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Alternative Fuels in the 21st Century

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What we are going to learn?

- *1. Fuel energy:* Comparison, fuel and combustion related terms.
- *2. Fuels and The Environment:* Pollutants and pollution indicators.
- *3. 21st Century energy/environment problems:* EU solutions – the 20 (10)/20/20 energy targets.
- *4. Energy solutions from above:* Ancient Greece.
- *5. World (EU) energy problems:* A closer look.
- *6. Alternative biofuels:* Main advantages and main problems.

3. Fuel and combustion related terms.

- **Combustible compound:** a compound which can be transformed in elementary chemical reactions with generation of a significant amount of energy - hydrocarbons, hydrazin (N_2H_4).
- **Oxidant:** a compound or a chemical radical, which oxidizes a combustible compound (in a combustion process) - oxygen, N_2O_4 (oxidizes N_2H_4), OH, O, H.
- **Fuel:** a material, containing combustible compounds, e.g. gasoline, coal.
- **Conventional fuel:** a fuel, which at a given time, is used widely in a given combustion installation – e.g., coal, gasoline, diesel fuel, etc.
- **Alternative fuel:** a fuel, which can be an alternative to a conventional fuel for a given combustion installation – e.g., natural gas, ethanol.
- **Renewable fuel:** a fuel, which can be reproduced by natural processes (within a reasonable time).

4. EU Energy solutions: The 2020 targets.

- Raise the *share of renewable* energy to **20 %** by 2020;
- Increase the share of *renewables* (biofuels) *in transportation fuels* up to **10 %** by 2020.
- Reduce *GHG emissions* by at least **20 %** (compared to 1990 levels) by 2020;
- Improve *energy efficiency* by **20 %** by 2020.

EU primary energy dependence on imports, *% of net imports, based on toe*.
Source: EU Stat Yearbook 2010

	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
All products	45.0	46.1	45.1	46.8	47.5	47.6	49.0	50.3	52.6	53.8	53.1
Solid fuels	25.1	26.6	27.8	30.7	33.8	33.1	34.9	38.1	39.6	41.2	41.2
Crude oil	76.0	77.2	73.1	76.1	77.6	76.3	78.7	80.1	82.6	83.8	82.7
Natural gas	45.2	45.7	47.9	48.9	47.3	51.2	52.5	54.0	57.7	60.8	60.3

5. Energy Solutions from Above: Ancient Greece



Chained Prometheus, by Peter Paul Rubens, (1611-1612).

6. Energy lessons from Ancient Greece

- Energy = Power.
- Energy problem: Those who have energy are Gods, those who do not have are Mortals.
- "Power to the people" leads to severe punishment.
- The energy problem can be solved by deception and manipulation, and/or by violence.
- Ecology and energy efficiency did not bother anybody yet.

7. Some exaggerated energy relevant statements

- Fossil fuels are depleting quickly and have to be Replaced By Mid-Century.
- Renewable fuels are produced From Wastes.
- Renewable fuels are Less Polluting than fossil fuels.
- Renewables are The Future fuels for heat engines.
- Zero emission vehicles (ZEVs) are The Vehicles of the 21st century.
- Hydrogen energy is At The Door Step.
- Energy problems can be Solved From Above.

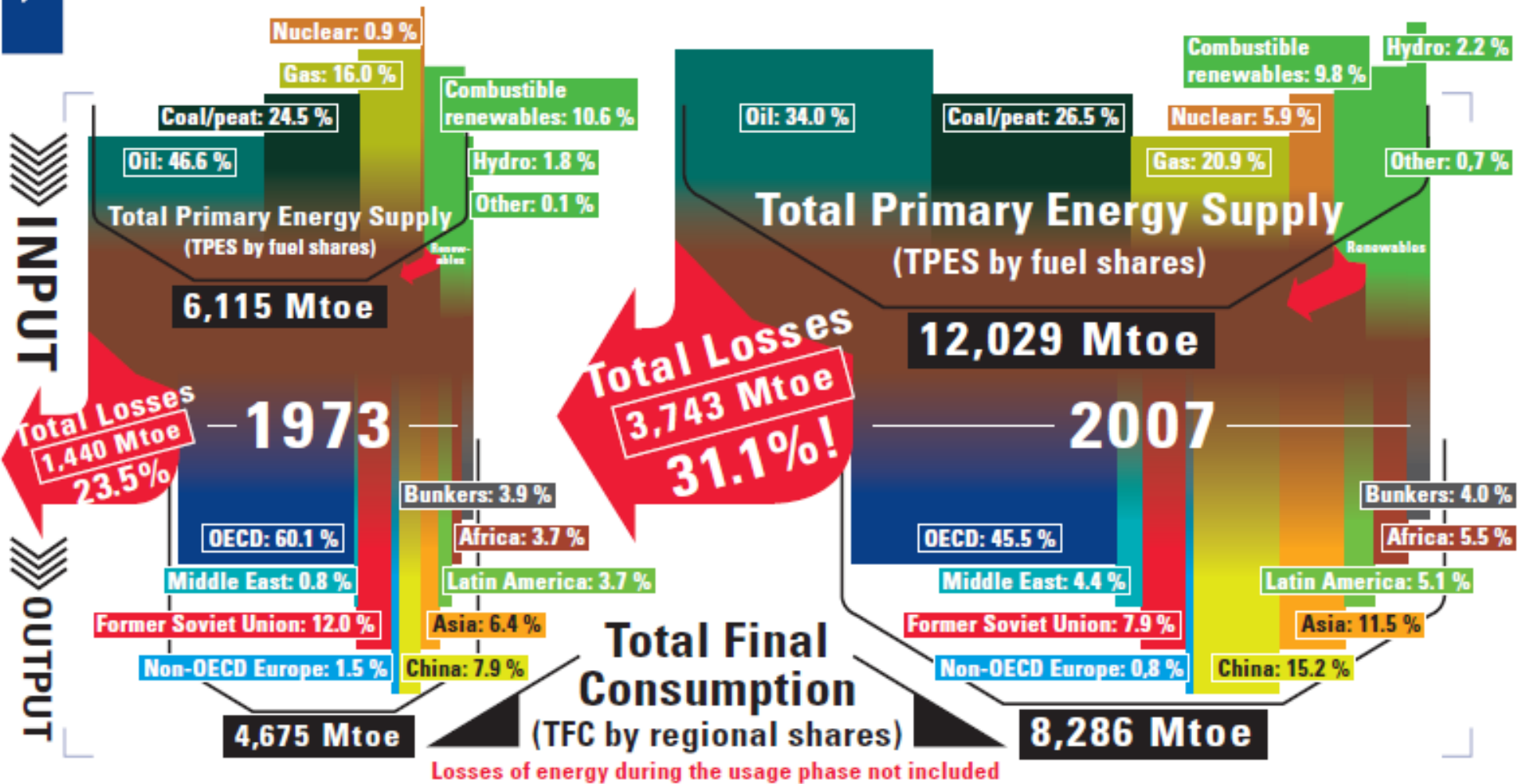
8. Oil equivalent, EU Stat

Fuel (NCV, i.e. excl. HVap)	MJ/kg	OE/kg
Oil equivalent (OE)	41.8	1.000
Coal	26.8 – 28.3	0.641 – 0.677
Crude oil	41.6 – 42.8	0.994 – 1.022
Gasoline	44.0	1.053
- bioethanol	37.0	0.885
Diesel fuel	42.3	1.012
- biodiesel	37.0	0.885
LPG	46.0	1.099
Natural gas (GCV, i.e. incl. Hvap)	For 1 MJ	0.022
Nuclear energy (GCV, i.e. incl. Hvap)	For 1 MJ	0.024
Biomass (GCV, i.e. incl. Hvap)	For 1 MJ	0.024
Electrical energy (GCV, i.e. incl. Hvap)	3.6	0.086

9. World energy balance

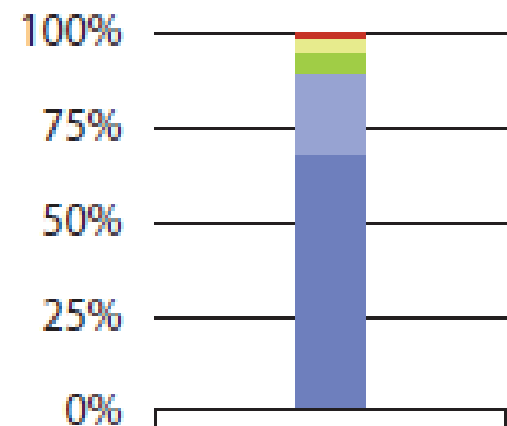
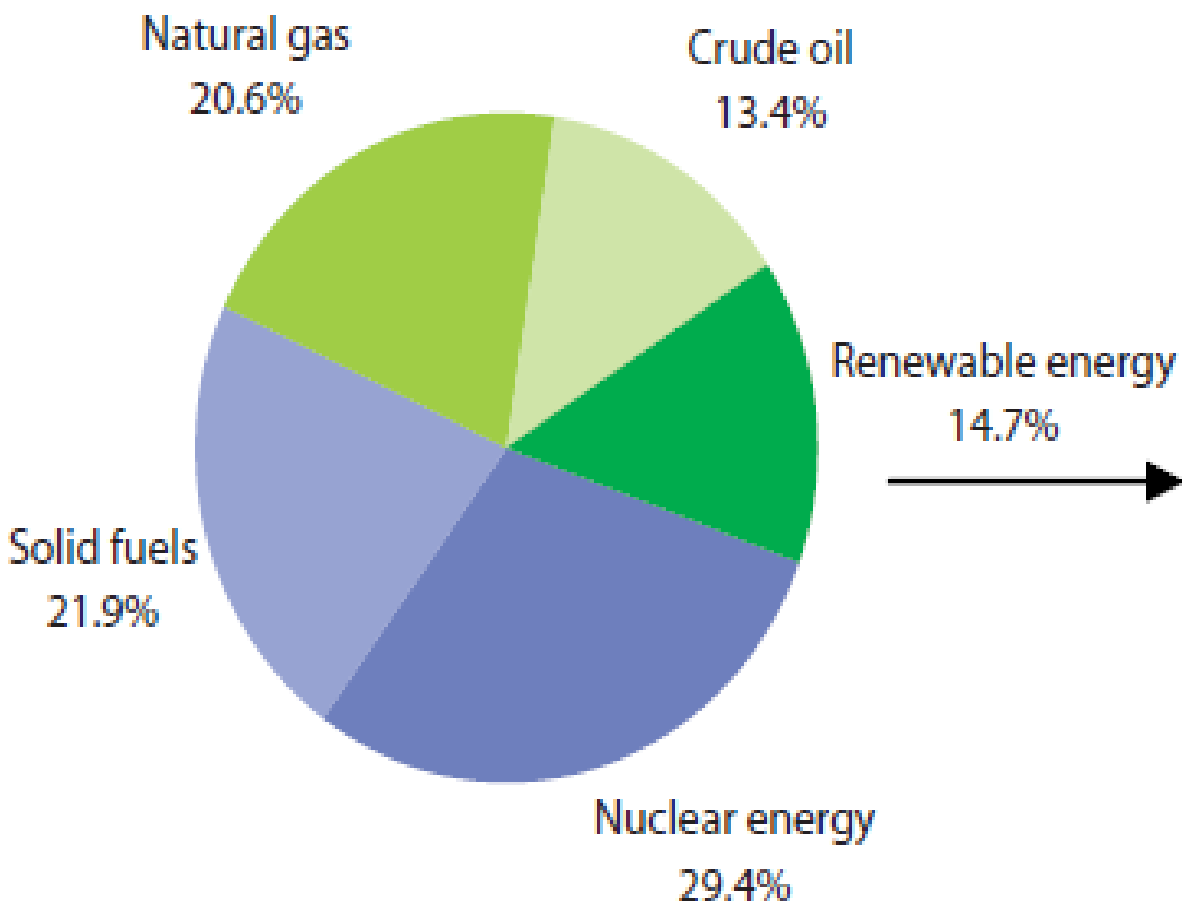
OECD: 18 % population, 45.5 % of energy; China 7.9 - 15.2 %.

World Energy Balance, Comparison 1973 to 2007



10. EU 27 production of primary energy, 2006

(EU Stat Yearbook 2009)



- Solar energy
- Geothermal energy
- Wind
- Hydropower
- Biomass and waste

11. Energy Imports, % of EU 27 Total (EU Stat Yearbook 2010)

Crude oil								
	2000	2001	2002	2003	2004	2005	2006	2007
Russia	18.7	22.7	26.1	28.1	30.0	29.9	30.4	30.3
Norway	19.3	17.9	17.4	17.5	17.3	15.5	14.3	13.8
Libya	7.6	7.3	6.6	7.6	7.9	8.0	8.5	9.1
Saudi Arabia	10.8	9.5	9.0	10.1	10.2	9.7	8.2	6.4
Iran	5.9	5.2	4.4	5.7	5.7	5.6	5.8	5.6
Iraq	5.2	3.4	2.7	1.4	2.0	2.0	2.7	3.1
Kazakhstan	1.6	1.5	2.3	2.6	3.5	4.2	4.3	3.0
Nigeria	3.7	4.3	3.1	3.8	2.4	3.0	3.2	2.5
Algeria	3.6	3.2	3.0	3.1	3.4	3.6	2.7	2.2
Others	23.7	25.0	25.4	20.2	17.5	18.5	20.0	24.1
Natural gas								
	2000	2001	2002	2003	2004	2005	2006	2007
Russia	40.4	38.5	36.7	37.2	35.9	33.5	31.9	30.7
Norway	17.7	18.6	20.9	20.5	20.3	18.1	18.4	20.1
Algeria	19.6	17.0	17.2	16.4	14.8	15.3	13.8	12.8
Nigeria	1.5	1.9	1.8	2.6	3.0	3.0	3.6	3.9
Libya	0.3	0.3	0.2	0.2	0.3	1.4	2.1	2.5
Egypt	0.0	0.0	0.0	0.0	0.0	1.4	2.1	1.5
Qatar	0.1	0.2	0.7	0.6	1.2	1.3	1.5	1.8
Trinidad and Tobago	0.3	0.2	0.2	0.0	0.0	0.2	1.1	0.7
Croatia	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.2
Others	20.0	23.3	22.4	22.4	24.4	25.8	25.3	25.9

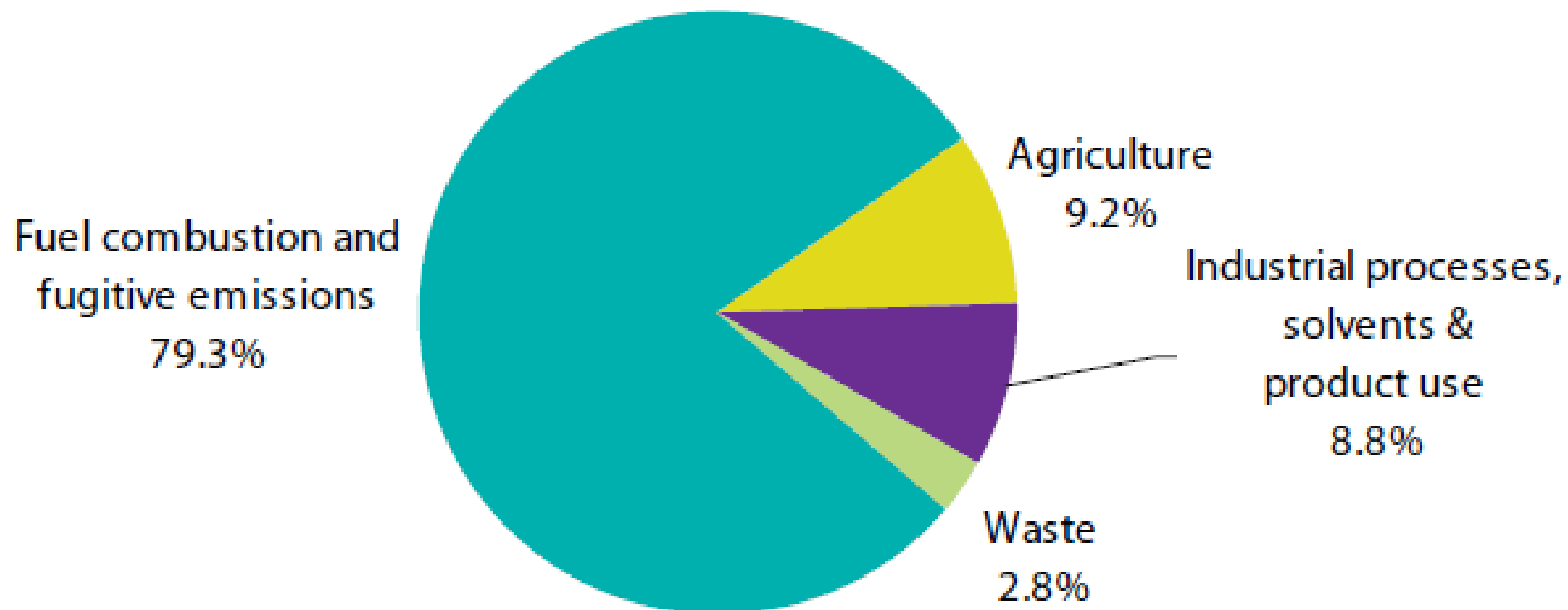
12. Environment and pollution.

- **Air: Main (criteria)** - CO_x , SO_x , NO_x , particulate matter (PM), methane, (non-methane) volatile organic compounds (VOCs), polycyclic aromatic hydrocarbons (PAH). **Specific** – halocarbons, acetone, etc.
- **Water: bio** - bacteria, viruses and parasites; **inorganic suspended and dissolved matter** – rock, sand, toxic and heavy metals, asbestos; **organic** – toxic compounds, industrial wastes.
- **Soil:** metals, chemicals, oils and tars, pesticides, radio- and bioactive materials from landfill and dumping, etc.

Life Cycle Analysis (LCA): Analysis of engineering (environmental) solutions from “cradle till grave”

13. 2007 EU Green house gases (GHG). 2008 reduction from 1990 was 11%. Source: EU Stat 2010.

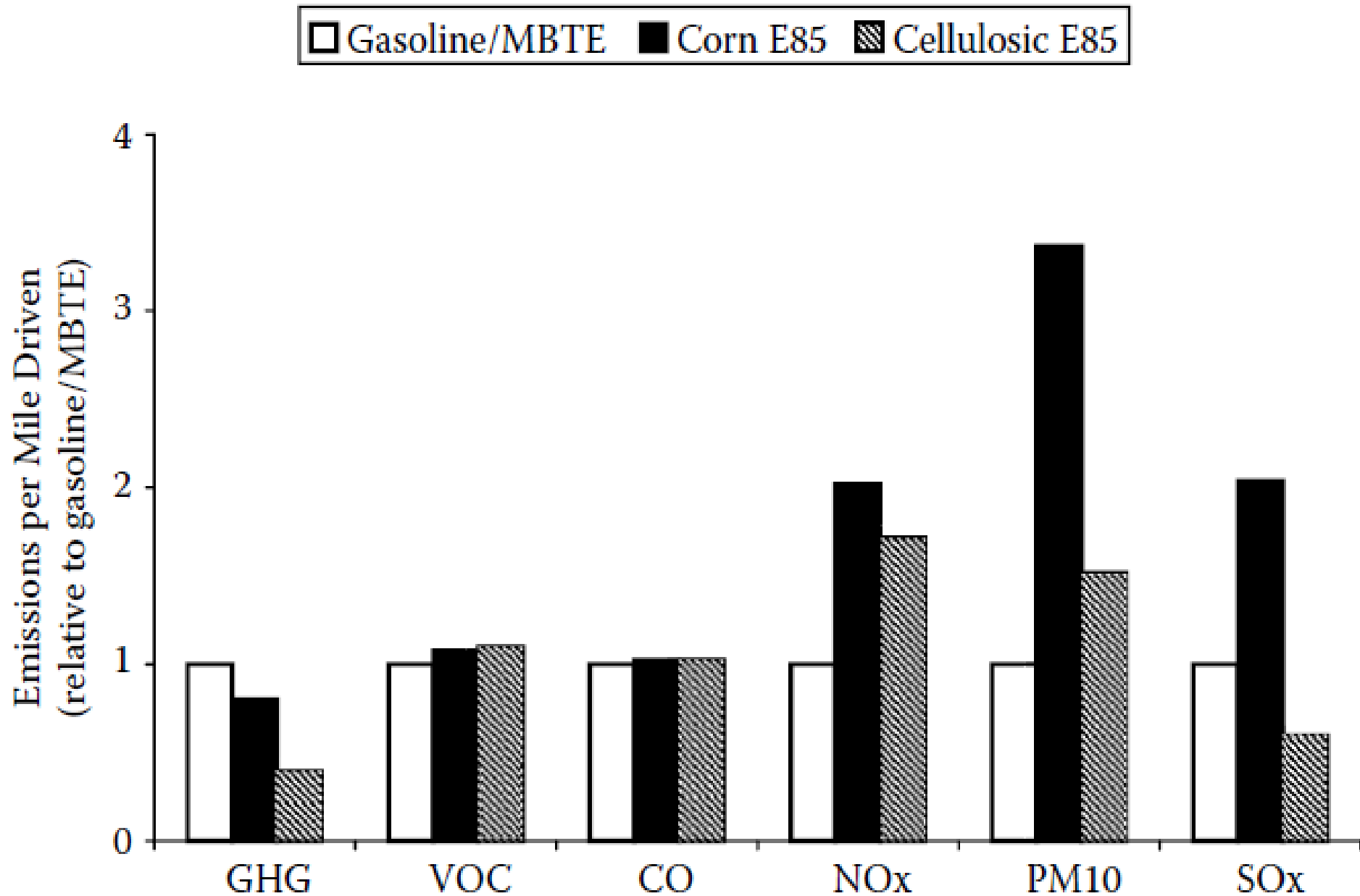
Chemical formula	Greenhouse gas	Global Warming Potential (1)
CO ₂	Carbon dioxide	1
CH ₄	Methane	21
N ₂ O	Nitrous oxide	310
HFCs	Hydrofluorocarbons	140 (C ₂ H ₄ F ₂) to 11 700 (CHF ₃)
PFCs	Perfluorocarbons	5 700 (CF ₄) to 11 900 (C ₂ F ₆)
SF ₆	Sulphur hexafluoride	23 900



14. Alternative liquid fuels. Bioalcohols.

- **Main advantages:** renewable; can be produced from waste biomass chemically or microbiologically (incl. from algae, which utilize CO_2); may be used for ethers (MTBE, etc.) syntheses, as motor fuel (gasoline) in conventional and *flexi*-engines; in diesel engines (in combination with biodiesel), in direct fuel cells; GHG reduction.
- **Main problems:** expensive *flexi*-engines, less energy intensive than gasoline, toxic and chemically reactive, fixed B.P., completely water soluble, corrosive, blends with gasoline separate, storage and distribution infrastructure needed, intensive land (including arable) use and higher food prices, contradicting data about LCA and emissions.

15. Comparison of total fuel cycle emissions of pollutants from bioalcohols (“Biofuels”, Taylor and Francis, 2008).

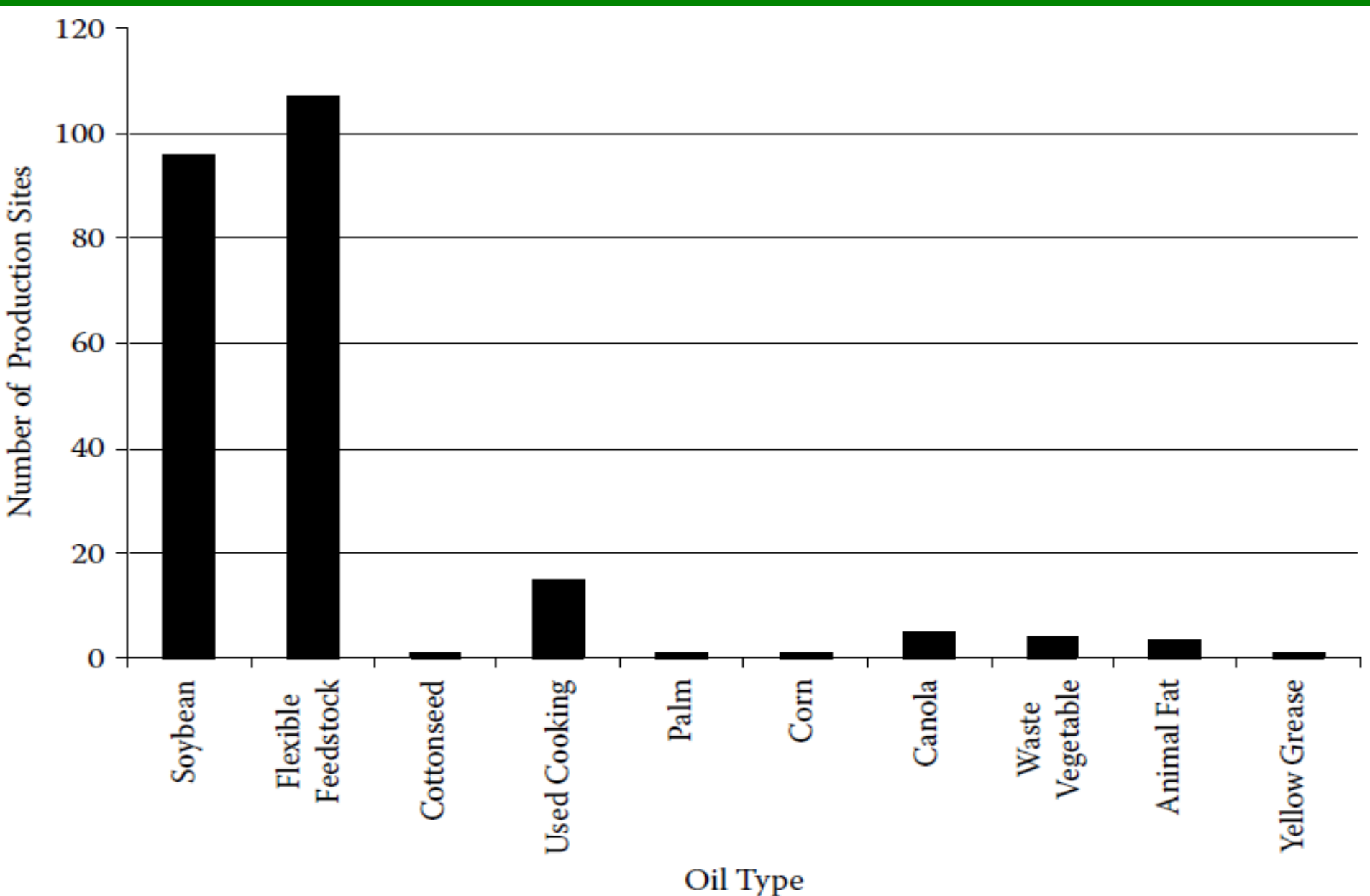


16. Alternative liquid fuels. Biodiesel.

- **Main advantages:** renewable and biodegradable; can be produced from different oils (biomass), incl. wastes and algae; GHG, pollutants reduction; good diesel fuel additive; CH_3OH can be produced from glycerol, competitive future technologies.
- **Main problems:** semi-batch acid/alkali transesterification polluting and not efficient; expensive; land-use and raw materials problems (intensification, arable land, food prices, etc); hygroscopic (40 times more than diesel fuel) - storage (biodegradability, hydrolysis) problems, fixed B.P., NO_x motor emissions higher; glycerides are raw materials for biodegradable lubricants, local (i.e. farm) production problems; contradicting LCA data.

17. US Biodiesel raw materials use, 2007

("Biofuels", Taylor and Francis, 2008).



18. Yields from sources for biodiesel

Chisti Y., *Biotechnol Adv.*, 2007

Comparison of some sources of biodiesel

Crop	Oil yield (L/ha)	Land area needed (M ha) ^a	Percent of existing US cropping area ^a
Com	172	1540	846
Soybean	446	594	326
Canola	1190	223	122
Jatropha	1892	140	77
Coconut	2689	99	54
Oil palm	5950	45	24
Microalgae ^b	136,900	2	1.1
Microalgae ^c	58,700	4.5	2.5

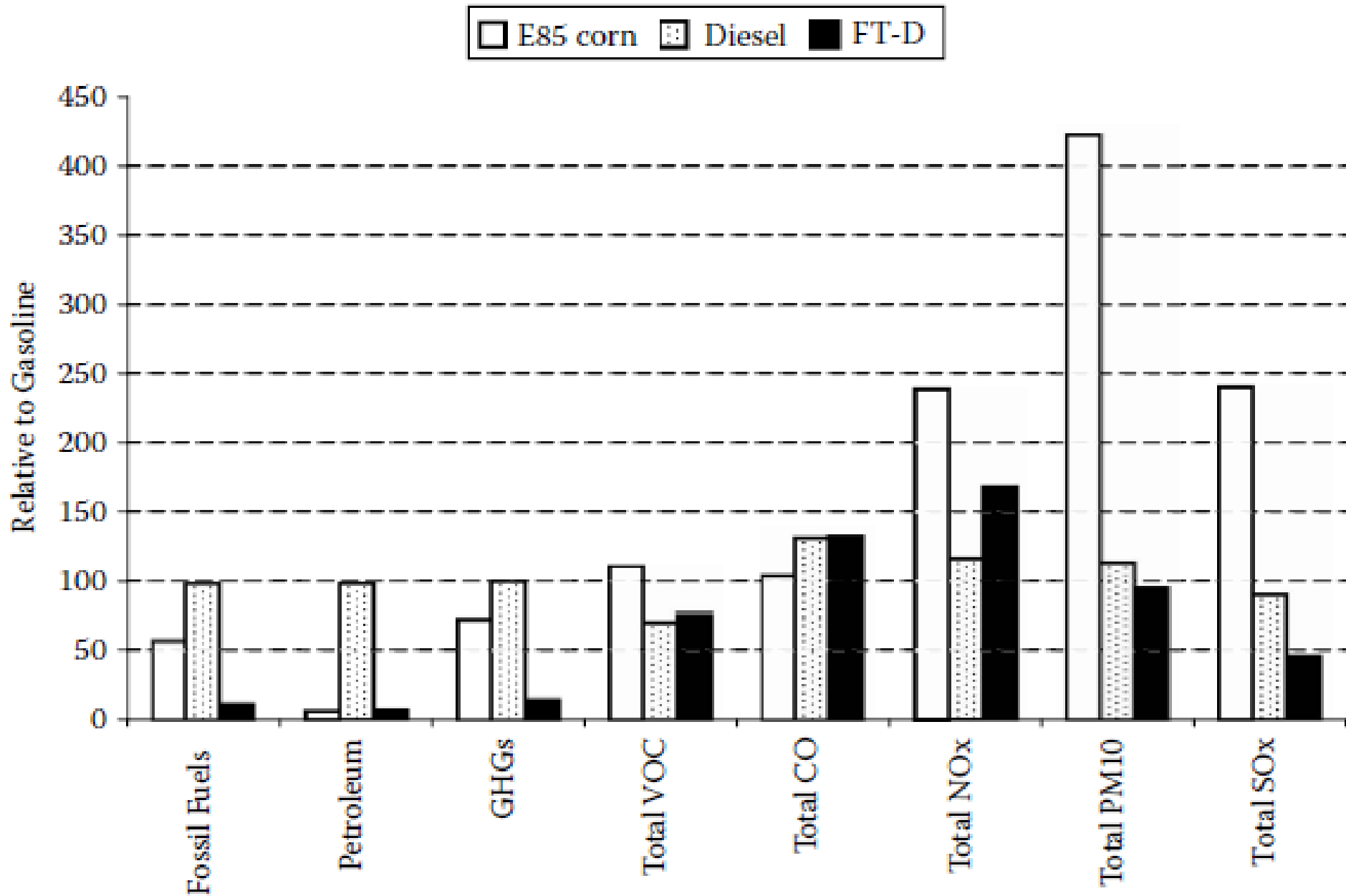
^a For meeting 50% of all transport fuel needs of the United States.

^b 70% oil (by wt) in biomass.

^c 30% oil (by wt) in biomass.

19. Fisher-Tropsch Diesel (FT-D): Well to wheel energy use and pollutants

("Biofuels", Taylor and Francis, 2008)



20. Alternative solid biofuels.

Main advantages: renewable; waste (agricultural, industrial, dead wood, etc.) biomass pollutes environment; CO_2 neutral or less, cheap to produce, can replace coal for local heating and electricity, can be processed further and costs might be decreased with production of synthetic chemicals (alkylphenols, etc.).

Main problems: small scale batch production from scattered raw materials with varying properties; low energy intensity (0.024 toe), storage and transportation problems (decays, low mass density, hygroscopic); furanes, dioxins, PM, S, ash, etc. in combustion; catalytic problems in processing), possibilities for uncontrollable use of raw materials (e.g., deforestation), LCA still not clear.

21. Alternative gaseous biofuels. Biogas (biomethane).

- **Main advantages:** Renewable; CH_4 (50 – 75 %) and % CO_2 (25 – 50 %) are the main components of biomass anaerobic decay gases (moor gas, sewage gas, land fill gas, mine gas, etc.); can be produced from farm and other wastes; low production costs, can be used for syntheses; easy storage and transportation; compost might be produced as side product of biogas.
- **Main problems:** CH_4 is 21 times more powerful GHG than CO_2 ; *biogas* has different impurities (depending on biomass) and low energy value, semi-batch biotechnology with solid residuals, explosion hazard in small scale production; *land-fill and sewage gases* contain uncontrollable impurities (arenes, PCBs, furanes, dioxins, etc.), LCA not clear.

- ADDITIONAL SLIDES

10. Environmental indicators, 2004

OECD set of key environmental indicators

POLLUTION ISSUES

Available indicators*

Medium term indicators**

Climate change

1. CO2 emission intensities
Index of greenhouse gas emissions

Index of greenhouse gas emissions

Ozone layer

2. Indices of apparent consumption of ozone depleting substances (ODS)

Same, plus aggregation into one index of apparent consumption of ODS

Air quality

3. SOx and NOx emission intensities

Population exposure to air pollution

Waste generation

4. Municipal waste generation intensities

Total waste generation intensities, Indicators derived from material flow accounting

Freshwater quality

5. Waste water treatment connection rates

Pollution loads to water bodies

NATURAL RESOURCES & ASSETS

Freshwater resources

6. Intensity of use of water resources

Same plus sub-national breakdown

Forest resources

7. Intensity of use of forest resources

Same

Fish resources

8. Intensity of use of fish resources

Same plus closer link to available resources

Energy resources

9. Intensity of energy use

Energy efficiency index

Biodiversity

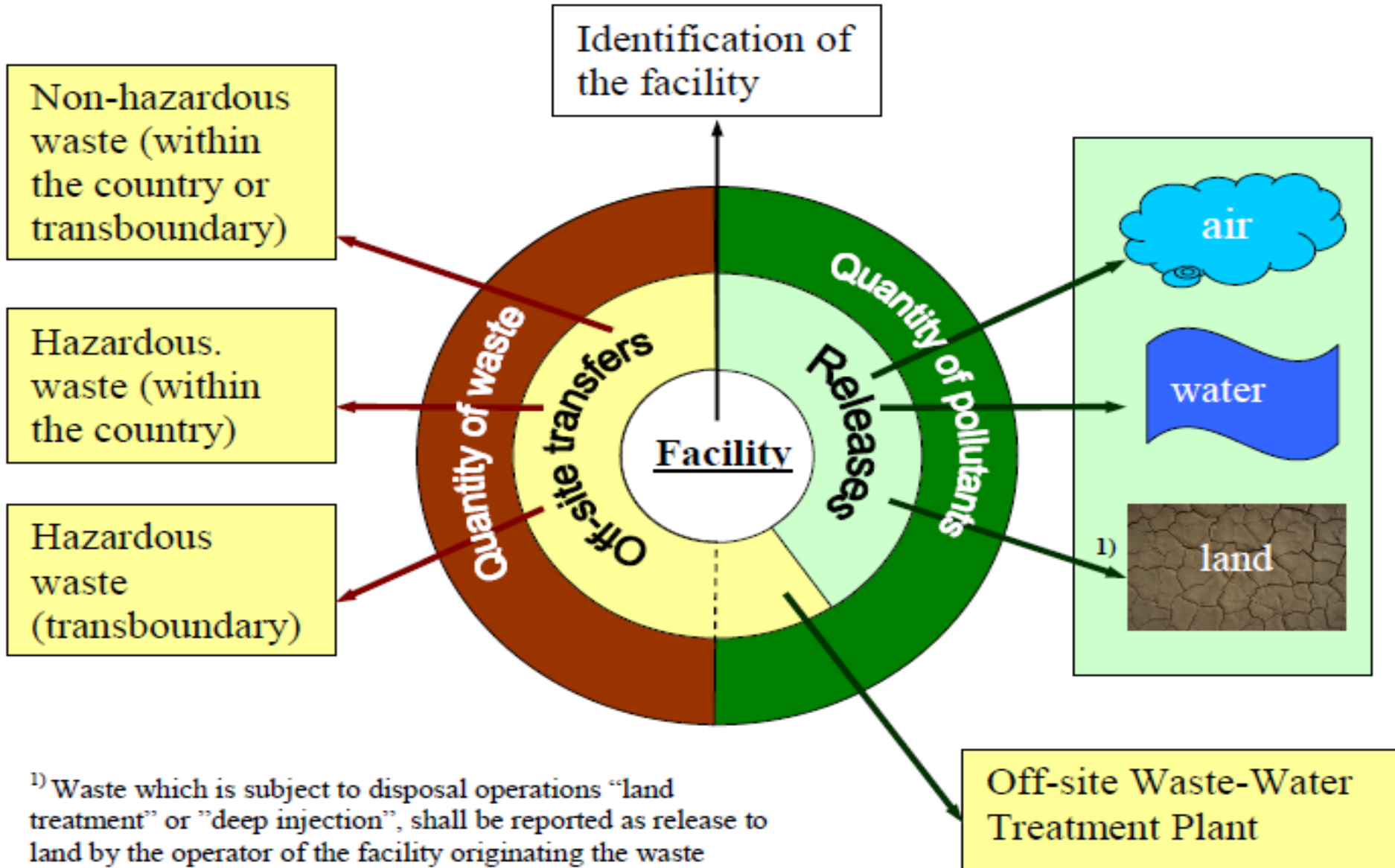
10. Threatened species

Species and habitat or ecosystem diversity
Area of key ecosystems

* indicators for which data are available for a majority of OECD countries and that are presented in this report

** indicators that require further specification and development (availability of basic data sets, underlying concepts and definitions).

11. EU Pollutant Release and Transfer Register, EPRTR (25000 operators, 31 countries, 91 pollutants)

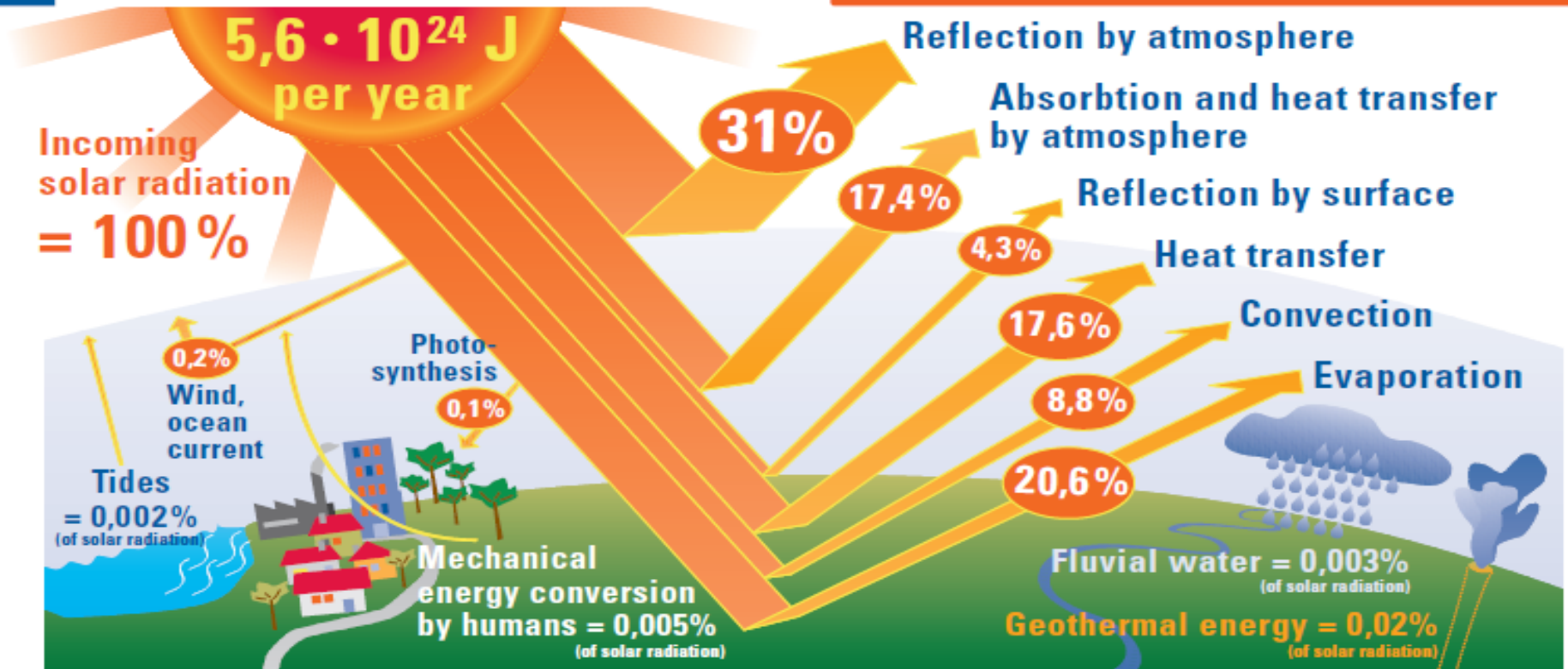


3. 21st Century Energy Data, Wikipedia.

- World energy consumption (2008): $474 \cdot 10^{12}$ MJ ($15 \cdot 10^6$ MW),
- World resources: all fossil (0.6 – 3.0) $\cdot 10^{18}$ MJ; nuclear $2.5 \cdot 10^{18}$ MJ; usable energy flux (mainly solar) $3.8 \cdot 10^{18}$ MJ.

> Earth's Energy Balance

The energy emitted in one hour by the sun is adequate to cover the energy needs of the entire world population for one year.



- Source of Figure: www.hydrogenambassadors.com