ENE 101: Introduction to Energy Engineering

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SYLLABUS OF THIS COURSE

WEEK 1: Energy Basics

WEEK 2: Climate

WEEK 3: Renewable Energies

WEEK 4: Energy Engineering Discipline

WEEK 5: Economics

WEEK 6: Energy Consumption And Conversion

WEEK 7-9: Energy Conversion

WEEK 10: Energy distribution/ transmission – electricity & Smart Technologies

WEEK 11: Energy Efficient Buildings

WEEK 12: Energy Management

OTHER IMPORTANT INFORMATION

Marking scheme:

Presentation: 30 %

Final Exam: 80 %

USEFUL INFORMATION SOURCES

- International Energy Agency: Excellent source of Global statistical information. http://www.iea.org

- US Department of Energy: Has huge free archive of global energy related information. http://www.energy.gov/

- **Energy and Natural Resources in TURKEY: Best source of statistics on Turkish Energy usage.** http://www.enerji.gov.tr/en-US/Mainpage

Week 1:
Energy Basics

What is Energy?

- The word '**ENERGY**' itself is derived from the Greek word 'en-ergon', which means 'in-work' or 'work content'.

- ***Energy*** is ***"the capacity to do work".*** It is the power to create, shape, transform and animate**.** "**work**" is the action of moving something against a force. The work output depends on the energy input.

- Energy is always conserved (or converted into mass) so is incredibly useful in working out the results of any kind of physical or chemical process.

- It's essential to modern life. We depend on energy.

* $\frac{1}{2} mv^2$
* mgh
* $P_{ext} \Delta V$
* $C_v \Delta T$
* I^2R
* $h\nu$
* mc^2

http://energytomorrow.org/energy-is-everything

History of Energy

The history of energy consumption shows how important energy is to the quality of life for each of us.

Before Industrial Revolution:

For heat: sun and burned wood, straw, and dried dung were used

For transportation: horses and the power of the wind in our sails were used.

For work: animals were used to do jobs that we couldn't do with our own labor. Water and wind drove the simple machines that ground our grain and pumped our water.

http://www.ucsusa.org/clean_energy/our-energy-choices/a-short-history-of-energy.html#.WblykcgjFPY

Before Industrial Revolution

six different periods of societal development from oldest to most recent

Table 1-1
Historical Energy Consumption [Cook, 1971]

Period	Era	Daily per capita Consumption (1000 kcal)				
		Food	H & C*	I & A**	Trans.***	Total
Primitive	1 million B.C.	2				2
Hunting	100,000 B.C	3	2			5
Primitive Agricultural	5000 B.C.	4	4	4		12
Advanced Agricultural	1400	6	12	7	1	26
Industrial	1875	7	32	24	14	77
Technological	1970	10	66	91	63	230

* H & C = Home and Commerce
** I & A = Industry and Agriculture
*** Trans. = Transportation

personal energy consumption was relatively constant until the Advanced Agricultural period when it increased substantially.

https://is.muni.cz/el/1423/podzim2013/MEB423/um/Energy_Concepts.pdf

Industrial Revolution (1750-1850)

- Machines replaced human/animal labor in manufacture and transportation
- Steam engines: heat energy into forward motion
- A single steam engine, powered by coal, could do the work of dozens of horses.
- Changes in agriculture, manufacturing, mining, transportation and technology ultimately affected social and economic conditions.

After Industrial Evolution

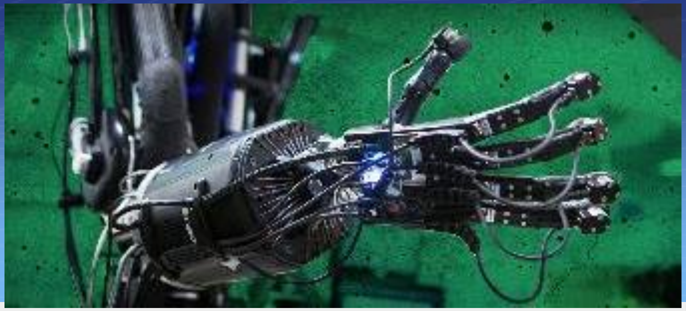
- Steam engines were soon powering locomotives, factories, and farm implements.
- Coal was also used for heating buildings and smelting iron into steel.
- In 1880, coal powered a steam engine attached to the world's first electric generator.
- Thomas Edison's plant in New York City provided the first electric light to Wall Street financiers and the New York Times.
- By the late 1800s, a new form of fuel was catching on: **petroleum**. By the turn of the century, oil, processed into gasoline, was firing internal combustion engines.
- Energy use grew quickly, doubling every 10 years.

http://www.ucsusa.org/clean_energy/our-energy-choices/a-short-history-of-energy.html#.WblykcgjFPY

After Industrial Evolution

- The cost of energy production was declining steadily, and the efficient use of energy was simply not a concern.
- After World War II (1939 to 1945) unleashed nuclear power, the government found it in electricity production. Over 200 nuclear power plants were planned across the country, and homes were built with all-electric heating systems to take advantage of this power.
- Gasoline use grew unchecked as well. Cars grew larger and heavier throughout the 1950s and 1960s. By 1970, the average mileage of an American car was only 13.5 miles per gallon, and a gallon of gas cost less than a quarter.

Nowadays……



- The invention of the automobile
  - increased the demand for oil products
  - 2% in 1900 to 40% in 2010

Within 200 years, energy consumption of industrialized nations increased eightfold.

- More cars
  - Job growth in automobile-related industries.
  - Major role in development of industrialized nations.
- Cars altered people's lifestyles:
  - Vacationers --greater distances.
  - People could live farther from work
    - Led to cities and suburbs.
    - labor-saving, energy-consuming devices became essential
    - Energy dependent

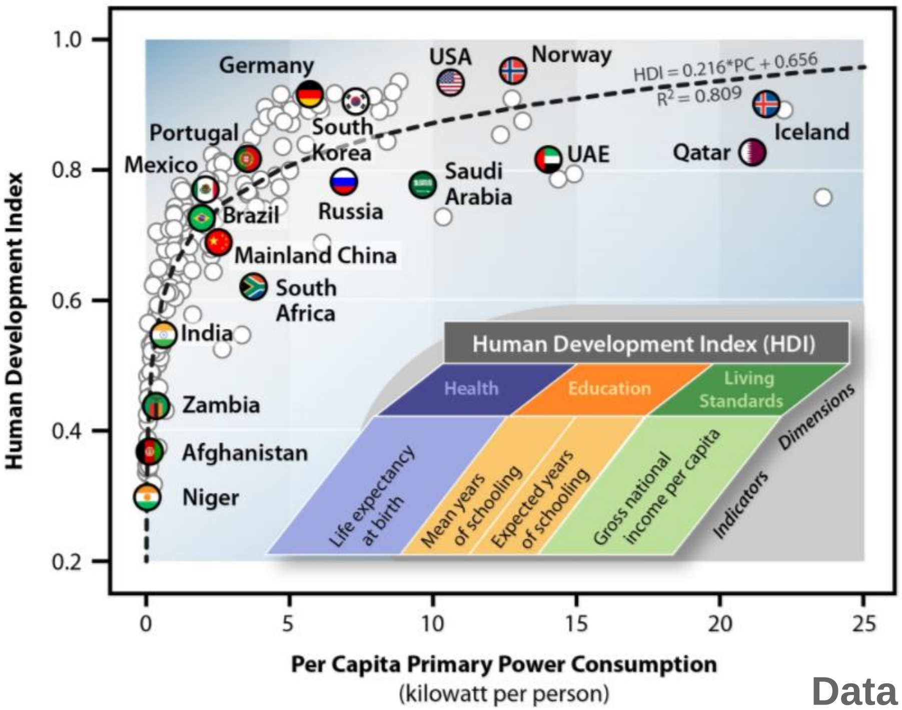
Energy Consumption and Standard of Living

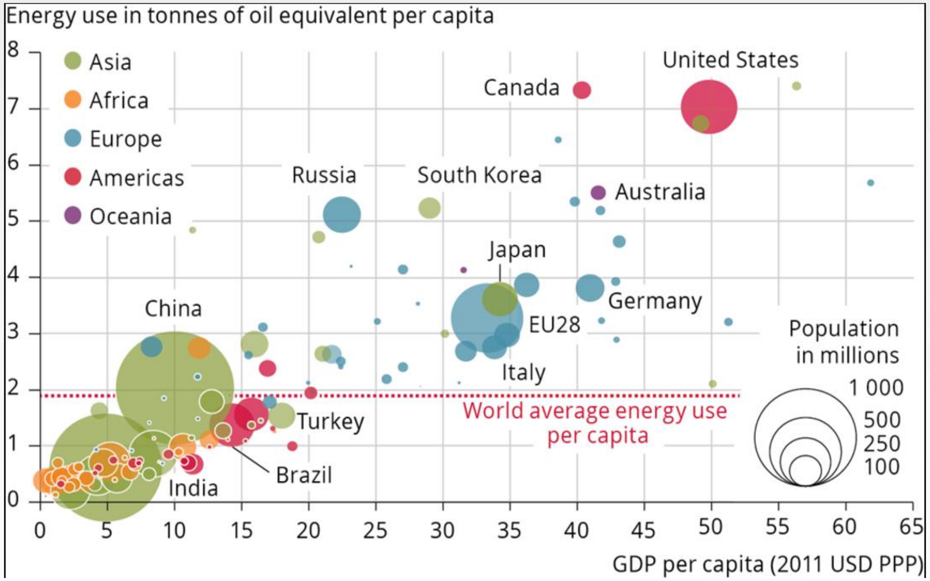
The energy consumption of a nation can be broadly divided into the following areas or sectors depending on energy-related activities:

- Domestic sector (houses and offices including commercial buildings)
- Transportation sector
- Agriculture sector
- Industry sector

Consumption of a large amount of energy in a country indicates increased activities in these sectors. This may imply better comforts at home due to use of various appliances, better transport facilities and more agricultural and industrial production. **All of this amount to a better quality of life.** Therefore, the ***per capita energy consumption of a country is an index of the standard of living*** or prosperity (i.e. income) of the people of the country.

Energy Consumption and Standard of Living





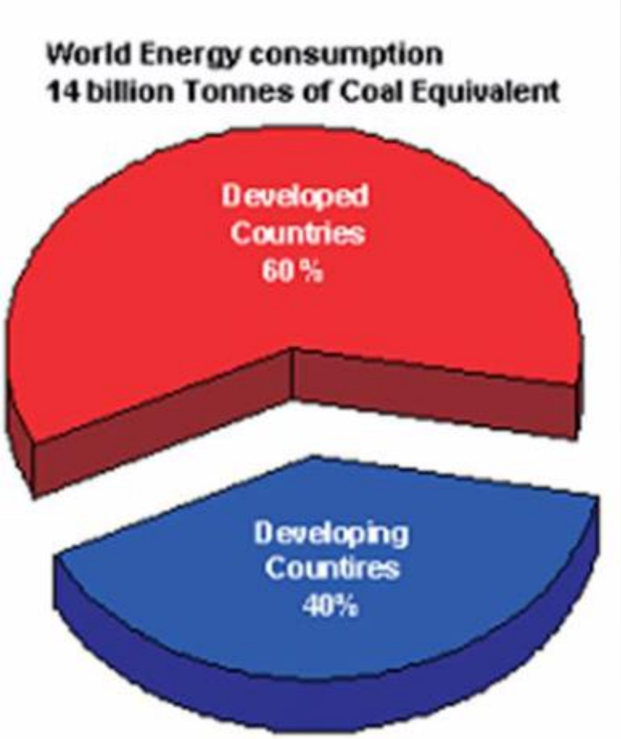
Data source: World Bank World development indicators

https://www.eea.europa.eu/soer-2015/global/competition

http://www.ourenergypolicy.org/growing-poor-slowly-why-we-must-have-renewable-energy/

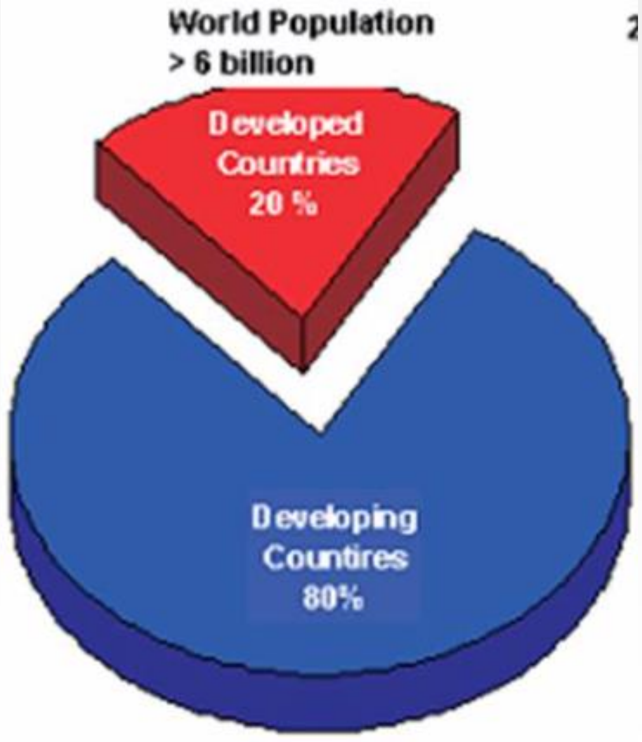
Energy distribution between developed and developing Countries

Although 80 percent of the world's population lies in the developing countries their energy consumption amounts to only **40** percent of the world total energy consumption.



Energy distribution between developed and developing Countries

- The world average energy consumption per person is equivalent to 2.2 tones of coal.
- In industrialized countries, people use 5 times more than the world average and 9 times more than the average for the developing countries.



Energy Balance

An energy balance is a set of relationships accounting for all energy which is produced, transformed and consumed in a certain period. It can be set up for a village, a household, a farm, or an agricultural unit, region or a country.

source + import = export + variation of stock + use + loss

Sources are the local (or national) primary energy sources, like coal, hydro, biomass, animate, etc.

Imports are energy sources which come from outside the region (or country).

Exports go to other regions (or countries).

Variations of stock are reductions of stocks (like of forests, coal, etc.), and storage.

Use can be specified sectoral, or by energy form, or by end-use, etc., as required.

Losses:

*technical losses are due to conversions and transport or transmission

*administrative losses are due to non-registered consumptions.

http://www.fao.org/docrep/u2246e/u2246e02.htm

Energy balance

- Energy balances provide overviews, which serve as tools for analyzing current and projected energy positions.
- Energy data are to be translated into economic terms, for a further analysis of options for action.
- It is useful for purposes of **resource management**, or for **indicating options in energy saving**, or for **policies of energy redistribution**, etc. However, care must be taken not to single out energy from other economic goods. That means that an energy balance should not be taken as our ultimate guide for action.

Basic Units and Dimensions

Table 1. Basic SI units

dimension	basic unit	symbol
length	meter	m
mass	kilogram	kg
time	Second	s
electric current	ampere	A
temperature	kelvin	°K

The unit of energy in this unit system is joule (J), and the unit of power is watt (W)

(*) The force exerted by a mass of 1 kg equals ca. 10 N.
(**) The energy required to lift 1 kg by 1 meter. Note that = W.s.

Table 2. Derived SI units

dimension	unit	symbol
area	square meter	m^2
volume	cubic meter	m^3
speed	meter per second	m/s
acceleration	meter per second	m/s^2
pressure	pascal	Pa (=N/m)
volume flow	cubic meter per second	m^3/s
mass flow	kilogram per second	kg/s
density	kilogram per cubic meter	kg/m^3
force	newton (*)	$N(=kg.m/s^2)$
energy	joule (**)	J(=N.m)
power	watt	W (=J/s)
energy flux	watt per square meter	W/m^2
calorific value	joule per kilogram	J/kg
specific heat	joule per kilogram kelvin	J/kg.K
voltage	volt	V (=W/A)

http://www.fao.org/docrep/u2246e/u2246e02.htm

Basic Units and Dimensions

Quantity	SI-unit	Alternative units
Time	s (second)	h (hour)
Length	m (meter)	in (inch)
		ft (foot)
Mass	kg (kilogram)	lb (pound)
Temperature	K (Kelvin)	°C (Celsius)
		°F (Fahrenheit)
Force	N (Newton)	kp (kilopond)
Pressure	Pa (Pascal) = N/m^2	bar
		atm (atmosphere)
		mm Hg (millimeter mercury column)
		psi (pound per square inch)
Energy	J (Joule) = Nm	kWh (kilowatt hour)
		cal (calorie)
		Btu (British thermal unit)
Power	W (Watt) = J/s	calorie/h, Btu/h

https://www.slideshare.net/samyji/si-units-and-horse-power

Energy Units and Dimensions

Important Units

- **Tonnes of Oil Equivalent** 1toe = 41.88 GJ
- **Billion Cubic Metres** (of Natural Gas) 1 bcm = 39 PJ (10^{15}J)
- **Barrels of Oil** 1 boe = 5.71 GJ
- **Joule = SI Unit of Energy**
- **kiloWatt Hour** = 1kWh=3.6 MJ
- **British Thermal Unit (BTU)=** 1055 J
- **Calorie** = 1 cal = 4.19 J

http://eleceng.dit.ie/kgaughan/notes/DT0214%20Energy%20Resources/Microsoft%20PowerPoint%20%20Lecture%201%20Introduction%20and%20General%20Energy%20Concepts.pdf

The examples are all equivalent to ~ 100 kJ;

- energy released in burning 3.5 g coal or 2.9 g petrol;
- the energy stored in 1/4 slice of bread
- a large object (1,000 kg) at a height of 10 m
- energy produced by a windmill of 3 m diameter in a wind speed of 5 m/s (a breeze) during 20 minutes;
- heat emanated in cooling three cups of coffee (0.4 kg) from 80°C to 20° C;
- the energy needed to melt 0.3 kg ice
- an iron flywheel of 0.6 m diameter and 70 mm thick, rotating at 1,500 revolutions per second
- energy consumed by a 100 W electric light bulb in 17 minutes

Q1 How much heat is produced by a human body?

A man doing no or very little physical work needs about 2,000 kcal (or less) of energy in his daily food. The body converts this energy almost entirely into heat.

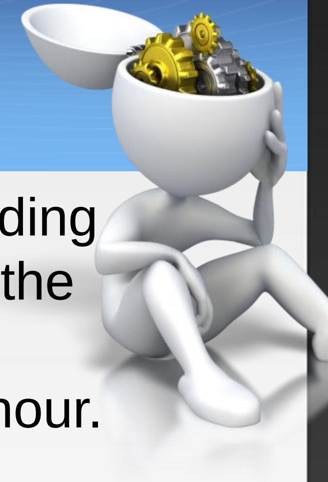
1 day = 24 x 60 x 60 s = 86,400 s 1 cal = 4.2 J

Hence

$$2{,}000\text{kcal}/\text{day} = 2{,}000 \times 4.2\text{kj}/\text{day} = \frac{8.4\,\text{Mj}}{86{,}600\text{s}} = 100\text{j}/\text{s} = 100\text{W}$$

We see that a human body doing no work is equivalent to a heat source of about 100 W -the equivalent of a good bulb.

Q2 How can we check that a human body can deliver 60 W during a few hours per day?



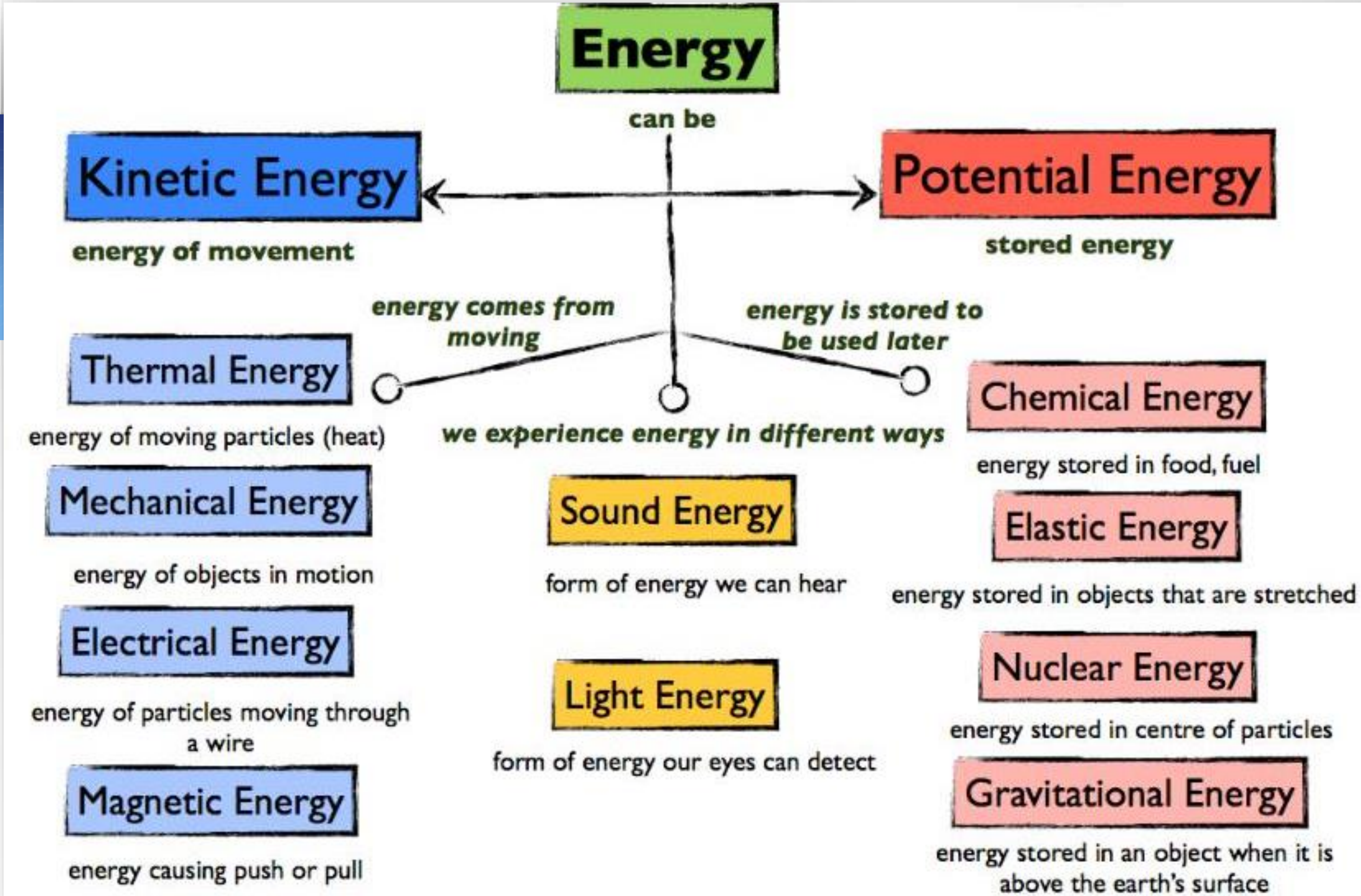
The actual value could be measured, and it will vary a lot, depending on many factors. One way of checking the order of magnitude is the following.

Mountaineers know that a man can climb about 300 meters per hour. Assume that his weight is 75 kg. The gravitational force he is counteracting is then:

75 x 9.8 Newton = 750 N The energy delivered by the man in an hour is:

300 m x 750 N = 225 kNm = 225 kJ.

The power delivered is $\frac{225kj}{3600s} = 62.5N/s = 62.5W$



http://mskuksclass.weebly.com/lesson-2-forms-of-energy.html

What is Energy Conversion?

Energy conversions means converting energy from one form into another.

- No energy can be created or destroyed.
- All we can do is transform or convert energy from one form into another.
- In all conversions, we find that part of the energy is lost. This does not mean that it is destroyed, but rather that it is lost for our purposes, through dissipation in the form of heat or otherwise.

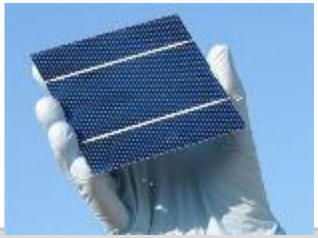
https://youtu.be/IqV5L66EP2E 4:38

http://www.fao.org/docrep/u2246e/u2246e02.htm

Examples of Energy Conversion

For Power generation we convert potential energy from hydro resources into mechanical energy, but for water pumping for lift irrigation, we do the reverse.

With Photovoltaic cells we convert radiation energy into electricity, whereas with light bulbs we do the reverse.



Wind turbine generates energy, which means it converts kinetic energy from wind into mechanical energy.

Diesel engine generates energy, which means that the engine converts chemical energy of oil into mechanical energy

Energy losses and efficiency

- Energy conversions always imply energy losses. The output energy in the desired form is only a part of the Input energy. The balance is the energy loss (usually in the form of diffused heat). It means the converter has less than 100% efficiency.

- The efficiency of an energy converter is now defined as the quantity of energy in the desired form (the output energy) divided by the quantity of energy put in for conversion (the input energy):

$$\eta = \frac{output\ energy}{input\ energy}$$

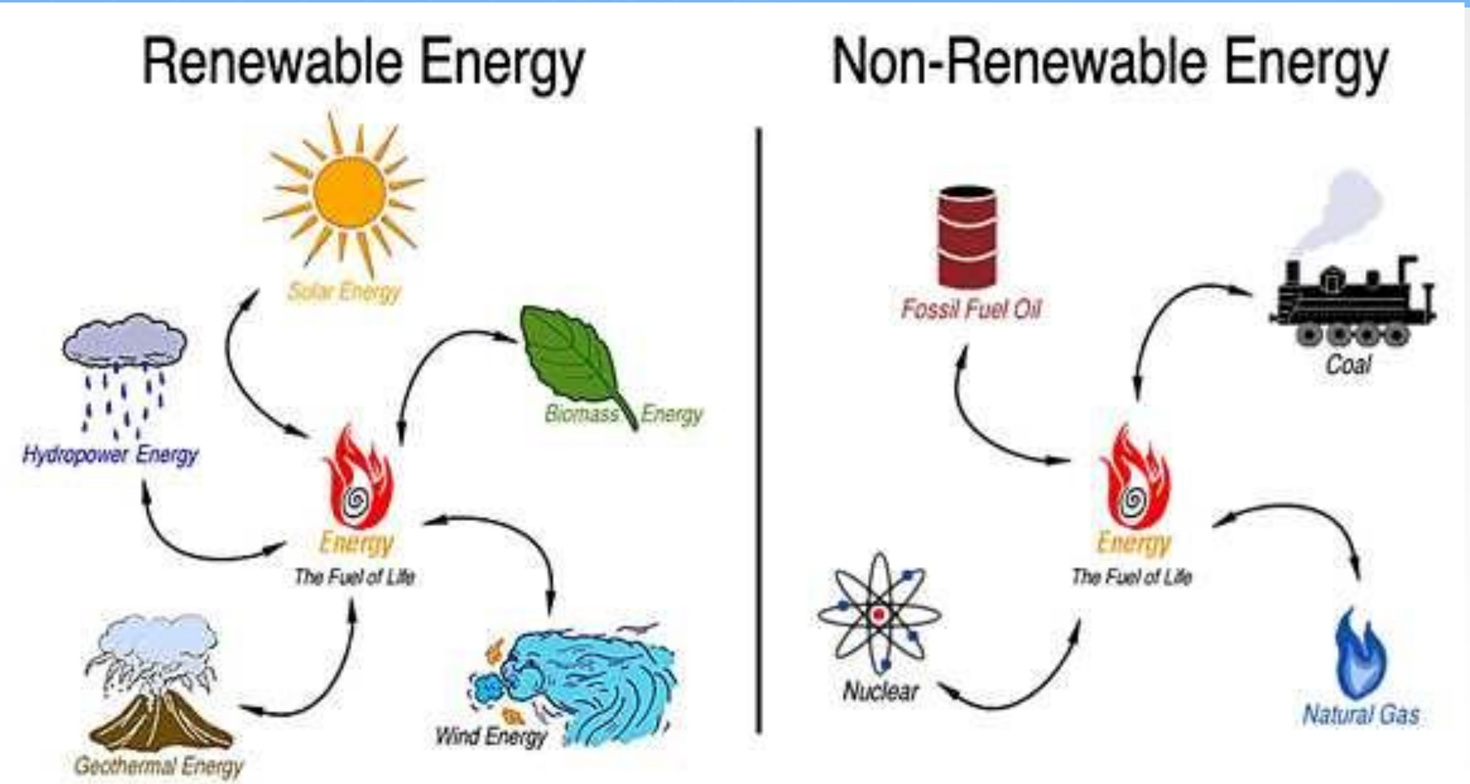
http://www.fao.org/docrep/u2246e/u2246e02.htm

Renewable vs. Non-Renewable Energy Resources

Renewable Energy is energy obtained from sources that are essentially inexhaustible. Examples of renewable resources include wind power, solar power, geothermal energy, tidal power, and hydroelectric power. The most important feature of renewable energy is that it can be harnesses without the release of harmful pollutants.

Non renewable energy is the conventional fossil fuels such as coal, oil, and gas, which are likely to deplete with time.

Renewable vs. Non-Renewable Energy Resources



http://worldartsme.com/images/forms-of-energy-clipart-1.jpg

Conventional (Non-Renewable) Energy Resources

- **Global Primary Energy Reserves**

The global primary energy consumption at the end of 2003 was equivalent to 9741 million tons of oil equivalent (MTones).

Global Primary Energy Reserves : COAL

1. Coal is the second most important energy source, covering 30% of global primary energy consumption. Hard coal and lignite (brown coal) is the leading energy source in power generation with 40% of globally generated power relying on this fuel.
2. The world currently consumes over 7 700 Milliontone of coal which is used by a variety of sectors including power generation, iron and steel production, cement manufacturing and as a liquid fuel.
3. Coal currently fuels 40% of the world's electricity.
4. Global coal consumption increased by 64% from 2000 to 2014. That classified coal as the fastest growing fuel in absolute numbers within the indicated period.
5. China contributes 50% to global coal demand and is shifting to clean coal technologies. India's coal consumption is set to increase, while the US is closing or replacing coal with gas in power plants.

Top coal producing countries and regions in the world for 2014 and 2015.

Table 1: Top coal producing countries in 2014 and 2015

Million Tonnes	Production	
Country	Total production 2014*	Total production 2015**
Australia	503.3	485
China	4000	3747
Germany	186.5	184
India	659.6	677
Indonesia	470.8	392
Kazakhstan	115.6	106
Poland	136.9	136
Russia	357	373
South Africa	253.2	252
USA	906.9	813

Top coal producing countries and regions in the world for 2014 and 2015.

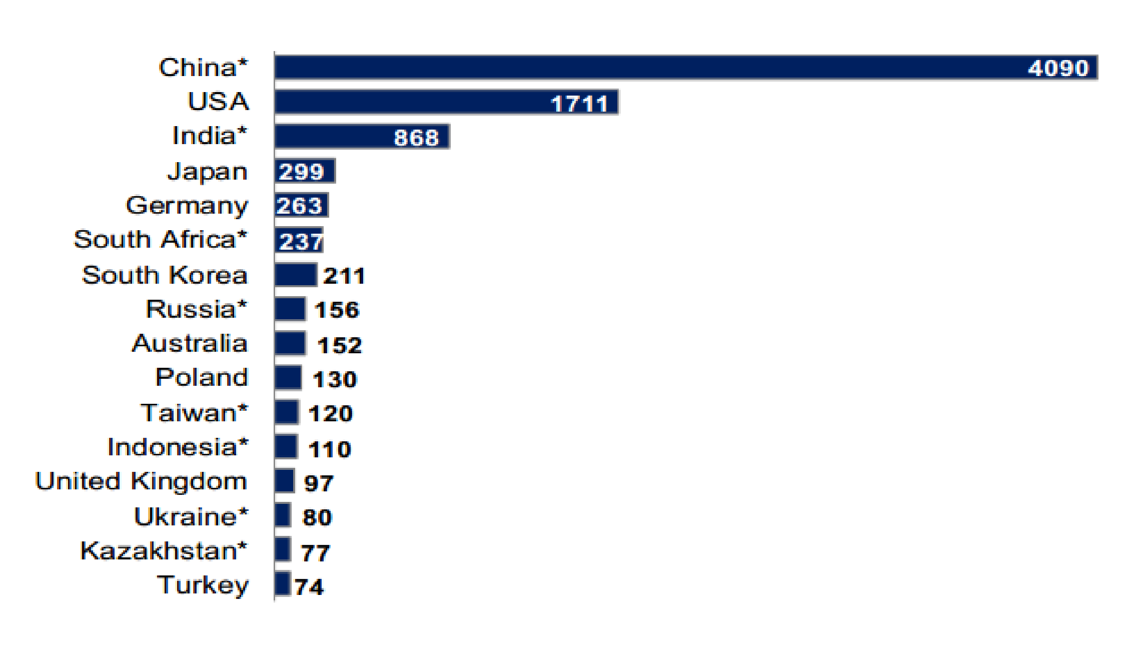
Table 2: Top coal producing regions in 2014 and 2015

Million Tonnes	Production	
Region	**Total production 2014***	**Total production 2015****
Total Africa	265.7	266
Total Asia Pacific	5 651.4	5440
Total CIS	544.8	527
Total EU	8 795.2	528
Total Middle East	2.8	1
Total North America	989.9	888
Total S. & Cent. America	103	98
World	8,176.4	7861

* BGR

** BP Statistical Review of World Energy 2016

2014 Country Ranking: Coal-fired Power Generation (Twh)



Source: IEA, Electricity Information, Paris 2015 (*for Non-OECD-countries numbers for 2013)

Global Primary Energy Reserves : OIL

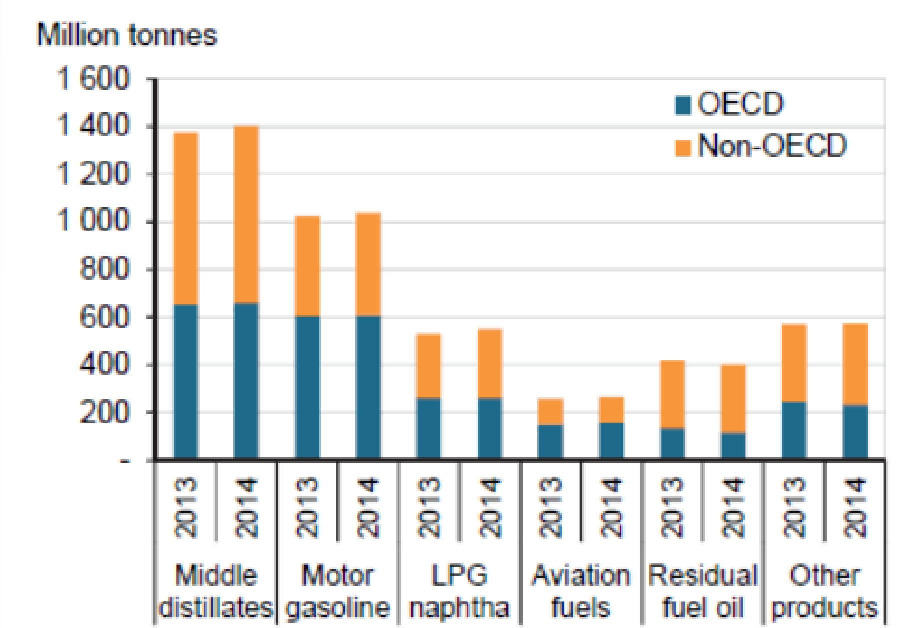
1. Oil remains the world's leading fuel, accounting for 32.9% of total global energy consumption. Although emerging economies continued to dominate the growth in global energy consumption, growth in these countries (+1.6%) was well below its ten-year average of 3.8%.
2. The growth of population and the consumer class in Asia will support oil demand increase and the main increase in consumption will come from transportation sectors.
3. Despite the temporary price drop, the fundamentals of the oil industry remain strong. Price fluctuations seen of late have been neither unexpected nor unprecedented.
4. Substitution of oil in the transport sector is not yet imminent and is not expected to reach more than 5% for the next five years.
5. Emerging economies now account for 58.1% of global energy consumption and global demand for liquid hydrocarbons will continue to grow. Chinese consumption growth slowed to 1.5%, while India (+5.2%) recorded another robust increase in consumption.

Global oil demand, by region from 2014-2020

Table 3: Global oil demand, by region from 2014-2020

	2014	2015	2016	2017	2018	2019	2020	2014-2020
OECD Americas	24.1	24.2	24.3	24.4	24.5	24.4	24.4	0.3
OECD Asia Ocean	8.1	8.0	7.9	7.9	7.9	7.9	7.8	-0.3
OECD Europe	13.4	13.3	13.3	13.2	13.1	13.0	12.9	-0.5
FSU	4.8	4.6	4.7	4.7	4.8	4.9	5.0	0.1
Other Europe	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.1
China	10.4	10.6	10.9	11.2	11.5	11.8	12.1	1.7
Other Asia	12.1	12.5	12.9	13.3	13.7	14.1	14.5	2.4
Latin America	6.8	6.9	7.0	7.1	7.2	7.3	7.4	0.6
Middle East	8.1	8.3	8.5	8.8	9.0	9.2	9.5	1.4
Africa	3.9	4.1	4.2	4.4	4.5	4.6	4.8	0.9
World	**92.4**	**93.3**	**94.5**	**95.7**	**96.9**	**98.0**	**99.1**	**6.6**

Product-market Consumption Trends



Source: IEA Medium Term Oil Report 2015

Global Primary Energy Reserves : Natural Gas

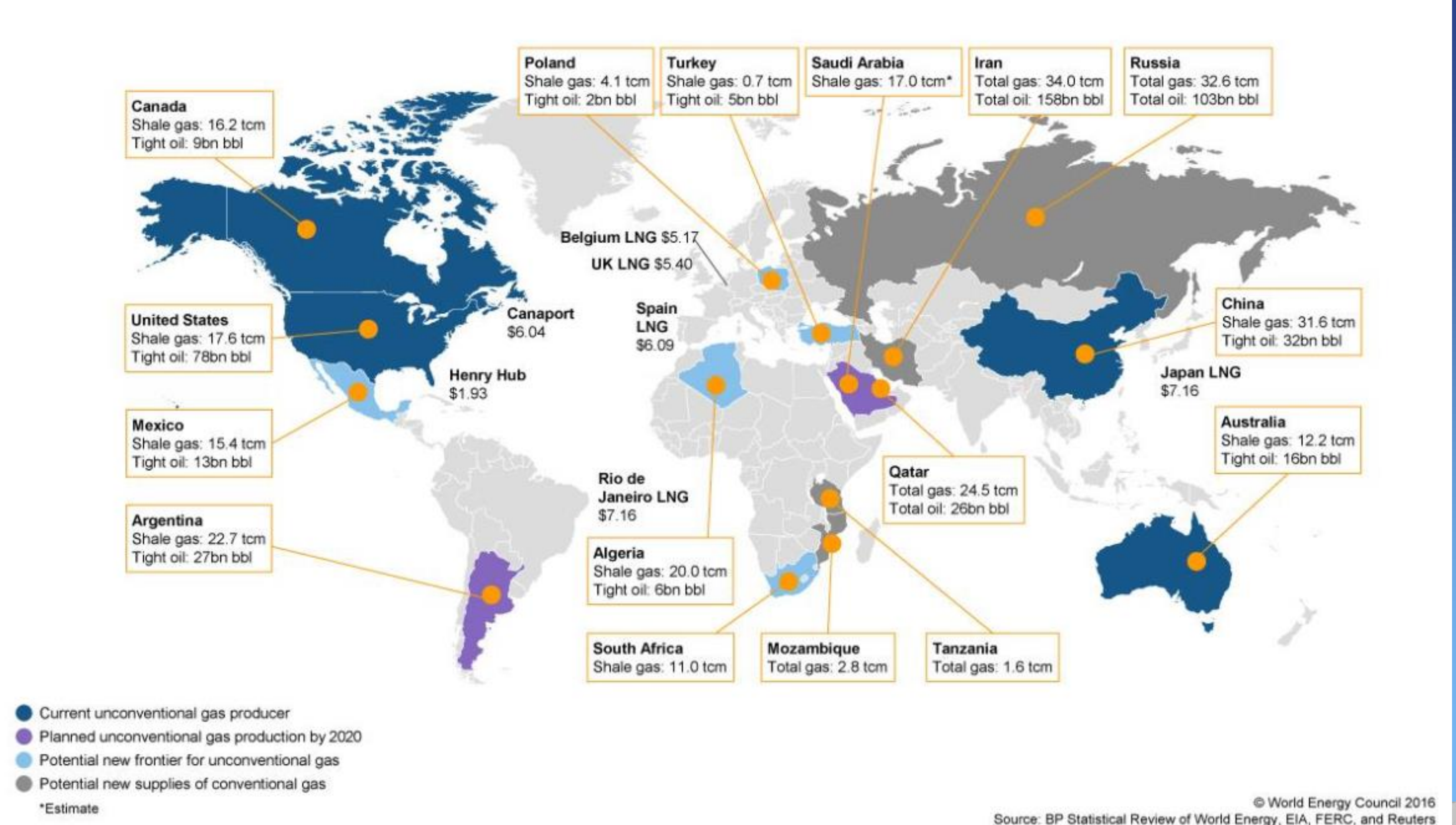
1. Natural gas is the only fossil fuel whose share of the primary energy mix is expected to grow and has the potential to play an important role in the world's transition to a cleaner, more affordable and secure energy future.
2. It is the number three fuel, reflecting 24% of global primary energy, and it is the second energy source in power generation, representing a 22% share.
3. The shifting dynamics in natural gas pricing in recent years can be attributed to regional supply and demand imbalances. North America prices collapsed in 2009, driven by a domestic oversupply, while from 2011-2013, the Japanese nuclear drove prices higher in Asia.
4. Currently, the fall in demand in Asia and growing export capacity in Asia and North America, have created an oversupply globally.
5. The future of demand is highly uncertain, new policy frameworks and continued cost improvements will be needed to make gas more competitive. Infrastructure build out, government support and the closure of regulatory gaps are needed to unlock the socioeconomic and environmental benefits of natural gas.

Regional Natural Gas Data by region

2015	Proved Reserves		Production		R/P Ratio
Region	Bcm	Bcf	Bcm	Bcf	Years
Africa Total	14064	496666.5	211.8	7479.2	66.4
Asia Pacific Total	15648.1	552607.7	556.7	19658.2	28.1
Europe & Eurasia Total	56778.4	2005109.3	989.8	34955.2	57.4
LAC Total	7591.5	268091.0	178.5	6302.1	42.5
Middle East Total	80040.9	2826617.7	617.9	21821.1	129.5
North America Total	12751.8	450326.0	984.0	34750.4	13.0
Global Total	186874.7	6599418.0	3538.6	124966.2	52.8

Sources: BP Statistical Review of World Energy 2015, OPEC Annual Statistical Bulletin 2015, EIA International Energy Statistics, CIA: The World Factbook, and published national sources

NEW SUPPLY LANDSCAPE (TECHNICALLY RECOVERABLE RESERVES)



Sources: BP Statistical Review of World Energy, EIA, FERC, and Reuters

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