COMBI

Calculating and Operationalising
the Multiple Benefits of
Energy Efficiency in Europe

Overview of COMBI scenarios and how they were constructed

D2.2 Annex

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1 Residential and tertiary sectors (buildings)

1.1 Decomposition method

The construction of scenarios for the buildings sector in COMBI is based on a decomposition approach. The resulting energy consumption is the product of changes in *activity levels*, *structural changes* and *energy efficiency improvements*, the latter also known as 'COMBI actions' (see the D2.2 report for a qualitative description, and the Excel file in annex for a detailed quantitative description).

1.2 Activity levels

The most relevant activity levels are *population* for residential buildings, and *value added* (VA) for non-residential buildings.

It is assumed that the number of private households equals the number of occupied dwellings. Strictly speaking, this is not entirely correct as some dwellings may not be occupied all year round. A dwelling is not synonym to a (residential) building, as certain buildings may contain more than one dwelling (e.g. a block of flats).

The number of households are obtained by dividing the population by the average household size (members per household). The population statistics for the base year (2015) and for each EU member state were obtained from EUROSTAT. Projections for both population and average household size are based on the PRIMES REFERENCE scenario. Because the actual 2015 population figures were not yet available to PRIMES, COMBI applied the given PRIMES' annual growth rates to the actual (EUROSTAT) base year population number. This explains the difference between COMBI and PRIMES concerning projections of the number of households, as they do not use the same base year values (actual ones in COMBI, estimated ones in PRIMES).

Table 1: COMBI projections of the number of occupied dwellings, private households (EU28, 2015-2030)

	[1000]	[1000]	[1000]
	2015	2020	2030
Austria	3 816	3 974	4 400
Belgium	4 699	4 835	5 172
Bulgaria	2 940	2 887	2 687
Croatia	1 494	1 466	1 446
Cyprus	290	303	321
Czech Rep.	4 644	4 735	4 800
Denmark	2 373	2 448	2 619
Estonia	572	575	576
Finland	2 623	2 671	2 737
France	28 920	29 527	31 960
Germany	40 258	41 030	41 452
Greece	4 376	4 307	4 138

Hungary	4 152	4 176	4 206
Ireland	1 712	1 803	1 970
Italy	25 789	25 941	26 570
Latvia	833	817	752
Lithuania	1 332	1 306	1 157
Luxembourg	229	251	311
Malta	151	162	186
Netherlands	7 622	7 894	8 594
Poland	14 113	14 604	14 914
Portugal	4 083	4 092	4 080
Romania	7 470	7 540	7 272
Slovakia	1 847	1 924	1 946
Slovenia	883	897	898
Spain	18 376	18 514	19 111
Sweden	5 100	5 329	5 817
United Kingdom	28 219	29 019	30 886
EU28	**218 913**	**223 027**	**230 980**

The COMBI model interpolates the projections for the in-between years. The interpolation is non-linear (polynomial), as linear interpolations occasionally yielded unrealistic results during the detailed stock analysis of the European building stock (see next chapter). The parameters of the polynomial regression are given in the attached Excel file.

Household projections are the same for both the COMBI reference and energy efficiency scenarios.

Table 2: Projections of the number of required tertiary buildings (EU28, 2015-2030)

	[1000]	[1000]
	2015	**2030**
Austria	43,189	50,619
Belgium	42,492	49,314
Bulgaria	25,031	29,627
Croatia	11,047	12,695
Cyprus	2,888	3,520
Czech Rep.	34,511	41,658
Denmark	47,074	57,383
Estonia	4,554	5,444
Finland	41,752	47,509
France	336,550	390,580
Germany	594,982	657,231
Greece	49,167	53,775

Hungary	34,921	43,410
Ireland	17,259	20,427
Italy	142,690	162,363
Latvia	6,034	7,213
Lithuania	11,822	12,803
Luxembourg	2,147	2,885
Malta	1,728	2,128
Netherlands	102,470	114,316
Poland	145,449	184,379
Portugal	37,415	43,851
Romania	18,146	22,120
Slovakia	14,762	19,647
Slovenia	10,017	11,856
Spain	122,773	149,660
Sweden	61,708	77,463
United Kingdom	266,998	309,862

To recapitulate, although activity levels play a primordial role in determining absolute energy consumption levels, they are less relevant when comparing COMBI reference and energy efficiency scenarios, as COMBI focuses on efficiency improvements and not on activity and/or structural changes (with the exception of 'modal shifts' for the transport sectors).

1.3 Structural changes

Structural changes for dwellings refer to shifts towards more compact buildings (e.g. from detached houses to apartment blocks). For the tertiary sectors structural shifts are related to different value added (VA) growth levels for the different subsectors (education, health, public and private offices, etc.).

Projections regarding population and VA are based on the latest PRIMES reference scenario, and are kept the same in both the COMBI reference and efficiency scenarios.

Although COMBI does make an explicit distinction between single and multifamily dwellings to calculate the technical energy efficiency improvements, it is assumed that the ratio between single and multi-family dwellings stays fixed at the level of the base year for each of the 28 EU member states, thus excluding a structural shift to more compact, and hence more energy efficient multi-family buildings.

COMBI uses the same projections for value added (VA) of the different tertiary subsectors in both the reference and efficiency scenarios. Value added projections are transformed to required number of buildings for the entire tertiary sector, based on literature values for number of employees required per unit of value added (VA), and floor area required per employee.

Another potential structural shift involves a trend towards smaller dwellings or tertiary buildings, in terms of *conditioned* floor area. The average floor area of dwellings and tertiary buildings for the

28 EU member states in 2015 were estimated, using various data sources. As it turned out, reliable statistics on floor area are very hard to obtain, and often contradict each other. For new dwellings and tertiary buildings, i.e. for buildings built after 2015, an average conditioned floor area was assumed, and kept constant throughout the time horizon (2015-2030). It was likewise supposed that the retrofit of existing buildings would neither increase nor decrease the average conditioned floor area.

Table 3: Average conditioned floor area of dwellings

	surviving retrofitted dwellings	new dwellings
	[m²/dwelling]	[m²/dwelling]
Austria	99,1	108,0
Belgium	86,3	106,0
Bulgaria	73,1	84,1
Croatia	81,6	88,4
Cyprus	144,8	178,0
Czech Rep.	77,7	107,5
Denmark	117,6	132,3
Estonia	61,5	117,3
Finland	98,4	87,7
France	91,7	112,8
Germany	91,2	113,4
Greece	85,0	100,1
Hungary	100,0	107,2
Ireland	119,6	87,7
Italy	94,0	77,8
Latvia	62,5	62,5
Lithuania	66,6	119,3
Luxembourg	130,3	104,1
Malta	106,4	106,4
Netherlands	124,4	120,0
Poland	72,8	102,4
Portugal	109,1	102,1
Romania	64,1	77,0
Slovakia	85,5	117,1
Slovenia	81,8	142,6
Spain	91,3	137,1
Sweden	93,1	83,0
United Kingdom	92,3	92,0

As previously mentioned, for tertiary buildings total conditioned floor area per building is based on an assumed average floor are per employee.

Given that the average conditioned floor area values in the COMBI energy efficiency scenario are the same as in the COMBI reference scenario, they do not play a significant role when directly comparing both COMBI scenarios. They do however play a significant role when determining absolute energy consumption levels.

1.4 COMBI actions

The energy efficiency improvements in COMBI point to actions concerning the building shell (insulation of roof, walls, floors and windows, airtightness), building systems (space heating, space cooling and ventilation + domestic hot water), lighting, and cold appliances. For a qualitative description of the COMBI actions we refer to the COMBI D2.2 report.

1.4.1 Stock analysis

The core of the COMBI building scenarios is a stock analysis model. An explicit distinction is made between new and retrofitted buildings.

The shares of new, retrofitted and existing non-retrofitted dwellings in a particular year are very important factors. The number of new dwellings or tertiary buildings not only depends on the number of *required* dwellings or buildings in a particular year, but also on the rate upon which surviving buildings are either being retrofitted or permanently abandoned (or demolished).

Based on assumed demolition and retrofit rates the annual shares of new and retrofitted buildings in the building stock can be determined for each individual year within the COMBI time horizon (2015-2030).

Annual demolition rates for dwellings remain low (around 0.1%) and are kept constant between the reference and efficiency scenario. Annual retrofit rates however reach a level of 2.5% in 2030 in the reference scenario, and of 3,0% in the efficiency scenario.

Table 4: Annual number of tertiary buildings permanently abandoned (or demolished)

	[1000]	[1000]
	2015	**2030**
Austria	0,176	0,401
Belgium	0,283	0,139
Bulgaria	0,050	0,099
Croatia	0,142	0,124
Cyprus	0,037	0,032
Czech Rep.	0,046	0,081
Denmark	0,302	0,485
Estonia	0,003	0,006
Finland	0,031	0,057
France	2,244	1,100
Germany	3,819	6,135

Greece	0,631	0,553
Hungary	0,020	0,057
Ireland	0,111	0,178
Italy	1,830	1,605
Latvia	0,005	0,008
Lithuania	0,009	0,016
Luxembourg	0,014	0,022
Malta	0,004	0,008
Netherlands	0,658	1,057
Poland	0,934	1,500
Portugal	0,080	0,182
Romania	0,010	0,030
Slovakia	0,020	0,035
Slovenia	0,128	0,113
Spain	0,261	0,596
Sweden	0,046	0,084
United Kingdom	1,714	2,753

For tertiary buildings a number of buildings permanently abandoned (and/or demolished) each year is assumed. This number remains constant in between the COMBI reference and efficiency scenarios.

1.4.2 Building shell (retrofitted and new)

In order to model efficiency improvements of the building shell, new and retrofitted buildings are subdivided as follows.

For new buildings a distinction is made between current building standards (until 2020), nearly zero energy buildings or nZEBs (from 2020 onward) and Passive Houses (PHs).

For retrofitted buildings COMBI distinguishes between low (or shallow) retrofit, medium retrofit and deep retrofit.

All these types of buildings have different “useful energy intensities” (UEI), i.e. energy consumption demand per unit of conditioned floor area, where “useful” refers to the energy demand *before* taking into account any “energy losses” caused by heat generation, distribution and emission. These useful energy intensities are given in the Excel file in annex.

The annual shares of these types of new and retrofitted buildings differ in the COMBI reference and efficiency scenarios.

Analysis shows that (both useful and final) energy consumption in the buildings sector in 2030 is very sensitive to assumptions made concerning annual retrofit rates and shares of the different types of new and retrofitted buildings. It should also be noted that the COMBI model allows for different rates and shares per EU member state. There are similarly minor but nonetheless significant differences between assumptions made for the residential and non-residential sectors.

Initially, COMBI intended to use existing EU scenario assumptions, notably the ones employed by PRIMES in their scenarios, but COMBI could not obtain detailed information on those assumptions in time. As an alternative, COMBI tried to make use of the assumptions described in the EU funded ENTRANZE project, but due to major differences in methodology, those could not be retained.

As a result of these setbacks, and aggravated by time and budget constraints, COMBI had to fall back on a set of simplified assumptions.

Very roughly speaking it is assumed that for newly constructed buildings in 2030 the share of nZEBS reaches 30% and of PHs 70% in the reference scenario, switching to 10% and 90% in the efficiency scenario. For retrofitted building the shares attain approximately 10% light retrofit, 50% medium retrofit and 40% deep retrofit in 2030 in the reference scenario, changing to 5% nZEBs and 95% PHs in the efficiency scenario. A full description of the COMBI scenarios is available in a separate Excel file.

1.4.3 Building systems (space heating, ventilation, cooling, lighting)

For building systems, including lighting improvements in energy efficiency are mainly realized through shifts in the technology mix, e.g. for space heating this could be a gradual shift from oil and gas boilers to heat pumps or district heating. With a few exceptions (e.g. LEDs for lighting), it is assumed that the efficiencies of the individual technologies will not change much, if at all (e.g. boilers) in the coming years.

Again COMBI uses a stock analysis model, implying that the assumed annual shares in the scenarios refer to shares in annual new sales of the different technologies and not to annual shares of those technologies in the total stock, although over the years the latter would naturally change as a result of some (inefficient) technologies being sold less and less, and more efficient technologies increasingly being sold more and more.

COMBI distinguishes 11 different types of space heating systems (including systems for the production of domestic hot water), and three types of space cooling and/or ventilation systems. Furthermore, all of these systems can (optionally) be implemented in combination with solar heating.

The COMBI stock model likewise recognizes six different types of lighting systems.

Given this amount of detail and the fact that scenarios not only differ between reference and efficiency scenarios but also between EU member states, it is impossible to describe in detail all the scenario assumptions, and once again we have to refer to the COMBI Excel file in annex. Suffice it to say that as a matter of course the efficiency scenario is characterized by a shift towards more efficient technologies, such as district heating and heat pumps for space heating, geothermal heat pumps for space cooling (in so far as space cooling cannot be avoided in new buildings or eliminated in retrofits), balanced ventilation with heat recovery for ventilation, and LEDs for lighting, To the extent possible, scenario assumptions for building systems, lighting are based on or inspired by scenarios given in various EU ECODESIGN reports. For heating systems in particular, COMBI also made limited use of scenarios constructed earlier by ECOFYS.

1.4.4 Cold appliances

A stock analysis is also applied to cold appliances. Three types of refrigerators and/or freezers are recognized: base case, life cycle cost or LCC (i.e. the most efficient technology with minimum life cycle cost), and best available technology or BAT (i.e. the most efficient appliance without necessarily being cost optimal). Extensive use is made of scenarios provided by the EU ECODESIGN reports. For example, in the residential sector the share of annual new sales for BAT would be 26% by 2030 in the reference scenario, and 67% by 2030 in the efficiency scenario. It is however somewhat unfortunate that the ECODESIGN studies only provide scenario figures for the EU28 as a whole, and not for the 28 individual member states.

2 Transport sectors (passengers and freight)

2.1 Decomposition method

The transportation scenarios in COMBI are based on a decomposition analysis, incorporating changes in *activity levels*, structural or *'modal' shifts*, and *energy efficiency improvements*.

The resulting final energy consumption is the end result of multiplying (or dividing) the following factors: activity levels in passenger-km for passenger transport or in ton-km for freight transport; average occupancy rates (number of passengers per vehicle) or average load factors (tonne freight per vehicle); average annual mileage (in vehicle-kilometres per year); and fuel efficiency (in MJ per vehicle-km).

2.2 Activity levels

The projections for the activity levels are (primarily) taken from the PRIMES reference scenario.

Table 5: projections of total passenger-km (million p-km)

	BASE YEAR	REFERENCE & EFFICIENCY SCENARIO		
	2015	2020	2025	2030
Austria	171 346	173 284	174 920	176 304
Belgium	206 236	209 220	211 282	213 124
Bulgaria	63 220	63 886	64 645	65 281
Croatia	42 671	43 305	43 734	44 172
Cyprus	17 464	18 104	18 517	18 830
Czech Rep.	124 207	126 623	128 634	130 649
Denmark	100 361	101 903	102 954	103 974
Estonia	13 970	14 119	14 227	14 347
Finland	82 169	82 708	83 254	83 842
France	1 124 777	1 140 045	1 149 012	1 158 512
Germany	1 181 691	1 185 628	1 192 131	1 198 344
Greece	162 970	164 590	165 582	166 890
Hungary	125 223	127 867	129 965	131 771

Ireland	83 037	85 034	86 655	87 905
Italy	956 587	966 717	972 818	979 875
Latvia	21 121	21 439	21 708	21 959
Lithuania	35 156	35 622	36 009	36 184
Luxembourg	43 470	44 390	45 298	46 223
Malta	6 335	6 544	6 642	6 707
Netherlands	229 294	231 463	233 300	235 036
Poland	378 944	389 013	396 179	402 926
Portugal	139 696	140 648	142 868	144 615
Romania	116 529	118 810	121 466	123 817
Slovakia	49 583	51 311	52 664	53 889
Slovenia	37 649	38 247	38 654	38 997
Spain	692 280	703 461	715 278	726 030
Sweden	152 017	153 285	154 920	156 676
United Kingdom	962 449	974 404	982 599	992 302

Table 6: projections of total ton-km (million t-km) for freight transport

	BASE YEAR	REFERENCE & EFFICIENCY SCENARIO		
	2015	**2020**	**2025**	**2030**
Austria	60 250	64 290	68 680	73 121
Belgium	63 124	72 251	80 073	87 760
Bulgaria	32 365	36 880	40 542	43 185
Croatia	16 020	18 216	19 704	21 283
Cyprus	1 589	1 686	1 810	1 914
Czech Rep.	75 233	82 167	88 748	95 659
Denmark	26 593	30 498	32 886	34 736
Estonia	13 714	15 857	17 584	19 274
Finland	44 536	47 572	50 567	54 165
France	320 785	365 360	403 972	448 404
Germany	537 428	591 616	628 340	664 964
Greece	40 454	42 579	44 113	45 696
Hungary	51 258	55 839	61 388	66 792
Ireland	23 730	27 515	31 427	35 265
Italy	252 323	269 804	285 100	300 896
Latvia	32 593	35 371	40 150	43 981
Lithuania	37 341	43 989	47 858	49 144
Luxembourg	13 706	16 716	18 297	19 929
Malta	365	408	439	480
Netherlands	142 687	155 420	164 723	171 786

Poland	320 364	362 844	411 784	456 346
Portugal	53 479	57 840	62 822	66 397
Romania	66 371	79 515	90 351	99 381
Slovakia	41 463	47 098	52 395	57 965
Slovenia	22 905	29 083	34 180	38 292
Spain	236 003	255 256	273 725	291 193
Sweden	67 744	75 813	81 901	87 766
United Kingdom	244 692	255 207	266 527	278 447

Although activity levels play a crucial role in determining absolute energy consumption levels, they do not differ between the COMBI reference and efficiency scenarios.

2.3 Structural changes (modal shifts)

Structural shifts in transport scenarios refer to shifts in transport modes or 'modal shifts' for short.

COMBI distinguishes the following transport modes for passenger transport: two separate slow modes (walking, cycling), private road transport comprising two kinds of motorized two-wheelers (moped, motorcycle) on the one hand and passenger car on the other hand, public road transport including bus or coach, two separate modes of rail transport (light rail and passenger train) and finally domestic and international aviation. Due to data problems vans for passenger transport were not considered separately but taken together with light duty vehicles in the freight transport module. Also, although light rail and aviation (passenger) and navigation (freight) are taken into account for determining the modal shifts, due to time and budget constraints their energy savings potentials are not explicitly modelled in COMBI.

For freight transport the transportation modes are light duty truck (LDT), heavy duty truck (HDT), freight train and inland waterways (or navigation).

Modal shifts are obtained by assuming different growth levels for the different transport modes. Although modal shifts are considered behavioural rather than technological changes, thus strictly speaking falling outside the scope of the COMBI project, different scenarios excluding and including modal shifts are provided. Indeed, the COMBI transportation models are construed in such a way that one can simulate energy efficiency improvements (efficiency scenarios) while either keeping the share of transport modes at the same level as in the reference scenario, or alternatively combining technological improvements with a significant modal shift. Furthermore, the COMBI models also allow simulating the effects of a modal shift only. The latter implies that energy efficiency levels do not change, or in other words that the technological levels (basically fuel efficiency of vehicles) are kept the same as in the reference scenario. Modal shifts had to be included in COMBI, because otherwise EU energy consumption reduction targets could not be reached by 2030.

The different growth levels for the various transport modes are based on existing EU scenarios, mainly the PRIMES scenarios. For ease of reference, the different growth levels are translated to shares of a particular transport mode in total passenger-km or total freight-km.

Table 7: shares of transport modes in 2030 in the REFERENCE scenario for passenger transport (%)

	WALKING	CYCLING	MOPED	MOTOR	CAR	BUS	LIGHT RAIL	RAIL	AVIATION
Austria	2,1%	0,8%	0,3%	0,8%	69,7%	13,0%	2,6%	6,7%	4,1%
Belgium	2,1%	1,8%	0,2%	0,9%	70,8%	15,9%	0,5%	5,1%	2,6%
Bulgaria	3,8%	1,1%	0,1%	0,5%	73,8%	16,3%	1,3%	3,0%	0,0%
Croatia	4,7%	1,7%	1,4%	2,2%	74,4%	6,4%	1,2%	3,7%	4,1%
Cyprus	1,8%	0,8%	0,9%	1,0%	62,3%	10,8%	0,0%	0,0%	22,3%
Czech Rep.	3,3%	1,3%	0,9%	1,7%	59,6%	17,0%	7,0%	5,1%	4,1%
Denmark	2,4%	5,3%	0,3%	0,6%	67,8%	9,8%	0,2%	6,5%	7,0%
Estonia	3,3%	1,9%	0,0%	0,3%	78,9%	10,9%	0,7%	2,3%	1,7%
Finland	2,5%	1,7%	0,4%	0,8%	65,6%	12,4%	0,7%	5,2%	10,7%
France	2,6%	0,6%	0,5%	1,5%	76,7%	6,0%	1,3%	8,2%	2,7%
Germany	2,8%	2,9%	0,6%	0,8%	74,5%	6,8%	1,7%	8,5%	1,5%
Greece	2,5%	0,6%	0,5%	8,5%	41,3%	37,7%	1,0%	0,8%	7,0%
Hungary	3,2%	1,3%	1,3%	0,6%	61,8%	21,2%	2,0%	6,3%	2,3%
Ireland	2,2%	1,2%	0,1%	0,9%	68,7%	16,2%	0,2%	1,9%	8,6%
Italy	2,8%	1,2%	2,2%	4,1%	74,9%	7,6%	0,8%	5,6%	0,8%
Latvia	3,4%	2,0%	0,1%	0,1%	61,1%	18,8%	0,7%	4,4%	9,3%
Lithuania	3,0%	1,9%	0,2%	0,3%	49,1%	37,9%	0,0%	0,8%	6,8%
Luxembourg	0,5%	0,0%	0,3%	0,7%	73,1%	23,8%	0,0%	0,8%	0,8%
Malta	2,5%	1,1%	0,0%	1,1%	40,2%	10,5%	0,0%	0,0%	44,6%
Netherlands	3,1%	6,7%	0,4%	0,9%	66,2%	9,5%	0,7%	7,6%	5,0%
Poland	3,6%	2,0%	0,3%	0,7%	79,1%	7,2%	1,3%	5,2%	0,7%
Portugal	2,8%	0,3%	0,7%	0,9%	72,4%	11,9%	0,9%	3,4%	6,7%
Romania	5,2%	2,7%	0,1%	0,2%	61,4%	12,0%	5,8%	4,4%	8,2%
Slovakia	4,4%	1,8%	0,1%	0,4%	66,7%	20,2%	0,6%	4,9%	0,9%
Slovenia	2,1%	0,9%	0,4%	0,5%	84,7%	8,1%	0,0%	2,5%	0,8%
Spain	2,47%	0,2%	1,2%	3,1%	72,2%	13,0%	1,2%	4,2%	2,4%
Sweden	2,53%	1,8%	0,2%	0,6%	69,1%	8,3%	1,7%	8,3%	7,6%
United Kingdom	1,85%	0,4%	0,0%	0,9%	67,8%	18,9%	1,1%	6,2%	2,7%

Table 8: shares of transport modes in 2030 in the EFFICIENCY scenario for passenger transport (%)

	WALKING	CYCLING	MOPED	MOTOR	CAR	BUS	LIGHT RAIL	RAIL	AVIATION
Austria	2,3%	0,8%	0,3%	0,7%	65,7%	14,0%	3,0%	7,6%	5,6%
Belgium	2,2%	1,8%	0,2%	0,9%	68,5%	17,8%	0,7%	6,6%	1,4%
Bulgaria	4,3%	1,0%	0,1%	0,4%	63,9%	17,5%	1,7%	3,9%	7,1%

Croatia	4,7%	1,7%	1,4%	2,2%	71,5%	8,1%	1,3%	4,0%	5,2%
Cyprus	2,0%	0,8%	0,9%	1,0%	59,5%	13,2%	0,0%	0,0%	22,6%
Czech Rep.	3,7%	1,3%	0,9%	1,6%	56,3%	18,2%	8,4%	6,1%	3,4%
Denmark	2,7%	5,7%	0,3%	0,6%	65,0%	10,1%	0,3%	7,7%	7,6%
Estonia	3,9%	1,9%	0,0%	0,3%	72,5%	13,1%	1,0%	3,4%	4,0%
Finland	2,6%	1,7%	0,4%	0,8%	63,6%	13,2%	0,8%	5,9%	11,0%
France	2,7%	0,6%	0,5%	1,5%	74,4%	6,7%	1,5%	9,5%	2,6%
Germany	3,0%	3,1%	0,5%	0,7%	71,7%	7,5%	1,9%	9,9%	1,6%
Greece	3,0%	0,7%	0,5%	7,9%	38,5%	38,8%	1,4%	1,1%	8,2%
Hungary	3,5%	1,3%	1,2%	0,6%	57,7%	22,9%	2,4%	7,5%	2,8%
Ireland	2,3%	1,3%	0,1%	0,9%	67,0%	15,6%	0,2%	2,1%	10,5%
Italy	3,0%	1,2%	2,1%	3,9%	71,5%	8,1%	1,0%	6,6%	2,5%
Latvia	4,3%	2,1%	0,1%	0,1%	56,9%	22,9%	0,9%	5,5%	7,1%
Lithuania	3,7%	1,8%	0,2%	0,3%	48,0%	37,9%	0,0%	0,9%	7,1%
Luxembourg	0,6%	0,0%	0,3%	0,6%	70,9%	25,0%	0,0%	1,0%	1,5%
Malta	2,5%	1,1%	0,0%	1,1%	39,0%	12,6%	0,0%	0,0%	43,7%
Netherlands	3,4%	7,2%	0,4%	0,8%	63,8%	10,9%	0,8%	8,9%	3,7%
Poland	3,9%	1,9%	0,3%	0,6%	75,7%	6,8%	1,6%	6,6%	2,5%
Portugal	3,1%	0,4%	0,6%	0,8%	70,5%	11,7%	1,1%	4,1%	7,7%
Romania	6,4%	2,2%	0,1%	0,2%	59,7%	12,9%	6,4%	4,9%	7,2%
Slovakia	5,1%	1,8%	0,1%	0,4%	63,0%	21,6%	0,8%	6,3%	0,9%
Slovenia	2,2%	0,9%	0,4%	0,5%	81,8%	8,9%	0,0%	3,7%	1,5%
Spain	2,8%	0,3%	1,2%	3,0%	69,6%	12,9%	1,4%	5,1%	3,8%
Sweden	2,7%	1,9%	0,1%	0,6%	65,4%	9,7%	2,1%	10,5%	7,0%
United Kingdom	2,0%	0,5%	0,0%	0,9%	66,2%	19,8%	1,3%	7,1%	2,3%

Table 9: shares of transport modes in 2030 in the REFERENCE and EFFICIENCY scenario for freight transport

	REFERENCE				EFFICIENCY			
	LDT	HDT	TRAIN	IWW	LDT	HDT	TRAIN	IWW
Austria	15,9%	60,2%	20,5%	3,5%	11,7%	44,4%	38,3%	5,6%
Belgium	16,1%	63,6%	8,3%	12,0%	13,4%	53,0%	17,5%	16,1%
Bulgaria	6,6%	69,2%	7,9%	16,3%	5,3%	55,9%	12,5%	26,3%
Croatia	21,8%	56,8%	16,7%	4,7%	21,4%	55,6%	16,7%	6,4%
Cyprus	31,2%	68,8%	0,0%	0,0%	31,2%	68,8%	0,0%	0,0%
Czech Rep.	8,7%	76,5%	14,8%	0,1%	8,0%	70,5%	21,3%	0,1%
Denmark	29,2%	61,9%	8,9%	0,0%	28,6%	60,9%	10,5%	0,0%
Estonia	4,3%	45,0%	50,6%	0,0%	4,1%	43,0%	52,8%	0,0%
Finland	9,6%	72,2%	18,1%	0,2%	8,6%	65,2%	25,9%	0,2%
France	28,0%	61,3%	7,8%	2,9%	26,1%	57,1%	13,4%	3,4%

Germany	6,8%	68,6%	13,9%	10,8%	5,1%	50,8%	29,2%	15,0%
Greece	24,7%	73,9%	1,4%	0,0%	24,6%	73,8%	1,6%	0,0%
Hungary	13,1%	72,3%	11,2%	3,4%	11,2%	62,2%	16,2%	10,3%
Ireland	49,4%	50,3%	0,3%	0,0%	49,3%	50,1%	0,5%	0,0%
Italy	24,9%	71,2%	3,8%	0,0%	24,1%	68,8%	7,1%	0,0%
Latvia	3,3%	44,4%	52,4%	0,0%	2,4%	32,8%	64,8%	0,0%
Lithuania	4,6%	68,5%	26,9%	0,0%	1,0%	15,0%	84,0%	0,0%
Luxembourg	21,0%	74,7%	1,8%	2,4%	20,7%	73,4%	2,8%	3,1%
Malta	30,4%	69,6%	0,0%	0,0%	30,4%	69,6%	0,0%	0,0%
Netherlands	10,7%	59,4%	4,3%	25,7%	8,4%	46,6%	8,4%	36,7%
Poland	5,3%	83,6%	11,1%	0,0%	4,7%	74,9%	20,3%	0,1%
Portugal	29,0%	66,7%	4,3%	0,0%	28,9%	66,6%	4,5%	0,0%
Romania	10,6%	60,2%	17,5%	11,7%	6,3%	36,1%	26,1%	31,5%
Slovakia	7,1%	74,7%	16,2%	2,0%	6,4%	67,4%	21,4%	4,8%
Slovenia	9,0%	75,6%	15,4%	0,0%	9,0%	75,3%	15,7%	0,0%
Spain	6,8%	90,0%	3,2%	0,0%	6,8%	89,7%	3,5%	0,0%
Sweden	12,3%	56,0%	31,6%	0,0%	10,7%	48,9%	40,4%	0,0%
United Kingdom	24,3%	67,9%	7,8%	0,1%	23,2%	65,0%	11,6%	0,1%

LDT=light duty truck; HDT=heavy duty truck; IWW=inland waterways

Average occupancy rates and load factors per transportation mode are considered behavioural changes and therefore do not change in between the COMBI reference and efficiency scenarios.

Average annual mileages per transportation mode are not explicitly modelled in the COMBI transportation models, and in principle do not change between the different scenarios. However, due to idiosyncrasies of the COMBI stock analysis models (see below), starting from initial values the COMBI models may have to make certain (minor) adjustments to the average mileages. This is the case, because annual mileages co-determine the required stock of vehicles, which in turn co-determines the annual new sales of vehicles. For example, the COMBI models may avoid certain unrealistic ‘jumps’ in annual new sales as a result of highly increased or decreased activity levels by moderately adjusting (increasing or decreasing) the average annual mileage in a particular year.

2.4 COMBI actions

COMBI uses two methods to explicitly model energy efficiency improvements in the transport sectors.

The first method is a gradual increase in the fuel efficiency (MJ or kWh per vehicle-km) of the different vehicle technologies.

The second method involves a shift in the shares of different vehicle technologies, per transportation mode. COMBI identifies the following vehicle technologies or ‘drive trains’: internal combustion engines (ICE) fuelled by either petrol (gasoline), diesel, LPG, CNG/LNG, ethanol or hydrogen; plug-in hybrid electric vehicles (PHEV) fuelled by petrol or diesel; battery electric (BEV) or full electric (EV) vehicles and fuel cell vehicles (FCV). Petrol and diesel can be blended with biofuels such as bio-ethanol or biodiesel.

For passenger cars, a further distinction is made between small, medium and large sized cars. For high duty truck (HDT) a distinction is made between rigid and articulated trucks.

Finally, COMBO distinguishes for passenger and freight trains between locomotives on the one hand and electric (EMU) or diesel (DMU) multiple units on the other hand.

One should keep in mind that – because of data constraints in COMBI - not all technologies may apply to all transport modes, e.g. LPG fuelled P-HEVs are not considered in COMBI.

Differentiated per transport mode, this gives a grand total of sixty-two (62) technologies for the passenger transport sector, and of thirty-two (32) technologies for the freight transport sector.

2.4.1 Fuel efficiency improvements

The COMBI reference scenario already recognizes an 'autonomous' increase in the vehicles' fuel efficiencies, depending on their drive train. COMBI assumes higher and/or accelerated penetration of efficiencies in the efficiency scenario, although it should be understood that for a number of vehicle technologies the future energy efficiency improvement potentials are rather limited.

Projections of energy (fuel) efficiency values are based on existing EU scenarios, mainly the ones employed by JRC in their TIMES energy system model, as well as values given in the TREMOVE, iTREN, ASTRA-EC and SULTAN models. PRIMES values were not used, as the data provided to COMBI were not sufficiently detailed. As usual, the comprehensive COMBI assumptions can be found in the EXCEL file in annex.

2.4.2 Shifts in drive trains

The bulk of the technology-related energy savings in the transportation sector, making abstraction of significant modal shifts, can be realized through a shift in vehicle technologies.

A technology shift basically boils down to moving away from ICE vehicles in the direction of larger shares of P-HEVS and (B)EVs in the vehicle stock. To that end COMBI developed highly detailed stock analysis models. A stock analysis model implies that scenario inputs are in the form of shares in annual new sales of a particular vehicle technology, per transportation mode. From these inputs and other variables the COMBI models automatically calculate the annual shares in the total stock of vehicles, per transport mode.

Given the number of different technologies (62 for passenger and 32 for freight transport), different values for 28 EU member states, and values for each year in the time horizon (2015-2030), it is impossible to give a detailed description of the scenarios, and once again we have to refer to the COMBI Excel file in annex.

Projections in COMBI are based on the aforementioned JRC TIMES, TREMOVE, iTREN, ASTRA-EC and SULTAN models, as well as expert judgment from the COMBI partners.

3 Industrial sectors

3.1 Decomposition method

The scenarios for industry are based on a decomposition analysis, where the resulting final energy consumption is the product of *activity levels* (unit of activity) and *energy intensities* (energy used per unit of activity).

3.2 Activity levels

COMBI recognizes eight (8) different subsectors, namely iron and steel, non-ferrous metal, chemical & pharmaceutical, non-metallic minerals, pulp, paper and print, food and beverage, machinery and transport equipment, and 'other industries'. Other industries also comprise textile and leather and wood and wood products, and are considered low energy intensity sectors.

Activity levels are represented by value added (VA) at factor cost. The relatively high aggregation levels of the COMBI industry model do not allow the use of physical outputs (e.g. tonnes of steel) as a representation of activity levels. The value added levels for the base year (2015) were extracted from the EUROSTAT database.

3.3 Structural changes

Structural shifts, i.e. shifts from high energy intensity industries to low or less high energy intensity industries are realized by taking into account different growth levels for the various industrial subsectors. Energy saving potentials for other industries are not explicitly modelled in COMBI.

Table 10: growth levels of value added for industrial sectors between 2020-2030 (%)

	I&S	NFM	C&P	NMM	PPP	FBT	M&T	other
Austria	0,0%	0,8%	1,0%	1,5%	1,7%	1,4%	1,8%	1,3%
Belgium	2,8%	1,9%	0,8%	2,0%	2,5%	1,1%	3,0%	0,7%
Bulgaria	0,2%	0,3%	1,0%	0,7%	1,1%	0,7%	1,9%	2,0%
Croatia	0,4%		1,5%	1,0%	1,3%	1,5%	1,8%	0,9%
Cyprus	0,9%	0,7%	1,2%	1,0%	1,0%	1,1%	2,3%	1,5%
Czech Rep.	0,6%	1,1%	2,0%	1,2%	1,1%	1,8%	1,6%	0,9%
Denmark	2,7%	0,3%	0,5%	1,6%	1,2%	1,2%	1,9%	1,9%
Estonia	0,6%	0,6%	0,7%	1,0%	0,5%	1,3%	1,1%	1,0%
Finland	-0,6%	0,5%	0,6%	1,3%	1,1%	1,1%	1,6%	1,0%
France	0,6%	0,3%	1,1%	0,5%	0,7%	1,0%	0,6%	0,6%
Germany	-0,1%	0,4%	0,5%	0,9%	0,6%	1,3%	0,2%	0,6%
Greece	2,9%	0,9%	1,8%	2,0%	2,1%	2,0%	2,4%	0,2%
Hungary	1,0%	0,3%	1,3%	1,1%	0,2%	1,3%	2,9%	1,8%
Ireland	0,0%	0,4%	0,9%	1,4%	0,9%	1,4%	0,7%	1,0%
Italy	4,5%	1,5%	1,9%	1,4%	1,5%	1,3%	2,2%	0,6%
Latvia	0,3%	-1,0%	-0,1%	0,8%	1,2%	0,2%	0,9%	1,3%

Lithuania	1,3%	1,2%	2,4%	1,1%	1,1%	2,3%	2,5%	0,7%
Luxembourg	1,4%			1,2%	1,5%	1,4%	1,8%	2,8%
Malta	0,9%	1,0%	1,0%	0,7%	0,8%	0,9%	1,1%	1,3%
Netherlands	1,6%	2,4%	2,0%	2,3%	2,9%	2,3%	3,5%	1,1%
Poland	0,7%	0,8%	0,8%	1,2%	1,1%	1,2%	1,4%	2,3%
Portugal	0,5%	0,4%	1,6%	1,4%	1,8%	1,9%	2,5%	1,1%
Romania	1,0%	1,3%	1,6%	2,4%	2,1%	2,4%	2,9%	1,7%
Slovakia	1,2%	1,3%	1,2%	1,2%	1,3%	2,0%	2,6%	2,1%
Slovenia	1,1%	0,7%	1,5%	1,9%	0,8%	1,2%	2,5%	1,0%
Spain	1,2%	1,3%	1,8%	1,1%	1,0%	1,7%	1,9%	0,7%
Sweden	-0,6%	-0,8%	0,7%	0,2%	-0,3%	0,1%	1,7%	1,8%
United Kingdom	1,4%	0,9%	1,3%	1,4%	1,1%	1,4%		0,4%

I&S=Iron & Steel; NFM=Non-Ferrous Metals; C&P=Chemicals & Petrochemicals; NMM=Non-Metallic Minerals; PPP=paper, pulp & printing: FBT: Food, Beverages & Tobacco; M&T=Machinery & Transport;

The value added projections for the different industrial subsectors are based on the PRIMES reference scenario. They do not change in between the COMBI reference and efficiency scenarios.

3.4 COMBI actions

COMBI distinguishes eight (8) different energy services for the industrial subsectors, namely high temperature process heating (mainly ovens or furnaces), medium and low temperature process heating (primarily industrial boilers), process cooling, process specific electricity (mostly electrochemical processes), motor drive (including pumps, fans and compressors), heating, ventilation and air conditioning (HVAC) in industrial buildings, lighting, and 'other energy services'. A detailed qualitative description of each of those energy services is given in the main COMBI D2.2 report.

Energy intensities, i.e. amount of energy used per unit of activity (in the case of COMBI kWh per unit of value added) are determined for the base year (2015) for each energy service and for each industrial subsector. Data sources for the derivation of energy intensities include EUROSTAT and ODYSSEE, with a very special mention for Fraunhofer-ISI, who were kind enough to provide COMBI with EXCEL files containing very detailed and invaluable data for all the industrial sectors in the 28 EU member states for the year 2012. Other data sources, such as PRIMES or JRC TIMES, were simply not detailed enough to be of any use to COMBI.

Based on literature, energy savings potentials by 2030 are estimated per energy service and per industrial subsector, for both a reference scenario and a (high) efficiency scenario. The chief data sources used by COMBI are a 2015 ICF study, and to a lesser extent a report by the European Copper Institute (ECI).

Unlike for the buildings and transport sectors, time and budget constraints in COMBI did not allow the construction of detailed stock analysis models for the industrial sectors.

It should also be noted that, in contrast with the buildings and transport sectors, data availability for the industrial sectors is dismal. This is most certainly the case when considering cost information. Furthermore, industry is an extremely complex sector, where – certainly for the high-intensive industries – one should ideally look at whole *production processes* rather than at the level of individual energy services.

As a result the COMBI scenarios for industry can only be considered a very rough approximation of the true energy saving potentials in that particular sector, with lots of room for future improvements of how industry is modelled in COMBI.

4 References

DATABASES - DATATOOLS

EUROSTAT, Population (Demography, Migration and Projections)

EUROSTAT, National accounts (including GDP)

EUROSTAT, Energy database

ODYSSEE Database

iNSPiRe Retrofit Solutions Database

ZEBRA2020 Datatool

European Commission, EU Building Stock Observatory

European Commission, EU Buildings Database

CommONEnergy Data Mapper

ENTRANZE, Maria Fernandez Boneta, D3.2 Database of EE and RES technologies: energy/cost matrices, National Renewable Energy Centre (CENER), February 2014

ENTRANZE, Lorenzo Pagliano and Marco Pietrobon, Cost Energy Calculation Tool v22.4, Politechnico Di Milano, end-use Efficiency Research Group eERG, April 2014

ENTRANZE Data Tool

ENTRANZE Scenario results

ASTRA-EC model (ASsessment of TRAnsport Strategies)

EU Transport GHG: Routes to 2050, SULTAN (SUstainabLe TrANsport) Illustrative Scenarios Tool, Last Updated on Wednesday 5 September 2012

European Commission, European Environment Agency (EEA), TRACCS database

Fraunhofer Institute for Systems and Innovation Research (ISI) et al., Mapping and analyses of the current and future (2020 - 2030) heating/cooling fuel deployment (fossil/renewables), Work package 2: Assessment of the technologies and division of heat production capacities, Data annex,1: Heating and cooling technologies in buildings - processed data, 15/03/2016.

Fraunhofer Institute for Systems and Innovation Research (ISI) et al., Mapping and analyses of the current and future (2020 - 2030) heating/cooling fuel deployment (fossil/renewables), Work package 2: Assessment of the technologies and division of heat production capacities, Data annex,2: Heat and cold supply technologies in the industry sector, 15/03/2016.

Fraunhofer Institute for Systems and Innovation Research (ISI) et al., Mapping and analyses of the current and future (2020 - 2030) heating/cooling fuel deployment (fossil/renewables), Work package 2: Assessment of the technologies and division of heat production capacities, Data annex,3: District heating technologies, 15/03/2016.

Fraunhofer Institute for Systems and Innovation Research (ISI) et al., Mapping and analyses of the current and future (2020 - 2030) heating/cooling fuel deployment (fossil/renewables), Work package 2: Assessment of the technologies and division of heat production capacities, Data annex,4: CHP > 1 MWth (industry and district heating), 15/03/2016.

E3M Lab National Technical University of Athens, EU28: Reference scenario (REF2016), Summary report Primes Ver. 4 Energy Model, 20/07/2016

REPORTS - PAPERS - ARTICLES

Fraunhofer Institute for Systems and Innovation Research (ISI) et al., Mapping and analyses of the current and future (2020 - 2030) heating/cooling fuel deployment (fossil/renewables), Work package 1: Final energy consumption for the year 2012 , EUROPEAN COMMISSION DIRECTORATE-GENERAL FOR ENERGY, March 2016

Fraunhofer Institute for Systems and Innovation Research (ISI) et al., Mapping and analyses of the current and future (2020 - 2030) heating/cooling fuel deployment (fossil/renewables), Work package 2: Assessment of the technologies for the year 2012 , Final report, EUROPEAN COMMISSION DIRECTORATE-GENERAL FOR ENERGY, March 2016

Fraunhofer Institute for Systems and Innovation Research (ISI) et al., Mapping and analyses of the current and future (2020 - 2030) heating/cooling fuel deployment (fossil/renewables), Work package 1: Useful energy demand and final energy consumption, Data annex, Data Final Energy for heating and cooling, 11/03/2016.

EUROPEAN COMMISSION, COMMISSION STAFF WORKING DOCUMENT , Review of available information, Accompanying the document Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions on an EU Strategy for Heating and Cooling, {COM(2016) 51 final} , Brussels, 16.2.2016 SWD(2016) 24 final

E3M-Lab et al., EU Reference Scenario 2016 , Energy, transport and GHG emissions Trends to 2050 , prepared for the Directorate-General for Energy, the Directorate-General for Climate Action and the Directorate-General for Mobility and Transport, Luxembourg: Publications Office of the European Union, 2016

The Hague: Ministry of the Interior and Kingdom Relations, Housing Statistics in the European Union 2010, (Kees Dol and Marietta Haffner, editors), Delft University of Technology, September 2010

iNSPiRe, Development of Systemic Packages for Deep energy Renovation of Residential and Tertiary Buildings including Envelope and Systems, (Robert Weitlaner et al.), D4.1 Report on artifiial lighting solutions, 15 December 2013

iNSPiRe, Development of Systemic Packages for Deep energy Renovation of Residential and Tertiary Buildings including Envelope and Systems, (Roberto Fedrizzi et al.), D6.3a Performance of Studied Systemic Renovation Packages – Methods , 30 September 2015

iNSPiRe, Development of Systemic Packages for Deep energy Renovation of Residential and Tertiary Buildings including Envelope and Systems, (Roberto Fedrizzi et al.), D6.3b - Performance of Studied Systemic Renovation Packages – Single Family Houses , 30 September 2015

iNSPiRe, Development of Systemic Packages for Deep energy Renovation of Residential and Tertiary Buildings including Envelope and Systems, (Roberto Fedrizzi et al.), D6.3c - Performance of Studied Systemic Renovation Packages – Multifamily Houses , 30 September 2015

iNSPiRe, Development of Systemic Packages for Deep energy Renovation of Residential and Tertiary Buildings including Envelope and Systems, (Marcus Gustafsson et al.), D6.3d - Performance of Studied Systemic Renovation Packages – Office Buildings , 30 September 2015

iNSPiRe, Development of Systemic Packages for Deep energy Renovation of Residential and Tertiary Buildings including Envelope and Systems, Sarah Birchall. BSRIA Ian Wallis, BSRIA David Churcher, BSRIA Simon Pezzutto, EURAC Roberto Fedrizzi, EURAC Emmanuelle Causse, UIPI, D2.1a Survey on the energy needs and architectural features of the EU building stock , 12 May 2014

iNSPiRe, Development of Systemic Packages for Deep energy Renovation of Residential and Tertiary Buildings including Envelope and Systems, Helen Bedford, BSRIA Sarah Birchall, BSRIA David Bleicher, BSRIA Ian Wallis, BSRIA Emmanuelle Causse, UIPI , D 2.1b Summary of Policies and incentives relevant to retrofit in the EU-27, 24 March 2014

iNSPiRe, Development of Systemic Packages for Deep energy Renovation of Residential and Tertiary Buildings including Envelope and Systems, Chiara Dipasquale, EURAC Roberto Fedrizzi, EURAC Alessandro Bellini, EURAC Matteo D'Antoni, EURAC Chris Bales, SERC Marcus Gustafsson, SERC Fabian Ochs, UIBK Georgios Dermentzis, UIBK Sarah Birchall, BSRIA, D2.1c Simulation results of reference buildings, 04 August 2014

BMVBS (Bundesministerium für Verkehr, Bau und Stadtentwicklung), Kosten energierelevanter Bau- und Anlagenteile bei der energetischen Modernisierung von Wohngebäuden, BMVBS-Online-Publikation, Nr. 07/2012, Juni 2012

IWU (Institut Wohnen und Umwelt), Eberhard Hinz, Kosten energierelevanter Bau- und Anlagenteile bei der energetischen Modernisierung von Altbauten Endbericht, Darmstadt, 10.08.2015

ZEBRA2020: NEARLY ZERO-ENERGY BUILDING STRATEGY 2020, Deliverable 5.1: Nearly Zero-Energy Building (nZEB) technology solutions, cost assessment and performance, September 2016

ZEBRA2020: NEARLY ZERO-ENERGY BUILDING STRATEGY 2020, Lukas Kranzl et al, Strategies for a nearly Zero-Energy Building market transition in the European Union, October 2016

ZERO+, Achieving near Zero and Positive Energy Settlements in Europe using Advanced Energy Technology H2020 - 678407, Morna Isaac, Luciano Pana Tronca and Marijan Gajsak, D 8.1 Report: Market analysis of trends in the construction of residential highly energy performing buildings, July 2016

ENTRANZE Lukas Kranzl, Andreas Müller, Agne Toleikyte, Marcus Hummel Energy Economics Group Vienna University of Technology Jan Steinbach, Judit Kockat, Clemens Rohde Fraunhofer ISI Carine Sebi, Kimon Keramidas, Bruno Lapillone Enerdata, Policy pathways for reducing energy demand and carbon emissions of the EU building stock until 2030, October 2014

BPIE Buildings Performance Institute Europe, Europe's Buildings under the Microscope, A country-by-country review of the energy performance of buildings, October 2011

ITREN-2030 Integrated transport and energy baseline until 2030, Overview on energy technologies and initial scenario on their diffusion into transport Deliverable D3, IPTS, April 2008

ITREN-2030 Integrated transport and energy baseline until 2030, The iTREN-2030 reference scenario until 2030 Deliverable D4 , TRT Trasporti e Territorio srl , November 27th 2009

ITREN-2030 Integrated transport and energy baseline until 2030, The iTREN-2030 Integrated Scenario until 2030 Deliverable D5, Fraunhofer Institute System and Innovation Research (ISI), February 26th 2010

EU Transport GHG: Routes to 2050 II project, Developing a better understanding of the secondary impacts and key sensitivities for the decarbonisation of the EU's transport sector by 2050 - Final Project Report, by Nikolas Hill, Charlotte Brannigan (AEA); Richard Smokers (TNO); Arno Schroten, Huib van Essen (CE Delft) and Ian Skinner (TEPR), FINAL, Updated 29 July 2012

G. Papadimitriou, L. Ntziachristos (EMISIA) P. Wüthrich, B. Notter, M. Keller (INFRAS) E. Fridell, H. Winnes, L. Styhre, Å. Sjödin (IVL), Transport data collection supporting the quantitative analysis of measures relating to transport and climate change Project acronym: TRACCS, Final Report, EMISIA SA Report No: 13.RE.025.V1, EMISIA, Thessaloniki, 20 December 2013

TML (Transport & Mobility Leuven), TREMOVE Service contract for the further development and application of the transport and environmental TREMOVE model Lot 1 (Improvement of the data set and model structure) Service Contract 070501/2005/420798/MAR/C1 FINAL REPORT, European Commission, 9 July 2007

E3MLab/ICCS (Energy-Economy-Environment Modeling Laboratory), P. Capros and Pelopidas Siskos, PRIMES-TREMOVE transport model v3, Model Description, November 2011

E3MLab/ICCS at National Technical University of Athens, PRIMES -TREMOVE Transport Model 2013-2014 Detailed model description

Nina Holck Sandberg, Igor Sartori, Oliver Heidrich, Richard Dawson, Elena Dascalaki, Stella Dimitriou, Tomás Vimmr, Faidra Filippidou, Gasper Stegnar, Marjana Sijanec Zavrl, Helge Brattebø, Dynamic building stock modelling: Application to 11 European countries to support the energy efficiency and retrofit ambitions of the EU, in: Energy and Buildings, (123) 2016, pp. 26-38

Sarah Birchall, Marcus Gustafsson, Ian Wallis, Chiara Dipasquale, Alessandro Bellini, Roberto Fedrizzi, Survey and simulation of energy use in the European building stock, in: CLIMA 2016 - proceedings of the 12th REHVA World Congress (Heiselberg, Per Kvols, eds.), Aalborg University, Department of Civil Engineering, Aalborg, 2016

EPISCOPE (Energy Performance Indicator Tracking Schemes for the Continuous Optimisation of Refurbishment Processes in European Housing Stocks), Monitor Progress Towards Climate Targets in European Housing Stocks Main Results of the EPISCOPE Project - Final Project Report - (Deliverable D1.2), Institut Wohnen und Umwelt, Darmstadt, March 2016

EPISCOPE (Energy Performance Indicator Tracking Schemes for the Continuous Optimisation of Refurbishment Processes in European Housing Stocks), Inclusion of New Buildings in Residential Building Typologies Steps Towards NZEBs Exemplified for Different European Countries - EPISCOPE Synthesis Report No. 1 - (Deliverable D2.4), Institut Wohnen und Umwelt, Darmstadt, October 2014

Simon Pezzutto, Agne Toleikyte, Matteo De Felice, Assessment of the Space Heating and Cooling Market in the EU28: A Comparison between EU15 and EU13 Member States, in: International Journal of Contemporary ENERGY, Vol. 1, No. 2 (2015), pp. 35-48

RESIDE (Boosting innovation in the European building REfurbishment sector through roadmaps for demand SIDE policy measures, Nicholas Shaw, Rudi Loossens, Deliverable 1.1 A baseline scenario for energy efficiency renovations in Europe’s residential buildings, Bax and Willems Consulting Venturing, CTECH, UU, CEFIC, 16th of February 2015

ODYSSEE, Energy Efficiency Trends and Policies in the Household and Tertiary Sectors An Analysis Based on the ODYSSEE and MURE Databases, June 2015

PassREgs (Passive House Regions with Renewable Energies), Final Aggregated Monitoring and Evaluation Report Deliverable 2.5 Based on the Success Models and Monitoring reports from PassREg’s frontrunner and aspiring regions, EnEffect, s.d.

ECOFYS, Thomas Boermans, Jan Grözinger, Bernhard von Manteuffel, Nesen Surmeli-Anac, Ashok John (Ecofys) Klemens Leutgöb, Daniela Bachner (e7), Assessment of cost optimal calculations in the context of the EPBD (ENER/C3/2013-414) Final report, Cologne, 19 November 2015

ECOFYS, Bernhard von Manteuffel, Carsten Petersdorff, Kjell Bettgenhäuser, Thomas Boermans , “EU pathways to a decarbonised building sector” How replacing inefficient heating systems can help reach the EU climate ambitions, Final report, Berlin, 13 April 2016

ECOFYS, Thomas Boermans, Kjell Bettgenhäuser, Markus Offermann, Sven Schimschar, Renovation Tracks for Europe up to 2050, Building renovation in Europe - what are the choices?, commissioned by Eurima - European Insulation Manufacturers Association, Köln, 2012

ECOFYS, Sven Schimschar, Jan Grözinger, Henning Korte, Thomas Boermans, Velizara Lilova, Riadh Bhar, Panorama of the European non-residential construction sector, Final report , 9 December 2011

ECOFYS, Sacha Alberici, Sil Boeve, Pieter van Breevoort, Yvonne Deng, Sonja Förster, Ann Gardiner, Valentijn van Gastel, Katharina Grave, Heleen Groenenberg, David de Jager, Erik Klaassen, Willemijn Pouwels, Matthew Smith, Erika de Visser, Thomas Winkel, Karlien Wouters, Subsidies and costs of EU energy Final report, 11 November 2014

ECOFYS, Kjell Bettgenhäuser, Markus Offermann, Thomas Boermans, Michelle Bosquet, Jan Grözinger, Bernhard von Manteuffel and Nesen Surmeli, Heat Pump Implementation Scenarios until 2030 An analysis of the technology's potential in the building sector of Austria, Belgium, Germany, Spain, France, Italy, Sweden and the United Kingdom, Köln, October 22 2013

STRATEGO Enhanced Heating and Cooling Plans, David Connolly, Kenneth Hansen David Drysdale, Creating National Energy Models for 2010 and 2050 Work Package 2 Background Report 1, Aalborg University; Copenhagen, 2015

STRATEGO Enhanced Heating and Cooling Plans, Urban Persson & Sven Werner, Quantifying the Heating and Cooling Demand in Europe, Work Package 2 Background Report 4, Halmstad University, 2015

Diana Urge - Vorsatz, András Reith, Katarína Korytárová, Mónika Egyed, János Dollenstein: Monetary Benefits of Ambitious Building Energy Policies . Research report prepared by ABUD (Advanced Building and Urban Design) for the Global Building Performance Network (GBPN), Janurary 2015

Igor SartorI, FederIco Noris, Sebastian Herkel, Cost analysis of nZEB/Plus energy buildings, in: REHVA Journal – May 2015, pp. 40-45

VHK (Van Holsteijn en Kemna), René Kemna, Juan Moreno Acedo, Average EU building heat load for HVAC equipment, Final report, Delft, August 2014.

Hans Erhorn & Heike Erhorn-Kluttig, Selected examples of Nearly Zero Energy Buildings Detailed Report, EPBD-CA, September 2014

CODE2 Cogeneration Observatory and Dissemination Europe, Micro-CHP potential analysis European level report, Energy Matters, December 2014

IEA (International Energy Agency), Technology Roadmap, Energy efficient building envelopes, 2013

BPIE, The Buildings Performance Institute Europe: Bogdan Atanasiu (project lead) Ilektra Kouloumpi (project assistance), IMPLEMENTING THE COST-OPTIMAL METHODOLOGY IN EU COUNTRIES, LESSONS LEARNED FROM THREE CASE STUDIES, March 2013

BPIE, Pathways to 80% Analysis of Different Scenarios for Achieving 80% Energy Saving in EU's Building Sector, s.d.

Katerina Tsikaloudaki, Kostas Laskos and Dimitrios Bikas, On the Establishment of Climatic Zones in Europe with Regard to the Energy Performance of Buildings, in: Energies 2012, 5, 32-44; doi:10.3390/en5010032

JRC, Marina Economidou, Energy performance requirements for buildings in Europe, in: REHVA Journal – March 2012, pp. 16-21

JRC, Nicolas Pardo Garcia, Kostantinos Vatopoulos, Anna Krook Riekkola (IET-JRC & Luleå University of Technology) Alicia Perez Lopez (IET-JRC), Lars Olsen (Danish Technology Institute), Best available technologies for the heat and cooling market in the European Union, Joint Research Centre of the European Commission, European Union, 2012

JRC, Delia D'Agostino, Paolo Zangheri, Barbara Cuniberti, Daniele Paci, Paolo Bertoldi, Synthesis Report on the National Plans for Nearly Zero Energy Buildings (NZEBs), Progress of Member States towards NZEBs , JRC Science Policy Report, European Union, Joint Research Centre, Ispra, 2016

JRC, N. Pardo K. Vatopoulos A. Krook-Riekkola J.A. Moya A. Perez, Heat and cooling demand and market perspective, Joint Research Centre of the European Commission, European Union, 2012

JRC, Martijn van Elburg (coordinator), VHK (Van Holsteijn en Kemna) Roy van den Boorn, VHK René Kemna, VHK, Development of European Ecolabel and Green Public Procurement Criteria for Hydronic Central Heating Systems Draft Report, Product definition and scope Economic and market analysis Technical analysis, June 2011

JRC, Sofia Simoes, Wouter Nijs, Pablo Ruiz, Alessandra Sgobbi, Daniela Radu, Pelin Bolat, Christian Thiel, Stathis Peteves, The JRC-EU-TIMES model, Assessing the long-term role of the SET Plan Energy technologies , Joint Research Centre, Petten, 2013

JRC, Paolo Bertoldi, Javier López Lorente, Nicola Labanca, Energy Consumption and Energy Efficiency Trends in the EU-28 2000-2014, Efficiency Trends of Energy-related Products and Energy Consumption in the EU-28, Joint Research Centre, European Union, 2016, EUR 27972 EN; doi 10.2788/581574

JRC, Hans Moons, Alejandro Villanueva, Maria Calero, Fulvio Ardente, Fabrice Mathieux, Nicola Labanca, Paolo Bertoldi, Ecodesign for Commercial Refrigeration, Preparatory study update Final report , Joint Research Centre, Seville, 2014

Danish Energy Agency, Technology Data for Energy Plants, - Individual Heating Plants and Energy Transport, Danish Energy Agency and Energinet.dk, May 2012

Colin Gleeson, Junli Yang and Tony Lloyd-Jones, European Retrofit Network: Retrofitting Evaluation Methodology Report, University of Westminster School of Architecture and the Built Environment, 10 August 2011

Jarek Kurnitski (Sitra, the Finnish Innovation Fund), Arto Saari (Aalto University), Mika Vuolle (Equa Simulation Finland Oy), Cost optimal and nZEB energy performance levels for buildings , Technical report, May 30, 2011

Jarek Kurnitski, How to calculate cost optimal nZEB energy performance?, in: REHVA Journal – October 2011, pp. 36-41

ICCT (International Council on Clean Transportation), ICCT Roadmap Model Version 1-0 , Global Transportation Roadmap Model Documentation and User Guide, December 2012

ICCT (International Council on Clean Transportation), Paul Wolfram and Nic Lutsey, Electric vehicles: Literature review of technology costs and carbon emissions, WORKING PAPER 2016-14, 15 July 2016

EEA (European Environment Agency) , Electric vehicles in Europe, EEA, Copenhagen, 2016

Trinomics , Assessing the status of electrification of the road transport passenger vehicles and potential future implications for the environment and European energy system, Specific Contract under Framework Contract EEA/ACC/13/003 LOT-1 Final Report – Task 2, Rotterdam, 20 September 2016

Transportation Research Board, Comparison of Passenger Rail Energy Consumption with Competing Modes, NATIONAL COOPERATIVE RAIL RESEARCH PROGRAM, NCRRP REPORT 3, Washington, D.C. 2015

Transport & Environment , Road to 2030: how EU vehicle efficiency standards help member states meet climate targets Transport emissions reductions in the context of the 2030 Effort Sharing Decision, June 2015

Amsterdam Roundtable Foundation, Evolution Electric vehicles in Europe: gearing up for a new phase?, prepared in collaboration with McKinsey & Company, April 2014

ASSIST (Assessing the social and economic impacts of past and future sustainable transport policy in Europe), The ASTRA-EC model user guide Extract of deliverable D6.1 of the ASSIST project, Fraunhofer-ISI (co-ordinator), Karlsruhe, s.d.

ASSIST (Assessing the social and economic impacts of past and future sustainable transport policy in Europe), ASSIST Deliverable D4.2: Description of the ASTRA-EC model and of the user interface, TRT Trasporti e Territorio, Milan, Italy, 21.11.2013

Will McDowall and Paul Dodds, A review of low-carbon vehicle and hydrogen end-use data for energy system models , UKSHEC Working Paper No. 5, UCL Energy Institute, University College London, 2012

ERRAC (European Rail Research Advisory Council), Metro, light rail and tram systems in Europe, s.l., s.d.

CE Delft, Bettina Kampman, Huib van Essen, Willem Braat (CE Delft), Max Grünig (Ecologic), Ravi Kantamaneni, Etienne Gabel (ICF), Impact analysis for market uptake scenarios and policy implications, Impacts of Electric Vehicles - Deliverable 5 , Final Report, Delft, April 2011

METROLINX, GO Electrification Study Final Report Appendix 4 Rolling Stock Technology Assessment, Toronto, December 2010

Piotr Lukaszewicz & Evert Andersson, Green Train energy consumption Estimations on high-speed rail operations, KTH Railway Group, Stockholm, 2009

LAT/AUTh (Zissis Samaras Project Manager), Leon Ntziachristos, Giorgos Mellios, Charis Kouridis, Thomas Papageorgiou, Maria Theodosopoulou, Zissis Samaras, Karl-Heinz Zierock, Nikos Kouvaritakis, Evaggelos Panos, Panayotis Karkatsoulis, Stephanie Schilling, Tamás Merétei, Péter Aladár Bodore, Slavitsa Damjanovic, Alain Petit, European Database of Vehicle Stock for the Calculation and Forecast of Pollutant and Greenhouse Gases Emissions with TREMOVE and COPERT, Final Report, LAT Report No: 08.RE.0009.V2 , Thessaloniki, 02 July 2008

Rail Safety and Standards Board, Roger Kemp, Research Programme Engineering, T618 Traction energy metrics, London, 20 December 2007

LS Transit Systems, in association with DKS & Nelson\Nygaard, Around the Bay Rail Study , 3.0 Diesel Multiple Unit Assessment, July 1998

Roland Berger, Integrated Fuels and Vehicles Roadmap to 2030 and beyond, April 27, 2016

Casey Mrazik, Mark Baron, Andrew Stabbert, A Cost Benefit Analysis of Diesel and Liquid Natural Gas for Locomotive Engines, The Pennsylvania State University, December 03, 2015

CONEBI Confederation of the European Bicycle Industry, European Bicycle Market 2016 edition Industry & Market Profile (2015 statistics), Brussels, October 2016

EPFL Ecole Polytechnique Féderale de Lausanne, J.P. Baumgartner, Prices and Costs in the Railway Sector, LITEP Laboratoire d'Intermodalité des Transports et de Planification, Lausanne, January 2001

Domenico Gattuso, Antonio Restuccia, A tool for railway transport cost evaluation, EWGT2013 – 16th Meeting of the EURO Working Group on Transportation, in: rocedia - Social and Behavioral Sciences 111 (2014) 549 – 558

ICF, Yeen Chan & Ravi Kantamaneni, Study on Energy Efficiency and Energy Saving Potential in Industry from possible Policy Mechanisms , Contract No. ENER/C3/2012-439/S12.666002, London, 1 December 2015

Copenhagen Centre on Energy Efficiency, Steven Fawkes, Kit Oung, David Thorpe, Best Practices and Case Studies for Industrial Energy Efficiency Improvement – An Introduction for Policy Makers, Copenhagen, February 2016

ECI (European Copper Institute), Ignacio Martin, CIRCE , Application Note – Options to Decarbonize Industrial Energy Use, ECI Publication No Cu0203, January 2015

topten.eu Topten International Group (TIG), Anette Michel, Sophie Attali, Eric Bush, Energy efficiency of White Goods in Europe: monitoring the market with sales data, Changes and trends regarding energy efficiency, energy consumption, size and price in the markets of refrigerators, washing machines and tumble driers in the EU, France and Portugal, 2004 to 2014, 3. June 2015

topten.eu Topten International Group (TIG), Anette Michel, Policy recommendations for household refrigerators and freezers, December 16th 2013

VITO, Sarah Bogaert (project management), Dominic Ectors, Helena Gerard, Sarah Bogaert & Koen Vanthournout (VITO), Marcel Perret-Gentil & Philippe Rivière (ARMINES), Jasmin Geppert & Prof. Rainer Stamminger (Rheinische Friedrich-Wilhelms-Universität Bonn)), Jan Viegand (Viegand Maagøe): Thomas Götz (Wuppertal Institut:), Preparatory study on Smart Appliances Task 2 Economic and market analysis, Task 2 report, 20 May 2016

VHK (Van Holsteijn & Kemna) and ARMINES (Association pour la Recherche et le Développement des Méthodes et Processus Industriels), Commission Regulation (EC) No. 643/2009 with regard to ecodesign requirements for household refrigeration appliances and Commission Delegated Regulation (EU) No. 1060/2010 with regard to energy labelling of household refrigeration appliances, FINAL REPORT, Preparatory/review study, in collaboration with Viegand & Maagøe and Wuppertal Institute contract co-ordination VITO, 4 March 2016

VHK (Van Holsteijn & Kemna) and ARMINES (Association pour la Recherche et le Développement des Méthodes et Processus Industriels), Ecodesign & Labelling Review Household Refrigeration Preparatory/review study Commission Regulation (EC) No. 643/2009 and Commission (Delegated) Regulation (EU) 1060/2010 Interim report, European Union, 1.6.2015

Navigant Consulting, EIA -Technology Forecast Updates – Residential and Commercial Building Technologies – Reference Case Presented to: U.S. Energy Information Administration, McLean, VA, March 2014

UK Department of Energy & Climate Change, Energy efficient products - helping us cut energy use, July 2014

RESCUE (Renewable Smart Cooling in Urban Europe), Magnus Swedblom, Peter Mattsson, Anders Tvärne, Henrik Frohm and Anders Rubenhag (Capital Cooling Energy Service AB, Sweden), District Cooling and the Customers' alternative cost, Work Package 2, s.l., s.d.

Martin Jakob, Tobias Fleiter, Giacomo Catenazzi, Simon Hirzel, Felix Reitze, Felipe Toro, The impact of policy measures on the electricity demand of the tertiary sector of the European countries: An analysis with the bottom-up model FORECAST, in: Improving Energy Efficiency in Commercial Building Conference (IEECB'12) Frankfurt 18-19 April 2012

Martin Jakob & Giacomo Catenazzi (TEP Energy), Tobias Fleiter (Fraunhofer institute for Systems and innovation Research iSi), Ex-ante estimation of the EU Ecodesign Directive's impact on the long-term electricity demand of the tertiary sector, in: ECEEE 2013 SUMMER STUDY – RETHinK, REnEW, RESTaRT, pp 2125-2136

Tobias Fleiter, Sibylle Braungardt, Tariq Sohaib, Barbara Schlomann, Wolfgang Eichhammer & Rainer Elsland (Fraunhofer Institute for Systems and Innovation Research ISI), Lukas Kranzl (TU Wien), Martin Jakob (TEP Energy), Assessing the impact of the EU Ecodesign Directive on a member state level, in: ECEEE 2015 SUMMER STUDY – FIRST FUEL NOW, pp. 1927-1938

ANEC (European Association for the Co-ordination of Consumer Representation in Standardisation), Angeliki Malizou, Simplifying the EU Energy Label Restoring the successful and well-understood closed A to G scheme Core conditions for ensuring an EU Energy Labelling scheme that is simple and clear for consumers as well as effective in transforming markets towards the most energy efficient appliances, Brussels, 2015

AEA Energy & Environment, Discussion Report: EU Ecolabel for Refrigeration, Oxfordshire, September 2008

ARMINES, Philippe Rivière (co-ordinator), Preparatory study on the environmental performance of residential room conditioning appliances (airco and ventilation) Contract TREN/D1/40-2005/LOT10/S07.56606 Draft report of Task 2, Economic and Market analysis, July 2008

VITO, in cooperation with VHK, Preparatory Study on Light Sources for Ecodesign and/or Energy Labelling Requirements ('Lot 8/9/19'), Final report, Task 7 Scenarios, 31 October 2015

VITO, Paul Van Tichelen, Wai Chung Lam, Paul Waide, René Kemna, Lieven Vanhooydonck, Leo Wierda, Preparatory study on lighting systems 'Lot 37' Annexes , Specific contract N° ENER/C3/2012-418 Lot 1/06/SI2.668525 Implementing framework contract ENER/C3/2012-418 Lot 1, s.l., 2015

DECC (UK, Department of Energy & Climate Change), European Commission Heating & Cooling Strategy Consultation, DECC Commentary, London, September 9th 2015