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Greenhouse gases emission factors for local emission inventories

Covenant of Mayors databases - Version 2022

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Abstract

The EU Covenant of Mayors for Climate and Energy initiative (CoM) brings together local and regional authorities voluntarily committing to develop and implement a Sustainable Energy and Climate Action Plan (SECAP), containing measures to reduce their energy related Greenhouse Gas (GHG) emissions. The Joint Research Centre (JRC) provides scientific, methodological and technical support to the EU CoM initiative; the JRC assists signatories with the preparation and implementation of their action plans through the development of methodological guidebooks, ensuring their coherence with the EU climate and energy policies as well as their scientific credibility.

In this context the JRC is responsible for regularly publishing GHG default emission factors used by local authorities to estimate GHG emissions due to: (1) consumption of fossil fuels and wastes (non-renewable); (2) consumption of biofuels, biomass, solar thermal and geothermal; (3) electricity consumption.

The dataset named “CoM Default Emission Factors” reports the default emission factors for the use of fuels and RES (Renewable Energy Sources), meanwhile the dataset named “GHG Emission Factors for Electricity Consumption” presents the default emission factors for indirect emissions from electricity consumption. The datasets are available on the Joint Research Centre Data Catalogue, under the Covenant of Mayors collection.

The main scope of this report it is to provide insights on the input data and methodologies used to build up the GHG emission factors datasets, highlighting the specific characteristics within the CoM context.

1 Introduction

The Covenant of Mayors for Climate & Energy (CoM) is an EU based initiative, launched in 2008 by the European commission to foster the implementation of climate change policies at urban level. Currently, the CoM has over 10000 signatories of local and regional governments committed to exceeding the EU's 2030 CO_2 reduction targets (Melica et al., 2022).

The Covenant of Mayors signatories commit themselves to develop a detailed knowledge of emissions, based on a commonly agreed methodology that proposes a framework for enabling local authorities to produce robust and comparable inventories of CO_2 emissions (Croci et al., 2017). The first step in this methodology involves establishing a Baseline Emission Inventory (BEI). The BEI is a production-based hybrid inventory, including both the direct Greenhouse Gases (GHG) produced within the territory and the indirect emissions due to heating, cooling, and electricity production consumed within the geopolitical boundaries (Kona et al., 2021).

The EC Joint Research Centre (JRC) manages the scientific and technical part of the CoM initiative, providing support to the local authorities, including, methodologies for emission accounting. This document provides an update to the GHG default emission factors initially published in the CoM reporting guidelines (Bertoldi, 2018; Koffi et al., 2017).

Box 1. Emission Factors Databases in the Covenant of Mayors initiative

The GHG emission factors are published and regularly updated on the Joint Research Centre Data Catalogue, under the Covenant of Mayors collection (https://data.jrc.ec.europa.eu/collection/id-00172).

The dataset named "**CoM Default Emission Factors**" reports the default emission factors for the use of fuels and RES (Renewable Energy Sources).

The dataset named "**GHG Emission Factors for Electricity Consumption**" presents the default emission factors for indirect emissions from electricity consumption.

The CoM Default Emission Factors (Chapter 2) quantify the direct CO_2 (in tCO_2/MWh) and GHG (in tCO_{2-eq}/MWh) emissions from the consumption of energy carriers and renewable energy sources (Standard approach) and their corresponding supply chains (Life Cycle Assessment approach).

- The CoM Standard default emission factors are the IPCC default factors for stationary combustion (IPCC, 2006)
- The Life Cycle Assessment (LCA) emission factors have been calculating by adding to the standard emission factors, the CO_2/CO_{2-eq} fossil emissions from the supply chain. LCA data were retrieved from the European Platform on Life Cycle Assessment[1], as well as other databases and literature reviews.

The GHG Emission Factors for Electricity Consumption (Chapter 3) estimate the indirect CO_2 (tCO_2/MWh) or GHG (tCO_{2-eq}/MWh) emissions due to local consumption of electricity.

The methodology used for building up the dataset "GHG Emission Factors for Electricity Consumption" is presented and discussed, highlighting the specific characteristics within the CoM context.

1 EPLCA (https://eplca.jrc.ec.europa.eu/index.html#menu1

2 CoM Default Emission Factors

2.1 Definition and use of CoM default emission factors

The CoM Default Emission Factors dataset[2] provides an update to the CoM emission factors initially published in Bertoldi (2010) and successively in Koffi (2017). According to the CoM methodology (Bertoldi, 2010; Bertoldi, 2018) the default emission factors have been calculated by applying two different approaches: the IPCC “standard” and the LCA (Life Cycle Assessment).

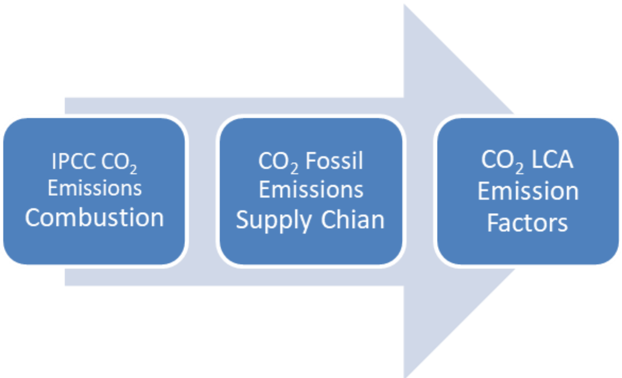
Tables 1 and Table 2 report the default emission factors for CO_2 (in tCO_2/MWh) and GHG (in $tCO_{2\text{-}eq}$/MWh) emissions from the consumption of energy carriers and renewal energy sources (Standard approach) and their corresponding supply chains (Life Cycle Assessment approach).

Box 2. Approaches used to estimate the default emission factors

In the **standard approach** (IPCC, 2006) the emission factors are based on the emissions released to the atmosphere in the combustion process. Such emissions are based on the carbon content of each fuel, when accounting for the CO_2 emissions only. While CoM commitment generally refers to CO_2 emissions, it can also include CH_4 and N_2O emissions. Therefore, both CO_2 (expressed in tCO_2/MWh) and GHG (expressed in $tCO_{2\text{-}eq}$/MWh) factors are provided. The GHG factors are calculated based on CH_4 and N_2O 100-year time horizon Global Warming Potential (GWP). Global Warming Potential values are from the IPCC (2007) Fourth Assessment Report.

The **Life Cycle Assessment** (JRC, 2022) approach takes into consideration the overall life cycle of each energy carrier, from the extraction/production process to the delivery to end-users. The default emission factors have been calculating by adding to the standard emission factors, the CO_2/$CO2_{\text{-}eq}$ fossil emissions from the supply chain. LCA data were retrieved from the European Platform on Life Cycle Assessment.

Figure 1: Elaboration of the LCA default emission factors



Source: JRC analysis, 2022

For fuels from biomass origin, all the upstream emissions from the cultivation, harvesting, collection, processing and transport of biomass are considered. Note that, LCA emission factors do not include emissions caused by land use change. In fact, CO_2 emission associated to direct and indirect land use changes (dLUC and iLUC) present a high degree of uncertainty, then we have chosen not to account for them.

The term “carbon neutrality” is used in this dataset to mean total compensation of CO_2 emissions from end-user consumption by the CO_2 removal by productive land. Carbon dioxide emissions from the combustion of biomass are not accounted for, as carbon dioxide was previously absorbed during the growth of biomass. Besides CO_2 emissions, the combustion of biomass may result in emissions of CH_4 and N_2O into the atmosphere, and therefore the emission of these two greenhouse gases are accounted for.

2 https://data.jrc.ec.europa.eu/dataset/72fac2b2-aa63-4dc1-ade3-4e56b37e4b7c

Table 1: Default Emission factors for fossil fuels and municipal wastes – update 2022

Energy carriers		**Standard (IPCC)**		**LCA**	
SECAP Template	*IPCC denomination*	*tCO_2/MWh*	*t CO_{2-eq}/MWh*	*tCO_2/MWh*	*t CO_{2-eq}/MWh*
Natural gas	Natural gas	0.202	0.202	0.226	0.242
Liquid gas	Liquefied Petroleum Gases	0.227	0.227	0.276	0.287
	Natural Gas Liquids	0.231	0.232	-	-
Heating Oil	Gas/Diesel oil	0.267	0.268	0.296	0.308
Diesel	Gas/Diesel oil	0.267	0.268	0.296	0.308
Gasoline	Motor gasoline	0.249	0.250	0.301	0.314
Lignite	Lignite	0.364	0.365	0.370	0.377
Coal	Anthracite	0.354	0.356	0.371	0.395
	Other Bituminous Coal	0.341	0.342	0.357	0.382
	Sub-Bituminous Coal	0.346	0.348	0.363	0.387
Other non-renewable fuels	Peat	0.382	0.383	0.388	0.391
	Municipal Wastes (non- biomass fraction)	0.330	0.337	0.429	0.437

Source: JRC analysis, 2022

Table 2: Default Emission factors for renewable energy sources - update 2022

Energy classes		Carbon neutrality	Standard (IPCC)		LCA	
	IPCC denomination	*cn=carbon neutrality* *ncn=not carbon neutrality*	*tCO_2/MWh*	*t CO_2-eq/MWh*	*t CO_2/MWh*	*t CO_2-eq/MWh*
Plant oil	Other Liquid Biofuels	*cn*	0.000	0.001	0.029	0.043
		ncn	0.287	0.287	0.316	0.330
Biofuel	Bio-gasoline	*cn*	0.000	0.001	0.124	0.177
		ncn	0.255	0.256	0.379	0.432
	Biodiesel	*cn*	0.000	0.001	0.068	0.105
		ncn	0.255	0.256	0.323	0.360
Other biomass	Wood/Wood Waste	*cn*	0.000	0.007	0.047	0.056
		ncn	0.403	0.410	0.450	0.460
	Municipal wastes (biom. fraction)	*cn*	0.000	0.007	0.053	0.061
		ncn	0.360	0.367	0.413	0.421
	Other Primary Solid Biomass	*cn*	0.000	0.007	0.008	0.019
		ncn	0.360	0.367	0.368	0.379
	Biogas	*cn*	0.000	0.0002	0.026	0.047
		ncn	0.197	0.197	0.222	0.244
Solar thermal	-	-	0.000	0.000	0.036	0.036
Geothermal	-	-	0.000	0.000	0.090	0.090

Source: JRC analysis, 2022

2.2 Input data for LCA emission factors

The LCA factors for the supply chain, have been revised based on European (and global) up-to-date Life Cycle Inventories (LCIs) retrieved from the European Platform on Life Cycle Assessment, as well as other databases and literature reviews (Table 3 and Table 4).

- Motor gasoline, gas/diesel oil, lignite, natural gas, and municipal wastes (non-biomass fraction): LCIs for the energy reflect the EU-27 average for the supply chains; data are valid until 2024.
- Anthracite, other bituminous coal and sub-bituminous coal: LCIs are not available from any database consulted nor in the literature review. Nevertheless, European Platform on Life Cycle Assessment offers LCIs of similar energy carriers that can be used as proxies with a sufficient data quality and approximation.
- Plant oil: the pathway reflects pure plant oil from palm oil; the data set represents the specific situation in Malaysia, focusing on the main technologies, the region specific characteristics and /or import statistics. Impacts of direct and indirect land use change are not included.
- Biogasoline: pathway of ethanol from wheat; the pathway covers all relevant process steps and technologies over the supply chain; this includes the cultivation of the crop, the transportation from the field to the ethanol production plant and the ethanol production.
- Biodiesel: the pathway reflects biodiesel from rapeseed methyl ester (RME); the figure covers all relevant process steps and technologies over the supply chain including the cultivation of the crop, the transportation from the field to the oil extraction and biodiesel production plant, the oil extraction and biodiesel production.
- Biogas: the pathway reflects the anaerobic fermentation of organic wastes and energy crops to biogas via wet fermentation process in a virtual biogas plant valid for fermentation of organic matter; three types of biogas are covered: biogas from biomass, biogas from landfill and biogas from sewage sludge.
- Municipal Wastes (biomass fraction): the data represents the thermal treatment in waste-to-energy plants with dry flue gas cleaning and SNCR (Selective Non-Catalytic Reduction) as NOx removal technology; the energy balance and the composition of the municipal solid waste reflect the situation in Europe.
- Wood: LCI reflects the production and local/regional transport of wood, representative for Germany, assuming timber spruce (65% moisture; 40% H_2O content); the primary product for production is trunk wood in various dimensions; when the trees have reached the desired height, they are harvested by harvester machines; the lumber is transported by truck to the sawmill and the average transport distance between the forest site and the sawing industry is 144 km; the wood is debarked and cut into the respective size by using big saws; the wood is ready for being packed and sold; besides the main product of timber, by-products such as bark, wood chips and sawdust are obtained.
- Other Primary solid biomass: the figure represents the specific situation in Germany, considering the country specific mix of different types of biomass and the respective transport to the power plants. The biomass mix includes materials such as: bagasse, biomass herbaceous, eucalyptus, hardwood, olive waste pellets, wastes (organic and municipal), palm oil residues, sewage sludge, slaughterhouse residue, softwood, winter wheat straw mix, wood chips, wood pellets and other wood residues according to the country specific situation.
- Geothermal technologies: heat pumps use electricity to extract heat from the external environment and through a compression system produce heat for space and/or water heating, mainly at domestic scale. Heat pumps can use air (ASHP), the ground (GSHP) and water (WSHP) as an external source of heat; the primary energy used for running the heat pump is a key consideration; the emission factors in this dataset refers to GHG emissions from GSHP installations in UK assuming an electricity mix based on 80% renewables (Greening & Azapagic, 2012).
- Solar thermal: data referring to a Domestic Hot Water (DHW) system with general solar heating unit and a thermochemical storage unit; the raw material acquisition and components manufacturing processes contributed 99% to the total environmental impact during the whole life-cycle (Lamnatou et al., 2015).

Table 3: LCIs for fossil fuels

Energy carrier in SECAP	Life Cycle Inventory (LCI)	Location	Reference year	Valid until
Motor Gasoline	Gasoline mix (premium) at refinery; from crude oil; production mix, at refinery; 10 ppm sulphur, 5.65 wt.% bio components	EU+EFTA+UK	2012	2024
Anthracite	Hard coal mix; technology mix; consumption mix, to consumer	EU+EFTA+UK	2015	2024
Gas /Diesel oil	Diesel mix at refinery; from crude oil; production mix, at refinery; 10 ppm sulphur, 7.23 wt.% bio components	EU+EFTA+UK	2012	2024
Other Bituminous Coal	Hard coal mix; technology mix; consumption mix, to consumer	EU+EFTA+UK	2015	2024
Sub-Bituminous Coal	Hard coal mix; technology mix; consumption mix, to consumer	EU+EFTA+UK	2015	2024
Lignite	Lignite mix; technology mix; consumption mix, to consumer	EU+EFTA+UK	2015	2024
Natural Gas	Natural gas mix; technology mix; consumption mix, to consumer; medium pressure level (< 1 bar)	EU+EFTA+UK	2015	2024
Municipal Wastes (non-biomass fraction)	Municipal waste in waste incineration plant; waste-to-energy plant with dry flue gas treatment, without collection, transport and pre-treatment; production mix (region specific plants), at plant; 10 MJ/kg net calorific value	EU+EFTA+UK	2018	2024
Peat	Peat mining; technology mix; production mix, at producer	Finland	2012	2024
Liquefied Petroleum Gas (LPG)	Liquefied Petroleum Gas (LPG) (70% propane, 30% butane); from crude oil; production mix, at refinery; mix of 70% propane and 30% butane	EU+EFTA+UK	2012	2024

Source: JRC analysis, 2022

Table 4: LCIs for renewable energies

Energy carrier in SECAP	Reference		Location	Reference year	Valid until
Biodiesel	LCI	Biodiesel based on rape seed methyl ester (RME); from rape seeds; production mix, at plant	EU+EFTA+UK	2012	2024
Bio gasoline	LCI	Bioethanol from wheat; from wheat; production mix, at plant	EU+EFTA+UK	2012	2024
Biogas	LCI	Biogas for bioenergy; technology mix/ anaerobic fermentation of different organic matter to biogas via wet fermentation; production mix, at plant; 44.3% vol. methane content, 15.1 MJ/m^3	EU+EFTA+UK	2015	2024
Municipal waste (biomass fraction)	LCI	Municipal waste in waste incineration plant; waste-to-energy plant with dry flue gas treatment, without collection, transport and pre-treatment; production mix (region specific plants), at plant; 10 MJ/kg net calorific value	EU+EFTA+UK	2018	2024
Other Primary Solid Biomass	LCI	Biomass (solid) for bioenergy; technology mix; consumption mix, to consumer	Germany	2012	2024
Wood	LCI	Timber spruce (65% moisture); technology mix; production mix, at plant; 65% moisture content	Germany	2018	2024
Other Liquid Biofuels	LCI	Palm oil, refined; technology mix; production mix, at plant; refined	Malaysia	2012	2024
Geothermal	-	Greening et Azapagic (2012)	UK	2012	-
Solar Thermal	-	Lammatou et al. (2015)	EU	2015	-

Source: JRC analysis, 2022

3 GHG Emission Factors for Electricity Consumption

3.1 Methodology and input data

The National and European Emission Factors for Electricity consumption (NEEFE) for end-user electricity consumption are calculated by dividing total national CO_2 emissions for the different input energy carriers consumed to produce electricity, by the total final electricity consumed. The total CO_2 due to electricity production was calculated by applying default emission factors (Annex 2) to the fuel consumed per energy carrier in the Electricity-only and in Combined Heat Power (CHP) plants.

According to the CoM methodology (Bertoldi et. al, 2018), NEEFE have been calculated by applying two different approaches to the energy carriers consumed to produce electricity: the IPCC "standard" and the LCA (Life Cycle Assessment) emission factors. The Eurostat Energy Balances (Eurostat, 2022) have been utilized to input the amount the energy carriers consumed. The emission factors for electricity were computed for each country as follow:

Total CO_2/GHG (electricity production) = $\sum I(c,p)EF(c)$

$$\text{NEEFE}= \frac{Total\ CO2\ /GHG\ (electricity\ production)}{Total\ electricity\ \ consumption} \quad \text{(Eq.1)}$$

I= fuel input

EF= IPCC/ LCA default emission factors

c= carrier

p= plant type (Main activity producer electricity only, Main activity producer CHP, Autoproducer electricity only, Autoproducer CHP)

Since CO_2/GHG emissions are expressed in tonnes (t) of CO_2/CO_2 equivalent and the electricity is expressed in MWh, the NEEFE is expressed in tCO_2/MWh or tCO_2eq/MWh.

Fuel inputs for electricity produced in CHP plants were separated from fuel inputs for heat production considering an energy conversion efficiency of 0.9 for heat (de la Rue du Can et al., 2015). For the CHP plants the amount of fuel used for the electricity was calculated as follows:

Fuel total= Fuel heat + Fuel electricity

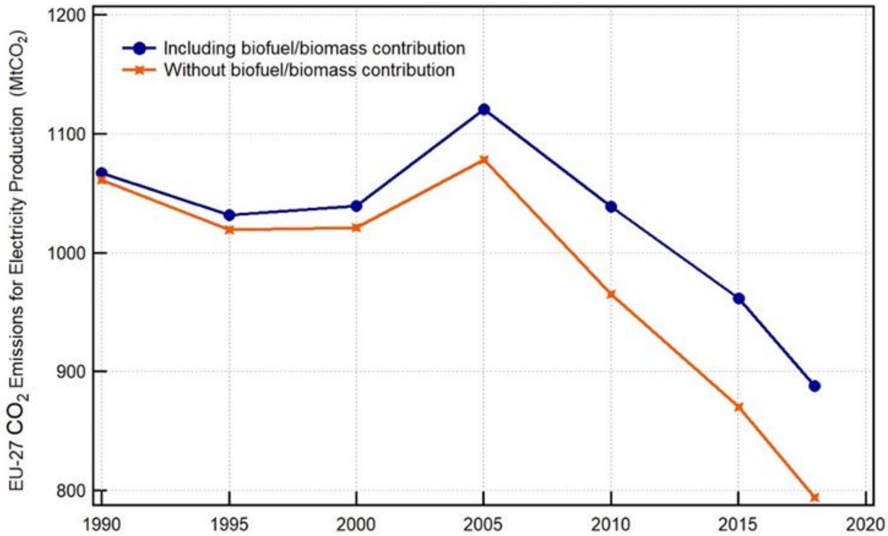
Fuel electricity= Fuel total - heat/0.90

3.1.1 Emissions from biofuel consumption in the NEEFE methodology

In the IPCC approach, the direct CO_2/GHG emissions from biomass/biofuels consumption are not included in the calculation of the NEEFE. In fact, it was applied the IPCC approach reporting only CO_2 emissions from fossil fuel and non-renewable (municipal and industry) wastes in the energy sector. In the frame of UNFCCC (United Nation Framework Convention on Climate Change) reporting, emissions from biomass/biofuels are reported separately, in the AFOLU sector.

In order to quantify the potential contribution of biofuels to CO_2 emissions from national electricity production, emissions from all fuels has been estimated for the years 1990 and 2018, assuming no carbon sink compensation in the biofuels/biomass production chain, i.e., applying IPCC default emission factors for Stationary Combustion to all energy carriers including biofuels (Figure 2). The estimated contribution of biofuels/biomass to CO_2 emissions from electricity production at EU-27 level in 2018 was 12%, with an increase from 1.0% to 8% over the period 1990-2010.

Figure 2: Estimated emissions ($MtCO_2$) due to electricity production in the NEEFE dataset, with biofuel/biomass contribution (blue line) and without the biofuel/biomass contribution (orange line)



Source: JRC analysis, 2022

It is worth noting that how emissions from biomass/biofuels consumption are accounted for in the context of the Covenant may be revised in the future, as their use in the EU is also expected to increase. Indeed, although the share of biofuels/biomass in the electricity production at EU level is expected to increase with time, the associated emissions should theoretically follow a less pronounced increasing trend, as sustainable production solutions are developed.

3.1.2 National CO_2 emissions accounting and electricity trade in the CoM context

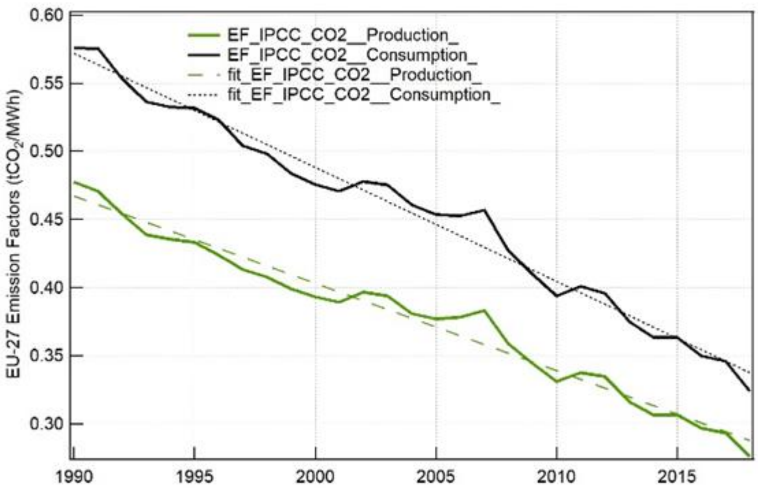
The NEEFE methodology is based on the assumption that all the GHG emissions produced nationally have to be allocated to the total amount of electricity consumed within the country. In a closed system without import or export, the electricity consumed is equal to the electricity produced minus the losses in the grid. Under this hypothesis the NEEFE definition leads to higher values of emission factors for electricity compared to emission factors for electricity production, attributing the grid losses to the final consumers (Koffi et al., 2017).

Moreover, export and imports of electricity have also an impact on NEEFE calculation. For countries that are net importers, imported electricity is counted on the consumption side without counting for production, while the opposite happens for next exporter countries. Consequentially the emission factors for electricity consumption could be both higher and lower than the emission factors for electricity production depending on the amount of import/export and grid losses.

At the European level, in fact the amount of electricity produced is higher than the electricity consumed, with an average ratio of 0.85 over the period 1990-2018. Figure 3 reports both the EU-27 emission factors for electricity consumption (black line) and emission factors for electricity production (green line). The latter are lower than the emission factors for electricity consumption due to combined effect of net electricity export and the losses of the electricity produced.

In the CoM perspective, the aspect of electricity trade has not been included, in fact these data would not fit the scope of the CoM initiative, which is in the end to compare CoM versus the national and EU CO_2 emissions from electricity.

Figure 3: 1990-2018 trends in the EU-27 emission factors for electricity consumption (black line) and for electricity production (green line)



Source: JRC analysis, 2022

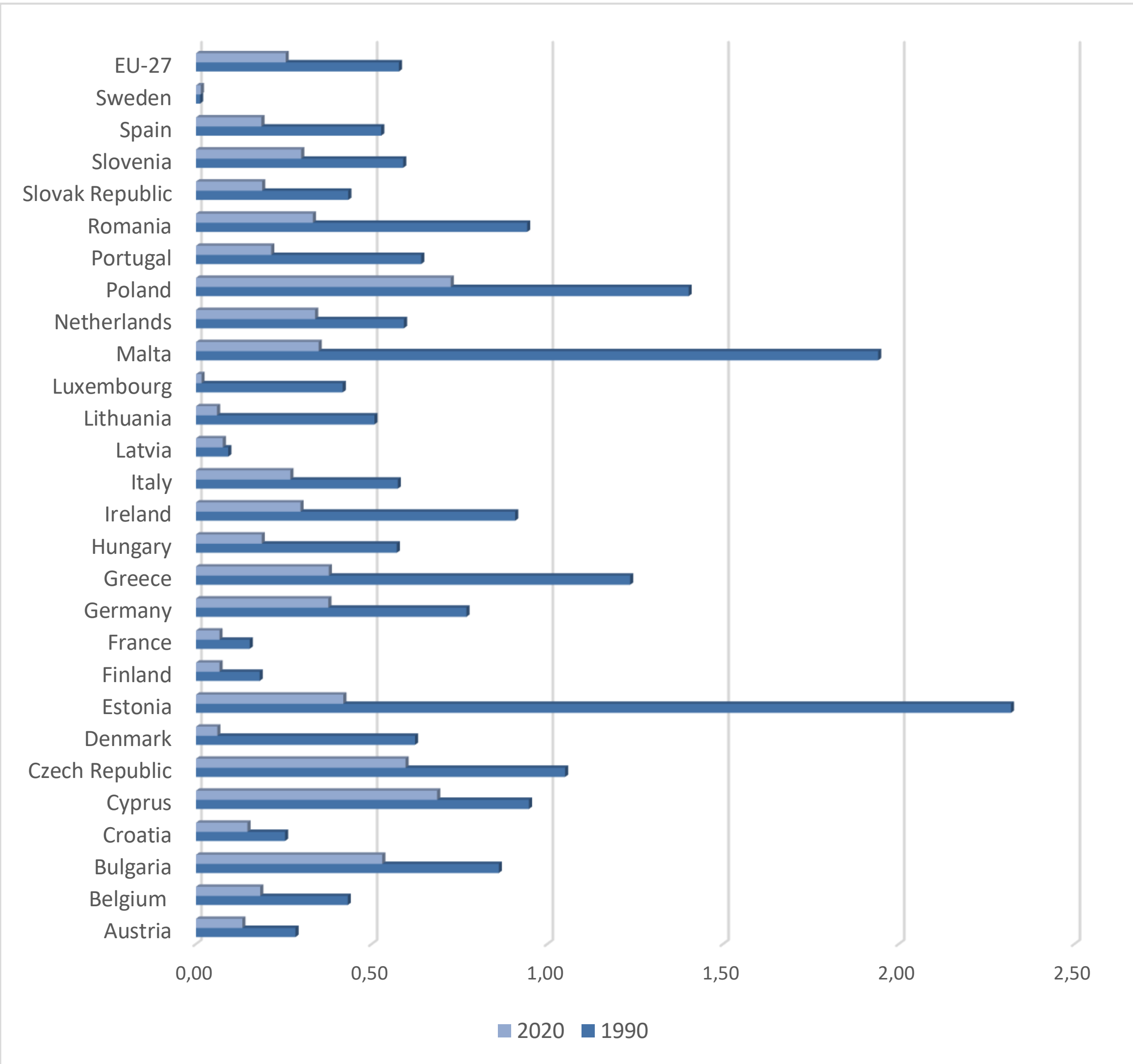
3.2 Current and future use of European/national emission factors for electricity consumption in the CoM framework

Our calculations show a general decrease in NEEFE over the 1990-2020 period, with an average annual rate of -1 %. In 2020, the GHG emissions due to electricity consumption were 56% less than in 1990 and 11% less than in 2019. This decreasing trend is expected to continue, mainly driven by the rapid transformation of the energy sector (Di Silvestre et al., 2018; Marrasso et al., 2019).

The EU electricity sector is expected to be one of the most relevant contributors to the climate mitigation by 2030 and be a keystone for the Union to reach net climate neutrality by 2050, according to recent EU legislation (COM/2021/550, 2021). Indeed, over the last decade across Europe the share of electricity from renewables has grown significantly. In 2018 more than 30% of electricity in EU has been produced from renewable based technologies, although with substantial differences among countries (Annex 1).

In 2020, Poland, Cyprus, Czech Republic and Bulgaria had the highest electricity consumption carbon intensity in the EU. The GHG intensities of electricity consumption were lowest in Sweden, Luxembourg, Lithuania and Denmark due to their high share of low-carbon electricity sources (Figure 4).

Figure 4: National and European Emission Factors for Electricity Consumption (tCO_{2-eq}/MWh)



Source: JRC analysis, 2022

The general rule of the Covenant of Mayors in estimating local emissions, requires the use of the same NEEFE emission factor in both the Monitoring and the Baseline Emission Inventory (Bertoldi, 2018). The rationale for using a constant NEEFE consists in the fact that under this assumption the trend in the local authority's emissions from electricity consumption will be solely driven by local consumption and, if applicable, local electricity production (Koffi et al., 2017). This helps local decision makers to understand their actual impact on the trend and changes in emissions from local energy consumption.

Box 3. Current use of NEEFE in the CoM framework

In the Covenant of Mayors Europe, the currently applied practice is to keep national emission factors constant, to clearly demonstrate the effect of increased local renewable energy production over time. At the same time Covenant cities calculate a local emission factor for electricity, by correcting the national emission factor for the baseline year based on local electricity production (Kona et al., 2019)

As at national level the energy mix changes with a higher Renewable Energy Sources (RES) share, at local level the CO_2 emissions linked to the final electricity consumption decrease. Clearly, this reduction is not directly linked to the actions taken at the local level that have still a limited influence on the overall national electricity generation mix.

The average GHG intensities of electricity consumption in 2020 was 0.254 ton $CO_{2\text{-eq}}$/MWh and according to the recent EU Reference Scenario (De Vita, A., 2021) the expected average emissions of the 2030 grid electricity mix, should reach a value of 0.176 tonnes $CO_{2\text{-eq}}$/MWh, due to the projected increase in the production of "carbon free" electricity from RES.

Box 4. Future use of NEEFE in the CoM framework

Probably in the next future, the benefit of the decarbonisation of the associated national grid will need to be included, because not accounting for the NEEFE trend may make it difficult for some signatories to reach their overall reduction target. Moreover, given their constantly decreasing trend, the use of non-updated NEEFE becomes lesser and lesser representative of the actual emissions generated by the cities with time passing.

Cities have key roles in mainstreaming renewable energy as well as facilitating system integration of renewable electricity in the urban energy system. On the supply side, local renewable energy generation can involve centralised and decentralised solutions for local electricity generation (Bertoldi et al., 2018). How in the cities will account for the emission due to the electricity consumption, will depend probably on the future role of energy production at local level.

4 Conclusions

In the framework of the EU Covenant of Mayors (CoM) the Joint Research Centre has developed a methodology for estimating the GHG default emission factors used by local authorities to report their GHG emissions due to: (1) consumption of fossil fuels and wastes (non-renewable); (2) consumption of biofuels, biomass, solar thermal and geothermal; (3) electricity consumption.

The CoM Default Emission Factors (Chapter 2) quantify the CO_2 (in tCO_2/MWh) and GHG (in tCO_2-eq/MWh) emissions from the consumption of energy carriers and renewable energy sources and their corresponding supply chains. The default emission factors have been calculated by applying two different approaches: the IPCC "standard" and the LCA (Life Cycle Assessment). The CoM Standard default emission factors are the IPCC default factors for stationary combustion. The Life Cycle Assessment (LCA) emission factors have been calculating by adding to the standard emission factors, the CO_2/$CO_{2\text{-eq}}$ fossil emissions from the supply chain. LCA data were retrieved from the European Platform on Life Cycle Assessment.

The default emission factors for electricity consumption (Chapter 3) are calculated by dividing total national CO_2 emissions for the different input energy carriers consumed to produce electricity, by the total final electricity consumed. The methodology is meant to fit the CoM purposes and it was designed to allow a comparison between the CoM members and the national and EU CO_2 emissions from electricity, assessing also the CoM contribution to the national/EU mitigation efforts.

Following the IPCC approach, reporting only CO_2 emissions from fossil fuel and non-renewable (municipal and industry) wastes in the energy sector, the direct CO_2/GHG emissions from biomass/biofuels consumption are not included. In the CoM perspective, the aspect of electricity trade has not been taken into account and the methodology is based on the assumption that all the GHG emissions produced nationally have to be allocated to the total amount of electricity consumed within the country.

Generally, the emission factors for electricity consumption show a decreasing trend over the period 1990-2020, mainly due to the increasing use of renewable sources in the power sector and the shift from coal to natural gas. The greater the share of renewables in the nation's energy mix, the lower the emissions for electricity consumption at local level. Probably in the next future, the benefit of the decarbonisation of the associated national grid will need to be included, because not accounting for the NEEFE trend may make it difficult for some signatories to reach their overall reduction target.

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List of abbreviations and definitions

AFOLU	Agriculture, Forestry and Other Land Use
ASHP	Air source heat pump
BEI	Baseline Emission Inventory
CHP	Combined Heat Power
CoM	Covenant of Mayors for Climate and Energy Initiative
DHW	Domestic Hot Water
dLUC	direct land use changes
EPLCA	European Platform on Life Cycle Assessment
GHG	Greenhouse Gas
GSHP	Ground source heat pump
GWP	Global Warming Potential GWP
iLUC	indirect land use changes
IPCC	Intergovernmental Panel on Climate Change
LCA	Life Cycle Assessment
LCI	Life Cycle Inventory
NEEFE	National and European Emission Factors for Electricity consumption
RES	Renewable Energy Sources
SECAP	Sustainable Energy and Climate Action Plan
SNCR	Selective Non-Catalytic Reduction
UNFCCC	United Nation Framework Convention on Climate Change
WSHP	Water source heat pump

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Annex 1. Share of electricity from renewable sources in total electricity generation

	Share of electricity from renewable sources in total electricity generation %					
	2000	**2005**	**2010**	**2015**	**2017**	**2018**
EU-27	15.5	15.4	22.1	29.8	29.9	32.3
EU-28	13.9	14.1	20.4	29.3	29.8	32.4
Austria	73	63	66	77	76	77
Belgium	1	3	7	21	19	23
Bulgaria	7	10	13	18	14	20
Croatia	57	54	63	67	60	72
Cyprus	0	0	1	9	9	9
Czechia	3	4	7	11	11	11
Denmark	16	27	32	65	70	68
Estonia	0	1	8	14	14	16
Finland	34	33	30	45	47	46
France	13	10	14	16	17	20
Germany	6	10	17	30	34	35
Greece	8	11	18	29	25	30
Hungary	1	5	8	11	11	12
Ireland	5	7	13	28	29	33
Italy	19	16	26	39	35	40
Latvia	68	70	55	50	73	52
Lithuania	3	3	19	42	76	80
Luxembourg	41	6	8	32	67	72
Malta	0	0	0	8	10	10
Netherlands	3	8	9	12	15	17
Poland	2	3	7	14	14	13
Portugal	30	18	53	48	39	50
Romania	29	34	34	40	38	41
Slovakia	15	15	22	23	24	22
Slovenia	29	24	29	29	28	32
Spain	16	15	33	35	32	38
Sweden	57	51	55	63	58	56
United Kingdom	3	4	7	25	29	33

Source: Eurostat, 2020

Annex 2: Emission factors for the direct CO_2/GHGs emissions from electricity generation

Energy Carriers	IPCC		LCA
	tCO_2/MWh	tCO_2-eq/MWh	tCO_2-eq/MWh
Anthracite	0.354	0.356	0.395
Coking coal	0.341	0.342	0.359
Other bituminous coal	0.341	0.342	0.382
Sub-bituminous coal	0.346	0.348	0.387
Lignite	0.364	0.365	0.377
Patent fuel	0.351	0.353	0.370
Coke oven coke	0.385	0.387	0.404
Gas coke	0.385	0.385	0.402
Coal tar	0.291	0.292	0.309
BKB	0.351	0.353	0.370
Gas works gas	0.160	0.160	0.177
Coke oven gas	0.160	0.160	0.177
Blast furnace gas	0.936	0.936	0.953
Other recovered gases	0.160	0.160	0.177
Peat	0.382	0.383	0.391
Oil shale and oil sands	0.385	0.387	0.387
Natural gas	0.202	0.202	0.242
Crude/NGL/FS if no detail.	0.264	0.265	0.306
Crude oil	0.264	0.265	0.306
Natural gas liquids	0.231	0.231	0.272
Refinery feedstocks	0.264	0.265	0.306
Additives/blending comp.	0.264	0.265	0.305
Other hydrocarbons	0.264	0.265	0.305
Refinery gas	0.207	0.208	0.248
Ethane	0.222	0.222	0.262
Liquefied petroleum gases	0.227	0.227	0.287
Motor gasoline excl. biofuels	0.249	0.250	0.314
Aviation gasoline	0.252	0.253	0.293
Gasoline type jet fuel	0.257	0.258	0.298
Kerosene (jet fuel excl.biofuels)	0.257	0.258	0.298
Other kerosene	0.259	0.260	0.300
Gas/diesel oil excl. biofuels	0.267	0.268	0.308
Fuel oil	0.279	0.280	0.320
Naphtha	0.264	0.265	0.305
White spirit & SBP	0.264	0.265	0.305
Lubricants	0.264	0.265	0.305
Bitumen	0.291	0.291	0.331
Paraffin waxes	0.264	0.265	0.305
Petroleum coke	0.351	0.352	0.392

Energy Carriers	IPCC		LCA
	tCO_2/MWh	tCO_{2-eq}/MWh	tCO_{2-eq}/MWh
Other oil products	0.264	0.265	0.305
Industrial waste	0.515	0.522	0.522
Municipal waste (non-renew.)	0.330	0.337	0.437
Municipal waste (renewable)	0.000	0.007	0.061
Primary solid biofuels	0.000	0.007	0.019
Biogases	0.000	0.000	0.047
Biogasoline	0.000	0.001	0.177
Biodiesels	0.000	0.001	0.105
Other liquid biofuels	0.000	0.001	0.043
Hydro	0.000	0.000	0.031
Geothermal	0.000	0.000	0.090
Solar photovoltaics	0.000	0.000	0.106
Solar thermal	0.000	0.000	0.036
Wind	0.000	0.000	0.031

Source: JRC analysis, 2022

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