Tables & Figures

Table 4.2.1. Total global primary energy consumption mix in 2002 (Enerdata, 2004)

	EJ	Share
Oil	148	35%
Natural gas	90	21%
Coals	101	24%
Nuclear power	30	7%
Biomass and organic waste	47	11%
Hydro	9	2%
Wind	0.185	0.04%
Solar electricity	0.004	0.001%
Solar heat	0.159	0.04%
Geothermal electricity	1.685	0.4%
Geothermal heat	0.120	0.03%
Total	**427.153**	100%

Table 4.2.2. Global electricity generation by fuel type since 1972 (TWh) compared with two scenarios for 2030 (Enerdata, 2004; IEA, 2004)

						IEA, 2030	
TWh	1972	1990	1995	2002	2002	Reference	Alternative
Oil	1299	1326	1244	1185	7%	1200	957
Natural gas	736	1629	1976	3009	19%	9600	8119
Other gases	96	721	844	1129	7%		
Coal	1877	3420	3684	4584	28%	12000	8608
Lignite	250	502	618	709	4%		
Biomass & waste	31	130	134	192	1,2%	620	920
Hydro	1281	2194	2549	2619	16%	4300	4319
Nuclear	152	2013	2332	2714	17%	3000	3400
Geothermal	5	36	40	49	0,3%	170	220
Wind	0	3	8	51	0,3%	920	1220
Solar	0	1	1	1	0,0%	120	170
Tide/wave	0	0	0	0	0,0%	40	40
Total	5729	11976	13429	16242	100%	31970	27973

Table 4.2.3. The Asia-Pacific region's share of global proven fossil fuel reserves, and regional annual production and consumption in 2003

	Proven reserves		Annual production		Annual consumption	
	Amount[1]	Global share	Amount (Mtoe/yr)	Regional share	Amount (Mtoe/yr)	Regional share
Oil	47.7	4.2%	375.8	10.2%	1,049.1	28.8%
Coal	292.5	29.7%	1,317.7	52.3%	1,306.2	50.7%
Natural Gas	475.6	7.7%	310.5	11.9%	310.9	13.3%
Total fossil fuels			2,004.0	23.4%	2,666.2	31.1%

[1] Oil: billion barrels; Coal: billion tonnes; Natural gas: trillion cubic feet Source: BP (2004)

Table 4.2.4. *Scenarios for 2050 from WEC, 2004 (A and C cases) and IEA (2005).*

	Actual year 2000	**C-2050**	**A-2050**	**IEA-2050**
Population (10^9)	6.2	10.1*	10.1*	8.7
GWP (US$ 10^{12})	30.0	84	110	173
Primary energy (EJ)	420**	600	1040	1013
Electricity (EJ)	34.9	73.5	126.0	n/a
Carbon (Gt)	6.4	5	12***	10

* Varied between 8.7 and 11.3 depending on scenario
** Did not include indigenous biomass
*** Average of actual range of 9-15

Table 4.3.1. *Approximate global energy resources (including reserves), annual rate of use, cost ranges for good locations and comments on associated environmental impacts. (Data from BP, 2005; WEC, 2004; IEA, 2004; IAEA, 2004 USGS, 2004; Johansson, 2004)*

Energy Class	Specific type of energy source	Estimated available energy resource (EJ)	Rate of use in 2003 (EJ/yr)	Cost when located on a good site[a] (US$)	Comments on environmental impacts	References
Fossil energy	Coal (conventional)	25,000	100	$3/GJ	25.1gC/MJ	(See title of Table)
	Coal (unconventional)	50,000	0	?		"
	Gas (conventional)	12,000	100	$360 /Mm^3; $11 /GJ	14.3gC/MJ	"
	Gas (unconventional)	68,000	Small	?		"
	Oil (conventional)	10,000	150	$40-70 / bbl	20.8gC/MJ Peak oil close?	"
	Oil (unconventional)	35,000	3	?	Higher cost of extraction?	"
Nuclear	U235	5700 @$130/kg	25	1-12¢/kWh	Spent fuel disposition	IAEA Redbook, 2005
	U238 and thorium	~400,000	Very small			Waltar & Reynolds,1981
	Fusion	?	0	?	Unlikely for decades	
Renewable	Hydro (>10 MW)	60/yr	25	2-10¢/kWh	Land use impacts	Johansson *et al.*, 2004
	Hydro (< 10 MW)	2/yr	0.8	2-12¢/kWh		"
	Wind	600/yr	~ 0.5	4-8¢/kWh	Bird kills	"
	Biomass	250/yr	~ 50 (44 trad.)	1-12¢/kWh/8-25$/GJ		"
	Geothermal	5000/yr	~2	2-10¢/kWh	Resource limited?	"
	Solar PV	1600/yr	~0.2	25-160¢/kWh		"
	Solar thermal	1.7/yr	0.03	12-34¢/kWh		"
	Ocean (tidal, waves, current, thermal)	7/yr (exploitable)	<1	8-40¢/kWh	Recreational use conflicts	"

[a] For example where a conversion plant is close to the coal or gas resource, or a site with high mean annual wind speeds, or with good solar radiation etc.

Table 4.3.2 Unconventional methane gas resources (Encyclopaedia of Energy, 2004)

	Worldwide resource in-place $10^{12}m^3$ (EJ)	*U.S. resource and production ($10^{12}m^3$)*		
		Resource in-place	*Remaining recoverable resources*	*2001 production*
Coal bed methane	*278 (9,990)*	*20.6*	*2.68*	*0.045*
Tight gas sands	*227 (8,158)*	*26.2*	*8.27*	*0.093*
Gas shale	*494 (17,753)*	*16.5*	*1.25*	*0.014*
Methane hydrates	*22,500 (800,000)*	-	-	-

Table 4.3.3. The multi-benefits of biomass uptake can be social, environmental as well as economic (based on IEA, 2005)

Social Aspects	Environmental Aspects	Economic Aspects
- Improved access to basic services (pumped water, electric lighting). - Creation of jobs, livelihoods. - Increase on labour, power, access to resources. - Pride and independence. - Support for rural communities - Improved social cohesion. - Reduced dependency on imported oil.	- Reduced pressure on finite natural resources. - Reduced landfill waste and associated issues. - Protection of groundwater supplies. - Reduced dryland salinity and soil erosion. - Maintenance of logging sites in a clean state for reforestation. - Increased terrestrial carbon sinks and reservoirs. - The return of derelict land into production with enhanced biodiversity. - Reduced GHG emissions via fossil fuel substitution.	- Concentrated sources of biomass (e.g. residues from sawmills, landfill gas), can already compete with fossil fuels. - Trade of "carbon credits" will impact on the economics of biomass and other energy systems. - US$/GJ of biomass delivered to the conversion plant gate needs to be secure and contracted for the medium to long term.

Table 4.4.1. Energy carriers of hydrocarbon substances

Primary energy	Energy carriers of secondary energy			
	Solid	**Slurry**	**Liquid**	**Gas**
Coal	Pulverized coal. Coke	CWM, COM	coal liquefied fuel. synthetic fuel	coal gas, producer gas, blast furnace gas, water gas, gasified fuel, hydrogen
Oil	—	—	Oil refinery products NGL. LPG	oil gas, synthetic gas, hydro-gen
Natural gas	—	—	LNG. Gas to liquid. alcohols. di methyl ethers. Fischer Tropsch synthesis.	methane, hydrogen
Biomass	Wood. En-ergy crops Refuse de-rived fuel	—	methanol. ethanol, biodiesel. di-methyl ethers	methane, hydrogen

Table 4.4.2. Reduction in CO_2 emission coefficient by fuel substitution in electricity production. (Danish Energy Authority, 2004)

Existing			Mitigation option			Change
Energy source	Efficiency	Emission coefficient gCO_2/kWh		Efficiency	Emission coefficient gCO_2/kWh	Emission change gCO_2/kWh
Coal, normal steam turbine	35%	973	Advanced steam pulverized coal	48%	710	264
Coal, normal steam turbine	35%	973	Natural gas, combined cycle	50%	404	569
Fuel oil, steam turbine	35%	796	Natural gas, combined cycle	50%	404	392
Diesel oil, diesel generator	33%	808	Natural gas, combined cycle	50%	404	404
Natural gas, single cycle	32%	631	Natural gas, combined cycle	50%	404	227

Table 4.4.3 Characteristics of CHP (cogeneration) plants.

Technology	Fuel	Capacity MW_e	Electrical efficiency (%)	Overall efficiency (%)
Steam turbine	Any combustible	0.5-500	7-20	60-80
Gas turbine	Gaseous & liquid	0.25-50+	25-42	65-87
Combined cycle	Gaseous & liquid	3-300+	35-55	73-90
Diesel and Otto engines	Gaseous & liquid	0.003-20	25-45	65-92
Micro-turbines	Gaseous & liquid	0.05-0.5	15-30	60-85
Fuel cells	Gaseous & liquid	0.003-3+	37-50	85-90
Stirling engines	Gaseous & liquid	0.003-1.5	30-40	65-85

Table 4.5.1 Current cost ranges for the components of a CCS system, applied to a given type of power plant or industrial source. (IPCC, 2005).

Costs component	*Cost range**	*Remarks*	*Cost reduction potential up to 2025*
Capture from coal- or gas-fired power plants	15-75 US$/t$CO_2$ net captured		Medium
Capture from ammonia production or gas processing	5-25 US$/t$CO_2$ net captured		Low
Capture from other industrial sources	25-115 US$/t$CO_2$ net captured		Medium
Transportation	1-8 US$/t$CO_2$ transported	Per 250 km pipeline or shipping for mass flow rates of 5 to 40 MtCO_2/yr	Low
Geological storage	0.5-8 US$/t$CO_2$ injected	Excluding potential revenues from EOR or ECBM	Low
Ocean storage	5-30 US$/t$CO_2$ injected	Including offshore transportation of 100-500 km	Low
Geological storage: monitoring and verification	0.1-0.3 US$/t$CO_2$ injected	Depend on the regulatory requirements	Low
Mineral carbonation	50-100 US$/t$CO_2$ net mineralized	Includes additional energy use for carbonation	Medium

Note) Low is below 10%, medium is between 10 and 50%, high is above 50%.
*Multiply $ values by 3.67 to obtain costs per tonne of C.

Table 4.5.2 Storage capacity for several geological storage options (IPCC, 2005).

Reservoir type	*Lower estimate of storage capacity GtCO_2 (GtC)*	*Upper estimate of storage capacity GtCO_2 (GtC)*
Oil and gas fields	900 (240)	1,200 (325)
Unmineable coal seams	3 – 15 (0.8-4)	200 (55)
Saline formations	1,000 (270)	Uncertain, could be on the order of 10,000 or more (2700)

Table 4.5.3 Primary use, technical potentials and projected costs for a range of primary energy resources

Energy resource	Current approximate use (EJ/yr)	Technical potential up to 2050 (EJ)	Inherent carbon (Gt)	Consumer costs[1] (2005) $US	Projected investment costs in 2050 ($/$W_e$)[2]	References
Oil	150	10000 - 40000[3]	200 – 800	~$9 /GJ	?	Wall St. J, 2005
Natural gas	100	12000 - 60000[3]	170 - 850	~$7 /GJ	0.2-0.8	Various, 2005
Coal	100	130000	3000	~$3 /GJ	0.4-1.4	EIA, 2005
Nuclear	25	6000 - 400000[4]	****	1-10 ¢/kWh (?)	1.5-3.0	IAEA, 2004 WEC/IIASA, 2001
Hydro	25	2500	****	2-10 ¢/kWh	1-3	Johansson *et al*. 2004 WEC/IIASA, 2001
Biomass – heat and power	50 (9[5])	>12500[6]	****	$8-12 /GJ 3-12 ¢/kWh	0.4-1.2	“
Biofuels	0.5		****		8-25 /GJ	
Solar PV	0.2	>80000[7]	****	$0.25-1.50 /kWh	0.6-1.2	“
Solar thermal	0.04		****	12-43 ¢/kWh	2.0-4.0	
Wind	0.5	30000	****	4-8 ¢/kWh	0.4-1.2	“
Geothermal	2	250000	****	5-6 ¢/kWh		“
Ocean	nil	>375000	****	8-40 ¢/kWh		“

**** To be completed from IAEA and other sources, but small amount.

[1] Volatile prices
[2] Excluding carbon capture and storage
[3] Includes undiscovered and unconventional oil and gas reserves
[4] Assumes nuclear fuel is recycled
[5] Modern biomass use only
[6] Combined heat and liquids
[7] Combined thermal and electricity

Table 4.7.1. General policy objectives and options used to reduce energy demand and hence greenhouse gas emissions from the energy supply sector.

Policy options / Policy objectives	Economic instruments	Technological development and diffusion	Regulatory instruments	Voluntary agreements	Information and other instruments
Energy efficiency	Higher energy taxes. Lower energy subsidies. Power plant emissions charges. Fiscal incentives. Tradable emission permits.	Cleaner power generation from fossil fuels	Power plant minimum efficiency standards. Best available technology prescriptions.	Voluntary commitments to improve power plant efficiency.	Information and education campaigns.
Energy source switching	CO_2 and CH_4 taxes. Emissions charges. Tradable emission permits. Fiscal incentives.	Increased power generation from renewable, nuclear and "clean" hydrogen sources.	Power plant fuel portfolio standards.	Voluntary commitments to fuel portfolio changes.	Information and education campaigns.
Renewable energy	Capital grants. Feed-in tariffs. Renewable energy certificates. CO_2 taxes. Emissions charges. Tradable emissions permits.	Increased power generation from renewable energy sources.	Targets.	Voluntary agreements to install renewable energy capacity.	Information and education campaigns. Green electricity validation.
Carbon capture and storage	Emissions charges. Tradable emission permits.	Chemical and biological sequestration. Deep ocean sequestration.	Emissions restrictions for major point source emitters.		Information campaigns.

Table 4.9.1 Summary of energy supply and related carbon emissions to 2020 and 2050 from various scenarios

ENERGY USE RATES FOR VARIOUS SCENARIOS

	2020				2050							
	GEP A1	GEP A3	GEP C2	IEA SD	GEP A1	GEP A3	WEA A	SRES A1-B	GEP C2	SRES B2	WEA C	IEA SD
Population (10^9)	7.9	7.9	7.9	7.6	10.1	10.1	10.1	8.7	10.1	9.4	10.1	8.7
GDP US$ (10^{12})	46.9	46.9	40.5	64.9	101.5	101.5	100.0	181.3	75.0	109.5	75.0	173.2
Primary Energy (EJ)	646.0	645.1	480.1	604.4	1042.9	1035.7	1041.0	1347.0	598.5	869.0	601.0	1013.0
Coal	155.8	122.2	95.8	135.6	159.2	94.1		186.0	61.7	86.0		99.3
Oil	195.7	178.9	126.8	178.5	331.8	181.9		214.0	110.0	227.0		181.3
Gas	152.0	161.3	124.3	157.3	197.4	332.2		465.0	140.3	297.0		267.1
Nuclear	38.2	43.3	35.7	18.1	121.8	118.4		123.0	74.3	48.0		114.5
Renewables	103.7	139.0	97.4	114.9	232.7	308.7		360.0	212.1	212.0		350.8
Biomass				69.3				193.0		105.0		159.0
Other				45.6				167.0		107.0		191.8
GtC	10.3	9.2	6.9	9.2	13.8	11.1	12*	16.0	5.9	11.2	5.0	10.0
Final Energy (EJ)	11.4	11.3	8.5		17.0	17.2		1002.0	9.9	654.0		
Non-Commercial								0.0		11.0		
Solids	2.7	2.7	2.4		2.7	3.1		75.0	2.0	19.0		
Liquids	4.4	4.1	2.8		7.2	5.6		302.0	3.4	268.0		
Gas								295.0		105.0		
Electricity	1.6	1.7	1.2		2.9	3.0		331.0	1.7	188.0		
Others	2.7**	2.8**	2.2**		4.3**	5.4**		0.0	2.8**	63.0		

*** net ave of 9-15**
**** includes gas**

GEP - Global Energy Perspectives, IIASA/WEC, Cambridge University Press, 1998
IEA SD - Sustainable vision scenario, Energy to 2050: scenarios for a sustainable future, IEA, 2005
WEA - World Energy Assessment: Energy and the challenge of sustainability, UNDP/UNDESA/WEC, 2000
SRES - Special Report on Emissions Scenarios, IPCC, 2000

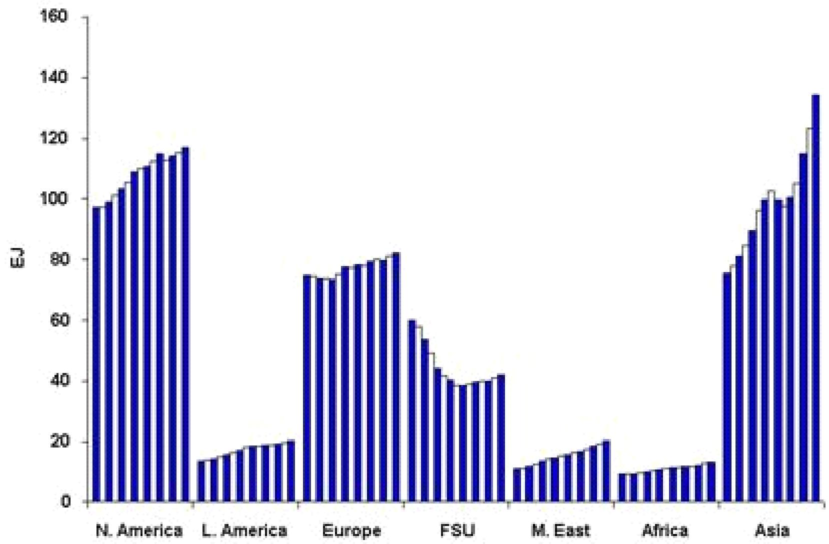


Figure 4.1.1 Global annual primary energy demand from 1990 to 2004 by region (BP, 2005).

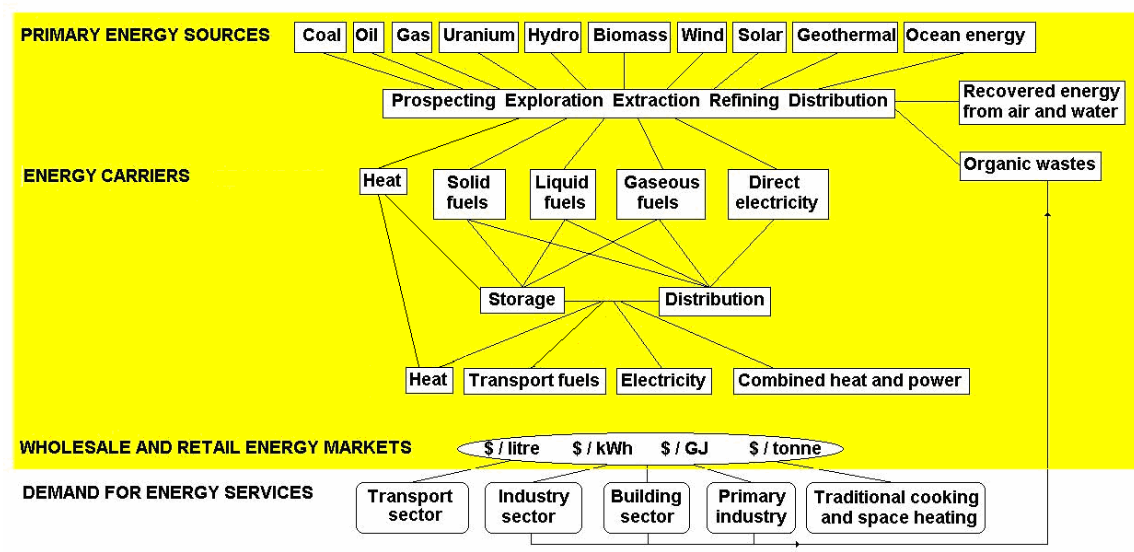


Figure 4.1.2 Primary and secondary energy supplies to meet societal needs for energy services. The Energy Supply chapter (yellow box) links with the sector chapters on industry, transport, buildings and wastes.

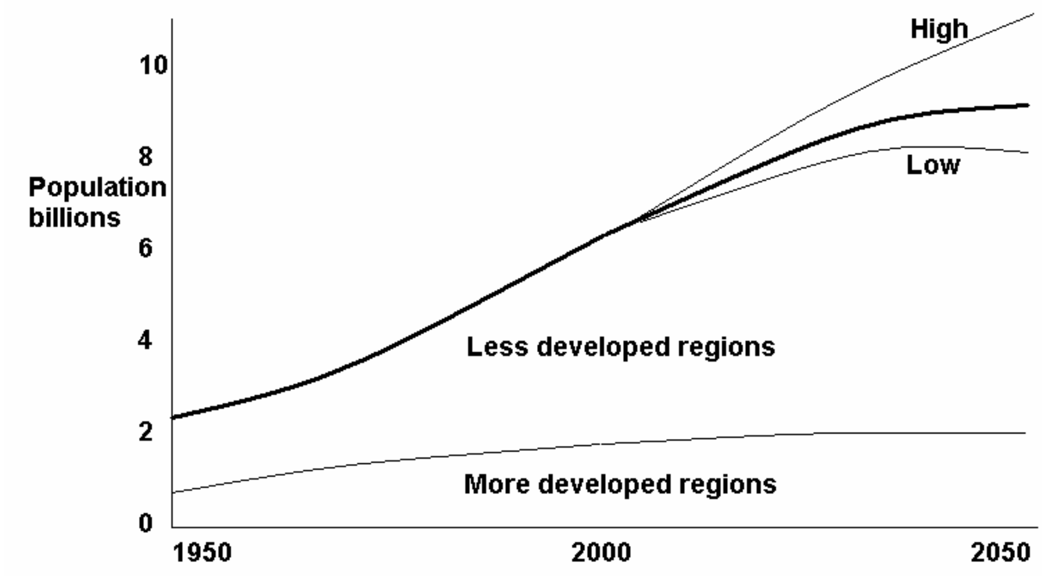


Figure 4.1.3 Estimated and projected world population from 1950 to 2050 (UN, 2002).

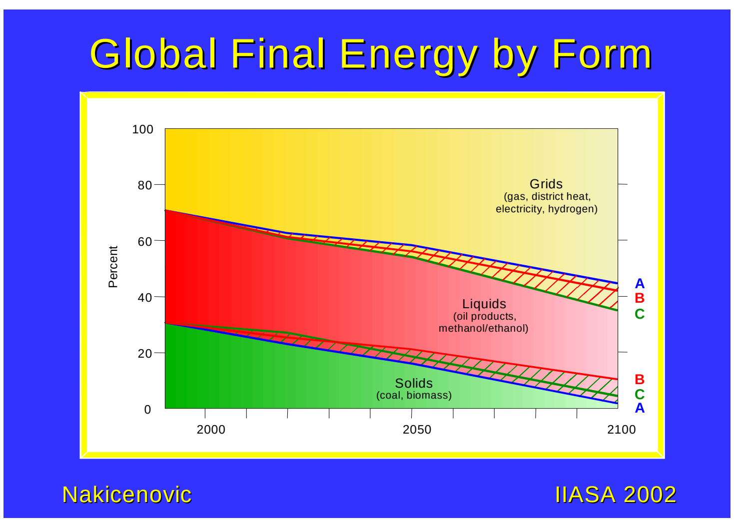


Figure 4.1.4 Final energy across three scenarios (A,B,C) showing a gradual shift toward grid-oriented energy carriers and away from the direct use of solids, which are instead converted to synfuels, electricity, and energy gases (WEC, 2004)

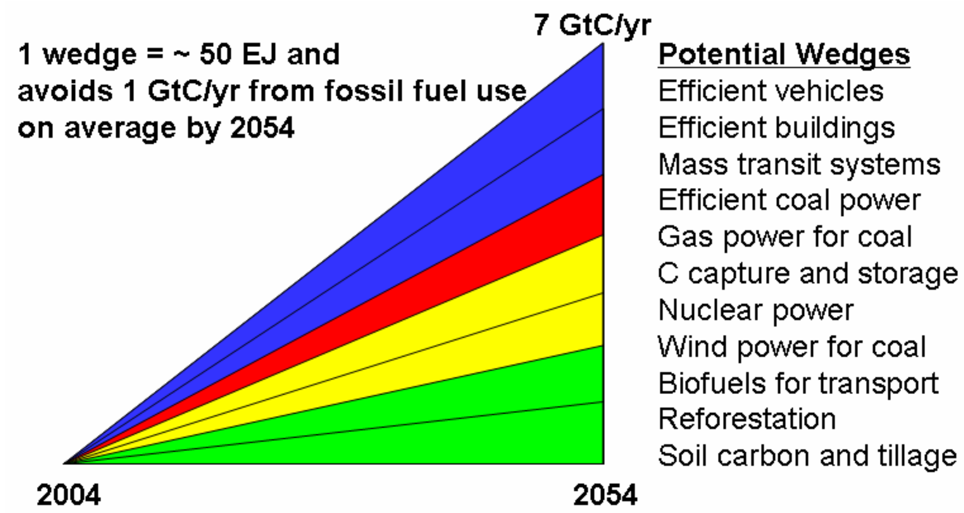


Figure 4.1.5. Technologies (wedges) that could conceivably each avoid releasing 1GtC/yr from fossil fuels by 2054 (Pacala & Socolow, 2004).

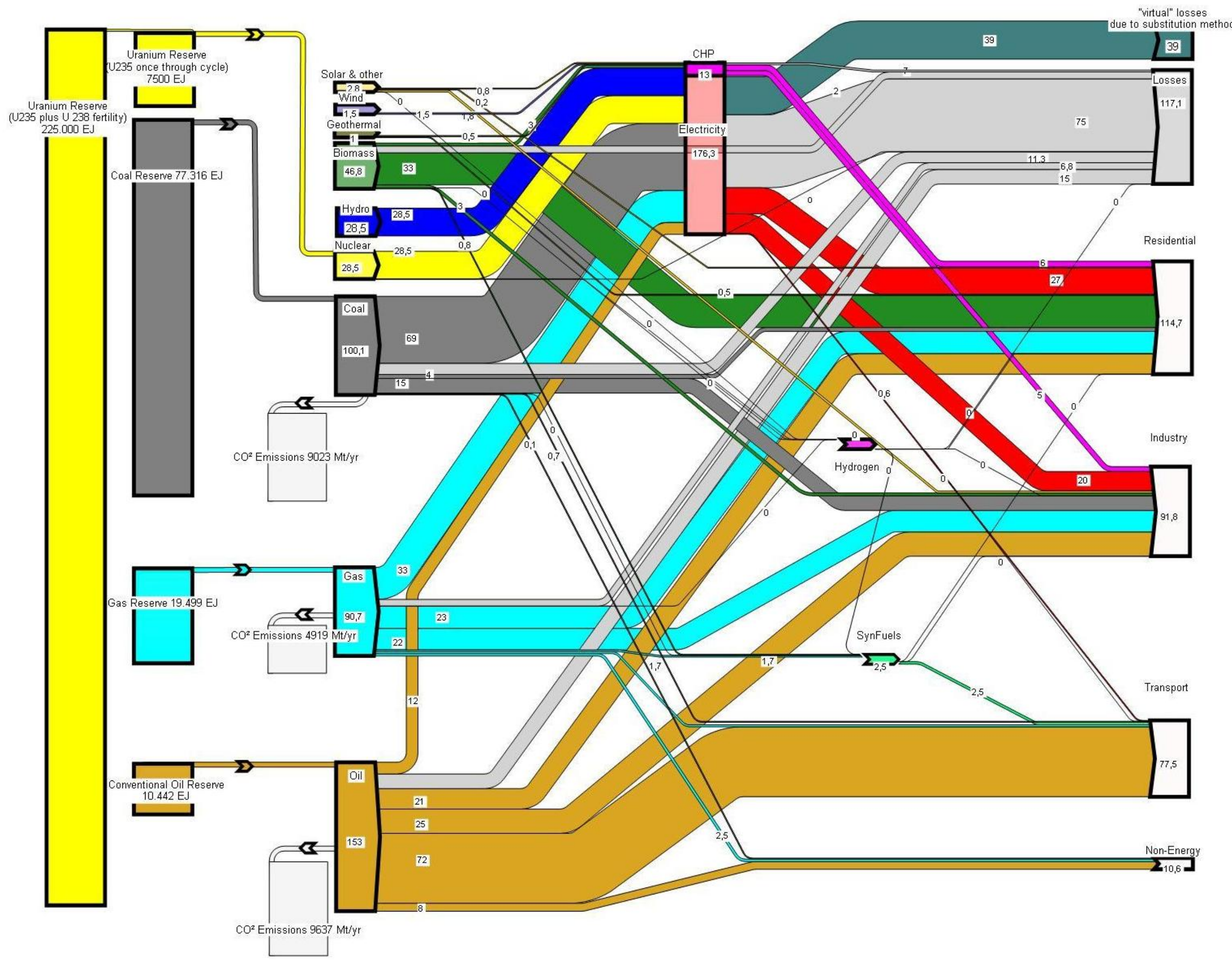


Figure 4.2.1 Global energy flows and carriers from primary energy through secondary energy conversions to end uses and showing annual carbon dioxide emissions.

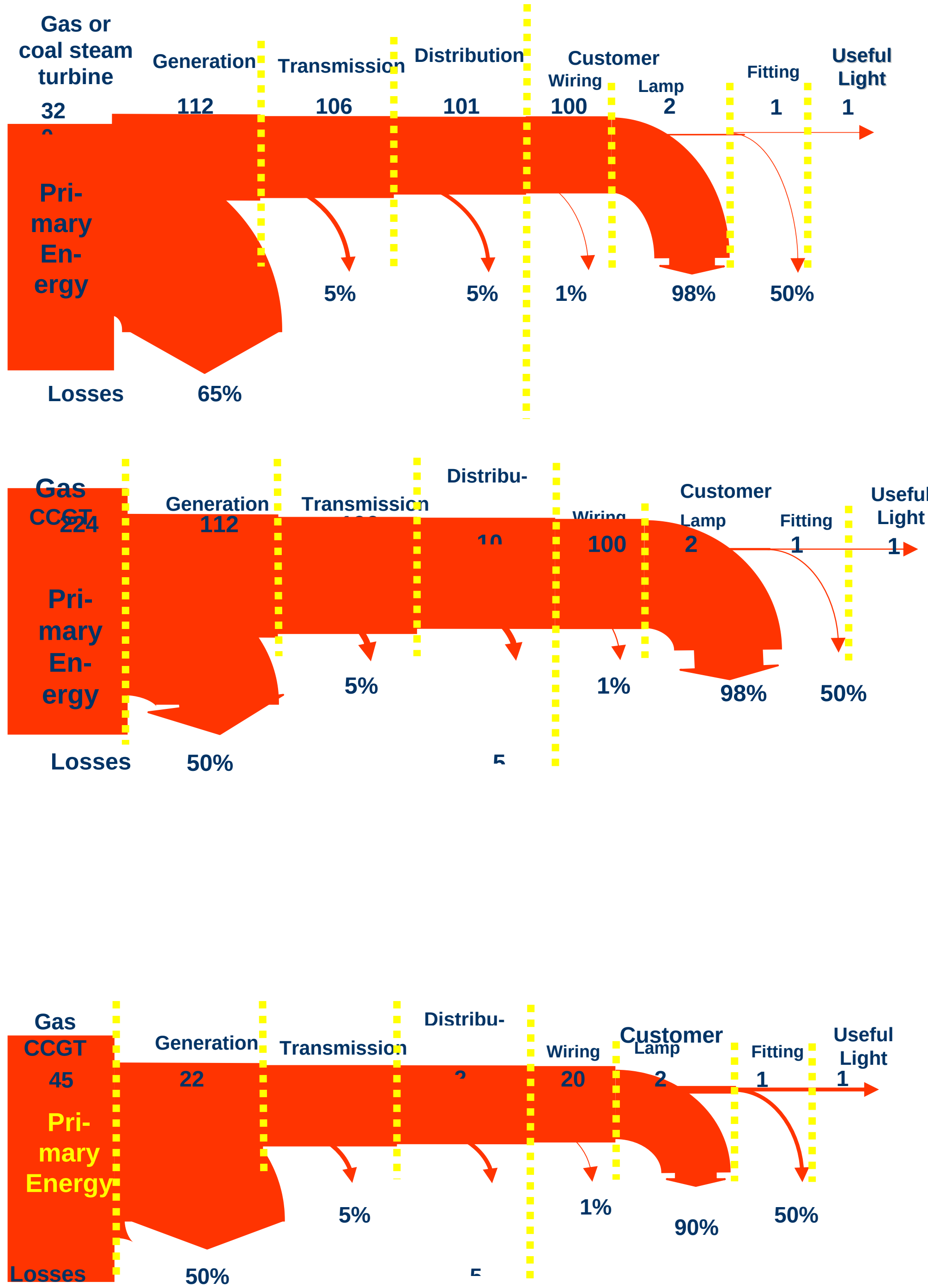


Figure 4.2.2. To obtain 1 energy unit of useful light requires 320 units of primary energy combusted in a thermal, steam turbine, power station to overcome the supply chain losses. Improving the generation plant conversion efficiency from 35% to 50% using a combined cycle gas turbine

plant (CCGT) would reduce this to 224 energy units but using a compact fluorescent light bulb instead of a standard light bulb would only require 45 units to be generated. (Cleland, 2005).

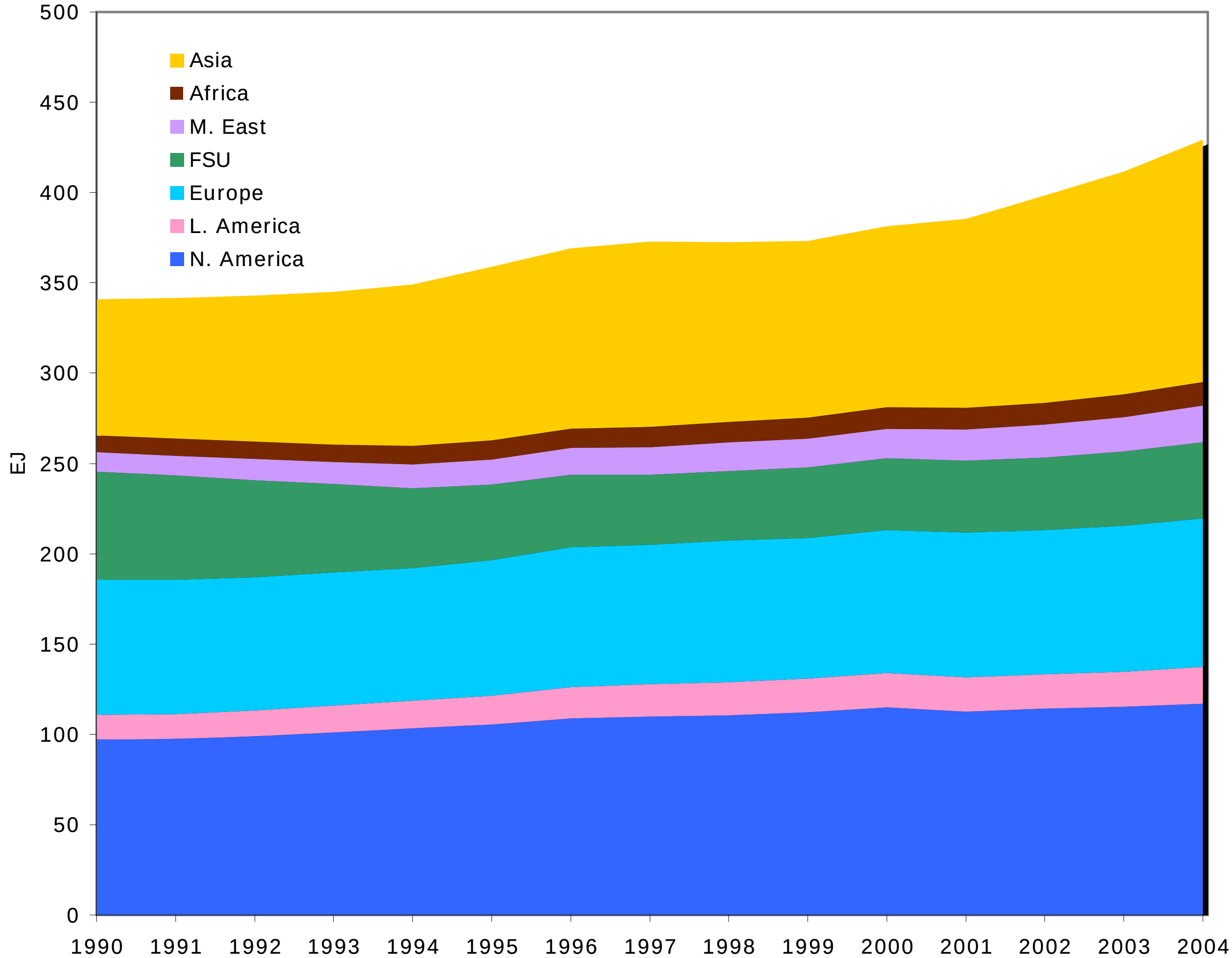


Figure 4.2.3. Trends in primary energy consumptions in world regions (BP, 2005)

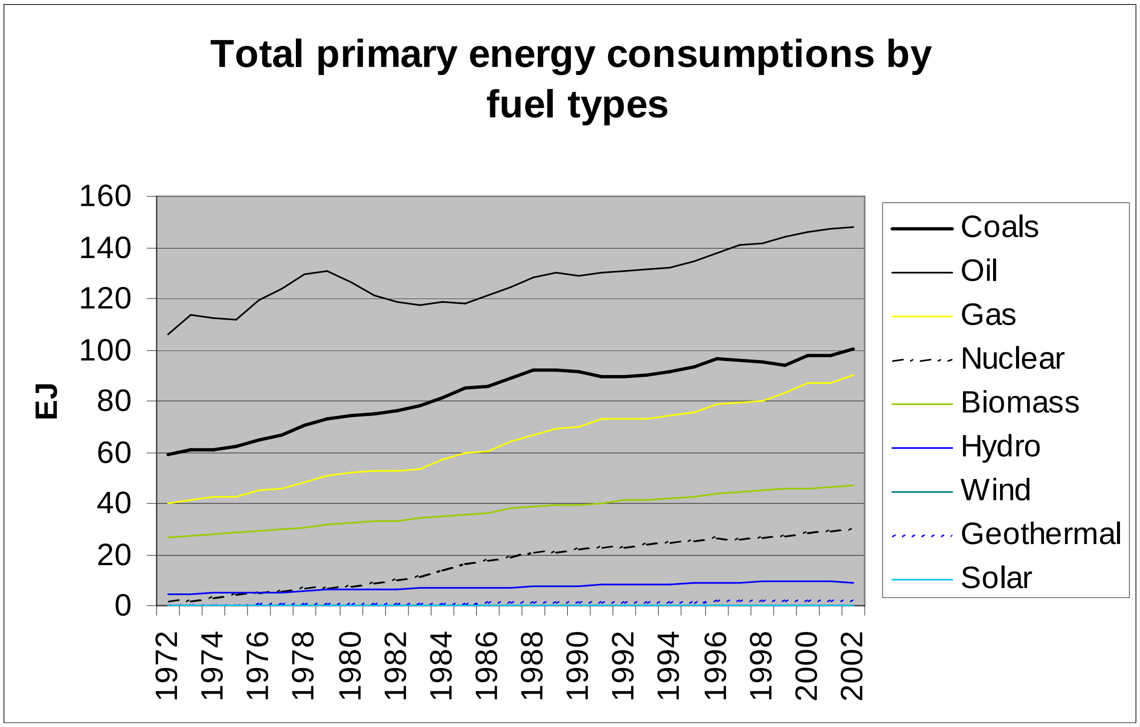


Figure 4.2.4. World primary energy consumption by fuel type (Enerdata, 2004).

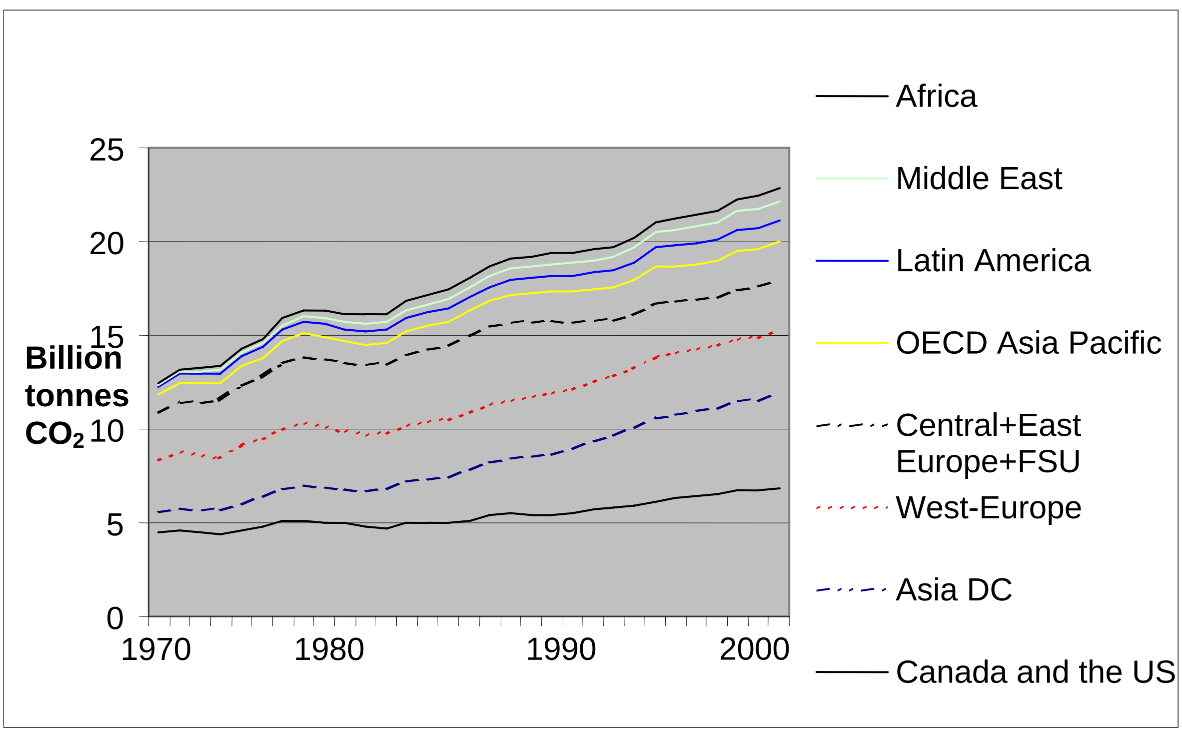


Figure 4.2.5 Global CO2 emission trends by region from 1972 to 2002 (Enerdata, 2004)

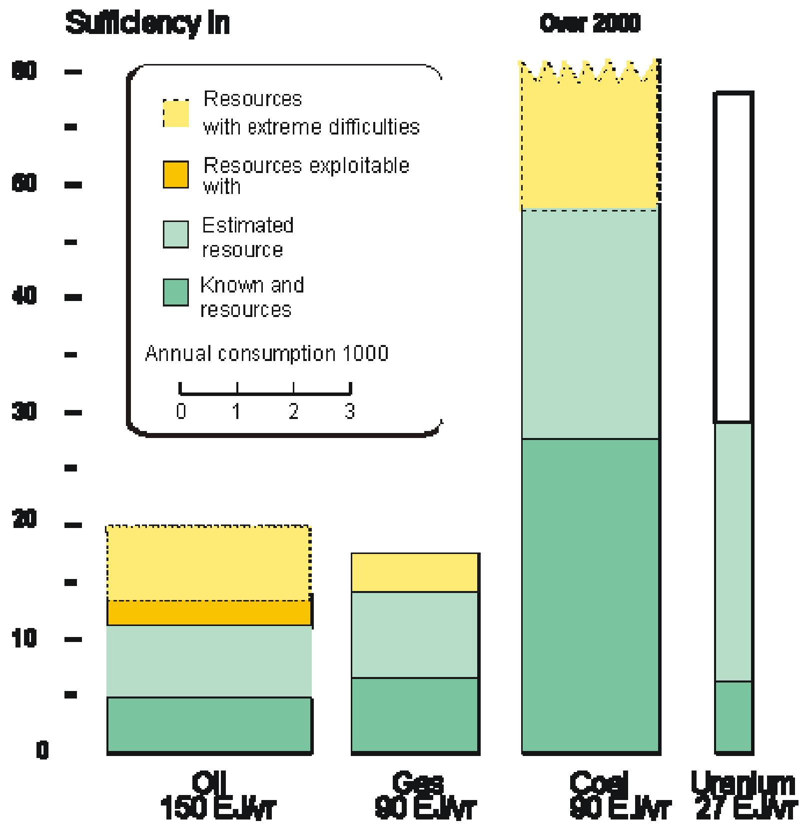


Figure 4.3.1. Sufficiency of conventional fossil fuel and uranium resources at current consumption levels.

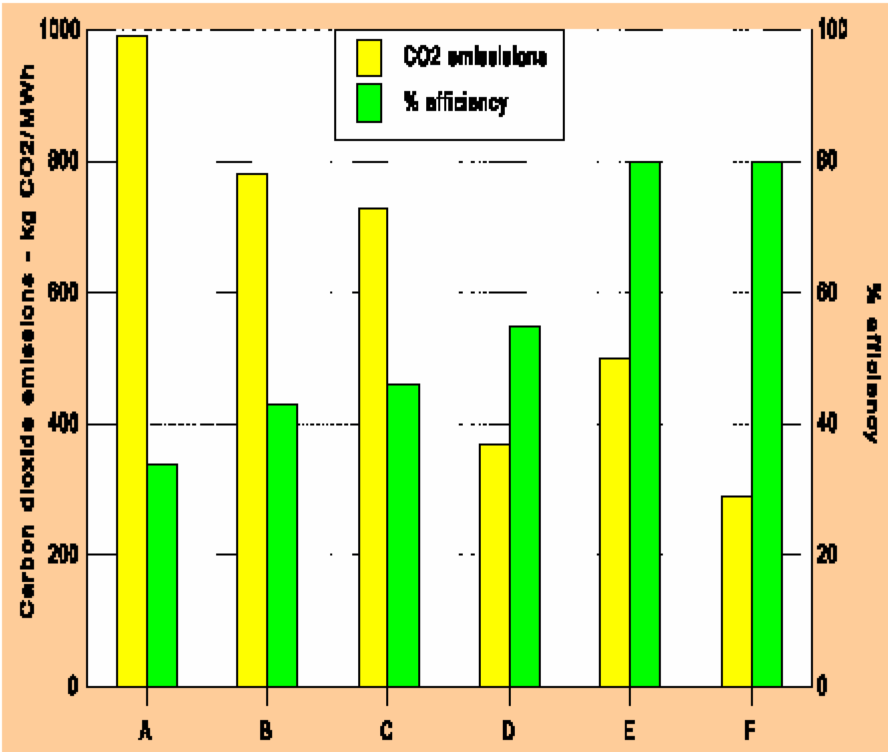


Figure 4.3.2. Carbon emissions and conversion efficiencies of selected coal and gas-fired power generation and cogeneration plant technologies: A) traditional coal-fired steam turbine; B) new clean coal-fired steam turbine; C) coal gasification/ gas turbine; D) new combined cycle gas turbine (CCGT); E) coal-fired cogeneration; F) gas-fired cogeneration. (Source: Minett, 2003).

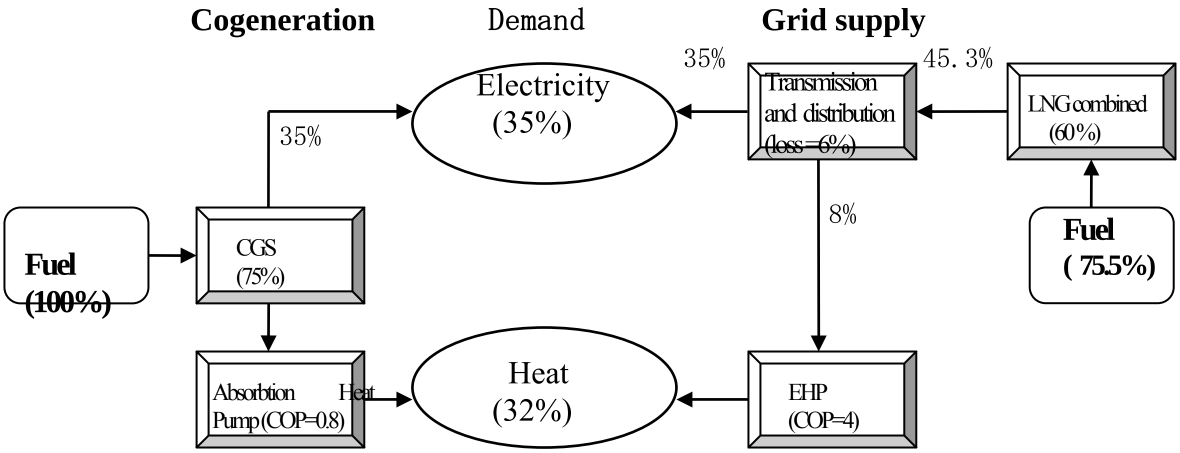


Figure 4.3.3 Comparison of system efficiency between cogeneration and heat pump when using a CCGT plant.
COP= coefficient of performance

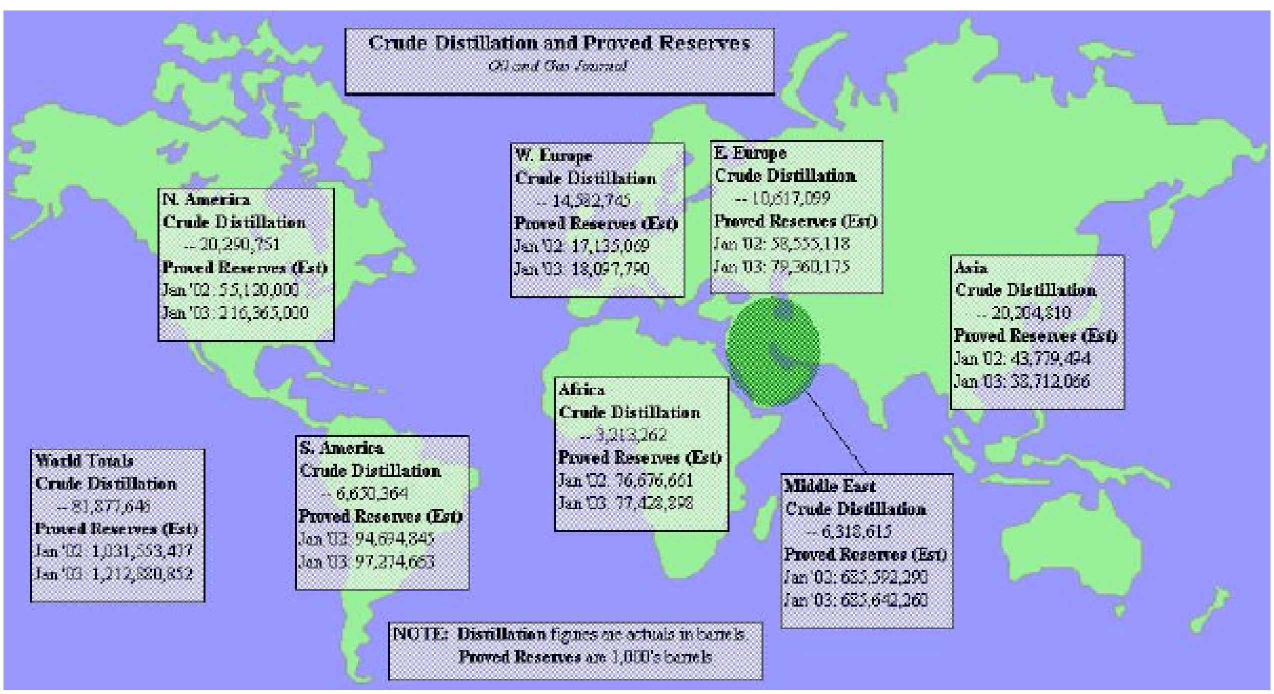


Figure 4.3.4 Crude oil production by region and refining of crude oil (Reference?).

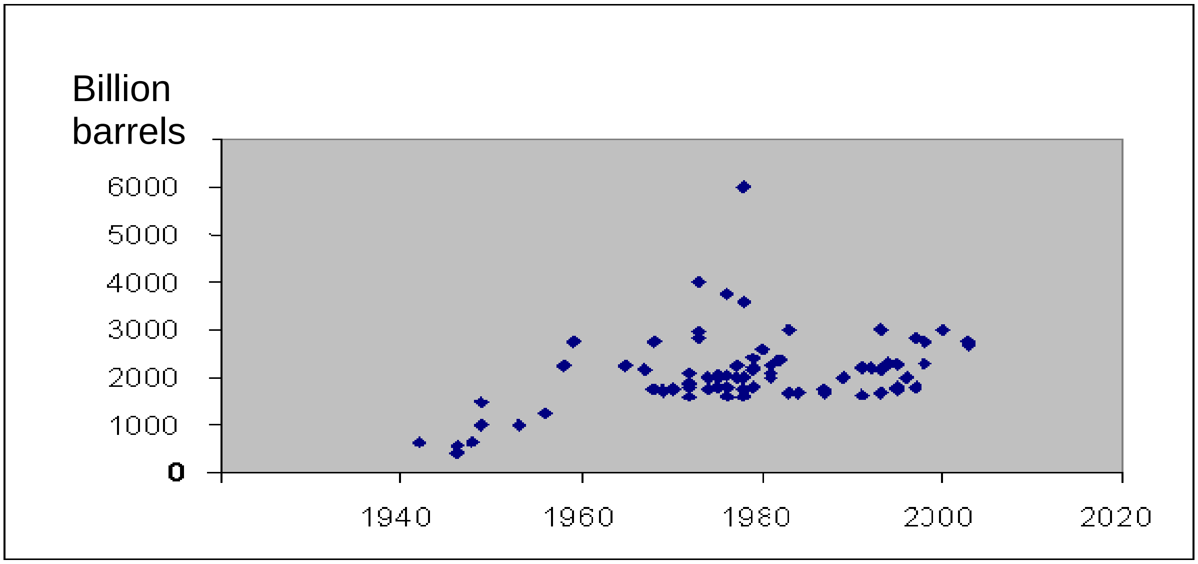


Figure 4.3.5 Estimates of the ultimate extractable conventional oil resource from evaluations (based on Bentley, 2002a; Andrews & Udal, 2003)

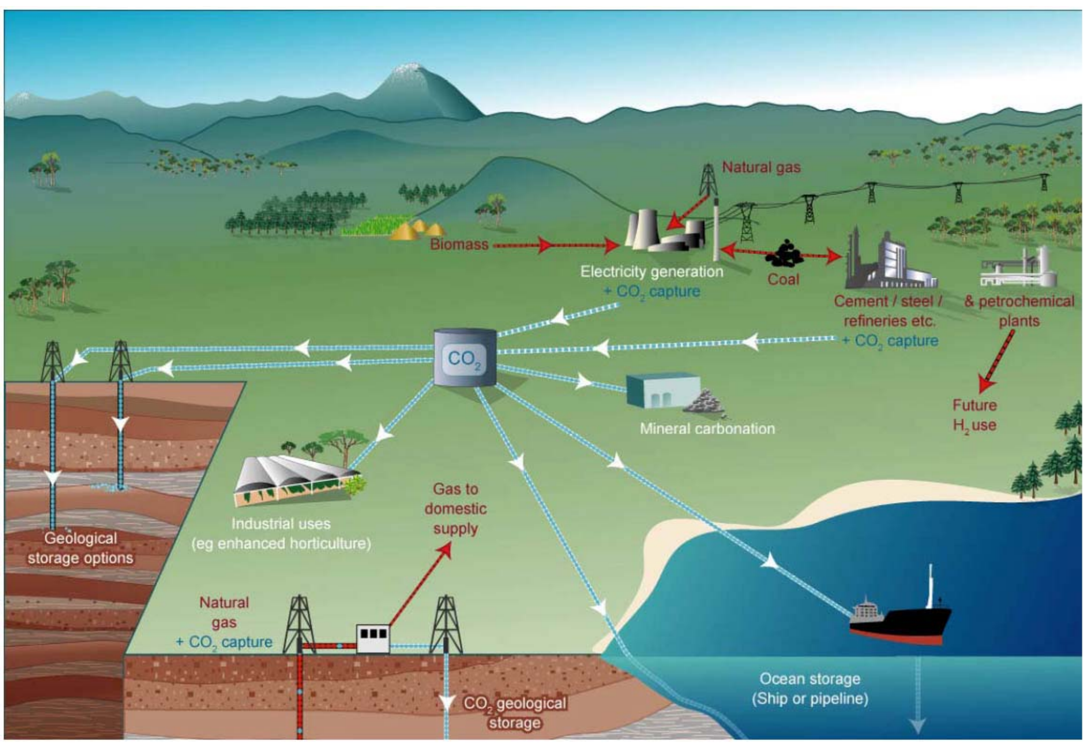


Figure 4.3.6 Sources of carbon dioxide for which CCS might be relevant and transport and storage options. (IPCC, 2005)

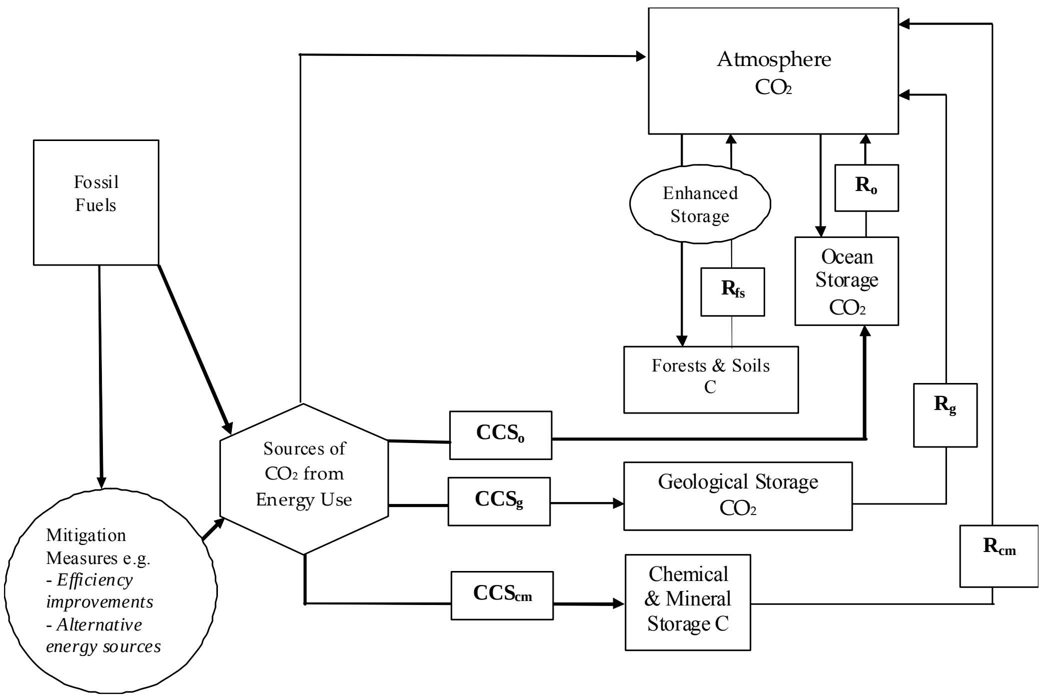


Figure 4.3.7. Stocks and flows of CO_2 with net flows of captured CO_2 to each reservoir (CCS) excluding residual emissions associated with the process of capture and storage which can be considered as additional sources.
R = the rates of emissions from each of the storage reservoirs.

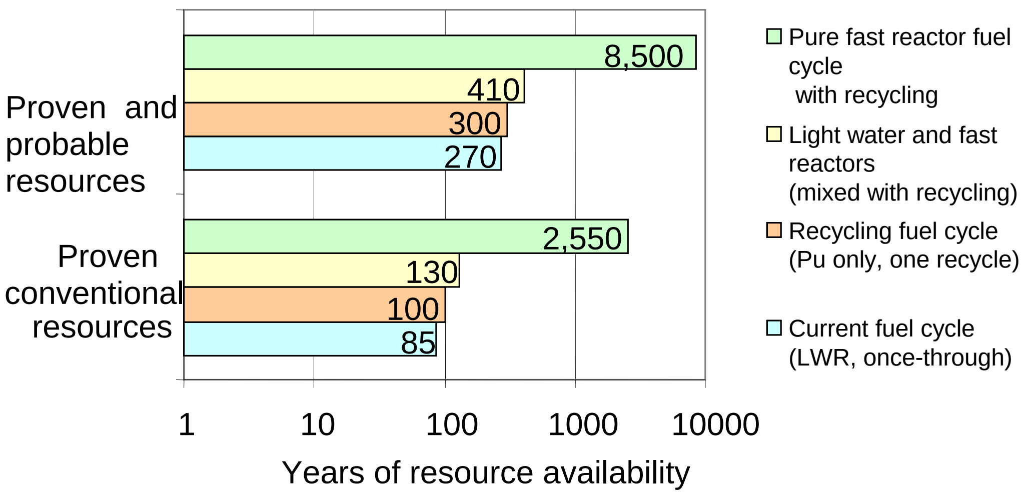


Figure 4.3.8. Estimated years of uranium resource availability for various nuclear technologies (OECD 2004; Red Book, 2003).

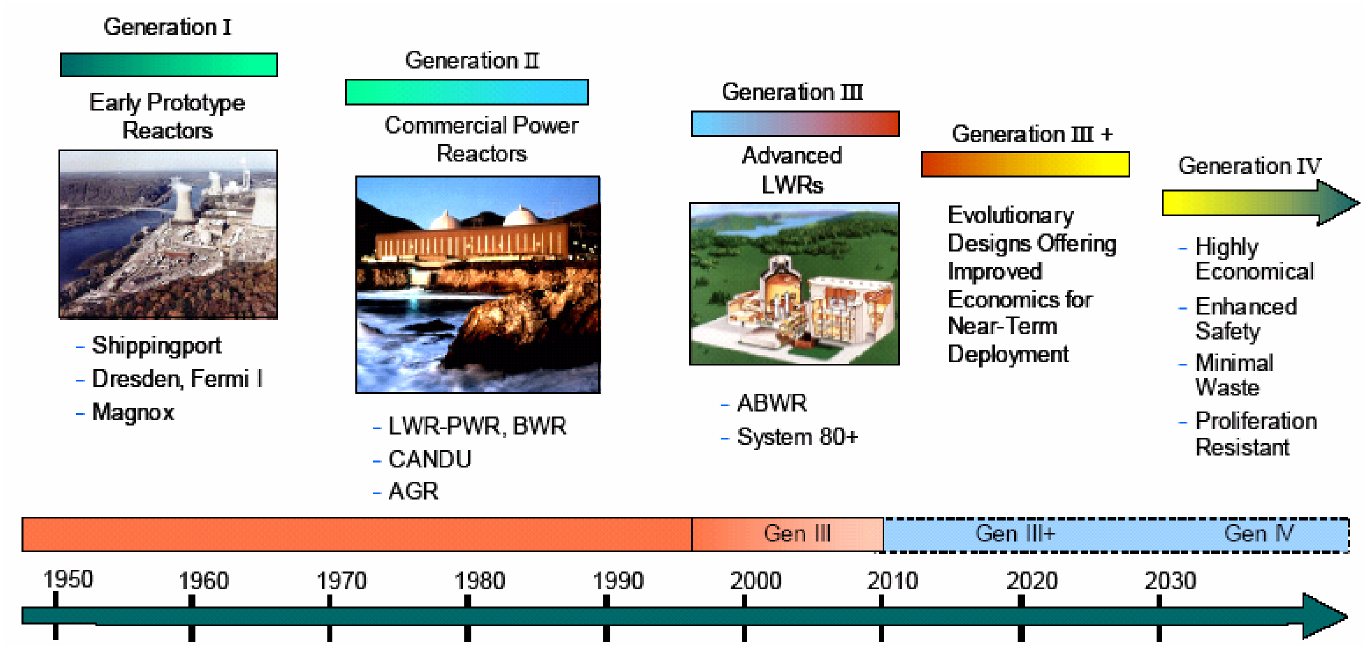


Figure 4.3.9. Evolution of nuclear power systems from Generation I commercial reactors in 1950s up to the future Generation III+ systems which could be operational after about 2030 [GIF, 2002].

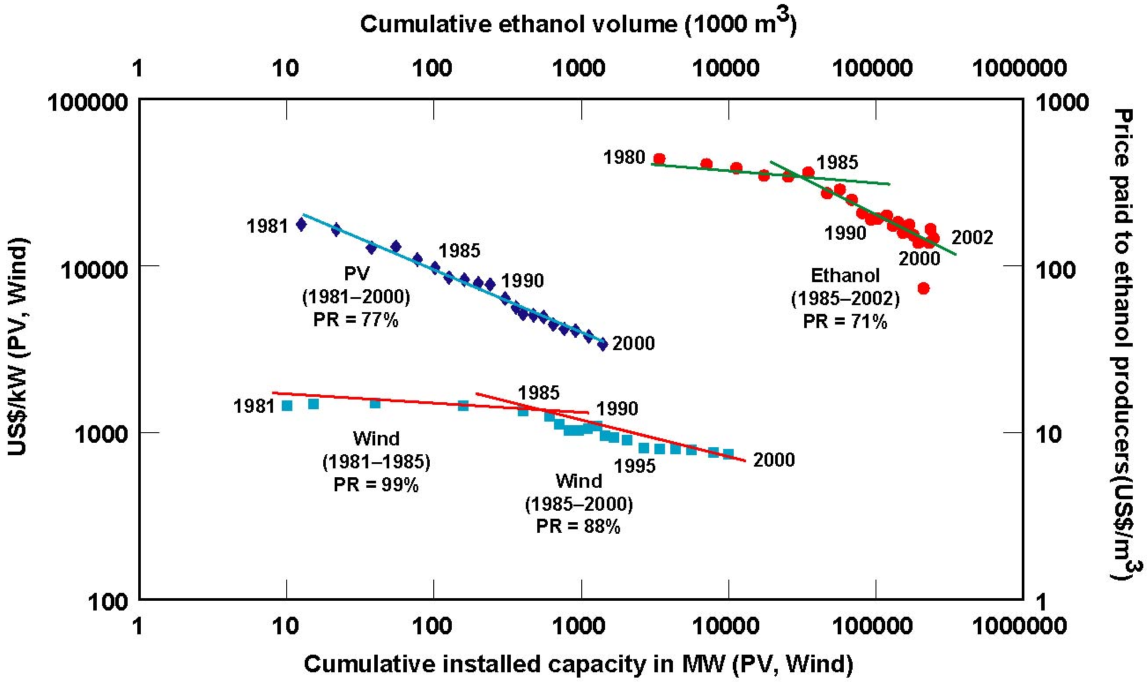


Figure 4.3.10. Investment costs and penetration rates for PV, wind and ethanol systems showing cost reductions of 20% due to technological development and learning experience for every doubling of capacity (Johansson *et al*., 2004).

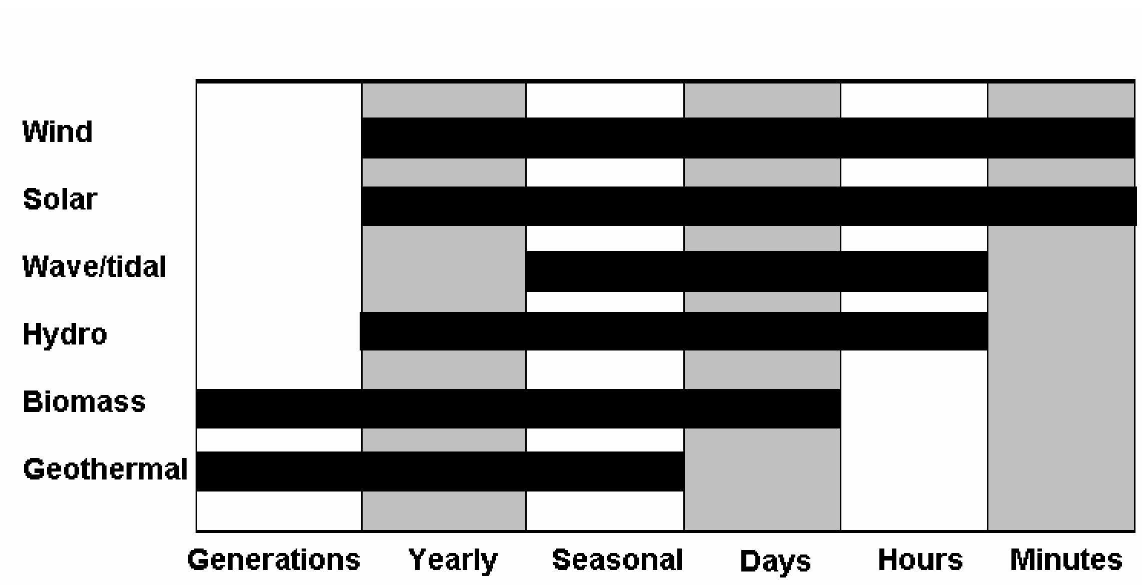


Figure 4.3.11. Renewable energy technologies are intermittent over various time frames and need to be managed accordingly if to provide reliable energy supply system (Based on Gul & Stenzel, 2005).

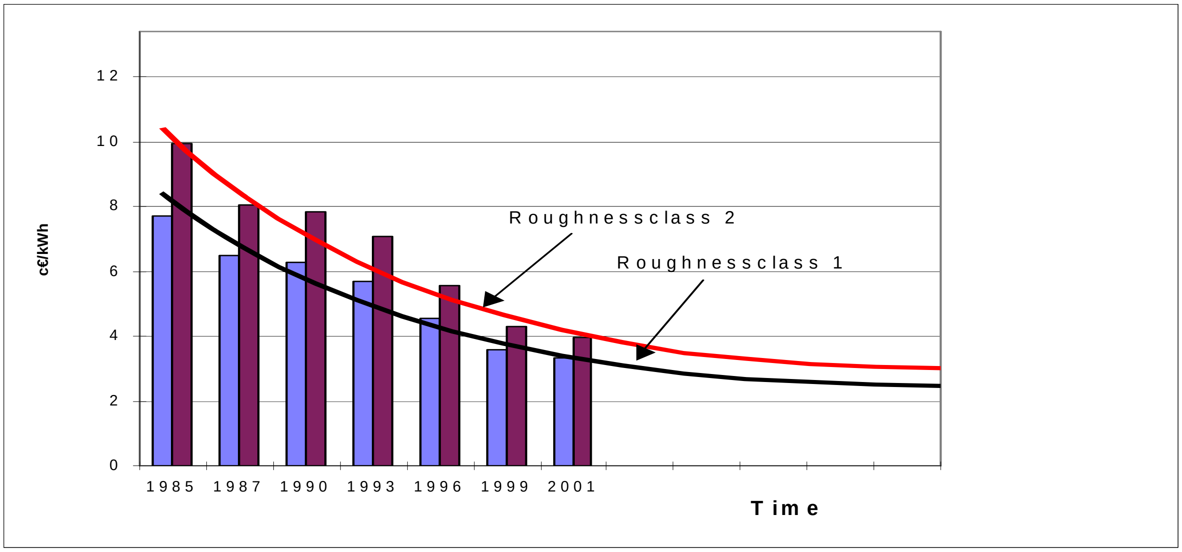


Figure 4.3.12. The development of wind turbine economics based on Danish experience since 1985 with variations due to land surface and terrain variations (Morthorst, 2004).

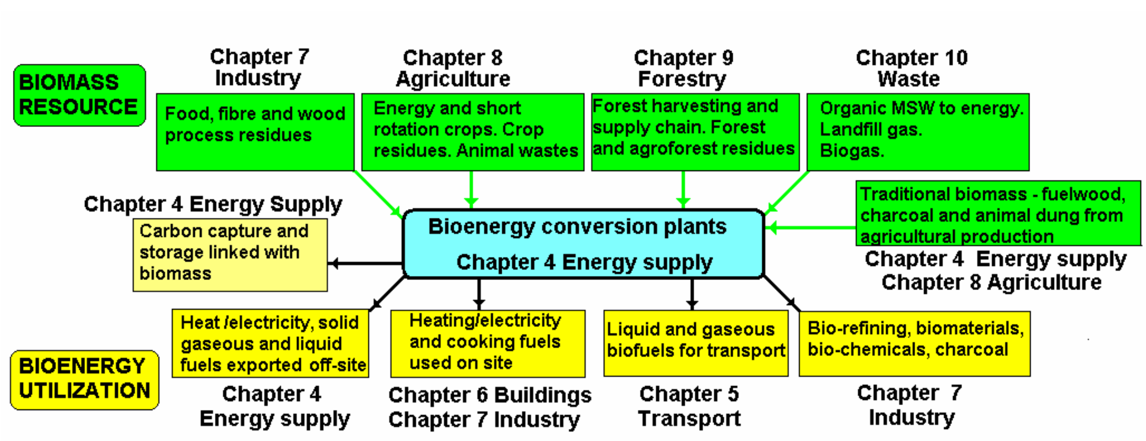


Figure 4.3.13. Biomass supplies originate from a wide range of sources and, after conversion in many designs of plants, from domestic to industrial scales, are converted to useful forms of bioenergy. Chapters containing sections on specific
biomass resources and the use of bioenergy carriers and biomaterials are shown.

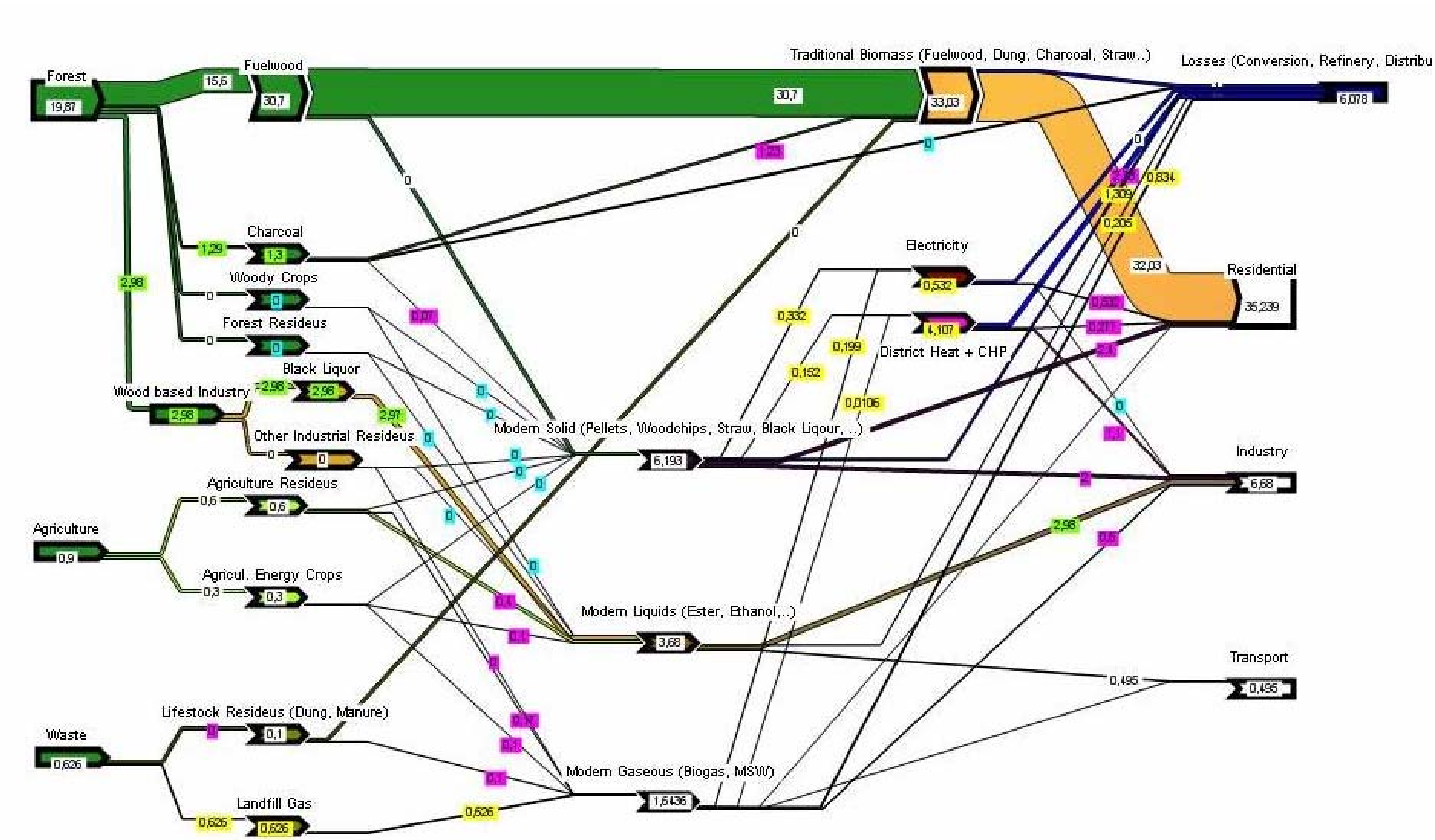


Figure 4.3.14 Global biomass energy flows to produce heat, power and transport fuels (EJ)

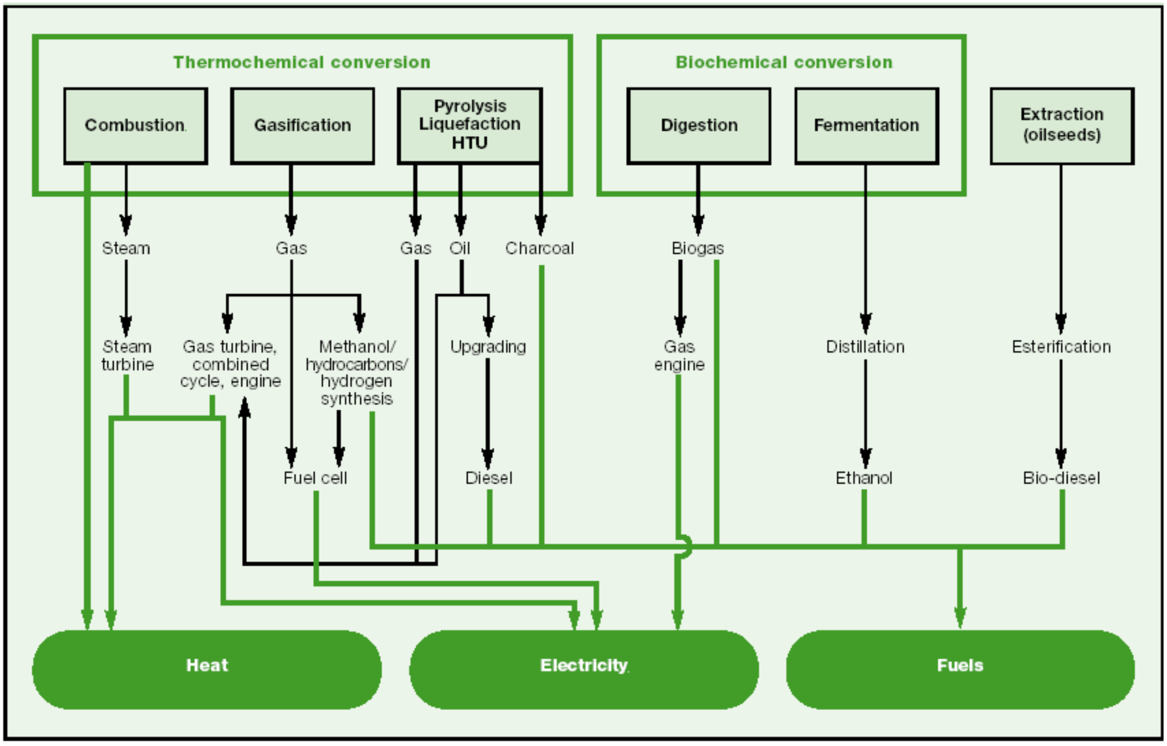


Figure 4.3.15 Thermochemical and biochemical conversions from a range of biomass feed-stocks to energy carriers and then to useful bioenergy.

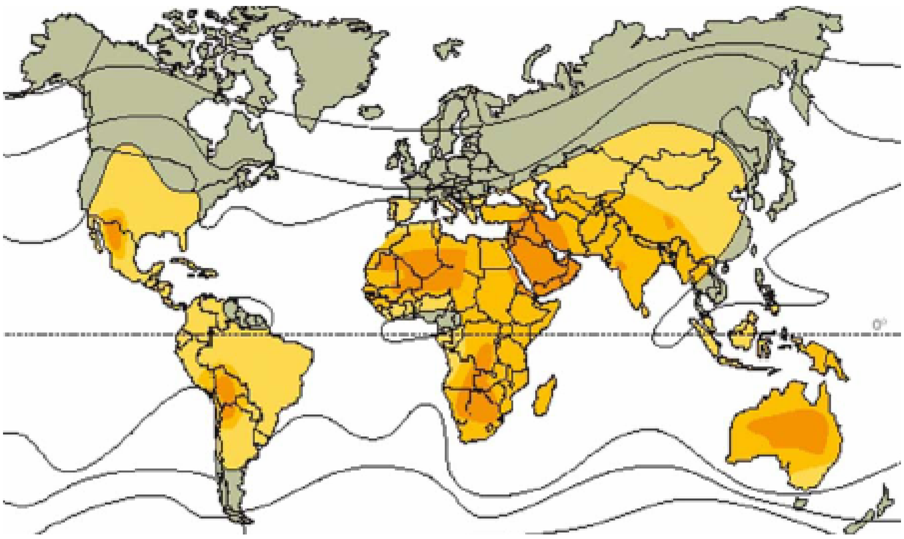


Figure 4.3.16 Regions of the world with high direct insolation (WEC, 2004)

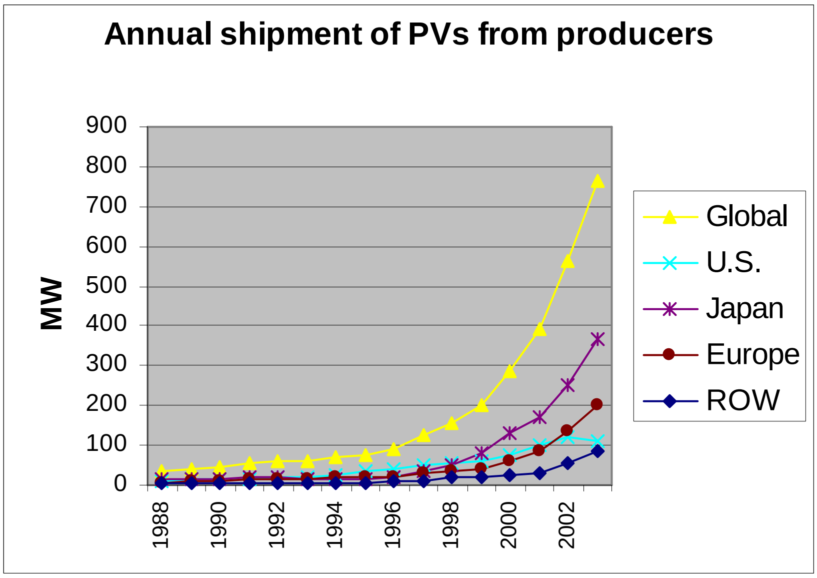


Figure 4.3.17. Annual production of PV modules (Mayrock, 2003)

Figure 4.3.18. Annual average wave power flux (kW/m) across the oceans (Wavegen, 2004).

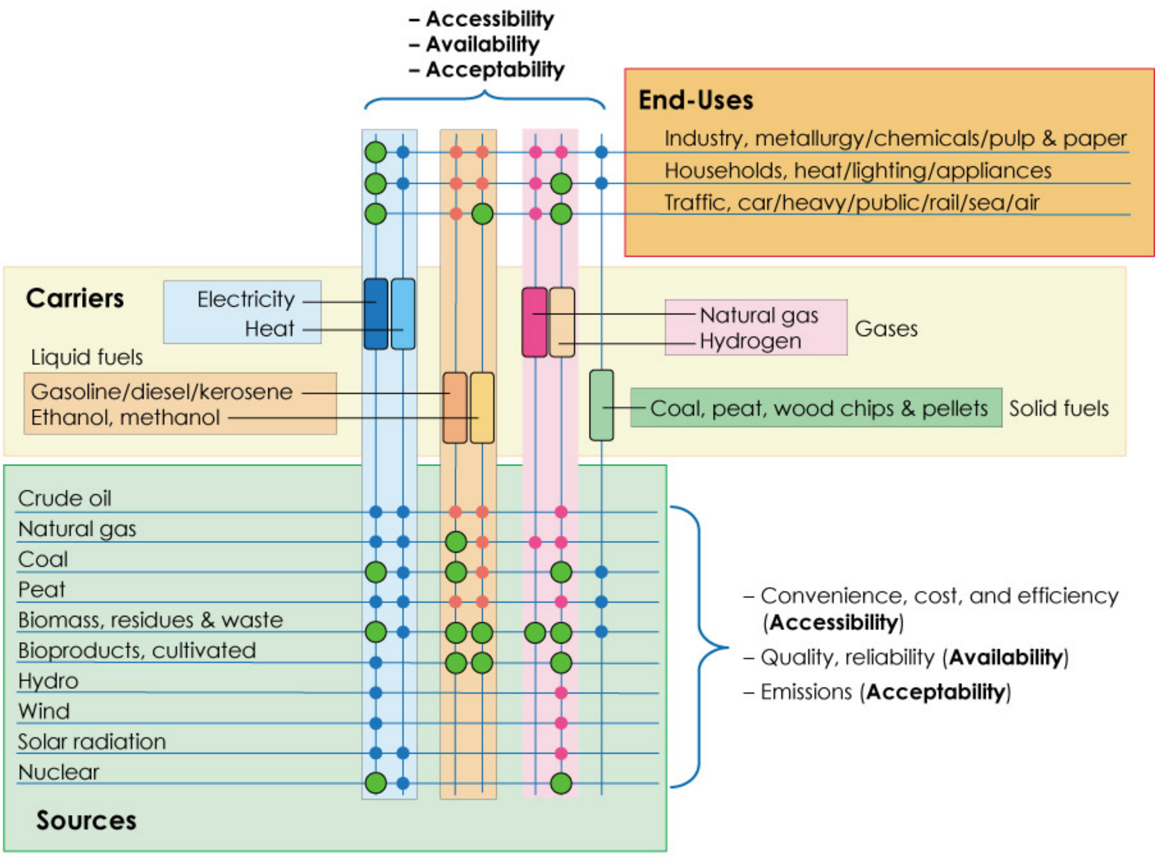


Figure 4.4.1. Dynamic interplay between energy sources, energy carriers and energy end-uses. Sources are in the lower left, carriers vertical in the middle, and end-uses on the upper right. Important intersections are noted with circles, small blue for transformations to solid energy carriers and small pink to liquid or gaseous carriers. Large green circles are critical transformations for future energy systems (WEC, 2004a).

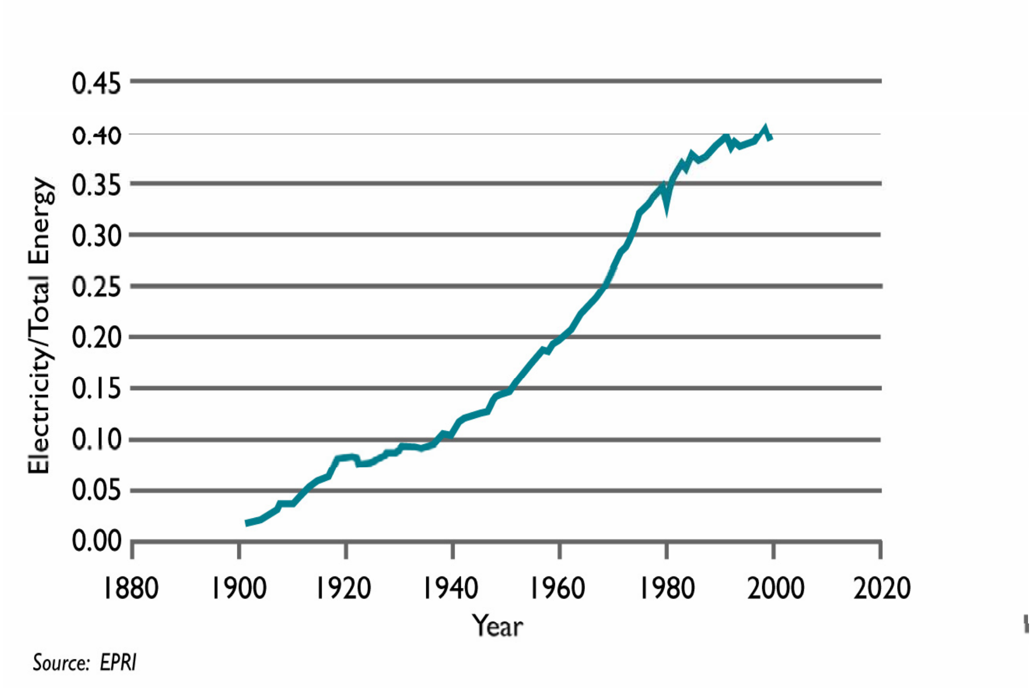


Figure 4.4.2. Ratio of electricity to total primary energy in the U.S. since 1900 (EPRI, 2004).

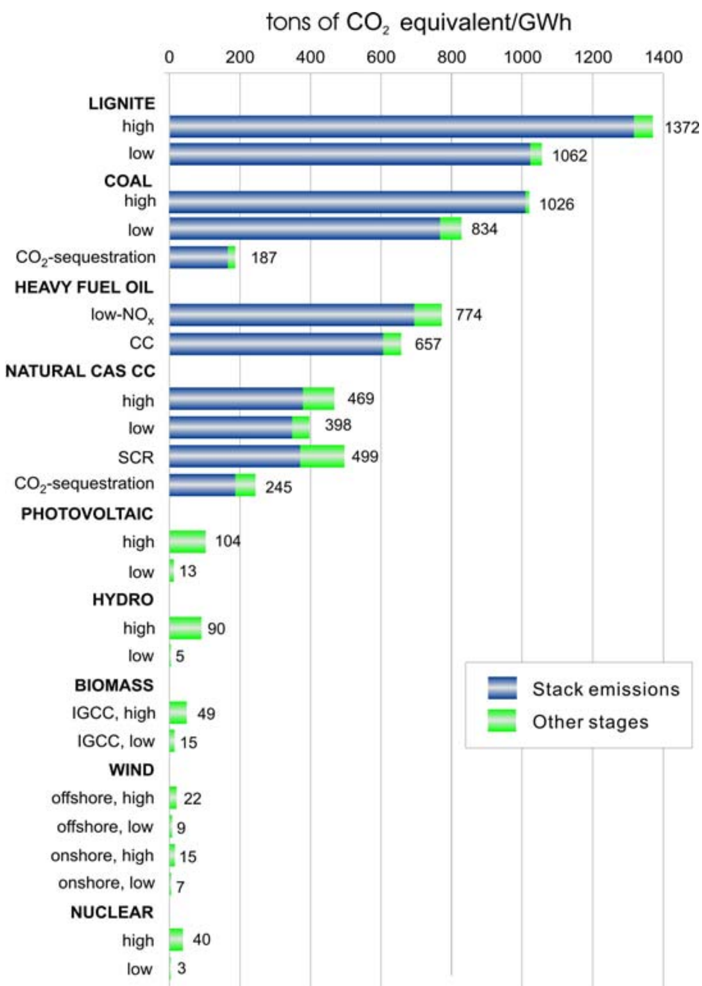
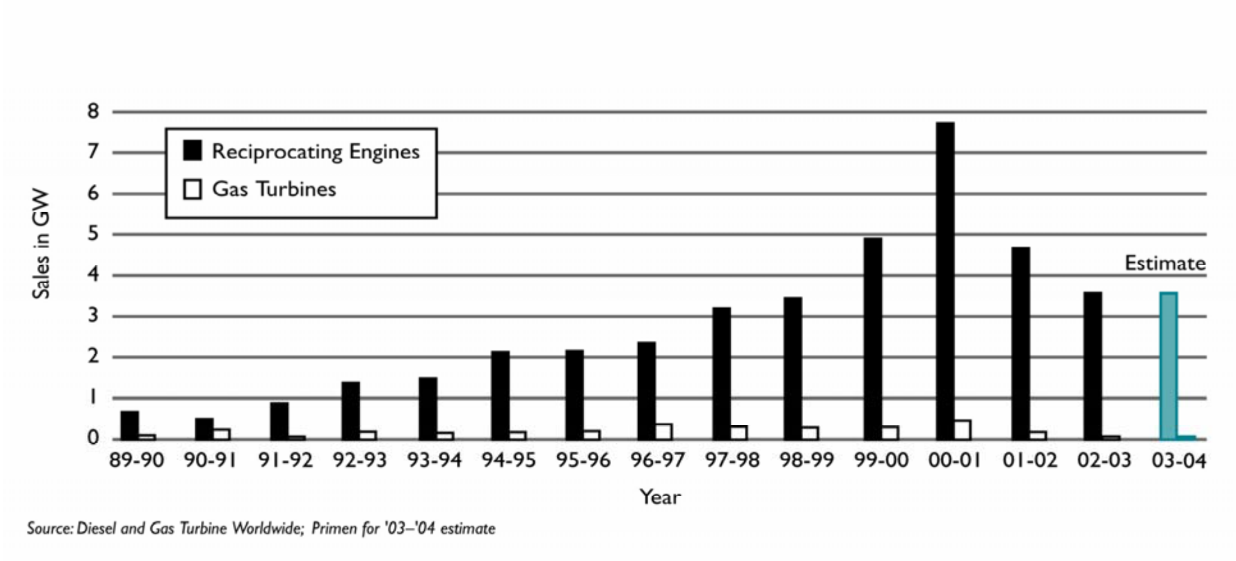


Figure 4.4.3 GHG emissions from alternative electricity production systems (WEC, 2004b)



5 **Figure 4.4.4. Recent growth in distributed electricity generation using fossil fuel distributed energy resources in North America (EPRI, 2004).**

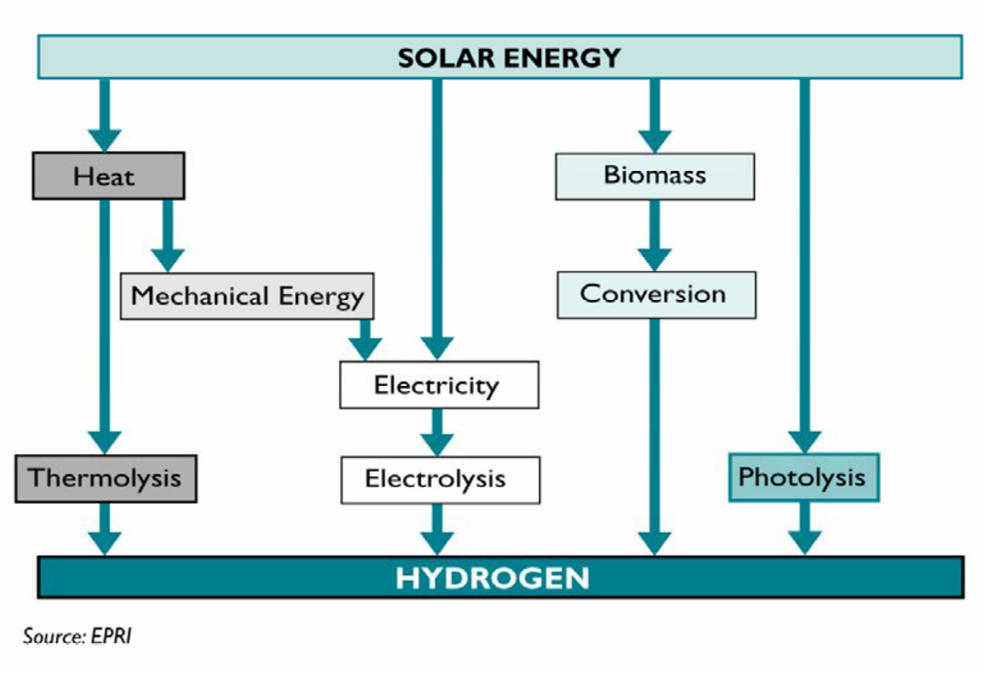


Figure 4.4.5. Sustainable paths to hydrogen energy carriers from solar energy sources (EPRI, 2004).

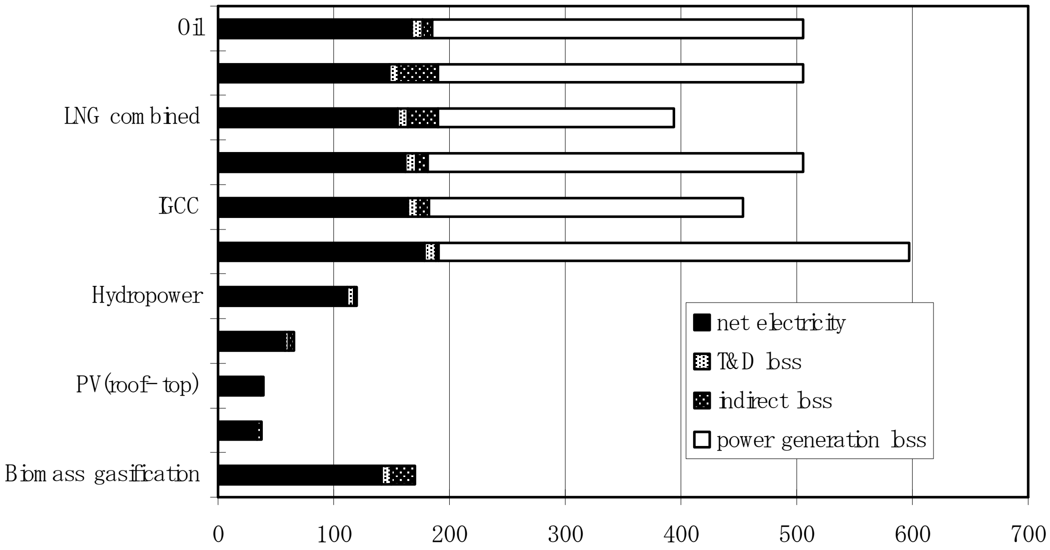


Figure 4.5.1 Net electricity supplied by a range of power generation systems each of 1,000MW$_e$ total capacity over 30 years plant life (Data updated from Uchiyama, 1996)

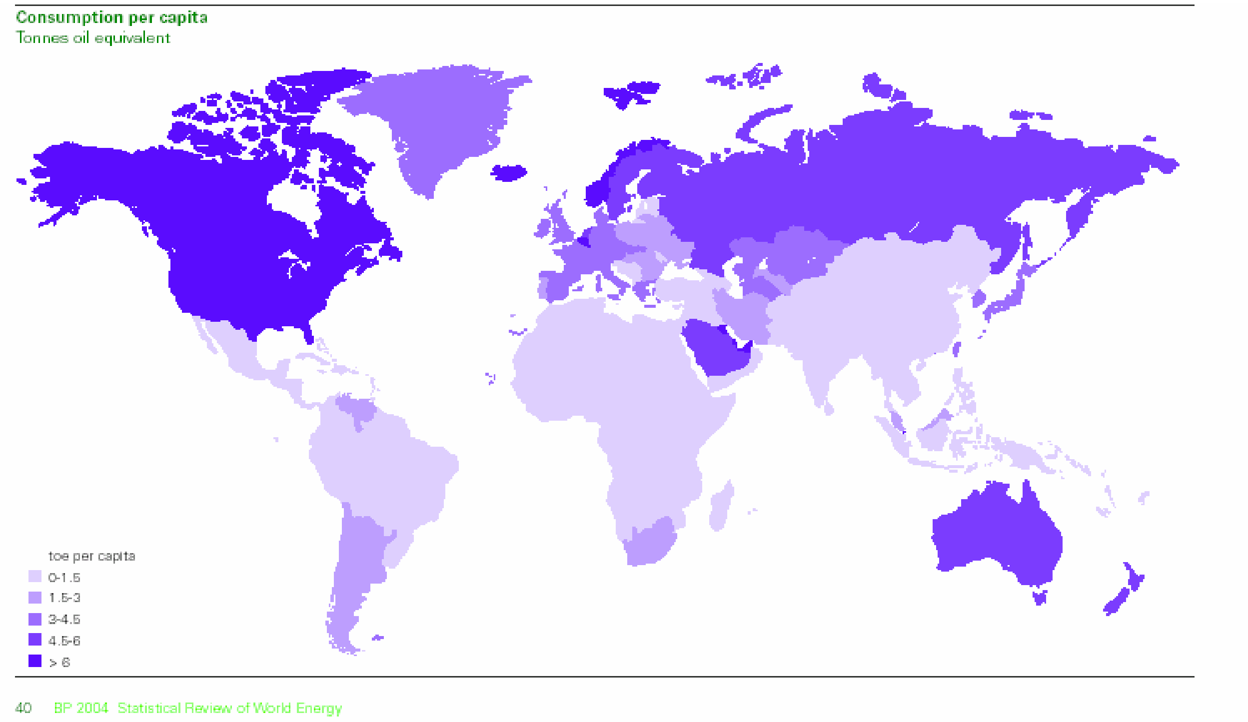
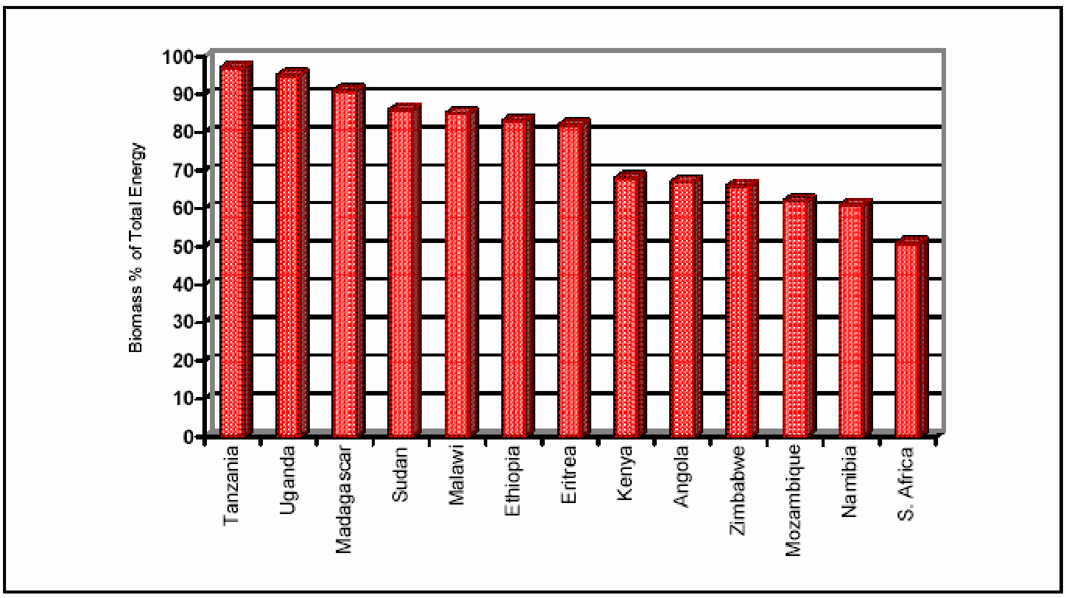


Figure 4.7.1 Global energy consumption by region (tonnes oil equivalent per capita) (BP, 2004).



Source: AFREPREN/FWD, 2003

Figure 4.7.2 Biomass as a percentage of total primary energy use in selected African countries. (AFREPREN/FWD, 2003)

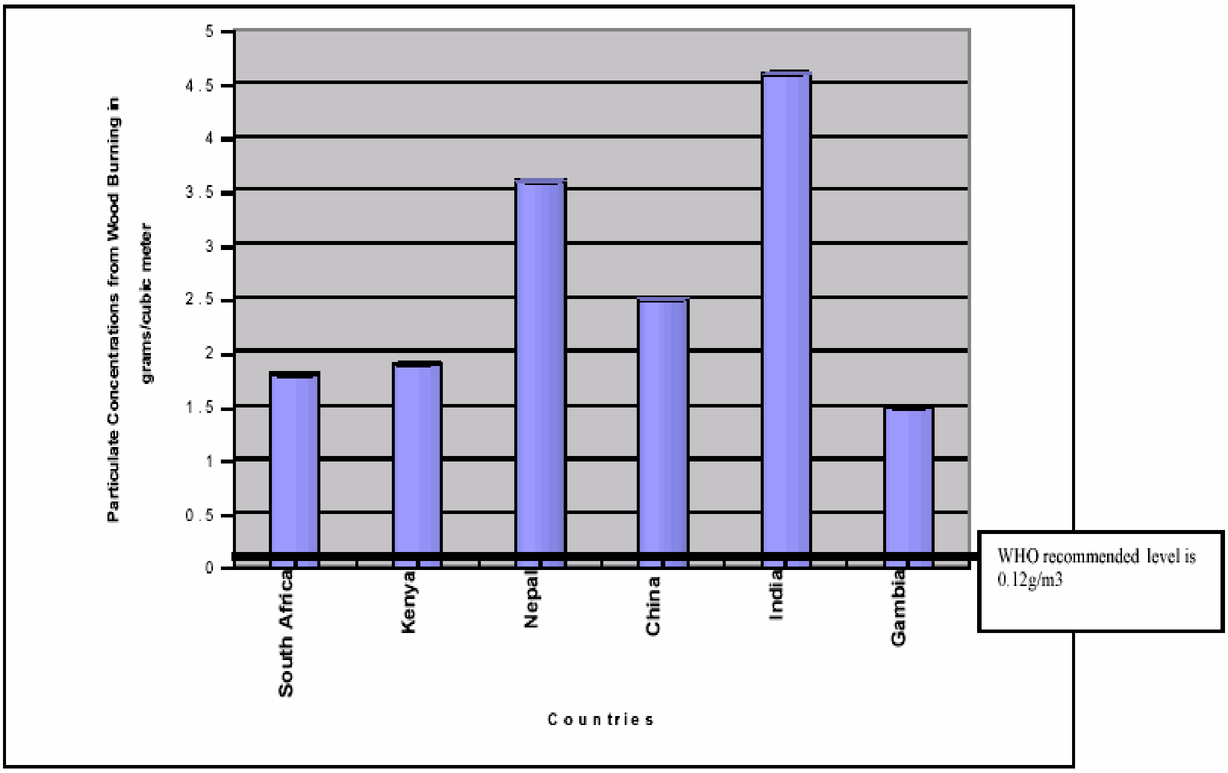
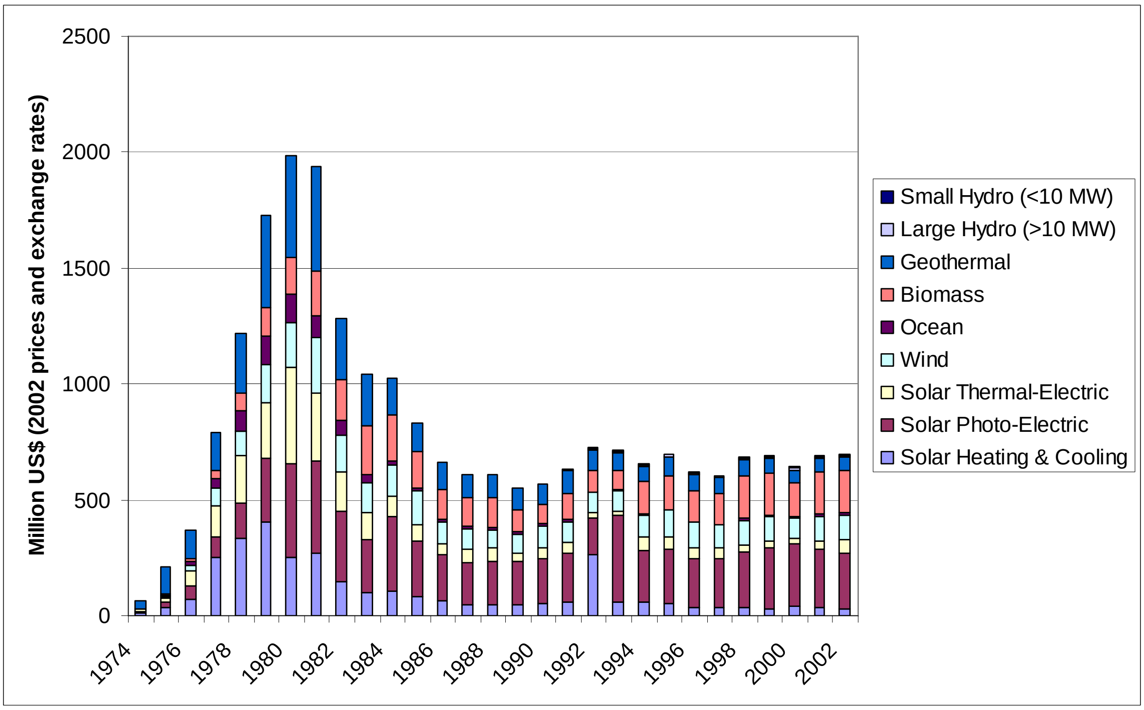


Figure 4.7.3. *Indoor levels of particulates emitted from woodfuel in selected developing countries (Karekezi & Kithyoma, 2003)*



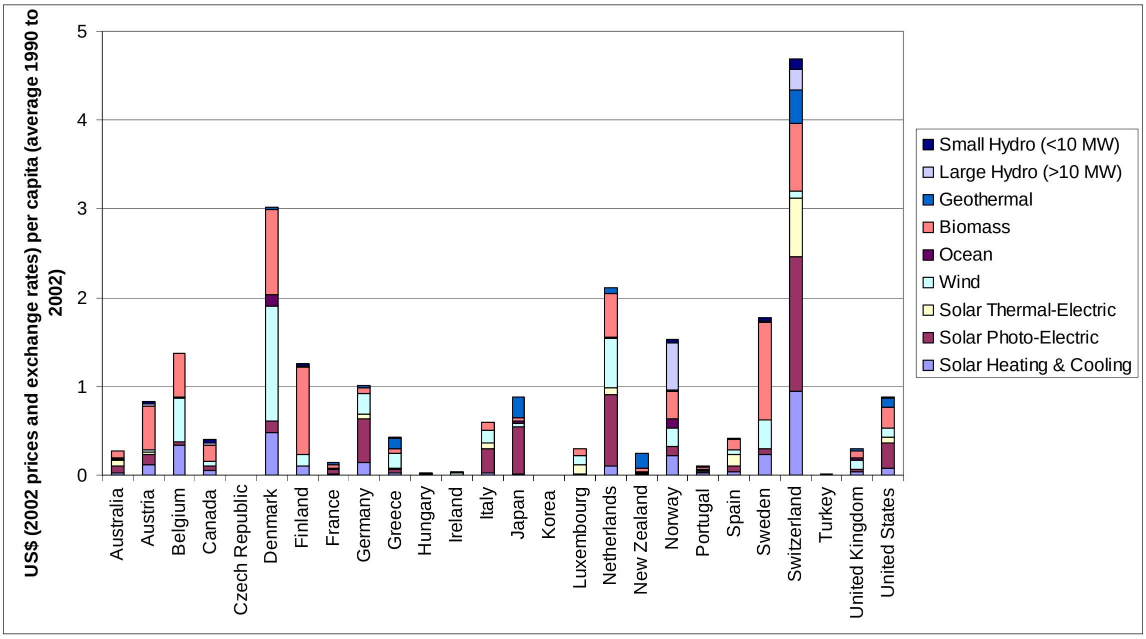


Figure 4.8.1. *IEA member government budgets for renewable energy R&D*

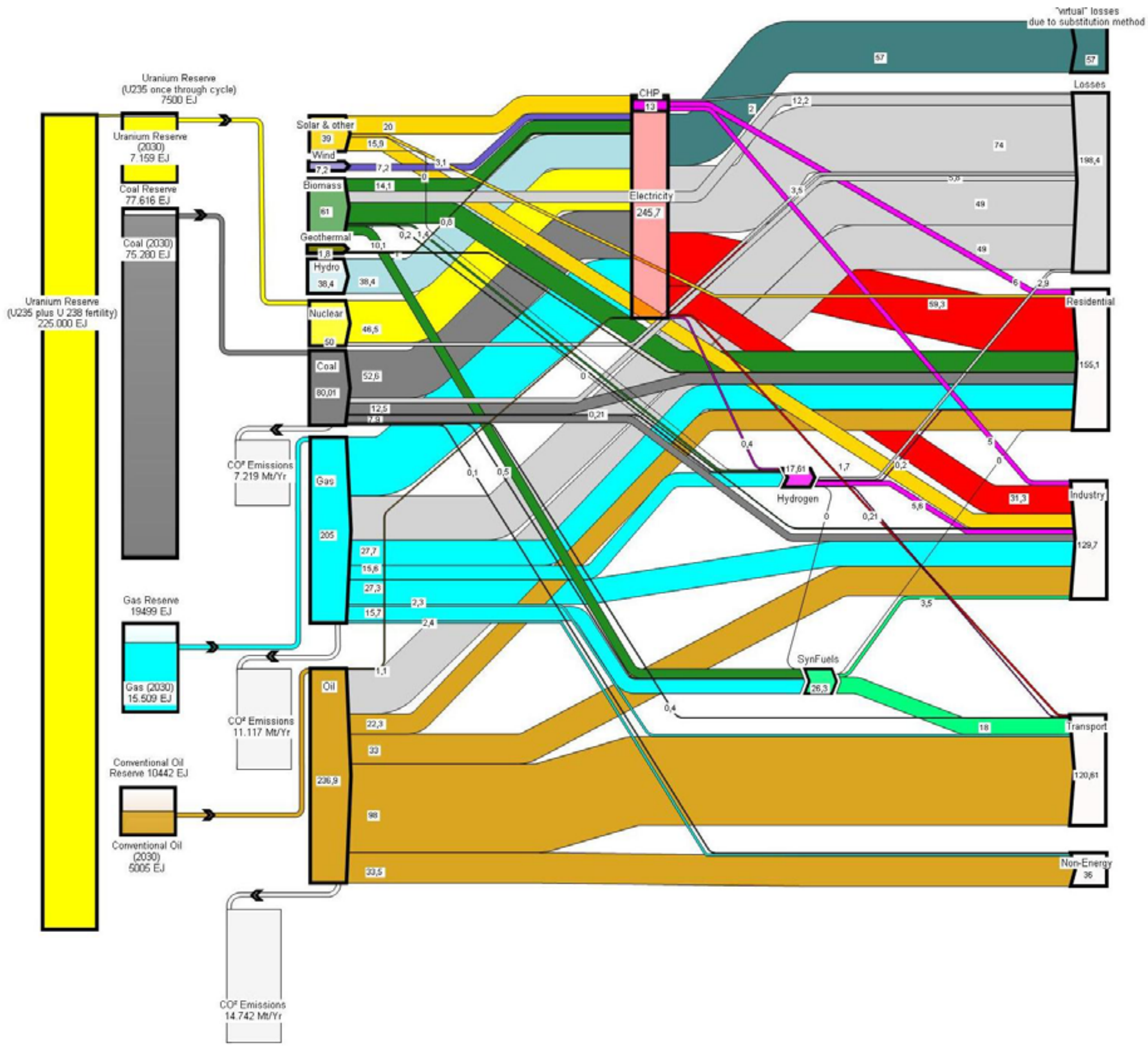


__Figure 4.9.1__ Predicted world energy sources to meet growing demand by 2030 based on the relatively conservative SRES B2 scenario (IPCC, 2001).
Source: IIASA, B2 Message Scenario, update 2005

Note: The ratio by which fast breeder technology increases the power production capability per tonne of natural uranium varies greatly from the latest OECD figure of 30 based on rather detailed fuel cycle analysis to 167 (INFCE, year to be completed, reference to be added in References).

NOTE: Similar chart for A1 scenario planned but data not yet to hand.

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