Annex : Methodology to compute investment needs and potential energy and emissions savings

The Energy Performance of Buildings Directive (EPBD, EU/2024/1275) indicates energy savings to be obtained in both the residential and non-residential sectors. For the expected energy savings by country (Table A3) we used the split indicated in the EPBD (Article 9): that by 2030 average primary energy use across residential buildings needs to decrease by at least 16 percent compared to 2020, with 55 percent of this reduction to happen in the 43 percent worst-performing buildings. For non-residential dwellings – public and private – the requirement is to renovate 16 percent of the worst energy-performing stock. The difference is significant because the worst-performing buildings consume two to three times more energy than the average. Therefore, even though in the EU building stock the number of square meters in non-residential buildings is a fourth of that in residential ones, the expected final energy savings[1] are 440 TWh from non-residential buildings, 255 TWh from worst-performing residential buildings and 208 TWh for the rest of the residential building stock, corresponding to a 21 percent reduction in energy consumption across the whole EU building stock.

To estimate the energy consumption of worst-performing buildings in kWh/m² (Table A1) we averaged the values in tables G.3 and G.5 of the EPBD recast impact assessment (European Commission, 2021) with twice the average energy consumption of buildings per country in kWh/m² in 2021. This was done to smooth the uncertainty surrounding some of the Commission's country estimates.

Table A.1: Estimated energy consumption in kWh/m2 of worst-performing buildings by country, 2021

Country	residential KWh/m2	non-residential KWh/m2	Country.	residential KWh/m2	non-residential KWh/m2.
Austria	464	453	Italy	197	591
Belgium	508	575	Latvia	301	448
Bulgaria	351	552	Lithuania	398	452
Croatia	275	110	Luxembourg	533	894
Cyprus	274	612	Malta	295	584
Czechia	430	548	Netherlands	609	732
Denmark	334	321	Poland	454	466
Estonia	470	594	Portugal	211	585
Finland	469	492	Romania	576	592
France	426	657	Slovakia	498	791
Germany	329	299	Slovenia	319	281
Greece	232	261	Spain	263	493
Hungary	506	484	Sweden	325	436
Ireland	455	748	**EU27**	**376**	**474**

Source: Bruegel based on Eurostat and the EPBD impact assessment (European Commission, 2021). Note: the estimates refer to the energy consumption of buildings rated below E in energy performance certificates.

Using Eurostat's figures on final energy consumption by households (2,893 TWh in 2020) and commercial and public sector (1,412 TWh in 2020), together with EPBD targets and our estimates on the energy consumption of worst-performing buildings, allowed the implicit energy savings and emission reductions prescribed by the EPBD by 2030 to be computed (Table A3). Following EPBD targets, by 2030 the 16 percent of worst-performing buildings need to be renovated for the non-residential sector, while energy use must decrease by 16 percent for the residential sector. Therefore, for non-residential buildings we have taken 16 percent of the total useful floor area (equivalent to 928 million square meters) and multiplied it by the estimated energy consumption of worst-

[1] Because of missing data, all our estimates are in final energy consumption and not primary energy as prescribed by the EPBD targets. The difference should not be major because energy use for heating largely happens at the end-user level.

performing buildings in the non-residential sector (estimated at 474 kWh/m²), giving 440 TWh. While for residential buildings we have just taken 16 percent of the 2020 final energy consumption, equivalent to 463 TWh, and then split the efficiency gains between worst-performing (55 percent) and other buildings (45 percent). The figure of 903 TWh from 2024 to 2030 is in line with the European Scientific Advisory Board on Climate Change (Bredahl *et al*, 2024) assessment of required energy savings of 98 to 113 TWh/y in the residential sector and 36 to 47 TWh/y in the tertiary sector by 2030.

To compute emissions savings, we first took the fuel mix of space heating and cooling and water heating, computing the share of each fuel for households (Figure 3), and extended it to all buildings. Then we attributed energy savings to the different fuels based on Eurostat's split and multiplied by the emission factors in Table A2.

Table A2: Emission factors

emission factors	Natural gas and LPG	Electricity	Wood	Diesel oil and kerosene	District heating	Coal
CO2/MWh	0.24	0	0	0.306	0	0.37

Source: European Commission.

Weighting potential energy savings by the fuel mix for heating and cooling in all countries gives fuel-specific energy and emission savings (Table A3).

Table A3: Potential EPBD fuel-specific energy savings in TWh and tCO2 (last column)

	Natural gas and LPG	Electricity	Firewood	Diesel oil and kerosene	District heating	Coal	Total in TWh	tCO2 from FF heating
EU27	378	85	203	103	103	30	903	133
Belgium	15	2	3	10	0	0	29	7
Bulgaria	1	2	5	0	2	1	11	0
Czechia	6	2	7	0	4	2	21	2
Denmark	2	1	3	1	7	-	15	1
Germany	106	9	28	33	18	1	195	36
Estonia	0	0	1	0	1	0	3	0
Ireland	3	1	0	7	-	2	14	4
Greece	3	3	3	6	0	0	14	2
Spain	22	7	12	15	-	0	56	10
France	64	40	39	22	8	0	174	22
Croatia	1	0	2	0	0	0	4	0
Italy	62	3	26	7	3	-	101	17
Cyprus	-	1	0	1	-	-	1	0
Latvia	0	0	1	0	1	0	3	0
Lithuania	1	0	2	0	2	0	5	0
Luxembou	1	0	0	1	-	0	2	0
Hungary	11	1	5	0	2	0	19	3
Malta	-	1	0	0	-	-	1	0
Netherland	41	2	2	0	2	0	46	10
Austria	6	2	7	4	3	0	22	3
Poland	14	1	19	1	16	19	69	10
Portugal	3	1	9	4	0	-	18	2
Romania	9	0	11	0	3	0	23	2
Slovenia	0	0	2	0	0	0	3	0
Slovakia	5	1	3	0	2	0	10	1
Finland	0	5	5	1	7	0	18	0
Sweden	0	7	4	0	13	-	25	0

Source: Bruegel based on Eurostat.

Our estimate of the emission savings from EPBD implementation implies emission reductions of 133 $MtCO_2$ equivalent between 2024 and 2030 at EU level. While sizable, these reductions would fall short of the Advisory Board's recommendation of 29 $MtCO_2$ equivalent/year. However, if firewood was to be considered not carbon

neutral and its emission factor was estimated at 0.420 (see Koffi *et al*, 2017), then the potential emission reductions would be as high as 218 $MtCO_2$ equivalent or 31$MtCO_2$ equivalent/year, in line with the Advisory Board's recommendations.

Table A4: implicit energy savings and emission reductions prescribed by the EPBD by 2030

	energy savnings in non-residential worst-performing buildings, TWh	energy savings in residential worst-performing buildings, TWh	energy savings in remaining residential buildings, TWh	Total energy savings, TWh	Potential emission reductions in Mt of CO_2eq
EU27	440	255	208	903	133
Belgium	15	8	7	29	7
Bulgaria	6	2	2	11	0
Czechia	8	7	6	21	2
Denmark	7	4	4	15	1
Germany	88	59	49	195	36
Estonia	1	1	1	3	0
Ireland	8	3	3	14	4
Greece	6	4	4	14	2
Spain	29	15	12	56	10
France	101	40	33	174	22
Croatia	NA	2	2	4	0
Italy	43	31	26	101	17
Cyprus	1	0	0	1	0
Latvia	1	1	1	3	0
Lithuania	2	1	1	5	0
Luxembourg	1	1	0	2	0
Hungary	8	6	5	19	3
Malta	0	0	0	1	0
Netherlands	29	9	8	46	10
Austria	9	7	6	22	3
Poland	30	22	18	69	10
Portugal	13	3	3	18	2
Romania	8	8	7	23	2
Slovenia	1	1	1	3	0
Slovakia	5	3	2	10	1
Finland	8	5	4	18	0
Sweden	11	7	6	25	0

Source: Bruegel

Note: Only emissions reductions from fossil fuels heating systems are included, hence the estimate does not reflect emission reductions from lower electricity consumption, nor from firewood or district-heating. The baseline is 2020.

For costs, we used the report *Comprehensive study of building energy renovation activities and the uptake of nearly zero-energy buildings in the EU* (Ipsos and Navigant, 2019), published by the European Commission.

The types of work included under 'energy renovations' are:

- Replacement of windows
- Replacement of the/a building entrance door
- Installation of thermal insulation on the facade (incl. cavity wall insulation)
- Installation of thermal insulation of the roof
- Installation of thermal insulation on the ground plate (floors)
- Installation of thermal insulation inside basements
- Installation of thermal insulation on the attic's floor
- Replacement or first-time installation of a space heat generator
- Replacement or first-time installation of a water heater (incl. solar thermal collector on the roof)
- Replacement or first-time installation of a radiator
- Replacement or first-time installation of a floor heating system
- Replacement or first-time installation of a mechanical ventilation system
- Replacement or first-time installation of a space cooling system (air- conditioner)
- Installation of a photovoltaic system (solar modules for electricity generation on the roof)

- (Automatic) shading system for windows to avoid overheating in summer

Ipsos and Navigant (2019) have tables reporting primary energy savings obtained between 2012 and 2016 by country and relative average investment costs. We computed the investment cost per lifetime energy saving of 1kWh as investment/energy savings, inflating the investment costs with a synthetic price index, obtained from the average between the two Eurostat price indices 'Construction producer prices or costs, new residential buildings' and 'Maintenance and repair of the dwelling' for 2015-2023. We took the average of the two indices as we could not find a specific index for deep energy renovations. The types of work involved in deep renovations generally require more interventions than the general repair and maintenance of dwellings, but also follow different dynamics than the price for construction works for new buildings.

Table A5: estimated investment costs for lifetime energy savings (EUR/kWh), in 2023

	Investment costs (EUR/kWh) after inflation					investment costs (EUR/kWh) after inflation			
	residential		non-residential			residential		non-residential	
Country	Medium	Deep	Medium	Deep	Country	Medium	Deep	Medium	Deep
EU27	*3.4*	*2.5*	*2.6*	*2.2*	Ireland	3.1	2.2	2.1	1.6
Austria	3.6	2.2	2.4	1.6	Italy	3.2	2.6	2.1	2.1
Belgium	3.6	3.4	1.8	1.9	Latvia	0.8	1.0	0.5	0.3
Bulgaria	3.2	1.4	2.7	1.3	Lithuania	1.2	0.3	0.8	0.2
Croatia	1.6	1.0	1.7	1.3	Luxembourg	4.9	3.5	3.3	2.7
Cyprus	2.4	1.6	2.5	1.8	Malta	3.5	2.2	2.4	2.8
Czechia	2.0	0.9	1.9	1.2	Netherlands	4.0	2.4	3.1	3.4
Denmark	4.4	2.1	2.3	2.0	Poland	1.5	1.3	1.0	1.0
Estonia	1.4	0.3	1.0	0.2	Portugal	4.4	3.4	3.6	3.2
Finland	3.8	3.8	1.5	1.2	Romania	1.7	0.9	3.1	5.7
France	3.2	2.5	2.5	2.4	Slovakia	2.8	1.0	1.9	1.5
Germany	5.1	3.0	3.7	3.1	Slovenia	1.9	1.0	1.3	0.8
Greece	2.6	1.8	1.0	0.8	Spain	1.3	0.7	3.7	1.6
Hungary	2.7	1.4	1.8	1.1	Sweden	6.7	3.6	3.3	2.9

Source: Bruegel based on the European Commission and Eurostat
Note: we do not use the EU's investment costs estimates to compute the overall investment gap, as this is the sum of the investment gap of single countries.

We then multiplied the investment costs for deep renovations[2] by the EPBD-prescribed energy savings and assumed that current investments in energy renovations are half the overall needs, in line with the EU Renovation Wave requirement for countries to double their renovation rates. So, for example, our estimate of the German energy savings for non-residential buildings is 88 TWh by 2030 and the estimated investment cost for deep renovations per kWh is €3.10; the total investment need for non-residential buildings is then €273 billion or €39 billion/year. Assuming that current investments in energy renovations are half that figure we obtain the additional investment need of €19.5 billion/year. We then did the same for all types of buildings and countries. The EU figure is the sum of all countries.

Potential energy savings were computed from 2021 country-specific energy prices for gas, diesel oil and electricity. Firewood prices were assumed to be geographic-area specific. A uniform coal price of €0.032/kWh – the 2021 retail price in Poland – was assumed, while the price of district heating was assumed to be the

[2] We decided to take the investment cost estimate for deep renovations only given the EPBD and the Renovation Wave focus on deep renovation. Moreover, the Advisory Board warns that shallow renovations may not be aligned with the EU's climate neutrality objectives and can create lock-ins (Bredahl *et al,* 2024). Given that deep energy renovations are the most cost-effective route to energy efficiency gains, our estimated investment costs might on the conservative side.

minimum of all other country-specific fuel prices. The fuel-mix of final energy consumption for space heating and cooling and water heating by county was used to weight the energy savings. A uniform carbon price of €60/tonne was also assumed; the price was multiplied by the relative potential emission reductions from the fossil fuels to be included in ETS II.

Table A.6: Assumed fuel prices in €/kWh

Fuel / Country	Natural gas and LPG	Electricity	Wood	Diesel oil and kerosene	District heating	Coal
EU27	0.071	0.229	0.036	0.115	0.036	0.032
Belgium	0.057	0.285	0.042	0.094	0.042	0.032
Bulgaria	0.054	0.106	0.042	NA	0.042	0.032
Czechia	0.056	0.184	0.021	0.102	0.021	0.032
Denmark	0.107	0.317	0.042	0.182	0.042	0.032
Germany	0.067	0.321	0.042	0.11	0.042	0.032
Estonia	0.059	0.163	0.023	0.114	0.023	0.032
Ireland	0.07	0.276	0.044	0.102	0.044	0.032
Greece	0.073	0.183	0.044	0.13	0.044	0.032
Spain	0.089	0.257	0.044	0.103	0.044	0.032
France	0.074	0.198	0.044	0.123	0.044	0.032
Croatia	0.039	0.13	0.044	0.102	0.039	0.032
Italy	0.085	0.231	0.044	0.152	0.044	0.032
Cyprus	NA	0.214	0.044	0.11	0.044	0.032
Latvia	0.036	0.164	0.023	0.118	0.023	0.032
Lithuania	0.034	0.141	0.023	0.097	0.023	0.032
Luxembourg	0.054	0.199	0.044	0.099	0.044	0.032
Hungary	0.031	0.1	0.025	0.161	0.025	0.032
Malta	NA	0.13	0.025	0.097	0.025	0.032
Netherlands	0.103	0.137	0.042	NA	0.042	0.032
Austria	0.067	0.225	0.042	0.119	0.042	0.032
Poland	0.042	0.156	0.021	0.121	0.021	0.032
Portugal	0.077	0.213	0.021	0.161	0.021	0.032
Romania	0.04	0.157	0.021	0.098	0.021	0.032
Slovenia	0.057	0.169	0.021	0.118	0.021	0.032
Slovakia	0.042	0.165	0.021	NA	0.021	0.032
Finland	NA	0.18	0.054	0.148	0.054	0.032
Sweden	0.175	0.236	0.054	0.129	0.054	0.032

Source: Bruegel based on Eurostat and publicly available information

Multiplying the values in Table A3 by the assumed prices (*Table A6*) gives the estimated energy savings in billions of euros.

Table A7 benchmarks our estimates of the additional yearly investment needs in energy renovations with the 2023 overall expenditures on all types of building renovations by country.

Table A7: total renovation expenditures in 2023 and additional yearly investment needs, in € billions

Country	2023 overall renovation expenditures (FIEC)	2024-2040 additional yearly investment needs in energy renovations (Bruegel)
Austria	7.1	3.2
Belgium	12.8	5.7
Bulgaria	0.2	1.2
Czechia	2.0	1.4
Germany	145.0	43.8
Denmark	5.6	2.1
Spain	11.9	4.7
Finland	7.8	2.7
France	42.1	30.8
Ireland	2.9	1.9

Italy	48.3	17.3
Netherlands	21.2	10.7
Portugal	2.7	4.2
Sweden	12.6	5.7

Source: Bruegel and FIEC