FME Form:
Reading and writing CityGML 2.0 data

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Last update: 3 September 2025

License

Foreword

- This **tutorial** is meant to guide your step-by-step with the basics of reading/writing (XML-based) **CityGML 2.0 data** with FME Form

- Besides FME Form, you are heartily suggested to:
  - Install and have the **KIT ModelViewer** and a decent **text editor** at hand (e.g. Notepad++)
  - Have the CityGML 2.0 **UML diagrams** at hand for reference
  - Have the CityGML 2.0 **Specifications** at hand for reference

- Further suggestions
  - Before jumping to FME Form, familiarize yourself with the KIT ModelViewer, too!
  - If you are totally new to FME Form, you should *really* first check the **FME tutorial for beginners**
  - Follow this tutorial AND try to repeat it on your PC what you see in the slides
  - Pay attention to the details that are highlighted in the screenshots

Foreword

- The following slides are based on the CityGML sample dataset **Alderaan**. The dataset consists of a fantasy city consisting of buildings, trees, and a DTM. The zipped file contains XML-based CityGML 2.0 data grouped into different files.
  - A quick introduction to the Alderaan dataset can be downloaded here
  - The zipped file containing the data can be downloaded here.

- The dataset is intended to be used as reference, to test and to learn. Therefore… do not worry! If you make mistakes, neither you nor your computer will be destroyed by an evil green super laser during this tutorial ☺

Foreword

WARNING

Just to be clear:

- No chance you can “survive” this tutorial without being familiar with the CityGML data model
- Hence: always have a copy of the UML diagrams at hand, and – possibly – a copy of the CityGML specifications!

- **Nota bene:** these slides are based on FME Form 2023 (or earlier). Since FME Form 2024, some GUI elements have been redesigned. The overall structure and functionalities, however, remain the same!

CityGML in FME

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- A CityGML file is read and written by means of **MULTIPLE readers/writers**.
- Simply put, each reader/writer corresponds to a **GML Feature**
  - i.e. all CityObjects (Building, BuildingPart, RoofSurface, …)
  - But also: Address, Appearance, etc.
- **Attributes** of a Feature are included inside the corresponding reader/writer
- **Generic attributes** are (by default) attached to the corresponding Feature
  - Optionally, they can be dealt with by means of a specific reader/writer
- **Nested data** (which are not a Feature) are accessible via attributes (XML path is flattened to a long attribute name)
  - Lists are used with properties that have a cardinality of 0..*
  - Example: citygml_function{}, citygml_usage{}

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- Geometries are mapped to/from the **FME geometry model**
  - *Geometry traits/properties* are fundamental to work with CityGML in FME
- Geometries referenced by **Xlinks** are instantiated within the workbench upon reading, and (optionally) written again as Xlinks by the writer
- **Implicit geometries** are supported, and mapped to FME Geometry Instances
- **Appearances** are also supported
  - User friendly approach: only **one** appearance per CityGML file
  - Advanced mode: many appearances per CityGML file
  - **Please note:** FME can read and write multiple appearances, but the Data inspector only shows one (the first written in the xml file)

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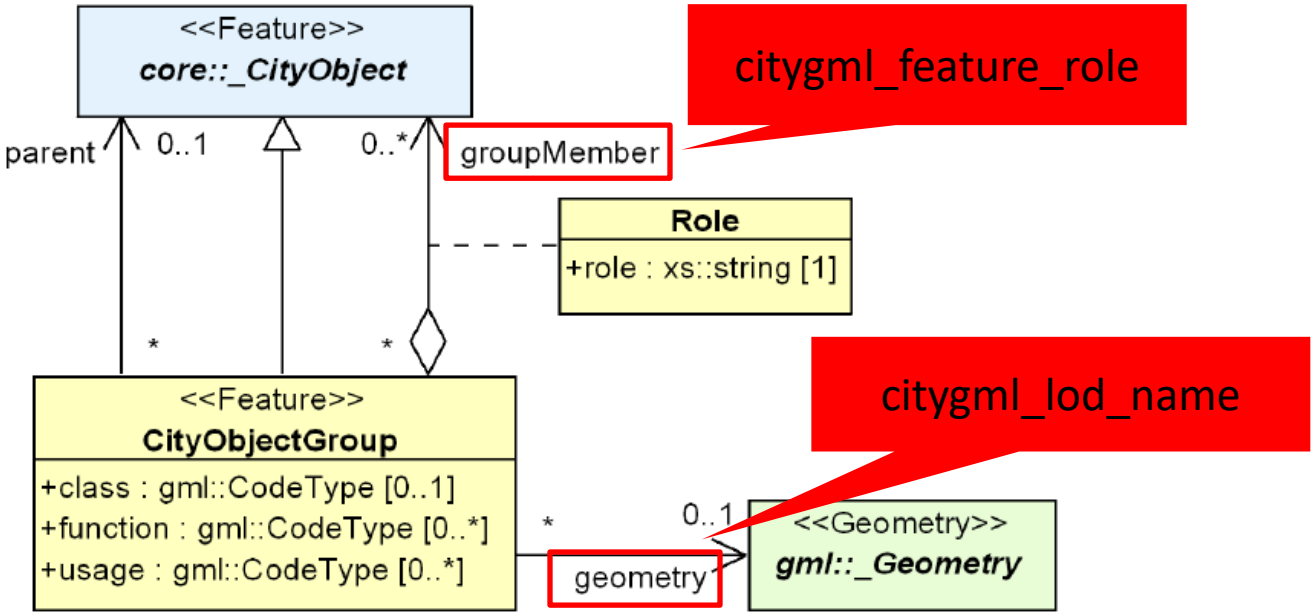
- Particular attributes play a major role when working with CityGML
  - The spelling of the attributes is important: they must be *exactly* as shown here!

- For non-spatial data:
  - gml_id
  - gml_parent_id
  - citygml_feature_role (see next slide)
  - *attribute_name*_xlink_href

- For geometries (via **geometry properties**, previously known as **geometry traits**)
  - gml_id
  - citygml_lod_name (see next slide)
  - xlink_href
  - gml_geometry_reversed (Boolean: true or false)

CityGML in FME: good habits

- As already said: ALWAYS have the UML diagrams of CityGML at hand!
- A **citygml_feature_role** attribute contains the name of the roles between two features classes
- A **gml_lod_name** attribute contains the name of the role between a geometry and a feature class



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CityGML in FME: good habits

- Use the **validation** option for reading and, above all, writing CityGML. It gives hints at what you may be doing wrong
  - As it slows down the ETL process, you may disable it when you are sure you are generating valid CityGML files

- Always **test** (and learn) **using few data** before going full scale
  - CityGML files *can* become very large!

- **Check the generated file** in a text/code editor
  - At least while testing at the beginning
  - Using Windows Notepad is a bad option. Go for something better (e.g. Notepad++)

- If you can, **use a multi-monitor** configuration
  - More real estate where to place the application windows
  - Your eyes will be thankful! ☺

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FME geometry model to/from (City)GML

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- For **spatial data**, FME has its own internal geometry model. All geometries are mapped to/from it
  - https://docs.safe.com/fme/html/FME_Desktop_Documentation/FME_Desktop/!FME_Geometry/FME_Geometry_Model.htm
- It is rather intuitive, however with some peculiar semantics
  - **Area**: a 2D polygon with or without holes is called a “Donut” or a “SimpleArea”
  - **Surface**: a 3D geometry (simple or composite) that is made of 3D entities (Face, RectangleFace, … Mesh) and generally has a surface normal
- Examples of series of geometrical transformations could be:
  - donut -> face -> multisurface
  - polygon -> face -> composite surface -> Brep-solid
- **WATCH OUT:** A “classical” 3D polygon can be many things in FME!
- Geometries can have “internal” attributes called *geometry traits*

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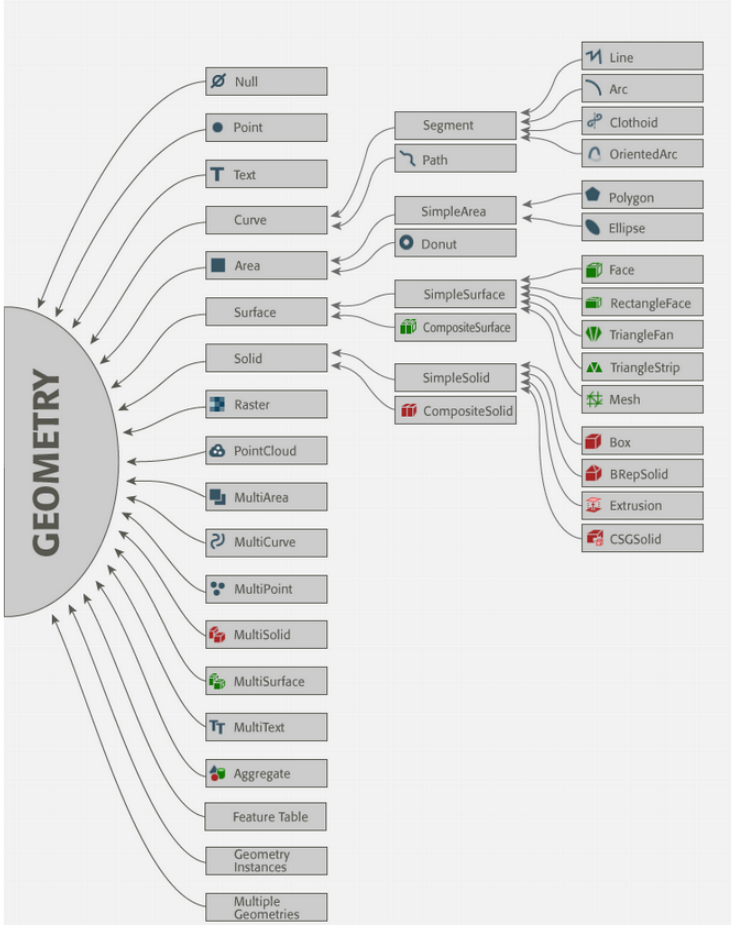
FME Geometry Model

FME provides a comprehensive geometry model that includes everything from the simplest geometry to the most complex.

Click on a geometry class for more information.



Understanding FME Geometry
Geometry Concepts
FME Geometry Model
Nulls (IFMENull)
Points (IFMEPoint)
Text (IFMEText)
Curves (IFMECurve)
Segments (IFMESegment)
Paths (IFMEPath)
Areas (IFMEArea)
Simple Areas (IFMESimpleArea)
Donuts (IFMEDonut)
Surfaces (IFMESurface)
Simple Surfaces (IFMESimpleSurface)
Composite Surfaces (IFMECompositeSurface)
Solids (IFMESolid)
Simple Solids (IFMESimpleSolid)
Composite Solids (IFMECompositeSolid)
Rasters (IFMERaster)
Point Clouds (IFMEPointCloud)
Multis
Aggregates (IFMEAggregate)
Feature Tables (IFMEFeatureTable)
Geometry Definitions and Instances
Multiple Geometries

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Reading CityGML in FME

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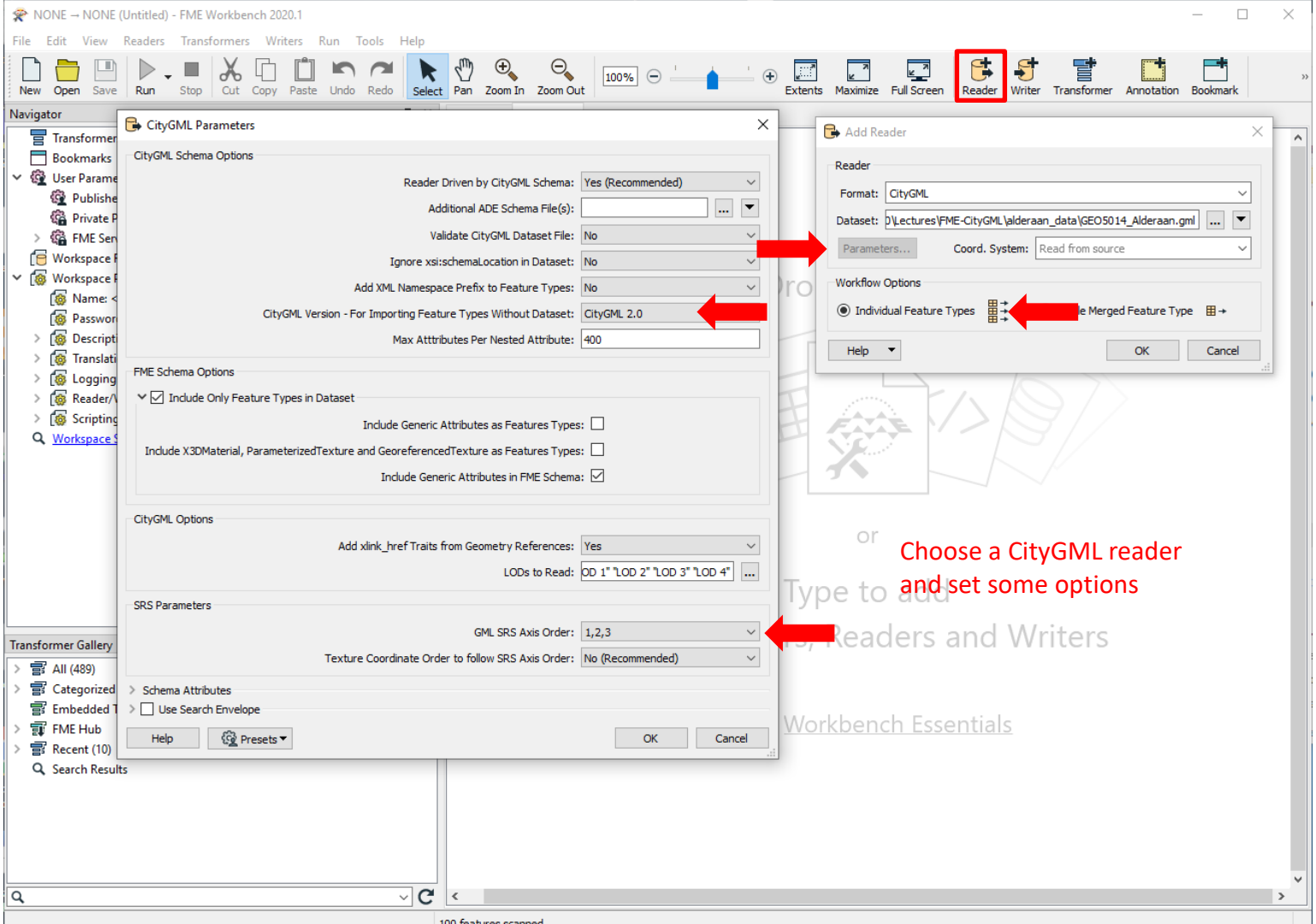

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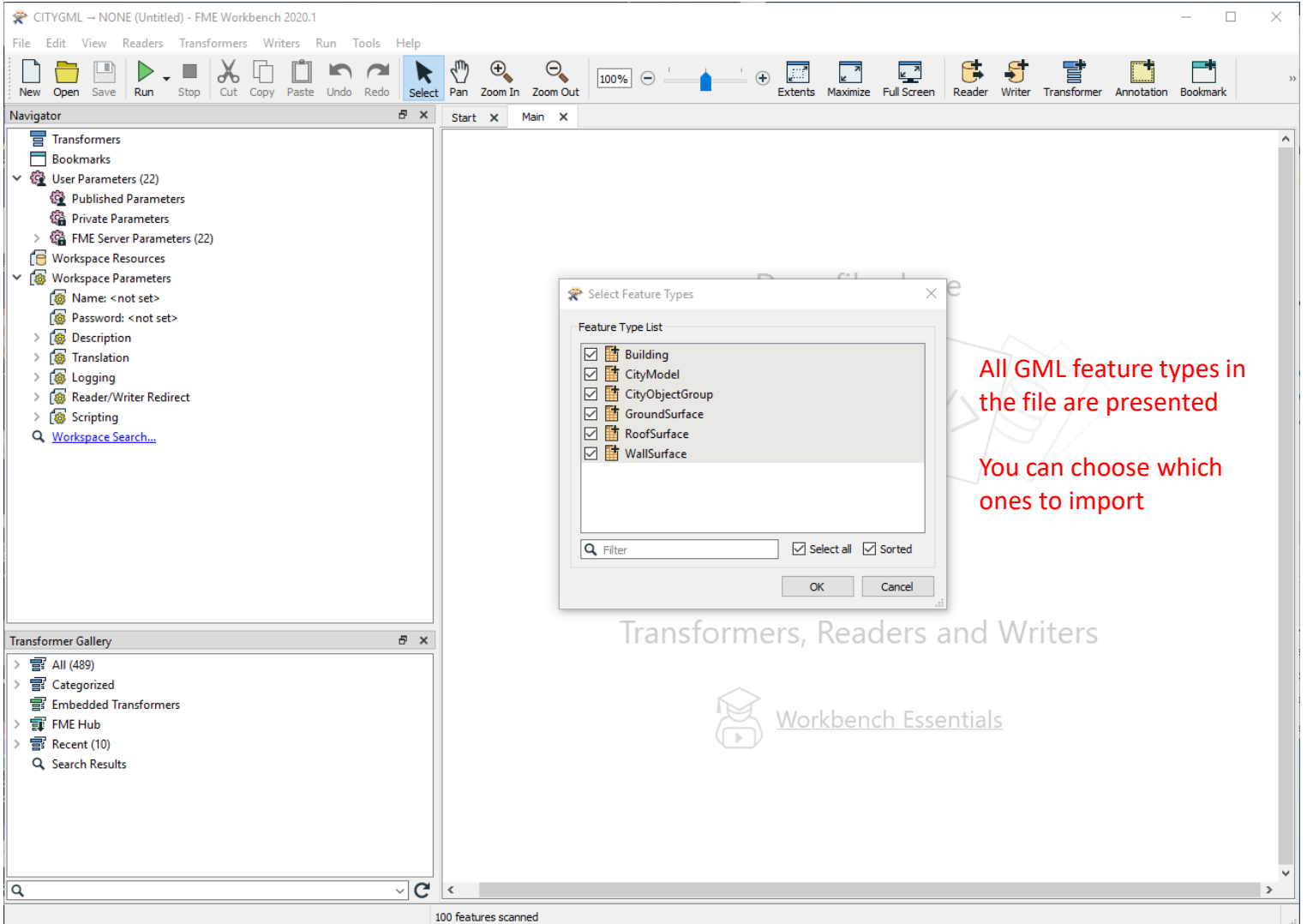

All GML feature types in the file are presented

You can choose which ones to import

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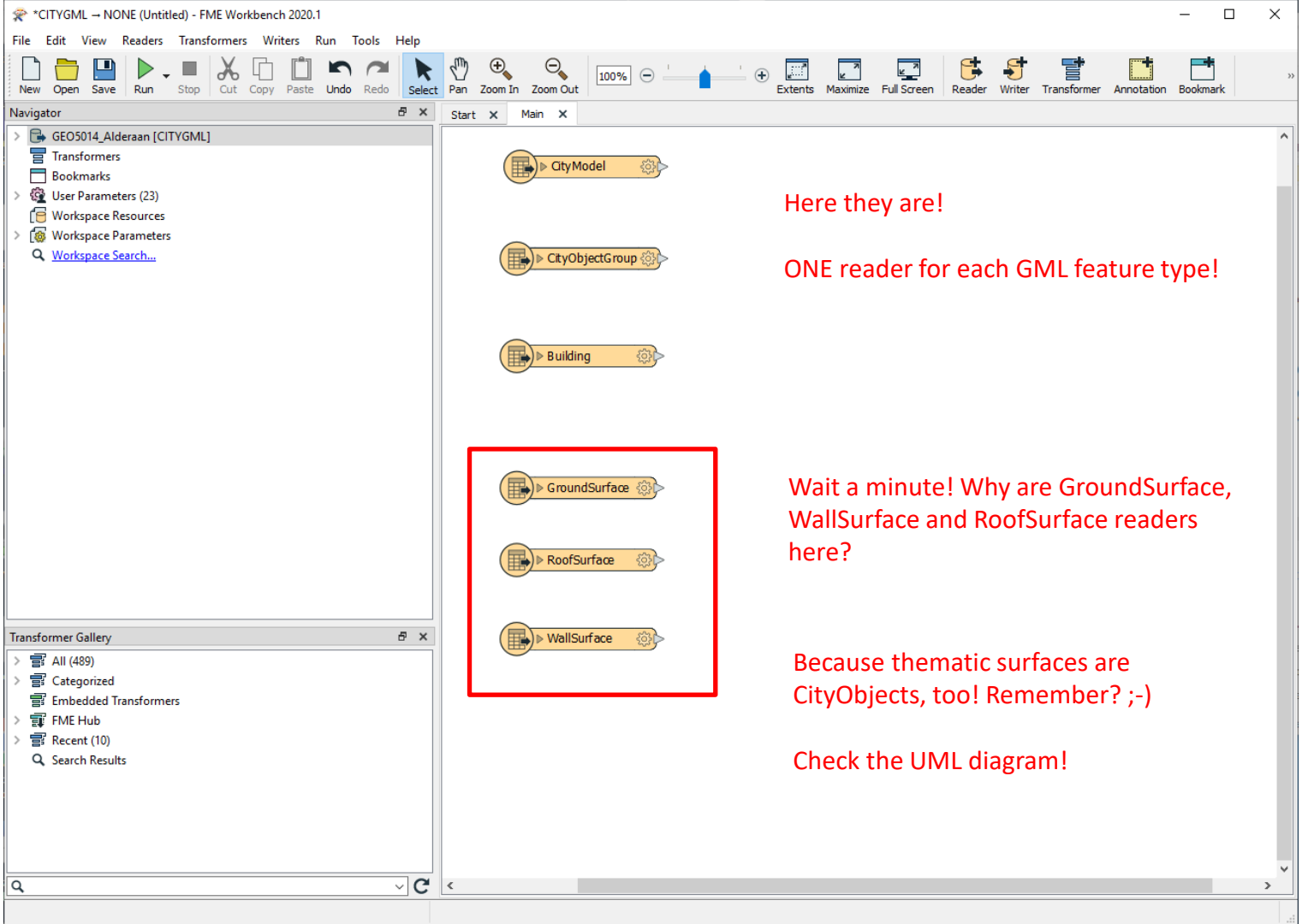

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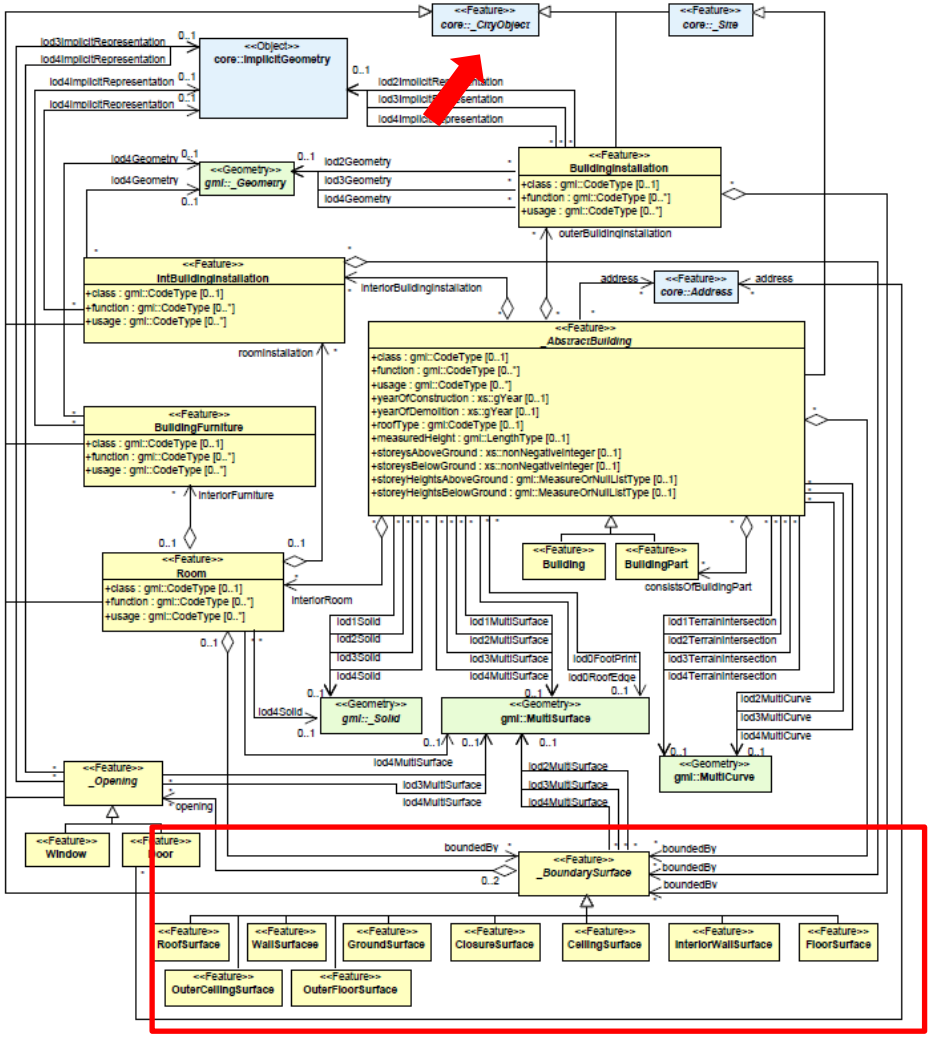
For example:

A RoofSurface:

- is a _BoundarySurface,
- which itself is a _CityObject!



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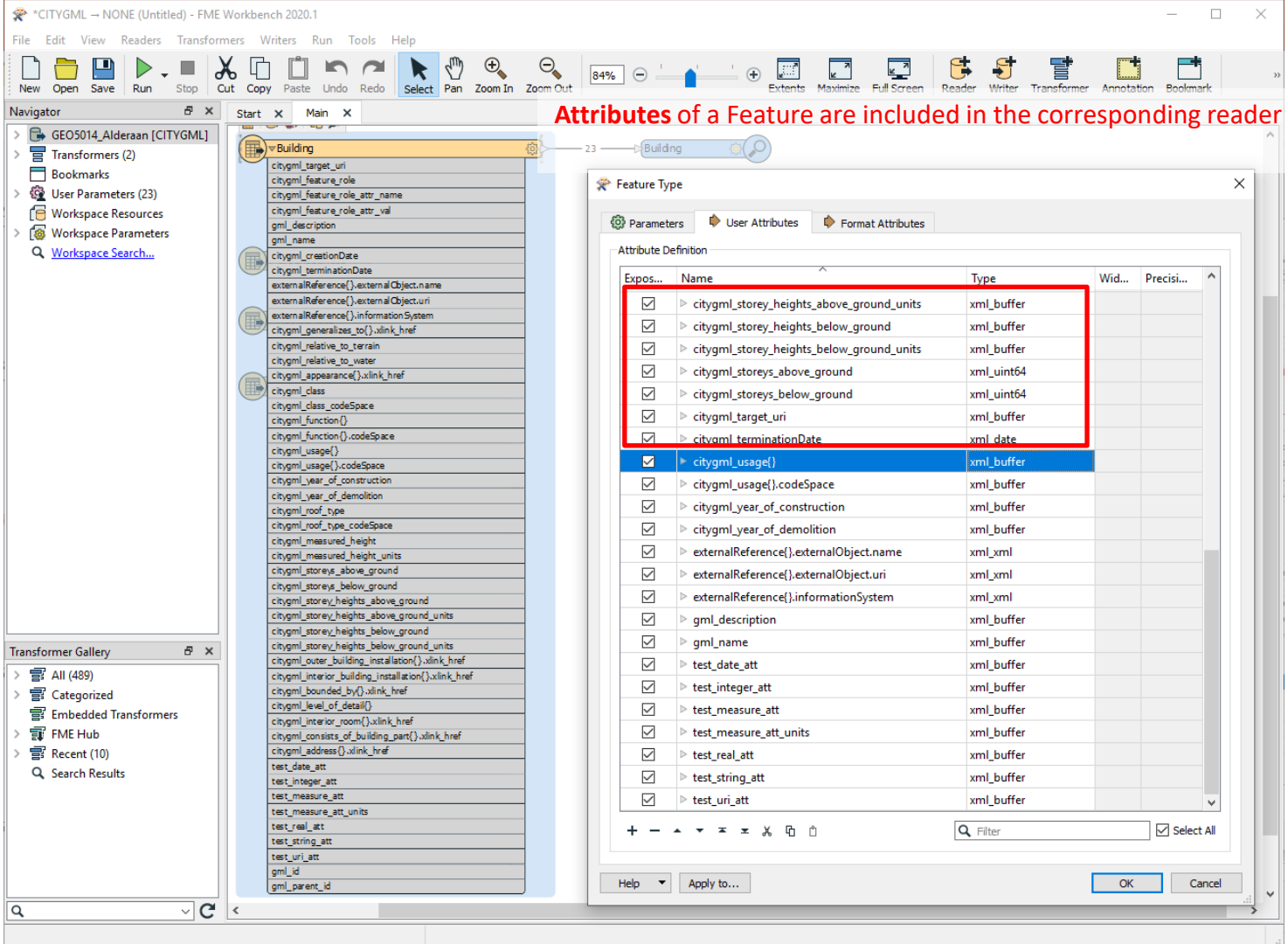

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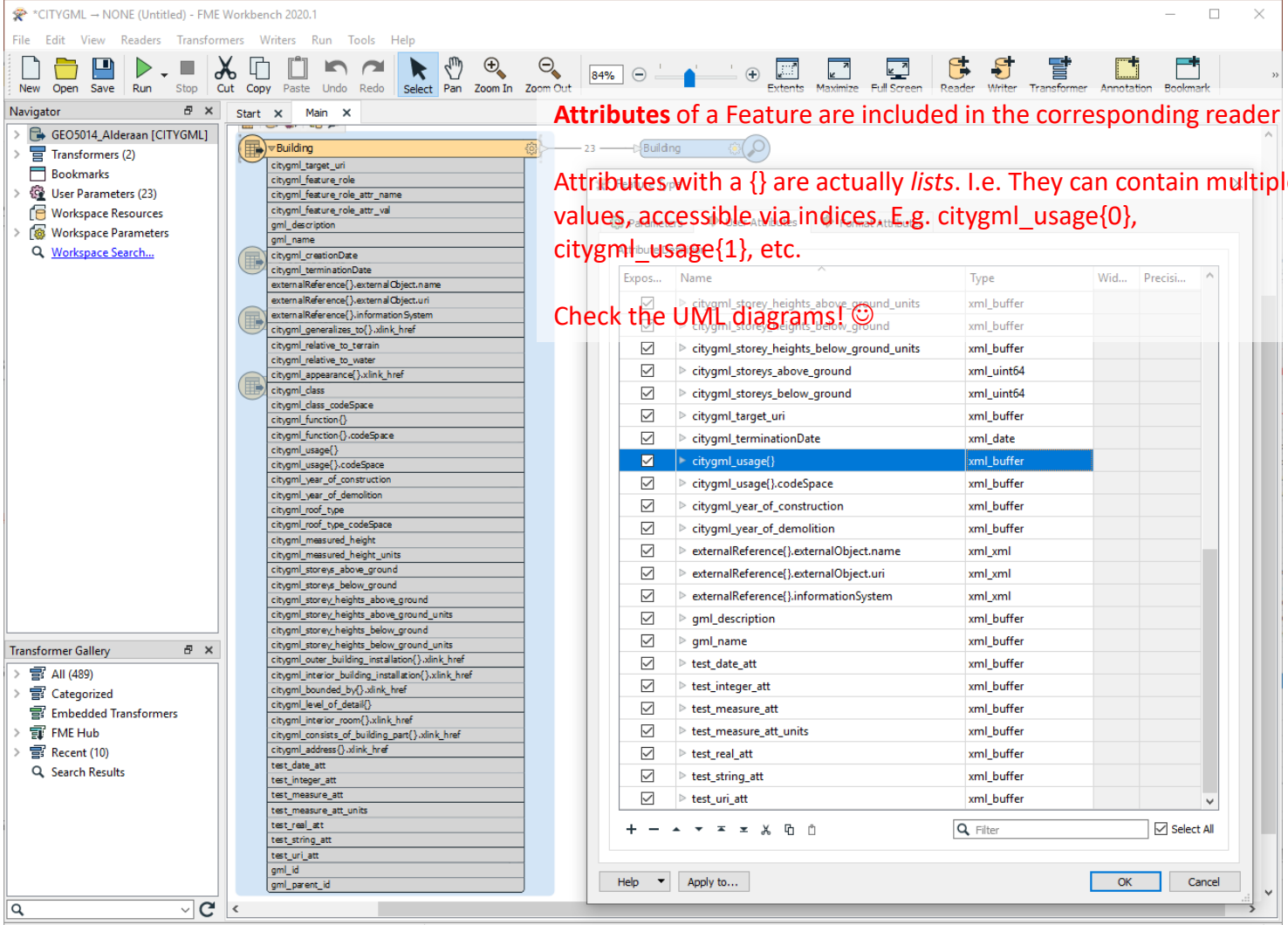

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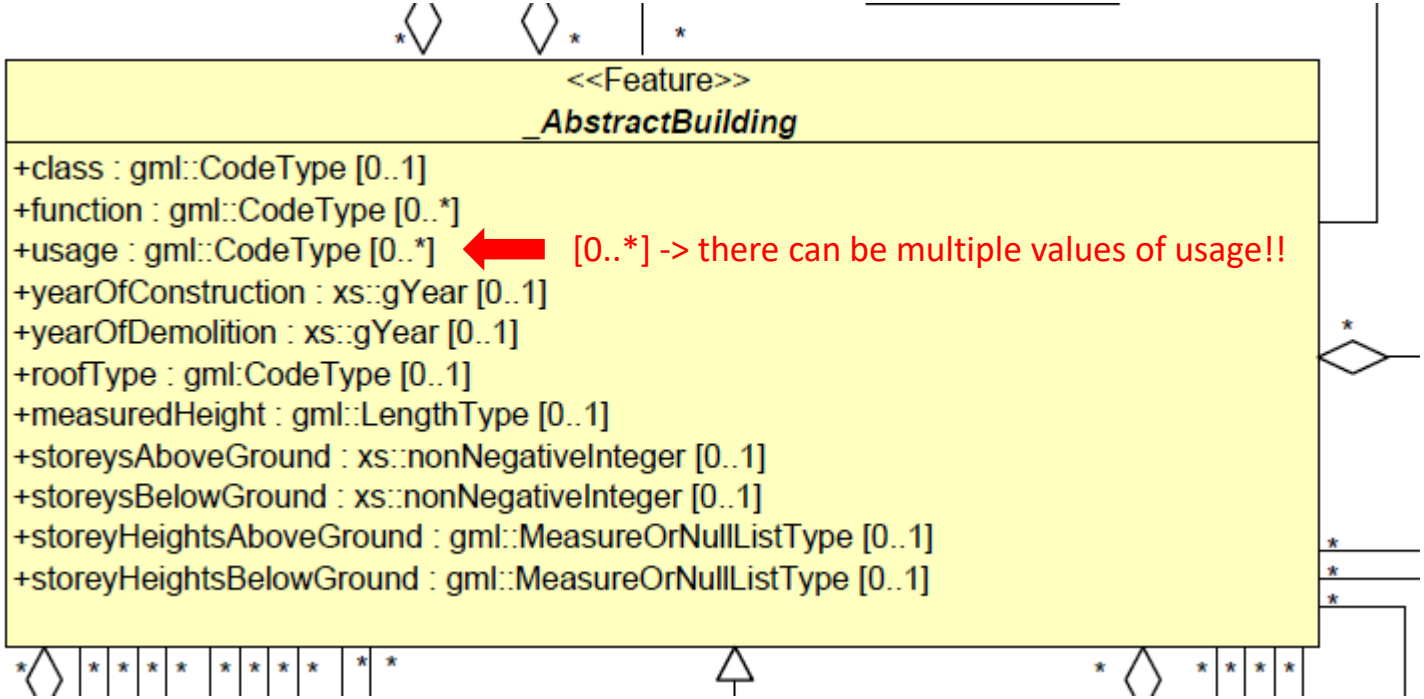

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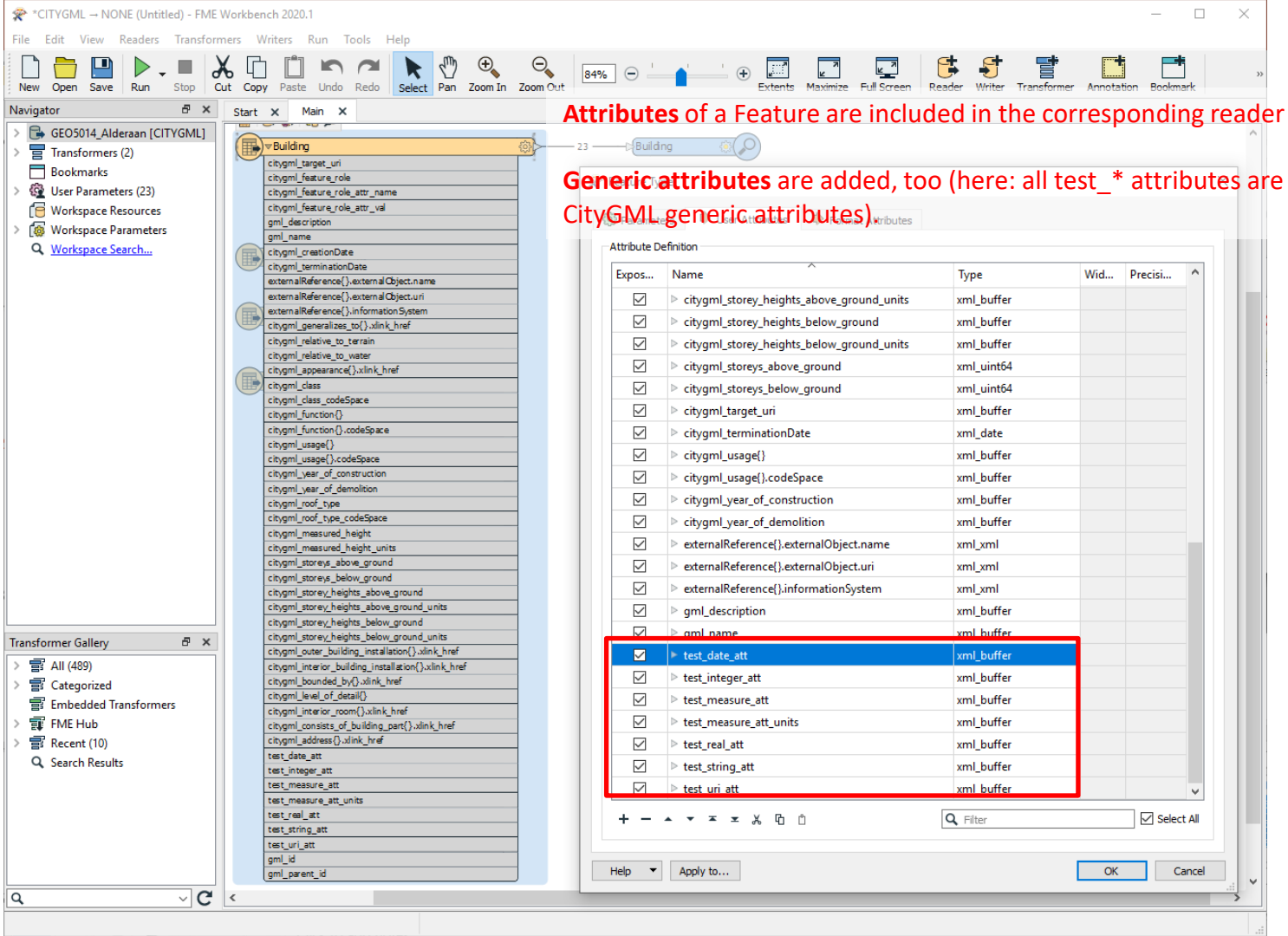

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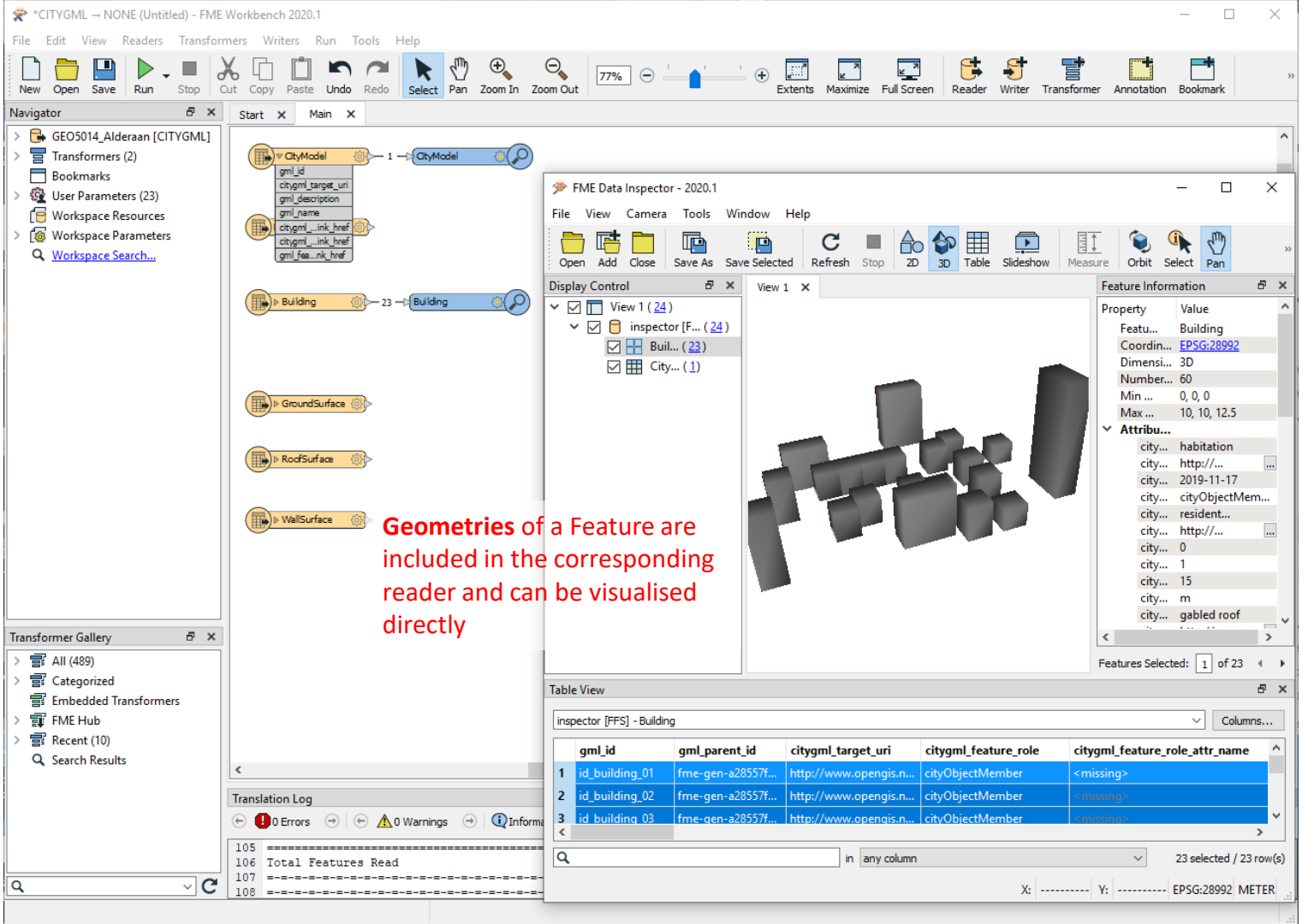

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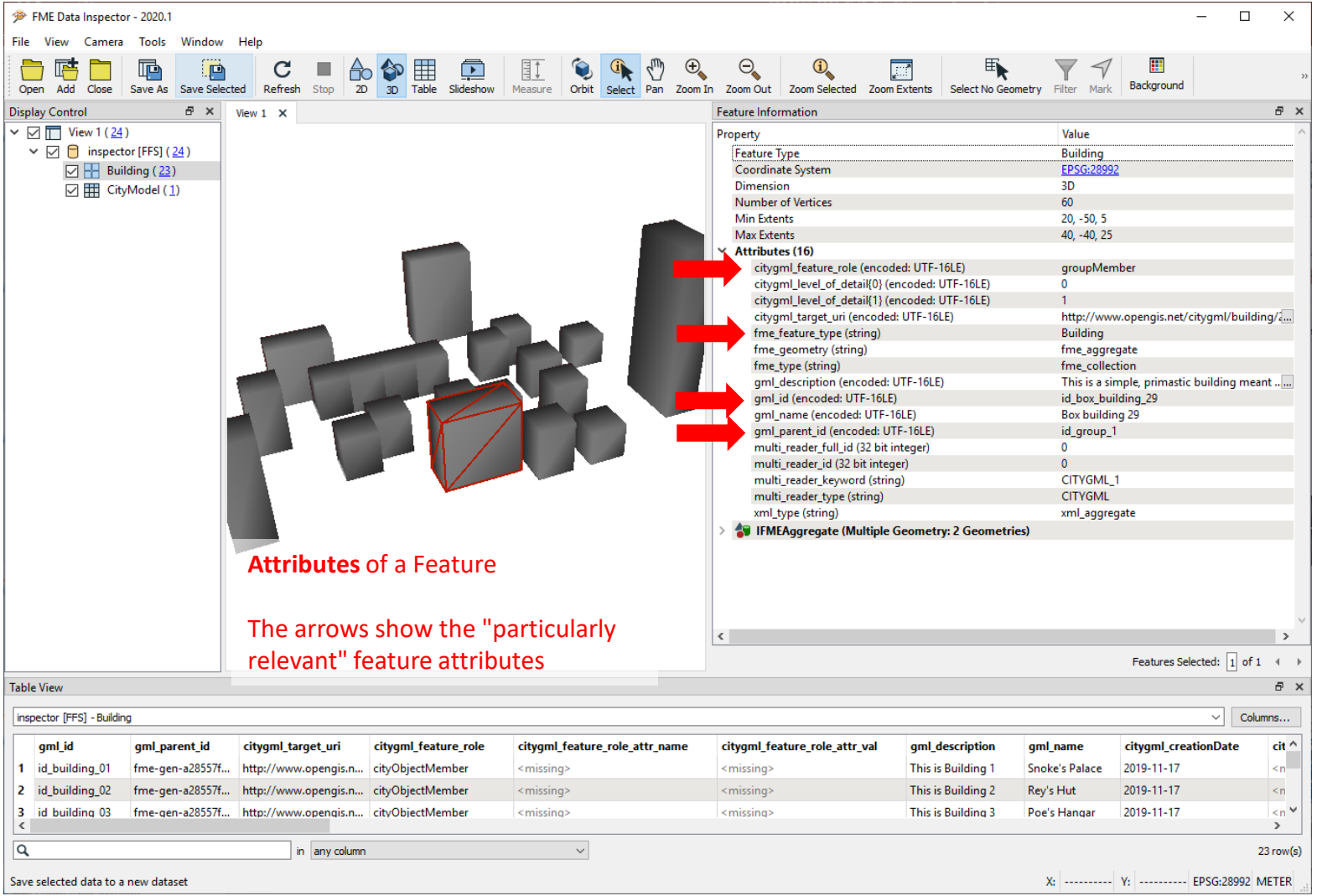

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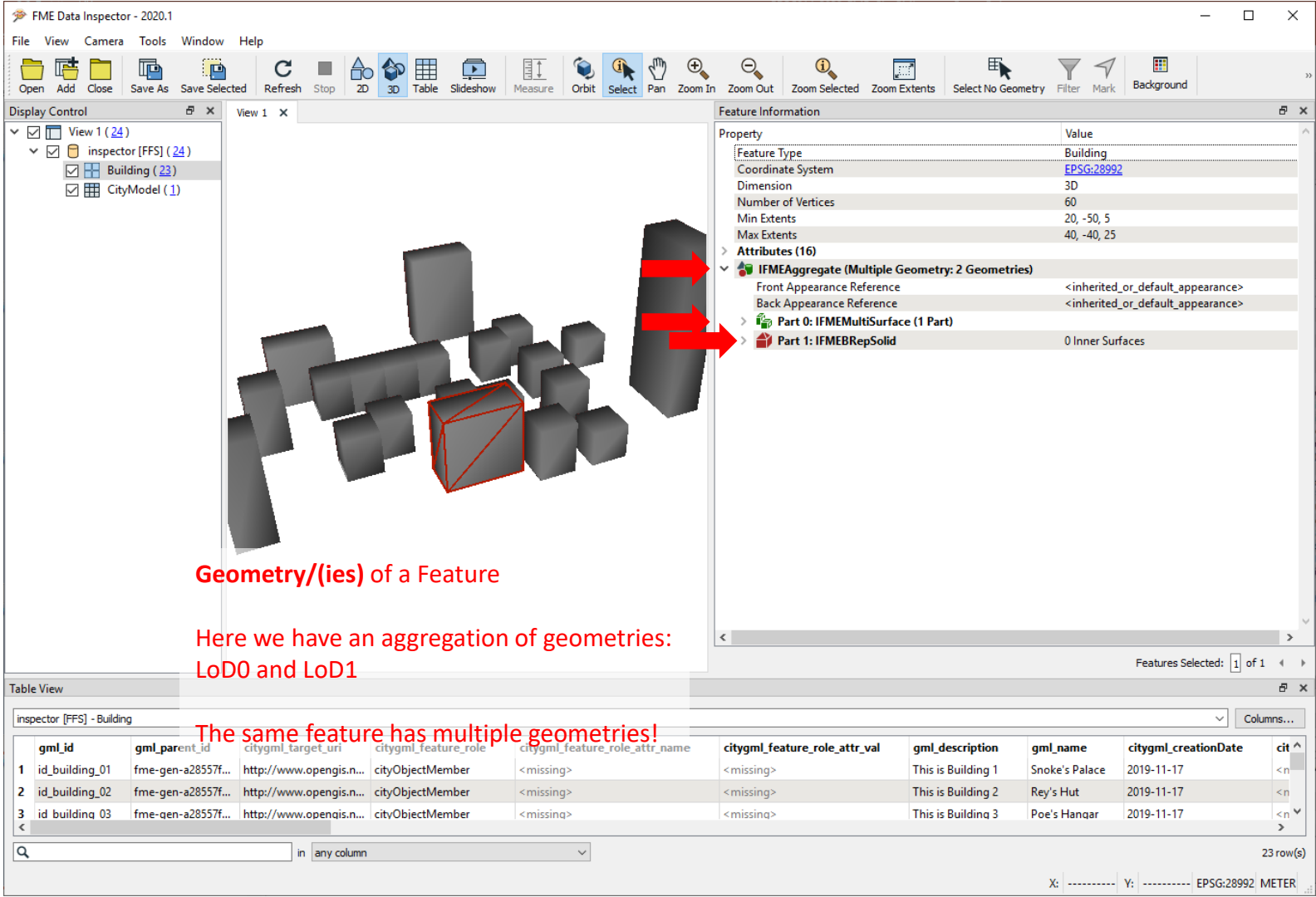

Geometry/(ies) of a Feature

Here we have an aggregation of geometries: LoD0 and LoD1

The same feature has multiple geometries!

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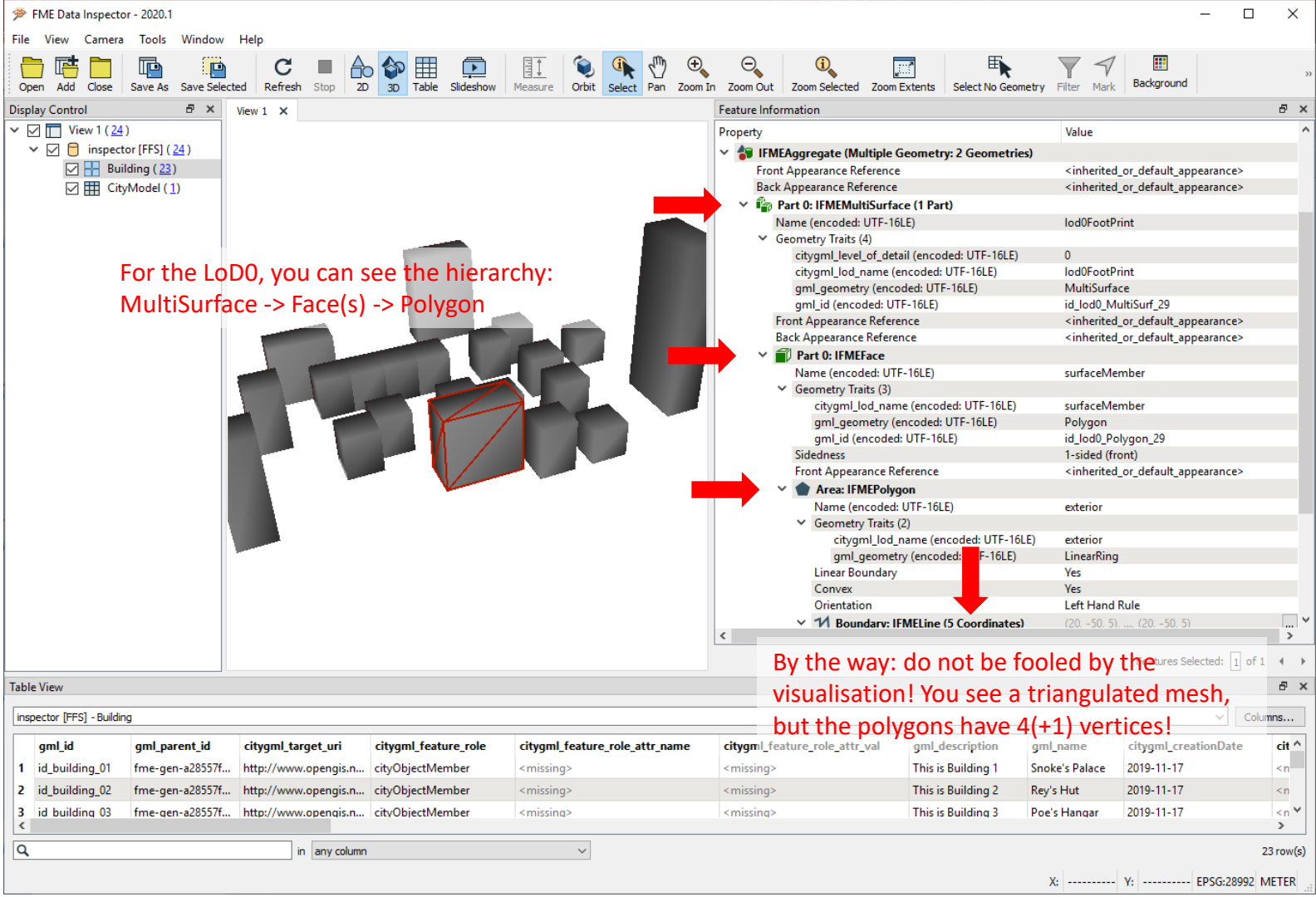

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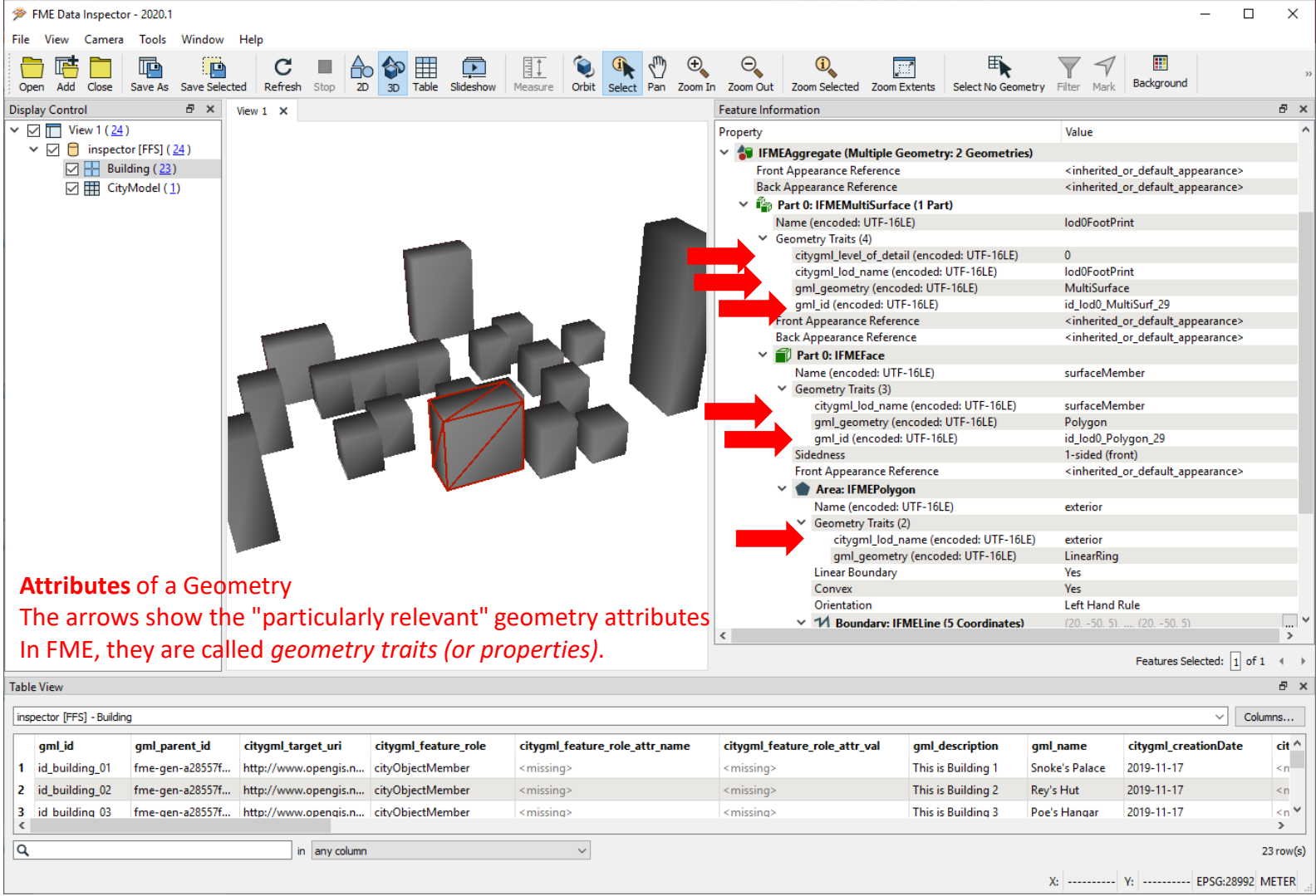

Attributes of a Geometry
The arrows show the "particularly relevant" geometry attributes
In FME, they are called *geometry traits (or properties)*.

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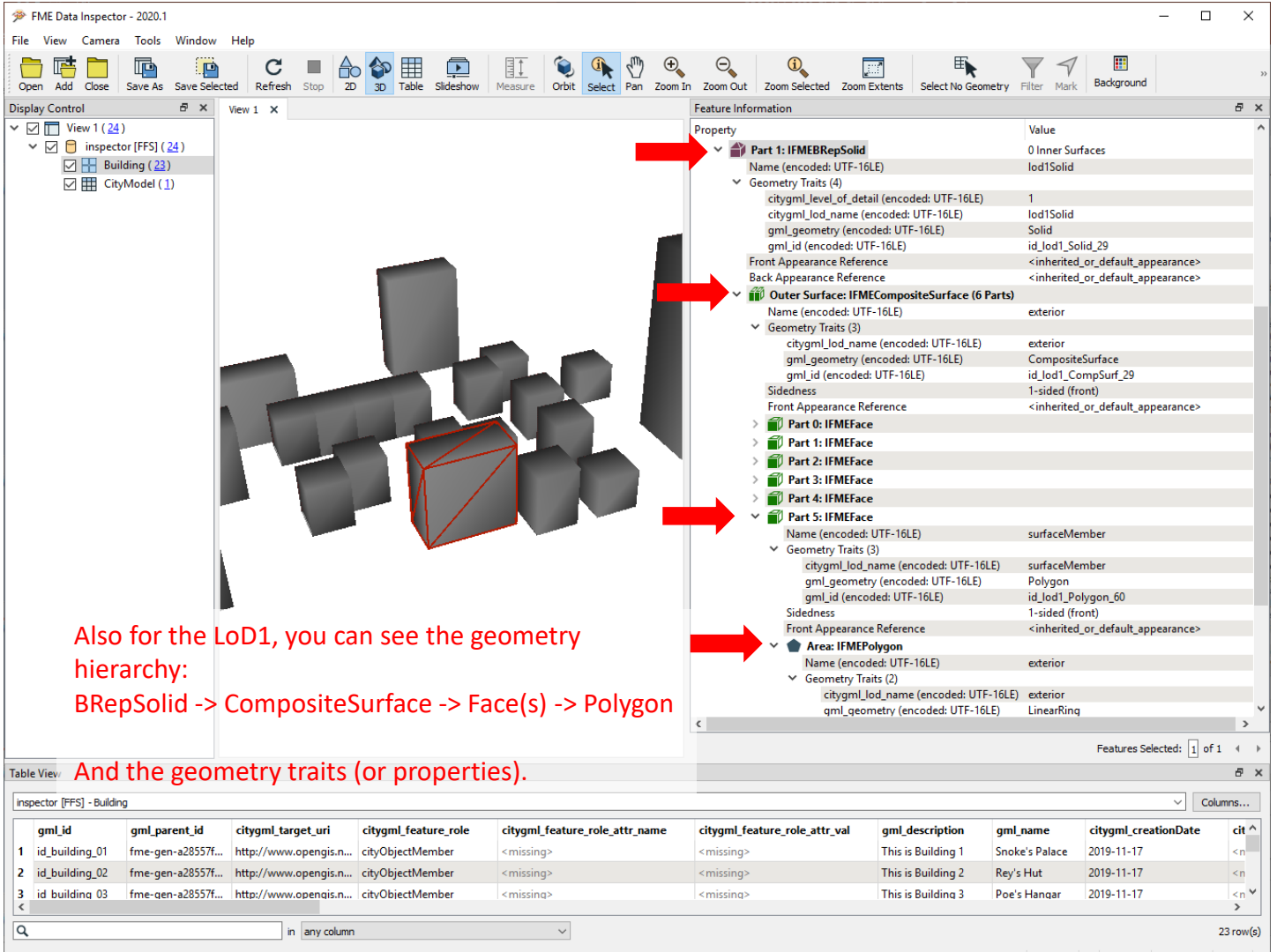

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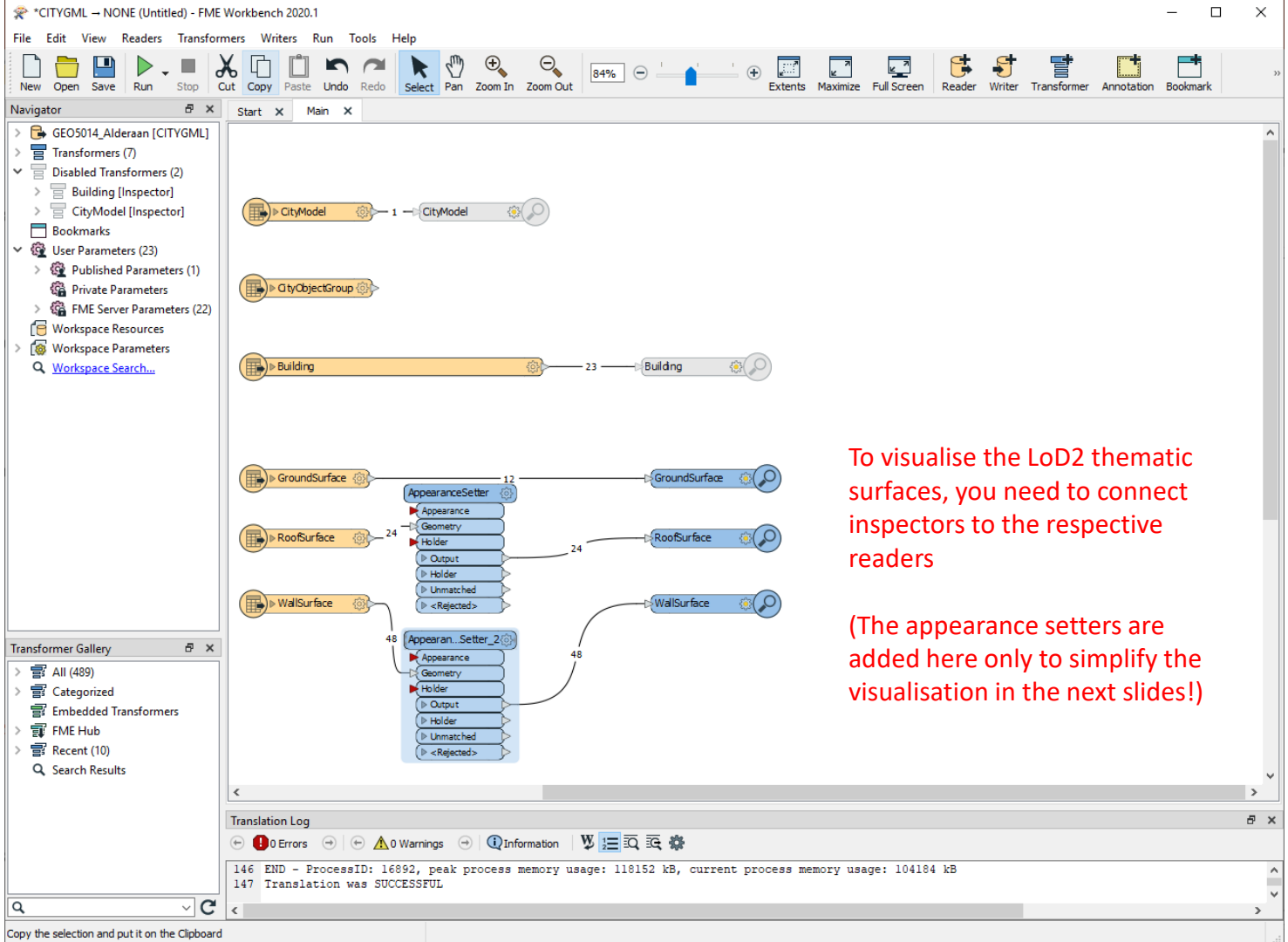

To visualise the LoD2 thematic surfaces, you need to connect inspectors to the respective readers

(The appearance setters are added here only to simplify the visualisation in the next slides!)

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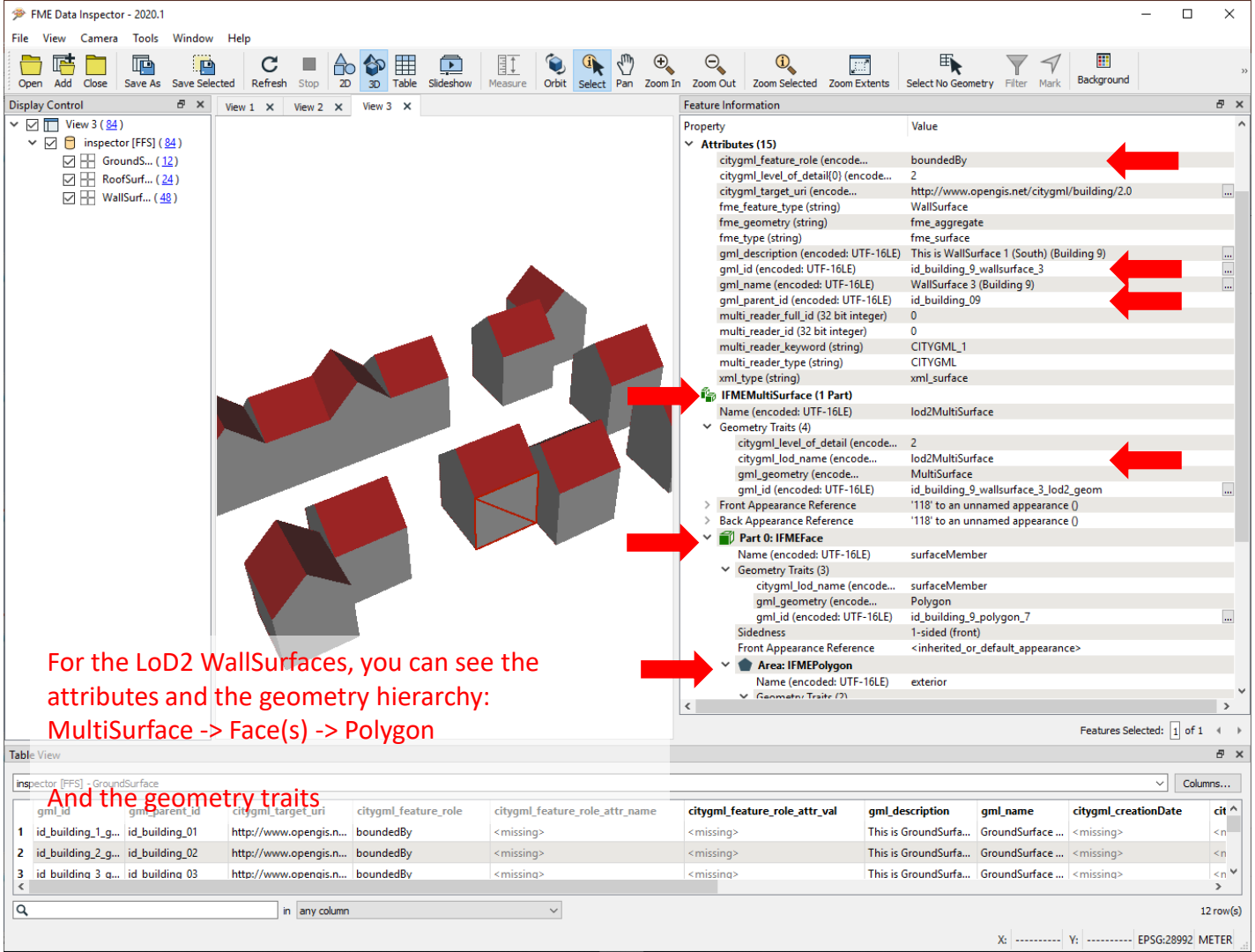

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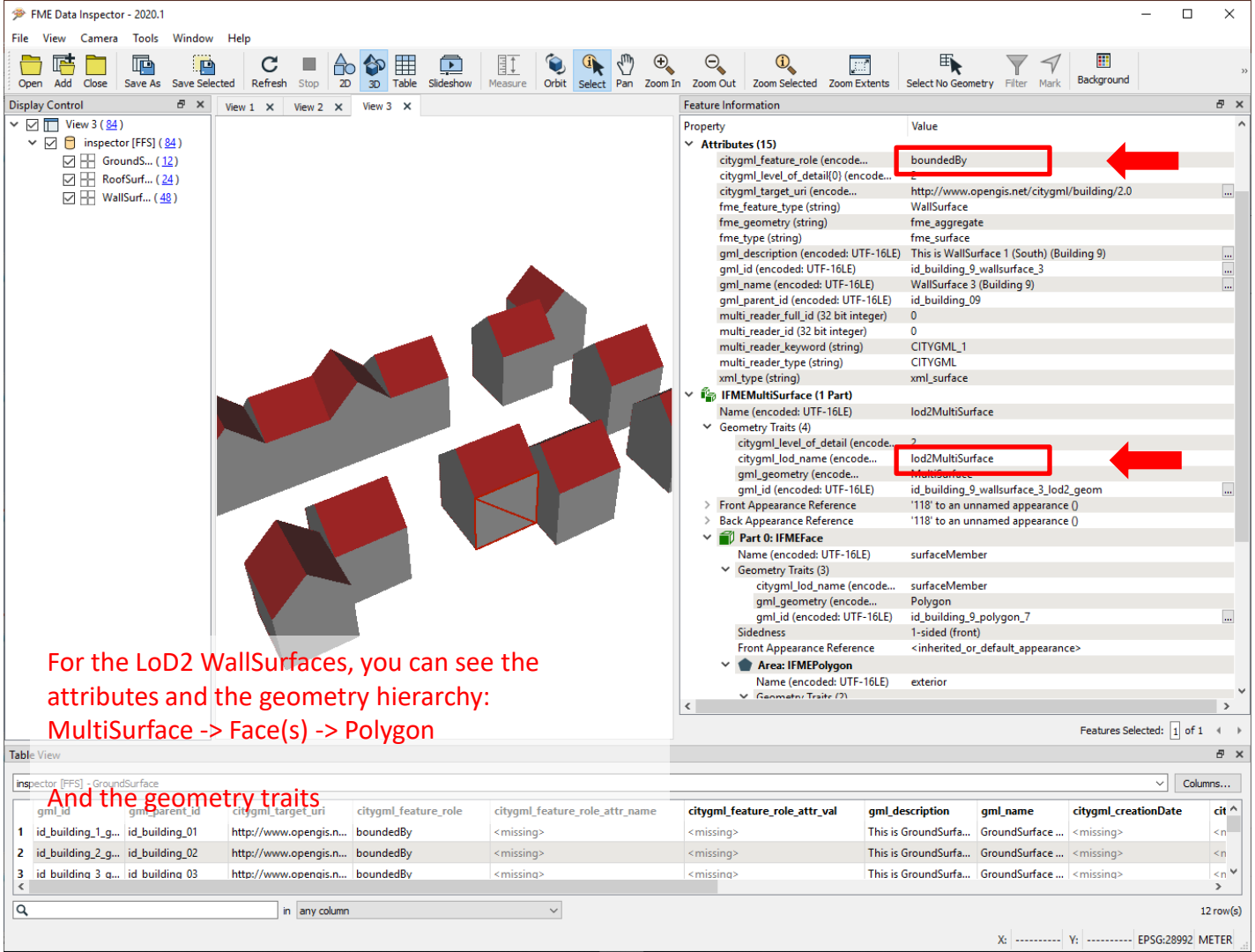

For the LoD2 WallSurfaces, you can see the attributes and the geometry hierarchy: MultiSurface -> Face(s) -> Polygon

And the geometry traits

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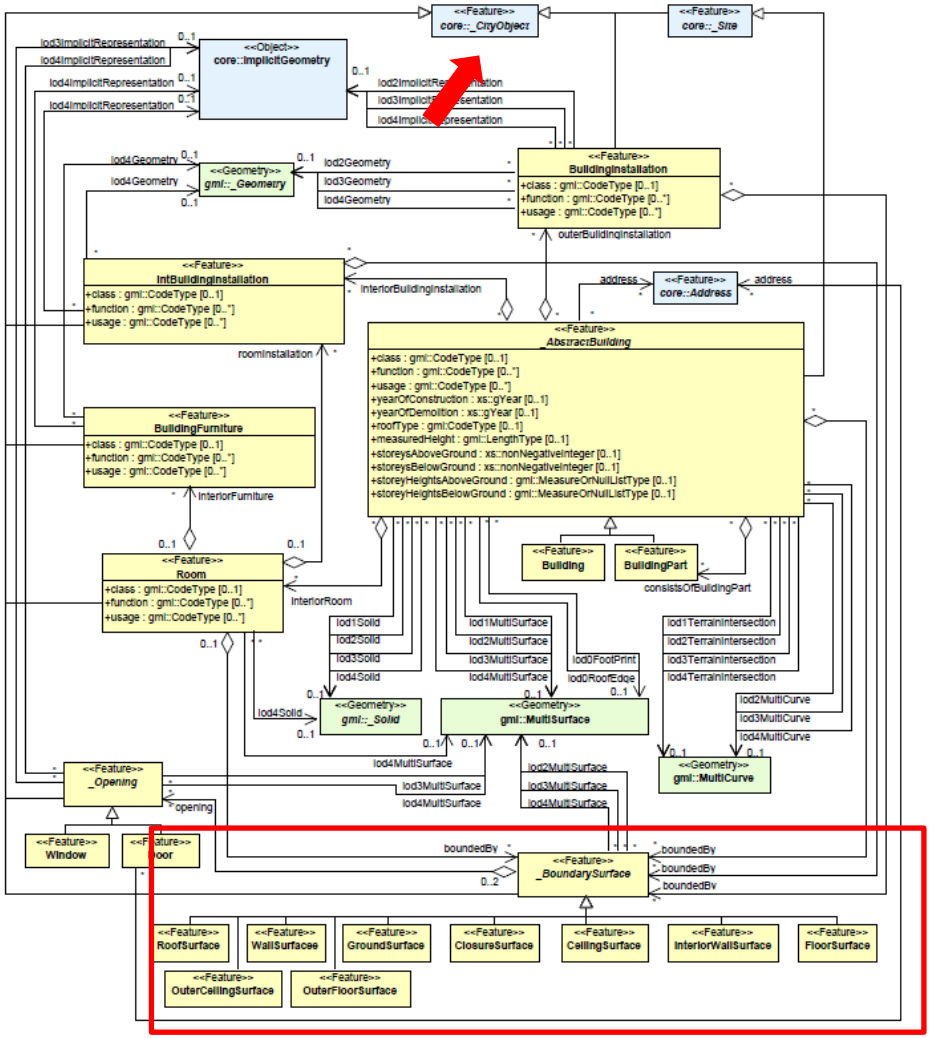

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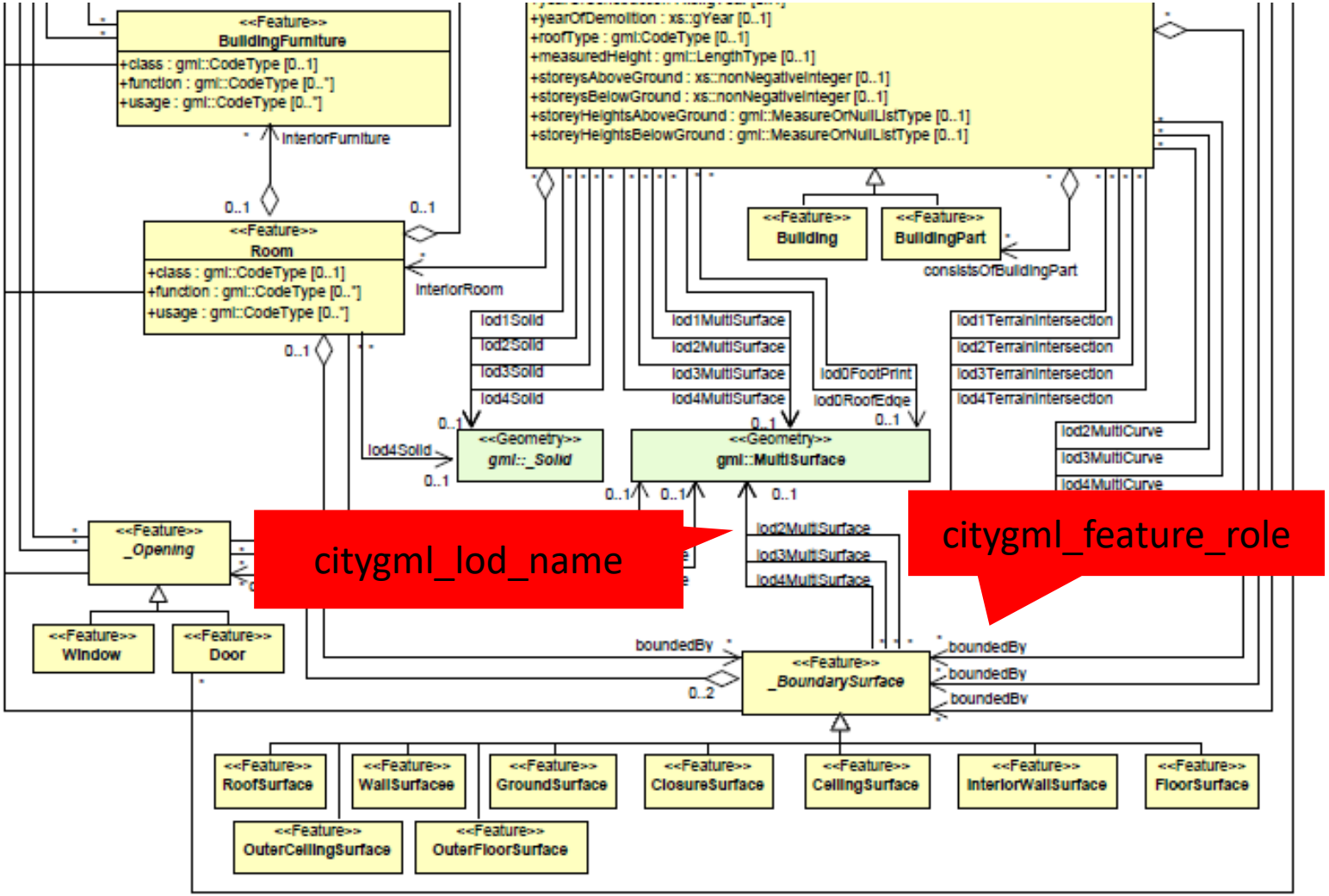

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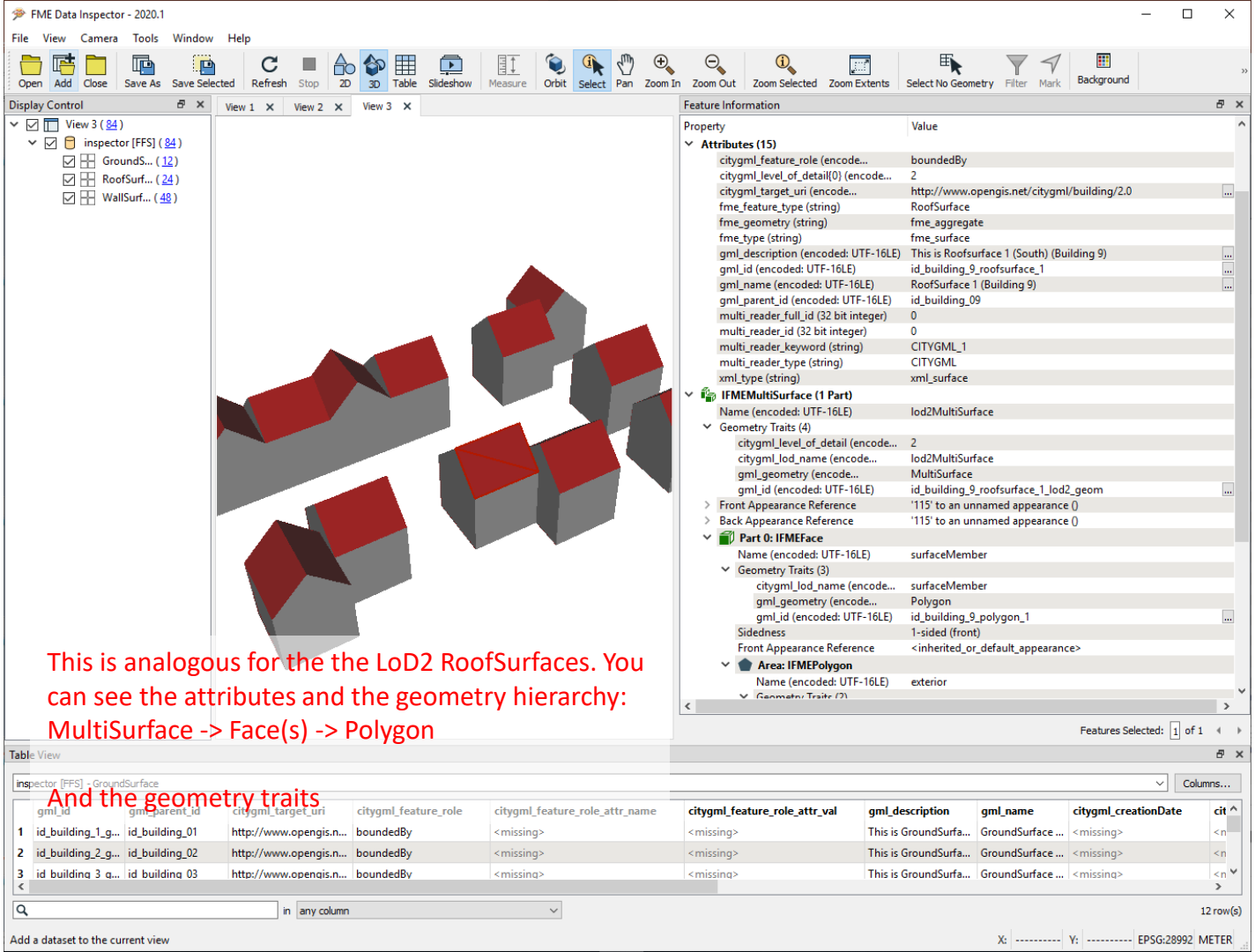

This is analogous for the the LoD2 RoofSurfaces. You can see the attributes and the geometry hierarchy: MultiSurface -> Face(s) -> Polygon

And the geometry traits

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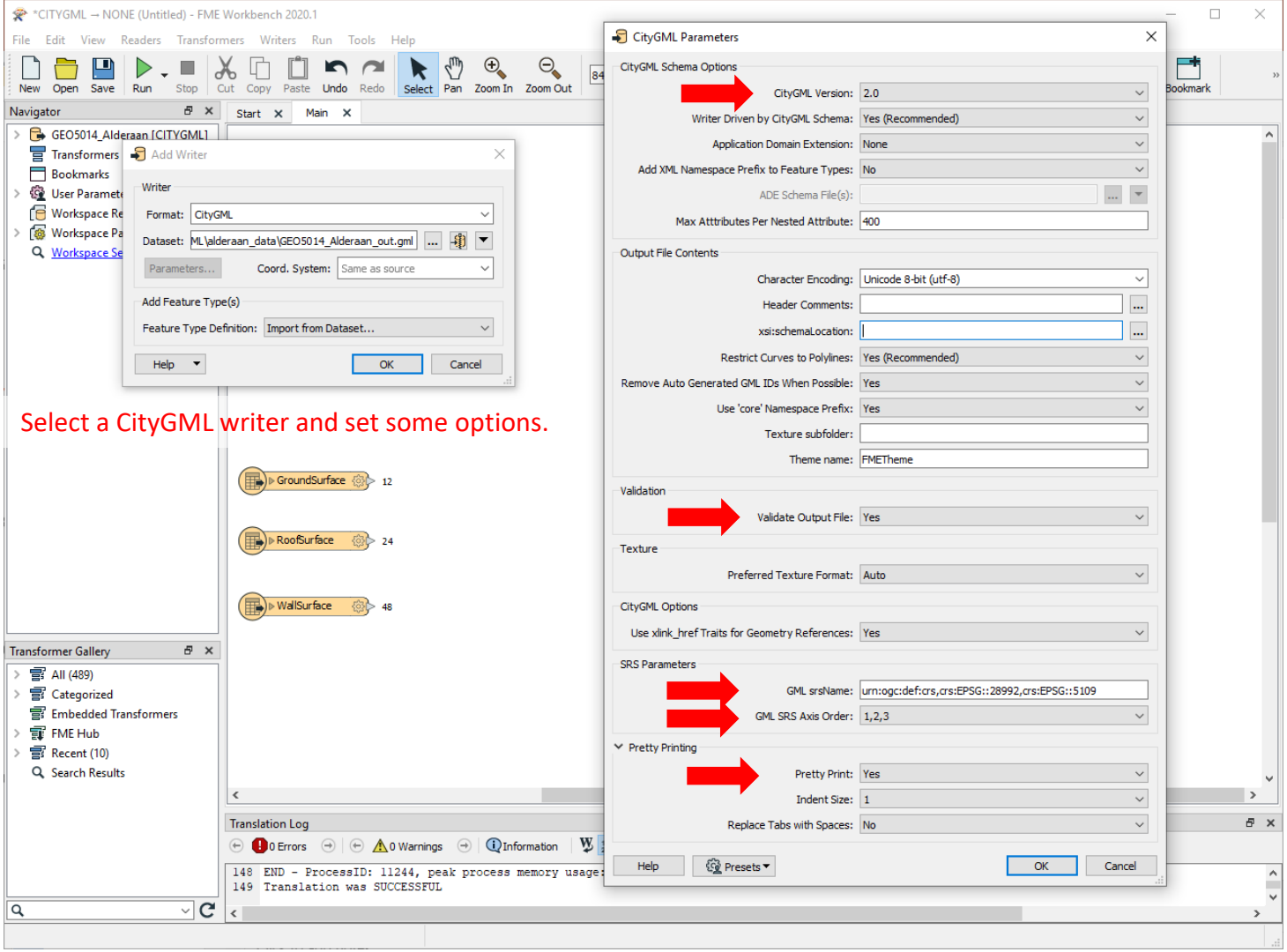

CityGML writer

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- **Suggestion:** turn output validation ON (at least at the beginning!)
- **GML srsName** is composed of information regarding the horizontal AND the vertical datum (we are dealing with 3D data)
  - urn:ogc:def:crs,crs:EPSG::28992,crs:EPSG::5109

Horizontal datum
Amersfort / RD New
https://epsg.io/28992

Vertical datum
Normaal Amsterdams Peil
https://epsg.io/5109-datum

- **Pretty print** allows you to write nicely indented XML using tab spaces
  - **Suggestion:** turn it on!

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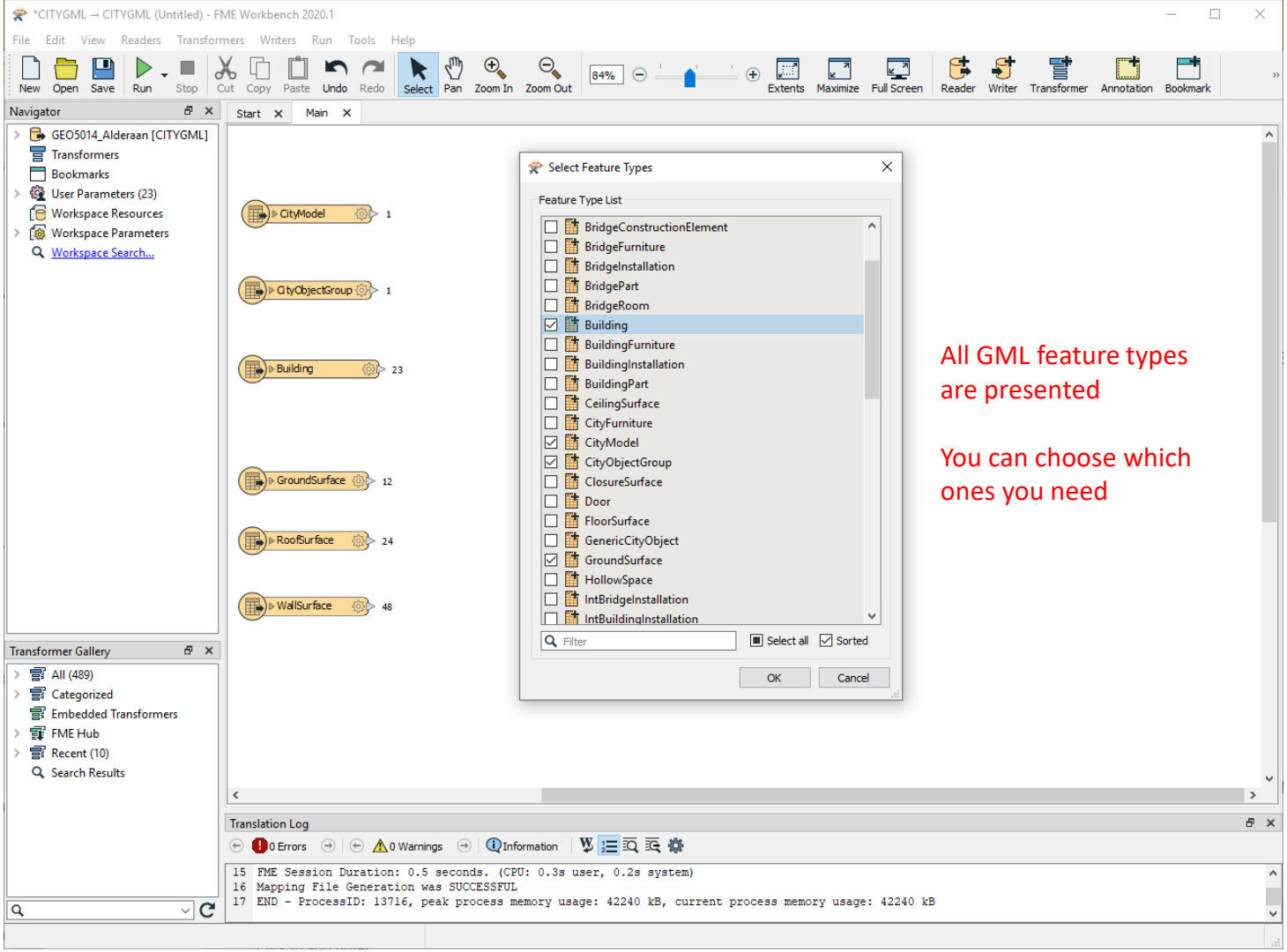

All GML feature types are presented

You can choose which ones you need

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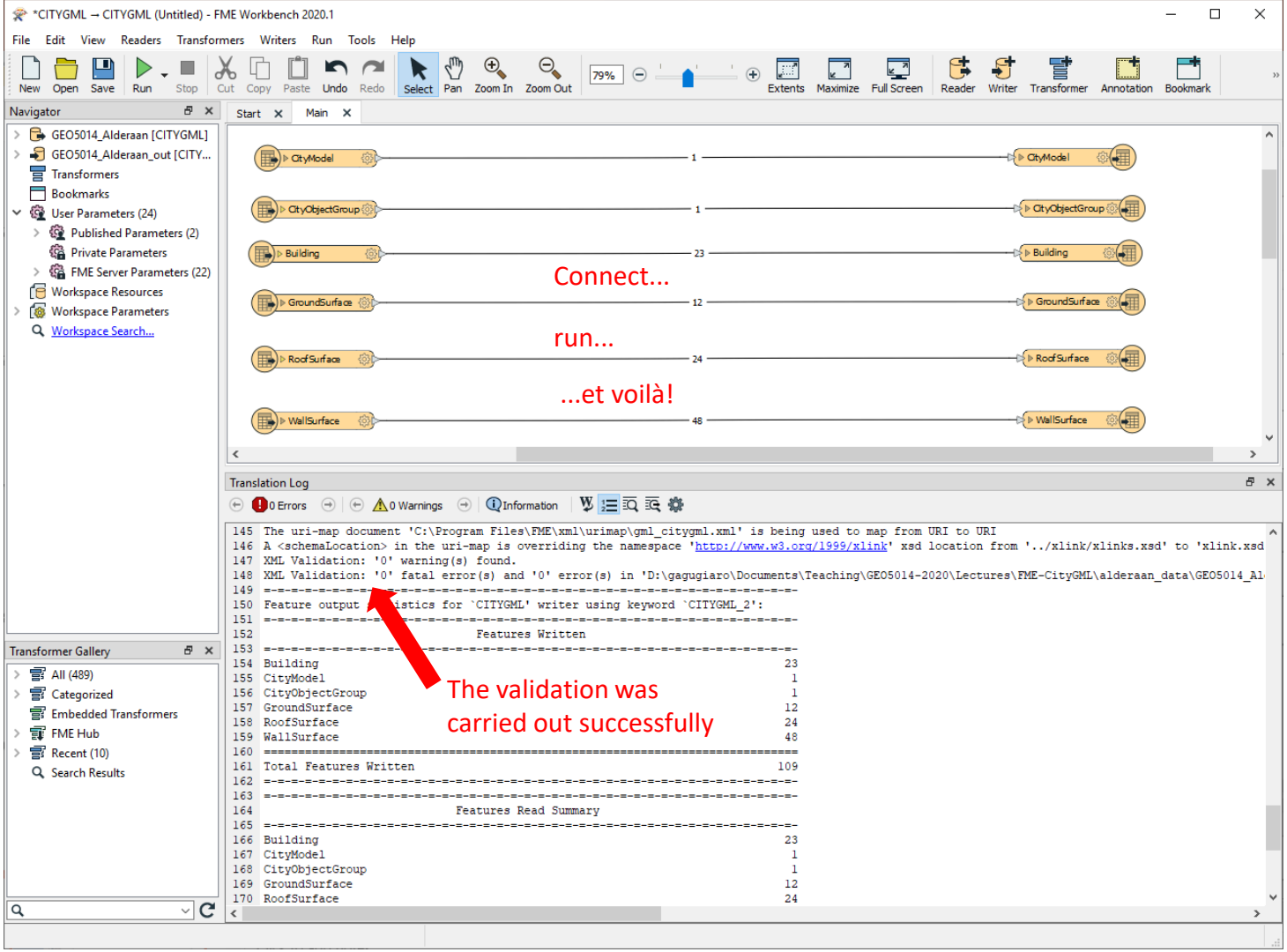

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D:\gagugiaro\Documents\Teaching\GEO5014-2020\Lectures\FME-CityGML\alderaan_data\GEO5014_Alderaan_out.gml - Notepad++

OUTPUT

File Edit Search View Encoding Language Settings Tools Macro Run Plugins Window ?

GEO5014_Alderaan_out.gml | GEO5014_Alderaan.gml

```
    <core:cityObjectMember>
        <bldg:Building gml:id="id_building_01">
            <gml:description>This is Building 1</gml:description>
            <gml:name>Snoke's Palace</gml:name>
            <core:creationDate>2019-11-17</core:creationDate>
            <bldg:class codeSpace="http://www.sig3d.org/codelists/standard/building/2.0/_AbstractBuilding_class.xml">habitation</bldg:class>
            <bldg:function codeSpace="http://www.sig3d.org/codelists/standard/building/2.0/_AbstractBuilding_function.xml">residential building</bldg:function>
            <bldg:yearOfConstruction>1955</bldg:yearOfConstruction>
            <bldg:roofType codeSpace="http://www.sig3d.org/codelists/standard/building/2.0/_AbstractBuilding_roofType.xml">gabled roof</bldg:roofType>
            <bldg:measuredHeight uom="m">15</bldg:measuredHeight>
            <bldg:storeysAboveGround>3</bldg:storeysAboveGround>
            <bldg:storeysBelowGround>0</bldg:storeysBelowGround>
            <bldg:storeyHeightsAboveGround uom="m">3</bldg:storeyHeightsAboveGround>
            <bldg:lod0FootPrint>
                <gml:MultiSurface gml:id="id_building_1_footprint_multisurf_1" srsName="urn:ogc:def:crs,crs:EPSG::28992,crs:EPSG::5109" srsDimension="3">
                    <gml:surfaceMember>
                        <gml:OrientableSurface orientation="-">
                            <gml:baseSurface xlink:href="#id_building_1_polygon_3"/>
                        </gml:OrientableSurface>
                    </gml:surfaceMember>
                </gml:MultiSurface>
            </bldg:lod0FootPrint>
            <bldg:lod1Solid>
                <gml:Solid gml:id="id_building_01_lod1_Solid_1" srsName="urn:ogc:def:crs,crs:EPSG::28992,crs:EPSG::5109" srsDimension="3">
                    <gml:exterior>
                        <gml:CompositeSurface gml:id="id_building_01_lod1_CompSurf_1">
                            <gml:surfaceMember>
                                <gml:Polygon gml:id="id_building_01_lod1_Polygon_1">
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                                    <gml:exterior>
                                        <gml:LinearRing>
                                            <gml:posList>0 0 0 10 0 0 10 0 12.5 0 0 12.5 0 0 0</gml:posList>
                                        </gml:LinearRing>
                                    </gml:exterior>
                                </gml:Polygon>
                            </gml:surfaceMember>
                            <gml:surfaceMember>
                                <gml:Polygon gml:id="id_building_01_lod1_Polygon_3">
                                    <gml:exterior>
```

eXtensible Markup Language file | length : 150,843 lines : 3,576 | Ln : 1 Col : 1 Sel : 0 | 0 | Unix (LF) | UTF-8 | INS

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D:\gagugiaro\Documents\Teaching\GEO5014-2020\Lectures\FME-CityGML\alderaan_data\GEO5014_Alderaan.gml - Notepad++

INPUT

File Edit Search View Encoding Language Settings Tools Macro Run Plugins Window ?

GEO5014_Alderaan_out.gml | GEO5014_Alderaan.gml

```
    <core:cityObjectMember>
        <bldg:Building gml:id="id_building_01">
            <gml:description>This is Building 1</gml:description>
            <gml:name>Snoke's Palace</gml:name>
            <core:creationDate>2019-11-17</core:creationDate>
            <!-- This is an exemplary set of generic attributes attached to a Building BEGIN -->
            <gen:measureAttribute name="test_measure_att">
                <gen:value uom="m^2">134.45</gen:value>
            </gen:measureAttribute>
            <gen:uriAttribute name="test_uri_att">
                <gen:value>https://www.brickset.com</gen:value>
            </gen:uriAttribute>
            <gen:intAttribute name="test_integer_att">
                <gen:value>12</gen:value>
            </gen:intAttribute>
            <gen:doubleAttribute name="test_real_att">
                <gen:value>12.34</gen:value>
            </gen:doubleAttribute>
            <gen:dateAttribute name="test_date_att">
                <gen:value>2020-08-06</gen:value>
            </gen:dateAttribute>
            <gen:stringAttribute name="test_string_att">
                <gen:value>This is a test string</gen:value>
            </gen:stringAttribute>
            <!-- This is an exemplary set of generic attributes attached to a Building END -->
            <bldg:class codeSpace="http://www.sig3d.org/codelists/standard/building/2.0/_AbstractBuilding_class.xml">habitation</bldg:class>
            <bldg:function codeSpace="http://www.sig3d.org/codelists/standard/building/2.0/_AbstractBuilding_function.xml">residential building</bldg:function>
            <bldg:yearOfConstruction>1955</bldg:yearOfConstruction>
            <bldg:roofType codeSpace="http://www.sig3d.org/codelists/standard/building/2.0/_AbstractBuilding_roofType.xml">gabled roof</bldg:roofType>
            <bldg:measuredHeight uom="m">15</bldg:measuredHeight>
            <bldg:storeysAboveGround>3</bldg:storeysAboveGround>
            <bldg:storeysBelowGround>0</bldg:storeysBelowGround>
            <bldg:storeyHeightsAboveGround uom="m">3</bldg:storeyHeightsAboveGround>
            <bldg:lod0FootPrint>
                <gml:MultiSurface gml:id="id_building_1_footprint_multisurf_1" srsName="urn:ogc:def:crs,crs:EPSG::28992,crs:EPSG::5109" srsDimension="3">
                    <gml:surfaceMember>
                        <!-- Please not that the geometry is referenced by means of an Xlink and its orientation is reversed
                             It is referencing the polygon contained in the LoD2 GroundSurface -->
                        <gml:OrientableSurface orientation="-">
                            <gml:baseSurface xlink:href="#id_building_1_polygon_3"/>
                        </gml:OrientableSurface>
                    </gml:surfaceMember>
                </gml:MultiSurface>
            </bldg:lod0FootPrint>
            <bldg:lod1Solid>
                <gml:Solid gml:id="id_building_01_lod1_Solid_1" srsName="urn:ogc:def:crs,crs:EPSG::28992,crs:EPSG::5109" srsDimension="3">
                    <gml:exterior>
```

eXtensible Markup Language file | length : 182,113 lines : 4,102 | Ln : 116 Col : 37 Sel : 0 | 0 | Windows (CR LF) | UTF-8 | INS

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D:\gagugiaro\Documents\Teaching\GEO5014-2020\Lectures\FME-CityGML\alderaan_data\GEO5014_Alderaan.gml - Notepad++

INPUT

File Edit Search View Encoding Language Settings Tools Macro Run Plugins Window ?

GEO5014_Alderaan_out.gml | GEO5014_Alderaan.gml

```
    <core:cityObjectMember>
        <bldg:Building gml:id="id_building_01">
            <gml:description>This is Building 1</gml:description>
            <gml:name>Snoke's Palace</gml:name>
            <core:creationDate>2019-11-17</core:creationDate>
            <!-- This is an exemplary set of generic attributes attached to a Building BEGIN -->
            <gen:measureAttribute name="test_measure_att">
                <gen:value uom="m^2">134.45</gen:value>
            </gen:measureAttribute>
            <gen:uriAttribute name="test_uri_att">
                <gen:value>https://www.brickset.com</gen:value>
            </gen:uriAttribute>
            <gen:intAttribute name="test_integer_att">
                <gen:value>12</gen:value>
            </gen:intAttribute>
            <gen:doubleAttribute name="test_real_att">
                <gen:value>12.34</gen:value>
            </gen:doubleAttribute>
            <gen:dateAttribute name="test_date_att">
                <gen:value>2020-08-06</gen:value>
            </gen:dateAttribute>
            <gen:stringAttribute name="test_string_att">
                <gen:value>This is a test string</gen:value>
            </gen:stringAttribute>
            <!-- This is an exemplary set of generic attributes attached to a Building END -->
            <bldg:class codeSpace="http://www.sig3d.org/codelists/standard/building/2.0/_AbstractBuilding_class.xml">habitation</bldg:class>
            <bldg:function codeSpace="http://www.sig3d.org/codelists/standard/building/2.0/_AbstractBuilding_function.xml">residential building</bldg:function>
            <bldg:yearOfConstruction>1955</bldg:yearOfConstruction>
            <bldg:roofType codeSpace="http://www.sig3d.org/codelists/standard/building/2.0/_AbstractBuilding_roofType.xml">gabled roof</bldg:roofType>
            <bldg:measuredHeight uom="m">15</bldg:measuredHeight>
            <bldg:storeysAboveGround>3</bldg:storeysAboveGround>
            <bldg:storeysBelowGround>0</bldg:storeysBelowGround>
            <bldg:storeyHeightsAboveGround uom="m">3</bldg:storeyHeightsAboveGround>
            <bldg:lod0FootPrint>
                <gml:MultiSurface gml:id="id_building_1_footprint_multisurf_1" srsName="urn:ogc:def:crs,crs:EPSG::28992,crs:EPSG::5109" srsDimension="3">
                    <gml:surfaceMember>
                        <!-- Please not that the geometry is referenced by means of an Xlink and its orientation is reversed
                             It is referencing the polygon contained in the LoD2 GroundSurface -->
                        <gml:OrientableSurface orientation="-">
                            <gml:baseSurface xlink:href="#id_building_1_polygon_3"/>
                        </gml:OrientableSurface>
                    </gml:surfaceMember>
                </gml:MultiSurface>
            </bldg:lod0FootPrint>
            <bldg:lod1Solid>
                <gml:Solid gml:id="id_building_01_lod1_Solid_1" srsName="urn:ogc:def:crs,crs:EPSG::28992,crs:EPSG::5109" srsDimension="3">
                    <gml:exterior>
```

Literally... *lost in translation*!

The generic attributes have not been written to the new file

eXtensible Markup Language file | length : 182,113 lines : 4,102 | Ln : 116 Col : 37 Sel : 0 | 0 | Windows (CR LF) | UTF-8 | INS

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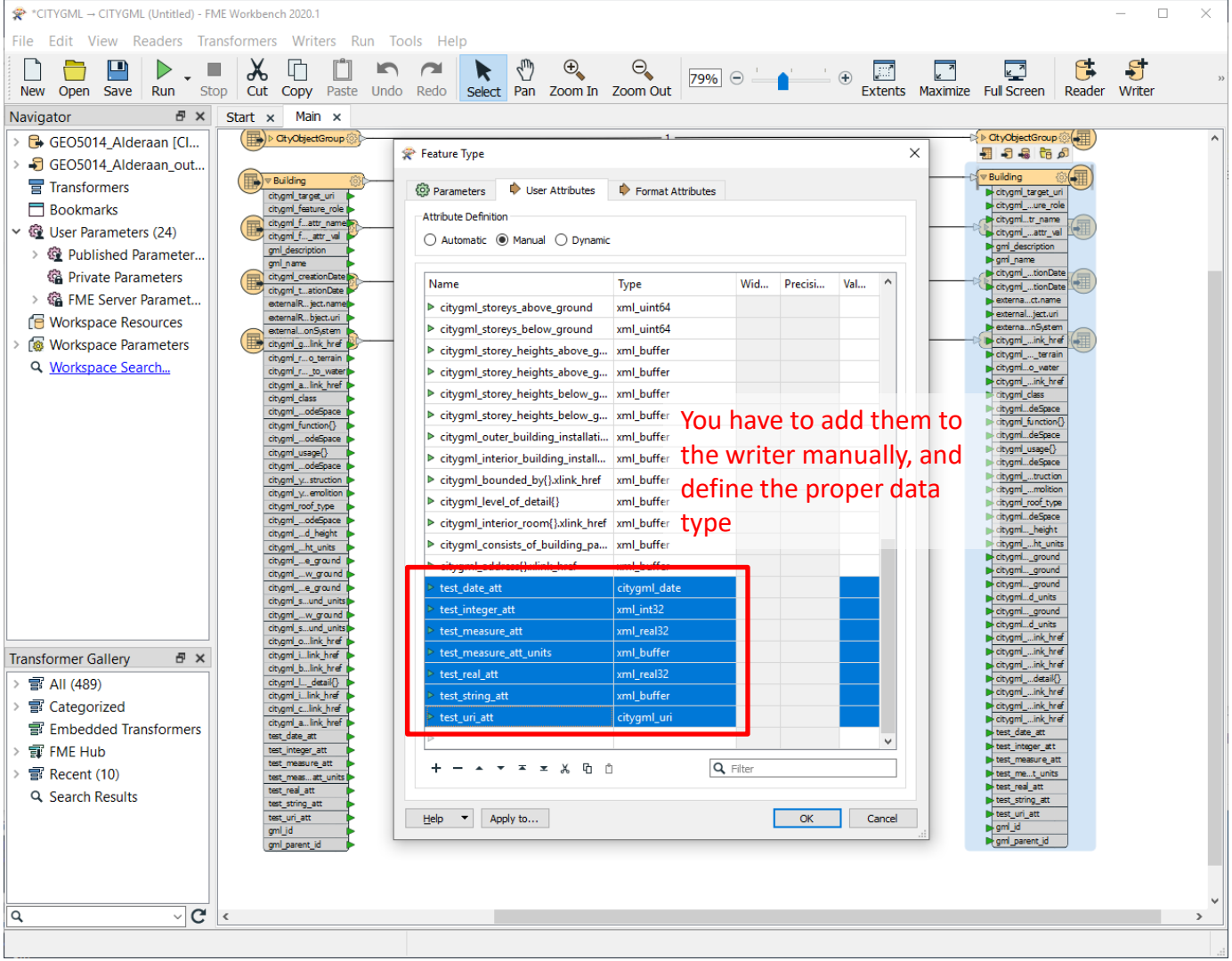

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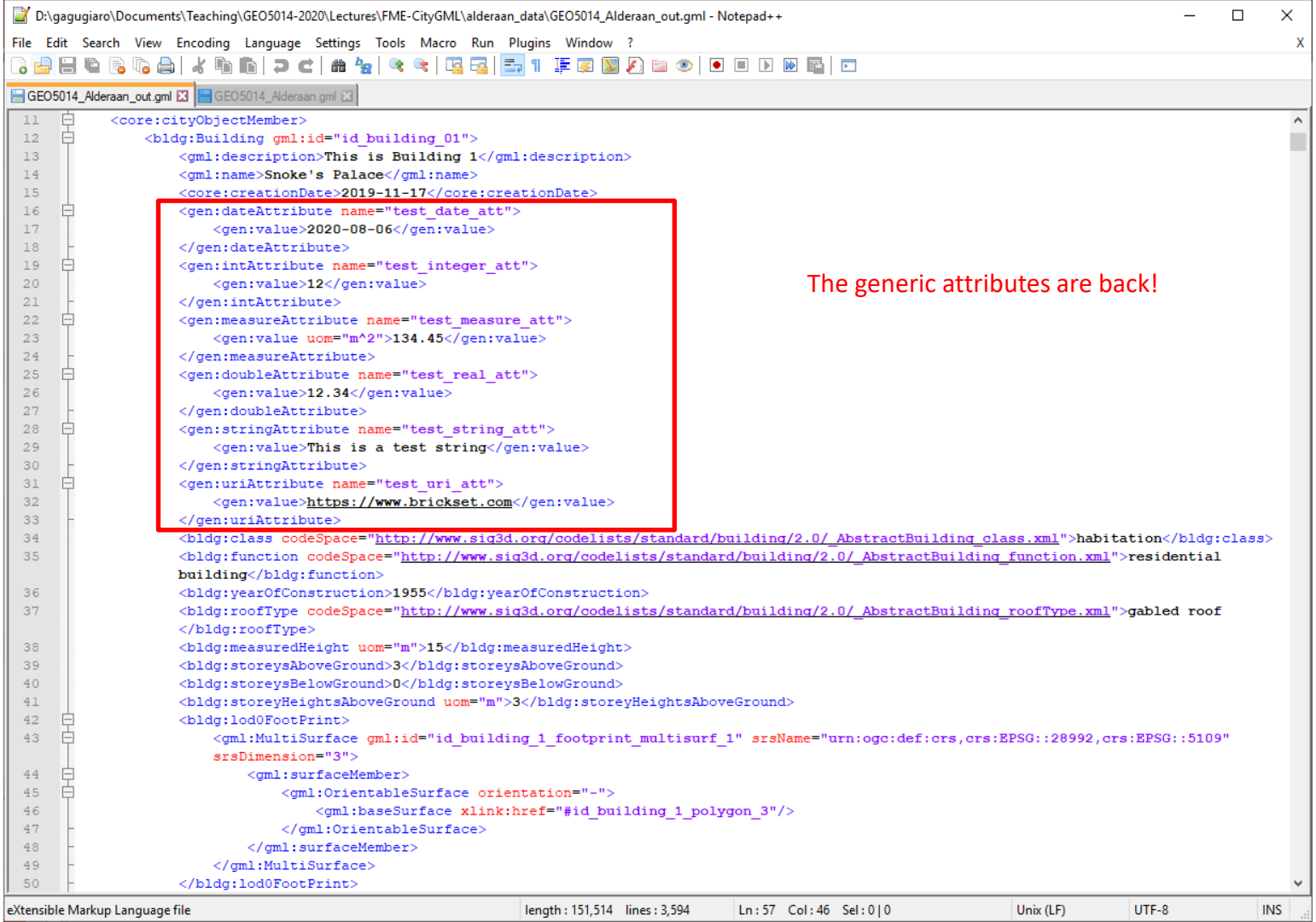

The generic attributes are back!

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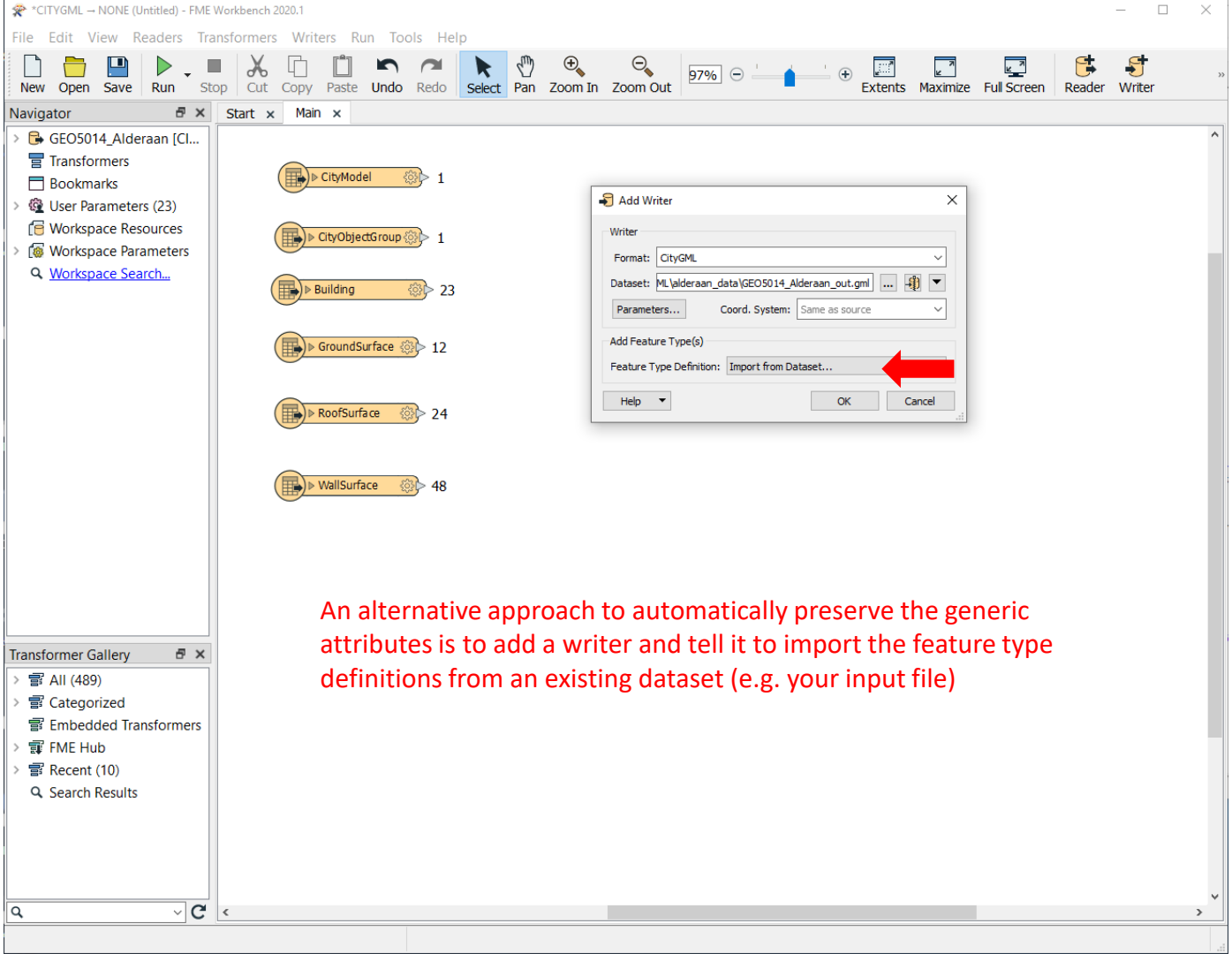

An alternative approach to automatically preserve the generic attributes is to add a writer and tell it to import the feature type definitions from an existing dataset (e.g. your input file)

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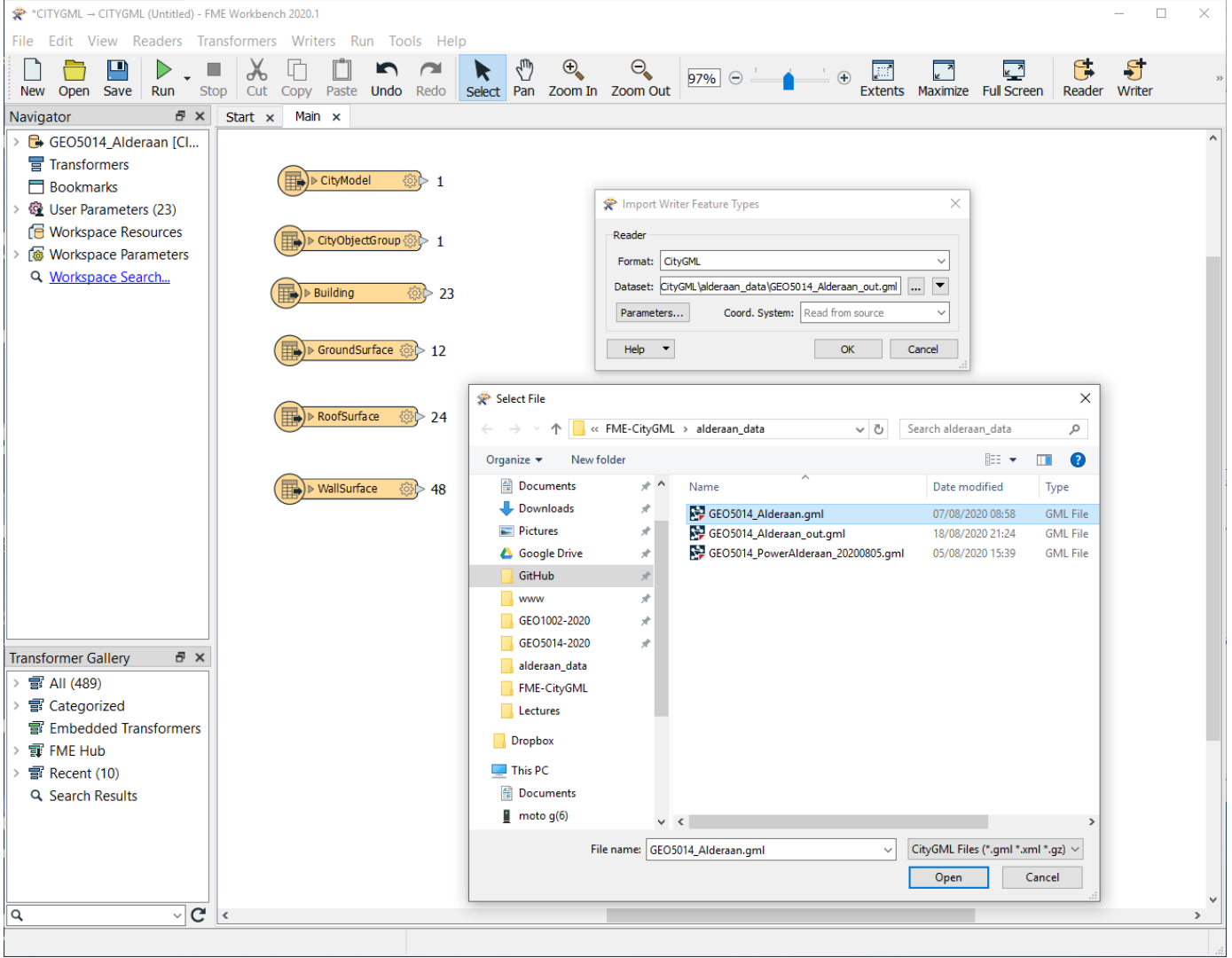

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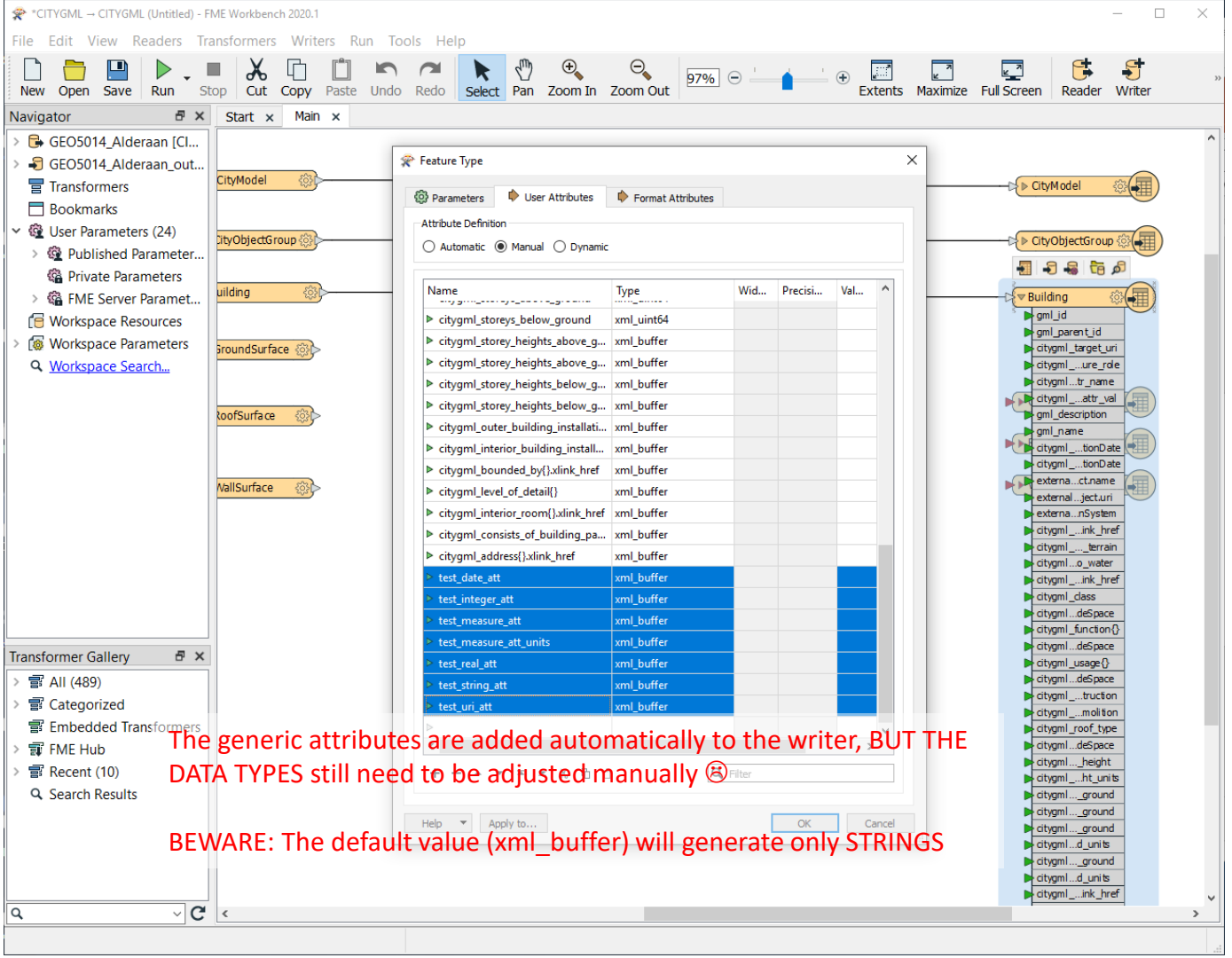

The generic attributes are added automatically to the writer, BUT THE DATA TYPES still need to be adjusted manually ☹

BEWARE: The default value (xml_buffer) will generate only STRINGS

CityGML in FME: good habits 2

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- When working with Features that have attributes and geometries, try to deal with attributes and geometries separately, and aggregate them at the very end before writing them
  - Not an official approach, just Giorgio's path to (FME) happiness ☺
- In order to separate different geometries associated to the same feature (e.g. a building), you can disaggregate and filter them, and afterwards aggregate them again
- You can extract geometry properties/traits with a **GeometryPropertyExtractor**. They will be added as normal attributes
- You can set geometry properties/traits with a **GeometryPropertySetter**. Refer to the UML diagrams to find out the exact value of the *citygml_lod_name* attribute.
- You can group transformers in order to reduce chaos in the workbench
- Do not be stingy on **GeometryValidator**s! They help "cleaning up" and correcting issues in geometries

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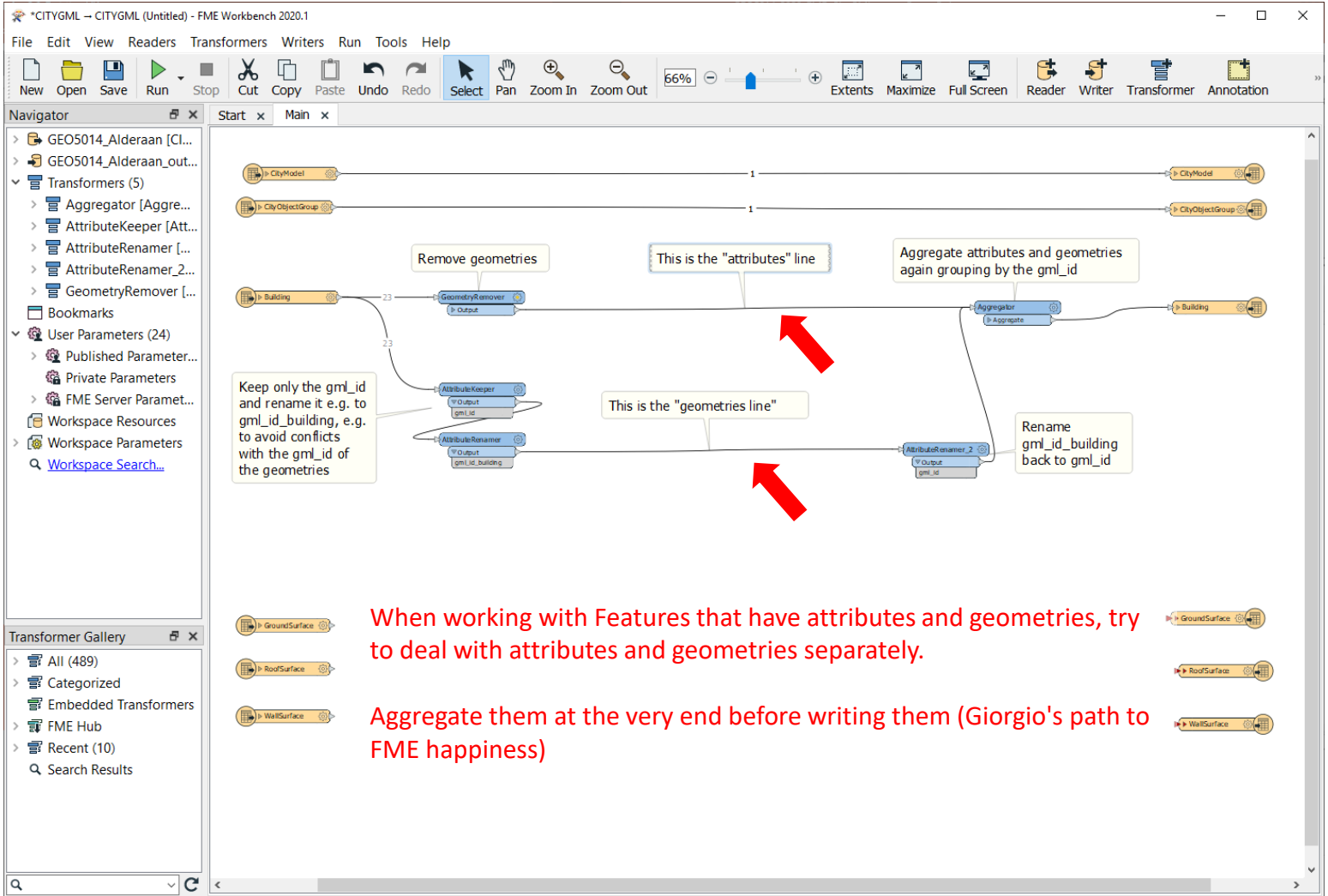

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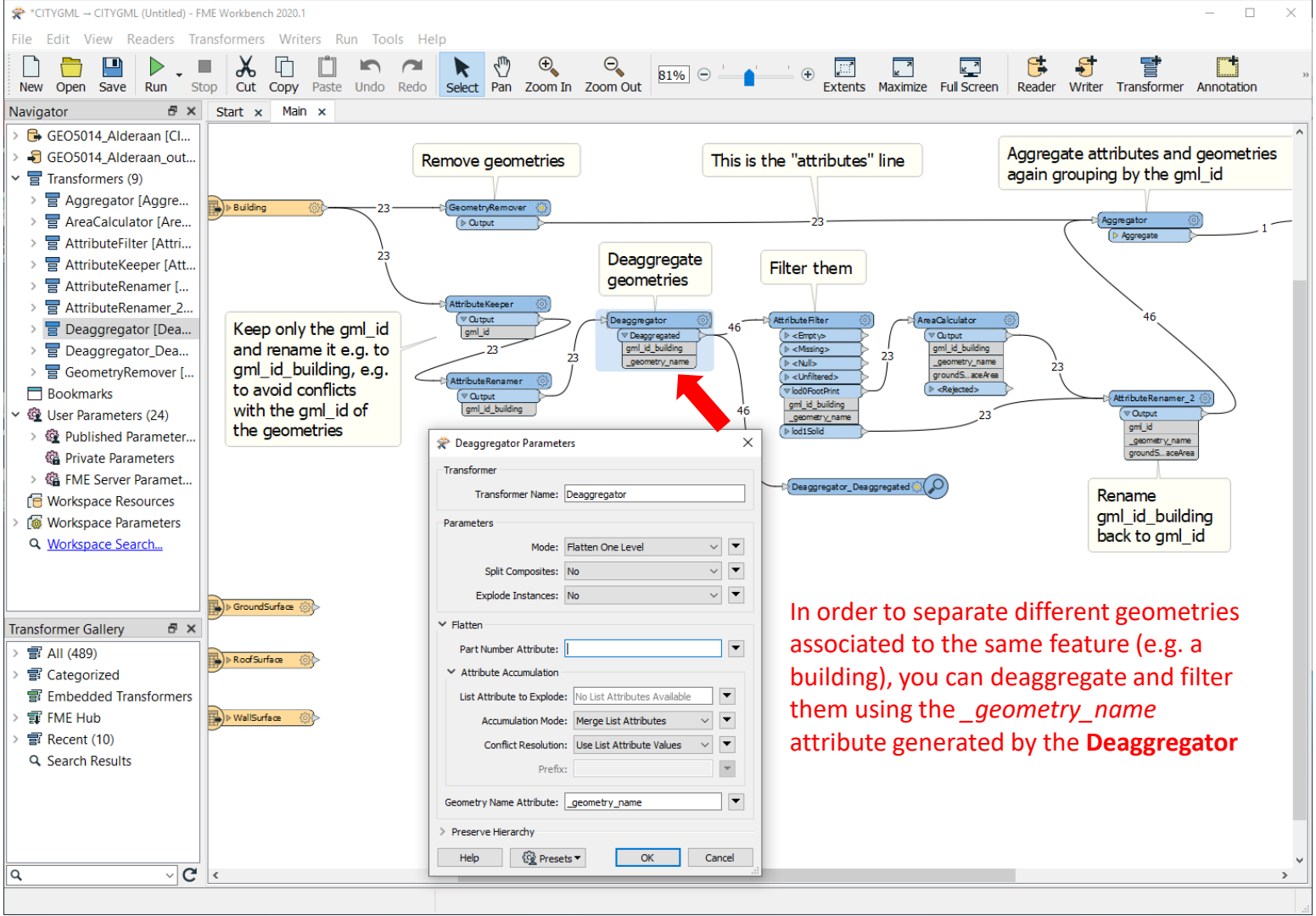

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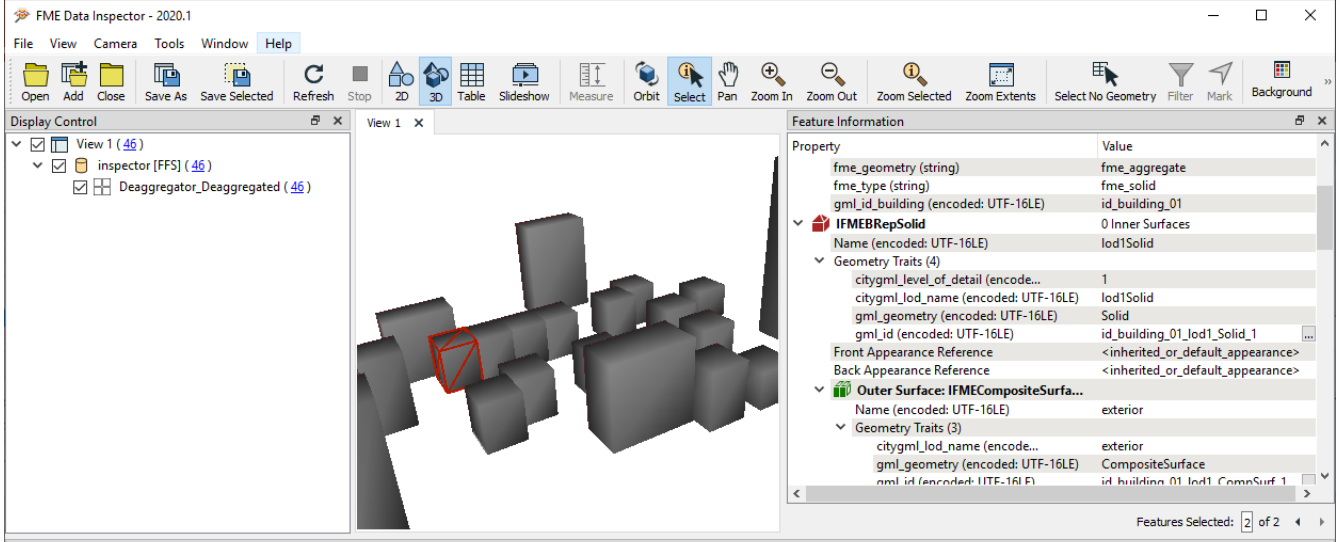

Example:
For each building, two geometries have been extracted, corresponding to the lod0Footprint and the lod1Solid

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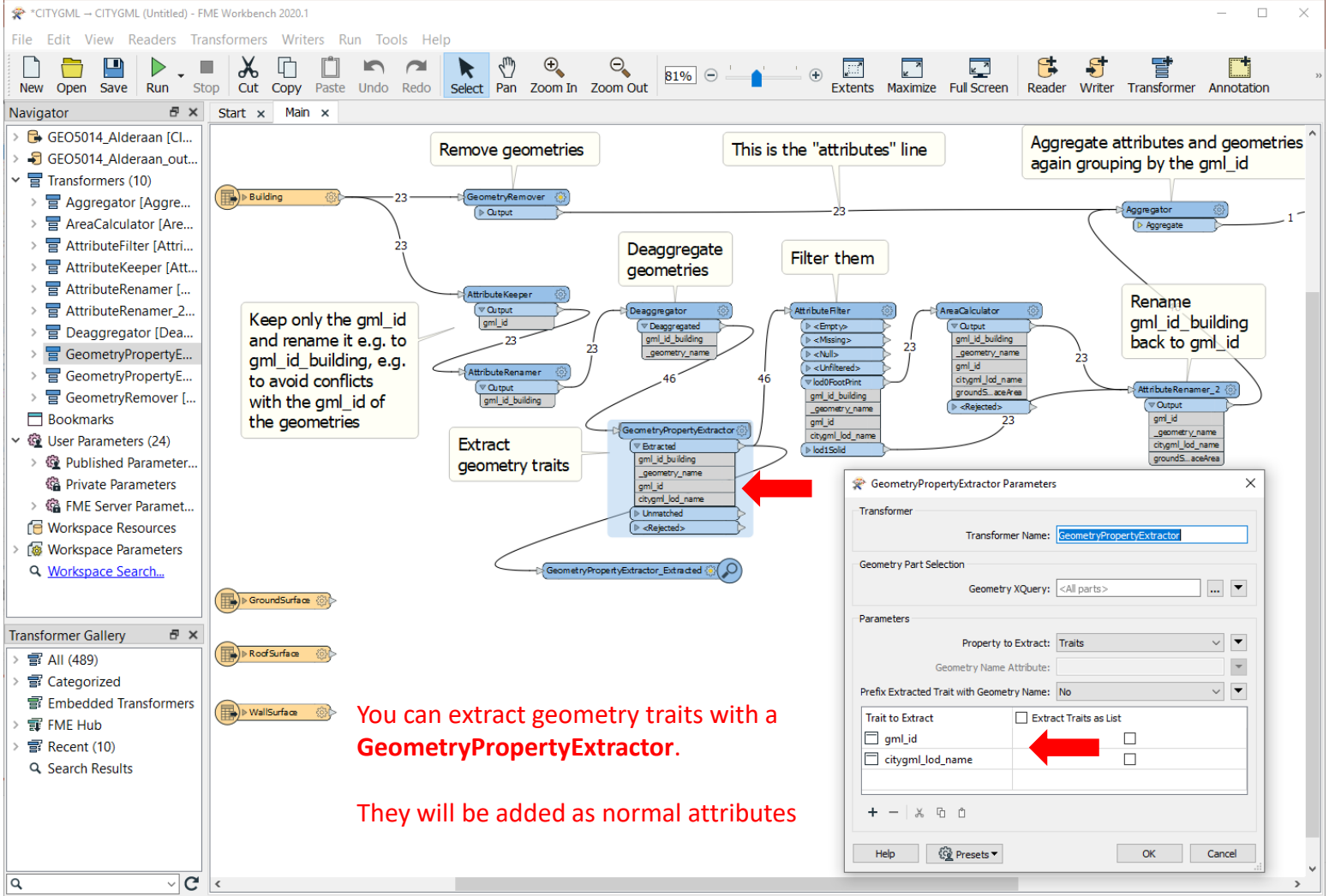

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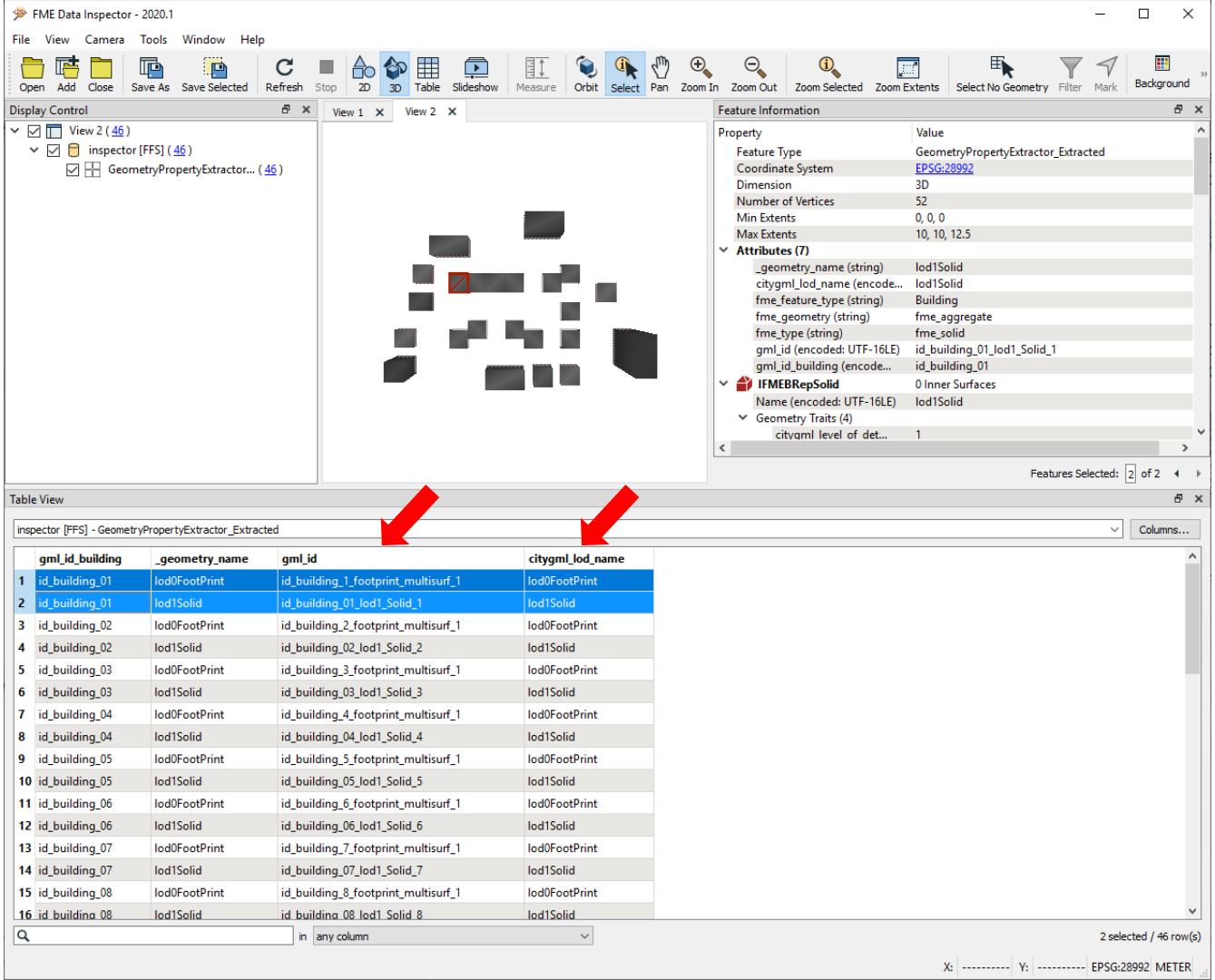

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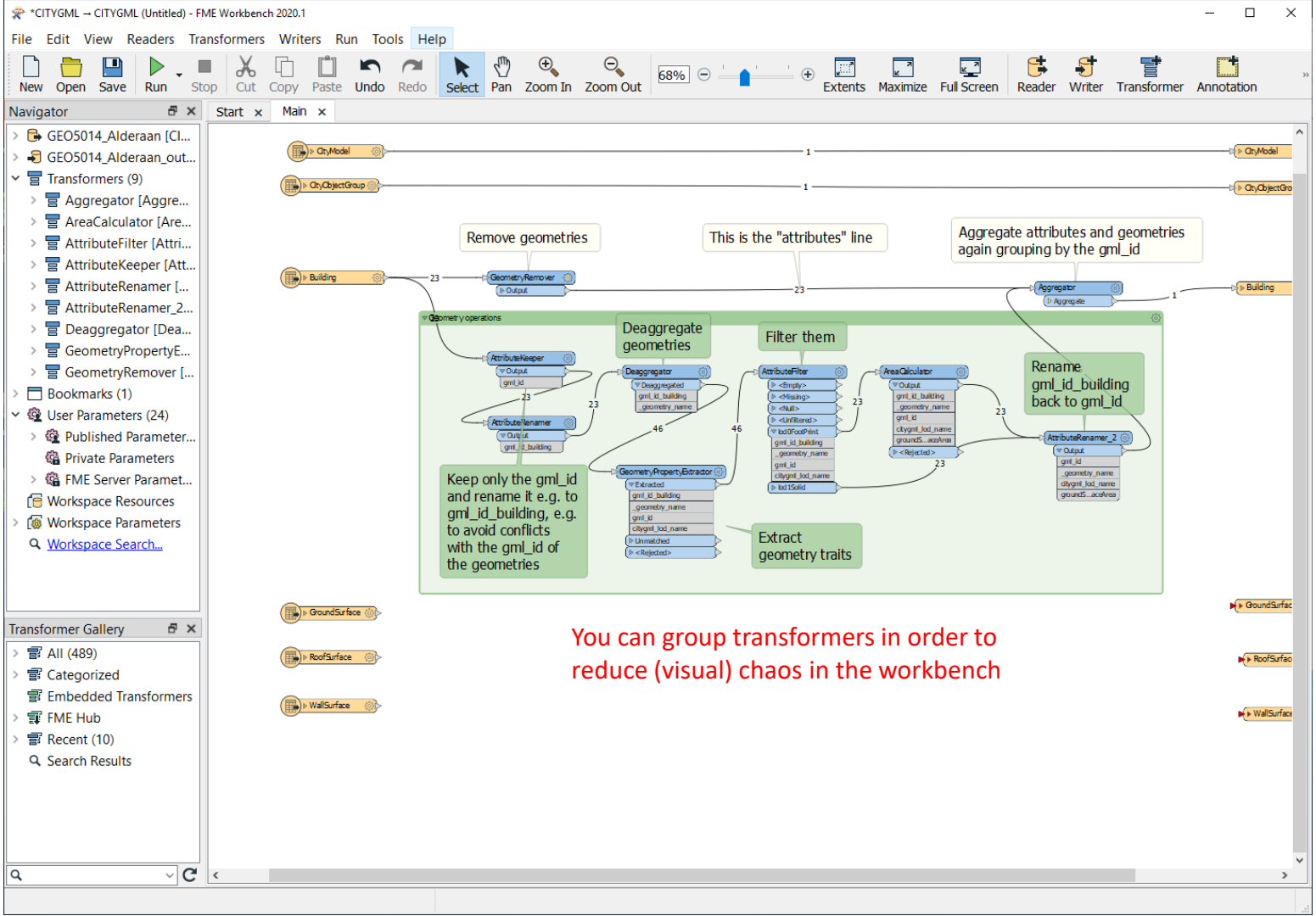

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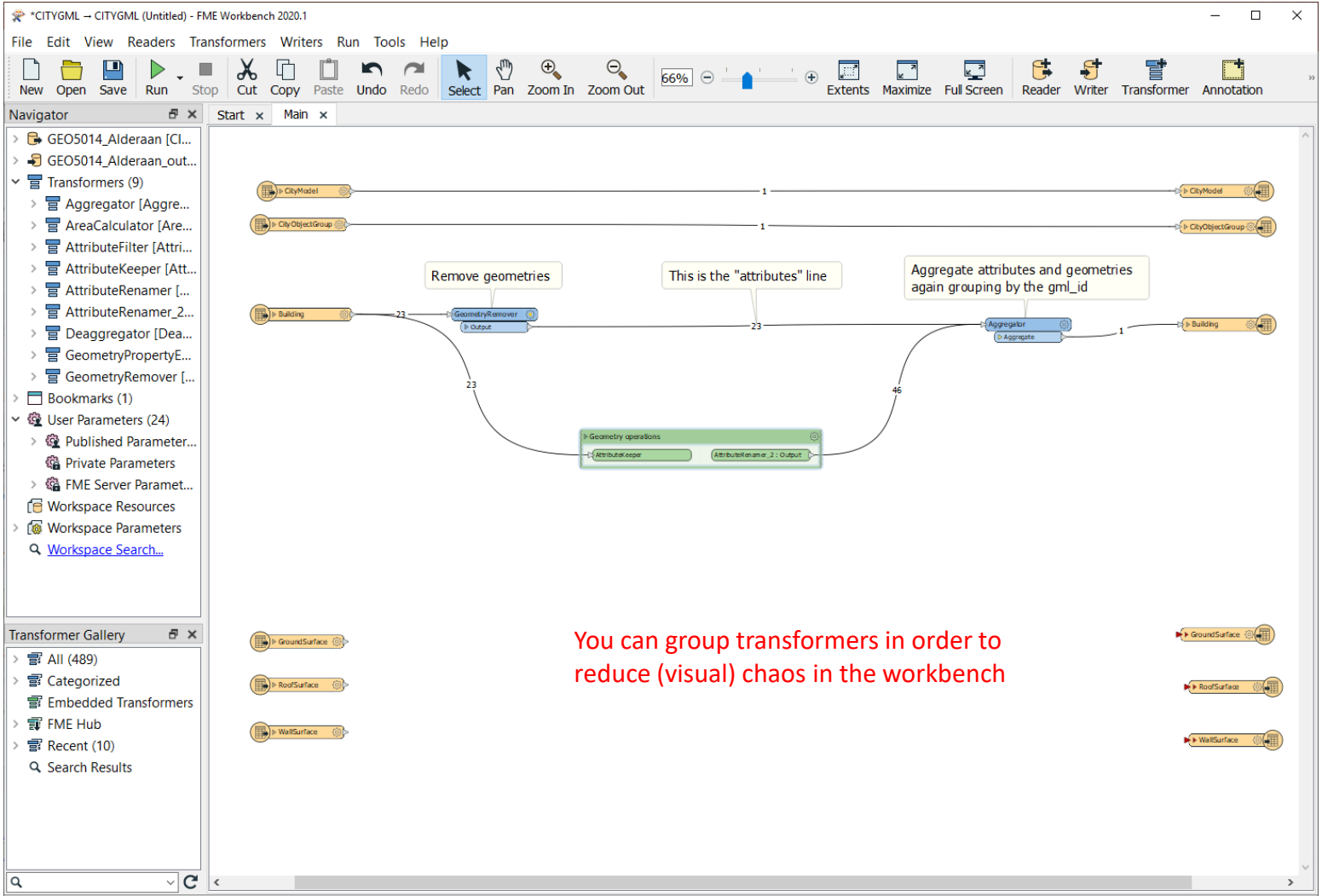

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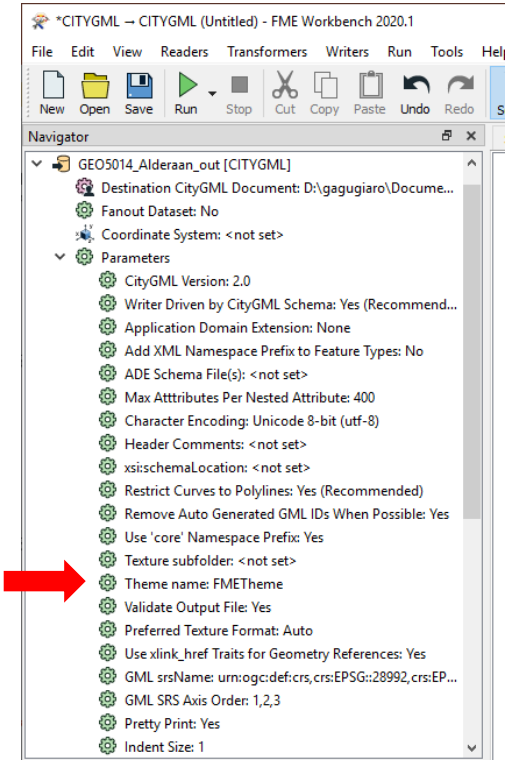
CityGML Appearances in FME

Appearances in FME

- To remove an existing appearance you use an **AppearanceRemover**, to add an appearance you use the **AppearanceSetter**; the **AppearanceStyler** gives you additional options
- If you are working with data that has no pre-existing appearance, and you want just one Appearance object, FME will take care of it automatically.
  - You can set the parameter Theme Name (default: *FMETheme*)
- If you are working with data that has one pre-existing appearance, and you want to keep it, FME will take care of it automatically
- If you are working with data that has two or more pre-existing appearances, FME will take only the first one by default. All the other will be lost, unless you "manually" load the **Appearance** and **X3DMaterial** (and/or **ParametrizedTexture** and/or **GeoreferencedTexture**) writers (see later)



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Appearances in FME

- FME generally creates global appearances by default
- Appearance, X3DMaterial, ParametrizedTexture and GeoreferencedTexture are **GML Features**! So
  - You still deal with them with *gml_id*, *parent_id*, *citygml_feature_role*, and possibly *attribute_name_xlink_href* attributes!
- Check the UML diagrams for reference

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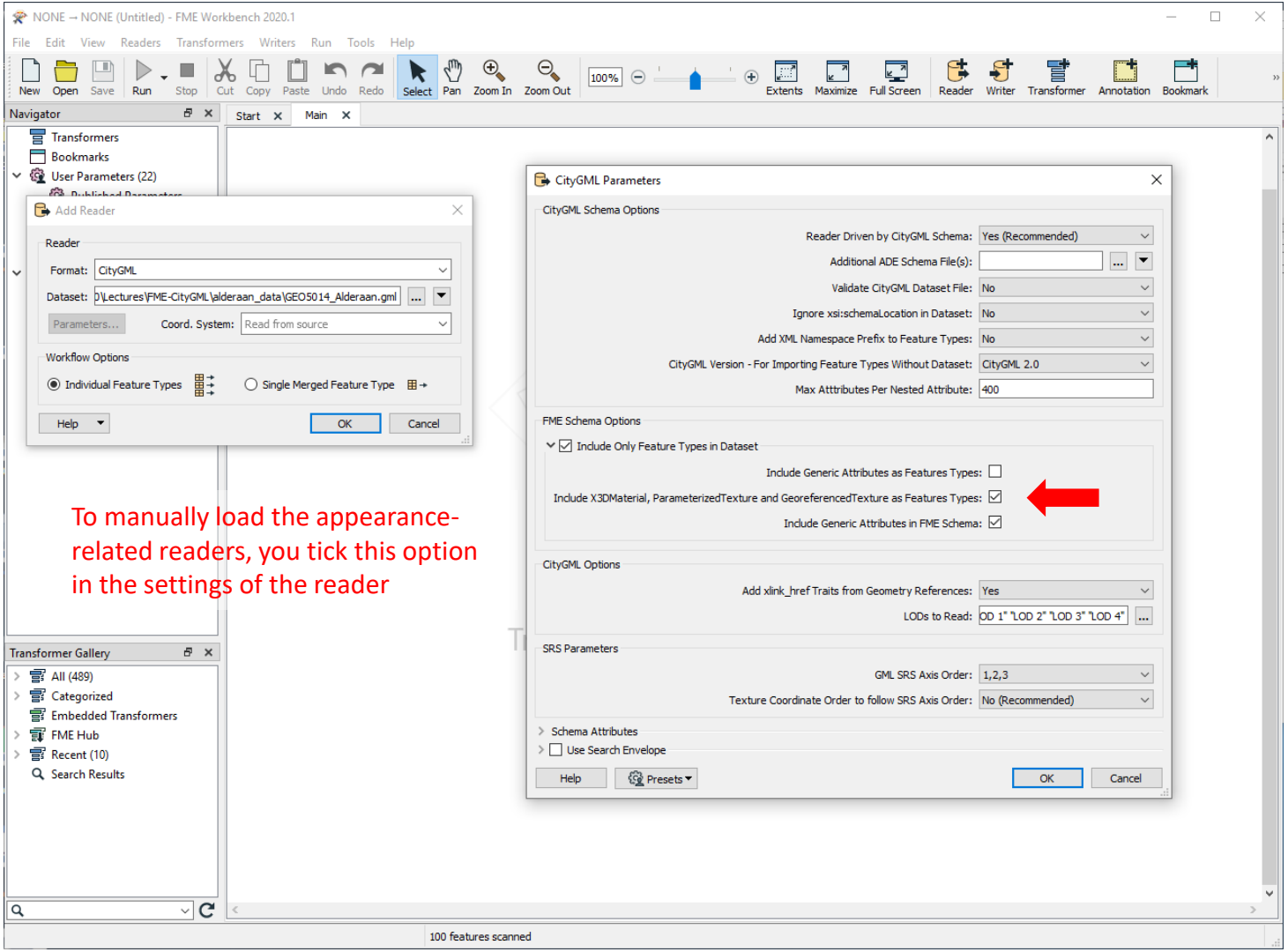

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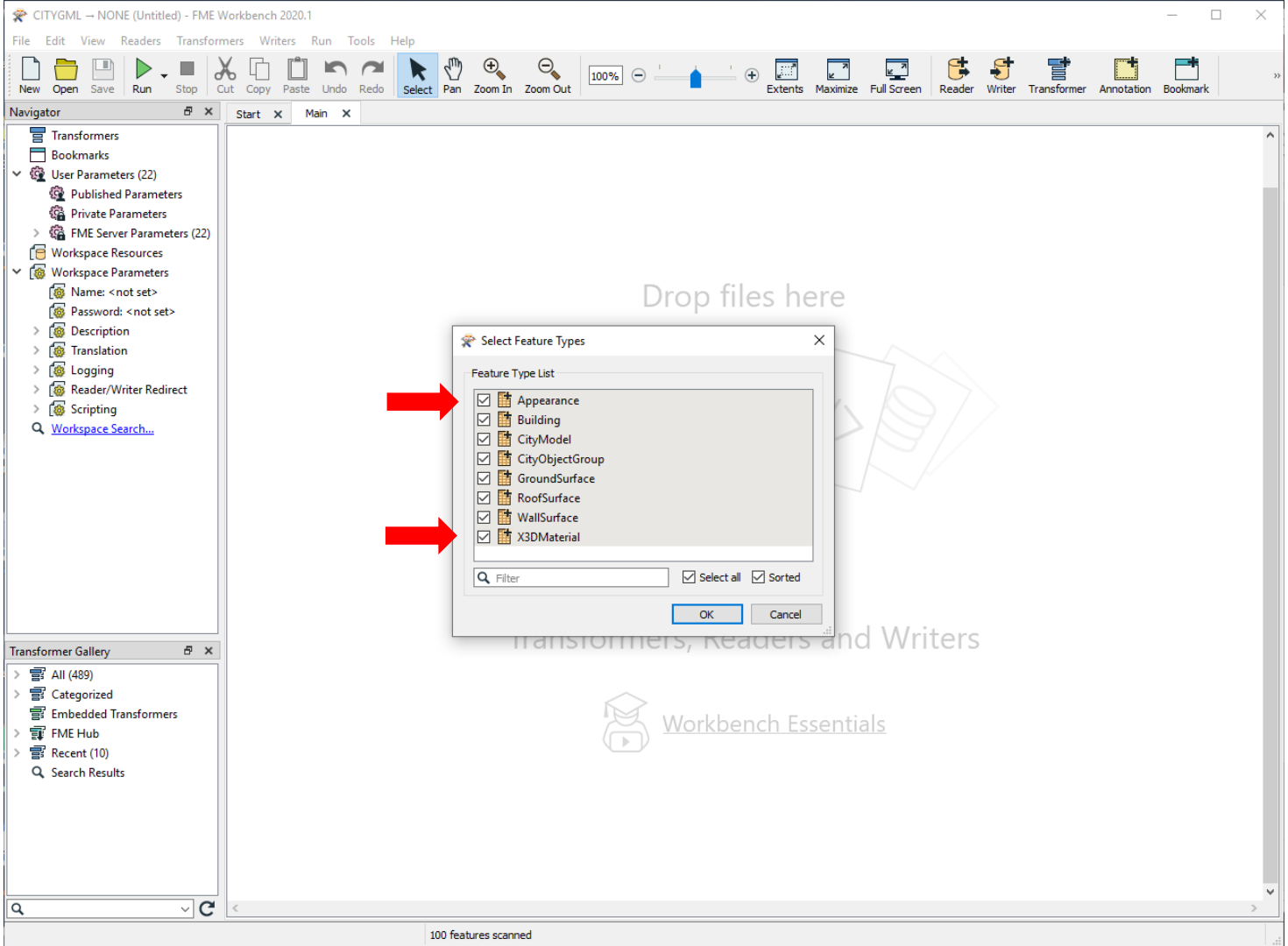

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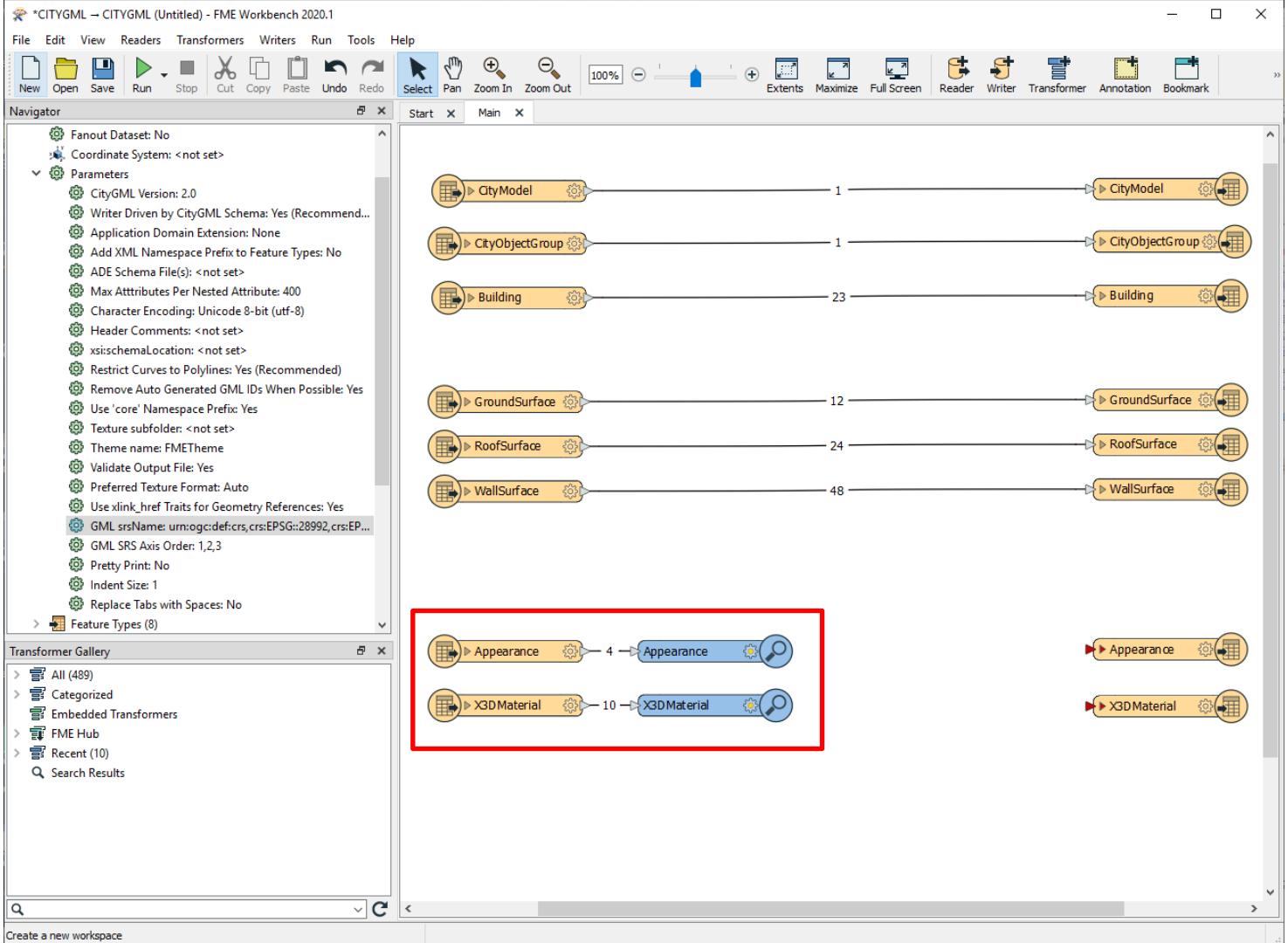

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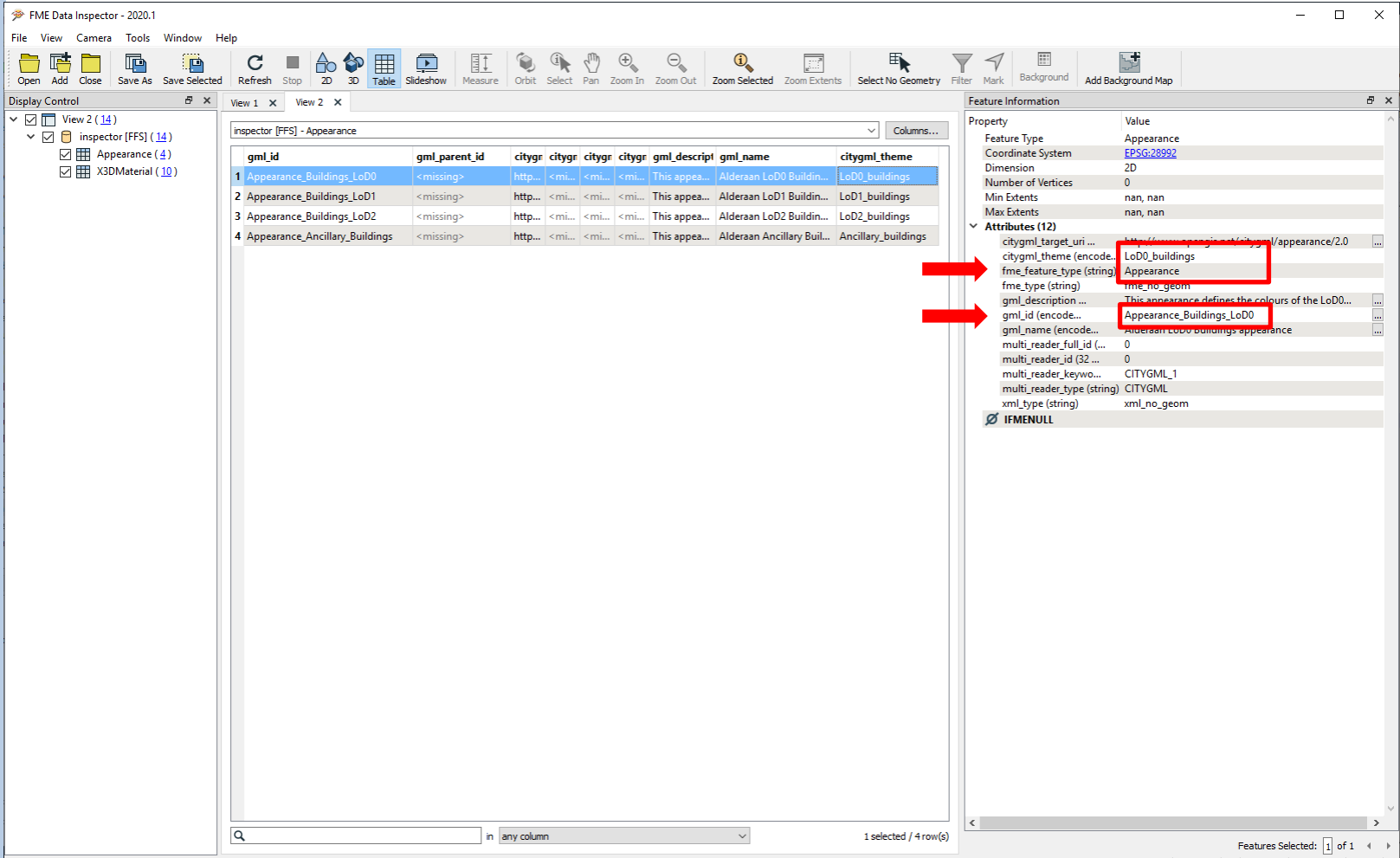

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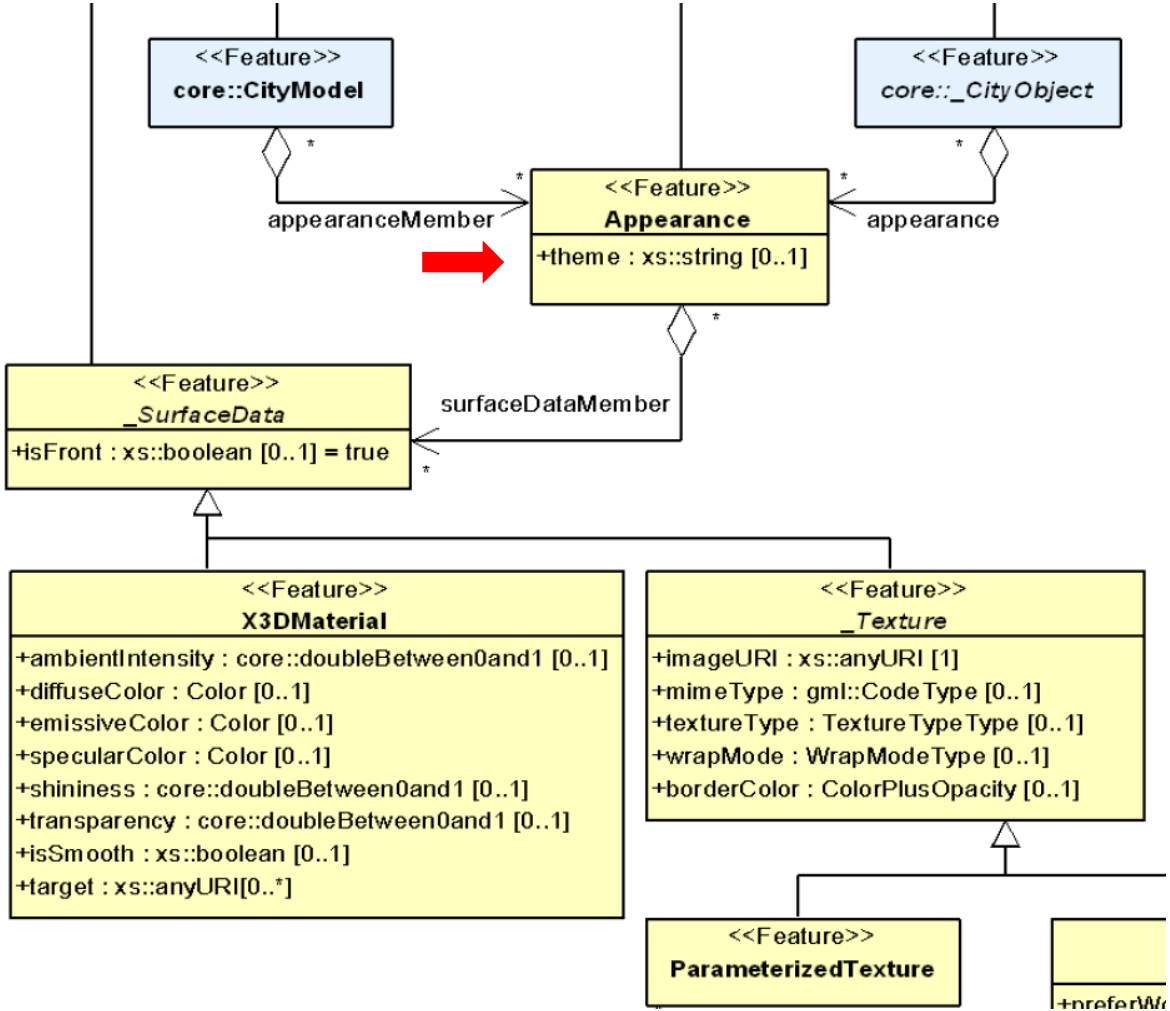

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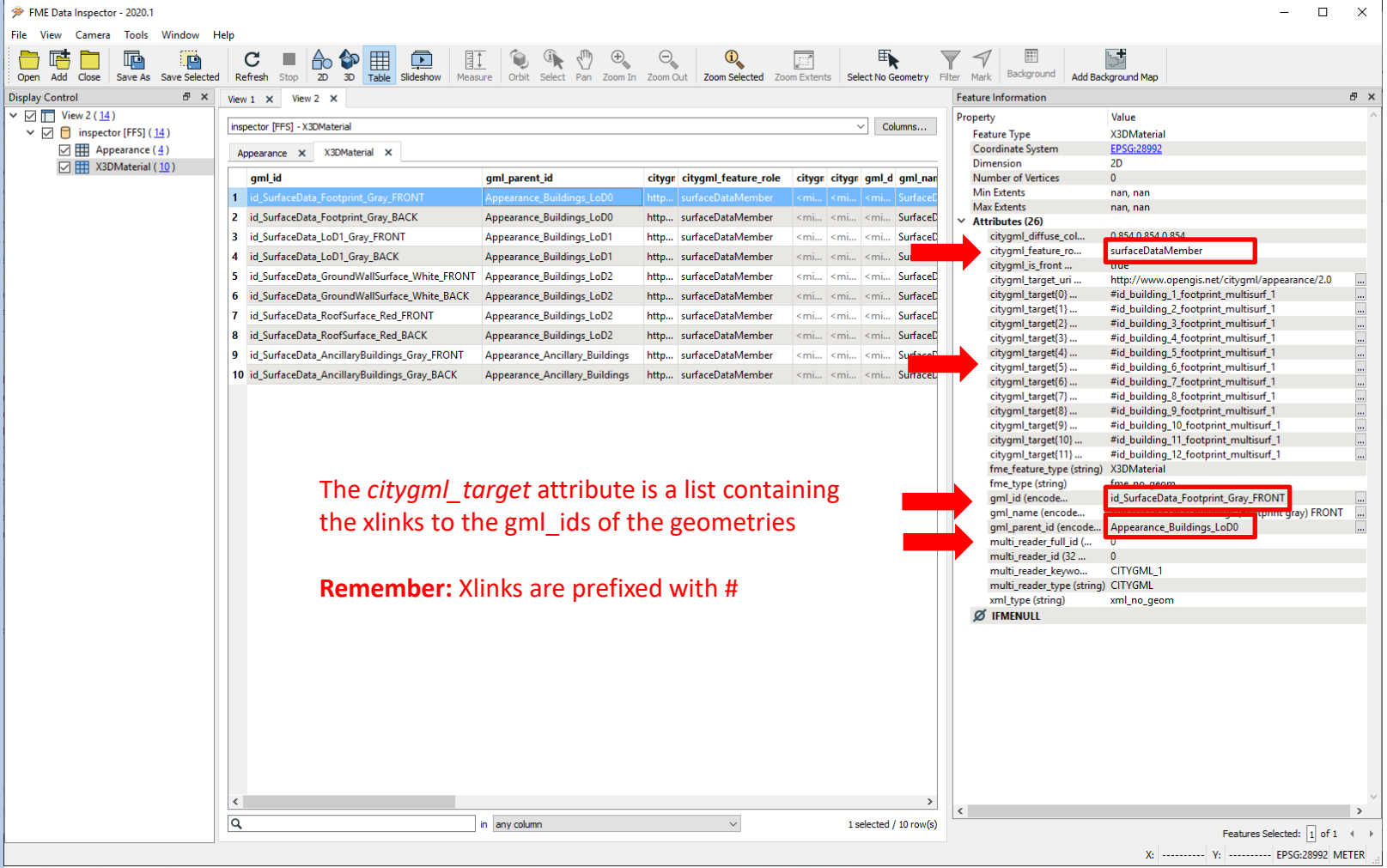

The *citygml_target* attribute is a list containing the xlinks to the gml_ids of the geometries

Remember: Xlinks are prefixed with #

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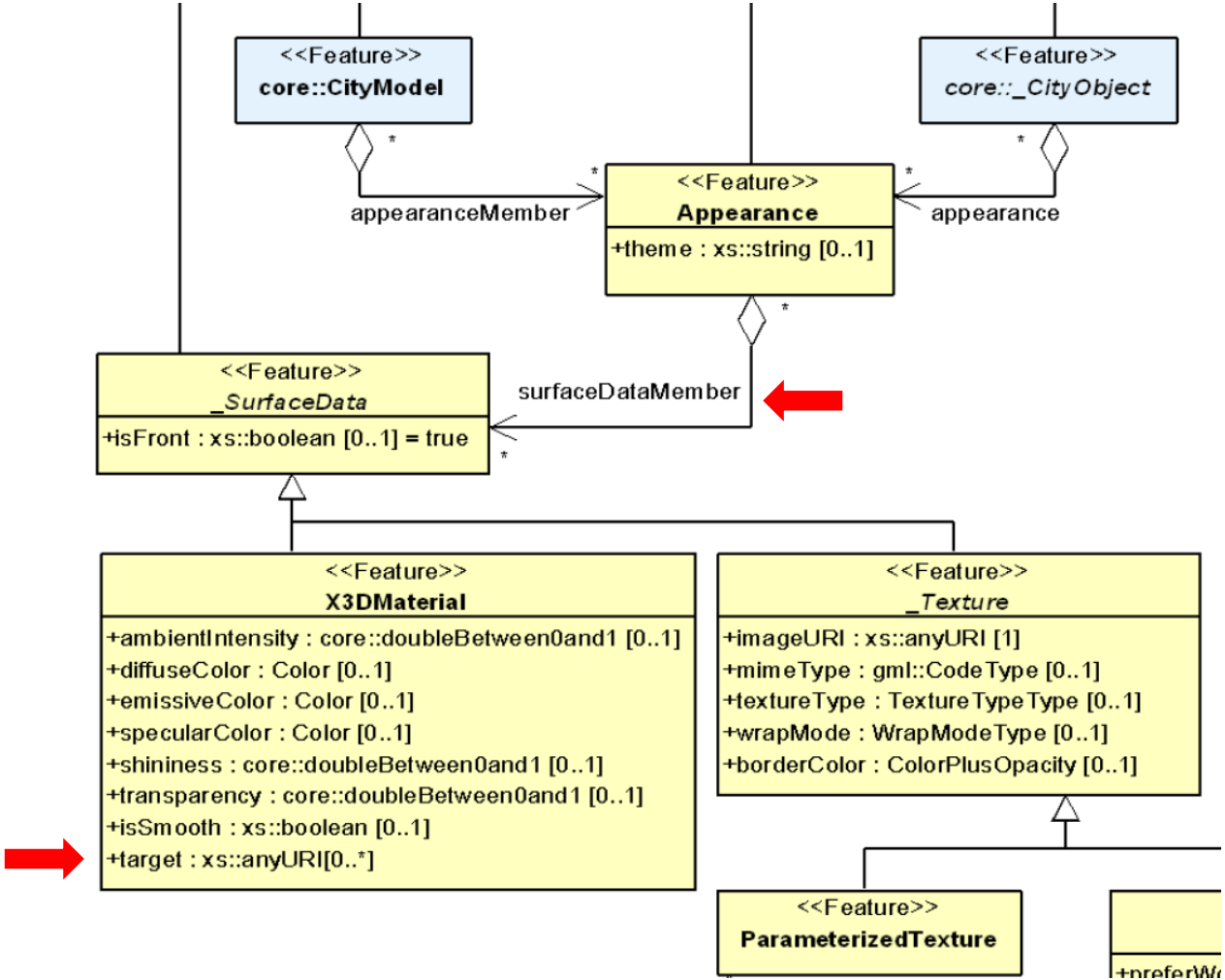

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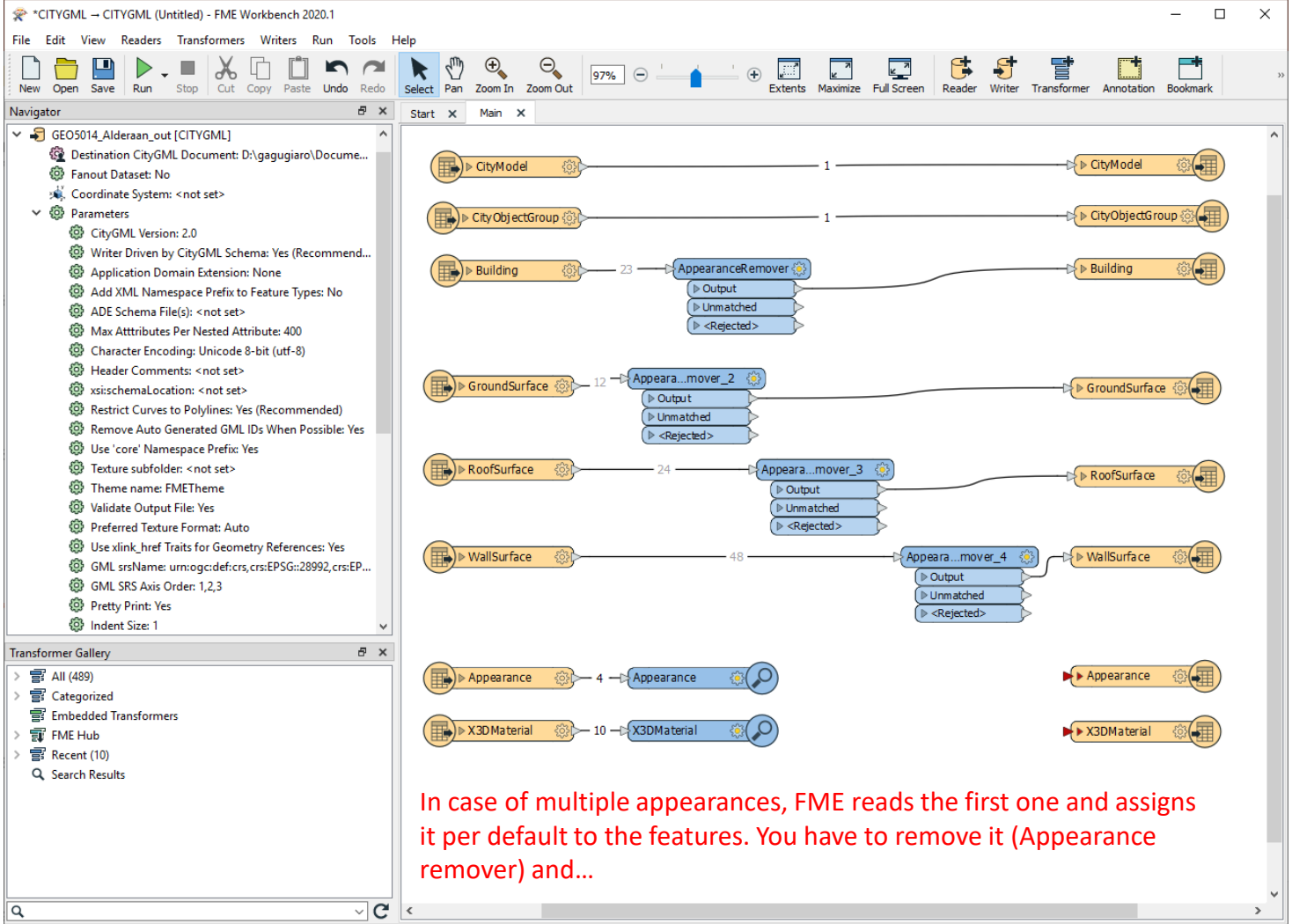

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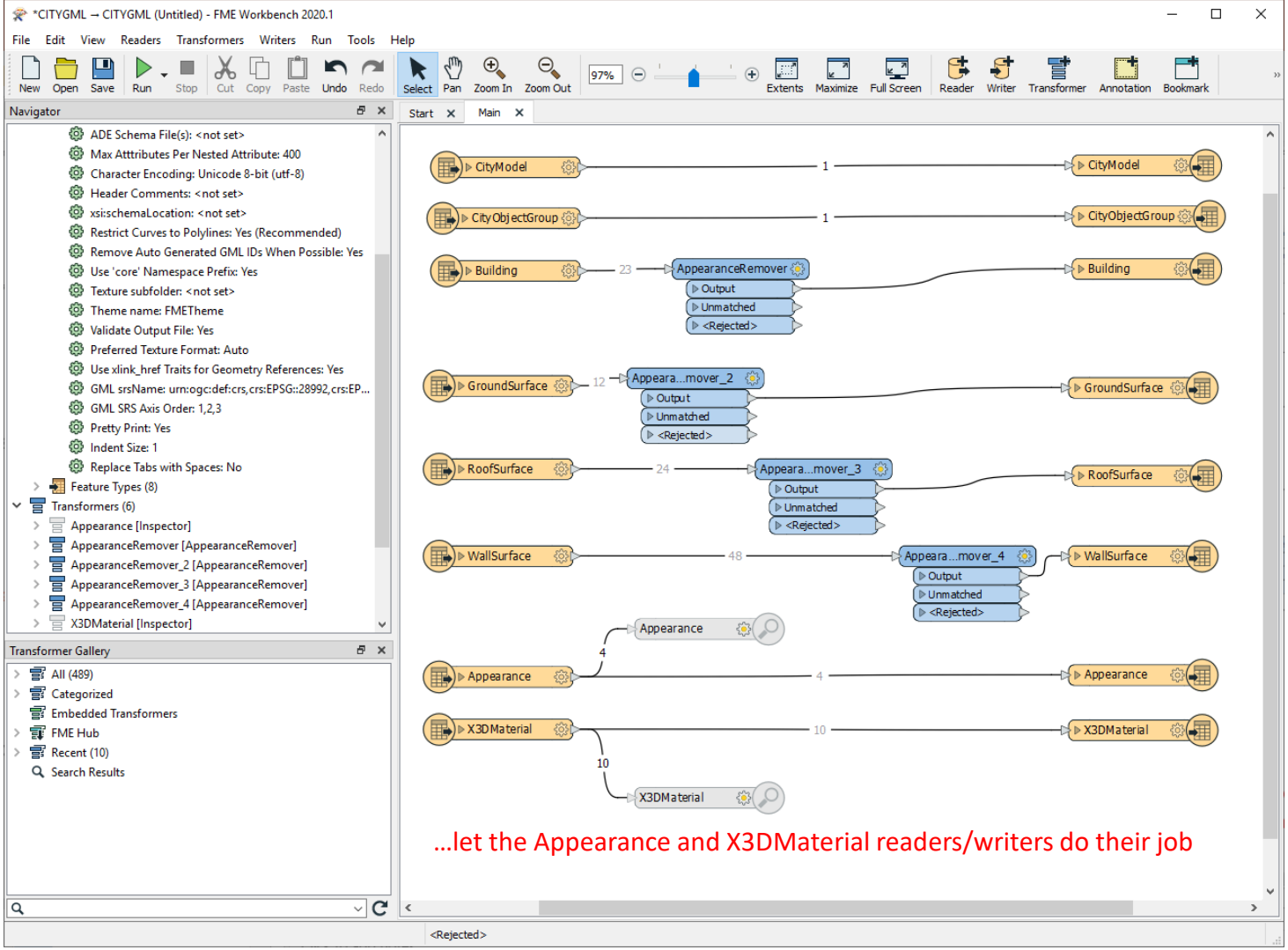

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CityGML Implicit Geometries in FME

This section is still work in progress and will be added in future

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CityGML ADEs in FME

CityGML ADEs in FME

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- FME supports CityGML Application Domain Extensions (ADE)
- To to read and write ADE contents, FME needs the **xsd file** of the corresponding ADE
- Both the CityGML reader and writer allow to select one (or more) xsd files, i.e. it is possible to work with multiple ADEs at the same time

- In principle, the same rules apply as with standard CityGML:
  - All new ADE classes that are derived from a **GML Feature** class are mapped to the corresponding reader and writer
  - Classes that extend existing CityGML classes via the so-called ADE-hook mechanism are "merged" with the corresponding CityGML reader/writer
    - For example: Energy ADE _AbstractBuilding properties are merged to those of standard Building or BuildingPart readers and writers

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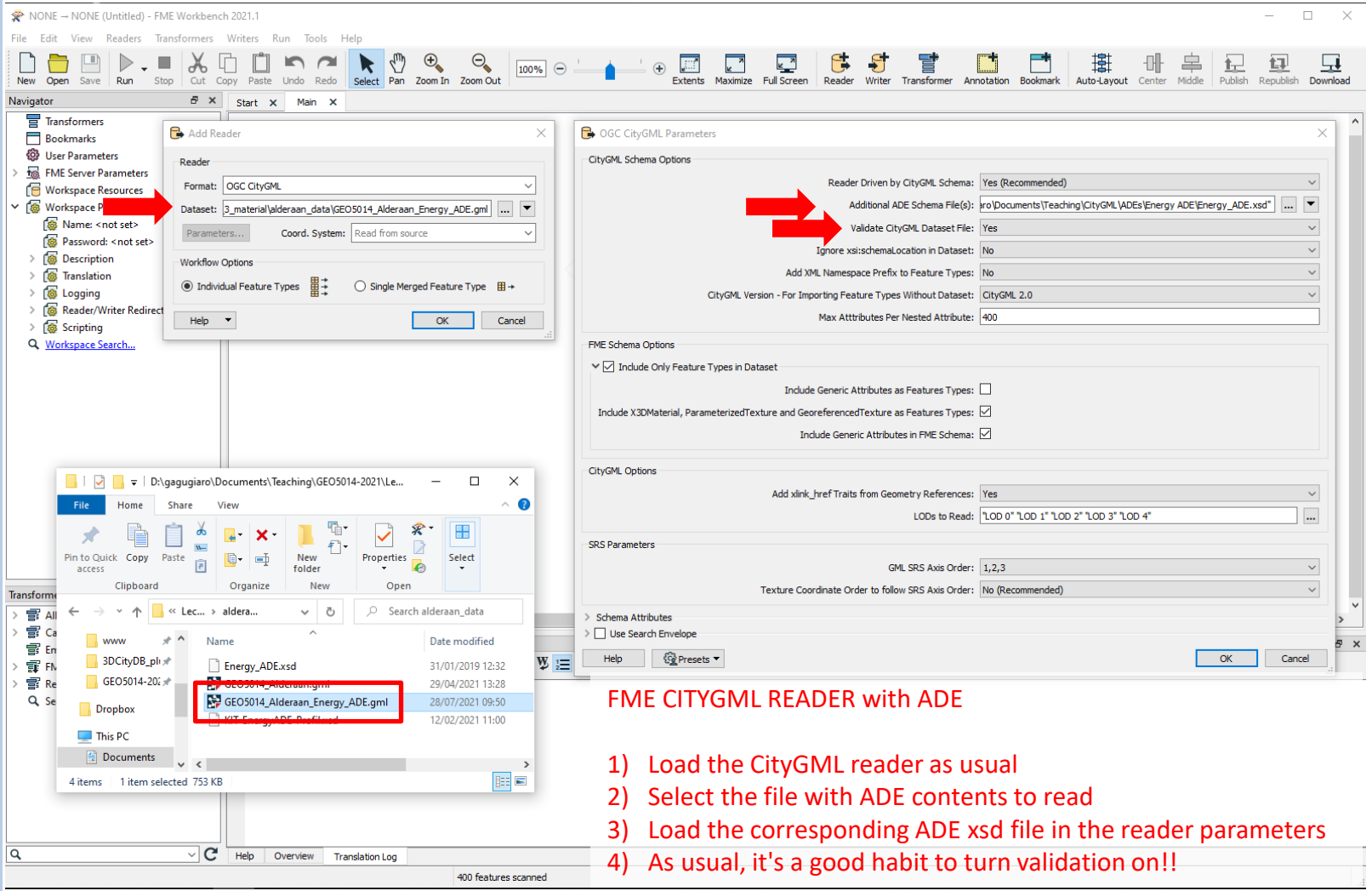

FME CITYGML READER with ADE

1) Load the CityGML reader as usual
2) Select the file with ADE contents to read
3) Load the corresponding ADE xsd file in the reader parameters
4) As usual, it's a good habit to turn validation on!!

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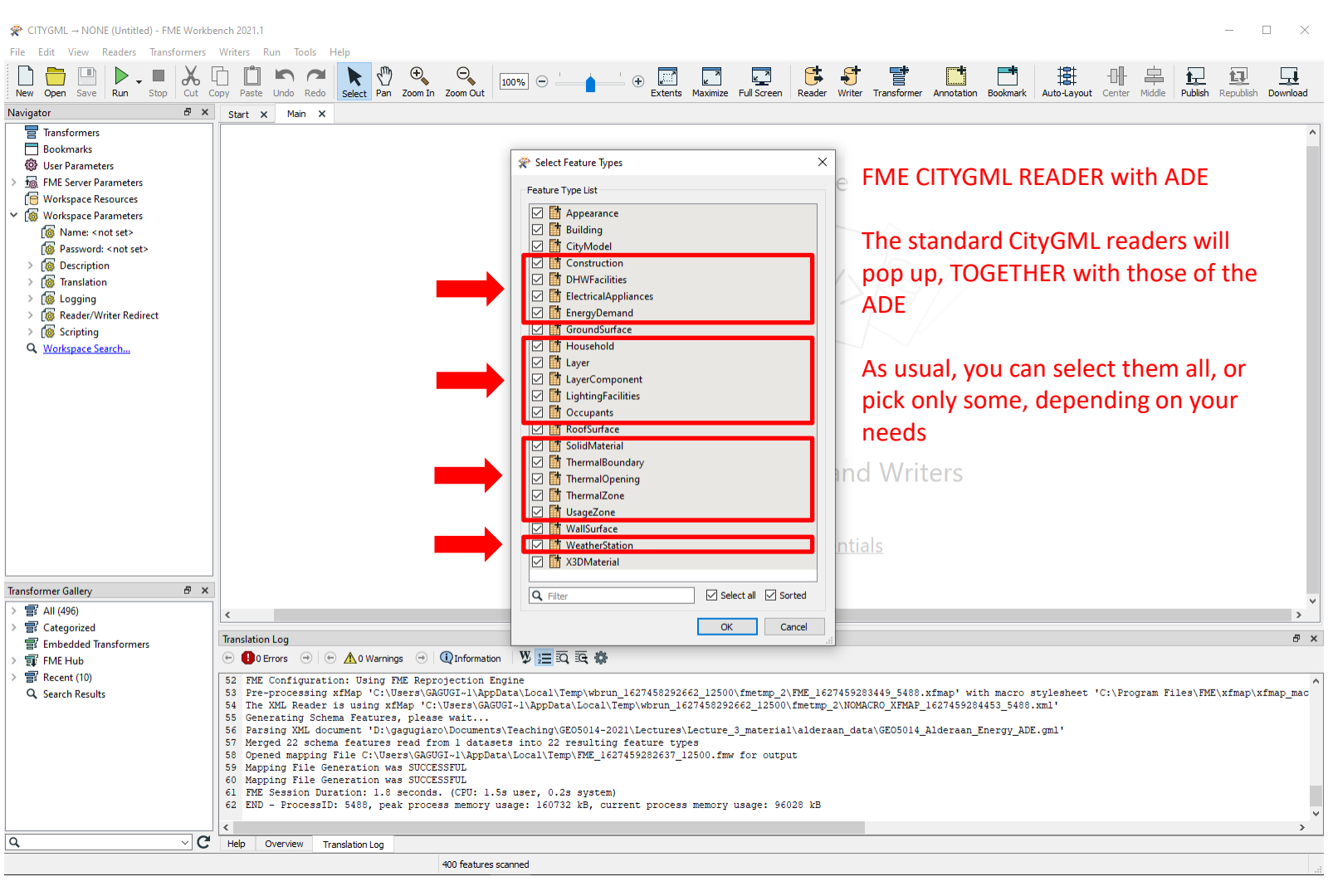

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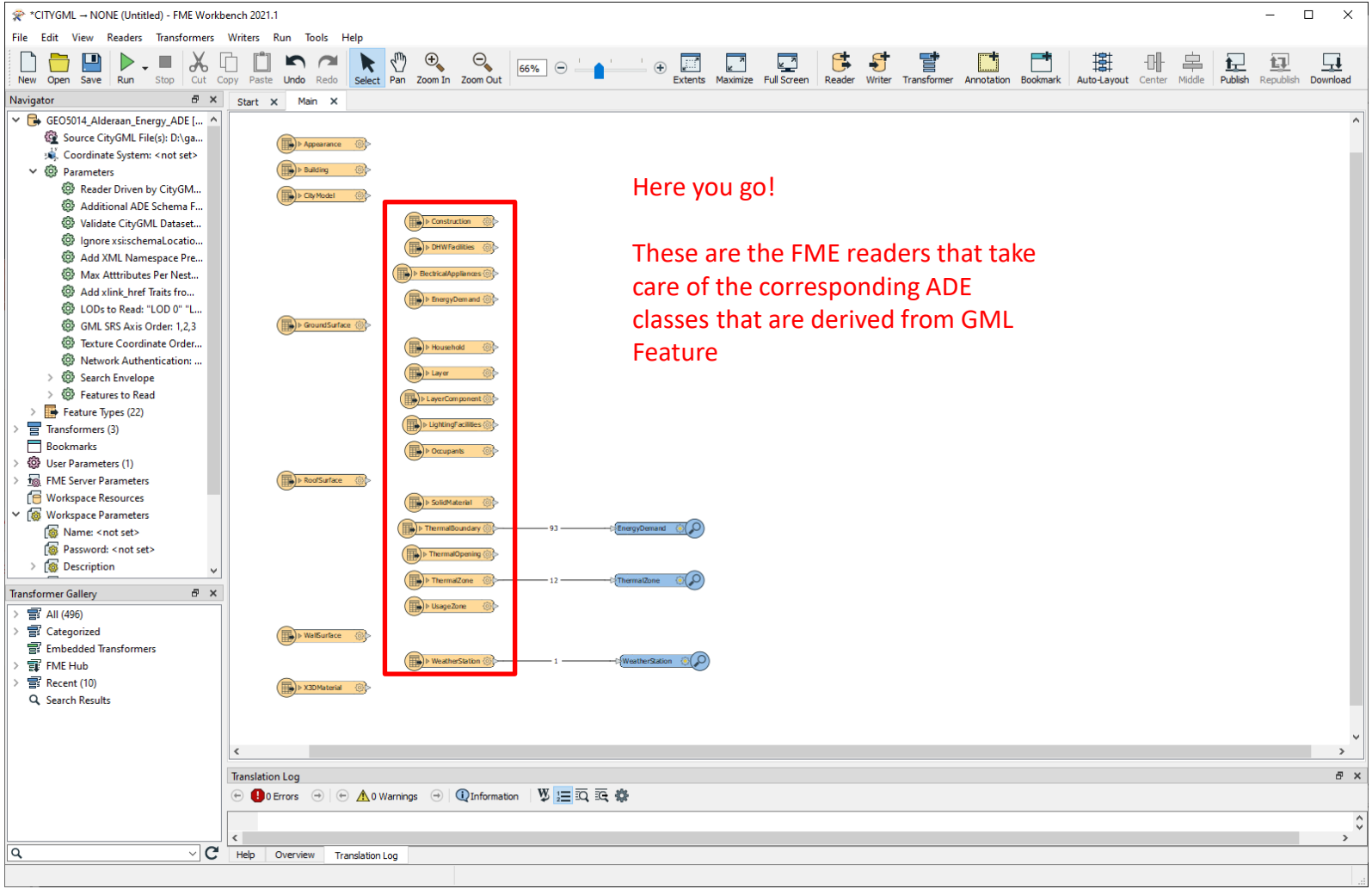

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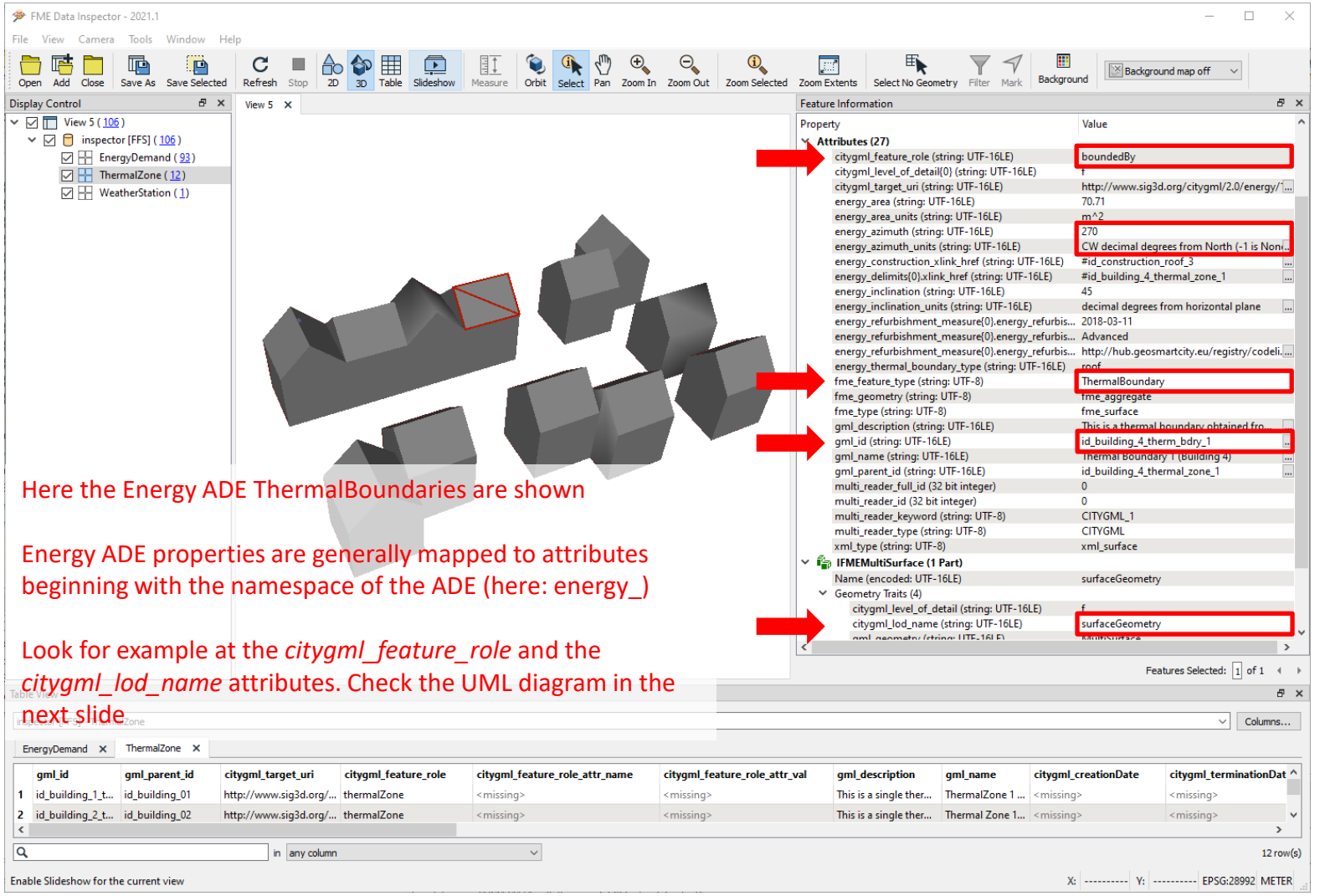

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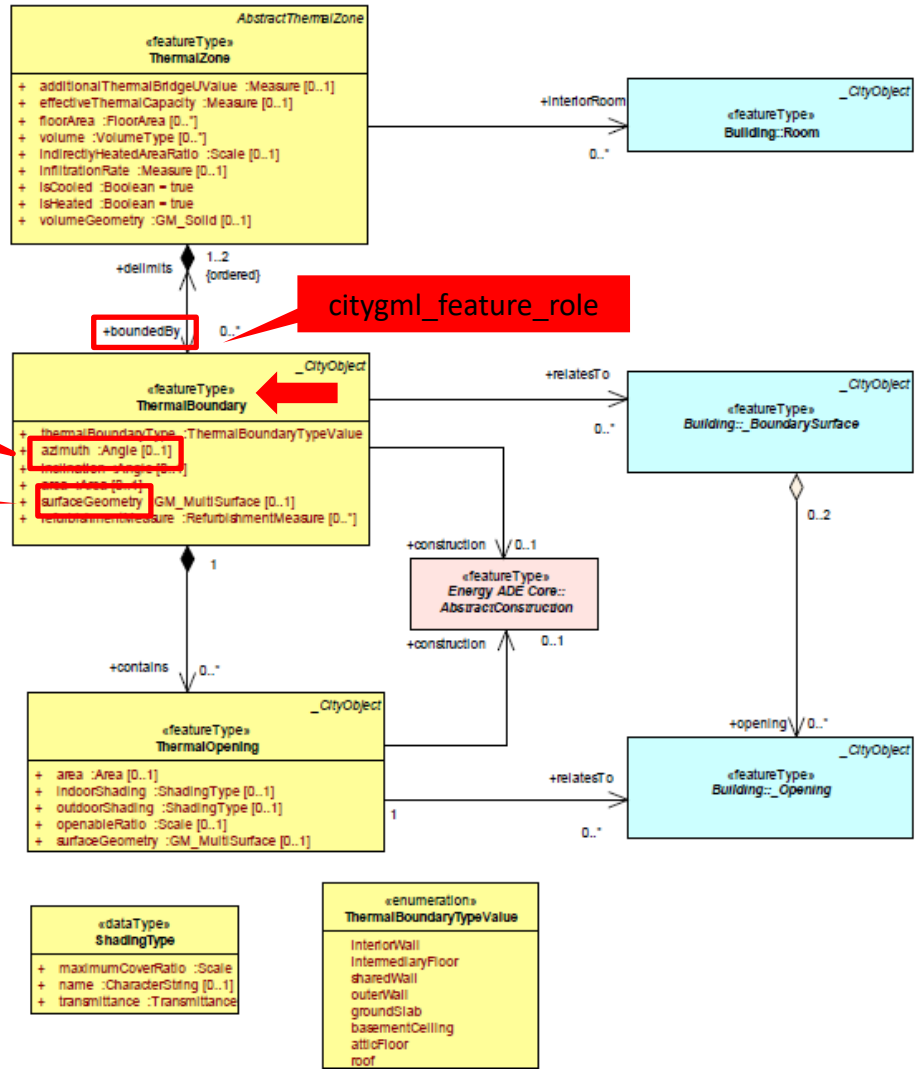
UML diagram of the Energy ADE Building physics module (excerpt)

Example of ADE property (by the way: the Angle type requires the unit of measure!)

citygml_feature_role

citygml_lod_name

Watch out! This is an alternative way of representing a relation to a GML class representing a geometry (here: GM_MultiSurface)



Screenshot taken from the UML diagram of the CityGML Energy ADE. More details in:
Agugiaro, G., Benner, J., Cipriano, P., Nouvel, R., 2018, **The Energy Application Domain Extension for CityGML: Enhancing interoperability for urban energy simulations.** Open Geospatial Data, Software and Standards, 2018 3:2. SpringerOpen, United Kingdom. (open access)
https://opengeospatialdata.springeropen.com/articles/10.1186/s40965-018-0042-y

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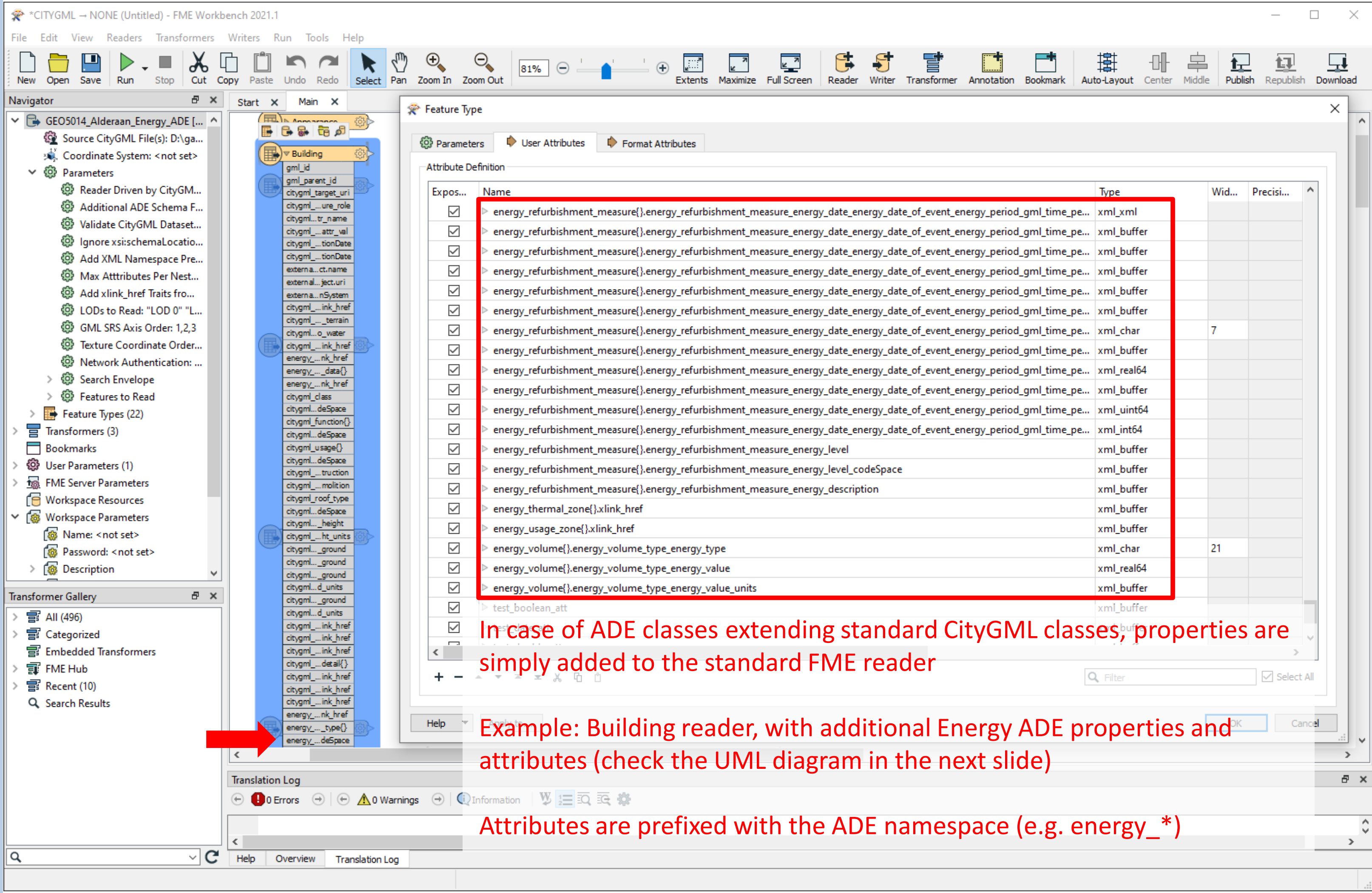

In case of ADE classes extending standard CityGML classes, properties are simply added to the standard FME reader

Example: Building reader, with additional Energy ADE properties and attributes (check the UML diagram in the next slide)

Attributes are prefixed with the ADE namespace (e.g. energy_*)

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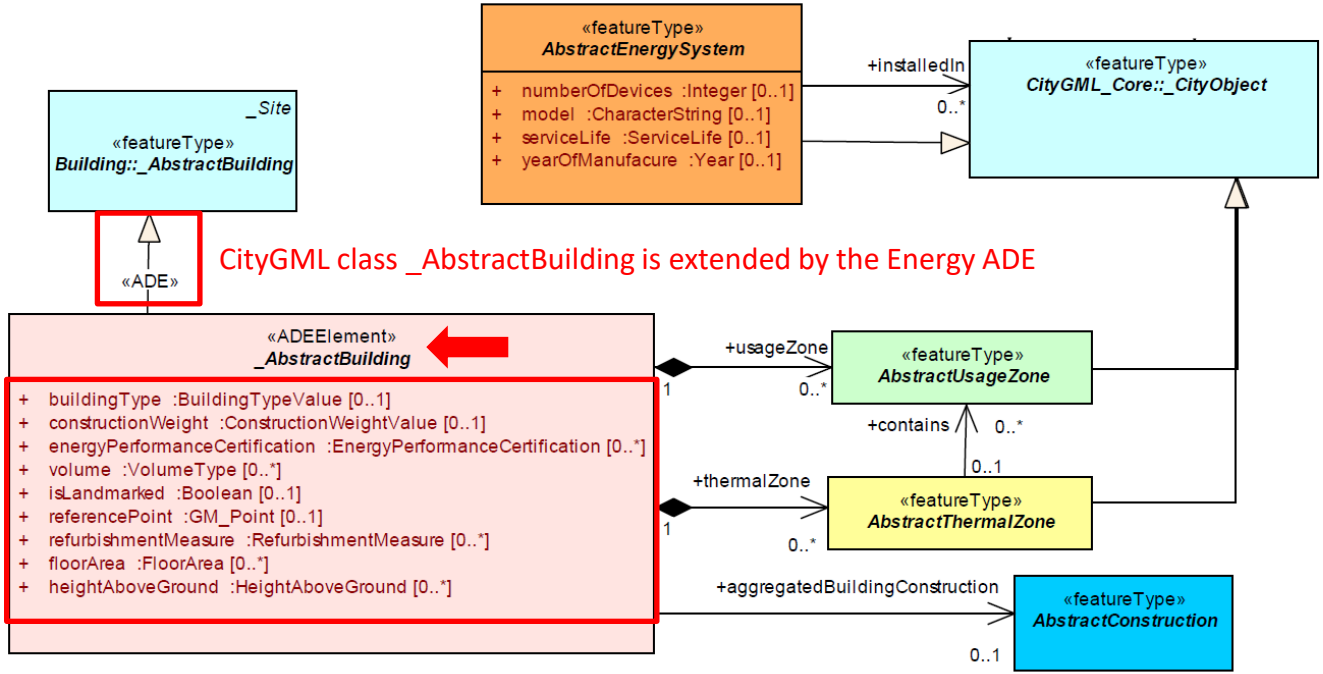

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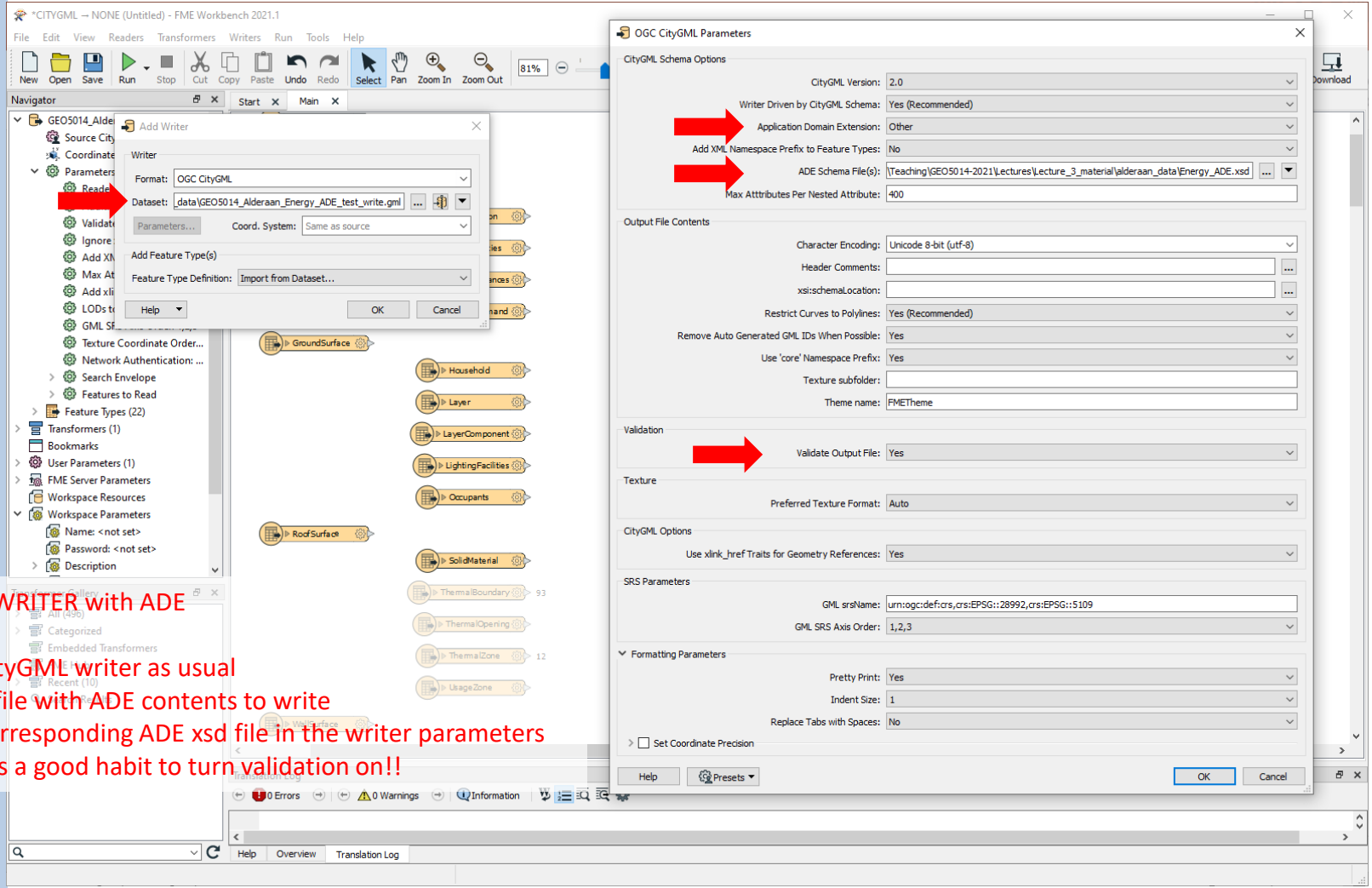
FME CITYGML WRITER with ADE

1) Load the CityGML writer as usual
2) Define the file with ADE contents to write
3) Load the corresponding ADE xsd file in the writer parameters
4) As usual, it's a good habit to turn validation on!!



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You create only writers for those classes that are contained in a certain CityGML file (example left), or lead ALL CityGML and ADE writers if you leave the field blank (example right).

In any case, you choose the needed writers

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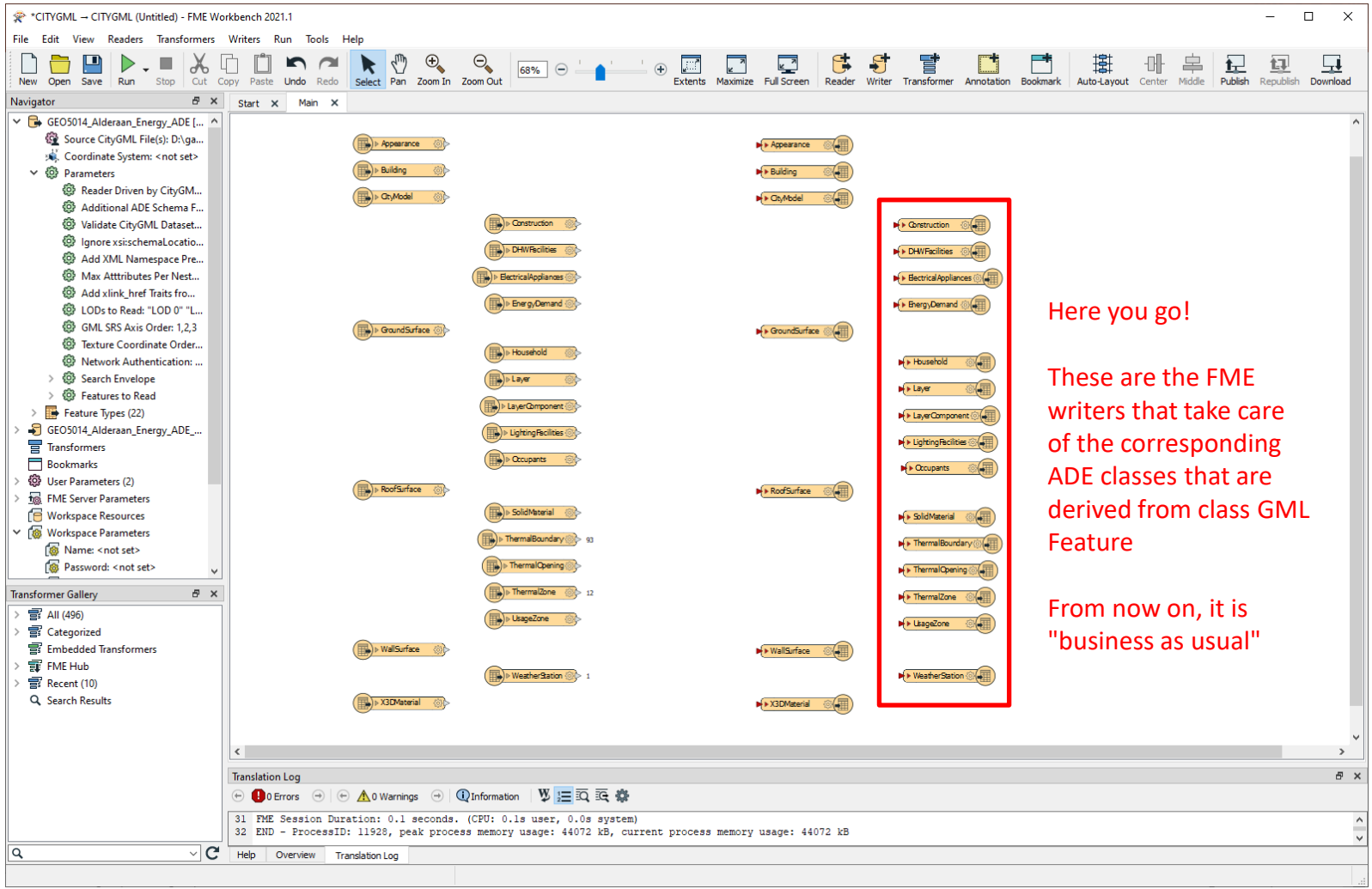

Here you go!

These are the FME writers that take care of the corresponding ADE classes that are derived from class GML Feature

From now on, it is "business as usual"

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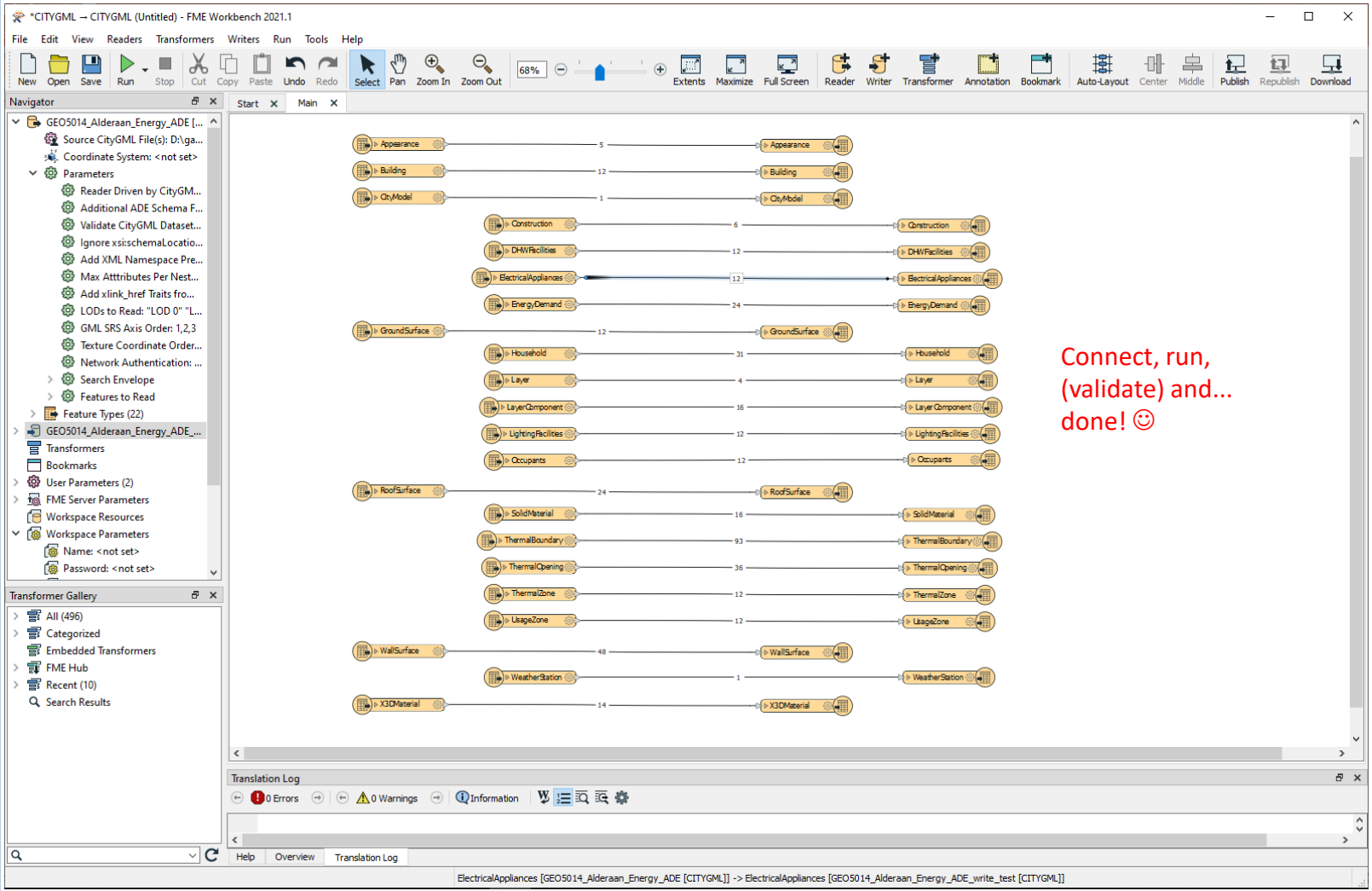

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