

# **TRAINING COURSES FOR NATIONAL EXPERTS INVOLVED IN THE DEVELOPMENT OF GHG INVENTORY – ENERGY SECTOR**

## **Energy sector overview**

Moldova, Chisinau

November 23-25, 2015

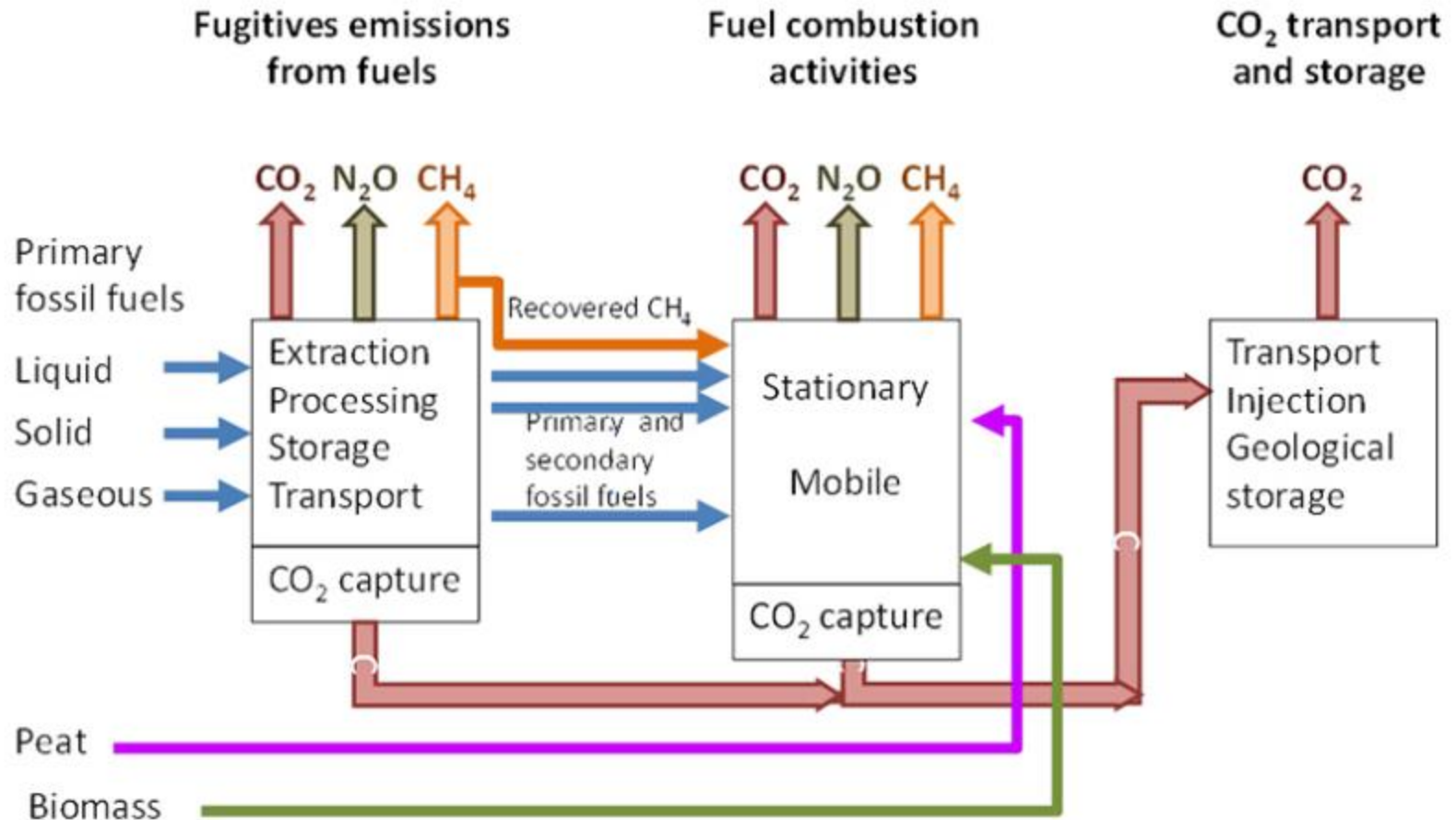
# Sector overview

Energy systems are extremely complex and widespread components of national economies. Greenhouse gases (GHGs) in the Energy sector result from the production, transformation, handling and consumption of energy commodities. For inventory purposes, the Energy sector is organized into three subsectors:

- A. fuel combustion activities;
- B. fugitive emissions from fuels; and
- C. CO<sub>2</sub> transport and storage.

- Sector content is given based on 2006 IPCC Guidelines, Part “C” is not accounting in the Revised 1996 IPCC Guidelines

# Main activities in the energy sector



Distinction from the Revised 1996 IPCC Guidelines

- CO<sub>2</sub> capture is considered
- Peat is considered as a separated fuel (not included into solid fuels)

# Fugitive emissions

Fugitive emissions mainly comprises:

- exploration and exploitation of primary energy sources,
- conversion of primary energy sources into more useable energy forms in refineries and power plants
- Transmission, storage and distribution of primary and secondary fuels

Fates of CO<sub>2</sub> and CH<sub>4</sub> deserve particular attention.

# Combustion of fuels

**For inventory purposes, *fuel combustion*** may be defined as *the intentional oxidation of materials within an apparatus that is designed to provide heat or mechanical work to a process, or for use away from the apparatus.*

Combustion converts the chemical energy of a fuel into another type of usable energy. Primary fossil fuels (coal and natural gas) and a diversity of secondary fossil fuels are combusted in stationary devices, while mostly liquid and a few gaseous fuels are combusted in vehicles such as aircraft, trains, road vehicles and waterborne vessels. Three other main types of materials, namely, biomass, peat and waste, are also combusted for energy purposes.

# Fuel types

The 2006 IPCC Guidelines		The Revised 1996 IPCC Guidelines
<b>ЖИДКИЕ ТОПЛИВНЫЕ РЕСУРСЫ (сырая нефть и нефтепродукты)</b>		
Сырая нефть		Сырая нефть (crude oil)
Природный газоконденсат (ПГК)		Природный газоконденсат (Natural gas liquids)
Бензин	Автомобильный бензин	Бензин
	Авиационный бензин	
	Бензин для реактивных двигателей	
Авиационный керосин		Авиационный керосин
Другие виды керосина		Другие виды керосина
Дизельное топливо		Дизельное топливо
Мазут, топливо печное бытовое		Мазут, топливо печное бытовое
Сжиженный нефтяной газ		Сжиженный нефтяной газ
Этан		Этан
Нафта (лигроин)		Нафта (лигроин)
Битум		Битум
Смазочные материалы		Смазочные материалы (Lubricants)
Нефтяной кокс		Нефтяной кокс (Petroleum coke)
Нефтезаводское сырье		Нефтезаводское сырье (Refinery feedstock)
Прочие виды нефтепродуктов	Нефтезаводской газ	Нефтезаводской газ(refinery gas)
	Парафины	
	Уайт-спирит и пром. растворители	
	Другие нефтепродукты	Другие нефтепродукты (Other oils)
<b>ТВЕРДЫЕ ВИДЫ (уголь и продукты переработки угля)</b>		
Антрацит		Антрацит
Коксующийся уголь		Коксующийся уголь
Другие виды битуминозного угля (каменный уголь)		Другие виды битуминозного угля (каменный уголь)
Бурый уголь/Лигнит		Бурый уголь/Лигнит
Горючий сланец и битуминозные пески		Горючий сланец (oil shale)
Брикетированный бурый уголь		Брикетированный бурый уголь и каменноугольные брикеты (ВКВ, Patent fuel)
Каменноугольные брикеты		
Кокс	Печной и доменный кокс	Печной и доменный кокс/ Газовый кокс (Coke oven / Gas coke)
	Газовый кокс	
Каменноугольная смола		
Производные газы	Заводской газ	
	Коксовый газ	Коксовый газ (Coke oven gas)
	Доменный газ	Доменный газ (Blast furnace gas)
	Газ кислородных плавильных печей	

# Fuel types (cont.)

The 2006 IPCC Guidelines		The Revised 1996 IPCC Guidelines
<b>ГАЗ (Природный газ)</b>		
Природный газ		Природный газ (Natural gas)
<b>ДРУГИЕ ВИДЫ ИСКОПАЕМОГО ТОПЛИВА</b>		
Бытовые отходы (небиологические фракции)		Отходы (waste) – <i>Рассчитывались в секторе Отходы</i>
Промышленные отходы		
Нефтяные отходы		
<b>Торф</b>		
Торф		Торф (Peat)
Брикеты и полубрикеты торфяные		
<b>БИОМАССА</b>		
Твердые виды биотоплива	Древесина/древесные отходы	Твердая биомасса
	Щелок (Черный щелок)	
	Другие виды первичной твердой биомассы	
	Древесный уголь	
Жидкое биотопливо	Биобензин	Жидкая биомасса
	Био-дизтопливо	
	Другие виды жидкого биотоплива	
Биогаз	Газ из органических отходов	Биогаз
	Канализационный газ	
	Другие биогазы	
Другие виды не ископаемого топлива	Бытовые отходы (фракция биомассы)	<i>Рассчитывалось в секторе отходы</i>

# Peat, biomass and waste

## **Biomass:**

- Activity data are generally more uncertain
- A large fraction of the biomass, used for energy, may be part of the informal economy, and the trade in these type of fuels (fuel wood, agricultural residues, dung cakes, etc.) is frequently not registered in the national energy statistics and balances.

The AFOLU Volume 4 Chapter 4 (Forest Land) provides an alternative method to estimate activity data for fuel wood use.

Where data from energy statistics and AFOLU statistics are both available, the inventory compiler should take care to avoid any double counting, and should indicate how data from both sources have been integrated to obtain the best possible estimate of fuel wood use in the country.

## **Peat:**

As peat is not strictly a fossil fuel, it is not classified as such in the 2006 IPCC Guidelines, as was done in the [Revised 1996 Intergovernmental Panel on Climate Change Guidelines for National Greenhouse Gas Inventories](#) (hereinafter referred to as the Revised 1996 IPCC Guidelines). However, its GHG emission characteristics have been shown to be comparable to those of fossil fuels; therefore, CO<sub>2</sub> and non-CO<sub>2</sub> emissions from peat are included in the national emissions as for fossil fuels. For solid, liquid and gaseous biomass fuels, CO<sub>2</sub> emissions from combustion are not included in national totals, while the corresponding non-CO<sub>2</sub> emissions are included. Nevertheless, CO<sub>2</sub> emissions from biomass combustion are estimated and reported as an information item for cross-checking purposes, as well as to avoid double counting.



# Peat, biomass and waste

## **Waste:**

Waste incineration may occur in installations where the combustion heat is used as energy in other processes. In such cases, this waste must be treated as a fuel and the emissions should be reported in the energy sector.

When waste is incinerated without using the combustion heat as energy, emissions should be reported under waste incineration.

Methodologies in both cases are provided in Volume 5 Chapter 5 - Waste.

CO<sub>2</sub> emissions from combustion of biomass in waste used for energy are not included in national totals, but are recorded as an information item for cross-checking purposes.



# Sub-sectors and categories – transport and fugitives

<b>3. Transport</b>
a. Civil aviation
b. Road transportation
c. Railways
d. Water-borne navigation
e. Other transportation
<b>4. Other sectors</b>
a. Commercial/institutional
b. Residential
c. Agriculture/forestry/fishing/fish farms
<b>5. Non-specified</b>
a. Stationary
b. Mobile
<b>B. Fugitive emissions from fuels</b>
<b>1. Solid fuels</b>
a. Coal mining and handling
<b>2. Oil and natural gas and other emissions from energy production</b>
a. Oil
b. Natural gas

<b>3. Transport</b>
a. Civil Aviation
b. Road Transportation
c. Railways
d. Navigation
e. Other Transportation ( <i>as specified in table 1.A(a) sheet 3</i> )
<b>4. Other Sectors</b>
a. Commercial/Institutional
b. Residential
c. Agriculture/Forestry/Fisheries
<b>5. Other (<i>as specified in table 1.A(a) sheet 4</i>)</b>
a. Stationary
b. Mobile
<b>B. Fugitive Emissions from Fuels</b>
<b>1. Solid Fuels</b>
a. Coal Mining and Handling
b. Solid Fuel Transformation
c. Other ( <i>as specified in table 1.B.1</i> )
<b>2. Oil and Natural Gas</b>
a. Oil
b. Natural Gas
c. Venting and Flaring
d. Other ( <i>as specified in table 1.B.2</i> )
Underground storage

# Sub-sectors and categories

## – other categories and memo items

<b>3. Other emissions from energy production</b>
<b>C. CO<sub>2</sub> Transport and storage</b>
1. Transport of CO <sub>2</sub>
2. Injection and storage
3. Other
<b>Memo items:<sup>(1)</sup></b>
<b>International bunkers</b>
International aviation
International water-borne transport
<b>Multilateral operations</b>

<b>Memo Items: <sup>(1)</sup></b>
<b>International Bunkers</b>
Aviation
Marine
<b>Multilateral Operations</b>
<b>CO<sub>2</sub> Emissions from Biomass</b>

# Carbon Dioxide (CO<sub>2</sub>) Emissions

- The calculation methodology is **mass-balance-based**.
- **Oxidation** of the carbon in fuels occurs during **combustion**.
- In perfect combustion conditions, total carbon content of fuels would be converted to CO<sub>2</sub>.
- **Real combustion processes** result in small amounts of partially oxidized and unoxidized carbon.

(The 2006 IPCC Guidelines assume full oxidation of carbon)

# Carbon Flow for a Typical Combustion Process

- **Most carbon is emitted as CO<sub>2</sub> immediately.**
- **A small fraction emitted as non-CO<sub>2</sub> gases:**
  - CH<sub>4</sub>, CO, non-methane volatile organic compounds (NMVOCs)
  - Ultimately oxidizes to CO<sub>2</sub> in the atmosphere
  - Integrated into overall calculation of CO<sub>2</sub> emissions
- **The remaining part of the fuel carbon is unburnt:**
  - Assumed to remain as solid (ash and soot)
  - Account by using oxidation factors.

# Non-CO<sub>2</sub> Emissions

- **Direct greenhouse gases:**
  - Methane (CH<sub>4</sub>)
  - Nitrous oxide (N<sub>2</sub>O).
- **Precursors and SO<sub>2</sub>:**
  - Nitrogen oxides (NO<sub>x</sub>)
  - Carbon monoxide (CO)
  - Non-methane volatile organic compounds (NMVOCs)
  - Sulphur dioxide (SO<sub>2</sub>).

# Global warming potential – CO2 equivalent

Aggregated GHG emissions and removals should be expressed in CO2 equivalents using the global warming potentials (GWP) provided by the IPCC in its Second Assessment Report

Annex 1 countries according to the Decision 24/CP.19 should use GWP provided by the IPCC in its Forth Assessment Report



# Non-CO<sub>2</sub> Emissions Require Detailed Process Information

- Combustion conditions
- Size and vintage of the combustion technology
- Maintenance
- Operational practices
- Emission controls
- Fuel characteristics.

# Methane (CH<sub>4</sub>)

- Emissions are a **function of**:
  - methane content of the fuel
  - hydrocarbons passing unburned through engine
  - engine type
  - post-combustion controls.
- Depends on temperature in boiler/kiln/stove.
- Highest emissions are in residential applications (e.g. small stoves, open biomass burning, charcoal production).

# Nitrous Oxide (N<sub>2</sub>O)

- Lower combustion temperatures tend to lead to higher N<sub>2</sub>O emissions.
- Emission controls (catalysts) on vehicles can increase the rate of N<sub>2</sub>O generation, depending on:
  - driving practices (i.e. number of cold starts)
  - type and age of the catalyst.
- Significant emissions for countries with a high penetration of vehicles with catalysts:

<http://unfccc.int/resource/docs/2004/sbsta/inf03.pdf>

# Methods for Estimating CO<sub>2</sub>

- **Reference approach (Tier 1):**
  - Estimates based on national energy balance (production + imports - exports) by fuel type without information on activities
  - Performed quickly if basic energy balance sheet is available
  - Way of cross-checking emission estimates of CO<sub>2</sub> with the sectoral approach.
- **Sectoral approach (Tier 1):**
  - Estimates based on fuel consumption data by sectoral activity.
- **Bottom-up approaches (Tier 2 or 3):**
  - More detailed activity and fuel data are required.

# Emissions by Source Categories - Fundamental Equation

$$\begin{aligned} & \text{carbon emissions} \\ & = \\ & \sum \text{fuel consumption expressed in energy units (TJ) for each sector} \\ & \quad \times \text{carbon emission factor} \\ & \quad - \text{carbon stored} \\ & \quad \times \text{fraction oxidised} \end{aligned}$$

Source: Revised 1996 IPCC Guidelines for national GHG inventories, Reference Manual – Volume 3, p. 1.30.

# Methods for Non-CO<sub>2</sub> Emissions

## Tier 1

- Multiply fuel consumed by an average emission factor:
  - Does not require detailed activity data
  - Rely on widely available fuel supply data that assume an average combustion technology is used.

## Tier 2

- Use national aggregated and country specific emission factors
- For some categories – use technology specific AD

## Tiers 3

- Activity data and emission factors are technology-specific,
  - estimate emissions according to activity types (km travelled or tonnes-km carried) and specific fuel efficiency or fuel rates.
  - Use model and measurements approaches

# Fundamental Equation

$$\text{Emissions} = \Sigma(\text{Emission Factor}_{abc} \bullet \text{Fuel Consumption}_{abc})$$

Where,

$a$  = fuel type

$b$  = sector activity

$c$  = technology type including emissions controls.

# Stationary Combustion

- **Default emission factors** for **CH<sub>4</sub>**, **N<sub>2</sub>O**, **NO<sub>x</sub>**, **CO** and **NMVOCs** by major technology and fuel type are presented in the Revised 1996 IPCC Guidelines.
- **Most notable CO<sub>2</sub>** emissions – from energy industries
- **Most notable: CH<sub>4</sub>** emissions from open burning and biomass combustion.
- **Charcoal production** is likely to produce methane emissions at a rate that is several orders of magnitude greater than from other combustion processes.



# Mobile Combustion

- Major transport activity (road, air, rail and ships).
- **Most notable: N<sub>2</sub>O** emissions from road transportation, affected by the type of emission control technologies.
- Non-Annex I Parties should focus their efforts on collecting data on the number of vehicles with catalytic emissions control devices that operate in their country.

# Mobile Combustion (cont.)

## Road transport activity data:

- Assume vast majority of motor gasoline used for transport
- Check data with equipment counts or vehicle sales/import/export data
- Base assumptions of vehicle type and emission control technology on vehicle vintage data (i.e. model year of sale) and assumed activity level (i.e. vehicle-km-travelled/vehicle)
- Consider national emission standards, leaded gasoline prevalence, and compliance with standards.

# Relationships with Other Sources and Sectors

## Industrial processes sector:

- Non-energy fossil fuel feedstocks data, if available, may not be reliable
- Petrochemical “feedstocks” may actually be used for energy
- Coal purchased by iron and steel industry may be used to make coke
- Focus on petrochemical industry and metal production (e.g. iron and steel)
- Conservative estimate: assume plastics, asphalt, and some lubricants stored
- Subtract carbon content from these products.

# Relationships with Other Sources and Sectors (cont.)

## **Waste sector:**

- Combustion of wastes for energy purposes included in energy sector
- Incineration of plastics.

## **LULUCF sector:**

- Biomass carbon implicitly accounted for.

**Autoproduction of electricity**

**Fuel use for military purposes**

**Mobile sources in agriculture**

# Quality Control and Completeness Checks

- All gases (**CO<sub>2</sub>**, **CH<sub>4</sub>** and **N<sub>2</sub>O**)
- All source and sub-source categories
- All national territories addressed
- Bunker fuels and military operations
- All fossil-fuel-fired electric power stations
- Blast furnaces and coke production
- Waste combustion with energy recovery
- Black market fuels
- Non-metered fuel use for pipelines by compressor stations.

# Uncertainty

- Uncertainty in carbon content and calorific values for fuels is related to the **variability in fuel composition and frequency of actual measurements**. Likely to be small for all countries.
- For most non-Annex I Parties the **uncertainty in activity data** (i.e. fuel consumption data) will be the dominant issue!
  - Effort should focus on collection of fuel consumption data

It is important to **document the likely causes of uncertainty** and discuss steps taken to reduce uncertainties.