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IMPACTS OF CIRCULAR ECONOMY ON CLIMATE TARGETS: M-LEVEL IN CONSTRUCTION AND RENOVATION

UPDATE M-LEVEL OPTIMALISATION

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DOCUMENTBESCHRIJVING

1 *Titel van publicatie:*
OVAM_M-peil.docx

2 *Verantwoordelijke Uitgever:*
OVAM

3 *Wettelijk Depot nummer: D/2025/5024/18*

4 *Trefwoorden:*
M-peil, milieuimpact, materialenpeil, voetafdruk, territoriale impact, broeikasgasemissies

5 *Samenvatting:*
Deze studie onderzoekt de impact in Vlaanderen (territoriale impacts) alsook de impact op de voetafdruk (globaal perspectief) van de invoering van een M-peil. De resultaten geven de impact van broeikasgassen weer, alsook een bredere kijk op de milieuvoetafdruk. Deze laatste is een combinatie van 16 impactcategorieën, waaronder broeikasgasemissies.

6 *Aantal bladzijden:* 35

7 *Aantal tabellen en figuren:* 8 tabellen, 10 figuren

8 *Datum publicatie:* 20.05.2025

9 *Prijs*:* /

10 *Begeleidingsgroep en/of auteur:* Maarten Christis, An Vercalsteren, Damien Trigaux, Joren Mijnendonckx

11 *Contactpersonen:*
Elke Meex, Evi Rossi (OVAM)

12 *Andere titels over dit onderwerp:* Impacts of circular economy on climate targets: M-level in construction and renovation (CE Center N°27)

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* Prijswijzigingen voorbehouden.

INHOUD

1 SUMMARY

In the coming years, OVAM will further investigate the introduction of a material level (M-level) for construction works. The construction policy program “Towards Circular Construction” (approved by the Flemish Government on 29 April 2022) plans to introduce an M-level by 2030.

This study examines the impact in Flanders (territorial impacts) as well as the impact on the footprint (global perspective) of the introduction of an M-level. The results reflect the impact of greenhouse gases, as well as a broader view of the environmental footprint. The latter is a combination of 16 impact categories, including greenhouse gas emissions.

The introduction of an M-level assumes an alternative with the lowest environmental impact is chosen for the components of each building element (e.g., roof, outer wall, or window). For each element, a substitute is determined for the combination of materials that make up 80% of the environmental footprint (ranked from largest to smallest).

The results focus on a comparison between scenarios without and with the introduction of an M-level. In addition to a business-as-usual scenario, a scenario has been added with an increased number of renovations. This scenario aims to renovate all dwellings with currently energy labels E and F to label A by 2050. A third and fourth scenario also aim for this increased renovation effort, but introduce the M-level. In scenario 3, this is limited to new construction; in scenario 4, the principles apply to both new construction and renovation. The results show that an increased number of renovations in combination with the introduction of the M-level for new constructions is not enough. It is important to introduce the M-level for renovations as well.

2 SAMENVATTING

De piste die de OVAM de komende jaren verder wil onderzoeken is het invoeren van een materialenpeil (M-peil) voor bouwwerken. Het beleidsprogramma bouw “Op weg naar Circulair Bouwen” (door de Vlaamse Regering goedgekeurd op 29 april 2022) plant de invoering van een M-peil tegen 2030.

Deze studie onderzoekt de impact in Vlaanderen (territoriale impacts) alsook de impact op de voetafdruk (globaal perspectief) van de invoering van een M-peil. De resultaten geven de impact van broeikasgassen weer, alsook een bredere kijk op de milieuvoetafdruk. Deze laatste is een combinatie van 16 impactcategorieën, waaronder broeikasgasemissies.

Binnen deze studie wordt aangenomen dat het M-peil wordt ingevoerd, waarbij er per bouwelement (bijvoorbeeld dak, buitenmuur, of raam) voor de onderdelen ervan een alternatief wordt gekozen met de laagste milieubelasting. Per element worden voor de onderdelen die samen 80% uitmaken van de milieuvoetafdruk een substituut gezocht (gerangschikt van groot naar klein).

De resultaten gaan in op een vergelijking tussen scenario’s zonder en met de invoering van een M-peil. Naast een business-as-usual scenario, is een scenario toegevoegd met een verhoogd aantal renovaties. Dit scenario beoogt om alle huidige woningen met energielabel E en F tegen 2050 te renoveren tot label A. Een derde en vierde scenario beogen ook deze verhoogd aantal renovaties, maar volgen wel de invoering van het M-peil. In scenario 3 is dit beperkt tot nieuwbouwwoningen; in scenario 4 gelden de richtlijnen zowel voor nieuwbouw en renovatie. De resultaten tonen dat meer woningen renoveren in combinatie met de invoering van het M-peil voor nieuwbouw niet volstaat. Het is belangrijk om het M-peil ook voor renovaties in te voeren.

3 CONTEXT AND INTRODUCTION

International and European[1] climate policy sets specific and clear targets to greenhouse gas (GHG) emissions: with a target of climate neutrality by 2050 and a reduction in European GHG emissions with 55% by 2030 compared to 1990. In a regional context, the Flemish Climate Policy Plan defines targets for the GHG emissions that occur in Flanders. One of the objectives of the Flemish Energy and Climate Plan 2021-2030 (VEKP[2]), which was approved in 2019, was to reduce greenhouse gas emissions in the non-ETS sectors by 35% by 2030 compared to 2005. On 5 November 2021, the Flemish Government decided to approve a package of additional measures, as a result of which the ambition in the VEKP 2021-2030 with regard to the reduction of **non-ETS emissions** was further increased to -40% by 2030 (compared to 2005). Although the plan focusses on the territorial emissions (in Flanders), it is stated that burden shifting should be avoided. Footprint (consumption) indicators are considered to identify potential risks of burden shifting. Indeed, an important share of the climate change footprint of production and consumption in Flanders is caused by GHG emissions elsewhere and originates from all life cycle production steps like extraction of materials, transportation, production, use, and end of life of all kinds of products.

"Which additional measures can contribute to the realisation of the current Flemish Energy and Climate Plan (VEKP) 2021-2030?" is a question by VEKA that OVAM would like to (partly) address via the implementation of a **material level** (**M-level) for the construction and renovation of buildings**. Correct figures should facilitate and substantiate that choice.

OVAM wants to focus in the coming years on the introduction of an M-level for construction works (both construction and renovation of buildings). The policy program on construction “Towards Circular Construction” (approved by the Flemish Government on 29 April 2022[3]) strives to introduce an M-level by 2030. In addition, the Flemish government aims to reduce the material footprint of Flemish consumption (broad, incl. construction) by an order of magnitude of 30% by 2030[4] compared to 17 ton per capita in 2010.

To this end, this study focusses on **the effect of the introduction of an M-level for construction, demolition, and renovation of residential buildings on the Climate Change impacts and the Environmental Footprint (both direct and indirect impacts)**.

The Environmental Footprint methods measure and communicate about the environmental performance of products (both goods and services) and organisations across their whole lifecycle, relying on scientifically sound assessment methods agreed at international level[5]. They cover 16 environmental impacts, including climate change, and impacts related to water, air, resources, land use and toxicity. The general methods are complemented with product- or organisation- specific calculation rules enabling comparison of environmental

[1] Regulation (EU) 2021/1119: Establishing the framework for achieving climate neutrality
[2] Vlaams Energie- en Klimaatplan (VEKP) 2021-2030 | Vlaanderen.be (p.145).
[3] Beleidskeuzes (vlaanderen.be)
[4] Beleidsnota 2014-2019. Omgeving | Vlaanderen.be; Vlaams Energie- en Klimaatplan (VEKP) 2021-2030 | Vlaanderen.be
[5] Environmental footprint methods - European Commission (europa.eu)

performances between similar products and companies active in similar sectors. The Environmental Footprint covers 16 different impact categories:

- Climate change (kg CO2-eq.)
- Ozone depletion (kg CFC-11 eq)
- Ionising radiation, human health (kBq U^{235} eq.)
- Photochemical ozone formation (kg NMVOC eq.)
- Particular matter (disease incidence)
- Human toxicity, non-cancer (CTUh; comparative toxic unit for humans)
- Human toxicity, cancer (CTUh; comparative toxic unit for humans)
- Acidification (mol H+ eq.)
- Eutrophication, freshwater (kg P eq.)
- Eutrophication, marine (kg N eq.)
- Eutrophication, terrestrial (mol N eq.);
- Ecotoxicity, freshwater (CTUe; comparative toxic unit for ecosystems)
- Land use (Pt; dimensionless; soil quality index)
- Water use (m^3 deprivation)
- Resource use, fossils (MJ)
- Resource use, minerals, and metals (kg Sb eq.; kilogram antimony equivalent).

This study builds upon the 2020-report from the circular economy policy research centre (CE Center) with the title “Impact of circular economy on climate targets: case housing”[6] and the figures and assumptions made in response to the previous adjustment of the VEKP (2021). Apart from an update of data and methodology, the major difference is in the elaborated scenarios. Here, we introduce three scenarios, next to a business-as-usual (BAU) scenario. A comparison of the results of the three (new) scenarios will allow to capture the environmental ‘profit’ resulting from an optimization of materials used in construction and renovation of buildings.

The TOTEM potential study (“Estimation of the potential of TOTEM for environmental impact - part 1”[7]) on the possible environmental impact reduction of buildings by optimizing material choices, serves as a basis for calculating the indirect savings on climate change emissions and the total environmental impact. For example, the study shows that the material-related environmental impact can be reduced by approximately 30%, and the total environmental impact by approximately 15%.

Table 1 visualises the level of detail of the results which are calculated for each of the three scenarios and the BAU. For example, the comparison between results of a scenario without and a scenario with the M-level will reveal the additional environmental gains of implementing this policy measure. The table shows the details of the results which are calculated for each scenario:

- A division between construction of new buildings and renovation.
- A distinction between emissions from ETS-activities and non-ETS-activities.
- A disaggregation between local (Flemish) emissions and emission originating from abroad.

[6] 12. Impact of circular economy on achieving the climate targets: case housing - Publication - Summa (vlaanderen-circulair.be)
[7] Buildings (vlaanderen.be)

Table 1: Overview of the level of detail of the results for climate change and the environmental footprint which are calculated for each scenario.

		Flanders		Rest-of-world	
		Construction of new buildings and demolition	Renovation	Construction of new buildings and demolition	Renovation
CO_2, direct, use phase, represented via the net energy demand	ETS			(Not calculated, no direct emissions)	
	non-ETS				
Climate change footprint (indirect or embodied): production + EOL	ETS				
	non-ETS				
Environmental footprint (indirect or embodied): production + EOL	ETS				
	non-ETS				

The following aspects are out of scope:

- Non-residential buildings are not modelled, and infrastructure works are also not included, which means that the environmental gain is underestimated.
- The modelling of the M-level is based on replacing new materials with other new materials with a lower impact. The replacement of new materials by, for example, reused materials, one of the cornerstones of material policy in construction, could lead to a further reduction of the environmental impact. Still in some specific cases reuse is already considered (see Chapter 3).
- Also, no account was taken of any other interventions that are often combined with an energy renovation (e.g., changes to plan layout and materials required for this).
- Nor has it been considered that the recuperation of demountable elements and materials through change-oriented construction can mean a considerable saving of materials, and therefore also a mitigation of environmental impacts.
- The installation and replacement of technical installations (e.g., boilers), kitchens, bathrooms, etc. are not considered. The scope of construction and renovation is limited to the impact of nine buildings elements (see Figure 1). The focus is on the structural elements, except for foundation and internal doors which are left out of scope.
- The material footprint is not assessed.
- The production stage (A1-A3), the construction stage (A4-A5) and the end-of-life stage (C1-C4) are included in the scope of this study. The use stage (B1-B5) is not considered. This phase contains the use, maintenance, repair, replacement, and refurbishments. Renovations are modelled via demolition of

specified elements (C1-C4) and the production and construction of the new elements (composed of different materials) (A1-A5). See Table 2 for more details.

This report focusses on the residential housing market exclusively, as almost half of the area of the built environment is for residential use[8]. The assessment in this study is based on a quantitative model that uses available data on impact of renovations of existing dwellings (the scope on dwellings includes all residential housing units, including apartments) and the construction of new dwellings (including all residential housing units, including apartments). The assessment starts from a footprint or consumption perspective and thus includes the production, construction, and end-of-life stages in the life cycle of products related to the construction/renovation of dwellings (e.g., the extraction of raw materials, production of building products, and their transportation to the building site). The use stage (B1-B5) is not considered.: the environmental impact caused by the usage of a building, such as regular maintenance (i.e., from cleaning to small renovations), is excluded from this assessment, as the focus is on the construction and renovation of residential buildings and how this can impact the reduction of GHG-emissions. However, one exception is that the quantitative model does include a module estimating the **net energy requirements for heating** of residential buildings in Flanders. The reason to include the net energy demand for heating is to allow to include the long-term effect of energetic renovations and improved construction methods (e.g., better isolation) on reduced energy demand for heating. The end-of-life (C1-C4) treatment of construction and demolition waste caused by renovation, construction and at the end-of-life of the dwellings is included in this study. In short, **this report analyses the embodied climate change emissions and environmental footprint of renovating and constructing residential buildings and the net energy requirement for heating of the current and projected housing stock in Flanders**. The quantitative model starts from the current (2022-data) situations and includes projections for the **2024-2050 period**.

[8] https://www.statistiekvlaanderen.be/bebouwde-oppervlakte

4 DATA AND METHODOLOGY

The quantitative model combines (historical) data, assumptions, and projections. The model starts from a description of the current situation based on data describing the year 2022. The projections focus on the 2024-2050 period. All data sources and assumptions are explained in this chapter, together with their link to the quantitative model. The model itself is compiled in an Excel file.

The model calculates the **climate change footprint** and **environmental footprint** of construction, renovation, and demolition. Also, the net energy demand for heating is estimated. The different modules of the calculation model are summarised in Table 2. The data per module is described in more detail below.

Table 2: The modules of the calculation model.

Element	Pitched roof and flat roof, external wall, outside door, outside window, floor on grade, storey floor, load-bearing internal/party wall, and non-load-bearing internal wall	**= [geometrical data]** *square metres per element per type of building* *** [inventory data]** *impact per element (i.e., the climate change or environmental footprint per square metre)*
Sector/region	ETS or non-ETS/Flanders or rest-of-world	**[emission data]**
Stage	<u>Construction of new dwellings</u>: production stage (A1-A3), and transport to and construction on site (A4-A5) <u>Renovation</u>: end-of-life stage (C1-C4), production stage (A1-A3), and transport to and construction on site (A4-A5) <u>Demolition</u> end-of-life stage (C1-C4)	**[inventory data]**
Type of building and building period	See Table 3. <u>Construction of new dwellings</u>: only ≥ 2018 is used	**[building stock]** **[timber frame construction]**
Projection	Projection of the number of housing units in construction, renovation, and demolition in the period 2024-2050.	**[projections]** based on **[number of households]** **[permits]**
Net energy demand for heating	The net energy demand, in GWh per year, for heating.	**[energy]**

A total of **44 types of buildings** are included in the quantitative model. The typology is based on a combination of the data from Statbel[9], Eeckhouts master thesis[10] and TABULA[11].

[9] Gebouwenpark | Statbel (fgov.be)
[10] Eeckhout, F. (2019). Development of environmental benchmarks for residential buildings, master thesis KU Leuven.
[11] BE_TABULA_TypologyBrochure_VITO.pdf (episcope.eu)

Table 3: The 44 types of buildings included in the quantitative model.

Construction period	Building style	Type of building
before 1945	solid construction	building: detached, semi-detached, and terraced apartment: enclosed, and exposed
between 1946 and 1970	solid construction	building: detached, semi-detached, and terraced apartment: enclosed, and exposed
between 1971 and 1990	solid construction	building: detached, semi-detached, and terraced apartment: enclosed, and exposed
between 1991 and 2005	solid construction	building: detached, semi-detached, and terraced apartment: enclosed, and exposed
between 2006 and 2011	solid construction	building: detached, semi-detached, and terraced apartment: enclosed, and exposed
	timber frame construction	building: detached, semi-detached, and terraced
between 2012 and 2017	solid construction	building: detached, semi-detached, and terraced apartment: enclosed, and exposed
	timber frame construction	building: detached, semi-detached, and terraced
2018 and later	solid construction	building: detached, semi-detached, and terraced apartment: enclosed, and exposed
	timber frame construction	building: detached, semi-detached, and terraced

For each combination of the construction period, the building style, and the type of building, **nine building elements** are described: pitched roof and flat roof, external wall, outside door, outside window, floor on grade, storey floor, load-bearing internal/party wall, and non-load-bearing internal wall.

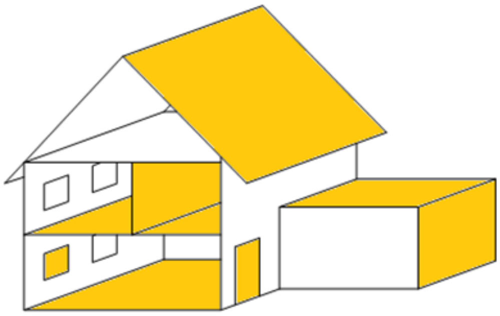

Figure 1: Highlighted parts of the building that are included in the quantitative model.

The quantitative model includes 44 types of buildings (based on construction period, building style and type of building). For each type nine building elements are included. Each building element consists of **different materials**. For example, a building from the construction period 1946-1970 (solid construction, all types of buildings) is assumed to have a floor on grade (i.e. a building element) consisting out of 4 materials: levelling layer of sand (180 kg/m²), reinforced concrete (372 kg/m²), screed (71,5 kg/m²) and ceramic tiles (incl. adhesive and grout; 24,93 kg/m²). The surface area of floor on grade per type of building is determined in section 2.3, and the environmental impact per surface area is determined in section 4.6. The composition of materials per building element is shown in the accompanying Excel-file.

The foundations and internal doors were excluded as there are no data on the amounts within the sources used. Only one type of floor finishing and wall finishing is considered per building period. There are no variations considered.

Enclosed and exposed flats are included separately in TABULA. We use the number of building layers for apartment buildings in several construction periods to derive how many apartments are situated on the top floor (i.e., how many apartments in an average building are 'exposed' to outdoors). In this way we can translate the numbers of the apartment buildings reported in the building registry to exposed and enclosed apartments. While the method is admittedly rough, the authors are not aware of better estimates that are available.

4.1 BUILDING STOCK

Information on the current housing stock was obtained from Statbel[12]. It reports a yearly update of the housing stock register ('kadaster', status on the 1st of January for each datayear). These data reveal the number of buildings from each construction period in the current housing stock of Flanders. The data is disaggregated into housing types:

- Houses in terraced construction (R1),
- Houses in semi-detached construction (R2),
- Houses in detached construction (R3),
- Apartments (R4),
- Commercial houses (R5),
- All other buildings (R6), and
- Total (R7).

Categories R5 and R6 (and R7) are not considered within this study.

Data on the Flemish Region shows the number of buildings in Flanders per construction period (year of construction is aggregated into 10 time periods). The conversion from these 10 time periods into the 7 time periods used in the quantitative model is shown in Table 4.

Table 4: Conversion from the building stock data from Statbel to the categories of the quantitative model.

Building stock from Statbel	Quantitative model	Remarks
before 1900	before 1945	Sum of three categories.
between 1900 and 1918		
between 1919 and 1945		
between 1946 and 1961	between 1946 and 1970	Sum of two categories.

[12] https://statbel.fgov.be/nl/themas/bouwen-wonen/gebouwenpark

between 1962 and 1970		
between 1971 and 1981	between 1971 and 1990	Although the overlap is not perfect, no correction is applied.
between 1982 and 1991		
between 1992 and 2001	between 1991 and 2005	This category includes the building stock of dwellings constructed between 1992 and 2001 and the newly constructed dwellings from 2001 till 2005. From 2001 onwards, the data of Statbel are available in time-series. We assume that the difference between 2001 and 2002 in the most recent category shows the number of newly constructed dwellings during 2001. The (negative) difference for the other time periods is assumed to equal the number of demolitions.
between 2002 and 2011	between 2006 and 2011	The building stock of dwellings constructed between 2006 and 2011 includes all buildings constructed in the years 2006 till 2010, based on the annual difference between the data on the building stock (see previous category).
2012 and later	between 2012 and 2017	The building stock of dwellings constructed between 2012 and 2017 includes all buildings constructed in the years 2012 till 2016, based on the annual difference between the data on the building stock (see category between 1991 and 2005).
	2018 and later	The building stock of dwellings constructed in 2018 and later includes all buildings constructed in the years 2018 till now, based on the annual difference between the data on the building stock (see category between 1991 and 2005).

The dataset also shows, next to the number of buildings, the number of residential units per housing type. A residential building can contain one or more than one residential unit. For example, the average detached building in Flanders in 2021 contains 1.01 residential units, while the average apartment building contains 6.52 residential units[12]. The model calculations are based on the number of residential units.

In January 2023, a total of **3,192,245 residential units** were available in Flanders. These residential units are distributed across **2,318,508 residential buildings**. Next to these residential buildings, there are another 414,081 buildings in Flanders for other than residential purposes. Figure 2shows the distribution of the total number of residential units across periods of construction and the building type.

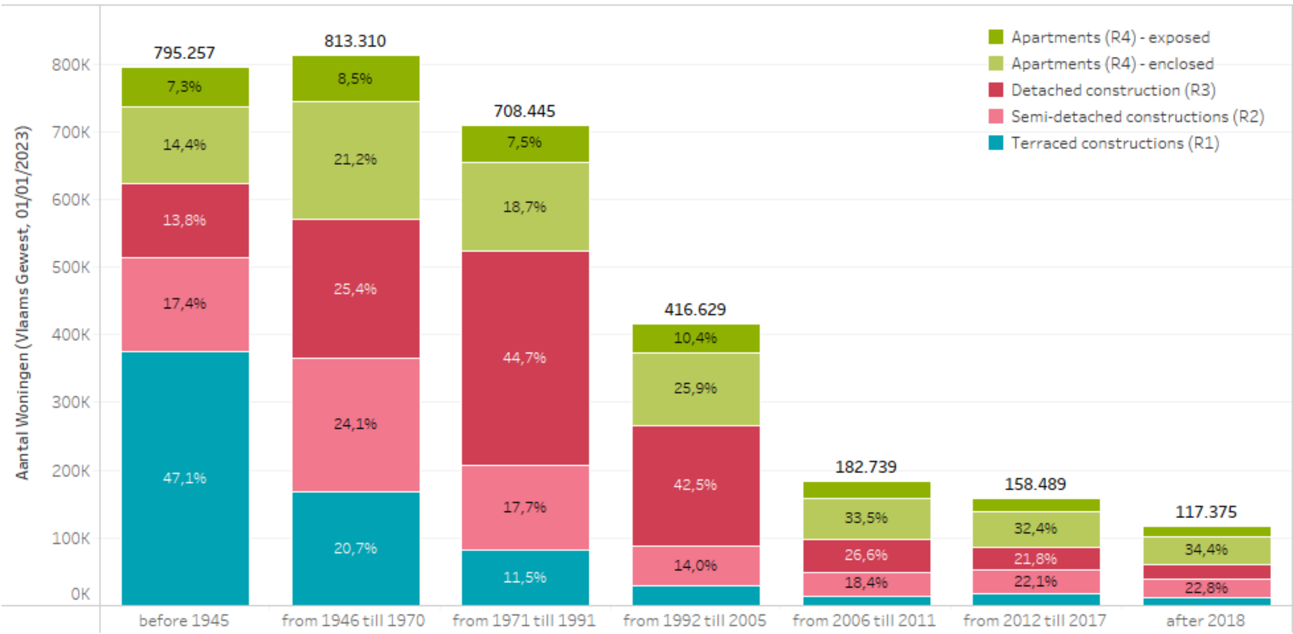

Figure 2: Stock of residential units in Flanders, January 2023. Source: Own calculations based on the building stock data from StatBel.

4.2 TIMBER FRAME CONSTRUCTION

TABULA nor the building stock registry available through Statbel hold information on the number of timber frame constructed buildings. These are instead derived from a questionnaire launched by Hout info bois[13]. This questionnaire does not have information on the fraction of timber frame constructed buildings prior to 2011 and the master thesis from Eeckhout only gives details for timber constructed dwellings from 2006 and onwards. We therefore assume it to have been zero in the building periods before 2006-2011 and assume it to be half of the fraction of 2011 of timber frame constructed buildings for the period of 2006-2011, implicitly if the share of timber frame construction started to increase during this period. Timber frame construction techniques are generally not used for the construction of apartment buildings which are therefore assumed to have no timber frame constructed buildings. For the timber frame constructed buildings, it is assumed that they have the same surface area as solid constructed buildings.

[13] Hout info bois (2018). Houtbouw in België 2017-2018. https://houtinfobois.be/nl/nieuw-houtbouw-in-belgie-2017-2018/

4.3 GEOMETRICAL DATA

Geometrical data describe the average surface area of each element per building types (Table 5). The composed dataset contains an estimate of the average surface area per element for each of the 44 building types. The geometrical data originates from the TOTEM-tool and TABULA-reporting.

Flat and pitched roofs consist of different building element compositions. While we have information on the composition of both roof systems, the building registry system that we use does not contain information on the roof system. It is thus necessary to obtain estimates on the share of buildings that have each roof system for each period. We derived this from the analysis of the EPC databank by Steunpunt Wonen[14]. We assume that after 2011 the ratio of flat-to-pitched roof remained unchanged.

[14] Verbeeck, G. and Ceulemans, W. (2015). Analyse van de EPC databank. Resultaten tot en met 2012. Steunpunt Wonen. Table 30 is the basis for our approximation. Since the frequency of the building periods is different than the one we apply in this study, we use when necessary the middle of the period estimate.

Table 5: Summary of the geometrical input data.

period	type of building	building style	Floor surface area	Protected volume	Roof	External wall	Floor on grade	Storey floor	Outside door	Window	Load-b. internal/party wall	Non-l-b. internal wall
			(m²)	(m²)	(m²)	(m²)	(m²)	(m²)	(m²)	(m²)	(m²)	(m²)
≤1945	terraced construction (R1)	solid construction	159.0	621.3	90.0	92.0	41.4	117.6	9.5	31.5	144.6	69.4
≤1945	semi-detached construction (R2)	solid construction	168.0	651.8	119.9	158.2	61.9	106.1	9.5	29.8	123.1	55.2
≤1945	detached construction (R3)	solid construction	210.0	766.0	158.4	0.0	87.3	122.7	9.5	41.2	70.0	113.6
≤1945	apartments (R4) - enclosed	solid construction	85.0	320.3	0.0	17.9	0.0	85.0	0.0	26.8	63.2	23.2
≤1945	apartments (R4) - exposed	solid construction	85.0	320.3	100.1	63.7	0.0	85.0	0.0	26.8	63.2	23.2
1946-1970	terraced construction (R1)	solid construction	160.0	546.6	90.8	79.1	35.7	124.3	9.5	29.8	145.5	69.9
1946-1970	semi-detached construction (R2)	solid construction	163.0	531.7	101.4	133.1	43.7	119.3	9.5	30.6	119.5	53.6
1946-1970	detached construction (R3)	solid construction	197.0	648.5	158.2	0.0	56.3	140.7	9.5	41.6	65.7	106.6
1946-1970	apartments (R4) - enclosed	solid construction	86.0	320.3	0.0	17.9	0.0	86.0	0.0	26.8	63.9	23.5
1946-1970	apartments (R4) - exposed	solid construction	86.0	320.3	100.1	63.7	0.0	86.0	0.0	26.8	63.9	23.5
1971-1990	terraced construction (R1)	solid construction	159.0	462.8	78.6	70.1	34.9	124.1	9.5	24.4	144.6	69.4
1971-1990	semi-detached construction (R2)	solid construction	162.0	509.6	108.5	122.9	52.5	109.5	9.5	32.3	118.7	53.3
1971-1990	detached construction (R3)	solid construction	220.0	655.7	170.0	0.0	54.8	165.2	9.5	40.2	73.3	119.0
1971-1990	apartments (R4) - enclosed	solid construction	86.0	320.3	0.0	17.9	0.0	86.0	0.0	26.8	63.9	23.5
1971-1990	apartments (R4) - exposed	solid construction	86.0	320.3	100.1	63.7	0.0	86.0	0.0	26.8	63.9	23.5
1991-2005	terraced construction (R1)	solid construction	166.0	526.9	80.9	75.2	37.9	128.1	9.5	26.7	151.0	72.5
1991-2005	semi-detached construction (R2)	solid construction	180.0	615.9	125.2	121.4	65.7	114.3	9.5	34.1	131.9	59.2
1991-2005	detached construction (R3)	solid construction	251.0	710.5	161.6	0.0	50.7	200.3	11.5	45.4	83.7	135.8
1991-2005	apartments (R4) - enclosed	solid construction	96.0	320.3	0.0	17.9	0.0	96.0	0.0	26.8	71.4	26.3
1991-2005	apartments (R4) - exposed	solid construction	96.0	320.3	100.1	63.7	0.0	96.0	0.0	26.8	71.4	26.3
2006-2011	terraced construction (R1)	solid construction	168.0	549.8	76.3	72.0	35.9	132.1	9.5	36.6	152.8	73.4
2006-2011	semi-detached construction (R2)	solid construction	187.0	642.7	118.0	118.3	62.2	124.8	9.5	47.1	137.0	61.5
2006-2011	detached construction (R3)	solid construction	247.0	741.4	152.3	173.2	48.0	199.0	9.5	62.9	82.3	133.6
2006-2011	apartments (R4) - enclosed	solid construction	96.0	320.3	0.0	17.9	0.0	96.0	0.0	26.8	71.4	26.3
2006-2011	apartments (R4) - exposed	solid construction	96.0	320.3	100.1	63.7	0.0	96.0	0.0	26.8	71.4	26.3
2006-2011	terraced construction (R1)	timber frame construction	168.0	549.8	76.3	72.0	35.9	132.1	9.5	36.6	152.8	73.4
2006-2011	semi-detached construction (R2)	timber frame construction	187.0	642.7	118.0	118.3	62.2	124.8	9.5	47.1	137.0	61.5
2006-2011	detached construction (R3)	timber frame construction	247.0	741.4	152.3	173.2	48.0	199.0	9.5	62.9	82.3	133.6
2012-2017	terraced construction (R1)	solid construction	168.0	549.8	76.3	72.0	35.9	132.1	9.5	36.6	152.8	73.4
2012-2017	semi-detached construction (R2)	solid construction	187.0	642.7	118.0	118.3	62.2	124.8	9.5	47.1	137.0	61.5
2012-2017	detached construction (R3)	solid construction	247.0	741.4	152.3	173.2	48.0	199.0	9.5	62.9	82.3	133.6
2012-2017	apartments (R4) - enclosed	solid construction	96.0	320.3	0.0	17.9	0.0	96.0	0.0	26.8	71.4	26.3
2012-2017	apartments (R4) - exposed	solid construction	96.0	320.3	100.1	63.7	0.0	96.0	0.0	26.8	71.4	26.3
2012-2017	terraced construction (R1)	timber frame construction	168.0	549.8	76.3	72.0	35.9	132.1	9.5	36.6	152.8	73.4
2012-2017	semi-detached construction (R2)	timber frame construction	187.0	642.7	118.0	118.3	62.2	124.8	9.5	47.1	137.0	61.5
2012-2017	detached construction (R3)	timber frame construction	247.0	741.4	152.3	173.2	48.0	199.0	9.5	62.9	82.3	133.6
≥2018	terraced construction (R1)	solid construction	168.0	549.8	76.3	72.0	35.9	132.1	9.5	36.6	152.8	73.4
≥2018	semi-detached construction (R2)	solid construction	187.0	642.7	118.0	118.3	62.2	124.8	9.5	47.1	137.0	61.5
≥2018	detached construction (R3)	solid construction	247.0	741.4	152.3	173.2	48.0	199.0	9.5	62.9	82.3	133.6
≥2018	apartments (R4) - enclosed	solid construction	96.0	320.3	0.0	17.9	0.0	96.0	0.0	26.8	71.4	26.3
≥2018	apartments (R4) - exposed	solid construction	96.0	320.3	100.1	63.7	0.0	96.0	0.0	26.8	71.4	26.3
≥2018	terraced construction (R1)	timber frame construction	168.0	549.8	76.3	72.0	35.9	132.1	9.5	36.6	152.8	73.4
≥2018	semi-detached construction (R2)	timber frame construction	187.0	642.7	118.0	118.3	62.2	124.8	9.5	47.1	137.0	61.5
≥2018	detached construction (R3)	timber frame construction	247.0	741.4	152.3	173.2	48.0	199.0	9.5	62.9	82.3	133.6

4.4 ENERGY

The national brochure on the residential unit typologies (TABULA-reporting) shows the net energy demand for heating, expressed in kWh/jr.m². The data are available per construction period and type of building. Both the current situation and a low-energy scenario are provided.

The Flemish Energy and Climate Agency (VEKA) put forward a monitoring path until 2050 for residential buildings (Figure 3). This 2050 monitoring path shows the minimum boundaries within which the labels (energy performance certificate) should evolve to achieve the 2050 target. The ambition is that by 2030 the share of homes with E and F labels will have fallen to a maximum of 15%. By 2040, this share should be less than 1%. Currently, a large part of the Flemish housing stock is in an energetically bad shape: almost 4 out of 10 homes currently have a very poor energy performance with energy label E (12%) or F (26%).

The renovation obligation for residential buildings from 2023 stipulates that all houses and apartments purchased from 2023 onwards with label E or F must be renovated to label D or better, within 5 years of purchase. The trajectory for buildings and apartments is stipulated in Figure 4 and Figure 5.

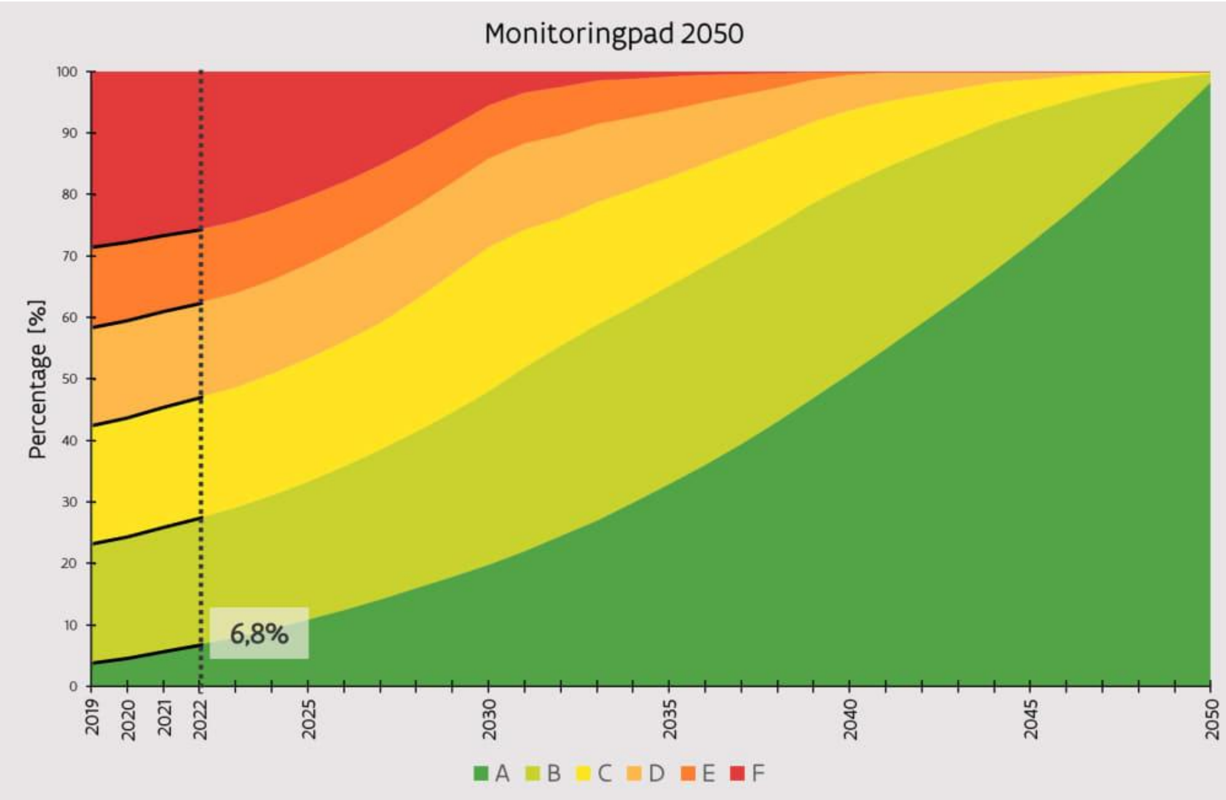

Figure 3: Monitoring path for energy performance certificates of existing residential buildings in Flanders, Flemish Energy and Climate Agency (VEKA), Source: VEKA press release 10/11/2022.

Figure 4: Trajectory for the renovation of residential units (buildings) in Flanders, Renovation obligation for residential buildings from 2023, Renovatieverplichting voor residentiële gebouwen vanaf 2023 | Vlaanderen.be.

Figure 5: Trajectory for the renovation of residential units (apartments) in Flanders, Renovation obligation for residential buildings from 2023, Renovatieverplichting voor residentiële gebouwen vanaf 2023 | Vlaanderen.be.

4.5 EMISSION DATA

The environmental impact climate change (in kg CO2-eq.) and the environmental impact Product Environmental Footprint (PEF, in milipoints) are based on current life cycle inventory (LCI) databases, and are available per combination of the element, period, type of construction and material. The data details between the production stage (A1-A3), transport to and construction on site (A4-A5), and end-of-life stage (C1-C4)[15].

These totals show a footprint per construction material. These footprints are disaggregated into a sectoral and a geographical dimension: a disaggregation is made between ETS and non-ETS sectors, and a disaggregation is made between Flanders and the rest of world (RoW). This means the total footprint is disaggregated into four parts: ETS-Flanders, non-ETS-Flanders, ETS-RoW, non-ETS-RoW.

[15] For more details: https://www.totem-building.be/services/rest/downloads/download?id=1&lang=EN&transId=1&v=7

The allocation of the total footprint into the sectoral and geographical dimension is based on a sector-based analysis using the interregional input-output tables of Belgium which are linked to a multi-regional input-output model to capture supply networks abroad as well.

4.6 INVENTORY DATA

To determine the current materials for the different building elements and construction periods the following sources were used:

- For the compositions and U-value of the elements per building period before 2006: the master thesis by Eeckhout[16] was used which is based upon the IEE TABULA project (2009-2012)[17]. The mentioned master thesis as well as the report of the TABULA project[18] were consulted to have a complete picture of all the needed details.
- For the elements from 2006 and onwards: the master thesis by Eeckhout was used for the compositions, but the U-value were based upon the EPB-cijferrapport[19]. Surface weighted U-values for the periods 2006-2011 and 2012-2017 were calculated based on the surface weighted U-values per year in the EPB-cijferrapport. As U-value for the elements from 2018 and onwards, the surface weighted U-values of the year 2017 were taken as starting point and not the maximum U-value requirement of 0.24 W/m^{2}K, as the EPB-cijferrapport show that the residential buildings in Flanders have better U-values than the legal requirements since 2006.
- A deviation was made from the master thesis by Eeckhout regarding the composition of the windows for solid construction after 1990: instead of only considering aluminium frames for dwellings from 1991 to 2011 inclusive and only PVC for dwellings after from 2012, both types were considered for all periods after 1990 with a 50-50 division[20], as the CO_2-footprint of aluminium frames stood out compared to the renovation impact of older dwellings. Wooden window frames are considered for timber frame constructions.
- The calculation model TOTEM[21] was used to model the building elements. To be specific: the amounts, thickness, thermal conductivity (λ) or thermal resistance (R) and weight of the materials, and the climate change footprint and aggregated PEF score to produce, to transport and to install, and the end-of-life (EOL) of the building materials[22].

An accompanying Excel-file presents the compositions and U-values per building period and building element applied within this study: the left side shows the values before renovation and the right side shows the values

[16] Eeckhout, F. (2019). *Development of environmental benchmarks for residential buildings*, master thesis KU Leuven.
[17] http://episcope.eu/iee-project/tabula/
[18] W. Cyx , N. Renders, M. Van Holm, S. Verbeke (2011). *IEE TABULA – Typology Approach for Building Stock Energy Assessment,* scientific report, VITO.
[19] Vlaams Energieagentschap (2019). *EPB-Cijferrapport, Procedures, resultaten en energetische karakteristieken van het Vlaamse gebouwenbestand – periode 2006-2018*.
[20] The market share of PVC frames is increasing and is around 50% currently in Belgium; followed by aluminum frames with a share of around 40%. The European market is showing a similar picture. (sources: https://www.ikgabouwen.be/ramen-in-hout-pvc-of-aluminium-wat-is-de-beste-keuze-voor-je-woning/; https://www.bouwenwonen.net/artikel/Omvang-Europese-kozijnmarkt-daalt/3178; http://www.abramenendeuren.be/wp-content/uploads/2011/09/Newsflash072009prestigebroch.pdf)
[21] TOTEM, https://www.ovam.be/materiaalprestatie-gebouwen-0. Version 2.4.5 was used.
[22] In terms of the CEN EN 15804 standard, the European building product LCA standard: module A1-A3 (production), modules A4 and A5 (transport and installation on building site), and module C (EOL).

for the renovation scenarios (more explanation on the renovation scenarios is included in section 3). However, first some remarks:

- The impact data and weight are based on current life cycle inventory (LCI) databases. The production processes used to model the environmental impacts represent current production processes and not processes from the respective building period, as such data is not available in LCI databases.
- The thermal conductivity (λ) values applied in this study to determine the U-value of an element are current values of modern building materials, and not values from the respective building period. The current thermal conductivity of materials is better than in the past, this means that a smaller thickness is calculated and consequently less material is considered.
- We have tried to reproduce the U-values as presented in the TABULA project and EPB-cijferrapport as much as possible, however there could be small differences due to the λ-values assumed in TOTEM, or because certain materials were not available in TOTEM in a certain thickness and could not be simply extrapolated because it would deviate to much from the building practice. For instance, TOTEM has some specific doors in its database with certain R-values that are very different than the ones presented in TABULA.

4.7 NUMBER OF HOUSEHOLDS

A projection of the number of households is available from Statbel[23]. The projection includes an estimate of the number of households in Flanders from now till 2071. The annual growth in the number of households can be deducted by calculating the difference of two consecutive years. Important to note is that these projections show a substantial reduction in the growth of the number of households, implying that the number of additional residential units will be projected lower compared to the current demand.

4.8 PERMITS

The number of building permits issued is taken from Statbel[12]. The data show the number of permits issued for residential units for buildings and apartments separately, as well as a number for annual renovations. All for the period 1996-2021.

4.9 PROJECTIONS

To obtain a complete picture of all the required construction materials up to 2050, **a projection on how construction of new housing units is set to evolve, as well as the number of renovations and demolition of residential units in Flanders** is needed.

[23] Source: Number of private households, by region on 1 January, Source: Statbel, 1992-2021-data.; 2022-2071: outlook - Update Ukraine, FPB and Statbel, Federal Planning Bureau, FPS Economy – Statbel.

The projection is based on the projected number of households in Flanders. The annual stock of residential units in the period is equal to the projected number of households in Flanders multiplied with an excess factor (f1).

$$residential\ units_t = households_t * f1$$

The excess factor (f1) represents the fact that there are more residential units than households in Flanders. In 2021, there are 2,867,565 households in Flanders and 3,114,921 residential units. The ratio between the two, or the excess factor, is 1.086. In our projection, we assume this factor to be constant over time, although this factor increased from 1.048 in 2002 to 1.086 in 2021. The difference between the total number of residential units in two consecutive years shows the net demand for new buildings, which is covered by the difference between construction and demolition.

$$net\ demand\ for\ new\ buildings_t = construction_t - demolition_t$$

The number of demolitions of residential units is assumed to equal, on average, 0.5 times the number of constructions, meaning for every two newly constructed residential units one residential unit is demolished. The 0.5 ratio is determined based on the historical ratio (2001-2021) between construction and demolition.

We assume a constant share for construction of detached, semi-detached, terraced and apartments of 9.0%, 20.7%, 16.4% and 53.9%. These shares are based on the 2021-ratios for construction.

We assume that the increasing trend in timber frame construction is continued.

Figure 6 shows the result of the projection for construction of residential units in Flanders. The decrease results from the decrease in the projected growth of households in Flanders.

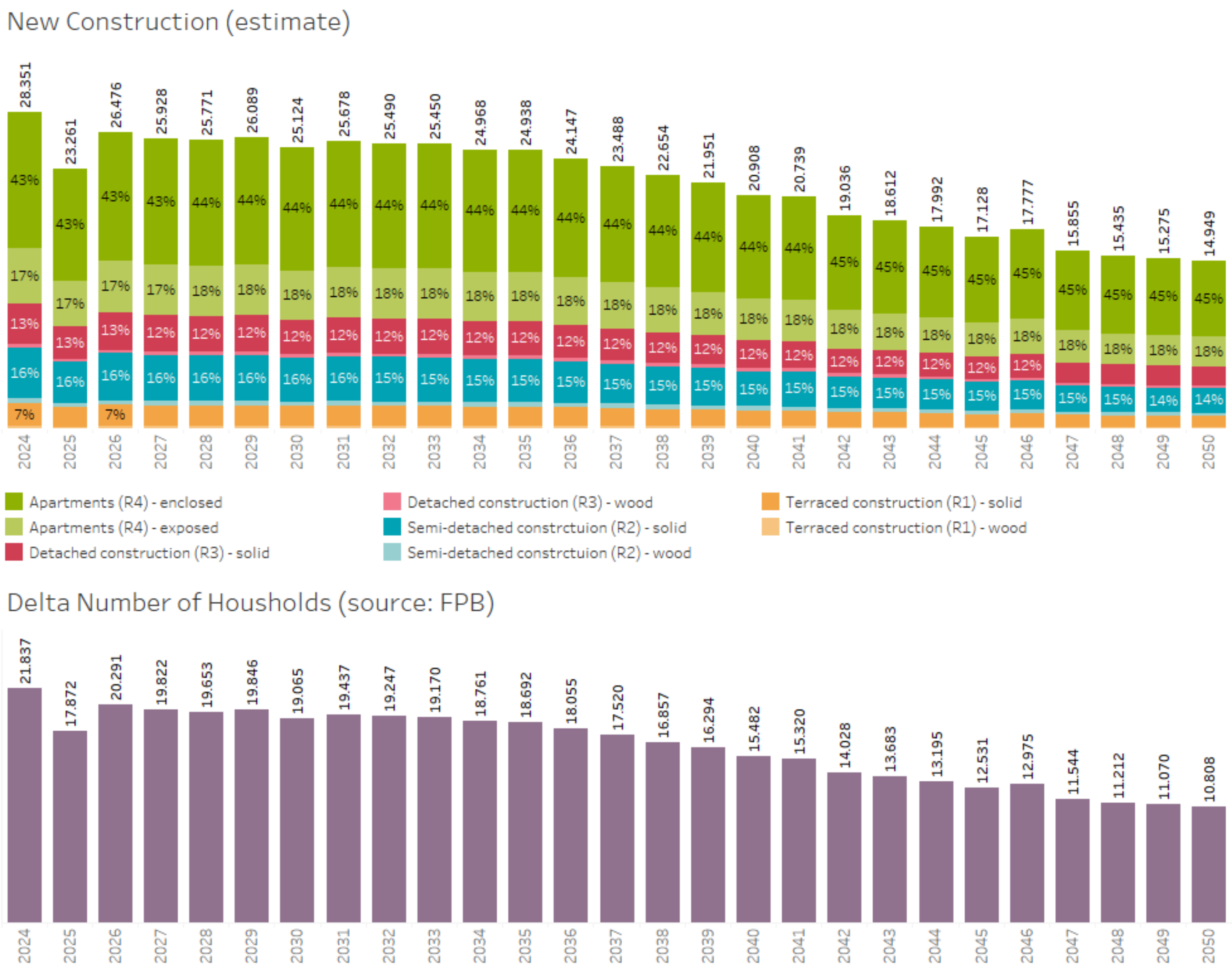

Figure 6: The number of newly constructed residential units, projection for Flanders, 2024-2050. Compared to the projected annual growth in the number of households, Flanders, source: FPB.

5 SCENARIOS

Six scenarios are elaborated in this study. Each of these scenarios includes renovation, construction of new buildings, and demolition for the period 2024-2050. Both new construction and renovation either do or do not introduce the M-level principles.

To model the **renovation** the following assumptions were considered:

- The energy goals 2050[24] are met by following track 1 which means that the following separate requirements[25] are met:
  - Roof, floor and walls: U = 0.24 W/m^{2}K
  - Glazing: Ug = 1.0 W/m^{2}K
  - Windows (= glazing and window frames together): Uw = 1.5 W/m^{2}K
- To meet the 0.24 U-value requirement of the roof, floor on grade and external wall, additional insulation is added:
  - The type of insulation material stayed the same in the renovation scenario. Existing insulation is completely removed before adding the new insulation, except for cavity insulation which is assumed to be left in cavity as it was. In this case, additional insulation is added (e.g., using PUR board) via the cavity or on the outside.
  - In practice, there are different ways of adding insulation to an existing construction (from the outside, inside or in case of cavity walls in the cavity), only one way is considered in this study based on the most likely option that can be applied in most situations. Except for solid constructed external walls: adding insulation from the inside as well as from the outside are considered. The way of insulating extra from the outside was specifically added for detached dwellings.
  - In case there are finishing layers or other layers applied on the insulation layer, then those layers are removed and newly installed for the renovation in case the materials cannot be reused properly, otherwise a 5% of replacement/repairs is considered with the reuse.
- To meet the requirements for the windows and glazing, the frame needs to be replaced completely by a new frame as in practice existing frames will not be suitable for double or triple glazing due to a bigger thickness of the glazing[26]. Based on the most recent numbers found on the distribution of the types of frames[27], it is assumed that 50% of the renovated frames used in solid construction buildings consist of PVC, 40% consist of aluminium and, finally, 10% are wooden frames. For timber frame construction, it is assumed that all the renovated frames consist of wood.

It is important to remark that the assumed renovation scenario is only considering a minimal energy renovation to meet the abovementioned energy goals at the minimal level. It is often the practice that when dwellings are

[24] https://www.energiesparen.be/energiedoelstellingen-tegen-2050

[25] Track 1 of the energy goals 2050 also has a fourth requirement regarding the efficiency of heating systems. This is not included in this study, as no data on heating systems is included.

[26] The case in which double glass is replaced by double glass with better performances, is not considered here.

[27] Ik ga bouwen en renoveren. (2016). Ramen in hout, pvc of aluminium: wat is de beste keuze voor je woning? Consulted on 29th of October, 2019. https://www.ikgabouwen.be/ramen-in-hout-pvc-of-aluminium-wat-is-de-beste-keuze-voor-je-woning/.

renovated more parts (e.g., internal walls, the kitchen, or the bathroom) are also renovated at the same time. However, our analysis is solely focused on the building elements mentioned above and the inclusion of kitchens, bathrooms, etc. would thus overly expand the scope of the analysis with elements that do not directly affect the energy performance of a dwelling within the scope of the Flemish climate plan.

The **M-level** implementation is simulated using the following 80% rule:

- For each element constructed or renovated (see renovation), the total embodied environmental impact is calculated.
  - Using PEF score
  - In TOTEM
- All components accumulating to at least 80% of embodied environmental impact (i.e., the normalised and weighted score of sixteen environmental impacts) or climate change (depending on the scenario) of the element are considered.
  - Largest impacts are considered first (ranked from biggest to smallest)
  - Once the 80% is reached, the other materials are not considered anymore.
- For each considered component, all relevant substitutes are compared.
  - Including the considered component itself
  - Substitutes available in the TOTEM library[28]
  - Only substitutes having a similar function and structure are included.
    - For example: a timber load bearing framework is **not** considered as a substitute for a brickwork load bearing wall element.
    - For example: a sand-lime brickwork load bearing wall element **is** considered as a substitute for a cellular concrete brickwork load bearing wall element.
  - Only reasonably common applications are included.
    - For example: straw bale insulation is excluded.
- The component having the lowest environmental score or lowest climate change impacts (depending on the scenario) is selected. Keep in mind that this substitute might technically be less opportune.
- The M-level is applied to new constructions in scenario 3 and scenario 5 and to new construction and renovations in scenario 4 and scenario 6.

The following scenarios are determined:

- **Scenario 1** (business-as-usual) shows the forecast if the current situation continues: 22,000[29] homes are renovated energetically every year (i.e., the rounded number of permits for renovations in 2021).
- In **scenario 2**, the number of energy renovations is doubled to 44,000 per year. This value makes it possible to renovate all current homes with energy label E or F to label A by 2050.
- **Scenario 3** is identical to scenario 2 but introduces the M-level (optimising for the environmental footprint) for new construction from 2024, optimizing the choice of materials and the associated impact.
- **Scenario 4** is identical to scenario 3 but applies the M-level (optimising for the environmental footprint) not only to new construction, but also to renovations from 2024.

[28] Results are based on our model run in December 2022.
[29] On the 1st of January 2022, only 6.8% of Flemish dwellings has a label A (Vlaams Energie- en Klimaatagentschap).

- **Scenario 5** is identical to scenario 2 but introduces the M-level for new construction (optimising for climate change) from 2024, optimizing the choice of materials and the associated impact.
- **Scenario 6** is identical to scenario 5 but applies the M-level (optimising for climate change) not only to new construction, but also to renovations from 2024.

Table 6: Summary of the scenarios for construction and renovation in Flanders.

	Construction		Renovation	
	Number	Scenario	Number	Scenario
Scenario 1	Based on projection*	Status quo	22,000	Status quo
Scenario 2	Based on projection*	Status quo	**44,000**	Status quo
Scenario 3	Based on projection*	**Construction based on the M-level principles - Environmental Footprint optimalisation**	44,000	Status quo
Scenario 4	Based on projection*	Construction based on the M-level principles - Environmental Footprint optimalisation	44,000	**Renovation based on the M-level principles - Environmental Footprint optimalisation**
Scenario 5	Based on projection*	**Construction based on the M-level principles – Climate Change optimalisation**	44,000	Status quo
Scenario 6	Based on projection*	Construction based on the M-level principles – Climate Change optimalisation	44,000	**Renovation based on the M-level principles – Climate Change optimalisation**

* See Section 4.9.

6 RESULTS

The results, presented from 2024 to 2050, show annual **Climate Change impacts** expressed in tons CO_2-equivalents (Figure 7 and Table 7) and the **Environmental Footprint** impact in points (Figure 8 and Table 8) from new construction and renovation. Next to the annual results, a summation for the period 2024-2050 is presented as well.

Figure 7 shows the annual Climate Change impacts for the period 2024 to 2050 in tons CO_2-equivalents of new construction, renovation, and demolition. To increase the readability, only the 5-year intervals are shown. The data present annual emissions (thus no cumulated impacts). The annual emissions are disaggregated according to the sector/region from which they originate: either emissions in Flanders or outside Flanders (i.e. rest of world, RoW), and either emissions from ETS-sectors or non-ETS-sectors.

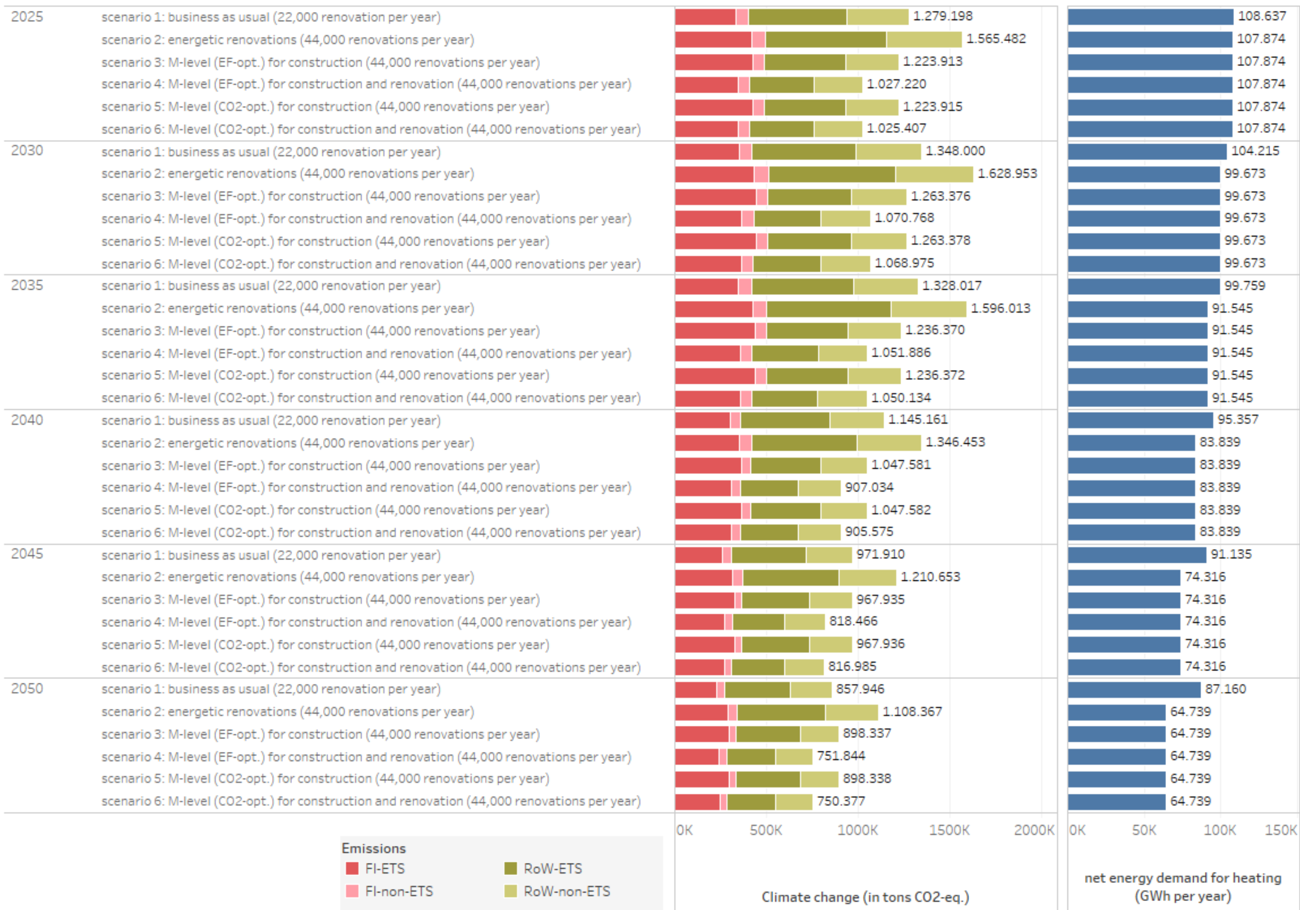

Figure 7: Annual results for Climate Change for scenario 1 to 6, in tons CO_2-equivalents per year.

The net energy demand for heating is added (on the right) to include the effect of renovations on the energy demand for heating residential units: due to energetic renovations (with or without following the principles of the M-level) the energy demand for heating decreases towards 2050, even with a projected increase in population and an accompanying increase in the number of residential units from 2024 to 2050 (from 3.2 million residential units in 2024 to a projected 3.7 million residential units in 2050).

Table 7 presents the total accumulated climate change impact for the period 2024-2050 and *in italic* an annual average value (average impact considering the whole period). The data is disaggregated into new construction, renovation, and demolition, as well into the sector/region origin of the emissions. Scenario 2 results in the highest accumulated Climate Change impact of 39.2 million tons CO_2-eq, followed by scenario 1 with 32.3 million tons CO_2-eq, scenario 3 and 5 with 30.7 million tons CO_2-eq, scenario 4 with 26.1 million tons CO_2-eq., and scenario 6 with 26.0 million tons CO_2-eq. In addition, the total energy demand for heating (see Table 7) is 10% lower for scenarios 2 to 6 (2.4 million GWh accumulated in the 2024-2050 period), compared to scenario 1 (2.6 million GWh).

Table 7: Total and average annual results for Climate Change for scenario 1 to 6, in tons CO_2-equivalents per year.

Scenario	Emissions	construction	demolition	renovation	Grand Total
scenario 1: business as usual (22,000 renovation per year)	FI-non-ETS	1.199.544 *42.841*	280.533 *10.019*	205.628 *7.344*	1.685.705 *60.204*
	FI-ETS	6.358.478 *227.088*	0 *0*	2.113.694 *75.489*	8.472.172 *302.578*
	RoW-non-ETS	6.717.824 *239.922*	0 *0*	1.819.735 *64.991*	8.537.558 *304.913*
	RoW-ETS	10.447.305 *373.118*	0 *0*	3.165.464 *113.052*	13.612.769 *486.170*
	Total	**24.723.151** ***882.970***	**280.533** ***10.019***	**7.304.521** ***260.876***	**32.308.205** ***1.153.864***
scenario 2: energetic renovations (44,000 renovations per year)	FI-non-ETS	1.199.544 *42.841*	247.030 *8.822*	390.118 *13.933*	1.836.692 *65.596*
	FI-ETS	6.358.478 *227.088*	0 *0*	4.014.875 *143.388*	10.373.352 *370.477*
	RoW-non-ETS	6.717.824 *239.922*	0 *0*	3.568.525 *127.447*	10.286.348 *367.370*
	RoW-ETS	10.447.305 *373.118*	0 *0*	6.320.409 *225.729*	16.767.715 *598.847*
	Total	**24.723.151** ***882.970***	**247.030** ***8.822***	**14.293.927** ***510.497***	**39.264.107** ***1.402.290***
scenario 3: M-level (EF-opt.) for construction (44,000 renovations per year)	FI-non-ETS	777.109 *27.754*	247.030 *8.822*	390.118 *13.933*	1.414.257 *50.509*
	FI-ETS	6.664.816 *238.029*	0 *0*	4.014.875 *143.388*	10.679.691 *381.418*
	RoW-non-ETS	3.748.107 *133.861*	0 *0*	3.568.525 *127.447*	7.316.631 *261.308*
	RoW-ETS	4.982.406 *177.943*	0 *0*	6.320.409 *225.729*	11.302.815 *403.672*
	Total	**16.172.437** ***577.587***	**247.030** ***8.822***	**14.293.927** ***510.497***	**30.713.394** ***1.096.907***
scenario 4: M-level (EF-opt.) for construction and renovation (44,000 renovations per year)	FI-non-ETS	777.109 *27.754*	247.030 *8.822*	480.938 *17.176*	1.505.076 *53.753*
	FI-ETS	6.664.816 *238.029*	0 *0*	2.140.461 *76.445*	8.805.277 *314.474*
	RoW-non-ETS	3.748.107 *133.861*	0 *0*	2.998.119 *107.076*	6.746.225 *240.937*
	RoW-ETS	4.982.406 *177.943*	0 *0*	4.041.009 *144.322*	9.023.415 *322.265*
	Total	**16.172.437** ***577.587***	**247.030** ***8.822***	**9.660.527** ***345.019***	**26.079.994** ***931.428***
scenario 5: M-level (CO2-opt.) for construction (44,000 renovations per year)	FI-non-ETS	777.110 *27.754*	247.030 *8.822*	390.118 *13.933*	1.414.258 *50.509*
	FI-ETS	6.664.818 *238.029*	0 *0*	4.014.875 *143.388*	10.679.692 *381.418*
	RoW-non-ETS	3.748.118 *133.861*	0 *0*	3.568.525 *127.447*	7.316.643 *261.309*
	RoW-ETS	4.982.423 *177.944*	0 *0*	6.320.409 *225.729*	11.302.832 *403.673*
	Total	**16.172.469** ***577.588***	**247.030** ***8.822***	**14.293.927** ***510.497***	**30.713.426** ***1.096.908***
scenario 6: M-level (CO2-opt.) for construction and renovation (44,000 renovations per year)	FI-non-ETS	777.110 *27.754*	247.030 *8.822*	386.501 *13.804*	1.410.641 *50.380*
	FI-ETS	6.664.818 *238.029*	0 *0*	2.169.350 *77.477*	8.834.168 *315.506*
	RoW-non-ETS	3.748.118 *133.861*	0 *0*	3.021.259 *107.902*	6.769.378 *241.763*
	RoW-ETS	4.982.423 *177.944*	0 *0*	4.038.855 *144.245*	9.021.278 *322.189*
	Total	**16.172.469** ***577.588***	**247.030** ***8.822***	**9.615.966** ***343.427***	**26.035.465** ***929.838***

cummulative climate change impact period 2023-2050 (in t CO2-eq)
average annual climate change impact 2023-2050 (in t CO2-eq per year)

Figure 8 and Table 8 should be interpreted like Figure 7 and Table 7, except for the impact category being different. The Environmental Footprint is the normalised and weighted results of 16 impact categories[30] of which Climate Change is one. The assessment covers the environmental impact categories of the Environmental Footprint (EF) method[31]. This method, endorsed by the European Commission, includes a wide variety of environmental impacts, and provides guidance to process (normalisation and weighting) impact results into a single aggregated score (expressed in points, Pt).

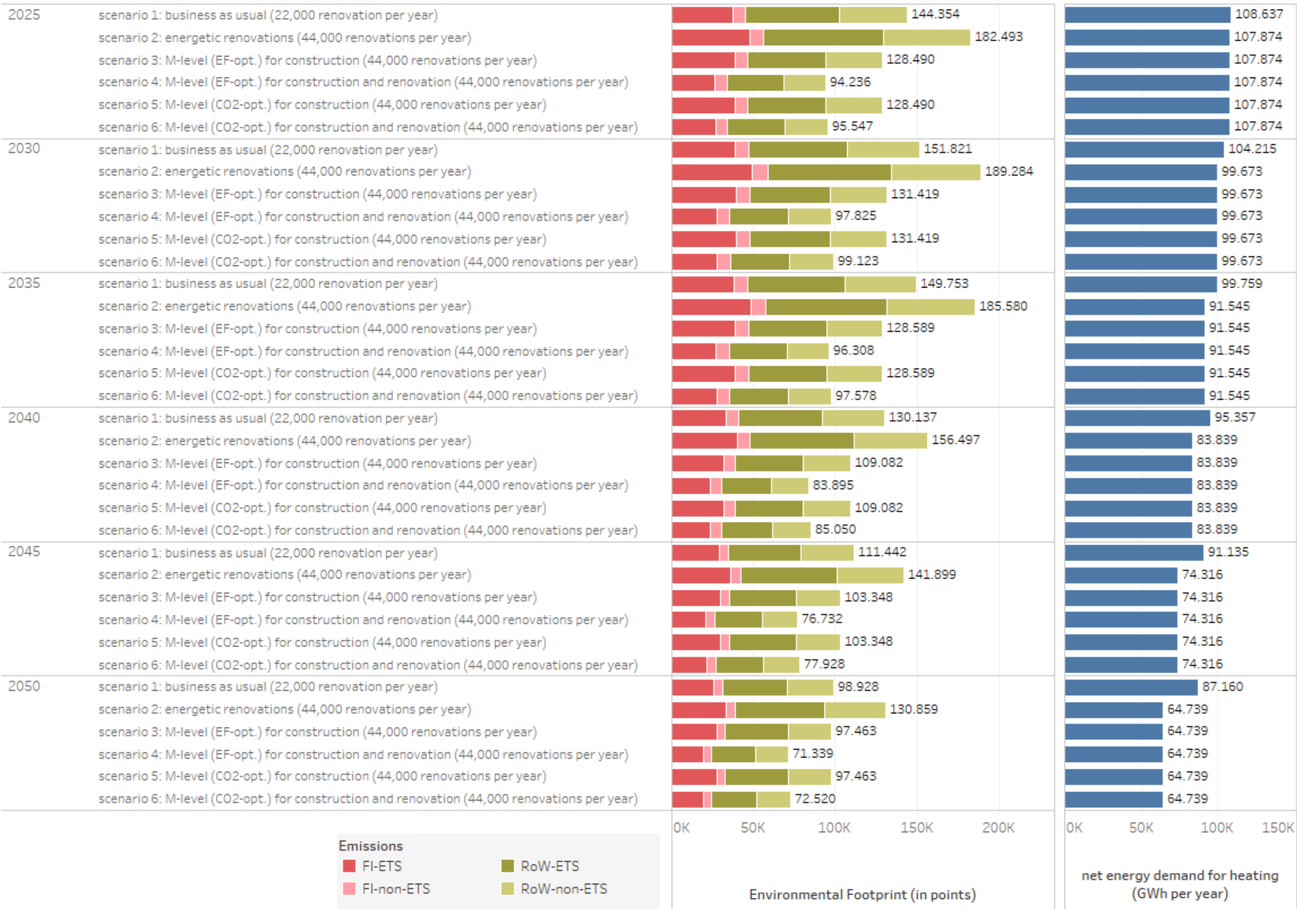

Figure 8: Annual results for Environmental Footprint for scenario 1 to 6, in points per year.

[30] See Table 6 of the report 'Environmental profile of buildings, update 2021' for more details: https://www.totem-building.be/services/rest/downloads/download?id=1&lang=EN&transId=1&v=7

[31] Environmental footprint methods (europa.eu)

Table 8: Total and average annual results for Environmental Footprint for scenario 1 to 6, in points per year.

Scenario	Emissions	construction	demolition	renovation	Grand Total
scenario 1: business as usual (22,000 renovation per year)	FI-non-ETS	117.914 *4.211*	57.706 *2.061*	25.591 *914*	201.211 *7.186*
	FI-ETS	666.157 *23.791*	0 *0*	273.968 *9.785*	940.125 *33.576*
	RoW-non-ETS	789.003 *28.179*	0 *0*	276.020 *9.858*	1.065.024 *38.037*
	RoW-ETS	1.053.071 *37.610*	0 *0*	400.558 *14.306*	1.453.629 *51.915*
	Total	2.626.145 *93.791*	57.706 *2.061*	976.137 *34.862*	3.659.988 *130.714*
scenario 2: energetic renovations (44,000 renovations per year)	FI-non-ETS	117.914 *4.211*	51.662 *1.845*	48.242 *1.723*	217.818 *7.779*
	FI-ETS	666.157 *23.791*	0 *0*	517.658 *18.488*	1.183.815 *42.279*
	RoW-non-ETS	789.003 *28.179*	0 *0*	535.034 *19.108*	1.324.038 *47.287*
	RoW-ETS	1.053.071 *37.610*	0 *0*	795.405 *28.407*	1.848.476 *66.017*
	Total	2.626.145 *93.791*	51.662 *1.845*	1.896.339 *67.726*	4.574.147 *163.362*
scenario 3: M-level (EF-opt.) for construction (44,000 renovations per year)	FI-non-ETS	73.210 *2.615*	65.931 *2.355*	48.242 *1.723*	187.383 *6.692*
	FI-ETS	440.502 *15.732*	0 *0*	517.658 *18.488*	958.160 *34.220*
	RoW-non-ETS	316.398 *11.300*	0 *0*	535.034 *19.108*	851.433 *30.408*
	RoW-ETS	426.597 *15.236*	0 *0*	795.405 *28.407*	1.222.002 *43.643*
	Total	1.256.707 *44.882*	65.931 *2.355*	1.896.339 *67.726*	3.218.977 *114.963*
scenario 4: M-level (EF-opt.) for construction and renovation (44,000 renovations per year)	FI-non-ETS	73.210 *2.615*	65.931 *2.355*	51.107 *1.825*	190.247 *6.795*
	FI-ETS	440.502 *15.732*	0 *0*	231.299 *8.261*	671.801 *23.993*
	RoW-non-ETS	316.398 *11.300*	0 *0*	339.451 *12.123*	655.850 *23.423*
	RoW-ETS	426.597 *15.236*	0 *0*	459.141 *16.398*	885.739 *31.634*
	Total	1.256.707 *44.882*	65.931 *2.355*	1.080.999 *38.607*	2.403.637 *85.844*
scenario 5: M-level (CO2-opt.) for construction (44,000 renovations per year)	FI-non-ETS	73.210 *2.615*	65.931 *2.355*	48.242 *1.723*	187.383 *6.692*
	FI-ETS	440.502 *15.732*	0 *0*	517.658 *18.488*	958.160 *34.220*
	RoW-non-ETS	316.400 *11.300*	0 *0*	535.034 *19.108*	851.434 *30.408*
	RoW-ETS	426.599 *15.236*	0 *0*	795.405 *28.407*	1.222.004 *43.643*
	Total	1.256.711 *44.883*	65.931 *2.355*	1.896.339 *67.726*	3.218.981 *114.964*
scenario 6: M-level (CO2-opt.) for construction and renovation (44,000 renovations per year)	FI-non-ETS	73.210 *2.615*	65.931 *2.355*	45.405 *1.622*	184.546 *6.591*
	FI-ETS	440.502 *15.732*	0 *0*	239.724 *8.562*	680.226 *24.294*
	RoW-non-ETS	316.400 *11.300*	0 *0*	355.267 *12.688*	671.667 *23.988*
	RoW-ETS	426.599 *15.236*	0 *0*	474.194 *16.936*	900.794 *32.171*
	Total	1.256.711 *44.883*	65.931 *2.355*	1.114.591 *39.807*	2.437.232 *87.044*

cummulative environmental footprint period 2023-2050 (in points)
average annual environmental footprint period 2023-2050 (in points per year)

Figure 7 and Figure 8 show the decrease in net energy demand for heating because of the increase in the number of renovations with an improved energy performance. In scenarios 2 to 6 this effect is a lower net energy demand for heating compared to scenario 1, because of the increased effort in renovations (doubling of the number of residential units being renovated). Of course, this increased renovation speed includes a rebound effect. The increased demand for building materials needed for renovation does also generate an environmental impact, i.e., the (indirect) Climate Change emissions and environmental footprint. A more detailed comparison between the scenarios is provided below.

First, the **total footprint** is discussed. The difference between **scenario 1 and 2** is an additional effort for renovations: the number of energetic renovations is doubled from 22,000 residential units per year to 44,000. In both scenarios the introduction of the M-level is not considered. The increased renovation effort almost doubles the cumulative indirect global Climate Change emissions from renovations from 7.3 to 14.3 million tons CO_2-eq at global level (including both ETS and non-ETS, and Flanders and RoW). Also, limiting the focus to the Flemish territorial emissions, including ETS and non-ETS, shows the same result: a doubling of indirect emissions from 2.2 to 4.4 million tons CO_2-eq (**Table 7**). Both scenarios result in the same impact from new construction and almost the same impacts from demolition, as scenario 2 differs from scenario 1 in the number of renovations only. Due to the higher renovation rate, the number of demolitions is slightly lower. The total indirect Climate Change emissions increase by 22% at global level and by 20% at Flemish level (including new construction, renovation, and demolition).

Similar results are focussing on the Environmental Footprint, show a doubling of the impact from renovations from 1.0 to 1.9 million points at global level (**Table 8**). At Flemish level, the Environmental Footprint increased from 300 to 566 thousand points.

The difference between **scenario 2 and 3** is the introduction of a M-level for new constructions of residential units. At global level, the Climate Change emissions triggered by new construction are reduced by 35% (from 24.7 to 16.2 million tons CO_2-eq), while the Flemish territorial emissions decrease with 2% (from 7.6 to 7.4 million tons CO_2-eq) (**Table 7**). The introduction of a M-level for new constructions mainly has an effect on Climate Change emissions abroad (-49%).

Again, comparing the scenarios 2 and 3, the results for the Environmental Footprint are similar. They show a substantial decrease from 2,626 to 1,256 thousand points at global scale (only construction). Looking at the Flemish territorial perspective only, the results show a decrease from 784 to 514 thousand points (**Table 8**).

Comparing **scenario 2 and 4** shows the introduction of a M-level (environmental footprintenvironmental footprint optimalisation) for both new construction and renovation (in both scenarios doubled to 44,000 renovations per year; in scenario 4 an M-level (environmental footprint optimalisation) is introduced), it can be seen that the total Climate Change emissions are sharply decrease from 39.3 to 26.1 million tons CO_2-eq, and the Flemish territorial emissions reduce from 12.2 to 10.3 million tons (**Table 7**).

Comparing the Environmental Footprint between scenario 2 and 4 shows, for the total, a decrease from 4,574 thousand points to 2,404 thousand points, it can be seen that at Flemish level the impact reduces from 1,402 to 862 thousand points (**Table 8**).

Comparing scenario 4 and 6, shows the difference in the effect from introducing the M-level for both construction and renovation between environmental footprint optimalisation and optimalisation for only climate change impacts. The difference is a (very) small decrease in the impacts on climate change from 26.1 to 26.0 million tons, but an (very) small increase in the environmental footprint from 2,403 to 2,437 thousand points.

Next to a discussion of the total values, a summary on the **average annual impact** for Climate Change (Figure 9) and the Environmental Footprint (Figure 10) is provided below. A distinction is made between total impacts and impacts from a Flemish territorial perspective. In general, the introduction of an M-level has a larger effect on the total global emissions and a smaller effect on the Flemish territorial emissions. The difference following from the two optimalisation options is very small.

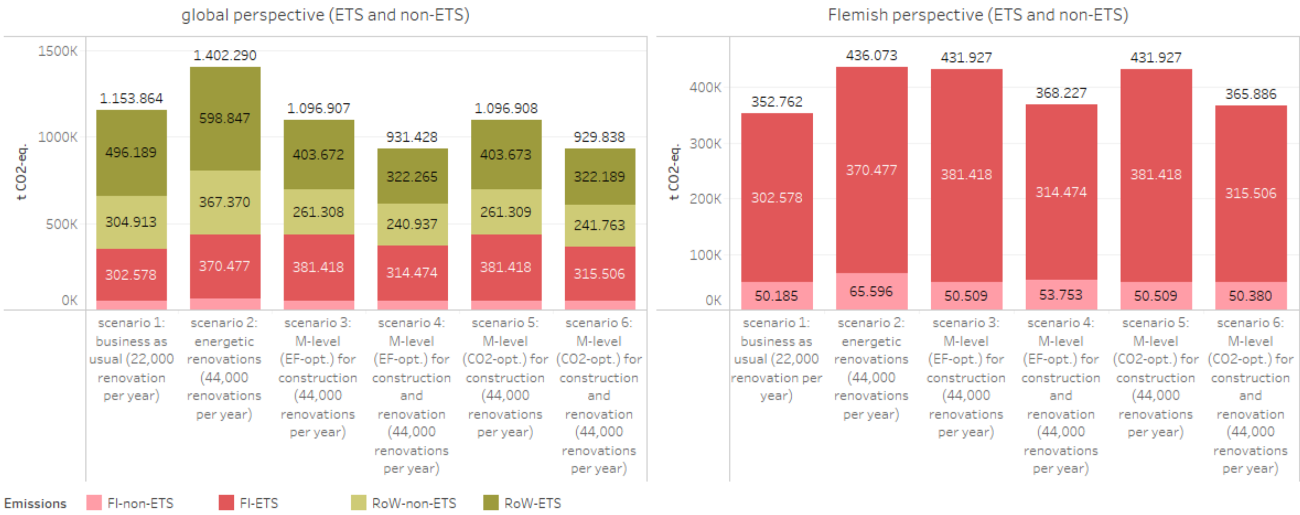

Figure 9: Summary of the average annual impact on **Climate Change** from the four scenarios, in t CO_2 eq.

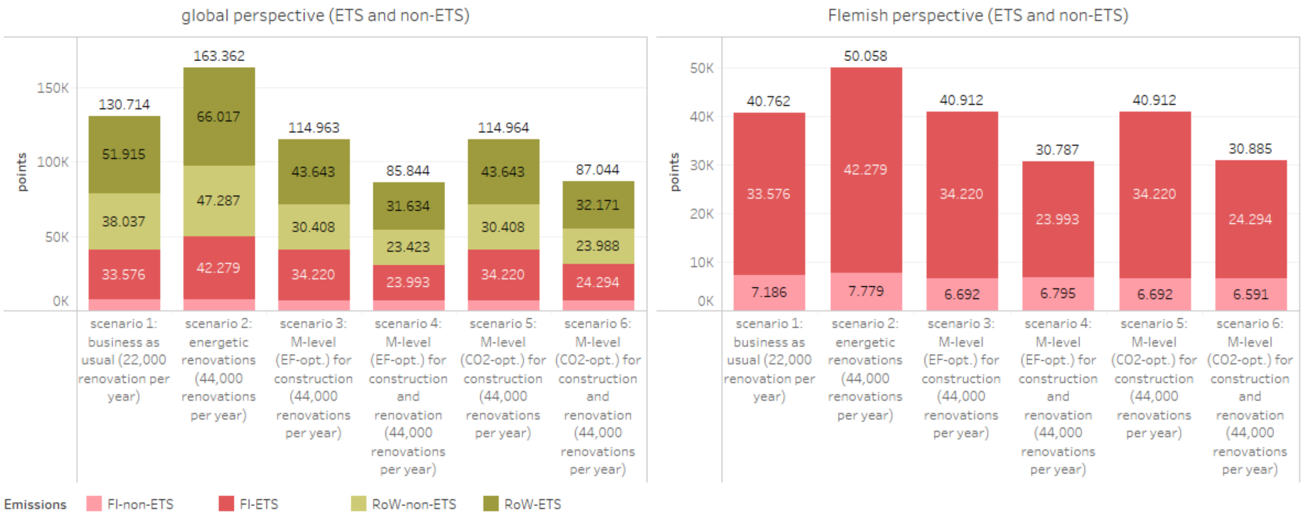

Figure 10: Summary of the average annual impact on **Environmental Footprint impacts** from the four scenarios, in points.

7 CONCLUSIONS

In its climate strategy and long-term renovation strategy, the Flemish Government aspires a drastic increase in the number of renovations to reduce direct emissions. More (energetic) renovation without additional (material-conscious) measures, however, will increase the indirect environmental impacts, due to the impacts generated in the different life cycle stages of these materials (mining, production, transport, end-of-life, etc.) needed for the renovations.

A comparison between the results of scenario 1 and 2 shows the additional effort for increasing the renovation rate: the number of energetic renovations is doubled from 22,000 residential units per year to 44,000. The results show a substantial increase in these indirect impacts, both from a footprint perspective and a territorial perspective. Although in the long term the energy demand for heating will decrease (which is the main driver of the direct impacts), the instant effect of renovations is an increase in indirect emissions. The increase from a Flemish territorial perspective is estimated at 71 kilotons CO_2-eq per year[32] (considering an increase from 22,000 renovations to 44,000 renovations per year).

This considerable increase in territorial emissions can be reduced via the introduction of an M-level. Based on our assumptions, the implementation of the M-level on only new construction (scenarios 3 and 5) does already reduce the effect on increased indirect emissions. A bigger lever is possible via introducing the M-level for renovations as well (scenario 4 and 6). The total indirect climate change impacts and the Environmental Footprints are the lowest for scenarios 4 and 6. Introducing the M-level for new construction and renovation (scenario 4 and 6) reduces the territorial indirect impact in Flanders by 16% for climate change and 38% for the Environmental Footprint (compared to scenario 2 without an M-level).

In total, the annual climate change gain of introducing the M-level for both construction and renovation for the Flemish non-ETS sector is estimated at ca. 12 kilotons of CO_2-eq per year; the annual Environmental Footprint gain is estimated at ca. 1 thousand points. (i.e. the difference between scenarios 2 and 4/6). Based on the results, the introduction of the M-level does not shift the burden: next to a reduction in the territorial impacts, also the footprint (including indirect impacts abroad) and impact within the ETS-sector decrease. These results stand firm looking at the Environmental Footprint as a whole, and with a narrower focus on Climate Change only.

As a reminder we refer to the limitation of the study explained in Chapter 1. The scope of these results only focusses on residential buildings. An introduction of an M-level for non-residential buildings is not considered. To fully grasp the potential of the M-level and to be able to successfully carry out projections, it is necessary to expand the scope.

[32] this value is the difference between scenario 1 and 2.