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Report on Adaptation of IPCC Guidelines and Software to Conditions of Ukrainian District-Heating Sector

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Introduction

Article 4 of the UN Framework Convention on Climate Change (UNFCCC) requires the countries (Parties) to "Develop, periodically update, publish and make available to the Conference of the Parties national inventories of anthropogenic emissions by sources and sinks of greenhouse gases" (GHG). This article requires that the national inventories be developed using compatible methodologies agreed to at the Conference of the Parties.

Fulfilling commitments under the UN Framework Convention on Climate Change is an obligatory precondition for Ukraine to participate in the international process of stabilizing GHG concentration in the atmosphere to fulfill it's commitments under the UNFCCC. Given Ukraine's considerable potential for reducing GHG emissions by implementing energy efficiency projects and other activities targeting GHG emissions, participation in the international process for stabilizing GHG concentrations provides for significant improvement in the energy efficiency of Ukraine's economy.

The requirements for developing a national inventory are defined in the Intergovernmental Panel on Climate Change (IPCC) Guidelines [1-2]. The main objective of these documents is to provide researchers from different countries with information on the requirements to ensure consistency in the calculation of GHG emissions.

One of the main issues for developing an inventory is selecting a method to estimate GHG emissions. The Guidelines [1-2] provide three approaches to prepare inventories – the reference approach, sectoral approach, and detailed approach. The latter is also referred to as the "bottom-up" approach because of the input data and calculation requirements.

The "bottom-up" approach provides the highest consistency for calculating inventories, but requires more resources. Due to resource limitations, the most accurate estimation methods cannot be applied for all GHG emission sources. This approach should be applied primarily for key emission sources, which account for largest contribution of total GHG emissions. According to the research in [3], the district-heating sector is one of the largest GHG emission sources in Ukraine. This paper defines the energy flows in the district heating sector, reviews preparation of the initial data for a detailed GHG emissions inventory, and provides instructions for filling in the worksheets that are consistent with the IPCC Guidelines.

1.District-Heating Sector

District-heating is defined [13] as heat supply to the consumers through the common heat network. In accordance with the form 1-ten [10] of statistical reports, consumers of heat, which are distributed through the district-heating include buildings in the residential and public sectors, and industrial facilities.

The public sectors [10] include heat consumption in secondary and higher education facilities, health care institutions, sport and trade institutions, catering enterprises, nursery schools, hotels, military divisions, etc., as well as heat consumption for the communal and cultural-household needs of all enterprises, institutions and organizations.

The source of GHG emissions in the district-heating sector is fuel combustion (mainly combustion of natural gas, but also coal and mazut) in boiler plants that are owned by the Ministry of Fuel and Energy, communal property enterprises, and other, mainly industrial enterprises.

Figure 1 shows the scheme of the main heat flows (marked with arrows) from sources to consumers. Heat exchange between enterprises may occur because not all possess boiler plants or have insufficient capacity to meet demand. Such enterprises purchase heat energy at the source level and are included in “Other enterprises”.

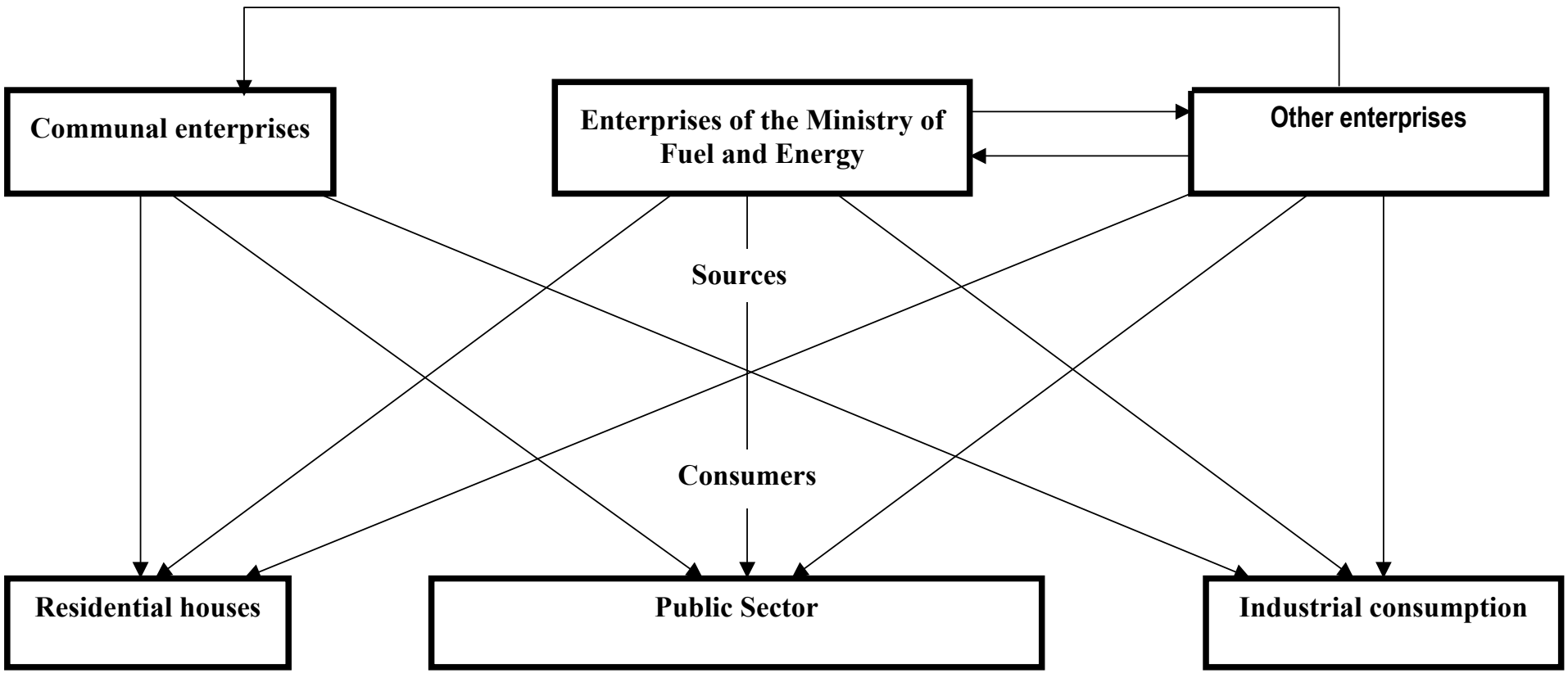

Figure 1. Scheme of heat flows in the district-heating sector

2. Methods to inventory greenhouse gases in the district-heating sector

2.1. Background

The objective of the GHG inventory provides for one of three methods to calculate emissions associated with heat production [1, 6]:

- The balance method (1st level) uses data on overall consumption of the main fuel types at the national or oblast level.
- The key source method (2nd level) uses data on fuel consumption in the branches and sectors of economic activity. This method enables calculation of emissions by key source categories located at the territory of a particular oblast or city;
- The enterprise method (3rd level) for calculating emissions uses data on fuel consumption at the particular enterprises level.

The GHG inventory methods used to meet the IPCC guidelines under the detailed approach are levels 2 and 3. Section 3.2 discusses the preparation of the preliminary data for constructing a detailed inventory of GHG's using the 2nd and 3rd levels.

2.2. Primary data

The amounts of GHG emissions are established by multiplying the volume of each fuel type combusted for heat production by the corresponding ratio of GHG emissions and fuel oxidation that result during combustion. Available sectoral fuel consumption data enable inventories to be calculated at the national and oblast levels (i.e. at the 2nd level). Confidentiality restrictions, enacted by the newly formed State Committee of Communal Sector (created in 2002), prevent the provision of more detailed data at the enterprise level, but this data may be obtained in the future through disclosure restrictions or directly from government institutions. Section 3.3 provides a brief discussion of the calculating GHG inventories at the 3rd level using this more detailed data.

2.2.1. Primary data for calculating GHG inventories using the key source (2nd level) method

Based on the structure of heat consumption shown on the Figure 1, district-heating sector GHG emissions can be established by the quantity of fuel combusted in the boiler plants of the communal property enterprises, Ministry of Fuel and Energy facilities, and other enterprises for the production of heat energy.

All enterprises in Ukraine report consumption and/or production of fuel and energy resource according in the following three forms:

- 1-tep – "Report on heat supply";
- 4-mtp – "Report on balance and consumption of fuel and combustive-lubricating materials";
- 11-mtp – "Report on the results of fuel, heat and electricity consumption".

Form 1-tep contains information on the number of the boiler plants (with the distribution of overall capacity of the boilers installed in each boiler plant), number of the boilers in each plant, volumes of production and delivery (to consumers and other enterprises), off-site receipt of heat, heat consumption for own needs and losses (with distribution by three consumer categories –

residential, public, and industrial), amount of fuel consumption (in tons of carbon equivalent) by urban and rural settlements, oblast centers, enterprises of the Ministry of Fuel and Energy, and enterprises of communal property) [10].

Form 4-mtp contains information on other fuels consumed by consumers' and suppliers' to include the quantity of combustive-lubricating materials in physical and heat value terms, fuel consumption in the energy sector (including production of heat by boiler plants), and consumption of combustive-lubricating materials for energy needs, industrial production, agricultural works and other activities, as well as fuel losses during extraction and production, treatment, processing, transmission and distribution at the oblast and state levels [11].

Form 11-mtp contains information on the consumption of fuel (in tons of carbon equivalent), for heat and electricity production, including heat production in the boiler plants with distribution into production and consumption by residential and public sector [12].

2.2.2. Primary data for calculating GHG inventories using the enterprise (3rd level) method

Calculation of GHG inventories using the enterprise method (3rd level) entails focusing on a more desegregated level than an oblast and utilizing an instrumental examination (audit) and/or a survey. The examinations can be performed in accordance with the methods of environmental and/or energy audit [7,8] for comparatively small objects – separate boilers, boiler plants or enterprises. Surveys or special questionnaires may be used for large enterprises, cities and regions. Examples of such questionnaires are included to Annex 1. It is recommended that a survey be conducted with the support of the interested ministry or department. In individual cases it is possible to use a combination of an examination and a survey.

3. Worksheet instructions for constructing an inventory of district heating sector greenhouse gases emissions

3.1. Background

A variety of gases are emitted during combustion – these include those having a direct greenhouses effect (carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O)), those having an indirect greenhouse effect (nitric oxide (NO_x), non-methane light organic compounds, and carbon monoxide (CO), as well as other gases such as SO_2.

Three electronic worksheets (located in Annex 2), constructed in accordance with the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories [1], are used to calculate the quantities of these gases associated with the fuel inputs.

Use of the worksheets enables estimates of emissions to be compared at different regional levels and across countries. In the general case for all emissions types the scheme of calculations is as follows:

Emissions = (data on the combusted fuel) × (conversion factor for carbon emissions and oxidized carbon fraction (for CO_2) or emissions factors of other greenhouse gases).

The following discussion provides instructions for the worksheets drawn from IPCC materials [1,6].

3.2. Carbon dioxide emissions

Worksheet 1-2: Step-by step calculations

The Worksheet contains the list of the most frequently used fuel types (according to the data of the State Committee of Statistics of Ukraine). If necessary, the empty rows at the bottom of the sheet can be filled with additional fuel types.

The Guidelines [1] recommend making calculations of CO_2 emissions during fuel combustion in the following order:

- Establish apparent fuel consumption in t.c.e.;
- Convert to common energy units;
- Multiply by carbon emission factors;
- Calculate carbon stored;
- Correct for unoxidized carbon;
- Convert to CO_2 emissions.

These six steps were programmed into Excel tables designed for each fuel combusted for heat supply. All operations are automated except for the first operation of Step 1, where user has only to enter information on the total quantity of all fuels consumed in the sector in physical units (1000 t or million m^3). The specific quantities of associated GHG emissions will then be calculated.

Step 1. Estimating Apparent Fuel Consumption in District-Heating Sector

1. Enter the physical amount (1000 t or million m^3) of the apparent consumption for each fuel type in column A of table D.2.1 contained in Annex 2.
2. Enter the conversion factor for each of fuel into column B to calculate tones of carbon equivalent (t.c.e.), column 3 of Table 1 (State Committee of Statistics of Ukraine (Table 1) [9]). The total quantity of each fuel consumed is then calculated in t.c.e. in column C.

Table 1. Conversion factors for converting volumes of consumed energy into tonnes of carbon equivalent

Fuel	Measure unit	Factor
Crude Oil, incl. gas condensate	thousand t/ thousand t.c.e.	1.430
Domestic furnace oil	thousand t/ thousand t.c.e.	1.451
Mazut	thousand t/ thousand t.c.e.	1.370
Antracite	thousand t/ thousand t.c.e.	0.973
Coal	thousand t/ thousand t.c.e.	0.664
Peat	thousand t/ thousand t.c.e.	0.341
Natural gas	million cubic m/ thousand t.c.e.	1.150
Solid biomass	thousand m^3/ thousand t.c.e.	0.265

Step 2. Converting to Common Energy Units (TJ)

1. The factor 29.309 TJ/thousand t.c.e. is entered into column D to convert fuel consumption (thousand t.c.e.) into tera-joules (TJ) in column E.

Step 3 Multiplying By Carbon Emission Factors

1. The carbon emission factor (CEF) presented in Table 2 for each fuel is entered into column F. These factors are used to calculate carbon emissions (tC/TJ) from apparent fuel consumption (in TJ).
2. Fuel consumption in TJ (column E) is multiplied by the carbon emission factor (column F) to obtain carbon content in tonnes (t), which is entered in column G.
3. Carbon content in tons (column G) is divided by 10^3 to give gigagrams (Gg) of carbon, which is then entered in column H.

Table 2. Carbon emission factor for fuel combustion

Fuel	Factor, tC/TJ
Crude Oil, incl. gas condensate	20.00
Domestic furnace oil	20.00
Mazut	21.32
Antracite	26.80
Coal	26.20
Peat	28.90
Natural gas	14.96
Solid biomass	29.90

Step 4. Calculating Carbon Stored

At this time, no carbon is stored during fuel consumption in the district-heating sector, so net carbon emissions are equal to the carbon content (column H) and no calculations are performed. This step is included to comply with the UPCC Guidelines [1]. Column K equals column H.

Step 5. Correcting for Carbon Unoxidised

The fraction of carbon that is oxidized (i.e. transformed to CO_2) from Table 3 is entered into column L of the worksheet 1-2, which is multiplied by net carbon emissions (column H) to calculate "Actual carbon emissions" in column M. The remainder (1 minus the factor) is emitted as soot.

Table 3. Correction factor for unoxidized carbon

Fuel	Factor
Crude Oil, incl. gas condensate	0.99
Domestic furnace oil	0.99
Mazut	0.99
Antracite	0.98
Coal	0.98
Peat	0.99
Natural gas	0.995
Solid biomass	1.00

Step 6. Converting to CO_2 Emissions

The "Actual carbon emissions" in column M are multiplied by 44/12 to calculate "Actual CO2 emissions," which are shown in column N. The sum of CO_2 emissions by fuel is the total emissions of carbon dioxide from fuel combustion in the district-heating sector.

3.3 Non-CO_2 Emissions from Fuel Combustion

A number of other emissions are also produced during fuel combustion. The quantities of these emissions depend on the fuel, emissions treatment technology, operation and maintenance, and age of the equipment. A precise estimate of these emissions requires additional data, but, given the low quantity of these emissions, approximate estimates are calculated. The fuels are first separated by type:

- coal;
- natural gas;
- oil and oil products, including fuel oil, petroleum and diesel oil;
- biomass, wood, and wood processing wastes etc.

Then other types of emissions are calculated by:

- Identifying the annual fuel consumption in the district heating sector (expressed in energy units);
- Estimating the emission factor for each fuel per sector;
- Estimating the emissions of the other GHG's.

The calculations are drawn from 1.3 of the IPCC Guideline [1], Non-CO_2 From Fuel Combustion by Source Categories, have also been programmed into Excel with the worksheets shown in Tables D 2.2 and D 2.3 of Annex 2.

Step 1. Estimate Annual Fuel Consumption In The District -Heating Sector

Data on TJ of fuel consumption in the district-heating sector from D.2.1 is automatically entered into columns A_1 – A_4 of Tables D.2.2 and Table D.2.3.

Step 2. Estimate Non-CO_2 Emissions Factors For Each Fuel In The District-Heating Sector

The emission factors (in kg/TJ) shown in Table 4 for methane (CH_4) and nitrous oxide (N_2O) are then entered into columns B_1 – B_4 of the worksheets (Tables D.2.2 and D.2.3 in Annex 2).

Table 4. Emission factor by fuel

Activity	Emission by Fuel			
	Coal	Nature gas	Oil	Wood/Wood Waste
Methane	10	5	10	300
Nitrous oxide	1.4	0.1	0.6	4

Step 3. Estimate The Emissions for Each Gas

In both worksheets (Tables D.2.2 and D.2.3), the fuel consumption data (TJ) in columns A1-A4 is multiplied by emission factors in columns B1-B4, respectively and the estimated emissions are shown in columns C1-C4.

The total emissions in Gg of CH_4 (Table D.2.2) and N_2O (Table D.2.3) are calculated by summing columns C_1-C_4 and dividing by 10^6.

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Annex 1. Tables for survey questionnaire on the preparation of primary data for greenhouse gases inventory at the boiler plants of enterprises

Table A-1. Technical performance of the boilers operation

Name (address) of the boiler plant	Boiler type	Fuel	Nominal capacity, Gcal/year; t/year	Annual fuel consumption, thousand nm^3; thousand t	Annual production of: heat, Gcal/year; steam, t/year	Operation hours during one year

Table A-2. Quality indicators of solid and liquid fuel, which is consumed by the boiler plant

Fuel type	Rank of coal or mazout	Annual consumption of fuel of this rank, thousand t

Table A-3. Heat delivered by the boiler plant

Annual delivery of heat Gcal/year; steam, t/year	including		
	population	communal and household needs	production needs

Annex 2. Worksheets on the inventory of greenhouse gases emissions in the district-heating sector.