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A Journal on Integrated Management of Occupational Health and the Environment

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THE FUTURE OF ENERGY

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ABSTRACT

In the XXIst century man consumes nearly one million times more in energy terms than primitive man did, especially in fossil fuels and particularly in petroleum. Developed countries consume almost 5 times more per inhabitant than developing countries. This option causes a severe impact, principally as far as climate changes and the depletion of underground reserves are concerned. Modern renewable sources of energy (solar, aeolic, small hydro-electric power stations and biomass) represent a just a small fraction of the world's matrix (2%), but they are beginning to compete commercially with traditional sources. Renewable energy sources are the solution for development issues, because they are intrinsically durable, pollute less, create jobs and reduce dependence on oil. To speed up the growth of renewable sources it is necessary to: (1) overcome market resistance and eliminate subsidies for non-renewable sources (fossil and nuclear); (2) help the introduction of new technologies, thereby reducing their costs; (3) establish mandatory and progressive policies for their introduction; (4) make information about these technologies widely available so that developing countries can incorporate them faster without having to go through intermediate and more polluting stages. Brazil is giving the best possible example in terms of bio-fuels and its Alcohol Program can be replicated in other countries.

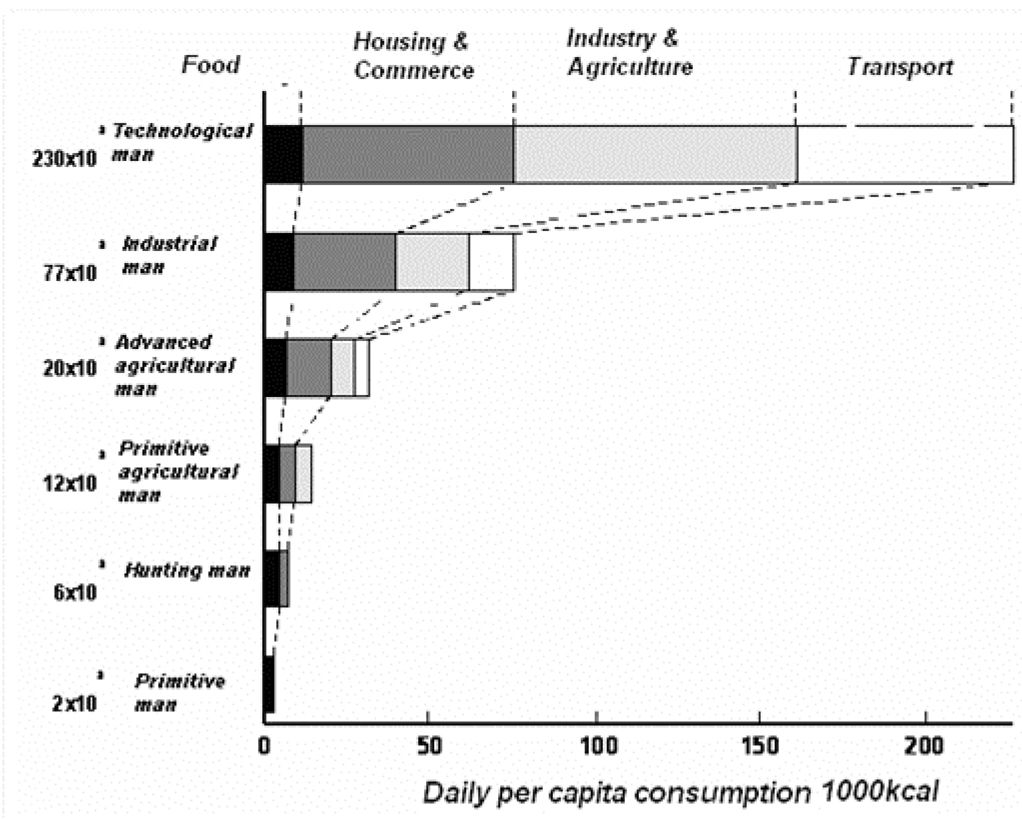
Key word: renewable energy; environment; sustainable development.

INTRODUCTION

A million years ago man's needs were intrinsically linked to his survival. He needed 2,000 calories (kcal) and got them by hunting and gathering his food. Seven thousand years ago agricultural man used the traction power of animals, thereby multiplying his strength by a factor of 8. At the time of the Romans a noble had, on average, the strength of 20 slaves at his disposal, over and above his traction animals. In Modern Times (1400 A.D.) man started using water-falls and wind to grind wheat and carry out other tasks. Little fossil energy was used; basically surface coal and oil for heating environments, in addition to a limited use for making steel. Whale-oil was considered better than petroleum oil for lighting. After the Industrial Revolution (end of the XIXth century) man developed the steam engine, thereby multiplying even further his capabilities in terms of industry and transport. In the XXth century humanity improved the steam engine and developed internal combustion engines powered by gasoline and diesel that derive from petroleum oil. Later came electric engines and nuclear energy, and consequently the world was never able to break its relationship of dependency on oil.

The population has grown and with it the consumption of energy. In 2003, every single one of the 6 billion inhabitants on earth consumed on average 1.69. 10^7 kcal (or 1.69 tons of oil equivalent *per capita* and per year), nearly one million times more than primitive man consumed (Figure 1).

Figure 1: Stages in the development and consumption of energy.



Stages in the development and consumption of energy

The 2,000 calories that man took all day trying to get hold of correspond to the amount contained in a glassful of oil. These same calories can also be obtained from a fast food snack. A Ferrari that has the strength of 600 horses generally only carries one person.

2. Renewable and non-renewable energy

The energy we consume comes basically from the sun: heat, winds, the hydraulic power of rivers, because of evaporation and condensation, and marine currents. A small part is incorporated in plants through photosynthesis and serves to sustain the earth's whole food chain. Over millions of years the organic material of beings that died has accumulated in the subsoil, forming the so-called **fossil energy sources,** among which are petroleum, coal, natural gas and bituminous schist. Some of the chemical elements present in the earth's crust are capable of generating nuclear energy. Replacement of fossil and nuclear energy sources does not happen in the time line of humanity and they are, therefore, considered to be **non-renewable sources**.

Renewable sources of energy are immediately replaced by nature; such is the case of hydraulic power, wind (aeolic), tides, waves, solar radiation and the heat from the depths of the earth (geothermal). Biomass is also a renewable source of energy and includes various sub-categories, from the most traditional (like firewood and animal and vegetable waste) to the most modern (like ethanol for automobiles, biodiesel, sugar-cane bagasse for energy co-generation and gas from sanitary landfill sites, used for generating electricity).

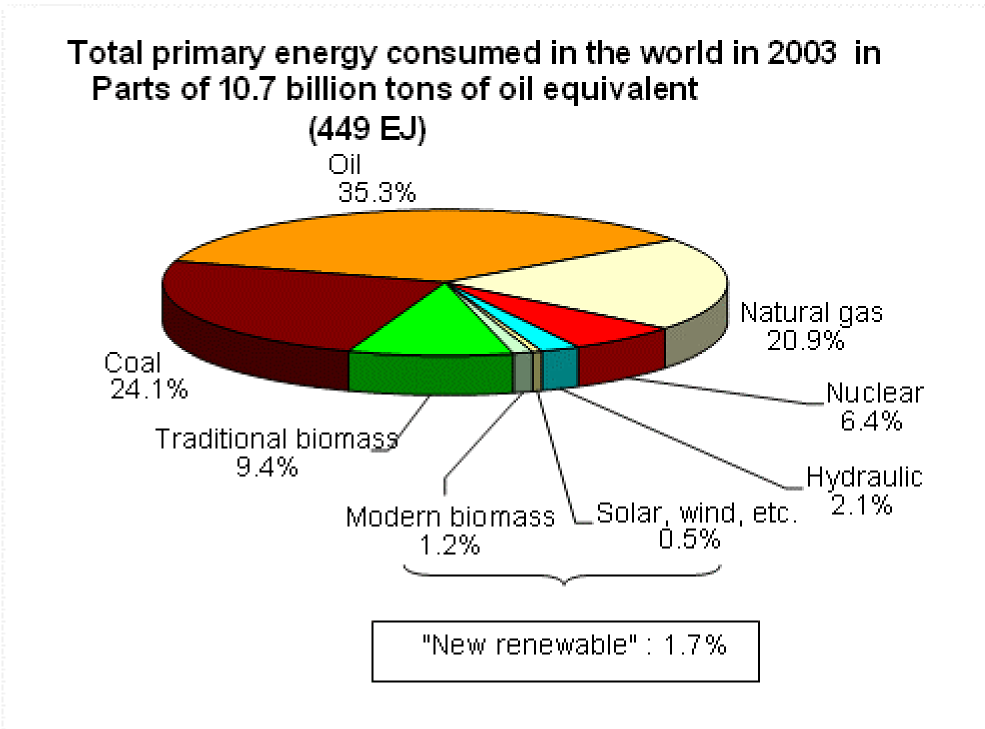
Some forms of renewable energy conversion are, therefore, *traditional* (the case of wood collected and burned in primitive fires). Modern sources are the "conventional" ones (like hydroelectric power stations, with commercially mature technology) and "new" (that are beginning to compete commercially with traditional sources: photovoltaic solar panels, solar heaters, small hydroelectricity plants, wind turbines, geothermal plants and "modern" biomass, like biofuels for transport).

3. World consumption and energy reserves

Fossil sources of energy predominate in the world energy matrix and in all countries, individually. In 2003, the world consumed nearly 80% fossil energy, for a total of nearly 10.7 billions tons of petroleum equivalent. The main fuel is oil (35% of the total), but coal (24%) and natural gas (21%) are also very significant. Nuclear fuel, also non-renewable, contributes with nearly 6%. Renewable sources contributed the rest. Nearly

9% of the world total corresponded to traditional biomass, basically wood burned in a primitive way. Only 4% of the world's energy matrix was supplied by hydroelectric power (2%) and with other "modern" options (2%) like aeolic, solar and bio-fuels.

Figure 2



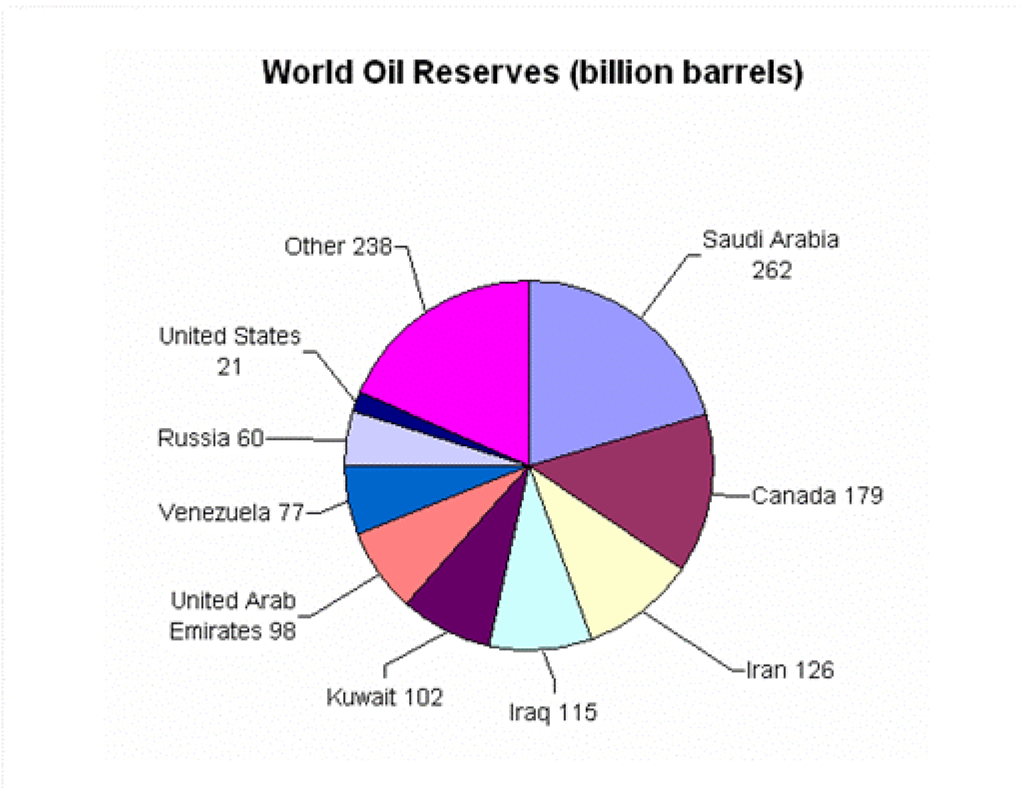
Each inhabitant on earth consumes nearly 1.7 tons of oil equivalent a year, but in very different ways between developed and developing countries, both in terms of quantity as well as in quality. Developed countries consume almost 5 times more than developing countries per inhabitant and much more fossil energy.

Non-renewable energy sources, such as fossil fuels like oil and natural gas, will undoubtedly run out sooner or later. Energy specialists know the bell curve very well, as presented by scientist, M. King Hubbert, at the beginning of the 70s. In an empirical way this curve represents the life cycle of a non-renewable fuel, as is the case with oil. Initially reserves were abundant and production grew at a given amount each year, accompanying technological development and the increase in consumption demand. But this growth reaches a peak and just like a roller-coaster, rapidly descends until it reaches zero in subsequent years.

Well, we are arriving at the top of this roller-coaster as far as petroleum oil is concerned. The world market, and especially the voracious North American market, needs this polluting and increasingly scarce fuel to maintain its unsustainable production and leisure patterns.

Energy resources are what are naturally available for exploring and obtaining primary energy. To define the limits for exploration the first step to be analyzed must be the energy resources that are available. A part of these resources are *reserves*, known or estimated quantities of natural energy deposits in a given location, based on exploration (geological, hydrological and wind regime) and engineering data, and that can be reached by commercial extraction and production technologies. Because it is extremely versatile and easily transported and stored, oil is currently the most important and strategic energy source on earth. However, most of the oil reserves are concentrated in just a few countries.

Figure 3: World oil reserves in billions of barrels (DoE, 2006)[1].



Of the nearly 2 trillion estimated barrels of oil that we originally had on this planet, between 45% and 70% has already been explored. Between 1965 and 2005, 0.92 trillion barrels of oil were produced (BP, 2006[1]). Nearly 1 trillion barrels remain to be explored and these will probably be depleted in around 50 years. Brazil has oil for the next 20 years

[1] 2006 BP Statistical Review of World Energy http://www.bp.com/liveassets/bp_internet/globalbp/globalbp_uk_english/publications/energy_reviews_2006/STAGING/local_assets/downloads/spreadsheets/statistical_review_full_report_workbook_2006.xls

(Table 2). The ratio between current reserves (measured, for example, in billions of barrels of oil) and current production (in this case in billions of barrels of oil per exploration year) is of the order of 40 years, if there are no significant technological changes. Despite consumption efficiency measures (like those in automobile engineering, for example) and all the technological and geopolitical production strategies (like the proposal to extract bituminous oil in Venezuela instead of the lighter oils that flow in the troubled subsoil of the Middle East), they will only allow us to reduce our speed of descent on the roller-coaster.

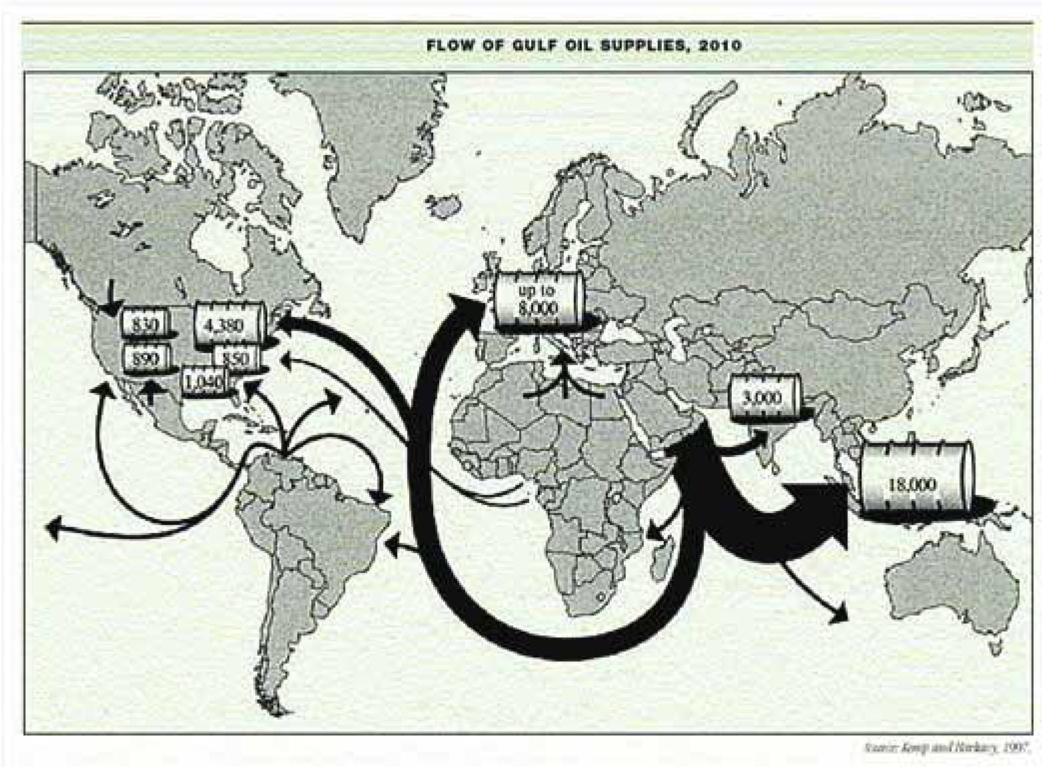
Table 1: Known reserves at the endo of 2005 (BP, 2006).

	oil			natural gas			coal		
	Billions of barrels = 1Gbbl=0.13 64 Gtep = 5.73 .10E18J	% total	R/P years	Trillions of cubic meters 1Tm3NG = 0.9 Gtep	% total	R/P years	Millions of tons = 0.67 Mtep	% total	R/P years
North America	59.5	5.0%	11.9	7.46	4.1%	9.9	254432	28.0%	231
Brazil	11.8	1.0%	18.8	0.31	0.2%	27.3	10113	1.1%	*
Total Latin America and Caribbean	103.5	8.6%	40.7	7.02	3.9%	51.8	19893	2.2%	269
Total Europe & Eurasia	140.5	11.7 %	22.0	64.01	35.6 %	60.3	287095	31.6%	241
Total Middle East	742.7	61.9 %	81.0	72.13	40.1 %	*	419	□	399
Total Africa	114.3	9.5%	31.8	14.39	8.0%	88.3	50336	5.6%	200
Total Asia Pacific	40.2	3.4%	13.8	14.84	8.3%	41.2	296889	32.7%	92
WORLD TOTAL	1200,7	100,0 %	40,6	179,83	100,0 %	65,1	909064	100,0%	155

As energy supply security is a vital aspect in the geopolitics of countries, the domestic reserves they have are strong determinants in their international negotiating position, in both commercial and environmental matters. Oil producing countries set up OPEC in the 70s to get better commercial deals. The Middle East is a vitally important region strategically. Many countries have vast reserves of largely unexplored coal, which guarantees they will have supplies for another 200 or 300 years, but this generates high levels of pollution. The R/P relationship of oil is much less, of the order of a few decades, leading many countries to look for and develop other energy options.

It is no coincidence that North America is interested in helping African countries, or in building a gas pipeline from Peru to the USA. But even with all these efforts reserves of these fuels will be depleted. Until this happens they will continue polluting and aggravating social inequalities.

Figure 4



4. Today's challenges

In addition to the limits in available reserves of oil and gas, continuing with the current situation is not possible because of the environmental impact it causes, particularly that of climate changes, which are today the main threat to the very existence of the human race. These are caused by the increase in atmospheric concentrations of gases that cause an increase in the greenhouse effect: carbon dioxide (CO_2), methane (CH_4) and others.

These gases are generated principally by combustion, whether of fossil fuels or of renewable fuels. However, in the case of renewable fuels the carbon is reabsorbed by the photosynthesis process of new plants that replace stocks of biomass, thus completing at least part of the cycle and reducing total net emissions. The problem lies with energy that has a fossil origin: the carbon that has been deposited in the earth's crust during the ages is being launched into the atmosphere (almost immediately in geological terms) by post-Industrial Revolution processes and by the burning of forests.

The participation of developing countries (a little less than 30%) in the total of all emissions from burning fossil fuels has been growing rapidly over the last few years and should be the same as the developed countries by 2035, when in total nearly 12 billion tons of CO_2 a year will be launched into the atmosphere (today it is a little less than 7 billion) [2] Cutting down forests is also an important source to consider: something less than 2 billion tons of CO_2 per year are emitted and Brazil emits the most, with nearly 120 million tons of carbon equivalent a year, even though it has an energy matrix that is considerably "clean".

Table 2: Estimates of carbon emissions in 2000.

Country		(1) Deforestation (000s tons of carbon equivalent)	(2) Fuels (000s tons of carbon equivalent)	(3) =(1)+(2) Total (000s tons of carbon equivalent)
1	USA	-10,476	1,528,796	1,518,320
2	China	-27,542	761,586	734,045
3	Russia	-1,890	391,664	389,774
4	Japan	-66	323,281	323,215
5	India	-694	292,265	291,572
6	Germany	0	214,386	214,386
7	Brazil	120,645	83,930	204,575
8	United Kingdom	-323	154,979	154,656
9	México	8,519	115,713	124,232
10	Canada	0	118,957	118,957

(1) Estimate multiplying net deforestation by the amount of wood in the forests (data from UN FAO, 2004) and by 25% (i.e., 50% dry wood and 50% carbon).
(2) Gregg Marland et. al, 2004.

Climate changes are having an impact on a **global scale,** but because of the world's energy system there are other impacts to consider, like oil spills, the loss of biodiversity, acid rain and urban pollution.

At the **regional level,** the precursors of acid rain (SO_2, NO_x and others) generated by combustion processes may be precipitated thousands of kilometers from their point of origin, frequently crossing country borders. Rain and snow converts these oxides into acids (like sulfuric and nitric), directly affecting ecosystems, growing crops, historic buildings and other vulnerable receptors.

[2] Environmental Protection Agency (2004) http://www.epa.gov/reg3artd/images/warm.jpg

At the **local level**, emissions from the burning of fossil fuels, including those coming from the transport sector, are primarily responsible for urban pollution and consequently for hundreds of thousands of deaths from respiratory and cardiovascular problems and cancer[3]. Half the world's population lives in cities. At the beginning of the last century there were only 3 cities that had more than 1 million inhabitants, while today there are 281. Various metropolises have more than 10 million people living in them, and the conurbation of small cities also creates problem hotspots, because of particulate material (PM, principally the fine and ultrafine particles that penetrate the pulmonary bronchioles), sulfur dioxide and sulfates (SO_2 and SO_4^{--}), nitrogen oxides (NO and NO_2, the so-called NO_x), volatile organic compounds (VOCs, that include the hydrocarbonates – HCs), carbon monoxide (CO), low altitude ozone (O_3 tropospheric[4]) and other pollutants.

4. Energy and development

The way in which energy has been produced and consumed is incompatible with sustainable development, defined as *"development that meets the needs of the present without compromising the ability of future generations to meet their own needs"*[5].

Development has various focuses: economic, social and environmental are probably the most important. There is a direct relationship between economic development and energy consumption, but these parameters are not inseparably linked. This is a very important fact because it teaches us that there are alternatives ways for society to develop without a corresponding increase in energy consumption. In other words it is possible to separate economic growth form consumption.

UNO's Millennium Goals aim at guaranteeing environmental sustainability, by eradicating extreme hunger and poverty, achieving minimum primary education with equal opportunities for men and women, reducing child mortality, with a special emphasis on fighting AIDS and malaria, and improving the living conditions of those who live in slums and of other needy populations. They aim also to widen access to drinking water and to develop a global development partnership that includes international trade and financing systems that are non-discriminatory and that meet the special needs of developing countries, thereby alleviating their external debt situation, providing work for the young and access to medicine and new technology. To achieve all this a solution that involves a commitment between nations is needed.

The world's energy industry generates huge amounts of money. Every year US$ 40 to 60 billion are invested in energy infrastructure. US$ 1.5 trillion is spent on the direct purchase of energy. Much more than this is spent on consumption systems, like vehicles,

[3] Molina and Molina (2004)

[4] Do not confuse this with stratospheric ozone (O_3) that is formed by electrical discharge, is located 40 km up and filters the ultraviolet rays that come from the sun. the tropospheric layer is basically the iar we breathe and "urban" ozone (O_3) is a pollutant that is toxic for the respiratory system and is formed principally by the action of the sun's rays on the NOx and HCs.

[5] Bruntland Report. Committee for the Environment and Development, "Our Common Future" report.

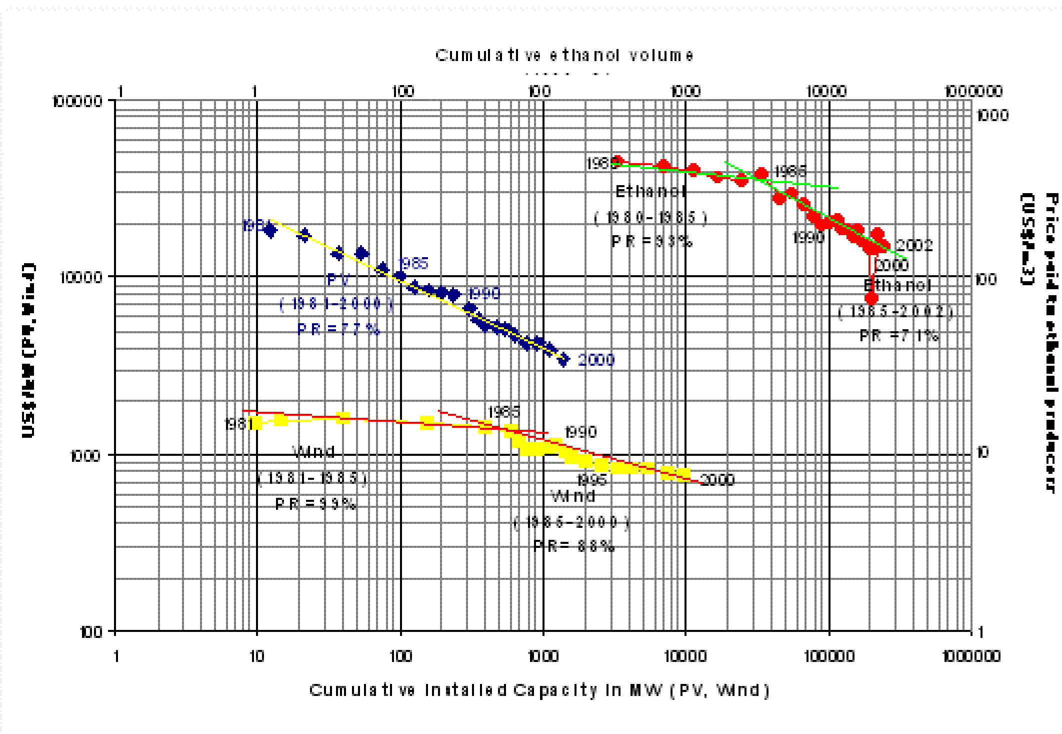
electro-domestic appliances and industrial and commercial machinery. Just a small redirection of these amounts could make all the difference for a sustainable future.

Renewable energy sources are the solution for development issues, because they are intrinsically durable, pollute less, generate jobs and reduce dependence on oil. Energy conservation (an increase in efficiency), whether that is fossil fuel or otherwise, means complementing the transition to a new development pattern that will prolong the useful life of existing reserves.

Something needs to change: while fossil energy received subsidies of the order of US$151 billion between 1995 and 1998, in the same period renewable sources received US$9 billion a year. To accelerate the growth of renewable sources it is necessary to: (1) overcome market resistance and eliminate subsidies to non-renewable sources (fossil and nuclear); (2) help the introduction of new technologies, thereby reducing their costs; (3) establish mandatory and progressive policies for their introduction; (4) make information about these technologies widely available so that developing countries can incorporate them faster without having to go through intermediate and more polluting stages.

This will serve to speed up even more the learning curves of “modern” renewable sources.

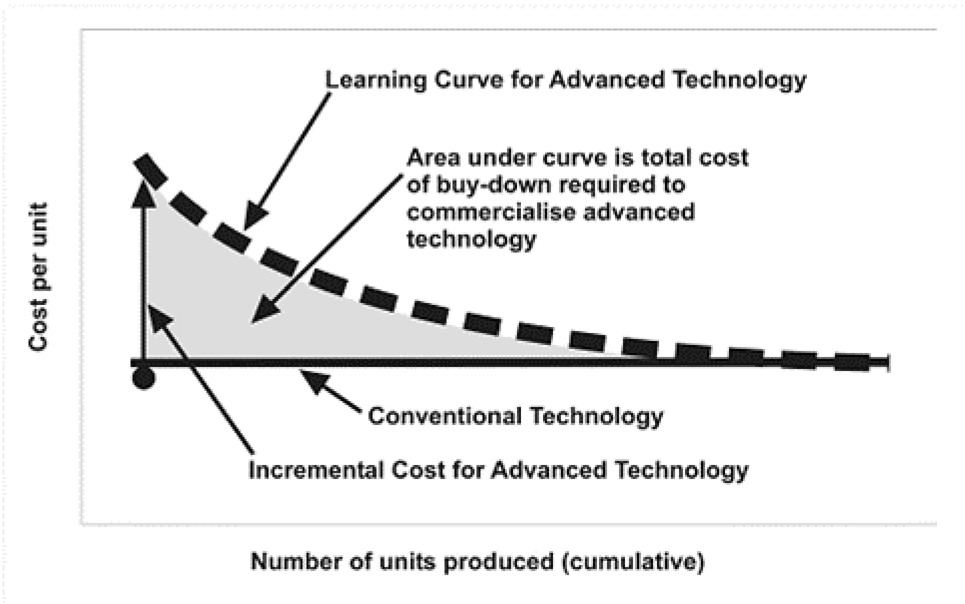
Figure 5: Learning curves of photovoltaic solar panels, wind turbines, ethanol and gas turbines for biomass[7].



Learning curves of photovoltaic solar panels, wind turbines, ethanol and gas turbines for biomass[6]

The learning curve concept is simple: the more you sell the less it costs. However, to sell more incentives or even policies that oblige the use of the technology are sometimes necessary.

Figure 6



5. The Brazilian example

Brazil proved that renewable sources of energy are viable, both with hydro-electricity as well as with its alcohol program. It started out on this path in the 1970s, when it created 'Proalcool' in order to face up to the oil crisis. Today, with an experience and leadership that is recognized worldwide in the fuel ethanol sector, the country is facing a strong increase in demand, both internally as well as externally. Today, we can buy a bi-fuel vehicle and choose at the filling station what to use based on economic, social and environmental criteria. We can create jobs and fight pollution when we fill up our tanks.

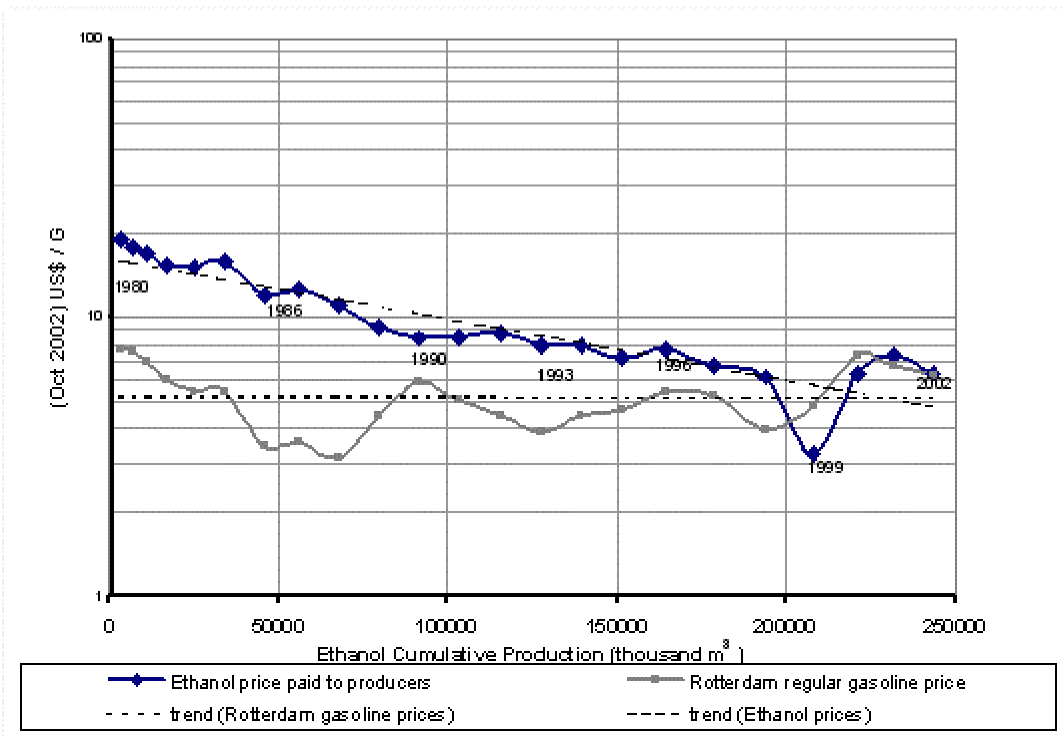
Because it can be produced in various countries (notably developing ones), because it has an extremely favorable energy performance (between 8 and 10 units of renewable energy obtained for every unit of fossil fuel applied) and because of the

[6] *UNDP, UNDESA and WEC, 2004*

freedom offered to the consumer by flex-fuel vehicles, sugar-cane ethanol is an excellent option in terms of biofuels. The production costs of Brazilian ethanol are lower than those of our competitors and at international prices cane alcohol is competitive even with gasoline. Furthermore, sugar cane ethanol is a reality on a commercial scale and not a technological promise, like cellulose alcohol.

With the Proalcool polices that obliged the addition of biofuel to gasoline, production grew, technology developed and today we have flex-fuel vehicles that give the consumer freedom of choice and a fuel that is competitive in international markets. Costs have reduced over time and made ethanol competitive with gasoline on the Rotterdam market.

Figure 7: International alcohol and gasoline prices[8].



Alcohol can be replicated all over the world. Approximately a hundred countries already produce sugar-cane and can produce ethanol for their consumption internally (substituting imports of oil and its derivatives) or externally (thereby obtaining export revenues), which provides them with local employment and better development options. Even countries that do not have fertile land and a climate that is favorable to sugar-cane growing (like Japan, for example), can direct their technological research towards producing and exporting capital goods for the ethanol industry. Furthermore, when flex-fuel vehicles are introduced on a large scale into their domestic markets, they reduce their dependence on oil, reduce their greenhouse gas emissions and help significantly when it comes to the bio-fuel learning curve.

Until 2030 transport will be the main sector causing the emission of greenhouse gases in the world. Taking into account that the changes needed in the energy and automobile industries may take several years to begin to happen we have no time to lose. Nature is not going to wait for us.

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Article received on 01.11.2006. Approved on 17.02.2007.