The Use of Energy Statistics to Estimate CO₂ Emissions

Joint IEA, ESCWA and RCREEE National Workshop on Energy Statistics
Cairo, Egypt
27 April – 01 May 2014
Outline

- International context
- Trends in emissions over time
- IPCC methodology
- Estimation of CO₂ emissions by the IEA
- Comparison of Reference and Sectoral approaches
- Conclusions
International Context
International Context

Stabilisation of greenhouse gas concentrations in the atmosphere.

- **1992:** United Nations Framework Convention on Climate Change (UNFCCC) at negotiated at the Earth Summit Conference, Rio de Janeiro.

- **1997:** Kyoto Protocol negotiated (entered into force in 2005).

- **2008-2012:** First commitment period of the Kyoto Protocol.
  
  38 developed countries agreed to reduce anthropogenic greenhouse gas emissions over this period by about 5% compared to 1990.

- **Ongoing:** Since 1995, the parties to the Convention have met once a year at the Conference of the Parties (COP) to discuss progress.

  COP19 is being held from 11-22 November in Warsaw, Poland.
Trends in emissions over time
Despite growth in renewable energy, fossil fuels still satisfy most of the world’s energy supply.
Energy sector emissions, which are predominantly CO₂, account for the largest share of global greenhouse gas (GHG) emissions.
Trend in CO₂ emissions from fossil fuel combustion

Since 1870, CO₂ emissions from fuel combustion have risen exponentially.
World electricity generation by fuel

Although non- and low-emitting sources of electricity are growing, electricity generation remains CO₂-intensive due to the increasing share of coal.
World CO$_2$ emissions by sector

Total emissions: 30.3 GtCO$_2$ (2010)

Electricity / heat generation and transport make up almost 2/3 of global emissions. This has increased from 1/2 in 1971.
World CO₂ emissions by sector in with electricity and heat re-allocated

Total emissions: 30.3 GtCO₂ (2010)

- Industry: 37%
- Transport: 23%
- Residential: 6%
- Other: 22%

When electricity / heat emissions are allocated to their consuming sectors, Industry becomes the largest emitting sector.
CO₂ intensity indicators

Emissions estimates can be combined with energy data and other socio-economic figures to produce useful indicators such as:

- CO₂ / population
- CO₂ / GDP
- CO₂ / TPES
- CO₂ / kWh
CO₂ intensities of major countries

CO₂ indicators can be used to compare emissions in countries with differing economic circumstances.
IPCC Methodologies
IPCC methodologies: overview

- Allow a complete inventory of emissions across countries to be calculated in a consistent, accurate, comparable and transparent manner.

- Two sets of Guidelines were published:

  *Revised 1996 IPCC Guidelines*
  *2006 IPCC Guidelines*

- Kyoto Protocol is based on the *Revised 1996 IPCC Guidelines*

Therefore, IEA CO₂ estimates are also calculated using the *Revised 1996 IPCC Guidelines*. 
IPCC methodologies: tiered approach

Tier 1
- Simplest method
- Use fuel consumption (activity) data available to all countries

Tier 2
- Country or technology-specific emission factor

Tier 3
- More detailed or country-specific methods

Although Tier 2 and 3 are more accurate in general, in the case of CO$_2$ from fuel combustion, the Tier 1 approach produces accurate results, as emissions are based on the carbon content of the fuels (conservation of carbon).
IPCC methodologies: basic computation

Basic computation for CO$_2$ emissions using the 1996 Guidelines:

- CO$_2$ emissions by product: $\text{Fuel Quantity} \times \text{Emission Factor}$
  (with corrections for stored and unoxidised carbon)
- Sum over all different products

Can be done from two independent sets of data:

Supply of fuels to the country
Reference Approach

Consumption by end-use sectors
Sectoral Approach
IPCC methodologies: what is not included?

*IPCC Guidelines:* Biomass is **not included** in national totals for CO$_2$ emissions from **fuel combustion**.

Biomass contains carbon, absorbed by plants through photosynthesis.

However, if biomass is sustainably grown, no additional CO$_2$ is considered as emitted into the atmosphere.

If there is a change in the biomass stocks, then the CO$_2$ is accounted for in *land-use, land-use change and forestry (LULUCF)*.
IPCC methodologies: what is not included?

**IPCC Guidelines**: international aviation and international marine bunkers are not included in national totals.
IEA CO$_2$ Emissions Estimates
How IEA estimates CO\(_2\) emissions from fuel combustion

- Energy Statistics
- Energy Balances
- IPCC Methodologies (Revised 1996 GLs)
- CO\(_2\) Emissions
## Step 1: Estimating sectoral fuel consumption

**Module:** Energy  
**Submodule:** CO₂ from Fuel Combustion (Tier I Sectoral Approach)  
**Worksheet:** Step by Step Calculations  
**Sheet:** Manufacturing Industries and Construction

<table>
<thead>
<tr>
<th>Step</th>
<th>MANUFACTURING INDUSTRIES AND CONSTRUCTION</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A</strong></td>
<td>Consumption</td>
</tr>
</tbody>
</table>

### Separate sheet filled out for each sector:
- Main activity producer electricity and heat
- Unallocated autoproducers
- Other energy industries
- Manufacturing industries and construction
- Transport of which: road
- Other sectors of which: residential

### Units:
Could be in natural units (e.g. 1000 tonnes) or in energy units (e.g. TJ)
## Step 2: Converting to a common energy unit

<table>
<thead>
<tr>
<th>Module</th>
<th>Energy</th>
<th>Worksheet</th>
<th>Step by Step Calculations</th>
<th>Sheet</th>
<th>Manufacturing Industries and Construction</th>
</tr>
</thead>
<tbody>
<tr>
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</table>

<table>
<thead>
<tr>
<th></th>
<th>STEP 1</th>
<th>STEP 2</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Manufacturing</td>
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</tr>
<tr>
<td>Industries and</td>
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</tr>
<tr>
<td>Construction</td>
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<td></td>
</tr>
<tr>
<td>B</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Conversion Factor</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(TJ/unit)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Consumption (TJ)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C=(AxB)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Equation:**

\[ C = (A \times B) \]

### SELECTED NET CALORIFIC VALUES FROM THE 1996 GLS

<table>
<thead>
<tr>
<th>Refined petroleum products</th>
<th>Factors (TJ/10^3 tonnes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gasoline</td>
<td>44.80</td>
</tr>
<tr>
<td>Jet kerosene</td>
<td>44.59</td>
</tr>
<tr>
<td>Other kerosene</td>
<td>44.75</td>
</tr>
<tr>
<td>Shale oil</td>
<td>36.00</td>
</tr>
<tr>
<td>Gas/diesel oil</td>
<td>43.33</td>
</tr>
<tr>
<td>Residual fuel oil</td>
<td>40.19</td>
</tr>
<tr>
<td>LPG</td>
<td>47.31</td>
</tr>
<tr>
<td>Ethane</td>
<td>47.49</td>
</tr>
<tr>
<td>Naphtha</td>
<td>45.01</td>
</tr>
<tr>
<td>Bitumen</td>
<td>40.19</td>
</tr>
<tr>
<td>Lubricants</td>
<td>40.19</td>
</tr>
<tr>
<td>Petroleum coke</td>
<td>31.00</td>
</tr>
<tr>
<td>Refinery feedstocks</td>
<td>44.80</td>
</tr>
<tr>
<td>Refinery gas</td>
<td>48.15</td>
</tr>
<tr>
<td>Other oil products</td>
<td>40.19</td>
</tr>
<tr>
<td>Coal oils and tars derived from coking coals</td>
<td>28.00</td>
</tr>
<tr>
<td>Oil shale</td>
<td>9.40</td>
</tr>
<tr>
<td>Orimulsion</td>
<td>27.50</td>
</tr>
</tbody>
</table>

Country-specific NCVs for natural gas and coal are given explicitly in the *Revised 1996 IPCC Guidelines*. 

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### Step 3: Multiplying by carbon emission factors

<table>
<thead>
<tr>
<th>Manufacturing Industries and Construction</th>
<th>Carbon emission factor (t C/TJ)</th>
<th>STEP 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crude Oil</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Natural Gas Liquids</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gasoline</td>
<td>18.9</td>
<td></td>
</tr>
<tr>
<td>Jet kerosene</td>
<td>19.5</td>
<td></td>
</tr>
<tr>
<td>Other kerosene</td>
<td>19.6</td>
<td></td>
</tr>
<tr>
<td>Shale oil</td>
<td>20.0</td>
<td></td>
</tr>
<tr>
<td>Gas/diesel oil</td>
<td>20.2</td>
<td></td>
</tr>
<tr>
<td>Residual fuel oil</td>
<td>21.1</td>
<td></td>
</tr>
<tr>
<td>LPG</td>
<td>17.2</td>
<td></td>
</tr>
<tr>
<td>Ethane</td>
<td>16.8</td>
<td></td>
</tr>
<tr>
<td>Naphtha</td>
<td>(20.0)</td>
<td></td>
</tr>
<tr>
<td>Bitumen</td>
<td>22.0</td>
<td></td>
</tr>
<tr>
<td>Lubricants</td>
<td>(20.0)</td>
<td></td>
</tr>
<tr>
<td>Petroleum coke</td>
<td>27.5</td>
<td></td>
</tr>
<tr>
<td>Refinery feedstocks</td>
<td>(20.0)</td>
<td></td>
</tr>
<tr>
<td>Refinery gas</td>
<td>18.2</td>
<td></td>
</tr>
<tr>
<td>Other oil</td>
<td>(20.0)</td>
<td></td>
</tr>
</tbody>
</table>

**Revised 1996 Guidelines**

**Carbohydrate Emission Factors (CEF)**

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Carbon emission factor (t C/TJ)</th>
<th>D Carbon Emission Factor (t C/TJ)</th>
<th>E Carbon Content (t C)</th>
<th>F Carbon Content (Gg C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crude Oil</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ethane</td>
<td>16.8</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Naphtha</td>
<td>(20.0)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bitumen</td>
<td>22.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lubricants</td>
<td>(20.0)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Petroleum coke</td>
<td>27.5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Refinery feedstocks</td>
<td>(20.0)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ethane</td>
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<tr>
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<td></td>
<td></td>
</tr>
<tr>
<td>Lubricants</td>
<td>(20.0)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Petroleum coke</td>
<td>27.5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Refinery feedstocks</td>
<td>(20.0)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Step 4: Calculating carbon stored

**Module**

**Energy**

**Submodule**

CO\(_2\) from Fuel Combustion (Tier I Sectoral Approach)

**Worksheet**

2 Step by Step Calculations

**Sheet**

Manufacturing Industries and Construction

<table>
<thead>
<tr>
<th><strong>Step 4</strong></th>
<th><strong>Step 5</strong></th>
<th><strong>Step 6</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>H=(FxG)</td>
<td>I=(F-H)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Manufacturing Industries and Construction</strong></th>
<th><strong>G</strong> Fraction of Carbon Stored</th>
<th><strong>H</strong> Carbon Stored (Gg C)</th>
<th><strong>I</strong> Net Carbon Emissions (Gg C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crude Oil</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Natural Gas Liquids</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gasoline</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jet Kerosene</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other Kerosene</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gas/Diesel Oil</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Residual Fuel Oil</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LPG</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Default values: fraction of carbon stored**

- Naphtha*: 0.8
- Lubricants: 0.5
- Bitumen: 1.0
- Coal Oils and Tars: 0.75
- Natural Gas*: 0.33
- Gas/Diesel Oil*: 0.5
- LPG*: 0.8
- Ethane*: 0.8

*When used as feedstocks
### Step 5: Correcting for carbon unoxidised

**Default values: fraction of carbon oxidised**

<table>
<thead>
<tr>
<th>Energy Source</th>
<th>Fraction of Carbon Oxidised</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal</td>
<td>0.98</td>
</tr>
<tr>
<td>Oil and oil products</td>
<td>0.99</td>
</tr>
<tr>
<td>Gas</td>
<td>0.995</td>
</tr>
<tr>
<td>Peat for elec. Generation</td>
<td>0.99</td>
</tr>
</tbody>
</table>

**Worksheet 2 - Step by Step Calculations**

**Sheet - Manufacturing Industries and Construction**

<table>
<thead>
<tr>
<th>Step 4</th>
<th>Step 5</th>
<th>Step 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>J: Fraction of Carbon Oxidised</td>
<td>K: Actual Carbon Emissions (Gg C)</td>
<td>K=(IxJ)</td>
</tr>
</tbody>
</table>

**Module: Energy**

**Submodule: CO₂ from Fuel Combustion (Tier I Sectoral Approach)**

**Workshop:** Revised 1996 Guidelines
### Step 6: Converting to CO₂ emissions

<table>
<thead>
<tr>
<th>Module</th>
<th>Energy</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Submodule</strong></td>
<td>CO₂ from Fuel Combustion (Tier I Sectoral Approach)</td>
</tr>
<tr>
<td><strong>Worksheet</strong></td>
<td>2 Step by Step Calculations</td>
</tr>
<tr>
<td><strong>Sheet</strong></td>
<td>Manufacturing Industries and Construction</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th><strong>Step 4</strong></th>
<th><strong>Step 5</strong></th>
<th><strong>Step 6</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Manufacturing Industries and Construction</strong></td>
<td></td>
<td></td>
<td>L Actual CO₂ Emissions (Gg CO₂)</td>
</tr>
<tr>
<td>Crude Oil</td>
<td></td>
<td></td>
<td>L=(K x [44/12])</td>
</tr>
<tr>
<td>Natural Gas Liquids</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gasoline</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jet Kerosene</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other Kerosene</td>
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<td></td>
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</tr>
<tr>
<td>Gas/Diesel Oil</td>
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</tr>
<tr>
<td>Residual Fuel Oil</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LPG</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Multiply by 44/12**

(the molecular weight ratio of CO₂ to C)
Reference vs. Sectoral Approach

Sectoral

Reference
Data Quality: Reference vs. Sectoral Approach

Reference Approach is generally an upper limit for Sectoral Approach

Comparing the Reference Approach and the Sectoral Approach is one way to control data quality.
## World CO₂ emissions

<table>
<thead>
<tr>
<th>Sector</th>
<th>Coal/peat</th>
<th>Other</th>
<th>Gas</th>
<th>Oil</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>2010 CO₂ emissions (million tonnes)</strong></td>
<td>13 065.9</td>
<td>6 179.1</td>
<td>140.6</td>
<td>11 007.0</td>
<td>31 102.3</td>
</tr>
<tr>
<td>Reference Approach **</td>
<td>13 700.9</td>
<td>6 253.8</td>
<td>140.6</td>
<td>11 007.0</td>
<td>31 102.3</td>
</tr>
<tr>
<td>Diff. due to losses and/or transformation</td>
<td>-395.0</td>
<td>-174.7</td>
<td>-670.6</td>
<td>-203.4</td>
<td>-943.5</td>
</tr>
<tr>
<td>Statistical differences</td>
<td>326.8</td>
<td>17.4</td>
<td>-6.6</td>
<td>-77.6</td>
<td>-51.1</td>
</tr>
<tr>
<td><strong>Memo: international marine bunker fuels</strong></td>
<td>-</td>
<td>6 179.1</td>
<td>-</td>
<td>-</td>
<td>- 6 179.1</td>
</tr>
<tr>
<td><strong>Memo: international aviation bunker fuels</strong></td>
<td>-</td>
<td>-3 282.6</td>
<td>-</td>
<td>-</td>
<td>-3 282.6</td>
</tr>
</tbody>
</table>

* Other includes industrial waste and non-renewable municipal waste.

** World includes international marine bunkers and international aviation bunkers.

We show both the reference approach and sectoral approach emissions (the difference coming from statistical differences, and losses and transformation).

We show emissions for main activity and autoproducer plants separately (we don’t have the required data to allocate autoproducers to their consuming sectors).

Residential only includes emissions from fuels actually combusted in households (hence its relatively small share), not electricity or heat consumption.

Bunker fuels are included in transport for the world total (but not for all countries and regions).

We show emissions from fuels actually combusted in households (hence its relatively small share), not electricity or heat consumption.

**World includes international marine bunkers and international aviation bunkers.**

* Other includes industrial waste and non-renewable municipal waste.
Conclusions
Dealing with energy-climate change challenges

- Emit less (be more efficient)
- Emit differently (switch fuels or processes to deliver same outcome)
- New technologies (CO$_2$ capture and storage,...)
- Change behaviour
- Adapt (learn to live with it)

A need for energy statistics to be able to monitor progress of the various policies
Concluding remarks

- Human influence on the climate system is clear. This is evident from the increasing GHG concentrations in the atmosphere... - IPCC 5th Assessment Report, Working Group I

- Effective emissions mitigation will require all countries, regardless of energy demand and infrastructure, to use energy in a sustainable manner.

- Up-to-date and accurate information on energy use and GHG emissions is essential for countries to monitor their progress in reducing GHG emissions.

Good energy statistics are crucial for estimating GHG emissions
The CO₂ Emissions from Fuel Combustion (2013 Edition) will be available shortly.

A large amount of data is available online for free at: http://www.iea.org/statistics/topics/CO2emissions

Thank you. emissions@iea.org
Exercises – things to remember

- Sectoral approach estimates CO₂ emissions using the consumption of fuels, not the supply.
- Consumption of fuels includes Own Use in the Energy Sector and Transformation of fossil fuels in the Electricity Sector.
- Certain fuels can be used for both energy and non-energy purposes – only estimate CO₂ emissions from energy use of these fuels.
- CO₂ from biomass use is not added to emissions totals (reported as memo items) but emissions of other greenhouse gases from biomass are added to totals.
- Emissions from consumption of bunker fuels are not included in totals for individual countries.