



This work has been supported by the ETSI Specialist Task Force 513

Extending the SAREF ontology for building devices and topology

María Poveda Villalón
Raúl García Castro
Ontology Engineering Group
Universidad Politécnica de Madrid, Spain

✉ mpoveda@fi.upm.es

🐦 [@MariaPovedaV](https://twitter.com/MariaPovedaV)

📅 20th June 2018

📍 LDAC2018, London



- This work is licensed under Creative Commons Attribution – Non Commercial – Share Alike License
- *You are free:*
 - *to Share — to copy, distribute and transmit the work*
 - *to Remix — to adapt the work*
- Under the following conditionss
 - *Attribution — You must attribute the work by inserting*
 - “[source <http://www.oeg-upm.net/>]” at every reused slide
 - A slide declaring: “This material is partially based on “Extending the SAREF ontology for building devices and topology” by María Poveda Villalón and Raúl García Castro”
 - *Non-commercial*
 - *Share-Alike*

Directors: Asunción Gómez-Pérez, Oscar Corcho

Position: 8º ranking UPM (200 groups)



Research group (30 people)

- 3 Full Professors
- 5 Associate Professors
- 3 Assistant Professors
- 7 Senior Postdocs
- 6 PhD Students
- 2 MSc and BSc Students
- 2 software engineers
- 1 system administrator
- 2 project managers

170+ Collaborations

50+ Visitors

<http://www.oeg-upm.net/>

 <https://github.com/oeg-upm>

 [@oeg-upm](https://twitter.com/oeg-upm)



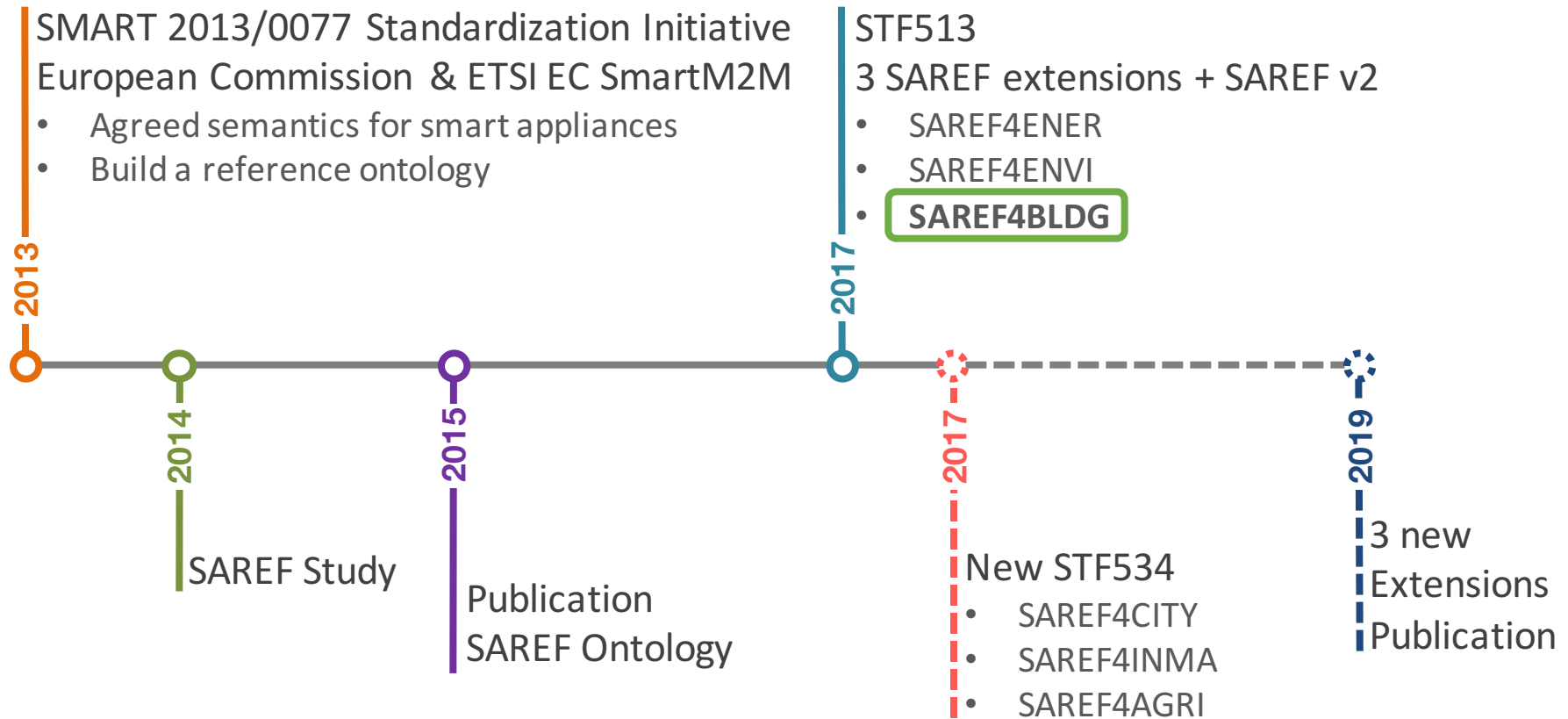
Post doc, Ontological Engineering, ontology development, evaluation, linked (open) data



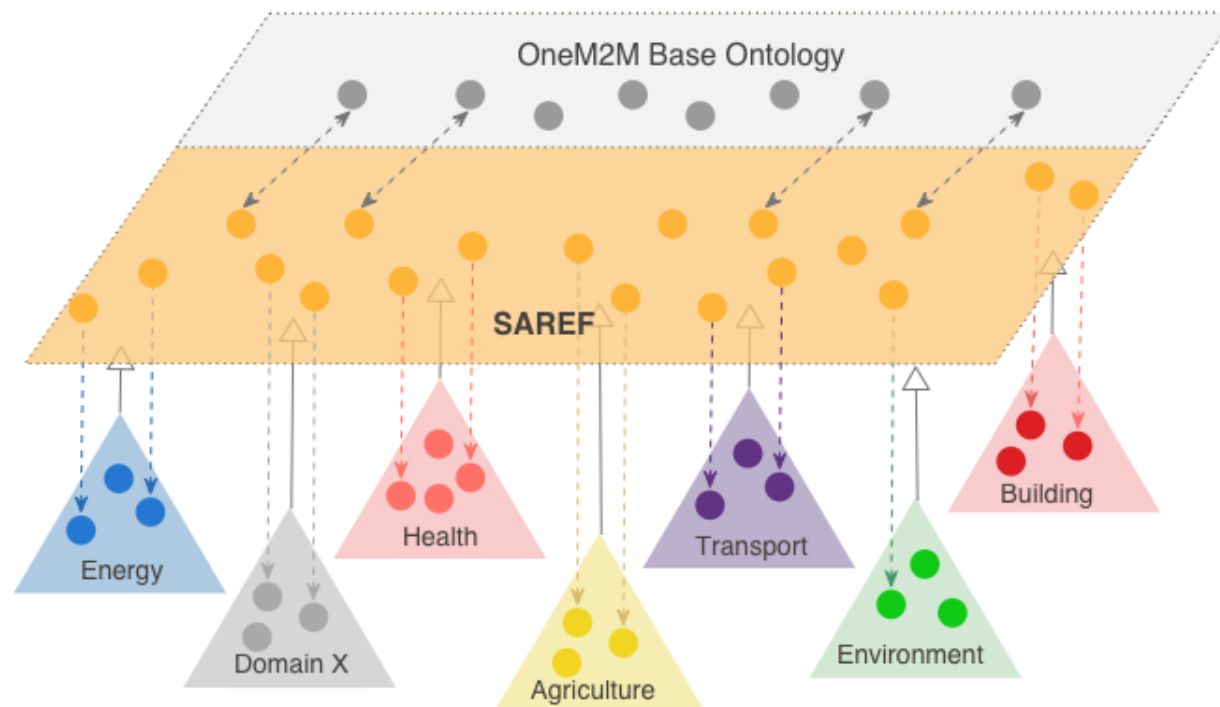
<https://github.com/mariapoveda>

@MaríaPovedaV





- SAREF is not intended to replace existing standards, its intention is to **link** information coming from **different smart appliances**, based on different **standards**
- SAREF is the **core model** to **connect** smart **appliances** from all domains
- As **different domains** have different information needs, **extensions** of SAREF will be defined to tune the standard for a domain



<http://saref.linkeddata.es/> Catalogue (UPM's site, not official)

Ontologies

SAREF extensions registry

Here you can find the list of SAREF family of ontologies

Filter by title or domain:

Ontology	Serialization	License	Authors	Language	Domain	Description
SAREF: the Smart Appliances REFerence ontology ⓘ	html turtle	CC-by4.0	Laura Daniele María Poveda-Villalón Raúl García-Castro	en	smart appliances IoT	The Smart Appliances REFERENCE (SAREF) ontology is a shared model of consensus that facilitates the matching of existing ... See more
SAREF extension for environment ⓘ	html turtle xml N-Triples	CC-by4.0	María Poveda-Villalón Raúl García-Castro	en	environment photometer light pollution SAREF	This ontology extends the SAREF ontology for the environment domain, specifically for the light pollution domain, including ... See more
SAREF extension for building devices ⓘ	html turtle xml N-Triples	CC-by4.0	María Poveda-Villalón Raúl García-Castro	en	building building device device IFC SAREF	This ontology extends the SAREF ontology for the building domain by defining building devices and how they are located in ... See more
SAREF extension for energy ⓘ	html turtle	CC-by4.0	Laura Daniele	en	smart appliances energy	SAREF4ENER is an extension of SAREF for the Energy domain that was created in collaboration with Energy@Home ... See more

Includes:

- SAREF ontology
- SAREF4ENVI
- **SAREF4BLDG**
- SAREF4ENER

To be included (when available):

- SAREF4CITY
- SAREF4INMA
- SAREF4AGRI

Powered by

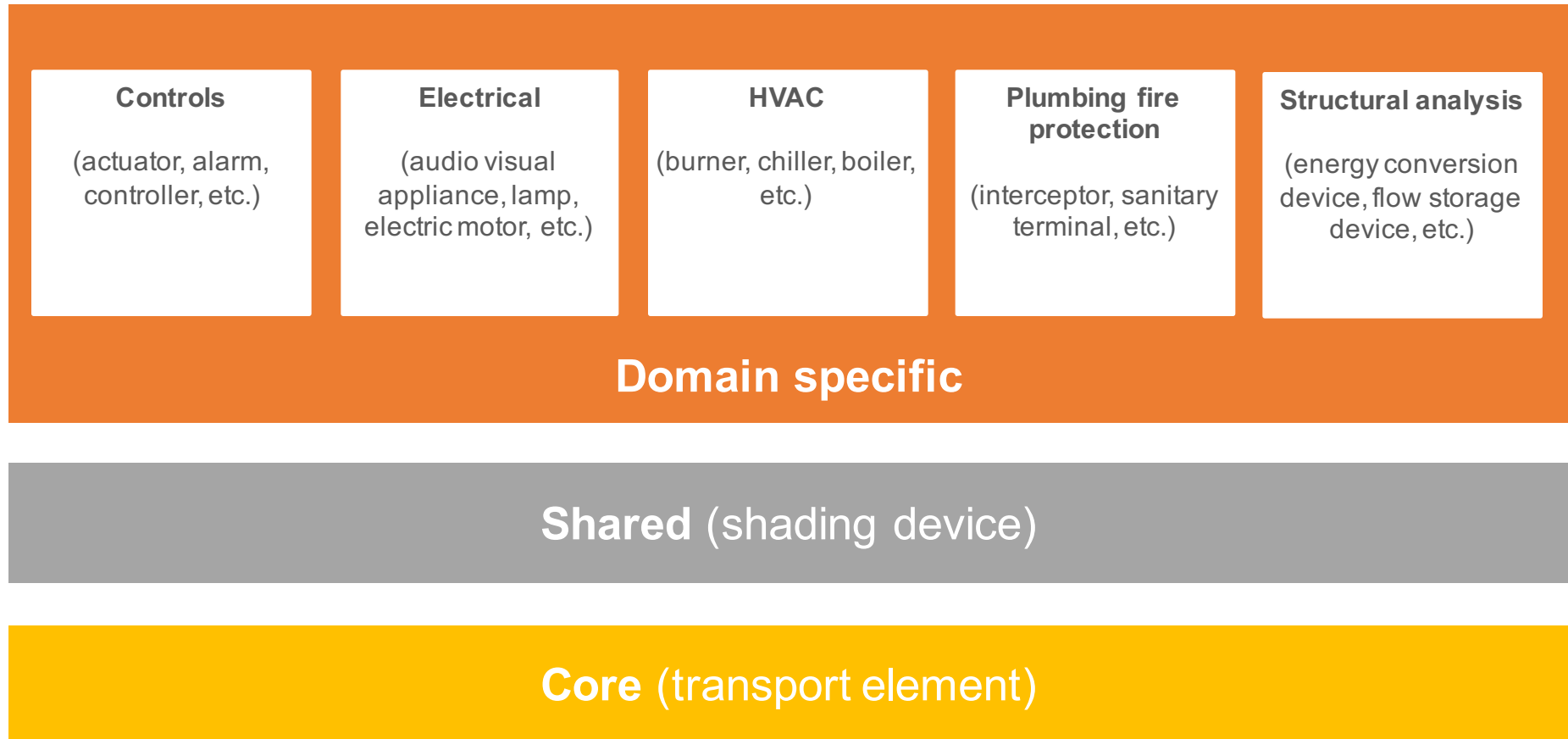


■ Problems

- *No clear taxonomy of **devices** in IFC*
 - Concepts in IFC organized by architectural views
 - Different devices in different views
- *No direct mapping from `saref:Device` to a concept in ifcOWL*
 - i.e., there is no `ifcowl:Device`

- **Goal:** To extend SAREF to cover building devices and appliances from IFC (and their properties)

In IFC Devices appear in different “views”



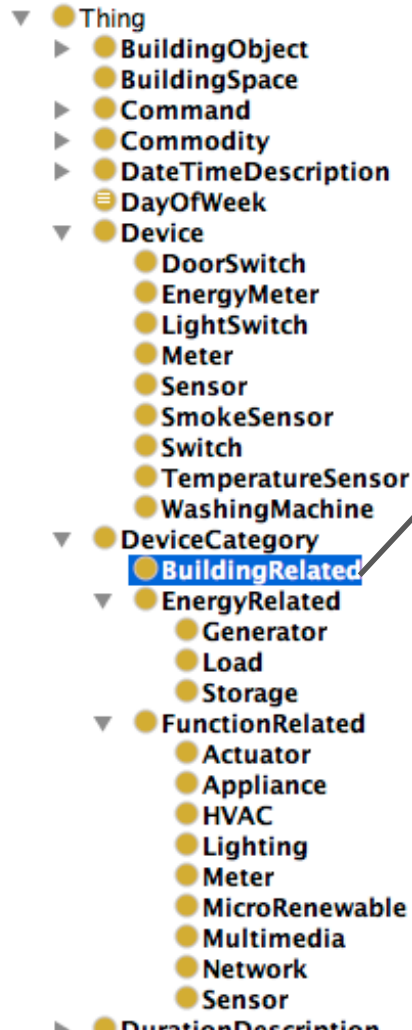
Which device types are defined in ifcOWL?

- **Difficult to find all the devices manually**
 - Massive ontology
- **Impossible to do so automatically**
 - No hierarchy for “Device” in ifcOWL
 - No documentation for terms (could detect mappings using NLP)
- Common ancestor for devices is **ifcElement**:
 - “Elements are physically existent objects, although they might be void elements, such as holes... Examples of elements in a building construction context are walls, floors, windows and recesses”

Ontology metrics: II	
Metrics	
Axiom	20480
Logical axiom count	13742
Class count	1300
Object property count	1578
Data property count	0
Individual count	1155
DL expressivity	ALCIQ
Class axioms	
SubClassOf axioms count	5005
EquivalentClasses axioms count	0
DisjointClasses axioms count	2429
GCI count	0
Hidden GCI Count	0
Object property axioms	
SubObjectPropertyOf axioms count	0
EquivalentObjectProperties axioms count	0
InverseObjectProperties axioms count	94
DisjointObjectProperties axioms count	0
FunctionalObjectProperty axioms count	1439
InverseFunctionalObjectProperty axioms count	0
TransitiveObjectProperty axioms count	0
SymmetricObjectProperty axioms count	0

Building devices in SAREF and IFC

SAREF

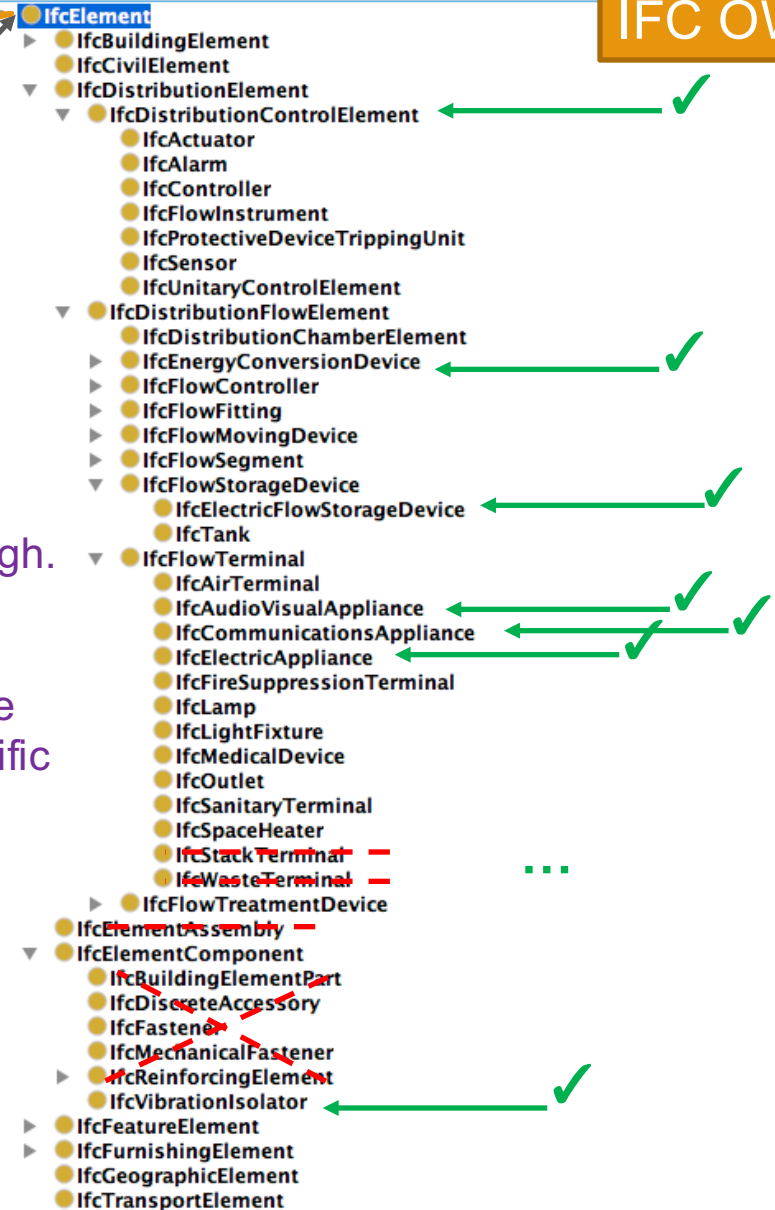


Common ancestor.
Too broad.

One mapping is not enough.

Many "subclassOf"
mappings needed or the
implementation of a specific
hierarchy

IFC OWL



- Approach followed:
 - Identify devices:
 - Review all IFC terms
 - Check their descriptions: Do they include the term “**device**”?

IFC4 - Addendum 1 [Final Standard] © 1996-2015 buildingSMART International Ltd.

Cover page Contents Foreword Introduction	1. Scope 2. Normative references 3. Terms, definitions, and abbreviated terms 4. Fundamental concepts and assumptions	5. Core data schemas 6. Shared element data schemas 7. Domain specific data schemas 8. Resource definition data schemas	A. Computer interpretable listings B. Alphabetical listings C. Inheritance listings D. Diagrams	E. Examples F. Change logs Bibliography Index
--	--	--	--	--

7.2.3.5 IfcController

7.2.3.6 IfcControllerType

7.2.3.7 IfcFlowInstrument

7.2.3.8 IfcFlowInstrumentType

7.2.3.9 IfcSensor

7.2.3.10 IfcSensorType

7.2.3.11 IfcUnitaryControlElement

7.2.3.12 IfcUnitaryControlElementType

7.2.4 Property Sets

7.2.4.1 Pset_ActuatorPHistory

7.2.4.2 Pset_ActuatorTypeCommon

7.2.4.3 Pset_ActuatorTypeElectrical

7.2.4.4 Pset_ActuatorTypeHydraulic

7.2.4.5 Pset_ActuatorTypeLinear

7.2.4.6 Pset_ActuatorTypePneumatic

7.2.4.7 Pset_ActuatorTypeRotational

7.2.4.8 Pset_AlarmPHistory

7.2.4.9 Pset_AlarmTypeCommon

7.2.4.10 Pset_ControllerPHistory

7.2.4.11 Pset_ControllerTypeCommon

7.2.4.12 Pset_ControllerTypeFlow

7.2.4.13 Pset_ControllerTypeMulti

7.2.4.14 Pset_ControllerTypeProgrammable

7.2.4.15 Pset_ControllerTypeProgrammable

7.2.4.16 Pset_ControllerTypeTwo

7.2.4.17 Pset_FlowInstrumentPHistory

7.2.3.5 IfcController

Natural language names

Change log

7.2.3.5.1 Semantic definitions at the entity

Entity definition

A controller is a device that monitors inputs and controls outputs within a building automation system.

A controller may be physical (having placement within a spatial structure) or logical (a software interface or aggregated within a programmable physical controller).

HISTORY New entity in IFC4

Attribute definitions

#	Attribute	Type	Cardinality	Description	C
9	PredefinedType	IfcControllerTypeEnum	[0:1]		X

Formal Propositions

Rule	Description
CorrectPredefinedType	Either the <i>PredefinedType</i> attribute is unset (e.g. because an <i>IfcControllerType</i> is associated), or the inherited attribute <i>ObjectType</i> shall be provided, if the <i>PredefinedType</i> is set to USERDEFINED.
CorrectTypeAssigned	Either there is no controller type object associated, i.e. the <i>IsTypedBy</i> inverse relationship is not provided, or the associated type object has to be of type <i>IfcControllerType</i> .

- Approach followed:

1. *Identify devices:*

- Review all IFC terms
- Check their descriptions: Do they include the term “**device**”?
- If no “device”, check with thesaurus (WordNet)
 - *Lamp*: A lamp is an artificial light source such as a light bulb or tube (from the IFC definition)

2. *Extend with devices’ properties*

Noun

- S: (n) **lamp** (an artificial source of visible illumination)
 - direct hyponym / full hyponym
 - direct hypernym / inherited hypernym / sister term
 - S: (n) source of illumination (any device serving as a source of visible electromagnetic radiation)
 - ✓ • S: (n) **device** (an instrumentality invented for a particular purpose) “the device is small enough to wear on your wrist”; “a device intended to conserve water”
 - S: (n) instrumentality, instrumentation (an artifact (or system of artifacts) that is instrumental in accomplishing some end)
 - S: (n) artifact, artefact (a man-made object taken as a whole)
 - S: (n) whole, unit (an assemblage of parts that is regarded as a single entity) “how big is that part compared to the whole?”; “the team is a unit”
 - S: (n) object, physical object (a tangible and visible entity; an entity that can cast a shadow) “it was full of rackets, balls and other objects”
 - S: (n) physical entity (an entity that has physical existence)
 - S: (n) entity (that which is perceived or known or inferred to have its own distinct existence (living or nonliving))
- S: (n) **lamp** (a piece of furniture holding one or more electric light bulbs)

Requirement					
Identifier	Responsible partner	Category (1..N)	Competency Question	Answer	Extracted from (provenance)
bldg1	UPM	building	What is a building?	A building represents a structure that provides shelter for its occupants or contents and stands in one place. The building is also used to provide a basic element within the spatial structure hierarchy for the components of a building project (together with site, storey, and space).	
bldg2	UPM	device	A building can contain devices		
bldg3	UPM	IfcSharedBldg	What is a shading device?	Shading devices are purpose built devices to protect from the sunlight, from natural light, or screening them from view. Shading devices can form part of the facade or can be mounted inside the building, they can be fixed or operable.	http://www.buildingsmart-tech.org/ifc/IFC4/Add1/html/schema/ifcsharedbldgdomain/lexical/ifcshadingdevice.htm
bldg4	UPM	IfcBuildingControlsDomain	What is an actuator?	An actuator is a mechanical device for moving or controlling a mechanism or system. An actuator takes energy, usually created by air, electricity, or liquid, and converts that into some kind of motion.	http://www.buildingsmart-tech.org/ifc/IFC4/Add1/html/schema/ifcbuildingcontrolsdomain/lexical/ifcactuator.htm
bldg5	UPM	IfcBuildingControlsDomain	What is an alarm?	An alarm is a device that signals the existence of a condition or situation that is outside the boundaries of normal expectation or that activates such a device.	http://www.buildingsmart-tech.org/ifc/IFC4/Add1/html/schema/ifcbuildingcontrolsdomain/lexical/ifcalarm.htm
bldg6	UPM	IfcBuildingControlsDomain	What is a controller?	A controller is a device that monitors inputs and controls outputs within a building automation system.	
				A controller may be physical (having placement within a spatial structure) or logical (a software interface or aggregated within a programmable physical controller).	http://www.buildingsmart-tech.org/ifc/IFC4/Add1/html/schema/ifcbuildingcontrolsdomain/lexical/ifccontroller.htm
bldg7	UPM	IfcBuildingControlsDomain	What is a flow instrument?	A flow instrument reads and displays the value of a particular property of a system at a point, or displays the difference in the value of a property between two points.	
				Instrumentation is typically for the purpose of determining the value of the property at a point in time. It is not the purpose of an instrument to record or integrate the values over time (although they may be connected to recording devices that do perform such a function). This entity provides for all forms of mechanical flow instrument (thermometers, pressure gauges etc.) and electrical flow instruments (ammeters, voltmeters etc.)	http://www.buildingsmart-tech.org/ifc/IFC4/Add1/html/schema/ifcbuildingcontrolsdomain/lexical/ifcflowinstrument.htm

Requirement					
Identifier	Responsible partner	Category (1..N)	Competency Question	Answer	Extracted from (provenance)
bldg69	UPM	IfcBuildingControlsDomain	Which properties has a controller?	no relevant, however is worth keeping the requirement as rejected for the records.	http://www.buildingsmart-tech.org/ifc/IFC4/Add1/html/schema/ifcbuildingcontrolsdomain/pset/pset_controllercommon.htm
bldg70	UPM	IfcBuildingControlsDomain	Which properties has a flow instrument?	no relevant, however is worth keeping the requirement as rejected for the records.	http://www.buildingsmart-tech.org/ifc/IFC4/Add1/html/schema/ifcbuildingcontrolsdomain/pset/pset_flowinstrumentcommon.htm
bldg71	UPM	IfcBuildingControlsDomain	Which properties has a sensor?	no relevant, however is worth keeping the requirement as rejected for the records.	http://www.buildingsmart-tech.org/ifc/IFC4/Add1/html/schema/ifcbuildingcontrolsdomain/pset/pset_sensorcommon.htm
bldg72	UPM	IfcElectricalDomain	Which properties has a protective device tripping unit?	- Standard: string. The designation of the standard applicable for the definition of the characteristics of the tripping unit. - Limiting terminal size: real. The maximum terminal size capacity of the device. Usually measured in square metre (m2).	http://www.buildingsmart-tech.org/ifc/IFC4/Add1/html/schema/ifcelectricaldomain/pset/pset_protectivedevicetrippingunitcommon.htm
bldg73	UPM	IfcBuildingControlsDomain	Which properties has a Unitary control element?	no relevant, however is worth keeping the requirement as rejected for the records.	http://www.buildingsmart-tech.org/ifc/IFC4/Add1/html/schema/ifcbuildingcontrolsdomain/pset/pset_unitarycontrolelementcommon.htm
bldg74	UPM	IfcElectricalDomain	Which properties has a audio visual appliance?	- Media source: string. Indicates media sources and corresponding names of ports (IfcDistributionPort with FlowDirection=SINK and PredefinedType=AUDIOVISUAL) or aggregated audio/video components (IfcAudioVisualAppliance). - Audio volume: real. Indicates discrete audio volume levels and corresponding sound power offsets, if applicable. Mixing values may be interpolated. Measured in watts.	http://www.buildingsmart-tech.org/ifc/IFC4/Add1/html/schema/ifcelectricaldomain/pset/pset_audiovisualappliancecommon.htm

IFC datatype	Transformation to OWL
logical	datatype property with range xsd:boolean
boolean	datatype property with range xsd:boolean
natural	datatype property with range xsd:nonNegativeInteger
integer	datatype property with range xsd:integer
string	datatype property with range xsd:string
{string}	datatype property with range xsd:string
Real (associated to a P_SINGLEVALUE)	object property that would be used to link to an instance of saref:Measurement
real (associated to a P_BOUNDEDVALUE)	two object properties (one for maximum value and another for minimum value) that would be used to link to an instance of saref:Measurement
ratio	object property that would be used to link to an instance of saref:Measurement
real ratio	object property that would be used to link to an instance of saref:Measurement
normalised ratio	object property that would be used to link to an instance of saref:Measurement
positive ratio	object property that would be used to link to an instance of saref:Measurement
complex	object property with open range



Google refine

Transformation patterns

Requirement					
Identifier	Responsible partner	Category (1..N)	Competency Question	Answer	Extracted from (provenance)
bldg1	UPM	building	What is a building?	A building represents a structure that provides shelter for its occupants or contents and stands in one place. The building is also used to provide a basic element within the spatial structure hierarchy for the components of a building project (together with site, storey, and space).	
bldg2	UPM	device	A building can contain devices		
bldg3	UPM	ifcSharedBldgControlsDomain	What is a shading device?	Shading devices are purpose built devices to protect from the sunlight, from natural light, or screening them from view. Shading devices can form part of the facade or can be mounted inside the building, they can be fixed or operable.	http://www.buildingsmart-tech.org/ifc/IFC4/Add1/html/schema/ifcsharedbldgcontrolsdomain/lexical/ifcshadingdevice.htm
bldg4	UPM	ifcBuildingControlsDomain	What is an actuator?	An actuator is a mechanical device for moving or controlling a mechanism or system. An actuator takes energy, usually created by air, electricity, or liquid, and converts that into some kind of motion.	http://www.buildingsmart-tech.org/ifc/IFC4/Add1/html/schema/ifcbuildingcontrolsdomain/lexical/ifcactuator.htm
bldg5	UPM	ifcBuildingControlsDomain	What is an alarm?	An alarm is a device that signals the existence of a condition or situation that is outside the boundaries of normal expectation or that activates such a device.	http://www.buildingsmart-tech.org/ifc/IFC4/Add1/html/schema/ifcbuildingcontrolsdomain/lexical/ifcalarm.htm
bldg6	UPM	ifcBuildingControlsDomain	What is a controller?	Alarms include the provision of break glass buttons and manual pull boxes that are used to activate alarms. A controller is a device that monitors inputs and controls outputs within a building automation system.	http://www.buildingsmart-tech.org/ifc/IFC4/Add1/html/schema/ifcbuildingcontrolsdomain/lexical/ifccontroller.htm
bldg7	UPM	ifcBuildingControlsDomain	What is a flow instrument?	A controller may be physical (having placement within a spatial structure) or logical (a software interface or aggregated within a programmable physical controller). A flow instrument reads and displays the value of a particular property of a system at a point, or displays the difference in the value of a property between two points.	http://www.buildingsmart-tech.org/ifc/IFC4/Add1/html/schema/ifcbuildingcontrolsdomain/lexical/ifcflowinstrument.htm



Google refine

Class definition

```
s4bldg:Compressor rdf:type owl:Class ;
```

```
  rdfs:label "Compressor"@en ;
```

```
  rdfs:subClassOf s4bldg:FlowMovingDevice ;
```

```
  rdfs:comment "A compressor is a device that compresses a fluid typically used in a refrigeration circuit."@en ;
```

Provenance information for class definition

```
  prov:hadPrimarySource
    schema/ifchvacdomain/lexical/ifccompressor.htm> ;
```

Provenance information for class properties

```
  prov:hadPrimarySource
    schema/ifchvacdomain/pset/pset_compressorstypecommon.htm> ;
```

Mapping to ifcOWL classes

```
  rdfs:seeAlso <https://w3id.org/ifc/IFC4_ADD1#IfcCompressor> .
```

<<http://www.buildingsmart-tech.org/ifc/IFC4/Add1/html/schema/ifchvacdomain/lexical/ifccompressor.htm>> ;

<http://www.buildingsmart-tech.org/ifc/IFC4/Add1/html/schema/ifchvacdomain/pset/pset_compressorstypecommon.htm> ;



Google refine

Compressor?

geometrically similar compressors. Usually measured in millimeters (mm).

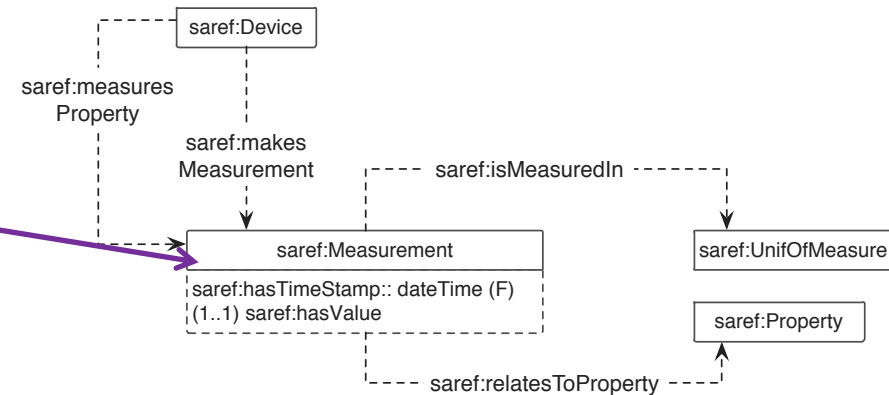
- refrigerant class: {CFC (Chlorofluorocarbons), HCFC (Hydrochlorofluorocarbons), HFC (Hydrofluorocarbons), hydrocarbons, ammonia, CO₂, H₂O, etc.}. Refrigerant class used by the condenser. CFC: Chlorofluorocarbons. HCFC: Hydrochlorofluorocarbons. HFC: Hydrofluorocarbons.
- external surface area: real. External surface area (both primary and secondary area). Usually measured in square metre (m²).
- internal surface area: real. Internal surface area. Usually measured in square metre (m²).
- internal refrigerant volume: real. Internal volume of condenser (refrigerant side). Usually measured in cubic metre (m³).
- internal water volume: real. Internal volume of condenser (water side). Usually measured in cubic metre (m³).
- nominal heat transfer area: real. Nominal heat transfer surface area associated with nominal overall heat transfer coefficient. Usually measured in square metre (m²).
- nominal heat transfer coefficient: real. Nominal overall heat transfer coefficient associated with nominal heat transfer area. Usually measured in Watts/m² Kelvin.

Which properties has a Condenser?

Class definition

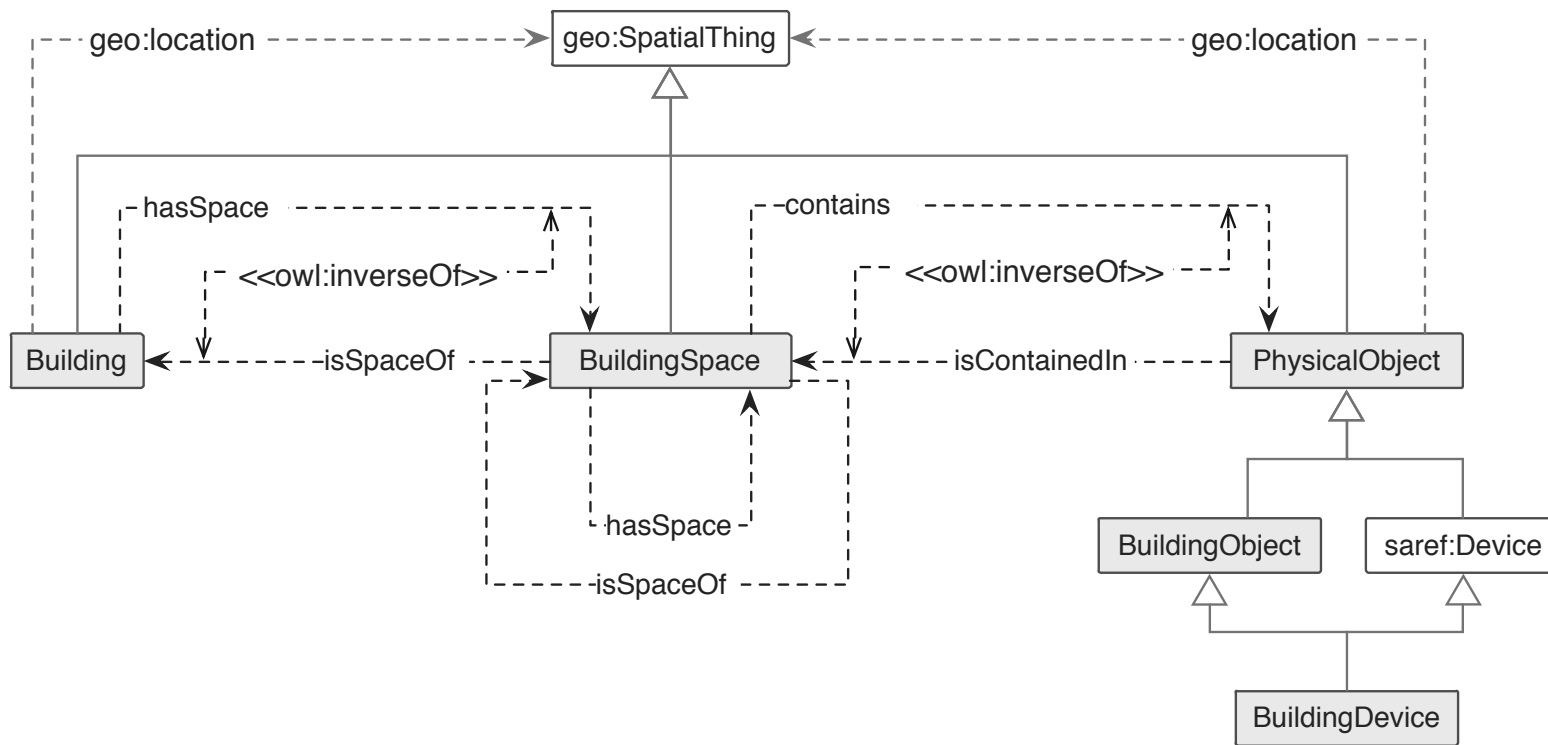
```

:Condenser rdf:type owl:Class ;
  rdfs:subClassOf :EnergyConversionDevice ,
  [ rdf:type owl:Restriction ;
    owl:onProperty :externalSurfaceArea ;
    owl:allValuesFrom saref:Measurement
  ] ,
  [ rdf:type owl:Restriction ;
    owl:onProperty :internalRefrigerantVolume ;
    owl:allValuesFrom saref:Measurement
  ] ,
  [ rdf:type owl:Restriction ;
    owl:onProperty :internalWaterVolume ;
    owl:allValuesFrom saref:Measurement
  ] ,
  [ rdf:type owl:Restriction ;
    owl:onProperty :refrigerantClass ;
    owl:allValuesFrom xsd:string
  ] ...
    
```

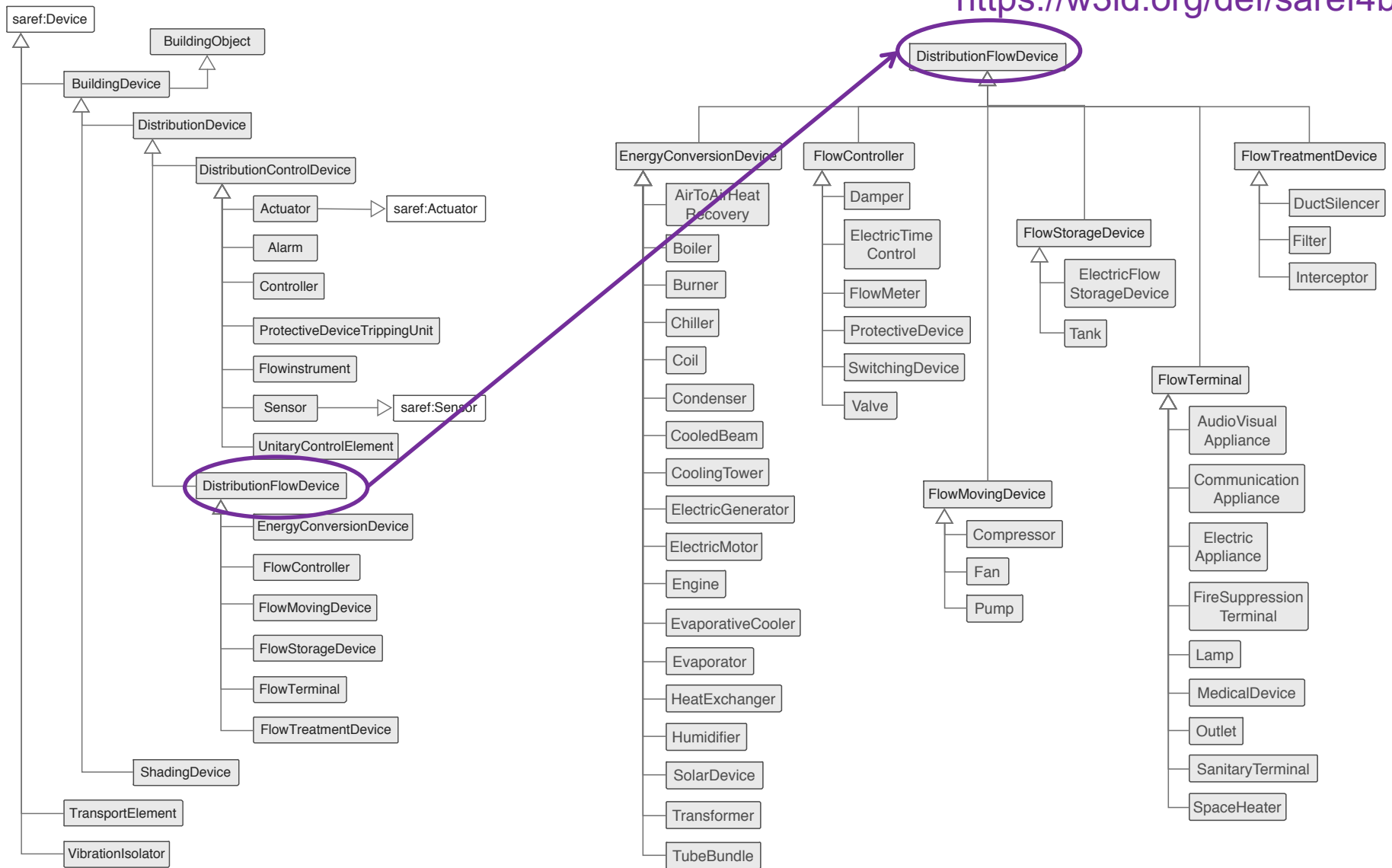


<https://w3id.org/def/saref4bldg>

Powered by  *Ontology*



<https://w3id.org/def/saref4bldg>



Modelling Measurements Aligned with SAREF4ENVI → Adopted in SAREF v2

Shading device^c

[back to ToC](#) or [Class ToC](#)

IRI: <https://w3id.org/def/saref4bldg#ShadingDevice>

Shading devices are purpose built devices to protect from the sunlight, from natural light, or screening them from view. Shading devices can form part of the facade or can be mounted inside the building, they can be fixed or operable.

has super-classes

[Building device](#)^c

[solar reflectance](#)^{op} **only** [Measurement](#)^c

[solar transmittance](#)^{op} **only** [Measurement](#)^c

[thermal transmittance](#)^{op} **only** [Measurement](#)^c

[visible light reflectance](#)^{op} **only** [Measurement](#)^c

[visible light transmittance](#)^{op} **only** [Measurement](#)^c

[is external](#)^{dp} **only** boolean

[mechanical operated](#)^{dp} **only** boolean

[roughness](#)^{dp} **only** string

[shading device type](#)^{dp} **only** string



- Based on IFC standard
 - ISO 16739:2013 Industry Foundation Classes (IFC) for data sharing in the construction and facility management industries
 - Buildingsmart IFC4 <http://www.buildingsmart-tech.org/ifc/IFC4/Add1/html/>
- 98 ontological requirements
 - Devices in buildings
- Extension:
 - 72 classes (67 defined in SAREF4BLDG and 5 reused from the SAREF and geo ontologies)
 - 179 object properties (177 defined in SAREF4BLDG and 2 reused from the SAREF and geo ontologies)
 - 83 data type properties (82 defined in SAREF4BLDG and 1 reused from the SAREF ontology)

- Technical **report**: *ETSI TR 103 411 “SmartM2M Smart Appliances SAREF extension investigation”*
 - Use cases
 - Requirements
- **SAREF4BLDG specification**: *ETSI TS 103 410-3 “SmartM2M; Smart Appliances Extension to SAREF; Part 3: Building Domain”*
 - URI: <https://w3id.org/def/saref4bldg>
- GitHub **repository**:
 - <https://github.com/mariapoveda/saref-ext>

- Balance of domains experts and ontology engineers
 - Enumeration types
 - Missing domain knowledge? Probably
- Impact on SAREF → SAREF v2
- Mechanisms for updates
 - SOSA/SSN
 - LBD ontologies
 - Custom datatypes
 - Etc.
- Guidelines and technological support for extensions
 - Schema.org, SPAR ontologies, etc.

Thanks for your attention :)

■ Ontology **evaluation**

- OOPS! Ontology Pitfall Scanner
<http://oops.linkeddata.es/>



■ Vocabulary **documentation**

- HTML: Widoco
<https://github.com/dgarijo/Widoco/>

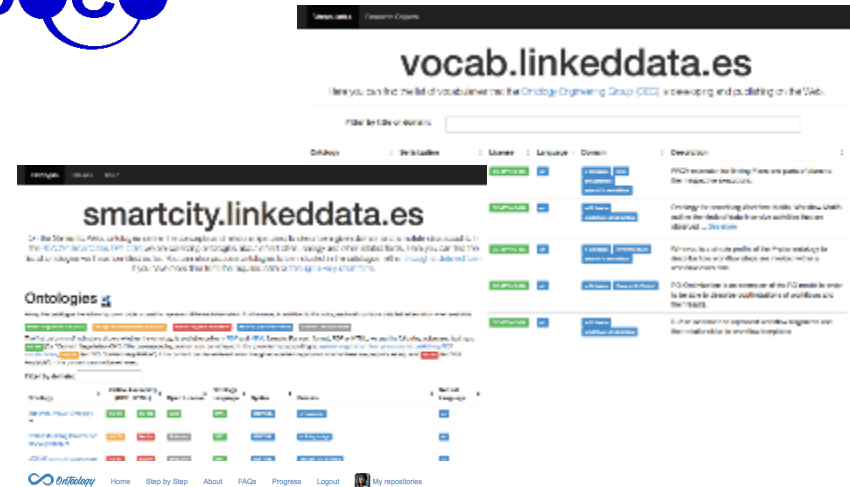


WIDOCO

vocab.linkeddata.es

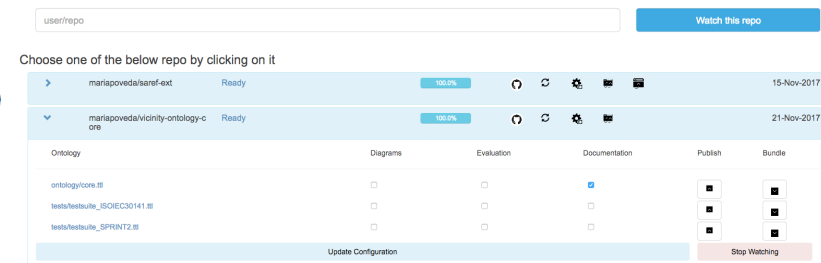
○ Vocabulary **registry**

- OEG vocabularies
<http://vocab.linkeddata.es/>
- Smart Cities <http://smartcity.linkeddata.es/>



○ Vocabulary **distributed development**

- OnToolology <http://ontology.linkeddata.es/>





This work has been supported by the ETSI Specialist Task Force 513

Extending the SAREF ontology for building devices and topology

María Poveda Villalón
Raúl García Castro
Ontology Engineering Group
Universidad Politécnica de Madrid, Spain

✉ mpoveda@fi.upm.es

🐦 [@MariaPovedaV](https://twitter.com/MariaPovedaV)

📅 20th June 2018

📍 LDAC2018, London

