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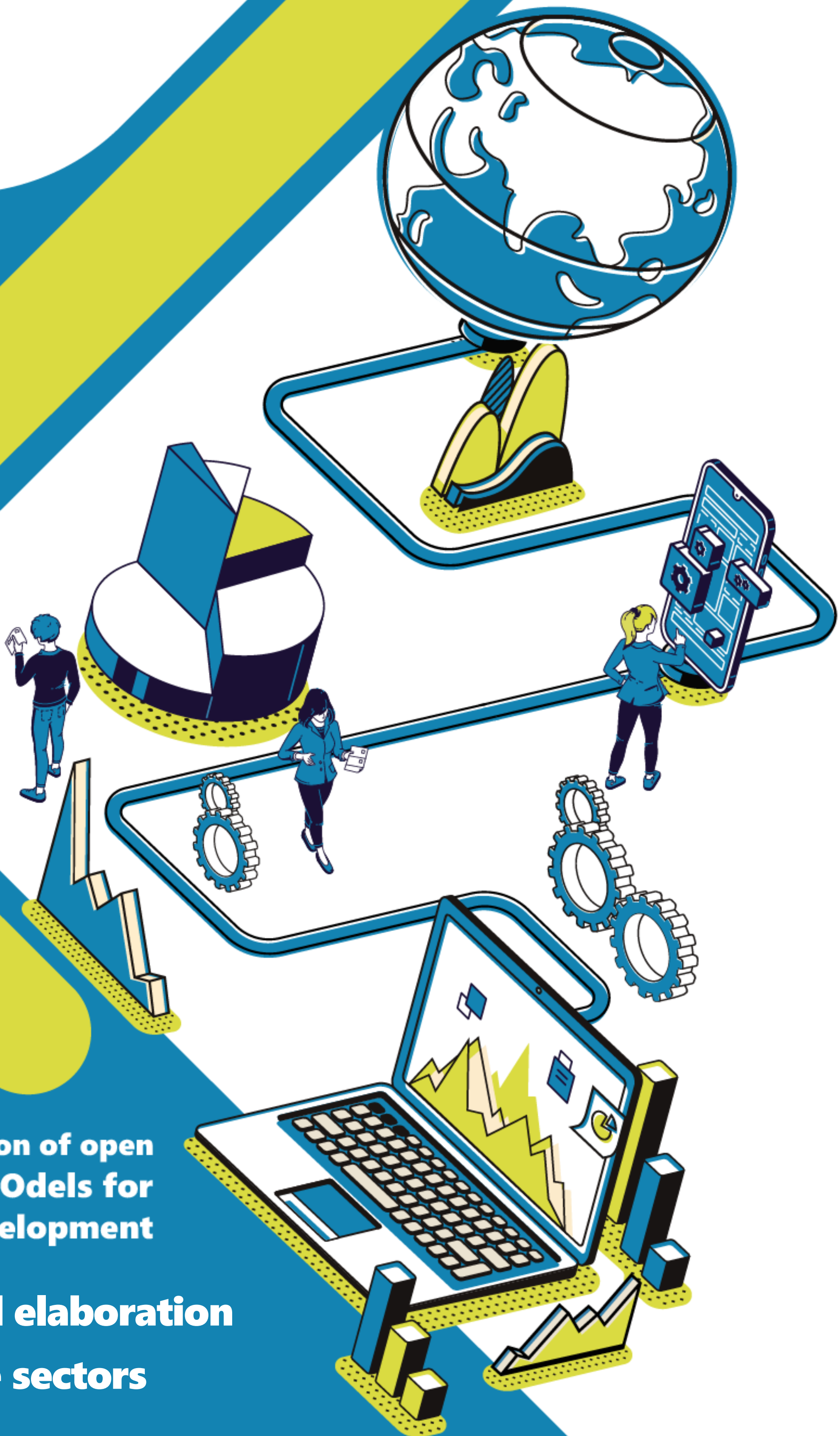

Delivering the next generation of open Integrated Assessment MOdels for Net-zero, sustainable Development

OMNIA Data input and elaboration

Residential and service sectors

18/07/2025

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Short summary (<250 words)

This report outlines the adaptations and improvements made to transition from the residential and service sectors' representation of the TIMES-GEO model, a TIMES global energy consumption model, to the residential and service sector's representation of the OMNIA model—an enhanced, more detailed, and flexible version. The TIMES-GEO model's input spreadsheet was revised to meet OMNIA's specific requirements. This report details these improvements and explains how they enhance the model's functionality and usability.

Model files Attachment

This report refers to the files with codes and data inputs in the OMNIA Github repository for the transport sector, VT_OMNIA_RSD. Also, in the same repository, in the folder OMNIA_RES_SRV_TRA there are the respective subfolders that include the documentation documents in the structure shown in Figure 0.1*, and the codes and data for the residential and transport sector respectively. This documentation also refers to the input of TIMES_GEO model, an older TIMES model, which can be found in the GitHub repository https://github.com/MaREI-EPMG/TIMES-GEO.*

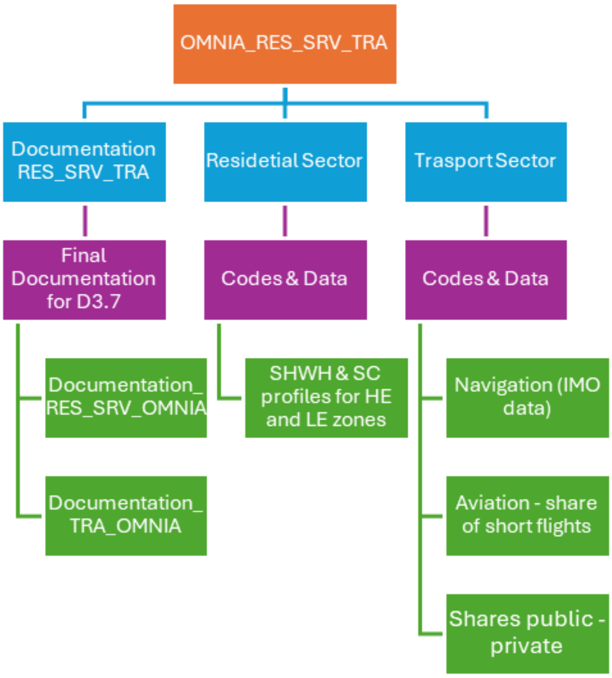

Figure 0.1 Figure illustrate the repository structure that includes the documentation of the OMNIA's transport and residential/service sector and the data ad codes used to developed the input files.

File name	***Type***	***Description & Location in directory of Figure 0.1***
Shares public-private based on cities.xlsx	*Excel doc*	*Excel file where calculations were done to estimate that share between public and private road transport in African regions. Can be found in OMNIA_RES_SRV_TRA >Residential Sector > Codes & Data > Shares Public transport*

Heating_Cooling_Distribution_output_final	*Matlab programme*	*OMNIA_RES_SRV_TRA >Residential Sector > Codes & Data >* SHWH & SC profiles for HE and LE zones

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1 Improvements and enhancements of the new design

The OMNIA model for the residential and service sector includes 28 regions for which the energy use is represented. Although the service sector has remained the same as in TIMES_GEO model, the residential sector has been further disaggregated versus the TIMES-GEO model. In **Error! Reference source not found.** OMNIA model for the residential sector now includes 6 type of end uses in the residential sector, Thermal uses, Air conditioning, Cooling, Lighting, Electric Appliances and "Other uses", 15 type of fuel used including fossil and renewable fuels and electricity. A detailed framework capturing global energy demand by breaking down fuel types, end uses, heating and cooling profiles, and future technological needs across regions and intensity zones, enabling precise modelling of residential energy consumption patterns and efficiency opportunities. Illustration of improvements made in OMNIA's residential sector, by including zonal (high thermal intensity VS low intensity zones) and temporal (according to the OMNIA time slices) disaggregation to provide improved world representation of the residential sector. Figure 1.1 summarises the dissagregation stages followed to model the residential sector versus the TIMES_GEO version.

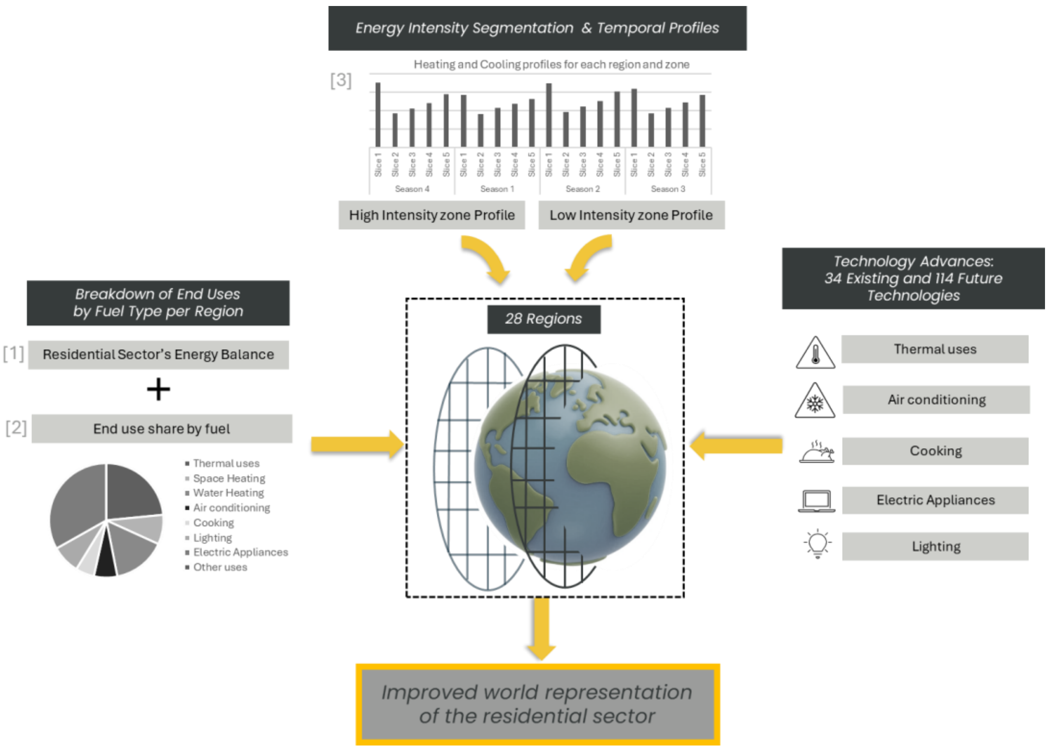

Figure 1.1 To improve the residential sector representation in OMNIA compared to the TIMES-GEO model, three key updates were made: End-Use Breakdown by Fuel, Region Segmentation in zones by Energy Intensity and Energy demand profiles, Technology Advances.

[1] UNSD Energy Balances 2019 (UNITED NATIONS DEPARTMENT FOR ECONOMIC AND SOCIAL AFFAIRS, 2022)

[2] TIMES_GEO input & modellers assumptions

[3] Sachs, J., Moya, D., Giarola, S., & Hawkes, A. (2019). Clustered spatially and temporally resolved global heat and cooling energy demand in the residential sector. Applied Energy, 250, 48-62.

There are three key improvements in how the residential sector is represented:

1. **End-Use Breakdown by Fuel**: For each region, energy balance data and the share of end uses by fuel were utilised to determine the distribution of energy consumption for various end uses (e.g., heating, cooling, lighting) by fuel type. This provides a detailed breakdown of end-use energy consumption by fuel for each region. (Section 2.1)

2. **Region Segmentation in zones by Energy Intensity and Energy demand profiles**: Each region is further divided into two zones based on energy intensity—**high-intensity** and **low-intensity** zones—primarily driven by thermal and cooling demands. This segmentation allows for more accurate modeling of heating and cooling needs in regions with different energy consumption profiles. Moreover, to improve the detail, temporal profiles for heating and cooling demands were generated based on OMNIA's time slices, offering detailed insights into hourly and seasonal behaviors for heating and cooling across the two intensity zones within each region. This data is used as input to the model, enhancing its precision. (Section 2.1.2)
3. **Technology Advances in the residential and service sectors:** For the residential sector, the model now includes more technologies versus the TIMES_GEO model, with a focus on differentiation between the technologies used in the high- and low-intensity zones. The service sector has remained the same as was in the TIMES_GEO model (Section 2.1.3).

Each of enhancement is presented in the Model Design: detailed description chapter (Section **Error! Reference source not found.**) in the subsections 2.1, 2.1.2 and 2.1.3 respectively.

1.1 Technology advances (Residential & Service Sectors)

The residential sector's model includes key end-use technologies representative of the residential sector's processes. The base year and future residential technologies for the residential sector in the OMNIA model are presented in Figure 1.2. The model includes 34 existing (ordinary) technologies for the base year 2019, disaggregated by end use: thermal uses, air conditioning, cooking, electric appliances, lighting, and other uses.

To simulate technological changes in the future, OMNIA's residential sector includes 114 future technologies, categorised as ordinary, improved, and advanced variants of the base-year technologies. Among the thermal technologies for the high intensity thermal zones, there is also district heating included, since the high intensity thermal zones represent high populated urban areas where district heating would be a likely scenario. Therefore, four extra thermal technologies for the high Intensity zones were introduced to the model to account for the use of district heating in the high energy intensity zones. This framework allows the OMNIA model to represent the residential sector's energy demand with high spatial, temporal, and technological granularity, aiding in understanding energy consumption patterns and potential efficiency improvements.

The base year and future technologies for the service sector respectively are presented in Figure 1.3. The model includes 23 existing (ordinary) technologies for the base year 2019, covering the main end uses: thermal uses, air conditioning, cooking, lighting, electric appliances, street lighting, and other uses. These technologies reflect energy use across multiple fuel types, including electricity, fossil fuels, and renewables. The model also includes 35 future technologies for the service sector that represent improved and advanced versions of the base-year technologies, supporting transitions to more efficient and low-emission systems.

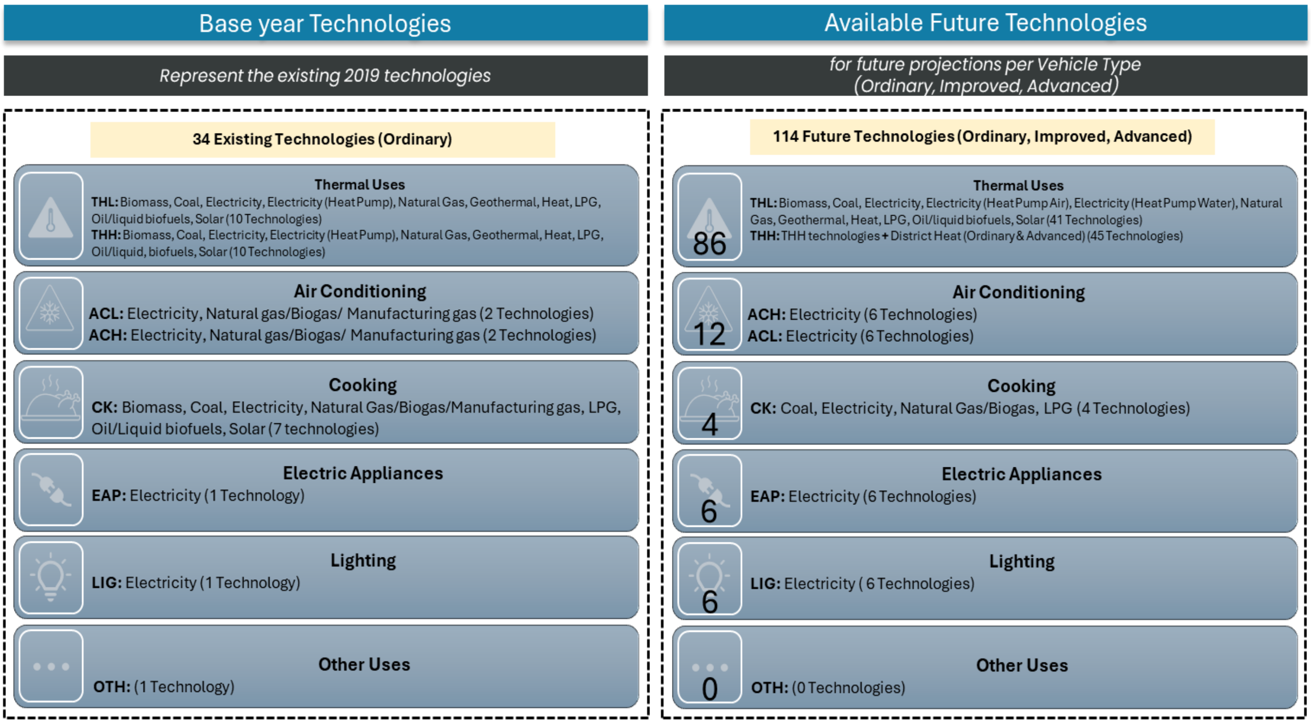

Figure 1.2 Base year and future technologies for the residential sector.

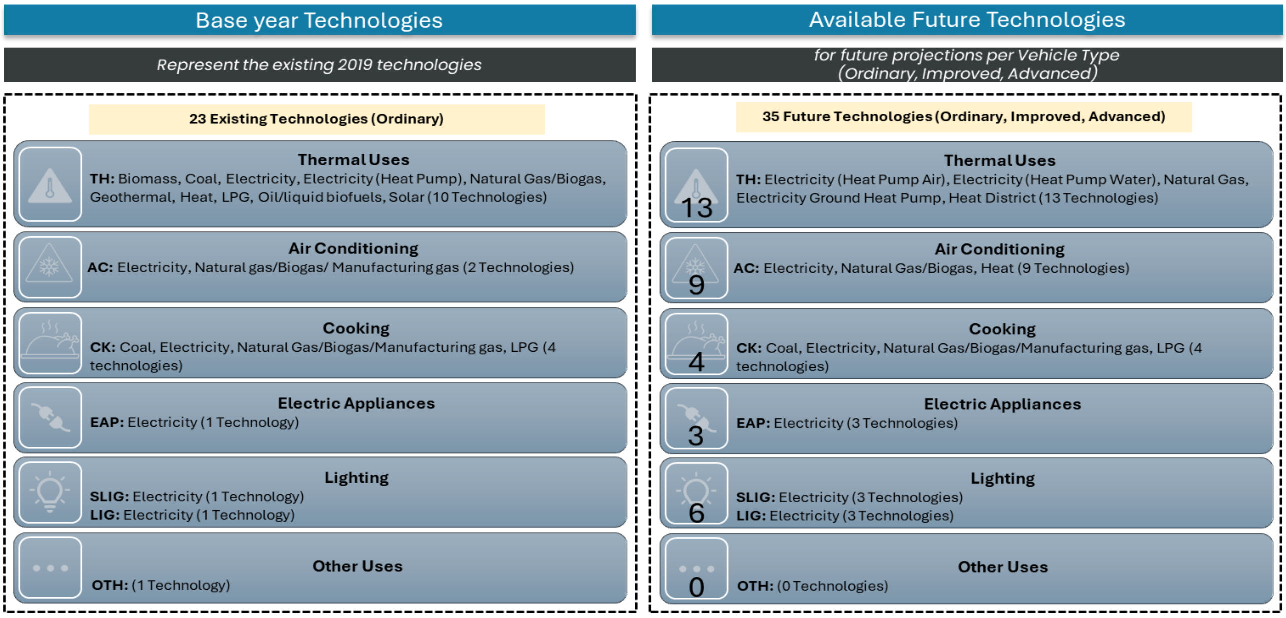

Figure 1.3 Base year and future technologies for the service sector.

2 Data requirements

Given that OMNIA's residential sector is a further built from the TIMES GEO model, Table 2-1 below shows the data already used in TIMES GEO and the new data used for the enhanced OMNIA's version.

Table 2-1 Main data inputs with references. The table also indicates if the source was already used in TIMES GEO or it is used for the first time for this OMNIA model.

Component	Source	Access	URL	Existing in TIMES GEO
Residential energy balance	UNSD Energy Balances	Public		
Residential technology database	EU Reference scenario 2020 - technology assumptions	Public	https://energy.ec.europa.eu/data-and-analysis/energy-modelling/eu-reference-scenario-2020_en	Yes
IEA ETSAP technology database	IEA ETSAP - Technology Brief R02 – June 2012	Public	https://iea-etsap.org/index.php/energy-technology-data/energy-demand-technologies-data	Yes
HDD and CDD	Degree Days	Public	www.degreedays.net	Yes
2019 Share of heat pump consumption	IEA Heat Pumps	Public	IEA (2022), Heat Pumps, IEA, Paris https://www.iea.org/reports/heat-pumps	Yes
GDP, Population data	World Bank data	Public	https://www.worldbank.org/en/home	No, first time used in OMNIA
Heating and cooling profiles	Journal Publication	Public	Sachs, J., Moya, D., Giarola, S., & Hawkes, A. (2019). Clustered spatially and temporally resolved global heat and cooling energy demand in the residential sector. Applied Energy, 250, 48-62.	No, first time used in OMNIA

2.1 Assumptions and input data used

2.1.1 Assumptions used to End-Use Breakdown by Fuel

In the ***VT_GEO_RSD_OMNIA*** excel doc for the share by fuel of the end uses in Table 2 assumptions based on expert perception were made in the ***VT_OMNIA_RES*** excel doc.

2.1.2 Region Segmentation in zones by Energy Intensity and Energy demand profiles

Data for the seasonal heating and cooling energy demand distribution by country were used, acquired from the paper "Clustered spatially and temporally resolved global heat and cooling energy demand in the residential sector" : https://doi.org/10.1016/j.apenergy.2019.05.011.(Sachs et al., 2019).

The profiles for the heating and cooling demand were taken from the supplementary material of the paper (**Figure 2.3**) which can be found in Appendix B, and is the Supplementary data 1 (https://ars.els-cdn.com/content/image/1-s2.0-S0306261919308657-mmc1.csv). The data used were for the year 2019 (base OMNIA year).

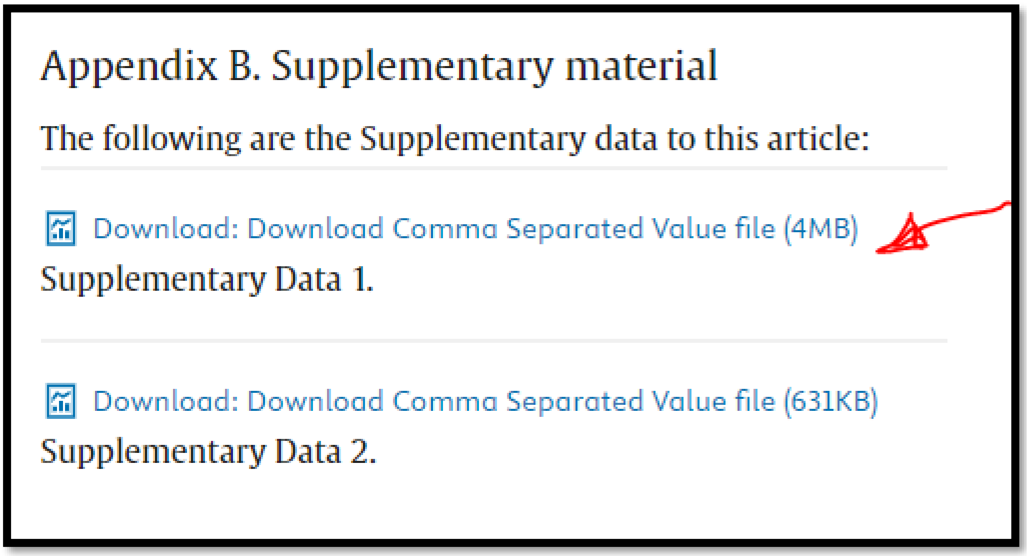

Figure 2.1The data used to extract the seasonal heating and cooling profiles.

The data presented the seasonal 24-hour profiles per country for up to 9 energy intensity zones for space heating, water heating and space cooling. The zones were split according to the estimated energy intensity based on spatial population distribution density and heating and cooling Energy degree days as shown in **Table 2.1**.

Table 2.1 Energy intensity bands of the paper (Sachs et al., 2019).

band	upbound [MW h/km^2]
1	1000
2	1790
3	5680
4	12080
5	21360
6	36930
7	63910
8	90000
9	125559.1

The total number of counties in the database was 165 covering 99.96% global energy users. Therefore, it is considered that the 165 countries in the database would be representative enough to represent the entire world (195 countries) covered in OMNIA. Figure 2.2 shows the countries of OMNIA, and highlighted in yellow are those countries that were covered by the database.

Abbreviati	Region	Country	Country	Country	Country	Country	Country	Country	Country	Country	Country	Country	Country	Country	Country	Country	Country	Country	Country	Country	Country	Country	Country	Country	Country	Country
AFE	Eastern Africa	Ethiopia	Kenya	Sudan	Mauritius	Eritrea	South Sud	Burundi	Comoros	Madagasc	Rwanda	Somalia	Uganda	Tanzania	Djibouti	Reunion	Seychelles									
AFN	Northern Africa	Egypt	Algeria	Morocco	Libya	Tunisia																				
AFW	Western Africa	Democrat	Cote dIvoi	Ghana	Cameroor	Gabon	Benin	Senegal	Togo	Niger	Republic c	Burkina Fa	Central Afi	Chad	Gambia	Guinea	Guinea-Bi	Liberia	Malawi	Mali	Mauritani	Sierra Leo	Cabo Verd	Equatoria	Sao Tome	Seychel
AFZ	Southern Africa	Angola	Mozambic	Zimbabwe	Zambia	Botswana	Namibia	South Afri	Lesotho	Eswatini																
ANZ	Australia and New	Australia	New Zealand																							
ASC	Central Asia	Kazakhsta	Uzbekista	Turkmeni	Azerbaijai	Mongolia	Georgia	Kyrgyzstar	Armenia	Tajikistan	Afghanistan															
ASE	Southeast Asia	Thailand	Malaysia	Singapore	Myanmar	Cambodia	Brunei	Laos	North Kor	Cook Islar	Timor-Les	Fiji	French Po	Kiribati	New Calec	Palau	Papua Ne	American	Solomon I	Tonga	Vanuatu	Niue	Samoa	Wallis anc	Micronesi	Nauru
ASO	South Asia	Banglades	Nepal	Sri Lanka	Pakistan	Bhutan	Maldives																			
BRA	Brazil	Brazil																								
CAN	Canada	Canada																								
CHL	Chile	Chile																								
CHN	China	China	Hong Kon	Macao																						
ENE	Non-EU Eastern Eu	Ukraine	Belarus	Serbia	Bosnia an	Moldova	Macedoni	Kosovo	Albania	Montenegro																
ENW	Non-EU Western Eu	Norway	Switzerlar	Iceland	United Kir	Gibraltar	Saint Hele	Liechtenstein																		
EUE	Eastern Europe Uni	Poland	Czech Rep	Romania	Hungary	Bulgaria	Slovakia	Croatia	Lithuania	Slovenia	Estonia	Latvia														
EUM	Mediterranean- Eu	France	Italy	Spain	Greece	Portugal	Cyprus	Malta																		
EUW	Western Europe Un	Germany	Netherlan	Belgium	Sweden	Austria	Finland	Denmark	Ireland	Luxembou	Greenlanc	Faroe Isla	Andorra													
IDN	Indonesia, Philippi	Indonesia	Philippine	Vietnam																						
IND	India	India																								
JPN	Japan	Japan																								
LAM	Latin America	Argentina	Venezuela	Colombia	Peru	Trinidad a	Ecuador	Guatemal	Cuba	Bolivia	Dominica	Honduras	Paraguay	Uruguay	Costa Rica	El Salvadc	Haiti	Panama	Nicaragua	Jamaica	Curaçao	Guyana	Puerto Ric	Suriname	Antigua ai	Aruba
MDA	Mediterranean Asia	Turkey	Israel	Syria	Jordan	Lebanon	State of Palestine																			
MEA	Middle East (Gulf S	Iran	Saudi Aral	United Ara	Iraq	Qatar	Kuwait	Oman	Bahrain	Yemen																
MEX	Mexico	Mexico																								
NIG	Nigeria	Nigeria																								
RUS	Russia Federation	Russia																								
SKT	South Korea, Taiwa	Taiwan	South Korea																							

Figure 2.2 Excel screenshot showing in yellow the countries covered by the database, and in red the countries not covered by the database.

2.1.2.1 Data processing

The data were download from the Appendix were saved as **SHWH_distribution** in the folder **SHWH & SC profiles for HE and LE zones** a CSV file type. This database was processed to produce seasonal profiles from a high and a low energy intensity zone per each region using the MATLAB main program named **Heating_Cooling_Distribution_output_final** in the folder **SHWH & SC profiles for HE and LE zones** in the **Codes & Data** folder of the **Residential Sector** folder in the repository (Figure 0.1). The regions were split into Low and high intensity zones based on the bands split in paper by grouping the bands 1-7 and 7-9 respectively as shown in **Table 2.2**.

2.1.2.2 Split between High and Low energy intensity zones

The high and low energy intensity zones for heating and cooling needs, were split and grouped as shown in Table 2-2 based on the energy intensity range for the heating needs for each region. This allowed to produce profiles for each zone and each region.

Table 2-2 Group bands to represent a Low and a High energy intensity zone for each region

band	upbound [MW h/km^2]	
1	1000	LE (Low energy zone)
2	1790	
3	5680	
4	12080	
5	21360	
6	36930	
7	63910	HE (High energy zone)
8	90000	
9	125559.1	

2.1.2.3 Seasonal profiles for heating and cooling demand

The data covered hourly (24 hours) and seasonal (4 seasons) data points. Each season was consisting of three months, starting with December. This means Winter includes December, January, and February; Spring includes March through May; Summer includes June through August; and Autumn includes September through November. All seasonal data is aligned with this structure, as illustrated in Figure 9 of (Sachs et al., 2019). Each day is represented by 24 hourly values, where hour 1 corresponds to the time interval from midnight to 1 a.m. in GMT. The values indicate the average demand during each hourly interval.

Therefore, to adapt to the OMNIA time slices shown in Table 2-3, the resolution of the data had to be reduced from 96 to 20 slices in total time slices. 5 time slices per day and 4 seasons per year.

Table 2-3 OMNIA time slices for which the profiles were produced.

4 annual time slices (Seasons)	5 daily time slices
3 months: Dec - Feb	5 h
3 months: Mar - May	4 h
3 months: Jun Aug	5 h
3 months: Sept - Nov	5 h
	5 h

The data base provided data from the energy intensity of space heating, water heating and water cooling measured in MW h/km^2. For the needs of OMNIA model, the energy intensity was not required, but what we were interested in were the trends of energy. Therefore, the normalised profiles were used. Moreover, the Water and Space heating demands was decided not to be disaggregated form OMNIA, as done in (Sachs et al., 2019), to avoid model's unnecessary complexity. This assumption practically means that in households the source for water and space heating is the same. Therefore, the data from Space and water heating were merged into one quantity named "Thermal uses". An example of how the plotted data look, in the OMNIA regions and timeslices for space cooling in the summer season and high energy zone is shown in Figure 2.3, while the respective space and water heating profiles are shown in Figure 2.4. From the figures the patterns of the demand along a day, and the different timezones across the OMNIA regions can be observed.

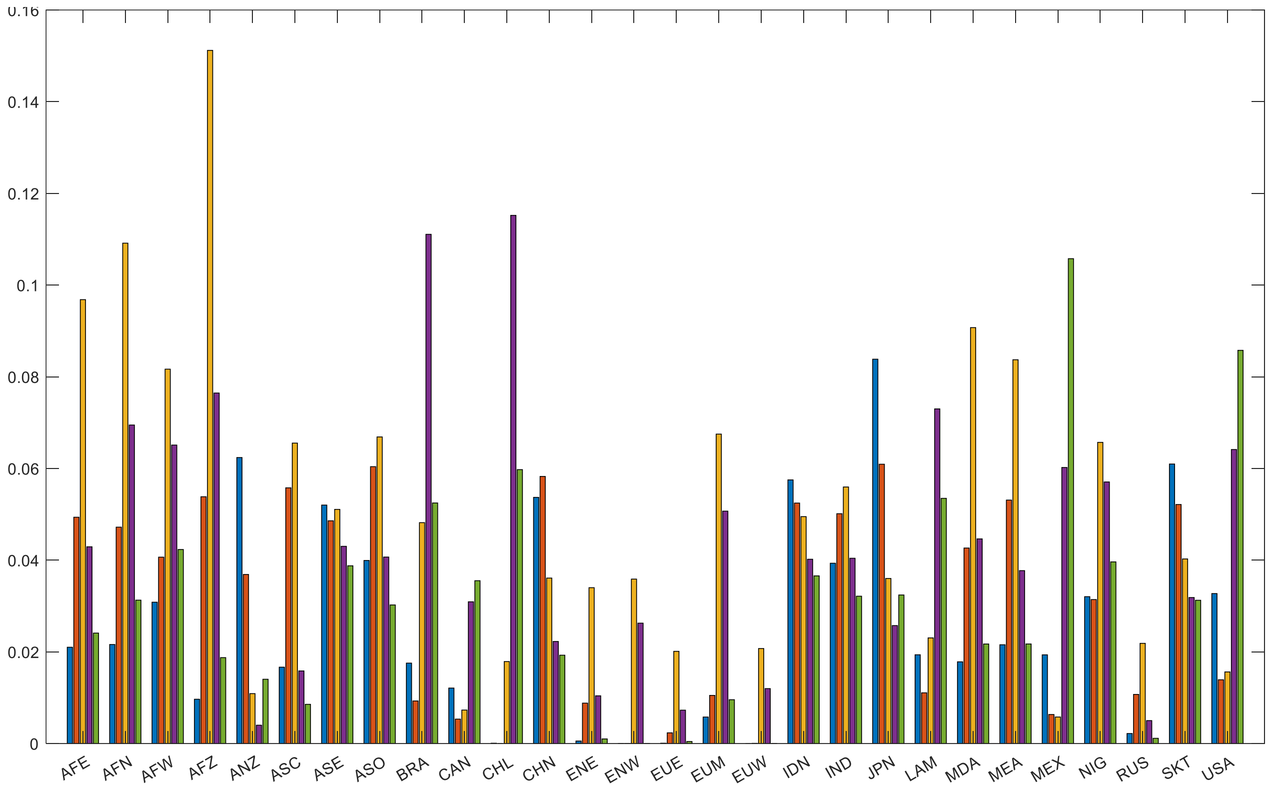

Figure 2.3 Normalised profile for space cooling in Season 3 (summer) in high intensity zones, 5-day slices for for all OMNIA regions.

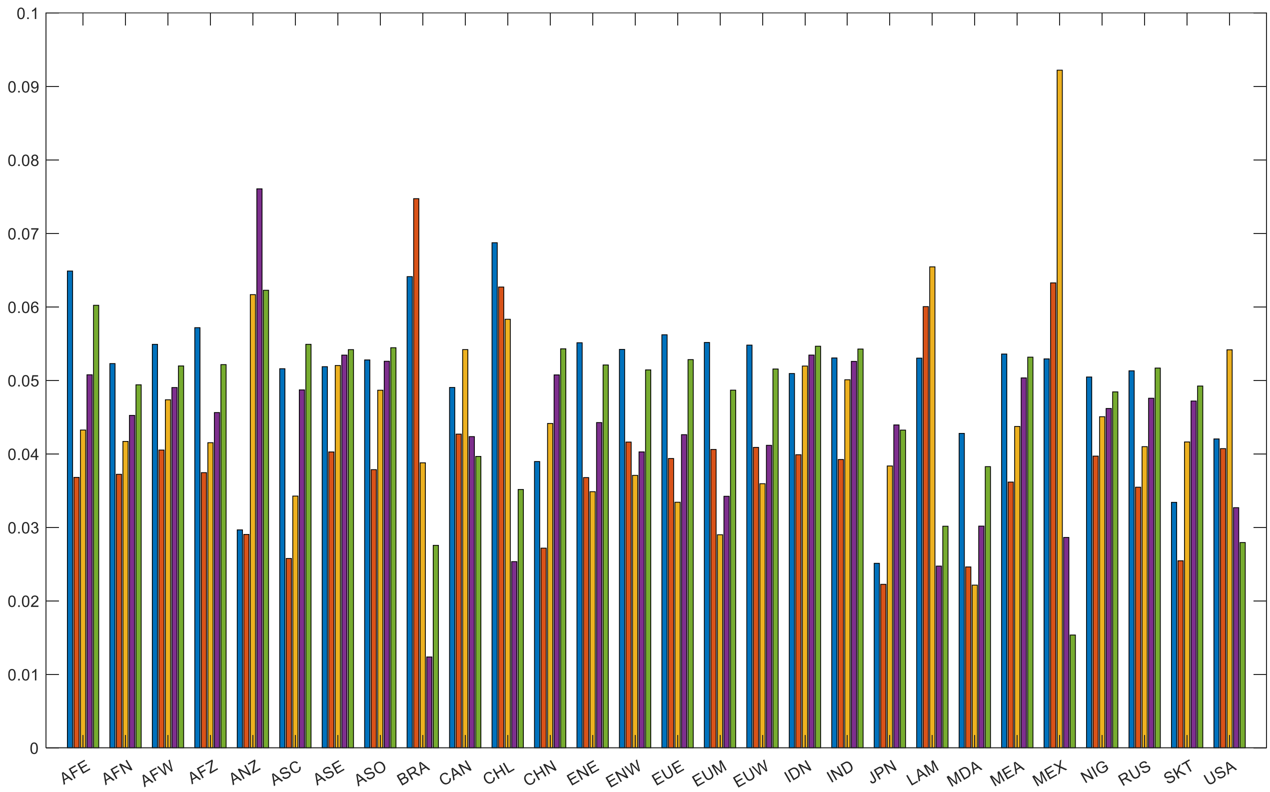

Figure 2.4 Normalised profile for space and water heating in Season 3 (summer) in high intensity zones, 5-day slices for all OMNIA regions.

2.1.3 Technology Advances

In the residential sector, as described in Section 1, the regions were split into high and low energy intensity zones, to allow for applying the option for District heating in the High Intensity zones that represent high dense urban areas. The district heating technology introduced is presented in Section 1.1 and Figure 1.2.

3 References

Sachs, J., Moya, D., Giarola, S., & Hawkes, A. (2019). Clustered spatially and temporally resolved global heat and cooling energy demand in the residential sector. *Applied Energy*, *250*, 48–62. https://doi.org/10.1016/j.apenergy.2019.05.011

UNITED NATIONS DEPARTMENT FOR ECONOMIC AND SOCIAL AFFAIRS. (2022). *2019 ENERGY BALANCES*. UNITED NATIONS.