ENERGY AND SUSTAINABLE DEVELOPMENT

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SUMMARY

A description of the present world energy system and its evolution is made for the industrialized and developing regions of the world. From such description it emerges clearly the lack of sustainability of the system. An analysis is then made of the precise meaning of a sustainable energy future, its consequences and the strategies to follow to achieve it.

I. INTRODUCTION

Sustainable development addresses today's society ability to meet

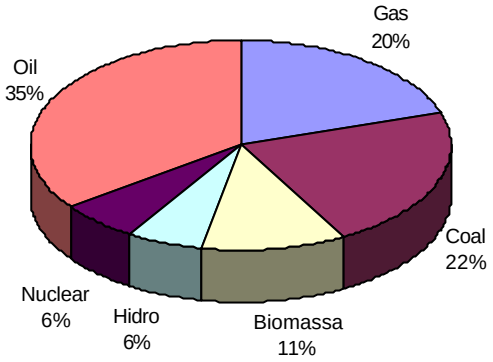
- economic
- environmental and
- socio – societal needs and concerns,

without compromising the same opportunities for future generations. In all these three components energy plays an essential role as one realizes when analyzing the features of the present energy system.

Figure 1 shows the sources of the primary energy in use in 1998 and some of its characteristics.

Figure 1

PROFILE OF THE WORLD'S PRIMARY ENERGY CONSUMPTION (1998)



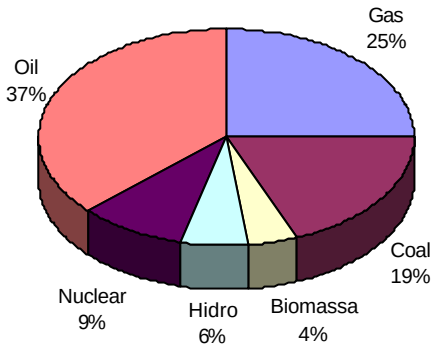
Population 5.90 billion
% of fossil fuel: 77%
Energy: 10,562 x 10^6 toe
1.79 toe/capita
GROWTH OF ENERGY CONSUMPTION
(1969-1999): 2.2%/year

As shown above the system is heavily dependent on the use of fossil fuels (coal, oil and gas) which accounts for 77% of total consumption.

The way primary energy is consumed in the industrialized and developing countries is shown in Figures 2 and 3.

Figure 2

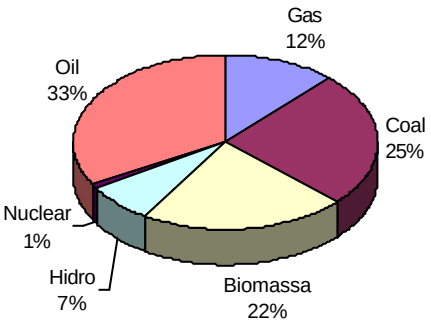
PROFILE OF THE PRIMARY ENERGY CONSUMPTION IN INDUSTRIALIZED COUNTRIES (1998)



Population 1.34 billion
(22.7% of total wold population)
% fossil fuels: 81%
Energy: 6,701 x 10^6 toe
5.0 toe/capita
GROWTH OF ENERGY CONSUMPTION
(1969-1999): 1.7%/year

Figure 3

PROFILE OF THE PRIMARY ENERGY CONSUMPTION IN DEVELOPING COUNTRIES (1998)



Population 4.56 billion
(77.73% of world population)
% of fossil fuels: 70%
Energy: 3,861 x 106 toe
0.85 toe/capita
GROWTH OF ENERGY CONSUMPTION
(1969-1999): 3.8%/year

There are significant differences in the structure of consumption between industrialized and developing countries: fossil fuel consumption accounts for 81% in industrialized countries and 70% in developing countries. To compensate for that, biomass represents only 4% in the former and account for 22% in the later. Nuclear energy is also significant in industrialized countries and makes a minor contribution in developing countries.

One can notice in Figure 1, 2 and 3 the extreme inequities in energy consumption per capita in different groups of countries.

Industrialized countries	**5.0 toe/capita**
Developing countries	**0.85 toe/capita**
World	**1.79 toe/capita**

One additional important consideration is the evolution the world's energy system. Table 1 shows the growth rate of primary energy consumption in various groups of countries in the last few decades.

Table 1

Growth rate of primary energy consumption

	1969 – 1999	**1989 – 1999**
World	2.2%	0,9%
OECD	2.1%	1,1%
Developing	3.8%	2,7%
Industrialized countries	1.7%	0,2%

Worldwide growth in the period 1969-1999 was 2.2% per year which has decreased in the last 10 years due to the decline of energy consumption in the former Soviet Union. However energy consumption in developing countries is growing at 2.7%/year almost the triple of the growth in OECD countries in the last 10 years (1.1%). In approximately 30 years consumption in developing countries will probably reach consumption in the OECD countries aggravating all the problems discussed above unless the profile of energy consumption changes dramatically.

What are the sustainability concerns resulting from this system?

II. ECONOMIC CONCERNS

In the first place, contrary to some perceptions, it is not the exhaustion of fossil fuels the immediate cause of concern. As shown in Table 2, coal is an abundant resource and should last for centuries. Oil and gas reserves are much smaller but they are in reality a "moving target": resources of conventional supplies do exist and technologies are being developed to tap them extending therefore the lifetime of oil and gas. Of course, consumption increases too and the "dynamic" resource base over production ratio is more than double the "static" resource production ratio. Shortage of oil and gas should not be a very serious concern in the 21th century although prices could climb significatively.

Table 2

Expected life of fossil fuels, 1998			
Source	**Static reserve production ratio (years)[a]**	**Static resource base-production ratio (years)[b]**	**Dynamic resource Base-production Ratio (years)[c]**
Fossil fuels			
Oil	45	~200	95
Natural gas	69	~400	230
Coal	452	~1,500	1,000

a. Based on constant production and static reserves. b. Includes both conventional and unconventional reserves and resources. c. Data refer a to the energy use of a business-as-usual scenario – that is, production is dynamic and a function of demand

In the second place there economic concerns. The intimate connection between primary energy consumption and economic development has been investigated in great detail. What experience shows is that during most of the 20th century energy has been cheap and abundant and as consequence the energy system has evolved with a disregard for optimization. The oil crisis of the 70's has highlighted the importance of energy efficiency which led ultimately to a significant decoupling of energy consumption and GDP which means that more products can be manufactured with less energy and that less energy is needed in general to perform the energy services required.

Expenditures in energy represent approximately 3% of the world's GDP of 30 trillion dollars in 1999, or 1 trillion dollars. Investments in energy requires an amount of 290-410 billion dollars per year.

III. ENVIRONMENTAL CONCERNS

Environmental problems resulting from the use of fossil fuels however, can be extremely serious because of the role of present use of fossil fuels in contributing to most environmental problems we face as shown in Table 3

Table 3

Environmental and Health Problems			
Insult	**Human disruption Index**	**Share of the human disruption caused by commercial Energy supply (%)**	
		Fossil fuels burning	**Other**
Lead emission to atmosphere	18	41	
Oil added to oceans	10		44
Cadmium emission to atmosphere	5.4	13	
Total sulfur emissions to atmosphere	2.7	85	
Methane flow to atmosphere	2.3		18
Nitrogen fixation (as NO_x and NH_4)	1.5	30	
Mercury emissions to atmosphere	1.4	20	
Nitrous oxide flows to atmosphere	0.5	12	
Particulate emissions to atmosphere	0.12	36	
Non-methane hydrocarbon emissions to atmosphere	0.12		35
Carbon dioxide flow to atmosphere	0.05	75	

Source: Updated from Holdren, 1992
The Human Disruption Index is defined as the rario of human-generated flow to the natural (baseline) flow

A detailed analysis of the problem shows that:

- Human health is threatened by high levels of pollution resulting from energy use at the household, community, and regional levels.
- The environmental impacts of a host of energy-linked emissions—including suspended fine particles and precursors of acid deposition—contribute to air pollution and ecosystem degradation.

- Emissions of anthropogenic greenhouse gases, mostly from the production and use of energy, are altering the atmosphere in ways that may already be having a discernible influence on the global climate.

IV. SOCIO – SOCIETAL NEEDS AND CONCERNS

Energy use is closely linked to a range of social issues, including poverty alleviation, population growth, urbanization, and a lack of opportunities for women. In addition to that poverty is the overriding social consideration for developing countries and poses one of the main threats to political stability in many countries.

Some 1.3 billion people in the developing world live on less than $1 a day. Income alone however is particularly inadequate to understand some social concerns such as reducing physical labour for household chores, providing safe potable water, reducing the need to collect fuelwood through the use of more efficient and/or better cooking with stoves which reduces indoor air pollution and improves women's health.

The problem in many cases is not one of more income which could lead automatically to more access to modern energy carriers but the use of better technologies to solve the problem with the same income which in any case is very low. In some cases it has been proven that poor people spend more with candles and kerosene for lighting than using a solar photovoltaic panel that not only provides better lighting but other energy services such as refrigeration, radio and TV.

In addition to that,although population growth tends to increase energy demand, it is less widely understood that the availability of adequate energy services can lower birth rates. Adequate energy services can shift the relative benefits and costs of fertility towards a lower number of desired births in a family. An acceleration of the demographic transition to low mortality and low fertility (as has occurred in industrialised countries) depends on crucial developmental tasks, including improving the local environment, educating women, and ameliorating the extreme poverty that may make child labour a necessity. All these tasks have links to the availability of low-cost energy services.

Attention to energy security is also critical because of the uneven distribution both of the fossil fuel resources on which most countries currently rely and of capacity to develop other resources. The energy supply could become more vulnerable over the near term due to the growing global reliance on imported oil. For example, the oil dependence (net imports as a share of total demand) of OECD countries is expected to grow from 56 percent in 1996 to 72 percent in 2010. In addition, although energy security has been adequate for the past 20 years, and has in fact improved, the potential for conflict, sabotage, disruption of trade, and reduction in strategic reserves cannot be dismissed. These potential threats point to the necessity of strengthening global as well as regional and national energy security.

Therefore although there seem to be no physical limits to the world's energy supply for at least the next 50 years, today's energy system is unsustainable because of equity issues as well as environmental, economic, and geopolitical concerns that have implications far into the future.

V. THE CHALENGE OF SUSTAINABILITY

Aspects of the unsustainability of the current system include:

- Modern fuels and electricity are not universally accessible, an inequity that has moral, political, and practical dimensions in a world that is becoming increasingly interconnected.
- The current energy system is not sufficiently reliable or affordable to support widespread economic growth. The productivity of one-third of the world's people is compromised by lack of access to commercial energy, and perhaps another third suffer economic hardship and insecurity due to unreliable energy supplies.
- Negative local, regional, and global environmental impacts of energy production and use threaten the health and well-being of current and future generations.

Globally such is the challenge.

VI. SOLUTIONS

Policies to avoid persevering along an energy pathway that is not sustainable have nuances as one looks at the industrialized countries and the developing part of the world.

The strategies to move to a more sustainable future are therefore bound to have important differences between two groups of countries and important worldwide consequences.

There is one important communality which is due to the fact that in developing countries the income distribution is concentrated in an upper middle class which usually represents less than 20% of the population but which consumes most of the conventional modern fuels (coal, oil and gas) using the same patterns of consumption of the industrialized countries. The rest of the population has little access to modern fuels or no access at all relying heavily in biomass use offten with primitive and inefficient technologies.

Whenever these commonalities apply physical resources and technical opportunities are available—or could become available—to meet the challenge of sustainable development. However policy changes and cost differentials may favour conventional fuels for years to come.

Options for using energy in ways that support sustainable development, which requires addressing environmental concerns, include:

- More efficient use of energy, especially at the point of end use in buildings, electric appliances, vehicles, and production processes.
- Increased reliance on renewable energy sources. Renewable energy sources (including biomass, solar, wind, geothermal, and hydropower) that use indigenous resources have the potential to provide energy services with zero or almost zero emissions of both air pollutants and greenhouse gases.
- Accelerated development and deployment of new energy technologies, particularly next-generation fossil fuel technologies that produce near-zero

harmful emissions—but also nuclear technologies, if the problems associated with nuclear energy can be resolved.

All three options have considerable potential, but realizing this potential will require removing obstacles to wider diffusion, developing market signals that reflect environmental costs, and encouraging technological innovation.

Altogether, new renewable energy sources contributed 2 percent of the world's energy consumption in 1998, including 7 exajoules from modern biomass and 2 exajoules for all other renewables (geothermal, wind, solar, and marine energy, and small-scale hydropower). Solar photovoltaics and grid-connected wind installed capacities are growing at a rate of 30 percent a year. Even so, it will likely be decades before these new renewables add up to a major fraction of total energy consumption, because they currently represent such a small percentage. (Table 4)

Table 4 Current status and potential future costs of renewable energy technologies

Technology	Present rate of increase (%/yr)	Operating Capacity in 1998	Capacity factor (%)	Energy production in 1998	Turnkey investment costs ($/kW)	Energy cost in 1998	Future energy cost (expected)
Biomass energy							
- electricity	4	40 GWe	40 - 50	160 TWh (e)	900–3000	5-15 ¢/kWh	4-10 ¢/kWh
- heat[a]	4	80 GWth	30 - 40	240 TWh (th)	250-750	1-5 ¢/kWh	1-5 ¢/kWh
- ethanol	3	18 bln liter		420 PJ		15-25 $/GJ	8-13 $/GJ
Wind electricity	30	10 GWe	20 - 30	16 TWh (e)	1000-1500	5-13 ¢/kWh	3-6 ¢/kWh
Solar PV electricity	15	500 MWe	8 – 20	0.5 TWh (e)	5000-10000	30-150 ¢/kWh	6-25 ¢/kWh
Solar Thermal Electricity	5	400 MWe	20-35	1 TWh (e)	3000-4000	10-18 ¢/kWh	4-6 ¢/kWh
Low Temp. Solar Heat	8	18 GWth (30 mln m^2)	7-10	14 TWh (th)	500-1700	4-20 ¢/kWh	3-10 ¢/kWh
Hydroelectricity							
- large	2.5	660 GWe	35-50	2600 TWh (e)	600-1500	2-5 ¢/kWh	2-5 ¢/kWh
- small	4	20 GWe	35-50	85 TWh (e)	1000-3000	3-10 ¢/kWh	2-7 ¢/kWh
Geothermal							
- electricity	4	8.2 GWe	45-90	46 TWh (e)	2000-4000	3-10 ¢/kWh	3-10 ¢/kWh
- heat	6	11 GWth	20-60	40 TWh (th)	800-3000	2-15 ¢/kWh	2-10 ¢/kWh
Marine Energy							
- tidal	0	300 MWe	20-30	0.6 TWh (e)	1700-2500	8-15 ¢/kWh	8-15 ¢/kWh
- wave	-	exp. phase	20-35	pm	1500-3000	8-20 ¢/kWh	?
- current	-	exp. phase	25-35	pm	2000-3000	8-15 ¢/kWh	?
- OTEC	-	exp. phase	70-80 ?	pm	not clear	?	?

Note: The cost of grid-supplied electricity in urban areas ranges from 2-3 (c/kWh (off-peak) to 15-25 c/kWh) (peak).

a. Heat embodied in steam (or hot water in district), often produced by combined heat and power systems using forest residues, black liquor, or bagasse.

There is however a vast area in which there are no commonalities between industrialized and developing countries: the vast majority of the developing countries consume non-commercial energy basically biomass (dung fuelwood and agricultural residues) which are used inefficiently. The main challenge there is to modernize the use of such fuels by converting them in gaseous or liquid fuels.

This has been done in some cases with success improving the efficiency of cooking stoves when the problem is cooking. In others sugarcane was converted into ethanol a good replacement for gasoline. Those developments an usually of no great interest in industrialized countries and require development in the developing world which in a way correspond to “leapfrogging” the path of development followed in the past since it involves the use of renewable resources which are desirable in many grounds.

There are clear indications that a shift in the direction of achieving a sustainable energy future in both the industrialized and developing regions of the world.