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JRC-EU-TIMES 2017 Upgrade

Buildings and heating & cooling technologies

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Contents

Abstract

The present report describes two main upgrades that have been made to the JRC-EU-TIMES model during the year 2017:

- An improvement of the description of residential and non-residential buildings
- An update of data and a new representation for heating &cooling and heat distribution technologies

The model updates have been validated through tests with the JRC-EU-TIMES model and with stylised models allowing isolating the observed effect of the changed model input. The updates performed greatly improve the ability of the JRC-EU-TIMES model to perform studies options for the decarbonisation of the heating and cooling sector.

1 Introduction

The Joint Research Centre of the European Commission develops and maintains tools and instruments for the analysis of European research and innovation policies in the field of energy and climate. One of such instruments is the JRC-EU-TIMES model.

The JRC-EU-TIMES model helps understanding the role of energy technologies and their innovation needs for meeting European policy targets related to energy and climate change. The model follows the energy system of the EU 28 and of neighbouring countries from the years 2010 to 2060. It produces projections (or scenarios) of the EU energy system under different sets of specific assumptions and constraints. In this function, the model is used for a number of research activities at DG JRC and for the Horizon 2020 project "Heat Roadmap Europe 2050" [1].

JRC-EU-TIMES follows the paradigm of the TIMES model generator from the ETSAP Technology Partnership of the International Energy Agency, which combines a detailed technology specification with an optimisation approach [2]. The model solves for the cost optimum investment portfolio of technologies for the entire period under consideration[1], along the supply chains for five sectors, while fulfilling the energy-services demand. This implies simultaneously deciding on asset investments and operation, primary energy supply and energy trade.

JRC-EU-TIMES is an improved offspring of previous European energy system models developed under several EU funded projects, such as NEEDS [3], RES2020 [4], REALISEGRID [5], REACCESS [6] and COMET [7]. JRC was partner in the NEEDS project in which the Pan European Times model was originally developed. Since then, the original project partners have developed different versions of the original model some of which are being used for EU funded research projects[2]. The JRC-EU-TIMES model has been further developed over the last years and is currently maintained by JRC unit C.7. The baseline scenario of JRC-EU-TIMES is always aligned to the latest EU reference scenario. The model can be used to assess which technological improvements are needed to make technologies competitive under various low-carbon energy scenarios.

The present report describes two model improvements that were added during the year 2017:

- An improvement of the description of residential and non-residential buildings
- An update of data and a new representation for heating &cooling and heat distribution technologies

[1] The TIMES paradigm also allows for alternative approaches such as limited foresight, see [2].
[2] E.g. the REEEM project (http://www.reeem.org/)

2 Enhancing the description of residential and non-residential buildings

2.1 Technology database

2.1.1 Datasets

Along with this report the following datasets have been developped:

- A technology database on residential buildings (*JRC_Database Technology Building.xlsx*).
- A new VEDA_FE *SubRes* (in spreadsheet form: *SubRES_RsdRetrofits.xlsx* and *SubRES_RsdRetrofits_Trans.xlsx*) and *Scenario* (in spreadsheet form: *Scen_RsdRetfitsetup.xls*) input files.
- Services sector retrofit cost curve (in spreadsheet form: *Retrofit Cost Curve Analysis_COM.xslx*).

2.1.2 Database structure and criteria

This section presents an overview of the technology database constructed as part of this model upgrade. The database collects and organises information regarding building stocks, thermal envelope performance, climate conditions, etc.; and provides a procedure to calculate the thermal requirement of relevant residential building typologies across EU countries. The non-residential buildings have been treated with a different approach, as the resolution of data available was not the same as for residential buildings. Section 2.4 provides details on the methodology used to characterise non-residential building stock.

The key criteria which have been used to develop the technology database for residential buildings are:

- The preparation of the technology database is driven by a “bottom-up” approach and, at the same time, by the attempt to minimise the number of assumptions and to maximise the use of publically available data (European projects and databases) in order to deliver a transparent and well-organised tool.
- The main focus of the technology database is to make explicit the energy-related characteristics of the existing residential building stock per each country, and to provide a set of possible refurbishment measures (described in terms of energy savings and costs). The basic goal is to use the information collected in the most suitable way, modelling explicitly differences of measures, costs and savings per different building type and period of construction.
- The new standards of construction (new U-values or/and new kWh/m^2-a) will be used for the update of the demand projections, but are not meant to be part of the technology database (no explicit technology will be modelled for the new constructions).

The technology database is spreadsheet-based and consists of several sheets as described in Table 1.

Table 1: Structure overview of the technology building database

Sheet name	Description
Cover	Key
Dwelling stock	Dwellings stock according to construction date
Ceiling-U	Ceiling U-values by construction period; Examples of U-values for retrofitted buildings.
Wall-U	Wall U-values by construction period; Examples of U-values for retrofitted buildings.
Floor-U	Floor U-values by construction period; Examples of U-values for retrofitted buildings.
Window-U	Windows U-values by construction period; Examples of U-values for retrofitted buildings.
HDD-by Country	Mean heating degree-days over period 1980 – 2004.
Data by dwelling type	Distribution of population by dwelling type; Dwelling stock surface; Stock of dwelling per type; Average size of dwelling by type; Average number of dwellings per building.
Energy Efficiency Measures-DBT	Assumed techno-economic characteristics of energy efficiency measures.
Detached	Bottom-up calculation of the thermal requirements based on geometrical analysis for detached buildings. Examples of estimation of the “new” (refurbished) building constants, and calculation of the savings for selected retrofit measures.
Semidetached	Bottom-up calculation of the thermal requirements based on geometrical analysis for semidetached buildings. Examples of estimation of the “new” (refurbished) building constants, and calculation of the savings for selected retrofit measures.
Flat	Bottom-up calculation of the thermal requirements based on geometrical analysis for flats. Examples of estimation of the “new” (refurbished) building constants, and calculation of the savings for selected retrofit measures.
All Stock	Thermal requirements (weighted average) of the whole stock. Preliminary calculation of the ratios (building type).
Savings_Detached	Bottom-up calculation of savings for detached buildings for all retrofit measures
Savings_SemiDet	Bottom-up calculation of savings for semidetached buildings for all retrofit measures
Savings_Flat	Bottom-up calculation of savings for flats for all retrofit measures
Population	Population by country, used to estimate the building stock for country with no available data

The analysis of the existing residential building stock has been performed via an “n-step” procedure:

1) **Data collection:** The database collects and organises all the relevant information about building stock, dwelling types distribution, dwelling average surfaces, envelope performance (U-values), degree-days, techno-economic characteristics of refurbishment measures[3], etc. For modelling transparency each data source have been univocally indicated.
2) **Geometrical analysis:** Based on nominal U-values (by country, period of construction and building component), the thermal requirements are calculated for three types of buildings (detached, semidetached and flats), per each period of construction (six periods), as well as for the entire stock (weighted average). This is a “bottom-up” calculation of the thermal requirements (kWh/m^2) based on technical characteristics of the building. To take into

[3] Costs of refurbishment measures include four components: material, labour, business profits and other fees.

account behavioural, fuel poverty, and others issues, which drives differences between *theoretical* (design) and *real* thermal requirements a logarithmic-like curve, based on Hens et al. [8], has been implemented to simulate the decoupling between theoretical and actual values of thermal requirements. The most relevant assumptions regard the building geometries, the glazed areas, the number of dwellings per each semidetached building, and the correction factors (including ventilation losses and gains from sun). All those assumptions are explicit in the database; any update or change of these parameters will be transposed to the dependent variables accordingly.

The results of this analysis are summarised in the Excel database in sheets *Detached* (rows 47-53), *Semidetached* (rows 48-54) and *Flat* (rows 48-54).

Savings analysis: Based on improved U-values of refurbishment measures per each building component (and period of construction), the expected savings due to different refurbishment measures have been calculated[4]. This is a bottom-up calculation of the *new* thermal requirements (kWh/m^2) and savings, based on improved U-values. The new building components (new windows, insulated walls, etc.) are explicitly described. In this analysis savings are determined for seven different refurbishment measures, for all three building types and six different construction periods. Examples of results of this analysis in the Excel database are summarized in sheets *Detached* (rows 60-94, 97-130, 133-166), *Semidetached* (rows 60-94, 97-130, 133-166), *Flat* (rows 60-94, 97-130, 133-166). A complete list of savings from all retrofit measures has been included in sheets *Savings_Detached*, *Savings_SemiDet*, *Savings_Flat*.

2.1.3 Data quality check

All the collected data have been subject to a data quality check. A detailed list of anomalies and warnings has been provided that included a number of suggested actions that, once agreed with JRC experts, have been used in the final version of the technology database. A complete summary of this analysis is provided in section 0.

2.1.4 Refurbishment measures

The technology database considers a broad range of refurbishment measures for residential buildings. It includes refurbishment options for walls insulation (2 options), ceilings insulation (2 options) and windows replacement (3 options). The impact of each retrofit measure is evaluated per each building types (3), construction period (6) and country (37). This equates to 4662 different heating requirement calculations. Any possible combination of measures will be also allowed in the JRC-EU-TIMES model SubRes (e.g. External insulation-10 cm + Window replacement-Triple glass-18mm; etc.), which is equivalent to 19,314 different combinations. For brevity all these combinations have not been explicitly indicated in the database.

Thermo-physical characteristics (U-values) and costs of refurbishment measures are based on the ENTRANZE project [9]. Costs of refurbishment measures include four components: material, labour, business profits and other fees. The database is structured in such a way that results will be automatically updated in case of any changes or improvement of these input assumptions. This will allow modellers to test also different retrofit measures. The detail of the assumed values is summarised in the Excel database in sheet *Energy Efficiency Measures-DBT*. A complete list of savings from all single retrofit measures has been included in sheets *Savings_Detached*, *Savings_SemiDet*, *Savings_Flat*.

2.2 Implementation of the residential buildings module in JET

The implementation of the residential buildings module required a review of the model structure. The new model Reference Energy Systems (RES) has been designed to meet JRC requirements for energy policy testing. One single process (vintaged) is meant to represent the entire stock of each building type (i.e. Detached, Semidetached and Flat), per each Country. Each refurbishment measure is modelled through the explicit representation of

[4] As concerns the ventilation losses, different correction factors (assumptions) may be applied to the retrofitted buildings (see rows 61, 94, 127 of the sheets Detached, Semidetached, Flats) taking into account the different requirements of ventilation for the more insulated options.

processes in the model. Single measures are supposed to have the same costs but different impacts (energy savings) across the vintaged building stock. Any possible combination of measures is allowed, in order to keep the model as flexible as possible. Up to 29 single/composed retrofits are possible per each building type. The contribution of multiple measures has been assumed linear, hence the impact of single retrofit measure has been considered *additive*. Redundancies or double counting problems are prevented through the use of ad-hoc constraints (per each vintaged period).

Figure 1 shows the new RES for the residential buildings.

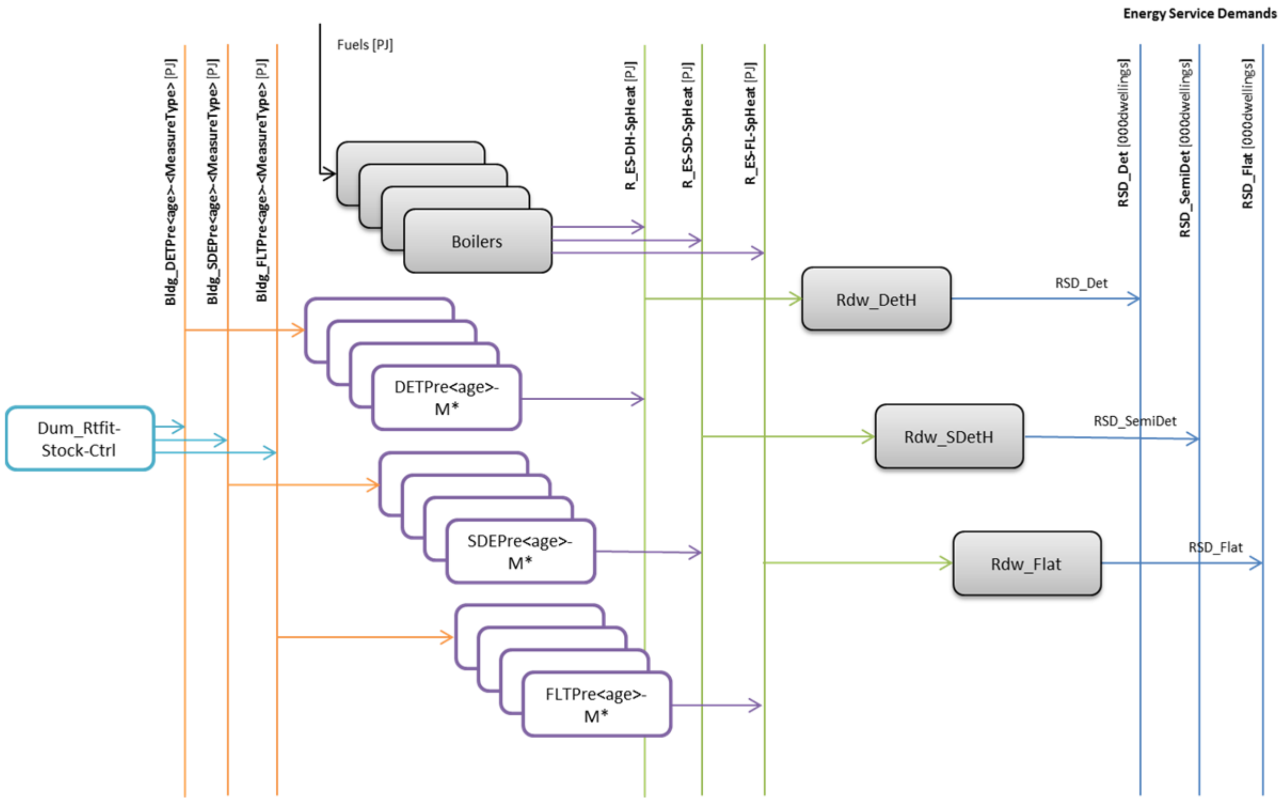


Figure 1: New RES for residential buildings in JET

Grey boxes and black lines represent the modelling elements (processes and commodities) which have been inherited from in the previous model structure. The blue boxes named *RSD_Exist_** and relative commodities are part of the new model structure which will be introduced in the new model BY templates. The new set of retrofit technologies (represented in purple in the figure) has been made available to the JRC-EU-TIMES model through the dedicated *SubRES* files named *SubRES_RsdRetrofits.xslx* and *SubRES_RsdRetrofits_Trans.xlsx*. The process *Dum_Rtfit-Stock-Ctrl* has been introduced in the new SubRes file as virtual process to control the maximum saving by type of refurbishment and building.

The spreadsheet structure is as follows:

1. *SubRES_RsdRetrofits.xslx* contains the declaration and topology information of all processes and commodities involved in the new *SubRes*.
2. *SubRES_RsdRetrofits_Trans.xslx* contains detailed country specific information about savings, costs, and maximum levels of retrofit. The key characteristic is that all input tables are directly related to the building database, allowing modellers to easily test or update different retrofit measures or input assumptions

To exclude measures with negative saving (this may happen when the current building stock is already pretty efficient), a scenario file named *Scen_RsdRetfitsetup.xls*, has been implemented.

2.3 Testing the implementation of the residential buildings module

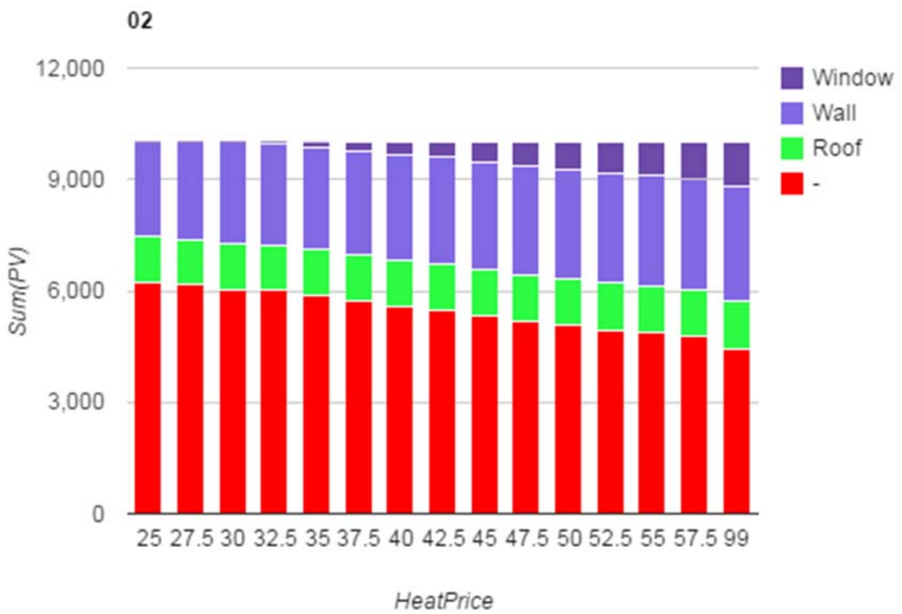
Once the activities described in sections 2.1 and 2.2 were finalised, the functioning of the residential buildings module was tested. The test of the new module has been performed using an ad-hoc developed test model, consisting in a multi-regional single sector model of the residential sector, which tests the penetration of retrofit measures under exogenously imposed heat prices. This approach allowed a rigorous testing of the building data avoiding interactions with other sectors. Impacts of different discount rates of the refurbishment options (aiming at representing the willingness to invest of households) have been also analysed during the test-phase of the updated JRC-EU-TIMES *SubRes*.

The analysis resulted in a large number of sensitivity runs which combine results for a combination of heat prices (from 25 €/GJ to 99 €/GJ) and discount rates (from 2% to 20%). This selection of scenarios was made to test the robustness of the new modelling approach. However it is worth noting that the following results have only illustrative purposes to verify the correct functioning of the model latest updates.

Figure 2 illustrates the penetration by 2030 of different retrofit measures across the EU+ region (consisting of 37 countries) as function of heat prices (exogenously assumed)[5]. Results for discount rates of 2% and 20% are shown. At DR of 2% (Figure 2-a) wall insulation is the measure that has the largest contribution, followed by roof insulation. Windows replacement is cost effective only at high heat prices. With a 20% DR (Figure 2-b) the overall contribution of retrofit measures reduces and windows replacement have no role at any heat price. However, it should be noted that windows replacement is usually less cost intensive compared to other measures and sometimes subsidised. Hence it is suggested to apply a lower discount rate to these measures.

[5] Non-retrofitted heat requirement is shown in red

a.



b.

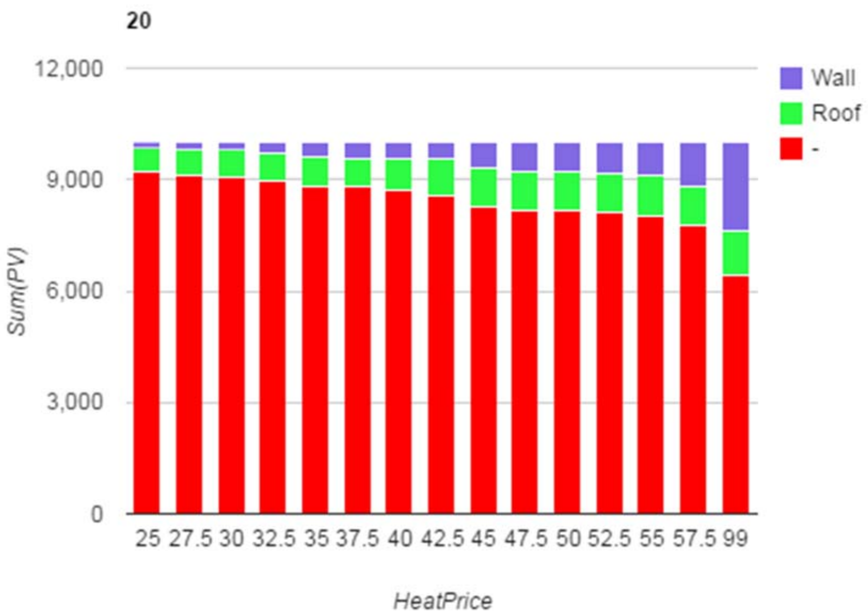


Figure 2: EU savings (in PJ) by component in 2030 as function of heat price (€/GJ) with discount rates of 2% (a) and 20% (b)

Figure 3 shows one of the key strengths of this modelling approach. The results indicate the role of retrofit measures across different building types. In all scenarios more than half of the savings are expected from the detached houses.

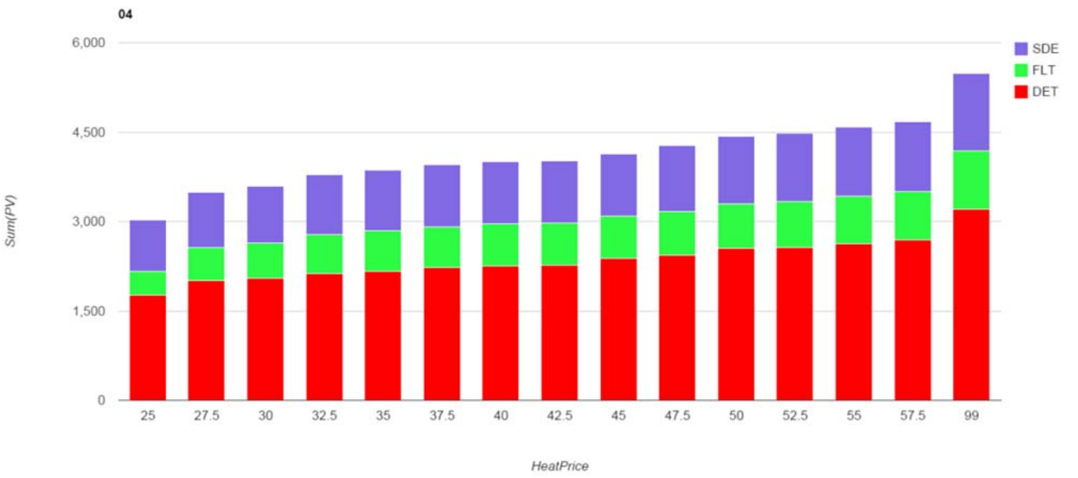


Figure 3: EU savings (in PJ) by building type in 2030 as function of heat price (€/GJ) with discount rates of 4% and heat price of 50 €/GJ

The geographical dimension is another key strength of the new module. All assumptions and data are differentiated by country, according to most recent available data. The impact of retrofit measures differs between countries according to specific building characteristics, climate conditions and costs. Figure 4 provides an overview of savings delivered by single retrofit measures in a case of a 4% discount rate and a heat price of 50 €/GJ.

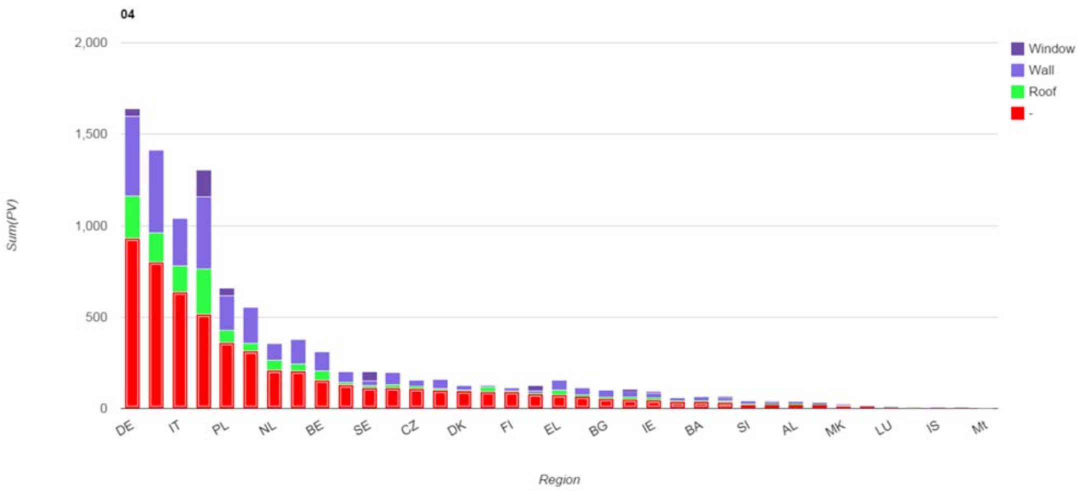


Figure 4: Savings (in PJ) by country in 2030 with discount rates of 4% and heat price of 50 €/GJ

2.4 Implementation of the non-residential buildings module

While the datasets of residential buildings are fairly comprehensive, the non-residential stock is far less covered, as the sector is associated with higher uncertainty levels due to the difficulties in tracking the existing stock of all different non-residential types and developing an appropriate statistical database. The explicit representation of more than one building type and explicit retrofit measures requires the characterisation of the building stocks in the BY and the definition of an ad-hoc set of new technologies per building type to completely track the energy consumptions. Sources do not provide information with such a level of detail.

The non-residential buildings have been therefore treated following a different approach. Instead of using a bottom up approach with explicit representation of refurbishment measures a cost curve approach has been applied. This approach is similar to the one previously applied in the JRC-EU-TIMES model to both residential and non-residential retrofit measures; however different retrofit cost curves have been estimated for each Country.

Cost curves have been developed making use of the sensitivity runs performed for residential flats for a range of discount rates between 5% and 10%. Figure 5 shows an example of results for the non-residential sector in Germany. The full set of data has been provided in spreadsheet form in *Retrofit Cost Curve Analysis_COM.xslx*.

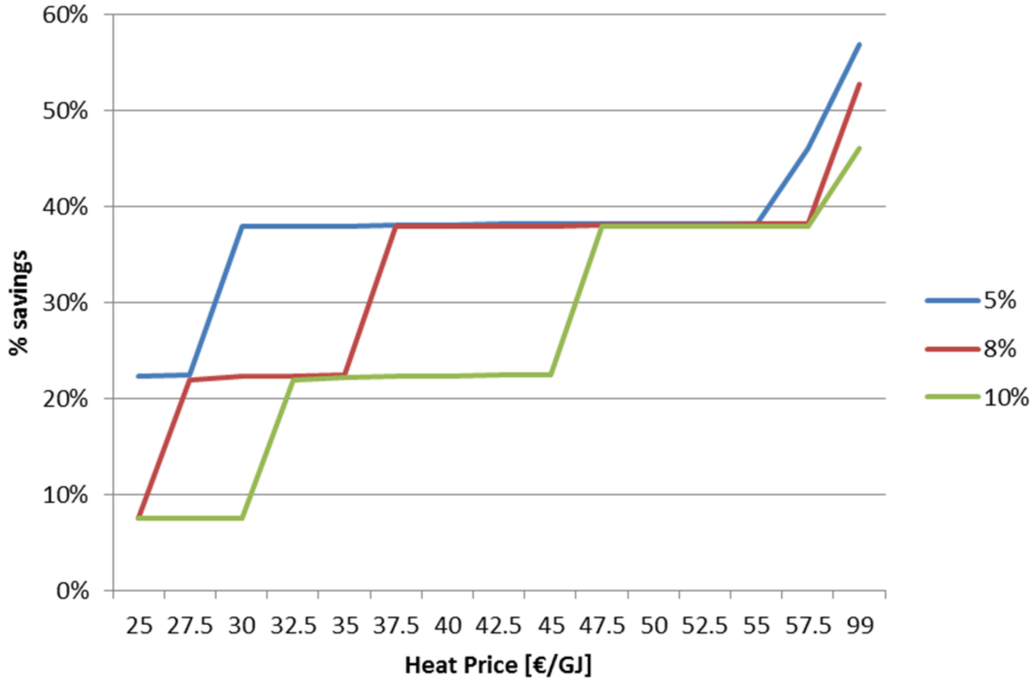


Figure 5: Cost curves for non-residential buildings for Germany (DE)

2.5 Data quality check for residential buildings

Table 2: Heating degree days

Sheet name	Cell	Country	Period	Value	Comments	Suggested change
HDD- by country	C22	Iceland	*"Mean"* HDD over period 1980 – 2004	626	Very low, due to null values in the data series record.	Suggested value: 4976 (2005-2009 average of *"actual"* HDD based. Source: Eurostat)

Table 3: ENTRANZE's "nominal" U-values (ceiling)

Sheet name	Cell	Country	Period	Value	Comments	Suggested change	
Ceiling-U	E34	Portugal	< 1945	3.10	High value when compared to other Southern countries: ES (1.75); IT (2.00).	No action. No alternative (reliable) information.	
	F34		1945-1969	2.90	High value when compared to other Southern countries: ES (1.37); IT (1.90).	No action. No alternative (reliable) information.	
	G34		1970-1979	2.70	High value when compared to other Southern countries: ES (1.37); IT (1.80).	No action. No alternative (reliable) information.	
	H34		1980-1989	2.60	High value when compared to other Southern countries: ES (1.00); IT (1.40).	No action. No alternative (reliable) information.	
	I34		1990-1999	2.40	High value when compared to other Southern countries: ES (1.00); IT (1.20).	No action. No alternative (reliable) information.	
	E15 => J15	Greece	<1945-2008	0.39	No differences across the periods. Low values. Same values of Northern European regions. SE: (Max: 0.45 / Min: 0.15) - FI: (Max: 0.40 / Min: 0.18)	< 1980	Alternative: 3.10 (like for multifamily and for some single family). (Source: National Observatory of Athens. TABULA-EPISCOPE, 2012)
						1980-2000	Alternative: 3.10 (like for multifamily and for some single family) (Source: National Observatory of Athens. TABULA-EPISCOPE, 2012)
						2001-2010	Alternative: 0.65 (Source: National Observatory of Athens. TABULA-EPISCOPE, 2012)
	E10	Cyprus	< 1945	1.52	Strange trend	Suggestion: 3.42 (Source: Building Typology Brochure – Cyprus. TABULA-EPISCOPE, 2014)	
	F10		1945-1969	3.33		Suggestion: 3.42 (Source: Building Typology Brochure – Cyprus. TABULA-EPISCOPE, 2014)	
	G10		1970-1979	3.33		Suggestion: 3.42 (Source: Building Typology Brochure – Cyprus. TABULA-EPISCOPE, 2014)	
	H10		1980-1989	3.33		Suggestion: 3.42 (Source: Building Typology Brochure – Cyprus. TABULA-EPISCOPE, 2014)	
	I10		1990-1999	0.56	It sounds a low value when compared to: Malta (1.81), and Greece (3.1).	Suggestion: 3.42 (Source: Building Typology Brochure – Cyprus. TABULA-EPISCOPE, 2014)	
	J10		2000-2008	0.55	It sounds a low value when compared to: Malta (1.81) and Greece (3.1).	Suggestion: 3.42 (Source: Building Typology Brochure – Cyprus. TABULA-EPISCOPE, 2014)	

Table 4: ENTRANZE's "nominal" U-values (floor)

Sheet name	Cell	Country	Period	Value	Comments	Suggested change
Floor-U	E40	United Kingdom	< 1945	5.98	High value when compared to: DE (1.08) - BE (1.02).	Suggestion: 0.72 (single family) - 0.45 (multi family) (Source: Building Typology Brochure – England. TABULA-EPISCOPE, 2014)
	F40		1945-1969	5.45	High value when compared to: FR (2.00) - DE (1.22) - BE (1.02).	Suggestion: 0.72 (single family) - 0.45 (multi family) (Source: Building Typology Brochure – England. TABULA-EPISCOPE, 2014)
	G40		1970-1979	2.73	High value when compared to: FR (0.95) - DE (0.97) - BE (1.02).	Suggestion: 0.72 (single family) - 0.45 (multi family) (Source: Building Typology Brochure – England. TABULA-EPISCOPE, 2014)
	E31	Netherlands	< 1945	5.76	High value when compared to: DE (1.08) - BE (1.02).	No alternative (Country-specific) information. Alternative: same values of BE or DE.
	F31		1945-1969	4.70	High value when compared to: FR (2.00) - DE (1.22) - BE (1.02).	No alternative (Country-specific) information. Alternative: same values of BE or DE.
	G31		1970-1979	4.70	High value when compared to: FR (0.95) - DE (0.97) - BE (1.02).	No alternative (Country-specific) information. Alternative: same values of BE or DE.
	E15	Greece	< 1945	4.28	High value when compared to: Malta (3.00)	Alternative: 3.10 (like for multifamily and for some single family). (Source: National Observatory of Athens. TABULA-EPISCOPE, 2012)
	F15		1945-1969	2.42	Strange trend	Alternative: 3.10 (like for multifamily and for some single family). (Source: National Observatory of Athens. TABULA-EPISCOPE, 2012)
	G15		1970-1979	1.51		Alternative: 3.10 (like for multifamily and for some single family). (Source: National Observatory of Athens. TABULA-EPISCOPE, 2012)
	H15		1980-1989	4.56		Alternative: 2.7 (like for multifamily and for some single family). (Source: National Observatory of Athens. TABULA-EPISCOPE, 2012)
	I15		1990-1999	3.69		Alternative: 2.7 (like for multifamily and for some single family). (Source: National Observatory of Athens. TABULA-EPISCOPE, 2012)
	J15		2000-2008	0.68		No action. It sounds consistent. (Source: National Observatory of Athens. TABULA-EPISCOPE, 2012)
	E21, F21, G21	Ireland	<1945-1979	Missing values		Alternative: Max 0.75 (Source: Building Typology Brochure – Ireland. TABULA-EPISCOPE, 2014)

Table 5: ENTRANZE's "nominal" U-values (windows)

Sheet name	Cell	Country	Period	Value	Comments	Suggested change
Window-U	E23	Italy	< 1945	5.60	High value when compared to: FR (4.2)	No action. No alternative (reliable) information.
	F23		1945-1969	5.60	High value when compared to: FR (4.2)	No action. No alternative (reliable) information.
	G23		1970-1979	4.80	High value when compared to: FR (3.5)	No action. No alternative (reliable) information.
	H23		1980-1989	4.50	High value when compared to: FR (3.04)	Alternative: between 2.8 - 3.7 (Source: Building Typology Brochure – Italy. TABULA-EPISCOPE, 2014, p.26)
	I23		1990-1999	4.00	High value when compared to: FR (1.90)	Alternative: between 2.8 - 3.7 (Source: Building Typology Brochure – Italy. TABULA-EPISCOPE, 2014, p.26)
	J23		2000-2008	4.00	High value when compared to: FR (1.82)	Alternative: 2.3 (Source: Building Typology Brochure – Italy. TABULA-EPISCOPE. 2014. p.26)
	E16	Spain	< 1945	5.70	High value when compared to: FR (4.2)	No action. Other sources (Building Typology Brochure – Spain. TABULA-EPISCOPE, 2014) confirm those values.
	F16		1945-1969	5.70	High value when compared to: FR (4.2)	No action. Other sources (Building Typology Brochure – Spain. TABULA-EPISCOPE, 2014) confirm those values.
	G16		1970-1979	5.70	High value when compared to: FR (4.2)	No action. Other sources (Building Typology Brochure – Spain. TABULA-EPISCOPE, 2014) confirm those values.
	E10	Cyprus	< 1945	2.70	Strange trend	No action. No alternative (reliable) information.
	F10		1945-1969	2.70		No action. No alternative (reliable) information.
	G10		1970-1979	5.80		No action. No alternative (reliable) information.
	H10		1980-1989	5.80		No action. No alternative (reliable) information.
	I10		1990-1999	1.60		No action. No alternative (reliable) information.
	J10		2000-2008	2.70		No action. No alternative (reliable) information.

Table 6: ENTRANZE's "nominal" U-values (walls)

Sheet name	Cell	Country	Period	Value	Comments	Suggested change	
Wall-U	E15-J15	Greece	< 1945 - 2008	0.55	No differences across the periods. Low values. Same values of NORDIC regions. SE: (Max: 0.48 / Min: 0.18) - FI: (Max: 0.60 / Min: 0.26)	< 1980	Alternative: 2.2 (like for multifamily and for some single family). (Source: National Observatory of Athens. TABULA-EPISCOPE, 2012)
						1980-2000	Alternative: 2.2 (like for multifamily) (Source: National Observatory of Athens. TABULA-EPISCOPE, 2012)
						2001-2010	Alternative: 0.60 (Source: National Observatory of Athens. TABULA-EPISCOPE, 2012)

Table 7: Other data

Sheet name	Table name	Cells name	Country	-	-	Comments
Data by dwelling type	Average size of dwelling by type (m^2)			**Multi-family**	**Single-family**	
		AE31	Netherlands	34.0		Very low value when compared with FR: 66 m^2; DE: 63 m^2; UK: 48 m^2. Suggested value: 75.8 m^2 as reported in BPIE.
		AE7	Belgium	113.9	-	Suggestion: to replace with AF7
		AF7		-	73.2	Suggestion: to replace with AE7
		AE15	Greece	91.5	-	Suggestion: to replace with AF15
		AF15		-	73.0	Suggestion: to replace with AE15
Data by dwelling type	Average number of dwellings per building			**Dwellings per b. multi-family**		
		AO40	UK	86		Different assumptions on the geometry of apartment-block have been done on the base of these data. High-rise blocks for UK, low-rise blocks for the others.

2.6 Data quality check for non-residential buildings

The aim of the present section is to check the data consistency for services energy consumption per sub sector and per use, between the two following sources:

- The JRC values provided for some European countries;
- The Italian values from the CESI report (REF).

The main result of this data quality check is that the values of the two datasets are not fully consistent, and that it is very hard to explain the reasons of the observed differences. In most cases, neither the utilisation factor, nor technological arguments can explain the gaps between values. Tracking possible allocation errors between energy uses, per sub sector and per country did not prove successful. Nevertheless this method works only in some occasions and thus does not permit all values to be adjusted. Data on non-residential energy needs might be a field for further research.

Some examples of this data quality check are presented below. The following code just permits the reader to have a brief overview of the main consistent and inconsistent values.

- The most inconsistent values are noted as x in brackets (x).
- The most consistent values (uncorrected or corrected) are noted as v in brackets (v).

Note: a missing (x) or (v) does not necessarily mean the value is consistent.

Table 8: Lighting - OFFICES

		Italy (CESI)	Spain	Germany	UK	Sweden	France
Lighting OFFICES	**Value (kWh/m^2)**	**14.6**	16.5 (v) Similar to the Italian value.	3.2 (x) About 4.5 times lower than the Italian value	21.2 About 1.5 times higher than the Italian value	23.9 (v) About 1.5 times higher than the Italian value	3.8 (x) About 4 times lower than the Italian value
	Utilization	-	Similar daylight duration	Similar daylight duration	Similar daylight duration	As daylight duration in Sweden is lower than in Italy, one expects electrical lighting cons. to be higher in Sweden	Similar daylight duration
	Tech.	-	No reason for significant technology efficiency gap for the whole office building stock	Such a technology efficiency gap for the offices whole office building stock is not consistent (it would be about 4.5 times more efficient)	No reason for significant technology efficiency gap for the whole office building stock. Nevertheless, it is difficult to state if the whole office building stock in UK could have (or not) a 1.5 times less efficient lighting technology than in Italy.	No reason for significant technology efficiency gap for the whole office building stock	Such a technology efficiency gap for the whole office building stock is not consistent (it would be about 4 times more efficient)
	CF & Corresp. value (kWh/m^2)	CF : 1.00 Value : 14.6	CF : 1.87 Value : 30.9 About 2 times higher than the Italian value. Not consistent	CF : 4.53 Value : 14.3 Corrected value is consistent with the Italian one	CF : 2.24 Value : 47.6 About 3 times higher than the Italian value. Not consistent	CF : 3.24 Value : 77.5 About 5 times higher than the Italian value. Not consistent.	CF : 3.30 Value : 12.4 Corrected value is consistent with the Italian one.
	Comments	➢ According to the Utilization and the technological arguments, values are expected to be quite similar between all these countries. ➢ The German and French values are highly inconsistent regarding to others countries. Neither Utilization nor technological differences can explain the gaps. ➢ Once applied the respective CF, values are consistent for these 2 countries. ➢ We assume the Spanish and Swedish values as consistent with the Italian one. ➢ The UK value is not easy to be qualified as consistent.					

Table 9: Cooling - OFFICES

		Italy (CESI)	Spain	Germany	UK	Sweden	France
Cooling OFFICES	**Value (kWh/m^2)**	**15.3**	45.4 (x) About 3 times higher than the Italian value	18.9 (x) Similar to the Italian value	35.8 (x) About 2.5 times higher than the Italian value	70.2 (x) About 4.5 times higher than the Italian value	25.6 (x) About 1.7 times higher than the Italian value
	Utilization	-	CDD Spain = 1.2 * CDD Italy Values are not consistent : As country climate conditions are South Mediterranean, we expect values to be quite similar.	CDD Ger. * 5 = CDD Italy Values are not consistent : According to CDDs, Italian value might be higher than the German one.	CDD UK * 9 = CDD Italy Values are not consistent: Factor 2.5 between values could explain about 30 % of the difference between CDDs. Furthermore, UK value is not consistent with German one : according to CDDs, UK value is expected to be about 2 times lower than German one.	CDD Sw * 13 = CDD Italy Values are not consistent : Factor 4.5 between values could explain about 35 % of the difference between CDDs.	CDD Fr * 2.5 = CDD Italy Values are not consistent : According to CDDs, Italian value might be higher than the French one.
	Tech.	-	No reason for significant technology efficiency gap for the whole hotel building stock. A factor 3 between these country equipment rates is unlikely.	No reason for significant technology efficiency gap for the whole hotel building stock. Equipment rate may be lower in Germany than in Italy.	No reason for significant technology efficiency gap for the whole hotel building stock. Equipment rate may be lower in UK than in Italy.	No reason for significant technology efficiency gap for the whole hotel building stock. Swedish equipment rate is expected to be lower than Italian one.	No reason for significant technology efficiency gap for the whole hotel building stock. Equipment rate may be lower in France.
	CF & Corresp. value (kWh/m^2)	CF : 1.00 Value : 15.3	CF : 1.87 Value : 85.0 About 5.5 times higher than the Italian one. Not consistent. Corrected value is worse.	CF : 4.53 Value : 85.5 About 5.5 times higher than Italian value. Not consistent according to CDDs: The Italian value might be higher than the German one.	CF : 2.24 Value : 80.22 About 5.5 times higher than Italian value. Not consistent according to CDDs: The Italian value might be higher than the UK one.	CF : 3.24 Value : 227 About 15 times higher than Italian value. Not consistent according to CDDs: The Italian value might be higher than the UK one.	CF : 3.30 Value : 84.4 About 5.5 higher than Italian value Not consistent according to previous arguments: The Italian value is expected to be higher than the French one.
	Comments	➢ According to the utilization and the technological arguments, values (even corrected) are inconsistent with the Italian one.					

Table 10: Food refrigeration - HOTELS

		Italy (CESI)	Spain	Germany	UK	Sweden	France
Food refrigeration HOTELS	**Value (kWh/m^2)**	**9.9**	26.2 About 2.5 times higher than the Italian value	6.8 (v) About 1.5 times lower than the Italian value	9.7 (v) Similar to the Italian value	15.0 (v) About 1.5 times higher than the Italian value	12.9 (v) About 1.3 times higher than the Italian value
	Utilization	-	Not consistent: one expects values to be quite similar.	Factor 1.5 between values may be consistent.	Consistent: one expects values to be quite similar.	Factor 1.5 between values may be consistent.	Factor 1.5 between values may be consistent.
	Tech.	-	No reason for significant technology efficiency gap for the whole hotel building stock. It is not expected to be significant differences in equipment rate between these countries.	No reason for significant technology efficiency gap for the whole hotel building stock. It is not expected to be significant differences in equipment rate between these countries.	No reason for significant technology efficiency gap for the whole hotel building stock. It is not expected to be significant differences in equipment rate between these countries.	No reason for significant technology efficiency gap for the whole hotel building stock. It is not expected to be significant differences in equipment rate between these countries.	No reason for significant technology efficiency gap for the whole hotel building stock. It is not expected to be significant differences in equipment rate between these countries.
	CF & Corresp. value (kWh/m^2)	CF : 1.00 Value : 9.9	CF : 1.11 Value : 29.1 About 3 times higher than the Italian value. Corrected value is worse. Not consistent	CF : 5.08 Value : 34.4 About 3.5 times higher than Italian value. Corrected value is worse. Not consistent	CF : 1.52 Value : 14.8 About 1.5 times higher than Italian value. Corrected value may also be consistent	CF : 0.98 Value : 14.7 About 1.5 times higher than the Italian value Corrected value may also be consistent	CF : 1.41 Value : 18.1 About 1.8 higher than Italian value Corrected value may also be consistent
	Comments	➢ The Spanish values (even corrected) are inconsistent with the Italian one. ➢ Others countries' values are quite consistent.					

3 Heating &cooling and heat distribution technologies

3.1 Datasets

The objective of this model improvement is to enhance the description of heating and cooling technologies in the JRC EU-TIMES model.

This task was completed in three phases. In a first phase, a set of technology databases were built in *Excel* in order to collect all relevant information on heating and cooling technologies and arrange information in coherent columns and rows so they can be readily used by the JRC-EU-TIMES model. In the second step, the collected data was transferred to a number of Veda_FE input datasheets. In the third step, the functioning of the new module was tested via scenario analysis.

The following datasets have been developed along this report:

- A technology database which summarises and adapts the techno-economic information contained in the datasets provided by JRC-IET on heating and cooling technologies for four geographic areas, i.e. South Europe (SE), Central Europe (CE), Eastern Europe (EE) and Northern Europe (NE).
- New VEDA_FE 'SubRes' files and other modified input files.

This final report is structured as follows: section 3.2 describes the structure and the approach used to develop the technology database. Section 3.3 discusses how the new heat and cool technology databases for residential and services sectors have been implemented in JRC-EU-TIMES SubRes; finally section 3.4 shows the results of scenarios used to test the new model configuration.

3.2 Technology database

This section presents an overview of the steps which underpin the development of a heating and cooling technology database.

3.2.1 Data source

The database has been developed using the technology catalogue developed by JRC in collaboration with PlanEnergi. This catalogue includes a set of techno-economic information about a number of existing and future options for residential and commercial buildings, which can provide primarily space heating, but also water heating and space cooling.

The data used includes:

1. A report which describes the methodology used for data collection and a description of key (qualitative and quantitative) characteristics of the selected heating and cooling technology options [10]
2. Four technology datasets by geographical areas across Europe. These are based on data collected in each representative area, selected basing on climatic preconditions and the general price levels. The following countries/cities have been chosen for data collection regarding energy performance and installation & operation costs:
    a. Copenhagen / Denmark, to represent North Europe (NE);
    b. Berlin / Germany; to represent Central Europe (CE);
    c. Budapest / Hungary, to represent East Europe (EE);
    d. Lisbon / Portugal, to represent South Europe (SE).
3. A datasheet comparing the most relevant technology attributes between key countries.

In the data collection process, a variety of sources is applied. When available, existing studies and/or comprehensive data sources like databases for the countries or regions under observation are used as a baseline. Where no comprehensive overview or study is identified, data is based on samples from available suppliers of heating/cooling technology in the corresponding countries. A full overview over the specific used data sources can be found under each technology datasheet. In general, the data quality is quite variable, i.e. few high-quality data source on specific technologies, are often accompanied by set of low-quality and/or missing data for others (as specified in [10]).

3.2.2 Database architecture

The technology database has been developed with the aim of summarising information about heating and cooling technologies. The core concept of the database development is to

1. collect and arrange in a single place all relevant information from the technology catalogue, maintaining the detail and the data granularity;
2. organise information into coherent columns and rows in Excel in order to facilitate analysis, validation and transfer of the date into JRC-EU-TIMES.

For this purpose, the database has been developed directly from the regionalised datasheets of the catalogue. From the existing four datasheets, a 'Summary' tab has been added to list into a single table the most relevant techno-economic information of heating &cooling technologies. This sheet includes by row all technologies included in the catalogue, and by column groups of most relevant techno-economic attributes (e.g. reference capacities, efficiencies, CAPEX, etc.)[6]. To facilitate data transfer from the database to the model SubRes, technology data are further processed into two additional sheets, namely 'RSDTechs' and 'COMTechs'. These sheets transfer technology information from the catalogue to a model-based database structure. They are designed to be readily used as input tables for the model SubRes transformation files (i.e. copying these sheets), as they include both quantitative information from the catalogue, and key modelling characteristics, such as input/output commodities, process/commodity names, etc.

Additionally, a comparison spreadsheet (file named Common Inputs to SubRes_final.xlsx) has been created to compare key technical assumptions and is used (sheet 'RTechs' and 'CTechs') to transfer these common assumptions (e.g. efficiencies, etc.) to the model SubRes.

The general flow diagram below (Figure 6) shows how in the four technology databases each of the worksheets interacts with the next.

[6] To ensure consistency between the four case-studies, some harmonisations have been performed.

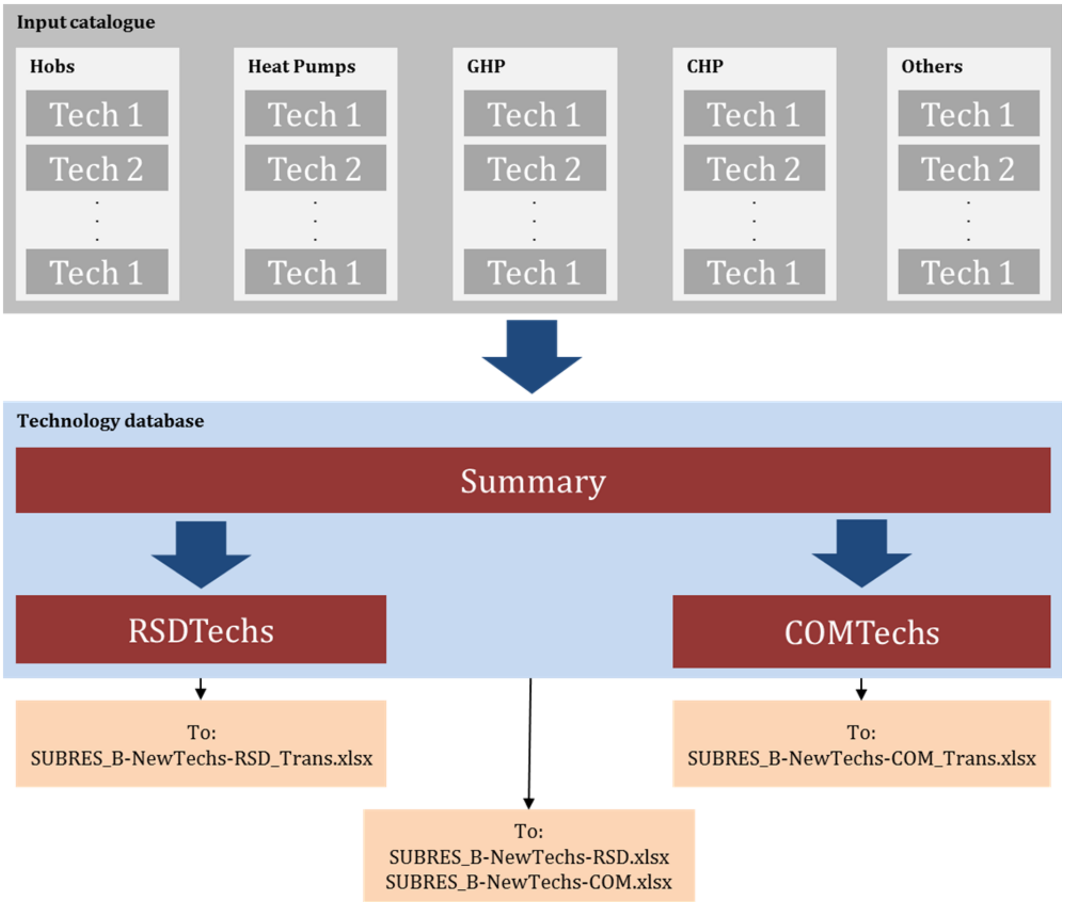


Figure 6: Workflow of Excel technology database

3.2.3 Quality check and manual adjustments

The technology database developed in this activity makes use of the information about the EU heating and cooling technologies as available. However, as stated previously in section 3.1, the gathered information is often incomplete or not reliable; and not fully consistent between countries (i.e. the regional catalogues do not cover exactly the same technologies). To overcome these issues a quality check and review of the key assumptions have been performed for each of the four regional databases.

Where information for some regions was missing or not reliable, data was estimated on the basis of the other technology databases where this information was available. To take into account differences between general price levels, price indexes from Eurostat have been used for selected technologies[7].

When data ranges were provided, average values have been used, if not otherwise stated. Each of these manual changes has been carefully reported in each database, marked in red and commented.

3.3 Model SubRes

During the development of this new technology repository (SubRes) for the JRC-EU-TIMES model, it was decided to review in part the structure of the residential sector. To enhance the representation of heat dynamics in residential buildings it was decided to:

[7] Not applied to most advanced technologies, in which only few producers at European level are available.

- Further disaggregate buildings typologies, subdividing the existing set of detached buildings (DH) into two types: i) detached buildings built before 1970 (DH) (the most energy greedy); and ii) detached buildings built after 1970 (DH-70).
- Change the representation of space heating (SH) devices, i.e. representing capacities as 'number of units' (i.e. '000units') instead of 'appliance size' (i.e. GW); and linking these to the building stock (number of dwellings). This approach avoids possible underestimation of investments from this sector driven by the introduction of retrofit measures in buildings.

As a result, the new SubRes has the following key characteristics:

- Includes all the most up to date space heating and cooling demand technologies (SH technologies), as listed in the JRC catalogue [10], including CHPs.[8]
- Applies to both residential (RSD) and commercial (COM) buildings.
- Introduces new features in the JRC-EU-TIMES model, as the representation by physical unit of heating & cooling capacities in the residential sector.[9]
- Assumes general (average) efficiencies, which are then regionalised by specific correction factors (as in the previous model versions).
- Differentiates the installation and O&M costs for heat/cool technologies between four representative areas, i.e. North, Central, East, South Europe. The assumed country aggregations are listed in Annex.

The following sections provide an overview of the steps which underpinned this model development.

3.3.1 SubRes architecture

The implementation of the new heating and cooling technology SubRes required a complete review of the previously existing SubRes.

To reduce the size of the database during the import in Veda_FE, the updated repository has been broken down in two parts: i.e. a residential technology SubRes; and a commercial technology SubRes (see the following section for a detailed description). Each of these new SubRes files contains both information from the newly developed set of technologies (SH technologies), and all the information about technology options for energy services not covered by the catalogue used in this service, such as water heating-only (WH) appliances, space cooling-only (SC) appliances, cooking (CK) appliances, etc.

3.3.1.1 Residential SubRes

This service has developed a new residential SubRes repository, which contains a set of technology options for the residential end-use sector.

It consists in the following two Excel files:

- **SUBRES_B-NewTechs-RSD.xlsx**, which defines the topology of new technology options (processes); and set key technical characteristics such efficiencies, technical life, etc. The file is composed by several worksheets as detailed in Table 11. All relevant new input information about SH technologies is stored in the 'RTechs' sheet, which has been transferred directly from the technology database. This layout ensures that for any future update from the database, the information can be easily transferred to the SubRes structure.
- **SUBRES_B-NewTechs-RSD_Trans.xlsx**, a 'Transformation' input file, which provides regionalized input information. The file is structured in several sheets as listed in Table 12. Key input information from the SH technology database are

[8] The catalogue includes both: i) space heating-only appliances; and dual appliances, such space/water heating and space heating/cooling. Water heating-only and Space Cooling-only devices are not included, i.e. excluded from this update.

[9] It is worth noting that in the commercial building capacities are represented in 'kW' as previously.

provided by ‘RTechs’ (for heat pumps efficiencies), and by ‘RSDTechsCE’, ‘RSDTechsEE’, ‘RSDTechsNE’, ‘RSDTechsSE’ (regionalised cost data). This data has been transferred directly from the technology database.

Table 11: Structure overview of SUBRES_B-NewTechs-RSD.xlsx

Sheet name	Description
Notes	Previously existing sheet
Generalized Data	Previously existing sheet
RSD_PRandCOM	Previously existing sheet: Updated removing previous SH processes
RTechs	New Sheet: Input sheet from Technology database
RSD_SH-all	New Sheet: Veda input tables for SH technologies
RSD_FuelTechs	New Sheet: Veda input tables for New ‘Fuel Tech’ processes
RSD_DH-WHSC	Previously existing sheet (renamed): Updated removing previous SH processes
RSD_SD-WHSC	Previously existing sheet (renamed): Updated removing previous SH processes
RSD_FL-WHSC	Previously existing sheet (renamed): Updated removing previous SH processes
RSD_Other	Previously existing sheet

Table 12: Structure overview of SUBRES_B-NewTechs-RSD_Trans.xlsx

Sheet name	Description
Fill Data	Previously existing sheet
RES_SpHeat	Previously existing sheet
RES_WatHeat	Previously existing sheet
RES_SpCool	Previously existing sheet
RES_Others	Previously existing sheet
RSD_HeatCAPEX	New Sheet: Regionalized SH CAPEX
RSD_HeatOPEX	New Sheet: Regionalized SH OPEX
RTechs	New Sheet: Input sheet from Technology database
RSDTechsCE	New Sheet: Input sheet from Technology database (CE)
RSDTechsNE	New Sheet: Input sheet from Technology database (NE)
RSDTechsSE	New Sheet: Input sheet from Technology database (SE)
RSDTechsEE	New Sheet: Input sheet from Technology database (EE)
RSD_HP	New Sheet: Veda input tables for SH efficiencies
RSD_SpaceHeat	New Sheet: Veda input tables for SH AFC
RSD_WaterHeat	New Sheet: Veda input tables for SH AFC
RSD_SpCool	New Sheet: Veda input tables for SH AFC
Country aggregations	New Sheet: Country aggregations
INS-UPD Heat	Previously existing sheet: few adaptations to the new structure
INS-UPD WaterHeat	Previously existing sheet: few adaptations to the new structure
INS-UPD SpCool	Previously existing sheet
INS-UPD Others	Previously existing sheet

Figure 7 provides an overview of the assumed overnight costs by region. Given the high number of technologies, the figure refers to DH houses and a specific reference year (2011) only. The same level of details might be shown also for other building typologies and years.

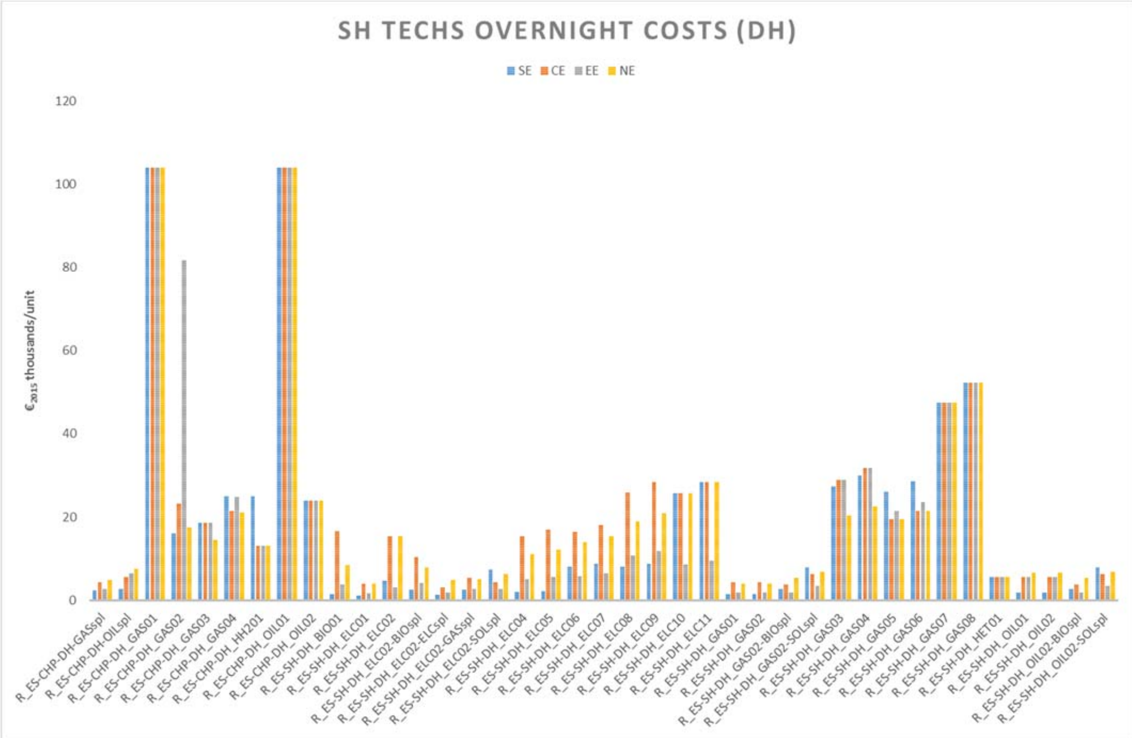


Figure 7: Assumed overnight costs for SH technologies by region (extract for DH buildings only)

3.3.1.2 Commercial SubRes

The commercial SubRes file has been structured in a similar way than the residential. It contains all technology options for the commercial end-use sectors in the following two Excel files:

- **SUBRES_B-NewTechs-COM.xlsx**, which defines the topology of new technology options (processes); and set key technical characteristics. The file includes several sheets as described in Table 13. The new SH input information is stored in the 'CTechs' sheet, which has been transferred directly from the technology database.
- **SUBRES_B-NewTechs-COM_Trans.xlsx**, the 'Transformation' input file, which provides regionalized input information. The file includes several sheets as described in

- Table 14. Key input information about SH technologies is stored in the 'CTechs', 'COMTechsCE', 'COMTechsEE', 'COMTechsNE', 'COMTechsSE' sheets. As previously, the data has been transferred directly from the technology database.

Table 13: Structure overview of SUBRES_B-NewTechs-COM.xlsx

Sheet name	Description
Notes	Previously existing sheet
Generalized Data	Previously existing sheet
COM_PRandCOM	Previously existing sheet: Updated removing previous SH processes
CTechs	New Sheet: Input sheet from Technology database
COM_SH-all	New Sheet: Veda input tables for SH technologies
COM_FuelTechs	New Sheet: Veda input tables for New 'Fuel Tech' processes
COM_HO	Previously existing sheet (renamed): Updated removing previous SH processes
COM_HR	Previously existing sheet (renamed): Updated removing previous SH processes
COM_SR	Previously existing sheet (renamed): Updated removing previous SH processes
COM_SL	Previously existing sheet (renamed): Updated removing previous SH processes
COM_SS	Previously existing sheet (renamed): Updated removing previous SH processes
COM_OF	Previously existing sheet (renamed): Updated removing previous SH processes
COM_Other	Previously existing sheet

Table 14: Structure overview of SUBRES_B-NewTechs-COM_Trans.xlsx

Sheet name	Description
Fill Data	Previously existing sheet
COM_HeatCAPEX	New Sheet: Regionalized SH CAPEX
COM_HeatOPEX	New Sheet: Regionalized SH OPEX
CTechs	New Sheet: Input sheet from Technology database
COMTechsCE	New Sheet: Input sheet from Technology database (CE)
COMTechsNE	New Sheet: Input sheet from Technology database (NE)
COMTechsSE	New Sheet: Input sheet from Technology database (SE)
COMTechsEE	New Sheet: Input sheet from Technology database (EE)
COM_HP	New Sheet: Veda input tables for SH efficiencies
Country aggregations	New Sheet: Country aggregations
COM_Share	Previously existing sheet
COM_All	Previously existing sheet
INS-UPD Heat	Previously existing sheet: few adaptations to the new structure
INS-UPD WaterHeat	Previously existing sheet: few adaptations to the new structure
INS-UPD SpCool	Previously existing sheet
INS-UPD Others	Previously existing sheet

3.3.2 Other model changes

The implementation of the new Residential and Commercial SubRes required a review of the following model files:

- **SysSetting**, where new commodities were added (RSDBGS and COMBGS), and existing commodities modified (added Ctype 'ELC' in RSDELC);
- **Scen_UC_RSD-COM**, in which the regionalised COP definitions for heat pumps (sheet 'COP_HP ') were moved, and some UC where added and/or adapted to the new structure.

3.4 Model tests and preliminary results

Once the activities described in sections 3.2 and 3.3 were finalised, the functioning of the new model structure of heating and cooling technology repository was tested by a series of JRC-EU-TIMES model runs for the years 2010 to 2050. The runs were performed using a preliminary version of the model as used for the Heat Roadmap Europe project [1].

For this study, the model was run with the following policy scenarios:

1. **Baseline:** a baseline scenario, consistent with the medium-term goals of the European Union;

2. **LowCarbon:** a long-term decarbonisation scenario that, in addition to the assumptions for 2020 and 2030 as in the baseline scenario, includes an overall emission reduction target of 80% below 1990 levels in 2050.

This selection of scenarios was made to test the model and to assess if mitigation targets influence choices on end-use heating and cooling technologies. However it is worth noting that the following results have only illustrative purposes to verify the correct functioning of the model latest updates, logical connections and identify and resolve issues.

3.4.1 Scenario results

This section presents a range of energy system configurations for EU-28+ (31 countries) countries. The results focus mainly on the residential and commercial sectors, while the implications for other sectors have not been fully explored. The full set of results is provided in the form of *VD* files which can be easily accessed and reviewed via Veda-BE software.

3.4.1.1 Key emissions dynamics

GHG emissions trajectories are mostly driven by the scenario assumptions. To check the correct functioning and responsiveness of the tool to these assumptions Figure 8 presents CO_2 emissions pathways for the whole energy system. A detailed split between energy sectors is provided. All sectors show steep decreases in emissions among the analysed horizon, which in some cases become negative (Supply and Power generation in the LowCarbon scenario).

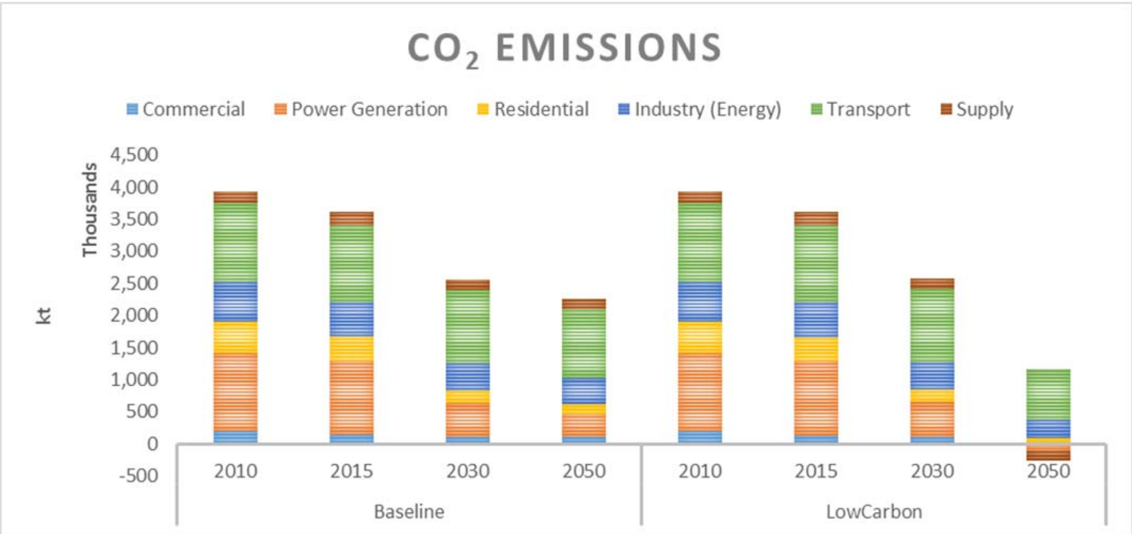


Figure 8: CO_2 emissions across the JRC-EU-TIMES regions (Mt)

A more detailed representation of emission trends in the building sectors (RSD and COM) is provided in Figure 9. The results show the level of responsiveness of the EU-28+ countries to the different levels of emissions bounds.

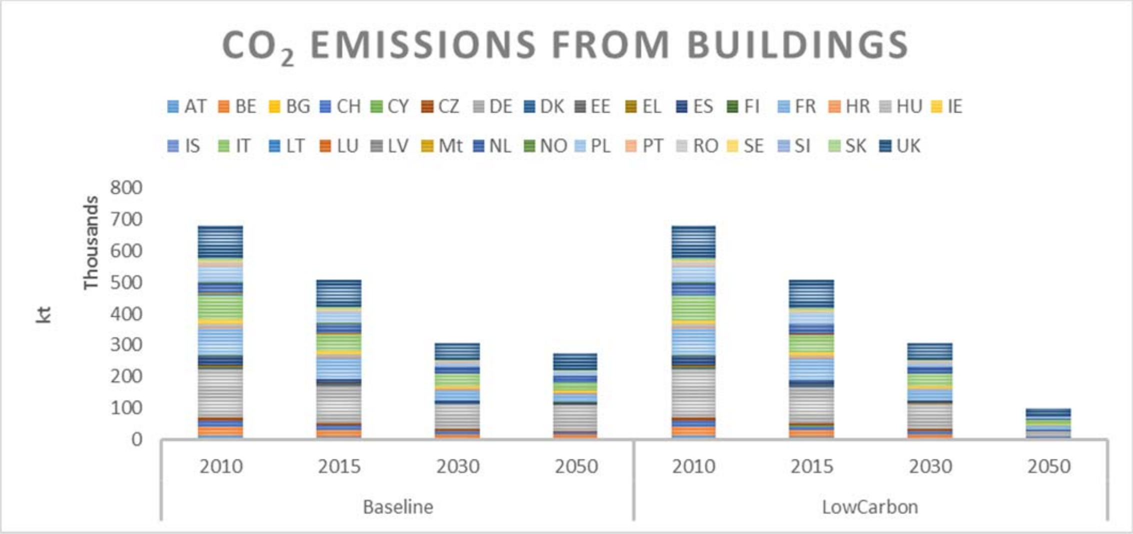


Figure 9:CO_2 emissions in the building sectors by region (Mt)

3.4.1.2 Key buildings energy dynamics

The following set of figures provides an overview of key energy dynamics in the residential buildings across the EU. The results demonstrate how the model, using the new Heating & Cooling database, is able to respond to policy signals (modelled as scenario assumptions).

Key findings are:

- The increased role of solar thermal in low carbon scenarios by 2050.
- The reduced role of gas by 2050 in all scenarios (transition fuel).
- The increased role of electricity (i.e. heat pumps) by 2050, which drives to increased efficiency.
- The reduced role of biomass by the long-term horizon.

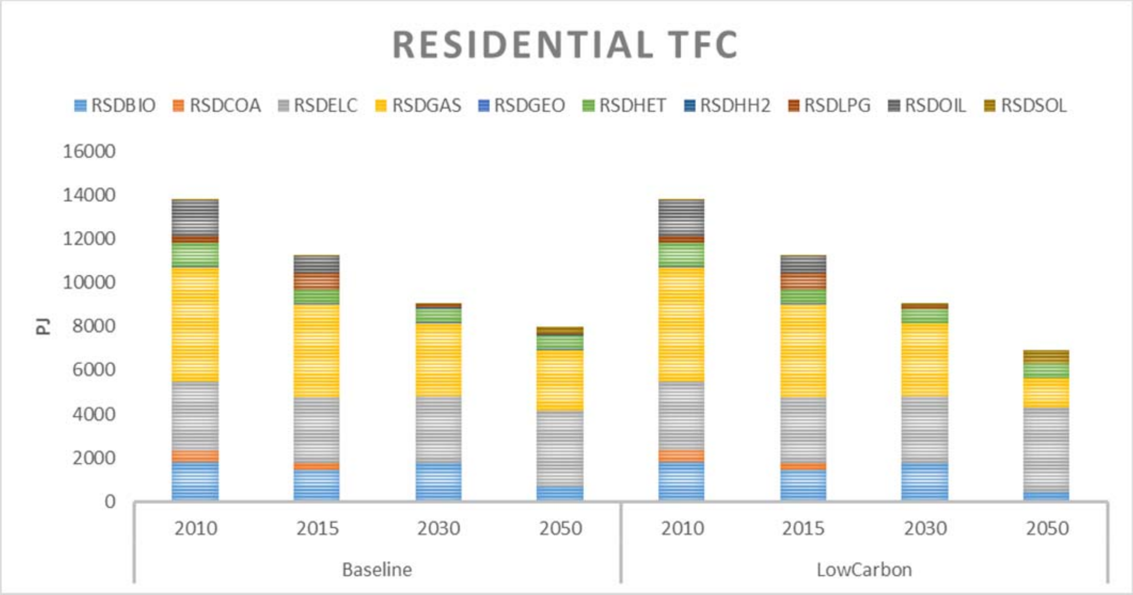


Figure 10: RSD TFC by fuel (PJ)

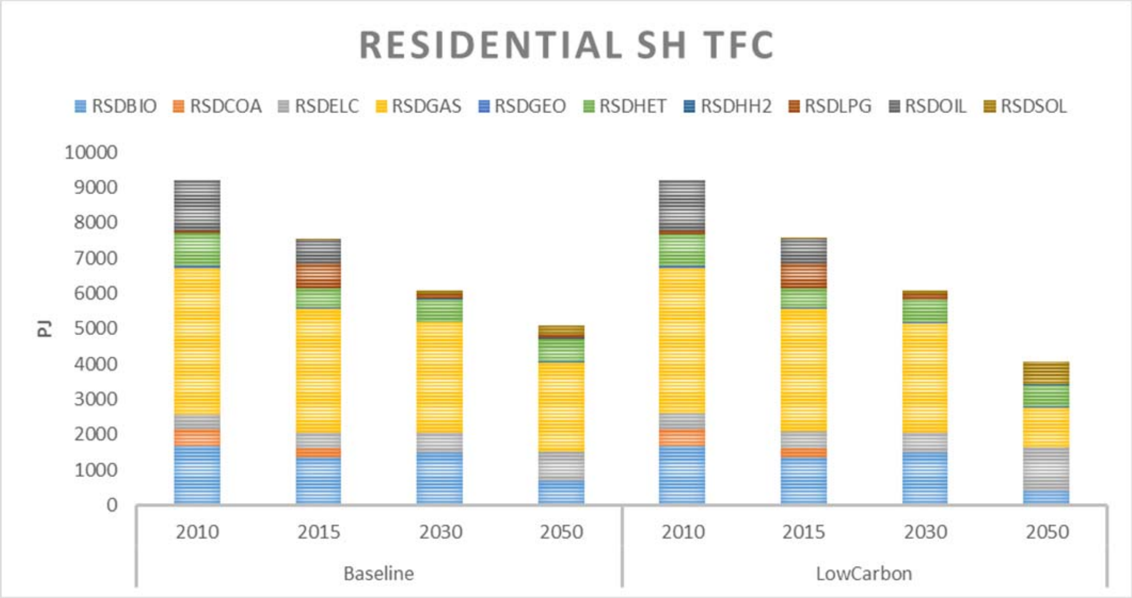


Figure 11: RSD TFC for Space Heating devices (SH) by fuel (PJ)

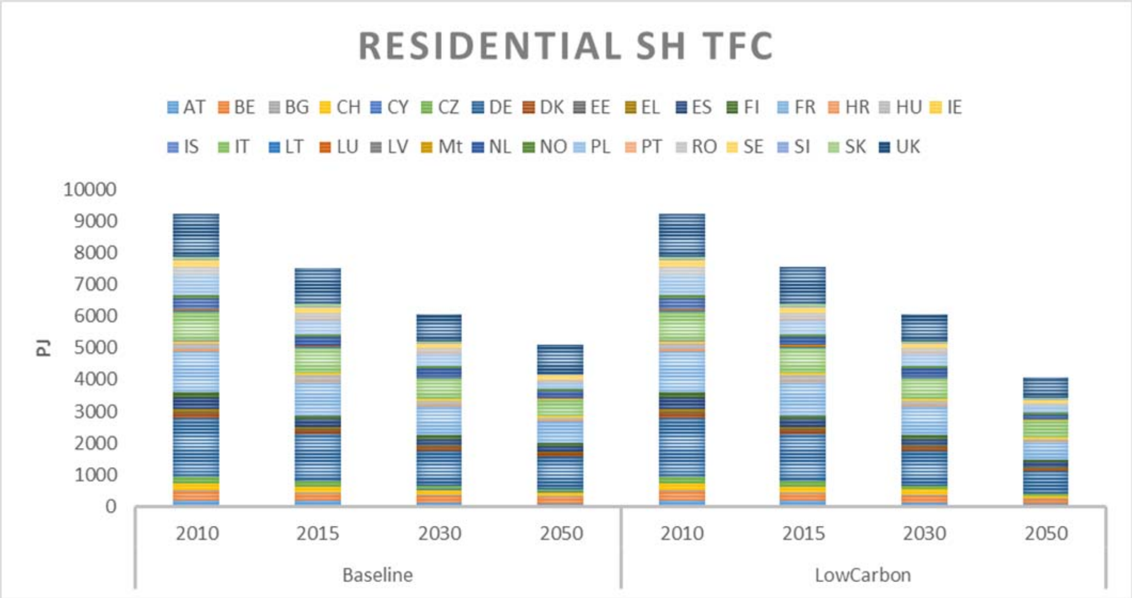


Figure 12: RSD TFC for Space Heating devices (SH) by country (PJ)

Similarly, the following set of *results provides an overview of commercial sector dynamics. Similar conclusion may be drawn from the results.*

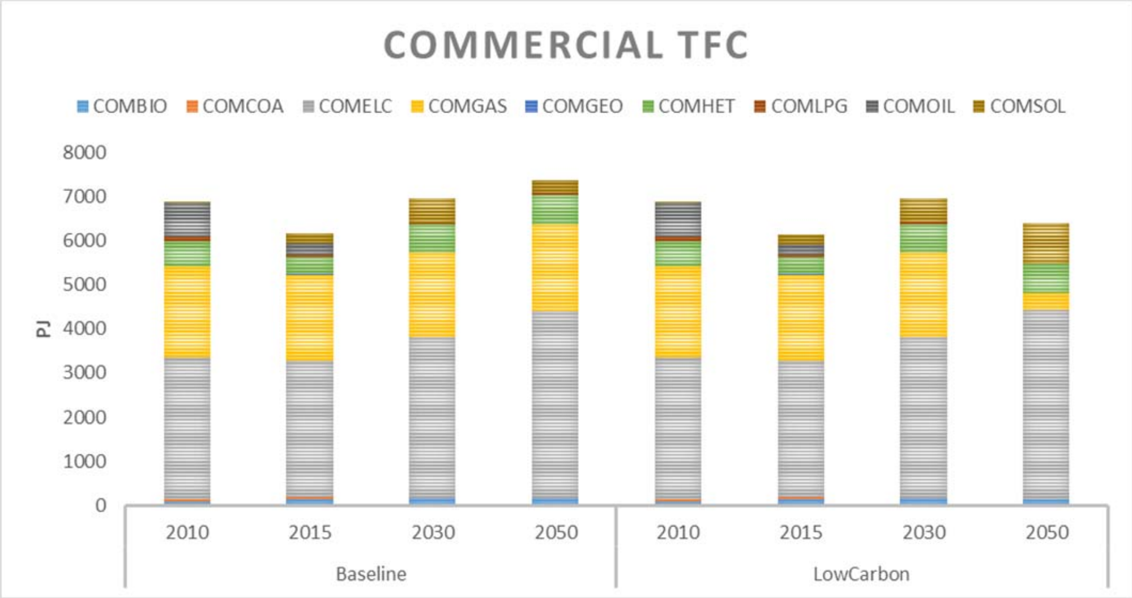


Figure 13: COM TFC by fuel (PJ)

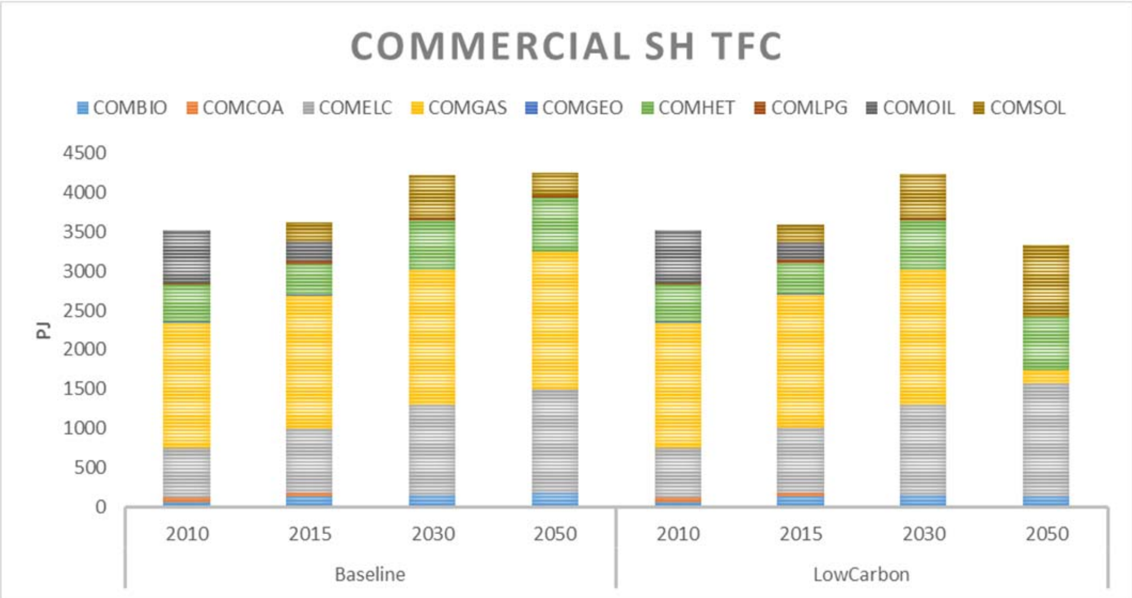


Figure 14: COM TFC for Space Heating devices (SH) by fuel (PJ)

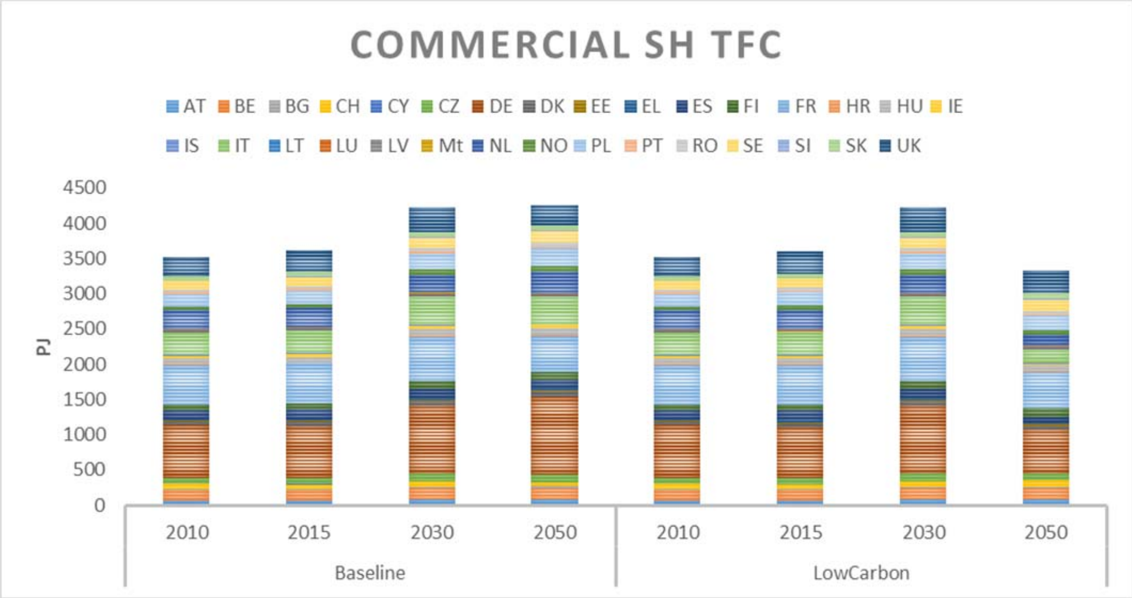


Figure 15: COM TFC for Space Heating devices (SH) by country (PJ)

3.4.2 Functioning of new features

The development of this database has been accompanied by the introduction of a number of new features, such the implementation of supplementary devices, which are required to complement the main heating system for some specific devices (e.g. air-to-air heat pumps). To control the correct installation of these devices a capacity constraint was developed. Figure 16 provides an example (for CHPs in DH) of the correct functioning of this setup. The stock of the supplementary technology ('*spl*' suffix, shown in blue) is, in all time periods and scenarios, exactly the same as the sum of the stock of the primary technologies (shown in orange).

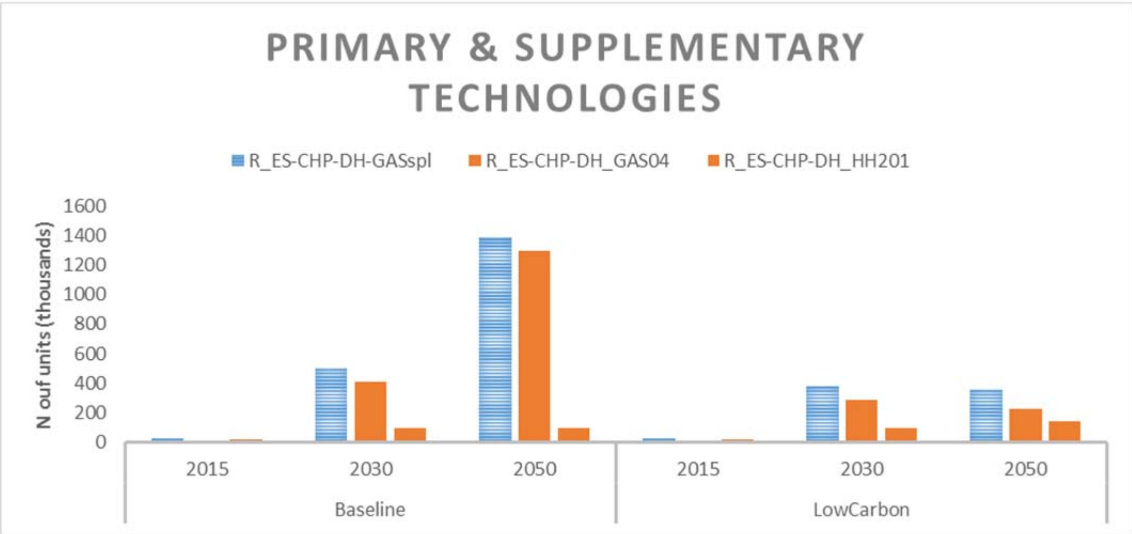


Figure 16: Example of functioning of the capacity constraint on supplementary heating devices (000units)

3.4.2.1 High-level comparison with previous model

This section compares the modelling results between the 'new' setup (the one with the updated Heating / Cooling SubRes) and the 'old' (without the update). The following figures compare for both RSD and COM the final energy consumption for space heat technologies.

The following key conclusions may be drawn:

- The new technology repository foresees a more limited role of gas compared to previous. Gas reduces in low carbon scenarios.
- The new model setup confirms that coal and oil will reduce to almost 0 in the next decade.
- Solar thermal technologies are expected to have a bigger role with the updated technology dataset.
- Biomass is expected to have a smaller role in the COM sectors.
- Efficiency gains in the commercial sector are expected to be lower.

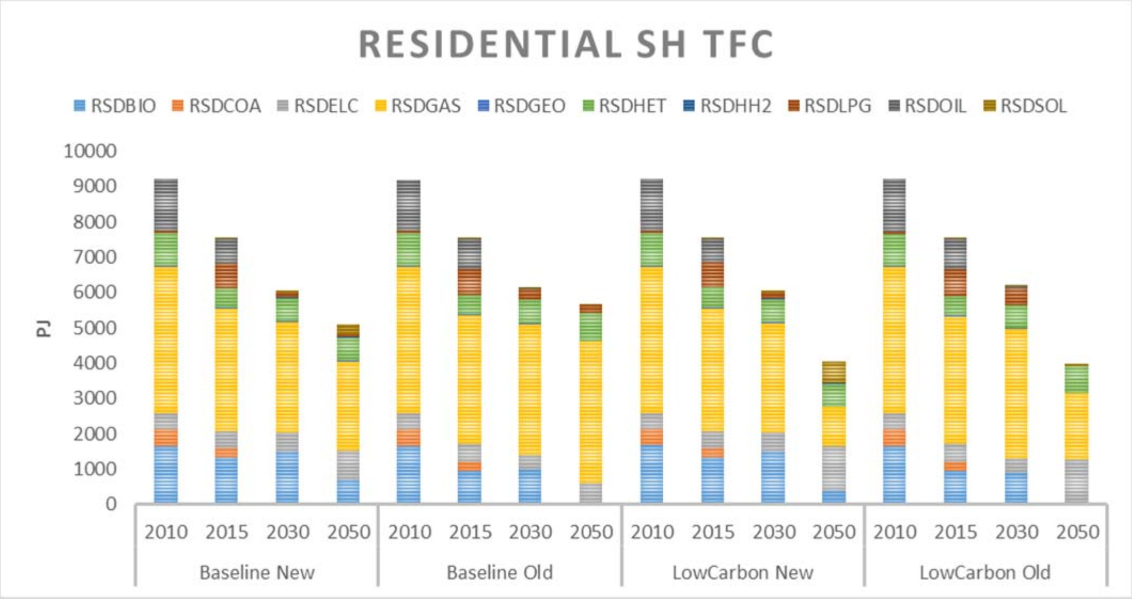


Figure 17: RSD TFC for Space Heating devices between Old and New setup (PJ)

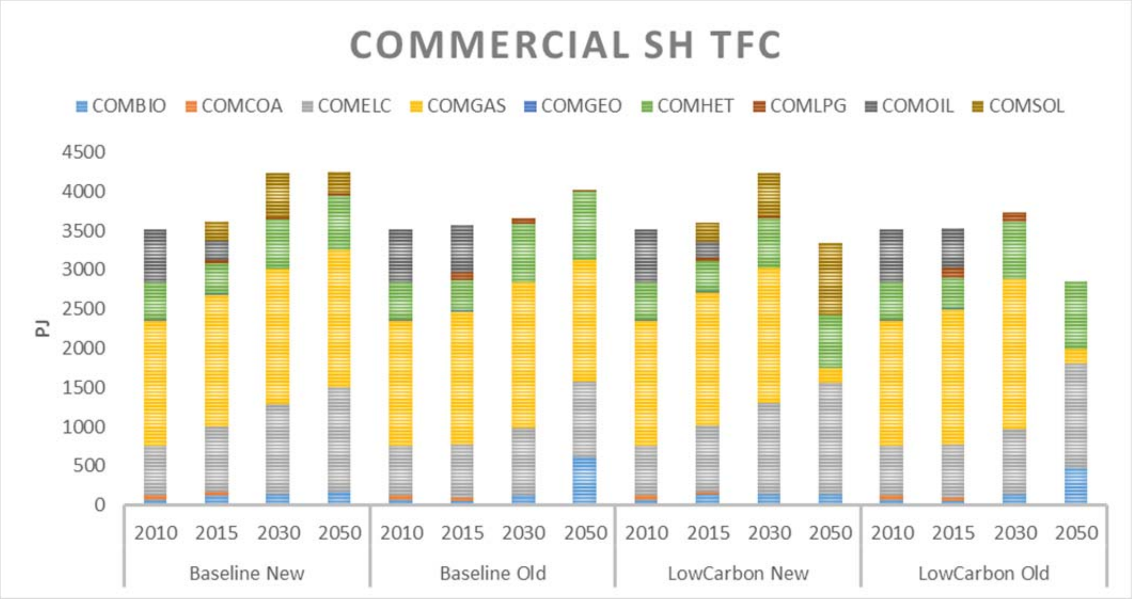


Figure 18: COM TFC for Space Heating devices between Old and New setup (PJ)

4 Conclusions

4.1 Buildings

The following conclusion can be gained:

- The new module provides a robust and explicit representation of the existing residential building stock, which are transparently modelled by typology and construction period.
- The new module includes a broad range of retrofit measures (7). Savings are evaluated for all possible combinations of measures, building typologies and vintages.
- Costs of refurbishment measures are estimate at country level (37 countries) and include four components: material, labour, business profits and other fees.
- Refurbishment cost curves for the non-residential sector have been estimated, on the basis of the findings from the residential sector, with country level detail.
- All the assumptions and referenced data are transparently linked to model input files. This will leave room for future improvements.
- Preliminary results show the key strength of the new module, which can produce country specific and technology explicit analysis of passive efficiency measures across Europe.

Further improvement could be achieved through data surveys on the following aspects:

- Energy consumption by service type;
- Building stock by service type;
- Technology used in the service sector by type and building.

4.2 Technologies for heating and cooling

The following conclusion on the new repository can be gained:

- The heating (and cooling) technology repositories for the residential and commercial sectors are now updated on the latest techno-economic data available at the JRC.
- Investment and O&M costs of heating technologies are now differentiated between four geographic and economic areas.
- As in the previous model versions, SH technology efficiencies are defined differently by country, depending of current technological advancement and climate conditions.
- The capacity unit of new SH technologies is expressed in '000units' (thousands of units), and is linked to the number of dwellings. This ensures a correct estimate of the sectoral investments on heating technologies also under deep retrofit scenarios.
- Preliminary results showed the key strength of the new model, which can produce robust country specific and technology explicit analysis for the EU-28+ countries.

It is nonetheless possible to identify the following areas for further improvement:

- Implement UCs to control supplementary capacities in the COM sector to improve realism on technology dynamics.
- Check the setup of retrofit measures in the RSD sector, where application bounds are applied to base year stock, but not adapted to retirement profiles across the horizon.
- Review the implementation of retrofit measures in the COM sector, which under the current setup are not working.

- Introduce geothermal-only options in the technology database, which are currently missing (even its impact is very limited).
- UCs in the RDS and COM should be reviewed as they still generate few small dummies (even reduced compared previous model setup).
- Review the assumptions behind the trade matrixes, as some external links may generate issues.
- Analyse and check the errors encountered during the complete re-importation of all the model files.

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List of abbreviations and definitions

000units	Thousands of units
AC	Air Conditioning
BY	Base Year
CHP	Combined Heat and Power
CO2	Carbon Dioxide
COM	Commercial sector
DET	Detached house
DH	Detached Houses
DR	Discount Rate
EU	European Union
EU	European Union
EU-28+	EU 28 Member States plus Switzerland, Norway and Iceland
FC	Fuel Cell
FL	Flats
FLT	Flat
GHG	GreenHouse Gas
H2	Hydrogen
JET	JRC-EU-TIMES model
JET	JRC-EU-TIMES model
JRC-IDEES	JRC Integrated Database on the European Energy Sector
JRC-IET	Joint Research Centre - Institute for Energy and Transport
JRC-IET	Joint Research Centre - Institute for Energy and Transport
LPG	Liquefied Petroleum Gas
MS	Member State
MS	Member State
O&M	Operation and Maintenance
RES	Reference Energy System

RES	Reference Energy System
RSD	Residential sector
SC	Space Cooling
SD	Semi-Detached houses
SDE	Semidetached house
SH	Space Heating
SH	Space Heat
SRV	Services sector
TFC	Total Final Energy Consumption
TIMES	The Integrated Markal-Efom System
UC	User Constraint
Veda_BE	Veda Back-End (software)
Veda_FE	Veda Front-End (software)
WH	Water Heat

List of figures

List of tables

Annexes

Annex 1: List of regions in the JRC-EU-TIMES model

AT	Austria
BE	Belgium
BG	Bulgaria
CH	Switzerland
CY	Cyprus
CZ	Czech Republic
DE	Germany
DK	Denmark
EE	Estonia
EL	Greece
ES	Spain
FI	Finland
FR	France
HR	Croatia
HU	Hungary
IE	Ireland
IS	Iceland
IT	Italy
LT	Lithuania
LU	Luxembourg
LV	Latvia
MT	Malta
NL	Netherlands
NO	Norway
PL	Poland
PT	Portugal
RO	Romania

SE	Sweden
SI	Slovenia
SK	Slovakia
UK	United Kingdom

Annex 2: List of geographical aggregations of countries in JRC-EU-TIMES

Country Code	Country		Area Code	Area
AL	Albania	<->	SE	South EU
AT	Austria	<->	CE	Central EU
BA	Bosnia	<->	SE	South EU
BE	Belgium	<->	CE	Central EU
BG	Bulgaria	<->	EE	East EU
CH	Switzerland	<->	CE	Central EU
CY	Cyprus	<->	SE	South EU
CZ	Czech Rep.	<->	EE	East EU
DE	Germany	<->	CE	Central EU
DK	Denmark	<->	NE	North EU
EE	Estonia	<->	EE	East EU
EL	Greece	<->	SE	South EU
ES	Spain	<->	SE	South EU
FI	Finland	<->	NE	North EU
FR	France	<->	CE	Central EU
HR	Croatia	<->	SE	South EU
HU	Hungary	<->	EE	East EU
IE	Ireland	<->	NE	North EU
IS	Iceland	<->	NE	North EU
IT	Italy	<->	SE	South EU

KS	Kosovo	<->	SE	South EU
LT	Lithuania	<->	EE	East EU
LU	Luxembourg	<->	CE	Central EU
LV	Latvia	<->	EE	East EU
ME	Montenegro	<->	SE	South EU
MK	Macedonia	<->	SE	South EU
MT	Malta	<->	SE	South EU
NL	Netherlands	<->	NE	North EU
NO	Norway	<->	NE	North EU
PL	Poland	<->	EE	East EU
PT	Portugal	<->	SE	South EU
RO	Romania	<->	EE	East EU
RS	Serbia	<->	SE	South EU
SE	Sweden	<->	NE	North EU
SI	Slovenia	<->	CE	Central EU
SK	Slovakia	<->	EE	East EU
UK	United Kingdom	<->	CE	Central EU

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