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# REGIONAL TRAINING ON MODEL-BASED INTEGRATED ENERGY AND CLIMATE ANALYSES

Almaty, 11-13 December 2024

# INTRODUCTION INTO ENERGY STATISTICS AND MAIN ENERGY INDICATORS

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# Introduction (1):

The most important/known OFFICIAL NATIONAL energy reports about the energy sector are:

- Annual statistical energy balance
- Monthly statistics on coal, electricity, natural gas, renewables
- Statistics on energy prices
- Statistics on capacities, etc.

The most general energy indicators that appear in reports:

- Energy intensities (per value-added, per capita)
- Energy dependency
- Energy efficiency of the power sector
- Share of RES in electricity generation

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# Introduction (1):

Energy statistics is a very complex and specific kind of statistics:

**It is a statistic of all legal and private persons in a country**

A unified approach to energy statistics activities is needed for various reasons:

- it helps policymakers in the decision-making process to be based on accurate, quality, timely, and consistent data;
- it reduces administrative workload in data collection, compilation, and dissemination;
- it reduces the appearance of errors and differences between similar datasets;
- it helps the general public to understand the energy situation in their country.

The unified approach enables benchmarking, monitoring, evaluation and verification of current situations and trends in the energy sector at local, national, regional, and global levels!!!

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# Introduction (2):

The institutional framework for energy statistics ensures the sustainability of producing energy statistics over time

An effective energy statistics system requires the existence of a strong legal framework complemented by appropriate institutional arrangements between all relevant stakeholders

The **legal framework** is a set of laws and regulations that specify the rights and responsibilities of organizations that collect, produce, disseminate, or use statistics or statistics outputs

The **institutional arrangements is** organization of the work on energy statistics among the relevant energy statistics stakeholders (coordination, divison of work, data sharing, planning of the new acttivities, consultancies

The most common energy statistics stakeholders: National Statistical Offices, Ministries responsible for energy sector, National Energy Agencies

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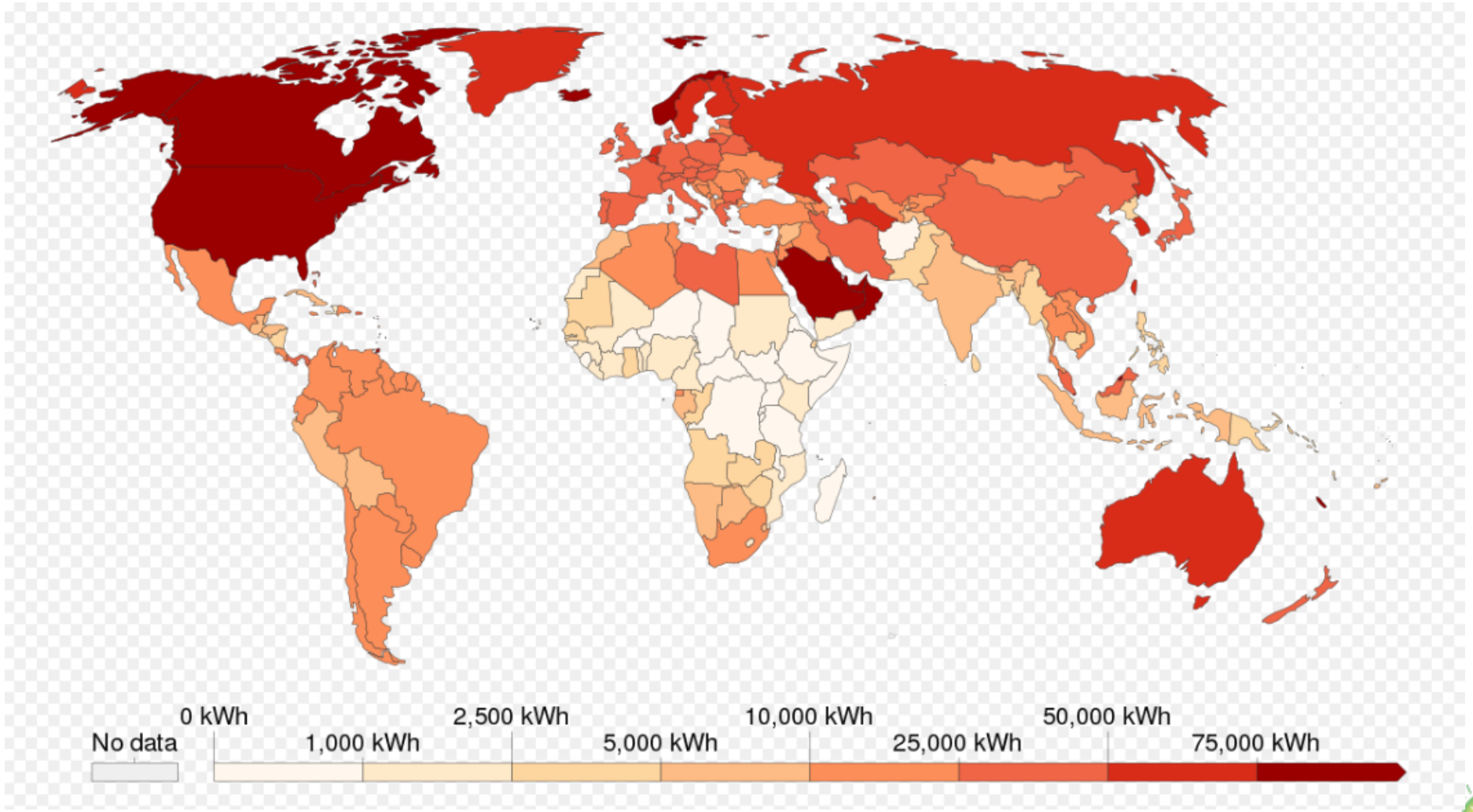
# Annual gross final electricity consumption per capita, kWh/capita

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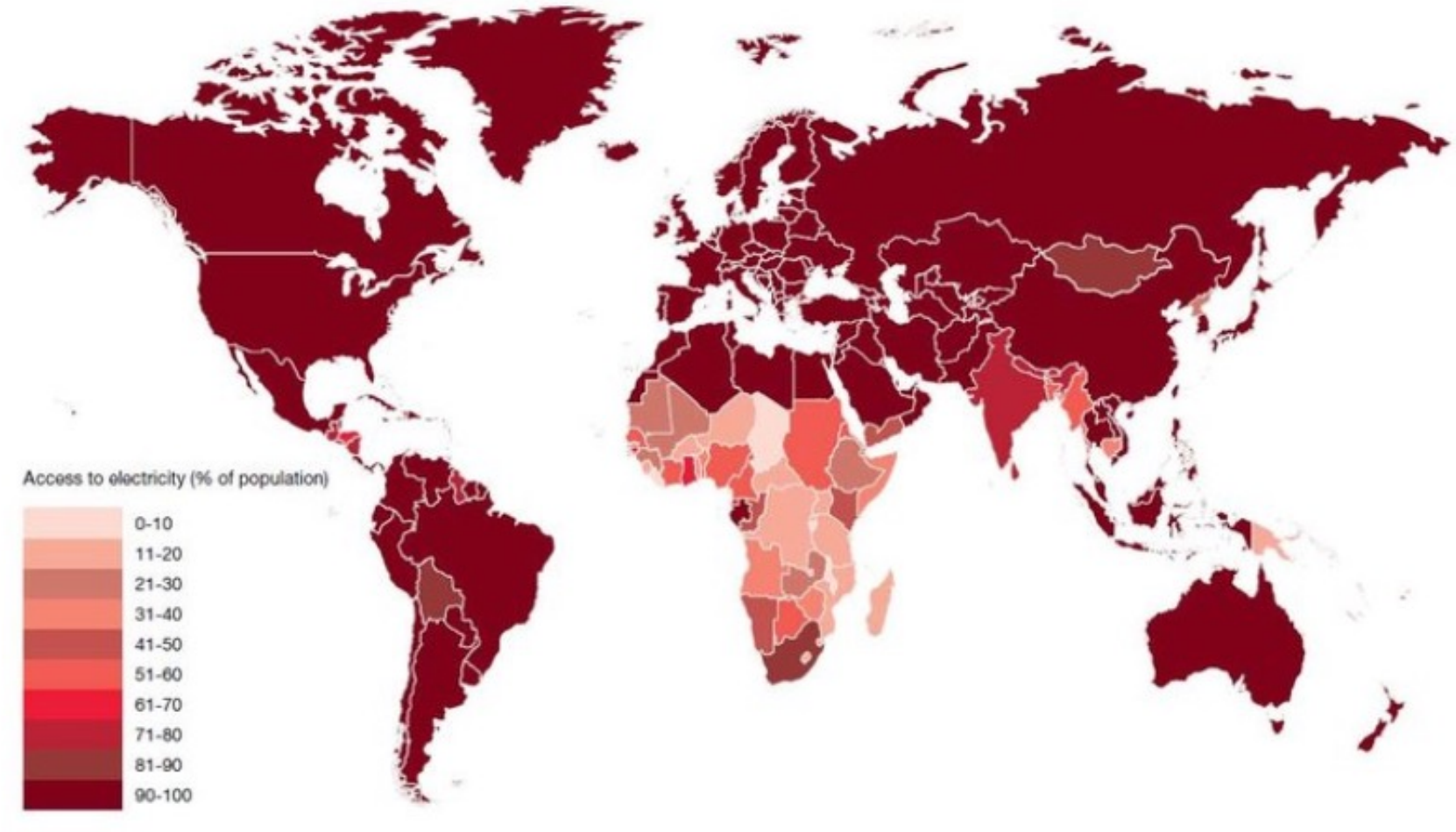
# Access to electricity, pecentage of population %

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# Energy statistics is the key for energy policies and strategies

**1. Understand situation and desired outcomes**

- Do we really understand what the problem or issue is? Are you sure there is a gap? What policy or evidence is already out there & what are others doing? What outcome would indicate success ?

**2. Develop scenario options**

- Understand, quantify & analyze impacts, costs, risks & benefits of policy options, including on GHGs;
- Address evidence gaps & identify research & analysis required

**3. Prepare implementation activities**

- Undertake pilots & collect good practice
- Benchmark against other schemes
- Put in place policy monitoring, evaluation & reporting mechanisms

**4. Implementation, monitoring, revision**

- Monitoring performance indicators and expected benefits
- Evaluation and reporting, eg. greenhouse gas emissions, energy efficiency improvement, RES shares

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## DEFINITIONS, MEASUREMENT UNITS AND CALORIFIC VALUES, DENSITIES

# 1. ENERGY PRODUCTS

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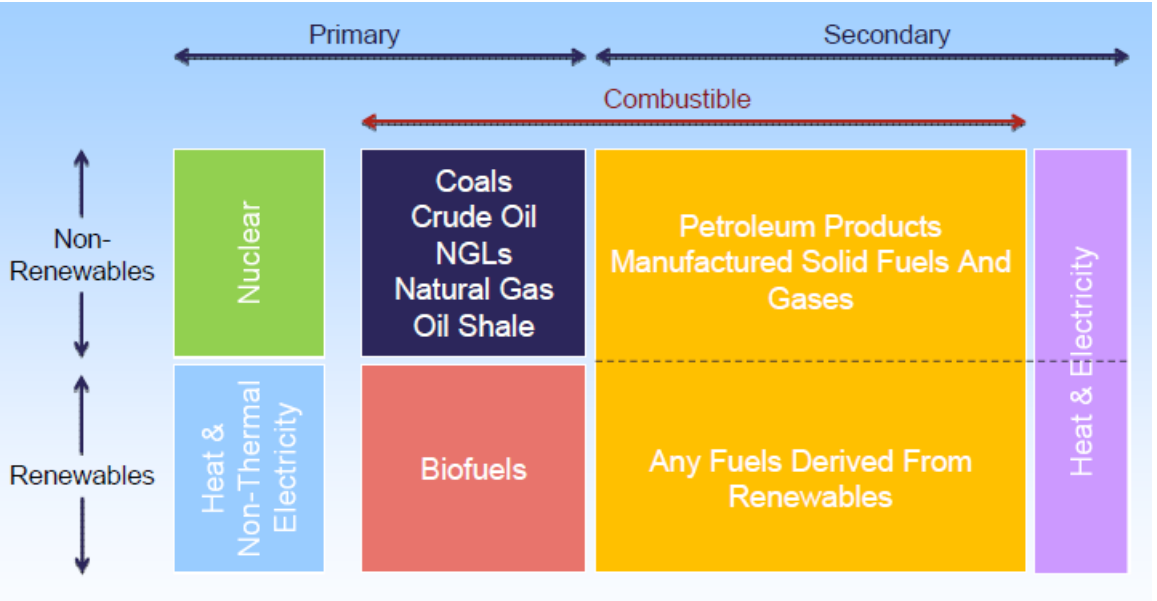
# Fossil Fuels and Renewable Energies

Energy products split:

- renewable/non-renewable
- primary / secondary
- combustible / non-combustible

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# How to measure Quantities and Heating values?
## Quantities: Natural Units

At the point of measurement of the fuel, the units should be the best suited to physical state (solid, liquid or gas)

This units are called natural of physical units

**Solid fuels: kilograms or tonnes**

**Liquids and gases: liters or cubic meters**

**Electricity: kilowatt–hours**

**Heat: calories or joules***

**Renewables: tones, m3, kWh,……**

*Heat from steam flows is rarly accurately measured but it tipically inferre from fuel used to produce it

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# How to measure Quantities and Heating values?

## Quantities: Energy Units

Natural units are often converted to a common unit to enable aggregations and comparisons between fuels, calculating indicators, estimating efficiencies, etc.;

**The most often energy units arem egajoule or tonne of oil equivalent.**

For thermal fuels, this requires a conversion factor that expresses the heat obtained from one unit of the fuel. This is called the calorific value (CV) of the fuel: *gigajoule/tonne for coal, megajoule/cubic metre for gas*.

Calorific Values vary between products and also countries!

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# Difference between Gross and Net Calorific Values

- Calorific values may be expressed in gross or net terms
- The difference is due to the latent heat of vaporization of the water produced during combustion
- IEA typically uses net calorific values (or lower heating values) in its energy balances. For reporting purposes, some data about energy products (e.g. manufactured gases) may be collected on a gross calorific value basis while other data (e.g. wastes and biogases) on a net basis
- Net calorific values are typically 5% to 6% less than the gross calorific value for solid and liquid fuels and about 10% less for natural gas

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# Coal and Coal Products


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# Coal and Coal Products

- Solid fuels are typically reported in thousand metric tonnes (kt)
- The range of calorific values may be hugely variable and differ from country to country depending on use
- For example, coal combusted in a power station will have completely different characteristics from coal used as a reductant in a steel-making process
- Calorific values for *each* country for *each* grade of coal (e.g. anthracite, coking, other bituminous, sub-bituminous, lignite) are needed
- Within *each* grade, the specific values for production, imports, exports, inputs to electricity/heat generation and coal used in coke ovens, blast furnaces, industry.... is needed
- Coal products such as patent fuel, coke oven coke, coal tar, BKB, and charcoal also have their own calorific values

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# Coal and Peat Calorific Values

| CALORIFIC VALUE | | MJ/tonne |
|---|---|---|
| high | Coal Tar | 30000 - 44000 |
| | Coking Coal | 25000 - 33000 |
| | Patent Fuel | 25000 - 32000 |
| | Coke Oven Coke | 24000 - 32000 |
| | Gas Coke | 24000 - 32000 |
| | Anthracite | 22000 - 29000 |
| | Other Bituminous Coal | 22000 - 29000 |
| | Sub Bituminous Coal | 16000 - 24000 |
| | Bkb | 15000 - 21000 |
| | Peat | 7000 - 13000 |
| low | Lignite/Brown Coal | 3000 - 18000 |

Coal Tar

Coking Coal

Patent Fuel

Coke Oven Coke

Gas coke

Anthracite

Other Bituminous Coal

Sub Bituminous Coal

Brown Coal Briquettes (BKB)

Peat

Lignite/Brown Coal

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# Country Specific Net Calorific Factors

| | Australia | Austria | Belgium | Canada | Czech Republic |
|---|---|---|---|---|---|
| **Coking coal** | | | | | |
| Production | 28500 | - | - | 24890 | 28621 |
| Imports | - | 29074 | 29308 | 28329 | 27046 |
| Exports | 28500 | - | 29308 | 24890 | 27600 |
| Coke ovens | 28500 | 29074 | 29308 | 28329 | 29148 |
| Electricity generation | - | | - | - | - |
| Indu | | | | | - |
| Othe | | | | | 29148 |
| **Other** | | | | | |
| Prod | | | | | - |
| Impo | | | | | - |
| Exports | 25700 | - | 25781 | 25514 | - |
| Coke ovens | - | - | - | - | - |
| Electricity generation | 27000 | 27804 | 25056 | 25514 | - |
| Industry | 25700 | 28778 | 29308 | 25514 | - |
| Other uses | 25700 | 28066 | 25781 | 25514 | - |
| **Sub-bituminous coal** | | | | | |
| Production | 18478 | - | 21967 | 17799 | 23857 |
| Imports | - | 22200 | - | 17799 | 28175 |
| Exports | - | - | 18662 | 17799 | 24658 |
| Electricity generation | 18914 | - | - | 17799 | 23500 |
| Industry | 19195 | 22200 | 18900 | - | 22221 |
| Other uses | 18478 | 22200 | 21967 | 17799 | 22493 |

Note the significant difference (14%) between indigenous production and imported coking coal

**Coking coal**
- Production
- Imports
- Exports
- Coke ovens
- Electricity generation
- Industry
- Other uses

**Other bituminous coal**
- Production
- Imports
- Exports
- Coke ovens
- Electricity generation
- Industry
- Other uses

**Sub- bituminous coal**
- Production
- Imports
- Exports
- Coke ovens
- Electricity generation
- Industry
- Other uses

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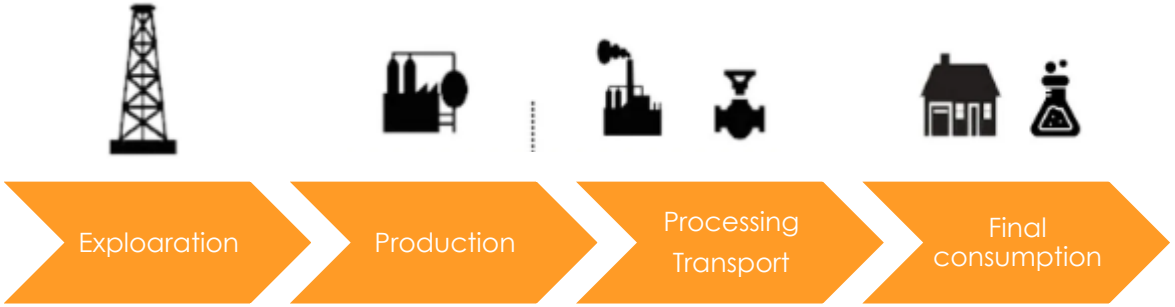
# Natural gas

There are 4 main flows to  be tracked in energy balance

Data are reported in two units:

- natural units: million cubic meters (mil. m3)
- energy units: terajoules (TJ), kWh

- Calorific values are typically reported in MJ/m3
- *Net calorific value* of natural gas is on average 10% less than the gross value.
- Warning: according to common practice many organisations report calorific value or natural gas in gross calorific terms.

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# Manufactured gas

Quantities of gases have been historically collected in terms of their gross energy (heat) content in terajoules (TJ). In energy balance converted values to net values are used

Calorific values of fuels are usually metered in laboratories

*Difference between Gross and Net Calorific Values*

| Gas | Gross to Net ratio |
|---|---|
| Gas-work gas | 0.9 |
| Coke-oven gas | 0.9 |
| Blast-furnace gas | 1.0 |
| Oxygen steel-furnace gas | 1.0 |

**Gross-to-net ratio**

Gas- work gas

Coke-oven gas

Blast-furnace gas

Oxygen steel-furnace gas

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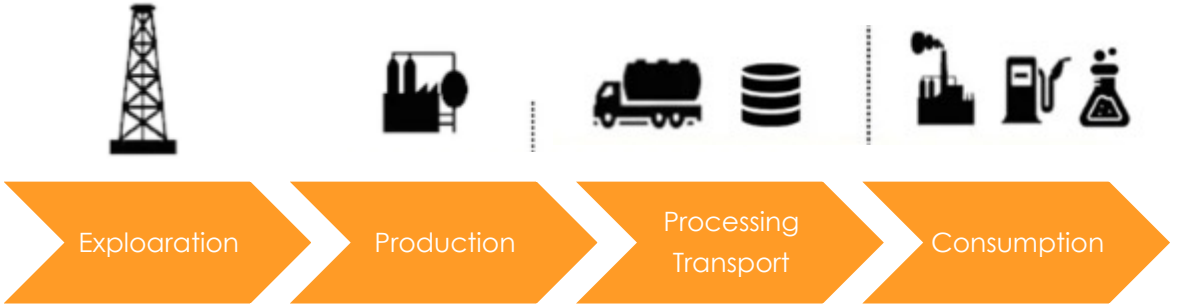
# Oil and petroleum products

A few units are used within the oil industry:

- mass (weight) using the metric tonne (or tonne)
- volume measured by the liter (l), the barrel (bbl) or cubic meter (m3)

To convert between mass and volume it is important to know the ***specific gravity*** or ***density*** of the liquid

Net calorific values are typically 5% to 6% less than the gross calorific value in the case of oil and petroleum products

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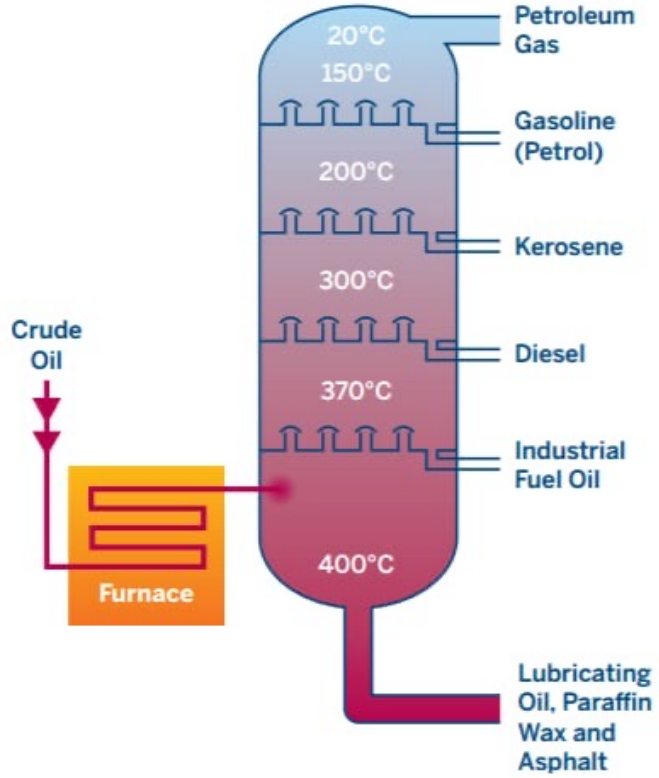
# Petroleum products

- are produced in refining processes using crude oil




| Petroleum products | Europe kJ/kg | North America kJ/kg | Pacific kJ/kg |
|---|---|---|---|
| Refinery gas | 49 500 | 48 100 | 48 100 |
| Ethane | 49 500 | 49 400 | 49 400 |
| Liquefied petroleum gases | 46 000 | 47 300 | 47 700 |
| Motor gasoline | 44 000 | 44 800 | 44 600 |
| Aviation gasoline | 44 000 | 44 800 | 44 600 |
| Gasoline type jet fuel | 43 000 | 44 800 | 44 600 |
| Kerosene type jet fuel | 43 000 | 44 600 | 44 500 |
| Kerosene | 43 000 | 43 800 | 42 900 |
| Gas/diesel oil | 42 600 | 42 600 | 42 600 |
| Residual fuel oil | 40 000 | 40 200 | 42 600 |
| Naphtha | 44 000 | 45 000 | 43 200 |
| White spirit | 43 600 | 43 000 | 43 000 |
| Lubricants | 42 000 | 42 000 | 42 900 |
| Bitumen | 39 000 | 40 000 | 38 800 |
| Paraffin Waxes | 40 000 | 40 000 | 40 000 |
| Petroleum Coke | 32 000 | 32 000 | 33 800 |
| Non-specified petroleum products | 40 000 | 40 000 | 40 000 |

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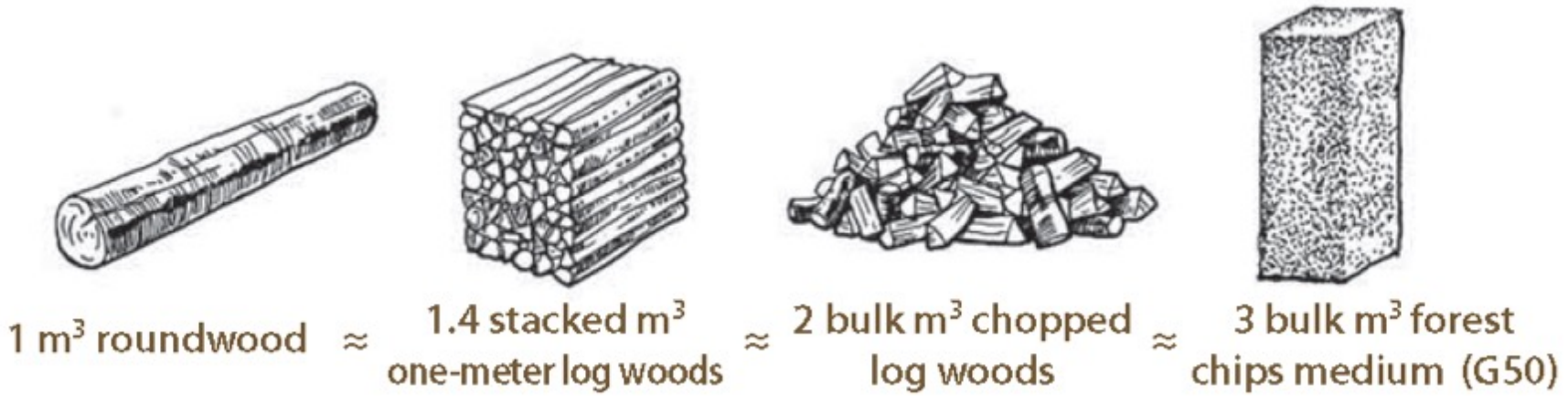
# Renewables - Fuel wood

**Solid cubic meter** (scm): 1 m³ solid wood, commonly used for timber (roundwood directly from forests)

**Stacked cubic meter** (stere): 1 m³ stacked wood pieces with a length of 1 m, 50, 33 or 25 cm, depending on the heating system; commonly used for fuel wood

**Bulk cubic meter** (bcm): 1 m³ loosely poured wood

Rough calorific value (Croatia): 1 m³ = 10000 MJ (Net calorific value)

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# Renewables - SOLAR HEAT in „SOLAR PANNELS”

How solar heat can be used?

- to heat swimming pools (normally unglazed collectors),
- for production of domestic hot water (DHW-Systems)
- for domestic hot water production and space heating (Combi Systems)

How to calculate heat from solar water heaters?

IEA/ESTIF method:

- Simply calculate heat delivered from solar heaters
- Data for the calculation can be easily collected
- Takes into account all systems relevant, for the time being
- Follows the EUROSTAT/IEA standards

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# Renewables - SOLAR HEAT in „SOLAR PANNELS" IEA/ESTIF method 1:

*Calculation methodology 1: As a function of the installed **solar collector area**:*

| | |
|---|---|
| ***Un-glazed collectors:*** | ***0.29 * H0 * Aa*** |
| ***Glazed collectors in DHW systems:*** | ***0.44 * H0 * Aa*** |
| ***Glazed collectors in combi-systems:*** | ***0.33 * H0 * Aa*** |

*Being:*

H0: Annual global solar irradiation in kWh/m²

Aa : Collector area in m²

The only information needed to calculate used solar heat is **the surface are of the sollar collector**

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# Renewables - SOLAR HEAT in „SOLAR PANELS”
# IEA/ESTIF method 2:

*Calculation methodology 2: As a function of the installed collector nominal thermal power:*

***Un-glazed collectors:*** ***0.42 * H0 * Pnom***
***Glazed collectors in DHW systems:*** ***0.63 * H0 * Pnom***
***Glazed collectors in combi-systems:*** ***0.47 * H0 * Pnom***

*Being:*

H0: Annual global solar irradiation in kWh/m²

Aa : Collector surface area in m²

Pnom : Nominal thermal power output of collector in kW

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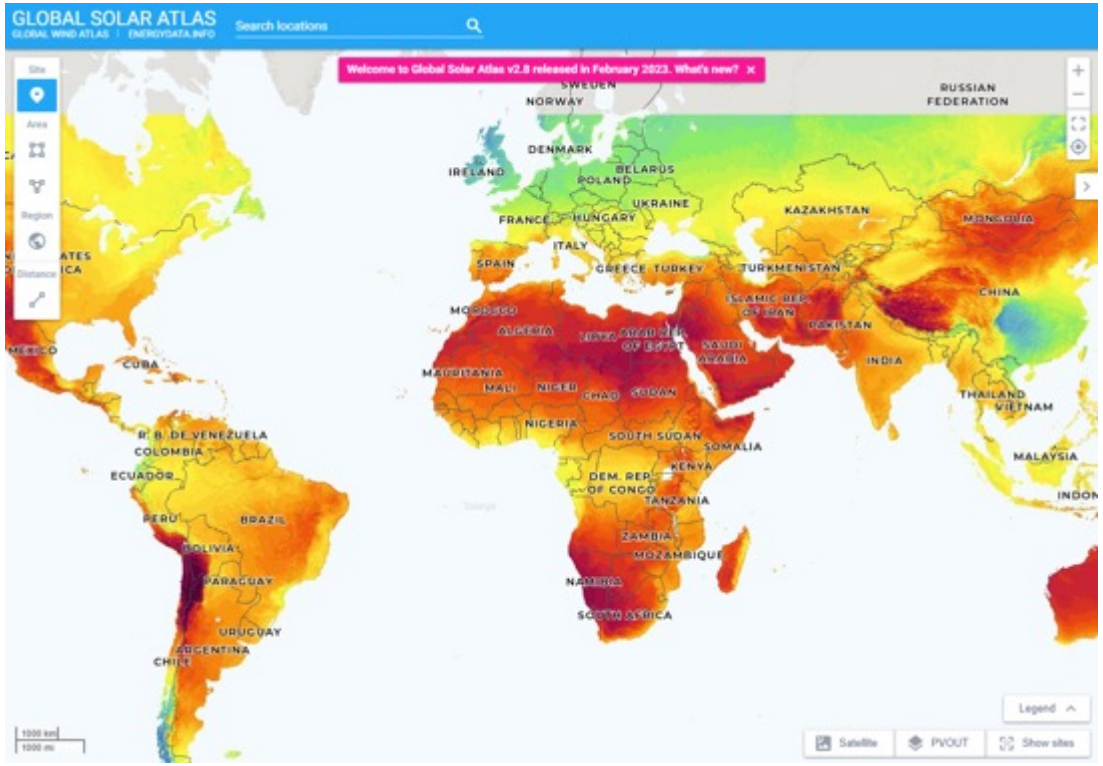
# Annual solar irradiation

## Global solar atlas - https://globalsolaratlas.info/map




Exercise:

Estimate solar heat use in glazed collector in a household in your town based on assumed following data:

Aa (collector area): 2 m²

H0 (annual global solar irradiation): XX* kWh/m²

* find in atlas!

Formula, IEA/ESTIF method 1:

Solar heat in glazed collectors: 0.44 * H0 * Aa

Result: _____kWh/year

Do you know what is annual electricity consumption in your household in kWh?

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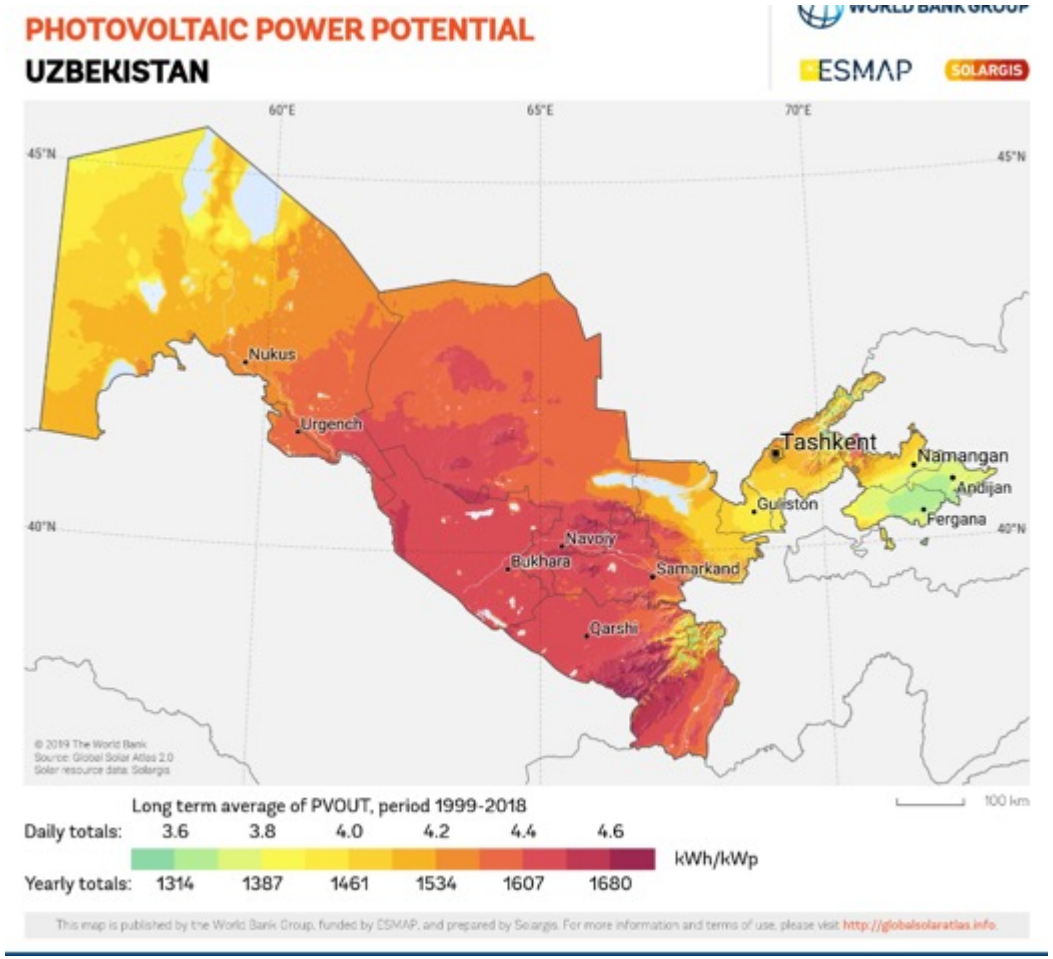
# Renewables - SOLAR HEAT in „SOLAR PHOTOVOLTAICS”

## Global solar atlas - https://globalsolaratlas.info/map

- Typically, residential solar PV vary from small-scale systems of around 1–3 kW, suitable for low-energy households, to more robust systems within the average home solar system size range of 5–10 kW for larger homes with greater energy demands
- Global Solar Atlas calculates annual electricity generation for location based on the installed capacity of solar PV

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# Renewables - SOLAR HEAT in „SOLAR PHOTOVOLTAICS”

## Global solar atlas - https://globalsolaratlas.info/map

Example: Zagreb, Croatia

Electricity generation in solar PV, capacity 1 kW

Exercise:

Estimate annual electricity generation from solar PV in a household in your country/town. The installed capacity of solar collector is 1 kW

Result:_____


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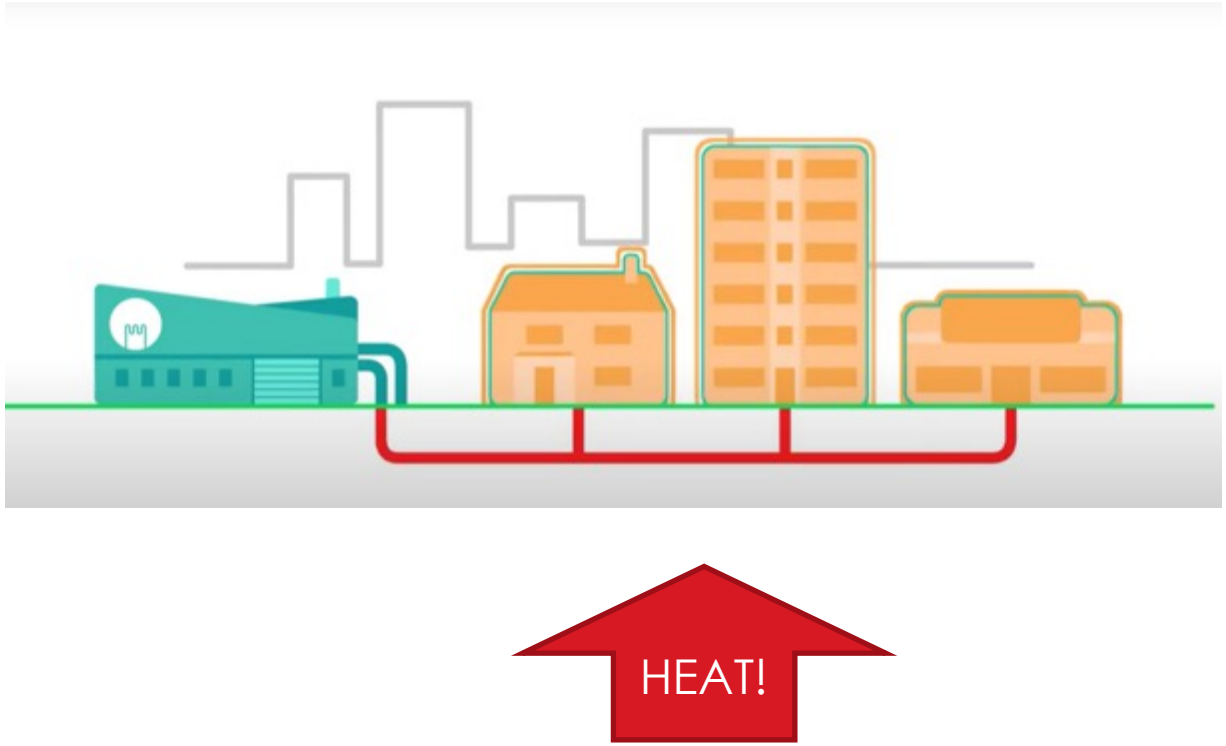
# HEAT - DISTRICT HEATING SYSTEMS (DHS)

District heating (heat networks) is a system for distributing heat generated in a centralized location through insulated pipes for residential and commercial heating requirements such as space heating and water heating

How do we estimate HEAT supply data for households, services, and industry?

Can heat suppliers distinguish economic activities and households?

Challenges: usually heat delivered to end-consumers is not metered, consumption is estimated based on some activity data, square meters, and persons.....

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# HEAT „COMUNAL HEATING SYSTEMS" or „BOILER HOUSES"

Communal heating systems are shared systems between several apartments.

Usually, the heat is produced from natural gas/fuel oil in a common boiler in the building, and heat is delivered through pipe to apartments

<u>Challenges:</u>

How to appropriately identify all communal heating systems? Who is responsible for registering of such type of service?

How to appropriately report the heat that is delivered to the property? Very often there is no metering devices!!!

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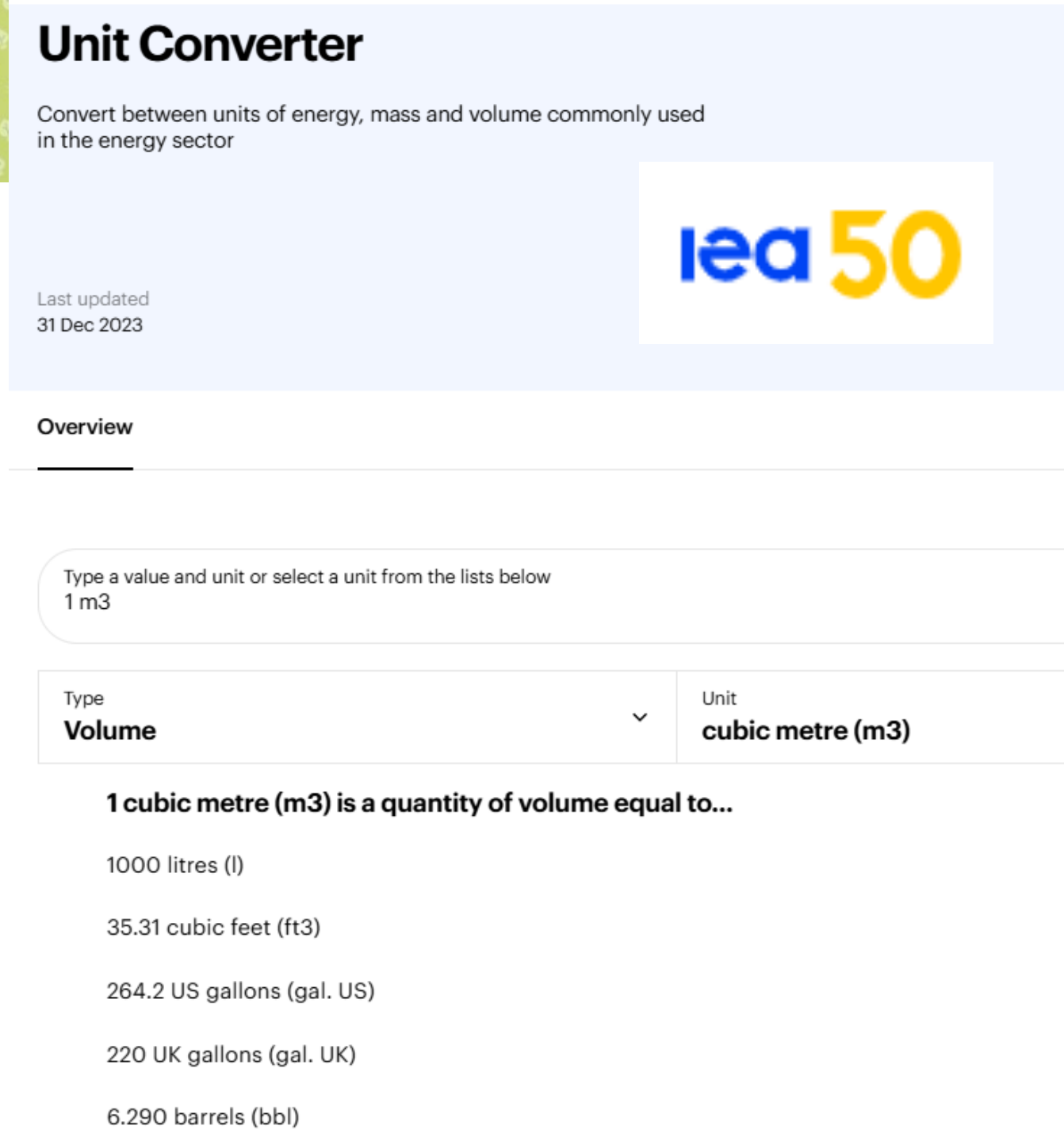
# Measurement units

In addition:

kWh – kilowatt-hour
kJ – kilojoule
kcal – kilocalorie
kgoe – a kilogram of oil equivalent
Btu – British thermal unit

1 kcal = 4,185 kJ
1 Btu = 1,055 kJ
1 kgoe = 41,88 MJ

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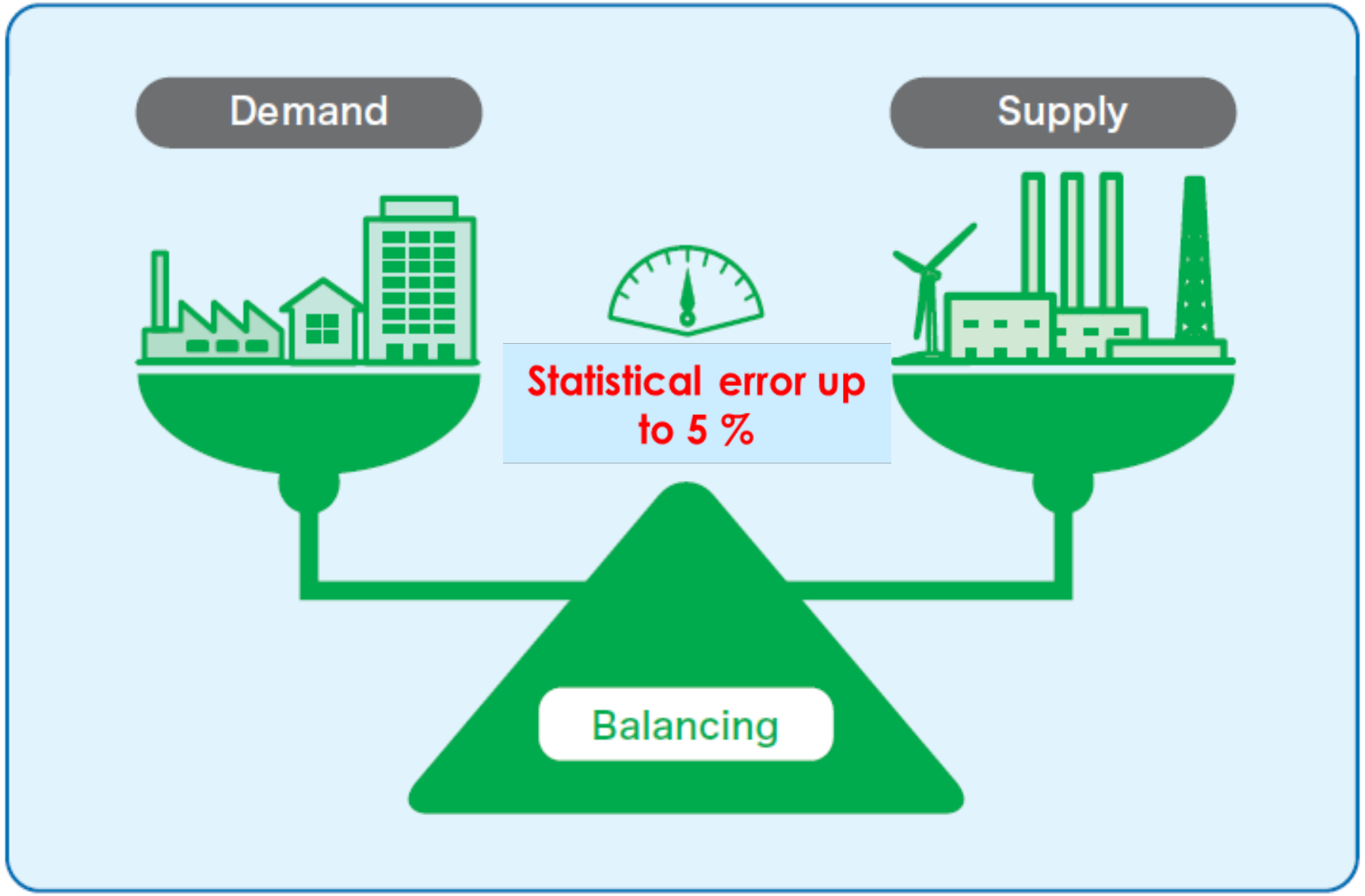
# 2. ANNUAL ENERGY BALANCE

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# Energy balance and related indicators

**1. Primary energy supply:**

Production, imports, exports, stock changes,

total primary energy supply

→ Total primary energy supply intensity; Import dependency

**2. Transformations, energy sector consumption, and losses:**

Transformations (electricity, petroleum products, …), own use in the energy sector, losses in transformation and distribution, available for energy consumption

→ RES shares in electricity and heat plant, transformation efficiencies

**3. Final and non-final energy consumption:**

Manufacturing, construction, non-fuel mining, transport, other: household, services, agriculture and forestry, fishing, non-specified;

Non-final energy consumption

→ Efficiencies in the final energy consumption sectors

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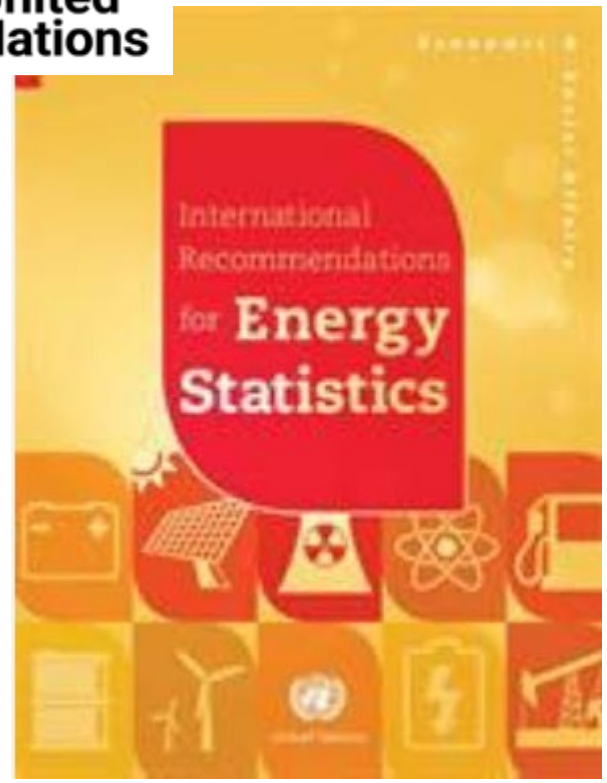
# International recommendations for energy statistics

United Nations






https://unstats.un.org/unsd/energystats/methodology/documents/IRES-web.pdf

https://www.iea.org/reports/energy-statistics-manual-2

https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Energy_statistics_-_an_overview

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# Simple energy balance matrix – 1. & 2. parts

## Total energy supply, Transformation, Losses, Energy Sector Own Use

**Uzbekistan**

Terajoules

| 2020 | Primary coal and peat | Coal and peat products | Primary Oil | Oil Products | Natural Gas | Biofuels and waste | Nuclear | Electricity | Heat | Total energy | of which: renewables |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Primary production | 61601 | .. | 126067 | .. | 1522987 | *959 | .. | 18054 | .. | 1729669 | 19013 |
| Imports | 47244 | 1400 | 30713 | 40969 | .. | 1473 | .. | 18746 | .. | 140545 | 1473 |
| Exports | -24 | .. | .. | -2372 | -93387 | -65 | .. | -9672 | .. | -105520 | -65 |
| International marine bunkers | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| International aviation bunkers | .. | .. | .. | *-4894 | .. | .. | .. | .. | .. | *-4894 | .. |
| Stock changes | 12806 | .. | 140 | 2664 | 20166 | .. | .. | .. | .. | 35776 | .. |
| **Total energy supply** | 121627 | 1400 | 156920 | 36367 | 1449767 | 2368 | .. | 27127 | .. | 1795576 | 20422 |
| Statistical difference | 8896 | 1400 | 65 | 1507 | 26700 | *2 | .. | -1 | 64343 | 102913 | 18056 |
| Transfers | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| **Transformation** | -58688 | 1130 | -156238 | 141969 | -492944 | .. | .. | 203931 | 148714 | -212128 | .. |
| Electricity plants | -31040 | .. | .. | -64 | .. | .. | .. | 11231 | .. | -19872 | .. |
| CHP plants | -26603 | .. | .. | -5715 | -457069 | .. | .. | 210174 | 74485 | -204728 | .. |
| Heat plants | .. | .. | .. | -992 | -21395 | .. | .. | *-17474 | 74229 | 34367 | .. |
| Coke ovens | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| Briquetting plants | -1045 | 1130 | .. | .. | .. | .. | .. | .. | .. | 85 | .. |
| Liquefaction plants | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| Gas works | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| Blast furnaces | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| NGL plants & gas blending | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| Oil refineries | .. | .. | -156238 | 148740 | .. | .. | .. | .. | .. | -7498 | .. |
| Other transformation | .. | .. | .. | .. | -14481 | .. | .. | .. | .. | -14481 | .. |
| Energy industries own use | -290 | .. | -131 | -5574 | -89321 | .. | .. | -8125 | 0 | -103441 | .. |
| Losses | -16 | .. | -486 | -198 | -34108 | .. | .. | -35910 | -7507 | -78226 | .. |

Primary energy production(PEP)

Total energy supply (TES)

RES shares,
Efficiency of transformations

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# Efficiency of energy systems (1)

Power generation

$$\eta = \frac{Power\ output}{Fuel\ input}$$

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# Efficiency of energy systems (2)

Power and heat generation

$$\eta = \frac{Power\ and\ heat\ output}{Fuel\ input}$$

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# Efficiency of energy systems (3)

Heat generation

$$\eta = \frac{Heat\ output}{Fuel\ input}$$

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# Simple energy balance matrix – 3. part
## Final energy and non-energy consumption

**Uzbekistan**

Terajoules

| 2020 | Primary coal and peat | Coal and peat products | Primary Oil | Oil Products | Natural Gas | Biofuels and waste | Nuclear | Electricity | Heat | Total energy | of which: renewables |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Final consumption** | 53737 | 1130 | .. | 171056 | 806693 | *2366 | .. | 187024 | 76863 | 1298869 | *2366 |
| **Final energy consumption** | 53737 | 1130 | .. | 156922 | 779397 | *2366 | .. | 187024 | 76863 | 1257439 | *2366 |
| **Manufacturing, const., mining** | 9635 | .. | .. | 4562 | 162865 | .. | .. | 71036 | 17970 | 266068 | .. |
| **Transport** | 157 | .. | .. | 126502 | 112574 | .. | .. | 3809 | .. | 243041 | .. |
| Road | .. | .. | .. | 121832 | 95749 | .. | .. | .. | .. | 217582 | .. |
| Rail | 157 | .. | .. | 4402 | .. | .. | .. | 1338 | .. | 5898 | .. |
| Domestic aviation | .. | .. | .. | *199 | .. | .. | .. | .. | .. | *199 | .. |
| Domestic navigation | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| Pipeline transport | .. | .. | .. | .. | 16824 | .. | .. | 2233 | .. | 19057 | .. |
| Transport, n.e.s | .. | .. | .. | 69 | .. | .. | .. | 238 | .. | 307 | .. |
| **Other** | 43945 | 1130 | .. | 25858 | 503958 | *2366 | .. | 112179 | 58893 | 748330 | *2366 |
| Agriculture, forestry, fishing | 643 | .. | .. | 147 | 9767 | .. | .. | 33129 | 2387 | 46072 | .. |
| Commerce, public services | 4261 | .. | .. | 6676 | 90244 | .. | .. | 18860 | .. | 120041 | .. |
| Households | 10893 | .. | .. | 17959 | 364572 | .. | .. | 55978 | 50121 | 499523 | .. |
| Other consumers | 28148 | 1130 | .. | 1077 | 39376 | *2366 | .. | 4212 | 6385 | 82694 | *2366 |
| **Non-energy use** | .. | .. | .. | *14134 | 27296 | .. | .. | .. | .. | 41429 | .. |

The most common energy indicators:

- Energy intensities,
- Energy efficiency,
- Demand forecast,
- Energy poverty
- Consumer protection (in case of crisis, natural disasters....)
- Price impacts

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