set up a collaboration agreement between JRC and the partner was a major delay factor for the execution of the activities. It is important to take this into account when planning future collaborations with external partners.

Data access and sharing issues

Restricted access to EPC registers and/or to cadastral data (or other ancillary data needed to georeferenced EPC datasets) is also an issue to tackle. Open data policies adopted by partners interested in re-using the methodology described in this report would simplify several processing steps to be made on source data. When open data are not available, it would be beneficial to know clear data licensing policies, stating the conditions applying to access to and use of the data, as well as any possible limitations on public access to the data.

Data privacy issues

Some potential data privacy issues emerged, because it was planned to make harmonised datasets available through the Internet, including potential sensitive data, e.g. energy performance labels of buildings combined with other information could lead to profile the energy behaviour of the building owners. The privacy concerns of private building owners is a major problem, also mentioned during the kick-off workshop held at JRC/Ispra from 24-26 November 2015 [5].

For these reasons, in the phase 1 of the use case it was decided to exclude from the harmonisation all the private buildings and elaborate only the EPCs of publicly owned buildings. This choice is also coherent with the best practice role assigned to public buildings by several European energy efficiency policies, hoping that private building owners will follow their example.

Technical issues

Two main issues were identified during the use case:

- the first one is related to the georeferencing of the source EPC dataset and was encountered and solved during the third step of the methodology shown in ***Figure 2***;
- the second one is related to the visual representation of buildings having more than one building unit with an EPC, which could be encountered during the use/visualisation of the of the harmonised data.

The first issue was caused by the presence of the spurious character "." in front of the values of some parcel numbers in the corresponding field of the shapefile of the cadastral data. The presence of the spurious character disabled the possibility to make the join with the corresponding records of the EPC dataset and therefore prevented the georeferencing of the EPC dataset. Hence, a cleaning procedure, consisting in the elimination of the spurious character, was made manually in QGIS.

The second issue is inevitably related to the 2D geometry of the source and, therefore, of the harmonised dataset. Indeed, the geometry of each building is represented by the building footprint contained in the cadastral dataset, without any information related to building height. Nevertheless, the EPC is related to a building unit and each building, apart single family houses, contains several building units, which are disposed on different floors. The only information contained in the EPC and indirectly related to a 3D

geometry representation is the attribute named "sub", whose value is an integer number, ranging from 1 to n. According to the Italian cadastral regulations, this number represents the identifier of the building units contained in each building, the latter uniquely identified by the triplet constituted by cadastral parcel number, cadastral sheet number and municipality code. Because there is not any unique rule to number the different building units inside a building, e.g. to relate it to the floor number nor to the position in each floor, the only possibility to retrieve the exact position of the building unit inside a building is to access the building floor plans, which are stored in a separate cadastral register and currently available only in pdf format by registered users. From the considerations made above, it is evident that providing a 3D representation of the building units to be retrieved from the source datasets is out of the use case scope.

However, it should be highlighted that in the elaborations currently made for the use case, the 137 buildings having an EPC[26] are public buildings with only one building unit for each building, and therefore this particular case has not any visualisation issue. Conversely, the typical case is when a building contains more building units and therefore there is an issue related to the need to distinguish, e.g. in a visualisation map, EPC data associated to different building units of the same building, when the only geometry available is the 2D polygon of the building footprint.

Several alternative options can be envisaged to solve this issue. Some of them are briefly described below:

- To represent in a GIS environment the multiple building units with separate point type geometries arbitrarily located inside the polygon of the building footprint; in this way, each EPC is associated with a unique point type geometry and the related EPC data can be therefore visually associated to the unique geometry; the association between EPCs and point type geometries can be made in two different ways:
    - during the data transformation step (sixth step of the methodology shown in ***Figure 2***), implying that multiple points have to be created in the source cadastral dataset, by means of ad-hoc GIS pre-processing;
    - after the whole data harmonisation process, by means of ad-hoc GIS post-processing routines to be developed and applied directly in the GIS environment used to visualise the harmonised data.
- To develop an ad-hoc routine to be applied in the GIS environment used to visualise the harmonised data[27], avoiding the burden of the point type geometry association mentioned before, enabling the user to make the following steps:
    - select a building from a map showing the 2D polygons of the building footprints;
    - if more than one EPC is associated with the selected building, therefore implying that the selected building has more than one building unit, then the user is given the possibility of selecting the building unit of interest (by means of the "sub" EPC attribute) and finally the system returns to the user the EPC data associated to the selected building unit.
- To develop an ad-hoc web application, which further processes the harmonised data, providing the same functionality described above but with a user interface accessible from a web browser instead of from a GIS environment. A similar solution was adopted by a web application developed in the Netherlands[28]. Screenshots of the web application, together with Google Maps screenshots, are shown in the following figures.

[26] More details about the elaborations are contained in the section 2.8
[27] For example, if the GIS environment is QGIS, the ad-hoc routine can be developed using Python programming language
[28] http://www.energielabelatlas.nl/

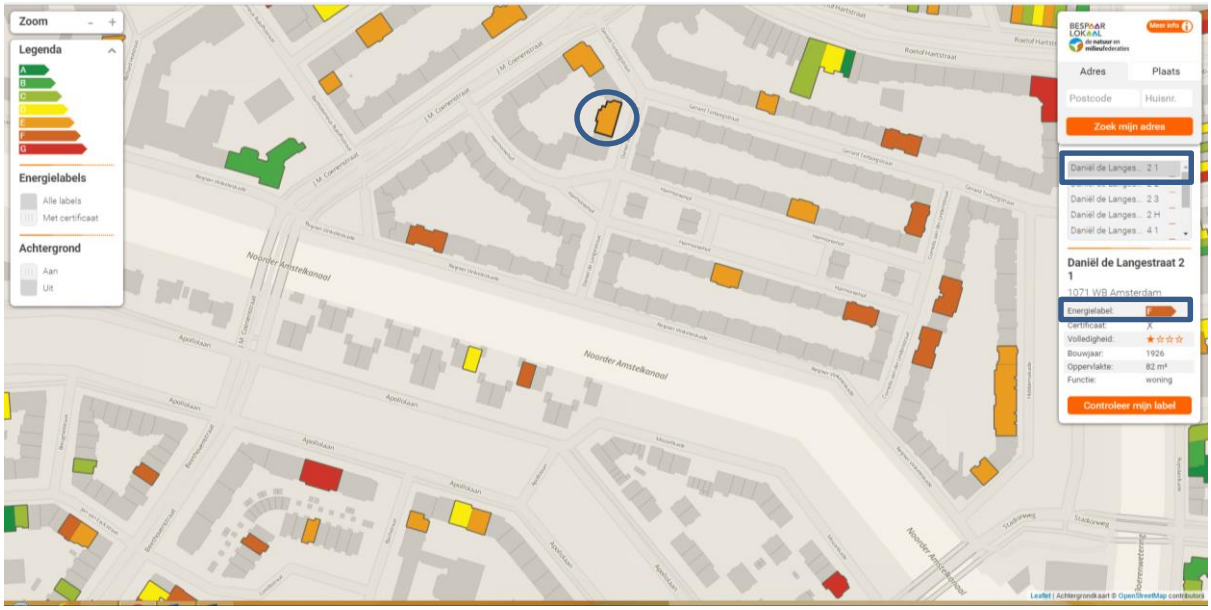


Figure 33 *– Screenshot of the web application developed in the NL, showing the energy label of a building unit belonging to the blue-circled building*

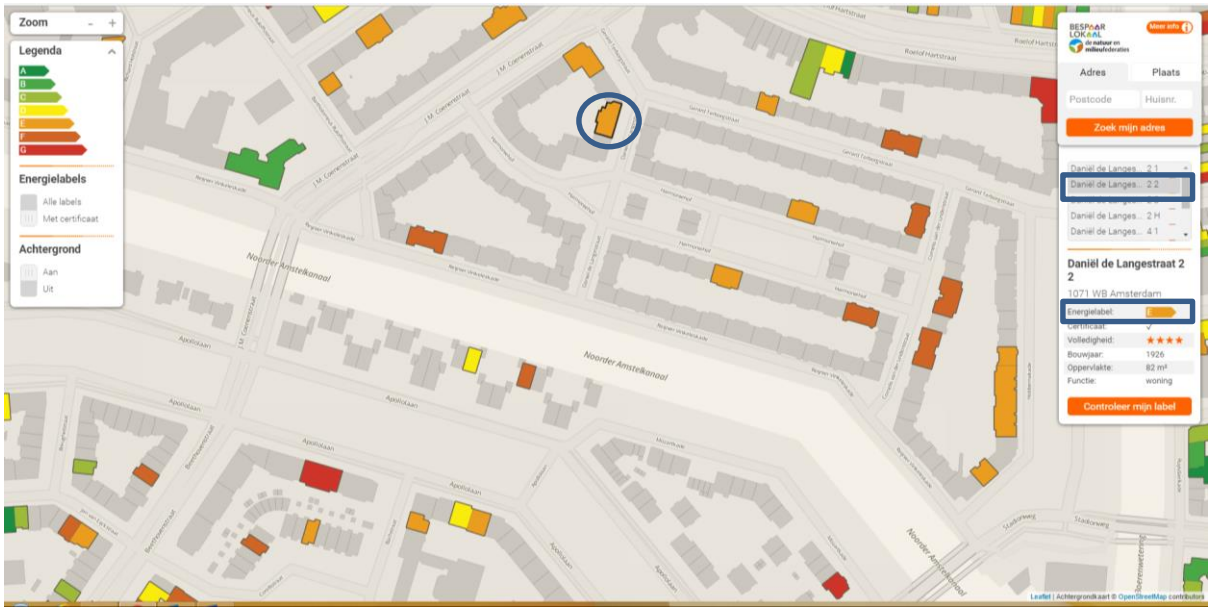


Figure 34 *– Screenshot of the web application developed in the NL, showing the energy label of a different building unit belonging to the same blue-circled building*

Figure 35 *– Screenshot of the Google Maps oblique view of the blue-circled building shown in* ***Figure 33***

Figure 36 *– Screenshot of the Google Maps street view of the blue-circled building shown in* ***Figure 33***

A third issue, mentioned in section 2.8, is represented by the case in which one EPC is associated to more than one building, therefore preventing the correct functioning of the on-the-fly join described in section 2.5. In these cases, a pre-processing activity is required which should be performed on the EPC source dataset, e.g. creating as many EPC replicas as each associated building.

5 Conclusions and next steps

5.1 Achievements and lessons learned

The main achievements of the activities documented in this report are listed below:

- set up of a good cooperation framework with the partner APRIE and start of promising contacts with other potential partners;
- definition and implementation of a robust methodology for the harmonisation and interoperability of EPC datasets, based on INSPIRE, starting from the processing of source datasets and ending with the deployment of a direct access download service of the harmonised dataset;
- re-use of the Re3gistry software, by means of the deployment of a new instance to manage the use case code lists;
- creation of a target data model which extends the INSPIRE core data model for Buildings;
- multi-purpose use of the harmonised data within a GIS desktop client environment.

In parallel to the above-mentioned achievements, the following main lessons were learned:

- the suitability of the data harmonisation methodology, tested with one EPC regional schema, to contribute to EPC data harmonisation across EU, which represents one of the challenges of the stakeholders' groups involved in the lifecycle of the energy policies;
- the suitability of hale studio and deegree open source software solutions, which, together with a proficient use of their functionalities, allowed all technical issues related to data transformation and publication to be overcome, providing therefore good examples for implementers involved in similar data harmonisation processes;
- the need to overcome potential data privacy issues raised by building owners/tenants, which could prevent access to and sharing of EPC datasets, and therefore reduce the benefits expected from the harmonisation process.

5.2 Next steps

This section contains a set of steps that should be undertaken in the near future, in order to contribute to the exploitation of the results achieved so far as well as to finalise some of the use case activities which could not be completed for time constraints.

Apply hale alignment to the whole dataset

As mentioned in sections 2.1 and 2.8, the data transformation step described in section 2.5 was applied to EPCs of public buildings located in the territory of the municipality of Trento, capital city of the Province Autonomous of Trento. Therefore, the harmonised data represent only a small portion of the whole source datasets, which consist of the EPCs of public and private buildings located in the whole Province. Despite this, the data harmonisation performed in the use case is fully representative in terms of technical issues related to the whole data harmonisation process. The transformation of the entire source dataset is encouraged, in order to move towards the operationalisation of the use case results. In order to achieve this goal, it will be necessary to apply to the entire source datasets the hale alignment used for the data subset. Some pre-processing of the source cadastral dataset may be needed, e.g. the merge of the 447 shapefile containing the cadastral datasets of the single municipalities.

Enrich code list register content with more detailed description of code list values and translation in English

As described in sections 2.3.3 and 2.4, new sixteen code lists were defined in the extended target data model and a register was implemented by means of an instance of the Re3gistry software. Due to time constraints, English version of LocalId and labels of code list values, as well as descriptive text of code lists and code list values both in English and in Italian are currently missing and, therefore, their provision is recommended.

Update the UML target data model in Enterprise Architect providing the missing text describing the spatial objects

Documenting a data model is crucial not only to support the data model development phase, but also to facilitate the understanding of the data model single components by its users and by those willing to re-use them in other circumstances, e.g. in data model extensions. To this end, it is recommended to update the UML target data model in Enterprise Architect, providing the currently missing text describing the spatial objects. As an example, ***Figure 37*** shows how to provide this information, i.e. editing the descriptive text of the coverageRenewableSources attribute of the Certficate feature type in the Notes box of the Enterprise Architect window showing the general properties of the Certficate feature type attributes.

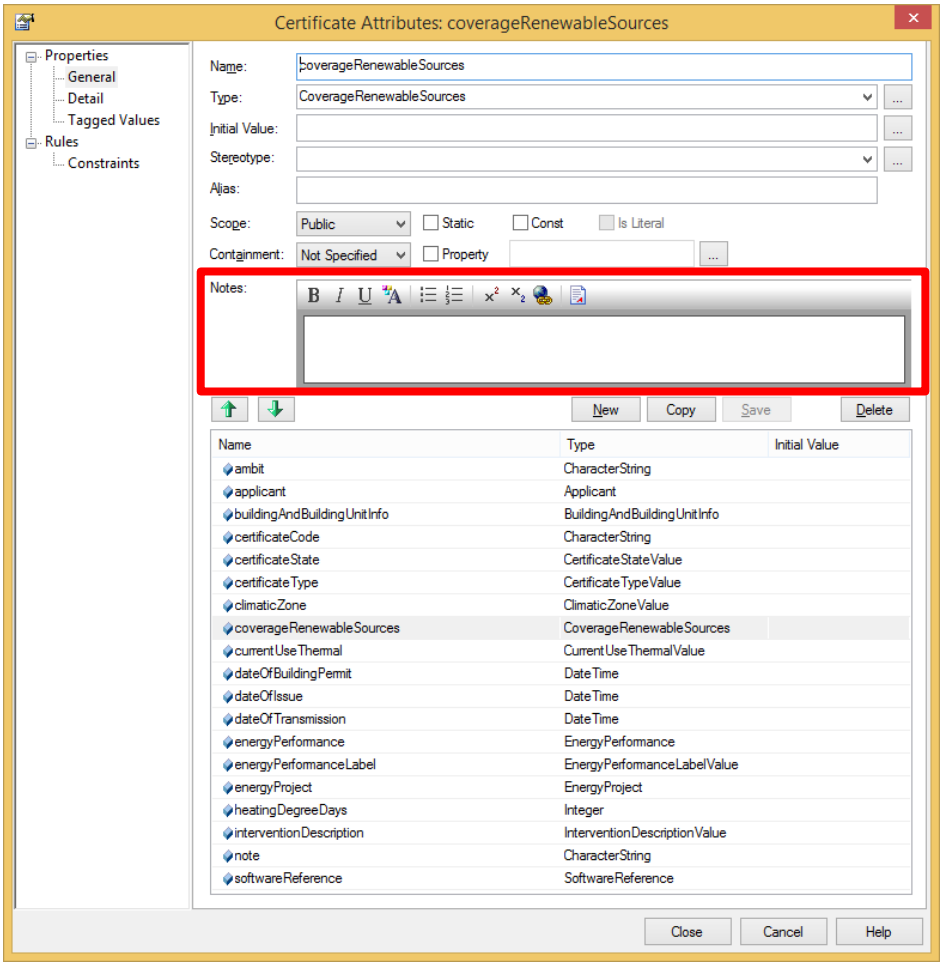


Figure 37 *– EA window showing the general properties of the Certificate feature type attributes*

Continue to work on INSPIRE Network Services deployment

As mentioned in section 2.7, a WFS 2.0 direct access download service was deployed, using the open source software deegree (installed on localhost), and in particular its memory feature store option, which enables a straightforward WFS setting publishing a gml file. Even though the above described localhost installation of degree allowed to speed-up the data publication step and to face most of the related technical issues, a set of activities are recommended in order to improve data accessibility and usability:

- to set-up a SQL feature store with degree (as an alternative to the memory feature store), which is needed when large harmonised datasets have to be published;
- to deploy a WFS direct access download service with GeoServer, which, together with deegree, represent the most popular open source solutions to deploy INSPIRE Network Services; moreover, GeoServer, in combination with hale (through the App-Schema Configuration hale functionality), offers a very efficient procedure for WFS/WMS setting directly within the hale environment; however, some technical issues are still hindering the full validation of the features served by GeoServer, and are under investigation in the INSPIRE community;
- to deploy a WMS;
- to deploy the network services on a publicly accessible server, in order to test data accessibility and usability from users connected to the web, in view of the operationalisation of the use case results within the partner organisation; the related tests can also benefit from similar tests already made in the frame of the EULF Marine Pilot[29].

Improve Persistent Identifier management in the target schema

During the data transformation step described in section 2.5, in order to speed-up the overall transformation process, it was decided to populate all the mandatory "id" (i.e. identifier) related attributes present in the target schema with unique values automatically generated by hale software. This was done using the "Generate Unique Id" hale functionality for the inspireId.Identifier.localId attribute and without applying any mapping rule to all the gml:id attributes required in all feature types (namely Building, Certificate, Certifier, Energy System, Professional). The effect of the mapping choice consisting in not applying any mapping rule is that hale populated the gml:id attributes with automatically generated unique values.

If on the one hand the above described mapping choices for the id-related attributes is formally correct and allows the transformed gml file to pass the schema validation, on the other hand there are in general better solutions to deal with identifiers, using identifiers more meaningful and reusable rather than strings of characters automatically generated by the transformation software. In particular, for this use case, proper mechanisms and rules should be established to build this type of identifiers for buildings, certificates, certifiers, energy systems and professionals.

For example, use of HTTP URIs identifiers is recommended whenever applicable, because it implements the possibility to refer to spatial objects published on the web, e.g. in on-line registers maintained by specific organisations.

Good reference documents on the subject are two ARe3NA studies[30][31] on persistent identifiers, as well as INSPIRE Generic Conceptual Model [7], which provides examples of recommended HTTP URIs structures.

[29] https://joinup.ec.europa.eu/community/eulf/og_page/eulf-marine-pilot
[30] https://joinup.ec.europa.eu/sites/default/files/are3na-pid_governance_final.pdf

Develop a web application facilitating the access to and use of harmonised data

In section 2.8 it was shown how harmonised data can be proficiently and effectively used in a GIS desktop environment. But this use requires specific skills in using GIS software, which only a small portion of the potentially interested stakeholders have. Therefore, in order to facilitate access to and use of harmonised data also by non-GIS experts, it is recommended to develop one or more web applications, accessible via browser by desktop or laptop computers and/or via mobile devices (smartphones and/or tablets). The design of the web application(s) has to be preceded with a detailed analysis of the requirements, focusing on the functionalities to be implemented, e.g. related to:

- reading or reading/writing access type to the EPC harmonised register;
- type of data to be accessed;
- type of elaborations eventually required on the data to be accessed (e.g. stored queries);
- user interface.

As an example, two mobile apps supporting the implementation of energy efficiency policies were developed in the frame of the European funded project SUNSHINE – "Smart UrbaN ServIces for Higher eNergy Efficiency"[32]. They are available in Google Play, where more details can be found (one app is called Sunshine Energy[33] and the other one Sunshine Map4Data[34]). A more detailed analysis of both the apps is recommended, in order to support the definition of the functionalities and the formalisation of the requirements to be implemented in the app that will be developed.

Support the partner to operationalise the use case workflows into its organisation

The most important exploitation activity is to support APRIE to operationalise the use case workflows into its organisation. Starting from the results achieved so far and presented in this report, the following activities should be performed in close cooperation with APRIE, in parallel to the activities above described in this section:

- analysis of the current business processes executed by APRIE to maintain the (non harmonised) EPC register/registry, identifying the actors and their roles, focusing on duties and interfaces of multiple departments and/or external organisations eventually involved in different steps of the processes;
- analysis of the APRIE geoICT infrastructure, e.g. in terms of:
    - the characteristics of its SDI, if existent;
    - the characteristics of its IT systems;
    - the geoICT skills of its human resources;
- analysis of the applicable data policies implemented by APRIE which can be relevant for the operationalisation of the use case results, e.g. related to open data, data and service sharing, data protection;
- collection and analysis of the geoICT requirements that APRIE may have to operationalize the use case results, e.g. related to:
    - the hosting of the server components (e.g. cloud-based vs. on premise, deegree vs. GeoServer, Oracle vs. Postgis);
    - eventual changes in the procedures currently in use to maintain the EPC register/registry;
- elaboration of proposals to fulfill the requirements collected and analyzed in the previous step.

[31] https://joinup.ec.europa.eu/sites/default/files/c0/7d/10/D7.1.3%20-%20Study%20on%20persistent%20URIs.pdf
[32] http://www.sunshineproject.eu/
[33] https://play.google.com/store/apps/details?id=it.graphitech.sunshinemobileApp
[34] https://play.google.com/store/apps/details?id=it.graphitech.sunshinemap4data

Re-use of the use case results in other regions/countries

The second most important exploitation activity is its re-use in other regions and/or countries, for two main reasons.

The first reason is that, according to the national/regional transpositions of EPBD [3], different MS and, sometimes, different regions in a MS, may adopt different EPC schemas. This aspect, as described in section 1.2 and in the documents referred therein, highlights the lack of harmonisation of EPC datasets at EU level. Therefore, applying the same methodological approach described in this report to other regions and/or countries will contribute to filling-in this gap and, consequently, to achieve the related benefits described in section 3. Some of the steps schematised in ***Figure 2*** may evidently change, e.g. the steps needed to obtain an EPC georeferenced dataset (which represents the output of step 4), as well as the step 5, related to the creation of the target data model, which, starting from the data model developed for this use case, will have to be updated for each re-use in order to fulfil the different data modelling requirements of the different regions/countries. In this way, new versions of the target data model will be created, each time a new element (e.g. a new attribute, a new data type, a new code list, a new element in an existing code list) will have to be added to the last version of the data model in order to fulfill new modelling requirements of the different regions/countries.

The second reason is that, independently from the different EPC schemas adopted by different regions/countries, the operationalisation of the use case results in different organisations will contribute to test the use case workflow(s) in different operational scenarios (e.g. different IT systems with different geoICT requirements). This will ultimately increase the interoperability of the solutions proposed.

Two potential partners, i.e. Lombardy Region and the organisation operating the EPC register in Sweden, were already identified in the context described in section 1.3. Contacts with a third potential partner were established during the INSPIRE Conference: in the parallel session INSPIREd energy[35], the Flanders Geographic Information Agency (AGIV, a Flemish governmental agency) presented its activities recently started aiming at "developing a building registry implementing the INSPIRE data specifications and UML feature catalogue"[36] and expressed to the authors of this report an interest to explore a possible cooperation scenario. Other potential partners can be identified at a later stage as well.

Assessment of the sustainability of the solution

An assessment of the use case sustainability will be done after that the activities planned will be carried out and sufficient feedback will be collected from several organisations potentially interested in operationalising the use case results.

In general, the three following main aspects can be considered to ensure the sustainability of the use case results: operationalisation costs, maintenance costs, time frame of the expected benefits.

Regarding operationalisation costs, they are strongly dependent on the level of maturity of the organisation in terms of geoICT competences of its human resources, adequacy of its geoICT infrastructures, implementation of energy policies. The less mature the level, the higher the costs. In addition, it has to be considered that it is foreseen an activity consisting of initial geoICT training provided by JRC to the partner's staff. The operationalisation costs should also vanish after an initial phase of few months.

[35] http://inspire.ec.europa.eu/events/conferences/inspire_2016/page/oral#session_34

[36] http://inspire.ec.europa.eu/events/conferences/inspire_2016/pdfs/2016_psessions/30%20FRIDAY_PSESSIONS_A_11.00-12.30_Vanderstraete_building_Registry_v5.pdf

Regarding the maintenance costs, they are primarily related to the modalities and time frequency of updating of the EPC register. The more complex the modalities and the higher the time frequency, the higher the costs.

Finally, regarding the time frame of the expected benefits, they are equally achievable in the short as well as in the long term and their level of achievement at different time intervals can be used to measure the profitability of the investments made.

Another important sustainability aspect is represented by the possibility that the organisations responsible for the EPC register operations develop web applications enabling energy auditors to directly update the EPCs. The use of these web applications may be subject to the payment of a fee by the energy auditors, or by the building owners, assuming their willingness to pay for an easier and faster procedure. The revenues potentially coming from these fees may be used by the organisations responsible for the EPC register operations to pay, even though partially, the maintenance costs.

6 References

1. European Commission, Directive 2007/2/EC establishing and Infrastructure for Spatial Information in the European Community, http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2007:108:0001:0014:en:PDF
2. Bloem J., Boguslawski R., Borzacchiello M.T., Cipriano P., Kona A., Martirano G., Maschio I., Pignatelli F., Location data for buildings related energy efficiency policies, JRC Technical Report, 2015, Publications Office of the European Union, ISBN 978-92-79-50572-0 (pdf), http://publications.jrc.ec.europa.eu/repository/handle/JRC96946
3. European Commission, Energy Performance of Buildings Directive, 2010, http://eur-lex.europa.eu/legal-content/EN/ALL/;ELX_SESSIONID=FZMjThLLzfxmmMCQGp2Y1s2d3TjwtD8QS3pqdkhXZbwqGwlgY9KN!2064651424?uri=CELEX:32010L0031
4. European Union (EU). (2012). Directive 2012/27/EU of the European Parliament and of the Council of 25 October 2012 on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC. http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32012L0027&from=EN
5. Bloem J., Boguslawski R., Borzacchiello M.T., Cipriano P., Kona A., Martirano G., Maschio I., Pignatelli F., Spatial data for modelling building stock energy needs: Proceedings of the workshop: Ispra, 24-25-26 November 2015, JRC Technical Report, 2015, Publications Office of the European Union, ISBN 978-92-79-55083-6 (pdf), http://publications.jrc.ec.europa.eu/repository/handle/JRC99902
6. INSPIRE Thematic Working Group Buildings, D2.8.III.2 INSPIRE Data Specification on Buildings – Technical Guidelines, 2013, European Commission Joint Research Centre, http://inspire.jrc.ec.europa.eu/documents/Data_Specifications/INSPIRE_DataSpecification_BU_v3.0.pdf
7. Drafting Team "Data Specifications", D2.5: Generic Conceptual Model - Version 3.4, 2014, Drafting Team "Data Specifications", http://inspire.ec.europa.eu/documents/Data_Specifications/D2.5_v3.4.pdf
8. European Commission, COMMISSION REGULATION (EU) No 1089/2010 of 23 November 2010 implementing Directive 2007/2/EC of the European Parliament and of the Council as regards interoperability of spatial data sets and services INSPIRE Implementing Rule on interoperability of spatial data sets and services, 2010, http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:02010R1089-20131230&from=EN
9. European Commission, COMMISSION REGULATION (EU) No 1253/2013 of 21 October 2013 amending Regulation (EU) No 1089/2010 implementing Directive 2007/2/EC as regards interoperability of spatial data sets and services, 2012, http://inspire.ec.europa.eu/documents/commission-regulation-eu-no-12532013-21-october-2013-amending-regulation-eu-no-10892010

List of abbreviations and definitions

Term/abbreviation	Description
ADE	Application Domain Extension
APRIE	Agenzia Provinciale per le Risorse Idriche e l'Energia della Provincia Autonoma di Trento (IT)
ARe3NA	A Reusable INSPIRE Reference Platform
CoM	Covenant of Mayors
CSV	Comma Separated Values
EA	Enterprise Architect
EED	Energy Efficiency Directive
EPBD	Energy Performance of Buildings Directive
EPC	Energy Performance Certificate
ESCO	energy service company or energy savings company
EULF	European Union Location Framework
GIS	Geographic Information System
GML	Geography Markup Language
HTTP	Hypertext Transfer Protocol
ICT	Information and Communication Technologies
IPR	Intellectual Property Rights
IR	Implementing Rule
ISA	Interoperability Solutions for European Public Administrations
JRC	Joint Research Centre
MS	Member State
SDI	Spatial Data Infrastructure
UML	Unified Modelling Language
URI	Uniform Resource Identifier
XML	Extensible Markup Language
XSD	XML Schema Definition
WFS	Web Feature Service

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Annex 1 – Source data model

Table 2 *– Source data model of EPC dataset*

Types		Attribute Association role Constraint					Attribute / Association role / Constraint documentation	Values	Multiplicity	Example value
attestatoCertificazioneEnergetica	edificio	comuneAmministrativo					Codice ISTAT del comune	Integer or CharacterString ?	1	22205
		edificioAccatastato (choise)	unitaImmobiliare	indirizzo				CharacterString or Address?	0..1	VIA DEI MUREDEI 12 - 38122 TRENTO
				annoCostruzione			Obbligatorio se lo statoCertificato è "Definitivo"	Integer	0..1	1969
				datiCatastali (1..*)	comuneCatastale		I valori devono essere presenti nella tabella dei comuni catastali della Provincia di Trento	Integer	1	406
					tipoParticella		Il valore deve essere obbligatoriamente "EDIFICIALE"	Codelist	1	EDIFICIALE
					numeroParticella			Integer	1	2610
					sub			Integer	1	16
					foglio			Integer	0..1	54
					porzioniMateriali (0..1)	porzioneMateriale	nonNegativeInteger Contiene i dati delle porzioni materiali che si riferiscono ad una particella o ad un subalterno	Integer	0..1	7
		edificioNonAccatastato (choise)	particelle	particella (1..*)	comuneCatastale		Contiene i dati catastali della singola particella su cui sorge l'edificio non ancora accatastato	Codelist	1	
					tipoParticella			Integer	1	
					numeroParticella			Integer	1	
	certificato	ambito						CharacterString	1	PAT
		classificazione						Codelist	0..1	F
		codiceCertificato						Integer	1	42
		~~proprietario~~					Cognome e Nome o Denominazione del richiedente l'attestato di certificazione energetica	CharacterString	1	intentionally left blank
		~~codiceFiscale~~						CharacterString	1	intentionally left blank
		coperturaFontiRinnovabili	EPElettrica					Real	0..1	
			EPElettricaSoglia					Real	0..1	
			EPSanitaria					Real	0..1	
			EPSanitariaSoglia					Real	0..1	
			EPSommatoria					Real	0..1	
			EPSommatoriaSoglia					Real	0..1	
			superficieCoperta					Real	0..1	
		dataEmissione						DateTime	0..1	2014-06-05
		dataInvio						DateTime	1	2014-08-27
		dataTitoloEdilizio						DateTime	0..1	All = 1900-01-01
		descrizioneIntervento						Codelist	0..1	TRASFERIMENTO
		destinazioniUso (0..1)	destinazioneUso					Codelist	1..*	E1-1

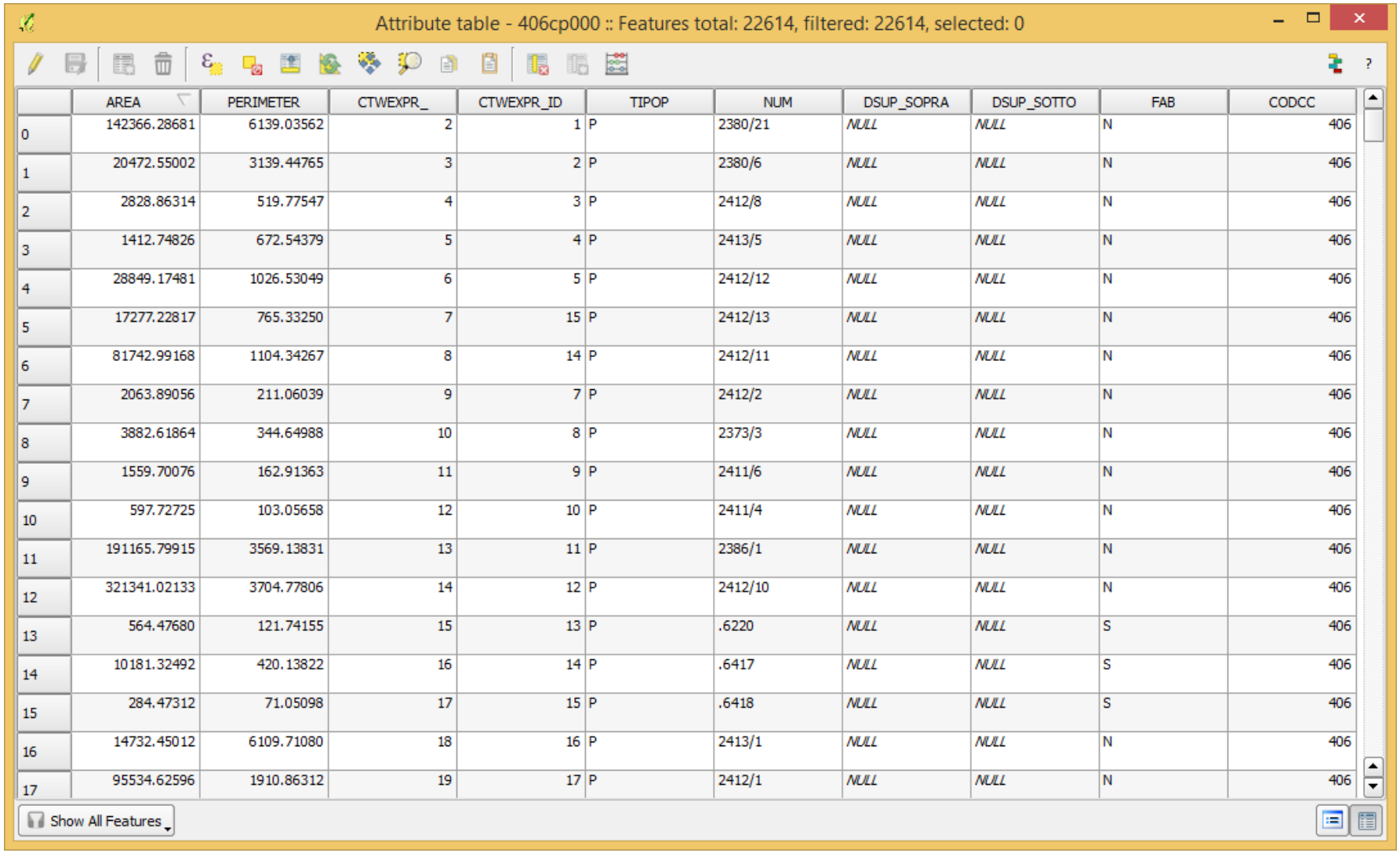
Types		Attribute Association role Constraint					Attribute / Association role / Constraint documentation	Values	Multiplicity	Example value
attestatoCertificazioneEnergetica	certificato	emissioneCO2					Obbligatorio se lo statoCertificato è Definitivo	Real	0..1	45.3
		energiaGlobaleUbicazione					Obbligatorio se lo statoCertificato è Definitivo	Real	0..1	242.5
		energiaEstivaUbicazione					Obbligatorio se lo statoCertificato è Definitivo	Real	0..1	
		energiaInvernale					Obbligatorio se lo statoCertificato è Definitivo	Real	0..1	150.5
		energiaInvernaleUbicazione					Obbligatorio se lo statoCertificato è Definitivo	Real	0..1	
		energiaSanitaria					Obbligatorio se lo statoCertificato è Definitivo	Real	0..1	92
		energiaSanitariaUbicazione					Obbligatorio se lo statoCertificato è Definitivo	Real	0..1	
		EPRaggiungibile						Real	0..1	
		gradiGiorno						Integer	1	2567
		metodologiaCalcolo						CharacterString	0..1	Conforme UNI TS 11300
		prodottoSoftware						Character string	0..1	DOCET
		produttoreSoftware						Character string	0..1	ITC - CNR ENEA
		versioneSoftware						Character string	1	2.09.11.02
		note		manufacturer				Character string	0..1	Trasmittanza componenti opachi valutata ai sensi UNI TS 11300-1 appendice A. Trasmittanza componenti trasparenti valutata ai sensi UNI TS 11300-1 appendice C. Unica caldaia centralizzata per riscaldamento e acqua calda sanitaria.
		numeroAppartamenti						Integer	0..1	1
		professionisti (0..1)	professionista (1..*)	categoriaProfessionale			Contiene i dati dei professionisti che hanno partecipato all'intervento	Codelist	1	
				cognome				Character string	1	
				fax				Character string	0..1	
				indirizzo				Character string	0..1	
				nome				Character string	0..1	
				telefono				Character string	0..1	
		progettoEnergetico						Character string	0..1	dato non fornito
		rilievoEdificio						DateTime	0..1	2014-06-03
		provenienza						CharacterString	0..1	elaborati progettuali forniti dalla proprietà
		responsabilita						Character string	0..1	
		sopralluoghi (0..1)	descrizione (1..*)					Character string	1..*	Verifica elaborati forniti e acquisizione informazioni.
		statoCertificato						Codelist	1	DEFINITIVO
		tipoCertificato						Codelist	1	RESIDENZIALE

Types		Attribute Association role Constraint					Attribute / Association role / Constraint documentation	Values	Multiplicity	Example value
attestatoCertificazioneEnergetica	certificato	qualitaInvolucro					Obbligatorio se lo statoCertificato è Definitivo	Codelist	0..1	II
		rapportoSV						Real	0..1	0.26
		superficieDisperdenteS					espressa in mq	Real	0..1	83.4
		superficieUtile					espressa in mq	Real	0..1	94.32
		volumeLordoRiscaldatoV					espresso in mc	Real	0..1	320.68
		tipologiaCostruttiva						Codelist	0..1	MISTA
		tipologiaEdilizia						Codelist	0..1	MULTIBLOCCO
		zonaClimatica						Codelist	1	E
	generatori (0..1)	generatore (1..*)	annoInstallazione					Integer	1	2007
			combustibili (0..1)	combustibile (1..*)			Obbligatorio se tipoFonteEnergetica= TRADIZIONALE	Codelist	1..*	METANO
			energia (0..1)	energiaProdotta (1..*)	energiaProdotta		Obbligatorio se tipoFonteEnergetica= RINNOVABILE	Real	1..*	
					UM			Codelist	1	
			idGeneratore				idGeneratore e' chiave per il generatore	Character string	1	68638
			matricolaGeneratore					Character string	0..1	VITOPLEX 300 MATR. 7324721 700054 105
			noteCombustibile					Character string	0..1	da rete
			noteTipologiaGeneratoreAltro				Note alla tipologia del generatore quando specificato “Altro”	Character string	0..1	
			potenza (0..1)	potenzaNominale (1..*)	potenzaNominale		Obbligatorio se tipoFonteEnergetica= TRADIZIONALE	Real	1..*	184
					UM			Codelist	1	
			tipoFonteEnergetica					Codelist	1	TRADIZIONALE
			tipologiaGeneratore					Codelist	1	CALDAIA_CENTR
	impianti (0..1)	impianto (1..*)	categoriaImpianto					Codelist	1	RISCALDAMENTO
			generatori	refGeneratore (1..*)				idGeneratore	0..1	68638
			rendimentoImpianto					Real	0..1	
			potenzaImpianto (0..1)	potenzaNominaleImp (1..*	potenzaNominaleImp		Contiene i dati di potenza complessiva dell'impianto	Real	1..*	
					UM			Codelist	1	
	certificatore	categoriaCertificatore						Codelist	1	TECNICO
		codiceCertificatore					nonNegativeInteger	Integer	1	70
		codiceOda						Character string	1	AA
		descrizioneOda						Character string	1	Odatech è l'Organismo di abilitazione e certificazione di Habitech – Distretto Tecnologico Trentino.
		cognome						Character string	1	MORI
		fax						Character string	0..1	0461340105
		indirizzo						Character string	0..1	via ai Piovesi, 7 (Lon)
		nome						Character string	1	DIEGO
		PEC						Character string	0..1	diego.miori@ingpec.eu
		telefono						Character string	0..1	0461340105
		titolo						Character string	0..1	Dott.Ing.

Table 3 *– Code lists of source data model of EPC dataset*

qualitaInvolucro	zonaClimatica	tipoParticella	tipologiaGeneratore	tipologiaEdilizia	tipologiaCostruttiva	tipoFonteEnergetica	tipoCertificato	statoCertificato	tipologiaGeneratore
I	E	FONDIARIA	ELETTRICO	SINGOLO	LEGGERA	TRADIZIONALE	RESIDENZIALE	IN_REDAZIONE	tipoFonteEnergetica = TRADIZIONALE:
II	F	EDIFICIALE	CALDAIA_AUTO	BIFAMILIARE	MISTA	RINNOVABILE	ALTRO	DEFINITIVO	ELETTRICO
III			CALDAIA_CENTR	MULTISCHIERA	PESANTE				CALDAIA_AUTO
IV			COGEN_AUTO	MULTIBLOCCO					CALDAIA_CENTR
V			COGEN_CENTR						COGEN_AUTO
			POMPA_AUTO						COGEN_CENTR
			POMPA_CENTR						POMPA_AUTO
			SOLARE_PIANO						POMPA_CENTR
			SOLARE _SVUOTO						TELERISCALDAMENTO
			SOLARE _ARIA						ALTRO
			SOLARE _AUTO						tipoFonteEnergetica = RINNOVABILE:
			F_VOLT_ISOLA						CALDAIA_CENTR
			F_VOLT_RETE						CALDAIA_AUTO
			EOLICO						SOLARE_PIANO
			POMPA_GEO						SOLARE _SVUOTO
			POMPA_NO_GEO						SOLARE _ARIA
			TELERISCALDAMENTO						SOLARE _AUTO
			IDRO_EL						F_VOLT_ISOLA
			ALTRO						F_VOLT_RETE
									EOLICO
									POMPA_GEO
									POMPA_NO_GEO
									TELERISCALDAMENTO
									IDRO_EL
									ALTRO

destinazioneUso	descrizioneIntervento	combustibile	classificazione	categoriaImpianto	categoriaCertificatore	categoriaProfessionale	UM energia Prodotta	UM potenzaNominale e UM potenzaNominaleImp
E1-1	NUOVO	METANO	A+	RISCALDAMENTO	TECNICO	PROG_ARCHIT	KWHE	KW
E1-2	SOSTITUZIONE	GASOLIO	A	SANITARIO	ENGY_MANAGER	PROG_IMPIANTI	KWHT	KWT
E1-3	DEMOLIZIONE	KEROSENE	B+	RAFFRESCAMENTO	ENTE	DIR_LAVORI		KWH
E2	AMPLIAMENTO	GPL	B	PROD_ENG_ELETTRICA	SOCIETA	COSTRUTTORE		
E3	RISTRUTTURAZIONE	OLIO_HIGH_ZOLFO	C+					
E4-1	CERTIFICAZIONE_VOLONTARIA	OLIO_LOW_ZOLFO	C					
E4-2	ALTRO	RINNOVABILI	D					
E4-3		LEGNA	E					
E-5		CIPPATO	F					
E6-1		PELLETS	G					
E6-2		BRICCHETTI						
E6-3		BIODIESEL						
E7-1		BIOGAS						
E7-2		OLI						
E.8		BIOMASSA						
		ALTRO						



	AREA	PERIMETER	CTWEXPR_	CTWEXPR_ID	TIPOP	NUM	DSUP_SOPRA	DSUP_SOTTO	FAB	CODCC
0	142366.28681	6139.03562	2	1	P	2380/21	NULL	NULL	N	406
1	20472.55002	3139.44765	3	2	P	2380/6	NULL	NULL	N	406
2	2828.86314	519.77547	4	3	P	2412/8	NULL	NULL	N	406
3	1412.74826	672.54379	5	4	P	2413/5	NULL	NULL	N	406
4	28849.17481	1026.53049	6	5	P	2412/12	NULL	NULL	N	406
5	17277.22817	765.33250	7	15	P	2412/13	NULL	NULL	N	406
6	81742.99168	1104.34267	8	14	P	2412/11	NULL	NULL	N	406
7	2063.89056	211.06039	9	7	P	2412/2	NULL	NULL	N	406
8	3882.61864	344.64988	10	8	P	2373/3	NULL	NULL	N	406
9	1559.70076	162.91363	11	9	P	2411/6	NULL	NULL	N	406
10	597.72725	103.05658	12	10	P	2411/4	NULL	NULL	N	406
11	191165.79915	3569.13831	13	11	P	2386/1	NULL	NULL	N	406
12	321341.02133	3704.77806	14	12	P	2412/10	NULL	NULL	N	406
13	564.47680	121.74155	15	13	P	.6220	NULL	NULL	S	406
14	10181.32492	420.13822	16	14	P	.6417	NULL	NULL	S	406
15	284.47312	71.05098	17	15	P	.6418	NULL	NULL	S	406
16	14732.45012	6109.71080	18	16	P	2413/1	NULL	NULL	N	406
17	95534.62596	1910.86312	19	17	P	2412/1	NULL	NULL	N	406

Figure 38 *– Source data model of the cadastral dataset: screenshot of the attribute table of the shapefile*

Annex 2 – Conceptual target data model

Table 4 *– Conceptual target data model (excel format)*

FeatureType	Attribute	Values	Attribute	Values
Building	administrativeCode	CharacterString		
Building	address	CharacterString		
AbstractConstruction	dateOfConstruction	DateOfEvent		
Building	cadastralData	CadastralData	phiscalCode	CharacterString
			parcelType	ParcelTypeValue
			parcelNumber	CharacterString
			sub	CharacterString
			cadastralSheet	CharacterString
			portions	Integer
Certificate	ambit	CharacterString		
Certificate	energyPerformanceLabel	EnergyPerformanceLabelValue		
Certificate	certificateCode	CharacterString		
Certificate	applicant	Applicant	name	CharacterString
			fiscalCode	CharacterString
Certificate	coverageRenewableSources	CoverageRenewableSources	EPElectricity	Decimal
			EPElectricityThreshold	Decimal
			EPDHW	Decimal
			EPDHWThreshold	Decimal
			EPGlobal	Decimal
			EPGlobalThreshold	Decimal
			surfaceCovered	Decimal
Certificate	dateOfIssue	DateTime		
Certificate	dateOfTransmission	DateTime		
Certificate	dateOfBuildingPermit	DateTime		
Certificate	interventionDescription	InterventionDescriptionValue		
Certificate	currentUseThermal	CurrentUseThermalValue		

FeatureType	Attribute	Values	Attribute	Values
Certificate	energyPerformance	EnergyPerformance	CO2Emission	Decimal
			energyGlobal	Decimal
			energySummer	Decimal
			energyWinterReference	Decimal
			energyWinter	Decimal
			energyDHWReference	Decimal
			energyDHW	Decimal
Certificate	heatingDegreeDays	Integer		
Certificate	softwareReference	SoftwareReference	calculationMethodology	CharacterString
			name	CharacterString
			producer	CharacterString
			version	CharacterString
Certificate	note	CharacterString		
AbstractBuilding	numberOfDwellings	Integer		
Professional	professionalCategory	ProfessionalCategoryValue		
Professional	contactDetails	ContactDetails	surname	CharacterString
			fax	CharacterString
			address	CharacterString
			name	CharacterString
			telephone	CharacterString
Certificate	energyProject	EnergyProject	name	CharacterString
			surveyDate	Date
			sourceOfInformation	CharacterString
			responsibility	CharacterString
			surveyDescription	CharacterString

FeatureType	Attribute	Values	Attribute	Values
Certificate	energyProject	EnergyProject	name	CharacterString
			surveyDate	Date
			sourceOfInformation	CharacterString
			responsibility	CharacterString
			surveyDescription	CharacterString
Certificate	certificateState	CertificateStateValue		
Certificate	certificateType	CertificateTypeValue		
Certificate	buildingAndBuildingUnitInfo	BuildingAndBuildingUnitInfo	envelopeQuality	EnvelopeQualityValue
			surfaceAreaVolumeRatio	Decimal
			surfaceArea	Decimal
			floorArea	Decimal
			grossHeatedVolume	Decimal
Building	costructionStyle	CostructionStyleValue		
Building	buildingType	BuildingTypeValue		
Certificate	climaticZone	ClimaticZoneValue		
EnergyConversionSystem	yearOfInstallation	Date		
EnergyConversionSystem	energyCarrierType	EnergyCarrierTypeValue		
EnergyConversionSystem	energyAmountProduced	Measure		
EnergyConversionSystem	energyConversationSystemCode	CharacterString		
EnergyConversionSystem	registrationNumber	CharacterString		
EnergyConversionSystem	energyCarrierNotes	CharacterString		
EnergyConversionSystem	otherConversionSystemTypeNotes	CharacterString		
EnergyConversionSystem	nominalPower	Measure		
EnergyConversionSystem	energySourceType	EnergySourceTypeValue		
EnergyConversionSystem	energyConversionSystemType	EnergyConversionSystemTypeValue		
EnergySystem	energySystemCategory	EnergySystemCategoryValue		
	hasEnergyConversionSystem	EnergyConversionSystem		
EnergySystem	nominalEfficiency	Measure		
EnergySystem	systemNominalPower	Measure		

In green background are shown the attributes of the use case extended data model taken as-is from CityGML Energy ADE modules.

FeatureType	Attribute	Values	Attribute	Values
Certifier	certifierCategory	CertifierCategoryValue		
Certifier	certifierCode	Integer		
Certifier	certifierDesignationCode	CharacterString		
Certifier	certifierDesignationDescription	CharacterString		
Certifier	contactDetails	ContactDetails	surname	CharacterString
			fax	CharacterString
			address	CharacterString
			name	CharacterString
			PEC	CharacterString
			telephone	CharacterString
			title	CharacterString

Annex 3 – Mapping table

Table 5 *– Mapping table*

SOURCE DATA MODEL										TARGET DATA MODEL				
Types		Attribute Association role Constraint					Attribute / Association role / Constraint documentation	Values	Multiplicity	FeatureType	Attribute	Values	Attribute	Values
attestatoCertificazioneEnergetica	edificio	comuneAmministrativo					Codice ISTAT del comune	Integer or CharacterString?	1	Building	administrativeCode	CharacterString		
		edificioAccatastato (choise)	unitaImmobiliare	indirizzo				CharacterString or Address?	0..1	Building	address	CharacterString		
				annoCostruzione			Obbligatorio se lo statoCertificato è "Definitivo"	Integer	0..1	AbstractConstruction	dateOfConstruction	DateOfEvent		
				datiCatastali (1..*)	comuneCatastale		I valori devono essere presenti nella tabella dei comuni catastali della	Integer	1	Building	cadastralData	CadastralData	phiscalCode	CharacterString
					tipoParticella		Il valore deve essere obbligatoriamente "EDIFICIALE"	Codelist	1				parcelType	ParcelTypeValue
					numeroParticella			Integer	1				parcelNumber	CharacterString
					sub			Integer	1				sub	CharacterString
					foglio			Integer	0..1				cadastralSheet	CharacterString
					porzioniMateriali (0..1)	porzioneMateriale	nonNegativeInteger Contiene i dati delle porzioni materiali che si riferiscono ad una particella o ad un subalterno	Integer	0..1				portions	Integer
		edificioNonAccatastato (choise)	particelle	particella (1..*)	comuneCatastale		Contiene i dati catastali della singola particella su cui sorge l'edificio non ancora accatastato	Codelist	1					
					tipoParticella			Integer	1					
					numeroParticella			Integer	1					

SOURCE DATA MODEL										TARGET DATA MODEL				
Types		Attribute Association role Constraint					Attribute / Association role / Constraint documentation	Values	Multiplicity	FeatureType	Attribute	Values	Attribute	Values
attestatoCertificazioneEnergetica	certificato	ambito						CharacterString	1	Certificate	ambit	CharacterString		
		classificazione						Codelist	0..1	Certificate	energyPerformanceLabel	EnergyPerformanceLabelValue		
		codiceCertificato						Integer	1	Certificate	certificateCode	CharacterString		
		~~proprietario~~					Cognome e Nome o Denominazione del richiedente l'attestato di certificazione energetica	CharacterString	1	Certificate	applicant	Applicant	name	CharacterString
		~~codiceFiscale~~						CharacterString	1				fiscalCode	CharacterString
		coperturaFontiRinnovabili	EPElettrica					Real	0..1	Certificate	coverageRenewableSources	CoverageRenewableSources	EPElectricity	Decimal
			EPElettricaSoglia					Real	0..1				EPElectricityThreshold	Decimal
			EPSanitaria					Real	0..1				EPDHW	Decimal
			EPSanitariaSoglia					Real	0..1				EPDHWThreshold	Decimal
			EPSommatoria					Real	0..1				EPGlobal	Decimal
			EPSommatoriaSoglia					Real	0..1				EPGlobalThreshold	Decimal
			superficieCoperta					Real	0..1				surfaceCovered	Decimal
		dataEmissione						DateTime	0..1	Certificate	dateOfIssue	DateTime		
		dataInvio						DateTime	1	Certificate	dateOfTransmission	DateTime		
		dataTitoloEdilizio						DateTime	0..1	Certificate	dateOfBuildingPermit	DateTime		
		descrizioneIntervento						Codelist	0..1	Certificate	interventionDescription	InterventionDescriptionValue		
		destinazioniUso (0..1)	destinazioneUso					Codelist	1..*	Certificate	currentUseThermal	CurrentUseThermalValue		
		emissioneCO2					Obbligatorio se lo statoCertificato è Definitivo	Real	0..1	Certificate	energyPerformance	EnergyPerformance	CO2Emission	Decimal
		energiaGlobaleUbicazione					Obbligatorio se lo statoCertificato è Definitivo	Real	0..1				energyGlobal	Decimal
		energiaEstivaUbicazione					Obbligatorio se lo statoCertificato è Definitivo	Real	0..1				energySummer	Decimal
		energiaInvernale					Obbligatorio se lo statoCertificato è Definitivo	Real	0..1				energyWinterReference	Decimal
		energiaInvernaleUbicazione					Obbligatorio se lo statoCertificato è Definitivo	Real	0..1				energyWinter	Decimal
		energiaSanitaria					Obbligatorio se lo statoCertificato è Definitivo	Real	0..1				energyDHWReference	Decimal
		energiaSanitariaUbicazione					Obbligatorio se lo statoCertificato è Definitivo	Real	0..1				energyDHW	Decimal

Types		Attribute Association role Constraint					Attribute / Association role / Constraint documentation	Values	Multiplicity	FeatureType	Attribute	Values	Attribute	Values
attestatoCertificazioneEnergetica	certificato	EPRaggiungibile						Real	0..1					
		gradiGiorno						Integer	1	Certificate	heatingDegreeDays	Integer		
		metodologiaCalcolo						CharacterString	0..1	Certificate	softwareReference	SoftwareReference	calculationMethodology	CharacterString
		prodottoSoftware						Character string	0..1				name	CharacterString
		produttoreSoftware						Character string	0..1				producer	CharacterString
		versioneSoftware						Character string	1				version	CharacterString
		note		manufacturer				Character string	0..1	Certificate	note	CharacterString		
		numeroAppartamenti						Integer	0..1	AbstractBuilding	numberOfDwellings	Integer		
		professionisti (0..1)	professionista (1..*)	categoriaProfessionale			Contiene i dati dei professionisti che hanno partecipato all'intervento	Codelist	1	Professional	professionalCategory	ProfessionalCategoryValue		
				cognome				Character string	1	Professional	contactDetails	ContactDetails	surname	CharacterString
				fax				Character string	0..1				fax	CharacterString
				indirizzo				Character string	0..1				address	CharacterString
				nome				Character string	0..1				name	CharacterString
				telefono				Character string	0..1				telephone	CharacterString
		progettoEnergetico						Character string	0..1	Certificate	energyProject	EnergyProject	name	CharacterString
		rilievoEdificio						DateTime	0..1				surveyDate	Date
		provenienza						CharacterString	0..1				sourceOfInformation	CharacterString
		responsabilita						Character string	0..1				responsibility	CharacterString
		sopralluoghi (0..1)	descrizione (1..*)					Character string	1..*				surveyDescription	CharacterString

SOURCE DATA MODEL										TARGET DATA MODEL				
Types		Attribute Association role Constraint					Attribute / Association role / Constraint documentation	Values	Multiplicity	FeatureType	Attribute	Values	Attribute	Values
attestatoCertificazioneEnergetica	certificato	statoCertificato						Codelist	1	Certificate	certificateState	CertificateStateValue		
		tipoCertificato						Codelist	1	Certificate	certificateType	CertificateTypeValue		
		qualitaInvolucro					Obbligatorio se lo statoCertificato è Definitivo	Codelist	0..1	Certificate	buildingAndBuildingUnitInfo	BuildingAndBuildingUnitInfo	envelopeQuality	EnvelopeQualityValue
		rapportoSV						Real	0..1				surfaceAreaVolumeRatio	Decimal
		superficieDisperdenteS					espressa in mq	Real	0..1				surfaceArea	Decimal
		superficieUtile					espressa in mq	Real	0..1				floorArea	Decimal
		volumeLordoRiscaldatoV					espresso in mc	Real	0..1				grossHeatedVolume	Decimal
		tipologiaCostruttiva						Codelist	0..1	Building	costructionStyle	CostructionStyleValue		
		tipologiaEdilizia						Codelist	0..1	Building	buildingType	BuildingTypeValue		
		zonaClimatica						Codelist	1	Certificate	climaticZone	ClimaticZoneValue		
	generatori (0..1)	generatore (1..*)	annoInstallazione					Integer	1	EnergyConversionSystem	yearOfInstallation	Date		
			combustibili (0..1)	combustibile (1..*)			Obbligatorio se tipoFonteEnergetica= TRADIZIONALE	Codelist	1..*	EnergyConversionSystem	energyCarrierType	EnergyCarrierTypeValue		
			energia (0..1)	energiaProdotta (1..*)	energiaProdotta		Obbligatorio se tipoFonteEnergetica= RINNOVABILE	Real	1..*	EnergyConversionSystem	energyAmountProduced	Measure		
					UM			Codelist	1					
			idGeneratore				idGeneratore e' chiave per il generatore	Character string	1	EnergyConversionSystem	energyConversationSystemCode	CharacterString		
			matricolaGeneratore					Character string	0..1	EnergyConversionSystem	registrationNumber	CharacterString		
			noteCombustibile					Character string	0..1	EnergyConversionSystem	energyCarrierNotes	CharacterString		
			noteTipologiaGeneratoreAltro				Note alla tipologia del generatore quando specificato “Altro”	Character string	0..1	EnergyConversionSystem	otherConversionSystemTypeNotes	CharacterString		
			potenza (0..1)	potenzaNominale (1..*)	potenzaNominale		Obbligatorio se tipoFonteEnergetica= TRADIZIONALE	Real	1..*	EnergyConversionSystem	nominalPower	Measure		
					UM			Codelist	1					
			tipoFonteEnergetica					Codelist	1	EnergyConversionSystem	energySourceType	EnergySourceTypeValue		
			tipologiaGeneratore					Codelist	1	EnergyConversionSystem	energyConversionSystemType	EnergyConversionSystemTypeValue		

SOURCE DATA MODEL										TARGET DATA MODEL				
Types		Attribute Association role Constraint					Attribute / Association role / Constraint documentation	Values	Multiplicity	FeatureType	Attribute	Values	Attribute	Values
attestatoCertificazioneEnergetica	impianti (0..1)	impianto (1..*)	categoriaImpianto					Codelist	1	EnergySystem	energySystemCategory	EnergySystemCategoryValue		
			generatori	refGeneratore (1..*)				idGeneratore	0..1		hasEnergyConversionSystem	EnergyConversionSystem		
			rendimentoImpianto					Real	0..1	EnergySystem	nominalEfficiency	Measure		
			potenzaImpianto (0..1)	potenzaNominaleImp (1..*)	potenzaNominaleImp		Contiene i dati di potenza complessiva dell'impianto	Real	1..*	EnergySystem	systemNominalPower	Measure		
					UM			Codelist	1					
	certificatore	categoriaCertificatore						Codelist	1	Certifier	certifierCategory	CertifierCategoryValue		
		codiceCertificatore					nonNegativeInteger	Integer	1	Certifier	certifierCode	Integer		
		codiceOda						Character string	1	Certifier	certifierDesignationCode	CharacterString		
		descrizioneOda						Character string	1	Certifier	certifierDesignationDescription	CharacterString		
		cognome						Character string	1	Certifier	contactDetails	ContactDetails	surname	CharacterString
		fax						Character string	0..1				fax	CharacterString
		indirizzo						Character string	0..1				address	CharacterString
		nome						Character string	1				name	CharacterString
		PEC						Character string	0..1				PEC	CharacterString
		telefono						Character string	0..1				telephone	CharacterString
		titolo						Character string	0..1				title	CharacterString
											from CityGML Energy ADE			

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