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HOW TO DEVELOP A SUSTAINABLE ENERGY ACTION PLAN (SEAP) IN THE EASTERN PARTNERSHIPAND CENTRAL ASIAN CITIES.

PART II BASELINE EMISSION INVENTORY

UPDATE OF EMISSION FACTORS

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Abstract

This technical update is a necessary compendium of the Guidebook 'How to develop a Sustainable Energy Action Plan (SEAP) in the Easter Partnership and Central Asian Cities', focusing on the calculation of updated Emission Factor for electricity in partner countries. This report provides the tables with country-specific emission factors and calculation procedures for power and heat plants and completes the emission factor time series up to 2012. In this way the signatories of the Eastern Partnership and Central Asian Cities can establish baseline emission inventories for recent years with updated emission factors.

ACRONYMS

BAU	Business-as-usual
BEI	Baseline Emissions Inventory
CH_4	Methane
CHP	Combined heat and power
CO	Carbon monoxide
CO_2	Carbon dioxide
CO_2EH	CO_2 emissions related to heat that is exported outside of the territory of the local authority
CO_2-eq.	CO_2-equivalent
CO_2GEP	CO_2 emissions due to the production of certified green electricity purchased by the local authority
CO_2IH	CO_2 emissions related to imported heat from outside the territory of the local authority
CO_2LPE	CO_2 emissions due to the local production of electricity
CO_2LPH	CO_2 emissions due to the local production of heat
CoM	Covenant of Mayors
CO_{2CHPE}	CO_2 emissions from electricity production in a CHP plant
CO_{2CHPH}	CO_2 emissions from heat production in a CHP plant
CO_{2CHPT}	Total CO_2 emissions of the CHP plant
EFE	Local emission factor for electricity
EFH	Emission factor for heat
ELCD	European Reference Life Cycle Database
ETS	Emission Trading Scheme
EU	European Union
EU-ETS	European Union Emissions Trading Scheme
GEP	Green electricity purchases by the local authority
GHG	Greenhouse gas
GWP	Global warming potential
IEAP	International Local Government Greenhouse Gas Emissions Analysis Protocol
ILCD	International Reference Life Cycle Data System
IPCC	Intergovernmental Panel on Climate Change
LCA	Life cycle assessment
LHC	Local heat consumption
LPE	Local electricity production
MEI	Monitoring Emissions Inventory
N_2O	Nitrous oxide
NCV	Net calorific value
NEFE	National emission factor for electricity
OECD	Organisation for Economic Co-operation and Development
P_{CHPH}	Amount of heat produced in a CHP plant
P_{CHPE}	Amount of electricity produced in a CHP plant
PV	Solar photovoltaic installation
RES	Renewable energy sources
SEAP	Sustainable Energy Action Plan
UNFCCC	United Nations Framework Convention on Climate Change
WBCSD	World Business Council for Sustainable Development

1. INTRODUCTION

This report was developed in order to present the most updated emission factors for the Easter Partnership and Central Asian Cities needed for the Baseline Emissions Inventory (BEI) that is required under the Covenant of Mayors (CoM) initiative. As the whole methodology and all technical issues are extensively explained in chapter II of the CoM East Giudebook (Iancu et al., 2013), this update focuses exclusively on the procedure for calculating the BEI and following Monitoring Emission Inventories (MEIs) with most updated emission factors covering years up to 2012.

The BEI quantifies the amount of carbon dioxide (CO_2) emitted due to energy consumption in the territory of the local authority (i.e. Covenant signatory) ([1]) in the baseline year. It allows an identification of the principal anthropogenic sources of CO_2 emissions and a prioritisation of the reduction measures accordingly.

Elaborating a BEI is crucial because the inventory will be the instrument allowing the local authority to measure the impact of its efforts on the emission reduction actions. The BEI allows for the provision of a reference base year from which changes in emissions and in particular reductions will be monitored in view of achieving the local authority's target of CO_2 reduction. Emission inventories are very important elements to keep all parties willing to contribute to the local authority's CO_2 reductions objective motivated by allowing them to see the results of their efforts.

In these guidelines, advice and recommendations for compiling a BEI under the CoM are presented. Some of the definitions and recommendations are chosen specifically for the inventories under the CoM in order to enable the inventories to demonstrate the progress being made towards the target of the Covenant.

However, as far as possible, the concepts, methodologies and definitions in internationally agreed standards are followed in these guidelines. For example, the local authority is encouraged to use emission factors that are in line with those of the Intergovernmental Panel on Climate Change (IPCC) or European Reference Life Cycle Database (ELCD). However, the local authority is given the flexibility to use any approach or tool that it considers appropriate for the purpose.

2. CALCULATING EMISSION INVENTORIES

2.1. Choice of emission factors: standard (IPCC) or life cycle based (LCA)

Two different approaches may be followed when selecting the emission factors:

a) *Using 'standard' emission factors* in line with the IPCC principles, which cover all the CO_2 emissions that occur due to energy consumption within the territory of the local authority, either directly due to fuel combustion within the local authority or indirectly via fuel combustion associated with electricity and heat/cold use within the area. The standard emission factors are based on the carbon content of each fuel, like in national GHG inventories in the context of the UNFCCC and the Kyoto Protocol. In this approach, CO_2 is the most important GHG, and the emissions of CH_4 and N_2O are of secondary importance for the combustion processes in the residential and transport sectors. Furthermore, CO_2 emissions from the sustainable use of biomass/biofuels, as well as emissions of certified green electricity, are considered to be zero.

   The standard emission factors given in these guidelines are based on the IPCC 2006 Guidelines (IPCC, 2006). However, the local authority may decide to also use own emission factors that are in line with the IPCC definitions.

b) *Using LCA emission factors*, which take into consideration the overall life cycle of the energy carrier. This approach includes not only the emissions of the final combustion, but also all emissions of the supply chain. It includes emissions from exploitation, transport and processing (e.g. refinery) steps in addition to the final combustion. Hence, this also includes emissions that take place outside of the location where the fuel is used. In this approach, the GHG emissions from the use of biomass/biofuels, as well as emissions of certified green electricity, are higher than zero. In the case of this approach, GHGs other than CO_2 may play an important role. Therefore, the local authority that decides to use the LCA approach can report emissions as CO_2-

[1] 'territory of the local authority' refers to the geographical area within the administrative boundaries of the entity governed by the local authority.

eq. However, if the methodology/tool used only counts CO_2 emissions, then emissions can be reported as CO_2 (in t).

LCA is an internationally standardised method (ISO 14040 series) and used by a large number of companies and governments, in particular for carbon footprinting. LCA is the scientific basis typically used, e.g., the Thematic Strategies on Natural Resources and Waste, the Ecodesign Directive and the Ecolabel Regulation. At the EU level, a series of technical guidance documents building on the ISO 14040 series had been developed and is regularly updated, coordinated by the European Commission's Joint Research Centre (JRC): International Reference Life Cycle Data System (ILCD) Handbook. The ILCD Handbook (available at http://lct.jrc.ec.europa.eu/) is the result of a comprehensive process of evaluation and selection of existing methods based on a set of scientific and stakeholder acceptance criteria (Sala et al., 2012), and it aims to provide detailed technical guidance in all steps required for a LCA. A related ILCD Data Network (JRC et al., 2009) is currently being established that would be open for all data providers to give access to consistent and quality-assured LCA data. The network can host, among others, cost-free data, licensed data and members-only data. The LCA emission factors given in these guidelines are based on the ELCD (JRC, 2009). The ELCD provides LCA data for most of the fuels and allows calculation of country-specific electricity mix data (see Section 3.4). Both the ELCD and the ILCD datasets work with the IPCC global warming factors (GWP100 of SAR) for the individual gases.

After selecting the emission factor approach, the local authority can either use the default emission factors provided in this Guidebook or choose other emission factors that are considered more appropriate. The standard emission factors depend on the carbon content of the fuels and therefore do not vary significantly from case to case. In the case of an LCA approach, obtaining information on the emissions upstream in the production process may be challenging and considerable differences may occur even for the same type of fuel. This is especially the case for biomass and biofuels. It is recommended that local authorities using the LCA approach evaluate the applicability of the emission factors presented in these guidelines before using them for the BEI/MEI, and try to obtain case-specific data where appropriate.

2.2. Greenhouse gases included: CO_2 or CO_2-equivalent emissions

The GHGs to be included in the BEI/MEI depend on the choice of sectors and also on the choice of emission factor approach (standard or LCA).

If the standard emission factors following the IPCC principles are chosen, it is sufficient to report only CO_2 emissions because the importance of other GHGs is small. In this case, the box 'CO_2 emissions' is ticked in the SEAP template, under the point 'emission reporting unit'. However, other GHGs can also be included in the baseline inventory if the standard emission factors are chosen. For example, the local authority may decide to use emission factors that also take into account CH_4 and N_2O emissions from combustion. Furthermore, if the local authority decides to include landfills and/or wastewater treatment in the inventory, then the CH_4 and N_2O emissions will also be included. In this case, the emission reporting unit to be chosen is 'CO_2 equivalent emissions'.

In the case of the LCA approach, GHGs other than CO_2 may play an important role, such as sulphur hexafluoride (SF_6), which has a global warming potential (GWP) 22 800 times higher than CO_2 in the time interval of 100 years (IPCC, 2007). Therefore, a local authority that decides to use the LCA approach will likely also include GHGs other than CO_2 in the inventory, and select the emission reporting unit 'CO_2 equivalent emissions'. However, if the local authority uses a methodology/tool that does not include any GHGs other than CO_2, the inventory will be based on CO_2 only and the emission reporting unit 'CO_2 emissions' should be chosen.

The emissions of GHGs other than CO_2 are converted to CO_2-equivalents by using the GWP values of the IPCC Second Assessment Report and Third Assessment Report (IPCC, 1995 and 2001). These are also used for the GWP evaluations of the national emission inventories reported to the UNFCCC (2006). For example, 1 kg of CH_4 has a similar impact on global warming as 21 kg of CO_2, when considered over a time interval of 100 years, and therefore the GWP value of CH_4 is 21.

In the context of the CoM, it is suggested to apply the GWP values that are used in the reporting to the UNFCCC and the Kyoto Protocol. These GWP values are based on the IPCC's Second Assessment Report (IPCC, 1995) and are presented in Table 1.

However, the local authority may decide to use other GWP values of the IPCC, for example, depending on the tool they use. The LCA emission factors presented in these guidelines are calculated using the GWP values of the Fourth Assessment Report of the IPCC (IPCC, 2007).

Table 1. Conversion of CH_4 and N_2O to CO_2-equivalent units

	GWP100 Years SAR	GWP100 Years AR4
Mass of GHG as t compound	Mass of GHG as t CO_2-equivalent	Mass of GHG as t CO_2-equivalent
1 t CO_2	1 t CO_2-eq.	1 t CO_2-eq.
1 t CH_4	21 t CO_2-eq.	25 t CO_2-eq.
1 t N_2O	310 t CO_2-eq.	298 t CO_2-eq.

Source: IPCC Second Assessment Report (SAR, 1995), Fourth Assessment Report (AR4, 2007).

2.3. Fuels and renewable heat

The standard emission factors following IPCC principles are based on the carbon contents of the fossil fuels that are released under the form of CO_2 into the atmosphere after combustion. For the biofuels IPCC considers the CO_2 release neutralized by the CO_2 uptake during the growth of the biofuel over a one-year period. Therefore in national GHG inventories no biofuels are accounted when calculating the CO_2 budget, however the biofuels are accounted when calculating the CH_4 and N_2O budget.

The LCA emission factors include the actual emissions from all life cycle steps including final combustion, as mentioned earlier. This is of special relevance for biofuels: while the carbon stored in the biofuels themselves may be CO_2 neutral, the cropping and harvesting (fertilisers, tractors, pesticide production) and processing of the final fuel may consume a lot of energy and result in considerable CO_2 releases, as well as N_2O emissions from the field. The various biofuels differ considerably regarding the life cycle of GHG emissions, and therefore the LCA approach supports the choice of the most climate-friendly biofuel and other biomass energy carriers.

For simplicity, the emission factors presented here assume that all carbon in the fuel forms CO_2. However, in reality, for incomplete combustion a small share of carbon (usually < 1 %) in the fuel also forms other compounds such as carbon monoxide (CO) and most of that carbon oxidises to CO_2 later on in the atmosphere. Please refer to Box 1 of chapter II of the main document (Iancu et al., 2013) for additional information on how to deal with biomass or biofuels that are used within the territory of the local authority.

The emission factors for the fuels that are most commonly used within the territories of the local authorities are presented in Table 2, based on 2006 IPCC Guidelines ([2]) - and the ELCD ([3]). Table 2 gives a more complete table of IPCC emission factors. However, the local authority can decide to use other emission factors that are considered appropriate, therefore if local authorities prefer to use or develop emission factors that better reflect the properties of the fuels used within the territory, they are welcome to do so. The choice of emission factor used in the BEI has to be consistent with the choice of the emission factor used in the MEI.

[2] Available at http://www.ipcc-nggip.iges.or.jp/public/2006gl/

[3] Available at http://lca.jrc.ec.europa.eu/lcainfohub/index.vm. Please note that the emission factors for fuel combustion are expressed as t/MWh_{fuel}. Therefore, the corresponding activity data to be used must also be expressed as MWh_{fuel}, which corresponds with the net calorific value (NCV) of the fuel.

TABLE 2. **CO_2 and CO_2-equivalent emission factors: standard (from IPCC, 2006) and LCA (from ELCD) for most common fuel types**

	Covenant of Mayors Template energy carriers	Standard denomination of energy carriers	Sustainability criteria [a]	IPCC		LCA	
				t CO_2 /MWh	t CO_2-eq. /MWh	t CO_2 /MWh	t CO_2-eq. /MWh
Fossil fuels	Natural gas	Natural gas	-	**0.202**	0.202	0.221	**0.237**
	Liquid gas	Liquefied Petroleum Gases	-	**0.227**	0.227	n.a.	**n.a.**
		Natural Gas Liquids	-	**0.231**	0.232	n.a.	**n.a.**
	Heating Oil	Gas/Diesel oil	-	**0.267**	0.268	0.292	**0.305**
	Diesel	Gas/Diesel oil	-	**0.267**	0.268	0.292	**0.305**
	Gasoline	Motor gasoline	-	**0.249**	0.250	0.299	**0.307**
	Lignite	Lignite	-	**0.364**	0.365	0.368	**0.375**
	Coal	Anthracite	-	**0.354**	0.356	0.379	**0.393**
		Other Bituminous Coal	-	**0.341**	0.342	0.366	**0.380**
		Sub-Bituminous Coal	-	**0.346**	0.348	0.371	**0.385**
	Other fossil fuels	Municipal Wastes (non-biomass fraction)	-	**0.330**	0.337	0.181	**0.174**
		Peat	-	**0.382**	0.383	0.386	**0.392**
Renewable energies	Plant oil	Other Liquid Biofuels	(s)	**0**	0.001	0.171	**0.182** [b]
			(ns)	**0.287**	0.302		
	Biofuel	Biogasoline	(s)	**0**	0.001	0.194	**0.206** [c]
			(ns)	**0.255**	0.256		
		Biodiesels	(s)	**0**	0.001	0.147	**0.156** [d]
			(ns)	**0.255**	0.256		
	Other biomass	Biogas	-	**0.197**	0.197	n.a.	**n.a.**
		Municipal Wastes (biomass fraction)	-	**0**	0.007	0.107	**0.106**
		Wood	(s)	**0**	0.007	0.006	**0.013**
			(ns)	**0.403**	0.410	0.409	**0.416** [e]
		Wood Waste	-	**0.403**	0.410	0.193	**0.184**
		Other Primary solid biomass	-	**0.360**	0.367	n.a	**n.a**
	Solar thermal		-	-	-	n.a.	**n.a.** [f]
	Geothermal		-	-	-	n.a.	**n.a.** [f]

a. IPCC emission factor should be reported as zero if the biofuels/biomass meet sustainability criteria; fossil fuel emission factors are to be used if biofuels are unsustainable. (s) sustainable, (ns) not sustainable

b. Conservative figure regarding pure plant oil from palm oil. Note that this figure represents the worst ethanol plant oil pathway and does not necessarily represent a typical pathway. This figure does not include the impacts of direct and indirect land-use change. Had these been considered, the default value could be as high as 9 t CO_2-eq./MWh, in the case of conversion of forest land in the tropics.

c. Conservative figure regarding ethanol from wheat. Note that this figure represents one of the less efficient ethanol production pathways and does not necessarily represent a typical pathway. This figure does not include the impacts of direct and indirect land-use change. Had these been considered, the default value could be as high as 9 t CO_2-eq./MWh, in the case of conversion of forest land in the tropics.

d. Conservative figure regarding biodiesel from palm oil. Note that this figure represents the worst biodiesel pathway and does not necessarily represent a typical pathway. This figure does not include the impacts of direct and indirect land-use change. Had these been considered, the default value could be as high as 9 t CO_2-eq./MWh, in the case of conversion of forest land in the tropics.

e. The figure reflects the production and local/regional transport of wood, representative for Germany, assuming: spruce log with bark; reforested managed forest; production mix entry to saw mill, at plant; and 44 % water content. CO_2 incorporation is considered. It is recommended that the local authority using this emission factor check that it is representative for the local circumstances. If not they should develop own emission factor that takes the local circumstances into account.

f. Data not available, but emissions are assumed to be low (however, the emissions from electricity consumption of heat pumps is to be estimated using the emission factors for electricity). Local authorities using these technologies are encouraged to try to obtain such data.

2.4. Electricity plants

In order to calculate the CO_2 emissions to be attributed to electricity consumption, it is necessary to determine which emission factor has to be used. The same emission factor will be used for all electricity consumption within the territory, regardless the sector and including that of rail transportation. The local emission factor for electricity may take the following components into consideration. The contribution of each of them in the estimation of the local emission factor is explained in more detail in the following sub-sections:

a) National emission factor
b) Local electricity production
c) Purchases of certified green electricity by the local authority

Because the estimation of emissions from electricity is based on electricity consumption, the emission factors are expressed as t/MWh_e. Therefore, the corresponding activity data to be used also has to be in the form of MWh_e; that is, in MWh of electricity consumed.

2.4.1. National emission factor

The city's electricity is consumed within the territory of each local authority, but often not produced whiting that territory. The main units that produce it are only concentrated on the territory of a few. These major production units are often large CO_2 emitters (in the case of fossil fuel power plants), but their electricity production is not meant to cover only the electricity needs of the municipality on which they are built, but the needs of a larger area. In other words, the electricity that is consumed in a particular municipality generally comes from different plants either inside or outside the municipality. As a consequence, the CO_2 that is emitted due to this electricity consumption actually comes from those various plants. To quantify this for each individual municipality would be a challenging task, as the physical flows of electricity cross the borders and vary depending on several factors. In addition, the municipalities in question usually have no control over the emissions of such plants. For these reasons, and keeping in mind that the focus of the CoM is on the demand (consumption) side, it is recommended to use a national factor as a starting point to determine the local emission factor. This emission factor reflects the average CO_2 emissions related to the national electricity production.

The national emission factors fluctuate from year to year due to energy mix used in electricity generation. These fluctuations are caused by the heating/cooling demand, availability of renewable energies, energy market situation, import/export of energy and so on. These fluctuations occur independently of the actions taken by the local authority. Therefore, it is recommended to use the same emission factor in the BEI and in the MEI in order to assess the progress in terms of impacts resulting from the local actions implemented; otherwise, the result of the emission inventory could be very sensitive to factors over which the local authority has no influence.

The country-specific emission factors for standard and LCA approaches are presented in 0 and 0 for all the Eastern Partnership and central Asian countries. These emission factors are calculated consistenly for all countries using the national energy mix and total energy consumption data reported to the international energy agency of OECD. The local authority is welcome to search for more up-to-date information from national sources such as reports and statistics of the National Environmental Agencies or equivalent institutions, or to use the emission factor from the abovementioned tables for the year closest to the inventory year.

Table 3.a National IPCC emission factors for electricity (t CO_2*/MWhe) for period 2000–2012 ([4])

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Armenia	0.609	0.652	0.375	0.336	0.374	0.357	0.265	0.254	0.252	0.221	0.219	0.218	0.222
Azerbaijan	0.874	0.810	0.778	0.737	0.701	0.680	0.713	0.900	0.891	0.943	0.855	0.924	0.925
Belarus	0.780	0.752	0.805	0.801	0.920	0.901	0.898	0.899	0.961	0.939	0.815	0.915	0.882
Georgia	0.201	0.215	0.074	0.090	0.121	0.135	0.282	0.211	0.174	0.112	0.066	0.070	0.074
Kazakhstan	1.398	1.409	1.406	1.483	1.538	1.475	1.459	1.507	1.508	1.435	1.418	1.405	1.401
Kyrgyzstan	0.233	0.280	0.272	0.208	0.242	0.212	0.193	0.231	0.149	0.159	0.131	0.144	0.141
Moldova	0.876	0.863	0.669	0.603	0.625	0.625	0.593	0.747	0.684	0.572	0.547	0.644	0.653
Tajikistan	0.014	0.011	0.008	0.010	0.009	0.007	0.013	0.021	0.017	0.015	0.012	0.011	0.008
Turkmenistan	1.369	1.398	1.397	1.397	1.397	1.397	1.396	1.395	1.395	1.395	1.395	1.395	1.395
Ukraine	0.923	0.998	1.009	0.982	0.830	0.851	0.933	0.927	0.924	0.931	0.880	0.899	0.912
Uzbekistan	0.689	0.701	0.708	0.684	0.663	0.664	0.659	0.693	0.615	0.627	0.610	0.604	0.612

*When reporting in CO_2-eq.:

- the same emission factor should be used by Armenia, Georgia and Tajikistan;
- 0.001 t CO_2-eq./MWh should be added to the factors used by signatories from Azerbaijan, Belarus, Moldova, Turkmenistan and Uzbekistan;
- 0.004 t CO_2-eq./MWh should be added to the factors used by signatories from Ukraine and Kyrgyzstan;
- 0.007 t CO_2-eq./MWh should be added to the factors used by signatories from Kazakhstan.

Table 3.b National LCA emission factors for electricity (t CO_2-eq./MWhe) for period 2000–20012 ([5])

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Armenia	0.637	0.682	0.418	0.406	0.442	0.422	0.368	0.374	0.386	0.338	0.336	0.336	0.340
Azerbaijan	1.168	1.028	0.980	0.992	0.953	0.937	0.962	0.929	0.896	0.948	0.860	0.929	0.930
Belarus	1.373	1.374	1.376	1.377	1.376	1.378	1.373	1.380	1.380	1.348	1.170	1.313	1.267
Georgia	0.332	0.315	0.139	0.167	0.217	0.238	0.406	0.289	0.249	0.160	0.095	0.099	0.106
Kazakhstan	2.016	2.027	2.002	2.045	2.081	2.093	2.111	2.115	2.149	2.044	2.021	2.003	1.997
Kyrgyzstan	0.257	0.289	0.300	0.238	0.243	0.239	0.233	0.250	0.191	0.204	0.168	0.185	0.181
Moldova	1.364	1.353	1.333	1.364	1.343	1.335	1.331	1.340	1.311	1.097	1.048	1.235	1.252
Tajikistan	0.070	0.066	0.062	0.064	0.062	0.059	0.068	0.079	0.074	0.063	0.025	0.026	0.035
Turkmenistan	1.363	1.363	1.363	1.363	1.363	1.363	1.364	1.364	1.364	1.364	1.364	1.371	1.364
Ukraine	1.427	1.451	1.472	1.448	1.266	1.348	1.500	1.532	1.533	1.545	1.459	1.492	1.513
Uzbekistan	0.928	0.930	0.920	0.925	0.943	0.943	0.940	0.935	0.821	0.837	0.815	0.806	0.817

The national emission factor for electricity has the acronym NEFE in the equation in Sub-section 2.4.4. The emission factor chosen is reported in the SEAP template as 'CO_2 emission factor for electricity not produced locally'. For local electricity and heating/cooling plants that are producing energy, consumed locally the procedure of sections 2.4.2, 2.5.1 and 2.5.2 has to be applied.

2.4.2. Local electricity production

Reducing CO_2 emissions through the improvement of energy efficiency (EE) and local renewable energy projects is a priority of the Covenant. However, other actions to reduce CO_2 emissions on the supply side can also be accounted for. First, the local authority has to decide whether to include local electricity production (LPE) in the BEI or not. In the event that all the SEAP measures are focused on the demand

[4] Methodology for the calculation according to UNFCCC, 2012 (tool to calculate the emission factor for an electricity system). Sources for the calculation: data on national energy consumption and national energy production per energy carrier from the International Energy Agency (IEA), 2010 (energy statistics of non-Organisation for Economic Co-operation and Development (OECD) countries); data on carbon intensity of each energy carrier from IPCC, 2006 (*Guidelines for National Greenhouse Gas Inventories*, Chapter 2 — Stationary Combustion); data on efficiency of each vector according to the technology of electricity production: ELCD, 2013 (electricity emission inventories). Consistency checks have been performed comparing results with EDGARv4.2 and v4.2FT2010 for the CO_2 emissions from fuel combustion (cfr. Emissions Database for Global Atmospheric Research (EDGAR) (http://edgar.jrc.ec.europa.eu/index.php); see also Olivier and Janssens-Maenhout, 2011).

[5] Source for LCA emission factors: as no specific Life Cycle Inventories database can be found for the countries involved in the project, the ELCD has been used as the primary source of life cycle emissions related to the different technologies of electricity production (http://lca.jrc.ec.europa.eu/lcainfohub/datasetArea.vm) (2002). The fine tuning of LCA emission factors may occur in the next update of the guidelines. Data on national electricity production from different energy vectors are acquired from the International Energy Agency (IEA), 2010 (energy statistics of non-Organisation for Economic Co-operation and Development (OECD) countries).

side, inclusion of LPE is not needed, and the factors LPE and CO_2LPE (CO_2 emissions due to the local production of electricity) in the equation in Sub-section 2.4.4 below are zero.

If the local authority decides to include LPE in the BEI, all the plants/units that meet the following criteria have to be included:

- the plant/unit is not included in an international Emission Trading Scheme (ETS);
- the plant/unit is below or equal to 20 MW_{fuel} as thermal energy input in the case of fossil fuel and biomass combustion plants ([6]), or below or equal to 20 MW_e as nominal output in the case of other renewable energy plants (e.g. wind or solar).

The criteria above are based on the assumption that smaller plants/units primarily serve local electricity needs, whereas larger plants primarily produce electricity for the larger grid. Usually, the local authority has more control or influence on smaller plants than larger ones. However, in some cases, larger plants or units can also be included in the BEI/MEI. For example, if a local authority owns utilities or plans to develop and finance large renewable installations like wind farms within its territory, such projects may be incorporated as long as the priority remains on the demand side (final energy consumption reductions).

The local authority can use the decision tree presented in Box 3 of the main document (Iancu et al., 2013) to decide, for each of the plants/units located within the territory, whether to include them in the BEI/MEI or not.

All plants that are to be included in the BEI/MEI, as per the above rule, should be listed in the SEAP template ([7]), with the corresponding quantity of locally generated electricity, energy inputs and corresponding CO_2 emissions. For convenience, similar production units may be grouped (for example solar photovoltaic installations (PVs) or combined heat and power plants (CHPs)).

Waste incineration plants that produce electricity are treated similarly to any other power plants. Waste incinerated in plants that do not produce electricity or heat is included in the ENERGY CONSUMPTION TABLE of the SEAP template and the related emissions in the EMISSIONS TABLE.

The emissions from LPE (CO_2LPE) are estimated, in the case of plants combusting fuel, by using emission factors in Table 2. In the case of local renewable electricity production (other than biomass/biofuels), the emissions can be estimated by using the emission factors in Table 4.

Table 4. Emission factors for local renewable electricity production

Electricity source	Standard emission factor (t CO_2/MWh_e)	LCA emission factor (t CO_2-eq./MWh_e)
Solar PV	0	0.020–0.050 ([a])
Windpower	0	0.025[b]
Hydropower	0	0.010–0.100 ([b])

[a] Source: Vasilis et al., 2008.
[b] Source: Evans et al., 2009.

2.4.3. Purchases of certified green electricity by the local authority

Instead of purchasing 'mixed' electricity from the grid, the local authority can decide to purchase certified green electricity. For the sake of comparability, transparency and consistency, it is strongly recommended to use the standard European definitions, described in the Directive 2001/77/EC (updated in the Directive 2009/28/EC). However, whenever the adequate national legal framework exists, green electricity can also be defined by the electricity that meets the criteria for *guarantee of origin of electricity produced from renewable energy sources* (RES) set in those national regulations. The local authority will report the amount of purchased green electricity (GEP) in the 'emission' section of the SEAP template.

In the case that the standard emission factors are used, the emission factor for certified green electricity is zero. If the LCA emission factors are used, the local authority has to estimate the LCA emissions of the green electricity purchases (CO_2GEP) either by requesting required information from the power provider

[6] 20 MW_{fuel} refers to fuel input of the plant, and corresponds to threshold for combustion installations, subject to trading in the European Emission Trading Systems. The threshold 20 MW_e set for other renewables refers to nominal electricity generation capacity, and is thus higher than the threshold for combustion installations.
[7] The SEAP template is published online at http://www.soglasheniemerov.eu/support/library_ru.html (both the Russian and the English versions are available).

or by using the default factors provided for local renewable electricity generation in Table 4, if they are deemed suitable.

Also, other actors within the territory of the local authority may purchase green electricity. However, it may be difficult to obtain data about such purchases. In addition, green electricity purchases reduce GHG emissions only in the case that electricity production by fossil fuels is actually replaced by production from new renewable electricity installations, due to such purchases, which is not necessarily the case. For these reasons, and also because the focus of the Covenant is on the demand side, the green electricity purchases of other actors (companies, consumers, institutions, etc.) within the territory are not accounted for in the local electricity emission factor.

2.4.4. Calculation of local emission factor for electricity

Based on the information presented in the sections above, the local emission factor for electricity (EFE) can be calculated using the equation ([8]):

$$EFE = \frac{(TCE - LPE - GEP) \times NEFE + CO_2LPE + CO_2GEP}{TCE}$$

Where:

EFE = local emission factor for electricity [t/MWh_e]
TCE = total electricity consumption in the local authority (as per ENERGY CONSUMPTION TABLE of the SEAP template) [MWh_e]
LPE = local electricity production (as per LOCAL ELECTRICITY PRODUCTION TABLE of the template) [MWh_e]
GEP = green electricity purchases by the local authority (as per the BEI/MEI section of the template) [MWh_e]
NEFE = national emission factor for electricity [t/MWh_e]
CO_2LPE = CO_2 emissions due to the local production of electricity (as per LOCAL HEAT/COLD PRODUCTION TABLE of the template) [t]
CO_2GEP = CO_2 emissions due to the production of certified green electricity purchased by the local authority [t]

In the exceptional case where the local authority would be a net exporter of electricity, then the calculation formula would be:

$$EFE = (CO_2LPE + CO_2GEP) / (LPE + GEP)$$

These principles and rules allow for rewarding the increase in local renewable energy production, or improvements of efficiency in the local energy generation, whilst still keeping the main focus on final energy (demand side).

2.5. Heating / cooling plants

If heat or cold is sold/distributed as a commodity to end users within the territory of the local authority (see ENERGY CONSUMPTION TABLE of the SEAP template), then it is necessary to establish the corresponding emission factor.

First, the local authority has to identify all the plants and units that provide heat/cold as a commodity to end users within the territory, e.g., from district heating, or a Combined Heat and Power (CHP) production plant. All such plants should be listed in the LOCAL HEAT/COLD PRODUCTION TABLE of the SEAP template, with the corresponding quantity of locally generated heat, energy inputs and corresponding CO_2 emissions. For convenience, similar production units may be grouped (e.g. CHPs).

Waste incineration plants that produce heat to be sold as a commodity to end users are treated similarly to any other heating plants. Amount of waste incinerated and the related CO_2 emissions from plants that do not produce electricity or heat are included in the ENERGY CONSUMPTION TABLE and EMISSION TABLE, respectively.

[8] This formula neglects transport and distribution losses in the local authority's territory, as well as auto-consumption of energy producers/transformers and tends to double count local renewable production. However, at the scale of the local authority, these approximations will have a minor effect on the local CO_2 balance and the formula may be considered as robust enough to be used in the context of the CoM.

2.5.1. District heating

Please note that energy consumption and CO_2 emissions related to heat and cold locally produced by end users for their own usage are already covered by the ENERGY CONSUMPTION TABLE and EMISSION TABLE (columns for fossil fuel and renewable energy consumption). In principle, the total amount of heat/cold produced referenced in the LOCAL HEAT/COLD PRODUCTION TABLE should be equal (or very close) to the quantity of heat/cold consumed and reported in the ENERGY CONSUMPTION TABLE, column 'Heat/cold'. Differences may occur due to:

- auto-consumption of heat/cold by the utility producing it;
- transport and distribution losses of heat/cold.

If a part of the heat/cold that is produced within the territory of the local authority is exported, then the corresponding share of CO_2 emissions should be deducted when calculating the emission factor for heating / cooling production (EFH), as indicated in the formula below. In a similar manner, if heat/cold is imported from a plant situated outside the local authority, then the share of CO_2 emissions of this plant that correspond to heat/cold consumed within the territory of the local authority should be accounted for when calculating the emission factor (see formula below).

The following formula may be applied to calculate the emission factor for heat, taking the above mentioned issues into consideration.

$$EFH = \frac{CO_2LPH + CO_2IH - CO_2EH}{LHC}$$

Where:

EFH = emission factor for heat [t/MWh_{heat}]

CO_2LPH = CO_2 emissions due to the local production of heat (as per the LOCAL HEAT/COLD PRODUCTION TABLE of the template) [t]

CO_2IH = CO_2 emissions related to any imported heat from outside the territory of the local authority [t]

CO_2EH = CO_2 emissions related to any heat that is exported outside of the territory of the local authority [t]

LHC = local heat consumption (as per the ENERGY CONSUMPTION TABLE) [MWh_{heat}]

A similar formula may apply for cold.

District cooling — i.e. purchased chilled water — is in principle a similar product as purchased district heating. However, the process to produce district cooling is different from the process to produce district heating, and there is a larger variety of production methods.

If local production of district cooling occurs, or if district cooling is consumed as a commodity by end users, it is recommended that the local authority contact the district cooling provider for information on the use of fuels or electricity to provide cooling. Then the emission factors for fuels and electricity presented in the sections above can be applied.

2.5.2. Combined heat and power production

Part or all of the heat used within the territory of the local authority may be generated in a CHP plant. It is essential to divide the emissions of a CHP plant between heat and electricity when filling in the LOCAL ELECTRICITY TABLE and the LOCAL HEAT/COLD PRODUCTION TABLE of the template. This is especially the case when the heat is used locally (input to the BEI) but the electricity is sold to the regional grid (no direct input to the BEI).

The fuel use and emissions can be allocated between heat and electricity generation by using the following equation:

$$CO_{2CHPH} = \frac{\frac{P_{CHPH}}{\eta_h}}{\frac{P_{CHPH}}{\eta_h} + \frac{P_{CHPE}}{\eta_e}} * CO_{2CHPT}$$

$CO_{2CHPE} = CO_{2CHPT} - CO_{2CHPH}$

Where:

CO_{2CHPH} denotes CO_2 emissions from heat production [t CO_2]
CO_{2CHPE} denotes CO_2 emissions from electricity production [t CO_2]
CO_{2CHPT} denotes total CO_2 emissions of the CHP plant calculated based on fuel consumption and fuel-specific emission factors [t CO_2]
P_{CHPH} denotes the amount of heat produced [MWh_{heat}]
P_{CHPE} denotes the amount of electricity produced [MWh_e]
η_h denotes the energy efficiency from heat production. The recommended value to be used is 90 %.
η_e denotes the energy efficiency from electricity generation. The recommended value to be used is 30 %.

2.6. Other sectors

In the case of other sectors, with the emissions that are not related to fuel combustion such as CH_4 from landfills, it is recommended that the local authority uses international or national methodologies.

The local authority can chose the standard emission factors in line with IPCC principles or those of the Local Governments for Sustainability (ICLEI). Both IPCCA and ICLEI's GHG Emissions include peer-reviewed and approved Specific Country Supplements for certain countries, with country-specific emission factors.

The 2006 IPCC Guidelines are available at http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.html online. If the local authority has chosen to use the LCA emission factors, such emission factors for landfills are available from the ELCD database, available at http://lca.jrc.ec.europa.eu/lcainfohub/datasetList.vm?topCategory=End-of-life+treatment&subCategory=Landfilling online.

The international Local Government GHG Emission Analysis protocol (IEAP) is available at: http://archive.iclei.org/index.php?id=ghgprotocol

3. OUTLOOK

The Covenant of Mayors initiative has in the European Union been shown to reach within six years almost half of the European citizen population. The CoM (West) Guidebook served as the basis for establishing first emission inventories. A guidance for standardisation and applying common definitions is fruitful in order to keep transparency, comparability and consistency across borders. The CoM East team at the JRC aims to reach with this guidebook a similar share of citizens and to help establishing good emission inventories for the different cities, using a standard that can be internationally recognised.

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ANNEX I. CONVERSION FACTOR AND IPCC EMISSION FACTOR TABLES

Table A. Basic conversion factors

To	**TJ**	**Mtoe**	**GWh**	**MWh**
From	Multiply by:			
TJ	1	2.388×10^{-5}	0.2778	277.8
Mtoe	4.1868×10^{4}	1	11 630	11 630 000
GWh	3.6	8.6×10^{-5}	1	1 000
MWh	0.0036	8.6×10^{-8}	0.001	1

A unit converter is available on the website of the International Energy Agency (IEA) (http://www.iea.org/stats/unit.asp).

Table B. Conversion of fuels from mass to energy units (IPCC, 2006)

Fuel type	Net calorific value [TJ/Gg]	Net calorific value [MWh/t]
Crude Oil	42.3	11.8
Orimulsion	27.5	7.6
Natural Gas Liquids	44.2	12.3
Motor Gasoline	44.3	12.3
Aviation Gasoline	44.3	12.3
Jet Gasoline	44.3	12.3
Jet Kerosene	44.1	12.3
Other Kerosene	43.8	12.2
Shale Oil	38.1	10.6
Gas/Diesel Oil	43.0	11.9
Residual Fuel Oil	40.4	11.2
Liquefied Petroleum Gases	47.3	13.1
Ethane	46.4	12.9
Naphtha	44.5	12.4
Bitumen	40.2	11.2
Lubricants	40.2	11.2
Petroleum Coke	32.5	9.0
Refinery Feedstocks	43.0	11.9
Refinery Gas 2	49.5	13.8
Paraffin Waxes	40.2	11.2
White Spirit and SBP	40.2	11.2
Other Petroleum Products	40.2	11.2
Anthracite	26.7	7.4
Coking Coal	28.2	7.8
Other Bituminous Coal	25.8	7.2
Sub-Bituminous Coal	18.9	5.3
Lignite	11.9	3.3
Oil Shale and Tar Sands	8.9	2.5
Brown Coal Briquettes	20.7	5.8
Patent Fuel	20.7	5.8
Coke Oven Coke and Lignite Coke	28.2	7.8
Gas Coke	28.2	7.8
Coal Tar	28.0	7.8
Gas Works Gas	38.7	10.8
Coke Oven Gas	38.7	10.8
Blast Furnace Gas	2.47	0.7
Oxygen Steel Furnace Gas	7.06	2.0
Natural Gas	48.0	13.3
Municipal Wastes (non-biomass fraction)	10	2.8
Waste Oil	40.2	11.2
Peat	9.76	2.7

Table C. CO_2 emission factors for fuels (IPCC, 2006)

Fuel type	CO_2 emission factor [kg/TJ]	CO_2 emission factor [t/MWh]
Crude Oil	73 300	0.264
Orimulsion	77 000	0.277
Natural Gas Liquids	64 200	0.231
Motor Gasoline	69 300	0.249
Aviation Gasoline	70 000	0.252
Jet Gasoline	70 000	0.252
Jet Kerosene	71 500	0.257
Other Kerosene	71 900	0.259
Shale Oil	73 300	0.264
Gas oil / diesel	74 100	0.267
Residual Fuel Oil	77 400	0.279
Liquefied Petroleum Gases	63 100	0.227
Ethane	61 600	0.222
Naphtha	73 300	0.264
Bitumen	80 700	0.291
Lubricants	73 300	0.264
Petroleum Coke	97 500	0.351
Refinery Feedstocks	73 300	0.264
Refinery Gas	57 600	0.207
Paraffin Waxes	73 300	0.264
White Spirit & SBP	73 300	0.264
Other Petroleum Products	73 300	0.264
Anthracite	98 300	0.354
Coking Coal	94 600	0.341
Other Bituminous Coal	94 600	0.341
Sub-Bituminous Coal	96 100	0.346
Lignite	101 000	0.364
Oil Shale and Tar Sands	107 000	0.385
Brown Coal Briquettes	97 500	0.351
Patent Fuel	97 500	0.351
Coke Oven Coke and Lignite Coke	107 000	0.385
Gas Coke	107 000	0.385
Coal Tar	80 700	0.291
Gas Works Gas	44 400	0.160
Coke Oven Gas	44 400	0.160
Blast Furnace Gas	260 000	0.936
Oxygen Steel Furnace Gas	182 000	0.655
Natural Gas	56 100	0.202
Municipal Wastes (non-biomass fraction)	91 700	0.330
Industrial Wastes	143 000	0.515
Waste Oil	73 300	0.264
Peat	106 000	0.382

ANNEX II. CO_2 INDICATIVE EMISSIONS WITH CO_2/CAP, CO_2-EQ./CAP AND TOTAL CO_2 COUNTRY AND SECTOR BREAKDOWN

Table A. CO_2 emissions per capita ([9])

	1990 Tonnes CO_2/cap	1995 Tonnes CO_2/cap	2000 Tonnes CO_2/cap	2005 Tonnes CO_2/cap	2008 Tonnes CO_2/cap	2009 Tonnes CO_2/cap	2010 Tonnes CO_2/cap
World Total	4.3	4.1	4.1	4.5	4.7	4.6	4.8
European Union EU-27	8.78	7.23	8.19	8.34	8.09	8.09	8.57
Luxembourg	30.74	22.06	20.16	25.88	22.49	20.35	20.54
Australia	16	16.3	18.6	20.3	20.3	19.9	17.9
USA	19.7	19.7	20.8	20	18.8	17.3	17.8
Canada	16.2	16.3	17.9	17.8	17	15.7	16
Estonia	23.26	11.13	10.7	12.58	13.89	12.99	13.54
Kazakhstan	15.47	11.37	9.34	12.64	14.54	12.92	13.2
Russian Federation	16.5	11.8	11.3	12	12.6	12.1	12.4
Taiwan	6.2	8.1	10.5	11.9	11.6	11.1	11.7
Czech Republic	16.25	12.59	13.58	12.49	12.01	11.16	11.56
Iceland	9.23	9.2	10.14	10.47	12.66	12.02	11.53
Finland	11.44	11.63	11.07	11.18	11.44	10.53	10.79
Netherlands	10.8	11.2	10.9	11	10.3	9.9	10.5
Belgium	11.57	12.09	12.09	11.17	10.95	10.07	10.32
Germany	12.9	11.2	10.5	10.2	10.4	9.7	10.2
Ireland	9.23	9.65	11.42	11.18	10.84	9.89	10.05
Japan	9.5	10	10.1	10.4	9.9	9.3	10
Turkmenistan	13.32	8.57	8.63	9.49	10.87	9.65	9.85
Israel	7.75	8.98	9.83	9.67	9.46	9.32	9.78
Singapore	9.96	11.53	9.8	9.61	8.93	8.64	9.05
Austria	8.18	8.18	8.37	10.05	9.52	8.77	9
Slovenia	7.65	7.49	8.37	8.89	9.23	8.6	8.93
Poland	8.2	8.3	7.5	8.1	8.5	8.1	8.8
Denmark	10.33	11.56	9.84	9.19	9.09	8.37	8.57
Greece	7.72	7.66	8.75	9.26	9.03	8.33	8.55
Norway	8.96	9.77	9.62	9.56	9.24	8.81	8.49
New Zealand	6.73	7.05	9.02	9.82	9.13	8.71	8.39
UK	10.3	9.6	9.3	9.2	8.7	7.9	8.1
Hong Kong	6.03	6.17	6.18	6.32	6.98	6.99	7.42
Slovakia	11.43	8.38	7.85	7.62	7.62	7.11	7.39
Bulgaria	9.4	7.11	5.86	6.64	7.24	6.81	7.14
South Africa	7.3	7	6.9	7.5	7.4	7	7.1
Cyprus	5.8	6.76	7.39	7.57	7.45	6.88	7.08
Belarus	10.24	5.92	5.73	6.47	7.47	6.75	7
Italy	7.5	7.7	8.1	8.2	7.6	6.8	6.9
Ukraine	14.9	8.8	7.2	7.1	7.4	6.1	6.7
China	2.2	2.9	2.8	4.5	5.9	6.2	6.6
Spain	5.9	6.4	7.6	8.4	7.4	6.6	6.3
Croatia	5.52	3.57	4.24	5.07	5.69	5.75	6.17
France	6.9	6.7	6.9	6.7	6.4	6.1	6.1
Venezuela	5.62	5.89	5.86	5.58	5.75	5.71	6.02
Switzerland	6.7	6.3	6.16	6.27	6.15	5.9	5.7
Other Annex I-EIT ([a])	10.3	6.1	5.4	5.6	6.2	5.6	5.7
Hungary	7.25	6.04	5.73	5.87	5.75	5.39	5.62
Bosnia and Herzegovina	5.69	1.12	3.78	4.38	5.13	5.18	5.57
Sweden	6.71	7.08	6.53	6.1	5.46	5.01	5.12
Portugal	4.36	5.26	6.24	6.39	5.21	4.81	4.94
Mongolia	6.43	4.35	4.66	4.1	4.6	4.57	4.82

[9] Source and complete database: JRC/PBL Netherlands Environmental Assessment Agency, 'Emission Database for Global Atmospheric Research (EDGAR)', release version 4.2, 2010. See http://edgar.jrc.ec.europe.eu online.

Argentina	3.27	3.47	4.03	4.08	4.45	4.45	4.73
Jamaica	3.18	3.58	3.99	4.19	4.32	4.35	4.64
former Yugoslav Republic of Macedonia	5.92	3.65	4.14	4.48	4.37	4.37	4.63
Lithuania	9.49	4.11	3.28	3.93	4.68	4.4	4.6
Serbia and Montenegro	6.2	4.02	3.96	2.22	4.25	4.28	4.58
Romania	7.96	5.7	4.27	4.67	4.53	4.24	4.43
Uzbekistan	6.05	4.41	4.8	4.41	4.69	4.17	4.26
Mexico	3.7	3.6	3.8	3.9	4	3.9	3.9
Latvia	7.5	3.79	3.04	3.48	3.71	3.48	3.64
Turkey	2.75	3.01	3.55	3.61	4.01	3.56	3.64
Azerbaijan	8.84	4.05	3.72	3.77	3.77	3.34	3.41
Thailand	1.6	2.7	2.7	3.4	3.3	3.1	3.3
Tunisia	1.81	1.93	2.22	2.28	2.5	2.5	2.65
Egypt	1.6	1.56	1.87	2.3	2.41	2.39	2.52
Armenia	5.9	1.14	1.21	1.47	2.6	2.33	2.41
Guyana	0.95	1.25	1.95	2.1	2.2	2.22	2.37
Dominican Republic	1.16	1.55	2.22	2.05	2.21	2.2	2.32
Other Big DC ([b])	1.5	1.7	1.8	2	2.2	2.2	2.3
Mauritius	1.14	1.26	1.64	1.91	2.08	2.09	2.22
Brazil	1.5	1.6	2	2	2.1	2	2.2
Ecuador	1.53	1.74	1.69	1.97	1.97	1.96	2.07
Indonesia	0.9	1.1	1.4	1.6	1.7	1.9	2
Morocco	0.91	1.07	1.22	1.75	1.76	1.76	1.86
Uruguay	1.25	1.47	1.66	1.65	1.69	1.7	1.81
Colombia	1.57	1.69	1.57	1.39	1.49	1.49	1.57
Moldova, Republic of	6.48	1.59	1.41	1.92	1.67	1.51	1.54
India	0.8	0.9	1	1.1	1.3	1.4	1.5
Albania	1.94	0.66	1.07	1.51	1.37	1.38	1.47
Bolivia	0.97	1.29	1.05	1.16	1.28	1.28	1.34
El Salvador	0.49	0.9	0.98	1.08	1.15	1.15	1.23
Kyrgyzstan	5.47	1.07	1	1.13	1.27	1.13	1.15
Georgia	5.5	1.48	1.05	1.04	1.21	1.09	1.13
Congo	0.95	0.91	1.33	1.18	1.07	1.05	1.1
Tajikistan	2.46	1.02	0.79	1.01	1.16	1.03	1.05
Pakistan	0.56	0.66	0.71	0.83	0.95	0.94	0.99
Zimbabwe	1.64	1.38	1.13	0.92	0.87	0.88	0.93
Angola	1.07	1	1.11	0.96	0.9	0.89	0.92
Nicaragua	0.47	0.58	0.74	0.81	0.81	0.81	0.86
Tonga	0.47	0.74	0.97	0.72	0.64	0.64	0.68
Bhutan	0.33	0.59	0.62	0.51	0.61	0.6	0.64
Nigeria	0.71	0.71	0.73	0.67	0.58	0.57	0.59
Western Sahara	0.73	0.63	0.69	0.51	0.49	0.48	0.5
Cameroon	0.62	0.41	0.41	0.36	0.34	0.34	0.35
Bangladesh	0.13	0.17	0.2	0.25	0.3	0.3	0.32
Kenya	0.31	0.3	0.31	0.29	0.3	0.3	0.31
Sudan	0.21	0.15	0.16	0.26	0.29	0.28	0.29
Haiti	0.16	0.14	0.19	0.24	0.24	0.24	0.25
Mozambique	0.09	0.08	0.09	0.13	0.15	0.15	0.16
Eritrea	0.07	0.25	0.18	0.14	0.14	0.14	0.15
Nepal	0.06	0.09	0.14	0.12	0.13	0.13	0.13
Laos	0.05	0.09	0.1	0.1	0.12	0.12	0.13
Madagascar	0.07	0.08	0.1	0.1	0.1	0.1	0.11
Cambodia	0.05	0.05	0.07	0.24	0.1	0.1	0.1

[a] Including other countries of the former Soviet Union and Turkey.
[b] Other large developing countries: Brazil, India, Iran, Mexico, Saudi Arabia and South Africa.

Table B. CO_2-eq. emissions per capita ([10])

	1990	1995	2000	2005	2008	2009	2010
	Tonnes CO_2-eq./cap	Tonnes CO_2-eq./cap	Tonnes CO_2-eq./cap	Tonnes CO_2-eq./cap	Tonnes CO_2-eq./cap	Tonnes CO_2-eq./cap	Tonnes CO_2-eq./cap
Iceland	85.36	78	75.81	72.74	72.89	72.07	71.63
Australia	28.19	26.98	31.55	30.67	29.65	30.47	28.24
Luxembourg	34.37	26.33	23.59	29.42	26.1	24.81	25.69
Mongolia	26.47	25.64	26.61	24.75	25.62	25.97	25.38
Finland	25.57	25.21	24.44	24.23	24.26	23.52	25.18
Estonia	35.35	21.95	21.16	22.5	23.42	21.03	23.87
Guinea	11.32	8.27	6.93	7.17	27.44	58.08	23
USA	24.14	23.81	24.72	23.86	22.7	21.17	21.63
Canada	21.82	28.33	23.99	24.31	22.19	21.05	21.41
Kazakhstan	22.51	15.52	12.95	17.35	19.69	17.5	19.82
New Zealand	19.3	18.9	20.18	20.88	19.98	18.53	18.29
Russian Federation	24.16	17.74	18.04	17.97	18.19	17.34	17.56
Turkmenistan	22.16	13.17	14.06	16.7	18.64	16.1	17.29
Ireland	18.45	18.8	20.2	18.92	18	16.71	16.47
Belarus	17.69	12.48	12.26	13.38	14.7	14.85	15.6
Bolivia	28.93	22.8	20.58	30.07	14.08	13.82	14.48
Czech Republic	19.01	14.52	15.82	14.48	13.93	13.29	13.98
Bahamas	14.03	12.62	11.1	12.12	13.21	13.56	13.91
Norway	15.74	15.96	16.01	15.68	15.04	13.93	13.76
Cambodia	2.05	1.86	1.79	4.55	12.43	9.86	13.55
Korea, Republic of	6.97	10.12	11.13	11.93	12.46	12.57	13.42
Netherlands	14.87	15.08	14.27	13.7	12.77	12.53	13.11
Bhutan	2.29	3.18	6.33	3.22	4.16	6.28	12.93
Belgium	13.76	14.33	14.28	13.16	12.97	12.34	12.93
Taiwan_Province of China	6.9	8.89	11.36	12.81	12.58	11.86	12.73
Denmark	14.04	15.15	13.36	12.47	12.35	11.9	11.96
Germany	15.85	13.8	12.72	12.28	12.41	11.92	11.9
Poland	12.4	11.88	10.81	11.41	11.63	11.21	11.76
Malaysia	10.88	12.15	10.86	12.88	12.14	12.74	11.62
Austria	10.36	10.17	10.29	11.88	11.37	10.67	11.25
Japan	10.65	11.4	11.23	11.42	10.98	10.42	10.9
Slovenia	10.37	9.6	10.63	11.26	11.6	10.68	10.87
Venezuela	10.65	10.3	10.4	10.16	10.88	10.37	10.7
Israel	8.78	9.96	10.91	10.82	10.62	10.28	10.62
Congo	26.6	21.21	18.74	15.01	10.49	10.25	10.23
Seychelles	5.14	5.38	6.8	8.24	9.42	9.81	10.22
UK	13.55	12.53	11.6	11.1	10.52	9.65	9.99
Singapore	10.79	12.78	12.31	11.19	10.52	9.6	9.91
Lithuania	14.57	7.93	7.51	8.66	9.75	9.13	9.88
Uruguay	8.4	9.43	9.18	9.85	10.19	10.11	9.85
Greece	9.45	9.27	10.34	10.73	10.38	9.99	9.47
Suriname	25.8	21.08	14.28	12.53	9.38	9.46	9.44
Slovakia	13.65	9.87	9.3	9.09	9.08	8.63	9.2
Sweden	10.67	10.91	10.35	9.84	9.13	8.53	9.15
Bulgaria	12.26	9.36	8.17	8.87	9.45	8.65	9.08
Bermuda	10.92	8.09	8.32	9.18	8.72	8.9	9.08
Ukraine	18.45	11.53	9.61	9.34	9.5	8.11	8.73
France	9.72	9.35	9.5	9.18	8.81	8.54	8.57
Solomon Islands	19.07	10.9	10.03	9.23	8.67	8.55	8.47
South Africa	9.45	8.93	8.82	9.53	9.31	8.8	8.41
Cote d'Ivoire	12.16	10.05	10.1	7.79	8.69	7.71	8.36
China	3.38	4.13	4	6.01	7.57	7.95	8.34
Equatorial Guinea	0.65	4.5	7.79	9.35	8.72	8.52	8.33
Latvia	12.61	7.53	6.72	7.64	8.09	7.82	8.33
Brazil	10.73	9.72	8.39	13.78	7.72	7.42	8.31
Bosnia and Herzegovina	7.27	1.97	5.15	5.58	6.49	8.1	8.23
Cyprus	6.69	7.71	8.34	8.63	8.51	8.38	8.14

[10] Source and complete database: JRC/PBL Netherlands Environmental Assessment Agency, 'Emission Database for Global Atmospheric Research (EDGAR)', release version 4.2, 2010. See http://edgar.jrc.ec.europe.eu online.

Indonesia	6.3	6.58	6.77	12.69	8.58	11.03	8.11
Italy	8.93	9.1	9.59	9.61	8.83	7.99	8.1
Argentina	8.16	7.89	8.09	8.21	8.46	7.77	7.79
Serbia and Montenegro	7.97	5.36	5.36	3.8	6.07	6.87	7.77
Spain	7.51	8.05	9.37	10.01	8.96	8.14	7.68
Switzerland	8.44	7.77	7.45	7.58	7.52	7.29	7.5
Hong Kong	6.43	6.61	6.68	6.82	7.5	7.93	7.23
Croatia	7.44	5.05	5.77	6.72	7.44	7.12	7.08
Hungary	9.32	7.46	7.35	7.56	7.21	6.67	6.73
Grenada	1.64	1.77	4.68	5.47	6.21	6.45	6.68
Uzbekistan	8.16	6.28	6.72	6.5	6.89	6.45	6.33
Portugal	5.84	6.82	8.03	8.33	6.99	6.9	6.32
Chile	4.14	4.6	5.74	6.13	6.47	6.09	6.27
Thailand	3.65	4.72	4.48	5.23	5.27	5.27	5.98
Mexico	5.81	5.54	5.69	5.95	5.87	5.74	5.83
Turkey	4.11	4.4	4.97	5.1	5.63	5.6	5.77
Botswana	9.67	7.66	5.51	6.52	5.49	5.53	5.73
Romania	10.55	7.61	5.99	6.46	6.35	5.6	5.54
Azerbaijan	10.83	5.48	5.22	5.52	6.01	5.47	5.44
Cuba	5.37	4.27	4.37	4.12	4.49	5.32	5.14
Malta	7.09	7.01	6.42	7.74	5.13	4.79	4.96
Algeria	4.19	4.37	4.34	4.43	4.65	4.76	4.76
Sudan	3.5	3.38	3.44	3.47	4.97	4.93	4.47
Jamaica	3.94	4.42	4.8	4.97	5.12	4.42	4.27
Colombia	5.25	4.91	4.51	3.79	4.23	4.31	4.03
Ecuador	3.01	3.42	3.13	3.58	3.4	3.63	3.71
Armenia	6.98	2.08	2.25	2.78	4.09	3.69	3.69
Tunisia	2.54	2.73	3.21	3.25	3.43	3.49	3.6
Vietnam	1.48	1.63	1.98	2.71	3.01	3.25	3.49
Egypt	2.32	2.35	2.71	3.28	3.44	3.36	3.4
Mali	3.55	3.2	2.72	2.74	3.89	3.34	3.27
Moldova, Republic of	8.71	3.84	2.63	3.39	3.05	3.06	3.17
Georgia	6.97	2.67	2.38	2.52	2.82	3.07	3.01
Albania	3.29	2.04	2.52	2.82	2.72	2.66	2.77
Nicaragua	2.49	2.32	2.57	2.64	2.59	2.6	2.63
Honduras	2.81	3.02	2.38	2.54	2.68	2.58	2.54
Kyrgyzstan	7.57	2.28	2.08	2.2	2.32	2.57	2.51
Morocco	1.49	1.54	1.75	2.3	2.32	2.26	2.43
Maldives	0.6	1.38	1.13	1.66	2.1	2.24	2.37
Costa Rica	2.78	2.88	2.51	2.34	2.39	2.31	2.36
Somalia	2.72	2.88	2.76	2.55	2.4	2.34	2.31
India	1.58	1.7	1.78	1.87	2.04	2.14	2.2
Tajikistan	4.06	2.2	1.63	1.89	2.13	2.08	2.14
Madagascar	4.29	3.54	3.42	3.44	2.12	2.1	2.07
Zimbabwe	3.34	2.59	2.42	2.22	1.96	2	2.06
Pakistan	1.54	1.62	1.7	1.88	2.02	2.02	1.96
Samoa	1.78	1.66	1.83	1.73	1.84	1.87	1.9
Senegal	1.52	1.44	1.57	1.61	1.76	1.75	1.86
Uganda	2.08	1.86	1.67	1.69	1.84	1.53	1.72
Yemen	1.08	1.18	1.36	1.58	1.63	1.61	1.54
Sri Lanka	1.06	1.13	1.24	1.37	1.37	1.33	1.43
Tonga	1.31	1.57	1.83	1.56	1.47	1.44	1.41
Kenya	1.66	1.52	1.42	1.41	1.42	1.42	1.39
Nigeria	1.67	1.67	1.64	1.49	1.65	1.39	1.36
Ethiopia	1.39	1.21	1.17	1.2	1.31	1.34	1.32
Mozambique	3.02	2.31	3.61	2.93	1.29	1.31	1.31
Nepal	1.32	1.25	1.18	1.11	1.09	1.1	1.09
Eritrea	1.06	1.17	1.29	0.99	0.95	0.94	0.92
Comoros	0.67	0.64	0.65	0.59	0.73	0.78	0.82
Haiti	0.75	0.76	0.83	0.85	0.85	0.85	0.8
Burundi	0.5	0.49	0.39	0.64	0.68	0.7	0.72
Malawi	0.91	0.82	0.7	0.69	0.64	0.63	0.65
Niger	0.89	0.89	0.86	0.67	0.64	0.62	0.64

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Abstract

This technical update is a necessary compendium of the Guidebook 'How to develop a Sustainable Energy Action Plan (SEAP) in the Easter Partnership and Central Asian Cities', focusing on the calculation of updated Emission Factor for electricity in partner countries. This report provides the tables with country-specific emission factors and calculation procedures for power and heat plants and completes the emission factor time series up to 2012. In this way the signatories of the Eastern Partnership and Central Asian Cities can establish baseline emission inventories for recent years with updated emission factors.

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