Lecture 1: About Energy

KEMS821 Renewable Energy Production, fall 2013

Source: Jussi Maunuksela (2012)

General information

- Course description / Objectives
- Course information
- Instructors
- Text, readings, materials
- Grading

Course description for KEMS821 Renewable Energy Production (4 ECTS cr.)

Description

This course will focus on renewable energy sources (bioenergy, wind energy, solar energy, planetary energy and geothermal energy) <u>especially bioenergy and related technologies</u> and the issues in their use to supply energy systems. <u>Wind, solar, etc. will be dealt with in more detail in KEMS823.</u>

Goals (KEMS821 and KEMS823)

Students will gain knowledge and understanding of the available renewable energy sources and their limitations.

Course information for KEMS821 Renewable Energy Production (4 ECTS cr.)

Teaching modes

Lectures (24 h)
Homework assignments (problem solving, article reviews)
Group work (?)
Self-study
Final Exam

Examinations

Final Exam on Wed, 23 Oct 2013
Re-exams x.xx.2012, x.xx.2012

Instructors for the course

Jukka Konttinen, Professor
Room YlistöF513, email: jukka.t.konttinen@jyu.fi
Topic(s): General about renewable energy, Bioenergy

Lectures and topics

	Paikka	Viikko	Päivä	Pvm	Klo	Ohjaaja	Lisätietoja	URI
1	YlistöKem3	37	ma	9.9.2013	10:15-12:00	Konttinen	Energy, energy consumption	
2	YlistöKem3	37	ke	11.9.2013	12:15-14:00	Konttinen	Renewable energy production and technologies	
3	YlistöKem3	38	ma	16.9.2013	10:15-12:00	Konttinen	Renewable energy production / Bioenergy, basics	
4	YlistöKem3	38	ke	18.9.2013	12:15-14:00	Konttinen	Bioenergy, basics	
5	YlistöKem3	39	ma	23.9.2013	10:15-12:00	Konttinen	Bioenergy & climate change & sustainability, small-scale applications	
6	YlistöKem3	39	ke	25.9.2013	12:15-14:00	Konttinen	Small-scale thermal and CHP applications continued	
7	YlistöKem3	40	ma	30.9.2013	10:15-12:00	Konttinen	Torrefaction, pellets. fluidized bed combustion	
8	YlistöKem3	40	ke	2.10.2013	12:15-14:00	Konttinen	Recovery boilers & gasification	
9	YlistöKem3	41	ma	7.10.2013	10:15-12:00	Konttinen	Environmental/emissions and abatement technologies, R&D methods	
10	YlistöKem3	41	ke	9.10.2013	12:15-14:00	Konttinen	Biorefineries	
11	YlistöKem3	42	ma	14.10.2013	10:15-12:00	Konttinen	Biorefineries continued, liquid biofuels, SNG	
12	YlistöKem3	42	ke	16.10.2013	12:15-14:00	Konttinen	Research at JYU: Hybrid energy/Biorefineries	
13	YlistöKem3	43	ma	21.10.2013	10:15-12:00	Konttinen		
14	YlistöKem3	43	ke	23.10.2013	12:15-14:00	Konttinen	Final exam	

Students are encouraged to use the textbooks and handouts for self-study.

Textbook(s):

Godfrey Boyle (ed.), *Renewable Energy – Power for Sustainable Future*, Oxford University Press

Volker Quaschning, *Understanding Renewable Energy Systems*, Earthscan

Raiko, Saastamoinen, Hupa, Kurki-Suonio (eds.), *Poltto ja Palaminen*. *Toinen täydennetty painos.* International Flame Research Foundation - Finnish Flame Research Committee. In Finnish. (Chapters 1, 2, 3, 5, 8, 10, 11- 13, 16 – 20, 22)

Handout(s):

Lecture material (slides, assignments) is available in Koppa.

The course evaluation is based on homework, group work and final examination.

Grading

The grading scale is from 1 to 5, with 1 as the lowest and 5 as the highest grade.

The grade is based on homework and group work (max. 12 points), and final exam (max. 48 points/exam) results.

N.B

Homework sets are given for each topic of the course and they are submitted for grading one week after the topic's last lecture.

For maximum homework points students should complete 90 % of all homework questions. For one point 20 % of all homework questions should be completed.

THE CONCEPT OF ENERGY

“Energy can be described as the capacity to do work.”

“Energy can be stored within systems in various forms.”

“Energy can be converted from one form to another and transferred between systems.”

“The total amount of energy is conserved in all conversions and transfers.”

Source: Jussi Maunuksela (2012)

The concept of energy helps us to describe many processes in the world around us.

Electrical Energy

Falling water releases stored "gravitational potential energy" turning into a "kinetic energy" of motion. This "mechanical energy" can be used to spin turbines and alternators doing "work" to generate electrical energy.

Photo by Hammer51012 on Flickr

Chemical Energy

Burning gasoline in car engines converts "chemical energy" stored in the atomic bonds of the constituent atoms of gasoline into heat that then drives a piston. With gearing and road friction, this motion is converted into the movement of the automobile.

Photo by C. Frank Starmer

Source: Jussi Maunuksela (2012)

Energy consumption is conversion of energy forms into another.

Conservation of energy principle

Energy can change from one form to another but the total amount remains constant.

Different forms of energy

Mechanical energy
Gravitational potential energy
Kinetic energy (thermal energy)
Magnetic energy
Electrical energy
Radiation energy
Nuclear energy
Chemical energy

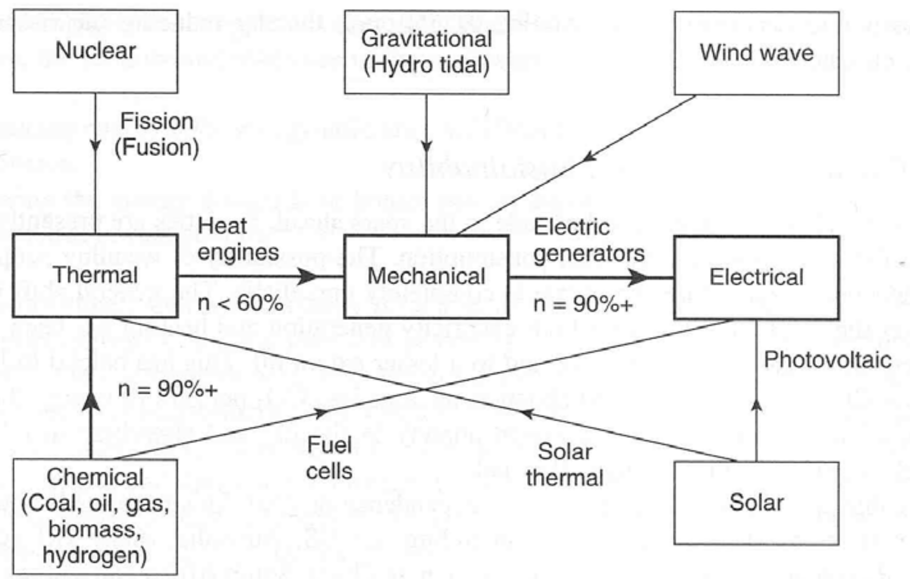


Figure 1.8 Conversion from a variety of energy forms into electricity

Figure from Freris & Infield "Renewable Energy in Power Systems" 2008

Source: Jussi Maunuksela (2012)

Any serious discussion of energy must be quantitative.

”My car uses very little oil.”

In driving a thousand kilometers, or standing in the garage?
Compared with Saudi Arabian exports or with a horse?

Photo by Albert Bridge

Requirements for comparing quantities

We must be able to measure them, i.e., we need units (*l*, *gallons*, *tons*).
We must know which type of quantity we are discussing (*l*, *l/km*, *l/h*).

Source: Jussi Maunuksela (2012)

Units and quantities of energy or power are mixed up frequently.

Energy (and work)
joule (J), watt-second (Ws)

Power
joule-per-second (J/s), watt (W)

TABLE 1.1. *Power and energy*

Power	
1 watt	= 1 joule per second
1 kilowatt	= 1000 joules per second
1 kilowatt	= 3 600 000 joules per hour
Energy	
1 kilowatt-hour	= 3 600 000 joules
1 kWh	= 3.6 MJ

Prefix	*Symbol*	*Value*	*Prefix*	*Symbol*	*Value*
Kilo	k	10^3 (thousand)	Milli	m	10^{-3} (thousandth)
Mega	M	10^6 (million)	Micro	μ	10^{-6} (millionth)
Giga	G	10^9 (billion)	Nano	n	10^{-9} (billionth)
Tera	T	10^{12} (trillion)	Pico	p	10^{-12} (trillionth)
Peta	P	10^{15} (quadrillion)	Femto	f	10^{-15} (quadrillionth)
Exa	E	10^{18} (quintillion)	Atto	a	10^{-18} (quintillionth)

Note: Words in parentheses according to US numbering system

Source: Jussi Maunuksela (2012)

Energies can be expressed as equivalent amounts of oil or coal.

Tonne of oil equivalent (toe)

When oil is burned its chemical energy is converted into heat energy, and 1 toe is simply the heat energy released in burning one tonne of oil.

1 Mtoe ≈ 42 PJ ≈ 12 TWh

Tonne of coal equivalent (tce)

Correspondingly, 1 tce is the heat released in burning one tonne of coal.

1 Mtce ≈ 28 PJ ≈ 7.5 TWh

Source: Jussi Maunuksela (2012)

The World present total consumption of primary energy is about 12 150 Mtoe (2009).

Primary energy

The total energy 'contained' in the the original source before its transformation into other useful forms like electricity.

Main resources

Fossil fuels (coal, oil, natural gas)
Biofuels (combustible renewables & waste)

Note:

'Other' includes geothermal, solar, wind, heat, etc.

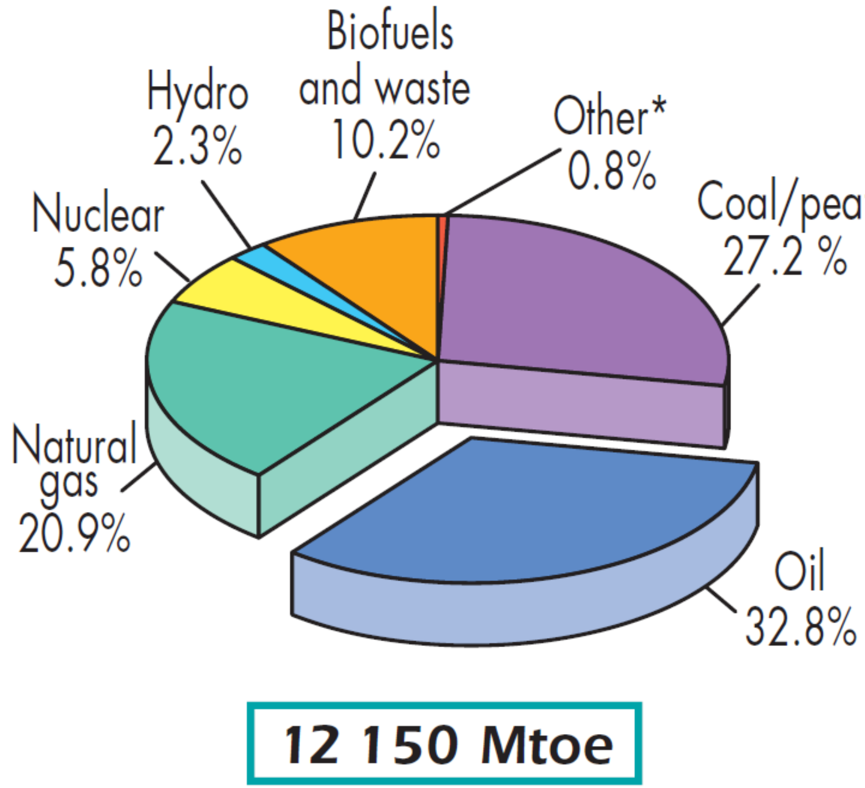


Chart from Key World Energy Statistics 2011 from IEA.

The average rate of World primary power consumption is 16 300 GW.

World primary <u>energy</u> consumption

12 267 Mtoe = 515 214 PJ ≈ 515 EJ

World primary <u>energy</u> consumption <u>*per capita*</u>

12 267 Mtoe / (6,8 x 10^9) = 1.8 toe

World primary <u>power</u> consumption

515 EJ / (365 h/days x 24 h/day x 60 min/h x 60 s/min)
= 0,0000163 EJ/s = 16 300 GJ/s = 16 300 GW

World primary <u>power</u> consumption <u>*per capita*</u>

16 300 GW / (6,8 x 10^9) = 2,40 kW *per capita*

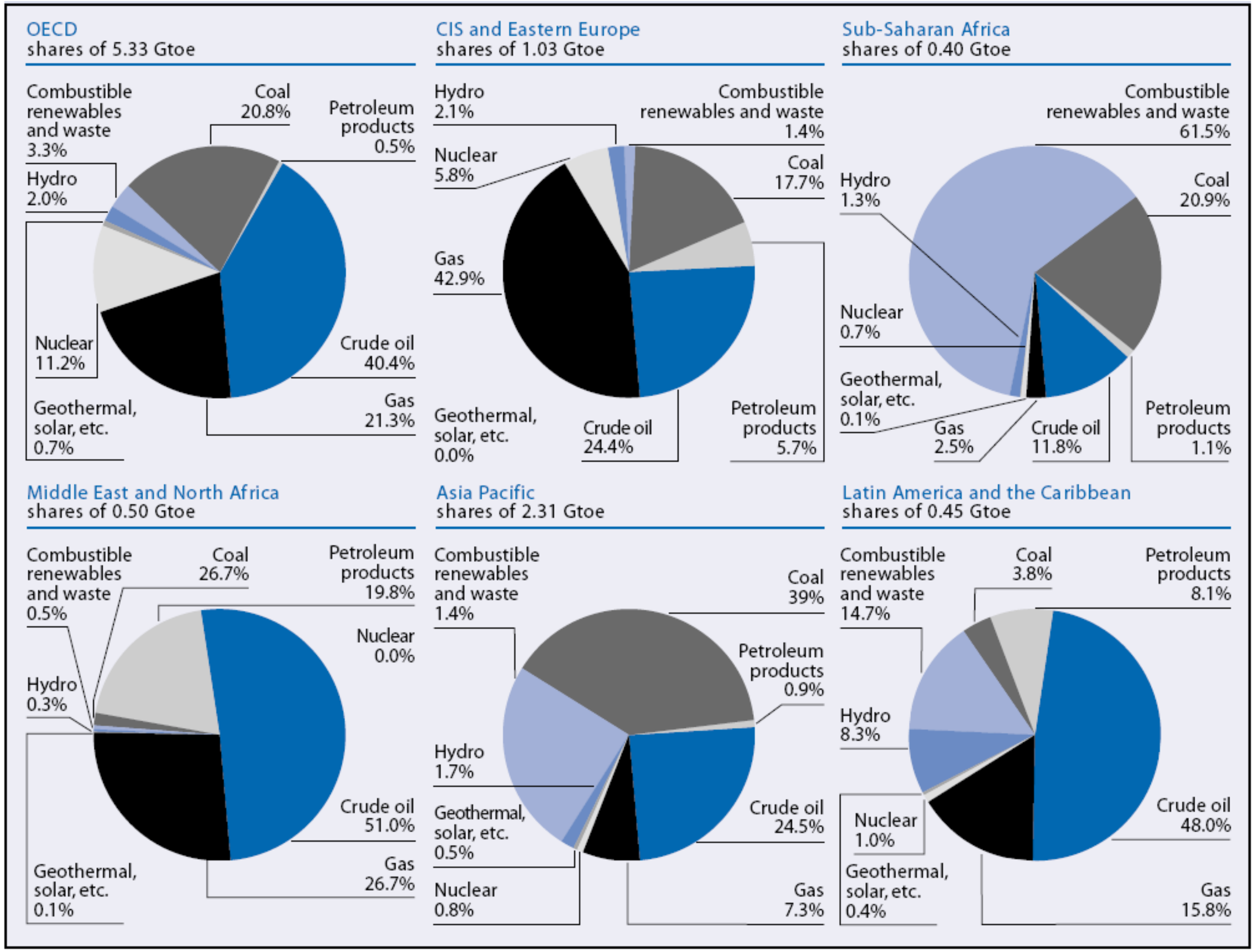
For example:

Refrigerator’s average rate of power consumption is 12,5-37,5 W.

Source: Jussi Maunuksela (2012)

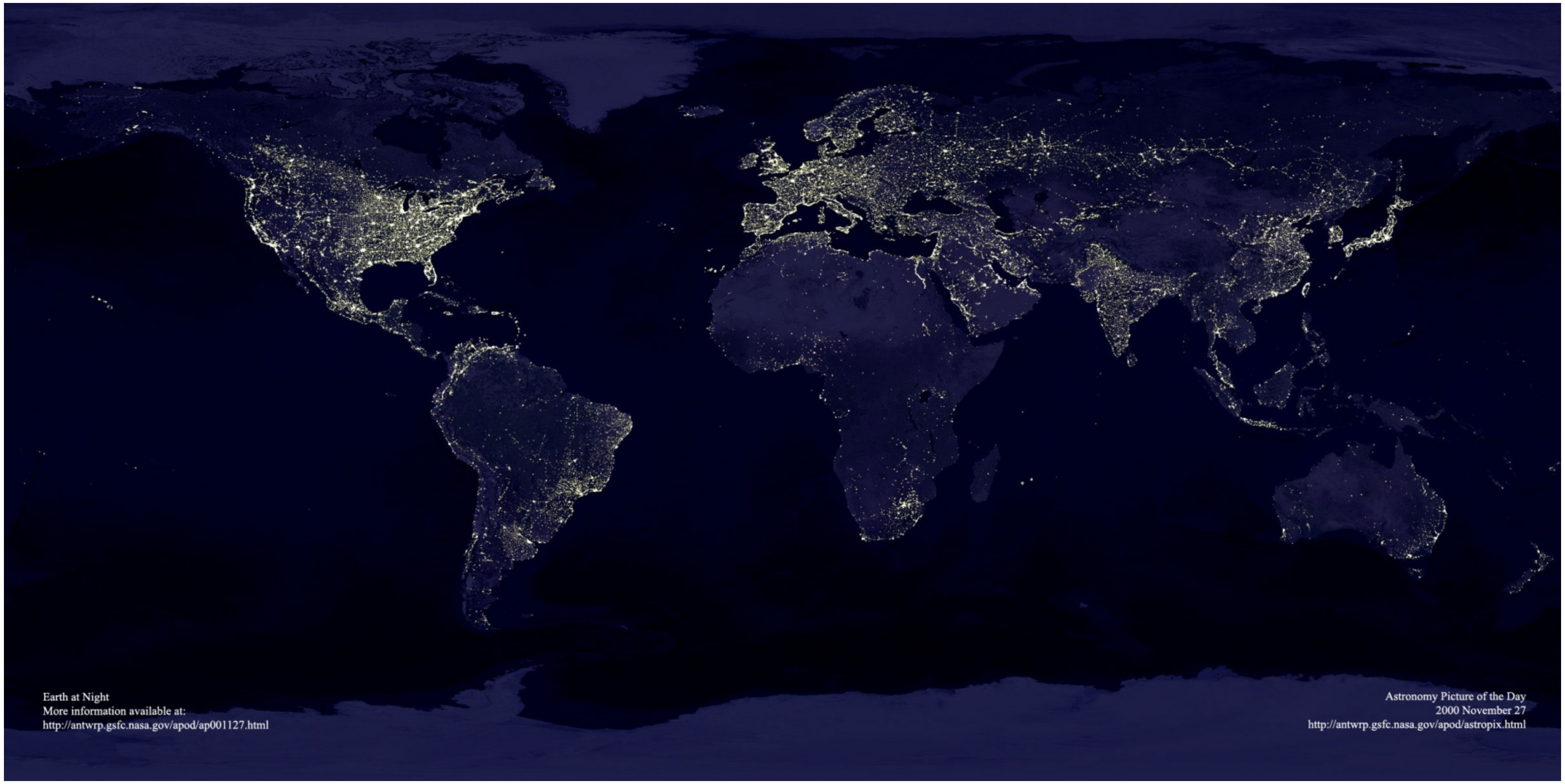
Availability and use of energy around the world is extremely heterogeneous.

Primary energy use in various regions, by energy source, 2001.



Source:
UNDP, World Energy Assessment Overview: 2004 update

Human-made lights highlight developed or polulated areas of the Earth’s surface.



Credit: C. Mayhew & R. Simmon (NASA/GSFC), NOAA/ NGDC, DMSP Digital Archive

In 2000, per capita use of primary energy in North America was >11 times as much as used by average sub-Saharan African.

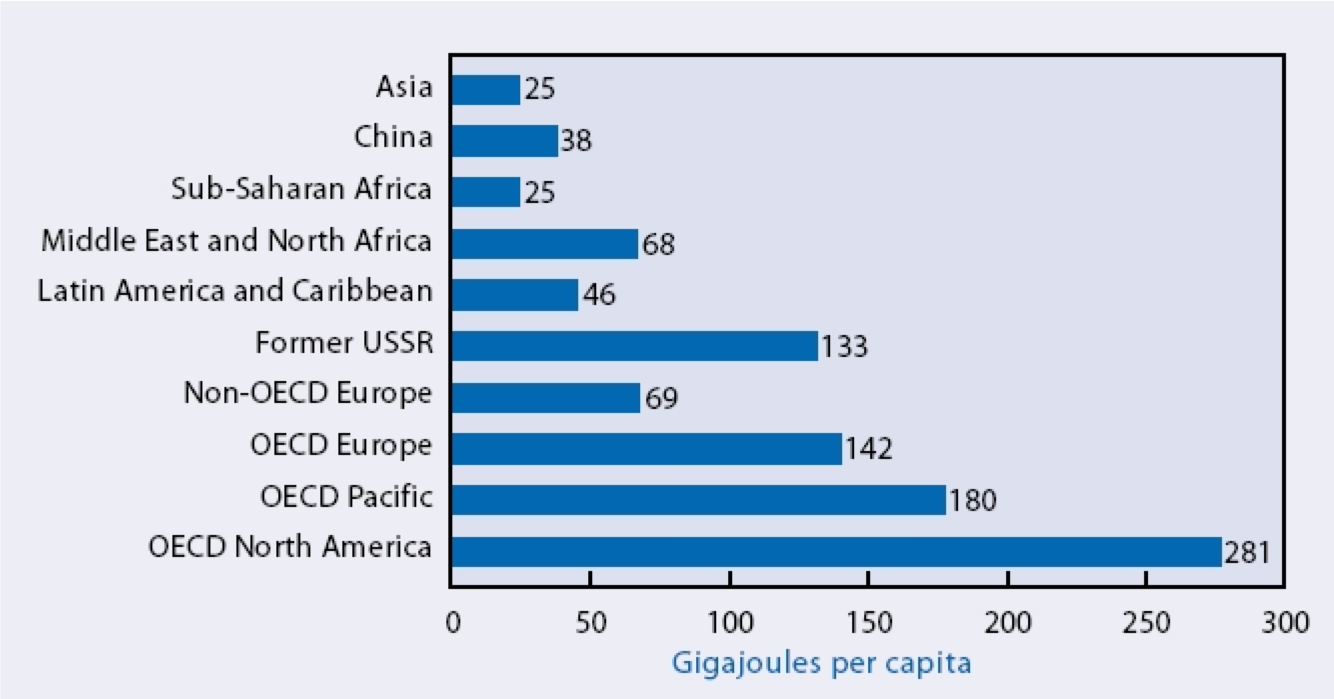
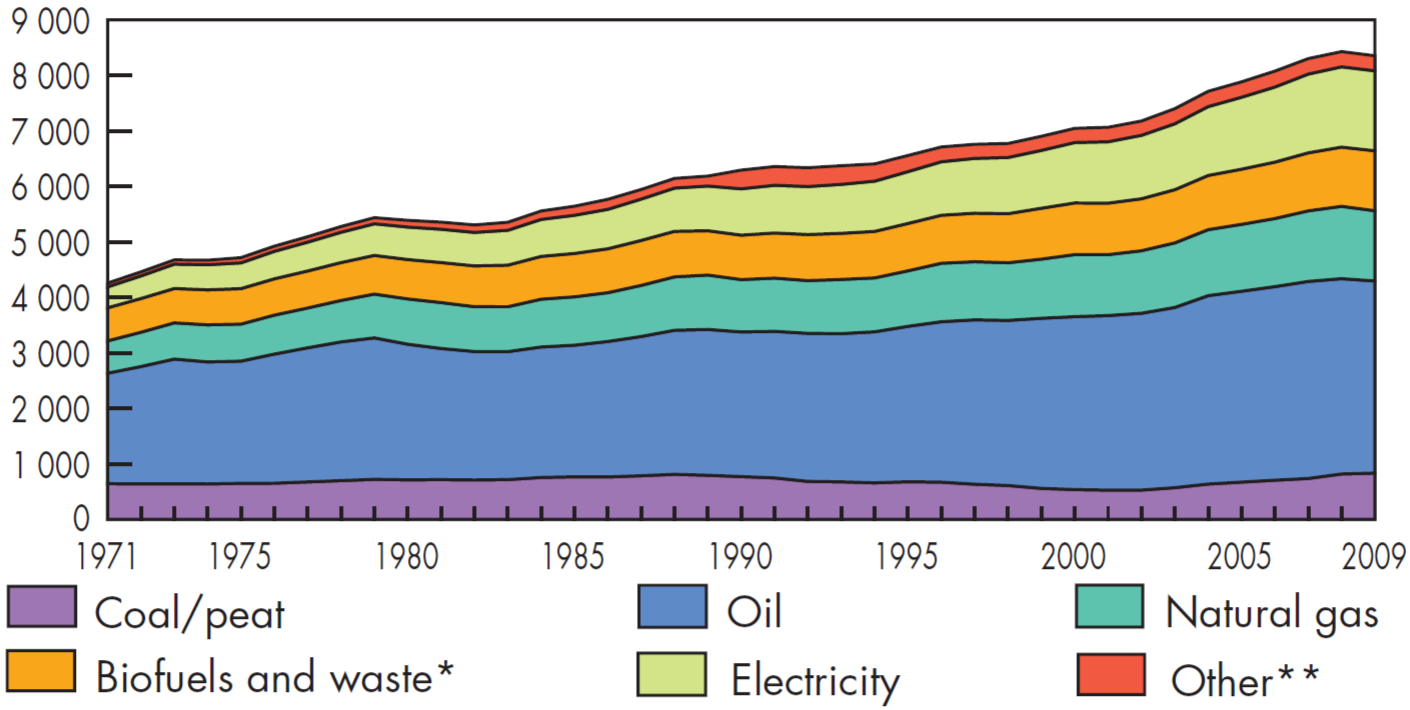


Chart from World Energy Assessment Overview: 2004 update

Source: Jussi Maunuksela (2012)

Since 1971, the World total primary energy consumption has grown twice-fold.



Evolution from 1971 to 2009 by fuel (Mtoe)

Chart from the International Energy Agency (IEA) Key World Energy Statistics 2011.

Technical conversion of energy has different conversion stages.

Primary Energy

Original energy, not yet processed
E.g. crude oil, coal, uranium, solar radiation, wind

Final Energy

Energy in the form that reaches the end used
E.g. gas, fuel oil, petrol, electricity, hot water or steam

Effective/Useful Energy

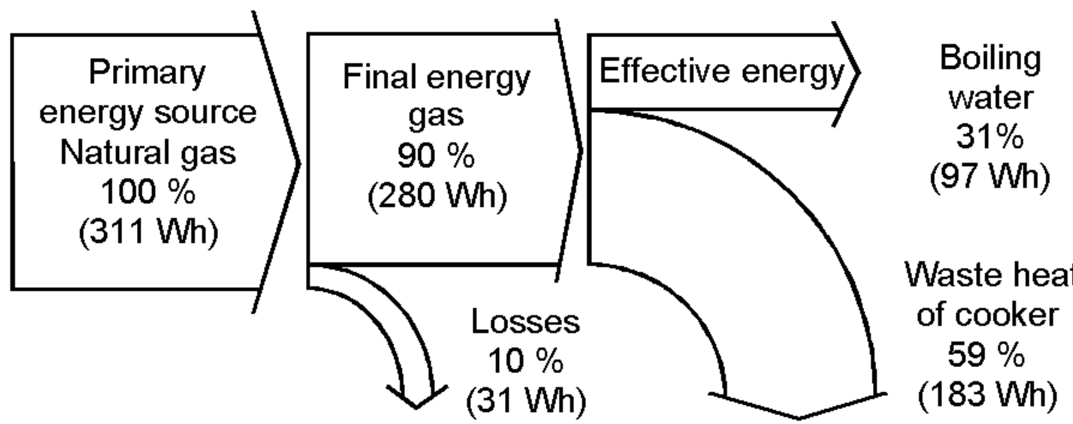
Energy in the form used by the end user
E.g. light, radiator heat, driving force of machines or vehicles

Source: Jussi Maunuksela (2012)

The quality of the energy conversion is described by the efficiency.

$$\text{Efficiency} \equiv \eta = \frac{\text{profitable energy}}{\text{expended energy}}$$

The comparison of energy efficiency should be based on <u>primary energy</u> when considering different energy carriers (gas, electricity).



<u>Source</u>: Volker Quaschning, Understanding Renewable Energy Systems, Earthscan, 2007

An energy system is used to deliver to consumers the benefits that energy use offers.

Energy System

An energy system is made up of
- an energy supply sector
- energy end-use technologies.

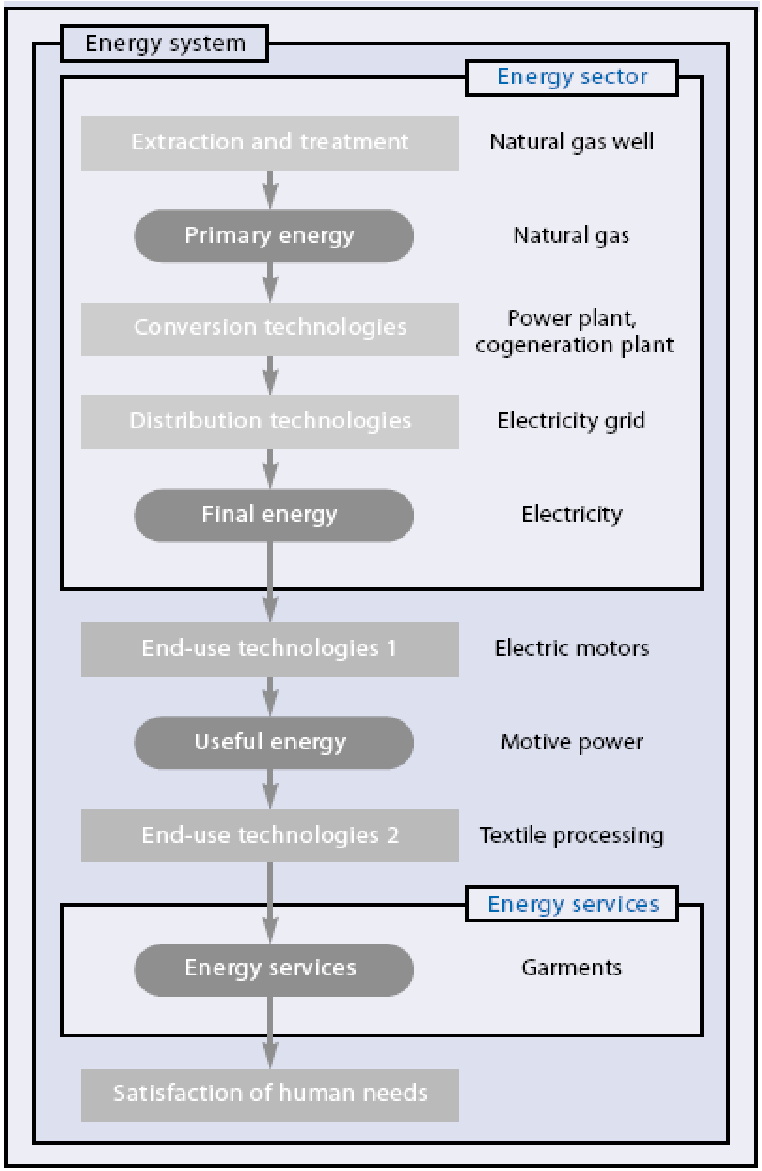
Energy Services

The term energy services is used to describe the benefits:
<u>Households</u>: illumination, cooked food, comfortable indoor temperatures, refrigeration, etc.
<u>Industry</u>: heating and cooling, motive power, electricity, etc.

Source: Jussi Maunuksela (2012)

An energy chain consists of energy supply sector, energy end-use technologies, and energy services.

E.g. energy chain beginning with natural gas extracted from a well (primary energy) and ending with produced garments as an energy service is shown on the right.



<u>Source</u>: UNDP, World Energy Assessment Overview: 2004 update, 2004

In most official statistics human activity is divided into four main end-use sectors.

Industry

Manufacturing, iron and steel, food and drink, chemicals, building, agriculture, etc.

Households

Domestic sector

Services

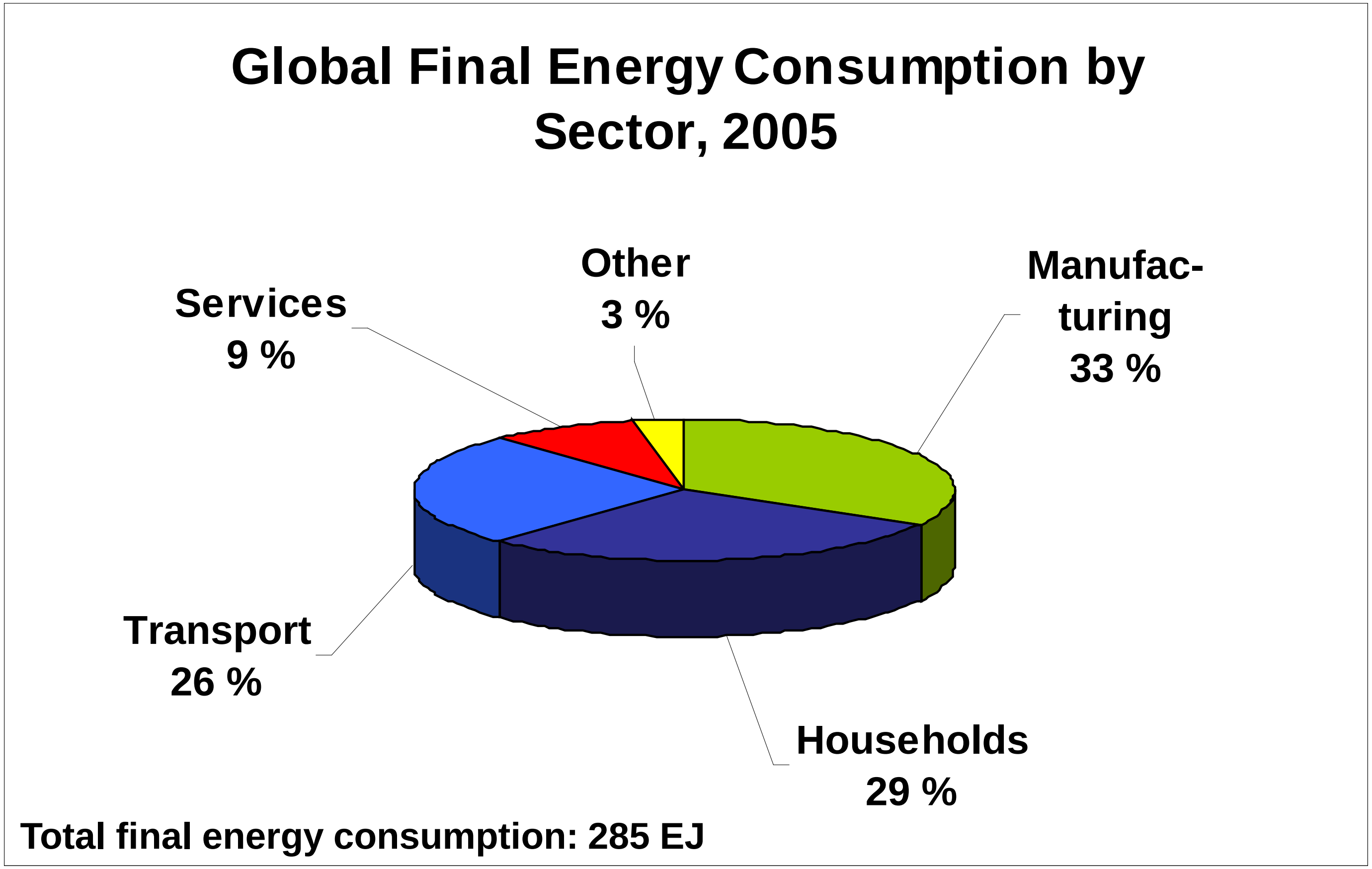
Government buildings, commercial offices, education, health, shops, restaurants, commercial warehouses, etc.

Transportation

Road, rail, air and water transport.

Source: Jussi Maunuksela (2012)

Globally, manufacturing is the biggest consumer of final energy.



<u>Source</u>: IEA, Worldwide Trends in Energy Use and Efficiency - Key Insights from IEA Indicator Analysis, 2008

What are the driving forces that influence our present energy supply?

Three main drivers can identified:

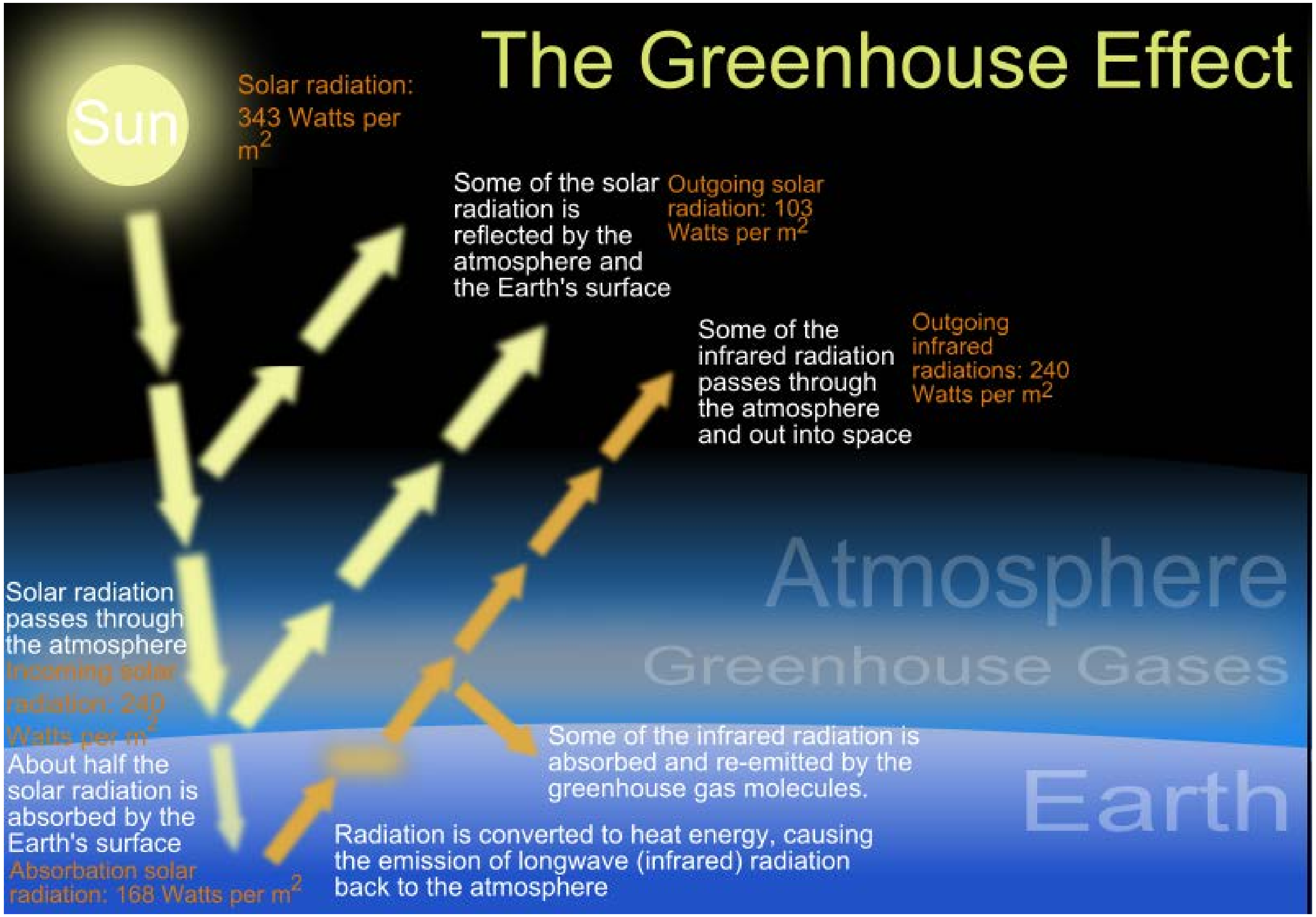
Environmental Issues

Energy prices and Energy Security

Improvements and Technical Innovations in the use of Renewable Energy Sources (RES)

Source: Jussi Maunuksela (2012)

The Earth’s climate is a hugely complex system dependent on many other systems.



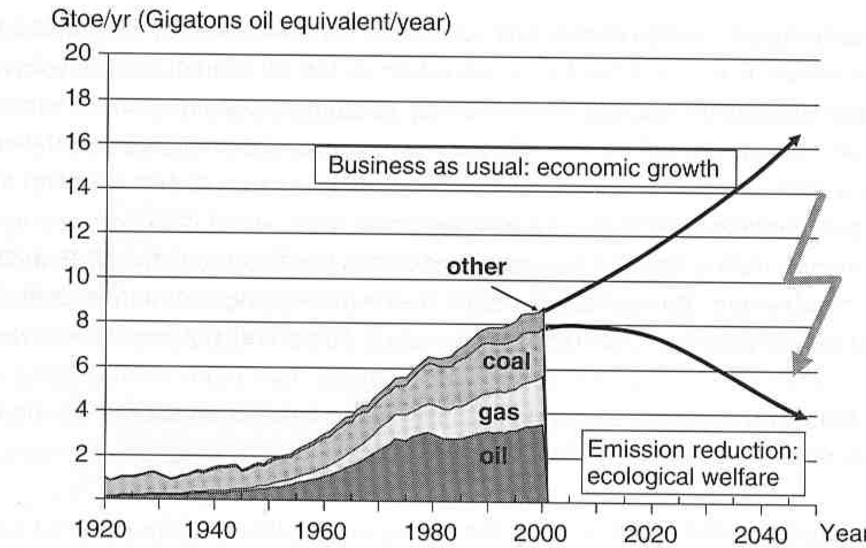
CO_2 released from the processing of undergroung stores of fossil fuels is throught to increase the strength of the ‘greenhouse effect’.

Source: From Wikipedia, the free encyclopedia

Source: Jussi Maunuksela (2012)

The history of World energy consumption is directly related to the level of GHG emissions.

Economic principles imply that GDP needs to grow each year in order to maintain the living standard of the population.



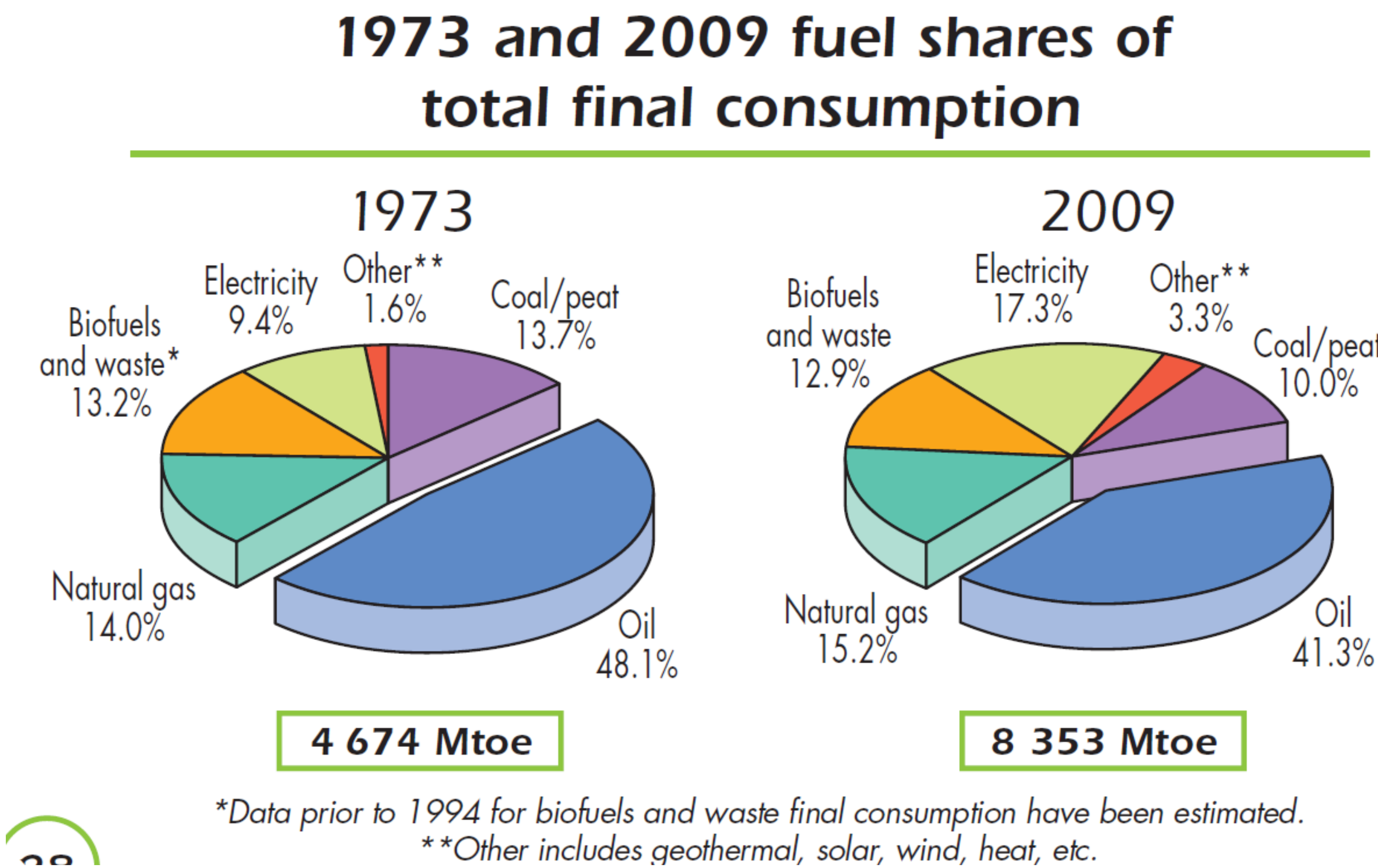
Source: BP Statistical Review of World Energy

FIGURE 1.2 The basic dilemma – Business as usual or climate policy; growing fossil energy consumption is tantamount to growing air pollution and reinforced greenhouse effect

The main advice to developing countries is to accelerate their economic growth. ⇒ Rising consumption of raw materials and fossil energy.

Source: Jussi Maunuksela (2012)

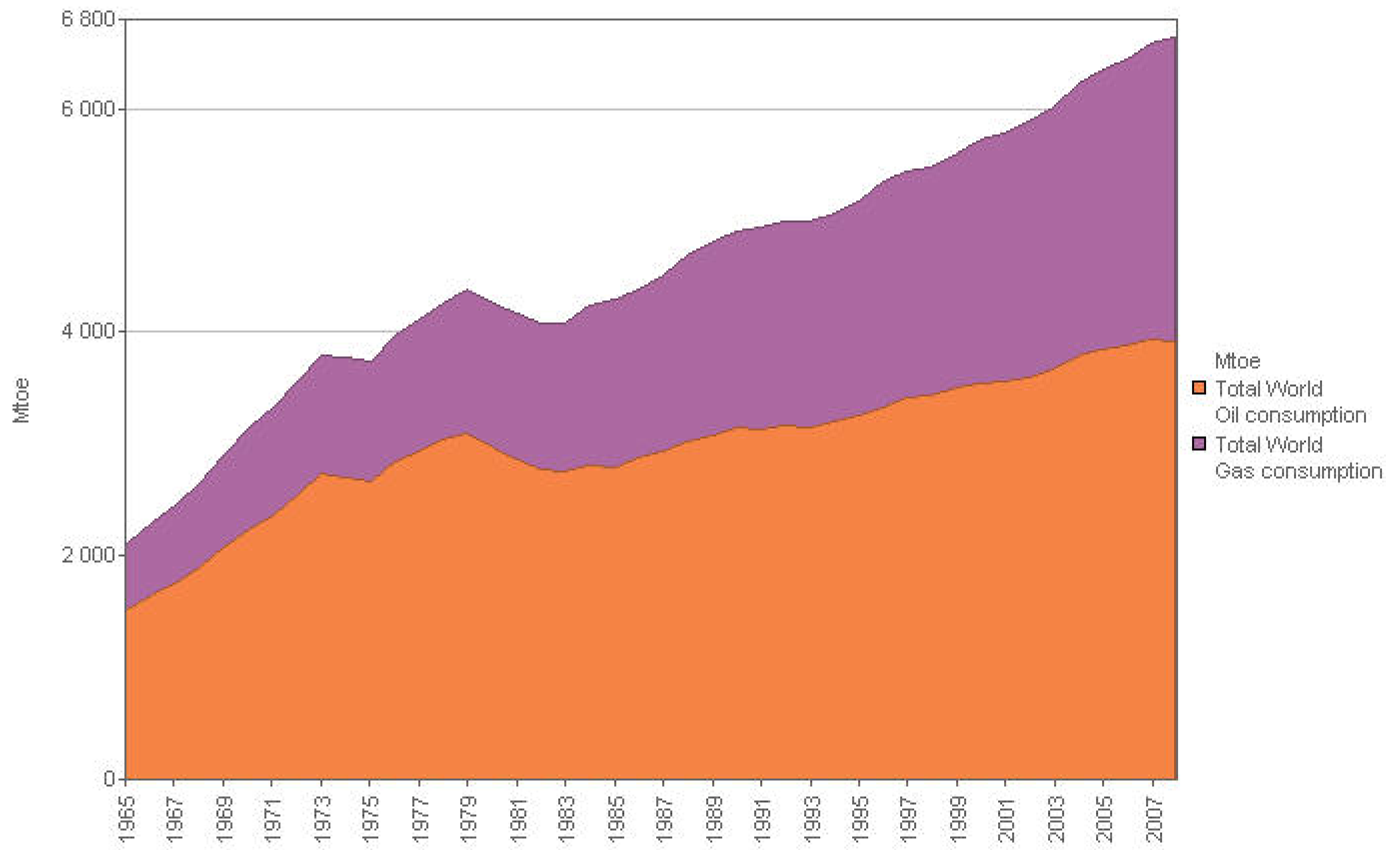
Oil products remain the most important final energy commodity.



Source: Key Energy Statistics 2011 from IEA

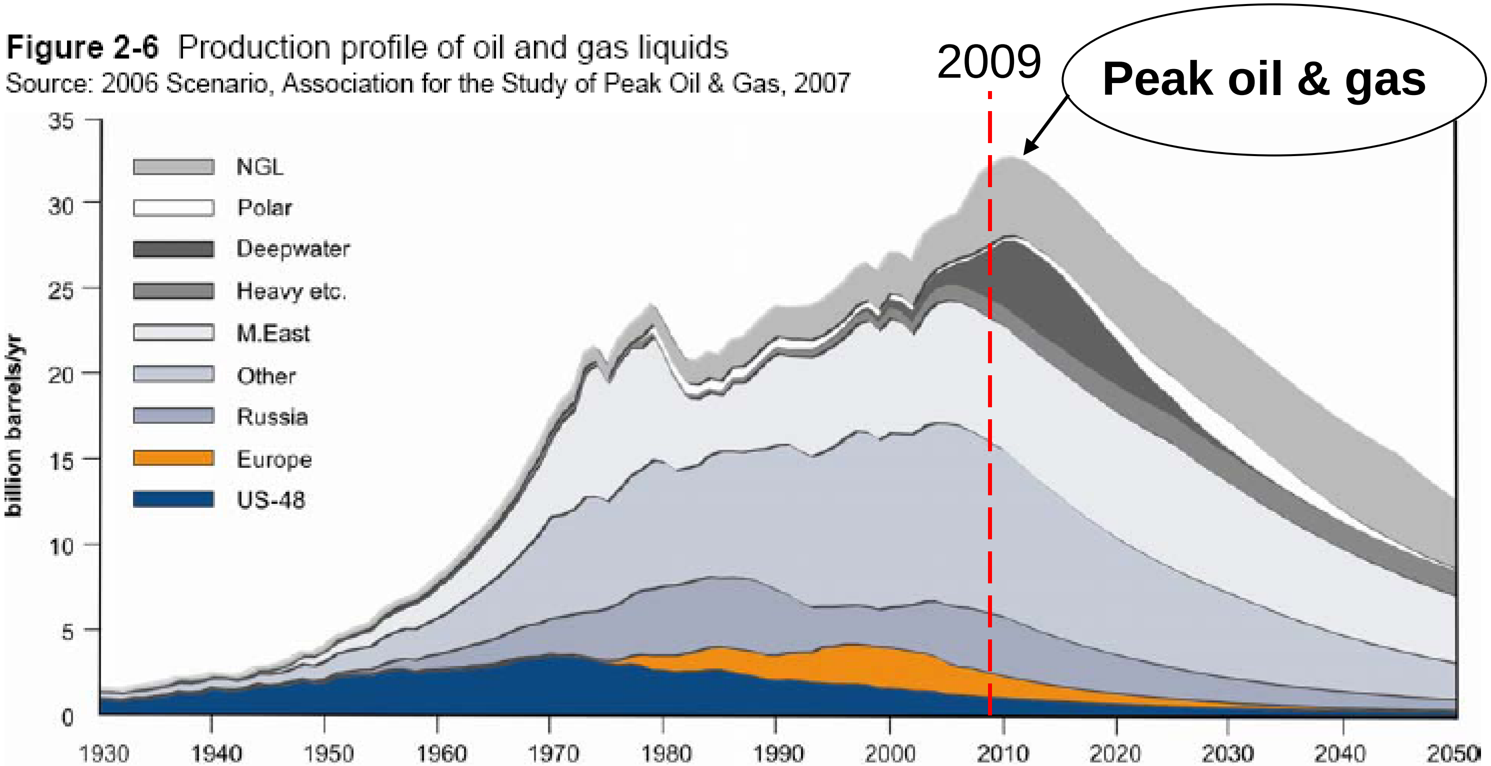
The world demand for oil and gas is increasing significantly each year.

The major part of this increase is currently taken by India and China.



Source: Jussi Maunuksela (2012)

The ultimate availability of fossil fuels is extremely difficult to determine.

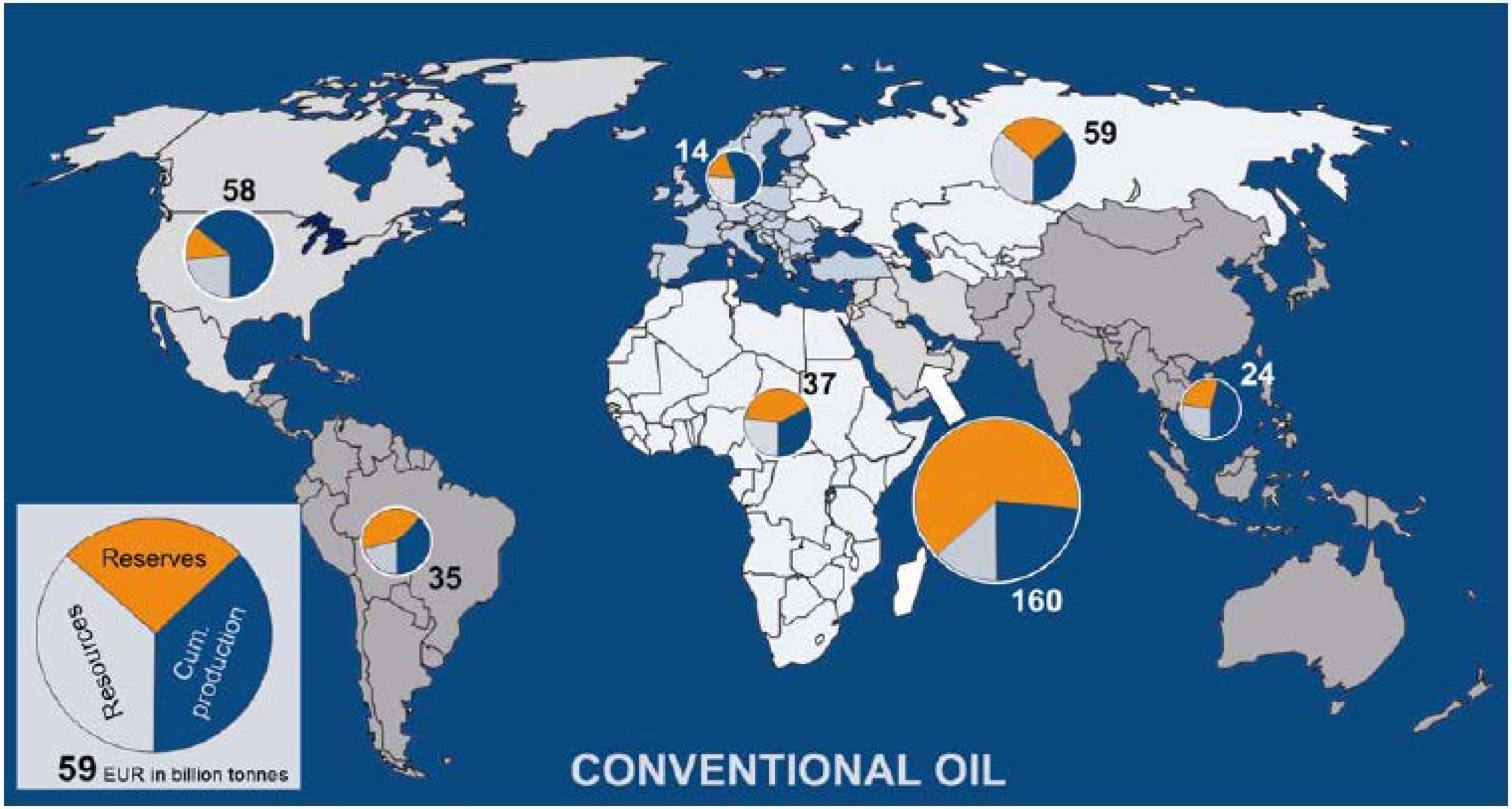


Definition: 'Resources' are detected quantities that cannot be profitably recovered with current technology, but might be recoverable in the future, as well as those quantities that are geologically possible but yet to be found.

Source: Jussi Maunuksela (2012)

Given the central position of oil in the modern economy, the onset of decline threatens to be a time of great economic and geopolitical tension.

Figure 2-1 Distribution of the estimated ultimate recovery of conventional crude oil in 2005
Source: BGR, 2006



Energy resources may be categorised as either finite or perpetual.

Resources / Reserves?

Resources refer to amounts that are known or deduced to be present and potentially accessible.
Reserves denote the amount within the designated finite resource that is recoverable under specified criteria.

Finite Resources

Coal, crude oil, oil shale, natural bitumen and extra-heavy oil, and natural gas, together with the metallic elements (U, Th).

Perpetual Resources

Solar energy, wind energy, bioenergy, tidal energy, wave power and ocean thermal energy conversion (OTEC).

Source: Jussi Maunuksela (2012)

There are two types of energy resource which are to some extent intermediate in nature.

Peat

Peat is part way between the biomass of which it was originally composed and the fossil fuel (coal) that it would eventually become, given appropriate geological conditions.
It is to a cetaing extent 'Renewable' since it is still being formed in many parts of the world.

Geothermal

On the one hand, geothermal energy is to a certain extent subject to attrition (individual geothermal wells are liable to decline and eventuallu exhaust).
On the other hand, the supply of geothermal energy can be boosted (e.g. by water-injection).

Source: Jussi Maunuksela (2012)

TABLE 1. WORLD PRIMARY ENERGY USE AND RESERVES, 2001

Source	Primary energy (exajoules, EJ)	Primary energy (10^9 tonnes of oil equivalent, Gtoe*)	Percentage of total (%)	Proved reserves (10^9 tonnes of oil equivalent, Gtoe*)	Static reserve-production ratio (years)[a]	Static resource base–production ratio (years)[b]	Dynamic resource base–production ratio (years)[c]
Fossil fuels	332	7.93	79.4	778			
Oil	147	3.51	35.1	143	41	~ 200	125
Natural gas	91	2.16	21.7	138	64	~ 400	210
Coal	94	2.26	22.6	566	251	~ 700	360
Renewables	57	1.37	13.7				
Large hydro	9	0.23	2.3		Renewable		
Traditional biomass	39	0.93	9.3		Renewable		
'New' renewables[d]	9	0.21	2.2		Renewable		
Nuclear	29	0.69	6.9	55			
Nuclear[e]	29	0.69	6.9	55	82[f]	~300to>10,000[f]	
Total[f]	418	9.99	100.0				

* 1 toe = 42GJ. a. Based on constant production and static reserves. b. Includes both conventional and unconventional reserves and resources. c. Data refer to the energy use of a business-as-usual scenario—that is, production is dynamic and a function of demand. Thus these ratios are subject to change under different scenarios. Dynamic resource base – production was calculated based on a 2 percent growth rate per year from 2000 to peak production (oil 6.1 Gtoe, gas 6.3 Gtoe, and coal 8.9 Gtoe), followed by a 2 percent decline per year until the resource base is exhausted. d. Includes modern biomass, small hydropower, geothermal energy, wind energy, solar energy, and marine energy. Modern biomass accounts for 6.0 exajoules; 2.9 exajoules comes from all other renewables. "Modern biomass" refers to biomass produced in a sustainable way and used for electricity generation, heat production, and transportation (liquid fuels). It includes wood/forest residues from reforestation and/or sustainable management, rural (animal and agricultural) and urban residues (including solid waste and liquid effluents); it does not include traditional uses of fuelwood in inefficient and pollutant conversion systems. e. Converted from electricity produced to fuels consumed assuming a 33 percent thermal efficiency of power plants. f. Based on once-through uranium fuel cycles excluding thorium and low-concentration uranium from seawater. The uranium resource base is theoretically 60 times larger if fast breeder reactors are used.

Sustainable development meets the needs of the present without compromising the ability of future generations to meet their own needs.

Options for using energy in ways that support sustainable development include:

More efficient use of energy, especially at the point of end use in buildings, transportation, and production processes.

Increased reliance on renewable energy sources.

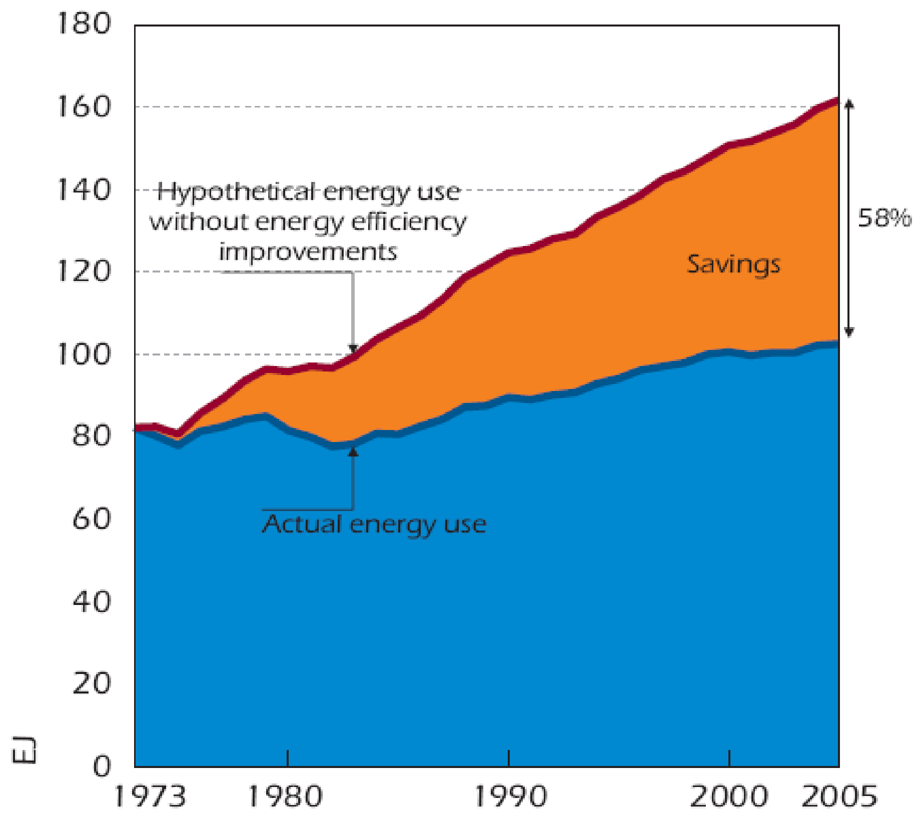
Accelerated development and deployment of new energy technologies.

Source: Jussi Maunuksela (2012)

Savings from improved energy efficiency are significant.

Without the energy efficiency improvements that occurred between 1973 and 2005, energy use in the IEA11 would have been 58%, or 59 EJ, higher in 2005 than it actually was.

<u>Source</u>: IEA, Worldwide Trends in Energy Use and Efficiency - Key Insights from IEA Indicator Analysis, 2008



Source: Jussi Maunuksela (2012)