ENERGY AND DEVELOPMENT

José Goldemberg

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Center for Energy and Environmental Studies
H102 Engineering Quadrangle
Princeton, NJ 08544-5263

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Although it is difficult to define development in a precise and quantitative way it is obvious that most struggles within countries and between countries, in the past, took place to guarantee access to natural resources and the services - including slavery - needed to supply the needs of some priviliged groups. The availability of such services is what distinguishes developed from underdeveloped countries or different social groups within countries.

Within national boundaries of today's developing countries (LDC's) with 3/4 of the world population one finds usually an elite that not only has the political power but a very comfortable standard of living surrounded by a majority of the people that does not have access to the amenities that one considers essential for a reasonable standard of living. The image of "islands of affluence sorrounded by a sea of poverty" characterizes reasonably well cities such as Nairobi, São Paulo, Jakarta and others.

For developing countries, <u>development</u> means satisfying the basic human needs of all the population including access to jobs, food, health services, education, housing, running water, sewages, etc. . The lack of access to such services and the fact that only a minority of the people

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** Visiting Senior Research on leave from University of São Paulo, Brazil has access to them is the fertile ground of political unrest, revolutions and more than that, the hopelessness and dispair that lead people to emigrate to the industrialized countries in search for a better future. The rising wave of legal and illegal emigration to the United States or Europe is due to these factors.

Several methods are used to measure development, the gross domestic product "per capita" being the one used by most economists. In industrialized countries the average GDP/capita is approximately US$ 20,000/per year; more than ten times larger than the GDP/capita in most developing countries.

GDP/capita can be a misleading indicator since the purchasing power of the dollar is widely different in countries around the world because of structural and other differences. Corrections to that have been attempted with the consequence that the GDP/capita of many poor countries had to be multiplied by 3 or 4. It is therefore an indicator whose usefulness has been questioned not only these grounds but also on the grounds that it does not deal with the question social inequalityes.

Primary energy consumption can also be used as an indicator of development. Energy consumption, of course, is not the only factor that determines development and therefore a simple cause-effect relationship between them cannot be firmly established but it is very clear that a lower energy consumption "per capita" means invariably higher infant mortality, illiteracy and smaller lifetime expectancy as shown in Figure 1. (Ref. 1)

Figure 1

For energy consumption "per capita" above 1 ton of oil equivalent (TOE) or 1.3 kw, infant mortality and iliteracy are dramatically reduced and life expectance increases.

There is a problem in these graphs which is due to the use of primary energy consumption. In reality, what counts for people is not the amount of primary energy spent but the services obtained from it, which leads immediately to the central question of energy efficiency, which has improved considerably in industrialized countries in the last 20 years. Accordingly these graphs suggest that to improve living conditions more energy services are needed.

Average "per capita" primary energy consumption in the OECD countries is about 6 tons of oil equivalent per year (8.5 Kw/capita/year) and less than 1 TOE (1.3 Kw/capita/year) in most of the developing countries.

Figure 2 shows the evolution of primary energy consumption in different parts of the world in the last 10 years. (Ref 2)

Figure 2

Worldwide energy consumption is growing at approximately 2% per year; in the OECD countries, which account for half of the total energy consumed, growth has been smaller (approximately 1% per year) and shows signs of saturation.

In the Eastern European countries (non-OECD Europe) energy consumption is declining but in developing countries where 3/4 of the world population lives, total consumption is growing at approximately 4% per year.

If such trends are to continue the situation in the early part of the 21st century will be the one shown in Figure 3.

Figure 3

Energy consumption in LDC's will surpass OECD consumption around year 2010 at 4% growth per year and around 2020 at 3% growth per year. If the sources of supply both in OECD and LDC's remain the same as today in the next 20-40 years great problems will be faced by the developing and industrialized countries above.

What problems are these?

1. A stiffer competition for sources of supply in a period where oil and gas reserves should be dwindling.

2. Severe world environmental problems due to the extensive use of coal, (mainly China and India). As one can see in Table I, coal in 1992 represented 39% of the total supply in LDC's and only 22% in the OECD countries.

Table I

Local environmental problems in the developing countries are not considered by some, in industrialized countries, a cause of concern since they are not directly affected. However regional and global environmental problems such as acid rain and greenhouse warming, caused increasingly by developing countries, should be a serious cause for concern of the OECD countries as it is in their self-interest to avoid being held at ransom - in environmental matters - by what happens outside their borders. Such concerns are further aggravated by the specter of millions of "economic/ecological refugees" seeking access to industrialized countries.

The exponential growth of energy consumption in the developing countries is driven by two factors:

1. population growth
2. increased access of the population to energy consuming devices

Both of these factors could lead inexorably to a non-sustainable energy future. Therefore, in order to face sucessfully the energy/environment crisis in the developing countries one has to reduce the pressures originating from these two factors.

Population growth alone - in the aggregate of all developing countries - is responsible for 50% of the annual growth rate of energy consumption in developing countries (China is an important exception in that regard). This would be an explosive situation if it were not for the fact that the total fertility rates (TFR) has decreased dramatically in the last 30 years, although it is still very high in some parts of Africa and the Middle East. (Ref 3)

One can try to gain some insights on the relationship between total fertility rates and energy consumption per capita by plotting one against the other, as shown in Figure 4. (Ref 3)

Figure 4

This relationship is a complex one because an increase in energy consumption goes hand-in-hand with other changes - income level, education, technology, the value of time, female labor force participation, income distribution and the like. Total fertility rate may also affect income level and distribution.

Regardless of the precise causes and mechanisms one learns from Figure 4 that greater energy consumption (more than 1kw/capita) could have a role in reducing the total fertility rate which will then accelerate further reductions in total energy consumption. This suggests that an improvement in energy services is one of the instruments capable of reducing population growth.

Figure 5 shows in greater detail the relationship between total fertility rate and energy consumption per capita for countries in which consumption is smaller than 3kw. (Ref 3)

Figura 5

Except for some countries, the behaviour of the curves in Figures 4 and 5 is consistent whith what one expects from theories of population growth.

Regarding acess to energy-consuming devices, we will explore the feasibility of channelling the aspirations of the large population in LDC's in such a direction so as to avoid retracing the path of development followed by today's industrialized countries and thereby to become less-energy intensive than OECD countries today.

The experience of industrialized countries shows that it is possible to achieve such goals through:

1. energy efficiency and
2. structural changes as countries move to a post-industrial economy.

Energy intensity has been falling 2% per year in most OECD countries since 1920, but it is growing in developing countries as shown in Figure 6. (Ref. 4)

Figure 6

China - an important exception - is a developing country where the energy intensity has fallen dramatically in the last few years.

The introduction of energy efficiency in LDC's has a long way to go and the extensive experience of OECD countries in this area should be transfered to LDC's.

The way to do it however is not through "energy conservation" in the sense of consuming less because energy consumption/capita is so small, but through "technological leapfrogging" the reason being the following: the growth in energy consumption in developing countries is inevitable due to the need to build an infrastructure in industry, transportation, urban design and development and the like. Since LDC's are growing, the extensive use better technologies - including energy efficient devices - has to be incorporated earlier in the process of development and not as retrofitting as happened in the industrialized countries. This is why

LDC's are important theaters for innovation and "leapfrogging" especially in the energy intensive basic materials industries (steel, chemicals,cement,...) where demand has reached saturation in the industrialized countries. It is indeed amazing the speed of adoption and diffusion of innovative and state-of-the art technologies as developing countries modernize: when villages in India are electrified lighting is provided by fluorescent lamps instead of old inefficient incandescent light bulbs. Other less spectacular technologies, such as communal biogas plant, can serve several purposes such as power for lighting, water pumping, fertilizer production and sewage treatment. TV cable is introduced as color TV and black and white TV is a thing of the past even in the remote areas of the Amazonia, the same has happened with celular telephones bypassing wire-connected telephones.

There are other examples of successful leapfrogging solutions involving more complex technologies: the alcohol program in Brazil is one of them. (Ref 5)

Appoximately 50% of the gasoline needed for the 10 million automobiles in Brazil has been replaced by ethanol from sugarcane which represents a consumption of approximately 250,000 barrels of alcohol per day. All the technology for the production and use of the alcohol (including adjustments needed in the automobiles) was developed in Brazil.

The expansion of the sugarcane plantations and processing plants has resulted in some 700,000 rural jobs. The environmental problems encountered initially, such as disposing of liquid affuents have been solved by converting them into fertilizers.

In the period 1979-1988 the reduction in the production cost of alcohol was 4% per year; this reduction resulted both from gains in agricultural production (16% increase) and from gains in alcohol yield per ton (23% increase) through improvements in sugar cane crushing, fermentation and distillation.

Presently a new leap forward is taking place. Cogeneration of electricity with alcohol production is permitting of the burning sugar cane bagasse more efficiently than in the past. This step required changes in the regulatory system of the electricity utilities. Under the new system one expects to provide additional 6,000 Mw of installed capacity in the State of São Paulo, when current capacity is 20,000 Mw.

A few other opportunities for innovation and "leapfrogging" are the following:

1. Photovoltaic (PV) technology could play an important role in the tropical areas - where most of developing countries are - not only in decentralized but also in centralized units.

While PV technology is perhaps the most inherently attractive of renewable technologies it is also the farthest from being commercial in bulk power markets. Aggregation of large international markets for PV sales could be a mechanism for accelerating the rate of price reduction for PV systems.

Costs could be brought down quickly via mass purchases that could be facilitated by various national and international organizations in conjunction with increased R & D.

2. Technologies for large-scale harnessing of wind power, based on the exploitation of good wind resources. When these resources are remote from areas having high electricity demand, key technologies besides wind turbines are compressed air energy storage and long distance DC transmission lines. This combination could offer "baseload wind electricity"

at the end of the transmission lines, with attractive economics, using present technology.

3. Conversion of the military jet engine industry to an aeroderivative gas turbine industry for stationary power generation.

4. Development of fuels suitable for use in fuel cell vehicles: hydrogen or methanol from natural gas (present technology) or from biomass via thermochenical gasification (with gasifiers that must be demonstrated commercially). Initially it is very likely that natural gas would be converted into hydrogen near the point of use (e.g. at centralized bus depots in urban centers) to be followed by biomass conversion.

This technology will have to compete with liquified petroleum gas (LPG) or compressed natural gas which is being experimented in a number of cities in buses as one way of reducing air pollution.

Leapfrogging could do for developing countries what energy conservation did for OECD countries. In my view the industrialized countries should take an active interest in technological leapfrogging in LDC's, transfering to them modern and efficient technologies, as a matter of self-interest and not philanthropy, the for following reasons:

1. it would open new and bigger markets for their exports
2. it would help ease the external debt problem for many developing countries, which spend more than 50% of their export earnings in energy imports.

In addition to all, that there are the new problems posed by the emission of CO_2, responsible for more than 50% of the greenhouse effect.

The expected growth in future energy consumption has given rise to many scenarios constructed to predict the future energy consumption and the supply mix early in the next century. Of these we will describe in some detail the recent WEC (World Energy Conference) scenarios (Ref 1) which represent well the spectrum of views presented so far. They represent a revision of the earlier WEC projections made in 1983

The WEC study adopted four possibilities for the future evolution of energy consumption. The projections extend to the year 2020 and their characteristics are given in Table II.

Table II

The results of the WEC studies are given in Figure 7

Figure 7

In case A, which is essentially a "business as usual" scenario, energy consumption would more than double in year 2020. In case C (ecologically driven scenario) energy consumption would grow some 50% and "new renewable" would represent 14% of total, up from 1% in 1990. All renewables ("new" and traditional) would contribute 30% to the total in 2020. Nuclear energy 6.2% which is almost as large as the contribution of hydro (Table III).

Table III

The consequences of the four WEC scenarios as far as CO_2 emissions are concerned are given in Table IV.

Table IV

Due to the increased concerns regarding global environmental degradation, policies of the OECD countries will probably be directed to reduce CO_2 emissions and therefore the energy system will envolve in a way that resembles scenario C.

Johansson, Kelly, Reddy and Williams (Ref 5) constructed a scenario for the year 2025 (labelled RIGES - Renewables Intensive Global Energy Scenario) in which they adopted the 16 TW total primary energy consumption goal of IPCC (The Intergovernmental Panel on Climate Change), the same level as scenario C of WEC, but tried to increase - within the bounds of reason - the contribution of renewables. In this study renewables represent 45% the total energy consumption. (Fig. 7)

In the year 2025, carbon emission from the RIGES scenario amounts to 5.5 Gtons, as opposed to 5.8 Gtons for the WEC scenario C and 5.9 Gtons for the 1988 world's emission

Table V compares the supply options of WEC's scenario C and RIGES.

Table V

Scenario C of WEC and RIGES however are not **sustainable** in the sense that they still rely heavily in fossil fuels, but their aggregate CO_2

emissions in the year 2020 or 2025 are essentially the same as today's and represent therefore an enormous progress as compared to other scenarios.

This is also true of the point labelled ESW in Figure 8 which comes from the work of Thomas Johansson, Amulya Reddy, Robert Williams and myself (Ref 6). (Fig. 8)

It was obtained calculating the energy needed to make available to all the population of the developing countries the amenities available to the population of Western European countries in the middle 70's, with the best technology available. In other words what ESW indicates is the extraordinary reduction in primary energy use that would result if developing countries were to adopt, by the year 2020, modern technologies of energy end-use. Even this somewhat optimistic scenario would not lead to a sustainable energy future.

The discussion above indicates clearly that in addition to energy efficiency improvements (both in supply and end-uses) it is necessary to increase the share of renewables of different types in the future energy mix.

At present the only alternative to renewables is the nuclear option which is facing - and will face - enormous difficulties. Nuclear power is not likely to play a large role in the developing world mainly because the national electric grids in most of the countries are not big enough for the large reactors currently being produced (of the order of 1,000 Mw eletric). Smaller reactors could do better but are not avaiable commercially yet. In the future other issues such as nuclear proliferation and safe disposal of nuclear waste will become the leading problems as they are today in Europe, the US and Japan.

Maybe the best example of that strategy is a strategy of increasing the share of renewables the BIG-GT project under development in Brazil (BIG-GT stands for Biomass Integrated Gasification-Gas Turbine).

The idea here is to use biomass in a highly efficient way coupling advanced-cycle gas turbines - which have already been developed for natural gas power generation - to biomass gasifiers (Ref 5). The peak cycle temperature of modern gas turbines (about 1260ºC) is far higher than that for steam turbines (about 540ºC) leading naturally to an higher efficiency of conversion.

Such a project has been funded by the Global Environment Facility (GEF) and is being conducted by a consortium involving the Brazilian Government, Shell and others. The adaptation of the gas turbines has been commissioned to General Eletric and the development of the gasifiers to two Swedish companies (Bioflow and TPS Termiska Processor).

It seems to be promising to conduct research and development on renewables in the industrialized markets to supply technology and equipament to developing countries since they will become huge future markets. In my view the European Community should incorporate that view in their strategic planning.

A demonstration plant for 25 MW-electric is scheduled to operate in 1996. Initial capital cost is likely to be high (approximately US$ 2500 per kilowatt) but in all likelihood after a "learning period" in which 10 or so units are built it will decrease to approximately US$ 1400/Km

If the project works well, it will open a new area in power generation of great interest to all countries - including the industrialized ones - because of the associated "energy plantations" this scheme will require. In a steady state, energy plantations could become a large new sink for carbon capable of absorving 1 Gton per year. For this reason joint implementation of projects through the growth "energy plantations" in developing countries - which are contemplated in the Climate Convention - could become very important.

This approach is also of interest to the European Community because of the decision taken in May'92 to set aside 15% of the land used for cereals, oilseed and protein crops. This will means 20 million hectares of the 130 million hectares currently farmed. The decision on what to do on such large areas of land should stimulate research in "energy farming" and related biomass use.

The recent decision of the EEC to put out bids for biomass gaseification and electricity generation is an important positive step, although the question of subsidies to conventional sources of energy will remain.

In LDC's there are immense areas of degraded lands which could be used for biomass plantations.

Another important example is the <u>New Car Initiative</u> of President Clinton. The quest for a zero (or very low) emission car will drive the Big Three car manufactures (GM, Ford and Chrysler) to highly efficient low emission cars; such requirements point to the use of fuel cells for electric cars.

The agreement reached between the Big Three and US Government will certainly stimulate research and development in areas not well covered presently. Its main objectives are to promote: (Ref 7)

- <u>Advanced manufacturing techniques to make it easier to get new product ideas into the marketplace quickly</u>, for example, rapid, computer-based design and testing systems and new automation and control systems that can lower production costs;

- Technologies that can lead to near-term improvements in automobile efficiency, safety, and emissions, for example, lightwight, recycable materials and catalysts for reducing exhaust pollution; and
- Research that could lead to production prototypes of vehicles capable of up to three times greater fuel efficiency, for example, radical new concepts such as fuel cells and advanced energy storage systems such as ultracapacitors, to produce more fuel-efficient cars that are affordable, meet or exceed current safaty standards and retain the perfomance and comfort avaiable today.

The increased emphasis on energy conservation and renewables will require a shift in present priorities of research and development in many countries.

One of arguments used against such shift, for example, is that R & D in biomass requires little fundamental research and in any case is not of the same degree of sophistication as research in nuclear fission energy or fusion. That is a very debatable argument. Some of the research in biomass is highly sophisticated as it involves genetic engineering in the quest of obtaining higher efficiency in the photosynthesis process. The design and operation of a gasifier requires advanced modelling, and gas turbines are one of the wonders of modern technology. Efficient fuel cells will have to rely on advanced new electrochemistry research.

More generally what we can say is that:

1. The present world energy system based heavily in fossil fuels is not sustainable.

2. Energy services are an integral part of development in all its facets, including a reduced rates of population growth; their need will grow in developing countries.

3. The growth of energy services in LDC's has to be made by "leapfrogging" the historical path wherever possible. The self-reliance and capacity building of developing countries in seeking such solutions should be encouraged.

4. Energy services must be derived from environmentally sound sources. Therefore renewable energy sources are bound to play a much greater role in the future.

5. Attaining a sustainable energy future is in the self-interest of the industrialized nations for political and environmental reasons.

6. Joint ventures - in an institutional setting that is conducive to societal needs - can accelerate the technology transfer and leapfrogging necessary as well as make sense as business propositions.

7. Official Development Aid (ODA) should be used as an instrument to facilitate and encourage "leapfrogging".

8. Joint implementation between industrialized and developing countries to reduce greenhouse gas emissions should be encouraged as it leads lead to reductions "above and beyond" what is established in international conventions.

A very qualitative view of the future of greenhouse gas emissions (GHG) into nest century can be visualized in Figure 9 which indicates that global warming - a direct consequence of business as usual scenario - can be averted.

Figure 9

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Table I

World Commercial Energy consumption by source

1992

	OECD (Gtoe)	%	LDC (Gtoe)	%	Non-OECD Europe (Gtoe)	%	Total	%
Oil	179.9	(43.5)	937.9	(43.5)	391.5	(25.9)	3.128.4	(40.0)
Natural Gas	886.4	(21.5)	269.6	(12.5)	625.0	(41.3)	1781.0	(22.8)
Coal	900.7	(21.8)	849.0	(39.4)	414.5	(27.4)	2164.2	(27.7)
Nuclear	442.7	(10.7)	30.9	(1.4)	58.3	(3.8)	531.9	(6.8)
Hydro	99.2	(2.4)	66.4	(3.1)	23.0	(1.5)	188.6	(2.4)
TOTAL	4,127.9		2,153.8		1,512.5		7,794.2	

REFERENCE 2

Table II

Description of the four WEC energy Cases 1990 - 2020

CASE NAME	A High Growth	B1 Modified Reference	B Reference	C Ecologically Driven
Global Economic Growth %p.a.	3.8	3.3	3.3	3.3
Energy Efficiency Improvements				
OECD	High	High	High	Very High
CEE/CIS	Moderate	Moderate	High	Very High
LDC's	Moderate	Moderate	High	Very High
Institutional Improvements	High	Moderate	High	Very High
Technology Transfer	High	Moderate	High	Very High
Longer-term Sustainbility (to 2020)	Low	Low	Moderate	High

REFERENCE 1

TABLE III

WEC SCENARIOS
ENERGY SUPPLY ASSUMPTIONS (Gtoe)

	1960	1980	2020			
			A1	B1	B	C
SOLID (wal)	1.4	2.3	4.8	2.6	3.0	2.1
LIQUID (oil)	1.0	2.8	4.6	4.9	3.8	2.7
GAS	0.4	1.7	3.5	3.5	2.9	2.4
NUCLEAR	0.0	0.4	1.0	1.0	0.8	0.7
LARGE HYDRO	0.2	0.6	1.2	1.3	1.0	0.9
TRADITIONAL RENEWABLE*	0.5	0.8	1.2	1.3	1.0	1.1
NEW RENEWABLE**	0.0	0.2	0.8	1.4	0.6	1.4
TOTAL RENEWABLE	**0.7**(20%)	**1.6**(20%)	**3.2**(19%)	**4.0**(25%)	**2.9**(22%)	**3.4**(30%)
TOTAL	3.5	8.8	17.2	16.0	13.4	11.3

* Traditional renewable - fuelwood, crop residues, dung

** New renewable - solar, geothermal, modern biomas, ocean and small hydro.

SOURCE: REFERENCE 1

Table IV

Carbon emissions for the WEC and RIGES Scenarios

		Economic growth rate (%)	Carbon emissions Gigatons of Carbon in 2020*
A (WEC)	High Growth	3.8	10.6
B_1 (WEC)	Modified Reference	3.3	9.5
B (WEC)	Reference	3.3	7.8
C (WEC)	Ecologically Driven	3.3	5.8
	RIGES (2025)		5.5

* Carbon emissions in 1988 were 5.89 Gtons (trends 90, "A Compendium of Data on Global Change", Oak Ridge Laboratory, August 1, 1990).

REFERENCE 1 for WEC Scenarios

REFERENCE 5 for RIGES

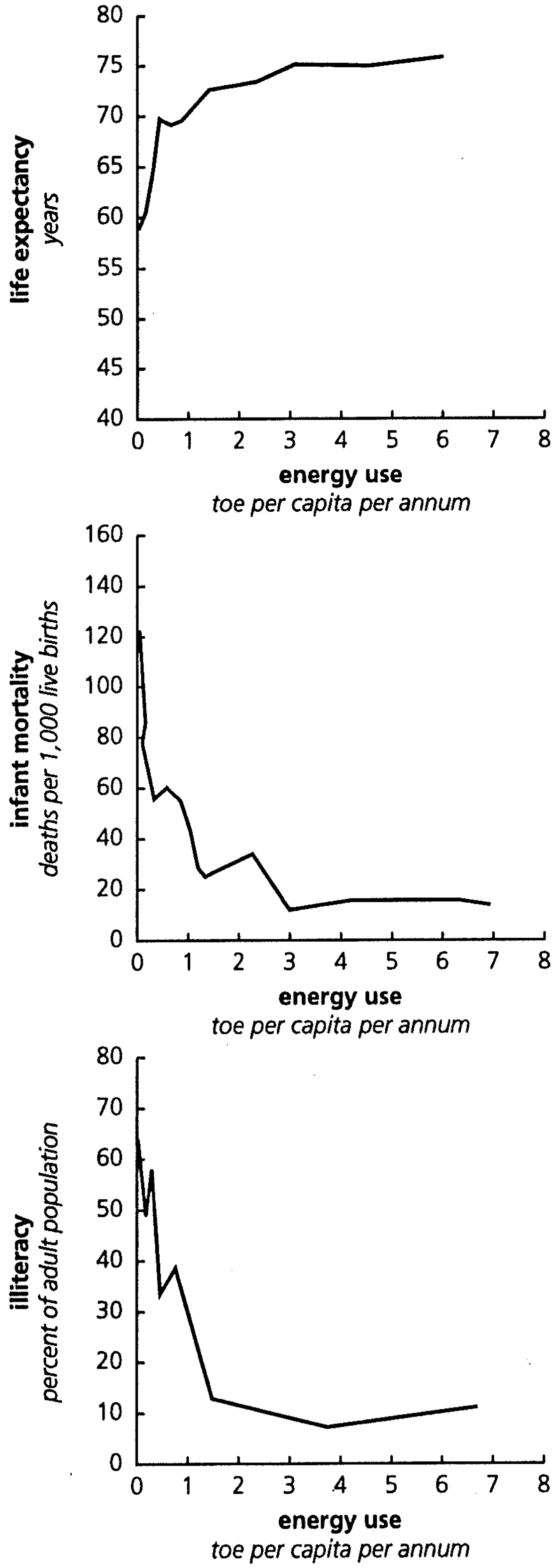
Table V

Comparison of scenarios
Primary Energy Consumption in Gtoe

		WEC Scenario* (Year 2020)		RIGES** (Year 2025)
Solid		2.1		2.00
Liquid		2.7		1.72
Gas		2.4		2.10
Nuclear		0.7		0.33
Large Hydro	0,9		0.68	
New Renewable*	1.4		0.68	
Intermitent Renewable	—	3.4	0.84	5.02
Traditional Renewable	1.1		—	
New Biomass	—		3.30	
Solar H2	—		0.2	
Geothermal	—			0.04
TOTAL		11.3		11.21

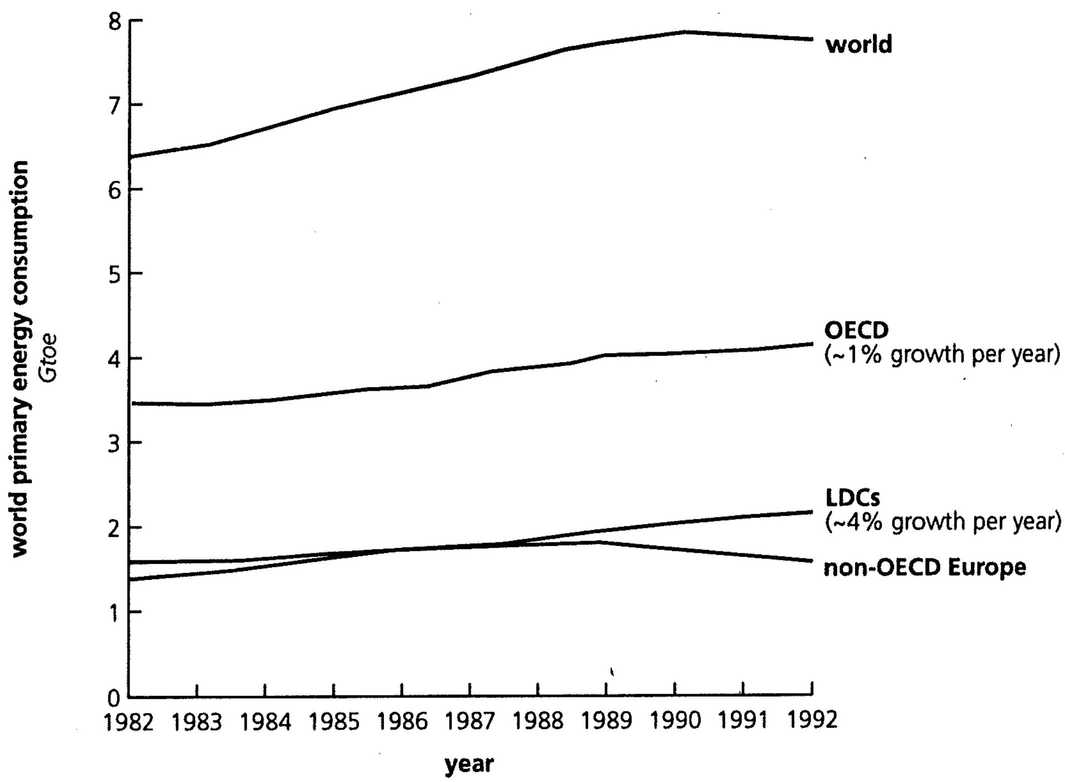
In "new renewable", "modern biomass" contributes 0.6 Gtoe. This category is considered "new biomass" in RIGES along with traditional biomass which is all converted in "new biomass" in the year 2025. The WEC Scenario thus gives 1.1 + 0.6 = 1.7 Gtoe for "new biomass" in the year 2020. Subtracting 0.6 Gtoe from "new renewable" in WEC it is reduced to 0.8 Gtoe for what RIGES considers "intermittent renewables". This compares well with 0.8 Gtoe in the RIGES Scenario.

Figure 1: Life expectancy, infant mortality and literacy as a function of energy consumption per capita.



Source: Reference 1.

Figure 2: The evolution of primary energy consumption in the period 1982–1992.



Source: Reference 2.

Figure 3: Projections of primary energy consumption 1991–2030.

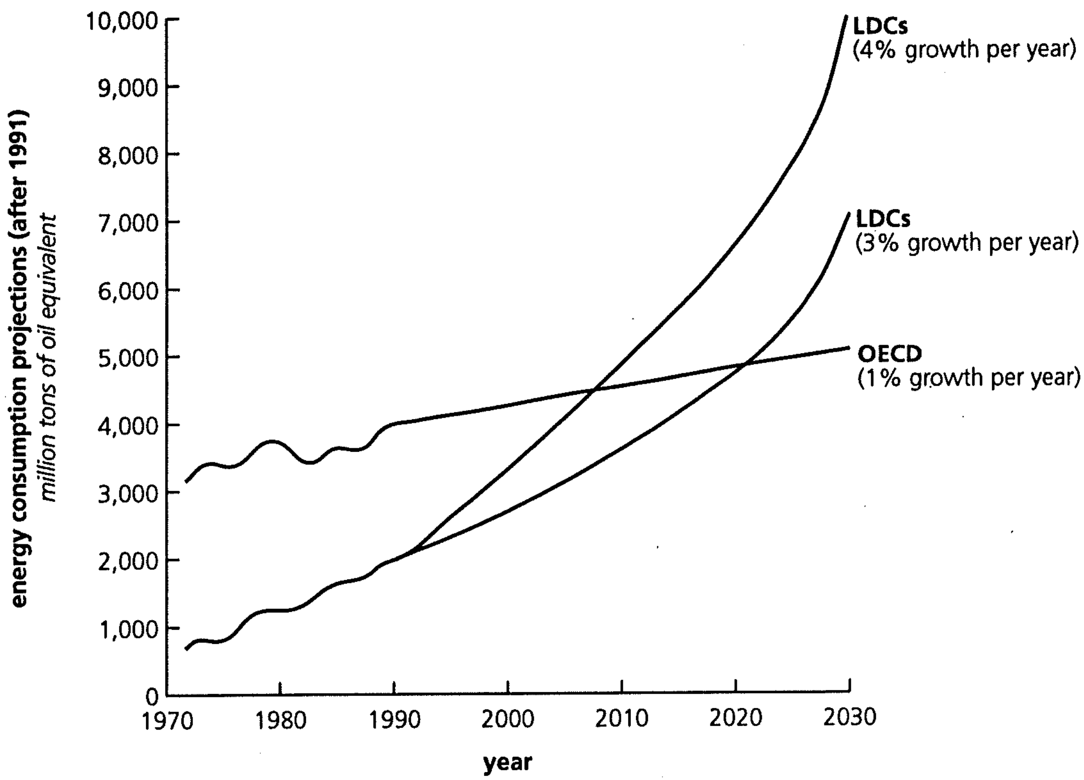
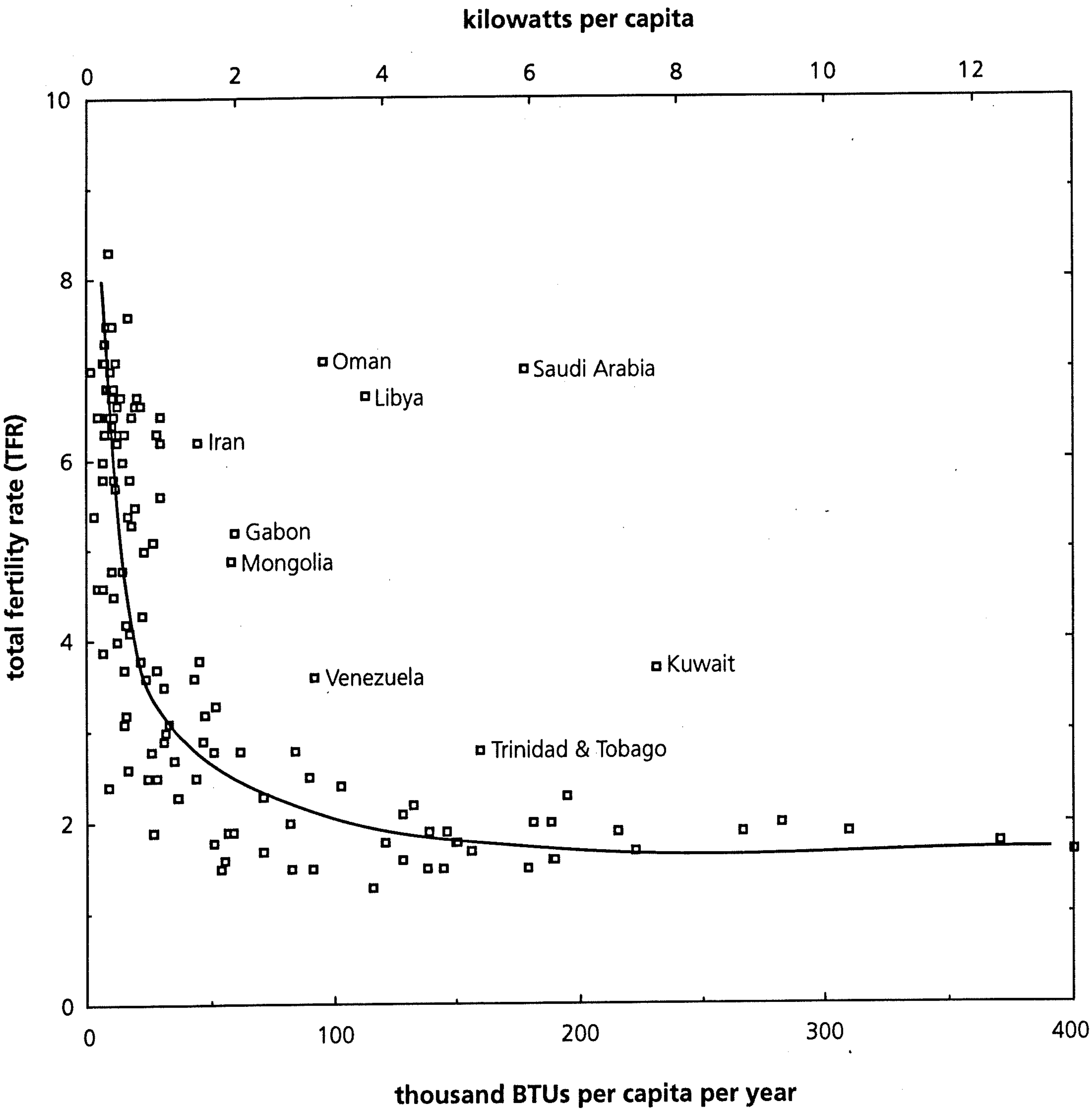
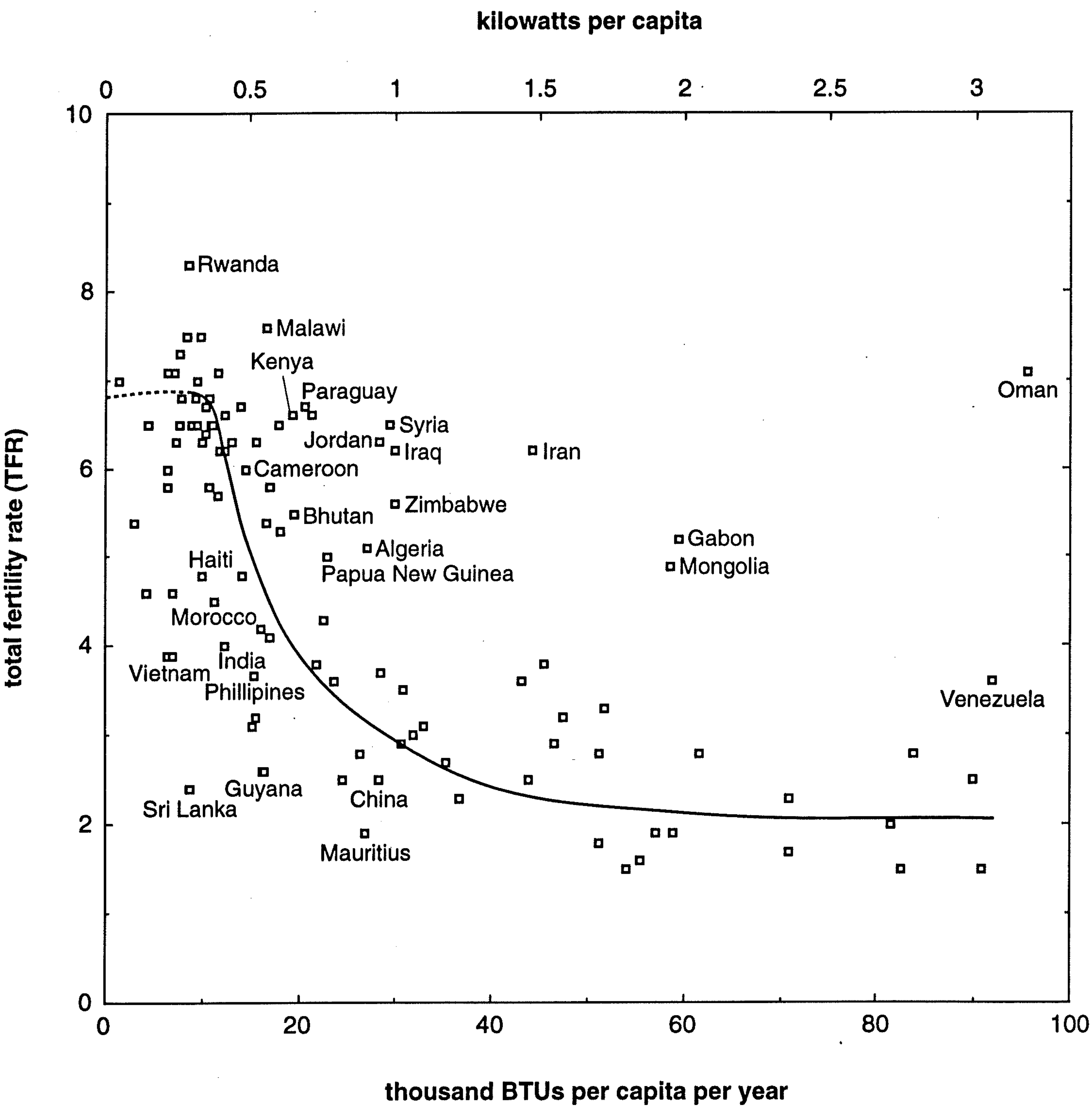


Figure 4: Total fertility rate as a function of per capita energy consumption (all countries).



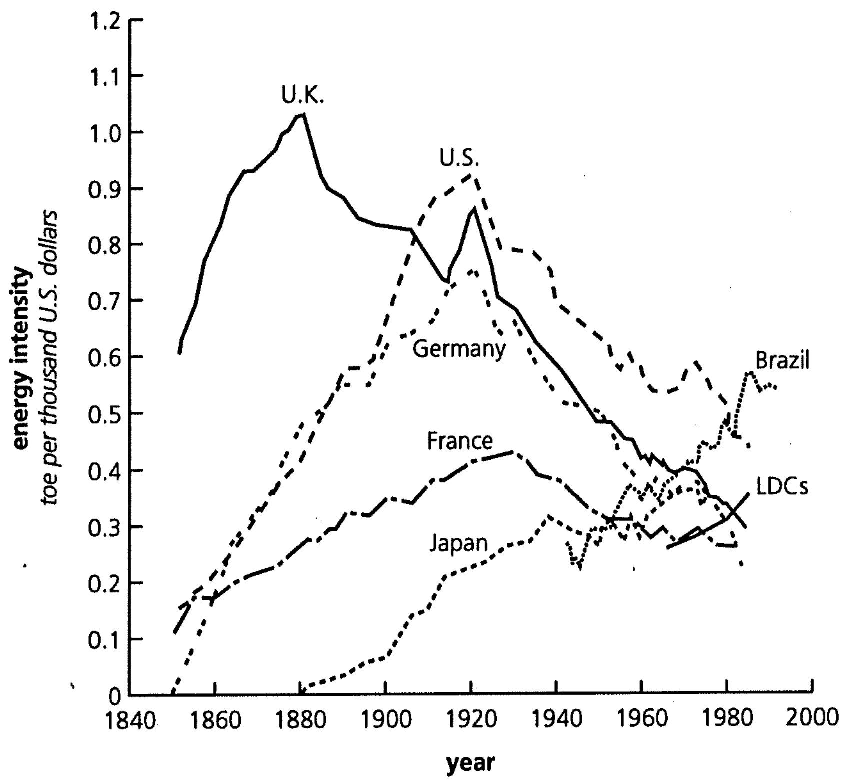
Source: Reference 3.

Figure 5: Total fertility rate as a function of per capita energy consumption (LCDs).



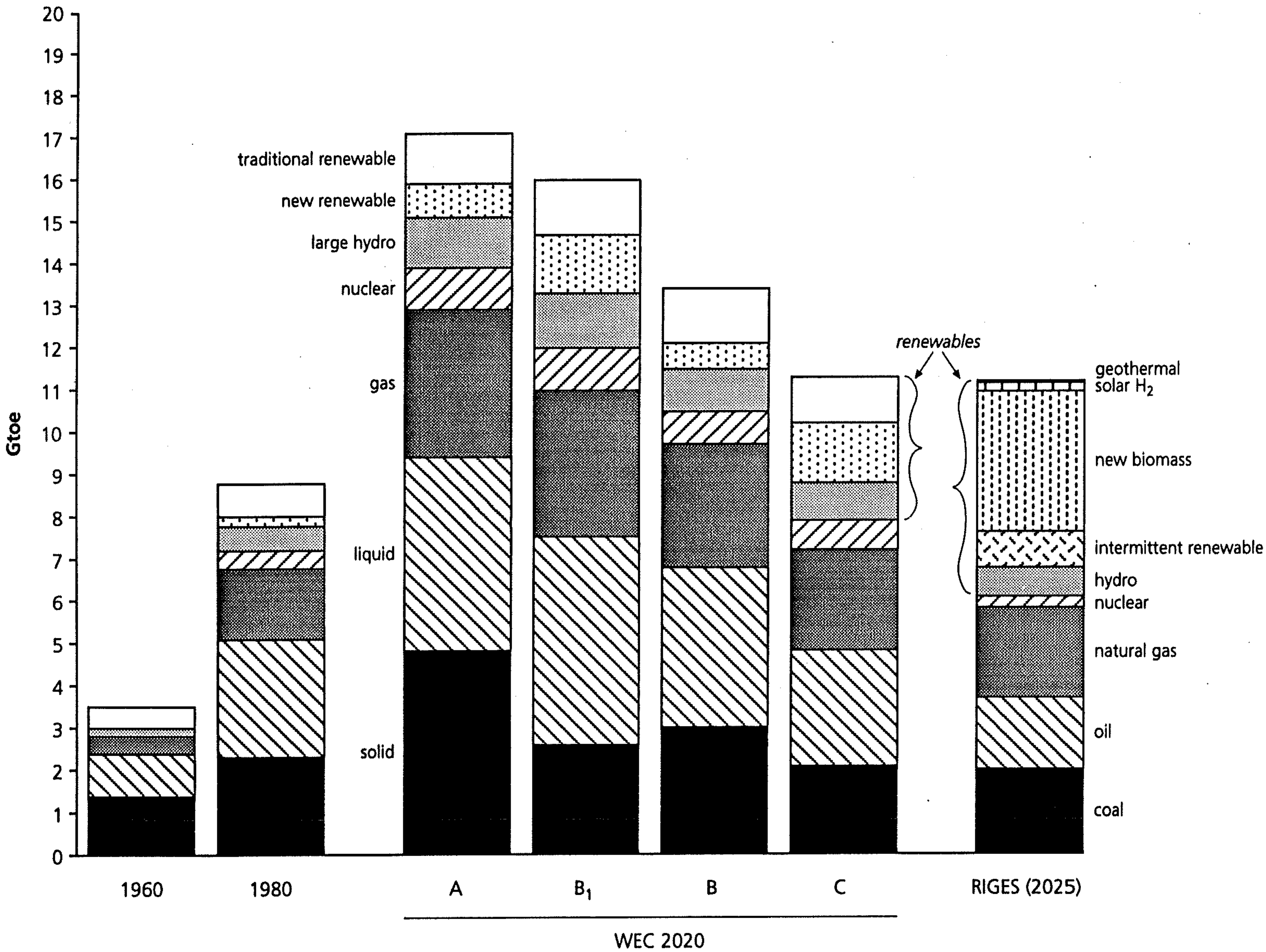
Source: Reference 3.

Figure 6: Energy intensity for a number of countries, 1850–1990.



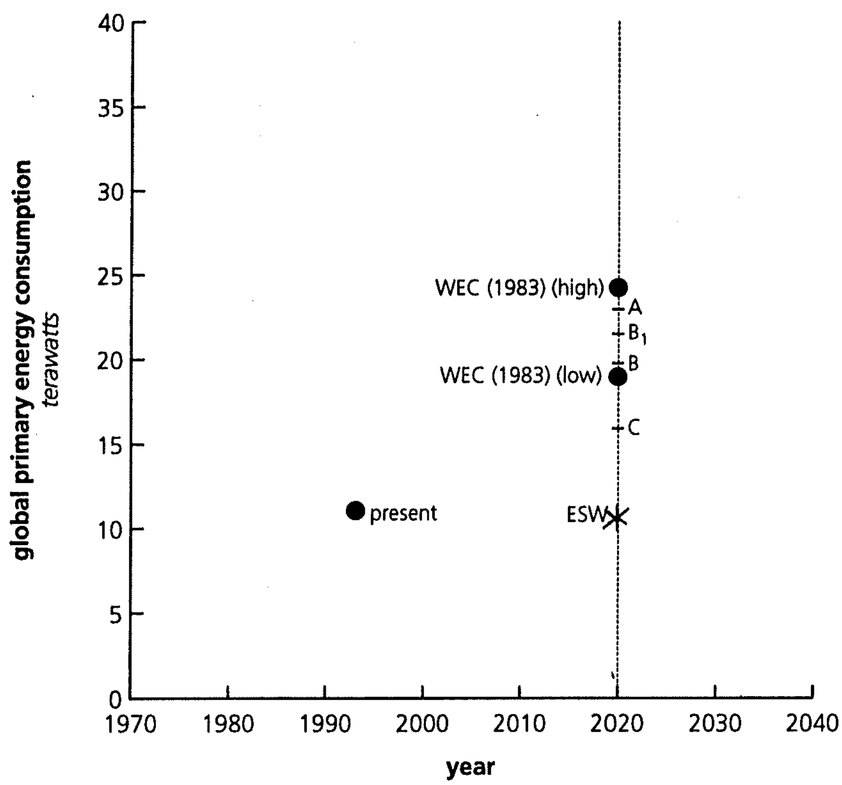
Source: Reference 4.

Figure 7: The future energy supply mix.



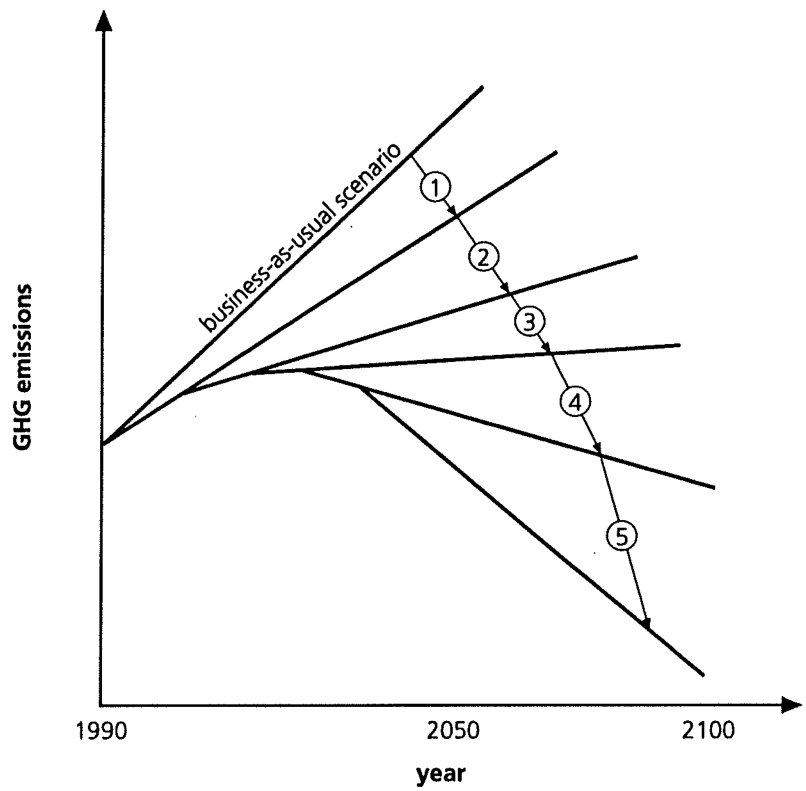
Source: Reference 1 in WEC countries; Reference 5 for RIGES.

Figure 8: Projections for the primary energy consumption for the year 2020.



Sources: Reference 1 for A, B, B_1 and C (WEC 1993 scenarios); Reference 6 for ESW.

Figure 9: Generic strategies to reduce greenhouse gaseous emissions.



1 intensified energy conservation programs, CFCs phase-out
2 renewable energy sources
3 carbon dioxide fixation and re-utilization technology
4 reforestation, stopping deforestation, enhancing oceanic sinks
5 future energy technologies