ENERGY, CLIMATE CHANGE AND THE OPPORTUNITY FOR LIQUID BIOFUELS

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Resumo

Este trabalho providencia um escopo geral da influência comprovada de ações antrópicas como as relacionadas à produção e uso de energia no meio ambiente. Como contraponto às perspectivas adversas relacionadas às mudanças químicas contínuas ocorridas no planeta, este trabalho apresenta oportunidades que podem garantir um desenvolvimento energético sustentável e em harmonia com o meio ambiente. Uma transição para um futuro mais correto e eficiente no uso final de energia é necessária a fim de reduzir os conflitos entre o desenvolvimento e o meio ambiente. Diferentes cenários que visam providenciar os caminhos ideais para um desenvolvimento futuro mais sustentável são apresentados. Algumas alternativas incluem uma eficiência energética melhorada, produção de energia renovável e desenvolvimento de tecnologias energéticas mais avançadas. Programas nacionais criados no Brasil como o do etanol e do biodiesel têm um impacto comprovado na busca de um futuro sustentável e devem ser mais intensos no futuro devido à ratificação do protocolo de Quioto.

Abstract

This paper provides an overview of the proven influence between anthropogenic actions such as those related with energy production and use on the natural environment. With the adverse perspectives of continued chemical changes occurring worldwide the paper also presents opportunities that can continue to ensure a more sustainable growth in harmony with the environment. A transition for a more efficient and environmentally correct final use of energy is needed in future in such a way as to diminish the conflicts between development and

environment. Different scenarios aiming to provide the ideal routes for development to occur addressing sustainability indicators are studied. Some typical options for a more sustainable future include improved energy efficiency, more renewable energy and advanced energy technologies. National programs undertaken in Brazil such as those of the ethanol and biodiesel have a proven impact in the search for a sustainable future worldwide and should be further emphasized in future by means of the ratification of the Kyoto Protocol.

1. Introduction

1.1. The Concept

It is known from chemistry that compounds occur in our natural environment. As a result of combined actions such as inner forces (volcanoes, earthquakes) and solar energy (including water and wind erosion) these compounds have been concentrated in geological areas, creating "reserves", such as fossil fuel reserves, for example petroleum, coal, methane hydrate, sand oil and natural gas.

In addition, nature has always maintained an equilibrium, although this balance has never actually rigorously existed, between incoming solar energy and the energy used by other forms of existing systems, including life.

However, modern anthropogenic action has been breaking this balance, even assuming that primitive humans were somehow part of the previous almost steady-state type of situation. Humans slowly started modifying their activities, controlling technologies, breaking the equilibrium and ending up by provoking an intensive use of natural resources and negative effects to the environment.

It can be seen, that modern man's actions have resulted in an intensive use of natural reserves (fossil fuels such as petroleum, coal, native forests, fertile land, fresh water and others) leading, chemically, to a series of highly irreversible processes with economic, environmental and thermodynamic significance and even ending up by affecting our quality of life.

1.2. The Greenhouse Effect Caused by the Combustion of Fossil Fuels

It would be impossible to speak of energy without taking in consideration that it has a dissolvable association with the environment. The exploration of natural resources for the production and use of energy originates in significant social, environmental and economic impacts. In the case of the exploration of renewable sources of energy (hydraulic, biomass, solar and wind and others) this occurs due to the extensive areas necessary for large-scale production of energy. Moreover, the improper use of alternative technology, even under normal conditions of operation, can hold considerable risks for human life and the environment.

The use of fossil fuels and other non-renewable sources of energy and power in large scale for the generation of energy and power in all sectors have also resulted in the emission of billions of tons of carbon to the global environment annually causing serious anomalies in the climate system, land, oceans, sources of water, ecological systems in general, and even in the chemistry of the atmosphere. These anomalies in the global environment can modify the capacity of the planet to sustain life (**NECCO, G., 2004**).

Even though, practically all types of energy generation bring unavoidable negative impacts to the environment, energy has become essential in modern society in such a way as to continue providing a means of growth and development and the realization of the continuing higher standards of living and economic well being of the population.

There needs to be, however, an increased awareness, towards a more effective form of resource exploration, in such a way as to ensure that energy production can be continued in greater harmony with the natural environment. Actions such as the use of primary power plants with minor or no impact for the environment (using more renewable[1] sources), the technological adequacy of current energy systems, and the development of modern and more efficient technologies can be achieved. In the current world socioeconomic context of development, the adoption of established energy strategies based in models of sustainable development is essential. It can also be mentioned, that a cultural change in the way in which energy is

[1] Actually the term "renewable" is incorrect. No form of energy is renewable.

consumed, looking to provide only for basic necessities and a more intelligent, rational and responsible use of energy, would also contribute to this goal.

2. The Context: energy and climate change

There is a significant proved influence of the present production and consumption structures of energy on the world climate change (**JANNUZZI, 2004**). The use of energy, by itself, is responsible for more than two thirds of the greenhouse gases emissions-GHG and accounts for about half of all the projects currently approved by the Kyoto Protocol carbon market flexibility mechanisms.

Atmospheric pollution is associated mainly with the combustion of coal and other petroleum derived fuels including natural gas. The aspects and impacts generated by the burning of gasoline and diesel may be seen in Table 1. These fuels presently feed large sectors of the world economy, including the generation of electricity, industrial production, and transportation, totalling around 90% of commercial energy utilized in the world today.

Table 1 - Aspects and Impacts from Energy Generation and Use from the Oil By-products (gasoline, oil-fuel, diesel, etc.) (**E,A&D, 2001**)

Aspect	Impact	Type	Category
Emissions of SO_2	Acid rain	Negative	Regional
Emissions of CO	intoxication	Negative	Local
Emissions of CO_2	Green House Effect-GHE	Negative	Global
Emissions of NOx	Acid rain and O_3 formation	Negative	Regional and global
Emissions of particulate material	Not identified	-	Regional or Local
Emissions of hydrocarbons	O_3 formation	Negative	Global
Emission because of O_3 formation	Problems during development of the vegetables and GHE	Negative	Regional an global
Emissions of aldehydes	Cancer in animals	Negative	Regional

The main primary contributors for the natural greenhouse effect are water vapor with 60%, carbon dioxide with 25%, ozone with 8%, and traces of gases including methane and N_2O (% by volume). Also, clouds have some importance in the greenhouse effect (**KARL e TRENBERTH, 2003**).

The main source inducing to climate change is the change in composition of the atmosphere due to anthropogenic activities. These anomalies, in principle, result in emissions formed from the intensive use of fuels for energy use, mainly fossil and, in a more local and regional scale, due to the urbanization and intensive use of land. The main uncertainties related to climate change are due to the analysis of the rate in which it is really changing.

What appears to be more evident is that these forces will act more intensively in the future. The parameters most sensitive parameters to quantify for these changes are: temperature, precipitation, decrease in the ice cap, seasonal and perennial snow, sea level rise and others (**KARL e TRENBERTH, 2003**).

During the XX century occurred an accelerated increase in the concentration of greenhouse gases – GHG in the atmosphere, altering abruptly its chemical composition. Reported values suggest an increase of the order of more than 31% for the CO_2 gas since the pre-industrial age to the present time, passing from 280 ppmv to more than 370 ppmv (parts per million in volume), more than 100% for methane CH_4, 15% for N_2O, besides the not well defined quantities for the halocarbons.

Large scale direct anthropogenic impacts on the planet`s surface are also a result of changes in land use that occur due to urbanization and bad agricultural practices. Such impacts, even though they have a local coverage, they are more significant where people live and work. Large scale deforestation and desertification in some regions of the planet are two of the most significant influences for local climate changes and also global warming.

In **KARL e TRENBERTH** (**2003**) it can be seen, that the global average increase of temperature on the planet`s surface is mainly a consequence of global warming. The increase in surface temperature of 0.2^{o}C in the first half of the XX century is an indication of human influence (Figure 1). In the absence of climate mitigation measurements it has been statistically verified, with 90% probability, that the global increase of temperature in 110 years (from 1990 to 2100) will increase the planet surface average temperature by 4.9^{o}C, half of this value credited to uncertainties of future emissions, and the other half due to uncertainties of climatic mathematical model.

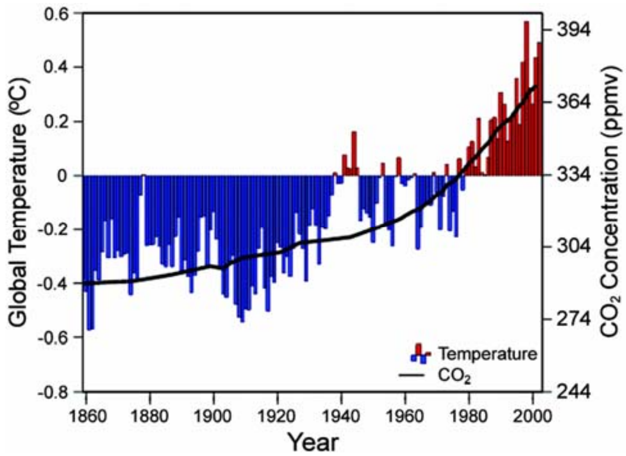

Figure 1 - Times series of departures from the 1961 to 1990 base period for an annual mean global temperature of 14^{o}C and for a carbon dioxide mean of 334 ppmv using data from ice cores and from Mauna Loa (**KARL e TRENBERTH, 2003**)

The implementation of programs that focus on supportive research and technological development are therefore necessary in the various aspects related to environment and climate change.

3. Energy and Socioeconomic: Brazil and World

Analyzing the main macro-economic indicators during the last 34 years we may affirm that Brazilian economy grew (there was an increase in the Gross Domestic Product-GDP), as a result of the expansion of the energy sector from the primary production, energy supply to the final consumption, and investments. During 2004 the domestic supply of energy grew 219% higher than in 1970, equivalent to 2% of the world demand or 213.4 MM toe. The final energy consumption increased to 191.1 MM toe.

Crude oil by-products presented just 2.3% of average growth in 2004. Ethanol and natural gas consumption increased 11.6% and 21.5% respectively, due to the expansion of the transportation and industrial sectors. The industrial sector participation responsibility increased about 36% during this period. The industrial sector consumption of energy based on biomass (firewood, charcoal, sugarcane bagasse and ethanol fuel and others renewable sources of energy) increased 8.4% during 2004.

Moreover, the Brazilian electric generation park grew from 11 GW in 1970 to 90.7 GW in 2004. The hydraulic installed capacity in 2004 was of 69 GW, 26.6% of the Brazilian total power. Brazil had Domestic Energy Supply-DES per capita of 1.2 toe in 2004. The world average was 1.65 toe/per capita in 2002. In terms of the DES related to the GDP, Brazil had in 2004 0.4 toe/10^3 US\$(1995). This indicator in the USA was in 2004 0.25 toe/10^3 US\$(1995) and 0.09 toe/10^3 US\$(1995) in Japan. Brazil's profile in terms of energy supply shows an evolution because the foreign dependency was reduced and there still is a significant use of renewable energy sources.

Figures 2 and 3 show models of production scenarios for primary energy in Brazil (base 2004) and in the world (base 2002). The environmental advantages of the Brazilian Energy Matrix in relation to the rest of the world can be observed with a participation of over 85 MM toe of the renewable primary energy production on 2004.

The structure of the matrix of production of electric energy in Brazil is based of almost 75% in hydraulic energy, in relation with only 17.1% in the world (**MME-BEN, 2003**).

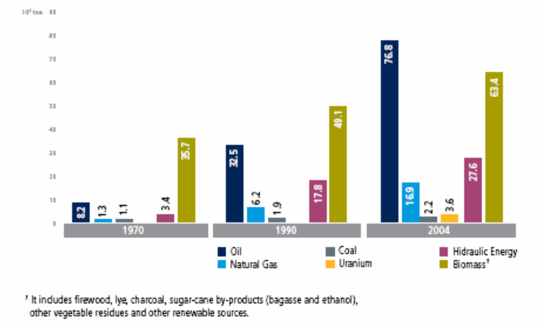

Figure 2 - Primary Energy Production – Data Evolution on the Primary Source Participation, Brazil 1970 to 2004 (**MME-BEN, 2005**)

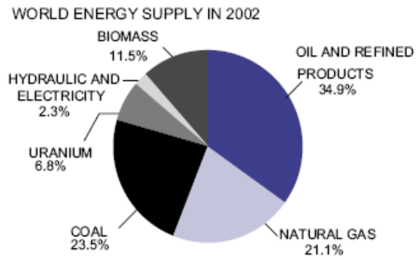

Figure 3 - Domestic energy supply in the world in 2002 (**MME-BEN, 2003**)

4. Emissions from the Energy System

The data of the CO_2 emissions for each sector of the economy in Brazil are shown in Table 2. The description of the CO_2 emissions by energy resource is shown in Table 3.

Table 2 - CO_2 emissions from fossil fuels by Brazilian economy sector (data of 1996 in millions of tons of carbon in the CO_2 form) (**EA&D, 2001**)

Sector	Emissions	Participation of total (%)
Farming	3,9	6
Industrial	21,4	34
Commercial	0,4	1
Public	0,4	1
Transport	31,2	49
Residential	5,3	8
Final consumption	62,7	100

Current GHG emissions due to the energy system in Brazil are considerably lower than those from land-use change. The figures presented here were calculated by Energy and Economics- NGO for the Ministry of Science and Technology – MCT (**ENERGY AND ECONOMICS – NGO, 2002** In: **LA ROVERE and ROMEIRO, 2003**)[2] following the IPCC guidelines adapted to Brazilian circumstances (**IPCC, 1996,** In: **LA ROVERE and ROMEIRO, 2003**).

[2] MCT is the coordinator of the Brazilian National Communication to the UNFCCC.

Table 3 - Data evolution of CO_2 Emissions in Brazil by Energy Source (in millions of tons of carbon) (**EA&D, 2001**)

Source	**1974**	**1980**	**1986**	**1990**	**1993**	**1996**
Gas	0,49	0,79	2,27	2,72	3,05	4,01
Oil	32,1	42,6	49,0	41,5	45,9	56,2
Coal	2,86	6,32	10,8	10,4	12,0	13,3
Total	35,44	49,66	52,11	54,60	61,0	73,5
GDP (US$)	367	546	621	635	659	749
Indicator (kgC/US$)	-	-0,94	-1,17	0,51	2,20	1,85

According to Tables 4 and **LA ROVERE and ROMEIRO** (**2003**), CO_2 emissions due to energy use were at a level between 33% and 66% of CO_2 emissions from deforestation in 2000. Emissions from the energy system are very low indeed with respect to population (0.527 tons of carbon per capita), but fairly high compared to economic activity (0.5231 kg of carbon per US$ of GDP), using data available of 2001.

Table 4 - Amazon Deforestation and CO_2 Emissions from Deforestation (**LA ROVERE and ROMEIRO, 2003**)

Period	Annual deforestation (thousand ha / year)	Annual emissions (million t C / year)	Annual emissions (million t CO_2 /year)
1978-1988	2,113	148 – 253	542 – 930
1989	1,786	125 – 214	458 – 785
1990	1,381	97 – 166	356 – 609
1991	1,113	78 – 134	286 – 491
1992	1,379	97 – 165	356 – 605
1993-1994	1,490	104 – 179	381 – 656
1995	2,906	203 – 349	744 – 1,280
1996	1,816	127 – 218	466 – 799
1997	1,323	93 – 159	341 – 583
1998	1,738	122 – 209	447 – 766
1999	1,749	123 – 210	448 – 769
2000	1,846	129 – 222	473 – 812

Source: own estimates based upon INPE (2000) data for deforested area and on biomass densities ranging from 70 to 120 t C / ha; they include all the area where forest removal occurred (and not only where the forest was burnt) but do not account for the carbon content losses in the topsoil.

The main indicators of emissions in Brazil in 2004 are shown in the Table 5.

Table 5 - Main Indicators of Emissions – Data Evolution on Carbon Dioxide (CO_2) Emissions, Brazil (reference 2004). Selected Countries and the World (reference 2002) (**MME, 2005**)

Specifications	Brazil	USA	Japan	Latin America	World
t CO_2 / inhab.	1.77	19.66	9.47	1.98	3.89
t CO_2 / toe Domestic Energy Supply	1.62	2.47	2.33	1.9	2.32
t CO_2 / 10^3 US$ of GDP[1]	0.27	0.6	0.4	0.3	0.6
t CO_2 / km^2 of surface	36.3	614.9	3,197.8	46	119.3

[1] US$ official rates during 1995.

5. Projections of development and emissions scenarios in the world

In a study carried through for the IIASA - International Institute for Applied System Analysis (**NAKICENOVIC, 2002**), some scenarios of development aiming at itself to evaluate several routes for sustainability were evaluated. The considered scenarios have been: scenario A that considers the maintenance of the current situation, scenario B characteristic of an average scenario, and a scenario C characteristic of an ecologically correct scenario. The established sustainable development indicators are summarized in Table 6 below.
In Figure 4, some projections for the world-wide population can be seen until the year of 2100. One can expect, that these projections are in agreeance with those carried through for the IIASA (**NAKICENOVIC, 2002**), an average growth of the world-wide population of something around 4 billion people until the end of the XXI century. All these people will need adequate services of energy. A transition for efficient and environmentally correct final use of the energy can diminish the possible conflicts between the development and the protection to the environment.

Table 6 - Sustainable development indicators (**NAKICENOVIC, 2002**)

Elements of sustainability	1990	Scenario A	Scenario B	Scenario C
Eradicating poverty	Low	Very High	Medium	Very High
Reducing relative income gaps	Low	High	Medium	Very High
Providing universal access to energy	Low	Very High	High	Very High
Increasing affordability of energy	Low	High	Medium	Very High
Reducing adverse health impacts	Medium	Very High	High	Very High
Reducing air pollution	Medium	Very high	High	Very High
Burden of long-lived radionuclides	Low	Very High	Very high	Low
Limiting GHG emissions	Low	High	Low	Very High
Diversifying primary energy sources	Medium	Medium	High	Low
Raising indigenous energy use	Medium	High	Low	Very High
Improving supply efficiency	Medium	High	Low	High
Increasing end-use efficiency	Low	High	Medium	Very High
Accelerating technology diffusion	Low	Very High	Medium	High
Freedom of international energy trade	Medium	Very High	High	Low

The projection of the world energy consumption until the year of 2100 is shown in Figure 5 below. Scenario C reveals to be very attractive from the environmental and energetic point of view for showing to be a scenario of low energy consumption and, probably, of high energy efficiency for the adoption of advanced technologies.

Figure 6 shows the projection of the primary energy supply from several sources worldwide. It can be observed that there is a reduction in the use of the fossil energy sources and an increase in the participation of some traditional renewable sources. Figure 7 shows the projections of the CO_2 emissions for the same scenarios considered in the study. It is observed that scenario C is the most promising in environmental terms (co-relates the characteristics of these scenarios for Table 6).

Figure 8 shows the published results of the variations in the temperature of the surface of the planet. Data is reconstructed and projections made up to 2100. Each considered scenario offers a result of foreseen increase of the temperature for the year of 2100.

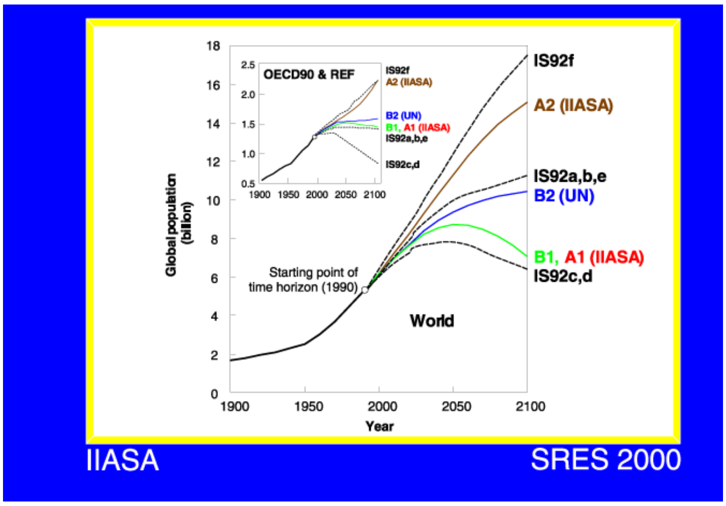

Figure 4 - Global population projections (**NAKICENOVIC, 2002**)

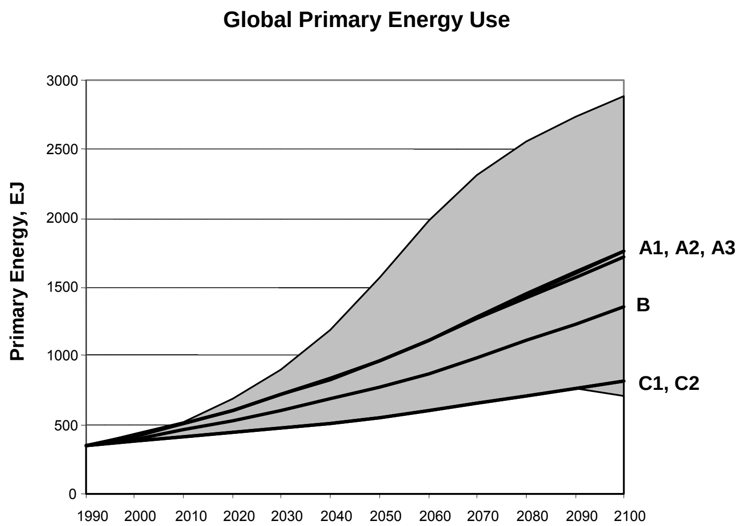

Figure 5 - Global Primary Energy Consumption Projections (**NAKICENOVIC, 2002**)

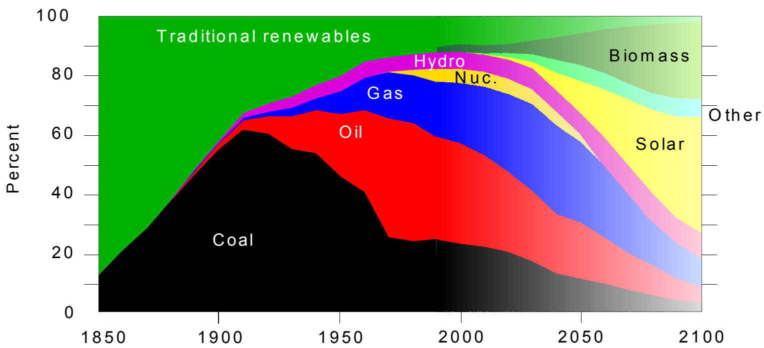

Figure 6 - Global Primary Energy Supply Projection (**NAKICENOVIC, 2002**)

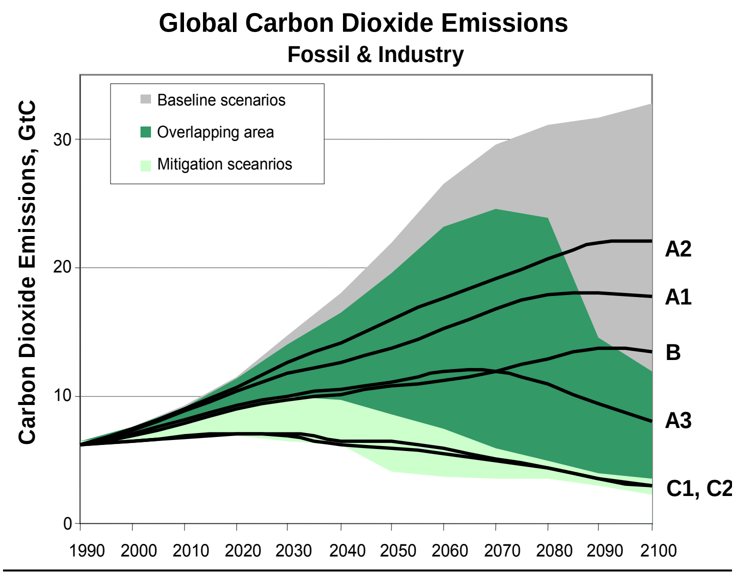

Figure 7 - Carbon Dioxide Emissions Projection (**NAKICENOVIC, 2002**)

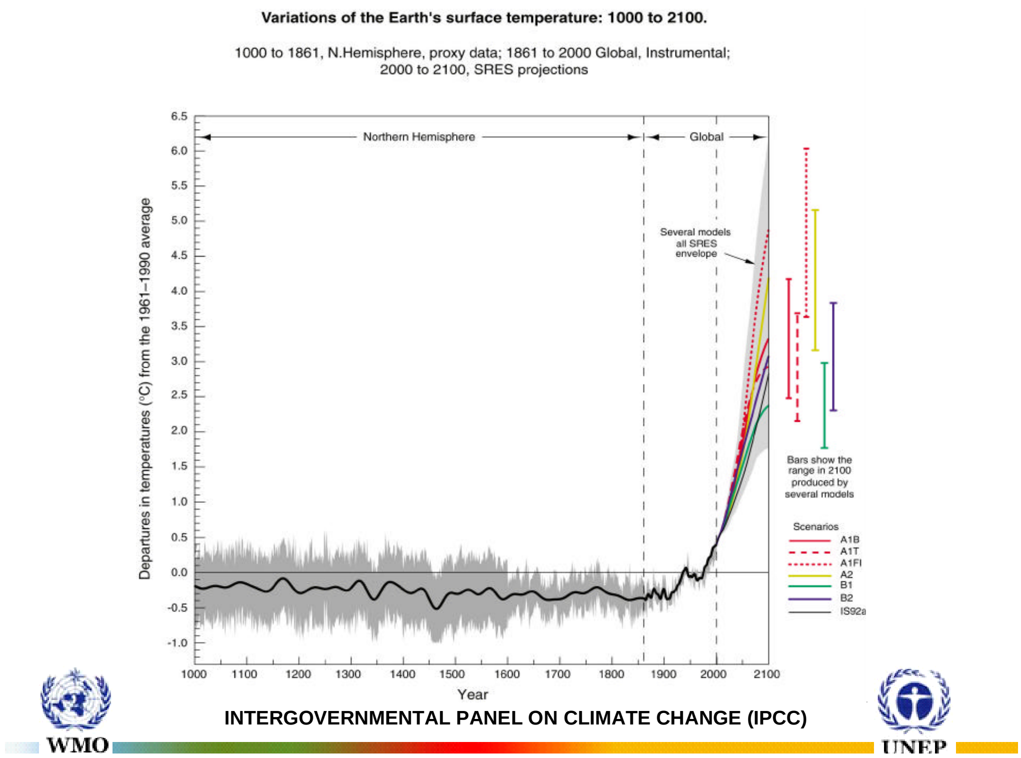

Figure 8 - Variations of the Earth's surface temperature – from 1000 to 2100 projection (**NAKICENOVIC, 2002**)

The main dimensions involved on the energy sustainable future are related below:

- **Energy Resources and Reserves:**
  1. Conventional oil and gas could last at least 50 – 100 years
  2. Total fossil fuel resources will last at least several hundreds of years
  3. Renewable energy flows are some 1000 times current global energy use

- **<u>Technological options for a sustainable future:</u>**
  1. **Improved Energy Efficiency** - especially at the point of end-use in buildings, electric appliances, vehicles, and production processes.
  2. **More Renewable Energy**: such as biomass, wind, solar, hydro, and geothermal
  3. **Advanced Energy Technologies**:
     - next generation fossil fuel technologies
     - nuclear technologies, if the issues associated with nuclear can be solved.

- **<u>Investments in Energy Supply:</u>**
  1. Mobilization of capital for energy supply investments;
  2. Investment in energy supply projected at US$ 300 - 500 billion per year for the next 20 years depending on path chosen;
  3. Less than 10% of total overall investments

- **<u>The Innovation Chain</u>**
  1. Research and Development
  2. Demonstration projects
  3. Early deployment (cost buy-down)
  4. Widespread dissemination

- **<u>Increasing Capacity:</u>**
  1. Policy support and institution building
  2. Education and training
  3. Technological leap- Investment-friendly environments those are socially and environmentally responsible
  4. Frogging
  5. Consumer credits, micro-finance

6. Brazilian Efforts leading to GHG Emissions Mitigation as a Co-Benefit

6.1. The Ethanol Program (**LA ROVERE and ROMEIRO, 2003**)

Since it was first launched in 1975, the Brazilian Ethanol Program remains to date the largest commercial application of biomass for energy production and use in the world. It succeeded in demonstrating the technical feasibility of large-scale ethanol production from sugarcane and its use to fuel car engines. Since 1979, 5.4 million ethanol powered cars have been manufactured in Brazil. In 1998, ethanol powered cars consumed 7.6 Gl (billion liters) of ethanol per year and 5.3 Gl of ethanol were used for the production of gasohol (a blend of 22 % to 24% ethanol with 78 % to 76% gasoline) for the remaining cars in the country.
The net amount of GHG emissions avoided by sugarcane ethanol and bagasse in Brazil has been well evaluated by **MACEDO (1997)**. The carbon released into the atmosphere when bagasse and ethanol are consumed for fuel is compensated for by an equivalent quantity of carbon which is sequestered or absorbed by the sugarcane biomass during it life. This author gives the results summarized in Table 7, using 1990-91 as a base year. This total of 9.45 MtC for the year 1990-91 corresponds to 10 % of the total emissions of carbon due to energy consumption in Brazil in 1990. Accounting only for the substitution of gasoline, the use of ethanol has avoided the release into the atmosphere of an average of 5.86 MtC per year from 1980 to 1990.

Accordingly, the future expansion of the Ethanol Program could be ensured through an adequate flow of foreign investment, considering its global environmental benefits, in the framework of the Clean Development Mechanism approved at the Kyoto COP meeting in December 1997. Naturally, meeting the additionality criterion required for CDM eligibility will depend upon the baseline levels of sugar cane availability in the country as well as its use either for ethanol or sugar production.

Table 7 - Brazil Net CO_2 Emissions Due to Sugarcane Production and Use, 1990-91 (**MACEDO 1997**)

	MtC/year
Ethanol Substitution for Gasoline *	- 7.41
Bagasse Substitution for Fuel Oil burning as Heat Source in Other Industries	- 3.24
Fossil Fuel Utilization in Sugarcane Industry	+ 1.20
Net Contribution (Uptake)	- 9.45

Notes: * includes both the blending of 22 % ethanol in gasoline and 4.2 million pure ethanol-fired cars

6.2. The Biodiesel Program

Biodiesel fuels are methyl or ethyl esters derived from a broad variety of renewable sources such as vegetable oil (soy, canola, rape seed), animal fat and cooking oil. This is certainly the case in Brazil, where biodiesel could be produced from a large variety of fatty materials such as soybeans, sunflower, colza, peanuts, corn, olives, cotton and sesame seeds, castor oil, jojoba, linseed, palm oil, palmiste and babaçu **(RAMOS, L, 2004)**.

In Brazil, a national program was launched in 2002 to evaluate the technical, economic, and environmental competitiveness of biodiesel in relation to the commercially available diesel oil.

Lately, biodiesel has received increased attention because of its potential to reduce emissions, particularly greenhouse gas (GHG) emissions. Since it is a renewable fuel that can be produced from plant and animal sources, an opportunity also exists to reduce GHG emissions when compared to nonrenewable petroleum diesel.

The fuel consumption of biodiesel per kilometer traveled is similar to that of diesel when biodiesel is used as a diesel blend. Biodiesel has a lower energy content than diesel. Thus there is increased fuel consumption when pure biodiesel is used **(IEA, 2004).** Biodiesel has 90.6% of the energy contained in diesel fuel (l/l).

The main benefit of biodiesel is the reduced GHG emissions over the life cycle of the fuel. The studies have shown that the emissions in the biodiesel life cycle are lower due to the fossil fuel energy demand required in the production of biodiesel, relative to petroleum based diesel. There is, however, more significant N_2O emission effects associated with agricultural practices used in crop production. The value of by-products formed from biodiesel production is also an issue in conducting an LCA.

A number of biodiesel life cycle studies have been conducted internationally using various crop sources. The LCA study represents the detailed analysis of GHG emissions for biodiesel. This study examines different feedstock at three blends B2, B20 and B100 **(BIOCAP – CANADA, 2003).**

Biodiesel 2% (Blend B2)

The B2 blend is of interest primarily because of its engine lubricating properties and as a result of the lower sulphur content in petroleum diesel (Table 8).

Table 8 - B2 GHG Lifecycle*

	Diesel Fuel	Biodiesel	Biodiesel	Biodiesel
		Canola	Soy oil	Animal Fat
	g/km	g/km	g/km	g/km
Total (full lifecycle)	1,436.3	1,419.1	1,419.1	1,410.4
% changes from diesel	--	-1.2	-1.2	-1.8

*Levelton / NRCan LevNRCan Study (2003) - The LevNRCan study is currently in a draft study phase, but represents the most detailed assessment and analysis of biodiesel on an emissions lifecycle basis in Canada.

Biodiesel 20% Blend (B20)

The B20 blend is the most popular for vehicle use and has been the test fuel from many demonstration projects. It is also being used on a regular basis in fleets throughout the U.S. and Europe (Table 9).

Table 9 – B20 GHG Lifecycle*

	Diesel Fuel	Biodiesel	Biodiesel	Biodiesel
		Canola	Soy oil	Animal Fat
	g/km	g/km	g/km	g/km
Total (full lifecycle)	1,436.3	1,258.2	1,259.6	1,180.6
% changes from diesel	--	-12.4	-12,3	-17,8

*Levelton / NRCan LevNRCan Study (2003) - The LevNRCan study is currently in a draft study phase, but represents the most detailed assessment and analysis of biodiesel on an emissions lifecycle basis in Canada.

<u>Biodiesel 100% Blend (B100)</u>

The 100% biodiesel fuel can be used in engines directly, usually without the need for modifications. This “neat” fuel use maximizes the environmental advantages but raises questions about engine manufactures acceptance (with respect to warranty) and cold weather properties (Table 10).

Table 10 - B100 GHG Lifecycle*

	Diesel Fuel	Biodiesel	Biodiesel	Biodiesel
		Canola	Soy oil	Animal Fat
	g/km	g/km	g/km	g/km
Total (full lifecycle)	1,436.3	521.4	530	119.2
% changes from diesel	--	-63.7	-63,1	-91,7

*Levelton / NRCan LevNRCan Study (2003) - The LevNRCan study is currently in a draft study phase, but represents the most detailed assessment and analysis of biodiesel on an emissions lifecycle basis in Canada.

The following reporter analyzed some feedstock for biodiesel from life cycle emissions and shows the analysis of the emissions avoided with the different mixtures of biodiesel (Table 11).

Table 11 - Total Life Cycles Emissions (per MJ) calculated for biodiesel*

Full Life cycle	Units	Canola biodiesel	Soybean biodiesel	Rape biodiesel	Tallow biodiesel	Tallow alternative allocation	Waste cooking oil biodiesel	Waste cooking oil alternative allocation	Uncertainty (%)
Greenhouse	kg CO_2	0.0433	0.0326	0.0443	*0.0420*	*0.0498*	*0.0062*	*0.0065*	15
NMHC total	g HC	0.145	0.172	0.146	*0.142*	*0.060*	*0.053*	*0.054*	43
NMHC urban	g HC	0.134	0.163	0.134	*0.131*	*0.059*	*0.052*	*0.053*	43
NO_x total	g NO_x	1.296	1.283	1.314	*1.292*	*1.184*	*1.179*	*1.184*	30
NO_x urban	g NO_x	1.219	1.235	1.221	*1.217*	*1.184*	*1.179*	*1.183*	30
CO total	g CO	0.171	0.219	0.172	*0.170*	*0.141*	*0.140*	*0.145*	72
CO urban	g CO	0.155	0.210	0.156	*0.155*	*0.141*	*0.140*	*0.144*	72
PM10 total	mg PM10	29.9	29.4	30.5	*29.8*	*27.6*	*27.5*	*27.5*	71
PM10 urban	mg PM10	28.4	28.5	28.4	*28.4*	*27.6*	*27.5*	*27.5*	71
Energy Embodied	MJ LHV	0.42	0.45	0.43	*0.41*	*0.17*	*0.14*	*0.15*	

*CSIRO (BEER et al., 2000 and 2001) - Commonwealth Scientific and Industrial Research Organization (CSIRO) GHG Lifecycle – Australia (2000) The Australian CSIRO Study is an extensive, internationally recognized study focusing on lifecycle emissions analysis of several alternative fuels including biodiesel.

8. Conclusions

The anthropogenic agents, in particular fossil fuel energy use, will have an important roll in the climate change in the next centuries. Human development, technological changes, population growth and the production and consumption of energy will affect future emissions.

It is very important to point out the importance of promoting research of highly competitive technologies through programs that search for financing in areas such as:

a) More efficient generation of electricity and heat, such as cogeneration for thermal power plants;

b) More investments in specific programs of liquid bio-fuels for the transport, systems highly dependent on “energy-agriculture-environment”;

c) Incentive to the use of more renewable sources and to the implementation of projects and enterprises in distributed energy generation, energy efficiency and energy conservation.

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