International Energy Agency

Fundamentals of Energy Statistics

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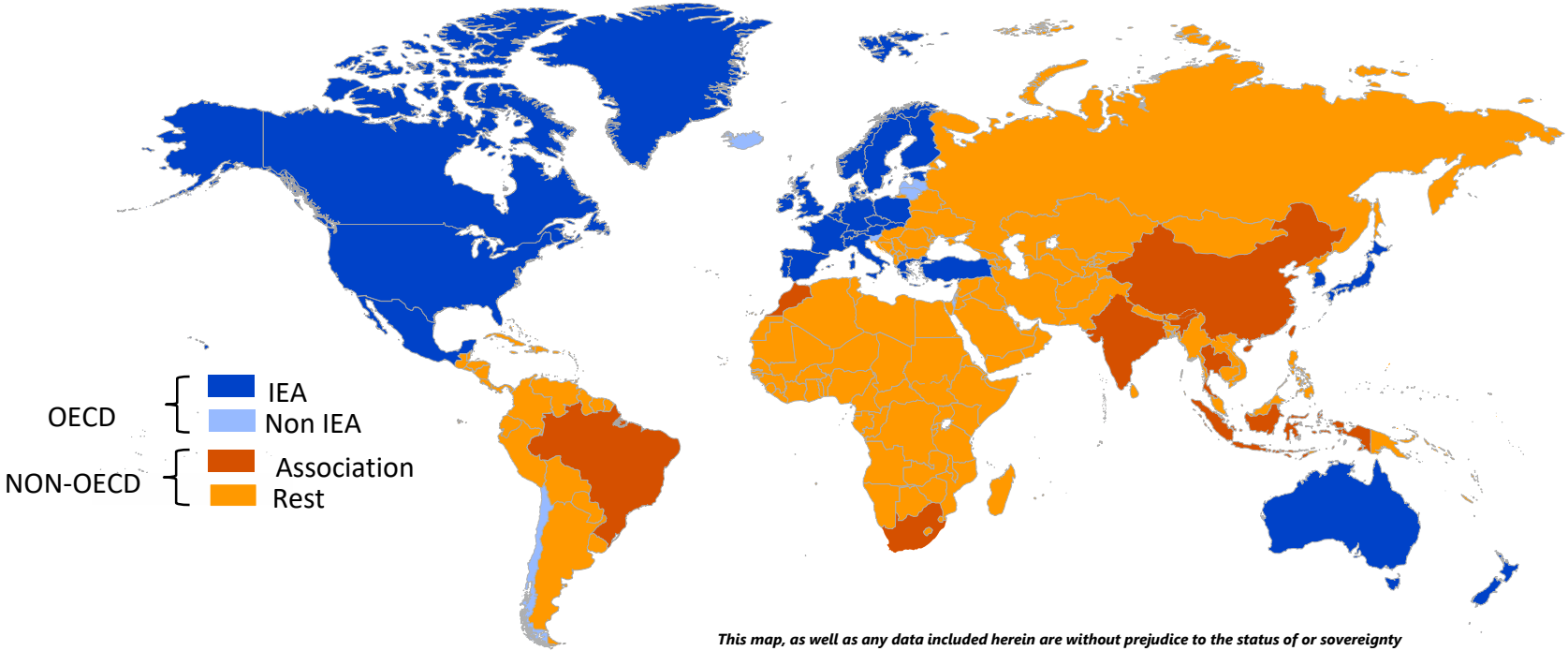
Fundamental of Energy Statistics

- A. Introduction: Our work
- B. Basic concepts
- C. Highlights by fuel
  - Oil
  - Coal
  - Natural gas
  - Renewable sources & waste
  - Electricity & heat

A. Introduction: IEA's Energy Data Centre



This map, as well as any data included herein are without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries and to the name of any territory, city or area.

*EDC's role is to **provide the global reference statistics needed to support the missions of the Agency**, enhancing dissemination to inform debate, improving countries ability to produce energy statistics, through training and cooperation and thus raising the profile of statistics and statisticians and its relevance to policy making.*

The Energy Data Centre

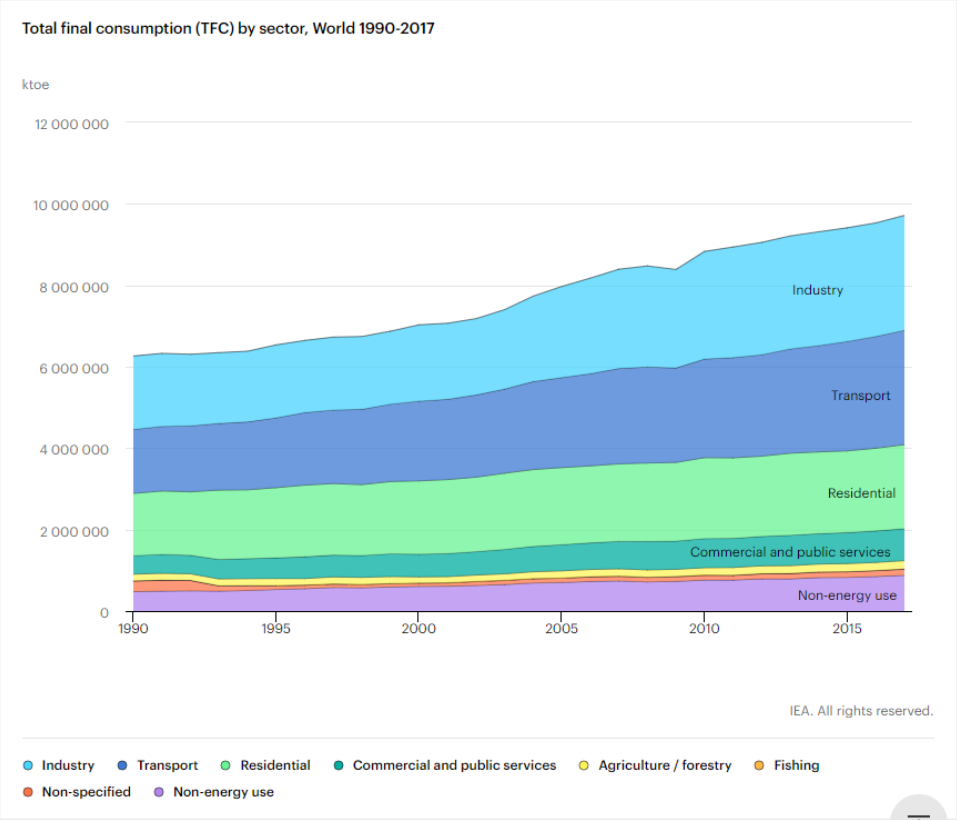
EDC

- Coal, Renewables, Electricity & Heat Statistics
- Oil and Natural Gas Statistics
- Energy Balances, Prices, Emissions & Efficiency
- Non-Member Countries
- Training and Capacity Building

- Data governance:
  - OECD countries have an obligation to submit data
  - Non-member countries' submission is based on voluntary cooperation
- Data collection:
  - Annual: Oil, gas, coal, electricity and renewables, but also CO_2, energy efficiency, RD&D
  - Quarterly: coal, energy prices
  - Monthly: oil, gas, electricity
- Data processing and validation
  - Internal validation
  - Iterations with data providers
  - Peer Review
- Data Dissemination: www.iea.org/data-and-statistics
- Training and capacity building:
  - Bi-annual Energy Statistics Course in Paris, as well as regional training sessions
  - Training material: online statistics school, energy statistics manuals, balance builder…

Importance of good & appropriate energy statistics

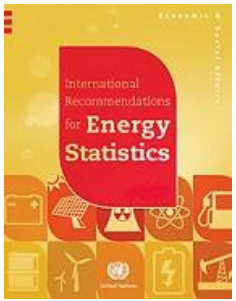
- Energy is ubiquitous in economic activity.
- Understanding energy use allows for identification of potential efficiency gains, greater output at lower cost.
- Need to understand the effects of market conditions and policy settings on energy flows.
- Required to address public goods problems (climate change) and social objectives (energy access).
- Needed to design, monitor and evaluate policies as well as to ensure security and understand potential disruptions.



World's total final consumption by sector

Data source: IEA, *Energy Balances 2019, All rights reserved.*

Harmonisation and Cooperation are key



International Recommendations for Energy Statistics (IRES)

IRES hyperlink

- Provide data compilers with a complete set of recommendations and internationally agreed definitions
- Covers all aspects of the statistical production process
- Harmonisation of all flows and products across countries
- Improved transparency
- Adopted by the UN Statistical Commission in 2011

Energy balances: a compact picture of the country’s energy system

Supply

Transformation and energy industries own use

Final consumption

Industry

Transport

Other final consumption

Non-energy use

Electricity and heat output

Million tonnes of oil equivalent

SUPPLY AND CONSUMPTION	Coal*	Crude oil*	Oil products	Natural gas	Nuclear	Hydro	Geotherm. / Solar / etc.	Biofuels / Waste	Electricity	Heat	Total
Production	952.55	933.13	-	1006.80	508.71	119.47	80.00	267.86	-	0.68	3869.21
Imports	387.11	1483.56	565.42	650.40	-	-	-	13.95	38.24	0.00	3138.70
Exports	-319.42	-348.40	-566.58	-316.50	-	-	-	-5.80	-39.47	-0.01	-1596.18
Intl. marine bunkers	-	-	-75.68	-	-	-	-	-0.05	-	-	-75.73
Intl. aviation bunkers	-	-	-87.09	-	-	-	-	-	-	-	-87.09
Stock changes	-0.38	-5.56	2.38	4.32	-	-	-	0.04	-	-	0.80
TPES	1018.87	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	80.00	[illegible]	[illegible]	[illegible]	6248.70
Transfers	-	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-	24.38
Statistical differences	-9.95	2.16	[illegible]	4.81	-	-	-0.05	0.09	0.47	[illegible]	-11.24
Electricity plants	-727.20	-11.67	-61.68	-383.80	-505.67	-119.47	-68.63	-43.96	833.30	[illegible]	-1089.06
CHP plants	-77.81	-	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-43.36	94.18	57.33	-101.80
Heat plants	[illegible]	-	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-6.31	-0.37	[illegible]	-4.53
Blast furnaces	-53.16	-	-0.44	-0.05	-	-	-	-	-	-	-53.65
Gas works	[illegible]	-	[illegible]	[illegible]	-	-	-	[illegible]	-	-	-1.88
Coke/pat. fuel/BKB/PB plants	-7.45	-	-1.07	-0.00	-	-	-	-0.01	-	-	-8.54
Oil refineries	-	-2019.35	1995.20	-0.90	-	-	-	-	-	-	-25.05
Petrochemical plants	-	28.90	-29.41	-	-	-	-	-	-	-	-0.51
Liquefaction plants	-0.90	1.37	-	-2.31	-	-	-	-	-	-	-1.85
Other transformation	0.00	0.73	-	-0.79	-	-	-	-0.45	-	-0.64	-1.16
Energy industry own use	-14.63	-0.07	-99.28	-130.96	-	-	-0.00	-1.17	-68.07	-8.71	-322.89
Losses	-0.86	-	-0.01	-2.96	-	-	-0.20	-0.03	-59.28	-6.10	-69.44
TFC	120.66	7.07	1687.43	708.16	-	-	9.30	180.77	799.00	60.12	3682.49
INDUSTRY	96.61	2.33	98.89	260.82	-	-	0.60	66.88	266.86	24.04	792.82
Iron and steel	38.07	-	3.47	24.26	-	-	-	0.11	28.30	1.19	95.41
Chemical and petrochemical	10.79	2.31	17.61	57.74	-	-	0.00	2.93	38.14	10.47	139.98
Non-ferrous metals	2.04	-	1.62	10.23	-	-	0.00	0.11	24.82	0.28	39.10
Non-metallic minerals	17.74	-	14.92	24.50	-	-	0.00	4.68	13.65	0.22	75.71
Transport equipment	0.20	-	0.80	7.18	-	-	0.00	0.02	10.70	0.88	19.78
Machinery	0.34	-	3.43	17.93	-	-	0.00	0.13	35.58	0.85	58.27
Mining and quarrying	0.44	-	12.06	16.50	-	-	0.00	0.10	11.20	0.10	40.40
Food and tobacco	5.80	0.00	5.27	31.74	-	-	0.00	3.83	20.22	1.75	68.62
Paper, pulp and printing	5.65	-	3.75	19.15	-	-	0.16	43.81	24.66	3.45	100.63
Wood and wood products	0.08	-	0.63	1.61	-	-	-	5.57	3.81	0.77	12.47
Construction	2.58	-	16.19	3.74	-	-	0.00	0.30	6.43	0.05	29.29
Textile and leather	0.33	0.01	0.63	4.17	-	-	0.00	0.08	5.70	0.73	11.64
Non-specified	11.44	-	16.30	32.18	-	-	0.43	5.30	32.63	3.31	101.60
TRANSPORT	0.16	-	1107.94	24.68	-	-	-	42.86	8.97	-	1184.48
Domestic aviation	-	-	65.08	-	-	-	-	-	-	-	65.08
Road	-	-	1000.36	3.33	-	-	-	42.24	0.17	-	1046.09
Rail	0.01	-	18.63	-	-	-	-	0.22	7.07	-	25.93
Pipeline transport	-	-	0.00	21.00	-	-	-	-	0.38	-	21.39
Domestic navigation	0.15	-	22.97	0.07	-	-	-	0.33	-	-	23.51
Non-specified	-	-	0.90	0.16	-	-	-	0.06	1.35	-	2.48
OTHER	22.69	-	201.35	400.38	-	-	8.70	70.84	534.17	36.07	1273.29
Residential	14.63	-	95.03	246.28	-	-	6.83	61.14	251.82	21.63	697.36
Comm. and public services	6.63	-	55.04	145.20	-	-	1.07	6.13	256.81	11.68	482.56
Agriculture/forestry	1.35	-	41.12	6.14	-	-	0.59	2.54	10.21	0.23	62.19
Fishing	0.00	-	4.50	0.05	-	-	0.05	0.00	0.30	0.02	4.92
Non-specified	0.08	-	5.65	2.69	-	-	0.15	1.12	15.03	1.52	26.25
NON-ENERGY USE	2.30	4.74	291.45	33.31	-	-	-	-	-	-	331.80
In industry/transf./energy	2.09	4.74	278.33	33.31	-	-	-	-	-	-	318.47
of which: chem./petrochem.	*0.96*	*4.74*	*207.09*	*33.30*	-	-	-	-	-	-	*246.09*
In transport	-	-	7.25	-	-	-	-	-	-	-	7.25
In other	0.21	-	5.87	-	-	-	-	-	-	-	6.08
Electricity and Heat Output											
Elec. generated - TWh	3477.84	56.84	331.87	2745.33	1951.68	1389.16	620.70	311.89	-	0.70	10784.88
Electricity plants	3184.82	55.84	282.01	2162.83	1940.37	1389.15	517.16	156.65	-	0.31	9689.14
CHP plants	293.02	-	49.65	582.50	11.21	-	3.54	155.25	-	0.39	1095.55
Heat generated - PJ	816.52	-	210.14	1369.24	4.99	-	35.21	654.31	8.82	38.36	3137.60
CHP plants	653.71	-	175.16	1093.09	4.99	-	16.69	456.95	0.36	17.63	2418.57
Heat plants	162.81	-	34.99	276.15	-	-	18.53	197.36	8.46	20.73	719.03

Comparable information for all products

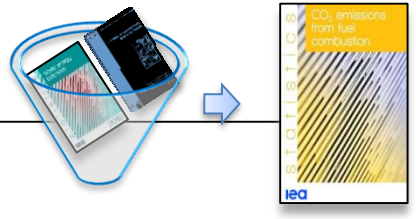
Energy intensity, Self-sufficiency …

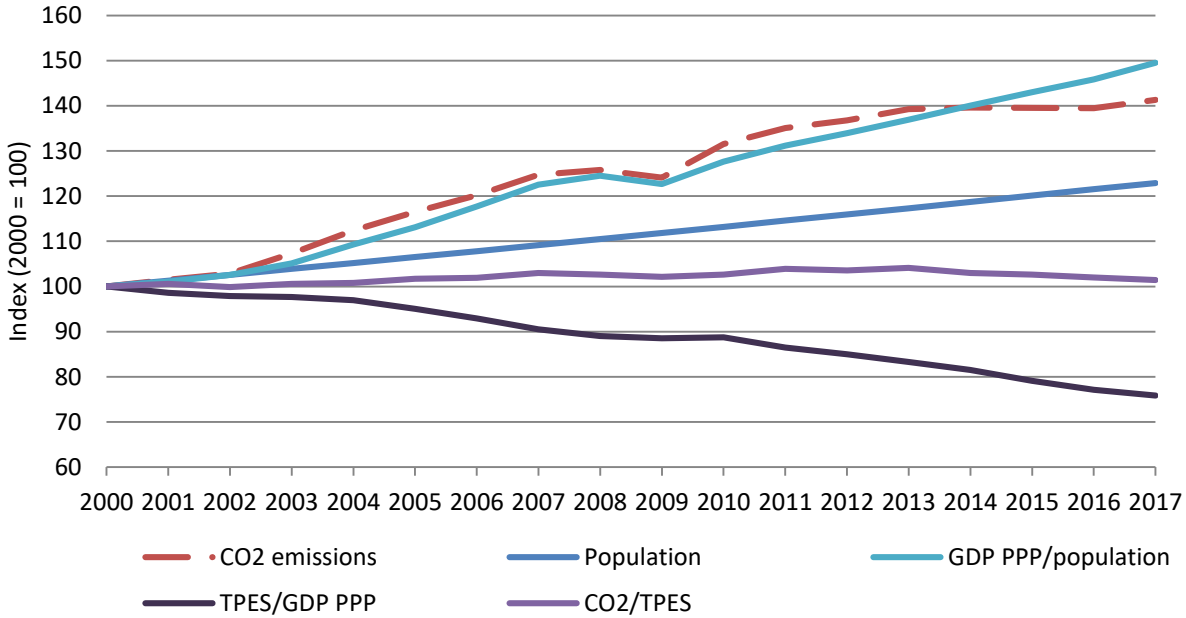
Efficiencies of transformation

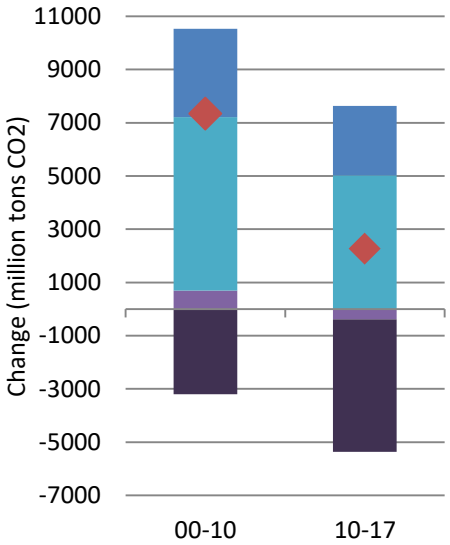
Shares of final energy consumption

iea

Beyond the energy balance: CO_2 emissions







Source: IEA (2019) - CO_2 Emissions from fuel combustion. www.iea.org/reports/co2-emissions-from-fuel-combustion-2019-2

IEA statistics feed all IEA studies and analyses

Data quality is critical for any model's accuracy!

B. Basic concepts in Energy Statistics

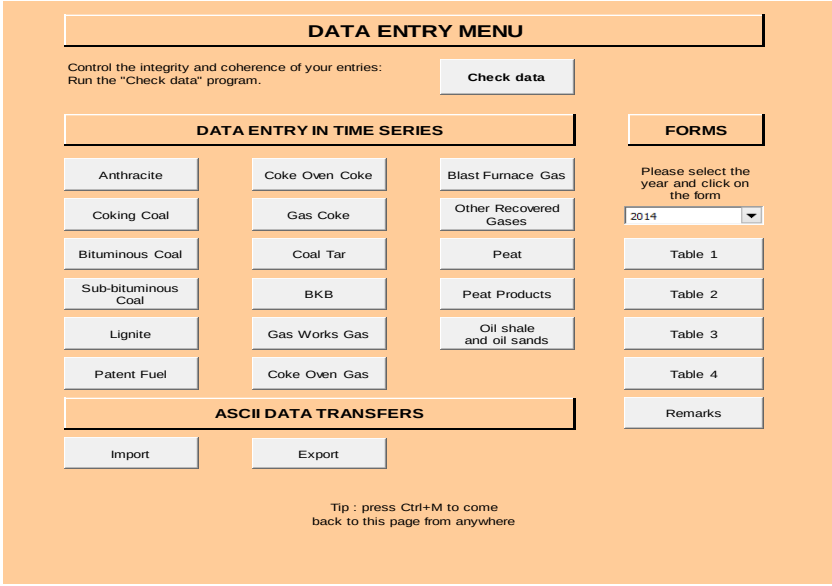
- Supply & demand breakdown
- Basic conversions
- Calorific values
- The weighted average
- Transformation & energy sector own use
- Main activity producers & autoproducers
- Non-energy use of energy products

The 5 Joint Annual Questionnaires

3 organizations

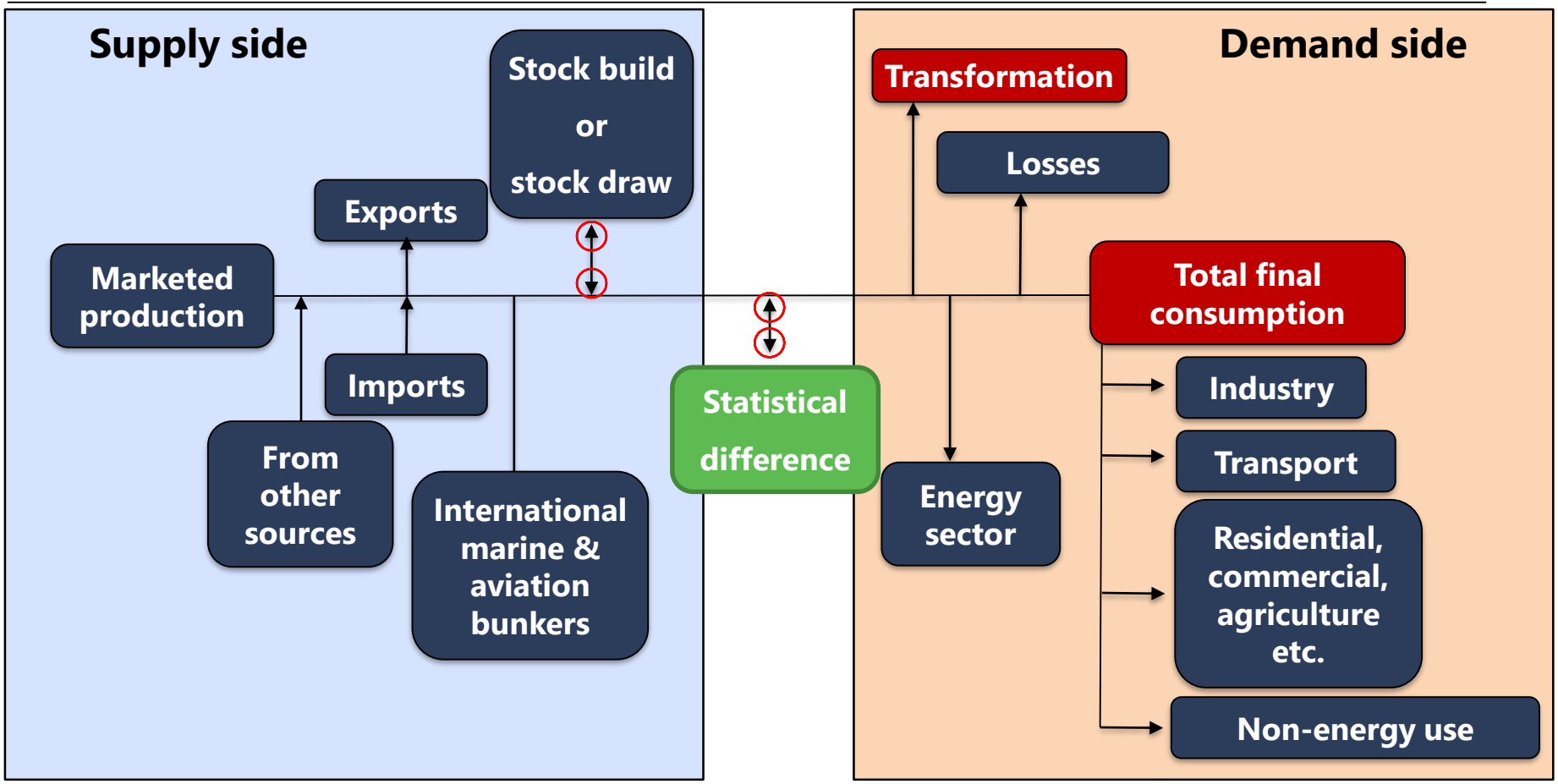
1 set of questionnaires

5 different fuel categories



But…many concepts in common

Supply & demand breakdown



The energy balance

Supply

Demand

Transformation

Final consumption

201· ▼ | Indicators | Balances | Coal and Peat | Electricity and Heat | Natural Gas | Oil | Renewables and Waste

	Coal and peat	Crude oil	Oil products	Natural gas	Nuclear	Hydro	Geothermal, solar, etc.	Biofuels and waste	Electricity	Heat	Total*
Production	33658	173317	0	132349	24390	32309	901	12106	0	0	409029
Imports	5954	34610	12790	25960	0	0	0	759	1287	0	81260
Exports	-20076	-118761	-19053	-76831	0	0	0	-570	-4430	0	-239722
International marine bunkers**	0	0	-524	0	0	0	0	0	0	0	-524
International aviation bunkers**	0	0	-1214	0	0	0	0	0	0	0	-1214
Stock changes	66	1064	-206	2092	0	0	0	0	0	0	3016
TPES	19603	90130	-8207	83569	24390	32309	901	12295	-3144	0	251845
Transfers	0	-3781	7993	0	0	0	0	0	0	0	4213
Statistical differences	2329	4585	4579	2410	0	0	0	-1	0	-32	13872
Electricity plants	-17629	0	-1820	-10824	-24390	-32309	-901	-2426	53814	0	-36484
CHP plants	0	0	-41	-2468							1047
Heat plants	0	0	0	0							-28
Gas works	0	0	0	0							0
Oil refineries	0	-91737	95461	-849							875
Coal transformation	-1182	0	0	0	0	0	0	0	0	0	-1182
Liquefication plants	0	802	0	-1940	0	0	0	0	0	0	-1138
Other transformation	0	0	0	0	0	0	0	0	0	0	0
Energy industry own use	-4	0	-7956	-13986	0	0	0	-1	-4019	0	-25966
Losses	0	0	0	0	0	0	0	0	-2984	0	-2984
Total final consumption	3117	0	90009	55912	0	0	0	9766	44625	546	203975
Industry	2450	0	6067	23876	0	0	0	5840	17698	545	56476
Transport	0	0	54404	2436	0	0	0	1637	331	0	58808
Other	33	0	8935	26208	0	0	0	2289	26596	0	64062
Residential	33	0	2647	14661	0	0	0	2279	13161	0	32782
Commercial and public services	0	0	3008	10823							464
Agriculture / forestry	0	0	3280	724							316
Fishing	0	0	0	0							0
Non-specified	0	0	0	0	0	0	0	0	0	0	0
Non-energy use	634	0	20603	3392	0	0	0	0	0	0	24629
-of which petrochemical feedstocks	*0*	*0*	*12022*	*3392*	*0*	*0*	*0*	*0*	*0*	*0*	*15415*

Basic conversions

- Energy statistics involve various units
  - **Mass:** kg, ton, kt, lb
  - **Volume:** L, bbl, gal, m^3
  - **Energy:** TJ, ktoe, ktce, GWh, kcal, BTU
- We use conversion factors to convert from one to another
- Between the same quantities, we <u>always</u> use a constant!

Remember!	
Kilo-	**10^3**
Mega-	**10^6**
Giga-	**10^9**
Tera-	**10^{12}**

- 1 kt = 1 000 ton
- 1 ton = 1 000 kg
- 1 kt = 1 000 000 kg

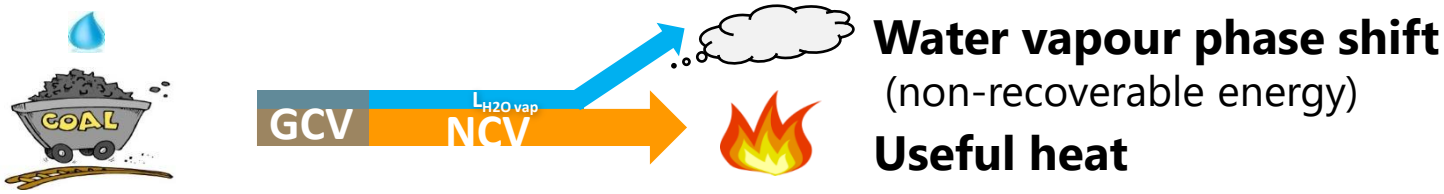
- 1 bbl ≈ 159 L
- 1 m^3 = 1000 L
- 1 GWh = 3.6 TJ
- 1 ktoe = 41.868 TJ
- 1 ktce = 0.7 ktoe

Calorific values

- The heat (energy) obtained from one unit of fuel when burned
- Indicates quality of the fuel
- Should be within expected ranges, but depends on quality
  - Bituminous coal – Kazakhstan: 18581 kJ/kg
  - Bituminous coal – New Zealand: 28201 kJ/kg

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**

The weighted average

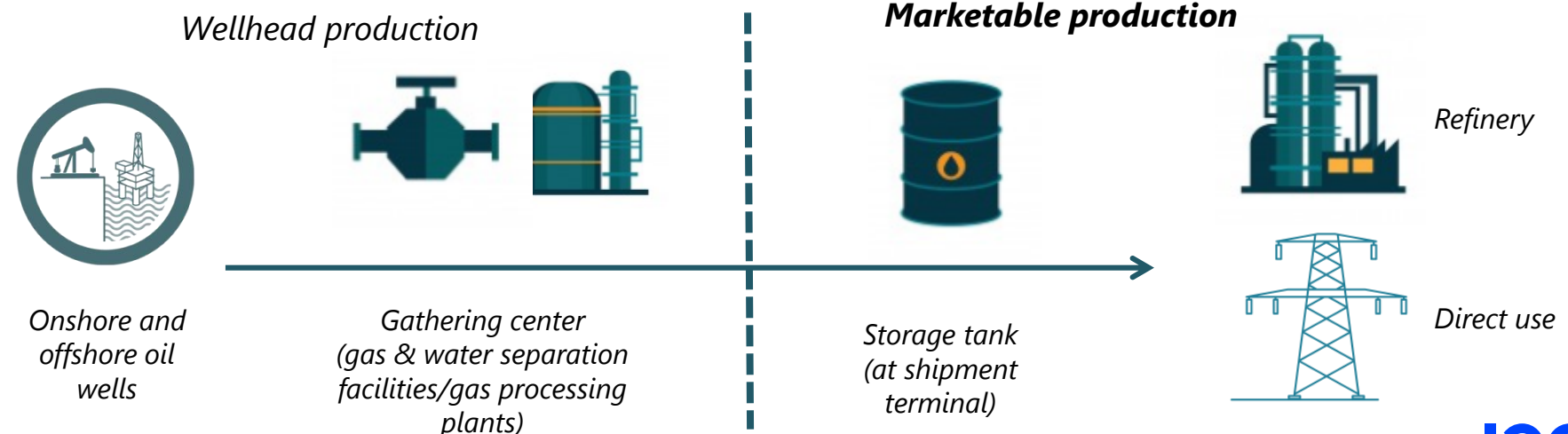
- If A country has 2 coal mines, for example A & B, then this has to be reflected in the average NCV

Mine A:	**400 kt**	**25000 kJ/kg**
Mine B:	**100 kt**	**20000 kJ/kg**

- $NCV_{TOT} = \frac{NCV_A \times PROD_A + NCV_B \times PROD_B}{PROD_A + PROD_B}$
- $NCV_{TOT} = \frac{25000\frac{kJ}{kg} \times 400kt + 20000\frac{kJ}{kg} \times 100kt}{400kt + 100kt} = 24000\frac{kJ}{kg}$
- Generic formula: $CV_{TOT} = \frac{\sum_i (CVi \times Quantityi)}{\sum_i (Quantityi)}$

Production - what to account for ?

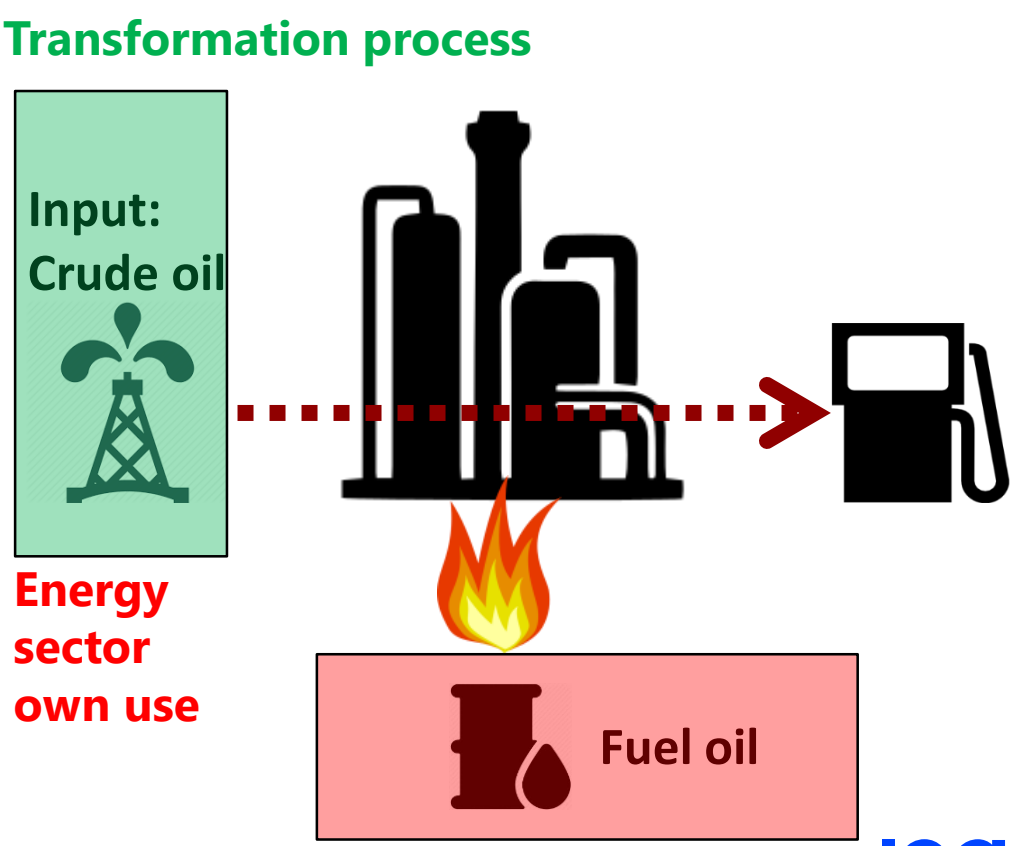
- Report all production within **national boundaries** (“territoriality principle”) including offshore production for commercial fuels measured when they are in a marketable state.
  - After the removal of impurities.
- Oil production example



Transformation & energy sector own use

- **Transformation:**
  - Inputs to transformation processes – from one form of energy to another
    - E.g. crude oil -> **refinery** -> oil products
    - E.g. gas -> **CHP plants** -> electricity and heat

- **Energy sector own use:**
  - Fuel used to support energy industry activities
  - E.g. Fuel oil, refinery gas used for refinery operations.



Main activity producers & autoproducers plants

Inland demand (Total consumption)	**0**	**0**	**0**
Transformation sector	**0**	**0**	**0**
Main activity producer electricity plants			
Autoproducer electricity plants			
Main activity producer CHP plants			
Autoproducer CHP plants			
Main activity producer heat plants			
Autoproducer heat plants			
Gas works (Transformation)			
Coke ovens (Transformation)			

Thermal power plant.

Hydropower station.

Aluminium smelter.

- Main activity producer plants
  - Facility generating electricity and/or heat for sale to third parties as their **primary activity**
    - In practice any plant called "power plant" or "heat plant"
- Autoproducer plants
  - Facility generating electricity and/or heat wholly or partially for their own use as **support** to their primary activity
    - E.g. steel mills, paper mills, waste recycling, etc.…

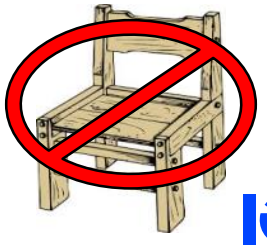
No distinction between state or privately owned plants

Non-energy use of energy products

- Fuels used as raw materials and **not** consumed as a fuel or transformed into another fuel (e.g. asphalt to make roads).
- Fuels that are transformed into non energy products (e.g. hydrogen transformed into ammonia to use as a fertilizer).
- It is very important to report these correctly.
  - For example when calculating CO_2 emissions non energy use of energy products is treated differently.

For biofuel commodities:

- only the amounts specifically used for energy purposes are included in the energy statistics (biofuels)



Exercises

Part 1

C. Highlights by fuel

Oil highlights: Transformation - Refineries

Primary products input into refinery

Crude oil

NGLs

Other hydrocarbons

Secondary products input into refinery

Additives/blending components

Refinery feedstocks

Refinery

Refinery fuel use

Refinery gas
Ethane
LPG
Naphtha
Motor gasoline
Aviation gasoline
JET Kerosene
Kerosene
Gas/Diesel Oil
Fuel oil
White Spirit and SBP
Lubricants
Bitumen
Paraffin Waxes
Petroleum Coke
Others

Lighter products

Heavier products

Inputs and outputs are reported in the oil tab

		Prim. Oil Products	Sec. Oil products
Refinery:	Input		
	Output		

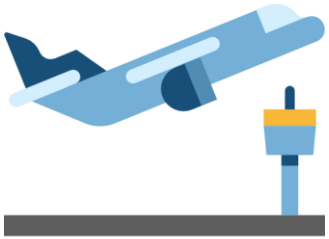
Refinery Losses = Input - Output

$$\text{Refinery Yield (\%)} = \frac{\text{Refinery Output (Secondary Products)}}{\text{Refinery Intake (Primary Products)}} \times 100$$

Oil highlights: International marine and aviation bunkers

International Marine Bunkers (-)	-10
International Aviation Bunkers (-)	

- Removed from consumption and supply of a country.



- Quantities of fuels delivered to sea-going **ships of all flags**.
- Ships undertaking **international voyages**.
- Deliveries of fuels to aircrafts for **international aviation**.
- Deliveries of fuel to *domestic* airlines for **international** departures.

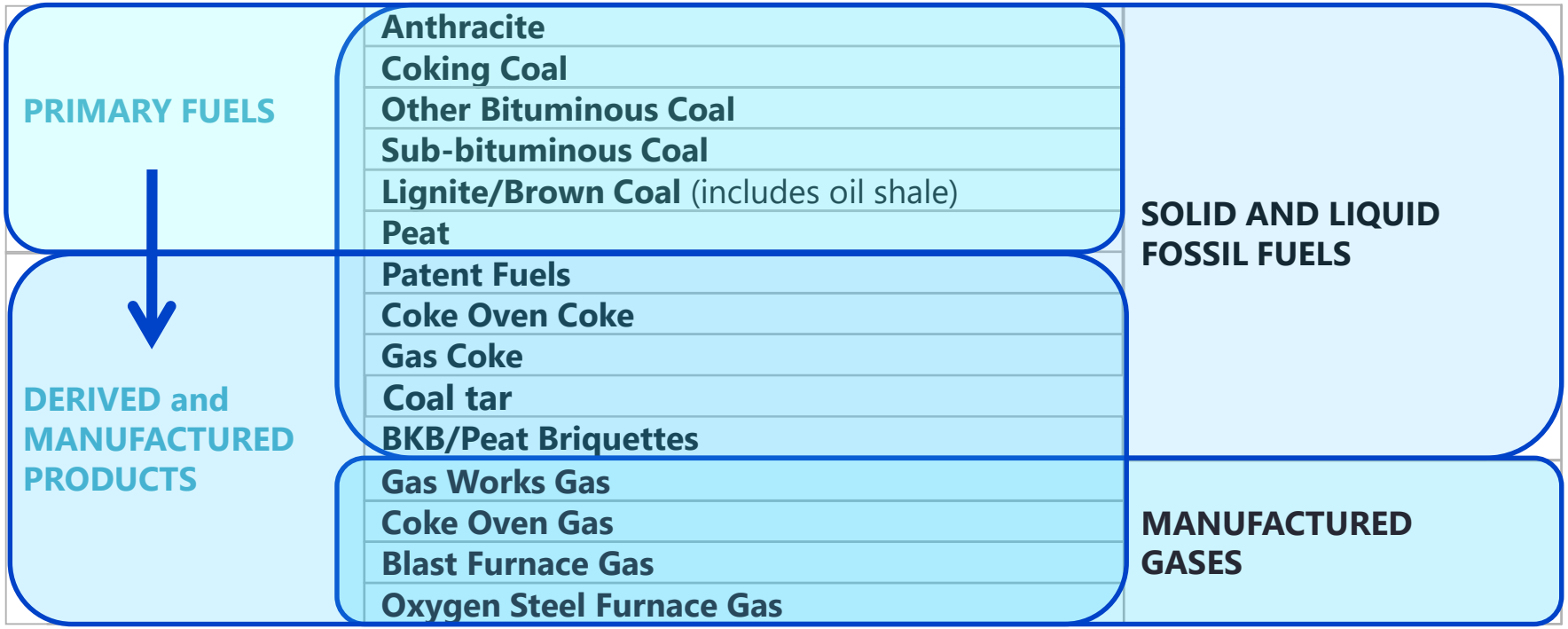
National/International split determined by the airport/port of departure and destination **not the nationality of the ship/airline**.

Coal highlights: Status currently in the World

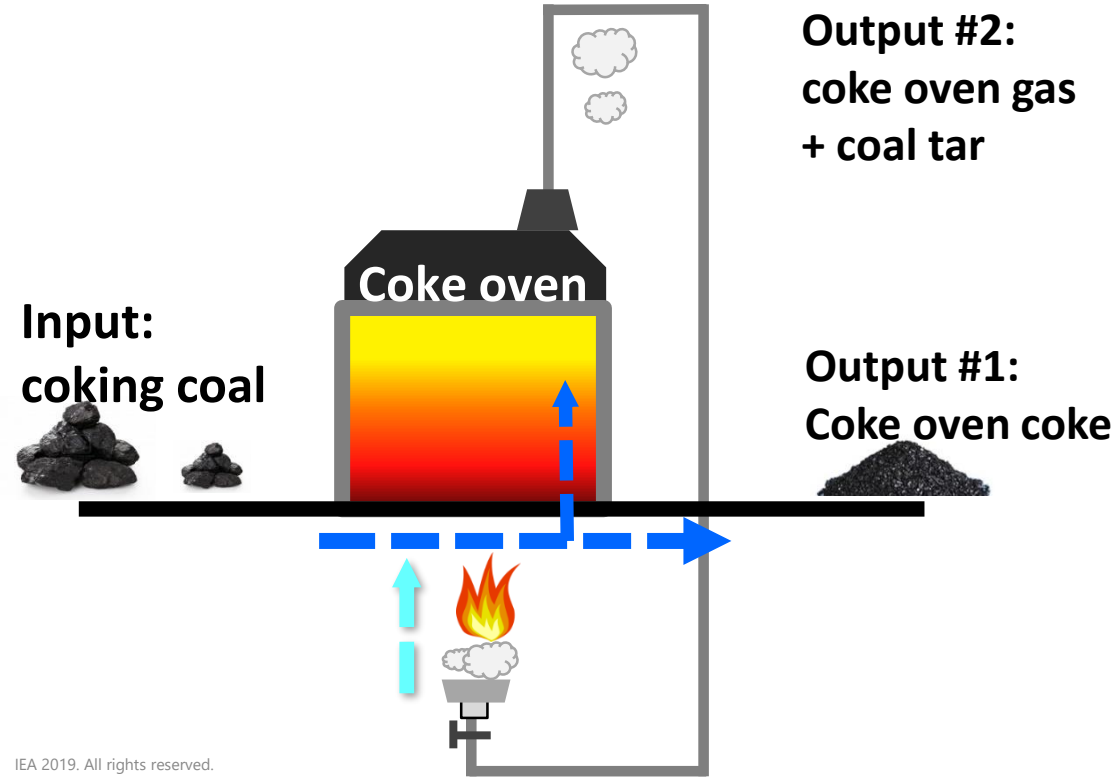
- Abundant, cheap with low technology barriers.
- Used for power generation, iron and steel production and cement manufacture.
- Environmental concerns: largest CO_2 emission per unit of energy among conventional energy sources.
- Potential for development and deployment of clean coal technologies such as carbon capture and storage.
- Energy security can be enhanced with coal-to-liquids, gas or chemicals.

Coal is the number one source for electricity generation globally

Coal: Classification - primary/derived coal and peat products



Coal highlights: Transformation processes



Fuels transformed into another energy form

Transformation

Fuels consumed to support operations

Energy industry Own-use

Coal highlights: Calorific values may vary for different flows

Fuel	Expected calorific value (kJ/kg, MJ/ton)	
Coking coal	25000	33000
Anthracite	22000	29000
Other bituminous coal	22000	29000
Sub-bituminous coal	16000	24000
Lignite	5000	18000
Peat	7000	13000
Oil Shale	2500	12000
Coal tar	30000	44000
Patent fuel	25000	32000
Coke oven coke	24000	32000
Gas coke	24000	32000
BKB	15000	21000
Peat products	8000	14000
Gas works gas	15000	22000
Coke oven gas	15000	22000
Blast furnace gas	2000	4000
Other recovered gases	2000	20000

Open pit mine

Coke Oven

Supply

- Production
- Imports
- Exports

Demand

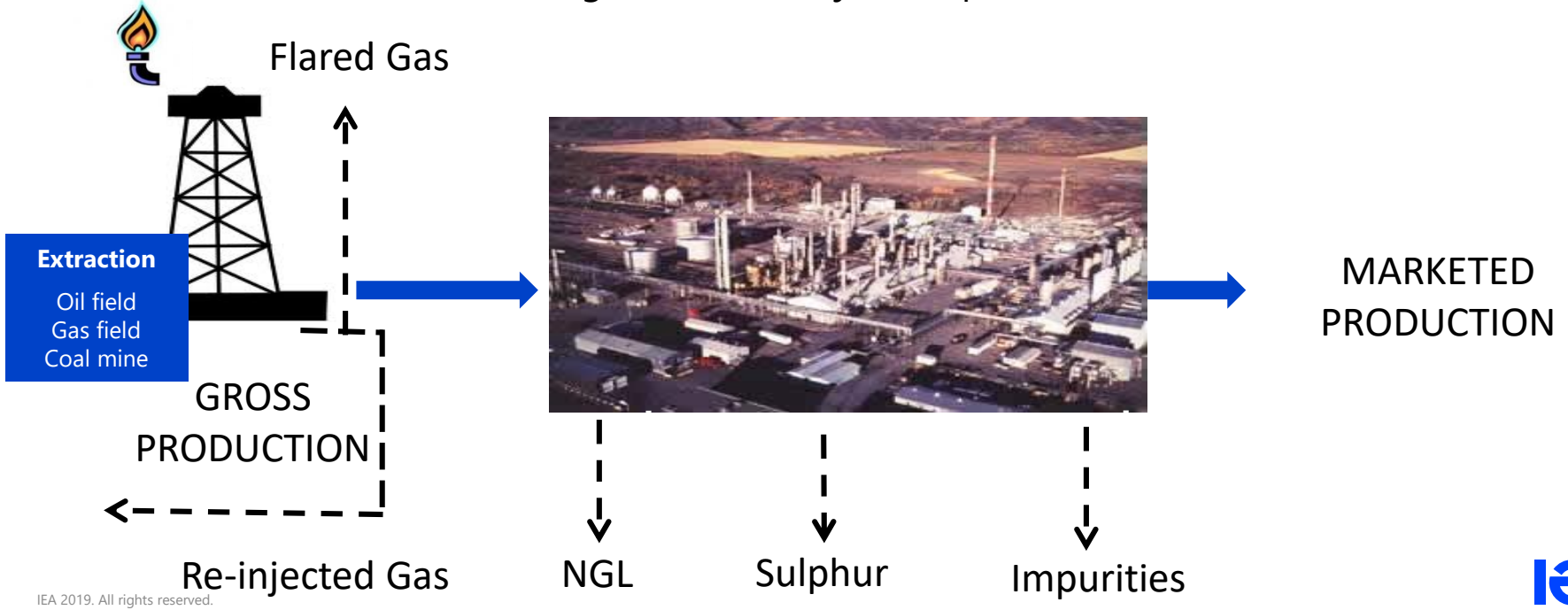
- Used in Coke Ovens
- Used in Blast Furnaces
- Used in main Activity Plants
- Used in Industry
- For Other Uses

Natural gas highlights: Collecting data

- Need to determine the measuring conditions.
  - Pressure and temperature affect the volume of natural gas.
  - LNG quantities should be reported in **standard conditions** (15 degrees, 1 atmospheric pressure). 1 m3 of LNG is approximately 600 m3 of natural gas at standard conditions
- Conversion to energy units
  - Report data in weighted average GCV (kJ/m^3).

Natural gas highlights: Production

- Production includes Dry marketable production (after purification and extraction of NGLs and sulphur)
  - Excludes vented and flared gas, losses, reinjected quantities



Natural gas highlights: Trade

- One product, two different physical states

- Gas is imported or exported when having crossed the physical boundary of a country
  - Imports by **ultimate** origin of gas; exports by **ultimate** destination
  - Excludes transit and re-exports

Renewables & waste highlights: Non-combustible renewable energy sources (1)

Hydro

Tide, Wave, Ocean

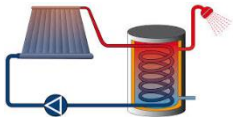
Solar photovoltaic

Wind

Energy Capture → Energy Transformation → Electricity Production

Primary energy form = electricity

Renewables & waste highlights: Non-combustible renewable energy sources (2)



Geothermal

Solar thermal

Energy Capture

Exports*

Imports*

Direct Use

Energy Transformation

Electricity Production

Heat Production

Primary energy form = Heat

* Very rare

Renewables & waste highlights: Products

Solid biofuels


Bagasse


Wood


Charcoal

Biogas


Landfill gas


Sewage Sludge gas

INPUTS


Wood


Agro residues (ex: bagasse)

Charcoal Transformation Plant

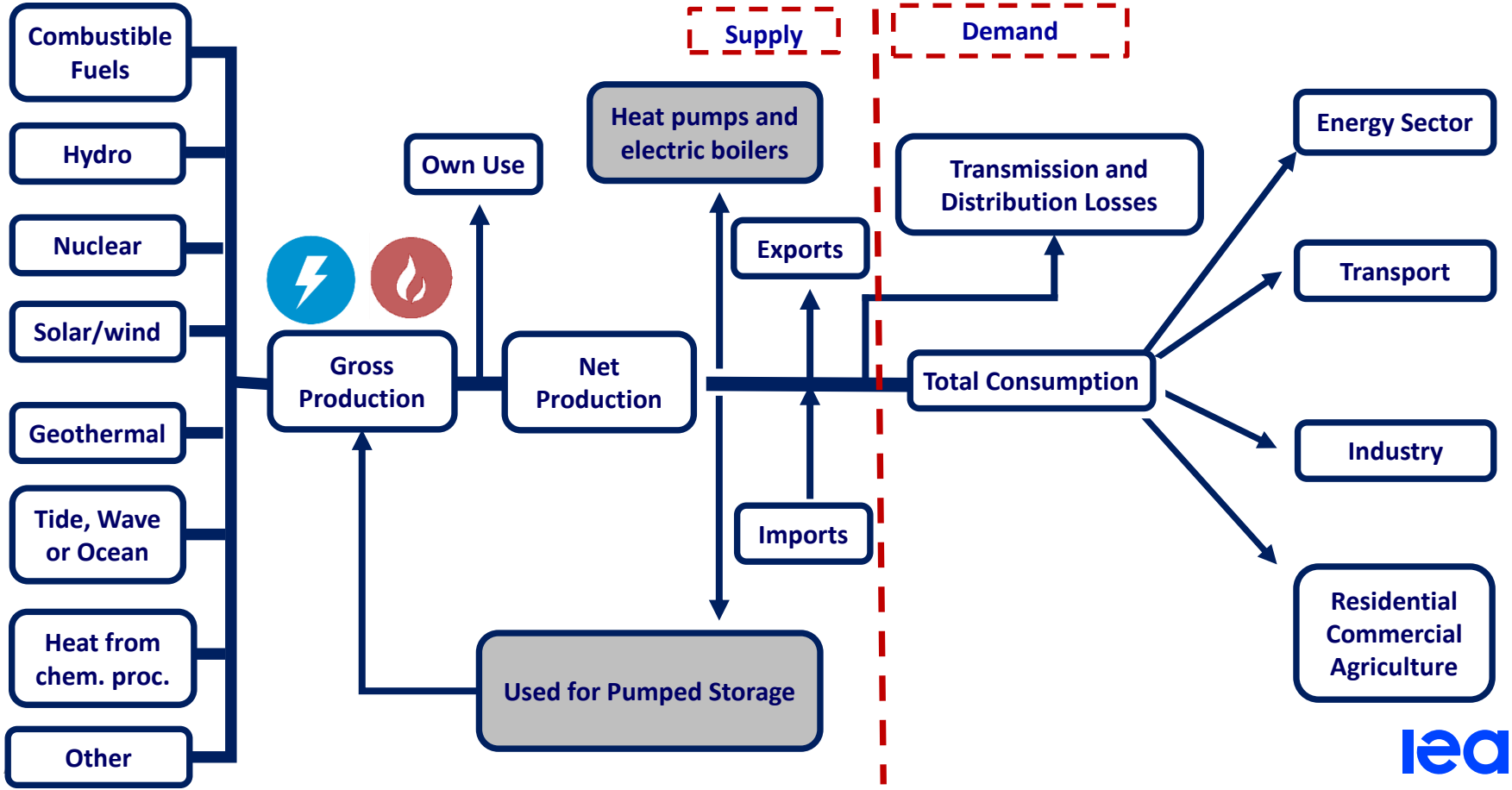
Power Plant

OUTPUTS


Charcoal

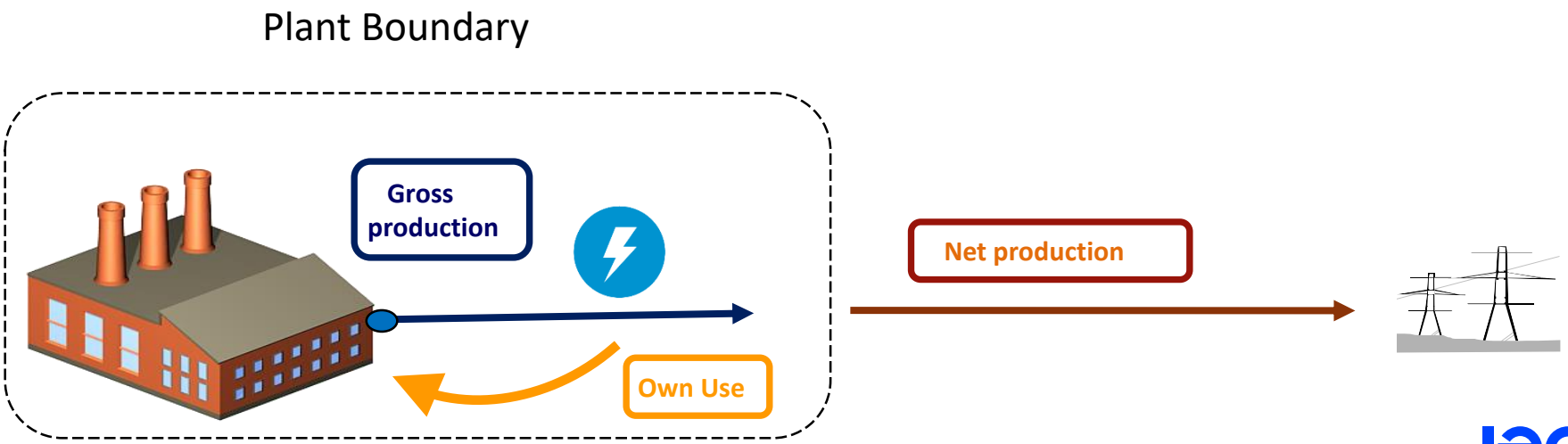

Electricity

Electricity and Heat highlights: Supply & Demand Chain



Electricity and Heat highlights: Electricity generation boundaries

- Gross Electricity – all the electricity produced
- Own Use – amount consumed to support the operations of the plant
- Net Electricity - Electricity sent to the grid



Electricity and Heat highlights: Electricity trade & checking efficiencies

- Reported differently from trade of most other fuels:
  Physical amounts crossing borders (not final destination)

Amounts that cross physical boarders

EFFICIENCY = OUTPUT / INPUT (in energy units)

Efficiency shall:
- be within the reference ranges
- be < 100%

Efficiency checks	Reference %	
Fuel Oil	25	50
Gas / Diesel Oil	25	50
Other Oil	15	35
Natural Gas	35	55
Coal / Coal Products	25	50
Manufactured Gases	15	50

Exercises

Part 2