International Energy Agency

Fundamentals of energy statistics

Byungho Jung

SESRIC WEBINAR SERIES ON STATISTICAL EXPERIENCE SHARING ENERGY STATISTICS FOR THE SDG7 INDICATORS - 9 November 2021

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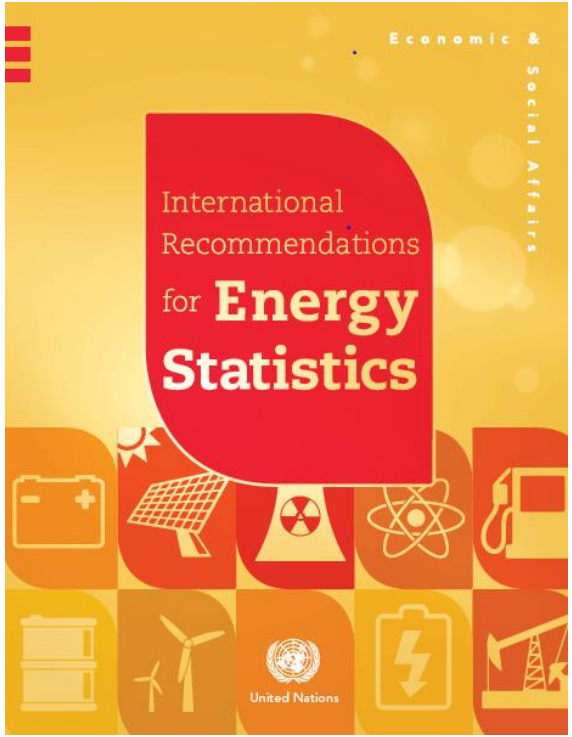
Our reference: International Recommendations for Energy Statistics



International Recommendations for Energy Statistics (IRES)

- Internationally agreed and adopted by the UN Statistical Commission (2011) – implementation encouraged in all countries
- Comprehensive framework on: scope of energy statistics, classifications, units, methods; data collection, institutional arrangements, quality assurance, dissemination
- Importance of developing energy statistics as official statistics (UN Fundamental principles)

https://unstats.un.org/unsd/energystats/methodology/ires/

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The scope of energy statistics

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Scope and boundaries of energy statistics (IRES): few key concepts

- **"Energy products":** forms of energy suitable for direct use and products that release energy while undergoing some chemical or other process (including combustion).
  Based on SIEC classification
- **"Energy flows":** various activities of economic actors undertaken on the national territory, such as production, trade and use. Based on ISIC classification
- **"Production":** production of energy products by any economic unit, including households, whether or not the production is i) principal/secondary activity; and ii) for sale/delivery/own use.
- **"Energy sector":** economic units whose principal activity is primary energy production, transformation or distribution of energy.
- **"Reference territory":** national territory, based on physical availability of energy and uses within the territory under economic control of government (land, airspace, territorial waters)

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How to bring all energy statistics together? The energy balance

"...An accounting **framework** for compilation of data on **all energy products entering, exiting, and used** within the **national territory** of a given **country** during a reference period."

Source: International Recommendations on Energy Statistics (IRES), UNSD, 2011

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The energy balance matrix: “products“ and “flows“

2019 - unit TJ	Coal	Crude oil	Oil products	Natural gas	Nuclear	Hydro	Geotherm., solar, wind, etc.	Biofuels and waste	Electricity	Heat	Total
Production	12037767	1581279		1061996	506972	620637	480115	8001291	-	-	24290057
Imports	5534266	9711177	1807047	1261200	-	-	-	65	20860	-	18334616
Exports	-22583	-	-2973253	-	-	-	-	-1899	-34167	-	-3031902
International marine bunkers	-	-	-67568	-	-	-	-	-	-	-	-67568
International aviation bunkers	-	-	-177469	-	-	-	-	-	-	-	-177469
Stock changes	-54485	-36157	14118	-	-	-	-	-1446	-	-	-77969
TES	**17494965**	**11256300**	**-1397129**	**2323196**	**506972**	**620637**	**480115**	**7998012**	**-13307**	**-**	**39269764**
Transfers	-	124401	-118025	-	-	-	-	-	-	-	6376
Statistical differences	-157780	-166578	-238656	-655	-	-	-	-1239	347691	-	-217216
Electricity plants	-11912369	-	-123796	-573310	-506972	-620637	-409389	-148650	5757672	-	-8561907
CHP plants	-	-		-	-	-	-24456	-584108	87616	-	-496492
Heat plants	-	-		-	-	-	-	-	-	-	-
Blast furnaces	-659947	-		-	-	-	-	-	-	-	-659947
Gas works	-924	-		-	-	-	-	-	-	-	-924
Patent fuel plants	-	-		-	-	-	-	-	-	-	-
Coke/pat. Fuel/BKB plants	-204904	-		-	-	-	-	-	-	-	-204904
Oil refineries	-	-11214123	11328232	-	-	-	-	-	-	-	114110
Petrochemical plants	-	-		-	-	-	-	-	-	-	-
Liquefaction plants	-	-		-	-	-	-	-	-	-	-
Other transformation	-	-		-	-	-	-	-279871	-	-	-279871
Energy industry own use	-84399	-	-744101	-311978	-	-	-	-	-485106	-	-1625584

Columns: commodity balances by product

Rows: Flows of energy across products (supply, transformation, final consumption)

Balanced horizontally and vertically

Comparable energy units

Can define total energy

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Understanding products within energy statistics (IRES)

Standard International Energy Product Classification (*SIEC*)

SIEC Headings			Correspondences	
Section/ Division/ Group	Class	Title	CPC Ver.2	HS 2007
0		Coal		
01		Hard coal		
011	0110	Anthracite	11010*	2701.11
012		Bituminous coal		
	0121	Coking coal	11010*	2701.19
	0129	Other bituminous coal	11010*	2701.12
02		Brown coal		
021	0210	Sub-bituminous coal	11030*	2702.10*
022	0220	Lignite	11030*	2702.10*
03		Coal products		
031		Coal coke		
	0311	Coke oven coke	33100*	2704*
	0312	Gas coke	33100*	2704*
	0313	Coke breeze	33100*	2704*
	0314	Semi cokes	33100*	2704*
032	0320	Patent fuel	11020	2701.20
033	0330	Brown coal briquettes (BKB)	11040	2702.20
034	0340	Coal tar	33200*	2706

- Standard classification (SIEC) (sections/divisions/groups/classes)
- Correspondence with CPC and HS

- Sections:
  - 0: Coal
  - 1: Peat
  - 2: Oil shale/oil sands
  - 3: Natural gas
  - 4: Oil
  - 5: Biofuels
  - 6: Waste
  - 7: Electricity
  - 8: Heat
  - 9: Nuclear fuels

Understanding flows within energy statistics (IRES)

Supply

Transformation / Energy

Demand

Final consumption

SUPPLY AND CONSUMPTION 2019 [TJ]	Coal	Crude oil	Oil products	Natural gas	Nuclear	Hydro	Geotherm., solar, wind, etc.	Biofuels and waste	Electricity	Heat	Total
Production	12037767	1581279	-	1061996	506972	620637	480115	8001291	-	-	24290057
Imports	5534266	9711177	1807047	1261200	-	-	-	65	20860	-	18334616
Exports	-22583	-	-2973253	-	-	-	-	-1899	-34167	-	-3031902
International marine bunkers	-	-	-67568	-	-	-	-	-	-	-	-67568
International aviation bunkers	-	-	-177469	-	-	-	-	-	-	-	-177469
Stock changes	-54485	-36157	14118	-	-	-	-	-1446	-	-	-77969
TES	**17494965**	**11256300**	**-1397125**	**2323196**	**506972**	**620637**	**480115**	**7998012**	**-13307**	**-**	**39269764**
Transfers	-	124401	-118025	-	-	-	-	-	-	-	6376
Statistical differences											216
Electricity plants											907
CHP plants											492
Heat plants											-
Blast furnaces											947
Gas works											924
Patent fuel plants	-	-	-	-	-	-	-	-	-	-	-
Coke/pat. Fuel/BKB plants	-204904	-	-	-	-	-	-	-	-	-	-204904
Oil refineries	-	-11214123	11328232	-	-	-	-	-	-	-	114110
Petrochemical plants	-	-	-	-	-	-	-	-	-	-	-
Liquefaction plants	-	-	-	-	-	-	-	-	-	-	-
Other transformation	-	-	-	-	-	-	-	-279871	-	-	-279871
Energy industry own use	-84399	-	-744101	-311978	-	-	-	-	-485106	-	-1625584
Losses	-	-	-	-	-	-	-	-	-974525	-	-974525
TFC	**4474641**	**-**	**8706530**	**1437254**	**-**	**-**	**46270**	**6984143**	**4720041**	**-**	**26368878**
INDUSTRY	**3952551**	**-**	**1282621**	**281437**	**-**	**-**	**2776**	**2668732**	**1968283**	**-**	**10156400**
TRANSPORT	-	-	4140044	142329	-	-	70477	44352	70477	-	4397202
OTHER	522090	-	1983756	162891	-	-	43493	4271060	2681281	-	9664571
NON-ENERGY USE	-	-	1300109	850597	-	-	-	-	-	-	2150706

IRES balance:
Three main "blocks" of flows

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1st block: Energy supply

2019 - unit TJ	Coal	Crude oil	Oil products	Natural gas	Nuclear							Total
Production	12037767	1581279	-	1061996	50697						-	24290057
Imports	5534266	9711177	1807047	1261200							-	18334616
Exports	-22583	-	-2973253	-							-	-3031902
International marine bunkers	-	-	-67568	-							-	-67568
International aviation bunkers	-	-	-177469	-							-	-177469
Stock changes	-54485	-36157	14118	-							-	-77969
TES	**17494965**	**11256300**	**-1397125**	**2323196**	**50697**							**39269764**

Producers, net exporters and net importers of crude oil[1]

Producers	Mt	% of world total
United States	706	17.0
Russian Federation	512	12.4
Saudi Arabia	511	12.3
Canada	255	6.2
Iraq	201	4.9
People's Rep. of China	195	4.7
United Arab Emirates	174	4.2
Brazil	153	3.7
Kuwait	131	3.2
Islamic Rep. of Iran	130	3.1
Rest of the world	1 173	28.3
World	**4 141**	**100.0**

2020 provisional data

Net exporters	Mt
Saudi Arabia	352
Russian Federation	269
Iraq	195
Canada	154
United Arab Emirates	148
Kuwait	102
Nigeria	99
Kazakhstan	70
Angola	63
Mexico	59
Others	531
Total	**2 042**

2019 data

Net importers	Mt
People's Rep. of China	505
India	227
United States	202
Japan	149
Korea	145
Germany	86
Spain	66
Italy	65
Netherlands	62
Singapore	53
Others	509
Total	**2 069**

2019 data

"High-level" information: production, trade, etc…

Source: IEA, Key World Energy Statistics, 2020

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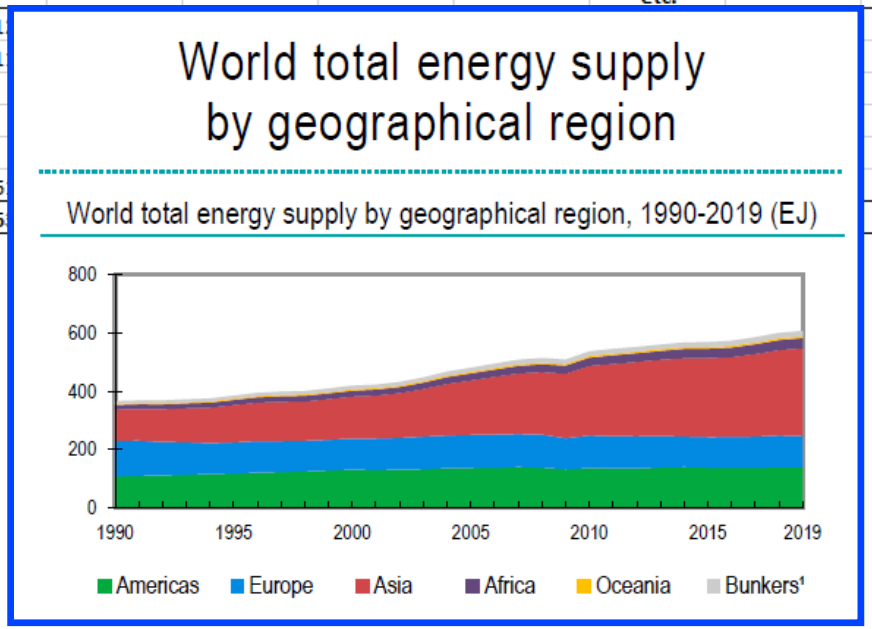
1st block: Energy supply

2019 - unit TJ	Coal	Crude oil	Oil products	Natural gas	Nuclear	Hydro	Geotherm., solar, wind, etc.	Biofuels and waste	Electricity	Heat	Total
Production	12037767	1581							-	-	24290057
Imports	5534266	9711							20860	-	18334616
Exports	-22583								-34167	-	-3031902
International marine bunkers	-								-	-	-67568
International aviation bunkers	-								-	-	-177469
Stock changes	-54485	-36							-	-	[illegible]
TES	**17494965**	**11256**							**-13307**	-	**39269764**



"High-level" information: Total energy supply

Source: IEA, Key World Energy Statistics, 2021

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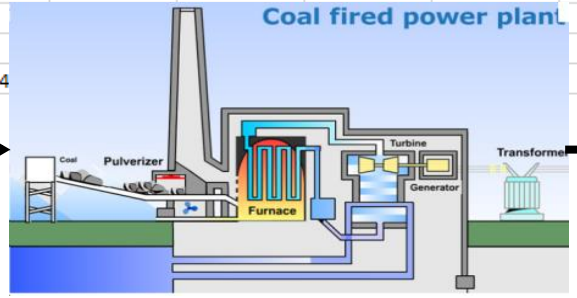
2nd block: Transformation and energy sectors

2019 - unit TJ	Coal	Crude oil	Oil products	Natural gas	Nuclear	Hydro	Geotherm., solar, wind, etc.	Biofuels and waste	Electricity	Heat	Total
Transfers	-	124401	-118025	-	-	-	-	-	-	-	6376
Statistical differences	157780	-166578	-238656	-655	-	-	-	-1239	347691	-	-217216
Electricity plants	-11912369	-	-123796	-573310	-506972	-620637	-409389	-148650	5757672	-	-8561907
CHP plants	-	-	-	-	-	-	-24456	-584108	87616	-	-496492
Heat plants	-								-	-	-
Blast furnaces	-659947								-	-	-659947
Gas works	-924								-	-	-924
Patent fuel plants	-								-	-	-
Coke/pat. Fuel/BKB plants	-204904								-	-	-204904
Oil refineries	-	-112141							-	-	114110
Petrochemical plants	-	-	-	-	-	-	-	-	-	-	-
Liquefaction plants	-	-						-	-	-	-
Other transformation	-	-						-279871	-	-	-279871
Energy industry own		-	-744					-			
Losses		-						-			

Transforming energy sources / producing secondary energy

Input (coal)



Output (electricity)

The concept of efficiency = output / input; also important for data quality checks

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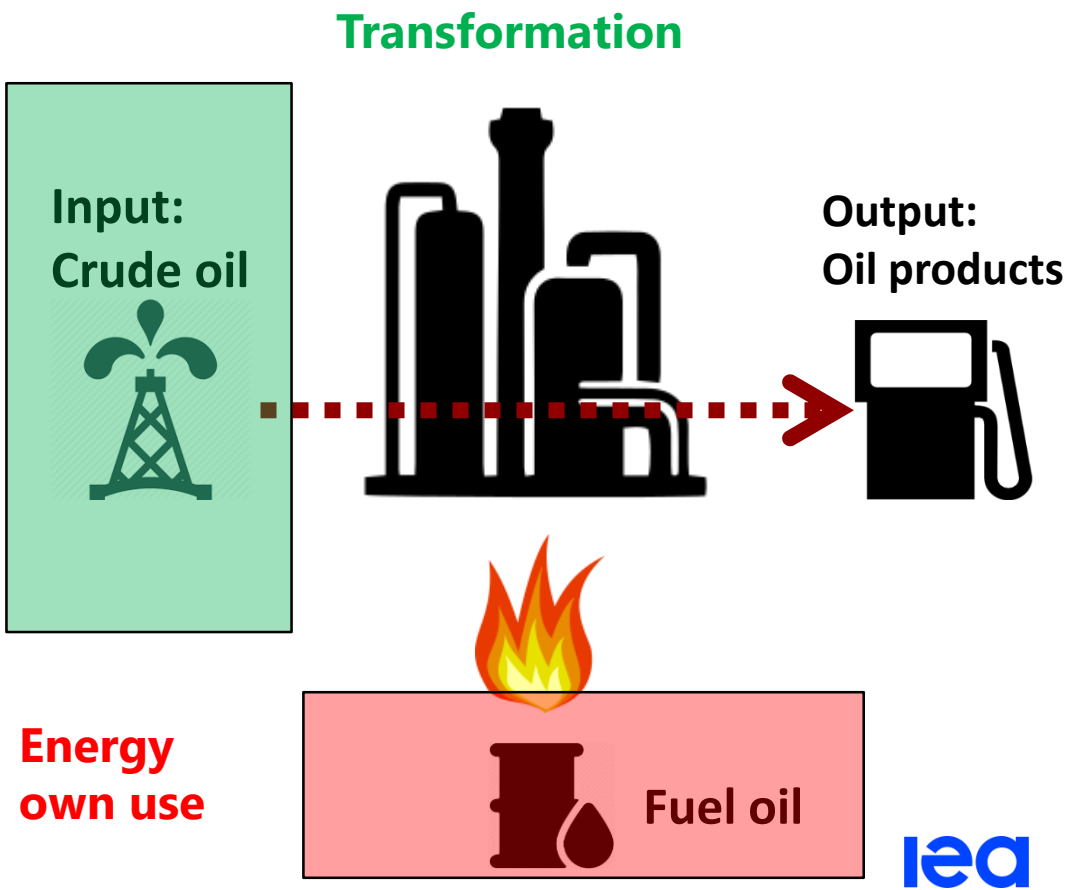
Note: transformation vs energy sector own use

Oil refineries example

- **Transformation**
  Crude oil gets transformed into secondary oil products for use

- **Energy own use**
  Energy used to run operations



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3rd block: Final consumption

2019 - unit TJ	Coal	Crude oil	Oil products	Natural gas	Nuclear	Hydro	Geotherm., solar, wind, etc.	Biofuels and waste	Electricity	Heat	Total
INDUSTRY	**3952551**	**-**	**1282621**	**281437**	**-**	**-**	**2776**	**2668732**	**1968283**	**-**	**10156400**
Iron and steel	2306515	-	24166	20464	-	-	-	-	350637	-	2701782
Chemical and petrochemical	50620	-	224537	-	-	-	-	-	65317	-	340474
Non-ferrous metals	21602	-	3708	-	-	-	-	-	38494	-	63804
Non-metallic minerals	554723	-	307453	-	-	-	-	-	6017	-	868192
Transport equipment	0	-	-	-	-	-	-	-	50167	-	50167
Machinery	0	-	14749	-	-	-	-	-	21345	-	36094
Mining and quarrying	0	-	72748	-	-	-	-	-	92169	-	164917
Food and tobacco	0	-	193	-	-	-	-	372963	262310	-	635466
Paper, pulp and print	34950	-	-	-	-	-	-	-	47201	-	82151
Wood and wood products	0	-	-	-	-	-	-	-	16402	-	16402
Construction	4429	-	27067	-	-	-	-	257175	602	-	289273
Textile and leather	26740	-	15669	-	-	-	-	-	6434	-	48843
Not-specified	952973	-	592333	260973	-	-	2776	2038594	1011187	-	4858835
TRANSPORT	**-**	**-**	**4140044**	**142329**	**-**	**-**	**70477**	**44352**	**70477**	**-**	**4397202**
Domestic aviation	-	-	179286	-	-	-	-	-	-	-	179286
Road	-	-	3784734	123381	-	-	-	44352	-	-	3952466
Rail	-	-	109999	-	-	-	-	-	70477	-	180476
Pipeline transport	-	-	-	18948	-	-	-	-	-	-	18948
Domestic navigation	-	-	64375	-	-	-	-	-	-	-	64375
Non-specified	-	-	1650	-	-	-	-	-	-	-	1650
OTHER	**522090**	**-**	**1983756**	**162891**	**-**	**-**	**43493**	**4271060**	**2681281**	**-**	**9664571**
Residential	113135	-	1186703	58377	-	-	37016	4161316	1145639	-	6702186
Commercial and public services	201290	-	127450	97296	-	-	4164	109744	403074	-	943018
Agriculture/forestry	-	-	453122	7218	-	-	-	-	821419	-	1281759
Fishing	-	-	-	-	-	-	-	-	-	-	-
Non-specified	207664	-	216481	-	-	-	2313	-	311148	-	737607
NON-ENERGY USE	**-**	**-**	**1300109**	**850597**	**-**	**-**	**-**	**-**	**-**	**-**	**2150706**

Deliveries of energy products to all final consumers for energy or non-energy purposes

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Note: non-energy use of energy products

- Fuels used as **raw materials** and not consumed as a fuel nor transformed into another fuel (e.g. asphalt, plastics, fertilizers)

- For commodities derived from **biomass**:
  - only the amounts **specifically used for energy purposes** are included in the energy statistics
  - Non-energy use of biomass is not taken into consideration and the quantities are **null** by definition

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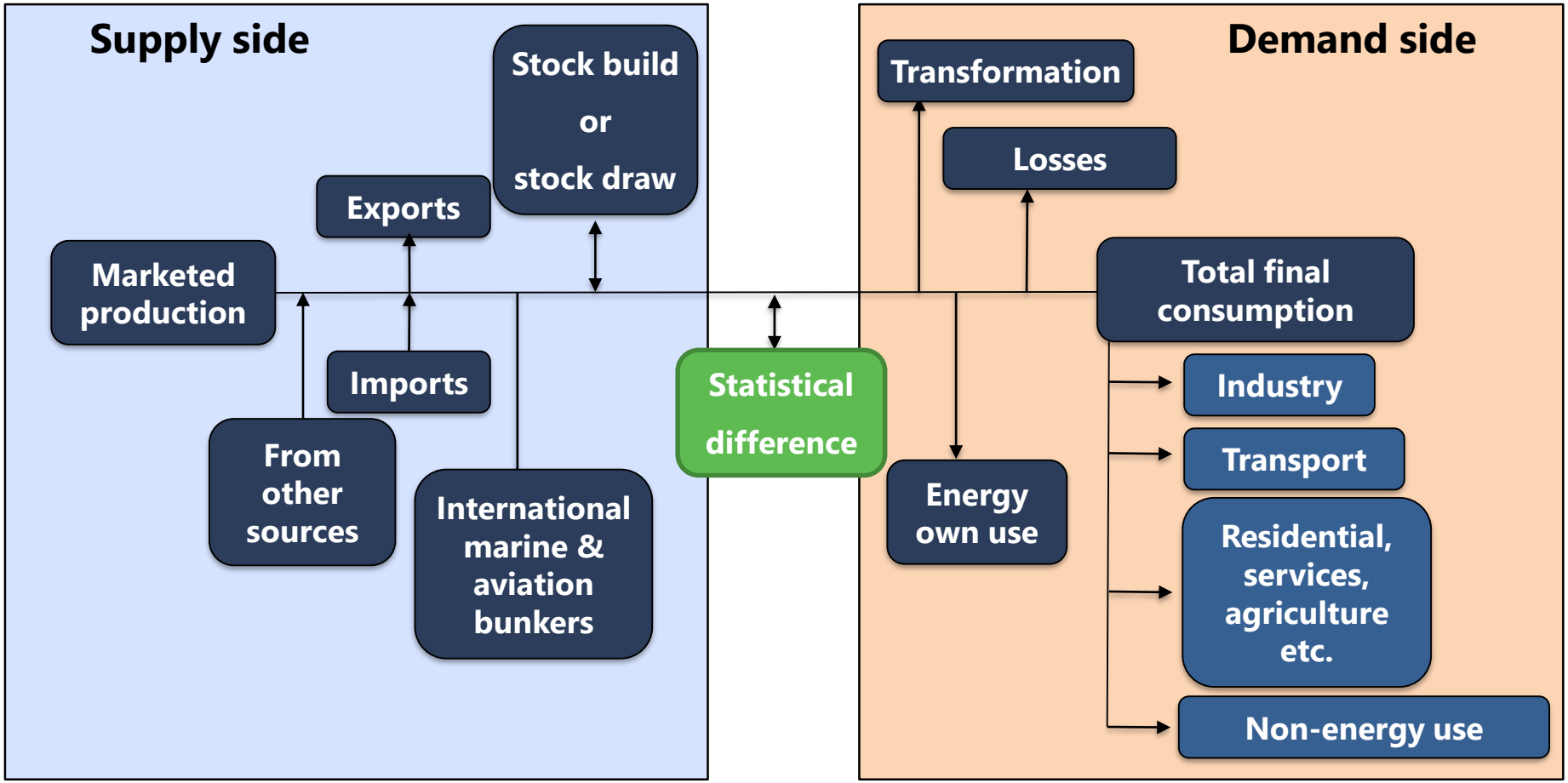
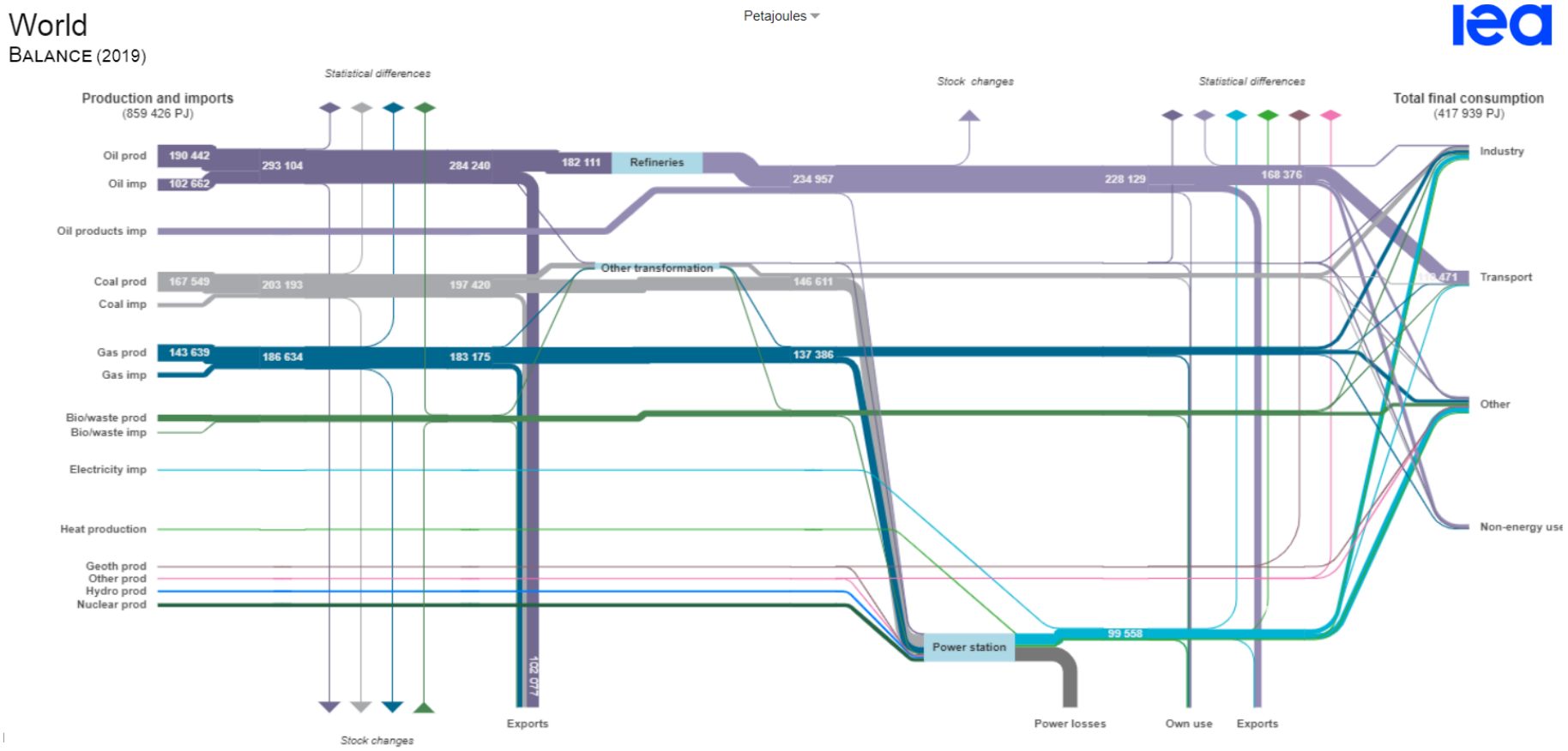
Summary of main energy flows



Visualising the energy flows through Sankey diagrams



Working with energy statistics: a few practical reminders on conversions

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Conversions within energy statistics

Energy statistics involve various variables and units

- **Mass:** kg, tonne, kt, lb
- **Volume:** L, bbl, gal, m^3
- **Energy:** TJ, ktoe, ktce, GWh, kcal, BTU

- Conversions involving **same variable** (e.g. energy to energy) are **fixed** (e.g. 1 GWh = 3.6 TJ; 1 tonne =1000 kg) http://www.iea.org/statistics/resources/unitconverter/

- Conversions **mass to volume vary** and require product-specific **densities** (e.g. density of gasoline: 715-780 kg/m3)

- Conversion **mass or volume to energy vary** and require product-specific **calorific values** (e.g. net calorific value of crude oil: 42-47 MJ/kg)

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Note on calorific values: data need to be collected

Physical units (e.g. metric tons) ← *Calorific values* → Energy units (e.g. TJ)

(kJ/kg, MJ/ton, kJ/m^3)

- The heat (energy) obtained from one unit of fuel when burned
- Indicate quality of the fuel and may vary by flow (e.g. production vs exports)
- Should be within expected ranges

  Bituminous coal – Kazakhstan: 18.6 MJ/kg

  Bituminous coal – New Zealand: 28.2 MJ/kg

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Calorific values

- When a fuel is combusted, water vapor is produced, but its energy rarely can be used for energy purposes

- Difference between GCV and NCV approximately:
  - NCV = **90%** of GCV for **natural gas**
  - NCV = **95%** of GCV for **oil**
  - NCV = **95%** of GCV for **coal**

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How to compute national calorific values for a given product/flow?

Example: NCV of coal production

- A country has 2 coal mines, A and B
  - Mine A produced **100 kt** with NCV_A = **25 MJ/kg**
  - Mine B produced **100 kt** with NCV_B = **20 MJ/kg**
  - NCV_{TOT} coal production = 22.5 MJ/kg

- But what if:
  - Mine A produced **400** kt with NCV_A = **25 MJ/kg**
  - Mine B produced **100** kt with NCV_B = **20 MJ/kg**
  - NCV_{TOT} coal production = ???

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Computing national calorific values requires weighted averages

- Most of the coal is of the higher-quality mine
  - This has to be reflected in the average NCV

Mine A:	**400 kt**	**25 MJ/kg**
Mine B:	**100 kt**	**20 MJ/kg**

- $\mathrm{NCV_{TOT}} = \frac{NCV_A \times PROD_A + NCV_B \times PROD_B}{PROD_A + PROD_B}$

- $\mathrm{NCV_{TOT}} = \frac{25\frac{MJ}{kg} \times 400kt + 20\frac{MJ}{kg} \times 100kt}{400kt + 100kt} = 24\frac{MJ}{kg}$

- **Generic formula for weighted average: $\mathrm{CV_{TOT}} = \frac{\sum_i (CV_i \times Quantity_i)}{\sum_i (Quantity_i)}$**

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Benefits of collecting energy statistics: few examples

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Users and uses of energy statistics

- Policy makers
  - Formulation of energy policies and monitoring their impact
  - Monitoring national energy security
  - Planning energy industries development
  - Policies beyond energy (health, climate, environment, …)
- Business community
- International organisations
- General public

"official statistics that meet the test of practical utility are to be compiled and made available on an impartial basis by official statistical agencies to honour citizens' entitlement to public information." (first fundamental principle of official statistics)

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Deriving user-oriented indicators relevant to economic, social, environmental dimensions

Table 11.2

Energy Indicators linked to the economic dimension

Theme	Sub-theme		Energy Indicator	Components
Use and production patterns	Overall use	ECO1	Energy use per capita	• Energy use (total primary energy supply, total final consumption and electricity use) • Total population
	Overall productivity	ECO2	Energy use per unit of GDP	• Energy use (total primary energy supply, total final consumption and electricity use) • GDP
	Supply efficiency	ECO3	Efficiency of energy conversion and distribution	• Losses in transformation systems, including losses in electricity generation, transmission and distribution
	Production	ECO4	Reserves-to-production ratio	• Proven recoverable reserves • Total energy production
		ECO5	Resources-to-production ratio	• Total estimated resources • Total energy production
	End use	ECO6	Industrial energy intensities	• Energy use in industrial sector and by manufacturing branch • Corresponding value added
		ECO7	Agricultural energy intensities	• Energy use in agricultural sector • Corresponding value added
		ECO8	Service/commercial energy intensities	• Energy use in service/ commercial sector • Corresponding value added
		ECO9	Household energy intensities	• Energy use in households and by key end use • Number of households, floor area, persons per household, appliance ownership
		ECO10	Transport energy intensities	• Energy use in passenger travel and freight sectors and by mode • Passenger-km travel and metric ton-km freight and by mode
		ECO11	Fuel shares in energy and electricity	• Primary energy supply and final consumption, electricity generation and generating capacity by fuel type

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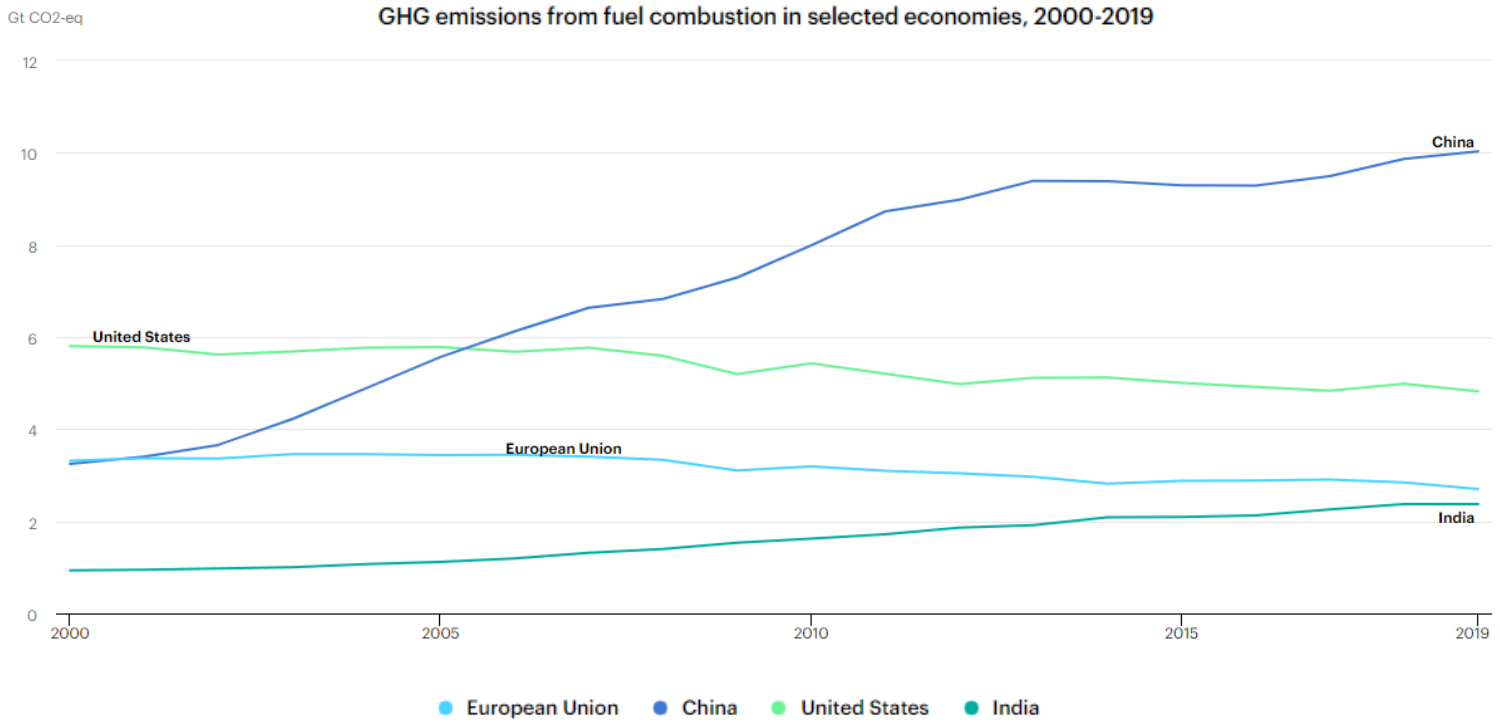
Energy statistics are key to estimating GHG emissions



Based on energy balances and IPCC methodologies

Source: IEA, World GHG Emissions from Energy, 2021

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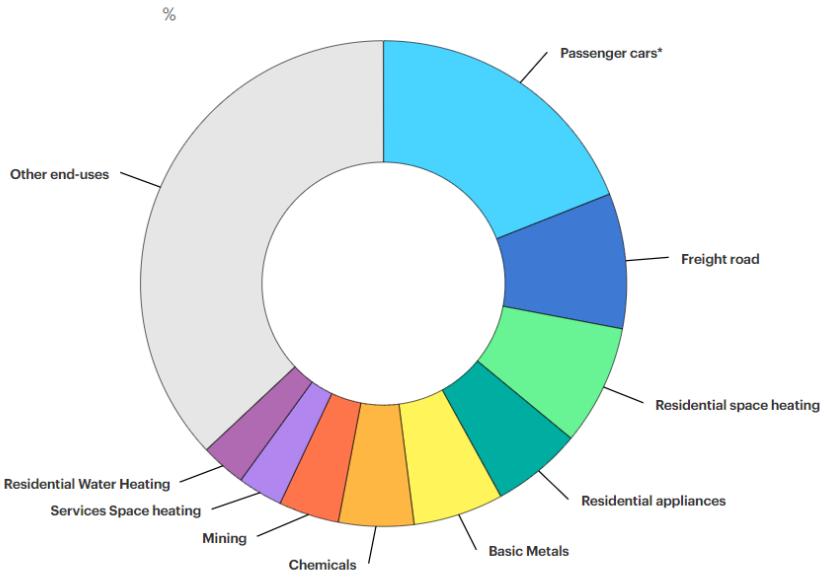
Supporting evolving policy priorities: tracking energy efficiency requires further data granularity…

Top ten CO2 emitting end uses in selected IEA countries, 2018



Our collective objective: to maintain policy-relevance of energy statistics!

Source: IEA, Energy Efficiency Indicators, 2021

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