The Winners of the Blue Planet Prize

2008

Dr. Claude Lorius (France)

Professor José Goldemberg (Brazil)

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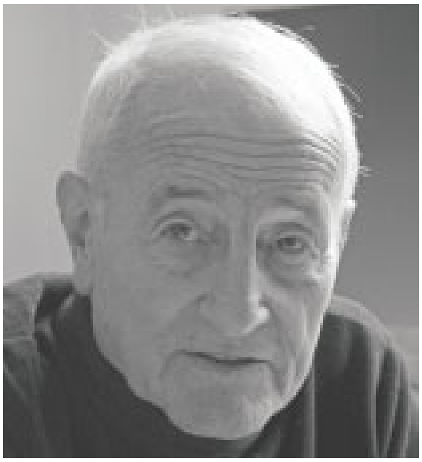
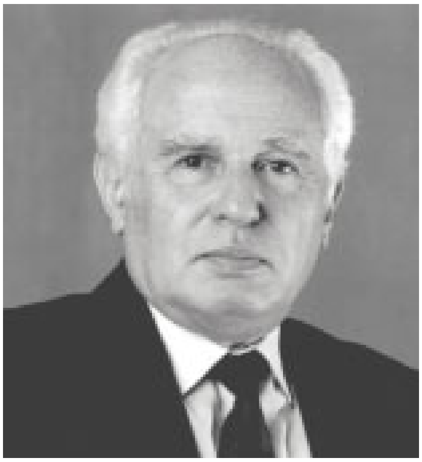
(France)
Director Emeritus of Research, CNRS
Member of the French Academy of Sciences

Professor José Goldemberg
(Brazil)
Professor, Institute of Electrotechnics and Energy, University of São Paulo
Former Rector, University of São Paulo





NAVIGATION:
Our Planet
The Blue Planet where all of us live
Carrying life in infinite numbers
Journeying towards the eternal universe

Do we mankind impose ourselves
To deeply think
Of the blue spaceship of life
Where it is going?
Given life on this planet

A tiny life
Although tiny, are we been responsible?
To care for others
Helping each other
For the destination
Of the "Ship of Life" Earth

We sincerely hope
That the film
Helps you
In letting you think
Of the wake of the "Ship of Life" Earth
Of the destination of the Blue Planet

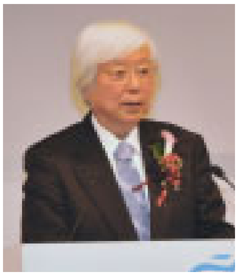
Selected from the Slide Show Presented at the Opening of the Awards Ceremony

His Imperial Highness Prince Akishino congratulates the laureates

Their Imperial Highnesses Prince and Princess Akishino at the Awards Ceremony

Hiromichi Seya, Chairman of the Foundation delivers the opening address

Dr. Jiro Kondo, Chairman of the Presentation Committee makes a toast at the Congratulatory Party



Dr. Hiroyuki Yoshikawa, Chairman of the Selection Committee explains the rationale for the determination of the year's winners

Ambassador Mr. Philippe Faure of the French Republic (left) and Ambassador Mr. Luiz Augusto Castro Neves of the Federative Republic of Brazil, congratulate the laureates

The prizewinners receive their trophies from Chairman Seya

Dr. Claude Lorius

Professor José Goldemberg

Profile

Dr. Claude Lorius

Director Emeritus of Research, CNRS
Member of the French Academy of Sciences

Education and Academic and Professional Activities

1932	Born in Besançon, France
1955	Researcher, Antarctic Committee, National Center for Scientific Research
1957-1958	Participated in the IGY Antarctic Expedition
1961	Researcher, CNRS
1962	Earned doctorate degree from the Sorbonne University
1979-1983	Associate Director, Laboratory of Glaciology and Geophysics of the Environment (LGGE)
1983-1988	Director, LGGE
1984-1986	Chairman, French Polar Expeditions
1986-1990	Chairman, Scientific Committee on Antarctic Research (ICSU)
1987-1994	Corresponding member, French Academy of Sciences
1989	Humbold Prize
1989	Belgica Medal
1992-1998	President, French Institute of Polar Research and Technology
1993-1995	Chairman of EPICA Project
1994-	Member, French Academy of Sciences
1994	Italgas Prize
1996	Tyler Prize for Environmental Achievement
1997	Seligman Crystal (International Glaciological Society)
1998-	Director Emeritus of Research, CNRS
2001	Balzan Prize for climatology
2002	The CNRS Medaille d'Or
2004	Petit Larousse illustré
2006	EGU Vladimir Ivanovich Vernadsky Medal
2008	SCAR medal

(As of June, 2008)

Dr. Lorius was born in Besançon, France in 1932 and received his bachelor's degree in physics in 1953. He began his research career in glaciology and climate change where he later accomplished many outstanding achievements by applying to an ad posted on the walls of the University of Besançon in 1955 which read "Needed: young researchers to join scientific expeditions organized in conjunction with the International Geophysical Year."

In 1957, as a fresh initiate in the emerging science of glaciology, he spent the winter at

Charcot Station, a small base camp perched in Antarctica at 2,400 meters elevation with two colleagues. He returned to Antarctica in 1959, joining the US Victoria Land Traverse Exploration and came up with an idea of obtaining the temperature of the air from the measurement of the oxygen and hydrogen isotopes of ‘solid water’ ice. Furthering the idea provided means of characterizing the successive seasonal layers of ice and an ice flow tracer, which enabled him to reconstitute past climate change and dating.

Afterwards, while leading the 1965 wintering-over team to the coastal base at Adelie Land, making casual observation of ice cubes melt in a glass of whisky and seeing the air bubbles trapped in the ice burst, Dr. Lorius came up with an idea of analyzing them. He thought that they would hold vital information of the composition of the air. After 1968, he proposed original ideas such as that to use crystal size in the field as an indicator of past climate change, and the information obtained from analyzing the ice sheets disclosed not only the climate but also information on the atmospheric environment.

Since 1974, Dr. Lorius began the hard work lasting several years at Dome Concorde, a high plateau located in central Antarctica, and in 1978 succeeded in drilling to a depth of 900 meters. By analyzing the ice sheet core, it was revealed that the bottom ice was to be about 35,000 years old, that the end of the last ice age was about 20,000 years ago and that the subsequent warm period had now lasted for 10,000 years.

In order to further conduct an analysis, there was a need to obtain older ice samples, and fortunately at the most remote and coldest station on earth Vostok of USSR, another series of core samples obtained by drilling 2,200 meters deep existed. Lucky for Dr. Lorius and his two companions, with the support from the Arctic and Antarctic Institute of Leningrad, the Geographic Institute of Moscow, and the National Science Foundation (USA), they were able to set foot on Vostok station in the midst of the cold war in 1984. Information obtained from the ice core were more than expected and for the first time a series of results undisturbed by any ice flow for over 150,000 years included all the last climatic cycle which took place in the quaternary era. Once back in France, Dr. Lorius gathered a squad of specialists and conducted a thorough study on the samples he brought back. As a result, it was disclosed that a long ice age occurred between the current interglacial period and the interglacial that existed about 120,000 years ago. The close correlation between atmospheric concentration of methane and carbon dioxide and climatic change during glacial and interglacial periods became a hot topic and the results were introduced in the editorial and other articles in *Nature* in 1987, also decorating the cover of the journal.

In 1989, Dr. Lorius was requested to reorganize polar research and established the French Institute of Polar Research and Technology (IFRTP) becoming the first president in 1992. While continuing his own research activities, he put efforts in planning Antarctic ice sheet deep drilling program at the international level.

In 1998, the joint team of Russia-France-USA reached at Vostok the depth of 3,623 meters and obtained a continuous ice sheet record for the past 420,000 years. Dr. Lorius recognized that there were four long cold and relatively shorter warm periods, namely glacial and interglacial periods, along this time scale and disclosed that during those periods atmospheric concentration of carbon dioxide fluctuated between minimum 200ppm (parts per million) and maximum 300ppm; during the last deglaciation carbon dioxide concentration increased by 40% and methane gas level doubled. Current atmospheric concentration of carbon dioxide has now reached almost 390 ppm and is increasing further. Dr. Lorius describes that the results obtained from the research on past glacial records gives credit to those arguments that the earth will continue to warm up through the 21st century and might potentially cause a disastrous effect on water supply, agriculture, health, biodiversity and human living conditions in general.

Dr. Lorius has made a total of 22 summer and winter expeditions to the polar ice sheets in Greenland and particularly in Antarctica, which represents more than six years spent in the Polar Regions. As operations in Antarctica, ice core analysis and interpretation require a lot of people's cooperation and participation, various achievements accomplished could be said to be those of the group he led, but without Dr. Lorius's highly prominent perspective, tenacity and organizational skill in forming international teams as a researcher, such research results could not be achieved so early.

From ice core studies, Dr Lorius believes we now entered in a new era, the "anthropocene", in which humans control the environment of our planet which is now a major and urgent international challenge. He has stated that although alarm raised was heard in case of the ozone layer depletion and some improvement had been noted, for the issue on climate only statements of intention had been heard so far, and that we have to maintain the pressure to ensure new technologies are developed and human attitudes continue to evolve.

Lecture

Climate and Environment
– 50 years of Adventures and Research in Antarctica –

Dr. Claude Lorius

50 years of adventures and research in Antarctica
Fifty years ago, I was first attracted by the human experience in the polar ice areas. My passion for research would come when we made our first discoveries, while exploring the mysteries of ice. Thanks to ice drillings, we aimed at going back in the past so as to discover the climate and environment of old times; a research that led us to the heart of one of the greatest challenges in our modern society. I would like to share with you this path on the field and in our research. I hope I could show you that polar ice are both survivors and guards of the earth climate and environment.

Based on missions, works and thoughts about polar ice, this presentation is three-fold:
Climate: past and future
Global Environment Mankind and Anthropocene
We will thus discover the Anthropocene epoch, a new era in which Mankind is responsible for damaging its own environment.

Slide 1* - The white planet: from pole to pole
Snow and ice spread over huge surfaces. In the Arctic, the pack ice is thin and formed by frozen sea water. It spans over 15 million square kilometres in winter and stays until summer as it is surrounded by a continental belt. However, the ice pack almost totally disappears during the hot season in the widely opened austral ocean. In both poles, huge ice sheets lay on bedrock: Greenland (over 2 million square kilometres) and Antarctica (its surface area is 12.3 million square kilometres which is bigger than Europe and about 30 times that of Japan). While the melting of the ice pack doesn't change the sea level, it is not the case with ice sheets: they contain such great volumes of ice that they would cause a sea level rise of more than 70 metres if they disappear.

Slide 2 - Polar ice "archives"
Ice sheets shelter unique archives, or records, on the history of our climate and atmosphere. Ice is solid water (H_2O) and contains isotopes. Isotope concentration in ice indicates the temperature at the time of ice formation. While filtering it, we collect the minuscule dust which has settled with snow. The dust can have natural origins (continental dust, sea salts, volcanic eruptions...) or can be linked to pollution (lead, radioactive wastes...) and thus measuring its magnitude becomes possible. Concentration of impurities is very low and requires sophisticated equipments for chemical measurements. If other types of archives do

* There are supplement slides *at the back of* the section.

exist on climate and pollution, ice holds a unique treasure with the air bubbles trapped in it: they are the only testimony of the atmosphere composition.

To date the ice, the easiest way is to count the annual layers, but this method quickly reaches its limits. Some events such as nuclear tests and volcanic eruptions can identify certain levels. To go further glaciologists have developed models that can wedge in comparison with better dated marine sediments or from the calendar of astronomers who punctuate climatic variations. Just recently glaciologists were able to detect on EPICA (European Project for Ice Coring in Antarctica) ice cores traces of the reversal of the magnetic field that occurred 780,000 years ago; a godsend to re-schedule the archives.

Slide 3 - Antarctica: 50 years of ice drilling
After the IGY (International Geophysical Year, 1957-58), glaciologists have carried out deep coring across Antarctica: the Americans (Byrd), the French and Europeans (Dome C), the Russians (Vostok) and the Japanese (Dome F). All along the years, as the ice drillings went on, more and more ancient periods began to emerge; core samples of only 10 centimetres in diameter will be our memory from the past.
Mechanical properties of ice and low temperatures require glaciologists to develop a specific technology to get ice cores. This is a complex, delicate craft and which needs constant attention. Engine, pumps, electronics are integrated into a drill suspended on a cable guided from the surface to get samples a few metres long. In it's slow getting down and up in a fluid that will avoid the closure of the hole it will know many failures and sometimes break down.

Slide 4 - Eastern Antarctica: 50 years of missions
Cold sites, with slight slow accumulation and undisturbed ice flow, contain long-term archives but they are situated in central areas hard to reach. Thanks to the logistic support mostly provided by the Americans and Russians, for French and Europeans these areas became reachable. In a white desert spreading over 5 million square kilometres, we used ski-equipped planes and tracked snow tractors to lead the survey. Then, we carried out the ice drillings with heavy means and larger teams were organized. To lead such projects, international collaboration, also based on friendship, was necessary to help us with providing heavy transportation equipment.

1956: Towards《Terra Incognita》
For the IGY, 12 countries, among which were Japan and France, combined their efforts to study the last continent almost entirely virgin: Antarctica. They set up 48 stations, among which 4 were on the ice sheet. The aim was to study the magnetic field and polar lights while the first satellites were launched into space; climatology, glaciology, a new branch of science, and exploration traverses were also planned.

1957: Overwintering at Charcot station
I spent one year with two workmates in a small station of 25 square metre, buried beneath the snow at an elevation of 2,400 metres, where the average temperature is -40°C. At that time,

Charcot was then one of the few inland stations that had ever been set up.

1957: Overwintering at Charcot station
On the horizon, nothing but a white desert and for months we would not have any ways of communicating with the coastal station and our far away families. My research concerned the “heat balance”, so as to understand why Antarctica is such a cold continent. This overwintering was a beautiful adventure, a physical and a human experience. After adapting myself again to civilization and to viruses contained in our atmosphere, I knew that I would come back.

1959: Victoria Land Traverse
After a year spent in France, I went back to the great South to take part in an American exploration traverse on Victoria Land, east of Adelie Land. Flying from New Zealand, we arrived on October 19th, 1959 at Mac Murdo, overlooked by Mount Erebus volcano. With six American, one New Zealander and one Dutch scientists, we covered 2,500 kilometres in 119 days, using tracked vehicles, thus opening a new track in the discovering of the inland ice.

1959: Victoria Land Traverse
We met with many difficulties and surprises: a hard access to the plateau among crevasses, engine troubles, cold and blizzards but also the discovery of a mountain range with Mount Lorius mentioned in the American atlas. A powerful scene in my memory: the opening of a “mail box” attached to a marker at the furthest southern point that had been reached by my French fellows of the IGY, two years before.

1957-59: Records from decades to centuries
At Charcot station, we dug snow pits of several metres deep to observe the sequence of summer snow, less dense and formed by bigger crystals than winter snow packed down by the wind ; a simple way to get the age of the latest layers and data on snow accumulation. In central regions, where it doesn’t snow very much, we can thus sample almost a century of records.

Hand drillings: towards the millennium
During the traverses, we made several stops for a few hours, sheltered from the wind by snow tractors and we carried out hand drillings from 10 to 20 metre deep, leading us further on in the past. Going deeper, we observed a progressive decrease of the range of the seasonal cycle of temperatures. A thermometer put at the bottom of the holes would give us the average annual temperature of the different sites we were exploring. Seismic shots showed that ice could be over 4,000 metres thick.

Slide 5 - The “isotopic thermometer”
The core samples collected during those missions were analyzed as soon as we went back to our laboratories. Snow and ice are solid water (H_2O) which isotopic composition can be measured and expressed by the concentration ratio $^{18}O/^{16}O$ or D/H. Comparing these ratios with temperatures found on the field led to a real discovery: the temperature at the time that

snow precipitation formed, left signs that analyses managed to decipher. This correlation would allow us to describe the climate thanks to samples of deep ancient ice.

At the core of polar ice: depths and ages

The quality of an ice drilling site depends on several elements: snow falls and temperatures, elevation and bedrock relief, thickness and ice flow of ice; these data, integrated into modelling, indicate the ages of ice that we could find in the depths. Cold sites, with low accumulation, deep and undisturbed ice flow, are situated in central areas, thus hard to reach. But this is where we would have to go to extract ancient records of the climate, where it will take hundreds of thousands of years for one tiny snow flake to reach the sea and melt. If more recent times are at stake, we would choose stations with higher accumulation in which it is easier to decipher the environment of our century.

Deep ice drillings

We developed drilling equipment when we carried out coring in the coastal ice of Adelie Land where I overwintered in 1965. One summer evening, our small glaciologist's team gathered in our caravan used as our shelter. We were sharing a relaxing moment, washed down with glasses of lukewarm whisky, in which we put - what a sacrilegious act! - bits of ice samples drilled from about a hundred metre deep. They melted...when we saw the air bubbles exploded in our glasses, released from their pressure; it came to our mind that these gases were perhaps testimonies of ancient atmospheres composition. But many years would be necessary for our team to prove the validity of the idea. Analyzing them would be a technical challenge but would "revolutionize" our understanding of the evolution of the earth climate.

In the last 30 years, deep ice drillings

After the site surveys, the deep ice drillings, that I am to talk about, would be carried out from 1977; firstly at Dome C, then in Vostok, and finally at Dome C again.

1974-1978: Ice drilling at Dome C

Within the context of the International Antarctic Glaciological Program, the American and English radar coverage identified an interesting drilling site at an elevation of 3,250 metres, where ice would be about 3,000 metres thick. We tried to reach this point from the French coastal station of Dumont d'Urville which is located more than 1,100 kilometres away. Two successive missions failed in this attempt but they allowed us to explore new territories.

1974: Leading site survey at Dome C

To obtain data on the spot, the U.S. Air Force embarked from Mac Murdo station a small team with 4 French, one American and one Russian, equipped with tents and snowmobiles. After one week of acclimatization at the South Pole station, we landed in December 1974 at Dome C where it was -35°C in the middle of summer. In a couple of weeks, we were able to gather information on snow accumulation (10 centimetres) and ice flow speed lower than a few metres per year: favourable features for ice drilling.

1974: Leading site surveys at Dome C

The end of the mission happened to be difficult, as two C-130 planes that were supposed to pick us up, crashed one after the other, while taking off. On the chaotic surface of sastrugi, the take-off assist rockets exploded, destroying skis and wings of the planes. After the last flight to assess the damages on the planes, that I well remember as I was petrified with fear, we were all back safe at Mac Murdo. Data confirmed that the site was promising but at that time, we did not expect to come back there. The Americans would manage to get back the damaged planes, and that was a real achievement.

Slide 6 - 1977: 900m deep ice drilling at Dome C

Three years after our first steps at Dome C, the Americans embarked our team of 13 people formed by drillers, technicians, researchers, a doctor and a cook, and tons of equipment. This ice drilling mission was a success as it reached 900 metres deep in two months; the maximum reachable depth without using any fluid. On the spot, we studied ice crystals and we found out that their size is correlated to the climate evolution, their growth being faster during hot periods than cold periods.

When we got back, we were able to describe the end of the last ice age era which took place about 20,000 years ago, and the beginning of the hotter climate of Holocene that we have experienced for ten thousand years now.

Although many other missions may be more fruitful with the drilling at Dome C, the risks and joy of this campaign that I experienced made us stand out in the very closed circle of nations who have carried out deep drilling in polar regions and shown its analyses capacity.

Vostok: the 1980's and 1990's

For a long time, I had been dreaming to go to the Soviet station, at the heart of Antarctica. The Cold War was threatening international relations but it did not prevent encounters and friendships between researchers on Antarctica. On December 31st 1984, a C-130 plane from the US Air Force brought three French glaciologists to Vostok station where Soviets were ice drilling. In ice caves, dug into the snow, they had stored core samples that had been extracted for years. This collaboration would last for years, giving access to samples spanning over 420,000 years.

The cold pole of the Earth

A temperature of -89°C was recorded at Vostok station, where polar night lasts for long months. The station had a Spartan-like comfort, where everyone spoke only Russian, there was no running water and supplies were scarce before the team change-off. But we had everything needed in the trunks that we brought to carry the core samples back. In the small rooms dug in the snow, we spent warm evenings with those who had overwintered and who had left their families for more than a year.

Slide 7 - 1984: Vostok, 150,000-year-old records

We were hoping for it: studying 2,083 metres of ice core revealed a 150,000-year-old history about climate and atmosphere composition. All along hot and cold periods stretching along the last great natural climatic cycle, we showed, for the first time, the correlation between climate and concentration of greenhouse gases in the atmosphere. On a very large time scale, before human beings presence, natural climatic variations were caused by the earth's path around the sun, during which it receives more or less energy according to its position. The path taken by our planet entails long hot and cold periods, modifying greenhouse gases concentration in the atmosphere in such a way that these gases accentuate significantly climate variations. A breakthrough, to which the Soviets and the Americans were associated, allowed us to announce, 20 years before now, the current global warming, caused by human activities which send out large quantities of greenhouse gases.

The cover of the prestigious *Nature* magazine with a comment describing these archives "cornucopia", was a recognition for our team and me; at this time I was elected as a member of the Academy of Sciences.

Slide 8 - 1998 Vostok: 420,000-year-old records

In 1998, ice drilling reached a depth of 3,623 metres where ice is 420,000 years old. Results are comforting evidence of the three fold correlation between climate, greenhouse gases and sea level and give a coherent explanation on large natural variations in our Quaternary climate. The average temperature change on Earth between ice ages and hot periods is 5°C, leading to sea level variations of 120 metres, caused by expansion or melting of the ice sheets. This testimony of old ice helps us to explain the current climatic warming and estimate the future one.

Dome C, Vostok, Dome Fuji: climate variability

These studies were also successfully led by the Japanese, on the other side of the continent, at Fuji Dome where they got a climatic record of 330,000 years old. On this time scale, comparison with data obtained from Vostok and Dome C gives a consistent picture of climate variability and reinforces the sense of getting a sample core as we hoped at the time of the Dome C and Vostok records.

Dome C- Epica, 800,000-year-old records

Near Dome C where we ice drilled 30 years before, twelve European countries reached the bedrock at a depth of 2,871 metres, in 2004, within the project EPICA. The link climate-greenhouse gases (carbon dioxide and methane) is still striking and show that the earth atmosphere has never known such high concentrations of greenhouse gases as today, for 800,000 years. We notice variations in both duration and amplitude of hot and cold periods, thus opening new paths for research on our future climate.

From 1974 to 2004: Dome C

This image illustrates the progress made in thirty years. We have moved from exploration to 800,000 years of archives. A great satisfaction for us, and I who initiated these two projects.

Slide 9 - 1,000 years: CO_2 and global warming
To come back to our day and age, data on the last millennium show a warming of nearly 1°C, observed for a hundred years comes essentially from CO_2 and other greenhouse gases of anthropic origins. In this context, what of our white planet? Our glaciers will go on declining, or even disappear for the most vulnerable ones.

To go off the tracks of my research field, I would like to present now some images of the consequences, even if they may still be moderate today, of global warming on polar areas, hoping I would heighten your awareness of a less austere side of our expeditions.

Climatic warming and ice pack
Satellite imagery shows the ice pack retreat in the Arctic between the end of summers 1979 and 2005. With climatic warming, new navigation routes thus open between the Atlantic and the Pacific oceans, intensifying commercial transportation and access to new sea fishing areas. The retreat which seems to accelerate will make easier exploitation of the sea bed that treasures significant hydrocarbon and gas resources. This has already aroused clashes of interests between the five bordering countries of the North pole.

Climatic warming and Inuit populations
Ancestral hunting people, Inuit populations suffer from the ice pack fragility which makes it dangerous for them to hunt seals and polar bears on which they live. It also reduces the social contacts in a society already not very numerous and spread over coastal areas, traditionally linked with dog-sledging. In this case, climatic warming is at the source of real cultural changes.

Climatic warming and polar bears
As their silhouettes are an icon of the great North, polar bears need a stable ice pack to reach their preys, i.e. seals, and to ensure the living of their cubs. The 20 to 25,000 polar bears have thus joined the black list of threatened species.

Climatic warming and Emperor penguins
A symbolic figure, with its unsteady gait, of the great South, Emperor penguins depend on the ice pack stability too, as they must ensure the survival of their chicks during winter because the latter won't be able to feed themselves in the sea as long as they keep their fluff. But this is not an urgent concern thanks to the cold temperature in this season in Antarctica.

Slide 10 - Temperature: past and future
The temperature increase predicted at the end of our century can vary from about 2°C to more than 6°C, a large range due to uncertainties concerning our knowledge about how the climatic system works and to our choice of future energies. It is necessary to remind us of the effect of past temperature changes: the average variations of 5°C have shaped quite different landscapes on our planet. It was thus white-coated during the last ice age. In the future, it could be partly covered with water.

Slide 11 - Climatic warming and sea level
Because of continental ice melting, sea level would rise from 10 centimetres to 1 metre at the end of this century. This is not a very accurate estimation because it mostly depends on the future of ice sheets. The first signs of significant melting appeared on Greenland and its expansion is visible through satellite images: a faster increase of melting could be feared. Much colder, Antarctica seems less vulnerable except for its hotter area, the Antarctic peninsula. Threats exist but on a very long-term scale considering the impressive ice masses, unless more sudden variations occur, in relation with the instability of some glaciers of which basis is located under the sea level.

Antarctica: glaciers and mass balance
From space, we can see "ice rivers" in central areas of Antarctica, flowing towards the sea. The mass balance of inland ice, i.e. the difference between snow accumulation and loss, due to glaciers flow and melting in coastal areas, is not yet well known. All the more since a temperature rise could increase snowfalls, thus slowing down the increase of sea level. This is one of several uncertainties for a faraway future, its ice volume representing the equivalent of 70 metres.

Ice and climate, a close link
As we have seen, ice and climate have a common destiny. Spreading over tens of millions of square kilometres, the white planet is both a testimony and a key element of the climate evolution. It is a testimony as ice expands in cold climate and melts in hot climate; it is a key element as it sends back towards space a more or less significant part of its energy received from the sun, according to the size of its surface, and thus it causes a decrease of temperatures or on the contrary in hot season. Thus, polar ice expansion shows and accentuates the climate evolution; a link more or less close according to its fragility which depends on its thickness. Because of the ice pack, Arctic warming is twice or three times more important than anywhere else on earth and, in fact, this foreshadows our tomorrow's climate.

50 years of adventures and research in Antarctica
Thanks to the discovery of secrets deeply buried in the ice records, we changed our views on the future climate. Moreover, polar ice contains many other information about our environment; a topic that I would like to develop now.

North pole - South pole: only one planet
In a few months time, going from pole to pole during my training to become a glaciologist, I discovered aurora polaris. These beautiful coloured veils are created by the collision between solar wind particles and our atmosphere, in a zone defined by the magnetic field that surrounds the earth; without this magnetic field, life would have never grown up on earth. From this time, before I became familiar with our earth and oceans, I realized that we have only one single planet.

North pole - South pole: only one atmosphere
Even before meteorologists scrutinized the atmosphere, early naturalist explorers discovered this fact, just from observing the migration of Arctic stern from the great North to the great South.

Slide 12 - Hemisphere pollution: Greenland 1
Sulphates concentration measured in Greenland snow have significantly increased since the 1900's and are an indicator of pollution at one hemisphere scale. Sulphates, to be blamed for arctic fogs, are naturally produced (sea salts, volcanic eruptions...), but they also come from coal combustion. This latter source is at the origins of the observed increase, whereas the recent decrease is due to the filtration of carbon emission in our biggest cities.

Slide 13 - Hemisphere pollution: Greenland 2
The evolution of the concentration of another polluter is also measured in Greenland snow: lead. It's rise is originally the result of industrial activities; but since the 1930's, it is the lead-based additives in gasoline used in industrialized countries that lead to concentrations of about 200 times the standard natural level of the early 19th century. With the use of unleaded gasoline, the concentration of this short-term life aerosol is in decrease but it will take decades before ice records attest a come-back to a less contaminated air.

Global pollution: radioactivity
In the early 1970's, I got really shocked when I discovered in South pole snow, fallout from radioactive wastes, sent out during nuclear explosions in the northern hemisphere. It was the evidence of a global atmosphere on Earth. For instance, we measured a strong peak in the years 1964-65, caused by tests carried out two or three years before in the other hemisphere. The signal was strong enough to manage to date the layers of recent snow. Radioactive halflife of tagging-agents such as strontium 90 and cesium 137 is around 20 years, which allows time to erase little by little evidence of irresponsible behaviours.

Slide 14 - Global pollution: "the ozone hole"
While ozone in the air that human beings breathe at ground level is dangerous for health, the abundant ozone present in the stratosphere is very crucial. Because it absorbs UV radiation before it reaches the earth surface, ozone protects life on our planet. And again as a proof of a global pollution, Antarctica is the place where researchers discovered the "ozone hole" caused by Chlorofluorocarbons (CFC) emitted by industrialized countries in the northern hemisphere. The "ozone hole" shows the consequences, sometimes unpredictable, of human activities on our global environment. The Montreal Protocol, signed in 1987, then extended to 190 countries in 2007, should lead to a drastic decrease of emissions and, hopefully, to a reduction of the "ozone hole".

North pole - South pole: only one ocean
During their travels around our blue planet, naturalist explorers saw the hump-back whale

from North to South, deducing from their observations the idea that there is only one ocean.

Global pollution: sea as a dust-bin

The ocean, cradle of terrestrial life, is now threatened by numerous pollutions. Here, soiling is more localized, oil dumpings reach the beaches and their fauna, while nuclear-powered submarines lying at the bottom of the Arctic water are a danger for the future. It is more difficult to give a global-scale estimation but it seems that more than 40% of the oceans are highly affected by human activities and that few sea areas remain virgin territories.

50 years of adventures and research in Antarctica: Mankind and Anthropocene

Since he first appeared, man has had to protect himself from nature to survive. First, he fed himself with gathering and hunting, then with farming and breeding. Discovering fire, during Holocene, was the starting point of greenhouse gases emissions; then, humans built towns to gather themselves as the population was getting more and more numerous, while the industrial era was beginning to take place. At that time, we entered Anthropocene, characterized by increasing pollutions, man deeply leaving his mark on the natural environment which he lives in. Warning signs came from polar areas, where almost no one lives and very far from the pollution sources.

Global warming challenges: human life conditions, resources, wars and conflicts

Global warming is the most urgent challenge that Anthropocene has given our societies to take up. It is most probable that human life conditions will drastically change, under the pressure of storms and droughts and biodiversity loss.

Vital resources in fresh water and food will become scarce and our current sources of energy will run out. Wars and conflicts already existing will multiply, aroused by migrations of a population looking for food or escaping sea floods. The first victims will be inhabitants of poor countries, those who already have their feet in water or are living in dry deserts.

Climatic warming: what can be done?

City lights of the world seen from space clearly show imbalanced distribution of population, activities and pollutions over our planet, for instance emphasized by the African night on one hand and United States or European lights on the other hand. Obviously, there are possibilities to reduce greenhouse gases emissions as several “Blue Planet” prize-winners proved it, among whom Professor José Goldemberg awarded this year. Among these possibilities, let us quote energy savings, lifestyle changes, research on climate and energies... But above all, people must be made aware that a real international solidarity is essential. But unfortunately, this is not the case today.

Climate and Environment: reactions

We like “burying our heads in the sand”. Too often, if politicians, policy-makers and citizens agree on the necessity to protect our planet, they don’t dare to make the first move, leading to action. Numerous reasons made them bury their heads in the sand.

Environment: Mankind facing the challenge
On our everyday horizon, and on the one of polar ice, we don't perceive the emergency to protect our planet, and furthermore other issues that are at stake: health, AIDS, famine, ... and we always hope, wrongly I think, that technological progress would make up for our consumption damages. In our private life, the quest of wealth, power and comfort justify our behaviour as citizen; a behaviour that doesn't make easy decisions from politicians and policy-makers, acting under the public judgment.

Anthropocene: our tracks in the ice
Nobel prize-winner Paul J. Crutzen (1995) suggested the word "Anthropocene" to characterize the new era which we entered, with pollutions entailed by human activities damage our environment on a global scale. An era in which dramatic rise is engraved in polar ice.

Slide 15 - CO_2: the birth of Anthropocene
The CO_2 content in atmosphere is an indicator that represents almost all the human activities, as emissions are mostly due to the use of fossil fuels as an energy source. The concentrations, measured during the last millennium in air bubbles trapped in Antarctic ice, are more or less stable until the early 19th century; then, they increased faster and faster until now, reaching levels representing a growth of 40%.

Environment and International Governance
To highly different extents, all citizens and countries are contributing to global warming and to environmental degradation. I think that solutions could be only found in the framework of international governance, but this doesn't seem to be realistic regarding our today's context with many conflicts. Maybe we would have to wait for genuine catastrophes which will lead man at the verge of chaos to make the governance possible; but why don't we dream about a future "Right for Environment"? Fifty years ago, scientists from the International Geophysical Year managed to convince the governments to sign the Antarctic Treaty.

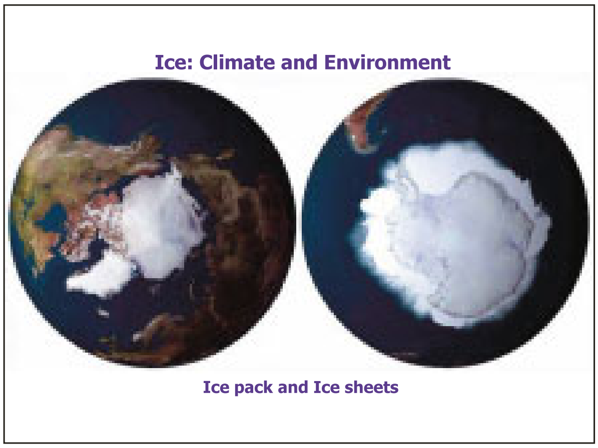
Let us be in Peace with Nature
As French hot desert explorer Theodore Monod said "Beyond the exploration and research led to understand the world that surrounds us, it is also important to think of human behaviour towards this small but so fragile sphere going around in the immensity of the Universe". And that is a short message that I would like to pass on, at the end of so many years of research in and about polar ice. It illustrates this drawing by Paul Emile Victor, founder of the French Polar Expeditions, "Let's be in peace with nature".

In our hands, Our planet
This logo symbolizes our liability in the future of the environment, and thus, in the future of our modern societies. To conclude this presentation, I would like to thank very simply but with much emotion, the "Blue Planet Prize" which aims at preserving our planet; I would like to thank all of you, ladies and gentlemen, who are here today. This gratitude, I am sure, holds in

high regard ice researchers and backs them up in their willingness to achieve a “fundamental” research which is at the same time so necessary to our civilization.

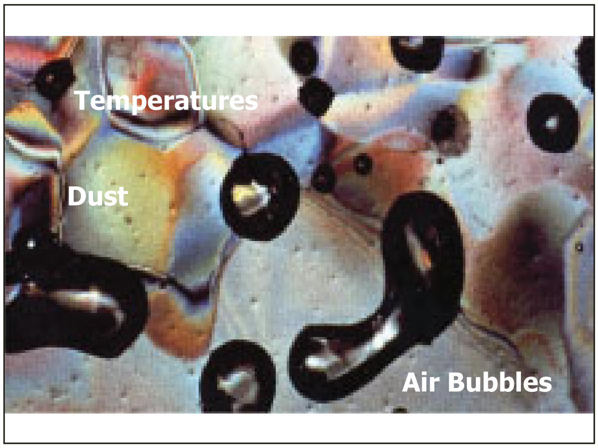
Slide 1

The White Planet: from Pole to Pole



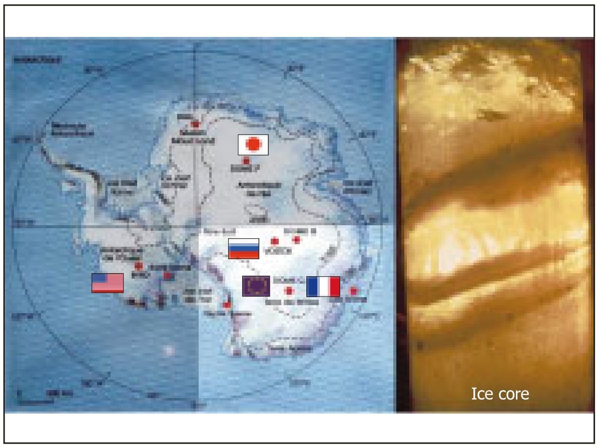
Slide 2

Polar Ice "Archives"



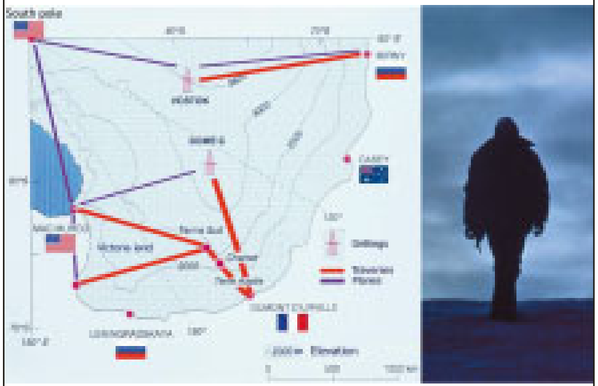
Slide 3

Antarctica: 50 Years of Ice Drilling



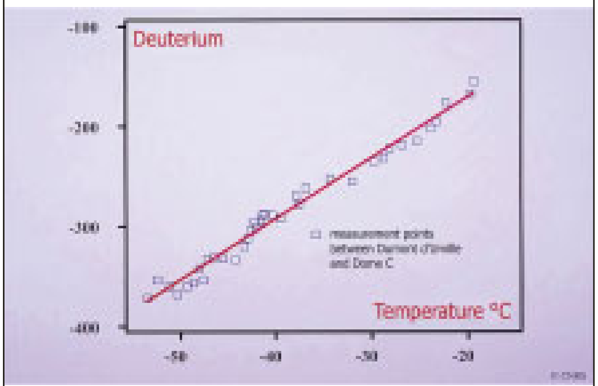
Slide 4

Eastern Antarctica: 50 Years of Missions



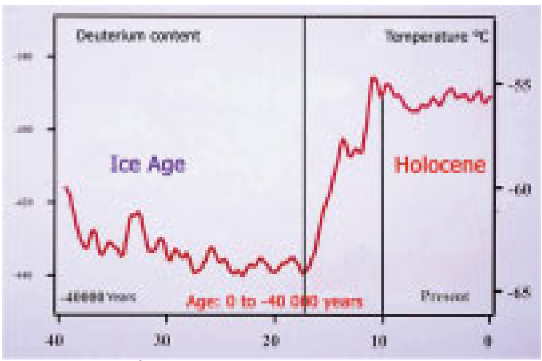
Slide 5

The "Isotopic Thermometer"



Slide 6

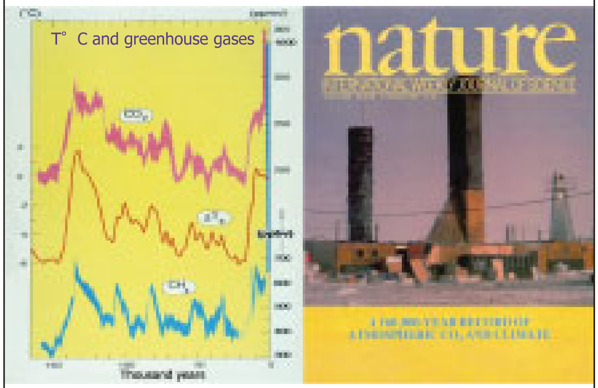
1977: 900m Deep Ice Drilling at Dome C



T° C from today to -40 000 years

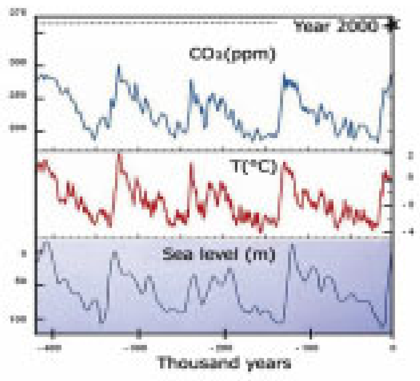
Slide 7

1984: Vostok, 150,000-year-old Records



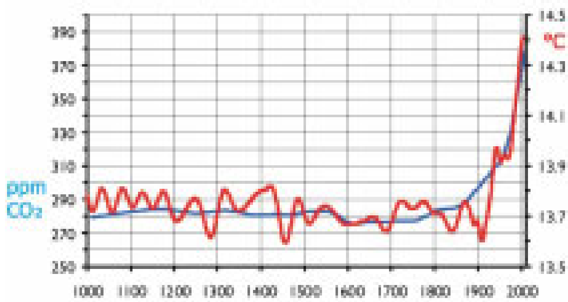
Slide 8

1998: Vostok, 420,000-year-old Records



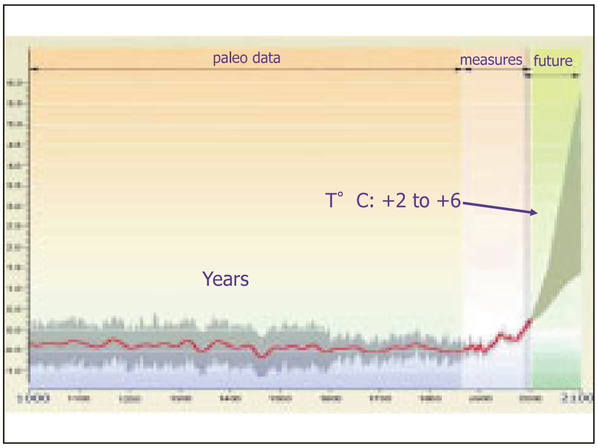
Slide 9

1000 years: CO_2 and Global Warming



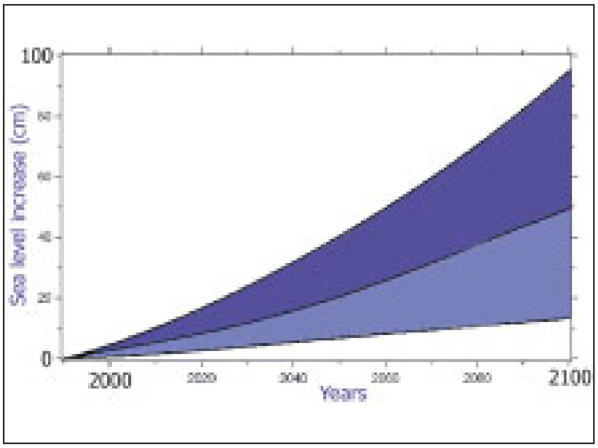
Slide 10

Temperature: Past and Future



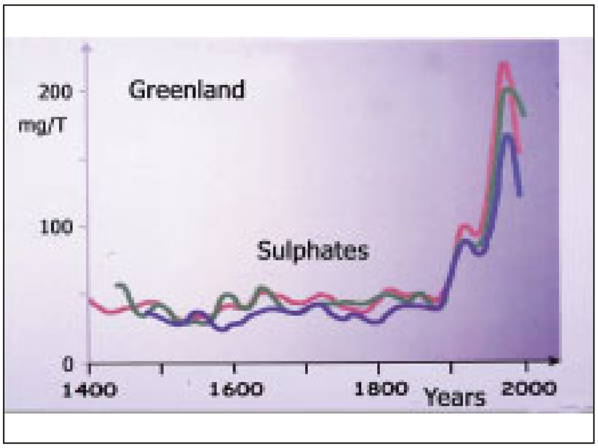
Slide 11

Climatic Warming and Sea Level



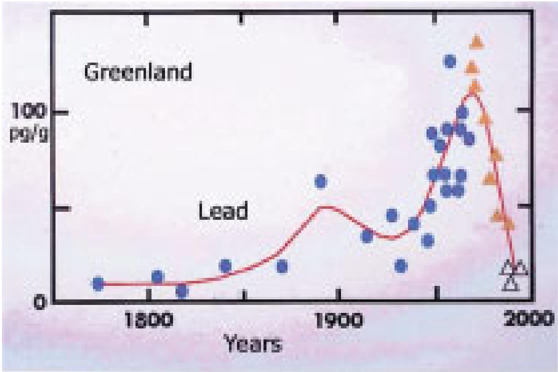
Slide 12

Hemisphere Pollution: Greenland 1



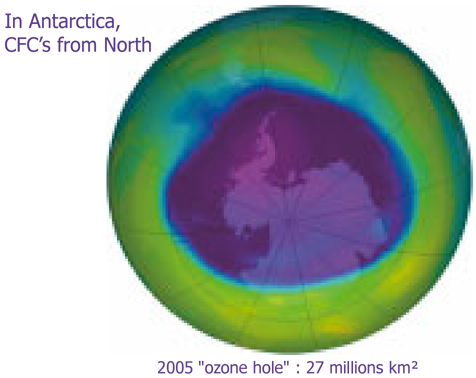
Slide 13

Hemisphere Pollution: Greenland 2



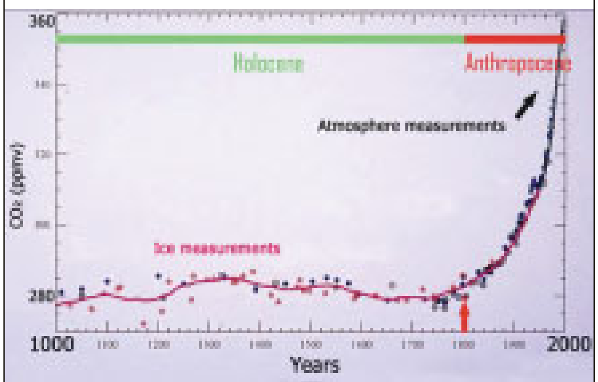
Slide 14

Global Pollution: "the Ozone Hole"



Slide 15

CO_2: the Birth of Anthropocene



Profile

Professor José Goldemberg

Professor, Institute of Electrotechnics and Energy, University of São Paulo
Former Rector, University of São Paulo

Education and Academic and Professional Activities

1928	Born in Santo Angelo, Brazil
1950	Graduated University of São Paulo
1954	Earned PhD in Physical Sciences from University of São Paulo
1955-1967	Associate Professor University of São Paulo
1967-	Professor of Physics University of São Paulo
1970-1978	Director of the Institute of Physics University of São Paulo
1982-1986	President of the Energy Company of the State of São Paulo
1986-1990	Rector of University of São Paulo
1990-1991	Secretary of State of Science and Technology, Brazil
1991-1992	Minister of State of Education, Brazil
1991	Mitchell Prize for Sustainable Development
1992	Acting Secretary of State of Environment, Brazil
1995-2000	Chairman of the Board, International Energy Initiative
2000	Volvo Environmental Prize
2002-2006	Secretary of State for the Environment of the State of São Paulo

(As of June, 2008)

Prof. Goldemberg was born in Brazil in 1928 and started his scientific activities in nuclear physics at the University of São Paulo (USP) and obtained his PhD in 1954 at the USP. In the 60's he spent two years in the High Energy Physics Laboratory of Stanford University. There he studied the scattering of electrons by nuclear magnetism. He then returned to Brazil and continued an active research in the field of nuclear research at USP.

The Brazilian government decided to introduce nuclear energy in the late 60's. Prof. Goldemberg was fully involved in the nuclear debate and this led him to a thorough study of energy problems, in order to better understand the possible alternatives for Brazil and the world in general. And with his visit to the Center for Energy an Environmental Studies at Princeton University in 1978, he completed his transition from a pure nuclear physicist to an energy analyst, thus became to get involved in energy policies.

Prof. Goldemberg realized that while improvements in the efficiency of energy use would be essential in order for the industrialized countries to reduce dependence on fossil fuel, for developing countries where energy demand itself was high, he proposed that the increased demand should preferably come from renewable energy sources such as biomass, an approach substantially different from the paradigms existing at that time.

In the 80's, together with R. H. Williams and others, Prof. Goldemberg wrote a remarkable book: "Energy for a Sustainable World", proposing a new vision on energy issues different from the past. Prof. Goldemberg et al, in this book, described the importance of a normative approach to energy planning by incorporating from the start, broad societal goals aimed at facilitating the achievement of, not merely a sustainable energy system, but what is more crucial, a *sustainable world*. It defined that at the most fundamental level the level of goals of society should be equity, economic efficiency, environmental harmony, long-term viability, self-reliance, and peace. With the book he showed an image of the future in which it was possible to build an energy future for the year 2020 where renewables play an important role and the total world energy consumption and emission of greenhouse gases would possibly be controlled. He expressed what was essential for this future was the adoption by the developing countries, early in the process of their development, of efficient end-use technologies like the ones used in the industrialized countries. As a consequence, he developed the "leapfrog strategy", by which a developing country could incorporate the available most efficient and modern technologies, but also at the same time introducing innovative ones, leapfrogging over some of the historic steps toward industrialization. Such vision exhibited by the book was incorporated in the UN Brundtland report, that led to the UNCED-92 Conference of Rio de Janeiro, and his vision, innovative ideas and influence were recognized worldwide.

From 1986 to 1990, Prof. Goldemberg served as Rector of the University of São Paulo, the largest of Brazil and perhaps the most respected of the southern hemisphere and directed his effort in raising the scientific level and performance of the university. During his term, he established two academic units with great importance in issues such as energy, environment, development and public policies. In the early 1990's, Prof. Goldemberg was chosen by the President as secretary of state for science and technology, and later as interim secretary of the environment. In that capacity he took a very active role in its preparatory process and the Climate Convention adopted in Rio-92, showing leadership at the Earth Summit.

In 1993 he established the International Energy Initiative (IEI), which has a mandate in the developing countries to disseminate a perspective on energy in which the level of energy services is taken as the measure of development, and to initiate and strengthen technological capability in energy analysis, planning, and implementation, influencing activities on energy in developing countries.

Prof. Goldemberg has written numerous papers and articles, and he has been very productive in the publication in the field of energy. Among them, especially important, is the book printed in 2000, edited by him as the Chair of the meeting sponsored by the World Energy Council and the United Nations titled *"World Energy Assessment - Energy and the Challenge of Sustainability"*.

From 2002 to 2006, he served as secretary of state for the Environment of the State of São Paulo and put into practice many of his ideas on sustainability, preservation and wise use of the environment.

Prof. Goldemberg states that the biggest environmental threat the world faces today is global climate change and meeting this challenge will require not only new energy strategies and policies but also the full involvement of major developing countries and abundant North-

South cooperation. He has recognized the importance of climate-friendly energy strategies and furthered securing cooperation of major developing countries such as Brazil and China, contributing in forging the type of North-South partnerships, and his active contribution will continued to be seen in the future.

Essay

Revisiting Technological "Leapfrogging"

Professor José Goldemberg

Technological learning and innovation in industrialized countries is usually a continuous incremental process which can lead to lower costs for existing, new or higher quality products that can enhance productivity, competitiveness and growth.

However, successful companies with a monopoly on particular technologies are bound to take fewer risks and stand to lose their technological leadership role when competitors willing to take more risks, adopt new technologies. Such are the "gales of creative destruction" described by Schumpeter[1], which are not necessarily successful, but increase technological options for development.

In developing countries, ("the periphery") many of them former colonies, the usual economic development followed a simple model: export of primary products (minerals and agricultural products) which did not involve advanced technology and import of manufactured products originating from the industrialized countries ("the center").

As the markets in such developing countries grew significantly, subsidiaries of the leading manufacturers installed factories for local production; frequently this was done by transferring obsolete factories to the colonies or former colonies, which were due to be dismantled in their countries of origin and replaced by modern ones.

The initial advantage of the "center" over the "periphery" is the technical and organizational superiority. In the short term, innovation and increased efficiency give to the "center" greater profits and a faster growth. In the long term however, the rate of growth of the "center" tends to decelerate and new economic activities migrate to the "periphery" which benefits, in the words of Gerschenkron[2], from the "advantages of the latecomers". These countries can initiate their industrialization process benefiting from lessons learned from the advanced countries when they industrialized in the past and can therefore "leapfrog" over some stages of development[3].

Such behavior is illustrated in Figure 1 by the evolution of the "energy intensity" (E/GDP) of the economy which measures the amount of energy required to generate one unit of GDP measured in tons of oil equivalent per thousand dollars.

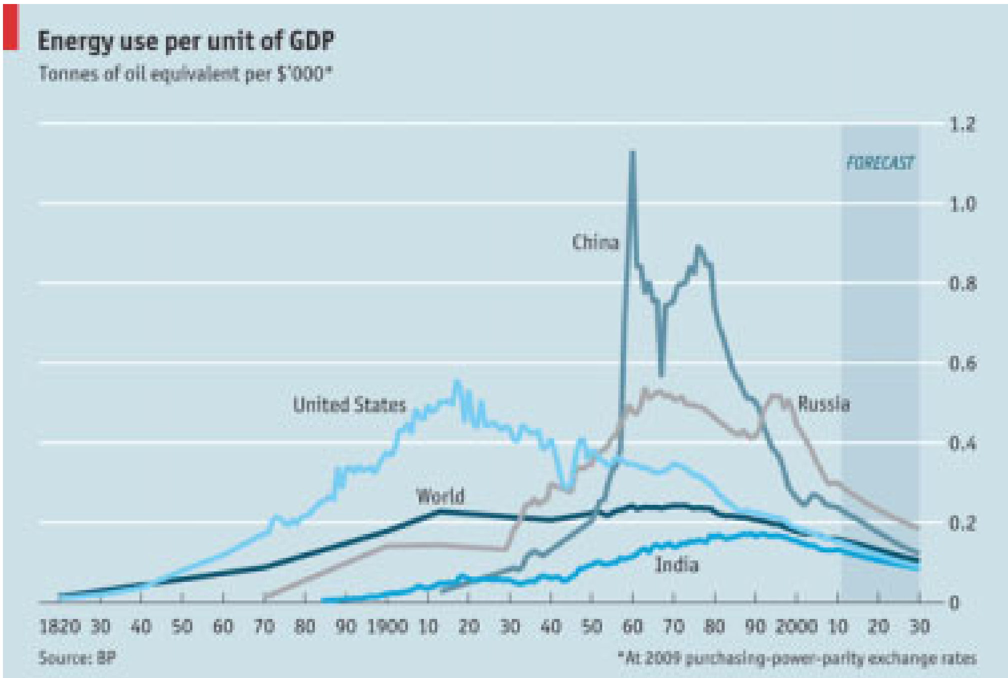


Figure 1

The evolution in energy intensity (energy per income, I = E/GDP) over time reflects the combined effect of structural changes in the economy, in the composition of energy sources and in the efficiency in energy use.

As Figure 1 shows, energy intensity grows during the initial phase of industrial development as heavy infrastructure is put in place, peaks, and then declines[4,5].

In the United States and other industrialized countries the energy intensity increased as the infrastructure and heavy industry developed, going through a peak and then a steady decline. Latecomers in the industrialization process, such as Russia, China and other developing countries peaked later and their energy intensity declined rapidly indicating early adoption of modern more energy efficient industrial processes and technology. The energy intensity of most countries is therefore converging rapidly.

The growth of electricity use is a characteristic of present consumption patterns which partially explains such behavior[6]. Electronic equipment of all kinds, computers, television sets as well as refrigerators, air conditioners and other domestic appliances are now found everywhere around the world. Electricity can be transmitted and distributed more easily than solid or gas fuels and can reach the most hidden locations in houses, offices and industries. In addition to that it can be converted with almost 100% efficiency to mechanical power in motors.

BOX

The energy intensity ($I = {}^{E}/_{GDP}$)

Despite being acknowledged as a very rough indicator, energy intensity has some attractive characteristics: whereas energy and the GDP *per capita* vary by more than one order of magnitude among the developed and developing countries, energy intensity does not change by more than a factor of two

The main factors determining the evolution of energy intensity are

(i) dematerialization;

(ii) fuel use intensity; and

(iii) recycling.

Dematerialization of economy

Dematerialization of economy means to use less material for the same end. An example of this is the use of glass fiber to replace copper in telephone transmissions. Other examples are the replacement of steel by polymers in automobiles or thinner sheets with higher resistance alloys to replace thicker sheets of conventional steel. In the US, the participation of basic materials in the GNP decreased by nearly 30% since 1970.

Fuel use intensity

Fuel use intensity measures the amount of energy necessary to manufacture a given product (as for example the fuel used per ton of steel or the power used per kilogram of polyethylene).

Recycling

Recycling expands the concept of dematerialization. The energy necessary for recycling a few basic materials is usually smaller than that necessary to produce them. For example aluminum recycling uses only a quarter of the energy needed to product it from the raw mineral.

Source: Goldemberg, J. and Lucon, O. - "Energy Environment and Development" Earthscan 2010

The decline of the energy intensity is directly reflected in the decline of the carbon intensity defined as

$$I_c = {}^{C}/_{GDP}$$

i.e the amount of carbon emitted per unit of GDP

The reason for that is that in most countries energy originates in fossil fuels (coal, oil, gas) which worldwide account for 80% of energy used.

Figure 2 shows the evolution of the carbon intensity of the OECD countries and the BRICS countries (Brazil, Russia, China, India and South Africa)[7]

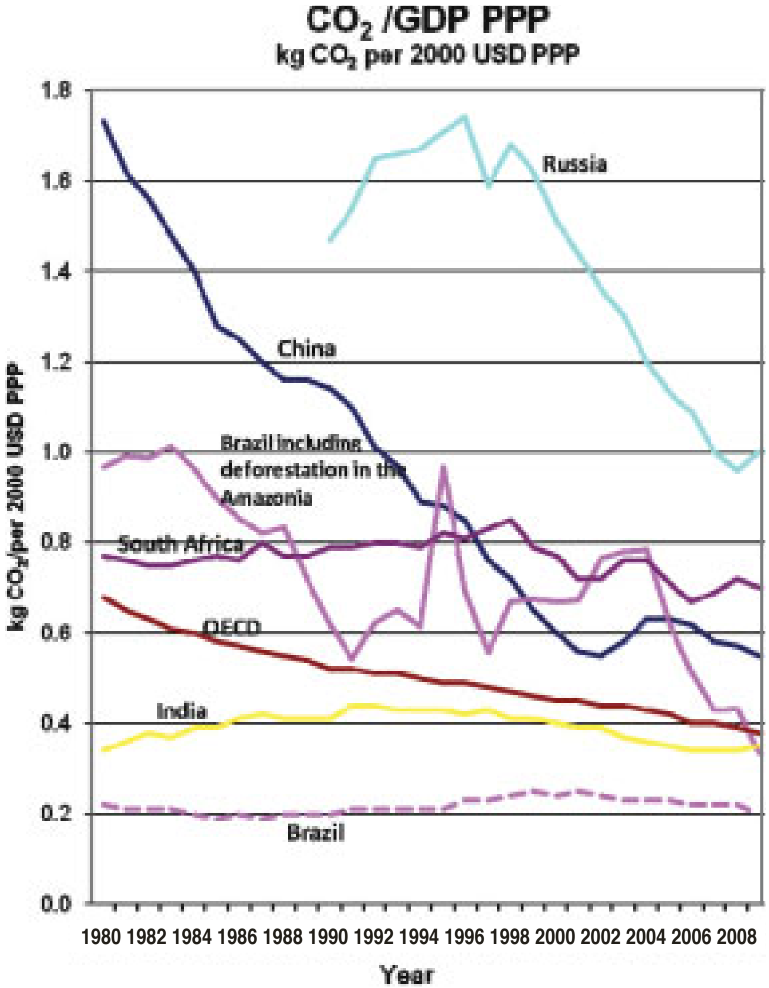


Figure 2

China and Russia, which are very dependent on coal, are making great progress in reducing rapidly their carbon intensity (CO_2/GDP) although their carbon intensity is significantly higher than the one in OECD countries.

The carbon intensity of China and Russia is decreasing 3.3-3.9% per year. In India it is decreasing at 1.5-1.9% per year, similar to the decrease in OECD countries.

South Africa is making small progress. India has a rather low carbon intensity being a less industrialized country. Brazil, excluding deforestation in the Amazonia, has a very low carbon intensity the main reason being the fact that electricity is produced almost entirely from hydroelectric plants. When the contribution to CO_2 emissions due to the deforestation in the Amazonia is included its carbon intensity rises considerably although it has been decreasing significantly more in recent years.

There is therefore an overall decline in the carbon intensity of the major carbon emitters which raises hopes that ultimately the growth of carbon emissions will be reduced avoiding some of the dire consequences of global warming.

It is clear therefore that developing countries which are latecomers in the industrialization process can either mimic industrialized nations and undergo an economic development phase that is dirty, wasteful, and creates an enormous legacy of environmental pollution, or they can "leapfrog" over some of the steps of development and incorporate currently available, modern, and efficient technologies into their development process.

This process is already taking place, as demonstrated by the amazing speed of adoption and diffusion of innovative and state-of-the-art technologies in developing countries. A shining example is the speed at which cellular telephones were introduced even in countries which did not had traditional telephone systems particularly in rural areas. Another example can be seen in Indian villages where lighting is provided by fluorescent lamps instead of old inefficient incandescent light bulbs. Other less spectacular technologies, such as biogas produced in large biogas units using waste products of the village, can serve several purposes such as power for lighting, water pumping, fertilizer production and sewage treatment. Black-and-white television is becoming a thing of the past even in the remote areas of Amazonia. The same has happened with cellular telephones which have bypassed wire-connected telephones in many places.

The potential for leapfrogging is inherent in both *processes* and *products*. Often, there is synergy between the two, as in between the use of renewable energy sources and energy efficiency. Take, for example, lighting in isolated villages, typically supplied by kerosene lanterns, batteries, or candles. Switching to a compact fluorescent light bulb (CFL), which is four times as efficient as a conventional incandescent bulb, makes it economical to supply power from a solar photovoltaic (PV) panel. Connecting to an electric grid - probably a requirement if inefficient conventional bulbs are used - is unnecessary, generating vast savings in capital equipment. The resulting lighting system is much more satisfactory than either its inefficient, low-tech predecessor (candles or kerosene) or inefficient, capital intensive alternative (incandescent lights and an electric grid). A PV-CFL system is some 100 times as efficient as kerosene and a half-million times more efficient than candles.

What the data shows is that the technologies adopted in the economys of most countries (OECD+BRICS) is evolving approximately the same way which means that the latecomers in the development process "leapfrogged" many of the steps followed in the past by the industrialized countries and their growth is based now in modern and relatively non-polluting technologies.

References

1. Schumpeter, J. - "Capitalism, Socialism and Democracy" New York, Harper, (1942).
2. Gerschenkeron, A - Economic Backwardness in Historical Perspective , Cambridge Becknap, UK (1962).
3. Goldemberg, J. - Leapfrog energy technology - Energy Policy 26 pp 729-741) (1998).

4. Martin, J. M. “L’Intensité Energetique de l’Activité Economique dan les Pays Industrialises: les Evolution de três Longue Period Livrent - ells des Enseignements Utiles?” Economies ei Societés - Chaiers de l’ISMEA 22 (4) 9-27 (1988).
5. BP Energy Outlook 2030 London (2011).
6. Goldemberg, J. and Prado, L. T. S - “The decline of the world’s energy intensity” Energy Policy 39 pp 1802-1805, (2011).
7. Goldemberg, J. and Prado, L. T. S - “The decarbonization of the world energy matrix” Energy Policy 38 pp 3274-3276, (2010).

Lecture

A Sustainable Energy Future

Professor José Goldemberg

What I will try to focus on in this lecture is the present "status" of the efforts leading toward a sustainable energy future and my own efforts in that direction in a developing country such as Brazil.

After many years as a professor and researcher in the energy area at the University of São Paulo, I was appointed in 1982 CEO of the Energy Company of the State of São Paulo - the most industrialized State of Brazil with a population of approximately 25 million people at that time. It was my first experience in large scale management and it forced me not only to preach about new and more sustainable energy strategies but also to do something about it.

One of the activities of the company was to build hydroelectric generating stations which brought me face to face with some unavoidable environmental and social impacts. In one of our stations 20,000 hectares of virgin forest had been lost to an artificial lake resulting from damming a river; we then decided to purchase another 20,000 hectares to compensate that loss and convert it into a state park.

I learned through this experience that generating electricity - which was essential to supply the needs of the population of São Paulo - could have negative environmental and social impacts such as displacing people, affecting the lives of others and leading to a biodiversity loss, while at the same time benefiting others, frequently more numerous. Compromises had to be negotiated and reaching them could be quite expensive.

More generally speaking man's impact on the environment in the past had been modest except in some extreme circumstances where it was really destructive. The best example is probably what happened in Easter Island. This isolated volcanic island in the Pacific was colonized by Polynesian people before 900 CE and gave rise to a rather sophisticated civilization attested by the large number of immense and strange statues weighing up to 100 tons spread out all over the island. However when the western navigators reached the island in 1722 it was completely denuded of the forest cover it had in the past and which had sustained the life of the estimated 30,000 people living there then: the few remaining islanders were found to be in a very precarious state. (Figure 1)

The consequences of large populations dependent on limited agricultural resources was studied in the past and given a very special "status" by the work of Malthus in the 19th century. Malthus argued that population growth reduces average "per capita" income, because he considered the globe, with its natural resources, a constant, so population growth would reduce natural resources per head and increase mortality due to insufficient food production. According to him "the carrying capacity" of the globe was finite and could not be exceeded.

The arguments of Malthus were given another version in the 20th century by the Club of Rome which pointed out the "limits of growth" due to the eventual exhaustion of minerals and other inputs essential to our civilization.

Figure 1
Easter Island

Table 1
The Action of Humankind on the Environment

Geological forces (wind, erosion, volcanic eruptions, etc.)	50 billion tons/year
Human activities world population 6,75 billion material used “per capita” 8 tons/year	54 billion tons/year

The basic argument of such current of thought is that human activities today have impacts on the environment comparable to the impacts of natural forces. In other words the action of human beings reached the level of geological forces. The basic reason for that is the following: in our regular activities around the year each person moves about 8 tons of materials; with 6.7 billion people on the earth today this corresponds to moving 54 billion tons/year, rather close to the amount of material moved by geological forces (wind, erosion, volcaniceruptions, etc) of 50 billion tons/year. (Table 1)

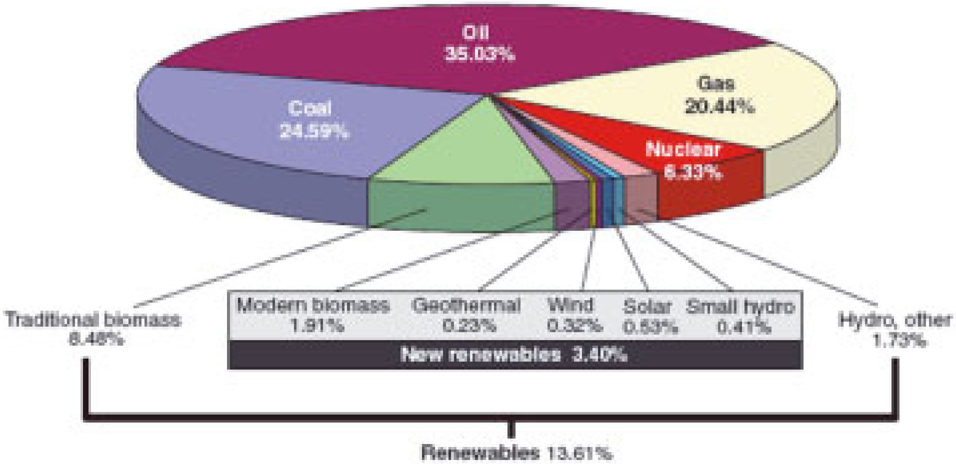


Figure 2
World Primary Energy Supply (2004)
(shares of 11.4 billions tons of oil equivalent)

The energy production is an important fraction of man's action on nature due to the fact that approximately 80% of all energy used in the world is of fossil origin. Figure 2 shows the sources of the world energy supply.

Traditional renewables used in primitive form in many less developed countries account for 8.5% of the consumption and "new", i.e. modern renewables (wind, solar, etc) for 3.4%.

The 2004 average "per capita" energy consumption was 1.74 tons of petroleum equivalent per year or 20% of all materials moved around. Such amount of energy corresponds to 50,000 kcal/day, 25 times the subsistence level of prehistoric men of 2,000 kcal/day.

The consequences of the large consumption of fossil fuels can be daunting giving rise to local, regional and global pollution.

Local pollution originates in impurities in coal and oil and is very visible in the air quality of São Paulo, Los Angeles, Beijing and other large cities. The health consequences of such problems are well documented.

Regional pollution is less visible but is becoming an important issue in Southeast Asia, where a "brown cloud" has been formed due mainly to emissions from coal burning in China and India.

Global problems were clearly identified only in the last 20 or 30 years particularly global warming. In this case the main culprit is also the use of fossil fuels. The consequences of our dependence on fossil fuels are leading to the point of reaching the limits of the "carrying capacity" of the atmosphere, not unlike Malthus' concerns in the 19th century.

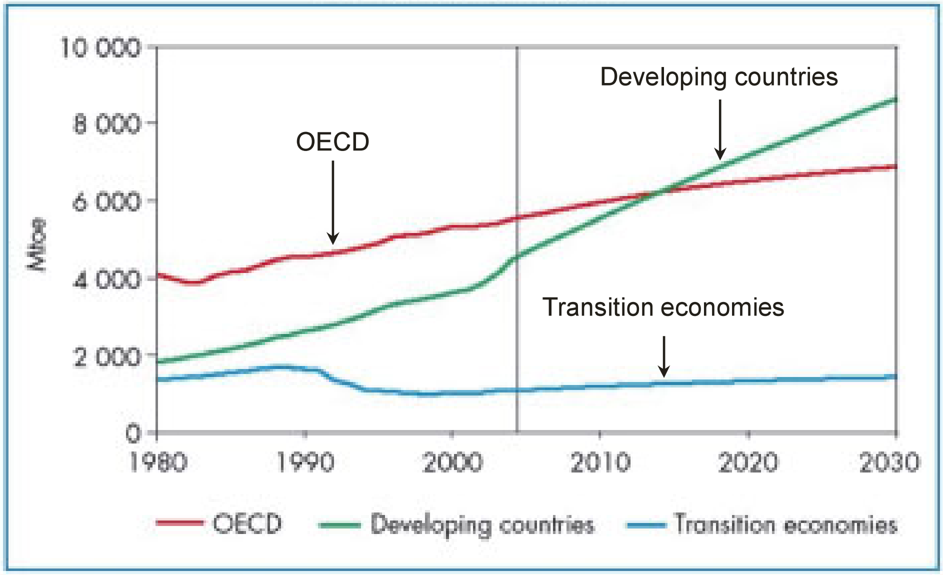


Figure 3
Projections of the Energy Consumptions until 2030

To aggravate our present concerns International Energy Agency (IEA)'s projections for energy consumption are alarming: present energy consumption should almost double by 2030 added to an increasing contribution from developing countries with a continuing dependence on fossil fuels. (Figure 3)

This is not only alarming but is also not a sustainable energy future since it cannot last for more than the estimated life of present fossil fuel reserves of 50-100 years.

The solution to this problem - probably the most serious our civilization faces today - lies in the fact that, as in the case of Malthus, the "carrying capacity" is not a constant because there can be substitution between different resources. The type of possible substitution depends on the particular resource endowment and other conditions for resource transfer or invention in the region under investigation.

A sustainable energy system as defined in the Brundtland Report in 1987 must comprise four components characterized as:

- Physical, related to securing supplies adequate to meet future energy needs and extending their lives;
- Environmental, related to the use of present supply sources at local, regional and global levels including averting global warming and catastrophic climate change;
- Geopolitical, related to security risks and conflicts that could arise from an escalating competition for unevenly distributed energy resources and
- Equitable, not strictly an energy problem, but similar to the one of access to food and other amenities provided by modern civilization.

Regarding equity Figure 4 indicates the progress made in different regions of the world in the period 1971-2004.

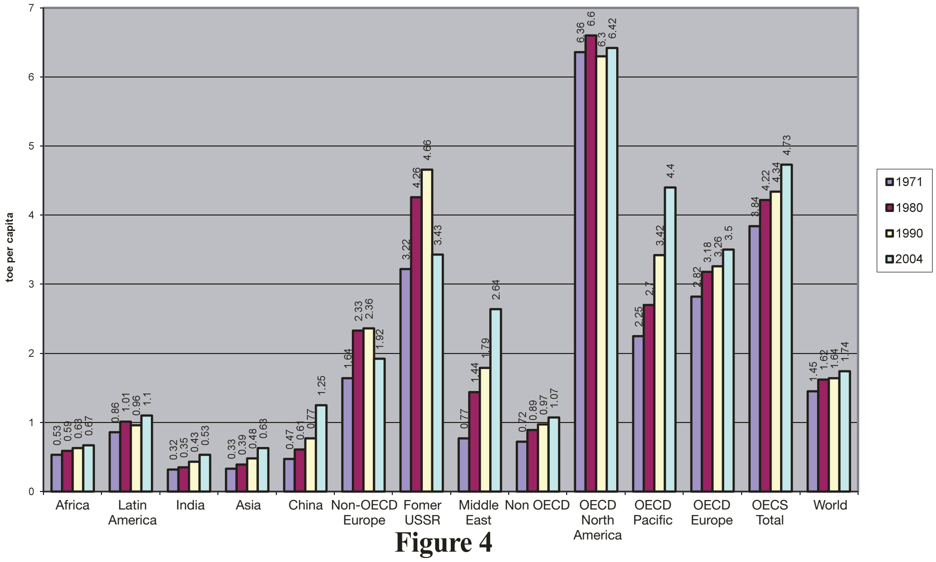


Figure 4

Evolution of the Energy Consumption “per capita” (1971 - 2004)

The average world primary energy consumption has approximately reached 1.74 toe/capita but there is a serious problem of distribution. The OECD North America region has 6 toe/capita and Asia (non OECD), Africa and India less than 1 toe/capita in primary energy consumption. The political consequences of such wide differences in consumption cannot be discussed and the energy consumption growth is unavoidable in developing countries particularly in China and India.

One could ask what energy would be necessary to offer the population of developing countries as an acceptable level of living. A possible answer can be given by analyzing the relationship between the Human Development Index (HDI) and the per capita consumption displayed in Figure 5.

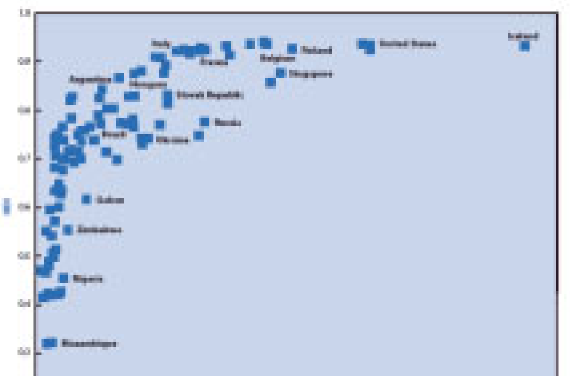


Figure 5

Relationship between HDI and per capita Energy Use, 1999/2000

As one can see in this figure the industrialized countries have an HDI above 0.9 reached when the "per capita" energy consumption is above 3.5 toe/capita, approximately twice the present average world consumption of 1.74 toe/capita. To reach that level in 20 years a growth rate of 3%/year energy consumption would be needed - which is rather modest compared to growth rates used in most projections of future energy consumption in developing countries. Even so if such growth follows the patterns adopted in the past by the industrialized countries in the 20th century when fossil fuels were cheap and abundant, environmental problems would be greatly amplified.

The contrast of today's industrialized countries with a large "per capita" consumption and the majority of the world's population consuming less than needed can be tackled by a two pronged approach:

i. the reduction of consumption in the industrialized countries through energy efficiency measures that can lead to supplying the energy needed for the desired end uses with less primary energy inputs and
ii. the introduction of renewable energy sources in large scale.

Energy efficiency was clearly identified as the "low hanging fruit" of the energy system, after the first (1973) oil crisis and it became an important element of energy policy in the mid 1970's. The enormous increase in oil prices and the resultant problem of oil shortages forced a reexamination of the way energy - and particularly fossil fuels - was used. The result was that many opportunities were found to increase production efficiency and energy use. On the supply side, it was found that the transformation of primary energy sources (coal, oil and gas) into electricity could be greatly improved. On the demand side, innumerable opportunities were identified (in lighting, building construction, transportation, domestic appliances) to perform the tasks and services needed with less energy.

The success of energy savings in the OECD is clearly displayed in Figure 6.

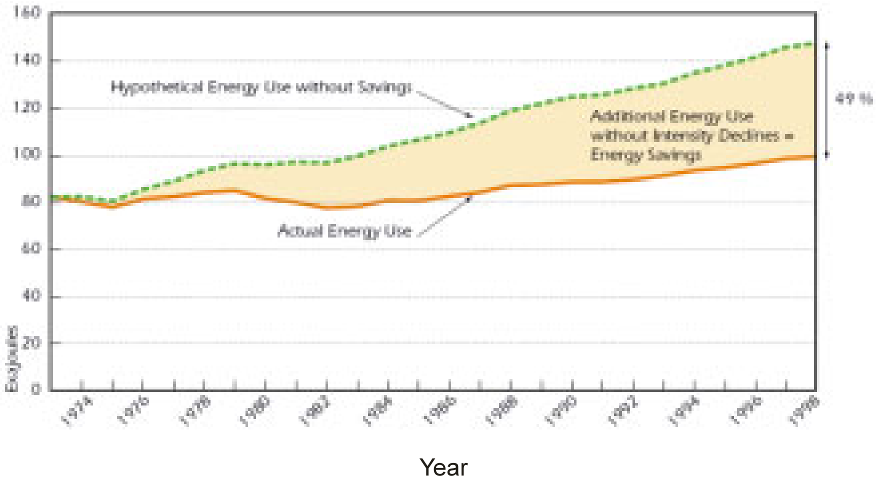


Figure 6
Energy Economy in the OECD (1973 - 1998)

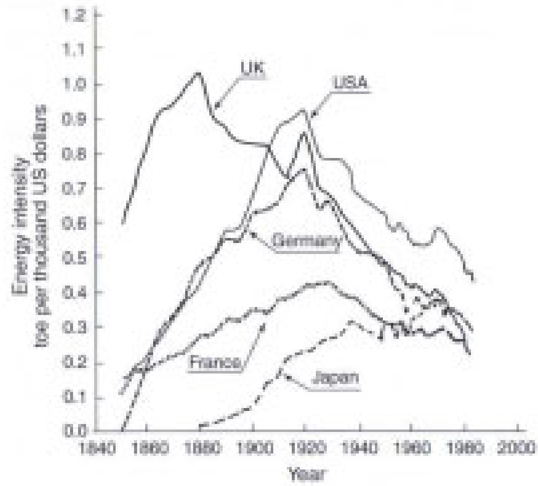


Figure 7
Long-term Trends in Energy Intensity of Industrialized Countries*

*Commercial energy includes all energy that is the subject of monetary transactions (generally coal, oil, gas, nuclear and hydro). Only commercial energy is considered in this graph.

Energy efficiency however is not a solution "per se" but can buy time for the world to develop a "low energy path", which should be the foundation of the future global energy, as the Brundtland Report pointed out.

The strategy of promoting energy efficiency, i.e. performing the same task with less energy and successful in OECD countries since 1973, is necessary but not sufficient for developing countries. As they build modern economies with attendant industrial infrastructure, transportation systems, and urban development, growth in commercial energy consumption is inevitable.

However, developing countries have an alternative: they can either mimic the industrialized nations and go through an economic development phase that is dirty, wasteful, thus creating an enormous environmental pollution legacy, or they can *leapfrog over* some of the steps originally followed by industrialized countries and early in the process of development, incorporate modern and efficient technologies into their development process. LDCs are important theaters for innovation and leapfrogging, especially in energy-intensive, basic material industries such as steel, chemicals, and cement.

Such process is occurring to some extent since the 19th century as can be seen in Figure 7 which displays the energy intensity in the UK, USA, Germany, France and Japan over the years. The energy intensity is an indicator that measures the energy needed to produce one unit of the gross national product in monetary units.

In the UK - the first country to industrialize - the energy intensity grew rapidly from 1850 to 1880 because the large infrastructure built in that period (railways, steel mills, etc) required large amounts of energy. After 1880 the energy intensity declined as the economic activity switched to less intensive energy activities. Germany and the USA - which industrialized later - benefited from the UK's experience and were less energy intensive. France and

Japan benefited from the two above ones and were even less energy intensive. One could see here the advantages of latecomers in the industrialization process.

The potential for leapfrogging is inherent in both *process and products*. Often, there is synergy between the two, as between the use of renewable energy sources and energy efficiency. Take, for example, lighting in isolated villages, typically supplied by kerosene lantern batteries, or candles. Switching to a compact fluorescent light bulb (CFL), four times as efficient as a conventional incandescent bulb, it makes it more economical to supply power from a solar photovoltaic (PV) panel. Connecting to an electric grid - probably a requirement if inefficient conventional bulbs are used - is unnecessary, thus generating vast savings in capital equipment.

Another major dividend from leapfrog technologies derives from the avoided costs of long-term environmental clean-up. Most current environmental expenditures (approximately $100 billion per year in the USA) go to mopping up old toxic sites, scrubbing coal power plants, and so on. A significant fraction of health care costs are linked to environmental pollution and degradation. Using leapfrog energy technologies minimizes these future costs.

Technological leapfrogging requires information knowledge and insights on the technologies in use around the world. This is why it is so important for developing countries to have an elite of scientists in all areas capable of making choices - thus the role of leading universities. My own efforts as Rector of the University of São Paulo in the late 80's were entirely dedicated to that.

It is however in the realm of renewable energy that great opportunities exist. They were described in the Brundtland Report in 1987 as the "untapped potential" and the report pinned great hopes on them since they "offer the world potentially huge primary energy sources, sustainable in perpetuity and available in one way or another to every nation of the world".

They are indeed the fastest growing source of energy (an average of 11% per year in the period 2002-2006) while total energy production grew only 1.6% per year in the same period. (Figure 8)

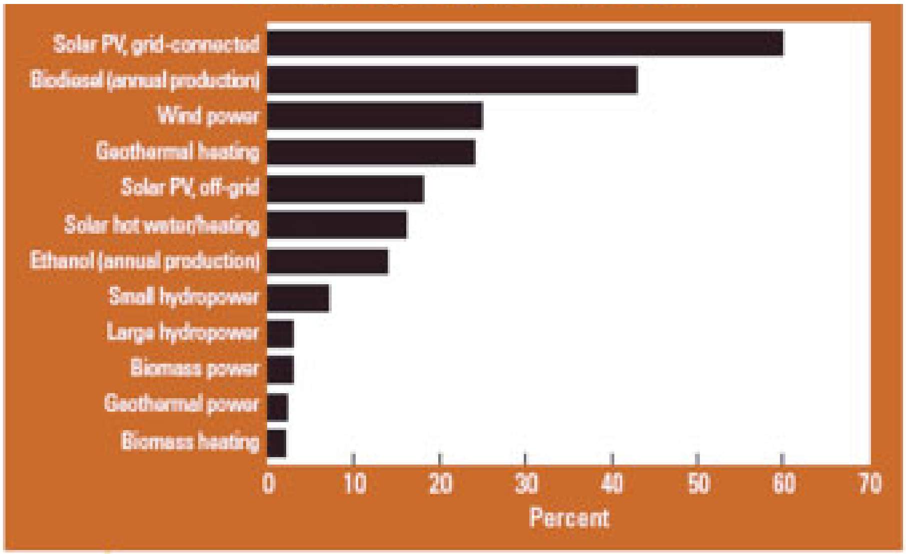


Figure 8
Average Annual Growth Rates of Renewable Energy Capacity, 2002-2006

If such growth was to persist over two decades, new renewables could represent 20% of the world's energy consumption in 2030. (Figure 9)

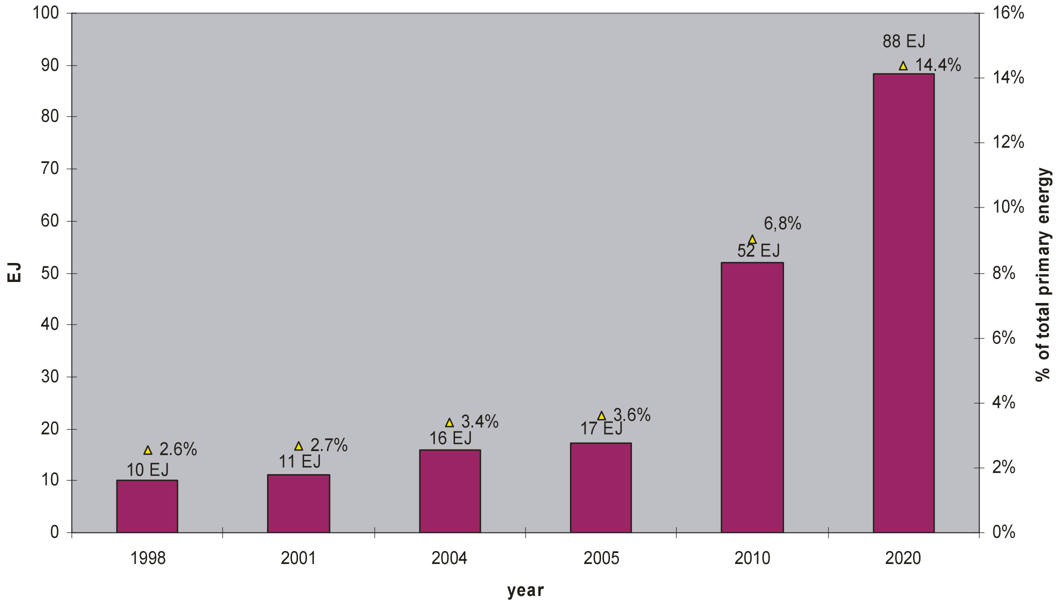


Figure 9
Modern Renewables
(including small hydro, excluding large projections for 2010 and 2020 based on growth 2001-2005)
(REN21 and WEA 2004 Update)

One of the most impressive examples of technological leapfrogging in the area of renewables is given by the alcohol program in Brazil through which approximately 50% of the gasoline used in the country was replaced by sugarcane derived ethanol.

Ethanol is superior to gasoline in some respects and being produced from an agricultural product is renewable on a life cycle basis except for the small inputs of fossil fuels (less than 10%) used in its preparation in the form of fertilizers. My own work in 1978 on the energy balance of ethanol production from sugarcane, maize and other crops clearly established the sugarcane advantages over other crops. The sugarcane bagasse is used as fuel to produce steam and electricity needed in the ethanol preparation. The ethanol cost in Brazil became competitive to gasoline when petroleum reached the cost of 40 dollars per barrel. (Figure 10)

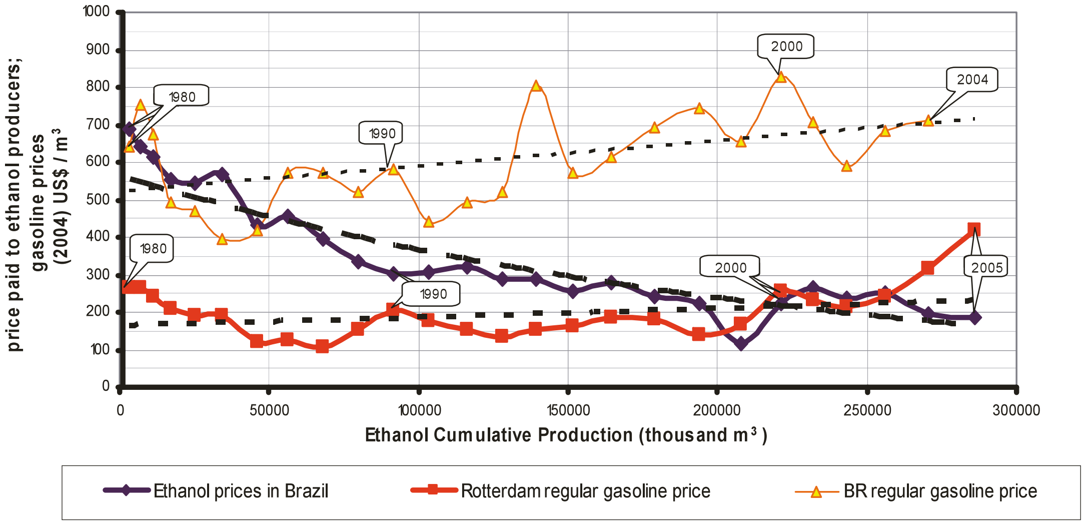


Figure 10
The Economic Competitiveness of
Alcohol Fuel Compared with Gasoline

Ethanol was used originally in two ways in Otto cycle automobiles:

i. as an additive replacing petroleum derived additives at a few percentages up, without any changes in current motors or

ii. as pure ethanol in adapted motors

Presently, with flex-fuel motors and electronic injection, any mixture of ethanol with gasoline is used and the mix is determined on the basis of the fuel price which since 2004 is fully competitive to gasoline, even after all subsidies - which had been required when the ethanol program started in the late 70's - had been removed.

Greenhouse gas emission in Brazil from the urban sector (excluding the deforestation contribution of Amazonia) has been reduced by 15%.

This leapfrogging strategy was developed entirely in Brazil but does not have to be restricted to this country; it could be replicated in many other tropical ones. Actually countries where sugarcane do not grow - which is the case of Japan - could import ethanol and use it in its gasoline consumption and thus reduce its greenhouse gas emissions.

One should be aware of course of the several problems that a large expansion of ethanol production from sugarcane could generate if proper measures and policies are not adopted.

These problems are being widely discussed today since ethanol production in the world has already reached the level of 1 million barrels of oil equivalent per day (approximately 1% of the world's oil production) and it is bound to increase substantially in the next few years.

The first of these problems is the amount of land used for ethanol production which could replace other crops and thus generate a conflict between fuel "versus" food. Just looking at the numbers will dispel such concerns. Ethanol production today uses 10 million hectares of land (half in Brazil, half in the United States) but the total agricultural area in use in the world is approximately 140 times larger (1,400 billion hectares) and there are still 800 million hectares of land suited for agriculture where many types of crops could expand.

Another concern that deals particularly with Brazil is that the expansion of sugarcane could reach the Amazonia region and lead to further deforestation. This is not taking place because sugarcane does not grow well in the very rainy conditions of Amazonia and also because the sugarcane expansion is taking place in degraded pastureland 10 million hectares of which only in São Paulo and 200 million hectares in overall Brazil.

One could wonder why it has taken so many years to materialize the expansion in the use of renewables. One of the reasons for that was the misconception that "new renewables" were significant only for small scale decentralized applications and that developing countries were used by industrialized countries as testing grounds (or "guinea pigs") for new technologies such as solar, wind and photovoltaics, primarily in isolated remote villages far from the electricity grid. Thus the false dichotomy was created i.e. that centralized application was for industrialized countries and decentralized solutions for developing countries.

For wind and photovoltaics, the solution to this problem came from Germany, Denmark, Japan and the United States which supported the wind and PV development by creating a large market for these products which the developing countries could not do with a small number of decentralized installations. In these countries, the wind and PV were linked to the grid solving thus the intermittency problem inherent in these sources. As production increased, costs decreased opening the way for the introduction of theses technologies in a large scale in developing countries mainly in China and India which have installed manufacturing industries in their countries. Other renewable energy sources using mature technologies such as minihydros to generate electricity as well as geothermal energy (for heat and electricity) are spreading fast in many Asian, Latin American countries, the Philippines and Indonesia and generally speaking they are economically competitive. Solar heating is a technology that really caught on in decentralized application, particularly in China.

A real understanding of the role of renewable energies in reducing poverty and contributing to the reduction of greenhouse gas emission was reached in the United Nations Johannesburg Conference in 2002 (World Summit and Sustainable Development) which marked the 10th anniversary of the adoption of the Climate Convention in Rio de Janeiro in 1992.

At the conference, the Government of Brazil presented a proposal - originated in my office of Secretary for the Environment of the State of São Paulo - to adopt a 10% target of renewables in the world's energy mix by the year 2010; in 2002 renewables represented only 3% of the world's energy matrix which meant that the contribution of renewables would have to contribute approximately an additional 1% per year in the 7 years between 2002 and 2010 which didn't seem unrealistic. The proposal was strongly supported by the European Union and many other countries but was not adopted due to the opposition of a few countries heavily committed to the use of fossil fuels. Nevertheless it strengthened the adoption of such targets by the European Union and many other countries in the world as well as some states of the United States of America.

Table 2
Some Policy Options to Speed-up the Diffusion of Renewables

- Rate-based incentives (e.g. feed-in tariff)
- Investment subsidies
- Renewable Portfolio Standards (RPS)
- Carbon tax
- CO_2 emission caps (plus tradable permits)
- Clean Development Mechanism
- and more…

Source: WEA, 2000

Status end 2005 (plus estimates for 2007):

- Countries with policy targets:	52 (66)
- States / provinces / countries with feed-in tariffs:	41 (46)
- States / provinces / countries with RPS policies:	38 (44)
- States / provinces / countries with biofuels mandates:	38 (53)

Source: REN21, 2007

Table 2 lists some of the policies adopted and their status in 2005 and estimates for 2007.

In terms of investments, renewables in 2007 represented approximately 150 billion dollars more than 10% of all investments in energy.

In conclusion, what I would like to convey is that the growth and development which are sought by three quarters of the world population outside of the OECD can be reconciled with the protection of the environment and that a sustainable development course is possible if the proper approach is adopted and benefited by the adoption of modern and non-polluting technologies.

I do not believe the energy future of mankind is set and immutable and that it is in our hands to shape this future.

Major Publications

Professor José Goldemberg

The role of biomass in the world's energy system J. Goldemberg - M. S. Buckeridge and G. H. Goldman (eds), Routes to Cellulosic Ethanol., DOI 10.1007/978-0-387-92740-4_1 Springer Science+Business Media, LLC, 2011.

Technological Leapfrogging in the Developing World J. Goldemberg - Georgetown Journal of International Affairs - Winter/Spring 2011 pp135-141.

Cancún: fracasso ou sucesso? - J. Goldemberg- Revista do Memorial da América Latina nº 41, 2011/2º trimestre pp58-61.

The decline of the world's energy intensity J. Goldemberg E Luiz Tadeo Prado - Energy Policy vol. 39 pp. 1802-1805, 2011.

News and Views: Perspectives for Nuclear Energy in Brazil After Fukushima Goldemberg, J., Sociedade Brasileira de Física SBF - Nuclear Physics - Edit. Springer 2011 DOI 10.1007/s13538-011-0027-0.

Has the situation of the Have nots improved? J. Goldemberg and Jannuzzi, M. Gilberto in publication.

Climate Change & Energy: Nuclear Power After Fukushima - Opinions Reality check shows nuclear energy is the wrong path Science and Development Network 28 September, 2011. http://www.scidev.net/en/climate-change-and-energy/nuclear-power-after-fukushima/opinions/reality-check-shows-nuclear-energy-is-the-wrong-path-1.html.

O future da energia nuclear J. Goldemberg REVISTAUSP
setembro/outubro/novembro catástrofes 2011 pp. 06-15.

Sugarcane ethanol: strategies to a successful program in Brazil Goldemberg, J Editor, Springer book project: Advanced Biofuels & Bioproducts.
James W. Lee, PhD Adjunct Professor Whiting School of Engineering Johns Hopkins University in publication.

Renewable energy options in developing countries Goldemberg, J. O, Lucon. - Making it - Industry for Development Magazine, number 2 pp. 16-18 - April 2010 - ISSN 2076-8508. http://www.makingitmagazine.net.

São Paulo: the other Brazil: Different Pathways on Climate Change for State and Federal Governments - J. Goldemberg, O. Lucon. The Journal Environment and Development 2010 DOI: 10.1177/1070496510378092
The online version of this article can be found at: http://jed.sagepub.com/content/19/3/335.

The decarbonization of e world's energy matrix. J. Goldemberg E Luiz Tadeo Prado - Energy Policy vol. 38 pp. 3274-3276, 2010. doi:10.1016/j.enpol.2010.03.040.

Defining a standard metric for electricity savings Environmental Research Letters Create an alert RSS this journal Issue Volume 5, Number 1.
Citation Jonathan Koomey et al 2010 Environ. Res. Lett. 5 014017doi: 10.1088/1748-9326/5/1/014017.

COP-15 em Copenhague: As Posições do Governo Brasileiro J. Goldemberg, Revista Interesse nacional, Ano 2, Número 8 janeiro-março, 2010 pp. 16-24. www.inteessencaional.com.

Copenhague: Um post mortem - J. Goldemberg, Revista Política Externa vol. 18 nº 4 Mar/Abr/Mai 2010 pp.15-24 ISSN 1518-6660 www.politicaexterna.com.br.

Are biofuels ruining the environment? - J. Goldemberg, Society of Chemical Industry and John Wiley & Sons, Ltd *Biofuels, Bioprod. Bioref*. 4:109-110 (2010); DOI: 10.1002/bbb.

Renewable Energy Sources abd Biofuels: The Brazilian Ethanol - S. T. Coelho, C. Brighenti & J. Goldemberg - Geographische Rundschau International Edition Vol.6 nº 4, pp22-27, 2010.

O TNP e o Protocolo Adicional J. Goldemberg Revista Política Externa vol. 19 nº2 pp.115121 Set/Out/Nov, 2010.

Renewable Energy, Energy Efficiency and Emissions Trading J., Goldemberg, Harnessing Renewable Ebergy in Electric Power System, Theory, Practice, Policy Edited by Boaz Moselle, Jorge Padilla and Richard Schmalensee - ISBN 978-1-933115-90-0 Chapter 6 pp.94-110, 2010.

Renewable energy options in developing countries Goldemberg, J. O, Lucon. - Making it - Industry for Development Magazine, number 2 pp. 16-18 - April 2010 - ISSN 2076-8508 http://www.makingitmagazine.net.

As perspectivas Brasileiras no Controle de Materiais Nucleares - Mafra, O., Alvim F. C. and Goldemberg, J. - International Panel on Fissile Materials - IPFM Spring 2009 Workshop on Fissile Materials and Nuclear Disarmament - Princeton, May 8-10, 2009 publicado em Revista Economia e Energia nº 73 ano XIII abril/junho 2009 pp.20-31 - ISSN: 1518-2932 - http//ecen.com.

O uso de carvão vegetal na indústria siderúrgica brasileira e o impacto sobre as mudanças climáticas Uhlig, A., Goldemberg, J., T. Coelho, Suani, - Revista Brasileira de Energia, Vol. 14, nº 2, 2º Sem. 2008, pp. 67-85, 2009.

The potential for first-generation ethanol production from sugarcane Goldemberg, J. and P. Guardabassi - Published online in Wiley InterScience.
(www.interscience.wiley.com); DOI: 10.1002/bbb.186 *Biofuels, Bioprod. Bioref.* (2009).

Renewable Energy in Latin America and the Caribbean Goldemberg, J. - Energlac Magazine, Year 1 nº 1 pp. 15-17 - OLADE october 2009 ISSN: 1390-5171. http://www.olade.org.

The Brazilian Experience with Biofuels. - J., Goldembergb Innovations. Fall Volume 4, issue 4 pp 91-107 2009. http://mitpress.mit.edu/innovations/.

Nuclear energy in developing countries - J., Goldemberg - Dædalus Fall 2009 Issue 138 pp. 71-80, http://www.mitpressjournals.org/toc/da7ed/138/4.

The Sustainability of ethanol production from sugarcane Goldemberg, J. T. Coelho, Suani and Guardabassi, P. Energy Policy 36 pp 2086-2097, 2008.

Are biofuels a feasible option? - Goldemberg, J., P. Guardabassi - Energy Policy 37 (2009) 10-14 .

Iluminando o caminho: um sistema energético sustentável - Goldemberg J. Nossa America - Revista do memorial da América Latina nº 29 - pp. 58-62 2008.

The challenge of biofuels - Goldemberg, J. - Energy & Environmental Science Sci., 2008, Vol.1, Nº 5 523-525 DOI 10.1039/b81417a, 2008 - Royal Society of Chemistry.

The Brazilian biofuels industry - Goldemberg, J. Biotechnology for Biofuels 2008, 16 DOI 10.1186/1754-6834-1-6 - This article is available from: www.biotechnologyforbiofuels.com/content/1/16.

Sustainable Biofuels Redux - Goldemberg, J. et al - Policy Forum Science vol. 322 pp.49-50 october 2008.

Pumping Renewables - Goldemberg, J. Pressure Point TWAS Supplement to Nature Publishing Group A World of Science in the Developing World p. 26-27, 2008.