European Commission

JRC TECHNICAL REPORTS

Covenant of Mayors for Climate and Energy: Default emission factors for local emission inventories

Version 2017

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2017

EUR 28718 EN

Joint Research Centre

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JRC Science Hub
https://ec.europa.eu/jrc

JRC107518

EUR 28718 EN

PDF ISBN 978-92-79-71479-5 ISSN 1831-9424 doi:10.2760/290197

Luxembourg: Publications Office of the European Union, 2017

How to cite this report: Koffi B, Cerutti A.K., Duerr M., Iancu A., Kona A., Janssens-Maenhout G., *Covenant of Mayors for Climate and Energy: Default emission factors for local emission inventories– Version 2017*, EUR 28718 EN, Publications Office of the European Union, Luxembourg, 2017, ISBN 978-92-79-71479-5, doi:10.2760/290197, JRC107518.

Table of Content

Acknowledgements

This technical specification document has been produced as part of the Covenant of Mayors (CoM) initiative. Authors thank the Directorate General for Energy (DG ENER) of the European Commission for their support to the activities of the Joint Research Centre (JRC) in the framework of CoM. We are also especially grateful to Suvi Monni (*Benviroc*, Finland; previously at JRC) and to our JRC colleagues, Marilena Muntean, Monica Crippa, Laura Lonza, Giulia Melica, Silvia Rivas Calvete, Paolo Bertoldi, Jean-François Dallemand and Julian Wilson, who provided valuable input and suggestions in revising the default emission factors and/or reviewing this report.

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Abstract

The Covenant of Mayors for Climate and Energy initiative, hereafter called "Covenant" or "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 (and non-energy) related Greenhouse Gas (GHG) emissions.

Within the CoM 2010 guidebook 'How to develop a Sustainable Energy Action Plan' (Bertoldi et al., 2010), Part II focuses on the compiling of local GHG emission inventories in the 28 Member States of the European Union (EU). This technical report provides an update of the CoM default emission factors, reported in Part II of the CoM 2010 guidebook and subsequently revised (CoM, 2014; CoM, 2016), together with information on the methodologies, assumptions and data sources, as well as recommendations for their application to the calculation of CO_2 and GHG (CO_2, CH_4 and N_2O) emissions due to local use or production of energy (fuel, municipal wastes, renewable energy sources (RES), electricity). As for previous versions, the CoM default emission factors - Version 2017 (expressed in tCO_2 or CO_2 equivalent/MWh), to be used to estimate *standard* direct emissions are the IPCC (2006) default factors for stationary combustion for the energy carriers and RES, the most commonly used in the European Union. The CoM default emission factors to estimate local emissions using the Life Cycle Assessment approach, which also includes emissions from the entire supply chain, have been updated using the lastest version (v3.2) of the European Life Cycle Database, as well as other Life Cycle databases and literature reviews. For indirect emissions from local consumption of electricity, national and EU annual factors have been calculated for the 1990 to 2013, using an updated methodological approach and an extended set of energy data (IEA, 2016). The GHG emission factors (in tCO_2-eq/MWh) have been estimated using the 100-year time horizon Global Warming Potential factors from the IPCC Fourth Assessment Report (IPCC, 2007), which are the ones currently recommended to the EU countries for the national inventory reporting, in the frame of the United Nations Framework Convention on Climate Change.

Regular updates of CoM default emission factors are foreseen for the future. New CoM signatories are therefore recommended to use the latest version of Annex I available from the Covenant on-line library[1]. It is important to note is that the emission factors used to calculate emission inventories should be consistent for the entire implementation process of the SECAP. In particular, since more recent knowledge and technologies can give substantial changes, it is strongly recommended when opting for the use of CoM default emission factors, not to modify the ones applied to the Baseline Emission Inventory during the monitoring phase, in order to identify the trends and changes in local emissions that are due to local energy production and consumption. When selecting the CoM default emission factors, it is also important to ensure that they are appropriate to local fuel quality and composition. If local authorities prefer to use emission factors that better reflect the properties of the fuels used in their territory for the calculation and update of their local emission inventories, they are welcome to do so, when more country specific or local data are available and reliable.

[1] http://www.eumayors.eu/Library,84.html

Introduction

The Covenant of Mayors for Climate and Energy initiative (hereafter called "Covenant" or "CoM") brings together local and regional authorities voluntarily committing to implementing a Sustainable Energy and Climate Action Plan (SECAP) containing measures to reduce their energy (and non-energy) related CO_2 or Greenhouse Gas (GHG) emissions. Initially, the CoM signatories had to submit a Sustainable Energy Action Plan (SEAP) to reduce their CO_2 emissions by at least 20% by 2020. Since 2015, the signatories committing to the "Covenant of Mayors for Climate and Energy" have to develop and implement a SECAP allowing reducing their CO_2 (or GHG) emissions by at least 40% by 2030. When joining the Covenant, local authorities have to define a minimum CO_2 emission reduction by the target year, relative to the emissions calculated for a baseline year (1990 or the nearest following year for which reliable data are available), which is set by the signatory. The Baseline Emission Inventory (BEI) for the baseline year shows where the local authority was at the beginning and the successive monitoring emission inventories (MEI) show the progress towards the target. Elaborating these reference emission inventories is therefore of critical importance, as they are the instrument for the local authority to measure the impact of its actions related to climate change.

The guidebook 'How to develop a Sustainable Energy Action Plan' (Bertoldi et al., 2010) provides a flexible but coherent set of principles and recommendations, which allow *local authorities to develop a SEAP in a way that suits their own circumstances, permitting those already engaged in energy and climate action to come on board of the Covenant of Mayors, while continuing to follow the approaches they have used before with as little adjustments as possible.* The Covenant of Mayors *concerns action at local level, within the competence of the local authority.* Therefore, *the SEAP should concentrate on measures aimed at reducing the CO_2 emissions and final energy consumption by end users* (Bertoldi et al., 2010).

The present report provides an update to the CoM default emission factors, initially published in part II of the above-mentioned Guidebook (which focuses on the building of local GHG emission inventories) and subsequently updated in CoM reporting Guidelines (CoM, 2014; CoM, 2016). The CoM default emission factors, which are the ones proposed to calculate the local emission inventories in the CoM online templates, are provided for both the standard and LCA (Life Cycle Assessment) approaches. In the standard approach, 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-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). The LCA approach takes into consideration the overall life cycle of each energy carrier, from the extraction/production process to the delivery to end-users. They have been calculated by adding the emission factors due to the supply chain to the standard emission factors. Only LCA GHG factors have been calculated because the emissions from the supply chain are usually provided in CO_2-eq.

This new version (2017) of CoM default emission factors includes:

a) Emission factors for the consumption of fossil fuels and wastes (non-renewable)
b) Emission factors for the consumption of biofuels, biomass, solar thermal and geothermal renewable energy sources (RES)

c) Emission factors for local electricity production from other RES (wind, hydroelectric, photovoltaics)
d) National and European Emission Factors for Electricity consumption (NEEFE)

The emission factors a) b) and c) can be used by local authorities to quantify the direct emissions due to the consumption of the energy carriers and RES (standard approach) and corresponding supply chains (LCA approach). They are provided in this report and in CoM online templates, for the most commonly used energy carriers and RES, in Europe. The NEEFE factors d) allow the estimation of the emissions from the production of electricity that is consumed in the local territory. These emissions are also calculated by both Standard and LCA approaches, by applying the relevant emission factors to all individual energy carriers used in the national production of electricity.

The definitions, methods and data sources applied to the calculation of CoM Default emission factors – Version 2017, for the "direct" use of fuels and RES (including the supply chain), and for the indirect emissions from electricity consumption are detailed in Chapter 1 and Chapter 2, respectively. The corresponding emission factors are provided in **Annex I,** as detailed in Table 1. The specific comments and recommendations when using these factors are provided in sections 1.4 and 2.5, respectively.

Table 1. The CoM default emission factors – Version 2017 provided in Annex I of this report ('X')

	Inventory approach	GHG(s)		Emission factor(s) per energy carrier or sector[2]	Coverage	Annex[3]
		CO_2 (tCO_2/MWh)	CO_2, CH_4, N_2O (tCO_2-eq/MWh)			
Emissions from consumption/ use of fuels and RES (Chapter 1)	Standard	X	X	One factor for each of the most commonly used fuel or RES	Global	a) AI.1 b) AI.2 c) AI.3[4]
	LCA		X	One factor for each of the most commonly used fuel or RES	EU-28 or global for the supply chain	a) AI.1 b) AI.2 c) AI.3
Emissions from electricity consumption (Chapter 2)	Standard	X	X	One factor for emissions from all input energy carriers[5] consumed at national and EU levels	National and EU-28	d) AI.4.1 d) AI4.2
	LCA		X	One factor for emissions from all input energy carriers consumed at national and EU levels	EU-28 or global for the supply chain	d) AI.4.3

[2] per MWh of fuel, waste, RES or electricity consumed
[3] See core text for the definition of points a, b, c and d
[4] No GHG emission are accounted for in the standard approach for wind, hydroelectric and photovoltaics
[5] No GHG emission is accounted for renewable municipal waste, biofuels and biomass in the calculation of the NEEFEs in the case of the standard approach (see section 2.3.1).

1. Update of CoM emission factors for the use of fuels and RES

CoM default *standard* emission factors: The emissions taking place due to consumption of energy carriers to be reported in the local inventory can be calculated using the standard approach, i.e. by applying IPCC "*standard*" emission factors in line with IPCC principles. The CoM default *standard* emission factors, which are proposed in the menu of the CoM on-line BEI/MEI templates for the CoM signatories using the standard approach (94% of EU-28 signatories as of September 2016; Annex II), correspond to the IPCC (2006) CO_2 emission factors for stationary combustion of the energy carriers the most commonly used in Europe, as in CoM 2010 Guidebook (Bertoldi et al., 2010) and CoM 2014 and 2016 guidelines. However, the GHG factors, which include the three CO_2, CH_4 and N_2O gases, are no longer calculated using the 100-year time horizon Global Warming Potential factors from IPCC Second Assessment report (IPCC, 1995), but instead we use those of the Fourth Assessment report[6] (IPCC, 2007), as these are the ones currently recommended for the national inventory reporting, in the frame of the United Nations Framework Convention on Climate Change.

CoM default LCA emission factors: As with the CoM default standard emission factors, the CoM default LCA emission factors are proposed by default in the CoM reporting template for the CoM signatories using the LCA approach (6% of EU-28 signatories as of September 2016; see Annex II for details). They are made up of the emission factors from fuels and RES consumption (i.e. the *standard* emission factors), together with the corresponding supply chains. The LCA factors for the supply chain, which exclude both the capture of CO_2 in the cultivation of biofuels/biomass raw materials and the CO_2 emissions from consumption by the end-users, have been revised by A. Cerutti (2016) for the current update of CoM default emission factors (see Annex III), based on European (and global) up-to-date Life Cycle Inventories (LCIs) and an exhaustive literature review, as summarized in the 1.1 to 1.3 following sections.

1.1 Updated literature and datasets on LCA emission factors

In general, there are three possibilities for choosing a LCA Emission Factor (EF) for an energy source:

a) calculate the EF for the actual example for which it will be applied
b) adopt as a proxy the EF of a different case study described in the scientific/technical literature
c) calculate the EF from the Life Cycle Inventory of the energy carrier as described in a database

In the case of the Covenant of Mayors initiative, the ad-hoc calculation of the EF for each energy technology for each country is not a viable solution. Adopting EFs from a literature case study (case b) is also very critical because case studies published are usually focused on a specific, local situation that can only rarely be generalised to a country or (even more difficult) to Europe. The type of literature that would be useful for adopting generalised EFs is review papers. Such papers usually contain several case studies for a given area or for a specific technology and their results can be considered of general value. In order to calculate the EF from a LCI database (case c), it is necessary to check the coherence of the inventory with the context in which it would be applied and the dates of validity of the inventory. It is of

[6] $GWP_{CH_4} = 25$; $GWP_{N_2O} = 298$

particular importance to check that the values reported are up-to-date and still match the typical technology used for energy supply.

- Updated literature review: In the preparation of the first version of the Covenant guidebook (Bertoldi et al., 2010), the number and the results of review papers were not sufficient to determine robust EFs that could usefully be used as general averages or proxies. An extensive literature search for LCA reviews for energy production technologies was conducted for the present update. Results of the literature search and reference values are presented in Table 2 for fossil fuels, waste and renewable energies used for heat generation and in Table 3 for electricity production from local renewable sources. The reference values found in all case studies show a high range of variability that can be due to several factors. As expected, the number of review papers has increased a lot in recent years but, with a consequent increase in the variability of the EFs.

- Updated LCI databases: In 2013-2014, the Joint Research Centre performed a significant update of the European Life Cycle Database (ELCD, 2015; http://eplca.jrc.ec.europa.eu/ELCD3/index.xhtml) including the LCI of several energy technologies, making such LCIs more robust than the ones previously recommended by CoM reporting guidelines (CoM, 2014; CoM, 2016). Details on LCI data available in ELCD v3.2 as well as in the NEEDS (http://www.needs-project.org/needswebdb/) and Ecoinvent (http://www.ecoinvent.org/database/ecoinvent-33/ecoinvent-33.html) databases used in this report, are reported in Tables 4 to 6.

Version 2017 of CoM default emission factors provided in Annexes I.1, I.2 and I.3 has been defined based on the information reported in Tables 2 to 6. The choice of the recommended reference value for each energy carrier was done through a case by case analysis as described in the following sub-sections.

Table 2. Review papers of case studies on heat generation from different energy carriers. For each review paper are reported the number of case studies considered, the minimum and the maximum LCA EFs found for the supply chain and, for few cases, if a suggestion for a general LCA EF is expressed

Source	Reference	Case studies	Min LCA EF [gCO_2/kWh]	Max LCA EF [gCO_2/kWh]	Suggested LCA EF or LCA EF average [gCO_2/kWh_e]
Motor oil	Turconi et al., 2013	10	530.0	900.0	Na
Motor oil	Weisser, 2007	5	500.0	1200.0	na
Motor oil	Ardente et al., 2008	6	780.0	900.0	na
Coal	Evans et al., 2009	48	na	na	1004.0
Coal	Weisser, 2007	7	950.0	1250.0	na
Coal	Ardente et al., 2008	6	900.0	1200.0	na
Coal	Turconi et al., 2013	36	660.0	1050.0	na
Lignite	Turconi et al., 2013	7	800.0	1300.0	na
Lignite	Weisser, 2007	3	800.0	1700.0	na
Natural Gas	Evans et al., 2009	48	na	na	543.0
Natural gas	Weisser, 2007	9	440.0	780.0	na
Natural gas	Ardente et al., 2008	6	400.0	500.0	na
Natural gas	Turconi et al., 2013	23	380.0	1000.0	na
Waste treatment	Amponsah et al., 2014	4	97.2	1000.0	na
Biomass	Bhat & Prakash, 2009	5	35.0	178.0	na
Biomass	Turconi et al., 2013	25	8.5	130.0	na
Biomass	Weisser, 2007	3	35.0	99.0	na
Biomass	Muench & Guenther, 2013	25	0.5	5.9	2.3
Biomass	Amponsah et al., 2014	14	25.5	550.0	na
Geothermal[1]	**Amponsah et al., 2014**	**4**	**11.0**	**78.0**	**50.0**
Geothermal	Evans et al., 2009	48	na	na	170.0
Geothermal	Asdrubali et al., 2015	20	16.9	142.0	33.6
Solar thermal[1]	**Amponsah et al., 2014**	**6**	**36.2**	**43.0**	**39.6**
Solar thermal	Bhat & Prakash, 2009	3	13.6	202.0	na

[1] **Source of the updated CoM Default LCA Emission factor (Annex I)**

Table 3. Review papers of case studies on electricity generation from local renewable sources. For each review paper are reported the number of case studies considered, the minimum and the maximum EFs found and, for few cases, if a suggestion for a general EF is expressed

Source	Reference	Case studies	Min LCA EF [gCO_2/kWh]	Max LCA EF [gCO_2/kWh]	Suggested LCA EF or LCA EF average [gCO_2/kWh_e]
Hydropower	Amponsah et al., 2014	11	2.0	60.0	20.0
Hydropower	Ardente et al., 2008	6	15.0	40.0	na
Hydropower	Asdrubali et al., 2015	11	2.2	74.8	11.6
Hydropower	Bhat & Prakash, 2009	3	3.7	237.0	na
Hydropower	Evans et al., 2009	48	na	na	41.0
Hydropower	Kadiyala et al., 2016	19	1.2	609.2	19.7
Hydropower	Raadal et al., 2011	39	0.2	152.0	2.9
Hydropower	Turconi et al., 2013	12	1.0	20.0	na
Hydropower	Weisser, 2007	4	1.0	34.0	na
Solar photovoltaic (PV)[1]	**Amponsah et al., 2014**	**19**	**9.4**	**300.0**	**30.5**
Solar PV	Ardente et al., 2008	6	50.0	100.0	na
Solar PV	Asdrubali et al., 2015	33	9.4	167.0	29.2
Solar PV	Bhat & Prakash, 2009	9	53.4	210.0	na
Solar PV	Evans et al., 2009	48	na	na	90.0
Solar PV	Nugent & Sovacool, 2014	57	1.0	218.0	49.9
Solar PV	Turconi et al., 2013	22	13.0	190.0	na
Solar PV	Weisser, 2007	5	43.0	73.0	na
Solar PV (amorphous)	Sherwani & Usmani, 2010	5	15.6	5.0	na
Solar PV (Mono-crystalline)	Sherwani & Usmani, 2010	7	44.0	217.0	na
Solar PV (Poly-crystalline)	Sherwani & Usmani, 2010	7	9.4	104.0	na

[1] Source of the updated CoM Default LCA Emission factor (Annex I)

Table 3 (continued). Review papers of case studies on electricity generation from local renewable sources. For each review paper are reported the number of case studies considered, the minimum and the maximum EF found and, for few cases, if a suggestion for a general EF is expressed.

Source	Reference	Case studies	Min LCA EF [gCO_2/kWh]	Max LCA EF [gCO_2/kWh]	Suggested LCA EF or LCA EF average [gCO_2/kWh_e]
Windpower	Asdrubali et al., 2015	20	6.2	46.0	9.4
Windpower	Bertasiene et al., 2015	34	1.0	185.0	10.7
Windpower	Bhat & Prakash, 2009	10	0.4	123.7	na
Windpower	Evans et al., 2009	48	na	na	25.0
Windpower	Lenzen and Munksgaard 2002	72	7.9	123.7	na
Windpower	Raadal et al., 2011	63	4.6	55.4	18.0
Windpower	Turconi et al., 2013	22	3.0	41.0	na
Windpower	Weisser, 2007	8	8.0	30.0	na
Windpower	Nugent & Sovacool, 2014	39	0.4	364.0	34.1
Windpower (Offshore)	Amponsah et al., 2014	5	5.3	24.0	13.0
Windpower (Offshore)	Arvesen and Hertwich, 2012	13	7.8	33.4	16.2
Windpower (Onshore)	Amponsah et al., 2014	14	1.7	81.0	16.0
Windpower (Onshore)	Arvesen and Hertwich 2012	44	6.6	55.6	19.5

Table 4. Details of LCIs available in ELCD v3.2 for fuels and energy carrier for heat

Energy carrier in SEAP or SECAP	Full LCI name	Proxy	Location	Reference year	Valid until
Motor Gasoline[1]	**Gasoline mix (regular) at refinery; from crude oil and bio components, fuel supply; production mix, at refinery;10 ppm sulphur, 5.75 wt.% bio components**	**no**	**EU-27[2]**	**2008**	**2015**
Anthracite[1]	**Hard coal mix; technology mix; consumption mix, at consumer**	**yes**	**EU-27**	**2008**	**2015**
Gas /Diesel oil[1]	**Diesel mix at refinery; from crude oil and bio components, fuel supply; production mix, at refinery;10 ppm sulphur, 5.75 wt.% bio components**	**no**	**EU-27**	**2008**	**2015**
Other Bituminous Coal[1]	**Hard coal mix; technology mix; consumption mix, at consumer**	**yes**	**EU-27**	**2008**	**2015**
Sub-Bituminous Coal[1]	**Hard coal mix; technology mix; consumption mix, at consumer**	**yes**	**EU-27**	**2008**	**2015**
Lignite[1]	**Lignite mix; technology mix; consumption mix, at consumer**	**no**	**EU-27**	**2008**	**2015**
Natural Gas[1]	**Natural Gas Mix; technology mix; consumption mix, at consumer; onshore and offshore production incl. pipeline and LNG transport**	**no**	**EU-27**	**2008**	**2015**
Municipal Wastes[1]	**Waste incineration of municipal solid waste (MSW);average European waste-to-energy plant, without collection, transport and pre-treatment; at plant**	**no**	**EU-27**	**2006**	**2010**
Wood	Heat; residential heating systems from wood pellets, boiler, max. heat output 14,9 kW; consumption mix, at consumer; at a temperature level of 70°C	(pellets)	EU-27	2006	2012

[1] Source of the **updated CoM Default LCA Emission factor** (Annex I)

[2] Croatia excluded but UK included.

Table 5. Details of LCIs available in other than ELCD v3.2 database for fuels and energy carrier for heat**.**

Energy carrier in SEAP or SECAP	Database	Full LCI name	Location	Reference year	Valid until
Peat[1]	**Ecoinvent**	**Peat extraction**	**World**	**2015**	**n.a**
Liquefied Petroleum Gases[1]	**Ecoinvent**	**ROW: market for liquefied petroleum gas**	**World**	**2015**	**n.a**
Natural Gas Liquids[1]	**Ecoinvent**	**GLO: market for natural gas, liquefied**	**World**	**2015**	**n.a**
Biogas[1]	**Ecoinvent**	**Biogas production from grass**	**World**	**2015**	**n.a**
Solar thermal	NEEDS	Electricity, solar thermal, at solar trough, DNI2000 with storage	Central EU	2007	n.a.
Geothermal	Ecoinvent	Electricity production, geothermal	World	2015	n.a
Wood[1]	**NEEDS**	**Electricity, at steam turbine (poplar), emission ctrl., Centr. EU, alloc. exergy**	**Central EU**	**2007**	**n.a**

[1] Source of the updated **CoM default LCA Emission factor** (Annex I)

Table 6. Details of LCIs available in ELCD v3.2 and NEEDS database for electricity generation from local RES.

Local RES	Database	Full LCI name	Location	Reference year	Valid until
Solar PV (I)	NEEDS	Electricity, PV, ground mounted power plant, c-Si, thick, Central Europe	Central EU	2003	2005
Solar PV (II)	NEEDS	Electricity, PV, ground mounted power plant, c-Si, low eff., Central EU	Central EU	2003	2005
Windpower	NEEDS	electricity, at offshore wind park 1440MW	DK	..	..
Windpower[1]	**ELCD v3.2**	**Electricity from wind power, production mix, at power plant, AC, < 1kV**	**EU-27**	**2008**	**2015**
Hydropower (I)	ELCD v3.2	Electricity from hydroelectric power plants, production mix, at power plant, AC, < 1kV	EU-27	2002	2010
Hydropower (II)[1]	**ELCD v3.2**	**Electricity from hydro power; AC; production mix, at power plant;230V**	**EU-27**	**2008**	**2015**

[1] Source of the updated **CoM default LCA Emission factor** (Annex I)

1.2 LCA default emission factors for fossil fuels and renewable energy sources

The update of the CoM default LCA Emission Factors for fossil fuels, municipal wastes and Renewable Energy Sources (RES) was performed based on the following assumptions and considerations (see Annexes I.1 and I.2, respectively):

- The ELCD v3.2 LCIs for the energy carriers motor gasoline, gas/diesel oil, lignite, natural gas and municipal wastes (non-biomass fraction) reflect the EU-27 average for the supply chains (they are not proxies, but the LCI of the actual carrier). Although ELCD v3.2 data are valid until 2015, they are considered as the best options for the CoM default factors, compared with those available from the literature.

- LCIs for anthracite, other bituminous coal and sub-bituminous coal are not available from any database consulted nor in the literature review. Nevertheless, ELCD v3.2 offers LCIs of similar energy carriers (see Table 4) that can be used as proxies with a sufficient data quality and approximation. For liquid gas and peat, we propose to use the world average provided in Ecoinvent database for the year 2015 (see Table 5) as CoM default value.

- For wood, there are two possible LCIs to be used: the first from ELCD v3.2 which refers to the combustion of wood pellet in 2006 in EU-27 Member States (Table 4), and the second from the NEEDS database, referring to Central Europe in year 2007 (Table 5). Although wood pellet is one of the forms the most used for heating with wood, it has a very specific supply chain, including transformation and management (which also makes the supply chain emissions very high). For the LCA-EFs update, it is therefore suggested to rather use the LCI for wood from the NEEDS database. For municipal waste (biomass fraction) and wood waste, no more recent reference value was found for Europe and it is proposed to keep ELCD (2009) as the previous update CoM (2014).

- For plant oil, biodiesel and biogasoline (bioethanol), no scientifically robust reference value, in terms of country coverage and technological advancements, was found either in the databases consulted or in the scientific and technical literature. We therefore suggest keeping conservative figures, using the same factors ELCD (2009) as the ones reported in the CoM 2010 guidebook (Bertoldi et al., 2010) and CoM (2014) update. For biogas, the world average value from the Ecoinvent database for 2015 is proposed.

- LCIs for solar thermal and geothermal technologies are not available in ELCD v3.2, whereas only one value is available in the NEEDS database for solar thermal that refers to Central Europe. On the other hand, some information is provided in the literature: Amponsah et al. (2014) calculated a harmonised average of 0.040 tCO_2eq/MWh for solar thermal and 0.050 tCO_2-eq/MWh for geothermal. Asdrubali et al. (2015) estimated a general average of 0.034 tCO_2-eq/MWh for geothermal. It has been decided to use Amponsah et al. (2014) values as CoM default factors, because they are based on a model that is capable of including different technologies from different countries.

1.3 LCA emission factors for local electricity production from other RES

Reducing CO_2 emissions through the energy efficiency gains and reduction in energy consumption is a priority of the Covenant. However other actions to reduce CO_2 emissions on the supply side can be also accounted for. If the local authority decides to include local electricity production[7] in its inventories, the related emissions can be estimated in the case of plants combusting fossil or biofuels, by using the emission factors as defined in section 1.2. In the case of local electricity production from other than biomass/biofuels Renewable Energy Sources (RES), the emissions can be estimated by using the specific emission factors provided in this section.

Electricity from renewable sources is getting more and more interest because of climate issues. As a consequence, although some technologies are quite young in relation to the fossil energy based technologies, the scientific literature is rich in case studies and reviews. Table 3 shows that a significant number of case studies are available, together with a high range of variability: Emission factors range from 0.001 to 0.300 tCO_2eq/MWh from solar photovoltaic (PV); from 0.0004 to 0.364 tCO_2eq/MWh for wind power and from 0.0002 to 0.609 tCO_2eq/MWh from hydropower. Because of the continuous evolution of the technologies and the local specificities, none of the investigated reviews proposes any general average for Europe. Based on these considerations, the new CoM default LCA Emission Factors for local RES production (Annex I.3) were defined as follows:

- An LCI for Photovoltaics (PV) is not available in the ELCD v3.2 database. There are some LCIs in other databases, including the NEEDS database, but in most cases they are out of date, or refer to very specific technology, or to a relatively small geographical area. Regarding the scientific literature (Table 3), Evans et al. (2009) calculated 0.090 tCO_2eq/MWh as a general average for solar PV based on 48 case studies. More recently, Amponsah et al. (2014) suggested a harmonized approach for evaluating the life cycle emissions of RES and calculated a harmonised average of 0.030 tCO_2eq/MWh for solar PV technologies, based on 19 case studies. The EF proposed by this latter work is very close to the one proposed one year later by Asdrubali et al. (2015), who calculated an average of 0.029 tCO_2eq/MWh from 33 case studies. Considering the lack for LCIs of solar PV representative for the CoM Countries, the harmonised average proposed by Amponsah et al. (2014) is considered as the best option for the CoM updated factor for solar PV.

- LCIs for wind power and hydroelectric power are available in several databases. The ELCD v3.2 provides updates of both technologies, with robust averages for all EU-27. As a consequence, ELCD v3.2 wind power and hydropower (II) updated factors were selected (see Table 6).

[7] Energy production is not a mandatory sector in the CoM emission inventories, but is considered for the calculation of local emission factors for electricity/heat/cold (see Chapter 2).

1.4 Comments and recommendations about CoM standard and LCA emission factors

- <u>Choice of the standard (IPCC) or LCA approach</u>

The CoM initiative allows *local authorities to develop a SEAP in a way that suits their own circumstances, permitting those already engaged in energy and climate action to come on board of the Covenant of Mayors, while continuing to follow the approaches they have used before with as little adjustments as possible* (Bertoldi et al., 2010). Several reasons may be behind the decision of a municipality or region to adopt either the standard or the LCA method. The different methodologies indeed have different aims and consequently present different advantages and disadvantages as summarised in section 3.1 of CoM 2010 guidebook and the forthcoming update. The standard approach, which is used by 94% of the EU-28 signatories representing 90% of the EU-28 signatories' population as of September 2016 (Table 7) is compatible with the country emission inventory reporting by activity sector as specified by the UNFCCC (United Nation Framework Convention on Climate Change) and the EU binding legislation on climate and energy[8]. The internationally standardised LCA method is also used in 14 EU Member States, particularly by Germany and Austria, but also France and Sweden, where it is used by more than 20% of the CoM signatories and/or covered population (see Annex II). This approach, which was originally developed for products environmental footprints, is particularly suitable for assessing potential trade-offs between different types of environmental impacts associated with specific policy and management decisions.

Table 7 . EU-28 CoM signatories and population in "CoM BEI dataset 2016" (Kona et al., 2016) as a function of the inventory approach and the size (in inhabitants) of the local territory

Inventory approach	Number of EU-28 signatories	Population covered (inh.)	Percentage of signatories	Percentage of population covered
LCA	**314**	**15,481,944**	100%	100%
<=50000 inh.	270	2,657,936	*86%*	*17%*
]50000-100000]	15	1,055,611	*5%*	*7%*
]100000-250000]	15	2,247,608	*5%*	*15%*
]250000-500000]	6	1,969,895	*2%*	*13%*
]500000-1M]	5	3,088,510	*2%*	*20%*
> 1M inh.	3	4,462,384	*1%*	*29%*
Standard	**4936**	**142,155,199**	100%	100%
<=50000	4,472	34,578,469	*91%*	*24%*
]50000-100000]	224	15,658,202	*5%*	*11%*
]100000-250000]	139	22,379,994	*3%*	*16%*
]250000-500000]	62	21,540,234	*1%*	*15%*
]500000-1M]	25	17,262,694	*1%*	*12%*
> 1M inh.	14	30,735,606	*0.3%*	*22%*
LCA	**314**	**15,481,944**	**6%**	**10%**
Standard	**4936**	**142,155,199**	**94%**	**90%**
Totals	**5250**	**157,637,143**	**100%**	**100%**

[8] https://ec.europa.eu/clima/policies/strategies/2030_en

Another important aspect to be considered when choosing the inventory approach is the availability of data for completing the BEI. The s*tandard* one is based on emissions from the energy users and on the use of IPCC emission factors that are easily available. The LCA approach includes both emissions from the user and emissions that take place outside the location where the fuel is consumed, which can be particularly difficult to ascertain (Cerutti et al., 2013).

- Use of CoM default emission factors for the "direct" use of fuels and RES

It is important to note that the CoM default *standard* and LCA emission factors, which are the ones proposed by default for the automatic calculation of the local emissions in CoM on-line templates, correspond to the most commonly used energy carrier(s) in EU (and not a weighted factor) for the given CoM main energy categories, and that they refer to European or global emission patterns. It is also worth noting that they are characteristic of stationary sources. If choosing to report in CO_{2}-eq, emission factors up to 3% higher than the values provided in Annex I might be considered for the transport sector (e.g., for gasoline), because of higher non CO_2 emissions compared to stationary sources (see Tables 2.2 and 3.2 of IPCC (2006) guidelines). We also note that it is highly recommended not to modify/update these CoM default emission factors during the monitoring phase if they were used for the calculation of the Baseline Emission Inventory, because it would affect the understanding and monitoring of the impact of local mitigation actions on the resulting changes in local CO_2 or GHG emissions.
Where local authorities prefer to use factors that better reflect the properties and mixture of the fuels used in their territory when calculating their local CO_2 or GHG emissions, they are welcome to do so as long as such local data are available and reliable. In this case, they must (recalculate and) report on-line weighted emission factors that allow the automatic calculation of CO_2 or CO_{2}-eq emissions, that are as close as possible to the ones estimated in their baseline emission inventory and published in their official SECAP document for the different key sectors. They must also update these factors during the monitoring phase in case of changes in the composition/properties of the energy carriers consumed locally. This is particularly important for municipal wastes, for which both the supply chain and combustion process are often under the direct control or responsibility of the municipality. In such cases, it is important to account for the changes in the collection, composition (e.g. biomass fraction) and treatment (plant) phases of the waste management process. For local authorities willing to look for IPCC and LCA factors that better reflect the fuels used in their territory or more generally interested in gaining further insights into the IPCC and LCA approaches, we refer to the IPCC (2006) guidelines (http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.html) and to the European Platform on Life Cycle Assessment (http://eplca.jrc.ec.europa.eu/), respectively.

- Consistency and Use of the updated LCA factors

The CoM Version 2017 default LCA emission factors have been mainly defined from the up-to-date ELCDv3.2 Life Cycle Inventory and a few other european and global LCIs, as well as from an exhaustive literature review (see Section 1.1). For each updated LCI, it has been verified that the functional unit in which the life cycle emissions are reported was coherent with the previous CoM default LCA factors. The LCA factors for emissions from the supply chain of Renewable energy sources (liquid biofuels, bio gasoline, biodiesels, biogas, wood, solar and geothermal) have been also checked for consistency against the values reported in the Directive 2009/28/EC on Renewable Energy (Annex III).

When choosing the CoM default LCA factors to be used in the calculation of the local emission inventories, it is important to note that LCI values have a period of validity. Therefore, both the previous (for BEI up to 2007) and present (for BEI from 2008) LCAs factors are reported in Annex I, and show substantial differences for some energy carriers, notably for coal products and for municipal wastes. For this reason, it is again highly recommended not to update the CoM default LCA factors that have been used for the Baseline Emission Inventory during the monitoring phase (see also above first paragraph), even for a BEI year after 2008. New CoM signatories are recommended to use the version of the LCA factors, whose validity period (before or after 2008) best corresponds to their BEI year.

- Accounting for biomass and biofuels emissions: about carbon neutrality

Under UNFCCC reporting, the key greenhouse gases (CO_2, CH_4 and N_2O) from biofuels/biomass are reported in a separate sector, called the AFOLU (Agriculture, Forestry and Other Land Use) sector, where emissions and removals of CO_2 are generally estimated on the basis of changes in ecosystem carbon stocks (above-ground and below-ground biomass, dead organic matter and soil organic matter). Net losses in total ecosystem carbon stocks are used to estimate CO_2 emissions to the atmosphere, and net gains in total ecosystem carbon stocks are used to estimate removal of CO_2 from the atmosphere. Under the Covenant, emissions from biofuels/biomass are reported under the different key activity sectors (Buildings, Transport and Others). A range of direct *standard* emission factors is therefore provided (Annex I.2) for biofuels/biomass, i.e. from 0 (carbon neutrality) to the IPCC (2006) value for Stationary combustion, when not accounting for any carbon sink compensation. The term “Carbon neutrality”[9] is used in this report to mean total compensation of CO_2 emissions from end-user consumption by the CO_2 removal by productive land. It is important to note that no negative emission factors can be applied in the calculation of energy-related emissions from both standard and LCA approaches in the frame of the Covenant of Mayors: in case of net CO_2 uptake, a factor of 0 has to be applied instead. If biomass/biofuels are not harvested in a sustainable manner (e.g., in case of declining carbon stocks in a forest), then a CO_2 emission factor that is higher than zero has to be applied, as stipulated in the legend of Annex I. We acknowledge that evaluating the carbon balance of the fuels is not an easy task, particularly because there is still a lot of scientific and political debate on the matter and no agreed binding criteria for sustainability of biomass/biofuels used for energy. We refer to Part II of the CoM guidebook (Bertoldi et al., 2010) and the forthcoming update, as well as to the Directive 2009/28/EC on Renewable Energy and more recent data (http://www.biograce.net/home) and recommendations (https://ec.europa.eu/energy/en/topics/renewable-energy/biomass) from the European Commission for further insights into this topic.

[9] stands for the terms “Sustainable / non sustainable” as currently reported in the CoM on-line templates

2. Update of CoM emission factors for indirect emissions from electricity consumption

2.1 NEEFE definition

NEEFE (National and European Emission Factors for Electricity) are used to estimate indirect CO_2 (tCO_2/MWh) or GHG (in tCO_2-eq/MWh) emissions due to local consumption of electricity. Depending on the approach followed by the local authority, they are calculated by applying the IPCC "standard" or the LCA emission factors to the energy carriers consumed to produce electricity. The electricity consumed within each local municipality or region is often not produced within its territory. Keeping in mind that the focus of covenant is on the demand side, it is recommended to use a NEEFE as a starting point to assess the emissions from local electricity consumption, which can be further corrected for the local situation where needed (see section 1.3). These 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 consumption. The underlying assumption of the NEEFE definition is that all emissions produced nationally have to be allocated to the GWh of electricity consumed within the country. Because it accounts for the imported electricity but not for the associated CO_2 emissions (which are emitted outside the country), in case of important import of electricity, this definition can lead to NEEFE that are significantly lower than the emission factors for electricity production and inversely in case of net loss/exportation (see section 2.3).

While only accounting for CO_2 derived from nationally produced electricity is meaningful in the frame of IPCC national reporting (because the emissions from the imported energy will be reported by another country), it might be debatable in the case of CoM, where the focus is on the local consumption side. An alternative approach would have been to consider all CO_2 indirect emissions due to the local electricity consumption, i.e. from electricity production both within and outside the country. This would require distinguishing between imported and nationally produced fractions, not only in terms of energy produced but also in terms of associated emissions. However, the later information, which depends on the supplier countrie(s) is generally not available in the existing international energy datasets. In any case, this would not allow anymore for comparing CoM versus the national and EU CO_2/GHG emissions from electricity, nor to assess CoM contribution to the national/EU mitigation efforts. For these different reasons, the same NEEFE definition (section 2.1) as in the CoM (2014) previous update has been applied.

2.2 Previous NEEFE factors

In the CoM 2010 guidebook (Bertoldi et al., 2010), the NEEFEs were either derived from Eurelectric (2005) 2002 energy data (17 Member States) or provided by the national agencies for one specific reference year (for 8 MS). The contribution of the supply chain to the LCA EFs was derived from a first release of the ELCD (JRC, 2009) European database (Table 8).

Table 8. Source and Reference year of the NEEFE factors published in Bertoldi et al. (2010)

Emission approach	Reference year	EU Member State	Source
IPCC	2008	Denmark	Average of emission factors for Eastern and Western Denmark including distribution loss of 5 %. http://www.energinet.dk
	2007	Germany	http://www.umweltbundesamt.de/
		Estonia	Personal communication with Estonian Environment Information Centre
		Portugal	Personal communication with Portuguese Agency for the Environment
		Slovenia	Personal communication with Environmental Agency of the Republic of Slovenia
		Slovakia	Personal communication with Slovak Hydro meteorological Institute
		Spain	Personal communication with Ministry of Environment, Spain
		United Kingdom	Personal communication with Department of Energy and Climate Change
	2002	Other Countries	Eurelectric (2005)
LCA	2002	All 27 Member States	JRC (2009)

In a previous update published in CoM reporting guidelines (CoM, 2014; CoM, 2016), the NEEFE were updated up to 2010 for both standard and LCA approaches by applying the variation (in percentage) of CO_2 or GHG emissions from electricity in the subsequent years, as derived from 2012 electricity output data per energy carrier of the International Energy Agency (IEA, 2012) to the Bertoldi et al. (2010) values. The CoM (2014) approach was the following: Trends in the emissions from electricity production were first calculated by aggregating the electricity produced from the 63 IEA energy carriers into 10 main energy carrier classes and applying the related IPCC factors (Annex IV). The corresponding LCA factors were calculated using the ELCD (2009) version of the European Life Cycle Database. The NEEFE were then estimated by i) dividing the total estimated CO_2 emissions by the final electricity consumption per year and per country and then ii) rescaling the values to the Bertoldi et al. (2010) NEEFE. While it was acknowledged that the approach might not be the best from the analytical point of view - because the 2010 Version of the NEEFEs were derived from different sources and possibly different approaches - it was chosen in order to maintain coherence with the EFs already published and used by CoM signatories. However, the following more questionable points have been identified in this previous JRC approach:

- The CO_2 calculation, based on the share of the contribution of each energy carrier to the total electricity produced, accounts for the changes in energy mix but not changes in the conversion efficiencies of the plants.
- The CO_2 calculation includes emissions from biofuels, all considered as 100% non-carbon neutral.
- The emissions from the 63 energy carrier classes were aggregated into the 10 most common energy carrier classes, which can lead to some lack of accuracy.
- The method did not include corrections/updates for the previous years.

These considerations have led us to look for a revised methodology, which is described in section 2.3.

2.3 Updated NEEFE calculation

The JRC now proposes to provide an yearly update of NEEFE time series from 1990 onwards based on the same general definition (see 2.1) of the National and European Emission Factors for Electricity consumption used in CoM (2014), but using a revised calculation approach, in order to ensure more complete, consistent and comparable NEEFE trends for the different Member States and for EU.

The 1990-2013 time-series of NEEFE for electricity consumption provided in this first release were calculated in two steps, using the “Extended World Energy Balances” data (version 2015) from the International Energy Agency (IEA, 2016), as described in the two following sections.

2.3.1 Emission factors per MWh of electricity generation ($NEEFE_p$)

National and European Emission Factors for Electricity <u>production</u> ($NEEFE_p$) were first calculated by applying IPCC and LCA emission factors to the energy consumed per energy carrier (fossil fuel and non-renewable waste) in the Electricity-only and in Combined Heat Power (CHP) plants. IEA 2015 national data (energy carriers consumed, electricity produced per energy carrier) for all individual IEA original energy carriers (see Annex IV) were used and both the *main activity producers* and *auto-producers* have been included in the calculation. The energy input in CHP plants has been corrected for the fraction used to produce heat, considering an energy conversion efficiency of 0.9 for heat, as recommended in section 3.5.1 of CoM guidebook (Bertoldi et al., 2010). This fixed-heat-efficiency approach is also the one that was used by IEA for several editions of its *World Energy Outlook* (see IEA (2014) for more details).

The IPCC approach in which only CO_2 emissions from fossil fuel and non-renewable (municipal and industry) wastes are included (except hydro pumped storage) in the energy sector has been applied to calculate the national and EU-28 emissions from electricity generation (in tCO_2 and in tCO_2-eq). This approach is also the one applied in the frame of UNFCCC (United Nation Framework Convention on Climate Change) reporting, in which all biomass/biofuels derived emissions are reported separately, in the AFOLU sector. Using this approach therefore allows for a direct comparison between CoM and EU-28 CO_2 emissions and facilitates the assessment of the contribution of CoM to EU emission reductions in the electricity sector. On the other hand, it also tends to under-estimate electricity-related emissions in CoM local inventories, in which emissions should be reported in each emitting sector (Energy production, Building, Transport).

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 2013, assuming no carbon sink compensation in the biofuels/biomass production chain, i.e., applying IPCC (2006) default emission factors for Stationary Combustion to all energy carriers including biofuels. Table 9 shows that, except for Sweden and Finland, the CO_2 emissions from biofuels/biomass would represent less than 30% of the total CO_2 emissions from national electricity production in 2013. The estimated contribution of biofuels/biomass to CO_2 emissions from electricity production at EU-28 level is below 10%, but shows an increase from 1.0% to 9.9% from 1990 to 2013. Because the share of biofuels/biomass generally increased since 1990, the general declining trend of the $NEEFE_p$ is slightly less pronounced when the emissions from biofuels are included (Figure 1). However, this result is also due to the assumption of carbon non-neutrality.

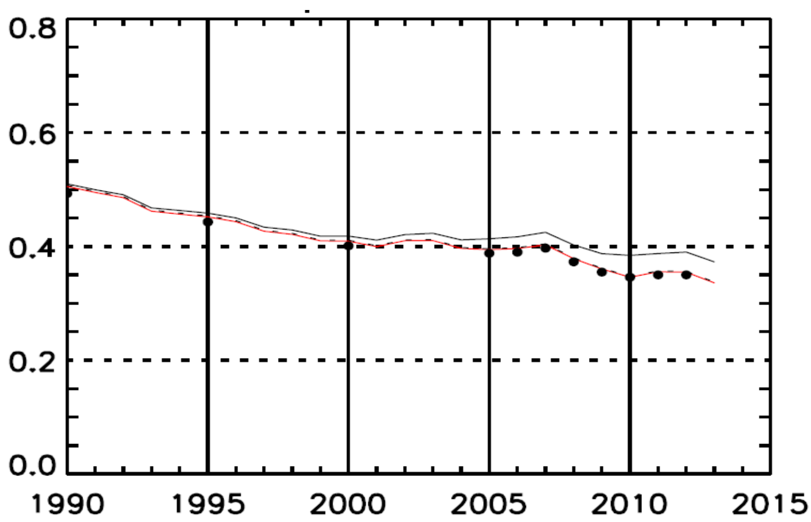

Figure 1. 1990 to 2013 trends in the EU-28 Emission factor for Electricity Production (tCO_2/MWh). Red line: current study, using IPCC (2006) default approach and emission factors; Black line: also including emissions from biofuels and biomass, assuming non carbon neutral process; Black dots : EFs values provided for some specific years in IEA (2014) documentation based on default methods and emission factors from the *Revised 1996 IPCC Guidelines* (IPCC, 1997).

Table 9. 1990 and 2013 NEEFEp for electricity production, as calculated when excluding (A) and accounting for (B) emissions from biofuels/biomass (assuming non carbon neutral process).

	1990			2013		
	A	B.	(B-A/B)	A.	B.	(B-A/B)
Country / EU	tCO_2/ MWh	tCO_2/ MWh	(%)	tCO_2/ MWh	tCO_2/ MWh	(%)
Austria	0.242	0.256	5.5%	0.165	0.222	25.7%
Belgium	0.357	0.365	2.2%	0.196	0.250	21.6%
Bulgaria	0.800	0.800	0.0%	0.506	0.507	0.2%
Croatia	0.385	0.386	0.3%	0.231	0.240	3.7%
Cyprus	0.847	0.847	0.0%	0.646	0.649	0.5%
Czech Republic	0.756	0.756	0.0%	0.515	0.545	5.5%
Denmark	0.685	0.695	1.4%	0.300	0.358	16.2%
Estonia	0.965	0.965	0.0%	1.016	1.040	2.3%
Finland	0.191	0.259	26.3%	0.174	0.269	35.3%
France	0.108	0.111	2.1%	0.064	0.076	15.2%
Germany	0.624	0.627	0.5%	0.484	0.532	9.0%
Greece	1.005	1.005	0.0%	0.646	0.649	0.5%
Hungary	0.502	0.503	0.2%	0.292	0.352	17.0%
Ireland	0.750	0.750	0.0%	0.435	0.452	3.8%
Italy	0.579	0.579	0.0%	0.342	0.394	13.2%
Latvia	0.119	0.119	0.0%	0.128	0.182	29.7%
Lithuania	0.160	0.160	0.0%	0.216	0.278	22.2%
Luxembourg	2.772	2.854	2.9%	0.306	0.339	9.7%
Malta	1.609	1.6098	0.0%	0.731	0.732	0.1%
Netherlands	0.616	0.632	2.5%	0.451	0.512	11.9%
Poland	1.027	1.028	0.1%	0.766	0.811	5.5%
Portugal	0.527	0.549	4.0%	0.281	0.332	15.4%
Romania	0.902	0.903	0.1%	0.348	0.351	0.9%
Slovak Republic	0.395	0.395	0.0%	0.175	0.219	20.1%
Slovenia	0.437	0.437	0.0%	0.318	0.328	3.0%
Spain	0.436	0.438	0.6%	0.247	0.265	6.8%
Sweden	0.011	0.017	35.3%	0.013	0.054	76.7%
UK	0.686	0.687	0.2%	0.459	0.503	8.7%
EU-28	0.505	0.510	1.0%	0.336	0.373	9.9%

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. As an example, the 2013 maximum potential contribution of biofuels calculated for Finland (35%) and Sweden (77%) are very likely over-estimated (Table 9), considering that a significant fraction of the biofuel/biomass consumed in these countries is assumed to be already sustainable (both countries reported net removals of CO_2 from forest land in their 2016 submissions to the UNFCCC). The fact that emissions from biofuels/biomass and their reporting at national level are subject to large uncertainties is an even greater justification for strictly applying the UNFCCC approach when calculating the NEEFEs, i.e. only accounting for CO_2/GHG emissions from fossil fuel and non-renewable (municipal and industry) wastes.

2.3.2 Emission factors per MWh of electricity consumption (NEEFE)

Likewise Bertoldi et al. (2010) and CoM (2014) update, the 1990-2013 national emission factors from end-user consumption (NEEFE) are calculated by dividing the total national CO_2 emissions from electricity production from all input energy carriers by the total final electricity consumption.

In the case of a "closed system" (without import or export of electricity), where Electricity consumed equals Electricity produced minus the losses in the grid, the NEEFE definition (section 2.1) logically leads to higher values compared to $NEEFE_p$, by allocating the grid losses to the consumer. In case of net export of electricity, both the losses in the national grid and the emissions related to the exported electricity (even if consumed outside the country) are accounted for. Inversely, for countries with higher consumed than produced GWh (net import of electricity), the derived NEEFE calculated is smaller than the $NEEFE_p$ factor, because it accounts for the imported electricity but not for the associated CO_2 emissions (which are emitted outside the country).

In case of important import or export of electricity, this definition can lead to NEEFE that are significantly different to the $NEEFE_p$ factor, as illustrated for the year 2013 in Table 10 (see notably Estonia, Lithuania and Luxembourg).

At EU-28 level, a ratio of 0.86 is obtained between the consumed and produced electricity, due a net electricity export and/or losses of 14% of the electricity produced, leading to higher emission factors for NEEFE (Figure 2) than for $NEEFE_p$ (Figure 1).

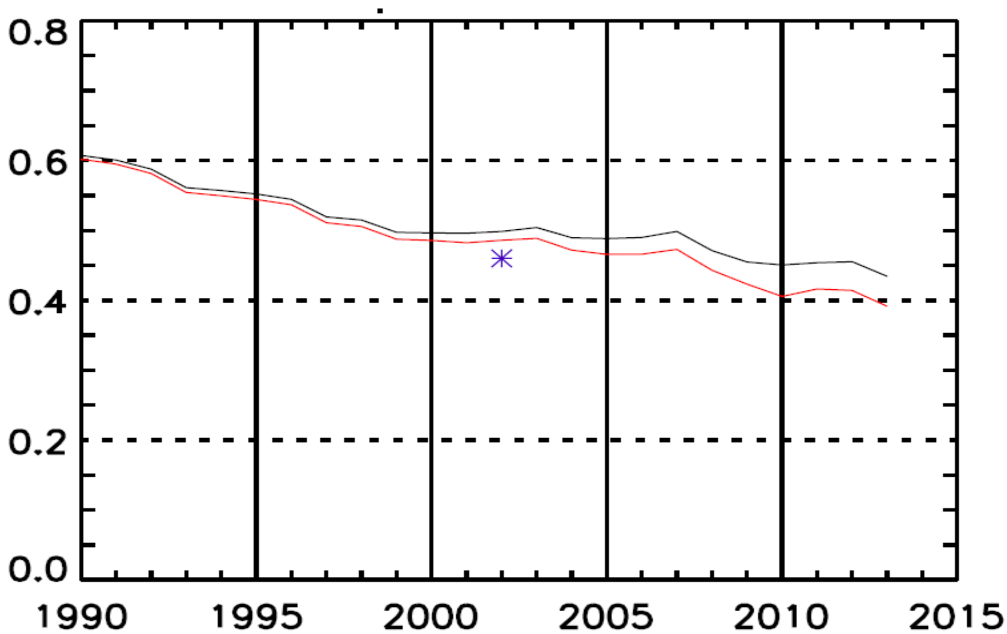

Figure 2. 1990 to 2013 in the EU-28 Emission factor for Electricity <u>Consumption</u> (tCO_2/MWh). Red line: current study, using the IPCC (2006) default approach and emission factors. Black line: also including emissions from biofuels and biomass, assuming they were produced through a non-carbon neutral process. Purple star: Bertoldi et al. (2010) 2002 value for EU-27.

Table 10. Electricity output and Final Electricity Consumption (GWh) in 2013 (IEA, 2016). Higher produced than consumed electricity leads to higher NEEFE than NEEFEp factors and inversely

Country / EU	Electricity production (E.Prod)	Final Electricity Consumption (E.Cons.)	E. Cons./E. Prod. (%) = NEEFEp/NEEFE
Austria	64539	62951	98%
Belgium	82113	80999	99%
Bulgaria	43069	27537	64%
Croatia	13326	15075	113%
Cyprus	4290	3922	91%
Czech Rep.	86160	56701	66%
Denmark	34749	31487	91%
Estonia	13275	6821	**51%**
Finland	71251	79932	112%
France	567366	440789	78%
Germany	627374	518182	83%
Greece	57114	48800	85%
Hungary	30273	34862	115%
Ireland	25777	24205	94%
Italy	287909	287450	100%
Latvia	6209	6577	106%
Lithuania	4214	8957	**213%**
Luxembourg	1849	6231	**337%**
Malta	2254	1891	84%
Netherlands	100875	106191	105%
Poland	163999	124081	76%
Portugal	50534	45265	90%
Romania	58536	40635	69%
Slovak Republic	28514	25089	88%
Slovenia	15793	12592	80%
Spain	279275	232051	83%
Sweden	153031	125039	82%
United Kingdom	356256	317358	89%
EU-28	3229924	2771672	86%

2.4 Updated NEEFE factors

Covenant default NEEFE "National and European Emission Factors for Electricity Consumption"– Version 2017 are provided in Annex I.4.

- The NEEFE using the IPCC approach and accounting for CO_2 (tCO_2/MWh) emissions are provided in Table AI.4.1. The NEEFE factors, including CO_2, CH_4 and N_2O emissions expressed in tCO_2-eq/MWh are provided in Table AI4.2.
- The NEEFE using the LCA approach (Table AI.4.3) were obtained applying the LCA emission factors of Annex IV to the IEA input energy carriers. For the fuels not documented in Annex I, supply chain factors (provided in Annex III) of fuels belonging to similar energy categories were applied.
- The plots of the national NEEFE time-series using the IPCC approach and accounting for CO_2 (tCO_2/MWh) are also provided in Annex VI. The values in Bertoldi et al. (2010) values available for one reference year per country, for 25 out of the 28 Member States (Annex V) are also reported on the plots.
- The 1990-2013 NEEFE absolute and mean annual changes are given in Table 11.

As expected, a general decrease in NEEFE is obtained over the 1990-2013 period for most countries (except for Latvia and Sweden) for both IPCC and LCA approaches, and for both CO_2 only and the sum of the 3 GHG (CO_2, CH_4 and N_2O) possibly included in CoM inventories. This results in a mean annual decrease of 0.9%/year (IPCC) and 0.8%/year (LCA) at EU-28 level. The most pronounced 1990 to 2013 decreases are obtained for Malta (4.7%/year and 5%/year), Romania (2.5%/year and 2.9%/year), Greece (2.0%/year and 2.1%/year), and Estonia (2%/year in both cases).

Comparison to Bertoldi et al. (2010): CoM Version 2017 NEEFEs are compared to Bertoldi et al. (2010) values in Annex V (Table V.2). A difference of +6% is obtained between our EU-28 results and the Bertoldi et al. (2010) EU-27 value for the year 2002 (Table V.1). At national scale, Version 2017 of CoM IPCC-based NEEFEs are generally in good agreement with Bertoldi et al. (2010) values, except for Estonia (+111%), France (+70%), Sweden (+39%) and Slovenia (-22%). For Estonia and Slovenia, it could be that the 2007 national electricity consumption versus production ratios applied in the current study (0.56 and 0.88 respectively), based on IEA (2016) energy data, are significantly different to the ones used by the national agencies, which are not available (NEEFE are referred to as "personal communication" in Bertoldi et al. (2010) for these countries). Another explanation could be discrepancies between the emission factors respectively applied to the main energy carriers. For France and Sweden, the absolute differences are indeed very small (0.04 tCO_2/MWh and 0.01 tCO_2/MWh, respectively) given the low NEEFE values (see Annex V) due the high share of nuclear (France) and biomass (Sweden) used for the production of electricity in these countries. Our calculations also reveal that the NEEFE excluding biofuels emissions are closer to the 2010 CoM guidebook values (see for instance Figure 2 for EU-28) indicating that most of the NEEFE factors reported in the 2010 Guidebook were very likely calculated by also excluding emission from biofuels/biomass, in line with the IPCC reporting principles. Most of the updated LCA-based NEEFE values (20 out of 25) are lower than the ones reported in CoM 2010 guidebook, resulting in an EU-28 European Emission Factor for Electricity Consumption that is 8% lower than the Bertoldi et al. (2010) value for EU-27. Identifying the reasons for all individual differences would require further case-to-case analyses, as they are the result of a combination of between different data sources and methodologies in Bertoldi et al. (2010) and improved knowledge, data and methods in the present study.

Table 11. 1990 to 2013 changes in NEEFE factor for electricity consumption. 1990 to 2013 changes in NEEFE factor for electricity consumption

Country / EU	1990-2013 absolute change (tCO_2 or tCO_2eq/MWh)		1990-2013 mean annual change (%)	
	IPCC tCO_2/MWh	LCA tCO_2eq/MWh	IPCC tCO_2/MWh	LCA tCO_2eq/MWh
Austria	-0.11	-0.10	-0.5%	-0.4%
Belgium	-0.24	-0.22	-1.0%	-1.0%
Bulgaria	-0.17	-0.11	-0.7%	-0.5%
Croatia	-0.05	-0.06	-0.2%	-0.3%
Cyprus	-0.23	-0.26	-1.0%	-1.1%
Czech Republic	-0.19	-0.16	-0.8%	-0.7%
Denmark	-0.30	-0.28	-1.3%	-1.2%
Estonia	-0.46	-0.44	-2.0%	-1.9%
Finland	-0.02	-0.01	-0.1%	-0.1%
France	-0.07	-0.07	-0.3%	-0.3%
Germany	-0.16	-0.12	-0.7%	-0.5%
Greece	-0.47	-0.48	-2.0%	-2.1%
Hungary	-0.20	-0.17	-0.9%	-0.7%
Ireland	-0.44	-0.45	-1.9%	-1.9%
Italy	-0.23	-0.23	-1.0%	-1.0%
Latvia	0.03	0.07	0.1%	0.3%
Lithuania	-0.28	-0.31	-1.2%	-1.4%
Luxembourg	-0.33	-0.32	-1.4%	-1.4%
Malta	-1.07	-1.15	-4.7%	-5.0%
Netherlands	-0.17	-0.18	-0.8%	-0.8%
Poland	-0.42	-0.41	-1.8%	-1.8%
Portugal	-0.32	-0.34	-1.4%	-1.5%
Romania	-0.57	-0.57	-2.5%	-2.5%
Slovak Republic	-0.23	-0.22	-1.0%	-1.0%
Slovenia	-0.19	-0.19	-0.8%	-0.8%
Spain	-0.23	-0.21	-1.0%	-0.9%
Sweden	0.00	0.02	0.0%	0.1%
United Kingdom	-0.28	-0.26	-1.2%	-1.1%
EU-28	-0.21	-0.20	-0.9%	-0.8%

2.5 Comments and recommendations about CoM NEEFE factors

- Consistency and Use of the updated NEEFE factors

Given that the electricity consumed within each local municipality is generally not produced within its territory, the CoM signatories are recommended to use the National or European Emission Factor for Electricity consumption NEEFE as a starting point to assess the emissions from local electricity consumption, further corrected if applicable for local electricity production (see section 1.3).

For the time being, as with the other CoM default Emission factors provided in Annex I, the general rule of the Covenant of Mayors is still to use the same NEEFE emission factor in the monitoring phase than the one used in the Baseline Emission Inventory. The benefit of using a constant NEEFE is that the trend in the local authority's emissions from electricity consumption will be solely driven by local consumption and, if applicable, local electricity production (see section 1.3). This helps understand the trend and changes in emissions from local energy consumption, which is the scope of the Covenant (see Part II of the CoM 2010 Guidebook). This is of particular importance for the NEEFE, which fluctuates considerably from year to year due to the heating/cooling demand, availability of renewable energies, energy market situation, import/export of energy and so on. For this reason, we also recommend checking the inter-annual variabilility of the NEEFE value around the BEI year (see Annex VI). In the case of high fluctuation, it is suggested to apply a more representative value, e.g. an average value over a 3-yrs (BEI year +/- 1) or 5-yrs(BEI year +/-2) period.

Our calculations show a general decrease in NEEFE over the 1990-2013 period, (except for Latvia and Sweden), which is expected to continue over the coming decades, due to the projected increase in the production of "carbon free" electricity from RES (Capros et al., 2016). At the same time, the latter study also shows that the share of electricity in the total energy demand at EU level is expected to increase by 2030. Because a 40% minimum target was set for all EU countries in the context of CoM and because some countries might experience a high increase in the share of electricity in the total energy consumption, not accounting for the NEEFE trend may make it difficult for some signatories to reach their overall reduction target. Given that both trends in NEEFE (see Table 11 and Annex VI) and in the percentage of electricity in total energy consumption are highly country dependent, how the NEEFE trend should be accounted for or not in future is currently being analysed in the frame of Covenant's extension to the 2030 target year. In case CoM signatories already account for the trend in the NEEFE when calculating and implementing their emission reduction target, this has to be explicitly specified in their official SE(C)AP document and accounted for in the on-line mitigation actions template for each relevant key sector (by applying "Other (national, regional,..)" label in the "Origin of action" column).

- Accounting for local production and purchase of electricity, including emissions from biomass/biofuels consumption

While a constant NEEFE has to be used, the local authority is allowed to take into consideration any changes in local electricity production. In case of local electricity production and/or purchase of certified green electricity by the local authority, the local emission factor for electricity has to be further assessed from the NEEFE to account for local production and purchase of electricity and related emissions. The calculation approach is provided in Part II (paragraph 3.4.4) of the CoM 2010 Guidebook and its forthcoming update.

For the reasons discussed in section 2.3.1, the CoM NEEFE default factors – Version 2017 do not account for emissions from biofuels/biomass consumption. However, when correcting the NEEFE for local production and purchase of electricity, it is encouraged to also include such emissions. As for the calculation of other emissions from local renewable energy use, this requires evaluating the carbon neutrality property of the fuels consumed in the plants, as discussed in section 1.4.

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 and updated UNFCCC related reporting recommendations are expected by 2019.

Conclusions

This document provides an update of the CoM default emission factors reported in previous CoM Guidebook (Bertoldi et al., 2010) and Reporting Guidelines (CoM, 2014; CoM, 2016) for the 28 EU Member States, together with information on the methodologies, assumptions, data sources and recommendations on the use of these factors (see notably sections 1.4 and 2.5). The new CoM default emission factors (Version 2017) provided in **Annex I** include both "standard" and LCA-based emission factors that can be used to estimate local emissions of CO_2 (in tCO_2) or GHGs (sum of CO_2, CH_4 and N_2O emissions expressed in tCO_2-eq) due to the direct and indirect (from electricity consumption) end use of fossil fuels, municipal wastes, and renewable energies. Because regular (annual for the NEEFE) updates are foreseen, we recommend checking for the latest version of Annex I in the Covenant website library[10]. It is also worth noting that how emissions from biomass/biofuels and electricity are accounted for in the frame of the Covenant might be revised in the future, as their use in the EU is expected to increase and updated UNFCCC related reporting recommendations potentially are expected by 2019.

Because the scope of Covenant is the final energy consumption within the boundaries of the local authority and because the current update leads to significant changes in some of the default emission factors (see **Annexes III and V)**, it is important not to update the CoM default factors during the monitoring phase, if they were selected for the estimation of the Baseline emission inventory, because it would affect the understanding and monitoring of the impact of local mitigation actions on the resulting changes in local GHG emissions. If local authorities prefer to use and update factors that better reflect the properties of the fuels used in their territory when elaborating their baseline and subsequent emission inventories, they are welcome to do so, in case more country- or local- specific data are available and reliable.

For further guidance on the elaboration of local emission inventories in the context of the Covenant, please also refer to Part II of CoM 2010 guidebook and its forthcoming update (JRC, 2017).

[10] http://www.eumayors.eu/Library,84.html

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List of Figures

List of Tables

List of acronyms and abbreviations

AFOLU	Agriculture, Forestry and Other Land Use
BEI	Base Emission Inventory
BKB	Brown Coal Briquettes
CH_4	Methane
CHP	Combined Heat power Plant
CO_2	Carbon dioxide
CO_2-eq	Carbon dioxide equivalent
CoM	Covenant of Mayors
EEFE	European Emission Factor for Electricity consumption
EF	Emission Factor
ELCD	European Reference Life Cycle Database
EU	European Union
EU-27	European Union's Member States, before adhesion of Croatia
EU-28	European Union's Member States, after adhesion of Croatia (before Brexit)
FS	Feed stocks
GHG	Green House Gases
GWP	Global Warming Potential
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
LCA	Life Cycle Assessment
LCI	Life Cycle Inventory
JRC	Joint Research Centre
MEI	Monitoring Emission Inventory
MS	Member States
NEEDS	New Energy Externalities Developments for Sustainability
NEEFE	National and European Emission Factors for Electricity consumption
NEEFEp	National and European Emission Factors for Electricity production
NGL	Natural Gas Liquids
N_2O	Nitrous Oxide
PV	Photovoltaic
RES	Renewable Energy Source
SBP	Special Boiling Point (Industrial) spirit
SECAP	Sustainable Energy and Climate Action Plan
UNFCCC	United Nation Framework Convention on Climate Change

Annex I - Covenant of Mayors Default Emission Factors - Version 2017

AI.1. CoM default emission factors for fossil fuels and municipal wastes (non-biomass fraction)

Energy carriers[1]		Standard (IPCC, 2006)		LCA[2, 4] up to 2007	LCA[3, 4] 2008-2015 (current update)
SECAP Template	IPCC denomination	t CO_2 /MWh	t CO_2-eq /MWh	t CO_2-eq /MWh	t CO_2-eq /MWh
Natural gas	Natural gas	0.202	0.202	0.237	0.240
Liquid gas	Liquefied Petroleum Gases	0.227	0.227	n.a.	0.281[a]
	Natural Gas Liquids	0.231	0.231	n.a.	0.272[a]
Heating Oil	Gas/Diesel oil	0.267	0.268	0.305	0.306
Diesel	Gas/Diesel oil	0.267	0.268[b]	0.305	0.306
Gasoline	Motor gasoline	0.249	0.250[b]	0.307	0.314
Lignite	Lignite	0.364	0.365	0.375	0.375
Coal	Anthracite	0.354	0.356	0.393	0.370
	Other Bituminous Coal	0.341	0.342	0.380	0.358
	Sub-Bituminous Coal	0.346	0.348	0.385	0.363
Other non renewable fuels[5]	Peat	0.382	0.383	0.392	0.390[a]
	Municipal Wastes (non-biomass fraction)	0.330	0.337	0.174	0. 295

[1]Default energy carriers of CoM SECAP on-line template. [2]ELCD (2009) and [3]ELCD v3.2 (ELCD, 2015) databases, except [a]Ecoinvent. [b]If choosing to report in CO_2-eq, please consider that the emission factors for the transport sector are up to 3% higher than the values provided here (e.g., for gasoline), which are characteristic for stationary sources. For municipal wastes, the LCA factor is lower than the IPCC (2006) factor because of the emission savings allowed by the waste treatment (see Annex III). [4]The validity range applies to the baseline year, i.e. to the year of the so-called Baseline Emission Inventory (BEI). For the subsequent monitoring emission inventories (MEIs), the same emission factors should be applied (see also section 1.4 for details on the use of local versus CoM default emission factors). [5]Referred to as "*Other fossil fuels*" in the on-line SEAP template.

Annex I - Continued

AI.2 CoM default Emission factors for renewable energy sources

Renewable energy			Standard[2] (IPCC, 2006)		LCA[3] up to 2007[5]	LCA[4] 2008-2015[5] (current update)
Energy classes [1]	IPCC denomination	*Carbon neutrality*	t CO_2 /MWh	t CO_2-eq /MWh	t CO_2-eq /MWh	t CO_2-eq /MWh
Plant oil	Other Liquid Biofuels	*cn*	0	0.001	0.182 [a]	0.182[a]
		ncn	0.287	0.302	0.484	0.484
Biofuel	Bio-gasoline	*cn*	0	0.001	0.207 [a]	0.207[a]
		ncn	0.255	0.256	0.462	0.462
	Biodiesels	*cn*	0	0.001	0.156 [a]	0.156[a]
		ncn	0.255	0.256	0.411	0.411
Other biomass	Biogas	*ncn*	0.197	0.197	n.a.	0.284 [b]
	Municipal wastes (biom. fraction)	*cn*	0	0.007	0.106	0.106[3]
	Wood *(/Wood waste)*	*cn*	0	0.007	0.013	0.017[c]
		ncn	0.403	0.410	0.416	0.420
	(Wood/) Wood waste	*ncn*	0.403	0.410	0.184[3]	0.184[3]
	Other primary solid biomass	*ncn*	0.360	0.367	n.a.	n.a.
Solar thermal			0	0	n.a.	0.040[d]
Geothermal			0	0	n.a.	0.050[d]

[1]Default energy carriers of CoM SECAP on-line template. [2] Standard emission factors should be reported zero if the biofuels/biomass meet CO_2 neutrality criteria (*cn*) in terms of CO_2 emissions versus CO_2 assimilation by plants; For fuels that do not meet carbon neutrality criteria (see section 1.4), the *ncn* (not carbon neutral) IPCC (2006) default emission factors reflecting the carbon content, potentially further corrected for the carbon assimilation, should be used (excluding emissions from the supply chain, which are included in the LCA factor). The sources of LCA values are [3]ELCD (2009) and [4]ELCD v3.2 (ELCD, 2015) databases except [a)]Bertoldi et al. (2010), [b)] Ecoinvent world value for the year 2015, [c)] NEEDS database and [d)] Amponsah et al. (2014). [5]The validity range applies to the baseline year, i.e. to the year of the so-called Baseline Emission Inventory (BEI), whereas for the monitoring emission inventories (MEIs), the same emission factors should be applied (see also section 1.4 for details on the use of local versus CoM default emission factors). The LCA factors for emissions from plant oil, biogasoline (bioethanol) and biogas have been checked for consistency against the values reported in the EU Renewable Energy Directive (see Annex III).

Annex I - Continued

A I.3. CoM default Emission factors for Local electricity production from RES

	Standard (IPCC)		LCA[2] Up to 2007[4]	LCA[3] 2008-2015[4] (current update)
Electricity generation RES Technology[1]	t CO_2 /MWh	t CO_2-eq /MWh	t CO_2-eq /MWh	t CO_2-eq /MWh
Wind	0	0	0.020-0.050[a]	0.010
Hydroelectric	0	0	0.007	0.006
Photovoltaics	0	0	0.024[b]	0.030[c]

LCA data sources: [1]RES Technologies as defined in CoM SECAP on-line template; [2]ELCD (2009) and [3]ELCD v3.2 (ELCD, 2015) databases except: [a)]based on results from one plant, operated in coastal areas with good wind conditions, [b)] Vasilis et al. (2008) and [c)] Amponsah et al. (2014). [4]The validity range applies to the baseline emission inventory. For the subsequent monitoring emission inventories, the same emission factors should be applied (see also section 1.4 for details on the use of local versus CoM default emission factors).

Annex I - Continued

Annex I.4 National and European Emission factors for Electricity consumption (NEEFE)

AI.4.1: CO_2 emission factors from Electricity consumption (standard approach, tCO_2/MWh) – 1990 to 2001

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Austria	0.279	0.281	0.221	0.209	0.229	0.248	0.257	0.259	0.228	0.222	0.201	0.200
Belgium	0.433	0.416	0.407	0.409	0.424	0.409	0.378	0.349	0.365	0.331	0.329	0.313
Bulgaria	0.956	0.867	0.981	1.008	0.912	0.857	0.799	0.880	0.897	0.833	0.816	0.993
Croatia	0.252	0.180	0.332	0.359	0.204	0.237	0.255	0.274	0.337	0.330	0.286	0.363
Cyprus	0.933	0.925	0.959	0.938	0.936	0.933	0.955	0.973	0.974	0.981	0.952	0.897
Czech Republic	0.977	1.024	1.002	1.052	1.021	1.020	0.992	0.995	1.003	0.958	1.077	1.135
Denmark	0.627	0.876	0.695	0.718	0.843	0.706	1.049	0.782	0.668	0.580	0.498	0.557
Estonia	2.436	2.092	2.093	1.878	2.032	2.093	2.030	1.897	1.899	1.946	1.841	1.768
Finland	0.176	0.193	0.155	0.193	0.254	0.223	0.299	0.252	0.185	0.185	0.164	0.214
France	0.149	0.172	0.134	0.092	0.093	0.107	0.112	0.102	0.138	0.120	0.108	0.096
Germany	0.750	0.753	0.734	0.725	0.729	0.708	0.718	0.685	0.675	0.638	0.641	0.580
Greece	1.228	1.165	1.198	1.180	1.164	1.166	1.022	0.973	0.956	0.967	1.033	1.023
Hungary	0.452	0.518	0.599	0.644	0.636	0.635	0.622	0.645	0.659	0.644	0.564	0.561
Ireland	0.899	0.902	0.906	0.884	0.879	0.872	0.855	0.840	0.837	0.812	0.758	0.807
Italy	0.575	0.549	0.535	0.516	0.512	0.546	0.524	0.514	0.513	0.493	0.496	0.476
Latvia	0.095	0.102	0.085	0.109	0.129	0.117	0.140	0.130	0.125	0.125	0.120	0.123
Lithuania	0.377	0.413	0.200	0.162	0.166	0.139	0.234	0.141	0.283	0.236	0.178	0.194
Luxembourg	0.417	0.440	0.414	0.404	0.300	0.182	0.150	0.089	0.030	0.032	0.034	0.068
Malta	1.945	1.335	1.227	1.662	1.491	1.255	1.218	1.173	1.155	1.116	1.012	1.260
Netherlands	0.603	0.592	0.586	0.596	0.585	0.542	0.523	0.496	0.494	0.461	0.442	0.508
Poland	1.435	1.479	1.503	1.474	1.498	1.406	1.361	1.328	1.291	1.296	1.278	1.356
Portugal	0.635	0.636	0.733	0.664	0.618	0.673	0.503	0.505	0.555	0.656	0.557	0.562
Romania	1.070	1.105	1.161	1.265	1.280	1.221	1.176	0.954	0.781	0.823	0.893	0.939
Slovak Republic	0.431	0.458	0.445	0.470	0.412	0.449	0.400	0.428	0.447	0.422	0.350	0.386
Slovenia	0.588	0.509	0.601	0.608	0.523	0.538	0.491	0.508	0.537	0.446	0.453	0.501
Spain	0.524	0.518	0.580	0.504	0.492	0.543	0.429	0.475	0.455	0.526	0.517	0.490
Sweden	0.014	0.023	0.023	0.025	0.029	0.026	0.053	0.031	0.034	0.032	0.024	0.027
United-Kingdom	0.794	0.771	0.759	0.665	0.640	0.606	0.593	0.550	0.555	0.516	0.545	0.567
EU-28	0.602	0.595	0.582	0.554	0.550	0.544	0.537	0.511	0.506	0.488	0.486	0.482

Annex I - Continued

Annex I.4 National and European Emission factors for Electricity consumption (*continued*)

AI.4.1 (*continued*): CO_2 emission factors from Electricity consumption (standard approach, tCO_2/MWh) – 2002 to 2013

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Austria	0.221	0.255	0.253	0.248	0.229	0.213	0.203	0.187	0.211	0.218	0.183	0.170
Belgium	0.304	0.297	0.290	0.302	0.275	0.274	0.260	0.252	0.247	0.221	0.220	0.198
Bulgaria	0.854	0.914	0.913	0.883	0.854	0.963	0.897	0.870	0.915	1.060	0.910	0.791
Croatia	0.374	0.408	0.305	0.287	0.278	0.335	0.282	0.241	0.208	0.231	0.214	0.204
Cyprus	0.854	0.936	0.875	0.880	0.855	0.854	0.840	0.827	0.769	0.773	0.785	0.707
Czech Republic	1.016	0.992	0.975	0.924	0.903	0.992	0.905	0.890	0.878	0.915	0.855	0.783
Denmark	0.531	0.686	0.501	0.405	0.628	0.506	0.446	0.467	0.430	0.351	0.254	0.331
Estonia	1.656	1.882	1.831	1.808	1.476	1.919	1.671	1.450	1.903	1.878	1.594	1.977
Finland	0.229	0.323	0.272	0.147	0.259	0.230	0.170	0.180	0.221	0.179	0.120	0.155
France	0.095	0.097	0.093	0.110	0.101	0.104	0.093	0.097	0.094	0.083	0.086	0.082
Germany	0.642	0.614	0.597	0.594	0.598	0.622	0.585	0.568	0.547	0.556	0.574	0.587
Greece	0.961	0.945	0.937	0.923	0.849	0.866	0.840	0.818	0.775	0.819	0.811	0.757
Hungary	0.521	0.551	0.475	0.412	0.395	0.437	0.411	0.341	0.346	0.331	0.334	0.254
Ireland	0.733	0.654	0.636	0.621	0.567	0.554	0.532	0.503	0.511	0.473	0.523	0.464
Italy	0.499	0.506	0.501	0.482	0.481	0.478	0.463	0.411	0.405	0.403	0.389	0.343
Latvia	0.101	0.096	0.080	0.072	0.086	0.075	0.087	0.085	0.128	0.126	0.078	0.121
Lithuania	0.174	0.166	0.165	0.181	0.143	0.134	0.124	0.147	0.192	0.134	0.138	0.096
Luxembourg	0.183	0.159	0.185	0.188	0.183	0.165	0.139	0.177	0.168	0.138	0.148	0.091
Malta	1.169	1.184	1.142	1.280	1.176	1.268	1.070	1.091	1.022	1.000	1.032	0.871
Netherlands	0.468	0.472	0.461	0.440	0.423	0.445	0.439	0.461	0.459	0.428	0.428	0.429
Poland	1.261	1.280	1.234	1.225	1.209	1.155	1.089	1.089	1.033	1.063	1.013	1.013
Portugal	0.584	0.461	0.472	0.525	0.443	0.383	0.375	0.396	0.274	0.329	0.363	0.314
Romania	0.863	0.940	0.764	0.751	0.799	0.817	0.795	0.725	0.604	0.724	0.666	0.502
Slovak Republic	0.290	0.351	0.300	0.309	0.287	0.255	0.245	0.240	0.224	0.231	0.234	0.199
Slovenia	0.483	0.440	0.428	0.421	0.423	0.433	0.432	0.471	0.441	0.435	0.418	0.399
Spain	0.519	0.455	0.466	0.480	0.449	0.472	0.402	0.364	0.289	0.354	0.378	0.297
Sweden	0.032	0.041	0.026	0.023	0.024	0.020	0.020	0.020	0.029	0.020	0.015	0.015
United-Kingdom	0.551	0.588	0.579	0.568	0.598	0.593	0.561	0.520	0.512	0.507	0.554	0.515
EU-28	0.486	0.489	0.472	0.466	0.466	0.473	0.443	0.423	0.406	0.416	0.414	0.391

Annex I - Continued

Annex I.4 National and European Emission factors for Electricity consumption (*continued*)

AI.4.2: GHG emission factors from Electricity consumption (standard approach, tCO_2-eq/MWh) – 1990 to 2001

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Austria	0.280	0.282	0.222	0.210	0.230	0.249	0.258	0.260	0.229	0.223	0.202	0.201
Belgium	0.435	0.417	0.409	0.410	0.426	0.411	0.379	0.350	0.367	0.332	0.330	0.314
Bulgaria	0.960	0.871	0.986	1.012	0.916	0.861	0.802	0.884	0.901	0.837	0.820	0.997
Croatia	0.253	0.181	0.333	0.360	0.205	0.238	0.256	0.275	0.338	0.331	0.287	0.365
Cyprus	0.936	0.928	0.962	0.942	0.939	0.936	0.958	0.977	0.978	0.984	0.955	0.900
Czech Republic	0.981	1.028	1.007	1.057	1.026	1.024	0.996	0.999	1.007	0.962	1.082	1.140
Denmark	0.630	0.881	0.698	0.722	0.847	0.710	1.054	0.785	0.671	0.583	0.500	0.560
Estonia	2.446	2.101	2.102	1.886	2.041	2.102	2.039	1.905	1.908	1.954	1.849	1.775
Finland	0.177	0.194	0.155	0.194	0.255	0.224	0.300	0.253	0.186	0.186	0.165	0.215
France	0.150	0.172	0.135	0.093	0.093	0.107	0.112	0.102	0.139	0.120	0.108	0.097
Germany	0.754	0.756	0.738	0.728	0.732	0.712	0.721	0.688	0.678	0.641	0.644	0.583
Greece	1.234	1.170	1.203	1.185	1.169	1.171	1.026	0.978	0.960	0.971	1.037	1.027
Hungary	0.454	0.519	0.602	0.647	0.638	0.637	0.624	0.647	0.662	0.646	0.567	0.563
Ireland	0.903	0.905	0.910	0.888	0.882	0.875	0.858	0.843	0.840	0.814	0.761	0.810
Italy	0.577	0.551	0.537	0.517	0.514	0.547	0.525	0.515	0.514	0.495	0.497	0.477
Latvia	0.095	0.102	0.085	0.110	0.129	0.117	0.140	0.130	0.125	0.125	0.120	0.124
Lithuania	0.378	0.414	0.200	0.163	0.166	0.139	0.234	0.142	0.283	0.237	0.178	0.195
Luxembourg	0.417	0.441	0.414	0.404	0.300	0.182	0.150	0.089	0.030	0.033	0.034	0.069
Malta	1.953	1.340	1.232	1.668	1.496	1.259	1.222	1.177	1.159	1.120	1.016	1.265
Netherlands	0.605	0.593	0.587	0.598	0.587	0.544	0.525	0.497	0.495	0.462	0.443	0.510
Poland	1.442	1.486	1.510	1.481	1.505	1.413	1.367	1.334	1.297	1.302	1.284	1.362
Portugal	0.638	0.638	0.736	0.666	0.620	0.676	0.505	0.507	0.557	0.659	0.559	0.564
Romania	1.073	1.109	1.165	1.269	1.284	1.225	1.180	0.957	0.784	0.826	0.897	0.943
Slovak Republic	0.432	0.460	0.447	0.472	0.414	0.451	0.401	0.430	0.449	0.424	0.351	0.388
Slovenia	0.591	0.512	0.603	0.610	0.525	0.540	0.493	0.510	0.539	0.448	0.455	0.504
Spain	0.526	0.520	0.582	0.507	0.494	0.546	0.431	0.477	0.457	0.528	0.519	0.492
Sweden	0.014	0.023	0.023	0.025	0.030	0.026	0.053	0.031	0.034	0.032	0.024	0.028
United-Kingdom	0.798	0.775	0.762	0.668	0.643	0.609	0.595	0.552	0.557	0.518	0.547	0.569
EU-28	0.604	0.597	0.584	0.557	0.552	0.546	0.539	0.513	0.508	0.489	0.488	0.484

Annex I - Continued

Annex I.4 National and European Emission factors for Electricity consumption (*continued*)

AI.4.2 (*continued*): GHG emission factors from Electricity consumption (standard approach, tCO_2-eq/MWh) – 2002 to 2013

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Austria	0.222	0.255	0.254	0.248	0.229	0.214	0.204	0.188	0.212	0.219	0.184	0.170
Belgium	0.305	0.298	0.291	0.303	0.276	0.275	0.261	0.253	0.248	0.221	0.221	0.199
Bulgaria	0.858	0.918	0.917	0.887	0.858	0.967	0.901	0.874	0.920	1.065	0.914	0.795
Croatia	0.376	0.409	0.306	0.288	0.279	0.336	0.283	0.241	0.209	0.231	0.214	0.205
Cyprus	0.857	0.939	0.877	0.883	0.858	0.856	0.843	0.830	0.771	0.775	0.788	0.709
Czech Republic	1.020	0.996	0.980	0.928	0.907	0.997	0.909	0.894	0.883	0.920	0.859	0.787
Denmark	0.533	0.689	0.504	0.407	0.631	0.509	0.448	0.469	0.433	0.353	0.255	0.333
Estonia	1.663	1.890	1.839	1.816	1.483	1.927	1.678	1.456	1.912	1.887	1.601	1.986
Finland	0.230	0.324	0.273	0.147	0.260	0.231	0.171	0.181	0.223	0.179	0.120	0.156
France	0.095	0.098	0.093	0.110	0.101	0.104	0.093	0.098	0.095	0.084	0.087	0.083
Germany	0.645	0.616	0.599	0.597	0.601	0.625	0.588	0.570	0.550	0.559	0.576	0.589
Greece	0.965	0.949	0.941	0.927	0.852	0.870	0.844	0.821	0.779	0.822	0.814	0.760
Hungary	0.522	0.553	0.477	0.414	0.397	0.438	0.412	0.342	0.348	0.332	0.335	0.255
Ireland	0.736	0.656	0.638	0.623	0.569	0.556	0.534	0.505	0.512	0.475	0.524	0.465
Italy	0.500	0.507	0.503	0.484	0.482	0.479	0.464	0.413	0.407	0.405	0.391	0.344
Latvia	0.101	0.096	0.080	0.072	0.086	0.075	0.087	0.085	0.128	0.126	0.078	0.121
Lithuania	0.175	0.166	0.166	0.181	0.143	0.134	0.124	0.148	0.193	0.134	0.138	0.096
Luxembourg	0.184	0.159	0.185	0.188	0.184	0.165	0.139	0.178	0.168	0.138	0.149	0.091
Malta	1.173	1.188	1.146	1.284	1.180	1.272	1.073	1.094	1.026	1.003	1.035	0.874
Netherlands	0.469	0.473	0.463	0.441	0.425	0.447	0.441	0.463	0.460	0.430	0.430	0.430
Poland	1.267	1.286	1.240	1.231	1.214	1.160	1.095	1.094	1.038	1.068	1.018	1.017
Portugal	0.587	0.463	0.474	0.528	0.445	0.384	0.376	0.398	0.275	0.330	0.365	0.316
Romania	0.866	0.944	0.767	0.754	0.802	0.820	0.798	0.728	0.607	0.727	0.668	0.504
Slovak Republic	0.291	0.352	0.301	0.310	0.289	0.256	0.246	0.241	0.225	0.232	0.235	0.199
Slovenia	0.485	0.442	0.430	0.423	0.425	0.435	0.434	0.473	0.444	0.437	0.420	0.401
Spain	0.521	0.457	0.468	0.482	0.450	0.474	0.404	0.366	0.290	0.355	0.380	0.298
Sweden	0.033	0.041	0.026	0.023	0.025	0.020	0.021	0.020	0.030	0.020	0.015	0.016
United-Kingdom	0.553	0.590	0.582	0.570	0.600	0.595	0.562	0.521	0.514	0.509	0.556	0.517
EU-28	0.488	0.491	0.474	0.468	0.468	0.475	0.445	0.425	0.407	0.418	0.416	0.393

Annex I - Continued

Annex I.4 National and European Emission factors for Electricity consumption (*continued*)

AI.4.3: GHG emission factors from Electricity consumption (LCA approach, tCO_2-eq/MWh) – 1990 to 2001

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Austria	0.314	0.317	0.254	0.248	0.274	0.293	0.300	0.298	0.267	0.262	0.232	0.238
Belgium	0.459	0.441	0.414	0.419	0.430	0.424	0.404	0.373	0.394	0.352	0.343	0.327
Bulgaria	0.938	0.855	0.973	1.023	0.910	0.852	0.809	0.913	0.933	0.869	0.852	1.040
Croatia	0.287	0.204	0.377	0.413	0.238	0.272	0.295	0.312	0.385	0.377	0.320	0.408
Cyprus	1.072	1.063	1.101	1.078	1.074	1.072	1.096	1.118	1.119	1.127	1.093	1.030
Czech Republic	1.011	1.060	1.038	1.091	1.061	1.060	1.031	1.036	1.044	1.001	1.123	1.190
Denmark	0.660	0.927	0.737	0.763	0.898	0.757	1.124	0.845	0.727	0.637	0.547	0.618
Estonia	2.452	2.104	2.107	1.888	2.040	2.105	2.042	1.909	1.915	1.963	1.858	1.787
Finland	0.220	0.234	0.189	0.233	0.299	0.267	0.340	0.295	0.225	0.224	0.205	0.280
France	0.159	0.184	0.144	0.099	0.100	0.114	0.120	0.109	0.148	0.128	0.107	0.096
Germany	0.782	0.781	0.762	0.747	0.756	0.735	0.745	0.713	0.703	0.665	0.672	0.607
Greece	1.291	1.227	1.261	1.242	1.223	1.225	1.075	1.025	1.007	1.023	1.094	1.085
Hungary	0.468	0.534	0.613	0.659	0.656	0.664	0.651	0.679	0.694	0.679	0.599	0.599
Ireland	0.971	0.976	0.979	0.960	0.954	0.948	0.934	0.925	0.924	0.902	0.842	0.897
Italy	0.654	0.626	0.614	0.594	0.589	0.626	0.603	0.593	0.592	0.571	0.575	0.549
Latvia	0.111	0.119	0.099	0.125	0.146	0.132	0.158	0.149	0.143	0.144	0.138	0.145
Lithuania	0.441	0.481	0.232	0.188	0.192	0.161	0.272	0.164	0.327	0.275	0.210	0.233
Luxembourg	0.425	0.449	0.423	0.412	0.305	0.187	0.156	0.094	0.032	0.035	0.037	0.078
Malta	2.156	1.485	1.371	1.852	1.672	1.431	1.398	1.347	1.327	1.282	1.162	1.447
Netherlands	0.665	0.656	0.651	0.661	0.646	0.595	0.576	0.547	0.540	0.511	0.488	0.569
Poland	1.498	1.545	1.570	1.539	1.564	1.468	1.421	1.387	1.349	1.354	1.336	1.422
Portugal	0.708	0.712	0.819	0.737	0.680	0.745	0.553	0.557	0.618	0.733	0.618	0.640
Romania	1.097	1.154	1.105	1.167	1.223	1.145	1.120	0.855	0.722	0.762	0.850	0.876
Slovak Republic	0.460	0.489	0.473	0.506	0.445	0.482	0.430	0.459	0.479	0.454	0.375	0.418
Slovenia	0.613	0.529	0.624	0.632	0.545	0.560	0.512	0.526	0.557	0.463	0.472	0.529
Spain	0.555	0.549	0.617	0.535	0.523	0.581	0.460	0.512	0.490	0.569	0.559	0.536
Sweden	0.018	0.028	0.030	0.031	0.037	0.033	0.063	0.039	0.042	0.039	0.034	0.050
United-Kingdom	0.845	0.820	0.810	0.716	0.692	0.657	0.646	0.605	0.611	0.574	0.606	0.625
EU-28	0.639	0.632	0.617	0.589	0.586	0.580	0.572	0.548	0.544	0.526	0.525	0.523

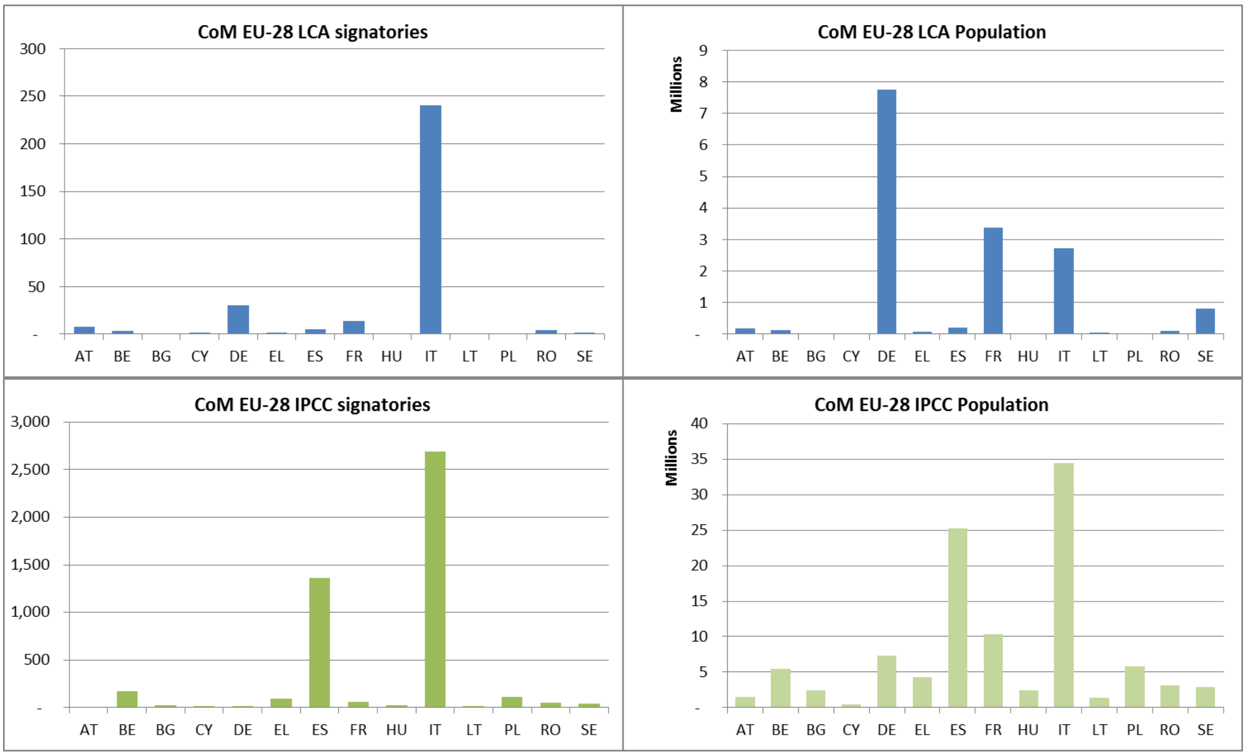
Annex I.4 National and European Emission factors for Electricity consumption (*continued*)

AI.6 (*continued*): GHG emission factors from Electricity consumption (LCA approach, tCO_{2}-eq/MWh) – 2002 to 2013

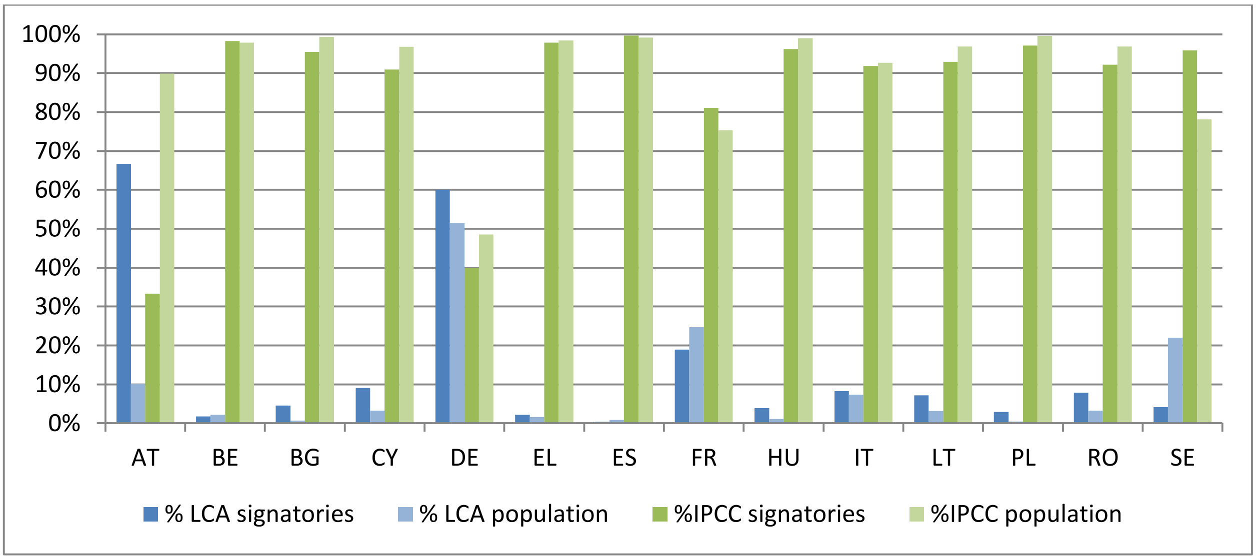
	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Austria	0.252	0.289	0.287	0.289	0.271	0.257	0.250	0.235	0.280	0.267	0.235	0.211
Belgium	0.315	0.327	0.321	0.338	0.310	0.313	0.300	0.299	0.298	0.263	0.265	0.239
Bulgaria	0.892	0.952	0.950	0.920	0.890	1.005	0.935	0.905	0.967	1.101	0.946	0.824
Croatia	0.419	0.455	0.340	0.318	0.310	0.376	0.314	0.270	0.238	0.257	0.240	0.228
Cyprus	0.981	1.075	1.004	1.011	0.982	0.981	0.966	0.952	0.886	0.891	0.906	0.817
Czech Republic	1.059	1.031	1.016	0.964	0.943	1.037	0.949	0.938	0.940	0.972	0.917	0.850
Denmark	0.588	0.753	0.562	0.457	0.693	0.562	0.497	0.523	0.549	0.405	0.301	0.380
Estonia	1.672	1.900	1.847	1.825	1.491	1.935	1.685	1.471	1.978	1.922	1.643	2.017
Finland	0.276	0.377	0.325	0.191	0.312	0.274	0.216	0.221	0.310	0.230	0.165	0.206
France	0.096	0.100	0.096	0.121	0.111	0.116	0.105	0.110	0.114	0.098	0.098	0.093
Germany	0.675	0.652	0.636	0.636	0.644	0.676	0.641	0.626	0.611	0.618	0.643	0.658
Greece	1.021	1.004	0.995	0.981	0.905	0.927	0.901	0.872	0.828	0.876	0.867	0.810
Hungary	0.554	0.593	0.529	0.481	0.455	0.506	0.487	0.411	0.431	0.389	0.388	0.297
Ireland	0.814	0.728	0.712	0.691	0.636	0.625	0.601	0.571	0.583	0.537	0.587	0.523
Italy	0.576	0.587	0.581	0.560	0.559	0.556	0.540	0.485	0.489	0.480	0.467	0.424
Latvia	0.120	0.116	0.100	0.090	0.107	0.093	0.109	0.107	0.194	0.160	0.115	0.183
Lithuania	0.208	0.197	0.196	0.214	0.170	0.161	0.149	0.178	0.276	0.166	0.172	0.128
Luxembourg	0.215	0.186	0.217	0.221	0.216	0.194	0.164	0.210	0.205	0.163	0.176	0.108
Malta	1.343	1.359	1.312	1.470	1.351	1.456	1.229	1.253	1.174	1.149	1.187	1.002
Netherlands	0.521	0.524	0.517	0.500	0.484	0.501	0.502	0.533	0.548	0.496	0.490	0.486
Poland	1.320	1.340	1.295	1.289	1.274	1.219	1.155	1.160	1.120	1.140	1.097	1.090
Portugal	0.652	0.512	0.527	0.589	0.495	0.434	0.427	0.452	0.333	0.388	0.423	0.368
Romania	0.834	0.937	0.812	0.796	0.846	0.864	0.839	0.762	0.652	0.760	0.702	0.532
Slovak Republic	0.310	0.373	0.319	0.327	0.308	0.273	0.266	0.266	0.270	0.269	0.279	0.241
Slovenia	0.505	0.461	0.449	0.441	0.443	0.453	0.461	0.499	0.476	0.462	0.444	0.424
Spain	0.567	0.503	0.517	0.535	0.500	0.524	0.456	0.416	0.336	0.403	0.429	0.343
Sweden	0.043	0.056	0.042	0.039	0.041	0.037	0.038	0.044	0.089	0.039	0.038	0.038
United-Kingdom	0.615	0.655	0.650	0.640	0.671	0.669	0.637	0.597	0.592	0.584	0.627	0.589
EU-28	0.527	0.532	0.517	0.513	0.514	0.523	0.494	0.475	0.467	0.469	0.468	0.444

Annex II - Standard versus LCA CoM statistics in EU Member States[1]

a) CoM signatories and covered population in the Member States using the *standard* (IPCC) and LCA approaches



b) LCA versus *Standard* ("IPCC") approaches in the Member States using both approaches



[1] AT: Austria; BE: Belgium; BG: Bulgaria; CY: Cyprus; DE: Germany; EL: Greece; ES: Spain; FR: France; HU: Hungary; IT: Italy; LT: Lithuania; PL:Poland; RO: Romania; SE: Sweden. CoM signatories in the 14 other Member States only use the standard (IPCC) approach. See also Table 7 of the report for EU-28 statistics as a function of the population size of CoM signatory's territory.

Annex III - Update of CoM LCA emission factors for the supply chain[1] : Comparison to previous values

Changes as compared to CoM(2014) version are highlighted in bold; Values from the RED directive 2009 are also reported.

Main categories	SECAP Template energy carriers		LCA emission factors for the supply chain (tCO_2-eq/MWh)				
	Main classes of energy carriers	Most common IPCC energy carriers (IPCC name if different)	Bertoldi et al. (2010)[2]	CoM (2014)[3]	Current update[4]	Directive 2009/28/EC on the use of energy from renewable sources (RED): Default GHG emission factors	
				< 2008[5]	2008-2015[5]	Range	Closest value to CoM current update
Renewable energy	**Plant oil**	Other Liquid Biofuels	0.182	0.182[a]	0.182[a]	0.104 - 0.223	Hydro treated oil from rape seed (0.158)
	Biofuel	Bio-gasoline	0.207	0.207[a]	0.207[a]	0.086 - 0.252	Wheat ethanol (process fuel, boiler) : 0.198
		Biodiesels	0.156	0.156[a]	0.156[a]	0.050 - 0.245	Sunflower biodiesel: 0.148
	Other biomass	Biogas	n.a.	**n.a.**	**0.087[b]**	0.054 - 0.083	Biogas from municipal waste (0.083)
		Municipal wastes (biomass)	n.a.	0.106	0.106[3]		
		Wood *(/Wood waste)*	0.002	**0.013**	**0.017[c]**		
		(Wood /)Wood waste	n.a.	-0.226	-0.226[3]		
	Solar thermal	Solar thermal	n.a.	**n.a.**	**0.040[c]**		
	Geothermal	Geothermal	n.a.	**n.a.**	**0.050[c]**		
Fossil fuels	**Natural gas**		0.035	**0.035**	**0.038**		
	Liquid gas	Liquefied Petroleum Gases	n.a	**n.a**	**0.054[b]**		
	Liquid gas	Natural Gas Liquids	n.a.	**n.a.**	**0.041[b]**		
	Heating Oil	Heating oil (Gas/Diesel oil)	0.038	0.038	0.038		
	Diesel	Gas/Diesel oil	0.038	0.038	0.038		
	Gasoline	Motor gasoline	0.050	**0.058**	**0.064**		
	Lignite	Lignite	0.011	**0.011**	**0.010**		
	Coal	Anthracite	0.039	**0.039**	**0.014**		
		Other Bituminous Coal	0.039	**0.039**	**0.016**		
		Sub-Bituminous Coal	0.039	**0.039**	**0.015**		
Other non renewable fuels[6]	**Peat**		n.a.	**0.010**	**0.007[b]**		
	Municipal Wastes (non-biomass fraction)		0.000	**-0.156**	**-0.042**		

[1] Capture of CO_2 in the cultivation of biofuels/biomass raw materials and CO_2 consumption by end-user are excluded. [2] JRC (2009), [3] ELCD (2009) and [4]ELCD v3.2 (ELCD, 2015) databases except a) JRC (2009), b) Ecoinvent, c) Amponsah et al., (2014). [5]The validity range applies to the baseline year, i.e. to the year of the so-called Baseline Emission Inventory (BEI), whereas for the monitoring emission inventories (MEIs), the same emission factors should be applied. Default ranges and closest values as provided in Directive 2009/28/EC are also reported for comparison. For municipal and wood wastes the LCA emissions from the supply chain are negative because of the avoided impact that waste treatment allows. [6] Referred as "*Other fossil fuels*" in the on-line SEAP template.

Annex IV - Energy classes and emission factors used for the updates of the NEEFEs

<table>
<tr><th rowspan="2">Energy Classes (IEA, 2016)</th><th colspan="3">Current update [a]</th><th colspan="3">CoM (2014) update [c]</th></tr>
<tr><th>IPCC[b] tCO_2/MWh</th><th>IPCC[b] tCO_2-eq/MWh</th><th>LCA[d] tCO_2-eq/MWh</th><th>Energy Classes</th><th>IPCC[b] tCO_2/MWh</th><th>LCA tCO_2-eq/MWh</th></tr>
<tr><td>Anthracite</td><td>0.354</td><td>0.356</td><td>0.370</td><td rowspan="14">Coal and coal products</td><td rowspan="14">0.341</td><td rowspan="14">0.380</td></tr>
<tr><td>Coking coal</td><td>0.341</td><td>0.342</td><td>0.359</td></tr>
<tr><td>Other bituminous coal</td><td>0.341</td><td>0.342</td><td>0.358</td></tr>
<tr><td>Sub-bituminous coal</td><td>0.346</td><td>0.348</td><td>0.363</td></tr>
<tr><td>Lignite</td><td>0.364</td><td>0.365</td><td>0.375</td></tr>
<tr><td>Patent fuel</td><td>0.351</td><td>0.353</td><td>0.370</td></tr>
<tr><td>Coke oven coke</td><td>0.385</td><td>0.387</td><td>0.404</td></tr>
<tr><td>Gas coke</td><td>0.385</td><td>0.385</td><td>0.402</td></tr>
<tr><td>Coal tar</td><td>0.291</td><td>0.292</td><td>0.309</td></tr>
<tr><td>BKB [1]</td><td>0.351</td><td>0.353</td><td>0.370</td></tr>
<tr><td>Gas works gas</td><td>0.160</td><td>0.160</td><td>0.177</td></tr>
<tr><td>Coke oven gas</td><td>0.160</td><td>0.160</td><td>0.177</td></tr>
<tr><td>Blast furnace gas</td><td>0.936</td><td>0.936</td><td>0.953</td></tr>
<tr><td>Other recovered gases[2]</td><td>0.160</td><td>0.160</td><td>0.177</td></tr>
<tr><td>Peat</td><td>0.382</td><td>0.383</td><td>0.390</td><td rowspan="2">Peat</td><td rowspan="2">0.382</td><td rowspan="2">0.392</td></tr>
<tr><td>Peat products[3]</td><td>0.382</td><td>0.383</td><td>0.390</td></tr>
<tr><td>Oil shale and oil sands[4]</td><td>0.385</td><td>0.387</td><td>0.387</td><td>n.a.</td><td>n.a.</td><td>n.a.</td></tr>
<tr><td>Natural gas</td><td>0.202</td><td>0.202</td><td>0.240</td><td>Natural gas</td><td>0.202</td><td>0.237</td></tr>
<tr><td>Crude/NGL/FS if no detail.</td><td>0.264</td><td>0.265</td><td>0.306</td><td>n.a.</td><td>0.264</td><td>0.305</td></tr>
<tr><td>Crude oil</td><td>0.264</td><td>0.265</td><td>0.306</td><td rowspan="3">Crude,NGL, Feedstocks</td><td rowspan="3">0.264</td><td rowspan="3">0.305</td></tr>
<tr><td>Natural gas liquids</td><td>0.231</td><td>0.231</td><td>0.272</td></tr>
<tr><td>Refinery feedstocks</td><td>0.264</td><td>0.265</td><td>0.306</td></tr>
<tr><td>Additives/blending comp.[5]</td><td>0.264</td><td>0.265</td><td>0.305</td><td rowspan="19">Oil products</td><td rowspan="19">0.264</td><td rowspan="19">0.305</td></tr>
<tr><td>Other hydrocarbons[6]</td><td>0.264</td><td>0.265</td><td>0.305</td></tr>
<tr><td>Refinery gas</td><td>0.207</td><td>0.208</td><td>0.248</td></tr>
<tr><td>Ethane</td><td>0.222</td><td>0.222</td><td>0.262</td></tr>
<tr><td>Liquefied petroleum gases</td><td>0.227</td><td>0.227</td><td>0.281</td></tr>
<tr><td>Motor gasoline excl. biofuels</td><td>0.249</td><td>0.250</td><td>0.314</td></tr>
<tr><td>Aviation gasoline</td><td>0.252</td><td>0.253</td><td>0.293</td></tr>
<tr><td>Gasoline type jet fuel</td><td>0.257</td><td>0.258</td><td>0.298</td></tr>
<tr><td>Kerosene (jet fuel excl.biofuels)</td><td>0.257</td><td>0.258</td><td>0.298</td></tr>
<tr><td>Other kerosene</td><td>0.259</td><td>0.260</td><td>0.300</td></tr>
<tr><td>Gas/diesel oil excl. biofuels</td><td>0.267</td><td>0.268</td><td>0.306</td></tr>
<tr><td>Fuel oil[7]</td><td>0.279</td><td>0.280</td><td>0.320</td></tr>
<tr><td>Naphtha</td><td>0.264</td><td>0.265</td><td>0.305</td></tr>
<tr><td>White spirit & SBP</td><td>0.264</td><td>0.265</td><td>0.305</td></tr>
<tr><td>Lubricants</td><td>0.264</td><td>0.265</td><td>0.305</td></tr>
<tr><td>Bitumen</td><td>0.291</td><td>0.291</td><td>0.331</td></tr>
<tr><td>Paraffin waxes</td><td>0.264</td><td>0.265</td><td>0.305</td></tr>
<tr><td>Petroleum coke</td><td>0.351</td><td>0.352</td><td>0.392</td></tr>
<tr><td>Other oil products[6]</td><td>0.264</td><td>0.265</td><td>0.305</td></tr>
</table>

Annex IV - Continued

Energy Classes (IEA, 2016)	Current update [a]			CoM (2014) update [c]		
	IPCC[b] tCO_2/MWh	IPCC[b] tCO_2-eq/MWh	LCA[d] tCO_2-eq/MWh	Energy Classes	IPCC[b] tCO_2/MWh	LCA tCO_2-eq/MWh
Industrial waste	0.515	0.522	0.522	Biofuels and waste	0.360	0.174
Municipal waste (renewable)	0.000[e]	0.000[e]	0.000[e]			
Municipal waste (non-renew.)	0.330	0.337	0.295			
Primary solid biofuels[8]	0.000[e]	0.000[e]	0.184			
Biogases[9]	0.000[e]	0.000[e]	0.284			
Biogasoline	0.000[e]	0.000[e]	0.206			
Biodiesels	0.000[e]	0.000[e]	0.156			
Other liquid biofuels	0.000[e]	0.000[e]	0.182			
n.spec. pr. biofuels and waste[10]	0.000[e]	0.000[e]	0.184			
Nuclear	0.000	0.000	0.000	Nuclear	0.000	0.000
Hydro	0.000	0.000	0.000	Hydro	0.000	0.024
Geothermal	0.000	0.000	0.050	Geotherm.	0.000	0.000
Solar photovoltaics	0.000	0.000	0.000	Solar, Wind, Other sources	0.000	0.030
Solar thermal	0.000	0.000	0.040			
Tide, wave and ocean	0.000	0.000	0.000			
Wind	0.000	0.000	0.000			
Other sources	0.000	0.000	0.000			

a. All fuel categories of IEA *Extended energy balances* are accounted for in the new update of the National and European Emission factors for Electricity consumption (NEEFE) to calculate CO_2/GHG emissions from electricity production, by applying the corresponding IPCC (2006) factors (Table 2.2). Where different from IEA's energy carrier name/class, IPCC default factors for the following IPCC energy classes have been used: [1] Brown Coal Briquettes, [2] Derived gases (e.g. Gas Works Gas), [3] Peat, [4] Oil shale and Tar Sands; [5] Lubricants; [6] Other Petroleum products, [7] Residual Fuel Oil; [8] Wood/Wood Waste; [9]Gas Biomass; [10] Wood/Wood waste

b. IPCC (2006) default emission factors for Stationary combustion in the Energy Industries (Table 2.2) converted to tCO_2/MWh. The emission factors in tCO_2eq/MWh were calculated as the sum of CO_2, CH_4 and N_2O default emission factors, applying the Global Warming Potentials from the IPCC (2017) Four Assessment report.

c. CoM (2014), Reporting Guidelines on Sustainable Energy Action Plan and Monitoring(http://www.covenantofmayors.eu/IMG/pdf/Reporting_Guidelines_SEAP_and_Monitoring.pdf); CoM (2016), The Covenant of Mayors for Climate and Energy Reporting Guidelines (http://www.covenantofmayors.eu/IMG/pdf/Covenant_ReportingGuidelines.pdf)

d. The current update of LCA-based NEEFE was done applying the LCA emission factors of Annex I (for the current update) to the corresponding IEA (2016) input energy carriers. For the fuels not documented in Annex I, the LCA emission factors (*in italic*) were calculated based on the emissions from the supply chain of fuels belonging to a similar CoM (2014) energy (sub)category.

e. Following the IPCC (2006) guidelines, the direct CO_2/GHG emissions from biomass/biofuels consumption are not accounted for in the calculation of the NEEFE. See Section 2.3. for further explanation.

Annex V - Updated NEEFEs: Comparison to CoM previous values

Table V.1 National and European Emission Factors for Electricity (per MWh of electricity) consumed (NEEFE) provided in CoM 2010 Guidebook (Bertoldi et al. 2010[a]). The NEEFEs were either derived from Eurelectric (2005)[b] 2002 energy data (highlighted in bold) or provided by the national agencies for another reference year. The LCA factors were calculated by adding emissions from the supply chain as provided in ELCD (2009)[c] dataset for the year 2002 to the standard emissions from fuel combustion.

		Standard	LCA
	Reference Year	tCO_2/MWh	tCO_2-eq/MWh
Austria	**2002**	**0.209**	**0.310**
Belgium	**2002**	**0.285**	**0.402**
Bulgaria	**2002**	**0.819**	**0.906**
Cyprus	**2002**	**0.874**	**1.019**
Czech Republic	**2002**	**0.950**	**0.802**
Denmark	2008	0.461	0.760
Estonia	2007	0.908	1.593
Finland	**2002**	**0.216**	**0.418**
France	**2002**	**0.056**	**0.146**
Germany	2007	0.624	0.706
Greece	**2002**	**1.149**	**1.167**
Hungary	**2002**	**0.566**	**0.678**
Ireland	**2002**	**0.732**	**0.870**
Italy	**2002**	**0.483**	**0.708**
Latvia	**2002**	**0.109**	**0.563**
Lithuania	**2002**	**0.153**	**0.174**
Netherlands	**2002**	**0.435**	**0.716**
Poland	**2002**	**1.191**	**1.185**
Portugal	2007	0.369	0.750
Romania	**2002**	**0.701**	**1.084**
Slovak Republic	2007	0.252	0.353
Slovenia	2007	0.557	0.602
Spain	2007	0.440	0.639
Sweden	**2002**	**0.023**	**0.079**
United Kingdom	2007	0.543	0.658
EU-27[1]	**2002**	**0.460**	**0.578**

[1] Croatia not included

a. Bertoldi, P., Cayuela, D. B., Monni, S., & de Raveschoot, R. P. (2010). How to develop a Sustainable Energy Action Plan (SEAP). Joint Research Centre Scientific and Technical reports, EUR 24360 EN, ISBN 978-92-79-15782-0.
b. Eurelectric, 2005. Statistics and prospects for the European electricity sector (1980-1990, 2000-2020). EURPROG Network of Experts.
c. ELCD (2009). European Reference Life Cycle Database (ELCD). LCA data sets of key energy carriers, materials, waste and transport services of European scope. Previously available at http://lca.jrc.ec.europa.eu/lcainfohub/datasetArea.vm

Annex V – Continued

Table V. 2 Difference (%) between the NEEFEs Versions 2017 (current update) and 2010 (Bertoldi et al., 2010) [a] . The 4 highest differences are highlighted in bold.

		Standard	Standard	LCA
	Reference Year	tCO_2/MWh	tCO_2-eq/MWh	tCO_2-eq/MWh
Austria	2002	6%	6%	-19%
Belgium	2002	7%	7%	-22%
Bulgaria	2002	4%	4%	-2%
Cyprus	2002	-2%	-2%	-4%
Czech Republic	2002	7%	7%	32%
Denmark	2008	-3%	-3%	**-35%**
Estonia	2007	**111%**	**111%**	21%
Finland	2002	6%	6%	**-34%**
France	2002	**70%**	**70%**	-34%
Germany	2007	-0.3%	-0.3%	-4%
Greece	2002	-16%	-16%	-13%
Hungary	2002	-8%	-8%	-18%
Ireland	2002	0%	0%	-6%
Italy	2002	3%	3%	-19%
Latvia	2002	-7%	-7%	**-79%**
Lithuania	2002	14%	14%	20%
Netherlands	2002	8%	7%	-27%
Poland	2002	6%	6%	11%
Portugal	2007	4%	4%	-42%
Romania	2002	23%	23%	-23%
Slovak Republic	2007	1%	1%	-23%
Slovenia	2007	**-22%**	-22%	-25%
Spain	2007	7%	7%	-18%
Sweden	2002	**39%**	**43%**	**-46%**
United Kingdom	2007	9%	9%	2%
EU[1]	2002	6%	6%	-9%

[1] EU-28 (this study; UK included) or EU-27 (Bertoldi et al., 2010; UK incl. but Croatia excluded)

a. Bertoldi, P., Cayuela, D. B., Monni, S., & de Raveschoot, R. P. (2010). How to develop a Sustainable Energy Action Plan (SEAP). Joint Research Centre Scientific and Technical reports, EUR 24360 EN, ISBN 978-92-79-15782-0.

Annex VI - 1990-2013 trends in the EU-28 NEEFEs factors

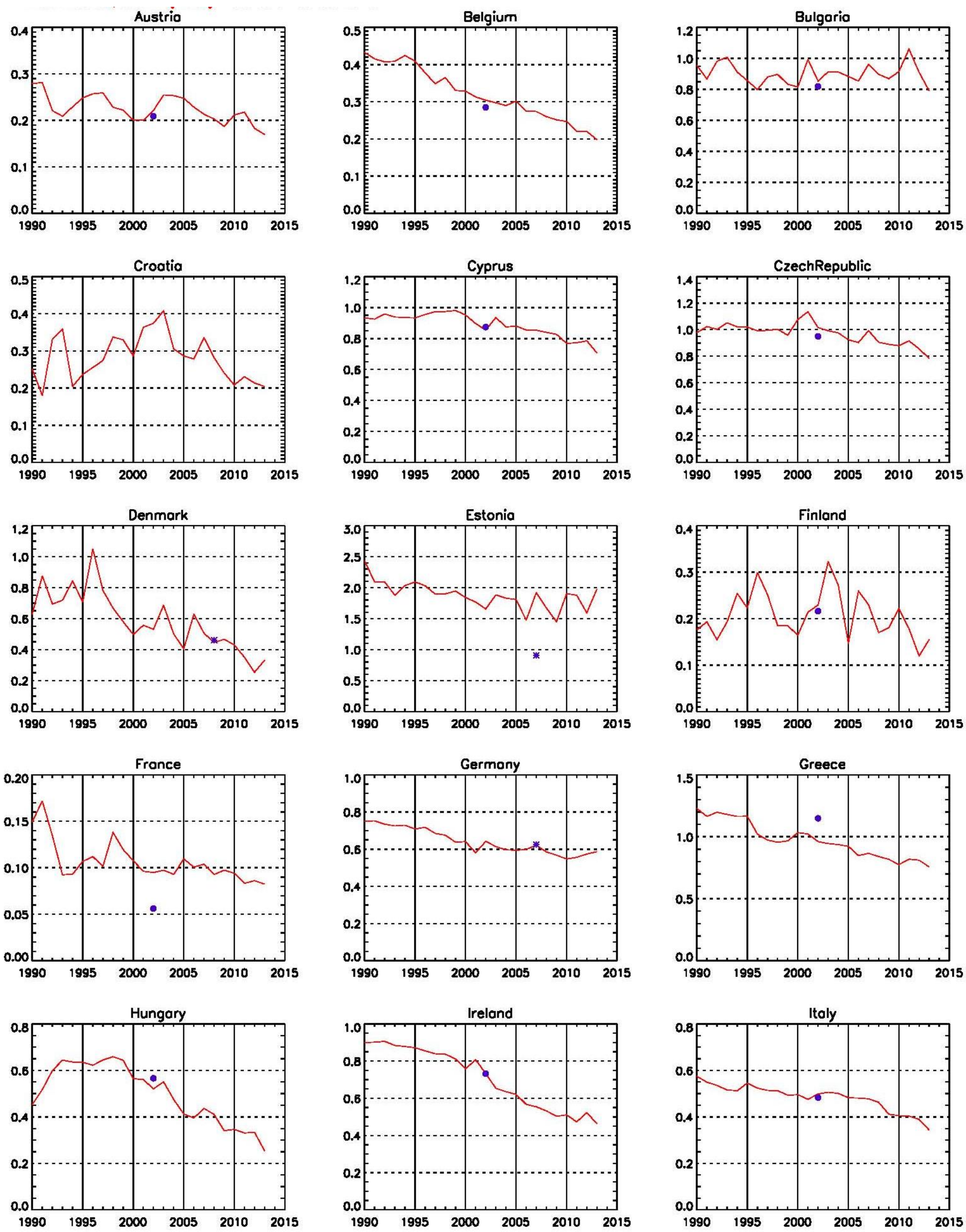


Figure IV.1: CoM NEEFE annual values Version 2017 (tCO_2/MWh) using IPCC (2006)[a] approach and emission factors (red line), as compared to Bertoldi et al. (2010)[b] values for specific years (purple circle = Eurelectric, 2005[c]; purple star= other source as provided in Bertoldi et al., 2010) for 15 EU Member States.

Annex VI – continued

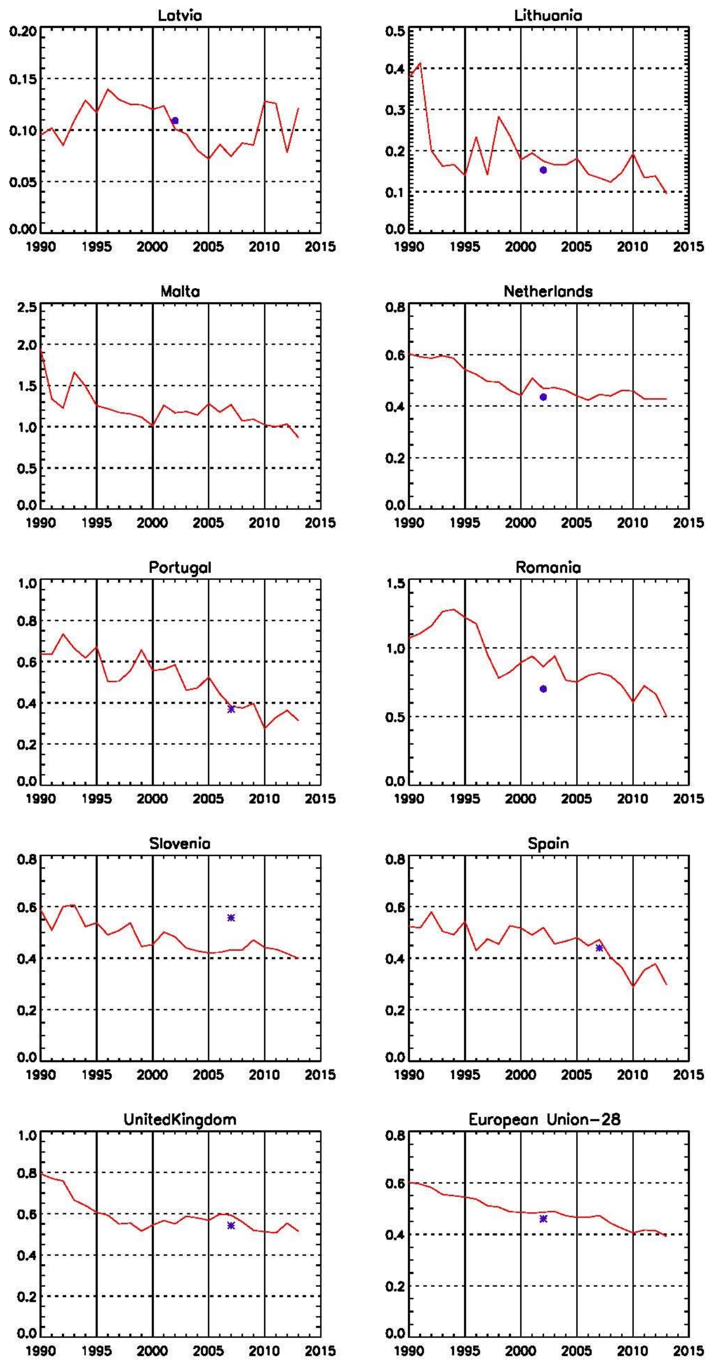


Figure IV.2: As Figure IV.1 but for the 13 additional Member States and for the EU-28 (current study) NEEFE values as compared to the EU-27 2002 value (Bertoldi et al., 2010)[b].

a. IPCC (2006), 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Prepared by the National Greenhouse Gas Inventories Programme. Eggleston H.S., Buendia L., Miwa K., Ngara T. and Tanabe K. (eds). Published: IGES, Japan. Available at http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.html.
b. Bertoldi, P., Cayuela, D. B., Monni, S., & de Raveschoot, R. P. (2010). How to develop a Sustainable Energy Action Plan (SEAP). Joint Research Centre Scientific and Technical reports, EUR 24360 EN, ISBN 978-92-79-15782-0.Eurelectric, 2005. Statistics and prospects for the European electricity sector (1980-1990, 2000-2020). EURPROG Network of Experts.

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doi:10.2760/290197
ISBN 978-92-79-71479-5