UNIVERSITÉ DE LIÈGE
FACULTÉ DES SCIENCES APPLIQUÉES
DÉPARTEMENT D'AÉROSPATIALE ET MÉCANIQUE
LABORATOIRE DE THERMODYNAMIQUE

ProCEBaR Model v1.1

User guide

S. GENDEBIEN, E. GEORGES, S. BERTAGNOLIO, V. LEMORT

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1 Description of the file

The file is composed of several sheets:

- the ***"user"*** sheet
- the ***"calculation"*** sheet
- the ***"freestanding"*** sheet
- the ***"semi-detached"*** sheet
- the ***"terraced"*** sheet
- the ***"apartment"*** sheet

} the so-called ***« type of building »*** sheets

- 101, 102,…403, 404, → the ***« building geometry»*** sheets
- Mean T

The structure of the *"**freestanding**"*, *"**semi-detached**"*, *"**terraced**"* and *"**apartment**"* sheets is the same. In the rest of the report, the nomenclature *"**type of building**"* sheet will be used. The same remark can be enounced for the sheet 101 to 404. Each of those sheets contains the geometry characteristics of each type of investigated housing.

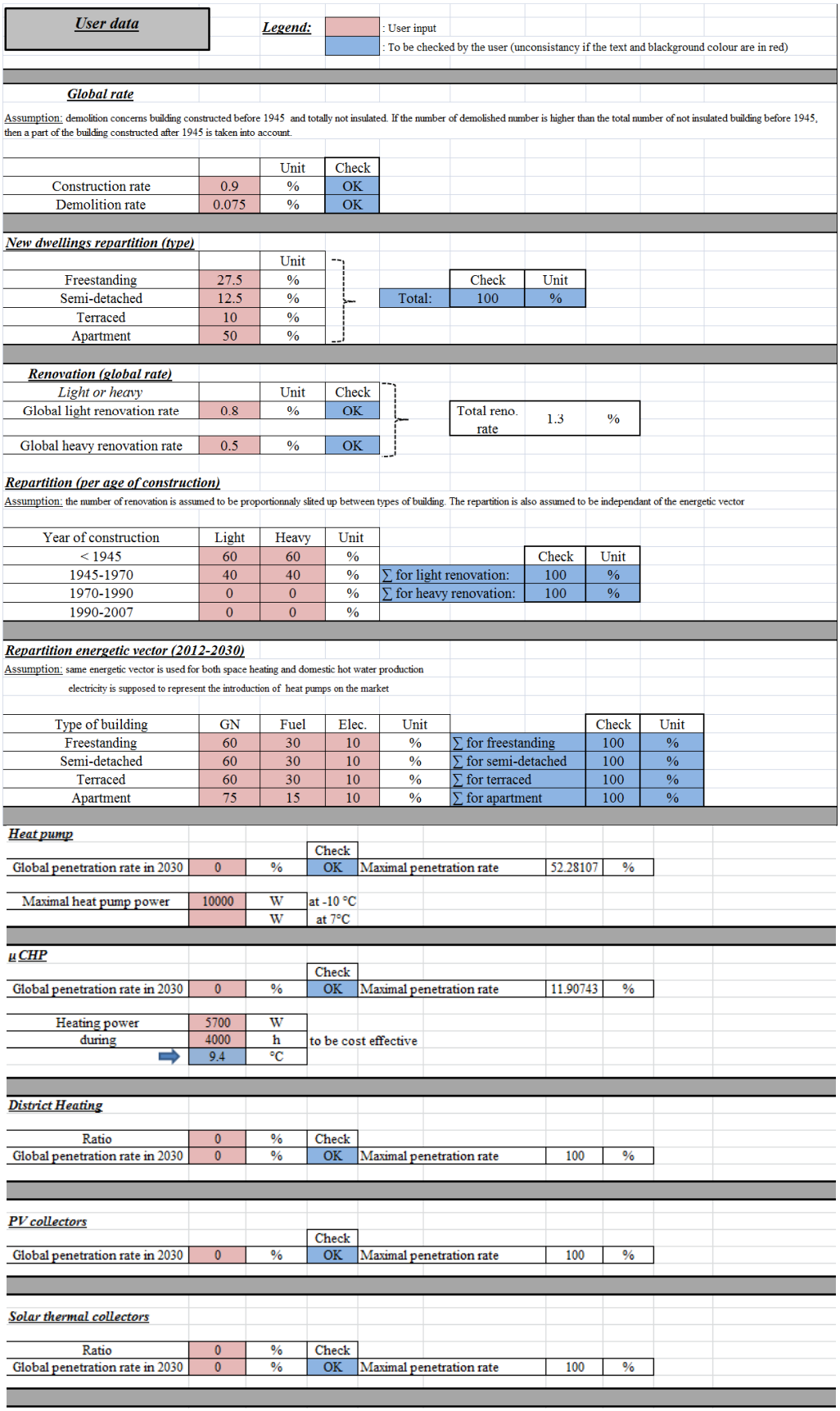
1.1 The "user" sheet

The *"user"* sheet is divided into two parts:

- The ***"user data "*** part,
- The ***"typical data"*** part.

The ***"user data"*** part allows the user to adjust the value of the construction, the demolition, the light renovation and the heavy renovation rates. The user can also adjust the new dwellings repartition per type of building and the new dwellings repartition per type of energy vector.
Global penetration rates of new HVAC technologies such as heat pump, µCHP, district heating and PV and solar collectors.

Figure 1 shows the “user data” part of the user sheet:



User data

Legend: : User input

: To be checked by the user (unconsistancy if the text and blackground colour are in red)

Global rate

Assumption: demolition concerns building constructed before 1945 and totally not insulated. If the number of demolished number is higher than the total number of not insulated building before 1945, then a part of the building constructed after 1945 is taken into account.

		Unit	Check
Construction rate	0.9	%	OK
Demolition rate	0.075	%	OK

New dwellings repartition (type)

		Unit
Freestanding	27.5	%
Semi-detached	12.5	%
Terraced	10	%
Apartment	50	%

	Check	Unit
Total:	100	%

Renovation (global rate)

Light or heavy		Unit	Check
Global light renovation rate	0.8	%	OK
Global heavy renovation rate	0.5	%	OK

Total reno. rate	1.3	%

Repartition (per age of construction)

Assumption: the number of renovation is assumed to be proportionnaly slited up between types of building. The repartition is also assumed to be independant of the energetic vector

Year of construction	Light	Heavy	Unit
< 1945	60	60	%
1945-1970	40	40	%
1970-1990	0	0	%
1990-2007	0	0	%

	Check	Unit
∑ for light renovation:	100	%
∑ for heavy renovation:	100	%

Repartition energetic vector (2012-2030)

Assumption: same energetic vector is used for both space heating and domestic hot water production

electricity is supposed to represent the introduction of heat pumps on the market

Type of building	GN	Fuel	Elec.	Unit
Freestanding	60	30	10	%
Semi-detached	60	30	10	%
Terraced	60	30	10	%
Apartment	75	15	10	%

	Check	Unit
∑ for freestanding	100	%
∑ for semi-detached	100	%
∑ for terraced	100	%
∑ for apartment	100	%

Heat pump

			Check			
Global penetration rate in 2030	0	%	OK	Maximal penetration rate	52.28107	%

Maximal heat pump power	10000	W	at -10 °C
		W	at 7°C

µ CHP

			Check			
Global penetration rate in 2030	0	%	OK	Maximal penetration rate	11.90743	%

Heating power	5700	W	
during	4000	h	to be cost effective
	9.4	°C	

District Heating

			Check			
Ratio	0	%	Check			
Global penetration rate in 2030	0	%	OK	Maximal penetration rate	100	%

PV collectors

			Check			
Global penetration rate in 2030	0	%	OK	Maximal penetration rate	100	%

Solar thermal collectors

			Check			
Ratio	0	%	Check			
Global penetration rate in 2030	0	%	OK	Maximal penetration rate	100	%

Figure 1: User data part of the user sheet

As shown in Figure 2, the "typical data" part gives rate values commonly given in the literature. Used references are also specified in the sheet.

Typical data

		Unit	Reference
Construction rate	0.1	%	http://www.iweps.be/evolution-du-parc-de-logements
Demolition rate	0.075	%	**Mc Kinsey Company.** Vers une efficacité énergétique de niveau mondial en Belgique. 2009.

		Unit	Reference
Freestanding	27.5	%	
Semi-detached	12.5	%	**VITO.** *TABULA Project,* http://www.building-typology.eu/ . 2011.
Terraced	10	%	**Lepur.** *PRODUCTION DE L'HABITAT ET ENJEUX TERRITORIAUX - région wallonne.* ULg : s.n., 2012.
Apartment	50	%	

	Range	Unit	Reference	
Total renovation rate	0.5-0.8	%	https://monitoringdesquartiers.irisnet.be/	Data for Brussels region (extended to the national level)
Repartition heavy/light	???	%	No information	

Year of construction	Light	Heavy	Unit	Reference
< 1945	???	???	%	
1945-1970	???	???	%	No information
1970-1990	???	???	%	
1990-2007	???	???	%	

Type of building	GN	Fuel	Elec.	Unit	Reference
Freestanding	60	30	10	%	
Semi-detached	60	30	10	%	http://www.building-typology.eu/downloads/public/docs/report/TABULA_TR2_D
Terraced	60	30	10	%	
Apartment	75	15	10	%	

Figure 2: "Typical" data part of the user sheet

1.2 The "calculation" sheet

The aim of the "calculation" sheet is to determine values that could be incorporated to the new tree structure and/or to be used to carry out intermediate calculus. As example, the total amount of demolished, constructed and refurbished buildings during the "2012-2030" period. These values are determined for each year from 2012 to 2030 in the calculation sheet. Users are not supposed to modify any content of this sheet.

Evolution							
Year	New dwellings	Demolished dwellings	Total number of dwellings	Heavy renovation	Light renovation	Total renovation	
2013	0.009	0.00075	1.00825	0.005	0.008	0.013	
2014	0.00907425	0.000756187	1.016568063	0.00504125	0.008066	0.01310725	
2015	0.009149113	0.000762426	1.024954749	0.00508284	0.008132545	0.01321538	
2016	0.009224593	0.000768716	1.033410626	0.005124774	0.008199638	0.01332441	
2017	0.009300696	0.000775058	1.041936263	0.005167053	0.008267285	0.01343434	
2018	0.009377426	0.000781452	1.050532238	0.005209681	0.00833549	0.01354517	Used formula
2019	0.00945479	0.000787899	1.059199128	0.005252661	0.008404258	0.01365692	C_t=C_0*(1+i)^t
2020	0.009532792	0.000794399	1.067937521	0.005295996	0.008473593	0.01376959	with
2021	0.009611438	0.000800953	1.076748006	0.005339688	0.0085435	0.01388319	C_0 =
2022	0.009690732	0.000807561	1.085631177	0.00538374	0.008613984	0.01399772	1
2023	0.009770681	0.000814223	1.094587634	0.005428156	0.008685049	0.01411321	
2024	0.009851289	0.000820941	1.103617982	0.005472938	0.008756701	0.01422964	
2025	0.009932562	0.000827713	1.11272283	0.00551809	0.008828944	0.01434703	
2026	0.010014505	0.000834542	1.121902794	0.005563614	0.008901783	0.0144654	
2027	0.010097125	0.000841427	1.131158492	0.005609514	0.008975222	0.01458474	
2028	0.010180426	0.000848369	1.140490549	0.005655792	0.009049268	0.01470506	
2029	0.010264415	0.000855368	1.149899596	0.005702453	0.009123924	0.01482638	Check
2030	0.010349096	0.000862425	1.159386268	0.005749498	0.009199197	0.01494869	Total - (light + heavy)
∑	0.173875929	0.014489661		0.096597738	0.154556381	0.25115412	0

Figure 3: New, demolished, lightly refurbished and heavy refurbished dwellings evolution

1.3 The "type of building" sheet

As already specified, a **sheet is dedicated to each type of building:** freestanding, semi-detached, terraced and apartment. Each sheet contains, for each type of building for the different time periods and insulation levels described in the paper:

- the "occurrence": the respective share of each building type in the whole building stock for year 2012, 2030 and for different scenarios of penetration of HVAC components.
- The corresponding geometry reference number.
- the constructive characteristics of the building envelope (U values, thermal capacitance,…)
- the type of energy source used for space heating and domestic hot water.
- the rated heating capacity for design outdoor conditions and heating demand for average Belgian year.

1.4 The "building geometry" sheets

Sheets "101" to "404" contains the geometry characteristics dedicated to each type of building investigated. The codes related to each building are given in Table 1:

Table 1: Nomenclature of "building geometry" sheet

Freestanding		*Terraced*	
101	<1945	301	<1945
102	1946-1970	302	1946-1970
103	1971-1990	303	1971-1990
104	>1991	304	>1991
Semi-detached		***Apartments***	
201	<1945	401	<1945
202	1946-1970	402	1946-1970
203	1971-1990	403	1971-1990
204	>1991	404	>1991

An example of such sheet is given in Figure 4. Each building is divided in 6 zones: life, night, kitchen, bathroom, unheated and corridor. For each zone of the building, the walls, windows and floors areas are provided in the sheet.

General characteristics

$A_{tot,floor}$	181.084
$A_{floor,0}$	104.86
Level	2
$h_{level,0}$	3.2
$h_{level,1}$	2.7
$h_{level,2}$	0
$h_{level,3}$	0

Zones floor area/volume

	Floor area [m2]	Volume [m^3]
A_{life}	50.716	162.24
A_{night}	22.784	72.64
$A_{kitchen}$	8.576	27.2
$A_{bathroom}$	6.182	17.6
$A_{unheated}$	85.666	154.0888
$A_{corridor}$	7.12	22.784

Zones

	Life	Night	Kitchen	Bathroom	Unheated	Corridor	Total
A_{wall}	23.176	29.524	18.816	16.032	40.6160691	1.05	129.214069
A_{wind}	7.25	3.5	1.25	0	2	0	14
A_{roof}	20.1	0	8.57	0	76.184	0	104.854
A_{floor}	50.7	22.7	8.57	6.18	9.482	7.12	104.752
A_{door}	2.15	0	0	0	0	2.15	4.3
A_{adj}	0	0	0	0	0	0	0
A_{int}	32.576	33.024	18.816	16.032	8.71	48.768	157.926

Figure 4: Building geometry sheet (sheet 101)

1.5 "Mean T" sheet

The "Mean T" sheet contains the hourly temperature sorted in ascending order for a typical Belgian year. This sheet is mainly used for the determination of the µCHP implementation.

2 Introduction of new HVAC technologies

This part of the user guide focuses on the introduction of new HVAC technologies in the tree structure of 2030. The same methodology is applied for each technology:

- The first step consists in determining the **maximum global rate** that could be implemented by the user, based on the identification of the buildings for which the technologies could be installed ;
- The second step consists in the **repartition of this new technology** in the tree structure.

2.1 Heat pumps

For a given maximal heat pump power in design conditions (-10°C outdoor temperature and indoor temperature of 20°C) which can be manually adjusted, the user interface indicates the maximum penetration rate in 2030 (Figure 5). Then, the user can choose a global penetration rate inferior or equal to the determined maximal penetration rate.

Heat pump						
Global penetration rate in 2030	0	%		Maximal penetration rate	54.6692	%
Maximal heat pump power	8600	W	at -10 °C			
	16000	W	at 7°C			

Figure 5: Heat pump implementation (user sheet)

2.2 µCHP

µ CHP						
Global penetration rate in 2030	8	%		Maximal penetration rate	13.4703	%
Heating power	5700	W				
during	4000	h	to be cost effective			
➡	9.4	°C				

Figure 6: µCHP implementation (user sheet)

In the example shown in Figure 6, the temperature in blue corresponds to the 4000th temperature of a typical Belgian year when sorted in ascending order (see section 1.5).

The user can adjust the number of hours for the unit to be cost effective for a heating power also specified by the user (5700W in the example of Figure 6). The maximal penetration rate is directly determined from this two values. Determination if a specific building could be powered by a µCHP is made by realizing a stationary balance taking into account the overall heat transfer coefficient of the building (AU), the air change rate (ach) and the DHW required power (assumed to be equal to 2500W).

2.3 District heating implementation

Identification of the maximal global rate is directly deduced from the global rates introduced by the user for the heat pump and µ-CHP cases.

2.4 Photovoltaic collectors

The penetration rate of photovoltaic collectors can be introduced independently from the other technologies and is homogeneously distributed among the building stock.

2.5 Solar thermal collectors

For houses equipped with a µ-CHP system, because of the size of the storage tank installed, it was chosen not to add solar thermal collectors. Otherwise, such collectors can be coupled both to traditional boilers and heat pumps. Therefore, the maximal penetration rates correspond to a hundred minus the penetration rate of µ-CHP units.

3 Relative share determination

First, as already mentioned, the user can adjust the yearly construction, demolition and retrofit rates in the "user" sheet. Introducing these rates modifies the share of each building type in the 2030 tree-structure. For example, in the "Freestanding" sheet, column "T – occurrence 2012" contains the relative share of each building for year 2012. The final share of each buildings in 2030, taking into account the above rates is available in column "Y – Occurrence 2013 BAU".

Secondly, different penetration rates can be chosen for HVAC systems (Section 2).

- For heat pumps, column "Z – heat pump" contains the relative share of buildings equipped with heat pumps, and column " AA – BAU unchanged after HP" contains the relative share of buildings non equipped with heat pumps and available for other HVAC systems.
- For µCHP, column "AB – micro CHP" contains the relative share of buildings equipped with µCHP, and column " AC – BAU unchanged after HP + micro CHP" contains the relative share of buildings non equipped with heat pumps or µ-CHP and available for other HVAC systems.
- For district heating, column "AD – district heating" contains the relative share of buildings connected to a district heating network, and column " AE – BAU unchanged after HP + micro CHP + DH" contains the relative share of buildings non equipped with heat pumps or µCHP or district heating.
- For solar collectors, column "AF – Occurrence 2030 BAU - MicroCogen" contains the relative share of buildings not equipped with µCHP (section 2.5), and available for thermal solar collectors. Column "AG – solar thermal repartition" contains the relative share of buildings equipped with solar collectors.