Greenhouse Gas Emissions Estimations from the Energy Sector

Ankara – Workshop on Energy Statistics, Balances, and Accounts for Informed Energy and Climate Policies

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International Energy Agency

Overview

I. Climate change – tracking climate targets with energy data

II. GHG estimates methodology – Sectoral and Reference Approach

III. Exercises & Conclusions

GHG Emissions Estimates from Energy - Overview

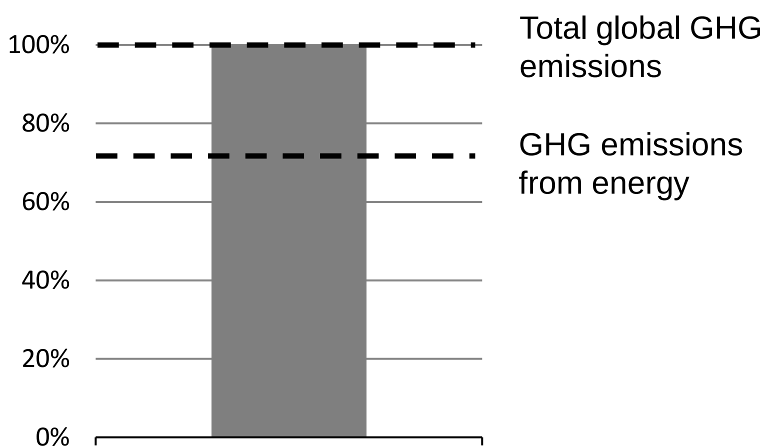
Why:	Energy accounts for **more than three-quarters of total greenhouse gas (GHG) emissions globally.** Thus, tracking the GHG emissions from energy is vital for developing sustainable energy policies and for mitigating **the Climate Change.**
What:	
Type of data:	**GHG emissions from energy** and related indicators, including CO2, CH4, N20 emissions from **fuel combustion, fugitive emissions, and emission factors** for electricity and heat generation.
Time granularity:	**Yearly data** for fuel combustion and fugitive emissions, **yearly, quarterly and monthly data** for emission factors.
Submissions:	No direct submissions – the emissions estimates are **based on energy data** submitted to the IEA **World Energy Balances** database. The emission factors, in addition, utilize the IEA **Monthly Electricity Statistics** and IEA **Electricity Information** databases.
Who:	
Emissions team:	at emissions@iea.org (RÍSQUEZ Arnau, TAGHAVI Pouya, KÖYKKÄ Juha)

Energy emissions defined

2006 IPCC Guidelines for national greenhouse gas inventories

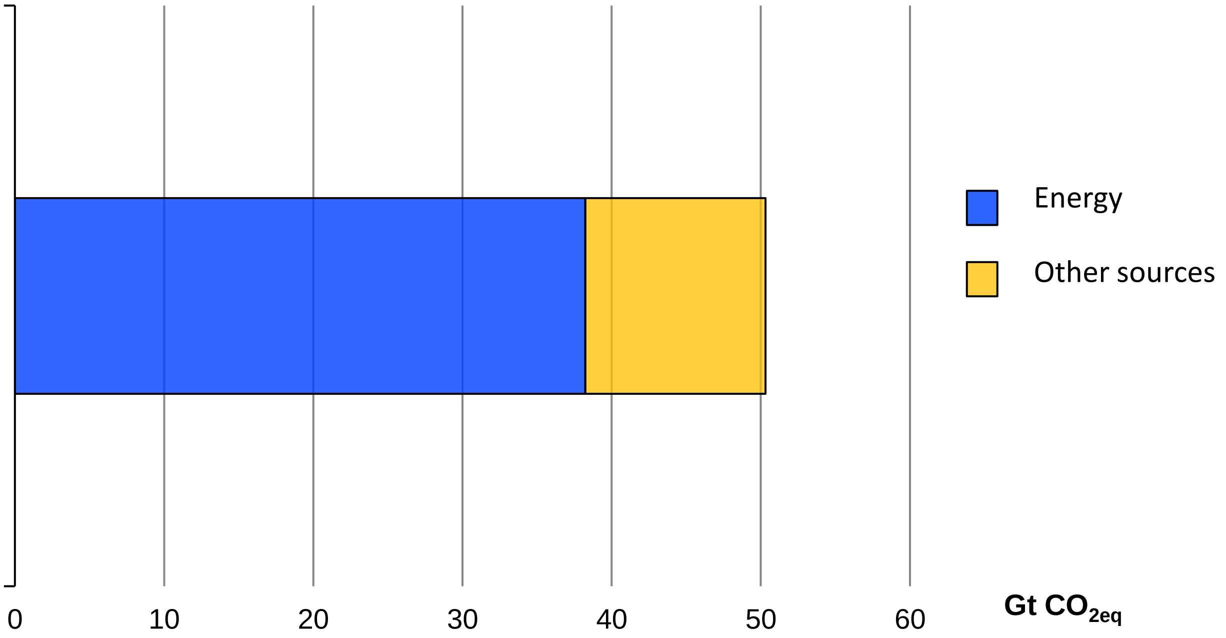
Greenhouse gas inventory to UNFCCC

- **1. Energy**
  - 1A. Fuel combustion activities
  - 1B. Fugitive emissions from fuels
  - 1C. Carbon dioxide transport and storage
- **2. Industrial Processes and Product Use**
- **3. Agriculture, Forestry and Other Land Use**
- **4. Waste**



The importance of energy data in tracking GHG emissions

GHG emissions: energy VS other sources



Energy includes IPCC categories ‘Fuel Combustion’ and ‘Fugitive’.

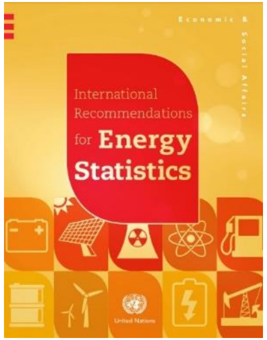
Source: IEA, 2022 – GHG Emissions from Energy – includes EDGAR modelled data.

Energy accounts for around three quarters of the global greenhouse gas emissions

Consistency - harmonized requirements and definitions

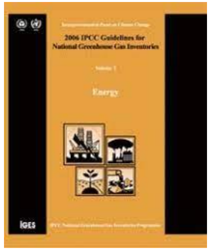
International Recommendations on Energy Statistics (IRES)

- Global reference for energy statistics methodologies



2006 IPCC Guidelines for National Greenhouse Gas Inventories

- Guidelines for estimating and reporting national GHG inventories



Volume 2 Energy

Comparability of energy statistics is key. IRES is consistent with IPCC methodologies.

IEA is a co-author of the IPCC Guidelines and contributes to the development of international standards on energy and emissions statistics.

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GHG Emissions estimates

Go to

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Or use QR code

Quiz ! Go to https://www.menti.com/ and use this code: 7937 2745

- Which sector was the highest emitter in the MENA region in 2021?

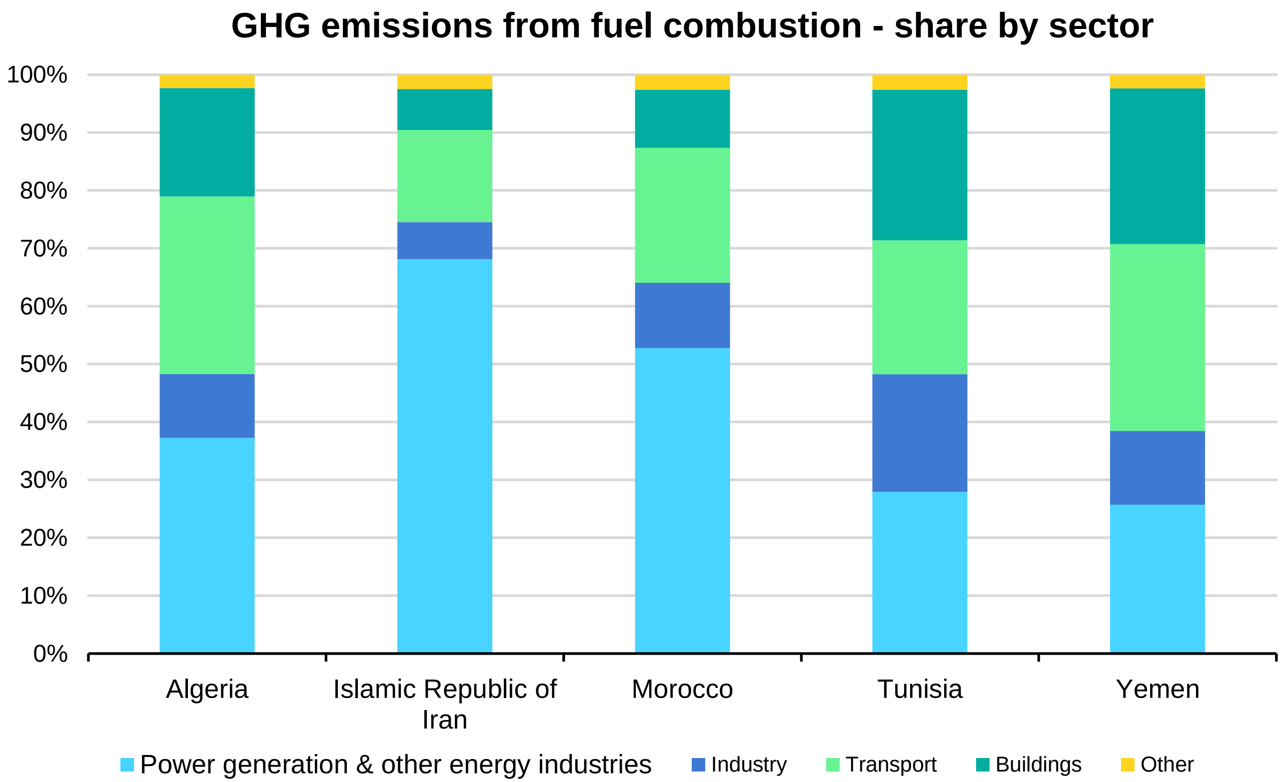
1. **Transport**
2. **Power generation & energy industry**
3. **Industry**
4. **Buildings**

GHG emissions and related indicators – Sectoral split

The sectoral division of emissions is connected to the **economic structure** of a country.

High share of emissions from power generation & other energy industries expected from countries with prominent energy industry.

Transport sector is another significant source of emissions. Connection to emissions from the power sector.

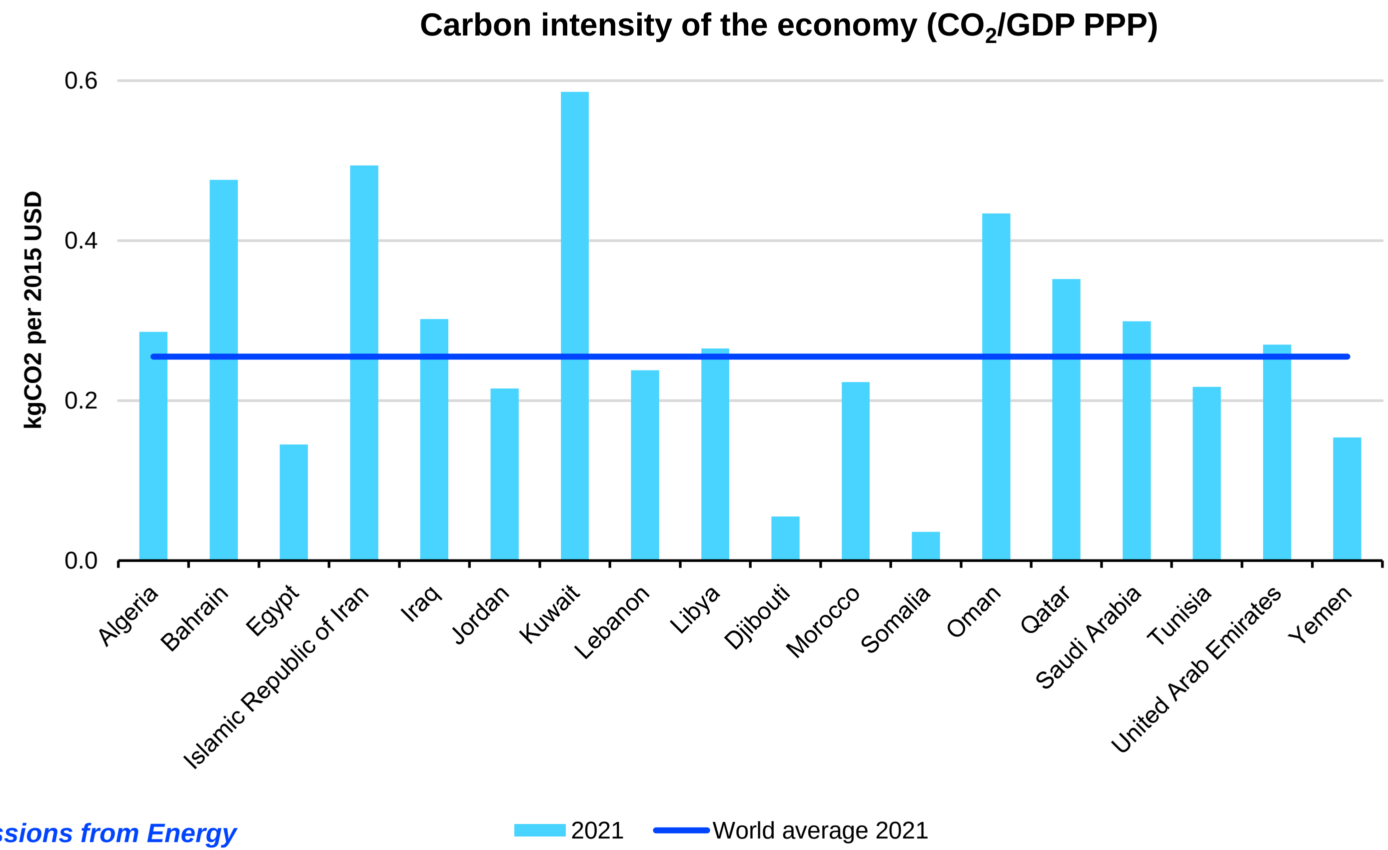


Source: IEA (2023) – GHG Emissions from Energy

The Buildings sector includes residential, commercial and public services.
The Other sector includes agriculture, forestry, fishing and non-specified consumption.

GHG emissions and related indicators – Carbon intensity

The carbon intensity is an indicator of the fossil fuel reliance of an economy



Source: IEA (2023) – GHG Emissions from Energy

Estimating emissions, supply vs. demand side approaches 1/2

2006 IPCC Guidelines for National GHG Inventories:
two approaches for estimating **fuel combustion** emissions

Sectoral Approach

Bottom up: from economic activity
i.e. **demand data** to emissions

	Sector 1	Sector 2	Sector 3
Product A			
Product B			
Product C			

Transformation &
Final consumption

Includes **all GHGs** from fuel combustion

Reference Approach

Top down: from **energy supply data** to emissions

	Supply
Product A	
Product B	
Product C	

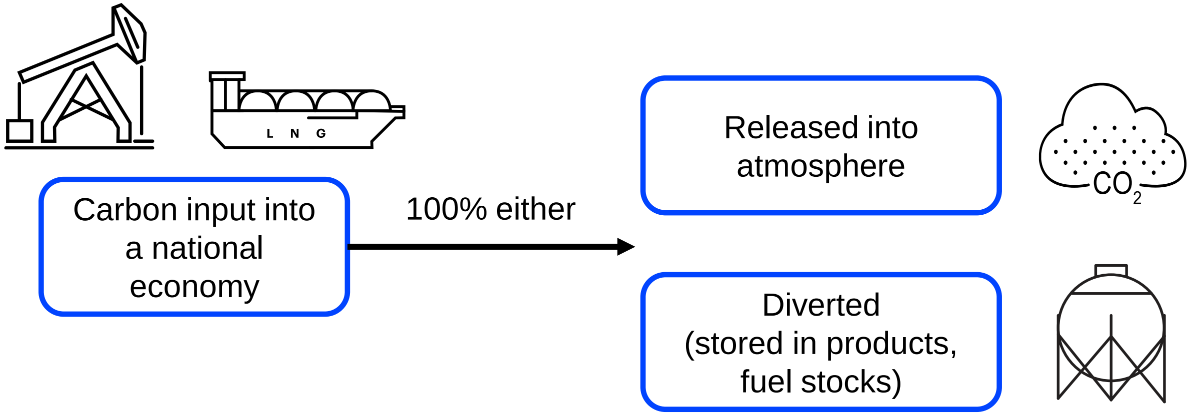
Energy supply

Includes only **CO_2** emissions from fuel combustion

Both approaches exclude the
non-energy use of fuels!

Reference Approach methodology (2006 IPCC guidelines)

Principle of mass conservation

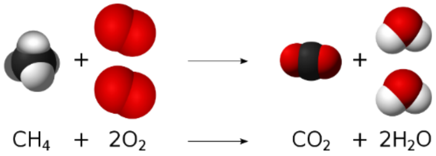


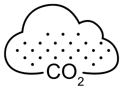
Top-down approach:

- Uses country's energy supply data
- **Only CO_2** emissions
- Primarily a benchmark method, used to verify results of the more granular Sectoral Approach

Sectoral Approach basics – carbon emission factors

Fuel combustion: Carbon conservation principle





Methane + Oxygen

combustion

CO_2 + Water

Known mass of carbon contained in fuel → All carbon is preserved and oxidised → known mass of GHG gases produced

$$\frac{kg_{GHG}}{kg_{fuel}}$$

Emission factor represents the amount of emissions released per unit of fuel combusted. Emission factors are fuel (here i) specific.

$$EF_i: Emission\ Factor\ \left[\frac{kg_{GHG}}{kg_{fuel}}\right]$$

In the sectoral approach, the unit of fuel is represented as energy instead of mass:

$$EF_i: Emission\ Factor\ \left[\frac{kg_{GHG}}{TJ_{fuel}}\right]$$

Sectoral Approach fuel combustion emissions (1A)

IPCC TIER 1 Methodology:

$$\text{Emissions}_{GHG} = \sum_{fuel} EF_{fuel} \times Fuel_{fuel} \text{ x } NCV_{fuel}$$

$EF_{fuel}: Emission\ Factor\ \left[\frac{kg_{GHG}}{TJ_{fuel}}\right]$ $Fuel_{fuel}: fuel\ combusted\ [Gg]$ $NCV_{fuel}: net\ colorific\ value [TJ/Gg]$ $fuel: fuel\ type\ (e.g. gasoline, natural\ gas, LPG)$

Bottom-up estimate: **sum over all the sectors** where combustion occurs:

- Total Final Consumption e.g. industry, residential, etc.
- Input into electricity & heat production
- Energy industries own use e.g. own use in refineries, etc.

Net Calorific Value (NCV) is a property of fuels. It represents the practical amount of energy received per unit of fuel combusted.

Quiz ! Go to https://www.menti.com/ and use this code: 7937 2745

➢ A car combusts 5 kg of motor gasoline per 100 km. How many kilograms of CO_2 is emitted during a 1000 km trip by this car?

- Motor Gasoline NCV = 44 MJ/kg
- Motor Gasoline CO_2 emission factor = 0.1 kg CO_2/MJ

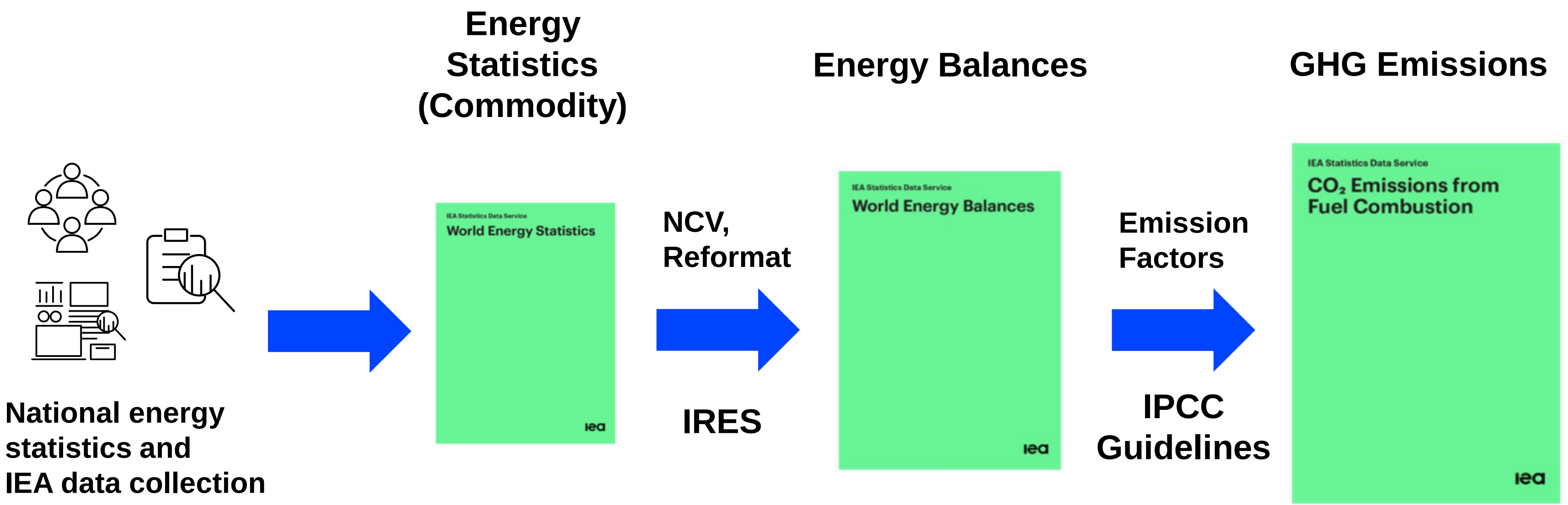
1. **2 200 kgCO_2**
2. **220 kgCO_2**
3. **11 kgCO_2**

Tracking biomass use for non-CO_2 emissions estimates

- 2006 IPCC Guidelines: **CO_2 emissions from biomass combustion** are **not included** in national totals corresponding to the **energy sector**, as they are estimated and reported in the ***Agriculture, Forestry and Other Land Use*** **sector**.

- Unlike CO_2, the **emissions of CH_4 and N_2O**, should be estimated and included in the energy sector and national totals since their effect is in addition to the stock changes estimates in the *Agriculture, Forestry and Other Land Use* sector.

From energy data to emissions - IEA



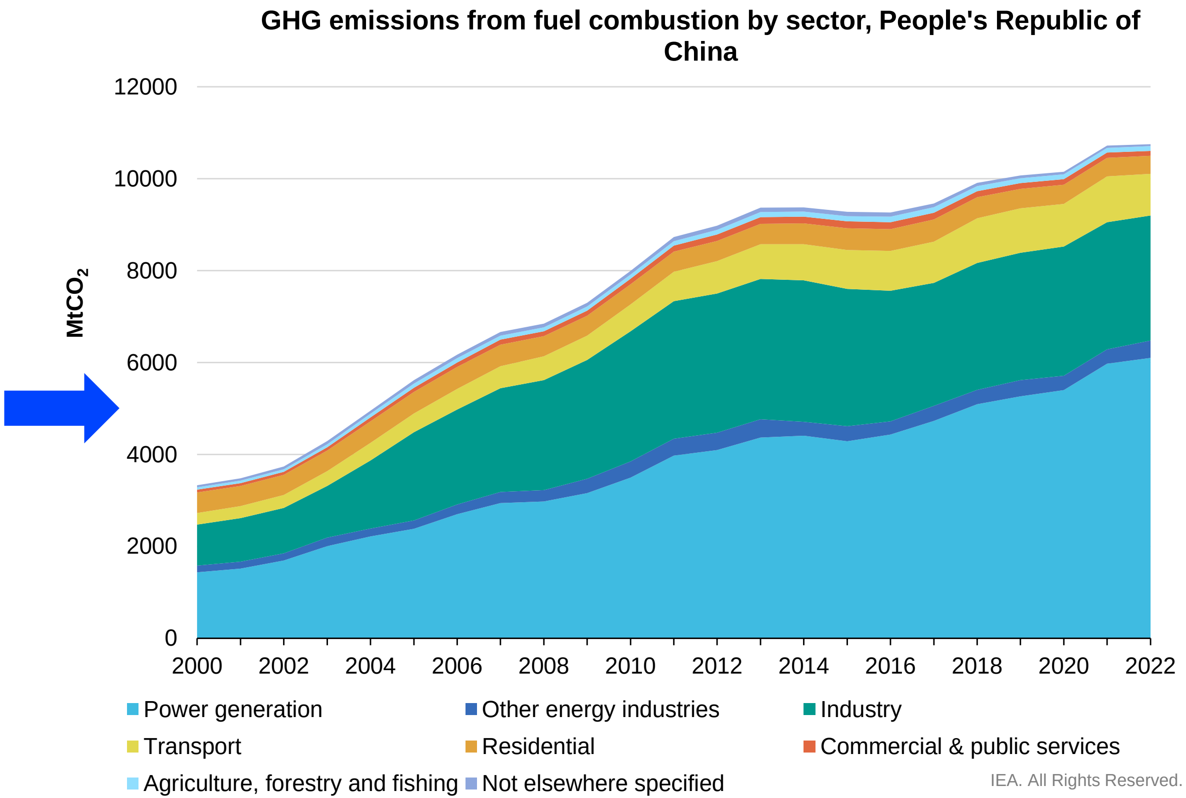
From energy data to emissions – China

Timeliness of emissions estimates relies on the availability of the energy data

Coal and coal products (2022) UNIT: Mtoe

Total final consumption	525.075
Industry	397.805
Mining and quarrying	4.769
Construction	1.732
Manufacturing	359.358
Iron and steel	169.046
Chemical and petrochemical	31.72
Non-ferrous metals	15.895
Non-metallic minerals	126.938
Transport equipment	0.408
Machinery	5.645
Food and tobacco	6.425
Paper, pulp and printing	2.273
Wood and wood products	0.052
Textile and leather	0.956
Industry not elsewhere specified	31.946

IEA estimations, based on IEA energy balances and IPCC Tier 1 methodology



Calorific values and data quality

Commodity balances	Bituminous coal kt	Product 2 m3	…
Production	100		
Import	20		
Export	40		
Supply	**80**		
Statistical differences	*0*		
Input to Electricity	50		
…			
Final consumption	30		
….			

Net Calorific Values	Bituminous coal TJ/kt	Prod… TJ/…	
Production	23		
Import	25		
Export	22.5		
Input to Electricity	22		
…			
Final consumption	20		

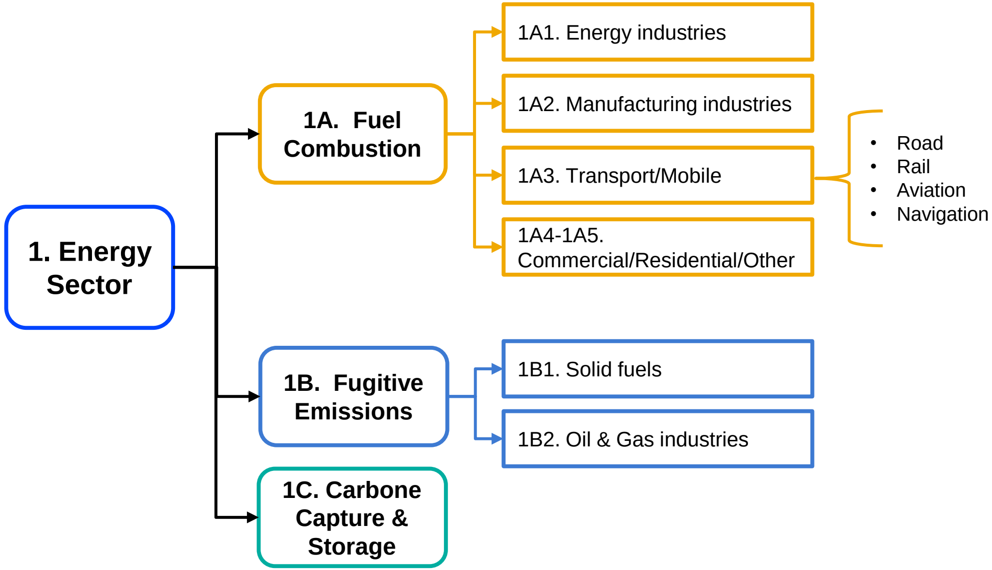
Energy balance (excerpt)	Bituminous coal TJ	Product 2 TJ	…
Production	2300		
Import	500		
Export	900		
Supply	**1900**		
Statistical differences	*200*		
Input to Electricity	1100		
…			
Final consumption	600		
….			

Need to collect good data for
physical quantities AND **calorific values**

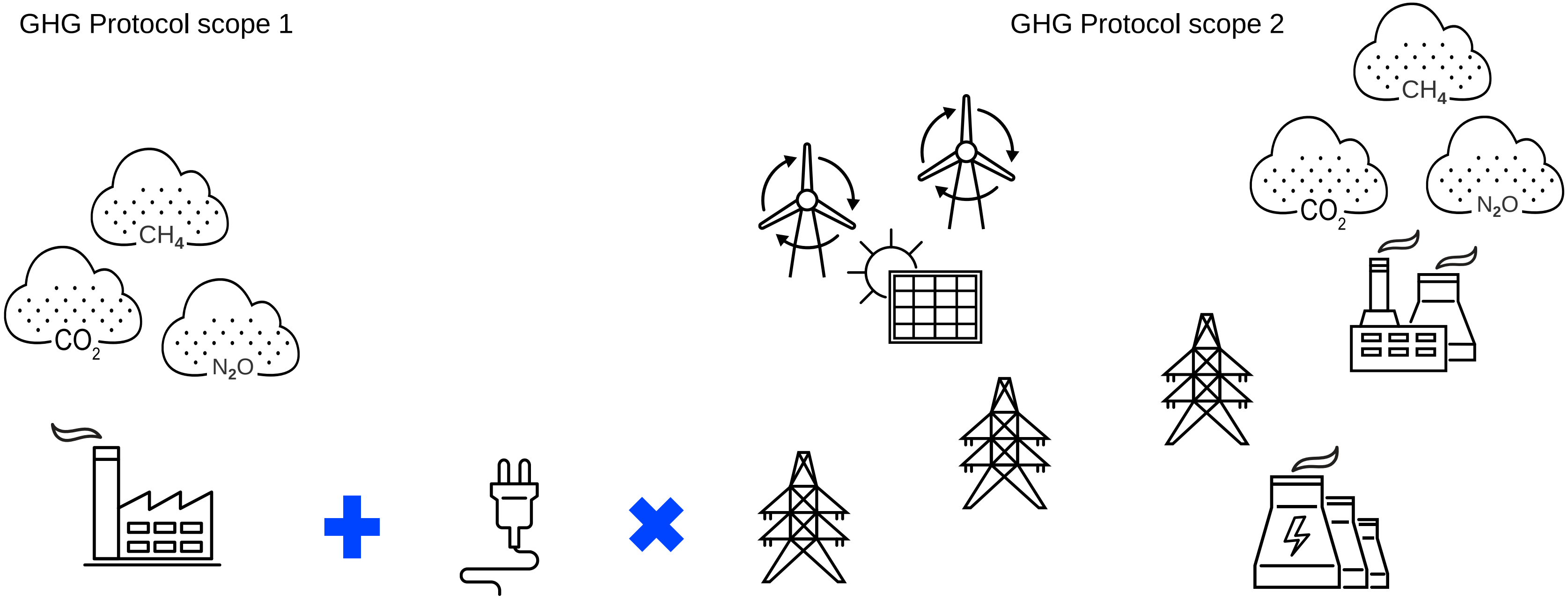
Disaggregation of end-use sectors important

The sectoral breakdown of UNFCCC CRF/CRT tables follows the IPCC source categories

1.A.3 Transport
a. Domestic aviation
b. Road transportation
i. Cars
ii. Light duty trucks
iii. Heavy duty trucks and buses
iv. Motorcycles
v. Other (please specify)
c. Railways
d. Domestic Navigation
e. Other transportation (please specify)
i. Pipeline transport
ii. Other (please specify)
Airport ground activities



Electricity grid emission factors



Emissions from on-premises fuel combustion

Electricity consumption

Average emissions intensity of the electricity grid
(= emission factor for electricity generation)

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- Which of the following are true for the 2006 IPCC Sectoral Approach of estimating GHG emissions?

1. **Is based on energy supply data**
2. **Is more granular than the Reference Approach**
3. **Accounts only for CO_2 emissions**
4. **Is affected by uncertainties in NCVs**

Quiz ! Go to https://www.menti.com/ and use this code: 7937 2745

- Calculate the Apparent Consumption of crude oil in Australia in 2021, using the formula:
  Apparent Consumption = Production(primary fuels) + Imports – Exports - International bunkers – Stock change

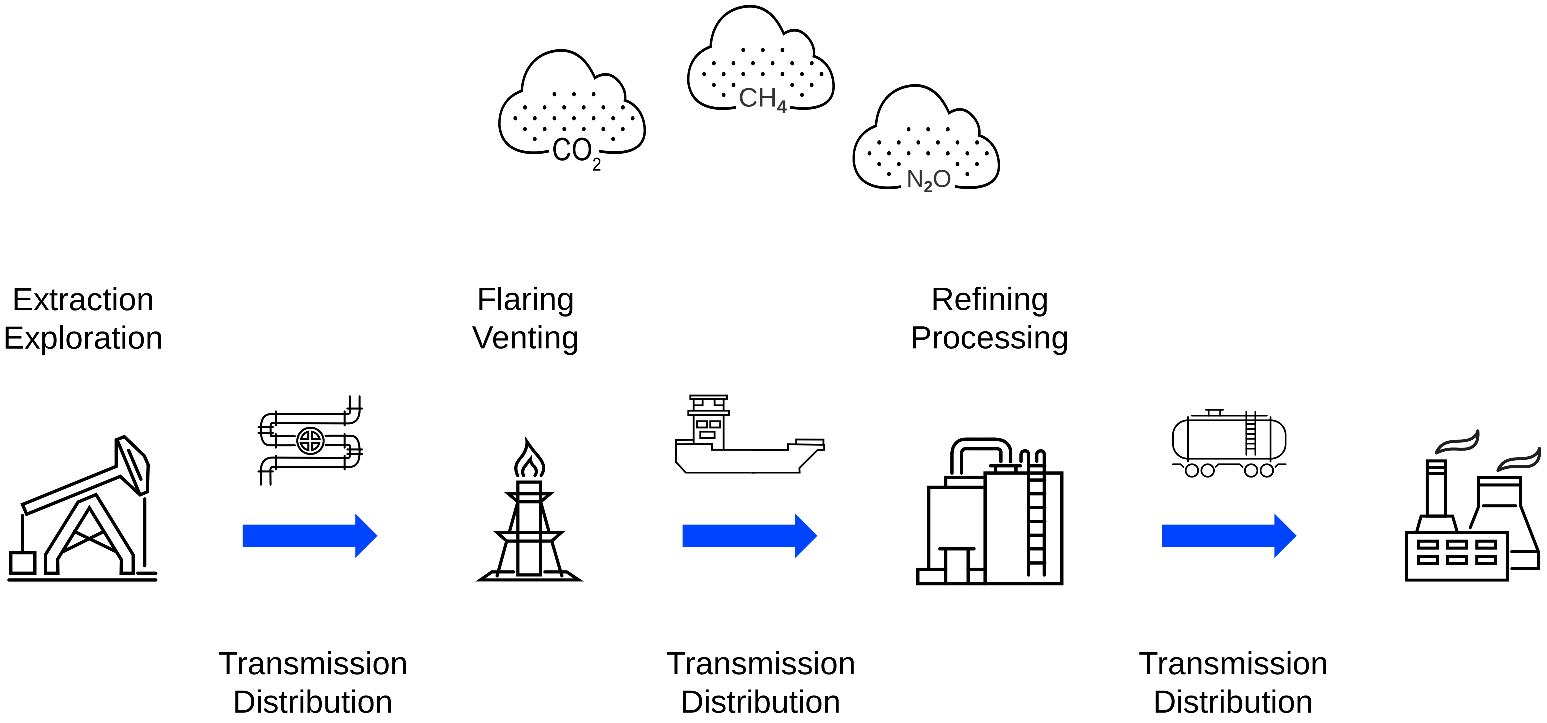
Product	Unit	Production	Imports	Exports	International bunkers	Stock change
Crude Oil	PJ	863	547	593		-31

Source: UNFCCC 2023 Annex I Party GHG Inventory Submissions

Which is the correct value?

1. **1972 PJ**
2. **786 PJ**
3. **848 PJ**

Fugitive emissions – leaks of gases and vapours



Fugitive emissions (1B) - estimation

Tier 1 approach: countries choose from a global average range of emission factors and use country-specific activity data to calculate total emissions.

Activity data:

- Volume of flaring
- Number of abandoned mines
- Refinery throughput
- Pipeline capacity
- Etc.

Specific to the category of fugitive emissions (solid fuels, liquid fuels etc.)

IPCC TIER 1 Methodology:

$$E_{GHG} = \text{Activity Data x Emission Factor}$$

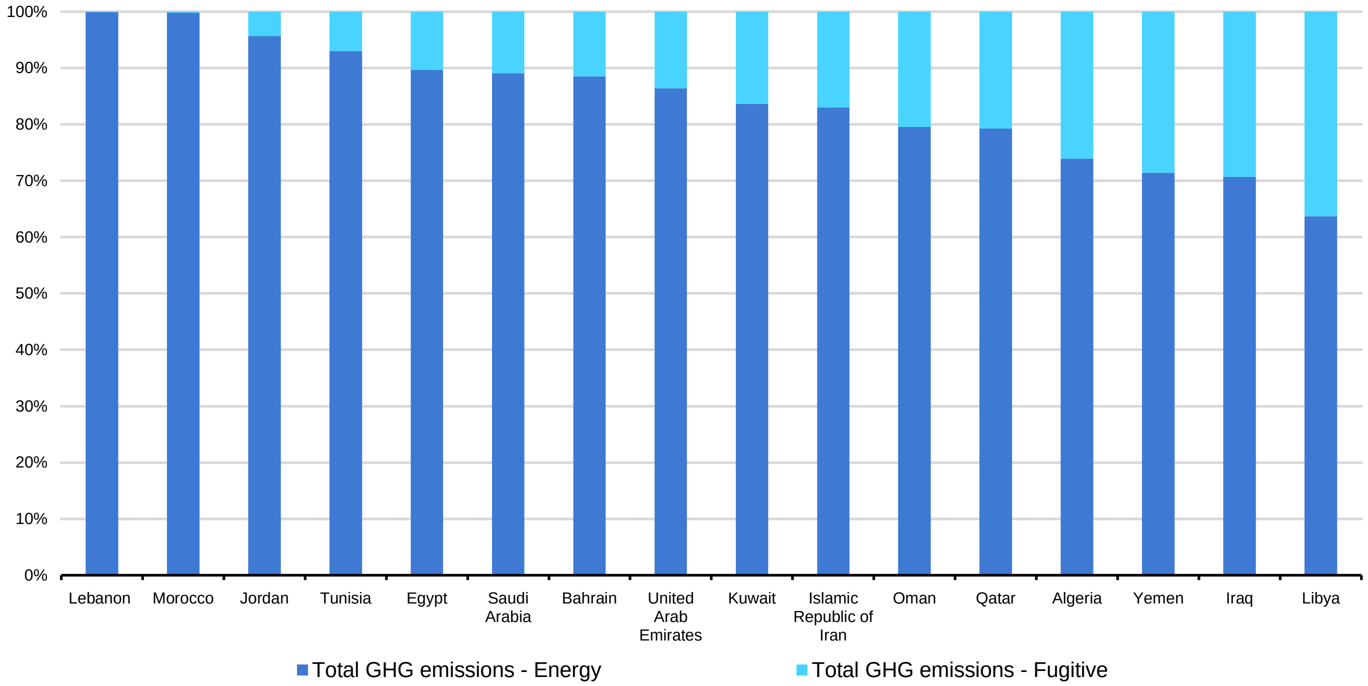
Tier 2 approach: country or facility specific emission factors that represent the average values.

Tier 3 approach: direct measurements on a mine or facility basis.

Quiz ! Go to https://www.menti.com/ and use this code: 7937 2745

- Fugitive emissions are significant for many fossil fuel producing economies. Which activities can release fugitive emissions?

Share of fugitive and total energy emissions, MENA region 2021



Key takeaways – national energy data

Apply sectoral approach, verify with reference approach

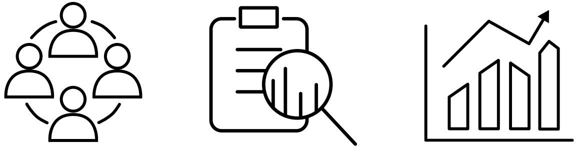
- Significant differences may indicate problems with activity data vs supply data, net calorific values, carbon content, excluded carbon calculation, etc.

Sectoral National energy data are the primary source for GHG emission estimates.

- Well-resourced and well-designed **national energy data collection** is essential for sound policy tracking and broader energy planning.

- Appropriate **institutional arrangement** facilitating the cooperation of stakeholders (energy and climate/environment) at the national level - improved data consistency.

IEA is ready to provide support: material, training, bilateral work.



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IEA Emission factors

1) **IEA Emission Factors database** (global coverage, 1990 to year minus 2 and provisional year for some countries):

a) Emission factors at the point of generation for electricity only as well as electricity and heat

b) Direct combustion factors of granular fuels

c) Adjustment factors for trade (only OECD countries) and T&D loss

Database is widely used for Scope 2 and Scope 1 reporting under the GHG Protocol.

2) **IEA Life Cycle Upstream Emission Factors database** (global coverage, 2015 to year minus 2 and provisional year for some countries):

a) Set of life cycle upstream emission factors corresponding to electricity grids
b) T&D adjustment factor from a life cycle perspective

Database is widely used for Scope 3 – Category 3 reporting under the GHG Protocol.

3) **IEA Monthly and Quarterly Emission Factors** (over 50 countries, 2015 to 2nd quarter of latest year)

Electricity grid emissions factors with monthly and quarterly temporal resolution developed by leveraging the IEA Monthly Electricity Stat

Overall methodology – A. total upstream and fuel-cycle emission factors

Step 1: Developing **country-specific or regional/global proxies** for **fuel-cycle** and **total upstream** emission factors for all the fuels/technologies used for electricity generation globally.

Output based factors: mass of CO_{2eq}/kWh electricity generation

Input based factors : mass of CO_{2eq}/kWh fuel input to the generation plant

Step 2: Multiply the developed factors by the **appropriate activity data** for each fuel/technology and divide by the total electricity generation as per the equation below:

$$EF_{upstream\ grid\ factor} = \frac{\sum_i EF_i \times activity_i}{Total\ Elec\ output}$$

EF_i: Fuel-cycle or total upstream emission factor per kWh output or per unit of energy as (gCO2eq/kWh) for fuel or technology i

$Activity_i$: Energy output or input to the plant for fuel or technology i

Total electricity output: total electricity generation from all fuels and technologies (kWh)

B. Life cycle adjustment factor for T&D losses

In order to account for the emission intensity induced due to the T&D losses from a life cycle perspective, the **overall life cycle emission intensity** of the electricity grid is multiplied by the **percentage of the T&D losses** occurred as detailed by the following equation:

$$T\&D_{life\ cycle} = (EF_{Total\ upstream} + EF_{Direct})\ x\ Loss\ factor$$

$$\text{Loss factor} = \frac{T\&D\ losses}{Grid\ electricity\ throughput}$$

Where:

- $T\&D\ Losses$ *: total transmission and distribution losses in the grid.*
- $Grid\ electricity\ throughput$ *: total amount of electricity flowing through the national electricity grid, computed as gross electricity generation – own use of electricity in generation plants + imports.*

Methodology monthly/quarterly

Weighted EFs for each month ***m*** based on estimated ***GrossEleOut*** by product ***p* (COAL, NATGAS, OIL and OTHER)**:

$$EF_m = \frac{\sum_{p=1}^{p=4}(EF_{p,Y-1} * GrossEleOut_{p,m})}{GrossEleOut_m}$$

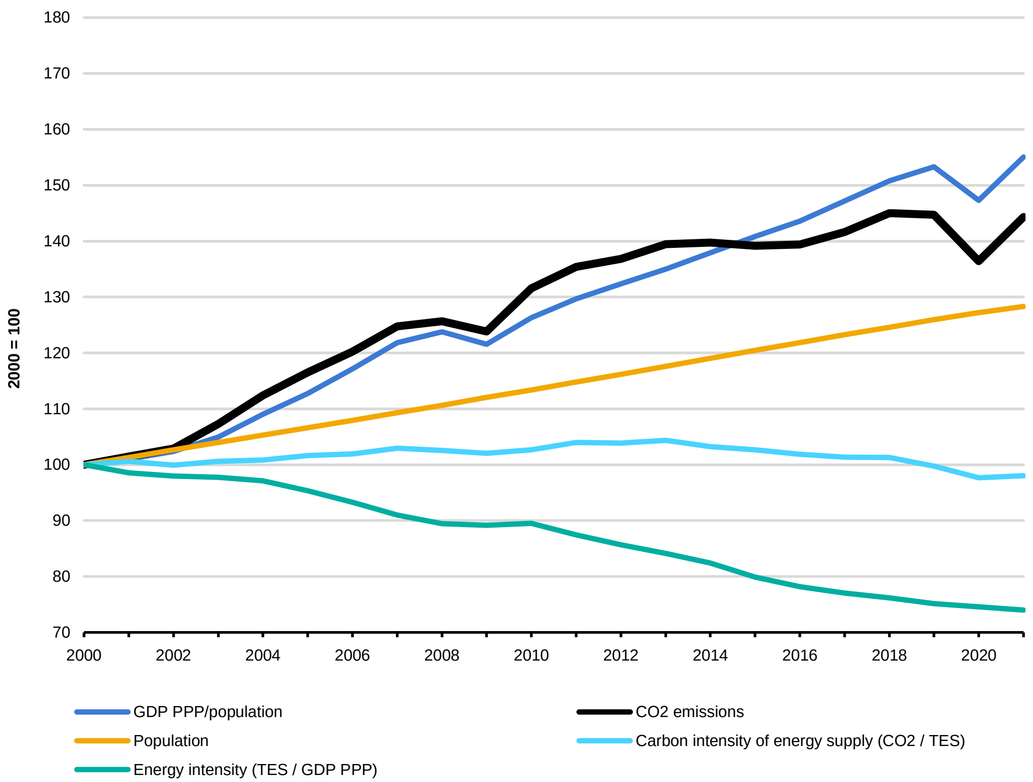
$$GrossEleOut_{p,m} = GrosstoNetRatio_{p,m} * NetEleOut_{p,m}$$

Where:

	Sources:
$EF_{p,Y-1}$: Emission factor for product p in year $Y-1$	CO2FACWV
$GrossEleOut_{p,Y-1}$: gross electricity output for product p in year $Y-1$	ELEBAL
$NetEleOut_{p,m}$: net electricity output for product p in month m	MES
$GrossNetRatio_{p,m}$: gross/net ratio for product p in month m	MESCONV

Macroeconomic drivers of CO_2 emissions

Global evolution of CO_2 emissions and drivers



The Kaya identity:
Relating CO_2 emissions to macroeconomic factors

$$CO_2 = P \times \left(\frac{GDP}{P}\right) \times \left(\frac{TES}{GDP}\right) \times \left(\frac{CO2}{TES}\right)$$

Increases in population and GDP per capita have been driving the global CO_2 emissions upward

Source: IEA (2023) – GHG Emissions from Energy

Sectoral approach – methodology (2006 IPCC guidelines)

GHG source and sink categories for fuel combustion - IPCC CRF Tables

Industry - Table1.A(a)s2

1.A.2 Manufacturing industries and construction
- Liquid fuels
- Solid fuels
- Gaseous fuels
- Other fossil fuels(4)
- Peat(5)
- Biomass(6)

a. Iron and steel
- Liquid fuels
- Solid fuels
- Gaseous fuels
- Other fossil fuels(4)
- Peat(5)
- Biomass(6)

b. Non-ferrous metals
- Liquid fuels
- Solid fuels
- Gaseous fuels
- Other fossil fuels(4)
- Peat(5)
- Biomass(6)

Transport - Table 1.A(a) s3

1.A.3 Transport
- Liquid fuels
- Solid fuels
- Gaseous fuels
- Other fossil fuels(4)
- Biomass(6)

a. Domestic aviation(10)
- Aviation gasoline
- Jet kerosene
- Biomass

b. Road transportation(11)
- Gasoline
- Diesel oil
- Liquefied petroleum gases (LPG)
- Other liquid fuels (please specify)
- Gaseous fuels
- Biomass(6)
- Other fossil fuels (please specify)(4)

i. Cars
- Gasoline
- Diesel oil

Other sectors –Table1.A(a)s4

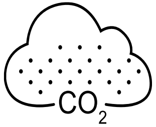
1.A.4 Other sectors
- Liquid fuels
- Solid fuels
- Gaseous fuels
- Other fossil fuels(4)
- Peat(5)
- Biomass(6)

a. Commercial/institutional(12)
- Liquid fuels
- Solid fuels
- Gaseous fuels
- Other fossil fuels(4)
- Peat(5)
- Biomass(6)

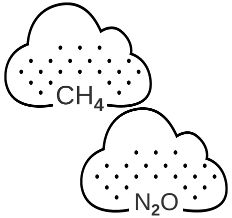
b. Residential(13)
- Liquid fuels
- Solid fuels
- Gaseous fuels
- Other fossil fuels(4)
- Peat(5)
- Biomass(6)

High quality demand data across sectors are key for estimating the emissions based on sectoral approach

Sectoral approach – fuel combustion emissions (1A) - notes



CO_2 emissions are consistent across technologies



CH_4 and **N_2O** emissions are strongly dependent on the technology applied in both stationary and mobile combustions. Thus, the EFs vary accordingly.

- Uncertainties in **NCVs** would result in uncertainties in the emission estimates.
- More sophisticated **Tier 2 or Tier 3** methods take into account more **detailed country-specific** information available (e.g. on different technologies or processes).

Reference approach – methodology (2006 IPCC guidelines)

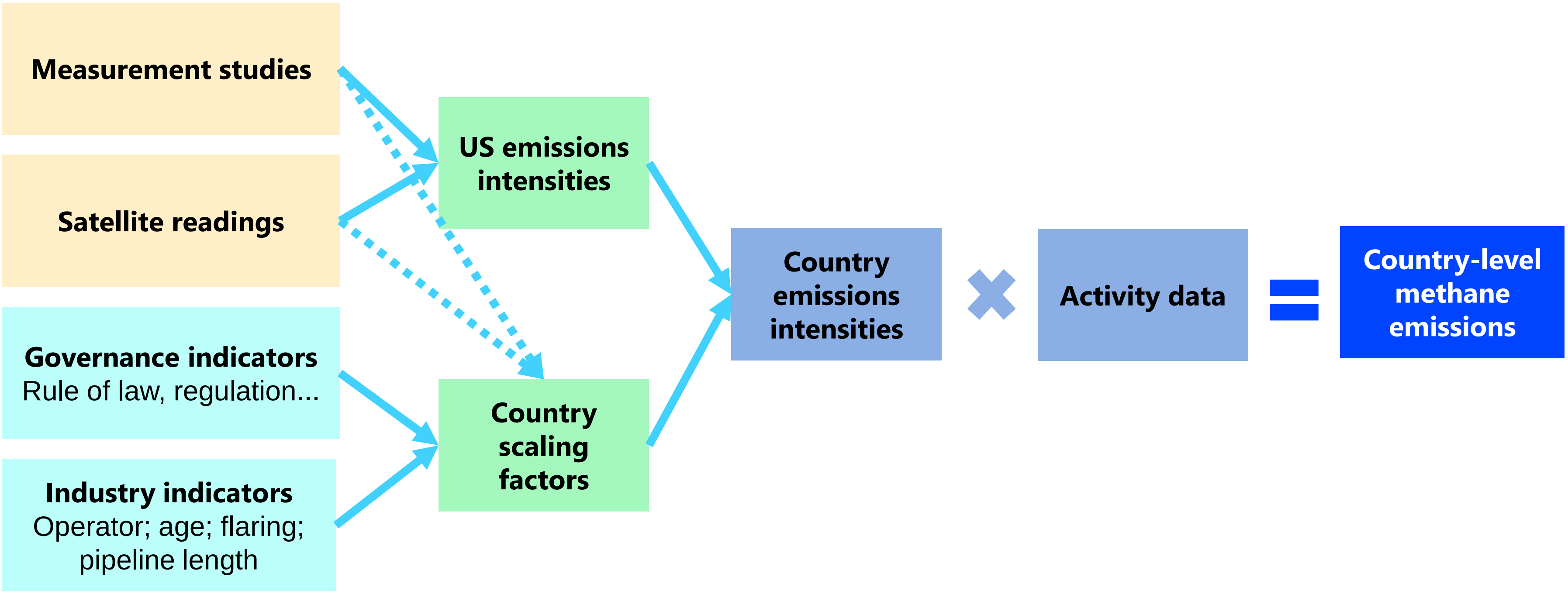
CRF Table 1.A(b)

FUEL TYPES			Unit	Production	Imports	Exports	International bunkers	Stock change	Apparent consumption	Conversion factor (TJ/Unit)[1]	NCV/ GCV [(2)]	Apparent consumption (TJ)
Liquid fossil	Primary fuels	Crude oil	kt	670.47	8333.37	NO		33.84	8970.00	42.50	NCV	381224.83
		Orimulsion	kt	NO	NO	NO		NO	NO	NO	NCV	NO
		Natural gas liquids	kt	17.74	NO	NO		NO	17.74	42.50	NCV	753.96
	Secondary fuels	Gasoline	kt		730.88	1060.26	NO	-49.34	-280.04	40.98	NCV	-11475.72
		Jet kerosene	kt		82.93	19.19	803.16	-7.09	-732.32	43.30	NCV	-31709.51
		Other kerosene	kt		0.80	0.11	NO	0.00	0.69	43.30	NCV	29.86
		Shale oil	kt		NO	NO		NO	NO	NO	NCV	NO
		Gas/diesel oil	kt		5064.91	1007.93	13.39	-25.40	4068.99	42.45	NCV	172719.36
		Residual fuel oil	kt		65.34	466.77	NO	-16.95	-384.49	41.15	NCV	-15821.68
		Liquefied petroleum gases (LPG)	kt		62.35	85.77		-1.47	-21.94	46.12	NCV	-1012.02
		Ethane	kt		IE	IE		IE	IE	NO	NCV	NO,IE
		Naphtha	kt		NO	186.45		5.89	-192.34	45.01	NCV	-8657.17
		Bitumen	kt		313.38	187.47		0.30	125.61	41.80	NCV	5250.29
		Lubricants	kt		143.60	108.93	NO	0.15	34.52	41.80	NCV	1442.97
		Petroleum coke	kt		62.84	0.48		-1.15	63.51	30.26	NCV	1921.76
		Refinery feedstocks	kt		101.11	95.18		4.40	1.53	42.79	NCV	65.48
		Other oil	kt		64.31	6.00		-0.08	58.40	46.01	NCV	2687.03
Other liquid fossil												
Liquid fossil totals												497419.44

Same product classification and flow definitions among energy statistics and climate reporting thanks to international harmonisation

WEO Methane Tracker Methodology

Methodological approach



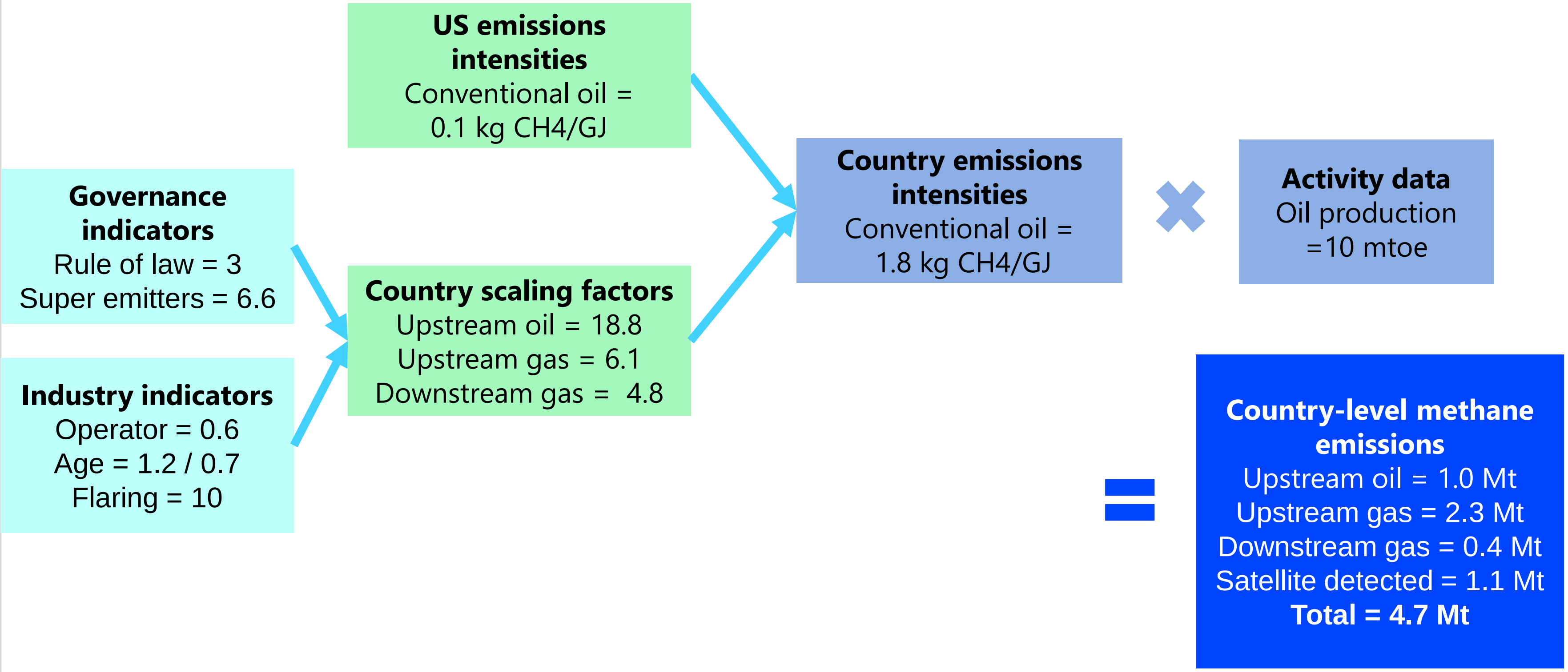
Our estimates take into account a range of auxiliary data that is calibrated to match available measurement data

Emission intensities in the United States

		kg CH_4/GJ	Emission intensity (energy ratio)
Oil	Offshore	0.10	0.57%
Oil	Onshore conventional	0.10	0.57%
Oil	Unconventional	0.16	0.91%
Gas	Offshore	0.12	0.67%
Gas	Onshore conventional	0.12	0.67%
Gas	Unconventional	0.21	1.14%
Oil	Downstream	0.00	0.01%
Gas	Downstream	0.07	0.41%
Total	Upstream	0.17	0.97%
Total		**0.21**	**1.17%**

- For **unconventional** oil and gas production in 3 major basins, we estimate emissions of about 4.5 Mt, aligned with Kayrros estimates based on basin-level inversion (2021).
- For **offshore** emissions, emissions are 0.43 Mt (0.47 Mt in 2018). This is within the 0.40-0.71 Mt range of Negron et al. (2020) for the Gulf of Mexico.
- **Total** US emissions for 2021 are taken as 13.2 Mt. Alvarez et al. (2018) indicate 13 ± 2 Mt for 2015.

Methodological approach – Turkmenistan example



Towards improving national data for energy and climate policy

ENERGY

Ministry of Energy
Statistical Office
Energy Agency
…

Institutional arrangements

CLIMATE

Ministry of Environment
Statistical Office
Hydrometerological service
…

National energy data

National GHG inventories

United Nations Statistics Division

United Nations Framework Convention on Climate Change

Ensure that one coherent set of national energy data is used for both purposes