

A detailed wireframe illustration of a cityscape, featuring various building shapes, trees, and urban structures, all rendered in a light gray line-art style against a dark background.

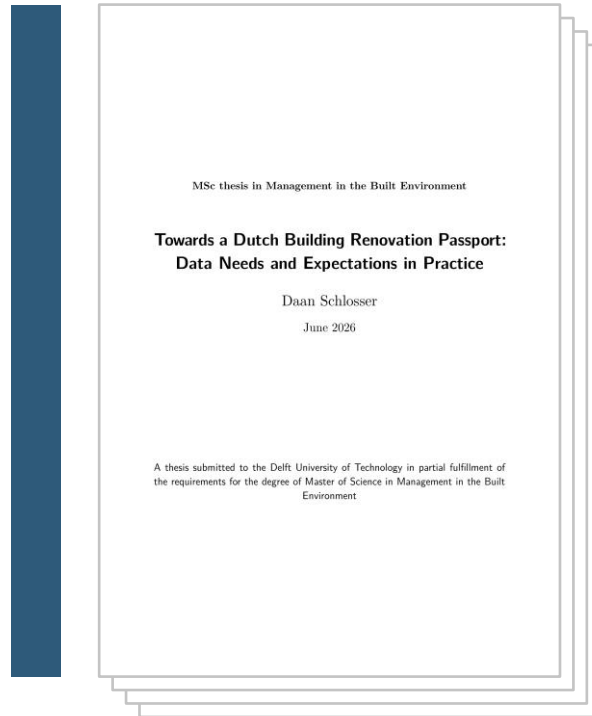
Building Renovation Passports

*What data does a renovation passport need,
and can an open model hold it?*

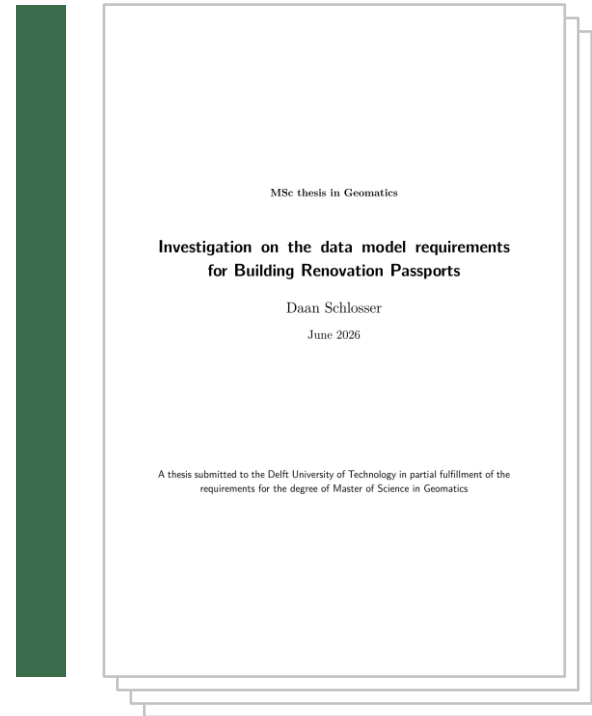
Daan Schlosser

15 June 2026

Two parallel MSc theses



MSc Management in the Built Environment
Henk Visscher & Sun-Ah Hwang



MSc Geomatics
Giorgio Aguiaro & Hiba Doi

The renovation challenge

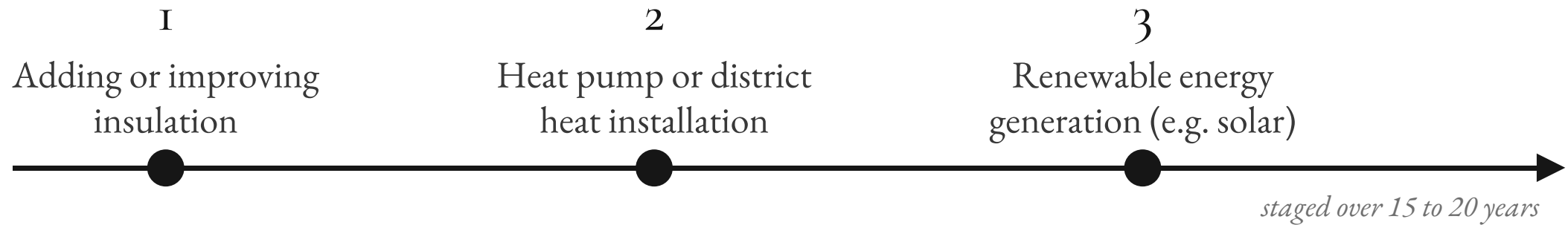
~40% of EU energy use is in buildings, and ~36% of energy-related emissions

85-95% of today's buildings will still be standing and in use in 2050

2050 the Dutch target: a zero-emission building stock (55% down by 2030)

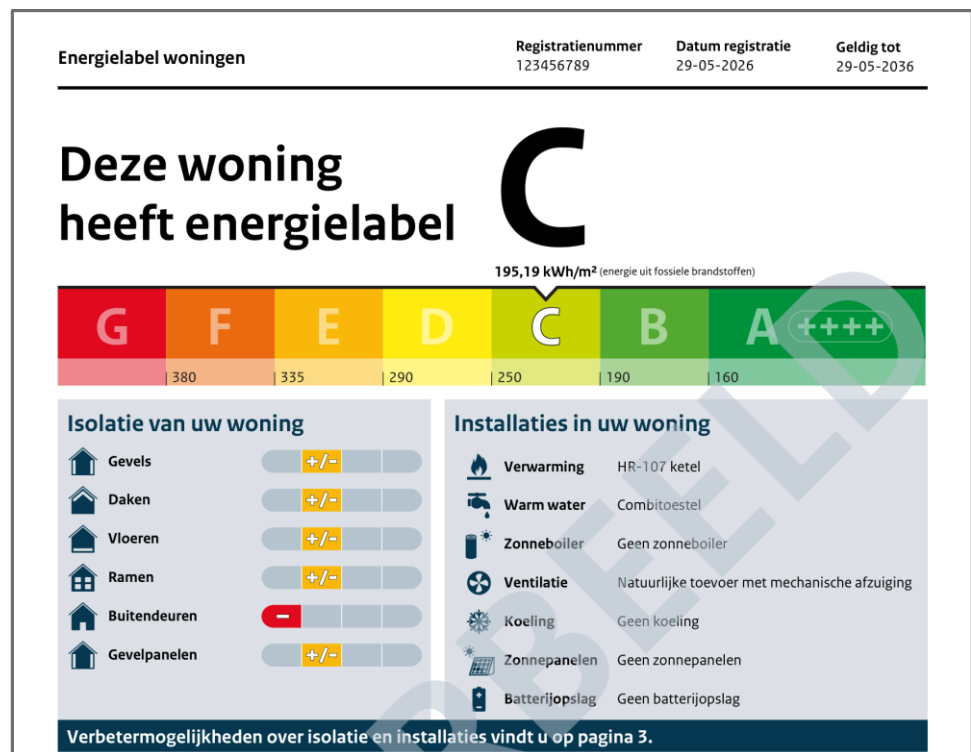
~1%/year renovated now, against the 2 to 3% the targets require

Renovation happens in stages

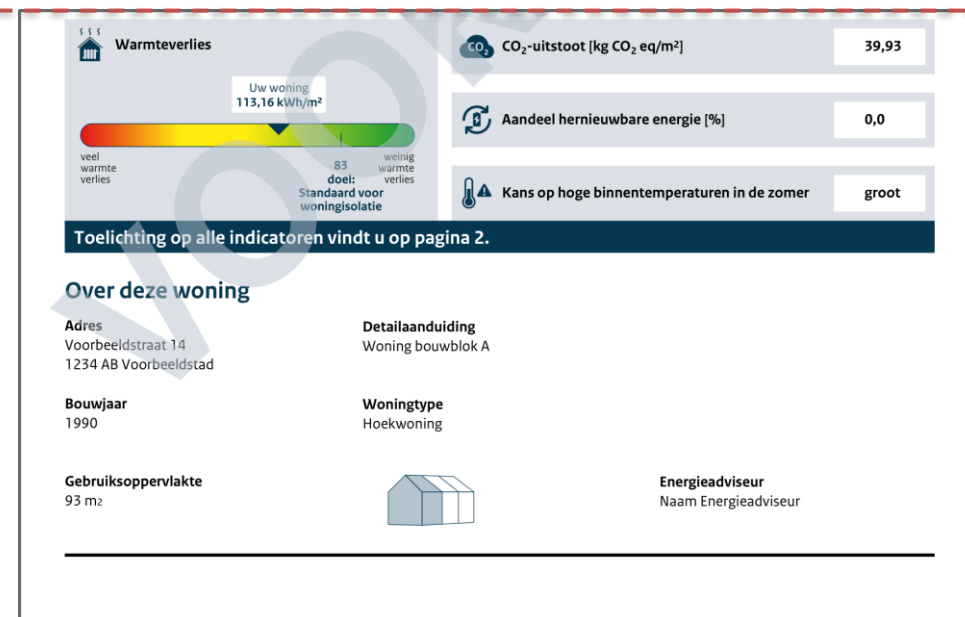


The Dutch energy label

Top half



Bottom half

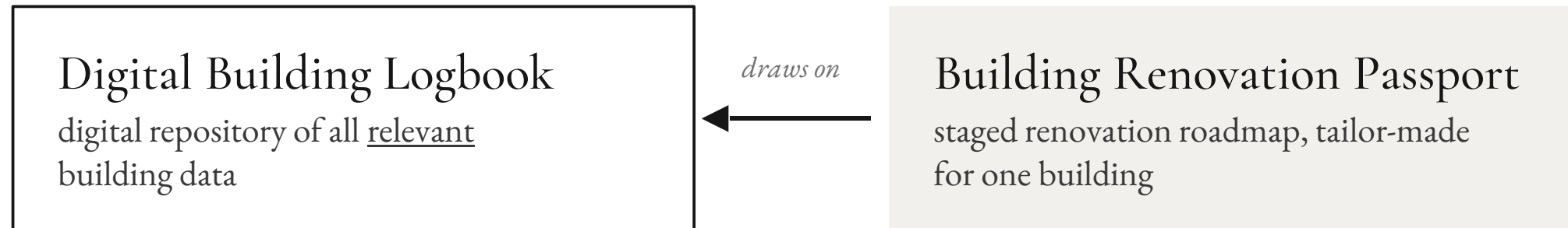


New energy label for a C-dwelling, shown as its two halves. Source: Voorbeeld nieuw energielabel, Volkshuisvesting Nederland / RVO.

Energy Performance Certificates (EPC)

- The EPC is the EU's existing instrument for disclosing performance (2002 EPBD)
- Classifies a building's expected performance on a comparable scale (A++++ to G)
- A model-based estimate of current performance; it does not track change over time
- Its recommendations are generic, not a sequenced roadmap
- It leaves open what to do, in what order, with which dependencies, and with which data

Instruments introduced by the European Commission



PART 1

Building data in practice

What do the professionals who advise homeowners actually need?

- 1 Who advises Dutch homeowners, and in what roles?
- 2 Which building data they use, how they gather it, and whether they share it

The research gap

No Dutch empirical research exists of the professional practice a BRP would build on, specifically:

- **Which stakeholders** advise owner-occupiers, and how each role functions
- **Which building data** each role requires, and at what level of detail
- **How that data is gathered**, and whether it is shared between actors or re-collected
- **What these stakeholders expect** of a Dutch BRP built on this practice

Research questions

- **Main research question** What are the building-data needs of the stakeholders involved in providing renovation advice to Dutch owner-occupiers towards an emission-free home, and what practical expectations do these stakeholders have of a Dutch BRP?
- **SQ1** Who are the stakeholders that play a role in providing renovation advice to Dutch owner-occupiers, and what are their roles in the advisory process?
- **SQ2** What building data do these stakeholders require to provide informed renovation advice, and at what level of detail?
- **SQ3** What practical expectations, concerns, and missing elements emerge regarding a Dutch BRP?

PART 2

Building data in a model

Can an existing open data model actually carry that dossier?

- 1 Compare existing initiatives to define a checklist (the MSRD)
- 2 Test whether an open data model can carry it

The research gap



There is no agreed definition of what are the relevant fields for a BRP

- Existing logbook/passport data models are often closed, only partly published, or just Excel spreadsheets
- So, you cannot tell what they cover, and each new one starts from scratch

→ no agreed, openly published list of required data fields, relations, etc.



An open standard exists, but is untested

- CityGML 2.0 + Energy ADE 3.0 is open, formally specified, and maintained for a decade for urban energy modelling
- Whether it is good enough as a BRP data model has never been tested

→ test whether it is a meaningful starting point, and whether and where further development is required

Research questions

- **Main research question** To what extent does CityGML 2.0 + Energy ADE 3.0 (beta 8) constitute a meaningful starting point for a Building Renovation Passport data model, and what targeted extensions are required to close the gaps?
- **SQ1** Which data fields constitute the MSRD for Building Renovation Passports?
- **SQ2** To what extent does the CityGML 2.0 + Energy ADE 3.0 (beta 8) data model cover the MSRD?
- **SQ3** What does testing CityGML 2.0 + Energy ADE 3.0 (beta 8) at per-building and city scales, using real Dutch building-stock data, reveal about its adequacy and gaps?

The research gap (recap)

No Dutch empirical research exists of the professional practice a BRP would build on, specifically:

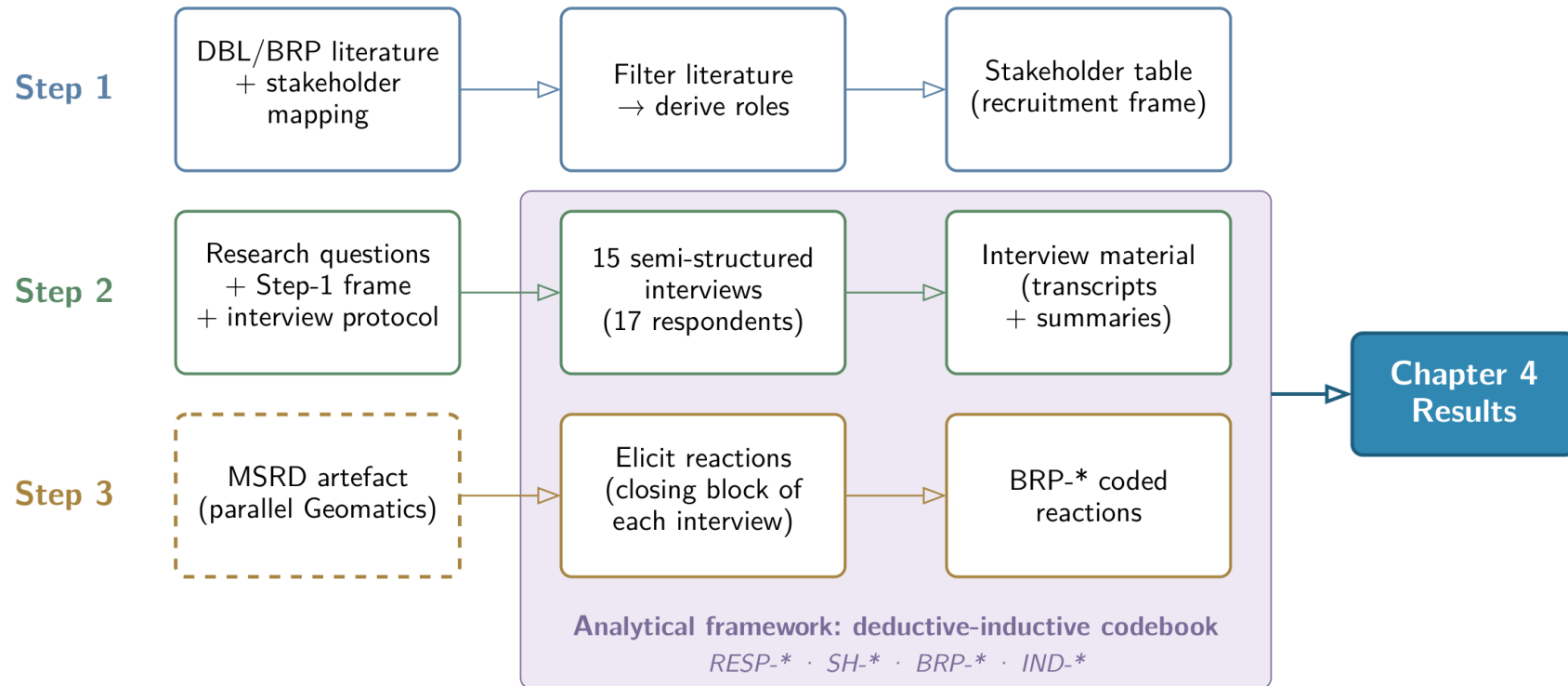
- **Which stakeholders** advise owner-occupiers, and how each role functions
- **Which building data** each role requires, and at what level of detail
- **How that data is gathered**, and whether it is shared between actors or re-collected
- **What these stakeholders expect** of a Dutch BRP built on this practice

Who advises homeowners, in the literature

Stakeholder group	[29]	[89]	[81]	[87]	[90]	[26]	[65]	[58]	[69]	Total
Energy auditor / EP advisor	✓			✓	✓				✓	4
Municipalities / local government	✓	✓	✓	✓	✓	✓	✓	✓		8
Installers & contractors	✓	✓		✓	✓	✓	✓	✓		7
Social networks and energy ambassadors	✓	✓	✓	✓	✓		✓	✓		7
Online tools / digital platforms	✓		✓		✓	✓	✓	✓		6
Energy / heat suppliers		✓		✓				✓		3
Government info agencies (RVO, Milieu Centraal)			✓					✓		2
One-stop shops	✓	✓		✓			✓	✓		5
Construction stores / DIY companies						✓	✓	✓		3

Nine roles derived from Dutch-context studies, and which sources name each. Own work.

Research design



Research design. Own work.

Interview respondents

Code	Stakeholder group	Sector
P01	Homeowner	Private
P02	<i>Energie-loket</i>	Public-funded
P03	Government (national)	Public
P04	Government (national)	Public
P05	Homeowner / Private landlord	Private
P06	Energy advisor / energy coach	Non-profit
P07	Energy advisor / energy coach	Non-profit
P08	Government (municipal)	Public
P09	Energy advisor / energy coach	Non-profit
P10	Contractor / installer	Private
P11	Government (municipal)	Public
P12	Government (municipal)	Public
P13-P15	Contractor / installer	Private
P16	Citizen initiative	Non-profit
P17	Energy cooperative	Non-profit

Anonymised list of participants and their roles. Own work.

Interview themes

- The building data they consider, and what is a must-have against a nice-to-have
- How they gather that data in practice, and from which (external) sources
- Where data is unavailable, and how they deal with that (estimation, proxies)
- Where the data is stored, who can access it, and what they share with others
- The software and tools they use, the inefficiencies they face
- A closing reaction to a live example of the data model

SQ_I The advisory field

- The nine roles from the literature all hold, but the real field is wider and more layered
- A wider intermediary field the literature misses: knowledge institutes (e.g. TNO, Milieu Centraal), cooperatives, citizen initiatives, energy coaches, banks
- The day-to-day relationship runs through intermediaries; the municipality is further from residents, often directing to these intermediaries, and/or subsidising them

SQ_I How the roles actually work

- Several of these roles are split in practice into more specialised roles
- The single certified energy advisor, for example, separates into two distinct roles
 - the certified EP-advisor, who issues the maatwerkadvies and stands behind the heat-loss calculation
 - the volunteer energy coach, who informs at a low threshold and stops short of the calculation
- Many roles draw, and actively guard, an inform-versus-advise boundary
- For these roles impartiality is essential, sustaining resident trust and keeping the guidance objective

SQ₂ The data fields

Data field	Professional				Government		Citizen
	AD	OSS	CO	CT	GN	GM	CI
Construction year (vintage)	○	●	●	○	●	●	●
Dwelling type / position in building	●	●	●	○	●	●	●
Surface areas (facade, roof, floor, glazing)	●	●	○	●	○	○	●
Orientation / solar exposure	●	○	○	○	–	–	●
Insulation status, materials, thickness	●	●	●	●	○	●	●
U-values / R _e -values per component	●	–	○	●	○	–	○
Glazing and window frames	●	●	●	●	○	–	○
Heating system	●	●	●	●	●	●	●
Ventilation system	●	○	○	○	○	–	–
Solar panels	○	○	○	○	○	–	○
Energy label	○	○	●	○	●	●	○
Energy consumption (gas, electricity)	●	●	●	–	●	○	●
<i>Warmteplan / aardgasvrij</i> district context	○	●	–	–	○	●	●
<i>Monumentstatus / welstand</i>	○	○	○	○	–	○	○
Building drawings and as-built records	●	○	○	●	–	○	○
Cost / price information	●	●	○	●	–	○	○
Resident behaviour and occupancy	●	●	●	–	‡	‡	○
Comfort complaints (draught, mould, cold)	●	●	●	○	–	○	○
Carried-forward renovation-history record	●	●	●	●	●	●	●

AD certified energy advisor · OSS one-stop shop · CO volunteer energy coach · CT contractor / installer

GN national government · GM municipal government · CI citizen initiative or cooperative

● primary ○ situational – not typically used ‡ deliberately excluded

What divides the field is **the level of detail**, not which fields.

SQ₂ Nationally-available data

Data source	Professional				Government		Citizen
	AD	OSS	CO	CT	GN	GM	CI
Nationally-available data and tools							
BAG	○	●	○	–	●	●	●
3DBAG	○	–	–	–	○	–	○
EP-Online / energy-label register	○	○	●	○	●	●	○
Kadaster	○	–	–	○	●	○	○
Aggregate energy data (CBS)	–	–	–	–	●	○	●
Google Maps / satellite imagery	–	●	○	–	–	–	–
Cost reference tables (RVO, Casa Data)	○	●	–	–	●	○	–
Subsidy register (RVO specific-purpose grants)	○	●	○	○	●	●	○
Municipal heat plan / heat-transition vision	○	●	–	–	○	●	●
Reference dwellings / tabular defaults	○	●	●	○	●	○	●
Certified EP / NTA 8800 software	○	–	–	–	●	–	–

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SQ₂ Building-specific data



Data source	Professional				Government		Citizen
	AD	OSS	CO	CT	GN	GM	CI
Individual-building data							
Building drawings (municipal archive)	●	–	○	●	–	○	●
Resident self-report (self-collected)	●	●	●	●	–	●	●
Resident self-report (used from others)	○	–	–	○	○	○	○
Hoomdossier (<i>Coöperatie Hoom</i>)	–	–	●	–	–	–	–
Resident-supplied energy bills	●	●	●	–	‡	–	○
Work invoices and quality declarations	–	●	○	●	○	●	–
On-site visual inspection (self-collected)	●	●	●	●	–	●	●
On-site visual inspection (used from others)	○	○	–	○	○	○	–
Thermal-camera survey (self-collected)	●	–	●	–	–	–	–
Thermal-camera survey (used from others)	–	–	–	–	–	–	–
Destructive sampling (self-collected)	○	–	○	○	–	–	–
Destructive sampling (used from others)	○	–	–	○	–	–	–

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The renovation-history gap

The gap is not a missing field, but the absence of records of what earlier professionals captured for the dwelling.

- Each professional already records some of it (photos, drawings, surveys, insulation values, executed measures), but **almost none of it travels**
- **Primary for every stakeholder**, with the most consistent demand across actors and the most consistent absence in practice

SQ3 Expectations of a BRP

- **Integration over replacement:** build on top of the systems they already run, with nationally uniform minimum requirements, not a new central database
- **Record once, reuse later:** the value of a central source is less repeated data collection and destructive on-site research

SQ3 The concerns they raise

- **Privacy** is a concern, particularly at the move to a public central layer, not in current professional contact
- **Cost and update** stay open, namely who pays and what triggers a refresh, with the energy-label fee as a warning example
- **Executability**: that a calculation says a measure should be taken does not mean it can be carried out on the specific dwelling

The BRP should become two things at once

Roadmap

- The stepwise route to a zero-emission building
- Delivered now, as the *maatwerkadvies* in EP-Online

Dossier

- The building data beneath the roadmap, across the 15-to-20-year horizon
- Holds every data-need, and the history gap

The launch ships the roadmap. The dossier is the half practitioners need it to grow into.

Recommendation 1 Capture once, reuse many

- Close the **renovation-history gap**: each fact about a dwelling is captured many times today, and reused almost never
- A shared **data model** keyed to the BAG *verblijfsobject*, holding a structured measure layer plus the evidence and assets each party already produces

Three routes, each a trade-off, offered as **options, not a sequence**:

■ Subsidy-conditional recording tied to the measure's subsidy; non-subsidised works stay invisible

■ Publicly funded capture a free public service; the cost falls on the public purse

■ Mandated on completion piggybacks on permits, insurance, and guarantees; quality depends on the executing party

Four further design recommendations

- 2 **Open contribution** beyond the certified *maatwerkadviseur*, with its source on each record; keep certification for the label
- 3 Design for **multiple granularities** of the same field: per-dwelling for advisors, aggregated reads for policy
- 4 **Integration over replacement**: APIs onto the systems they already run, plus nationally uniform minimum requirements
- 5 **Layered privacy** by default: factual data open, offer and pricing owner-controlled, behaviour stays with the resident

PART 2

Building data in a model

Can an existing open data model actually carry that dossier?

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The research gap (recap)



There is no agreed definition of what a BRP must hold

- Existing logbook/passport data models are often closed, only partly published, or just Excel spreadsheets
- So you cannot tell what they cover, and each new one starts from scratch

→ no agreed, openly published list of required data



An open standard exists, but is untested

- CityGML 2.0 + Energy ADE 3.0 is open, formally specified, and maintained for a decade for urban energy modelling
- Whether it is good enough as a BRP data model has never been tested

→ test whether it is a meaningful starting point; even a negative result would be a useful contribution

Existing initiatives

ID	Initiative	Aim	Type	Building types	Year(s)	Geographic scope
I1	EUB SuperHub DBL	Development of DBL structure for all types of buildings	Data model proposal	Entire stock	June 2021 to Dec. 2024	Transnational (7 countries)
I2	ALDREN	DBL/BRP development for deep renovation of non-residential buildings	Data model proposal	Non-residential	Nov. 2017 to Sep. 2020	Transnational (8 countries)
I3	Gómez-Gil et al.	Academic proposal for DBL data structure	Data model proposal	Entire stock	Oct. 2024	European (comparative analysis)
I4	iBRoad	BRP development for residential buildings, later integrated with EPC schemes and extended to multi-family and public buildings	Data model proposal including roadmap	Residential	June 2017 to Aug. 2024	Transnational (7 countries)
I5	Woningpas	Digital building passport and renovation decision-making support tool	Implementation	Entire stock	Dec. 2018 to ongoing	Regional (Flanders, Belgium)
I6	X-tendo	Next-generation EPC schemes toolbox	Data model proposal	Entire stock	Sep. 2019 to Aug. 2022	Transnational (10 countries)
I7	EU DBL (by Ecorys)	EU Framework for Digital Building Logbooks	Framework study	Entire stock	Nov. 2023	European
I8	BUILDCHAIN	Blockchain-based DBL for trustworthy building lifecycle knowledge	Data model proposal	Entire stock	Jan. 2023 to June 2026	Transnational (6 countries)
I9	OneClickRENO	Automatically generated, customisable BRPs via web tools	Data model + tool	Entire stock	Nov. 2023 to Oct. 2026	Transnational (5 countries)
I10	EPA (by Vitec Vabi)	Software for energy auditors to calculate energy usage and generate EPC scores	EPC software	Entire stock	Since 2008	National (Netherlands)
I11	BuurtWarmteWijzer	Digital tool for residents to explore district heating options and assess collective heat network feasibility	Decision-support tool	Residential	Since 2020	National (Netherlands)
I12	CLÉA	Digital building logbook for housing information management, maintenance tracking, and energy renovation support	Implementation	Residential	Since 2020	National (France)
I13	iSFP	Individual Building Renovation Roadmap (Germany's national BRP)	Implementation	Residential	Since July 2017	National (Germany)
I14	Hoomdossier	Digital building dossier used by energy coaches to gather building data and support residents with renovation advice	Implementation	Residential	Since 2018	National (Netherlands)

The 14 assessed initiatives (I1-I14), the raw material the MSRD is synthesised from. Own work.

Defining the Minimum Set of Required Data (MSRD)

I

Review past initiatives

Review of 14 EU logbook/passport initiatives.

Through research output, policy documents, web-platforms, software, Excel files, etc.

2

Compare them field by field

Break each model into fields; group them by meaning into 13 modules across 3 layers (repository, assessment, functional).

Match up fields that mean the same thing but are named differently.

3

Define the MSRD

Relevance filter: weigh how often a field appears, what the EU directive (EPBD) requires, and what practitioners need.

Relevant? → into the MSRD.

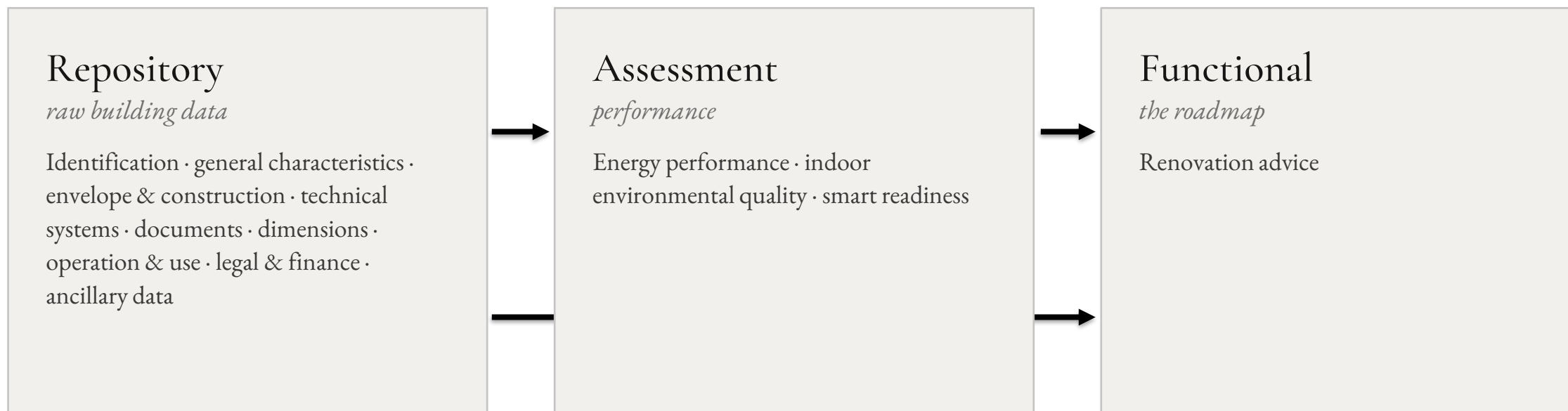
Comparing the initiatives

Feature	I1	I2	I3	I4	I5	I6	I7	I8	I9	I10	I11	I12	I13	I14	Total	%	Relevant?
Building address details	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	14	100%	Yes
Building identification (Cadastral/INSPIRE)	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			11	79%	Yes
Ownership details and occupancy details	✓	✓	✓	✓		✓	✓	✓		✓	✓	✓	✓	✓	12	86%	Yes
Geospatial Coordinates (latitude, longitude, altitude)	✓	✓	✓	✓		✓	✓				✓				7	50%	Yes
DBL author/ assessor qualifications and information	✓	✓		✓	✓	✓		✓	✓	✓			✓	✓	10	71%	Yes
Details on the building with building-unit relation			✓	✓	✓		✓		✓	✓	✓				7	50%	Yes
Timestamps on collection, provision or modification**			✓	✓	✓	✓	✓	✓	✓	✓	✓		✓		10	71%	Yes
Building owner address details			✓							✓		✓	✓	✓	5	36%	No

Module 1 as an example: each field against the 14 initiatives (I1-I14), its frequency, and whether it passed the relevance filter into the MSRD. Own work.

The Minimum Set of Required Data

276 fields · 13 modules · 3 layers



How the initiatives cover the modules



The 14 initiatives across the 13 modules, grouped into the repository, assessment, and functional layer. Own work.

Mapping the MSRD to CityGML + Energy ADE



Feature	%	MSRD	Module	Class	Attribute	Type
Building address details	100%	Yes	Core*	Address	Multiple	Multiple
Building identification (Cadastral/INSPIRE)	79%	Yes	Core	_CityObject	identifier	Code [0..1]
Ownership details and occupancy details	86%	Yes	Building Building	_AbstractBuilding _AbstractBuilding	bdgOwnerName bdgOwnershipType	CharacterString [0..1] OwnershipTypeValue [0..1]
Geospatial Coordinates (latitude, longitude, altitude)	50%	Yes	Core	_CityObject	referencePoint	GM_Point [0..1]
DBL author/ assessor qualifications and information	71%	Yes	DataTypes	Metadata	Multiple	Multiple
Details on the building with building-unit relation	50%	Yes	Building	BuildingUnit	N/A (done by composition)	
Timestamps on collection, provision or modification**	71%	Yes	Core Core	AbstractADEFeature AbstractADEFeature	creationDate terminationDate	Date [0..1] Date [0..1]
Building owner address details	36%	No	X			

Module 1: each MSRD field assigned its place in the model. Own work.

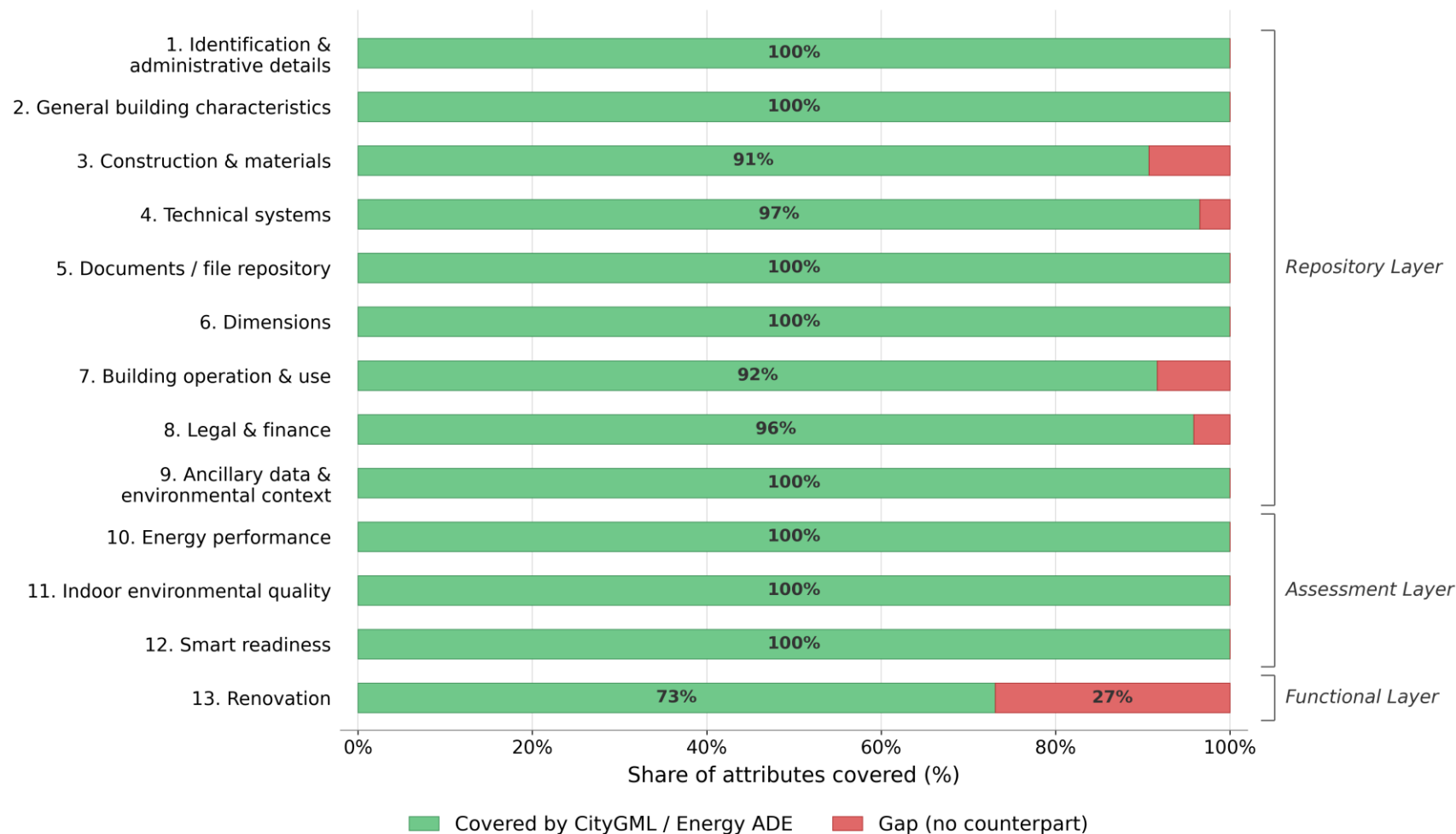
Feature	%	MSRD	Module	Class	Attribute	Type
Only general recommendation to include renovation data	21%	N/A	N/A			
Administrative (step) information						
Renovation measure proposals on specific elements	71%	Yes	Core	Intervention	action	InterventionActionValue [0..1]
			Core	Intervention	type	InterventionTypeValue
			Core	Intervention	interventionStartDate	Date [0..1]
			Core	Intervention	interventionEndDate	Date [0..1]
Textual renovation (stage) description	64%	Yes	X			
Year of this renovation/ stage	43%	Yes	Core	Intervention	interventionStartDate	Date [0..1]
Attachable documents which relate to the renovation	57%	Yes	Core	AbstractADEFeature	externalReference	ExternalReference [0..*]
Achieved/ desired renovation depth (descriptive)	36%	Yes	X			
Energy & resource consumption improvements						
Resource consumption (kWh) vs. pre-renovation	79%	Yes	Resources	Energy	amount	Measure [0..1]
Energy label before/after (letter or colour)	64%	Yes	Building	EnergyPerformanceCertificate	label	CharacterString
Resource demand (kW) vs. pre-renovation	43%	Yes	Resources	Energy	maximumLoad	Measure [0..1]
Energy efficiency before / after renovation	43%	Yes	Core	DeviceOperation	yearlyGlobalEfficiency	Decimal [0..1]
Finances						
Investment costs per measure/ step	71%	Yes	Resources	OtherResource	expense	Measure [0..1]
Current total energy costs per year	57%	Yes	Resources	AbstractResource	expense	Measure [0..1]
Business as usual costs (or if it can be derived)	50%	Yes	Resources	AbstractResource	revenue	Measure [0..1]
Public funding program details	50%	Yes	Resources	Energy	expense	Measure [0..1]
Public funding investment amount (available)	43%	Yes	Resources	AbstractResource	revenue	Measure [0..1]
Overall total investment costs (staged or all at once)	21%	Yes	Resources	OtherResource	expense	Measure [0..1]
Tax incentive (name)	14%	Yes	Core	AbstractADEFeature	externalReference	ExternalReference [0..*]
Reasoning & timelining						
Renovation measure priority level	50%	Yes	X			
Motivation on why this specific measure is necessary**	29%	Yes	X			
Estimation of the renovation works time**	14%	Yes	X			
The first/best opportunity to do this renovation**	14%	Yes	X			
Ideal season for executing the renovation step**	14%	Yes	X			
Non monetary benefits						
Indication of new thermal comfort**	43%	Yes	Core	_CityObject	indicator	Indicator [0..*]
Descriptive explanation of other non-monetary benefits**	36%	Yes	Core	_CityObject	indicator	Indicator [0..*]
Negatives						
Constraints that limit/block certain renovations	36%	Yes	Core	_CityObject	indicator	Indicator [0..*]
Estimation of users' disruption**	14%	Yes	Core	_CityObject	indicator	Indicator [0..*]
Renovation risks (e.g. mold growth if not done properly)	21%	Yes	Core	_CityObject	indicator	Indicator [0..*]

Module 13: each MSRD field assigned its place in the model. Own work.

Feature	%	MSRD	Module	Class	Attribute	Type
Reasoning & timelining						
Renovation measure priority level	50%	Yes	X			
Motivation on why this specific measure is necessary**	29%	Yes	X			
Estimation of the renovation works time**	14%	Yes	X			
The first/best opportunity to do this renovation**	14%	Yes	X			
Ideal season for executing the renovation step**	14%	Yes	X			

Module 13: each MSRD field assigned its place in the model. Own work.

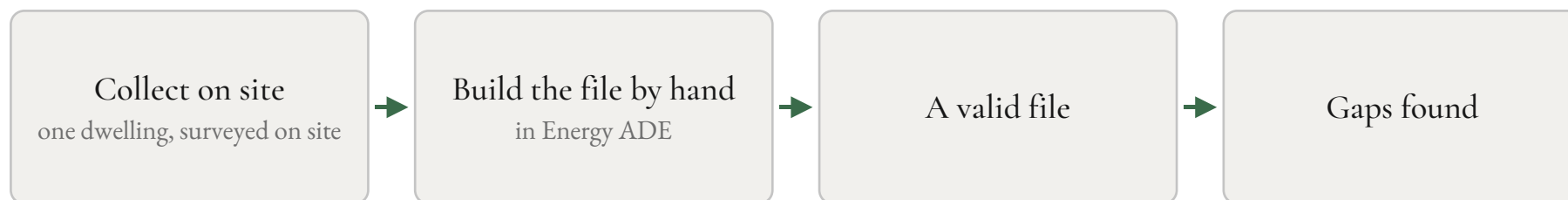
262 of 276 fields covered $\approx 95\%$



Coverage of the MSRD as defined here (via the relevance filter, not an external ground truth); 100% for 8 of 13 modules. Own work.

Testing at two scales: one building, then a whole city

Scale 1 *one building*



Scale 2 *a whole city*

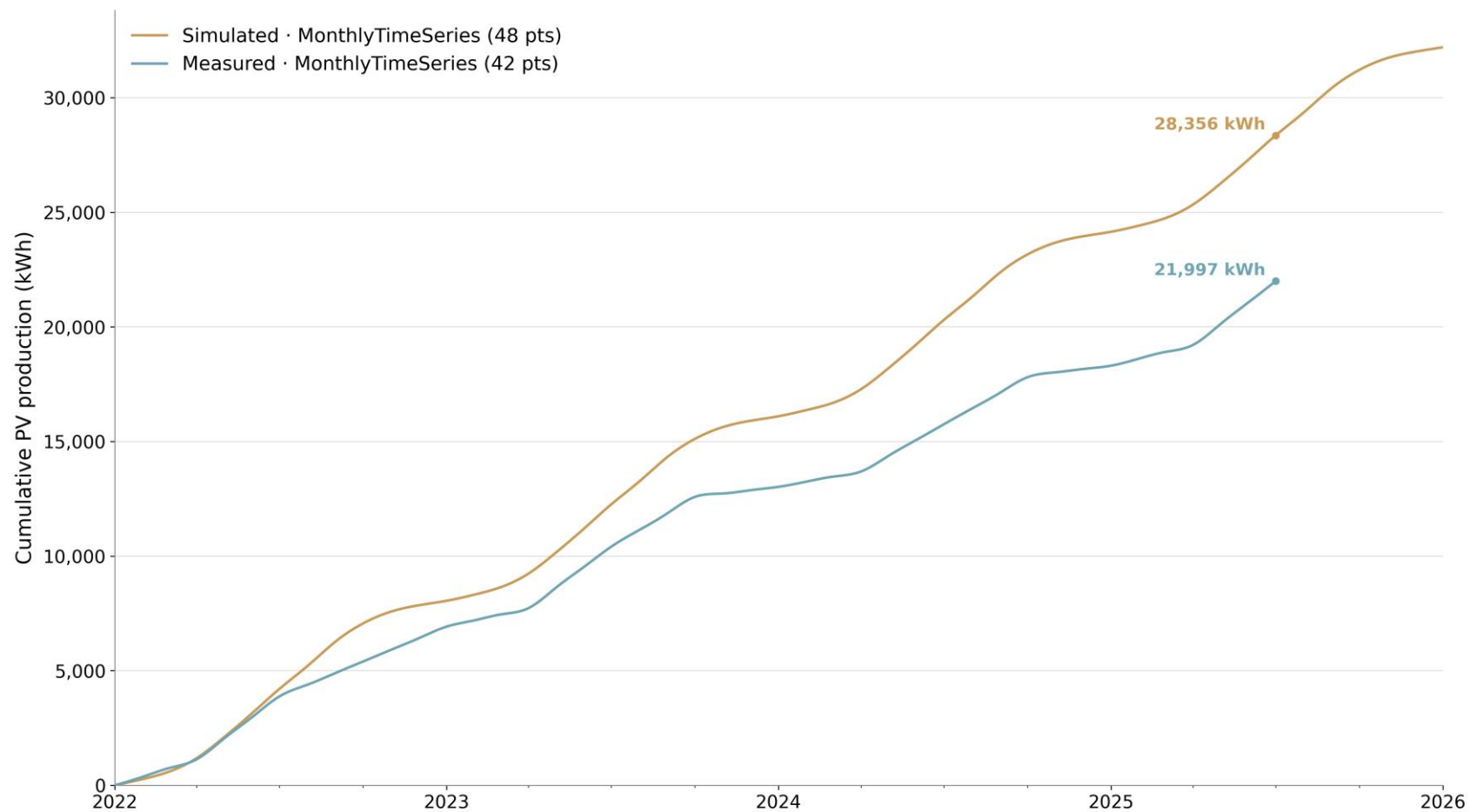


Storing multiple datasets/sources, simultaneously

Name	Value	Description
nrg3:device → nrg3:PhotovoltaicCollector		rooftop array, 36 modules, one feature
└─ nrg3:resource → nrg3:Energy		measured PV production
└─ nrg3:timeDependentAmount → nrg3:MonthlyTimeSeries	42 pts	metered · 2022 to 2025 · 21,997 kWh
└─ nrg3:resource → nrg3:Energy		simulated PV production
└─ nrg3:Metadata → nrg3:acquisitionMethod	simulation	NTA 8800:2024, reference climate
└─ nrg3:timeDependentAmount → nrg3:MonthlyTimeSeries	48 pts	estimate · 2022 to 2026 · 28,356 kWh

The same rooftop solar collector carries two production histories at once, the metered output and an independent simulation, each as its own monthly time-series. Own work.

PV production, measured vs simulated

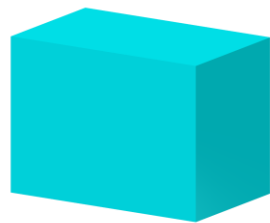


Metered against an independent NTA 8800 simulation, both on the same collector. Own work.

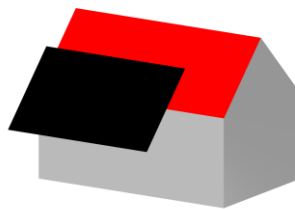
Geometrical representations



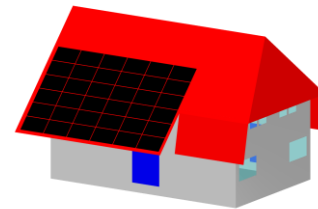
LoDo



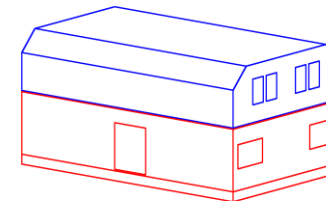
LoD1



LoD2



LoD3



ZoneParts

One owner-occupier dwelling authored across LoD 0-3, with heated zones split into zone-parts (right). Own work.

Mapping open data sources

Source field	Mapped to	How
BAG vbo · gebruiksdoel	nrg3:type (Dutch term, own code space)	Native
3DBAG · b3_h_dak_max	nrg3:bdgHeight (qualified-attribute extension)	Native
3DBAG · LoD2 face	nrg3:bdgBdrySurfTotalSurfaceArea (from geometry)	Computed
EP-Online · Energieklasse	nrg3:EnergyPerformanceCertificate / label	Native
EP-Online · NTA 8800 vs legacy	nrg3:Energy with explicit uom (regimes kept separable)	Native
EP-Online · Gebouws subtype	gen:stringAttribute (no native slot)	GenericAttribute
Solar panel polygon	nrg3:GenericSolarCollector + installedOn	Computed
CFTree · crown_porosity	gen:doubleAttribute (no native slot)	GenericAttribute
BGT · lokaal_id	core:externalReference (marks a public-space tree)	Cross-ref
CBS Postcode-6	nrg3:UrbanFunctionArea + grp:groupMember to its buildings	Native

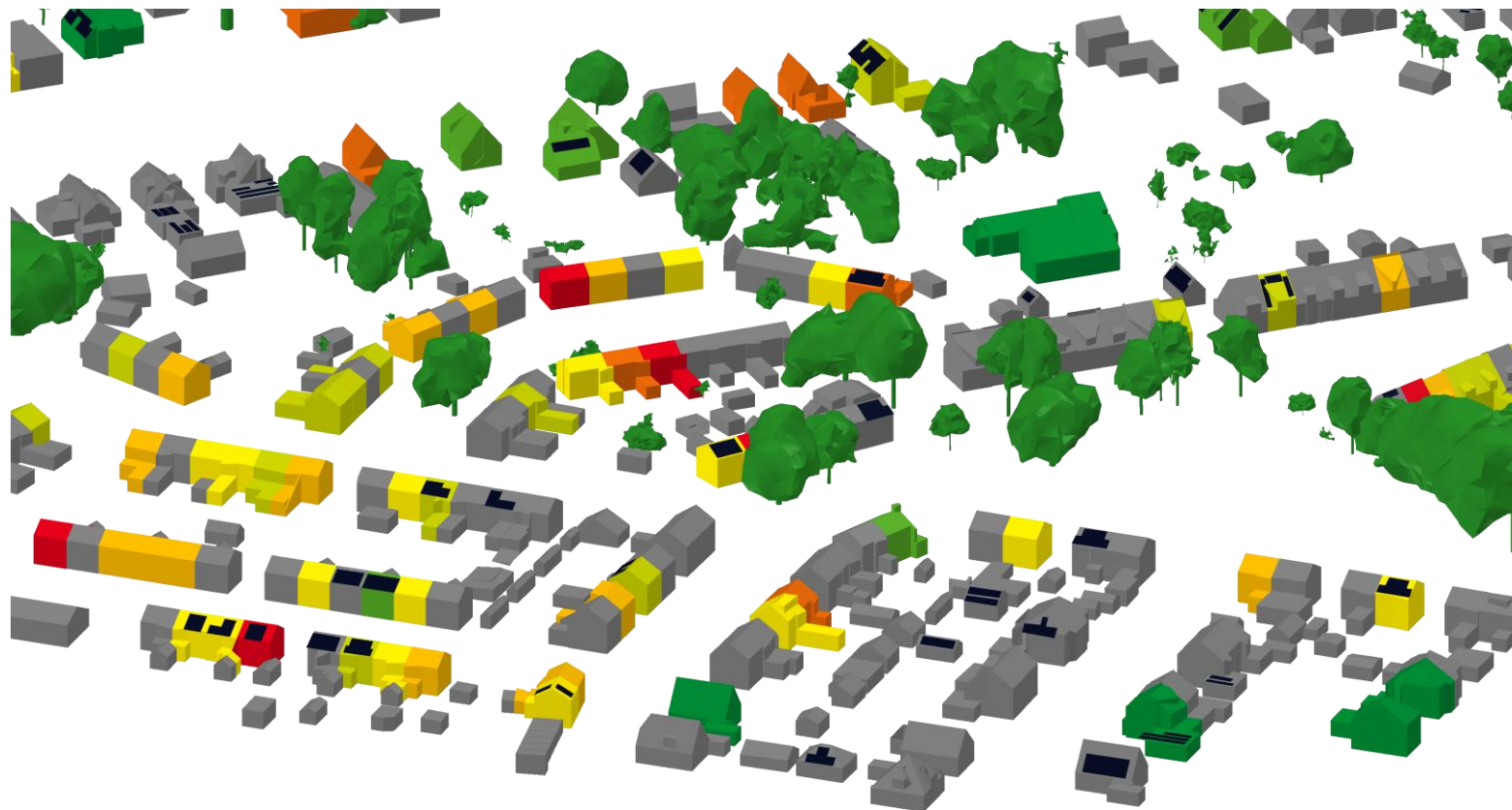
Mappings of the six data sources. Own work.

A building and its EPC

Name	Value	Description
bldg:Building		from BAG <i>pand</i>
└ nrg3:identifier	0114100000280857	BAG pand code space
└ bldg:yearOfConstruction	1926	BAG
└ bldg:address → core:Address		Hoofdkanaal WZ 38, 7881AB Emmer-Compascuum
└ nrg3:BuildingUnit		from BAG <i>verblijfsobject</i>
└ nrg3:identifier	0114010000280857	BAG vbo code space
└ nrg3:address	xlink	references the Address above
└ nrg3:EnergyPerformanceCertificate		from EP-Online
└ nrg3:label	G	
└ nrg3:type	totalEnergyDemand	
└ nrg3:status	actual	

One building linked from its BAG identity to its EP-Online certificate. The link is built into the model, not a manual spreadsheet lookup each time. Own work.

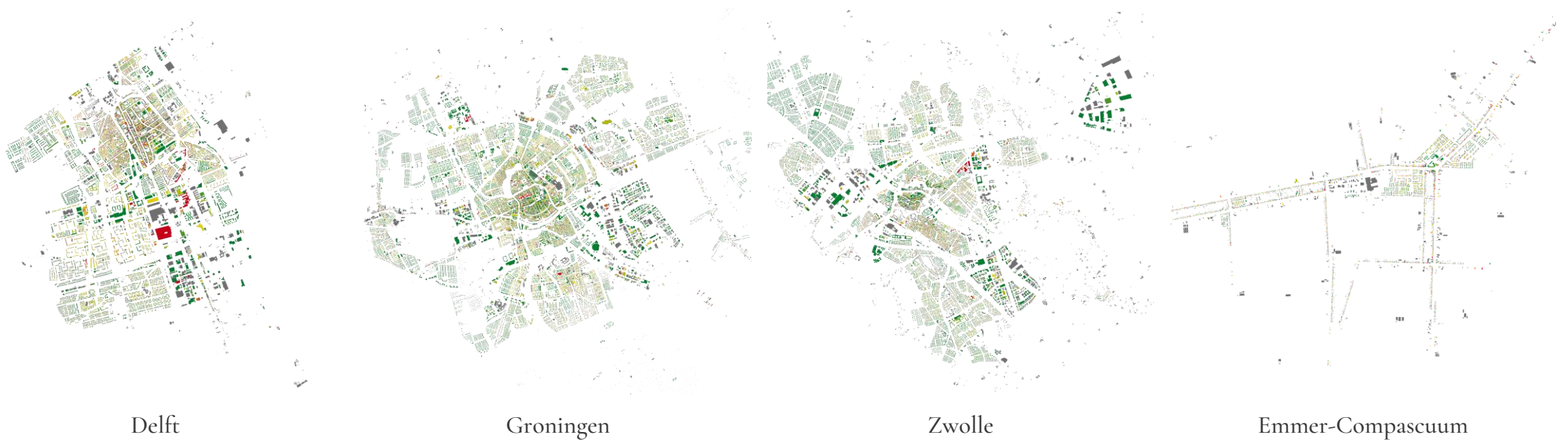
Small area model, built from open sources



Emmer-Compascuum from BAG, 3DBAG, EP-Online, the solar-panel dataset, BGT, and CBS, in the KITModelViewer. Own work.

BAG, Basisregistratie Adressen en Gebouwen · BGT, Basisregistratie Grootchalige Topografie · CBS, Centraal Bureau voor de Statistiek

Scaling up



The same pipeline run on four areas, the municipalities of Delft, Groningen and Zwolle plus the Emmer-Compascuum settlement (up to ~94,000 buildings), each coloured by its energy label. Own work.

Integration makes data quality visible

- BAG and EP-Online disagree on the construction year for about 2 in 5 buildings
- EP-Online uses 1930 as a placeholder year for ~7-12% of labelled buildings (highest in Delft)
- EP-Online years cluster on round numbers: ~1 in 4 ends in zero, against ~1 in 10 expected
- About two-thirds of building units link to an energy certificate at all
- Rooftop solar area is decoupled from the energy label

Answering the sub-questions

SQ_I the MSRD

276 fields in 13 modules and 3 layers, once the relevance filter is applied across the 14 initiatives

SQ₂ coverage

≈95% (262 of 276); complete for 8 of 13 modules, including the whole assessment layer

SQ₃ adequacy

adequate to carry the data and to make its quality tractable; holds at both scales; gaps localised, not structural

Answering the main research question

- CityGML 2.0 + Energy ADE 3.0 (beta 8) is a meaningful, strong starting point
- The gaps are localised, not structural, and the model holds on real Dutch data at both scales
- The one substantial gap is Module 13, the renovation roadmap (73%)
- Practitioners (and open data) weight and use fields differently. The model lets almost every field be optional, which fits that divergence well

What is still missing, and should be added

Renovation roadmap

Missing now

The model records one planned measure, but not the renovation as an ordered, described sequence of steps, each with its timing, depth, and expected effect on energy and cost. This is the largest gap.

To add

A structure that groups the ordered steps into one roadmap, queryable inside Energy ADE now, with the draft Scenario ADE as a richer route later.

Cost & finance

Missing now

Costs and revenue tied to energy use already fit, but subsidies, grants, insurance and certification (the one-off costs) have no place in the model.

To add

A home for these one-off costs; how to model money belongs on the Energy ADE development agenda.

Implications and recommendations

Policy (EU & NL)

The roadmap gap is exactly EPBD Article 12 / Annex VIII, so the extensions double as close-the-gap recommendations. The Dutch gebouwrenovatiepaspoort (live 29 May 2026) is benchmarkable against the MSRD; the data-quality patterns are concrete inputs to the national building-data facility (LVG).

The Energy ADE effort

A CityGML 3.0 port is beneficial but not required for these fixes: the features used are already backported, and a tested 1.0-to-3.0 mapping exists (Bachert, 2024). The proposals are offered for the development effort to review.

The RenoDAT consortium

Three deliverables to build on: the two open-source pipelines, the named data-quality reconciliation targets, and the MSRD as a candidate field set to test, contest, and extend.

Two halves of one answer

Building data in practice

- What people need is a dossier, built around a renovation history that travels
- It should integrate, not replace the systems they already run

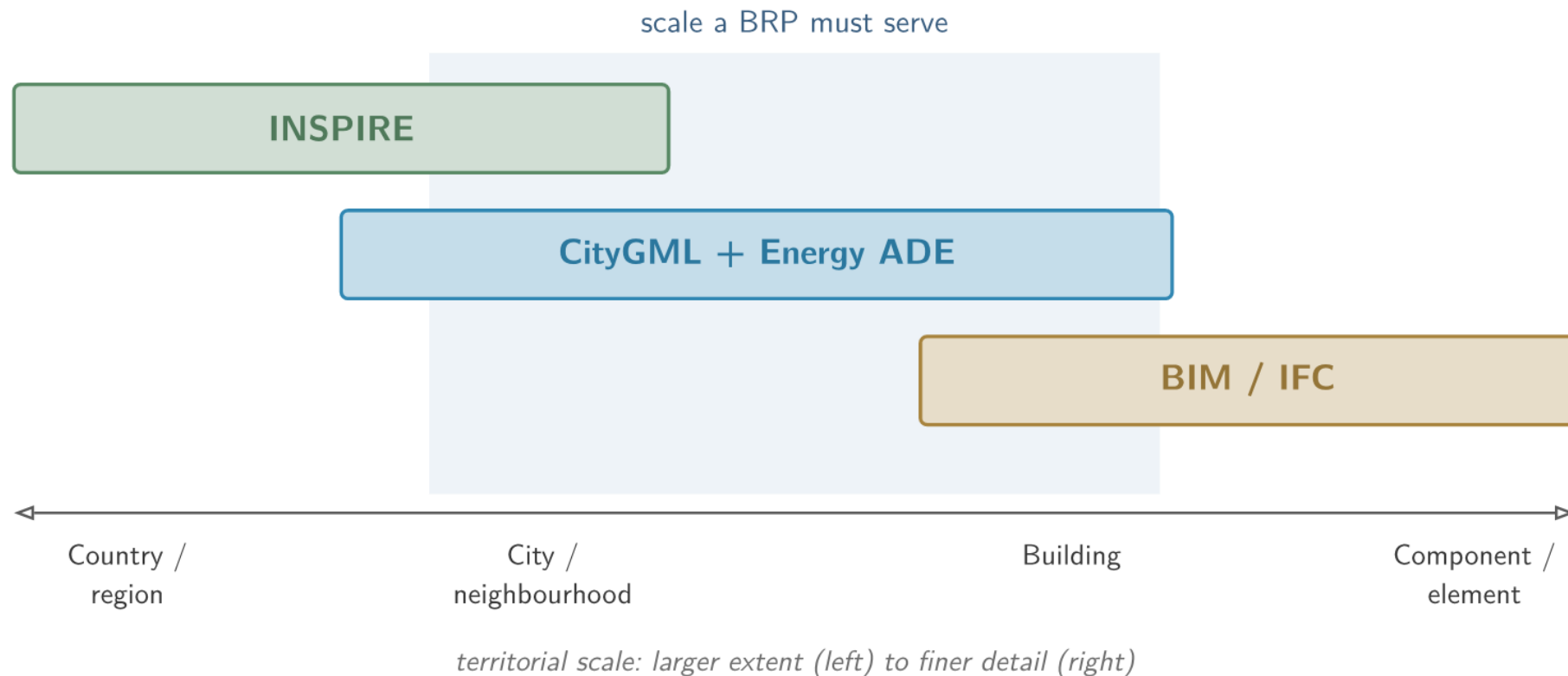
Building data in a model

- An open model can hold such a dossier — about 95% already fits
- The gaps are localised; the main one is the roadmap itself

The foundation largely exists. The next step for the Dutch passport is to build the dossier half around a record that carries forward.

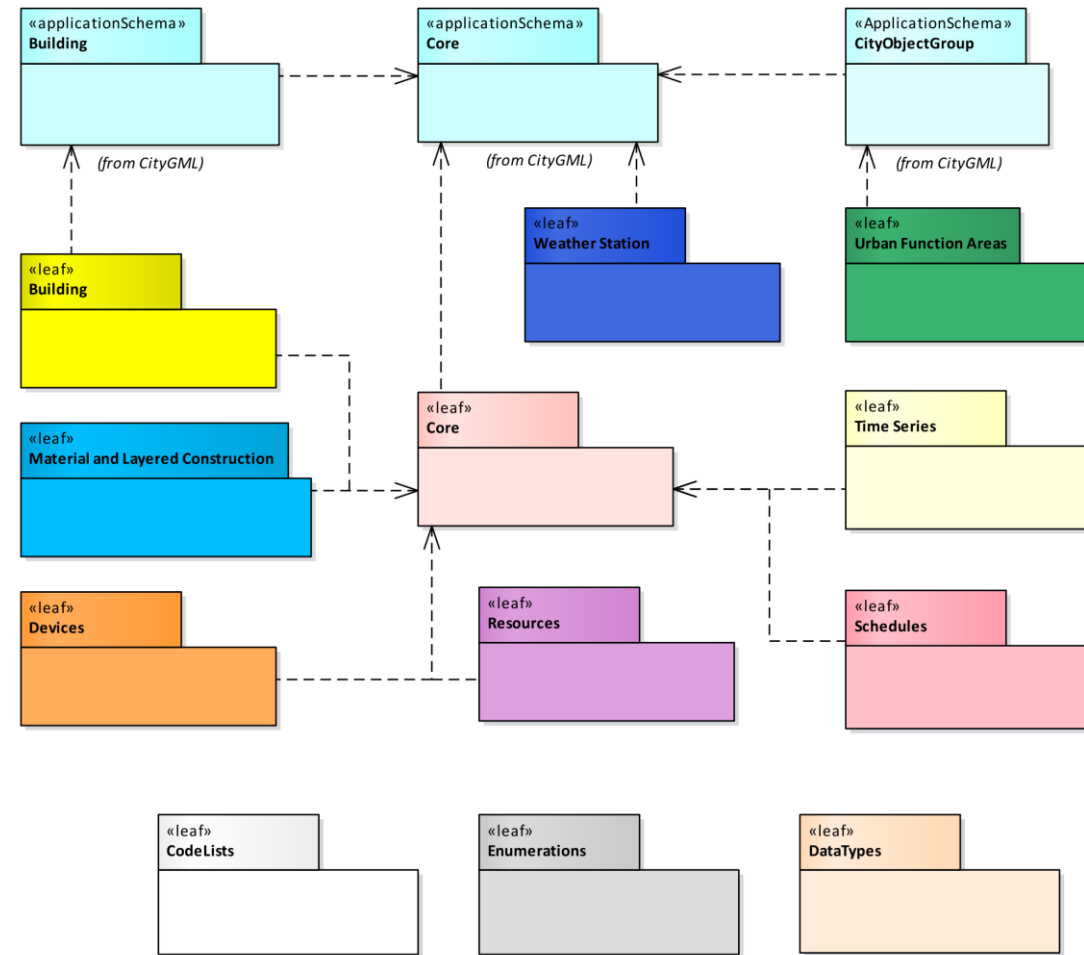
Thank you

The candidate data model



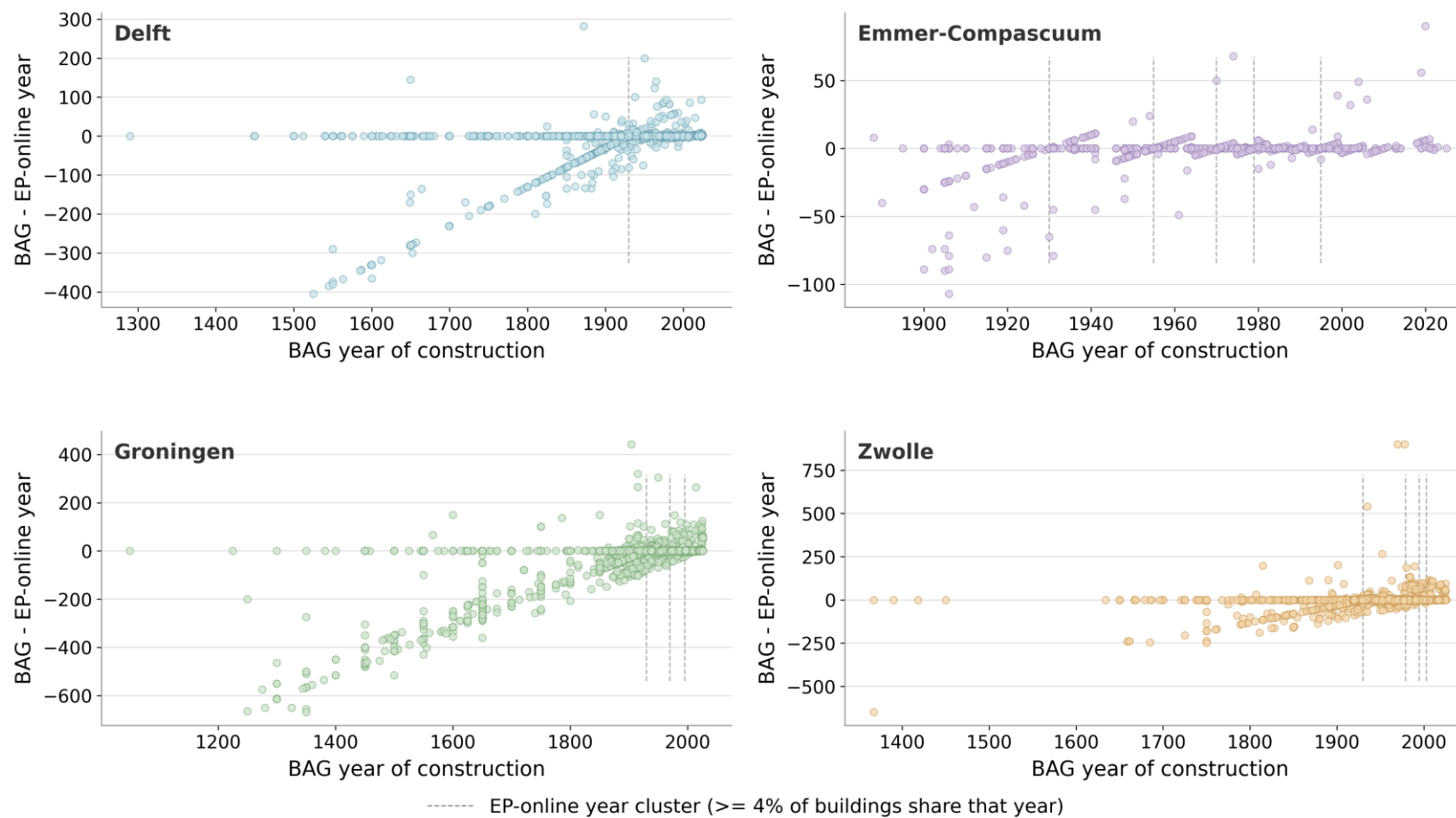
Spatial-scale spectrum. Own work, derived from Agugiaro et al.

The Energy ADE 3.0 modules



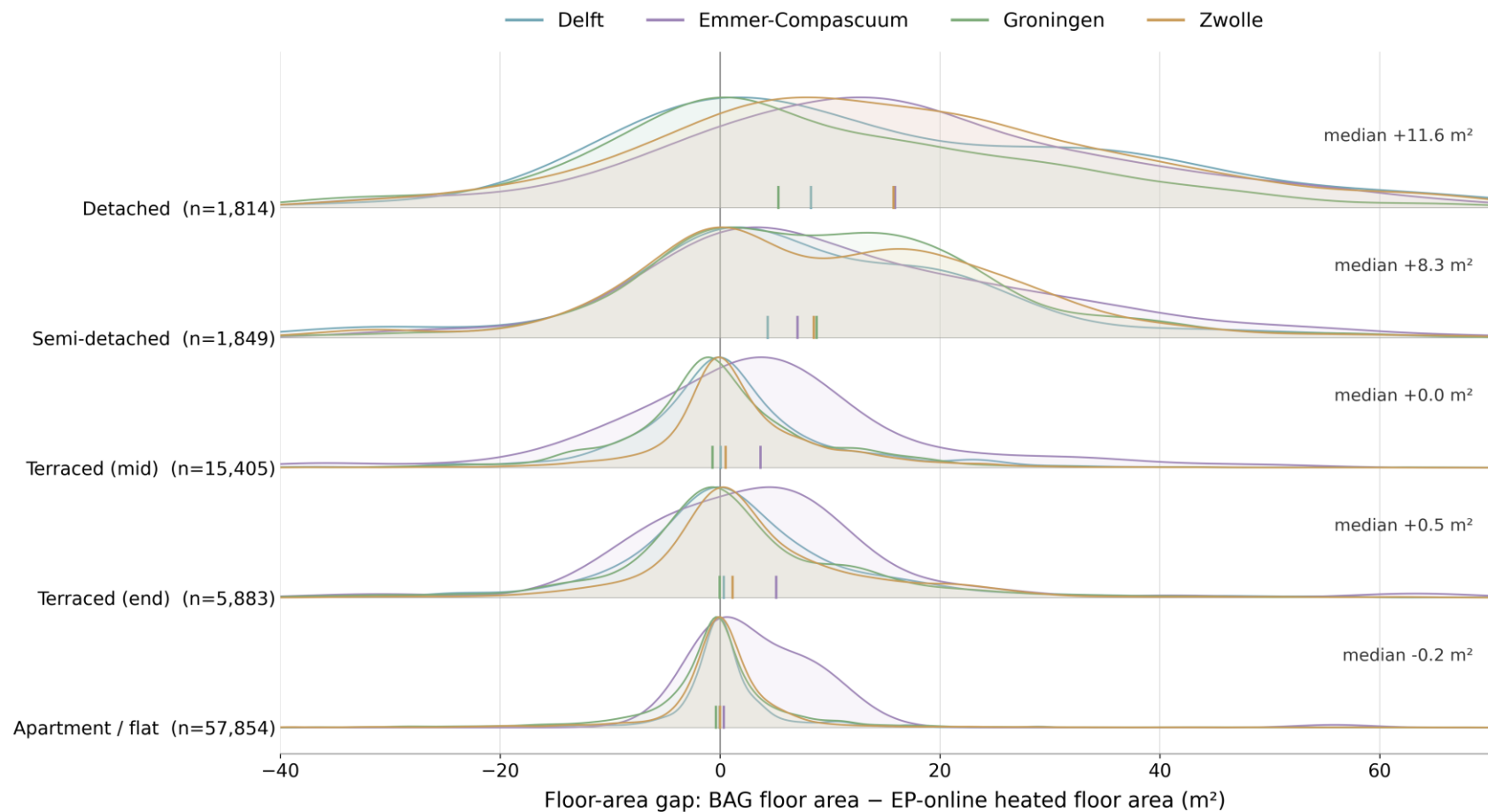
Package overview of CityGML 2.0 + Energy ADE 3.0 (beta 8). Reproduced from the Energy ADE 3.0 (beta 8) UML documentation.

Year disagreement



Signed BAG vs EP-Online year difference as a clustered scatter. Own work.

Floor area by building type



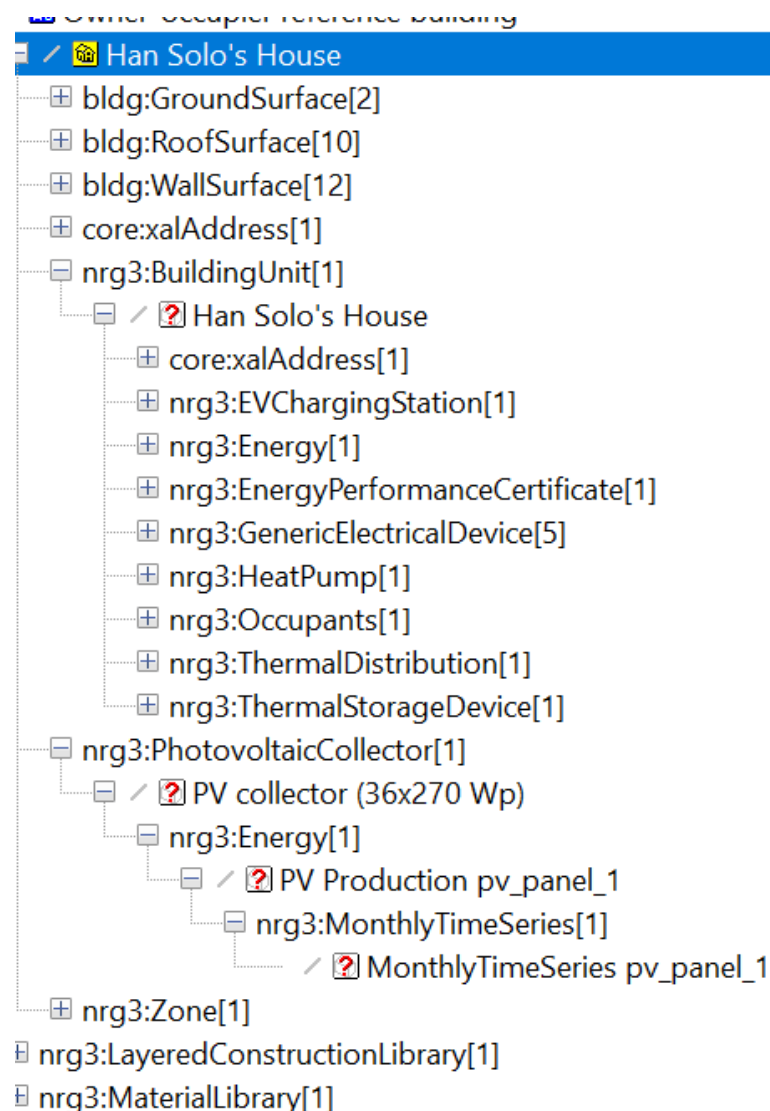
Floor area and its signed cross-register difference, by building type. Own work.

Step 3 The data model shown to interviewees

The screenshot displays the KITModelViewer x64 V 7.5.2 interface. The main window is titled 'owner_occupier_building.gml'. The left sidebar shows a hierarchical tree of the building model, with 'Han Solo's House' selected. The central 3D View shows a simple wireframe model of a house with a red 'X' and a blue 'Z' axis. The right sidebar shows the 'Property Toolbar' with tabs for 'Attributes', 'Properties', 'Relations', and 'Visibility'. The 'Attributes' tab is active, displaying a table of building attributes.

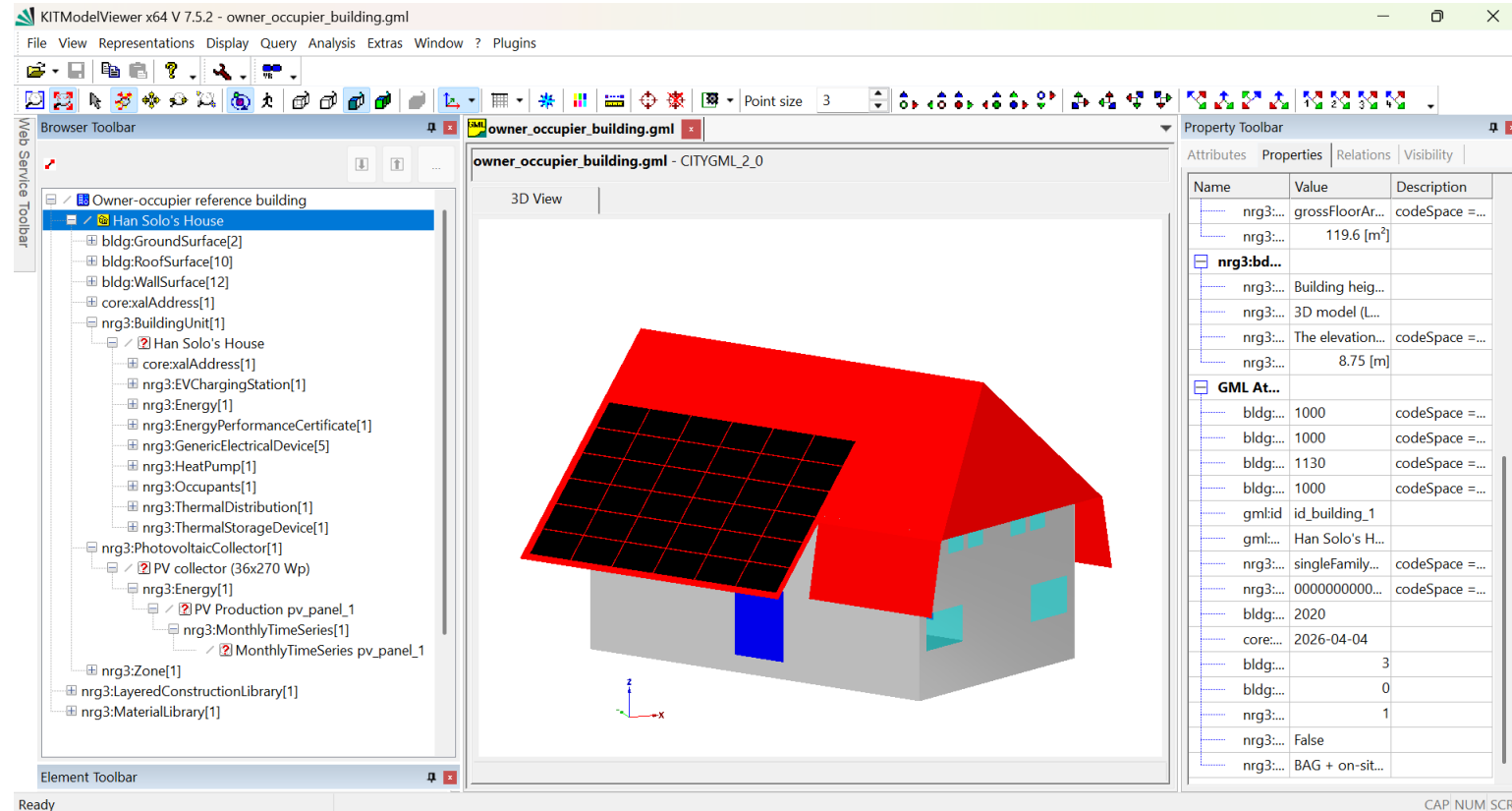
Name	Value	Description
nrg3:type	grossFloorArea (grossFloorArea)	codeSpace = http://3dcities.bk.t...
nrg3:QualifiedArea	119.6 [m²]	
nrg3:bdgHeight		
nrg3:description	Building height measured from ...	
nrg3:source	3D model (LOD3 STEP geometry)	
nrg3:type	The elevation has been captured...	codeSpace = http://3dcities.bk.t...
nrg3:QualifiedHeight	8.75 [m]	
GML Attributes		
bldg:class	1000	codeSpace = http://www.sig3d...
bldg:function	1000	codeSpace = http://www.sig3d...
bldg:roofType	1130	codeSpace = https://www.sig3d...
bldg:usage	1000	codeSpace = http://www.sig3d...
gml:id	id_building_1	
gml:name	Han Solo's House	
nrg3:bdgType	singleFamilyHouse (singleFamily...	codeSpace = http://3dcities.bk.t...
nrg3:identifier	000000000000000001	codeSpace = http://bag.basisre...
bldg:yearOfConstruction	2020	
core:creationDate	2026-04-04	
bldg:storeysAboveGrou...		3
bldg:storeysBelowGround		0
nrg3:bdgNumberOfBuil...		1
nrg3:bdgIsProtected	False	
nrg3:source	BAG + on-site measurement sur...	

The MSRD data model from the parallel Geomatics thesis, one owner-occupier dwelling, shown live. Own work.



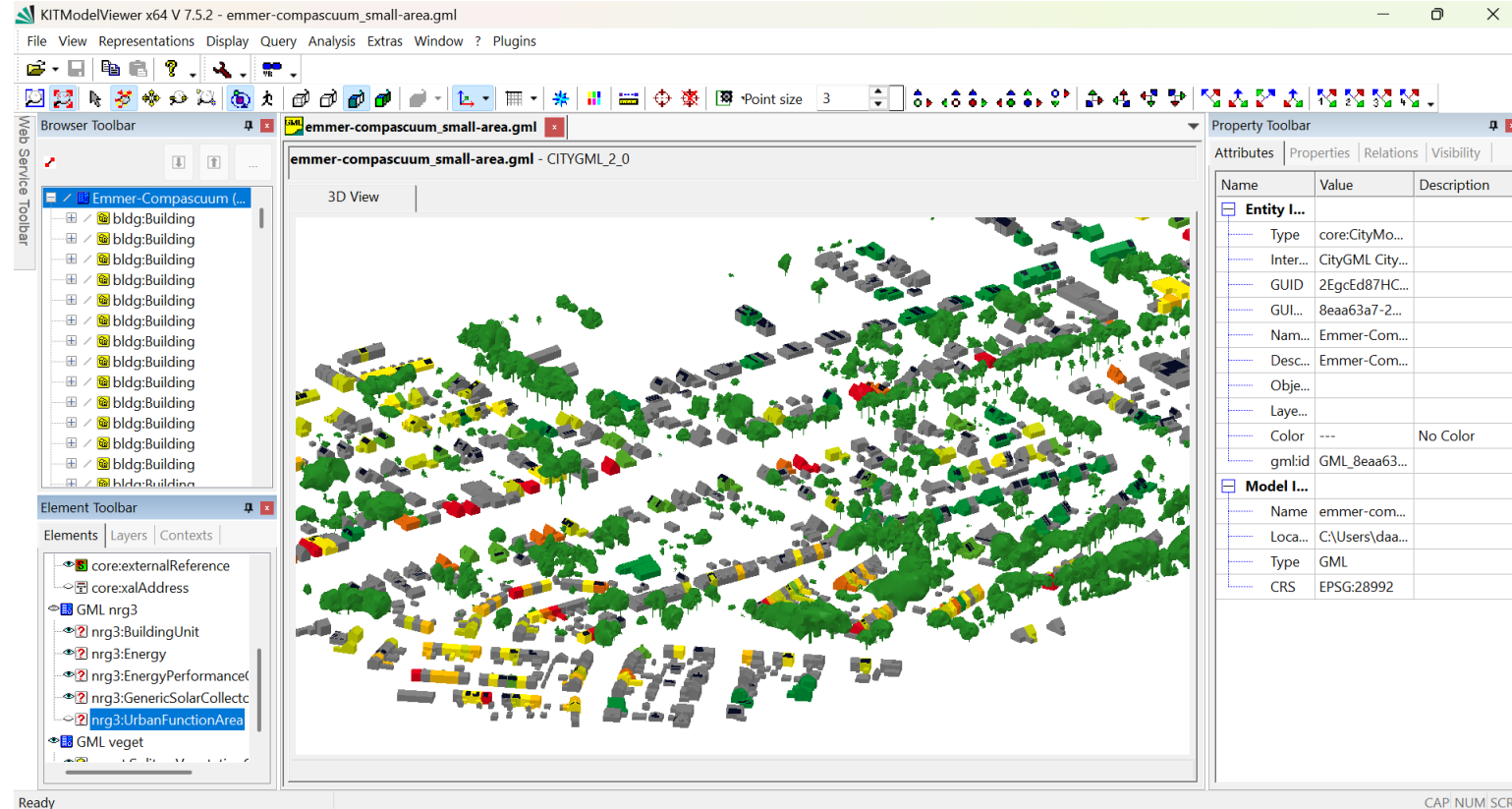
nrg3:type	grossFloorArea (grossFloorArea)	codeSpace = http://3dcities.bk.t..
nrg3:QualifiedArea	119.6 [m²]	
nrg3:bdgHeight		
nrg3:description	Building height measured from ...	
nrg3:source	3D model (LOD3 STEP geometry)	
nrg3:type	The elevation has been captured...	codeSpace = http://3dcities.bk.t..
nrg3:QualifiedHeight	8.75 [m]	
GML Attributes		
bldg:class	1000	codeSpace = http://www.sig3d....
bldg:function	1000	codeSpace = http://www.sig3d....
bldg:roofType	1130	codeSpace = https://www.sig3d..
bldg:usage	1000	codeSpace = http://www.sig3d....
gml:id	id_building_1	
gml:name	Han Solo's House	
nrg3:bdgType	singleFamilyHouse (singleFamily...	codeSpace = http://3dcities.bk.t..
nrg3:identifier	00000000000000001	codeSpace = http://bag.basisre...
bldg:yearOfConstruction	2020	
core:creationDate	2026-04-04	
bldg:storeysAboveGrou...		3
bldg:storeysBelowGround		0
nrg3:bdgNumberOfBuil...		1

The same model, with the geometry



The same file with the geometry layer revealed, at LoD3. Own work.

And it scales beyond one building



A small-area model, showing the same data model can also scale to a neighbourhood. Own work.