UNIVERSITY OF CHEMICAL TECHNOLOGY AND METALLURGY - SOFIA

# Fossil Fuels in the 21st Century

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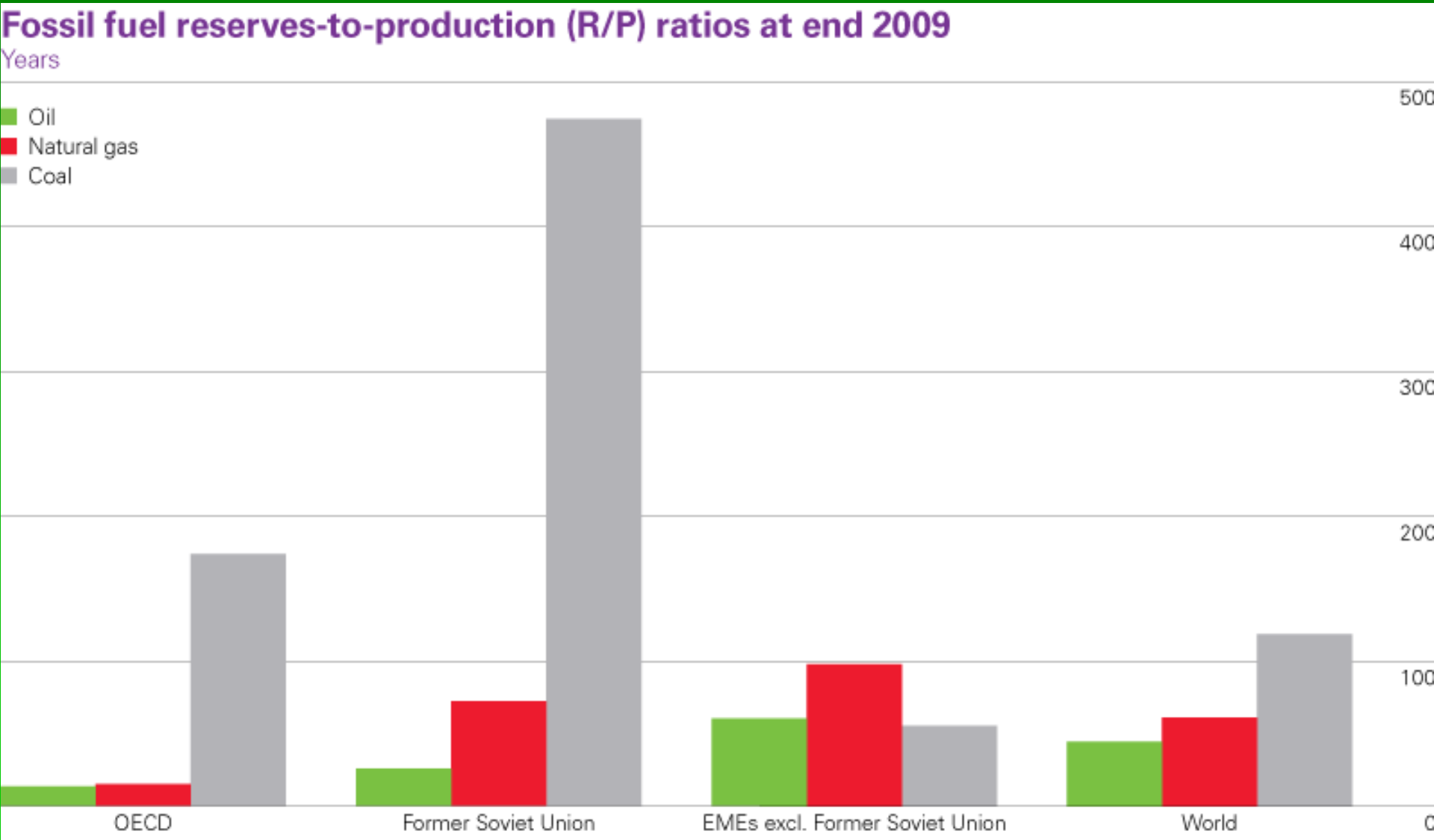
# Fossil Fuels in the 21st Century.

*What we are going to learn?*

- *1. EU Energy: Status, targets, problems.*
- *2. World fossil energy: Consumption, reserves, when will it deplete?.*
- *3. Fossil alternative fuels: Main advantages and main problems.*
- *4. Energy lessons in the 21st Century. Do we know better?*
- *5. Optimistic energy scenarios. If everything goes as planned?*
- *6. Pessimistic energy scenarios. If something goes wrong?*

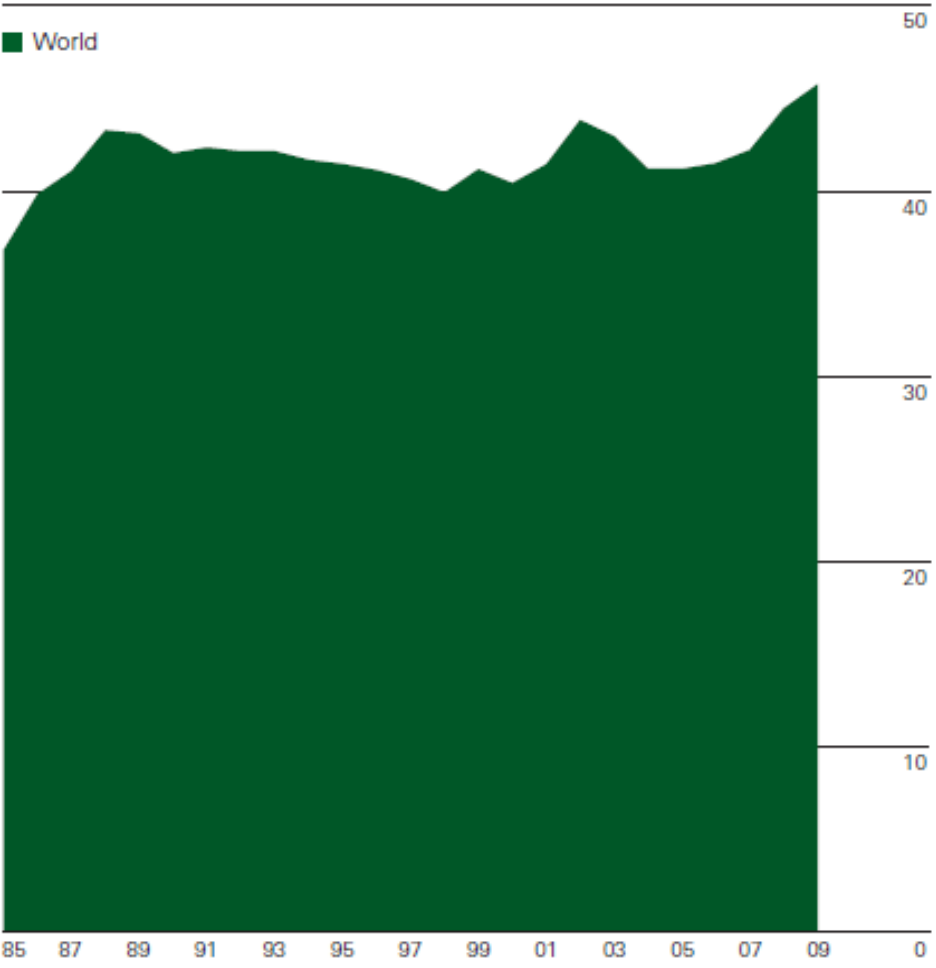
# 3. Fossil Fuels Are Depleting ?
# Reserves/production ratios in 2009, years, BP Review'10

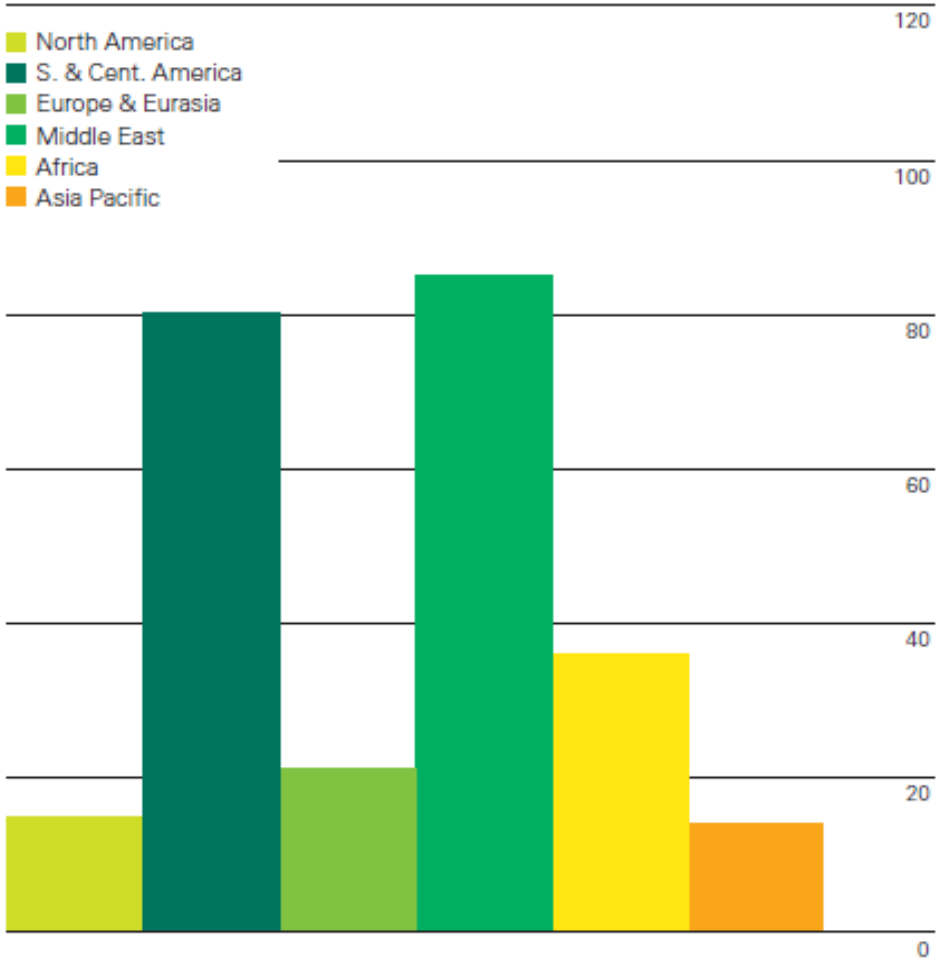



While coal remains the world's most abundant fossil fuel, with an R/P ratio of 119 years, proved reserves of oil and natural gas increased in 2009 and have tended to rise over time. OECD countries account for less than 10% of global proved reserves for oil and natural gas, but 42.6% of proved coal reserves.

# 10. Fossil Fuels Are Depleting ?

## Crude Oil Reserves/production ratios in 2009, years, BP Review'10




- Proved reserves of oil: Quantities that geological and engineering information indicates with reasonable certainty can be recovered in the future from known reservoirs under existing economic and operating conditions.

# 4. Alternative liquid fossil fuels.

- ***Main advantages***: many years of experience; LCA validated technologies for production and use; installa-tions, vehicles, etc. designed for them; existing fuel storage and supply infrastructure, crude oil is a major resource for synthesis of organic materials and lubri-cants production; energy intensive; future molecular level processing technologies from different feed stocks, incl. renewable, $H_2$ availability, and future engines make them very competitive.
- ***Main problems***: not renewable, max 40 % of reserves extractable at present; pollution from production, processing, transportation, marketing and use of crude oil and its products; carbon intensive; high energy consumption (5 – 8 % oil equiv.) for processing.

# 5. Alternative solid fossil fuels. Coal.

- ***Main advantages***: huge reserves, cheap, many years of experience; LCA validated technologies for production and use; a major resource for synthesis of organic chemicals; can be used for production of liquid fuels if $H_2$ is available.
- ***Main problems***: not renewable, many reserves not extractable at present; coals (i.e., anthracite, lignites, etc.) are different and require different technologies; on average coal is the most polluting and $CO_2$ intensive solid fuel; storage and transportation problems (low mass density, hygroscopic, oxidative), expensive processing, incl. by "clean coal" technologies; least energy intensive of fossil fuels.

# 6. Alternative gaseous fossil fuels. CNG and LPG.

- ***Main advantages***: huge reserves of CNG; least and polluting, most energy intensive and least $CO_2$ intensive hydrocarbon fuels; LCA validated; best for pro-duction of $H_2$, "gas to liquids (GTL)", $CH_3OH$, etc.; can be used in vehicles, incl. hybrid and fuel cell; CNG is used also for electricity and heat production; replacement of coal with NG lead to greatest $CO_2$ reduction; low storage and transportation problems.
- ***Main problems***: not renewable; **NG** is mostly $CH_4$; hygroscopic (forms hydrates), only CNG fits into vehicles; low cetane number, **LPG** is a $C_3 - C_4$ hydrocarbon mixture, produced by refineries with all consequences.

# 7. Alternative fossil fuels. Nuclear fuel.

- ***Main advantages***: high energy intensity and conversion efficiency; low radioactive emissions in electricity production; present $^{235}U/^{239}Pu$ technology limited by reserves and weapons; New fuels ($^{238}U/^{239}Pu$ and $^{232}Th/^{233}U$, etc.) and Generation IV reactors promise increase in fuel reserves, energy efficiency, reliability, easy degradable wastes and abundance of additional energy for $H_2$ production from $H_2O$.
- ***Main problems***: uranium mining technology (storage, transportation, etc.) is polluting; nuclear wastes and closed reactors remain active for a long time; accidents are disastrous; new technologies are not expected earlier than after 20 years, their LCA is not clear.

# 8. Alternative fuel. Hydrogen.

- ***Main advantages***: can be produced from fossil or re0-newable sources, even from $H_2O$; burns without emis-sions (some thermal $NO_x$, with air); highest energy in-tensity; "backbone" of fuel cell technology for elect-ricity at different scales, incl. vehicles; CNG reduction.
- ***Main problems***: low energy density, storage and gasification problems in vehicles; 96 % presently produced by gasification of fossil fuels with emissions, etc. problems; expensive; corrosive to metals; storage and supply infrastructure has to be created; LCA not clear; direct split of $CH_4$ and $H_2O$ technologies by solar and/or nuclear energy far away; fuel cell applications still very expensive.

# 9. Energy lessons in the 21st century.

- "Gods" have exclusive access to energy resources and/or the best technology to use and save them. New (renewable energy) "Gods" are coming. All "Gods" are mortals and live on The Earth.
- Environmental decisions in the 21st century should be evaluated by impartial LCA "from cradle till grave".
- Energy problems should not be solved by violence, but by concerted common efforts of all to use and save all resources (energy and other), and preserve environment.
- "Power to the People" = "Impartial knowledge, transparency and diversified choices for the People"

# 10. Optimistic energy scenarios. Energy efficiency.

**N.B. Energy losses in 2007 were 31.1 %, so:**

- ***Renewable energy systems***.
- ***$CO_2$ capture and use.***
- ***Saving in everyday life***: from "share a shower", a car and public transport to "AAA" class cookers, fridges, etc.
- ***Saving in fuels production***: molecular refineries, biorefineries and co-processing, optimized and managed by information technologies.
- ***Saving in industry:*** tribology (friction, wear and lubrication).
- ***Saving in transportation***: hybrid vehicles, battery electric vehicles; fuel cell vehicles, aerodynamics, etc. losses.
- ***Saving in power production***: new nuclear technologies; cheap $H_2$; lower power (electricity, heat, water, etc.) trans-mission losses.

# 11. Optimistic energy scenarios. $CO_2$ capture and use.

- ***Capture***: by chemical reaction (e.g. with ethanolamines) and/or membrane separation.
- ***Storage***: in depleted mines and/or in the ocean.
- ***Use***: for drinks (released back); as supercritical fluid; for increasing crude oil yield with 10 – 15 % or replacing coal-bed methane, in syntheses reactions, etc.
- ***Main problems***: LCA (environmental $CO_2$ balance) not clear; sudden release from storage and/or production facilities in air will be disastrous; price of capture, storage, etc. not clear.

# 13. Optimistic energy scenarios. Hydrogen.

- *A. Gasification (chemical and/or bio)*

- of Natural gas: $CH_4 + 2\ H_2O \rightarrow 4\ H_2 + CO_2$
- of Crude oil residues, biomass ($nCH_2$ groups):

$$>CH_2 + 2\ H_2O \rightarrow 3\ H_2 + CO_2$$

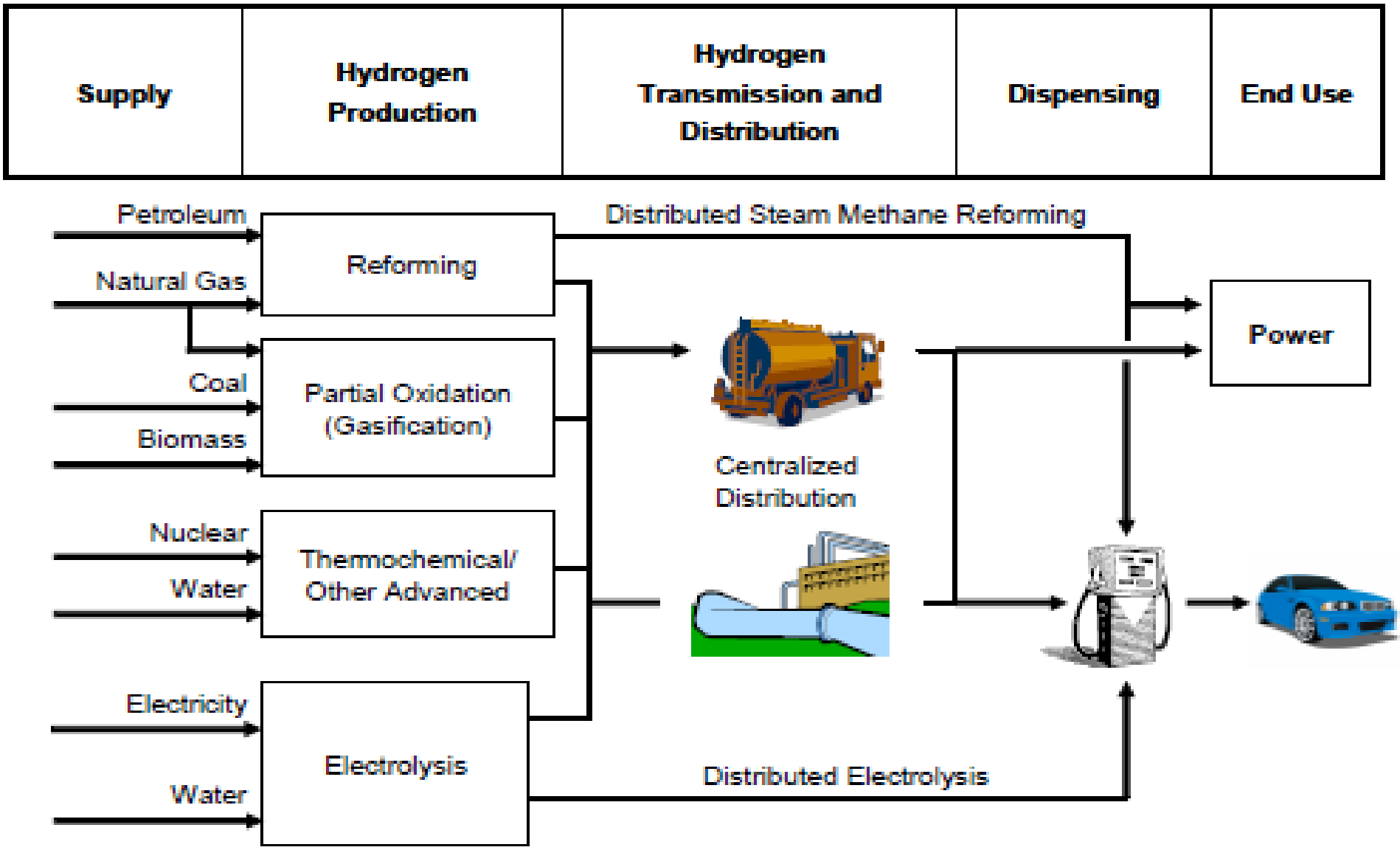
- of Coal (also some $CH_2$ groups): $C + 2\ H_2O \rightarrow 2\ H_2 + CO_2$

*B. New chemical technologies*

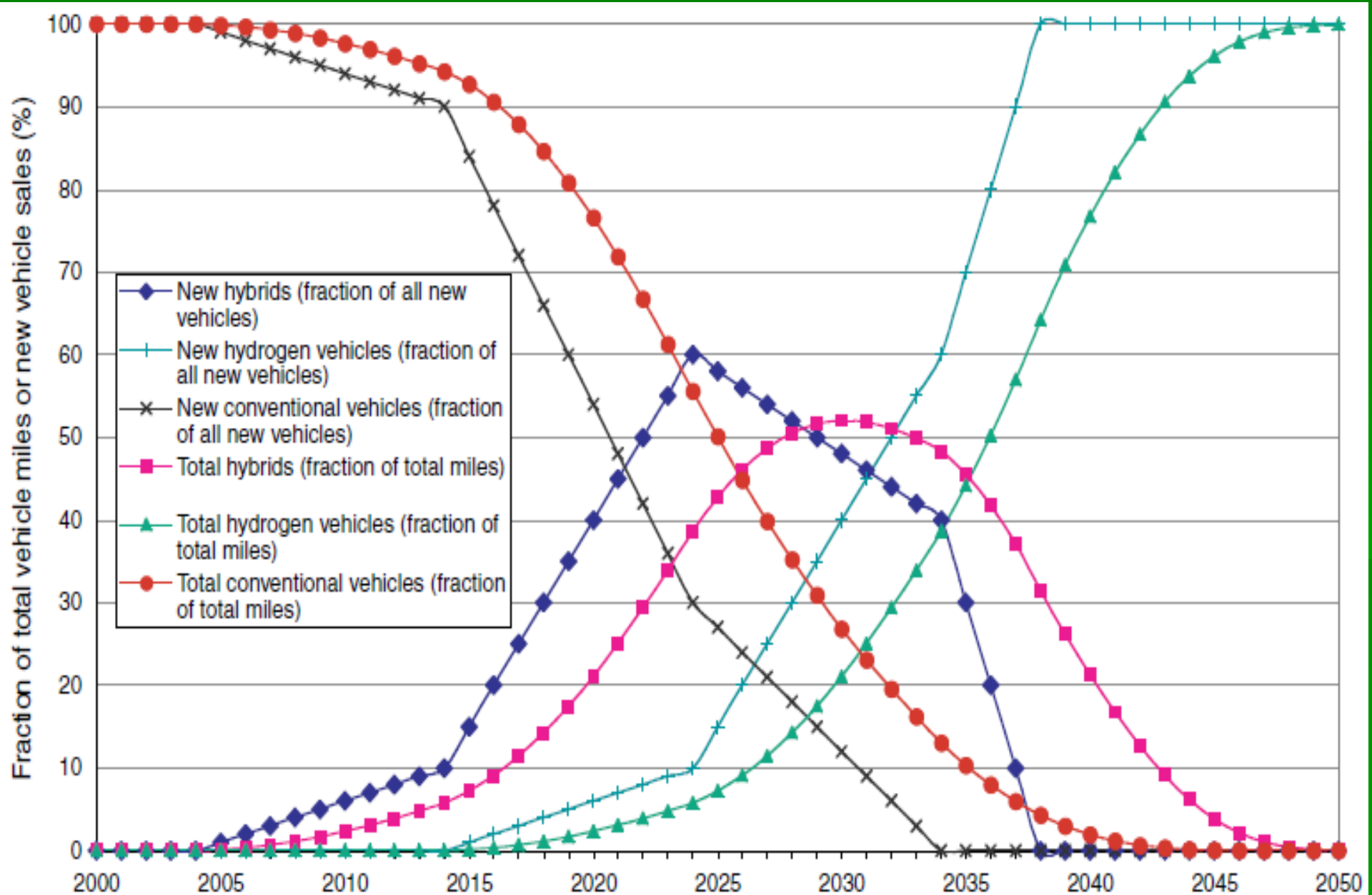
- (solar, nucl., bio) water split: $ZnO \rightarrow Zn + H_2O \rightarrow ZnO + H_2$
- (solar, nucl., bio) $CH_4$ split: $CH_4 + \text{energy} \rightarrow C + 2\ H_2$
- Photocatalytic reduction of $CO_2$ in carbon nanotubes:
  - $CO_2 + H_2 \rightarrow CH_4$, hydrocarbons, $CH_3OH$, acids, etc.

# 14. Optimistic energy scenarios. Hydrogen.

- A Simplified view of $H_2$ Economy

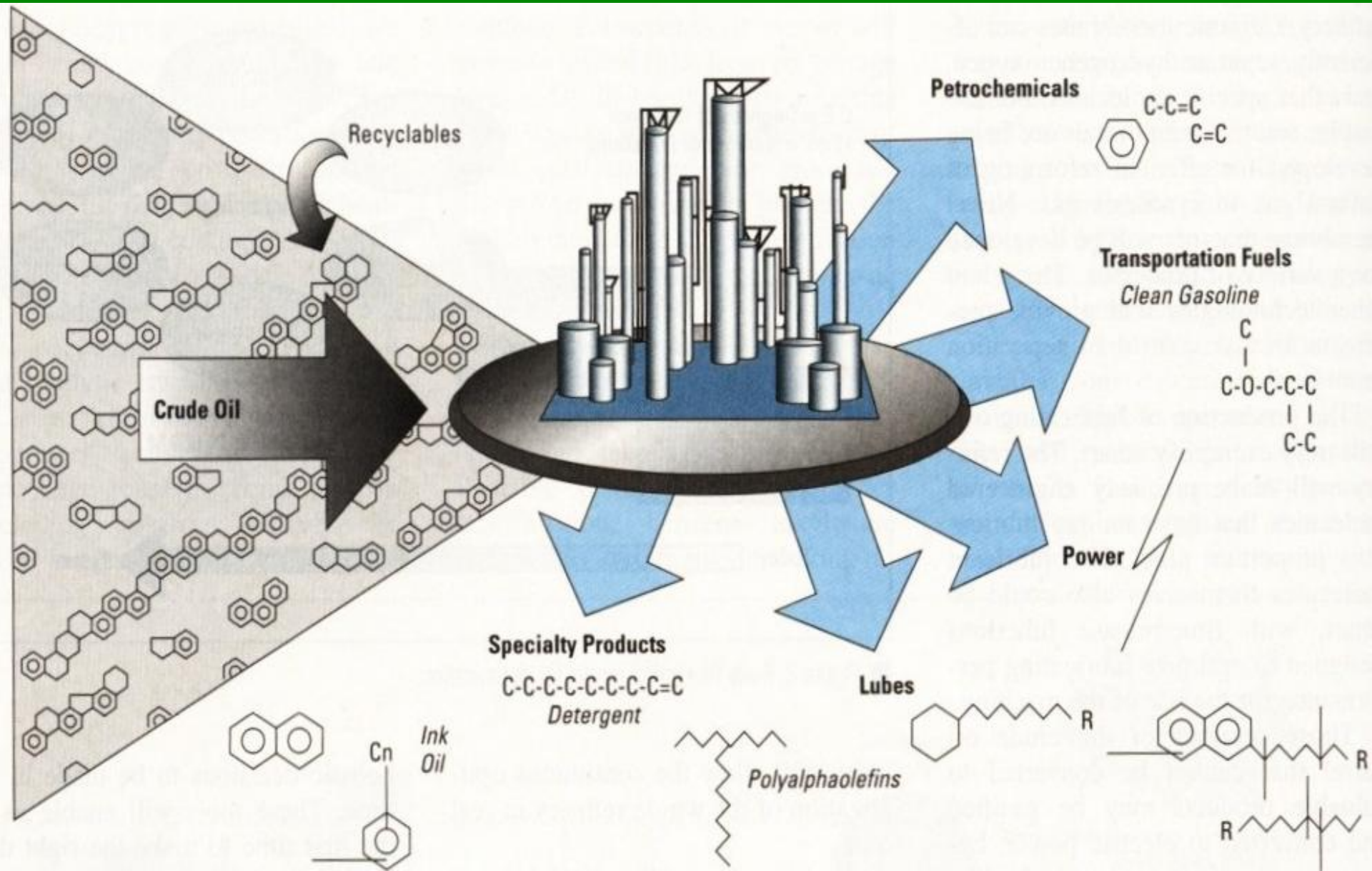


# 16. Optimistic: US New H2 Vehicles (2004 view)

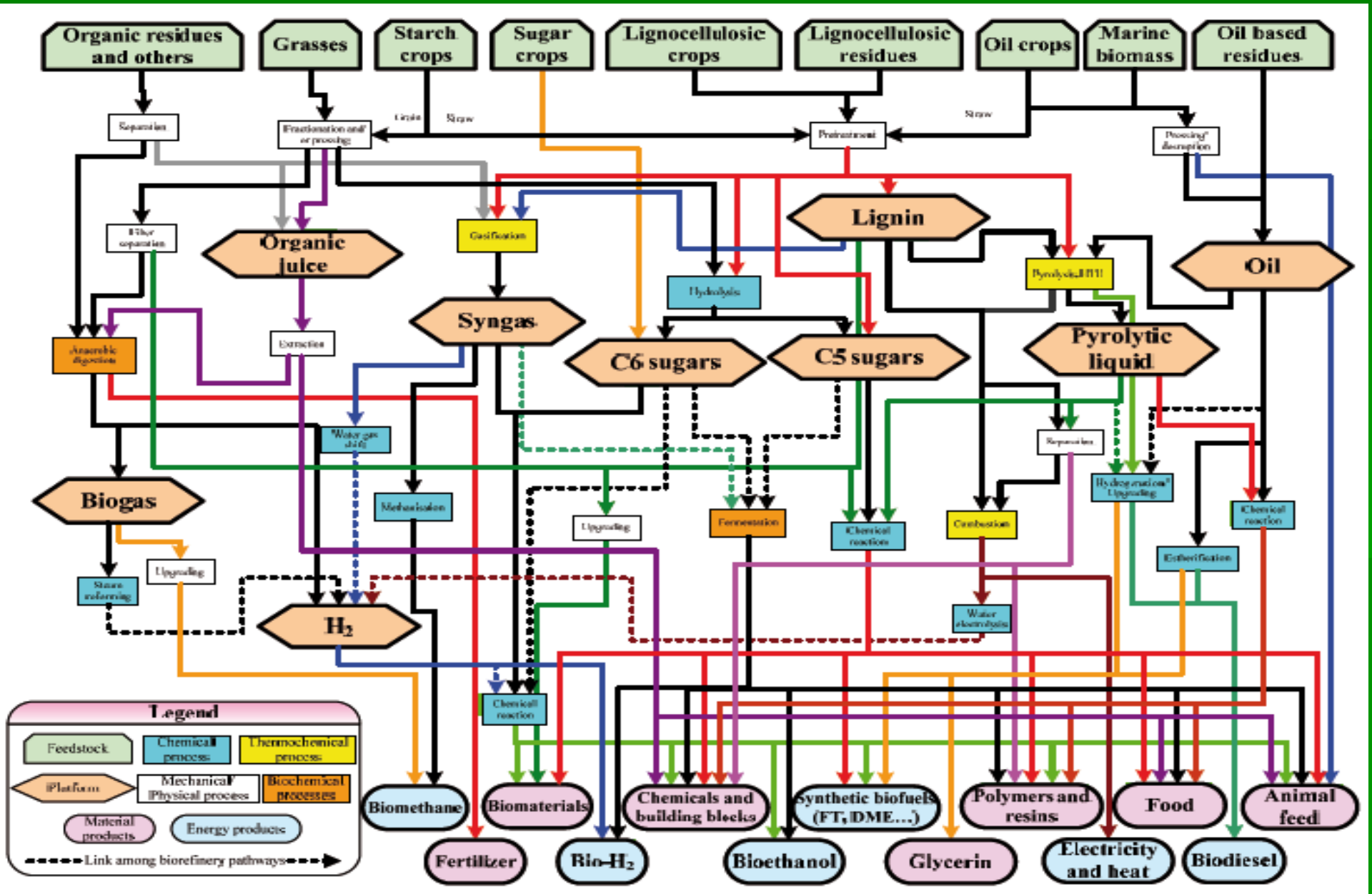


# 17. Optimistic energy scenarios. A Molecular refinery.

## Exxon's view, CEP, 2000.

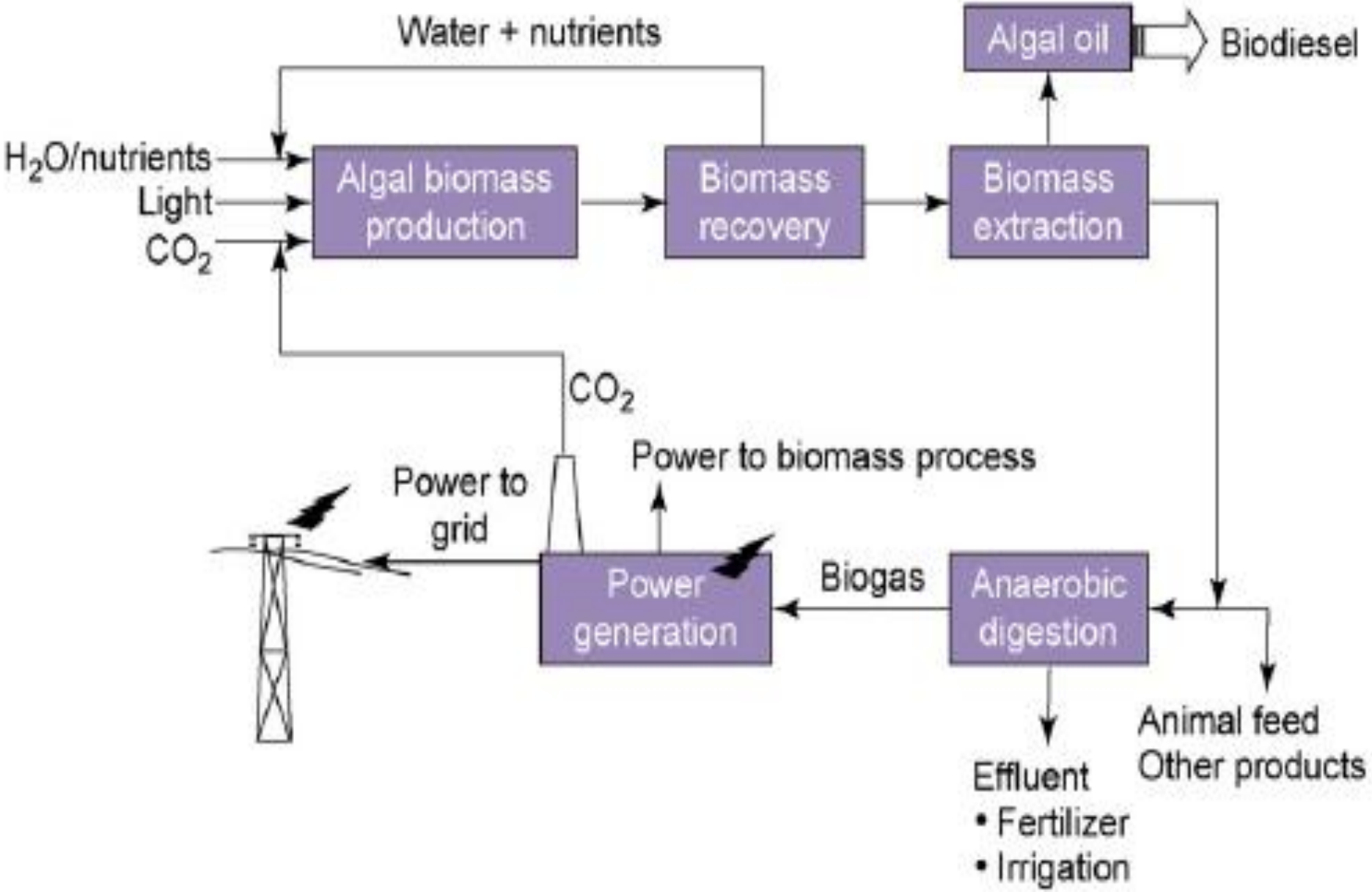


# 18. Optimistic energy scenarios. A biorefinery. IEA Task 42, 2009.



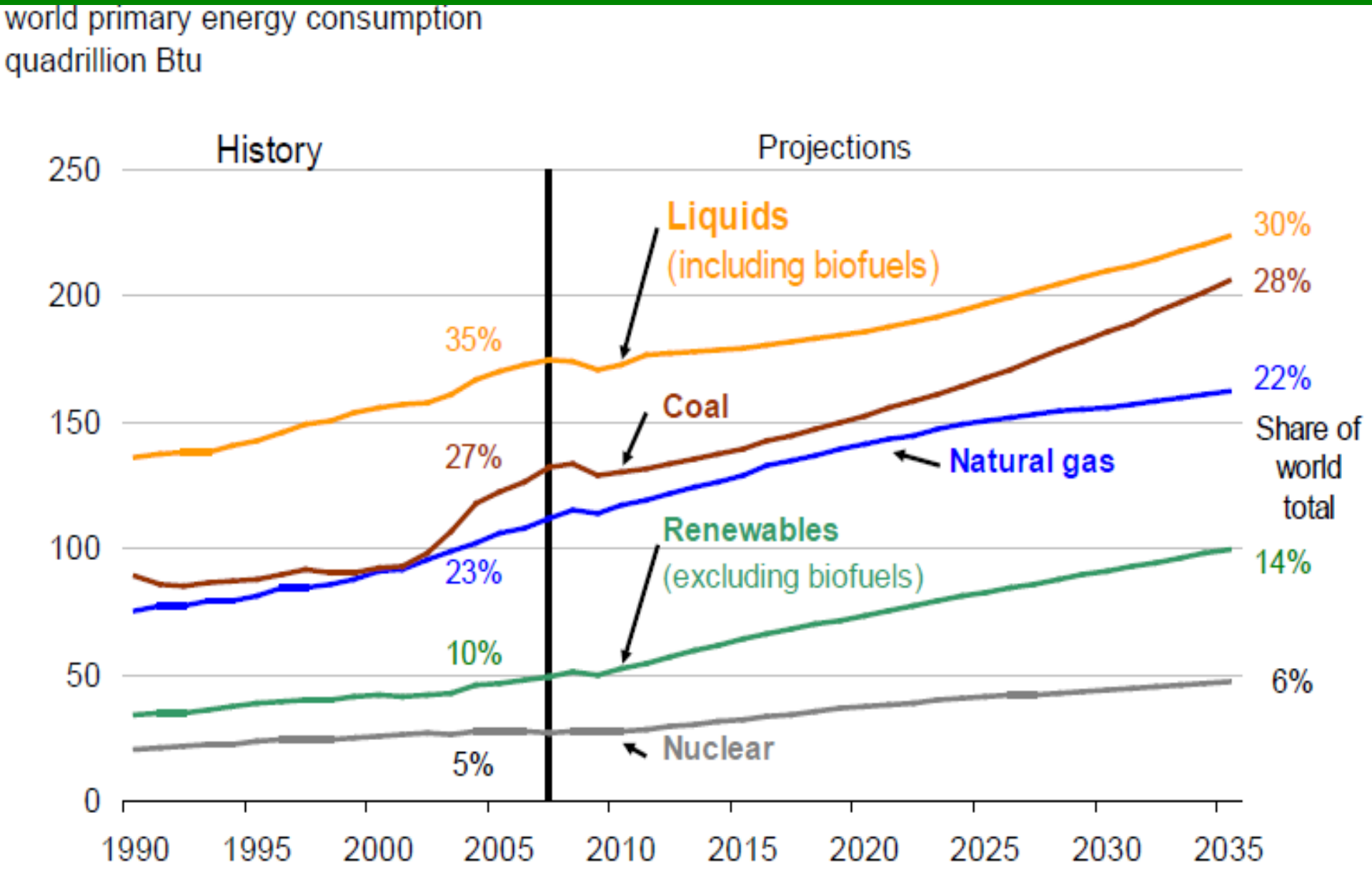
# 19. Optimistic energy scenarios. Biomass sources. Algae?

Chisti Y., Trends in Biotechnol (2008).



# 20. Optimistic energy scenarios. Energy Outlook,

H. Gruenspecht, US EIA, May 25, 2010



# 21. Optimistic energy scenarios. It might be You?

# Fuel of the future is just past Woolies

Britain's first filling station for hydrogen, the new 'wonder alternative' to petrol, is about to open, writes **Emma Smith**

Ann Johansson/AP

**Schwarzenegger has switched to a hydrogen Hummer as part of his drive to promote the fuel in California**

On a grey strip of dual carriageway alongside the unremarkable town of Hornchurch, Essex, are the unlikely beginnings of a green revolution. Follow the road out of town, past a Woolworths and a Wimpy, onto the A127, and, behind a line of makeshift wire fencing, Britain's first hydrogen filling station is almost ready for business.

It might not look much but on this muddy spot, BP, the world's third largest oil company, is taking the first small steps towards an environmentally friendly, petrol-free future.

Hydrogen is increasingly being billed as the environmental wonder fuel of the future and the motor industry's catch-all solution to toxic fumes, acid rain, climate change and dwindling oil reserves. Like the alchemist's dream, a plentiful substance — water — can be turned into a virtually inexhaustible supply of fuel. Public and private money is

# 22. Pessimistic Energy Scenarios. Guess Who is Who?

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

# Additional Materials for reading and discussion

## *"Chemistry of combustion and pollution from vehicles"*

1. Introduction to combustion phenomena, fuels and lubricants.
2. Combustion reactions of the fuel constituents.

## *"Encyclopedia of Life Support Systems (EOLSS)"*

3. Hybrid Vehicles.
4. Control of pollution in power generation.
5. Control of pollution in the petroleum industry.

# ADDITIONAL SLIDES

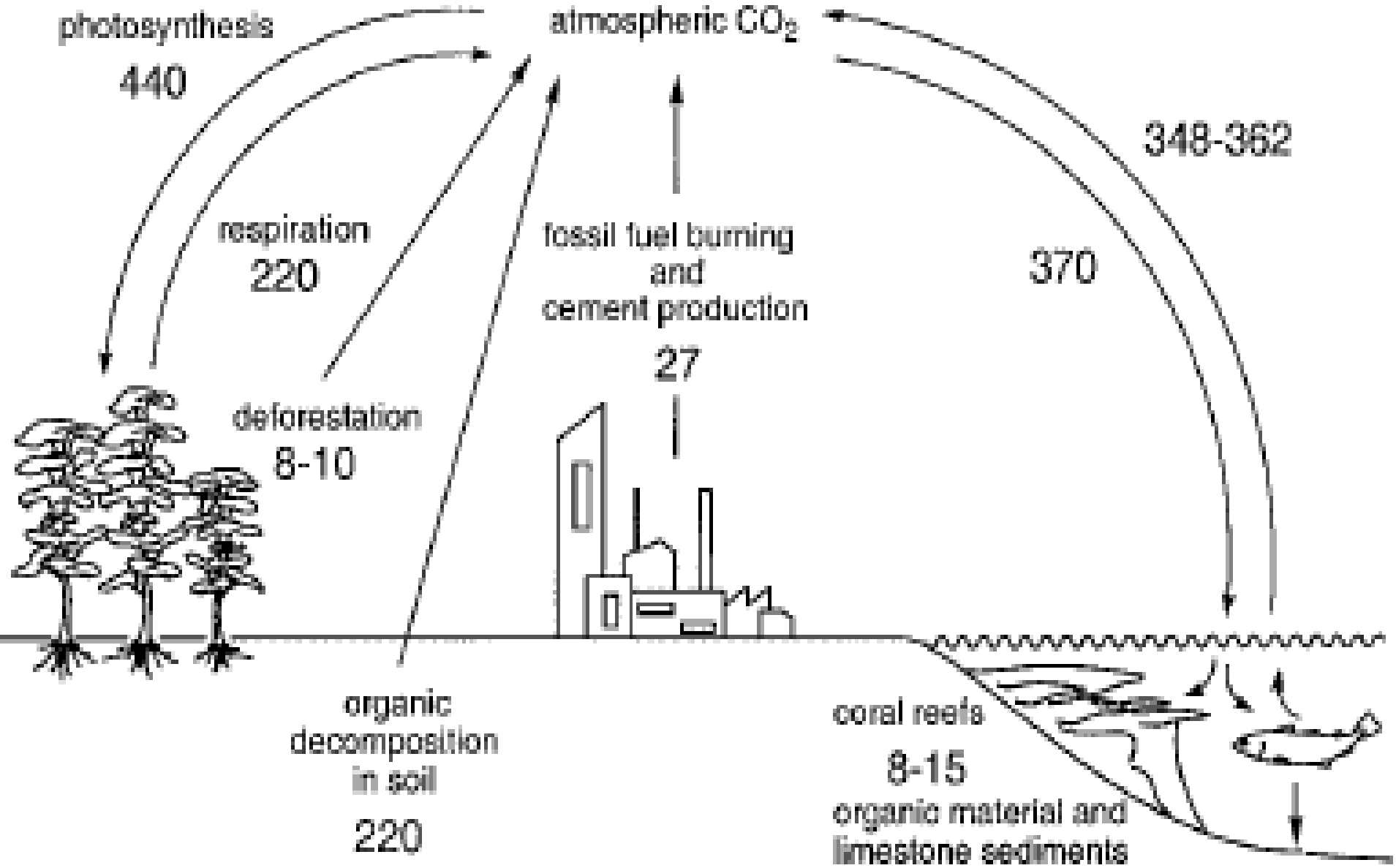
# 1. World energy consumption, mln toe, BP Report'09

| Region | 2008 | % Change 2008/2007 | 2008 share of world energy, % |
|---|---|---|---|
| North America | 2799.1 | -2.0 | 24.8 |
| - USA | 2299.0 | -2.8 | 20.4 |
| Total S.& Central America | 579.6 | 2.6 | 5.1 |
| Total Europe & Eurasia | 2964.6 (1728.2 EU) | 0.26 (-0.5 EU) | 26.2 (15.2 EU) |
| Middle East | 613.5 | 5.9 | 5.4 |
| Africa | 356.0 | 4.1 | 3.2 |
| Asia & Pacific | 3981.9 | 4.1 | 35.3 |
| - China & H-Kong | 2026.3 | 7.2 | 17.7 |
| World Total | 11104.4 (5508.4 OECD) | 1.4 (-1.3) | 100.0 (48.8) |

# 2. World fossil (*recov.*) reserves in 2008, BP Report'09 :
## (8 countries = 81 % Oil; 6 – 70 % NG; 8 – 89 % Coal)

| Region | Crude Oil, mln t | Natural Gas, $10^{12}$ $m^3$ | Coal, mln t | Nuclear energy consumption, mln toe |
|---|---|---|---|---|
| North America | 9700 | 8.87 | 246097 | 215.4 |
| - USA | 3700 | 6.73 | 238308 | 192.0 |
| Total S.& Central America | 17600 | 7.31 | 15006 | 4.8 |
| Total Europe & Eurasia (EU) | 19200 (800) | 62.89 (2.87) | 272246 (29570) | 276.7 (212.7) |
| Middle East | 102000 | 75.91 | 1386 | - |
| Africa | 16600 | 14.65 | 32013 | 3.0 |
| Asia & Pacific | 5600 | 15.39 | 259253 | 119.8 |
| - China | 2100 | 2.46 | 114500 | 15.5 |
| World Total | 170800 (no sands) | 185.02 | 826001 | 619.7 (reserve 17 Mt $U^{235}$) |

# 12. Optimistic energy scenarios. $CO_2$ capture and use.



# 15. Optimistic: US Cost of Hydrogen

## The Hydrogen Economy, 2004