2008

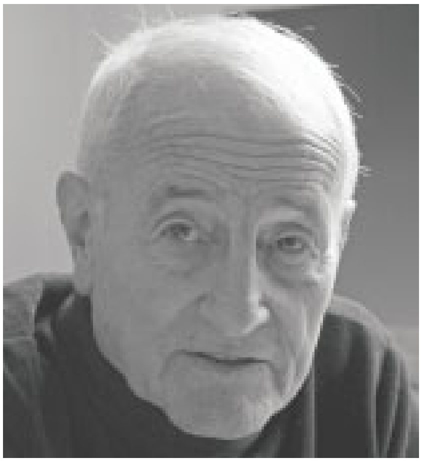
Blue Planet Prize

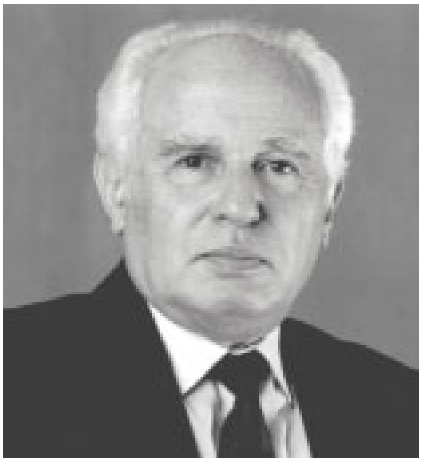
Dr. Claude Lorius (France)

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

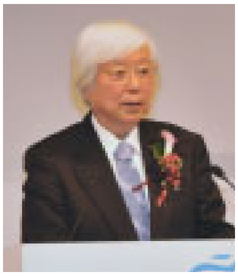
Selected from the Slide Show Presented at the Opening of the Awards Ceremony

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

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.

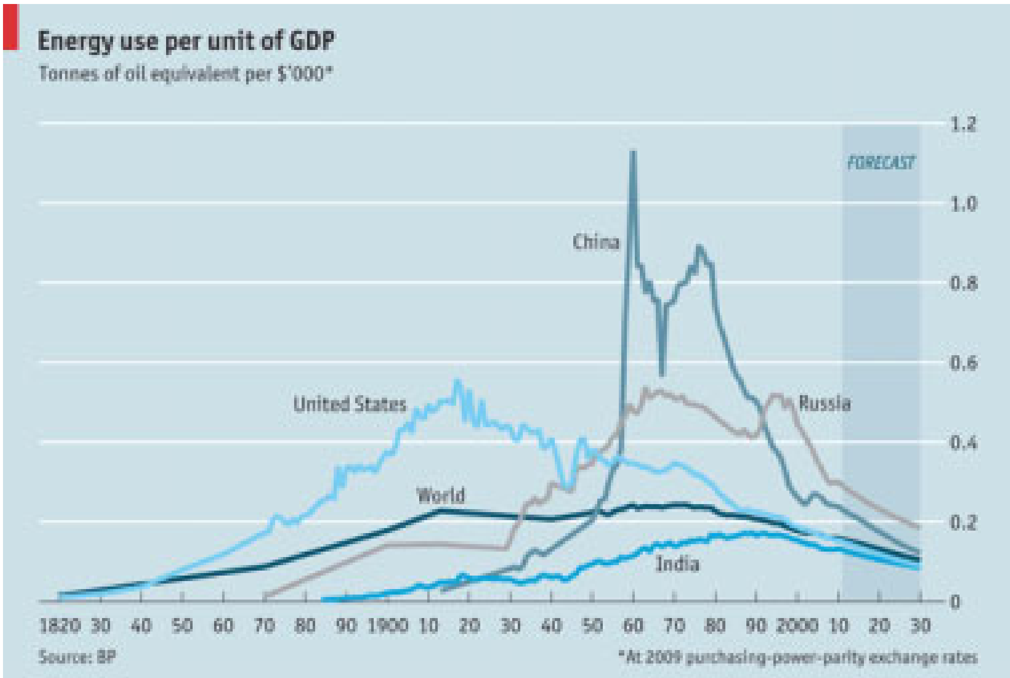


Figure 1

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]

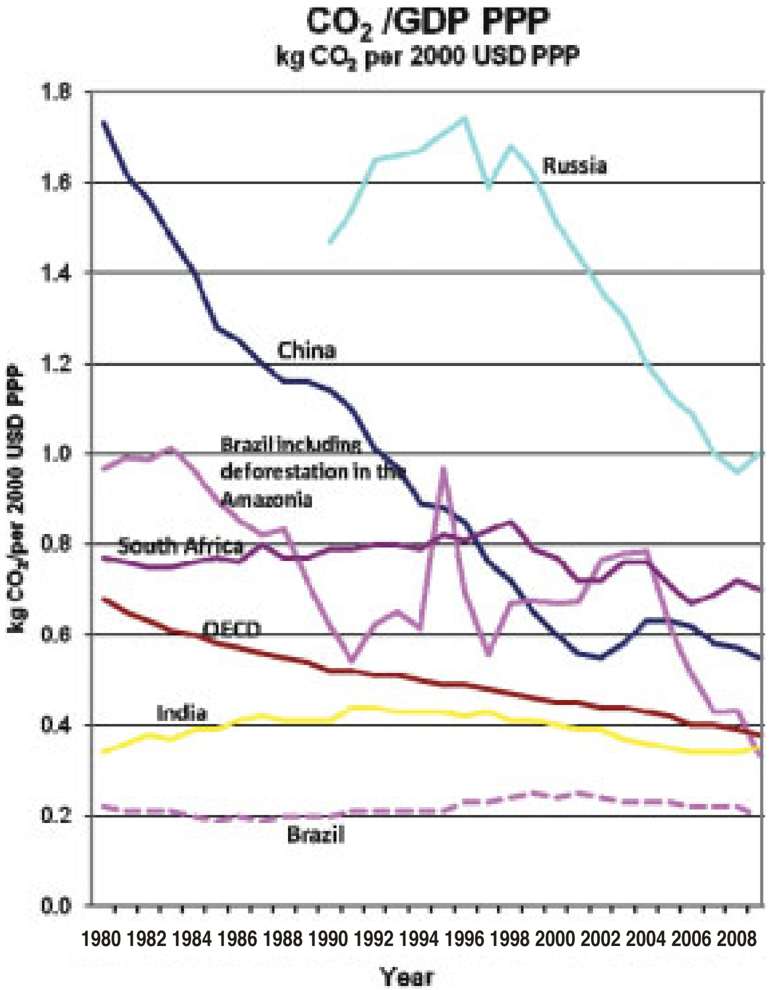


Figure 2

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)

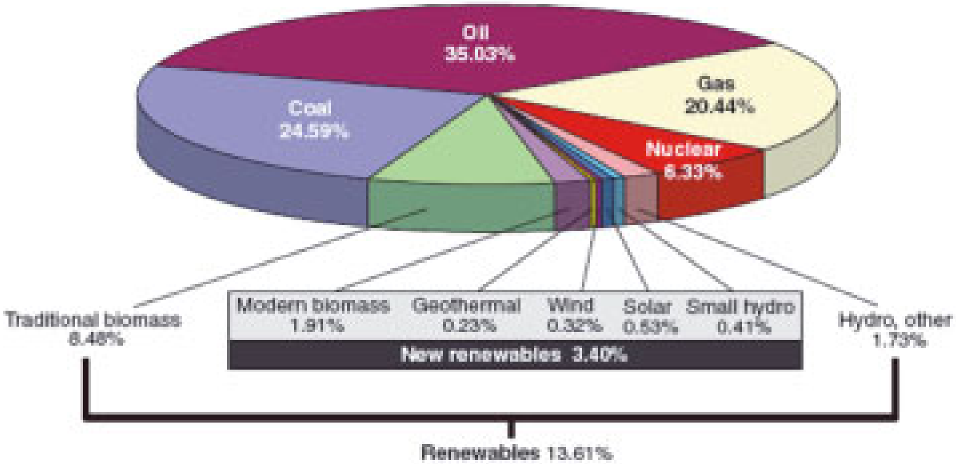


Figure 2
World Primary Energy Supply (2004)
(shares of 11.4 billions tons of oil equivalent)

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.

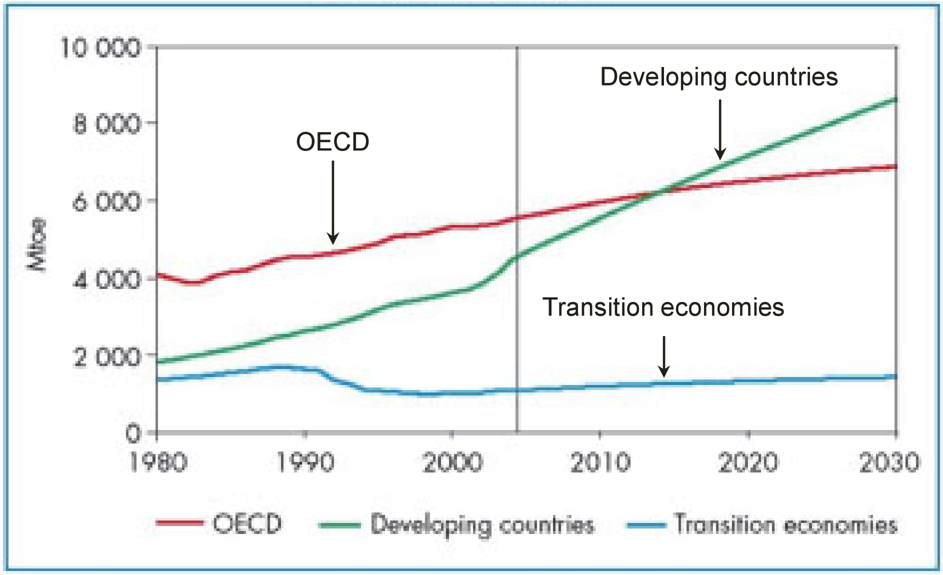


Figure 3
Projections of the Energy Consumptions until 2030

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.

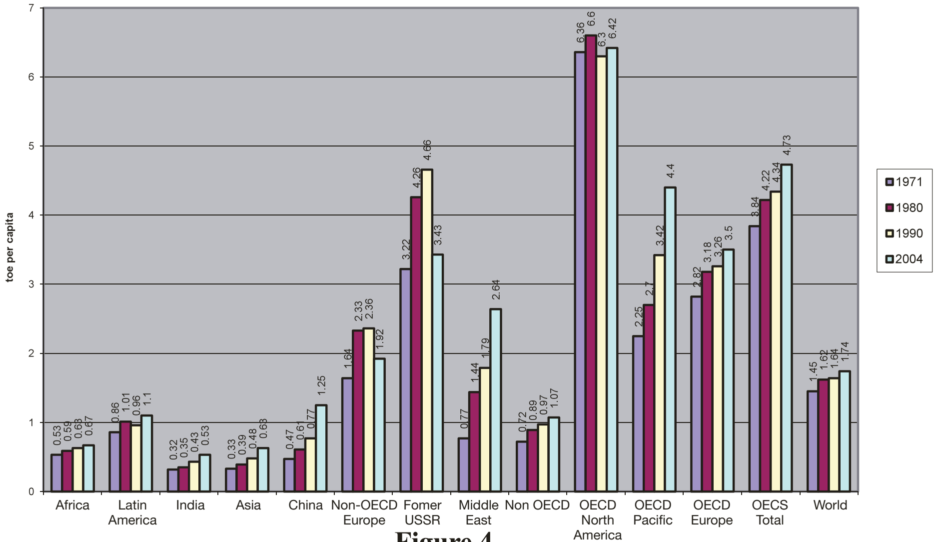


Figure 4

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.

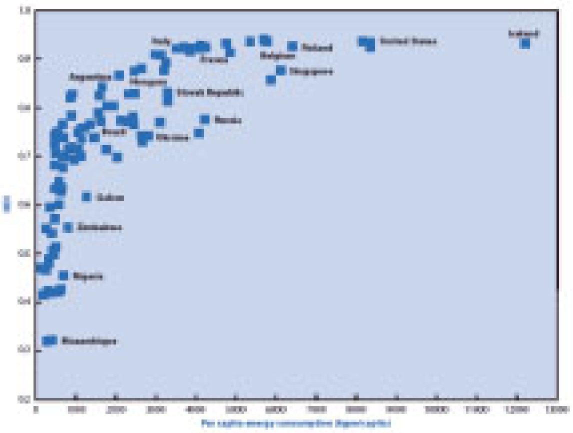


Figure 5

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.

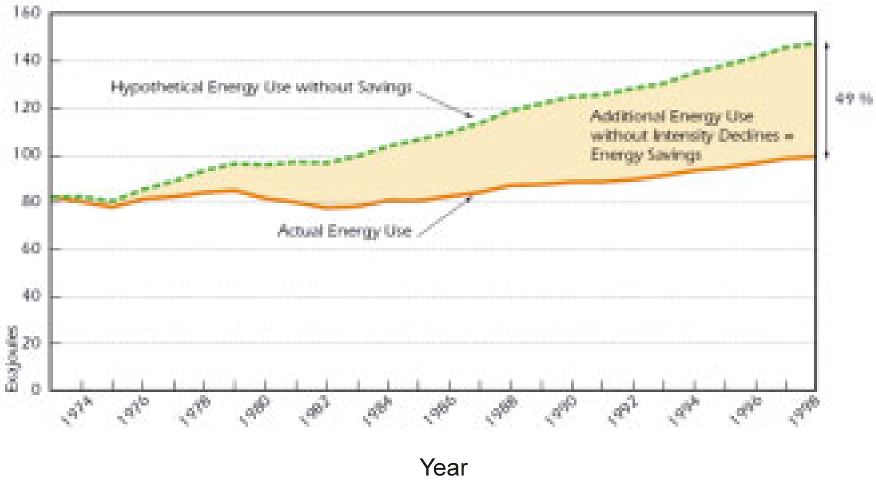


Figure 6
Energy Economy in the OECD (1973 - 1998)

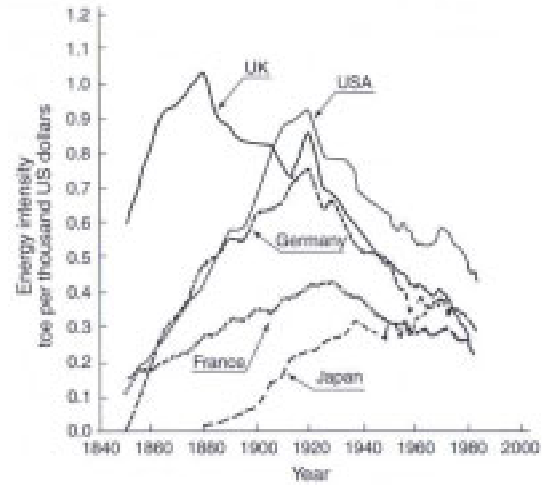


Figure 7

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)

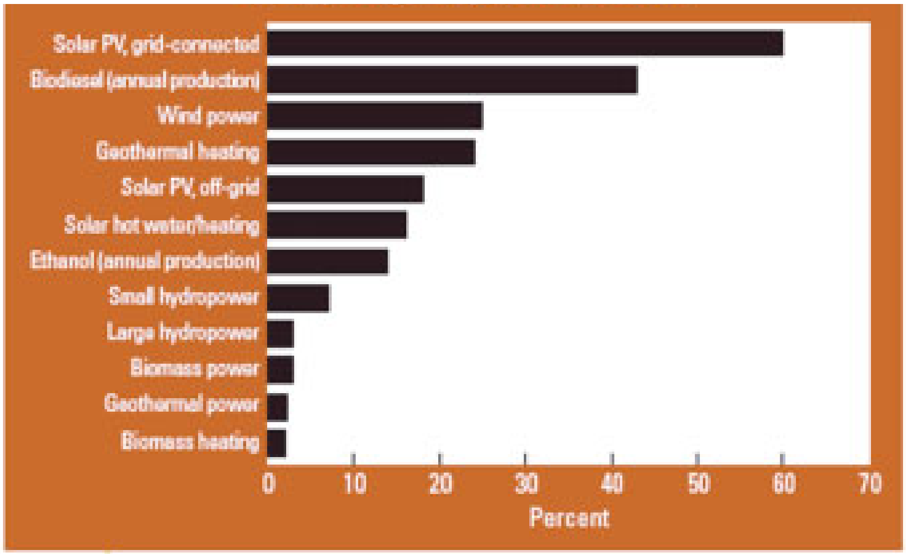


Figure 8
Average Annual Growth Rates of Renewable Energy Capacity, 2002-2006

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

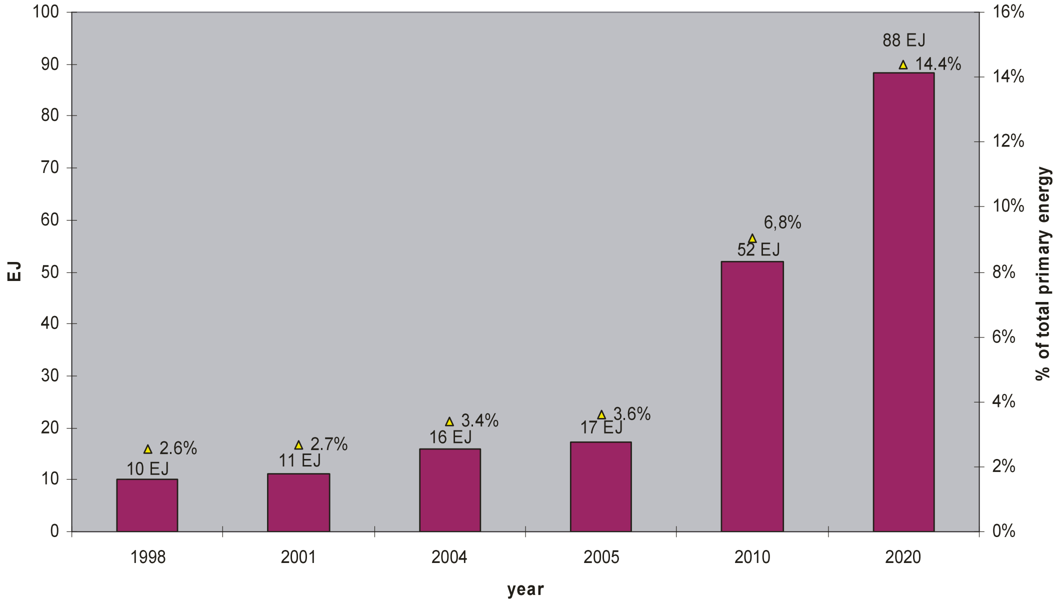


Figure 9
Modern Renewables
(including small hydro, excluding large projections for 2010 and 2020 based on growth 2001-2005)
(REN21 and WEA 2004 Update)

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)

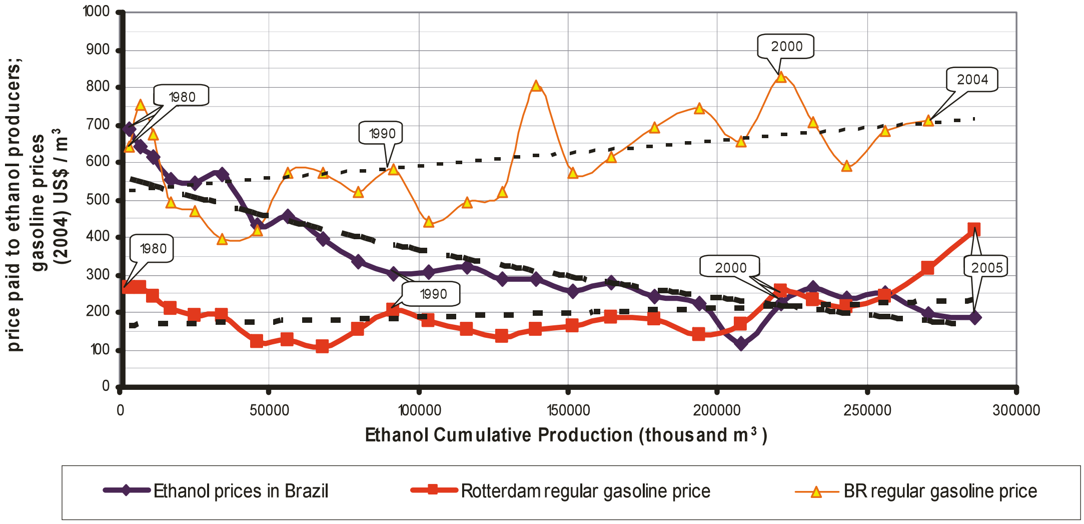


Figure 10
The Economic Competitiveness of
Alcohol Fuel Compared with Gasoline

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.