

# CHAPTER 3

---

## *PART I* *THE SCENARIOS AND THE ADVANCED* *MATERIALS*

*Sarita Albagli and Carlos C. Peiter*  
*CETEM/CNPq*



---

### ***3.1 THE SCENARIOS AND THE ADVANCED MATERIALS***

#### ***THE MATERIALS AND THE SCENARIOS***

Starting from the general features that distinguish Scenarios I and II discussed earlier, the following are presented: (1) an overview of the meaning, for the materials field, of the different dimensions considered important for evaluating the development style adopted, going into more details for Scenario II, because it represents a more sweeping change in comparison with current tendencies; (2) an introduction to the sectorial approach, through which the repercussions of the two scenarios on the demand for Advanced Materials in Brazil are analyzed (analysis by materials consumer sectors).

#### ***The materials and the dimensions of development sustainability***

The materials role in industrialized societies is fundamental, because they are the intermediate goods that compose the structures and products (components, pieces and final goods), by which industrial processing, consumption and the discarding of goods are materialized. This means that any revision of the development models prevailing until now would imply a substantial alteration in the production standards and of materials utilization.

Broadly speaking, according to the Brundtland Report, a sustainable development scenario would call for “a change in the growth content, so as to make it less intensive in raw materials and energy and more equitable in its impact”.

It should be considered in this analysis that the quantity of materials consumed, even if it might give indications about the impacts produced on the environment, does not say everything about its contribution to social welfare. What is fundamental is to appraise the uses and applications of the materials, as well as the quality with which they carry out such functions. As aptly exemplified by Young (1991, p. 65), “a kilo of steel can be used in a building that lasts hundreds of years or in several cans that end up in a garbage dump right after being used only once”.

Furthermore, in the same way as in the general plan, in the specific field of materials, important differences have come to light among the developed and peripheral countries <sup>40</sup>. These differences must be taken into account in future strategies for the materials sector.

---

<sup>40</sup> See S. Albargi. Strategic and geopolitical elements of the recent evolution of materials. Rio de Janeiro, CETEM, 1992.

The consideration of the **social dimension** of materials, in Scenario II, makes it imperative to give priority to materials that meet the demands of the greater part of the population in a given society. Evidently, this will vary in time and in space, according to the degree of attention to basic necessities and the consumption standard attained by each societal formation. While in the peripheral countries, structural shortages persist in terms of housing, health and food, in the developed countries these shortages have been largely remedied and the average standard of demand for goods is much more sophisticated. This means that the list of priorities for the production and use of materials is different among those countries, which also applies to the profile of jobs generated by the economic activities on that list.

On the other hand, in Scenario I, the technological development of the materials is essentially directed toward even more selective and sophisticated consumer markets, which are attended and formed from jobs generated for highly specialized labor. It is therefore part of a system which is intrinsically excluding in its social dimension.

The **economic dimension** of the materials is also manifested differently in more and less developed countries: the availability of manufactured materials and of energy per capita in the developing countries is on average 100 times less than in the developed countries. Furthermore, the cost differential in the selection of the materials (traditional X advanced) has a much higher weight in relation to the income of the poorer countries. This means that there are market conditions that restrict the introduction of new products and new materials in such countries.

In Scenario II, the economic dimension is closely related to the social dimension, in the sense that in that scenario, the macrosocial criterion must prevail over strictly economic logic. In this case, therefore, the question of the cost of the materials is important, not only from the business point of view (maximizing profits), but it is also essentially related to the mass of the population's access to the products that incorporate them.

Another important economic aspect is the repercussion of materials production on the generation of jobs. These features raise important questions for technological strategies, according the technological advance of materials has been accompanied by an immediate rise in costs and less intensive labor in their production <sup>41</sup>. If, on the one hand, the initial tendency of growing costs is reverted through technological diffusion, on the other, at medium and long terms, the job question persists and, there is an additional requirement for more professional qualifications, besides less generation of direct employment, so the labor profile is altered.

In Scenario I, emphasis is put on materials designed for increasing competitiveness in the external market. The innovations, as the mainspring of such

---

<sup>41</sup> See H.V. Medina and L.A.A. Reis. Minerals and advanced materials: economic implications of the new paradigm. Rio de Janeiro, CETEM, 1992.

international competitiveness, have their rhythm conducted by the logic of the market, and involve all and any technological advance in production, from raw materials to new methods of managing production (flexibility).

The **ecological dimension** of the materials, in the two scenarios, is bound to such factors as<sup>42</sup> :

- availability of natural resources necessary for their production;
- quantity of energy required for production or for material and product recycling as well as the energy lost in the process;
- quantity and toxicity of tailings, the degree of difficulty of treating such tailings and the possibility of making use of them;
- toxicity, durability and possibility of recycling the end product.

The answer to the environmental problems and challenges imposed on the materials sector, if healthy environmental development is to be achieved, depends on solving such problems. This goes from production up to the consumption and discarding of materials and the objects they are made. That is: how to handle materials originating from renewable sources more rationally expanding the possibility of replacing faster than the rate at which such resources are used; how to maximize the use of resources originating from exhaustible sources; how to attenuate the environmental impact of the extracting process and raw materials processing and how to reduce the quantity and toxicity of the waste produced in discarding.

In the case of mining, some developments directed toward the environmental issue have been occurring, such as:

- reworking mines already opened, to extract residual ores and metals in such deposits, through technological development;
- developing and improving methods that are less harmful to the environment, such as biohydrometallurgy, involving for example: bacterial leaching, including in low content ores and/ore mining tailings; and the recovery of heavy metals from liquid effluents;
- developing environmental engineering for treating tailings;
- developing recycling methods.

On the other hand, a change in the materials consumption standards has been noted in developed countries, due to changes in their technical-industrial base, such as: a decline in the intensity of use of certain materials and ores; the substitution of materials that are more intensive in exhaustible resources with materials that are less intensive in such resources; and more rational use of materials in general, particularly through recycling.

In the peripheral countries, the low consumption of materials is not due so much to the impacts of technical and scientific progress, but mostly to their specific socioeconomic situation, which is strongly marked by their populations' low

---

<sup>42</sup> See T.R. Andrade, *Environmental Aspects of Materials Production*, Rio de Janeiro, CETEM, 1992.

purchasing power. The question with regard to such countries is: how to meet their basic social and economic needs, without increasing pressures on natural and energy resources and the environment in general? Scientific and technological strategies are fundamental for dealing with this issue. In Scenario II, the efforts of science and technology should be guided by policies capable of extending their benefits and preventing environmental and social impacts on the broader portions of the population. In Scenario I, on the other hand, the environmental concern with materials is predominantly corrective and confined to the impacts on the equilibrium of the planet's physical environment.

The **cultural dimension** with regard to materials, in Scenario II, has a double meaning: (1) Modification of behaviors and mentalities, at the levels of the Government, the business sector and society in general, to persuade them to adopt new standards of use and consumption of materials, which include concern over environmental and social issues. (2) Achieving compatibility between the local "materials culture" and advances made in this field, worldwide. That is, creative absorption of technological development in the field of materials, at a global level, with emphasis on making better use of local natural resources, and enhancing endogenous scientific and technological and industrial capability.

In the developed countries, most of the effort should be focused on solving the first aspect, considering that keeping up the current rate and style of consumption of the well-to-do economies cannot be considered environmentally sustainable. This transformation is all the more important considering that the technical and scientific culture prevailing today in the world originates in such countries, which are the privileged *locus* of the advanced production of scientific and technological knowledge in general, and of materials in particular.

The peripheral countries, in their turn, will have to revert the historically predominant tendency to adhere to imported cultural standards, and achieve a synthesis between "modern" (usually coming from abroad) and "traditional" (local).

In Scenario I, the agenda of priorities in materials is established from the consumption standards prevailing in the developed countries, which are imposed on the other countries by the globalization process.

The **spatial dimension**, in Scenario II, will be reflected in the rational and balanced distribution of activities related to materials, inside territories, starting from the conditioning factors established by the other dimensions. Here the world, national, regional and local scales must be considered, insofar as they are realities that are differentiated but equally important. This means the end of such practices as: exportation of ventures that pollute or have a strong environmental impact for politically fragile regions; the spatial concentration of human and financial activities and resources; the pure and simple overlapping of macrospatial (world) parameters on microspatial (local) parameters.

In Scenario I there is concentration and spatial specialization of activities in materials ranging from R&D to innovation in final production, on national and international levels.

Finally, it is the **political-institutional dimension** that will offer the conditions for the other dimensions to take shape on the internal and external levels. As already indicated earlier, it will be necessary to coordinate efforts and, particularly, interests between the different players taking part in the materials sector, to be able to implement sustainable development in this field. And also, as a result of this coordination between players, it will be necessary to build up a firm institutional base here in Brazil and abroad, to see that the desired goals are attained: systemic coordination between long-term government policies, guided by sustainability parameters. All these measures will have to be followed up by policies and measures in the educational field and in training human resources, which are essential for development and for absorbing a new technological standard on sustainable bases.

In Scenario II, legislation should be prepared that will foster generation, industrialization and dissemination, particularly to needy areas related to complexes considered as deserving priority, and also to encourage technology transfer agreements between Brazilian and foreign companies as a way of bridging the technological gap. Special attention should be paid to barriers obstructing the transfer of technology held by the private sector and to the adoption of appropriate general measures for breaking down such barriers. A series of measures should be planned for encouraging the technologically more advanced countries to transfer technology on non-commercial bases, to countries whose technical and scientific base is less developed, as well as the purchase of patents held by the more advanced countries by the less developed countries, such as: legislation restricting the utilization and production of materials that have a strong environmental impact, and that fosters development and the transfer of environmentally suitable technologies in that field<sup>43</sup>, and financing and incentives systems that promote and make the proposed aims feasible.

For this purpose, legislative and executive bodies should pay special attention to the industrial property code and to legislation governing technology transfer agreements. Cooperation between Brazilian and foreign companies and universities and companies, as well as research partnerships should be encouraged. To this effect, legislation will have a leading role in creating legal ways of achieving such objectives.

This process of adapting legislation to government policies related to the new materials is called "institutionalizing modernization". In Scenario I, where the control of the technological development process and of dissemination of materials

---

<sup>43</sup> See M.L. Barreto. The industrial property system in the institutionalization of the new technological and industrial standard, Rio de Janeiro, CETEM, 1992.

is held by the developed countries, this internal process must be tuned to the international process in the growing standardization of certain criteria and basic principals which would point the way to a harmonization of local legislations through conventions and agreements. The standardization would occur in areas in which the political and, consequently, overall juridical commitment, would play a key role. The environmental area itself could be mentioned, and that of the generation and transfer of technology. This harmonization of legislations would have to be done at the universal, regional and subregional levels, taking into account the various degrees of development of the countries and their specific features. In this aspect, and particularly, in the case of Scenario II: priorities and obligations must be defined, particularly in the areas listed above, so that they will support and provide the developing countries with access to the transfer of technology, broadly speaking, such as environmental technologies and also their management<sup>44</sup>.

The chart III.1 shows a synthesis of these different dimensions and of how they are related to the materials field, in each of the scenarios.

**Chart III.1 The Scenarios and the materials: Macro Dimension**

SCENARIO I	SCENARIO II
<b>Social Dimension</b>	
Emphasis on materials intended for increasingly selective and sophisticated consumer markets, and highly specialized jobs.	Emphasis on materials intended for meeting social needs and generating accompanied by training local labor.
<b>Economic Dimension</b>	
Emphasis on materials intended for increasing competitiveness in the external market.	Emphasis on strategies for materials that produce a positive effect on earnings and employment.
<b>Ecological Dimension</b>	
Emphasis on substituting materials that are scarce in the developed countries.	Emphasis on materials based on renewable and/or abundant resources, according to the availability of local natural resources.
<b>Political-institutional Dimension</b>	
Technological control by the developed countries	International technological cooperation in the materials field.
<b>Cultural Dimension</b>	
Materials based on consumer standards imposed by the globalization process.	<ul style="list-style-type: none"> <li>- Materials based on the endogenous natural and mineral reality;</li> <li>- Materials based on endogenous S&amp;T and business experience/capability;</li> <li>- Materials intended for the local consumption standards</li> </ul>
<b>Spatial Dimension</b>	
Spatial concentration of activities on materials	<ul style="list-style-type: none"> <li>- Materials that can be processed locally;</li> <li>- Regional coordination in the materials;</li> <li>- Balance in the territorial distribution of activities in materials (at international and local levels).</li> </ul>

<sup>44</sup> Quotations taken from the United Nations Conference on Environment and Development. Report of the Brazilian Delegation, 1992 - IPRI - International Affairs Collection - N. 16.

### ***The Demand for Advanced Materials in the Alternative Scenarios: Introduction to the Sector Approach***

A methodology involving case studies of selected sectors was used for identifying the demand for materials, as well as to indicate opportunities for advanced materials in Brazil.

These studies began with a definition of the sectors, their prospects of recent evolution, and made an evaluation of their demand for materials. Lastly, they sought to enumerate those that would be the most prominent in light of the scenarios considered by specialists of each sector studied.

The participation of specialists was achieved through interviews, which followed a standard script, and involved a total of 15 among technical staff of companies or researchers of universities or research centers (see appendix 3).

When choosing the sectors to be studied, information was sought on the situation and prospects of industrial complexes that seemed most important in view of the conditioning factors established for alternative scenarios used in this project.

The sectors chosen have at least two features in common. The first is that they depend on materials which embodied a great deal of technology, which are significant either in volume or due to their high value, and strategic technological field of action. The second lies in the strategic nature they have for Brazil in the dimensions considered in the scenarios used, which are: social, economic, environmental, technological and political-institutional. Working along these lines, the following industrial sectors were given priority for making case studies:

- 1. Energy**
- 2. Transportation**
- 3. Microelectronics and**
- 4. Telecommunications**

The first two have an intrinsically infrastructural nature. They have direct impacts on society and the environment, they use up a large amount and variety of materials and, by and large, benefit from innovations developed in other sectors. The latter two show an enormous capacity for innovation and technological diffusion of products, processes and materials, which are disseminated through other sectors by means of the goods and services they offer.

Based on the profiles of these sectors with respect to Scenarios I and II, on one side national capability is noted at a technological and industrial level, and a current situation of supply side is presented and, on the other, the potential and future demand of each sector is projected.

Lastly, these two sides are compared by groups of materials, according to the main fields of application of advanced materials in the sectors studied, and then an analysis is made of the essential points in each of the alternative sustainable development scenarios for Brazil.



# CHAPTER 3

---

***PART II***  
***THE ENERGY SECTOR: THE SCENARIOS AND***  
***THE ADVANCED MATERIALS IN BRAZIL***

*Bruce B. Johnson, Carlos C. Peiter, Heloisa V. Medina,*  
*Ivan C. Marques, Maria Laura Barreto,*  
*Sarita Albagli and Teresinha R. Andrade*  
*CETEM/CNPq*



---

## ***3.II THE ENERGY SECTOR: THE SCENARIOS AND THE ADVANCED MATERIALS IN BRAZIL***

### ***INTERNATIONAL TRENDS***

Energy generation and use feature widely on agendas for international discussions today, reflecting society's concern with energy resource availability, consumption patterns and related environmental impact. Important developments that mark the present include:

a) a transition in the structure of the primary energy supply matrix, from predominance by oil (and the OPEC cartel) towards a diversity of energy sources;

b) globalization of the approach to environmental issues, with especial attention to the intensifying greenhouse effect<sup>45</sup> and possible climatic changes due to global warming, as opposed to dealing with local problems (e.g., urban fog) and regional problems (e.g., acid rain); and

c) energy prices holding steady at relatively low levels - a situation which should continue to a long-term horizon of around 20 years due to increasingly efficient production processes, the emergence of information-intensive processes (as opposed to energy- and materials-intensive processes) and considerable technological development (and thus cost reduction) at all stages of the cycle of energy exploration, production, transport and use.

At the more general level, activities in the energy sector at the end of the century are marked by two major trends, efficiency and diversification. The former includes programs seeking greater energy generation efficiency and reduction of losses in transmission, distribution and use systems. The latter includes research and development into new, alternative and preferably renewable energy sources. In both, new materials can make a decisive contribution to improving performance by present systems and in making new technological solutions technically and economically feasible.

Reflecting these concerns, expectations for consumption growth up to 2015 differ by energy source and by the scenario chosen. The following discussion of how each energy source will evolve takes as its point of departure the position defined by the present global energy matrix, shown in Table III.1.

---

<sup>45</sup> The greenhouse effect is caused by the emission of gases, chiefly CO<sub>2</sub>, CFH and CH<sub>4</sub>, into the atmosphere, preventing the escape of infrared radiant energy emitted by the Earth and thus raising the temperature at its surface. The main causes are fossil fuel combustion and large scale deforestation.

**Table III.1 - Participation in the Global Energy Consumption Matrix by Source - 1990**

SOURCE	%
Oil	32
Gas	20
Coal	26
Nuclear	5
Water	6
New Renewables	2
Traditional Renewables	9
Total	8.7 x 10 <sup>9</sup> OTE

Source: 15th Congress of the World Energy Council, 1992.

In Scenario I, natural gas consumption levels should rise most, displacing coal and oil, as a result of international efforts to cut emissions of air pollutants and the prospect that known reserves, which nearly doubled over the last decade, will expand further, according to data in Table III.2.

**Table III.2 - Proven World Natural Gas Reserves\***

Region	1980	1990
North America	8.0	7.5
Latin America	4.3	7.5
Western Europe	3.9	5.7
Eastern Europe	26.5	53.4
Africa	6.1	8.6
Middle East	18.1	37.8
Asia and Oceania	4.9	11.2
Total	72.2	131.7

\* trillion m<sup>3</sup>

Source: Cedigaz, 1991, see Rodrigues, M.G.: "Uma Revisão de Estratégias e Uso de Gás Natural" in Anais do VI CBE, 1993.

Average participation by natural gas in the world energy balance is 21.6%, while percentage participation is highest in the former USSR and Canada, at 42.2% and 32.0% respectively, as in Table III.3.

**Table III.3 - Natural Gas in Energy Balances - Primary Energy Demand (%)**

Country	1980	1990
Canada	21.9	32.0
USA	26.8	24.8
EEC	17.4	18.5
Belgium	19.5	16.5
Spain	2.2	5.5
France	11.7	12.2
Italy	17.2	25.3
Germany	16.5	17.5
Great Britain	20.0	23.1
Ex-USSR	26.5	42.2
Japan	6.0	10.4
Total	17.8	21.6

Source: Cedigaz, 1991, see Manoel Gonçalves Rodrigues, op.cit.

In this scenario, consumption of oil and coal, the traditional sources, grows less steeply but their participation continues to follow the logic of natural resource use controlled by large international groups, and of investment in the existing structure for the production and consumption of petrochemical fuels and derivatives, installed according to internationalized standards.

Of total oil reserves, 80% is concentrated in 8 countries, and oil accounts for 32% of world energy consumption through a refining and distribution structure controlled predominantly by 7 private firms and, more recently, by state enterprises in producer countries<sup>46</sup>.

Use of coal will continue to be justified by the long availability horizon of reserves and by consumption for thermoelectric generation. In the USA alone, nearly 60% of electric power generation is coal-fired. Of total world coal production, 60% is destined for electricity generation, 25% for iron and steel and the rest for industrial and residential use. As concerns demand by the iron and steel industry, despite a strong tendency towards increasing use of the direct reduction process, 75-85% of the steel produced in the world still follows the blast furnace/converter route; that is, using coke.

<sup>46</sup>The "seven sisters": Exxon, Royal Dutch/Shell, British Petroleum, Mobil, Chevron, Texaco and Atlantic. Producer country state enterprises: Saudi Aramco, PDVSA e Pemex.

Growth in use of renewable energy sources is thus less intense. Although these have far lower environmental impact, specially as regards emission of greenhouse effect gases, they - particularly wind and solar sources - are less readily adaptable to blanket models of production and consumption. Even investment in hydroelectricity is likely to favor incremental-type innovations, such as modernization of existing plants and transmission lines.

Investment in new nuclear power installations is being limited by the risks, technological bottlenecks and social pressures involved, principally in European countries. In countries like Japan, however, future energy demand will be met primarily by dozens of new plants within a 15-year horizon.

In this scenario, the tendency to diversification does not favor alternative energy sources, thus maintaining the present ranking led by non-renewable sources. The most striking trend in Scenario I is the drive for greater efficiency in existing power generation systems, associated with reductions in transmission and distribution losses. There is also great emphasis on energy conservation programs, extending from generation through to final consumers, and ranging from equipment and process development through to encouraging energy end user consciousness.

In Scenario II, the composition of the energy matrix results from policies grounded on decentralization and the exploitation of regional comparative advantages. The overall trend towards rationalization in power generation and use would thus be reinforced here by the use of renewable sources, by integrating power generation units with production systems and by exploiting the potential for power cogeneration.

Biomass shows a more marked tendency to growth than the other sources because of the diversity and scale of its potential applications, besides its simultaneously meeting the requirements of environmental preservation, utilization of agro-industrial waste and power cogeneration.

For the other renewable energy sources, expectations are for growth to greatly surpass present rates in response to environmental constraints and flexibility in terms of scale of production. Of these, water resources command a technological structure capable of meeting more immediate energy consumption demands. Even in countries where the potential of these resources was considered exhausted, new technologies are enabling the capacity of thousands of small, old installed plants to be expanded by using modern turbines and rearranging plant layouts. At present, small hydroelectric plants in six European countries<sup>44</sup> account for 5,632 MW of installed capacity - equivalent to six nuclear plants in the 1,000 MW range. There is potential for these plants' capacity to reach 9,000 MW or more.

Utilization of solar and wind energy tends to expand precisely because they are better suited to small-scale consumer systems, involve lower environmental impact and because costs per installed kWh are being steadily reduced by recent technological advances. Use of wind energy was widely encouraged in the period following the oil crisis, but today is still unattractive for large scale power

generation. Technological developments in turbines and rotors continue, however. Solar energy is being harnessed via the small number of 0.1 to 8.0 MW range photovoltaic converter plants that exist in the world, at an average price of US\$1.16/kW. There are also experiments in centralized generation of large blocks of energy via photovoltaic conversion, but under these conditions, the cost of the energy is still prohibitive compared with conventional options. In particular, it forfeits one of its chief advantages, that of dispensing with transmission and distribution networks.

It is still expected that consumption of natural gas as fuel and for electric power generation will increase. Decisions in this direction will meet the criteria of regional availability of such fuel materials and opportunities for energy production in association with other sources.

Finally, as non-renewable resources and producers of greenhouse effect gases, oil and coal will be gradually replaced by other energy sources, except in regions so well-endowed with these resources and the related infrastructure for exploiting them as to justify their use. Oil's priority use in motor vehicles, particularly, will be discouraged by policies in favor of electric or other urban public transport systems and favoring more efficient, less energy-demanding cargo transport.

### ***Recent Developments and the Present Situation of the Brazilian Energy Sector***

In 1992, Brazil generated 213,070 GWh gross electric power and had installed capacity of 49,020 MWh. Even today, power generation is principally hydroelectric, accounting for 95% of gross electric power, and oil-derivate fueled. Brazil's potential energy sources can be listed as follows:

Non-renewable	Renewable
Oil	Water
Natural Gas	Firewood/Charcoal
Coal	Sugarcane and Derivates
Uranium	Other Biomass
	Solar and Wind

In constructing future energy production and consumption matrixes - besides considering energy sources available to Brazil at the overall and regional levels, and also future trends suggested by in international agendas - one cannot disregard the sector's evolution in the past.

The evolution of the energy sector both influenced and was influenced by structural changes in the economy. Brazil's increasing industrialization over the last 30 years was marked by intensive use of energy. Energy efficiency indicators testify to the importance of energy-intensive industries, such as aluminum, iron and steel and chemicals in the economic growth model that was adopted. Between 1970 and 1990, total industrial energy consumption and electric power consumption both grew more than proportionally in relation to the value of industrial production obtained, as shown in Table III.4.

On the grounds that Brazil has concluded its basic industrialization and also that technological advances have made industry more energy-economic at the international level, it is to be expected that, over coming decades, the development process will entail less growth in energy intensity, at least as regards its most significant component, industrial consumption.

**Table III.4 - Energy Efficiency Indicators**

	1970	1980	1990
Total Industrial Energy Consumption / Industrial Production (*)	0.671 OTE /thou.US\$ <sup>47</sup>	0.564 OTE/thou.US\$	0.765 OTE/thou.US\$
Industrial Electric Power Consumption / Industrial Production	0.619 GWh/thou.US\$	0.756 GWh/thou.US\$	1.294 GWh/thou.US\$

(\*) Oil Ton Equivalent (OTE) - equivalent quantity of energy contained in 1.0t of oil . 1 OTE=44 GJ.  
Source: Balanço Energético Nacional e Conjuntura Econômica. Taken from "Eficiência Energética Global" by Pinhel A.C. da Costa and Navegantes M.S.R. Lúcia, Anais do VI Congresso Brasileiro de Energia, vol.III pp 953-958, 1993.45

Meanwhile, according to data from the IBGE Anuário Estatístico 1992, 12% of residences in Brazil are still without electricity. Of this total of residences without electricity, 2% are urban and 45% rural. Added to this, there is a housing deficit - acknowledged to be high, though not officially measured - which may affect something close to the 32 million people considered as below the poverty line by the "Programa Nacional de Segurança Alimentar" (National Food Security Program). This introduces into the energy debate the condition that energy be

<sup>47</sup> Germany, France, Italy, Austria, Switzerland and Liechtenstein. Nickel, v.9, n.2, Dec1993.

generated and distributed at prices accessible to a predominantly low-income <sup>48</sup> population on the basis of a non-exclusionary model for broadening the market. Even though industry dominates the energy consumption structure, residential use occupies a significant second place, as shown in Table III.5.

**Table III.5 - Electric Power Consumption: Percentage Composition by Sector**

SECTOR	1982	1992
Industrial	51%	52%
Residential	21%	23%
Commercial	12%	11%
Others(*)	16%	14%

(\*) Includes the public, agriculture and livestock and transport sectors, where the drop is due to the agriculture and livestock sector.

Source: Estatísticas Energéticas MME/ELETRÓBRÁS 1993.

In its comparative analysis of results, the last IBGE Industrial Census (1985) recognizes that "structural differences between 1985 and 1980 can be attributed to the great advances made by mining, which has come to contribute significantly to the value of processing industry, and to gains by chemicals". This was due, in large measure, to production of primary and secondary energy products, like oil extraction, petrochemicals and PRÓALCOOL (National Alcohol Program). As a result of performance by these sub-sectors, chemicals lead Brazil's industrial capability, representing 15.8% of the value of industrial processing in 1985.

Along with this production effort, Brazil's energy balance also shows that consumption of oil and derivatives is being strongly curbed, growing only 9% between 1980 and 1992. The energy source whose participation in consumption grew most in this period was natural gas, with aggregate gains of 315%, as can be seen from Table III.6.

<sup>48</sup>According to data of the IBGE Anuário Estatístico, 1991, the total population of Brazil in 1990 was 119 million. Of these, 62 million formed the economically active population, of which 32 million earned up to 2 minimum wages. This is the so-called low income market.

**Table III.6 - Energy Sector Evolution in Brazil -**

<b>Energy Production and Consumption (OTE)</b>						
SOURCES	PRODUCTION			CONSUMPTION		
	1980	1992	var. %	1980	1992	var. %
TOTAL	91.808	151.471	65%	138.760	185.118	33%
NON-RENEWABLE	13.653	40.344	195%*	60.605	73.991	22%
Oil	9.083	31.750	250%*	54.319	59.261	9%
Natural Gas	2.134	6.753	216%*	1.078	4.479	315%
Power Coal	1.463	1.762	20%	1.195	2.015	76%
Metallurgical Coal	973	79	-92%	4.013	8.146	102%
RENEWABLE	78.155	111.127	42%	78.155	111.127	42%
Water	37.383	64.778	73%	37.383	64.778	73%
Wood	30.695	25.469	-18%	30.695	25.469	-18%
Sugarcane	9.082	18.517	103%	9.082	18.517	103%
Others	995	2.363	137%	995	2.363	137%

\*These figures are strongly influenced by oil production going on-line in the Campos Basin (RJ) in 1984.  
Source: Estatísticas Energéticas 1993. Ministério das Minas e Energia - MME/ELETRÓBRÁS.

The most salient characteristic of Brazil's energy matrix is the constant predominance of renewable sources, responsible at present for 73% of total energy produced. Among these sources, hydroelectricity represents greatest volume, accounting for 43% of total energy generation.

As can be seen from Table III.6, the significant changes in the composition of energy consumption by source between 1980 and 1992 were:

- a) among the renewable sources, the increase in participation by hydroelectricity, as a direct result of investment in infrastructure during the 1970s;
- b) disincentives on the use of oil held growth in consumption to a scant 9% during the period, accompanied by significant growth in Brazilian oil production. This source thus rose to second place in Brazil's energy matrix, on the production side, which represents greater national autonomy with regard to this energy source;
- c) firewood's share of total energy production shrank, and this source dropped to third place - the only case of an absolute reduction in consumption during the period;
- d) sugarcane derivatives and other renewable sources more than doubled their participation; and

e) natural gas overtook coal for power purposes in both production and consumption, although the overall figure - no more than 4% of the total - is still negligible.

To summarize, still from the data in Table 6, Brazil's energy consumption profile for the last 12 years shows that the tendency to use energy from renewable sources has firmed. In the breakdown of total consumption, these grew by 42% while non-renewable sources grew by only 22%. On the production side, non-renewable sources took pride of place as a result of new oil and natural gas strikes, mainly in the Campos Basin (Rio de Janeiro). These served to reduce dependence on oil imports, which met 83% of Brazil's consumption needs in 1980 against 46% in 1992.

If one projects the same annual energy consumption growth rate by source to the year 2015, aggregate growth rates rank other renewable sources (solar and wind), hydroelectricity and natural gas <sup>49</sup>in the first three places. Although leading the growth rate projections field, solar and wind energy do not achieve a significant share of the Brazilian energy matrix. By virtue of the great volume of hydroelectric power already generated, plus the second highest growth rate, this will continue to be the form of energy most used in Brazil.

Use of biomass deserves an aside, because although below the three sources mentioned above, it does show a strong tendency to growth due to environmental conservation constraints, the opportunity it offers for the utilization of agricultural and industrial waste and for power cogeneration. However, within this group of energy sources, one has to distinguish the declining use of firewood and charcoal produced by extractive activities, from consumption of sugarcane for production of fuel alcohol, from sugarcane bagasse and cane straw for power cogeneration and from vegetable fuel oils.

### ***Brazil's Energy Matrix in 2015 and Opportunities for Materials***

Table III.7 shows Brazil's energy matrix for the year 2015 in the two scenarios considered, based on each energy source's expected share over the next 20 years and on an understanding of the technical and infrastructural bases already existing in Brazil. Figures were obtained in interviews with specialists from the energy sector <sup>50</sup>and by forecasting performed by the members of the project staff.

---

<sup>49</sup>Projection based on data shown in Table 3 and working methodology of Moura et alli "Contribuição das energias renováveis para redução das emissões de gases poluidores: perspectiva da matriz energética vis-a-vis ao meio ambiente". VI CBE, pp. 241-247, 1993.

<sup>50</sup>Experts interviewed:

1. **Luiz Pinguelli Rosa** - Forum de Ciência e Cultura - UFRJ
2. **Roberto Scheffer** - Programa de Energia - COPPE/UFRJ
3. **Walter Manheimer** - COPPE/UFRJ
4. **Carlos Camerine** - CENPES/Petrobrás
5. **Pedro Penido** - CENPES/Petrobrás

**Table III.7 - Profile of Brazil's Energy Consumption Matrix in 2015****(sources by intensity of use)**

SCENARIO I			SCENARIO II		
SOURCES	% 1992	% 2015	SOURCES	%1992	%2015
1° - Hydroelectricity	35,0	39,0	1° - Hydroelectricity	35,0	39,4
2° - Oil	32,0*	24,0	2° - Biomass	24,0**	26,8
3° - Biomass	24,0**	19,0	3° - Oil	32,0*	19,0
4° - Natural Gas	2,4	11,6	4° - Natural Gas	2,4	6,8
5° - Coal	5,5	4,4	5° - Solar and Wind	1,1	5,4
6° - Solar and Wind	1,1	2,0	6° - Coal	5,5	2,6

\* In 1980, oil already accounted for 40%. \*\*Alcohol production has remained stationary over the last 3 years and use of firewood fell 20% in 10 years.

It is important to note that although Brazil interacts in the international economic context, its present and future energy matrix reflects far more the diversity of its energy resources than international trends in the sector. Its high renewable energy source use rate and the potential for utilization of natural gas give Brazil a comparative advantage over the rest of the world and allow it to carry out a broad R&D agenda.

It should also be noted that this analysis does not consider nuclear energy, because it accounts for only a 1.0% share of the present energy consumption matrix and because of the lack of definition surrounding the Brazilian Nuclear Program at this stage.

In order to identify an agenda of opportunities for research and development in materials to meet the needs of growing energy consumption as well as the sector's technology needs, one must consider the following aspects of Brazil's situation, which may be responded to differently in the two scenarios analysed.

a) The Brazilian energy sector is firmly based on the public sector. Backed by massive investment, mainly during the 1970s, state power enterprises set up production, distribution and research infrastructure capable of meeting the demand required by the growth model adopted in Brazil up to that point. Today, Petrobrás dominates leading edge technology in all branches of the oil sector, giving grounds for the claim that Brazil will become self-sufficient in oil and natural gas on the basis of projects currently in progress. Eletrobrás, the electric sector holding company, is responsible for planning future power generation, transmission and distribution, for the sector's research and development projects and for a collection of utilities operating in the area. State enterprises today control more than 95% of electric power generation and 98% of distribution in Brazil. Even the National Alcohol Program, which includes private producers, is coordinated at the

government level and, when set up, was 59% government-financed and 49% government-funded.

b) Brazil's economic model excludes an enormous segment of its population which, if contemplated, will greatly influence demand for energy. Meeting this need will necessarily entail basic investments in, for example, expanding and improving the electric network, expanding urban transport systems or supplying gas for cooking and heating.

c) The transport sector, particularly urban and cargo transport, offers great potential for technologies directed to energy conservation and energy source substitution.

In Scenario I, state owned energy enterprises would be privatized, so they would come into line with the tendency to globalization in the world economy, and the internationalization and democratization associated with economic liberalism. The resumption of growth, although unable to absorb structural unemployment, would create new employment opportunities based chiefly on information flows, new management processes and skilled labor. Technological development would be concentrated in leading edge sectors, especially in international niches. Ecological pressures, market competition and consumer demands would oblige energy enterprises - including any that were not privatized - to strive for productivity and quality.

In this scenario, there are no major changes in the various sources' shares in the energy matrix, except for increasing use of natural gas. There would be changes, however, in investment priorities, which would come far more to obey the logic of the market and of private capital than to serve government policy interests.

The tendency towards increasing consumption of natural gas for fuel and for electric power generation would prompt a need for new materials or new linings to fit equipment for operation with a fuel of greater calorific power. For the country's bus fleet alone, growth is projected at between 2.3 and 3% per year, depending on the degree of optimism involved. This would mean a potential need, by the year 2010, to replace nearly 4 million OTEs in diesel oil in a fleet of some 85,000 vehicles, the largest urban bus fleet in the world.

Given that, in this scenario, part of the electric power will have to be supplied by thermoelectric plants <sup>51</sup>, there is a readily identifiable demand for the development of sophisticated materials like superalloys and others offering great resistance to corrosion at high temperatures for use in gas- or coal-fired thermoelectric facilities.

In Scenario II, privatization of energy enterprises is limited and their policies are directed towards serving the public interest. Meanwhile, a set of policies would make it possible to restore public finances to health, revive the State's capacity to

---

<sup>51</sup>According to Eletrobrás Plano 2015, as of the year 2005 it will be necessary to invest in thermo-electricity, which will come to meet 20% of electric power demand by 2015.

invest and change the attitude of the business sector, which would gradually come to invest. As concerns technology, there is a strong emphasis on using and forming a technological capability in Brazil by encouraging research and postgraduate programs.

In this scenario, energy policy - in the sector and in the region - gains greater coordination, making it possible to undertake projects scaled to local needs and capacities. Decisions on new investments are governed by criteria which aim to integrate technical, environmental, social and economic considerations.

Regardless of the scenario, hydroelectricity continues to account for the largest share of the future energy matrix, although alternative renewable energy sources and natural gas increase their shares in the energy balance. Some opportunities for materials, besides those required by energy conservation needs, can be identified.

a) Materials for the construction and operation of small hydroelectric plants, chiefly to harness the potential of basins already exploited and apparently exhausted, but which can supply an additional 8,000 MW of energy. Besides materials and technology already mastered by Brazil, there need for new materials and design for hydropower turbines.

b) Also associated with the potential electric power market, there is opportunity for the development of insulating and dielectric materials, mainly polymers, and technology for circuit breakers which, to date, are imported for lack of materials.

c) In the solar and wind energy fields, the market for development of materials is still difficult to quantify, although perceptible and quite competitive in some regions of the country for rural electrification and complementing conventional electric power supply.

d) There should be greater demand for certain metallurgical products - among them stainless steels and sophisticated materials like superalloys - for supplying the basic power generation and distribution infrastructure. There should thus be more demand for raw materials like nickel, chrome, cobalt, molybdenum and others. Markets for common steels may also expand, especially for uses in gas pipelines and distribution lines, despite competition from plastics.

From the foregoing discussion it is possible to conclude that increasing demand for energy should be met, at first, by expanding the capacity of installations presently in operation or projects in the process of implementation. In the near future, hydroelectricity and oil will still be responsible for more than 60% of our energy consumption matrix. However, as the value structures defined in the two scenarios settle, so the opportunities for advanced materials begin to crystallize. Some are common to the two scenarios, such as those relating to energy conservation measures; others appear more clearly in one or the other scenario. In Scenario I, preferential implementation of thermoelectric plants will boost the market for turbines and accessory equipment - a market ever more demanding of

special materials. In Scenario II, utilization of biomass, although representing quite a diffuse market, is quite significant for materials that make for more efficient processes and equipment.

### ***Demand for Technology and Materials, by energy Source in Scenarios I and II***

From the way the Brazilian energy matrix has evolved and considering expected growth by the sources that compose it, one can infer the chief demands for technology and materials to be developed for energy generation and distribution systems in both scenarios. The tables below group these demands for each energy source and relate them to the new materials which are to meet these technological requirements.

#### ***a) Hydroelectricity***

**General:** The leading position of hydroelectricity in the Brazilian energy matrix is the result of massive investment, mainly in the 1970s, which led to a complete mastery of dam technology and access to equipment which, even when multinational in origin, was developed to meet specific project conditions. In the 1990s, although competent to meet new demands, the sector faces considerable challenges:

- Plants in operation are mostly 20 or 30 years old and need investment in conservation and to improve the efficiency of installed capacity, so as to increase its useful life;
- Generation capacity of more than 10,000 MW (equivalent to approximately 20% of Brazil's installed capacity and still under construction) is at a standstill or semi-paralyzed. This is due chiefly to lack of investment capacity on the part of the utilities, to electric power market growth below values forecast by sector planning and to construction work having begun too far ahead of demand;
- The environmental impact of building hydroelectric facilities and their effects on populations displaced by the reservoirs and on those upstream and downstream of the dams can no longer be ignored in executing new projects, which means projects will become more complex and costly;
- It is imperative that wastage be reduced immediately. According to Eletrobrás Plan 2015, electric power consumption forecast for 2015 falls by up to 12.6% if the necessary conservation measures are taken, from generation through to consumption.

In Scenario I, according to the same Eletrobrás Plan 2015, electric power generating capacity installed in the South and Southeast regions would be exhausted. In this scenario, expansion of this capacity would include, besides installation of natural gas-fired thermoelectric plants, the construction of new hydroelectric facilities to take advantage of Amazon Basin potential. This raises the

challenge of developing new technologies and materials to reduce long distance transmission losses and permit viable power distribution to consumer centers

Another development front which should broaden in this scenario, in line with international trends, involves equipment and systems for energy conservation, from generation through to the consumer. The main effect of conservation measures is to postpone investment in new installations for longer. For these measures to be successful, new consumption habits, new tariff management methods and systems are required, besides technological development. There is a potential market for equipment and devices, including lamps, which should become increasingly widely used among both residential and commercial consumers, alert to demands for new standards of energy conservation. There is also a virtual demand for building materials and linings and finishes that can improve indices of illumination and thermal insulation, thus reducing electric power consumption in big city office buildings

In Scenario II, expectations are that a considerable portion of the 80% of the population which is currently a poor consumer of electric services and products will be incorporated by the market. The precarious situation of electrification in rural and low income urban areas will require a set of measures directed towards expanding the supply of power and pursuing energy conservation programs. Just to meet basic needs, some technological developments and innovations in materials can be identified:

a) More widespread use of fuel gas, for both cooking and heating in the residential sector, will open up a market option represented by replacement of the present network of carbon steel pipelines and connectors by polyethylene and lighter, more corrosion-resistant materials. One of the aims of this replacement will be to reduce power consumption from the use of electric shower-heads, which today account for nearly 30% of low-income residential power consumption and is responsible for an additional 30 to 40% on average peak-hour demand

b) Expansion of the urban electric transport sector (trains, buses and subways) - conservation considerations aside - would be an immediate priority here and would lead to a consequent increase in electric power consumption and in the market for materials, particularly metals, for building up the fleet and expanding distribution infrastructure.

**Implications for the Materials Sector:** Chart III.2 summarizes the chief demands for technology and new materials for the generation and distribution of hydroelectric power. The major trend is towards development of materials that are more efficient, environmentally acceptable and entail lower implementation and operation costs. Besides the innovations as such, this would include technology for incremental improvements, applied to modernizing existing plants and transmission lines, and for utilizing small heads of water.

**Chart III.2 - Technological and Advanced Materials Demands of the Hydroelectricity**

Demands for Technology	Demands for New Materials
* Transmission of large amounts blocks of power over long distances, requiring: <ul style="list-style-type: none"> <li>- minimization of electric losses;</li> <li>- reduction of width of rights-of-way and areas of substations;</li> </ul>	<ul style="list-style-type: none"> <li>- Insulating materials, especially polymers, for transmission.</li> <li>- Materials for contacts (electromechanical devices for connection, disconnection and protection)</li> <li>- Superconductors for power transmission and use in electrical equipment.</li> </ul>
<ul style="list-style-type: none"> <li>- Conservation technology.</li> </ul>	<ul style="list-style-type: none"> <li>- Materials for thermal insulation in civil construction.</li> </ul>
<ul style="list-style-type: none"> <li>- To improve generation efficiency and increase plant useful life.</li> </ul>	<ul style="list-style-type: none"> <li>- More durable materials for generator and turbine blades and runners.</li> </ul>

One of the chief demands is for long-distance electric power transmission, but the position of aluminum as the main conducting material used in high voltage cables should not change unless technology for using superconductors for transporting large amounts of power becomes feasible. As concerns **metallic superconductors**, the problem continues to be that of cooling the system to temperatures close to absolute zero, currently obtained by using helium, which is scarce in nature <sup>52</sup>. Even though the problems of manufacturing technologies and cooling costs associated with **ceramic superconductors** have been surmounted, difficulties still remain as regards their mechanical and electrical properties. Moreover, some of the necessary elements in the composition of these superconductors are scarce in nature - **yttrium**, for instance - and even when used in minute quantities may become exhausted in a short time. In this case, the more noble uses, in electrical and electronic equipment, should take preference.

***b) Biomass: sugarcane and derivatives, firewood and charcoal and vegetable oils.***

**General:** The use of biomass for producing energy is still incipient in Brazil given the great range of sources available and the climatic conditions which favor their renewal. Only sugarcane and forest biomass are used on a significant scale. The present situation can be summarized as follows:

<sup>52</sup>In his interview, Prof. A.W. Manheimer (UFRJ) mentioned that a single superconductor cable would be able to transport energy sufficient to supply, for example, Manhattan Island in New York. The risk involved in depending on a single cable is too great, however, and makes the project unworkable.

– Large-scale use of **sugarcane and its by-products** is backed by the high level of technology attained by fuel alcohol production, but exploitation of the potential for cogeneration processes is only incipient, because of the low yields of the equipment used and deficiencies in related regulations. While, on the one hand, implementation of the Alcohol Program demonstrated Brazil's capacity to utilize its natural resources, to create a technological capability and generate employment, on the other, it also triggered serious environmental and social impact, such as production of enormous volumes of effluents and pollutant by-products <sup>53</sup>and the use of large areas of good land more adequate to food production.

b) Use of firewood and charcoal must be subdivided into one portion that depends on exploitation of native forests (which accounts for nearly 60% of total production) and another based on efficient systems of reforestation. Although the use of firewood is falling off sharply in Brazil, the figures still reveal a situation in which this energy source predominates in many regions of the country among low income populations and even in industrial installations like brickworks and coking plants. Here the efficiency of the technologies, both for obtaining raw material and in the carbonization process, is poor. Charcoal accounts for nearly 17% of the energy consumed by iron and steel industries, and nearly 30% of this value is obtained from reforested areas

c) **Vegetable oils** come from a wide variety of raw materials, but palm oil (from a variety of the African oil palm) is the most attractive, incorporating genetic improvements which ensure greater productivity and biological pest resistance. The technology for obtaining the oil is consolidated, but there remain problems in optimizing it for use as a fuel, either pure or mixed with diesel, and in competing on the market with petroleum-based products.

In Scenario I, the energy potential of biomass would be utilized primarily in large-scale programs directed to filling gaps in the international energy use model, as was the case with the Alcohol Program, designed to serve the motor vehicle sector. It is thus not expected that new fronts will be opened up for utilization of biomass, in addition to those already installed for production of fuel alcohol. If these were to be justified by market conditions, technological increments would focus on this product, in an effort to improve the fuel's efficiency and upgrade the materials and coatings of automobile components to impart greater durability.

In Scenario II, biomass could be better utilized in all its diversity. The sugar-alcohol industry's cogeneration potential alone represents something like 8000 MW, not to mention potential production of cane straw if mechanical harvesting were introduced. This process, besides being environmentally preferable, has an additional advantage: peak electric power supply occurs during the 6- to 8-month

---

<sup>53</sup>The environmental impact of ethanol production (pollutant emissions from burning of canefields, effluents from cane washing discharged directly into rivers and production of vinasse) have been considerably reduced today thanks to R&D efforts and specific regulations. In São Paulo, industries associated to COPERSUCAR already utilize 100% of the vinasse produced for fertilization and irrigation.

dry season, which is precisely when hydroelectric supply is in crisis. At present, most large sugar mills are already self-sufficient in electric power and even supply a surplus of 4.0% to the distribution network. The prospect of increasing this supply opens up opportunities for materials, both for improving the traditional technology of the steam cycle, and for introducing combined cycle systems (gasifier and gas turbine). The former case calls for materials more resistant to corrosion and to the high working pressures and temperatures needed to increase process yields. In the latter case, economic studies point to figures which, although varying with harvest and inter-harvest conditions, are put forward by suppliers of this technology as viable and competitive in relation to electricity generated by fuel oil-fired thermal electric plants. The bottlenecks are technological and relate to the need for materials appropriate to process conditions.

Use of agricultural waste for small-scale energy generation, for which the technology exists, gains in scale in this scenario. The planting and exploitation of forests may also contribute to creating employment and fixing rural populations. One example is the recent experiment in reforesting the stretch of Atlantic Forest on the southern coast of Bahia State with species of African oil palm. This planting forms part of a settlement program which, besides generating employment, will provide the families with the conditions to plant food crops.

**Implications for the Materials Sector:** As listed in chart III.3, technological development for utilization of biomass for energy generation involves a wide range of efforts, including genetic engineering to improve plant strains, forest management, development of processes and equipment, innovations in materials and research into utilization of agricultural waste for energy purposes.

Combustion of biomass to generate electric power, even in the conventional manner, already demands materials more resistant to high temperatures, corrosion and wear. The most recent innovations are incremental developments to materials currently in use, such as stainless steels, superalloys, and developments in the use of new composite materials and in linings for metallic parts subjected to critical working conditions. Introduction of the combined cycle process has made it crucial to develop materials for fluidized bed reactors, for gas filtering and cleansing equipment and for turbine parts and linings. In the light of these prospects, metals like **chromium, cobalt, molybdenum** and **nickel** continue to be essential. Meanwhile, advanced ceramic materials gain space as linings and for components with refractory functions.

As regards green fuels, improvements are expected in relation to materials for parts that come into contact with the alcohol and combustion gases in motor vehicles. These applications are dominated by stainless steels and alloys resistant to corrosion by water. Certain thermoplastics, like high density polyethylene, are being used in fuel tanks and may displace metals for use in parts that do not operate at high temperatures.

New technology for separating the components of mixtures, especially membranes, may replace traditional equipment for distilling and purifying alcohol, thus reducing the use of stainless metals.

**Chart III.3 - Technological and Advanced Materials Demands of the Biomass Energy**

SUGARCANE AND CO-PRODUCTS (ENERGY GENERATION AND FUEL PRODUCTION)

DEMAND FOR TECHNOLOGY	DEMAND FOR NEW MATERIALS
<ul style="list-style-type: none"> <li>- Power cogeneration using sugarcane bagasse and straw: improvement to the conventional steam cycle and introduction of the combined cycle.</li> </ul>	<p>Steam cycle:</p> <ul style="list-style-type: none"> <li>- more resistant materials for contact with combustion gases (more durable refractories; alloys and linings more resistant to corrosion and wear for heat exchanger parts).</li> <li>- more resistant materials for contact with steam: improvements to steels and other alloys to permit higher steam temperature and pressure, thus improving efficiency of generation.</li> </ul> <p>Combined cycle:</p> <ul style="list-style-type: none"> <li>- refractory materials for gasifiers</li> <li>- materials for gas turbines: improvements to superalloys used.</li> </ul>
<ul style="list-style-type: none"> <li>- Improvements to fuel alcohol production technology: introduction of separation/concentration processes using membrane technology, such as reverse osmosis for separating alcohol and water, pre-treatment of sugarcane syrup by ultra-filtration; concentration of vinasse to reduce pollution problems.</li> </ul>	<ul style="list-style-type: none"> <li>- polymer membranes for pervaporation, reverse osmosis and ultra-filtration processes;</li> <li>- improvements to corrosion-resistant materials to increase plant equipment durability.</li> </ul>
<ul style="list-style-type: none"> <li>- Improvements to hydrated alcohol-driven motor vehicle parts.</li> </ul>	<ul style="list-style-type: none"> <li>- new materials and/or coatings resistant to corrosion by alcohol or exhaust gases.</li> </ul>
<b>Firewood and Charcoal</b>	
<ul style="list-style-type: none"> <li>- Increased steam cycle efficiency for use with firewood / charcoal: smaller units for local electric power supply.</li> <li>- Use of combined cycle for large units.</li> <li>- Refinement of reforestation techniques.</li> </ul>	<p>As for sugarcane and co-products, for both steam and combined cycles.</p>
<b>Vegetable Oils</b>	
<ul style="list-style-type: none"> <li>- Adaptation of internal combustion motors to vegetable fuel oils.</li> <li>- Utilization of peels and waste for cogeneration (conventional steam cycle).</li> <li>- Improvements to species by biotechnology to increase productivity.</li> </ul>	<ul style="list-style-type: none"> <li>- Appropriate materials for vegetable oil-driven motor vehicles.</li> <li>- As for other biomass sources.</li> </ul>

### *c) Oil and Natural Gas*

**General:** Petrobrás, Brazil's state enterprise responsible for its oil and natural gas production, ranks 18th in the world, is a leader in deep-water extraction technology, 9th in refining capacity, 11th in reserves and 20th in production.

As a result of technological advances achieved by Petrobrás, chiefly in deep-water prospecting<sup>54</sup>, Brazil's oil production has increased 250% in the last decade, as shown by the figures in Table 3, surpassing the 180% growth in world reserves in the same period. At present production levels and with existing reserves, Brazil has oil for 34.2 years (the most recent - 1993 - discovery of new reserves in the Santos Basin should extend that expectation considerably)<sup>55</sup>.

Oil is most important in the transport sector, based on an eminently road-related model in Brazil. Even so, its position is not exclusive, since fuel alcohol substituted part of the gasoline, while vegetable oils offer alternatives from diesel. Diesel oil is used both in cargo transport and in urban and interurban passenger transport. It is in urban passenger transport that, technologically and environmentally, there appears to be the greatest potential for employing fuels alternative to diesel, with significant implications for the demand for diesel, in detriment to solutions via importation or by making its use more efficient<sup>56</sup>.

Brazil's natural gas reserves, estimated in 1991 at 123.7 billion cubic meters, are equivalent to 30% of its oil reserves. These reserves, however, are distant from consumer centers - this, in Petrobrás' opinion, being the reason for their having such a low share in the energy matrix (still limited to 2.4%). Besides this, technical factors and a lack of transport and distribution infrastructure are holding back the expansion of gas production in Brazil today.

It is important to note that there are certain environmental and social impacts associated with oil and gas production. There is the risk of explosion at the research, prospecting, extraction and industrial production stages; of spills during transport and storage; as well as the discharging of effluents - all with serious physical impact on the environment and nearby population.

The gravest concern in terms of environmental degradation, however, is with the use of oil as fuel and the corresponding emission of CO<sub>2</sub>. At the end of the 1980s, oil consumption for transport in industrialized countries alone represented 60% of total oil consumption. Road transport accounted for 50% of that consumption. This means that it was the transport sector that contributed most to environmental degradation. Use of oil derivatives is responsible for a significant

---

<sup>54</sup>The discovery of gigantic fields in the Campos Basin between 400 and 2,000 meters, warranted Petrobrás research program and Brazil's technological capacitation in deep-water production.

<sup>55</sup>Engenharia em Revista. "40 anos de trabalho da Petrobrás". Clube de Engenharia. Oct/93.

<sup>56</sup>BERNI, SÉRGIO V.B.M.D. Transporte Urbano: Planejamento Energético e Ambiental. VI CBE, Rio de Janeiro, 1993.

portion of air pollution in large cities, involving considerable emissions of nitrogen, carbon monoxide and hydrocarbons <sup>57</sup>.

In Scenario I, given the emphasis on natural gas use, it seems more economical for Brazil to import natural gas from Bolivia or even Argentina directly via gas pipelines to the main consumer centers in South and Southeast Brazil. However, increased use of natural gas by sectors of industry and for transport depends more on institutional factors and infrastructure than on technological considerations as such.

In this scenario, however, the projections for the future are optimistic. Participation by gas in domestic energy supply was expected to increase 4.5% by 2000, and 6% by 2010. These figures were revised upwards to 9.8% by 2000 and 11.9% in 2010 <sup>58</sup>.

The principal user of natural gas in Brazil is industry, in particular sectors that need a clean-burning fuel to avoid contamination or permit better control of combustion so as to improve the value of their products and make them more competitive. Supplying a greater volume of natural gas to the Brazilian market would spur development of the specialized segment of the capital goods industry, in order to produce equipment for use with this energy source, thus attracting new technologies and improving existing technologies for burning gas.

Increased use of natural gas as a fuel for public transport and cargo transport would reduce pollutant emissions of CO<sub>2</sub>, NO<sub>x</sub>, hydrocarbons and carbon monoxide, to the benefit of air quality in urban centers.

The main obstacles to expansion of natural gas use in Brazil are:

- an inappropriate pricing policy which always favored oil derivatives;
- precariously defined institutional arrangements for gas distribution;
- the existence of potential renewable sources of hydroelectric power and biomass;
- limited known resources reserves made widespread use difficult.

For oil, Scenario I should reinforce the following demands for technology:

- development of multiphase pumping technology, making it possible to dispense with platforms or bring them in to shallower waters;
- developments in the onshore production area where Brazil lacks modern

technology and which is necessary to permit exploration and production, especially of its Amazon reserves. Particularly important here are Three-dimensional Seismic Interpretation to reduce the need for drilling, and robotics for performing high-risk tasks and increasing levels of process control. Horizontal well drilling, enhanced oil recovery by injection of steam and/or carbon dioxide to increase recovery levels from strikes and permit reduction of emissions and spillage of solids, liquids and toxic gases.

---

<sup>57</sup>BERNI, S.V.B.M.D., op.cit.

<sup>58</sup>BERNI, S.V.B.M.D., op.cit.

In Scenario II, one of the chief applications of natural gas would be as a motor vehicle fuel in city buses. Feasible implementation of a program to replace liquid fuels with gas depends more on the cost of infrastructure necessary for fueling the fleets and on the storage capacity of the vehicles themselves, than on yields from use of gas as fuel. Use of natural gas in thermoelectric plants may also come to constitute an alternative to hydroelectric projects in the Amazon region.

**Implications for the Materials Sector:** The demands for technologies and new materials for oil and natural gas are summarized in Table 10. In the case of oil, offshore prospecting and production techniques have made use of important innovations in terms of materials, such as high-strength, low-alloy steels (niobium, particularly - of which Brazil has the largest reserves in the world - has found a large market here). To date, efforts have been directed to technological solutions for deepwater exploration. A breakthrough is expected with regard to development of multiphase pumps which, placed at the head of subsea wells, would enable extracted material to be transported to shallower water, where existing installations could even be used to complete the remaining stages of production. This kind of innovation would reduce the demand for materials for building platforms, where use of steel is standard practice.

The chart III.4 also points to there being more demand for innovations to permit the adaptation of current technology to use with natural gas than for development of new processes. Steel is commonly used for building gas pipelines and distribution lines, but there are prospects of its being replaced by plastics which are lighter and more resistant to corrosion<sup>59</sup>.

**Chart III.4 - Technological and Advanced Materials Demands of the Oil and Natural Gas Energy**

O I L / N A T U R A L G A S	
Demands for Technology	Demands for New Materials
1. Drilling	
- Bits with longer useful life.	- New materials more resistant to wear and high temperatures.
- Drilling columns.	- Materials with greater resistance to fatigue.
- Horizontal wells.	- Flexible risers with appropriate materials.
- Wells for deposits with H <sub>2</sub> S	- Materials more resistant to corrosion and hydrogen cracking.
2. Production (including off-shore)	
- Progressive cavity pumps.	- Elastomers more resistant to abrasion and temperature.
- Deepwater wells.	- Materials for tubing linings with better resistance to highly corrosive environments (H <sub>2</sub> S, chlorides, etc.)
	- Improvements in materials and techniques for subsea welding.
	- Materials for flexible risers and chains for subsea use: polymers.
	- Materials for electrical and electro-mechanical devices for submarine vehicles and equipment.
3. Transport and Storage (Tanks).	
	- Composite materials for floating tanks.
	- Cryogenic materials for refrigerated tanks.
4. Refineries	
	- Metals and alloys resistant to creep.
N A T U R A L G A S	
1. Combined cycle thermal electric plants	- Demand similar to those for other thermal sources
2. Adaptation for motor vehicle use	- Lighter materials (composites) for vehicle storage cylinders that also preclude fragmentation explosion

<sup>59</sup>ILHA,M.S.O.; GONÇALVES,O.M.;MARIOTONI,C.A. Estudo sobre a implantação do sistema de gás combustível em conjuntos habitacionais de baixa renda. VI CBE. pp.415-420. Rio de Janeiro, 1993.

#### ***d) Coal***

**General:** Brazilian coal has an average calorific power of between 3,200 and 3,850 kcal/kg, sulfur content ranging from 0.4 to 2.6% and a high ash content, on average 51%, which makes its use in electricity generation competitive only when used at the mine surroundings, thus restricting application to the country's southern states <sup>60</sup>. The main market for Brazilian coal is thus thermoelectricity, although this accounts for only 5% of total electricity generated in Brazil <sup>61</sup>. Brazilian production for metallurgical use fell 92% in the last decade, while increased consumption was met by importation <sup>62</sup>.

From the environmental point of view, the inefficient use of coal for thermoelectric generation may seriously compromise the planet's environmental resources. Two major problems are worthy of note <sup>63</sup>: acid rain and the greenhouse effect. Sulfur dioxide (SO<sub>2</sub>) and nitrogen oxides (NO<sub>x</sub>) produced during combustion and discharged into the atmosphere, form acids which may return to earth in the form of acid rain. Carbon dioxide (CO<sub>2</sub>), also produced when coal is burnt, contributes to the greenhouse effect. Worldwide, it is estimated that the use of fossil fuels is responsible for 66% of all CO<sub>2</sub> emissions, while the coal used for thermoelectric generation accounts for 24% of this fraction.

Even though in 1990 most CO<sub>2</sub> emissions in Brazil were due to oil by-product (57,8%) and firewood (16,4%), participation by coal (11,7%) and natural gas (3,7%) has been growing markedly. These figures mean that, regardless of the scenario being considered, increased use of coal in Brazil should be accompanied by environmental preservation measures.

In Scenario I, use of coal for thermal electric generation will be more intensive. In Brazilian electric sector planning, the aim is to expand present installed capacity of 1,040 MW to 7,850 MW over a 20-year period. New installations however will be restricted to the south region. For this purpose, it is essential that so-called "clean technologies" be developed at competitive prices. There already exists technology, proven at the world level, for burning coal and removing from the exhaust gases between 90 and 99% of the SO<sub>2</sub> and between 80 and 90% of the NO<sub>x</sub> produced.

In Scenario II, although there is no expectation that use of coal in thermal electric generation will increase, the development of clean technology is a precondition for the continued operation of plants installed in the south of Brazil and responsible for an industrial capability built around mining.

---

<sup>60</sup> CODECEIRA NETO, A. et alli, op.cit.

<sup>61</sup> ALBUQUERQUE, G.A.S.C. et alli. Indústria carbonífera brasileira: conveniência e viabilidade de sua recuperação. Relatório Final de Projeto. CETEM/CNPq. Rio de Janeiro, 1993.

<sup>62</sup> Ministério das Minas e Energia, op.cit.

<sup>63</sup> CODECEIRA NETO, A. et. alli, op.cit.

**Implications for the Materials Sector:** The chart III.5 summarizes the demands in the area of "clean coal technology", including reduction of particle emissions, improved plant efficiency, fuel flexibility and reduction in investment costs.

The broad use horizon of coal as a fuel, principally in the northern hemisphere, justifies these innovations, including the combined cycle, which produces a jump in generation efficiency by introducing gas turbines in series with a conventional steam cycle. This technology, originating from the aviation industry, may boost demand for superalloys and, thus, for minerals like nickel and chrome.

**Chart III.5 - Technological and for Advanced Materials Demands of the Coal Energy**

Demands for Technology	Demands for New Materials
1. Combined thermal electric cycle. – Pressurized gasification on fluidized beds. – Refinements to gas turbines.	– Materials resistant to wear, corrosion and to increased gas temperature: new stainless steels (ferritics and austenitics), more durable refractories and lining materials.

### *e) Solar and Wind Energy*

**General:** In Brazil, the chief limitations to the use of solar energy persist: the high cost of energy storage, whether thermal or photovoltaic (nearly 2/3 of photovoltaic equipment uses mono- or polycrystalline silicon crystal), the photovoltaic cells' sensitivity to environmental change, and the price and performance of photovoltaic panels are not yet competitive with those possible with hydroelectric power generation<sup>64</sup>. Even so, heating systems using solar energy, mainly in residential and commercial buildings, are now available at competitive prices<sup>65</sup> and the experimental use of photovoltaic conversion for rural electrification is beginning to achieve costs comparable with those necessary for extending the conventional electricity network for locations distant from the distribution network.

In Scenario I, use of solar and wind energy should not be favored although certain special industrial applications of photovoltaic conversion, like autonomous energy sources for enterprises in remote regions or cathodic protection systems, represent prospects for a select, lucrative market.

In Scenario II, the introduction of these new technologies broadens the opportunities for electrification in rural and remote regions. Today, more than 300 locations in Brazil that depend on diesel generators could incorporate these new systems, dependent on incidence of sunlight and wind. Despite the potential for their use, the first large wind turbine was installed only in 1992, in Fernando de Noronha, to operate a hybrid wind/diesel system.

<sup>64</sup> SOUZA, M.M.N.; NOGUEIRA, E.M. Energia solar - uma análise prospectiva com um modelo de simulação de uma planta fotovoltaica. Anais do VI Congresso Brasileiro de Energia, pp1100-1103. Rio de Janeiro, 1993.

<sup>65</sup> SOUSA, K.Q.M.; SOUSA, R.M.A. Energia solar: uma fonte de energia alternativa viável. Anais do VI Congresso Brasileiro de Energia, pp850-854. Rio de Janeiro, 1993.

Another use for wind energy which should be encouraged in this scenario is for conversion into mechanical energy (e.g., for pumping water) which is quite widespread in some regions.

**Implications for the Materials Sector:** The chart III.6 lists the demands for technology for generating and storing energy from solar and wind sources. In these specialties, development of materials has a pivotal role. In the case of solar energy, the **semiconductor** devices that offer greatest feasibility are, firstly, **silicon** and, secondly, the new materials using **group and III-IV and II-IV elements**. The technology associated with the production of silicon is already consolidated and the amorphous type for solar cells is already being used successfully at production costs lower than the new semiconductors. The latter, already widely used in microelectronics and in electro-optical devices for optical fiber telecommunications, contain rare elements like **gallium** and **indium**. Nonetheless, **silicon** should be encouraged for more widespread use in solar cells.

In response to energy storage problem, new lead-acid, Ni-Cd and hydride batteries are the present option for wind and solar power intermittent generation. Safe storage and reliable use of hydrogen depends on the development of batteries using materials known as hydrogen-storing alloys. Production of these alloys at present uses alloys with **rare earth elements**.

In the case of wind energy, given the tendency to locate wind farms far from urban centers, there is a demand for transmission cables capable of meeting the power and design requirements of the generating plants.

**Chart III.6 - Technological and Advanced Materials Demands of the Solar and Wind Energy**

Demands for Technology	Demand for New Materials
– Improved efficiency of semiconductor photovoltaic conversion	<ul style="list-style-type: none"> <li>– Development of solar panels, especially silicon-based semiconductors; emphasis on amorphous silicon.</li> <li>– Development to reduce costs of the raw material production process: emphasis on solar-grade silicon, which is cheaper than electronic-grade silicon.</li> <li>– Opportunities for use of group III-IV semiconductors providing production costs are reduced.</li> </ul>
– Development of energy storage systems: batteries	– Development of materials for batteries that are more compact, lighter, durable and hold more charge; opportunity in the direction of metallic hydride batteries, or storage of hydrogen in "metallic glasses".

**REFERENCES**

- 1) ALBUQUERQUE, G.A.S.C. (Coordenador). Indústria carbonífera brasileira: conveniência e viabilidade de sua recuperação. Relatório Final de Projeto. CETEM/CNPq. Rio de Janeiro, 1993.
- 2) BAJAY, S.V.; BERNI, M.D. Transporte Urbano: planejamento energético e ambiental. VI CBE - Rio de Janeiro, 1993. p. 389-395.
- 3) BARBOSA, T.; BREJON, P.; BASTOS, L. Análise energética em prédios de escritórios em clima tropical. Anais do VI Congresso Brasileiro de Energia, pp 861-867. Rio de Janeiro, 1993.
- 4) BARTELD, J.; CIEREMANS, J.A.; HOWARD, J.; IKEDA, C.; LIND, Y.; NOYÈRE, J-
- 5) B.; OSANI, H.; TARALLI, C. A report on the development of renewable energy sources. BICC Cables, Aug 1993.
- 6) BERNI, S.B.M.D. Transporte Urbano: Planejamento Energético e Ambiental. VI CBE, Rio de Janeiro, 1993.
- 7) CATÃO, S. Seminar "Energia de Biomassa". VI Congresso Brasileiro de Energia. Rio de Janeiro, 1993.
- 8) CODECEIRA NETO, A.; RIBEIRO FILHO, A.P.; SILVA, S.P.R. Carvão mineral importado-competitividade para geração de energia elétrica no Nordeste. Anais do VI Congresso Brasileiro de Energia, pp 931-938. Rio de Janeiro, 1993.
- 9) DANIEK, A.C.; PRADO JUNIOR, F.A.A.; FERREIRA, M.J.G. Sistemas fotovoltaicos - alguns usos viabilizados pela CESP no Vale da Ribeira: energia, meio ambiente e desenvolvimento. Anais do VI Congresso Brasileiro de Energia, pp1126-1130. Rio de Janeiro, 1993.
- 10) ELETROBRÁS. Plano 2015 : Perspectiva do mercado e da Conservação de Energia Elétrica - Projeto 3. Rio de Janeiro, 1992.
- 11) CLUBE DE ENGENHARIA . 40 anos de trabalho da Petrobrás.. Engenharia em Revista, Oct/93.
- 12) FANTINE, J. Abertura ou Fechamento do Setor de Petróleo: uma Grave Questão. Engenharia em Revista , Oct. 1993.

- 13) FEITOSA, E.N. in: E o vento gerou... eletricidade. Article by André Falcão. *Ciência Hoje - Tecnologia*. Mar, 1994.
- 14) FEITOSA, E.N.; PEREIRA, A.L.; ROHATGI, J.S. Projeto e operação da primeira turbina eólica de grande porte do Brasil/Ilha de Fernando de Noronha. *Anais do VI Congresso Brasileiro de Energia*. pp793-798. Rio de Janeiro, 1993.
- 15) FORUM DE CIÊNCIA E CULTURA. Proposta de Agenda ao Executivo e ao Congresso visando o equacionamento da crise do Setor Elétrico. Rio de Janeiro, Dec/92.
- 16) HIRATA, M.H. Perspectivas do aproveitamento da energia eólica. *Anais do Seminário Introdução de Tecnologias Energéticas Alternativas no Brasil até o ano 2000*. V.2. pp313-332. Rio de Janeiro, 1985.
- 17) IPEA. O Mapa da Fome: subsídios à formulação de uma política de segurança alimentar. *Documento de Política*, n.14, March 1993.
- 18) ILHA, M.S.O.; GONÇALVES, O.M.; MARIOTONI, C.A. Estudo sobre a implantação de sistema de gás combustível em conjuntos habitacionais de baixa renda. *VI CBE - Rio de Janeiro*, 1993. pp.415-420.
- 19) JOHNSON, B.B. Alternative Energy Sources and their impact in the electric cable industry. March, 1993.
- 20) KELLER, C. Talk given at the Instituto Nacional de Tecnologia -INT, April/1994.
- 21) MACEDO, I.C. Mesa Redonda: Alternativas tecnológicas na expansão da produção e uso de energia. *VI Congresso Brasileiro de Energia*, Rio de Janeiro, 1993.
- 22) MARIOTONI, C.A. ; PRADO JR, F.A.A., Considerações sobre o modelo institucional do setor elétrico e sua influência no processo de planejamento. *Anais do VI Congresso Brasileiro de Energia*, Rio de Janeiro, 1993.
- 23) MEDEIROS, J.X. Suprimento energético de carvão vegetal no Brasil: aspectos técnicos, econômicos e ambientais. *Anais do VI Congresso Brasileiro de Energia*, pp.107-112. Rio de Janeiro, 1993.
- 24) MINISTÉRIO DAS MINAS E ENERGIA - Estatísticas Energéticas, 1993.

- 25) MOREIRA, J.G.S.; COLACCHI, F.; MARTINS, L.F.C.; PINHÃO, C.M.; HERSZTERG, I. Contribuição das energias renováveis para redução das emissões de gases poluidores: perspectiva da matriz energética vis-à-vis ao meio ambiente. Anais do VI Congresso Brasileiro de Energia. pp 241-247. Rio de Janeiro, 1993.
- 26) OLIVEIRA, R.X.; SILVA, A.P.; ALVES, J.C. Energia solar fotovoltaica: uma alternativa para eletrificação rural. Anais do VI congresso Brasileiro de Energia, pp1137-1141. Rio de Janeiro, 1993.
- 27) PETROBRÁS - O Brasil e o Mundo no Horizonte 2001 - Macrocenários do Sistema Petrobrás. Serviço de Planejamento . Oct/91.
- 28) RODRIGUES, M.G. Uma revisão de estratégias e uso de gás natural. Anais do VI Congresso Brasileiro de Energia, pp445-449. Rio de Janeiro, 1993.
- 29) ROSA, L.P. & CECHI, J.C. O efeito estufa e a queima de combustíveis fósseis no Brasil. Ciência Hoje, V.17, n.97, jan/fev, 1994.
- 30) SORELL, G. Tidd shows how to burn coal cleanly. Nickel, V.9. n.1, Sept.1993.
- 31) SOUZA, M.M.N.; NOGUEIRA, E.M. Energia solar - uma análise prospectiva com um modelo de simulação de uma planta fotovoltaica. Anais do VI Congresso Brasileiro de Energia, pp1100-1103. Rio de Janeiro, 1993.
- 32) SOUSA, K.Q.M.; SOUSA, R.M.A. Energia solar: uma fonte de energia alternativa viável. Anais do VI Congresso Brasileiro de Energia. pp850-854. Rio de Janeiro, 1993.
- 33) UNESCO - International Council for Science Policy Studies. Science and Technology in Developing Countries - strategies for the 90s. A report for UNESCO, Paris, Jan/1990.
- 34) YOSHIKI-GRAVELSINS, K.S.; TOGURI, J.M.; CHOO, R.T.C. Metals production, energy and the environment, Part I: energy consumption. JOM, V.45, N.5, May 1993.
- 35) ZATS, J. Seminário Energia de Biomassa. VI Congresso Brasileiro de Energia. Rio de Janeiro, 1993.
- 36) ZYLBERSTAJN, D.; COELHO, S.T. Colheita mecânica da cana e economicidade da cogeração. Anais do VI Congresso Brasileiro de Energia. Rio de Janeiro, 1993.

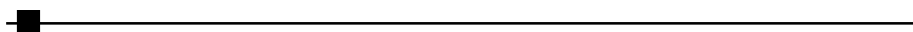


# CHAPTER 3

---

## *PART III* *THE TRANSPORTS SECTOR: THE SCENARIOS* *AND THE ADVANCED MATERIALS IN BRAZIL*

*Carlos Cesar Peiter, Sarita Albagli and Teresinha Rodrigues*  
*CETEM/CNPq*



### ***3.III THE TRANSPORTS SECTOR: THE SCENARIOS AND THE ADVANCED MATERIALS IN BRAZIL***

The transports sector is analysed here through four of its subsectors - road, railroad, aeronautical and maritime/waterways. Relationships are established between the transportation equipment and the demand for materials, starting with their possible future developments within the concept of Scenarios I and II described earlier.

#### ***THE RECENT EVOLUTION AND PRESENT SITUATION OF THE TRANSPORTS SECTOR***

##### ***A) International Situation***

The growth of the volume and importance of international exchanges in recent decades, and the strategic nature of transportation for supplying products and for foreign trade, impelled in the 70s and 80s the sector's technological development as a whole, making the traffic system more rational and shifting the emphasis to intermodal transportation (BARAT, 1993).

At the world level, it was waterways transportation that underwent the greatest transformations, both in technological and organizational terms, due to their importance for the growing international trade. Railroads also had their track and support facility infrastructures renewed and their traction and other rolling stock technologically modernized. Railroads became more specialized with the largest use of containers and pallets. (Barat, op.cit.) On the other hand, the pipeline transportation system was expanded, mainly for large cargoes with low unit values. Figures taken from the experience of 13 European countries show that just in the period 1965 to 1988, the use of pipelines increased from 30 thousand t/km to 140 thousand t/km. This tendency may crush hopes of expanding the railroad system for transportationing cargoes (RATTON, NETO, 1993).

At the same time, in the last thirty years, there was a tendency in the developed countries to increase the share of road transportation in the total movement of passengers and goods. This tendency, although restrained by energy pressures deriving from the oil "shocks" of the 70s, giving more thrust to the railroad and waterways systems, is still evident today in the predominance of road transportation among the others, as Tables III.8 and III.9 show.

**Table III.8 - Cargo Transportation, per Country - Tons-km (1990)**

COUNTRY	AIR	PIPELINE	RAILROADS	WATERWAYS**	ROADS
W. Germany	4,142	11,737	61,716	140	169,800
U.S.A	17,395*	852,346	1,513,776	867	1,182,615
India	689	-	233,292	-	-
Japan	5,402*	-	26,652	796	246,088*
Mexico	150	-	36,384	177	107,243
U.K.	2,692	11,045	15,828	294	137,400

\* 1989 figures

\*\* Tons transported by ocean shipping

SOURCES: Transportation Statistics Yearbook and World Road Statistics

Table prepared from GEIPOT data (1993)

**Table III.9 - Passenger Transportation, per Country Passengers - Kilometer (1990)**

COUNTRY	AIR*	RAILROADS	ROADS
W. Germany	42,144	42,276	617,100***
U.S.A	693,936**	21,145	4,925,741
India	16,524	277,272	-
Japan	61,368	383,700	845,124*
Mexico	18,384	5,9764	272
U.K.	81,732	34,078	608,000

\* Domestic and international flights

\*\* 1989 figure

\*\*\* 1988 figure

SOURCE: Transportation Statistics Yearbook and World Road Statistics

Table prepared from GEIPOT data (1993)

Table III.8 shows that in countries whose territory is very large, like the U.S.A., railroad cargo transportation continues to eclipse the other kinds of transportation, even though it is gradually being displaced by the faster and more versatile road and air transportation. This tendency, which is clearer in Japan, U.K. and Germany, had the support not only of a good road infrastructure, but also the emergence of the new process technical and social development which is dematerializing production, aggregating more value per unit of weight and/or volume, besides requiring great flexibility for using manufacturing organizing procedures, such as "just in time" (UNESCO, 1990).

In the case of passenger transportation, as shown in Table III.9, the differences are greater in the sense of the predominance of road transportation in developed countries, while in the examples presented of developing countries, railroads still prevail. It is clear, however, that the introduction of high speed trains like the TGV (Train a Gran Vitesse), are competing advantageously with road and air transportation in certain situations. The development of new infrastructures and specially their complementary facilities and integration with those already existing, emerge as an important strategic public policy area at long term, unlike the present

morries about problems of traffic jam and negative externalities, such as environmental pollution, associated to high urban traffic densities and international transit outlets(UNESCO, 1990).

The six hundred million vehicles existing at present in the world and the projection of growth, according to UNO, to 1.1 billion within 20 years (UFSCAR), reflects the expected maintenance of the relative positions of the kinds of transportation. At the moment, the international automobile industry is going through a phase of adjustments, marked by surplus offer, which contributes toward increased competition and concentration of capital in this segment. The U.S.A., Europe and Japan concentrate 87% of the world automobile demand. These markets are at the point of saturation, with annual growth rates of 1% to 2% (PEITER; BORGES, 1992).

### ***B) The Brazilian Situation***

Since the 50s, road cargo transportation has predominated in Brazil. During that period, Brazil's automobile industry was set up, while railroad transportation developed slowly, in spite of programs and projects for reequipping and modernizing Brazil's railroads after the II war. The aeronautical industry in Brazil was started between 1930 and 1950, and gained greater technological impetus after the foundation of the Aeronautical Technical Center - CTA (1945) and its Institute - ITA (1950), and after the company Empresa Brasileira de Aeronáutica S.A. - EMBRAER (1969) was opened.

In spite of the energy crisis of the 70s, road cargo transportation continued to predominate, due largely to freight costs differences, compared with railroad and waterways transportation. In its turn, the problem of fuels supply was partly resolved with the Alcohol Program and through technological solutions found by Petrobrás for raising diesel oil production through cracking oil. Intermodal transportation continued to represent a very small portion of the overall movement of cargoes in Brazil.

Passengers continued to be transported mostly by road (in 1992, this represented 96.03% of the total), followed by air transportation (1.76%), railroad (1.56%) and subways (0.65%) (GEIPOT, 1993).

The automobile sector of industry is the market to which foreign companies in Brazil have gained the most access, in a process which began in the 50s. In 1985, the foreign assemblers were responsible for 99% of the sector's sales, particularly Volkswagen, Ford, GM Brasil, Mercedes Benz and Fiat. There is small-scale production by Brazilian companies, using the mechanical parts of vehicles made by the larger assemblers (BNDES, 1988). Autolatina, which resulted from the merger of the Volkswagen and Ford subsidiaries, thereafter represented 60% of the sales of vehicles and utilities, accentuating the concentration process of this segment.

**Table III.10 - Brazil: Cargo Transportation - Cargo Transported, per Type of Transport (1988/92)**

KIND OF TRANSPORTATION	1988		1990		1992	
	t.km 10 <sup>3</sup>	%	t.km 10 <sup>3</sup>	%	t.km 10 <sup>3</sup>	%
Air	1,523	0.29	1,763	0.32	1,411	0.25
Pipeline	19,734	3.70	20,930	3.74	18,059	3.20
Railroad	120,036	22.52	120,370	21.54	116,529	20.62
Waterways/Marit	90,617	17.00	102,664	18.37	97,199	17.20
Road	301,000	56.49	313,229	56.03	331,880	58.73
Total	532,910	100.00	558,929	100.00	565,078	100.00

SOURCES: CVRD-Cia. Vale do Rio Doce; DAC-Civil Aviation Dept.; DNTA-National Waterways Transportation Dept.; Estrada de Ferro Campos do Jordão; Estrada de Ferro Mineração Rio do Norte; Estrada de Ferro Amapá; Estrada de Ferro Votorantim; Ferrovia Perus-Pirapora Ltda.; FOSFÉRTIL-Fertilizantes Fosfatados S.A.; MQN-Mineração Química do Nordeste S.A.; PETROBRÁS-Petróleo Brasileiro S.A.; RFFSA-Rede Ferroviário Federal S.A. and Samarco Mineração S.A.

NOTES: Air Transportation: Domestic flights; Waterways: Inland and Brazilian coastal shipping.  
Table prepared from GEIPOT data (1993).

**Table III.11 - Road Transportation Agregated Indicators for the main grid (1950-1990)**

INDICATOR	1950	1960	1970	1980	1990
a) ton.km (in billions)	17.3	41.9	124.1	208.7	320.3
b) km of main roads <sup>(1)</sup>	63.3	108.5	181.2	205.5	259.7
c) ton km/km of roads <sup>((a)/(b))</sup>	273.3	386.2	685.4	1015.5	1233.3
d) cargo vehicles <sup>(2)</sup> (in thousands)	157.4	320.2	452.2	915.9	810.0
e) ton.km/vehicle <sup>((a)/(d))</sup>	109.9	130.9	274.7	227.9	395.4

(1) Federal and state-run roads, paved and unpaved.

(2) light, medium, semiheavy and heavy trucks (excluding utility vehicles and pick-ups).

Source: IBGE, Statistical Yearbook of Brazil.

Table taken from Barat (1993).

In the Brazilian vehicle components manufacture there is much less foreign participation, although it is still significant, representing about 35% of gross billing of this business. Products made by companies which have foreign held capital have a high technological content and high aggregate value. There are also large local companies working in the sector, such as Cofap and Metal Leve, which in 1988 ranked in first and third places, respectively, in terms of sales.

Here the presence of foreign maritime transportation companies is smaller than in the automobile sector (one of the leaders is Ishibrás, whose capital is Japanese). Nonetheless, less than 10% of the freights produced by Brazilian foreign trade sent by sea (adding up to US\$5 billion) are generated by ships belonging to Brazilian ship owners. The Brazilian shipbuilding industry reached its peak production in the 70s, funded by the Merchant Navy Fund, which in turn is heavily

subsidized by the Federal Government. Nonetheless, it was unable to compete with the shipbuilding industries in other countries such as Korea, although it continued to be given preference by large Brazilian transportation companies, such as Petrobrás and CVRD.

The Brazilian railroad system consists of five state-controlled railroads - four belonging to the Federal Government and one to the São Paulo State Government. It extends mainly over the southern, southeastern and northeastern regions, in an approximate total of 30 thousand km of lines. In the cargo's segment, the main operator is the Federal Railroad Company, which has about 22 thousand km of lines, followed by Fepasa, the São Paulo State company, and the Vitória-Minas and Carajás railroads, which are run by Cia. Vale do Rio Doce, also federal government-owned. In the **passenger** transportation segment, the main railroad belongs to the Cia. Brasileira de Trens Urbanos, which has services in several metropolitan areas (ABIFER, 1992). The privately owned railroads, which are used for tourism or for carrying special cargoes, do not amount to more than 2% of Brazil's total railroad grid.

Brazil's railroad industry is basically installed in the States of São Paulo, Rio de Janeiro and Minas Gerais, where there are about fifteen large and medium equipment companies operating. Brazil's industrial railroad complex is the largest in Latin America, consisting of more than 700 thousand square meters of plant facilities able to produce equipment of all types. With investments made in the 70s, the industry achieved a nationalization rate for producing locomotives between 70% (line locomotives) and 90% (industrial locomotives) and 100% for passenger and freight cars. For some components produced on a small scale, although we have the technical capability here, to import is still considered the best economical choice (ABIFER, 1992).

With regard to aeronautical materials and equipment, this sector is essentially concentrated around Embraer (state-controlled), the only large assembler installed in Brazil<sup>66</sup>, which is able to compete at an international level in various segments. Similar to the automobile sector, this industrial sector is complemented by a parts and components manufactures which, however, still needs to import a long list of items. Brazilian and foreign companies supplying parts and components for the Brazilian assembler numbered more than 700 in 1989.

The economic recession in the 80s resulted in a strong retraction in production and transportation materials market. IBGE (Brazilian Institute of Geography & Statistics) figures show that in 1992, the volume produced by this sector was 5% less than in 1981.

The total automotive vehicles production which at the end of the 70s was more than one million vehicles, declined sharply in the 80s and recovered with

---

<sup>66</sup> The other smaller assemblers are Neiva, controlled by Embraer, which makes aircraft for agricultural, executive, air ferry and sports use; and Helibrás, a helicopter assembler, in whose equity the French Aerospatiale company has an interest.

effect from 1992 to break its historic record in 1993, due mainly to the introduction of low-cost automobiles at cheaper prices. This was due to the agreement to reduce taxes signed by the assemblers, the workers' union and the various state governments. Another strategy for replacing profit margins was to produce more sophisticated units and to incorporate innovations into the engineering and into the management of production (e.g. total quality and just in time). Since 1988, these new practices have shown some beneficial results<sup>67</sup>. Furthermore, new vehicle parts production lines using new materials<sup>68</sup> point to the beginning of a new phase in the sector.

The railroad materials industry at present has half the productive capacity it had in the 70s and 80s, when it was equipped to supply government orders which did not materialize in the amounts planned. Reflecting the crisis which began at the end of the 80s, in this decade the manufacturers of **freight cars** stepped up their services, such as reconditioning equipment, because of the shortage of new orders; the **locomotives** segment adapted itself to the market reality, with the merger of two manufacturers in Brazil; the **components** segment has been affected by a shrinking spare parts market, because the railroads invested little in maintaining their fleet and, lastly, the manufacturers of **passenger cars** are the only ones hopeful about a recovery of the sector, due to the construction of the Brasília subway. As a consequence of this situation, the industry's participation in the overall billing of 1992 (US\$215.5 million) was: **components and services** - 68%; **reconditioning of wagons, cars and locomotives** - 15.7%; **production of new cars** - 7%; **production of locomotives** - 6.4% and **production of wagons** - 2.4% (ABIFER, 1992).

Railroad passenger transportation underwent much pressure from road and aeronautical carriers, particularly on the more profitable routes. A striking example was the Rio-São Paulo-Belo Horizonte triangular route, on which the passenger trains were taken out of circulation in spite of their good performance. Furthermore, as a result of the expansion of the road grid, as from the 50s, and, later on, due to the economic stagnation which began in the 80s, the population that used railroad transportation has been declining mainly in the interior of Brazil. Between 1988 and 1992, the number of passengers-kilometer dropped 35.76% on railroads in the interior, while the same happened with suburban transportation, which dropped 20.35%.

There has also been a severe shortage of financing for shipbuilding, resulting in the aging of the merchant fleet and the Brazilian merchant navy's loss of competitiveness (Barat, op.cit.). Except for the oil tanker fleet, almost all of which belongs to Petrobrás, the Brazilian merchant fleet's obsolescence and deterioration has been accelerating since 1980. The average age of the vessels is 22 years - one

---

<sup>67</sup>Through this modernization process, Fiat is said to have raised its labor productivity by 70% in 1993, compared with the 1988 figure (*Exame* magazine, edition 554, No. 7, 30/3/94).

<sup>68</sup> For example, engineering plastics supplied by COPLEN (Campinas-SP), a joint venture between GM and Nitriflex.

of the oldest in the world. And, according to IBGE figures (1993), in December, 1993, the production level of Brazil's shipbuilding industry was about 52% lower than the production level in December, 1981.

Domestic aircraft production today amounts to about 120 aircraft per year, after having reached 700 in the 70s. Embraer, the only Brazilian assembler, in spite of the technical and commercial success of the Bandeirantes, Brasília and Tucano models, built up heavy debts recently and is being privatized.

In 1993 alone, the transportation materials sector showed a recovery, registering the highest production of the decade, or 22% higher than in 1981. The autovehicles subsector, particularly automobiles, has been leading this recovery. But, according to ANFAVEA figures, heavy trucks have been leading the sector's sales, having accumulated up to February, 1993, a growth of 53% in comparison with February, 1992<sup>69</sup>. Also noteworthy is the shipbuilding industry, which although it has not recovered from the 1980 and 1990 crises, showed positive results in the years 1991 to 1993.

Also because of the 80s crisis, the various means of transportation saw their infrastructures deteriorating, mainly due to declining public investment in the sector and to the economic recession. For instance, with regard to roads infrastructure in 1990, 34% of the federal paved grid (almost 50 thousand km) were in fair condition, 28% in a poor state and 7% in a very bad state (Barat, op.cit.). For this reason, in Barat's opinion (op.cit.), the top priorities for a future government strategy for transportation at short and medium term, must be to recover the existing infrastructure and to integrate modal operations.

If the profile of the Brazilian transportation sector is compared with that of the developed countries, similarities will be found. One example is the predominance of road transportation, although there are big differences relating to the contribution of railroad and aeronautical transportation, both for cargoes and passengers. The Brazilian economy which today is sustained by a significant contribution from the industrial complex, still plays a major role, particularly through export products, mining and farming commodities, such as iron pellets, soy beans, and orange juice which increasingly need massive low-cost transportation structures if they are to compete in the foreign market. Even the domestic market is still prejudiced by the high freight prices due to the enormous distances and to the shortcomings of the present infrastructure. Hence, it is imagined that the railroad, pipeline and waterways types of transportation will have to be expanded, also for

---

<sup>69</sup>The traditional truck fleets have been going through a process of degradation, with the exception of the introduction of heavy trucks (trucks and trailers) with a higher technological content. According to Barat (op. Cit.), the aggregate production of trucks fell from 102 thousand vehicles in 1981 to 77 thousand in 1989, and the estimated fleet was reduced by about 80 thousand vehicles, throughout the decade. In 1990, the average age of trucks was 12 years. On the other hand, road transportation productivity rose, expanding the volume of tons-kilometer transportation, due to: its partial modernization with the growing introduction of heavy vehicles, expanding the unit capacity of the vehicles, and the growth of the main roads grid by expanding the state government-run roads.

reaching new production regions which are gradually emerging in the center-west and north of Brazil. One example of this tendency, even though it has happened rather late, is the Tietê-Paraná waterway, which is coming into use, while the idea of reaching the Pacific Coast by a waterway/railroad, should not be discarded. It should be remembered that the most important river drainage basins in the northeast and center-south of Brazil have been crossed by countless hydroelectric plants and that no care was taken to guarantee the continuation of river navigation through the construction of dams in most of them.

New solutions for the traditional road transportation continue being implemented, strengthening its situation. Among them is the "Train-truck", a heavy duty truck which can only travel on the more modern roads, which have already been designed to receive this class of vehicle.

Aeronautical transportation should develop in the future as and when the companies operating domestic routes realize that they must charge prices that are more accessible to users. A slow, although continuous, multiplication of regional routes is being noticed and used on which aircraft whose operating and servicing costs are lower.

Finally, the Brazilian transportation equipment industry, in any of its segments, is very complete and capable of attending a future revival of demand with a high level of nationalization of parts and components.

### ***THE TRANSPORTS SECTOR IN SCENARIOS I AND II***

Considering the possible or likely future growth of means of transports starting with the contingencies mentioned earlier for Scenarios I and II, it is possible to arrive at differentiated growth rates in the future use of the kinds of transportation considered here. Chart III.7 gives an example of this, also indicating the relative importances of passenger (individual and collective) and cargo transportation. It is felt that this behavior applies as much to the international as to the domestic level.

**Chart III.7 - Means of Transports Growth Tendency**

SCENARIO I	SCENARIO II
1) Road: passenger (individual and collective) and freight)	1) Railroad: freight and passengers*
2) Aeronautical: passengers and mainly freight	2) Waterways: freight
3) Railroad: passengers* and freight	3) Road: passengers (mainly collective)
4) Waterways: freight	4) Aeronautical: mainly passengers

\*Includes metropolitan transportation (subways)

Increasingly, any alteration of the transportation system depends upon what happens in the energy and environment areas. This means that efforts made to use

means of transportation rationally, to achieve energy efficiency and environmental preservation, is a common characteristic of the two scenarios, although of course taking their individual features into account. Some important innovations in the materials area are those that contribute toward improving efficient use of fuels and those that make it feasible to use renewable alternative sources, already mentioned in the tables referring to the energy sector. In both scenarios, there is strong tendency for intermodal transportation to grow, that is, interconnection between two or more types of transportation.

In Scenario I the growth of individual transportation, represented by automobiles would continue strong, while the resultant environmental problems would be dealt with by resorting to new low environmental impact technologies. Passenger railroad services would also be competitive over longer distances, particularly with a greater number of bullet-trains in service, gaining over aeronautical transportation which would, however, retain its importance for intercontinental stretches. In Scenario I, maritime/waterways transportation would hold on to its role of being the most appropriate way of large-scale transporting of the principal goods and commodities in international trade.

In Scenario II, railroad transportation would contribute more both in the urban segment (subways) and in interurban traffic, because of its flexibility in using the same infrastructure for transporting cargoes and passengers, and due to its lesser environmental impact, when compared with road transportation. Maritime/waterways transportation would gain ground in those regions of the world where there is a high potential for utilizing river drainage basins and sea ports which are not yet much used, such as in Brazil. Road transportation would expand much less and only as and when low environmental impact technologies are developed better and made more accessible, also in terms of cost. There would be emphasis on the use of green fuels, particularly in regions where there are greater possibilities of using biomass. Aeronautical transportation would not increase its participation beyond the present rates, because it has the highest cost per unit of weight carried among all of them.

Scenario I, which is marked by the continuation of the strong participation of individual transportation, tends to stimulate even more the development of advanced materials, because they will be of great help for meeting energy conservation requirements and lessening the environmental impact, although while seeking to safeguard the comfortable profitability of the transportation industry in the world economy.

Within the concept of Scenario II, the expansion of the cargo and passenger transportation system to serve larger portions of the population, underscores the use of lower cost methods, therefore pointing to railroads and waterways. Innovation in materials continues important, but it is not decisive for an efficient transportation system which, if this is to be achieved in this case, will depend much more on planning criteria and on taking advantage of regional potentialities and facilities.

## ***TECHNOLOGICAL DEMANDS AND DEMAND FOR MATERIALS FOR THE TRANSPORTS SECTOR IN BRAZIL IN 2015***

### ***A) Road Transportation***

In this study, basically the motorvehicles segment has been analysed and, in this segment, more specifically automobiles, trucks and buses.

#### **General Aspects**

Until recently, the strategy of the assembler companies in Brazil indicated that technological updating was not a priority. Until the beginning of this decade, the assemblers blamed the low level of the sector's absorption of technology on the lack of production scale and on government protection of the domestic market (BNDES, 1991). However, with the continuation of opening up the economy to international trade, pressure began to be exerted for modernizing the sector. The first step was the adoption of a the "lean production" model, accelerating the incorporation of new materials to the productive assembling processes (PEITER; BORGES, op.cit.).

Legal and regulatory measures regarding the emission of pollutants are also pressuring the sector in Brazil to incorporate advances in vehicle design and manufacturing ideas (recycling of materials, better performance and fuel saving), and they may also stimulate or revive interest in renewable fuels, particularly those made from biomass (alcohol, vegetable oils), as well as others such as electric energy obtained from renewable sources (for example including solar accumulating batteries, solar/hydrogen fuel cells).

In the meantime, Table III.12 shows that, recently, there was a change in the profile of energy consumption of these vehicles, with alcohol which has predominated at the early 80s, being replaced by gasoline, as from 1990.

This table also shows a strong decline of motorvehicle production in the period 1988 to 1992, as a manifestation of the domestic market crisis mentioned earlier. An expected revival of economic growth in Brazil would stimulate the automobile sector, resulting in a considerable expansion of the installed production capacity (forecast for 2 million vehicles by the end of the decade). At present, the automobile industry in Brazil is still working with idle capacity, even though in 1993 there was a surprising growth of vehicle purchases which resulted in record production by the assemblers, reaching a figure of approximately 1.3 million vehicles.

**Table III.12 - Brazilian Automobilitic Industry - Production of Vehicles, per Type of Fuel and Class (1988/1992)**

A) PER FUEL AND CLASS			
VEHICLE CLASS	1988	1990	1992
<b>Gasoline:</b>	248,573	640,265	600,225
Passenger	194,434	530,705	499,211
Light Commercial	53,907	109,252	100,711
Goods Transportation	232	308	303
<b>Alcohol:</b>	569,310	83,259	193,441
Passenger	492,967	71,523	163,127
Light Commercial	76,222	11,736	30,314
Goods Transportation	121	-	-
<b>Diesel:</b>	148,999	120,123	111,272
Passenger	497	317	4,891
Light Commercial	63,943	58,728	53,203
Collective transportation	16,032	12,957	22,521
Goods Transportation	68,527	48,121	30,657
<b>Total</b>	<b>966,882</b>	<b>843,647</b>	<b>904,938</b>
B) PER CLASS			
Passenger	687,898	602,545	667,229
Light Commercial	194,072	179,716	184,228
Public Transportation	16,032	12,957	22,521
Cargo Transportation	68,880	48,429	30,960
<b>Total</b>	<b>966,882</b>	<b>843,647</b>	<b>904,938</b>

SOURCE: ANFAVEA-National Association of Manufacturers of Autopropelled Vehicles  
Tables prepared from GEIPOT data (1993)

### Technological demands and the demand for advanced materials

By and large, besides the growing pressure coming from consumers for better quality and lower prices, other factors have been exerting pressure on the sector. The more important are protecting the environment, controlling the noise level of engines, conserving energy and traffic safety. In the developed countries there are incentives for taking old vehicles out of fleets, for limiting the polluting emissions of new cars and for using cleaner fuels, while it is sought to make the use of renewable energy sources feasible (UFSCAR).

There is still a growing tendency toward the dissemination of the "Lean Production" method, based on a strategy for meeting consumers' needs and eliminating wasting of time, movement, space and materials. The new market requirements and the environmental issue have been particularly stimulating new technological developments in the sector (Peiter; Borges, 1992):

a) the introduction of light materials (aluminum, thermoplastics, etc.), to reduce the weight of vehicles and their energy consumption;

b) recycling of vehicles, making greater use of materials and reducing discarding, introducing into the design not only concern with assembling, but also with the disassembly of the vehicle; materials that are recyclable become a decisive factor;

- c) utilization of new energy sources (ethanol, methanol, electric energy, etc.);
- d) introduction of automotive electronics in vehicles, providing not only greater comfort and safety, but also contributing toward saving fuel and lowering pollution.

Some comments are made below on the utilization of traditional materials and the prospects of incorporating some advanced materials in the manufacture of automobiles, based on a diagnosis of the automobile segment prepared by Peiter and Borges (1992).

### **Steels**

According to data from the International Iron and Steel Institute (IISI, 1991), in the 70s there was a considerable decline in the use of metallic materials, particularly mild steel and cast irons, in European, Japanese and American automobiles. On the other hand, the leadership of steels was not threatened, because of the following aspects:

- a) They are keeping their competitiveness, when the costs of molding, painting and the depreciation of molds and tools are considered, and when the values of the break-even points for solutions available between steels and plastics are calculated for individual parts and pieces.
- b) Although it is simpler to mold plastics, the finishing necessary to attain a suitable standard is more laborious and costly. Furthermore, the introduction of extra-low and ultra-low carbon steels, and materials free from interstitial defects, represented an evolution in mechanical molding.
- c) Resistance to corrosion of steels was much improved by the introduction of surface coatings through prepainted steels and coated steels.
- d) The introduction of high-strength low-alloy steels (HSLA) considerably improved the safety of vehicles, besides helping to reduce their weight.
- e) Steels also offer advantages with regard to recyclability, when compared with plastics, which continue to present technical, environmental and economic problems in recycling.

### **Polymers**

In spite of the optimistic forecasts of the iron and steel industry, polymeric resins have been progressively gaining ground in the automobile sector, through innovations and improvements. Thermoplastic and thermosetting polymers are being used both for car bodies and engines and under the-hood (battery housings, blowers, air and fuel ducts, etc.). The inner parts represent approximately 2/3rds of the current possibilities for using plastics in automobiles (particularly PVC, polyethylene and polystyrene), while the remaining 1/3rd is left to engineering polymers.

### **Aluminum**

The use of light metals, specially aluminum and its alloys, is already widely accepted for engine blocks, radiators, piston rods, pistons, bushings and wheels, as well as for the bodies of some models of sports or luxury cars. Aluminum is also used in metal die composites, mostly for engine parts.

### **Ceramics**

The use of structural ceramics in engines (specially those made from alumina, zircon, silicon nitride, silicon carbide and alumina die composites) has been bringing improvements, even though the technical feasibility of engines mostly made from ceramic materials seems a long way off.

Among other uses already incorporated to vehicles, including in Brazil, are ceramic catalyst supports intended for reducing the carbon monoxide emissions of exhaust gases. Another prospect is the utilization of advanced ceramics in developing gas turbine propellers, which could possibly be used in overland transportation vehicles.

Chart III.8 shows a summary of the main demands for technological development of automobile transportation equipment and their demands for advanced materials in Brazil.

**Chart III.8 - Technological and Advanced Materials Demands of the Automobilitic Segment**

TECHNOLOGICAL DEMANDS	DEMANDS FOR ADVANCED MATERIALS
<p>1.Improved performance of vehicles by reducing weight without safety loss.</p>	<p>1. Structural Parts (body)</p> <ul style="list-style-type: none"> <li>- high strength low alloy steels already in use in a series of structures</li> <li>- polymers natural components with safety requirements; and polymeric alloys, specially thermoplastics, reinforced or not, for parts that do not affect safety (hood, baggage compartment, mud guards, bonnet); tendency to change to the "cage" structure which favors assembling of plastic panels.</li> <li>- increased use of metals such as aluminum and magnesium alloys (including to shift to total Al car body)</li> </ul>
<p>2. Evolution of designs taking into consideration the full life cycle of products up to recycling of the materials.</p>	<p>2. Improvement of materials envisaging durability desassembly of parts andrecycling of materials</p> <ul style="list-style-type: none"> <li>- metals have the advantage over the other materials because repairs are easier, because of modern methods for protecting against corrosion and recycling.</li> <li>- thermoplastic polymers have the advantage over thermosetting polymers, but the question remains about the large number of different formulations used, which cannot be mixed for recycling.</li> <li>- ceramic materials, still used in small amounts in vehicles, are those that offer the least possibilities for recycling, because they are difficult to regenerate.</li> </ul>
<p>3. Evolution determined by the need to maintain competitiveness (new management tools for attaining the world manufacturing class and lean production)</p> <ul style="list-style-type: none"> <li>- continuous production flow;</li> <li>- automation technologies;</li> <li>- design as the central point of the venture's functions;</li> <li>- simultaneous engineering;</li> <li>- simultaneous manufacturing based on materials.</li> <li>-rapid prototyping;</li> <li>- prospective ergonomics</li> </ul>	<p>3. Implications for all materials used in the construction of vehicles;</p> <ul style="list-style-type: none"> <li>- new materials taylor made call for new design and product manufacturing concepts;</li> <li>- the design/synthesis of the material, and its processing/manufacturing route in the form of a product/component, must be carried out simultaneously;</li> <li>- the design of the end product (vehicle) and its manufacturing/assembling process, must be done simultaneously with the design of the material/ component that will be put in it.</li> </ul>

---

4. Low environmental impact technologies:

- hybrid vehicle (electric/combustion)
- hydrogen-propelled
- electrically-propelled
- propelled by green fuels
- optimization of combustion cycle by new electronic devices

4.1 Electrically propelled:

– Storing energy in batteries is still the greatest problem due to their weight, loading and reloading capacity, safety and materials used in the electrodes (the existing options are lead, nickel and cadmium and rare earths for the existing types of batteries or those being developed; conductive polymers may become an interesting alternative).

4.2 Hydrogen-propelled:

– Electrochemical generation of hydrogen must be done using another renewable source, such as in the earlier case;  
– Storage must be safe, with a prevalence of "metallic glass" materials; propulsion would use fuel cells and/or metallic hydride batteries feeding electric engines;

4.3 Propulsion using green fuels:

– the dissemination of these fuels requires few alterations in terms of engines technology, and consequently materials technology;  
– In some cases, like in that of hydrated alcohol, new types of coating could be developed for parts which come into contact with fuel and exhaust gases.

---

If the Brazilian automobile sector begins to pursue better quality and higher productivity, the capacity of Brazilian producers of traditional materials seems to be capable of satisfying the most demanding requirements for their products. Usiminas and Cia. Siderúrgica Nacional are ready to supply steel sheets to the transportation sector. Also regarding steels, no major technical difficulties are expected; among the high strength low alloy steels, the sector has already mastered the preparation of niobium alloy steels. In the case of aluminum, in addition to local producers, some large international companies have plants in Brazil. Whereas plastics depend more on the transfer of technology by the petrochemicals sector. Brazil is facing more difficulties in the field of the more advanced materials used in high performance parts and components, such as ceramics.

## ***B) Rail Road Transportation***

### **General Aspects**

– As from the 70s, due to the expansion of the roads system, more and more passengers lines were taken out of service in railroad transportation, at the same time as cargo transportation was expanded through export corridors. This means that the length of the Brazilian railroad grid which in 1975 (best year), was 30,809 km, altered only slightly, to 30,114 km of lines in 1992 (GEIPOT, 1993).

– The electrification of Brazil's railroads is still incipient, which means that most of the locomotives are diesel-fueled (2,119 locomotives in 1992, compared with only 178 electric trains operating in the same year) (GEIPOT, 1993).

### **Technological Demands and Demand for Advanced Materials**

Three new projects of railroads<sup>70</sup>, one subway<sup>71</sup> and one VLT<sup>72</sup> (Light Vehicles on Rails) are at the moment in progress in Brazil. There is also a series of proposals for installing light trains in state capitals and medium-sized cities, although without immediate prospects of installation (ABIFER, 1992). The sector is cautious about longer term projections.

Expansion of the passenger transportation railroad system, integrating it with other transportation systems so as to permit point-to-point connections, would require more modern equipment for faster and more comfortable interurban travel.

---

<sup>70</sup> They are: (1) **Ferronorte**, installed by private enterprise, will connect the western part of São Paulo state and the "Triângulo Mineiro" to Mato Grosso and Rondônia, to take agricultural produce to consumer regions and to the port of Santos; the first stretch of 311 km will be finished in December 1994. (2) The state government-run **Ferroeste**, will be used to take production from Western Paraná and Mato Grosso do Sul to the port of Paranaguá; the first stretch of 248 km will be finished in January, 1995. And (3) the **Transnordestina**, which is a group of works for interconnecting Federal Railroad Company lines in the northeast, in a total of 531 km.

<sup>71</sup> The Brasília subway consists of a 40 km line which will connect the Pilot Plan to 5 satellite towns. It will have 33 stations and 3/4 of the track will be on the surface. It had its first 20 km stretch inaugurated in March, 1994, which has 6 substations.

<sup>72</sup> Brazil's first VLT has been operating experimentally since 1990 in Campinas, SP, along an 8 km stretch. This project, whose conclusion is not yet foreseen, is using the unused track bed of old railroads, and for this reason did not require expropriations.

**Chart III.9 - Technological and Advanced Materials Demands of Railroad Transportation**

TECHNOLOGICAL DEMANDS	DEMAND FOR ADVANCED MATERIALS
Lighter trains, specially for passenger cars of express trains (intercity).	Structural materials such as aluminum and thermoplastics increase their participation: use of new designs for panels, e.g. honeycomb; new materials for rails (less friction) and for brakes (more friction), e.g. carbon-carbon composites.
New kinds of propulsion: levitated trains.	These depend on the successful development of magnets and of superconductors. Those that have a metallic base have already been found feasible but not economical, due both to the costs of the materials and to the complex cooling system which uses helium gas. There is still the expectation regarding ceramic superconductors, if they achieve levels of properties similar to those of metallic superconductors.

### ***C) Maritime/Waterways Transportation***

#### **General Aspects**

Brazilian ports have been operating mostly in foreign trade, which has been imposing on them new packing, handling, storage and transfer standards, in spite of the deterioration caused by the recent economic crisis. Elsewhere, the loading and unloading speed in ports is being increased by intensive rationalization based on greater automation of port equipment, whose effect has been a considerable drop in operating costs. An intense campaign is under way for privatizing the ports, as a solution for the impasse brought about by the public sector's failure to invest in this segment's infrastructure.

Another factor stimulating the sector's technological development has been demands for greater shipping safety, also due to their serious implications for the environmental issue. Automation in shipping has helped reduce such accidents, because most of the accidents on vessels have been caused by human failure, and not equipment.

The question of the certification of the reliability of vessels is another item under discussion again at an international level. The criteria will tend to become stricter from now on, making insurance premiums increasingly more costly for the older vessels. This is paving the way for a new phase of modernization of the world fleet and, consequently, of the Brazilian fleet, using our own shipyards.

### Technological Demands and Demand for Advanced Materials

The following Chart summarizes the main technological demands at present referring to this kind of transportation, and their implications on the demand for advanced materials which, as shown, are not very strong.

**Chart III.10 - Technological and Advanced Materials Demands of Maritime Transportation**

TECHNOLOGICAL DEMANDS	DEMAND FOR ADVANCED MATERIALS
Naval architecture: improvement of naval design procedures using computer tools, e.g. CAD and CAM.	This sector is not notable for the introduction of new structural materials; the tendency is for materials already in use to be improved with regard to durability and resistance to corrosion, considering that metallic materials are well entrenched in this sector, particularly steels for both hulls and compartments and tanks.
Propulsion: in maritime navigation there are prototypes being tested that combine the use of the present turbines with sets of sails; tests with magneto-hydrodynamic propulsion have also been reported.	<ul style="list-style-type: none"> <li>– In sail propulsion, materials for large areas of sails will have to be developed, particularly in the polymers specialty.</li> <li>– In magnetic propulsion, (magneto-hydrodynamic), the use of supermagnets depends on the new superconductor materials, particularly ceramics.</li> </ul>

### *D) Aeronautical Transportation*

#### General Aspects

Among the different kinds of transportation, the aeronautical segment is the most technology intensive, because it requires more sophisticated equipment and total performance safety. (PEITER, PINHÃO, 1992). In the developed countries, this segment has been an important stimulant of development in the materials area, due to the high cost of aerospace transportation (which depends largely on the weight of the aircraft) and the reliability requirements which must be met by the materials used. They have to comply with stricter specifications. (UFSCAR).

Recently, the technical requirements imposed by the energy crisis and by pressure exerted for safeguarding the environment, have been largely responsible for technological modernization in civil aviation, which earlier was mainly due to developments in the defense area. (PEITER; PINHÃO, 1992).

The technological demands made because of the environmental impacts caused by the aeronautical sector are guided, mainly, toward solving the following problems:

- environmental pollution resulting from the use of fossil fuels in the sector;
- sound pollution, specially in areas near airports which are mostly located in urban or suburban areas;
- impacts caused by the occupation of large areas by airports;

– effects on the ozone layer caused by high-altitude flights, by turbine combustion.

The Brazilian aeronautical materials and equipment sector may be considered one of the most important among those in developing countries. Due to the low consumption scale, materials specially developed for aeronautical use are not manufactured in Brazil<sup>73</sup>. However, what is very important is the knowledge that Brazilian companies have acquired regarding the design, selection and use of materials in processes for manufacturing parts and pieces. Some avionics, machined parts, tires, rubber fuel tanks, are produced here, among the items that comply with international quality standards. There are also very competent repairs and servicing of engines and turbines, either through the servicing centers of Varig, the largest Brazilian operator, or in the specialized company Celma.

Mention should be made of Embraer's competitive position, at an international level, in the segments of military training aircraft, regional transportation and agricultural use aircraft. In the 80s, Embraer began three extensive programs which considerably altered its technological profile: Brasília/EMB-120, AMX (Italian-Brazilian design) and CBA-123 (a joint project with Argentina). The absorption of composite materials technology was essential in those programs.

#### **Technological and Advanced Materials Demands**

The following chart III.11 summarizes these demands.

For many years the aeronautical sector excelled in the development of advanced materials, because of demand coming from the defense area. Many of the improvements used in today's passenger aircraft were assimilated from that area. The composite materials, along with the superalloys, were the subject of the most development efforts in recent times. Regarding composites, large conglomerates of the world chemicals industry have contributed systematically toward the development of special resins and strengthening fibers based on very varied formulas.

In the metallurgical segment also, countless innovations have arisen, such as Al-Li alloys, and new types of processing which have enabled materials such as superalloys to have their properties gradually improved to meet the requirements of increasingly sophisticated propellers.

---

<sup>73</sup>Mention should be made, however, of a special steel for landing gear developed by the company Eletrometal.

**Chart III.11 - Technological and Advanced Materials Demands of Aeronautical Transports**

TECHNOLOGICAL DEMANDS	DEMAND FOR ADVANCED MATERIALS
Aircraft for passenger and cargo transportation - more economical and safer.	<p>- A tendency already established for reducing the weight of aircraft by increasing the use of composite materials in various parts of the wings and fuselage, instead of aluminum alloys; polymeric matrix composite are mostly being used, specially thermosetting resins, strengthened with carbon fibers, among other important fibers.</p> <p>- Lithium-aluminum alloys may be able to compete in these uses, but there are still technical and economic obstacles to be overcome.</p> <p>- Design alterations, made possible by the new materials, are also being included in aircraft, reducing the aerodynamic drag and making them more economical.</p>
Development of more efficient and low noise engines and turbines.	<p>- Regarding turbines, new materials have made it possible to increase the operating temperature, which makes them more efficient. Among them are nickel-based superalloys and titanium and its alloys; some other innovating materials may also be able to compete, among which are some metal matrix composites and intermetallics</p>

### ***REFERENCES***

- 1) ABIFER/Associação Brasileira da Indústria Ferroviária. 1992 Report. São Paulo, 1992.
- 2) BARAT, J. Infrastructure services in transportation and competitiveness. Technical thematic note of the block "Infrastructure Conditions and Competitiveness" of the Study of the Competitiveness of Brazilian Industry. MCT/FINEP/PADCT, Campinas, 1993.
- 3) BNDES/Studies Department. Foreign capital in Brazilian industry: present situation and prospects. BNDES, Rio de Janeiro, 1988. (BNDES Studies, 10).
- 4) BNDES/Development Strategies Department. Organization of production and quality management. BNDES, Rio de Janeiro, 1991. (BNDES Studies, 18).
- 5) CABRAL, A. "Science and technology policy: the Brazilian experience in the aeronautical industry". Science and Public Policy. Vol. 19, No. 1, February, 1992, pp. 35-41.

- 6) GEIPOT/MT. Statistical Transportation Yearbook - 1992/93. Brasília, 1993, V. 20.
- 7) IBGE/DEIND - Industry Department. Monthly Industrial Research: Cyclical Indicators of Industry.
- 8) INTERNATIONAL COUNCIL FOR SCIENCE POLICY STUDIES. Science and Technology in Developing Countries - Strategies for the 90s. A report for UNESCO, Paris, 1990.
- 9) PEITER, C.C.; BORGES, C. Diagnosis on the situation and tendencies of materials from the perspective of the consumer sector. Transportation Industries Complex - Automobile Sector. Methodology Workshop on the IDRC/CETEM Project Advanced Materials and Sustainable Development: Strategies for Brazil. CETEM, Rio de Janeiro, November 17-19, 1992.
- 10) PEITER, C.C.; PINHÃO, C.M. Diagnosis on the situation and tendencies of materials from the perspective of the consumer sector - Transportation Industries Complex - Aeronautical Sector. Methodology Workshop on the IDRC/CETEM Project Advanced Materials and Sustainable Development: Strategies for Brazil, CETEM, Rio de Janeiro, November 17-19, 1992.
- 11) RATTON NETO, H.X. The Future of the railroads. Revista Ferroviária, pp. 21-32, December, 1992.
- 12) SALOMÃO, S. "Guidelines for a marine and maritime transportation policy". Ports and Ships Yearbook 93/94.
- 13) UFSCAR/SEBRAE, Workshop "Brazilian Technological Updating and the Importance of Advanced Materials", São Carlos, October 20, 21, 22, 1993. (Panel 2: Materials in the Capital Goods and Automobile Complex; Panel 4: Materials in the Aeronautical, Aerospace and Industrial Quality Complex).

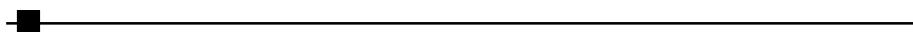


# CHAPTER 3

---

*PART IV*  
*THE MICROELECTRONICS SECTOR: THE*  
*SCENARIOS AND THE ADVANCED MATERIALS*  
*IN BRAZIL*

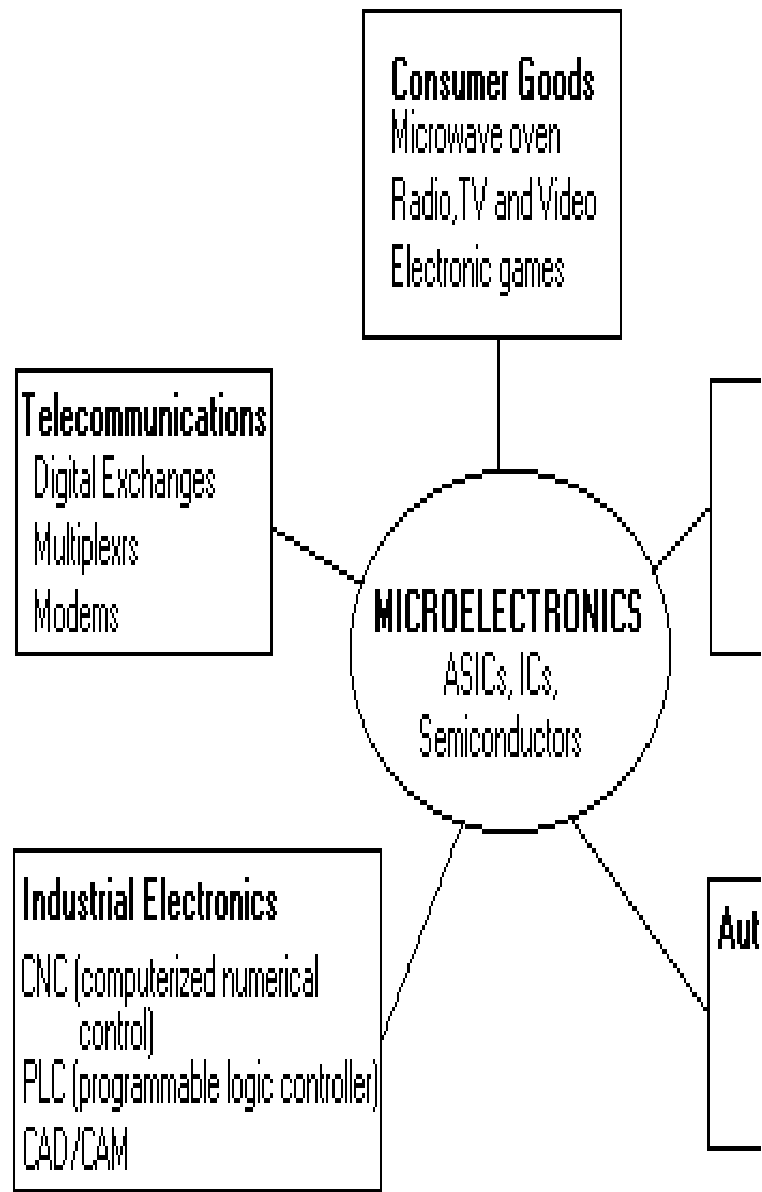
*Heloisá V. Medina, Ivan C. Marques and Maria Laura Barreto*  
*CETEM/CNPq*



### ***3.IV THE MICROELECTRONICS SECTOR: THE SCENARIOS AND THE ADVANCED MATERIALS IN BRAZIL***

#### ***ELECTRONICS COMPLEX: INTERNATIONAL AND NATIONAL PANORAMA***

This paper takes as its point of departure a specific conception of microelectronics in the "electronics complex". This universe comprises not only microelectronics but also the related user segments - consumer goods, telecommunications, informatics, automotive and industrial electronics, including automation and robotics - which at the same time constitute the main branches of the complex. As microelectronics is the physical expression of miniaturized electronification, it represents the base of this complex. Its main products are microelectronics components which enter into the assembly and working of electronic goods and services. The diagram below illustrates how microelectronics radiates out into the segments of the electronics complex.



This paper offers a brief international and Brazilian national overview of these segments, followed by a description of recent developments in microelectronics and telecommunications in Brazil and worldwide. It incorporates the opinions of experts specially interviewed for the project. Finally, it describes future trends for the scenarios considered, and endeavors to identify opportunities and impacts for Brazil in the field of new materials.

### ***A) International Panorama***

The "electronics complex" embraces a large number of activities that represent an ever growing number of products and an ever larger share of international trade. The electronics industry is extremely dynamic and of great strategic importance for economic and technological development. That it is so dynamic and all-embracing can be attributed to the digitalization of information brought on by information science after the first electronic computers were built in the 1940s. This coding of all information into **bits** has brought about a prolific marrying of techniques from the fields of electronics and linguistics, to generate artifacts (systems: machines and programs, **hardware** and **software**) which, once built, are capable of acting upon the digitally coded information with extreme efficiency in terms of space, time and energy and of generating opportunities and a series of innovations for a variety of the economy sectors. At a time of growing environmental concern, the informatics industry (more and more inseparable from the "electronics complex") tirelessly exploits, in its publicity, the hitherto unimaginable success of this marriage<sup>74</sup>.

The economic sectors that are the direct or adopted children of this marriage today constitute the "electronics complex" and their inter-relations go beyond the simple relationship of purchase and sale of inputs. They share the same technical base constituted by microelectronics components, which generates great synergy within the complex.

This set of industries characteristically involves activities with a high technological content. The great volume of funds for investment in research and development raises barriers to entry by new companies, especially in leading edge areas where access to technology is limited to those companies that develop it.

The electronics goods markets are led by great international corporations originating in developed countries and the so-called "Asian tigers", most of which operate worldwide on a global market basis. Tables III.13, II.14 and III.15 show that the informatics (information processing equipment), telecommunications

---

<sup>74</sup> "If automobile technology had developed as much as computer technology, a Rolls Royce would cost one dollar and would travel round the world at more than 1,000 mph on one quart of fuel", boasted computer manufacturers, ten years ago.

equipment and consumer (entertainment) sectors are the main markets for the electronic complex's final products; in United States, Europe and Asia markets respectively.

**Table III.13 - Electronics Goods Market in the United States\***

	1992	1993	1994
Informatics Equipment	98	140	148
Communications Equipment	36	39	42
Consumer (entertainment)	12	12	12
Industrial Automation	9	8	8
Semiconductors	17	35	45
<b>Total</b>	<b>176</b>	<b>234</b>	<b>255</b>

\*(US\$ billion)

Source: Electronics, V.66, N. 1, 11 Jan 93, p. 4 and V.67, N. 1, 10 Jan 94, p. 6.

**Table III.14 - Electronics Goods Markets in Europe\***

	1992	1993	1994
Informatics Equipment	49	52	54
Communications Equipment	35	41	42
Consumer (entertainment)	29	30	31
Industrial Automation	2	2	5
Semiconductors	7	7	11
<b>Total</b>	<b>129</b>	<b>132</b>	<b>136</b>

\*(US\$ billion)

Source: Electronics, V.66, N.1, 11 Jan 93, p. 6 e V. 67, N. 1, 10 Jan 94, p. 12.

**Table III.15 - Electronics Goods Markets in Asia\***

	1992	1993			1994		
	Total	Asia	Japan	Total	Asia	Japan	Total
Informatics	54	27	54	81	29	54	83
Communications	25	14	27	41	15	27	42
Consumer	40	19	31	50	20	30	50
Ind. Automation.	8	3	5	8	3	5	8
Semiconductors	24	8	37	45	11	40	51
<b>TOTAL</b>	<b>161</b>	<b>71</b>	<b>154</b>	<b>225</b>	<b>78</b>	<b>156</b>	<b>234</b>

\*(US\$ billion)

Source: Electronics, V.66, N.11, Jan. 93, p.8 e V.67, N.1, 10, Jan. 94, p.8 e 10.

It can be seen that the world microelectronics industry is largely concentrated in the United States and Asia. Given that the production of the microelectronics industry appears in the tables under the item "Semiconductors", the singular position of Asia, followed by the United States, is particularly striking when one turns to

Table III.16, which compares the rates of production of semiconductors with the total of final goods in Asia, United States and Europe. Note also that, although the table does not distinguish between semiconductors forming part of microelectronics components and those used in discrete components, it is quite probable that the percentage of discrete components is greater in Europe than in Japan or the United States, concentrating microelectronics even more in Asia and the United States. Moreover, the recent success and consolidation of a portfolio of semiconductor patents by Korean companies like Goldstar and Samsung means that the Asian presence in microelectronics cannot be reduced to Japan.<sup>75</sup>

**Table III.16 - Semiconductors Participation in the Final Goods Market**

	1992	1993	1994
United States	9,6 %	14,9 %	17,6 %
Europe	7,8 %	5,3 %	5,1 %
Asia (total)	14,9 %	20,0 %	21,8 %
Asia except Japan	-	11,2 %	14,1 %
Japan	-	24,0 %	25,6 %

Sources: Tables 1, 2 e 3.

Generally speaking, in terms of business strategies, North American and European firms have opted for greater specialization - unlike their Japanese counterparts - and concentrate their activities in a specific segment of the complex.

The USA, on the basis of their mastery of systems, processing memory and software technology, lead in the data processing equipment segment. In the so-called leading edge sectors - supercomputers and artificial intelligence - the United States constitute the only substantial market.

From the European electronic goods market, represented by West Germany, the United Kingdom, France and Italy, it can be seen that Europe is relatively backward in all segments. Moreover, growth rate indicators and forecasts are also more moderate.

Companies are achieving the volume of funding necessary for R&D by cooperating in research areas of common interest. These initiatives are generally supported and sponsored by governments. One example are the EEC programs directed to closing the technology gap with the USA and Japan, of which the EEC bears 50% of the cost and the companies involved the rest.

In this regard, the same trends present in Asia and the USA are to be seen in Europe, although the European market lags behind in terms of microelectronic components.

---

<sup>75</sup>Already in 1989 it was estimated that Samsung held patents that would be of great interest to IBM for reducing the launch time of some of its products, like the 3090 series (*Electronic Engineering Times*, April 3, 1989: 2, cited by Evans, P. *Predators and Midwives: An Analysis of States and Industrial Transformation*, in print).

Among semiconductors, integrated circuits (ICs) are increasing their share of the market by incorporating functions of discrete semiconductors. Performance by dedicated ICs (ASICs) is outstanding, although standardized ICs like memories and microprocessors still constitute the major segments.

Table III.17 shows the world semiconductor market and Table III.18 lists the main market suppliers of semiconductor components.

**Table III.17 - World Semiconductor Market\***

	1993	1994	1995
North America*	41,0	52,4	51,1
Japan	33,1	26,5	33,0
Europe	5,5	6,2	6,2
Rest of the World**	5,5	11,0	10,6

(\*) N.A.F.T.A.

(\*\*) Includes the "Asian tigers".

Source: Electronics, V.67, N.1, 10 Jan 94, p. 6.

**Table III.18 - Major World Suppliers of Semiconductors**

Classification in 1993	Classification in 1992	Companies	Billing (US\$ million)
1	2	Intel	7,842
2	1	NEC	6,436
3	4	Motorola	6,007
4	3	Toshiba	5,873
5	5	Hitachi	4,740
6	6	Texas instrument	3,842
7	7	Fujitsu	3,298
8	12	Samsung	3,092
9	8	Mitsubishi	3,039
10	3	Matsushita	2,430

Source: Electronics, V. 66, N. 23, 13 Dec. 1993, p. 8.

### ***B) Brazilian Panorama***

The production of electronic consumer goods is concentrated in the Manaus Free Zone and represents nearly 70% of this region's industrial billing. In 1989, eighty-five industrial electronics companies constituted a final goods production capability which manufactured approximately 3.3 million appliances, including television sets (color and black and white), video cassette recorders and audio

equipment<sup>76</sup>. According to IBGE figures, industrial production of TV sets, radios and audio in 1993 grew 56% in relation to the prior year, after falling three years in succession, as shown in Table III.19.

**Table III.19 - Industrial Production Index: Annual Growth Rates (%)**

Sectors	1990	1991	1992	1993
<i>Processing Industry</i>	-9,5	-0,5	-5,0	10,1
<i>Consumer Durables</i>	-5,4	-1,2	-7,1	41,0
<i>Electrical / Communications Material</i>	-5,6	-4,5	-18,4	26,9
Office Equipment	-4,4	5,3	-12,5	13,4
Power Equipment	-9,7	-9,8	-8,5	26,6
Electrical Conductors	-24,3	3,1	-2,4	0,4
Electrical Material f/Vehicles	-8,7	-8,1	-12,7	17,0
Motors and Appliances	-6,4	-9,8	-10,7	20,1
TV, Radio and Audio	7,4	2,8	-26,8	56,1

Source: IBGE/DEIND. Pesquisa Industrial Mensal/Produção Física. Dec. 90/91/92/93.

In the electrical and communications sector's first year of recovery, the worst performing segment was electrical conductors, due principally to low production of copper wire, reflecting technological changes brought about by entry of optical fibers.

According to Vanda Scartezini<sup>77</sup>, the consumer segment, based on importation and maintained by tax incentives, follows a model supported by supply agreements with international manufacturers. Japan is the main source of technology for these contracts, which include trademarks and products and the importation of main components, parts and units. One consequence of this model is tied technology which prevents Brazilian consumer electronics manufacturers from competing internationally, despite their occasionally achieving international-scale production<sup>78</sup>. On this model, Brazilian firms have no direct, autonomous access to markets for latest-generation microelectronics components, where a good part of technological innovation is concentrated and through which final product costs can be substantially reduced. One of the pre-conditions for international competitiveness and domestic efficiency - in terms of cutting costs - would be to reformulate this model, besides technical upgrading for engineers in the sector, modifications to curricula and investment in design and product engineering.

<sup>76</sup> Scartezini, Vanda: "Microeletrônica - Silício", IPT/FECAMP project report, mimeo, 1990.

<sup>77</sup> Scartezini, Vanda. op.cit.

<sup>78</sup> Note that this impediment will not generate conflict since Brazilian firms themselves are conceived on the understanding that their area of operations is restricted to the domestic market or markets previously negotiated with the suppliers of trademarks, patents and technology. The case of Sharp is one example.

In Brazil, during the 1970s and 80s, the telecommunications and informatics sectors followed mutually independent policies, practically in isolation from policy adopted for the Manaus Free Zone. That is, like other places - and unlike East Asia - Brazil failed to implement a policy that would effectively deal with and integrate the "electronics complex". The country thus failed to benefit from the economies of scale and scope offered by the gradual fusion of consumer, telecommunications and informatics electronics technology.

During those decades, the telecommunications sector levered the development of microelectronics in Brazil. Stringent regulations covering acquisition of equipment and systems by way of the state telecommunications monopoly made it possible to apply a policy seeking to encourage local development in microelectronics. These measures are possible both because of the volume involved - in the case of user interface terminal equipment (which is steadily diversifying since the classic telephone) - and because of the complexity and specificity - in the case of network composition interface equipment. In this situation of opportunities in the 1970s and 80s, telecommunications sector policy on acquisition of equipment permitted foreign capital to participate by sought to encourage partnerships both with Brazilian capital and with Brazilian technology and engineering, giving preference to and funding local project design and development.

The other lever which seems to have caused greatest impact on prospects for microelectronics during the 1970s and 80s was the informatics. The policy adopted here was to prevent foreign capital from participating directly in a growing portion of the market, which was reserved to industry under Brazilian control<sup>79</sup>. The offset was that companies were expected to earmark investment for establishing patents, learning the technology and, in the long term, achieving international standards of quality and price based on national engineering.

So informatics industry's success and stable high growth rates (25-30% for nearly fifteen years) led Brazilian private capital to lay ambitious plans for microelectronics. The largest groups involved in the sector - including Itaú, Guinle and Macline - went as far as to consider investing hundreds of millions of dollars to implement the complete process (including diffusion) for manufacturing standard microelectronics components (ICs). It is also believed that, following the technical feat of successfully managing to open computer black-boxes, knowledge of application specific integrated circuits (ASICs) and related opportunities became widespread, particularly as concerned the chip sets which were steadily reducing the number of components in equipment as techniques for miniaturizing semiconductor artifacts (microelectronics) were refined.

---

<sup>79</sup> As of 1980, the market reserve extended to practically all but medium and mainframe computers.

Within the electronics complex, it is the automotive electronics segment that most stands out today in terms of potential market, as it has evolved little or nothing in recent decades. While in developed countries, automotive electronics represents an average US\$1,100 per car, in Brazil the figure is around US\$200.

For the industrial sector, including motor vehicles and robotics, growth projections from 1992 are of an expected 20% per year until the end of the decade<sup>80</sup>, despite the sector's being considered little developed. Except in specific product niches, it is a sector that has provided little leverage for microelectronics, involving high prices despite the small volume of orders. Input/billing ratio figures stand at around 14%, with semiconductor devices and sensors in first place. Most products offered on the market are products of imported technology, despite the manufacturing companies' being Brazilian.

The main Brazilian figures related to Eletro-eletronic sector performance, production and Companies are shown in tables III.20, III.21 and III.22 respectively.

**Table III.20 - Electro-electronics Sector Performance in Brazil - Annual Rates**

Areas	1993/1992	1992/1991	1991/1990	1990/1989
Electrical and Electronic Components	27%	-28%	-40%	-7%
Household Appliances	16%	-21%	6%	-7%
Industrial Equipment	21%	-13%	-8%	-16%
Electric Power Generation, Transmission and Distribution	0	-15%	-32%	-14%
Image and Sound	34%	-16%	-3%	6%
Informatics	10%	-20%	-15%	-14%
Industrial Automation	0	-21%	-38%	-20%
Telecommunications	-20%	-12%	35%	-25%
Overall Performance	14%	-17%	-7%	-12%

Source: Departamento de Economia da ABINEE, Informativo. Dec., 1993.

---

<sup>80</sup> Scartezini, Vanda op.cit.

**Table III.21 - Electronics Complex in Brazil / 1988**

Production	US\$ million	%
<i>Final Goods</i>	7.140	100
Informatics	2.693	37.7
Consumer Goods	2.800	39.2
Communications	1.050	14.7
Industrial Automation	597	8.4
<i>Components</i>	1.200	100
Semiconductors	850	70.8
Others	350	29.2
Total	8.340	-

Source: BNDES. op. cit.

**Table III.22 - Electronics Component Manufacturing Companies in Brazil**

Companies	Began Production of Semiconductors in	Terminated production in	Origin/Control
Philco	1964	1984	USA
Ibrape	1965		Holland
Semikron	1967		West Germany
Icotron	1973		West Germany
Texas	1973		USA
Thonson/CDF	1974		France
Fairchild	1974		USA
Bourroughs	1974	1982	USA
Transit	1974	1981	Brazil
RCA	1975	1978	USA
Philips ND	1976		Holland
Sanyo	1978		Japan
NEC	1979		Japan
Westinghouse	1979	1988	USA
Politronic	1979		Brazil
Rohn/Toyo	1980		Japan
MC Microc	1980		Brazil
Hitachi	1981		Japan
Stevenson	1981		West Germany
Telefunken			-
Bosh	1981		West Germany
Multitel	1982		Brazil
Heliodinâmica	1983		Brazil
Aegis	1984		Brazil
SID/VSI	1984		Brazil
Itaucom	1984		Brazil
Tecnowatt	1985		Brazil
Eletra	1986		Brazil
ABC XTAL	1986		Brazil
Autel	1987		Brazil
Inepar	1988		Brazil

Source: GEICOM/SEI. In Microeletrônica. BNDES. op. cit.

## **RECENT EVOLUTION AND PRESENT SITUATION OF MICROELECTRONICS IN THE WORLD AND IN BRAZIL**

### ***A) Microelectronics in the world***

The microelectronics industry is typically a highly-concentrated oligopoly, with high growth rates and a market that is considerably internationalized, dominated by North American and Japanese producers.

The technology is new, not accessible and thus dominated exclusively by whoever develops it. It is an activity that demands economies of scale and thus markets of large dimensions. Its products have a very short life cycle. Prices of ICs decline very quickly, beginning while still at the growth or expansion stage, which means that half of related billing is generated at the initial stages of the cycle, at the introduction and growth stages.

The high technology content of IC production entails heavy investment in R&D, at around 10-20% of gross company billing, and requires state backing. The form this backing takes has varied, depending on whether one considers East Asia, the United States or Europe.

A glance at market participation by major blocs over the last five years reveals the departure of the Dutch holding company, Phillips, and the arrival of the Korean giant, Samsung, among the ranks of the largest manufacturers of products for the semiconductor market. This can be seen by comparing Table III.18 above and Table III.23 below.

**Table III.23 - World's Ten Leading Semiconductor Manufacturers**

Company	Nationality	Sales in US\$ million		Order	
		1988	1992	1988	1992
NEC	Japan	4,650	5,360	1	2
Toshiba	Japan	4,545	5,370	2	1
Hitachi	Japan	3,610	4,305	3	5
Motorola	USA	2,900	4,470	4	4
Texas Instrument	USA	2,750	3,080	5	6
Intel	USA	2,330	4,950	6	3
Matsushita	Japan	2,080	2,085	7	9
Fujitsu	Japan	2,075	2,965	8	7
Philips	Holland	2,010	2,030	9	10
Mitsubishi	Japan	1,940	2,720	10	8

Source: ICE, Status 1989 In BNDES op. cit. and ICE Mid-Term 1993.

Meanwhile, in 1993 the firm VLSI Research Inc., of San José, California, forecast that towards the end of this century, the United States will take Japan's place as the world leader of semiconductors and greatest investor in the sector. They foresee Japan's relative position declining as indicated the next tables III.25 and III.26. The prediction is based "on that striking fact about the semiconductor industry, regarding capital investments. And the hard truth is that the once all-powerful Japanese have not kept up their historical levels of investment. As a

result, semiconductor manufacturers in the United States and other Asian nations, especially Korea, are expanding their market share at the cost of the Japanese".<sup>81</sup>

**Table III.24 - Semiconductors World Marketshare by user Sectors**

Sector	Participation %
Military	5
Industrial	11
Telecommunications	17
Consumer/Motor Vehicle	29
Informatics	38
Total (US\$)	51

Source: ICE, Status 1989. In BNDES, op. cit.

**Table III.25 - Forecast of "Competitiveness" on the Semiconductor Market (by region, in percentages of the world market)**

	1990	1993	1998	2000
North America*	37,5	45,3	52,1	54,0
Japan	48,9	40,8	22,4	15,0
Europe	8,7	7,0	6,2	6,0
Rest of the World**	4,9	7,0	9,4	25,0

(\*) N.A.F.T.A. (\*\*) Includes the "Asian tigers".

Source: Electronics, V. 66, N. 23, 11 Dec. 93, p. 8.

**Table III.26 - Forecast of World Capital Investments, by Region, in %.**

	1990	1993	1998	2000
North America*	30,9	53,1	52,2	50,9
Japan	47,7	22,2	13,0	9,8
Europe	8,9	8,5	7,1	6,5
Rest of the World**	12,5	16,1	27,8	32,9

(\*) N.A.F.T.A. (\*\*) "Includes the "Asian tigers".

Source: Electronics, V. 66, N. 23, 11 Dec. 93, p. 8. 2.

Integrated circuits can be divided into standard circuits, which are standardized and marketed as commodities, and the so-called Application Specific Integrated Circuits (ASICs), designed and manufactured for specific applications. This division is not necessarily fixed, since there is a tendency to standardize ASICs which come to establish themselves as market standards.

<sup>81</sup>Quotation source: Electronics, Vol. 66, No. 23, 13 Dec 1993, p. 8.

**Table III.27 - World ASIC Sales from 1987 to 1993 in US\$ million**

Segment	1987	1988	1989	1990	1991	1992	1993	Average Annual Growth (%)
Gate Arrays	2,110	2,830	3,250	3,400	3,900	5,000	5,250	16
Linear Arrays	110	140	160	170	200	250	275	16
<b>Total Semi-Custom</b>	<b>2,220</b>	<b>2,970</b>	<b>3,410</b>	<b>3,570</b>	<b>4,100</b>	<b>5,250</b>	<b>5,525</b>	<b>16</b>
Standard Cell	945	1,200	1,450	1,750	2,200	3,100	3,900	27
Full Custom	905	1,040	1,110	1,200	1,320	1,480	1,500	9
<b>Total Custom</b>	<b>1,850</b>	<b>2,240</b>	<b>2,560</b>	<b>2,950</b>	<b>3,520</b>	<b>4,580</b>	<b>5,400</b>	<b>20</b>
PLD	500	775	1,000	1,025	1,250	1,500	1,600	21
<b>Total ASICs</b>	<b>4,570</b>	<b>5,985</b>	<b>6,970</b>	<b>7,545</b>	<b>8,870</b>	<b>11,330</b>	<b>12,525</b>	<b>18</b>

Source: ICE, Status 1989

In 1983, ASICs represented 10% of world demand for ICs; by 1988, this figure had risen to 15%. The earliest ASIC manufacturing firms are basically Japanese and North American in origin, predominantly the latter.

**Table III.28 - Leading ASIC's Manufacturers - 1988 Sales(1)\***

Company	Nat.	Semicustom	Standard Cell	PLD	Total	% (2)
Fujitsu	Jap.	525	20	-	545	27
Nec	Jap.	360	28	-	388	11
AMD/MMI	USA	10	-	376	386	33
LSI Logic	USA	340	10	-	350	97
Toshiba	Jap.	260	68	-	328	11
AT&T	USA	75	210	-	285	46
TI	USA	25	120	95	240	9
National	USA	125	5	80	210	12
Motorola	USA	130	36	-	166	8
Plessey/Ferranti	UK	145	15	-	160	52

\* (US\$ million)

(1) Excludes Full Custom (2) In relation to total company IC billing

Source: ICE, Status 1989

As ASICs are not a homogeneous product, market competition is determined by a series of factors ranging from the manufacturer's knowledge and familiarity with the equipment or system in which the ASIC is to be inserted, through to the ASIC's performance, quality and price (as well as those of the services involved in development), and including the relationship between the manufacturers of the ASIC and the equipment/system, their mutual business confidence, etc.

For standard ICs, given their nature as commodities or homogeneous goods, competition is determined by price. For standards, the dynamics of competition are

among the most intense, with new products being launched very frequently and with ever shorter life cycles. Innovations are associated with the IC's density; that is, its capacity. There are also innovations to improve performance or alterations in processing level, as is the case with BICMOS technology.

Although less markedly, this technological dynamism can be seen in ASIC markets, the rate of innovation being more intense for CMOS products than for those manufactured using Bipolar technology.

The chief strategy of integrated circuit and semiconductor manufacturers has been to cooperate in areas of R&D, at times even with government backing. One example is the role of military programs in the USA in relation to demand for semiconductors at a time when commercial demand had not yet firmed. It is estimated that, up to the mid-1960s, these programs accounted for two-thirds of sales. At present, military demand represents 10-12% of ASICs, particularly PLDs. The space program plays an important role and holds a large portion of semiconductor patents. Of all patents originating with NASA, 46% relate to semiconductor devices.

In the cases of Japan and South Korea, state action involves a series of measures taken in coordination with their giant national corporations: tax and credit policy, government purchasing, and restrictions on access to the Japanese market. To this day, there are restrictions on access to the semiconductor market. The government played a role in coordinating the contracting of technology abroad with a view to technological capacitation. There were regulations and various types of control, on the formation of joint ventures with foreign companies, to guarantee effective technology transfer.

### ***Trends***

The environment of the so-called commodities segment is one of fierce competition, which is expected to intensify, eliminating a large number of the companies currently involved in the international dispute for leading edge commodities.

- Growth rates make the ASICs market attractive, especially the semi-customs segment. It is expected that to a ten or fifteen year horizon, ASICs may come to represent half the total ICs market.

- The market for customs and semi-customs should undergo change which will hamper the activities of smaller companies, even in so-called market niches.

- As proprietary ICs come into increasingly widespread use and technological evolution permanently simplifies the design stage of development, opportunities should be generated for entry into this stage of production. The proximity of markets and the relationship between suppliers and customers come to be of strategic importance in designing totally dedicated ICs.

– IC miniaturization, capacity, processing speed and reliability are all expected to increase, which should result in improved product quality and performance at lower costs and prices.

– The basic material from which ICs are constructed will continue to be silicon.

– GaAs technology offers the best performance and highest manufacturing costs, only lower than superconductors alone.

– Increasing use of ICs is depressing demand for discrete components, which. Although is growing at rates lower than sector averages, is expected a expansion by 12% per year to a long-term horizon.

– Development of chip sets - making it possible to incorporate various functions in a single chip and thus replace tens or even hundreds of circuits with a chip set - is opening up an interesting market.

### ***B) Microelectronics in Brazil***

The microelectronics industry began to develop in the 1970s with the incorporation of integrated circuits into electronic consumer goods and telecommunications equipment<sup>82</sup>. Three companies - Philips, Philco and Semikron - operated in the 1960s. In the 1970s, other multinational enterprises were installed, like Texas, Fairchild, Siemens and RCA<sup>83</sup>. At the time, there was only one Brazilian company, Transit, which designed and produced special integrated circuits, but terminated its operations in 1981.

The first multinationals of the sector to set up here were American and European. The Japanese, more recent arrivals, concentrated their activities in assembling discrete components and linear integrated circuits of low complexity, considered "mature technology" on the international market.

Technological and human resource capacitation was based on contracts with the state telecommunications enterprise (TELEBRÁS), the Universities of São Paulo (USP) and Campinas (UNICAMP), as well as the creation of the TELEBRÁS R&D Center (CPqD). The following decade, in 1980, saw the creation of the Special Secretariat for Informatics (SEI), linked to the Presidency of the Republic. Creation of this Secretariat, by Law No.7232 (known as the informatics market reserve law), along with the National Informatics and Automation Plan, laid the institutional foundations for building a Brazilian microelectronics industry.

According to Vanda Scartezini, the policy of incentives (reduction of the import products/inputs tax rates) which was designed to offer greatest benefits for those stages with greatest technological content, was responsible for the development of the national industry. It selected competences and capacitation in

---

<sup>82</sup> At the time, consumer goods were responsible for 60% of demand for microelectronics components and telecommunications for nearly 7%.

<sup>83</sup> Scartezini, Vanda. op.cit.

IC designs, established trade organizations, installed modern, new factories and created a local capability for negotiation with foreign suppliers.

**Brazil - Microelectronics - List of Brazilian and Foreign Companies**

Brazilian Companies	Foreign Companies
ABC Xtal	Nacional
Aegis	Philips Components
AsGa Microeletrônica	Icotron
Heliodinâmica	NEC
Itaucom	Bosch
MC Micro	Rohm
Multitel Microeletrônica	Semikron
Politronic	Texas
Sid Microeletrônica	
Tecnowatt	
Vértice	

Source: Vanda. op. cit.

The manufacturers listed above cover all the specialties of microelectronics: discrete semiconductor components, ICs, hybrid circuits and opto-electronics.

In 1990, the Brazilian semiconductor market represented 1.2% of the world total. This market is considered small for the purpose of economies of scale given the need for increasing investment in installations and R&D to accompany the rate of technological change, plus the demands of rapid amortization pressured by ever-shorter product life cycles.

The trade structure of the semiconductor market in Brazil was set up by international semiconductor companies. These companies can be divided into two groups: those which have factories here and those which have only a trading subsidiary or representation offices. One important aspect in the commercial structure is supply of raw materials, semi-processed materials like gold wire, lead frames, chips and wafers, untested components and finished products. The great majority of inputs is foreign in origin, accounting for 35% of gross sales in the sector.

**Table III.29 - Brazilian Semiconductor Market by User Sectors**

User Sector	Brazilian Market
Informatics	34,0%
Consumer	31,1%
Automotive	9,3%
Telecommunications	19,1%
Industrial	6,5%
Military	n.a.

Source: SID. In BNDES, op.cit.

As shown in Table III.30, in 1988, the IC sector alone reached US\$ 394 million on the Brazilian semiconductor market.

**Table III.30 - Brazilian Semiconductor Market\***

User Sector	1987	1988
Brazilian ICs	114	184
Imported ICs	228	210
Total ICs	342	394
Total Discretes	396	456

\* (US\$ million)

Source: GEICOM. In BNDES, op.cit.

According to the BNDES study<sup>84</sup>, one of the most significant measures was the establishment of a market reserve which prevented foreign companies from operating in the digital microelectronics sector. Three companies - Itaúcom, Elebra Microeletrônica and Sid Microeletrônica - were thus selected to begin production of ICs. By 1986, the three companies represented investments of the order of US\$ 169 million and more than US\$ 25 million in tax incentives.

By 1989, in spite of the entry of more companies to local production (chiefly of discrete components), these measures had not yet produced any reduction in semiconductor imports to the domestic market, which held steady at the 50% level, while ICs held at 54%. Other Brazilian companies came onto the market manufacturing hybrid circuits, optical fibers, opto-electronics and other inputs directed to supplying the telecommunications sector.

As regards the structure of demand, Table III.31 points up the importance of the informatics and entertainment sectors in demand for ICs. Note that, according to 1987 figures, 35% of total demand for ICs by the entertainment sector is met by imports.

**Table III.31 - 1987 IC Demand in Brazil, by Main User Sectors**

1987	
Sector	%
Telecommunications	12,1
Informatics	30,6
Entertainment	31,7
Others	4,1
Miscellaneous	21,5

Source: GEICOM. BNDES, op.cit.

It has to be emphasized, however, that all the figures above are extremely imprecise and indicate no more than the order of greatness of Brazilian industry's capacity to absorb electronic components, for two reasons:

---

<sup>84</sup> BNDES. "Microeletrônica e Informática: Uma Abordagem sobre o Enfoque do Complexo Eletrônico", 1990.

1) the high rate of inflation makes it difficult to calculate, in constant currency, the value of purchases on the domestic market for purposes of comparison. Conversion of the yearly aggregate by an average dollar rate, for example, could introduce significant differences; and

2) the impact of contraband is harder to correct for, since the quantity of contraband components and even equipment is high and cannot be accurately estimated. Both the 1990 BNDES study and more recent estimates published in the *Jornal do Brasil* by industrial associations consider that approximately 50% of the market is met by contraband.

Finally, perhaps the most important structural factor is that the Brazilian domestic market is diversified and dependent on foreign engineering. Marketing here works on the basis of substitution: seller and customer jointly consider the possibility of replacing the imported product with a Brazilian counterpart - "me too" marketing. The advent of ASICs design companies ushered in prospective marketing, where the seller is supposed to offer the customer a new product adding advantages which will contribute to the customer's satisfaction or a component which will bring the customer a new product on a market yet to be exploited.

The greatest difficulty with this kind of marketing is the lack of engineering from the customer. To some extent, the informatics and telecommunications sectors already have the capability to specify their chips, which does not happen with the consumer of goods and electrical appliance sectors, which could be the major consumers of ASICs. Most firms in these sectors are multinationals, which import ICs.

The ambitious plans of past decades, not just to implement the complete microelectronics cycle, for at least some of the standard ICs, but also to found it on Brazilian engineering, have been abandoned once and for all. As for the search for local ASICs design opportunities, identified with the capability acquired by Brazilian engineers to open equipment black-boxes and, from there, to design modifications or introduce electronics into hitherto electro-mechanical control machinery (like washing machines or dish washers), a few laboratories persist, but the only firm of any significance at the moment is Vértice.

As for opportunities for automotive electronics sector, it remains to know how the wide gap between the sparse use of electronics in automobiles made in Brazil for export and current international standards will be surmounted. In a paper published in 1990, Vanda Scartezini, present director of Vértice (Macline Group), practically the only Brazilian company with any chance of penetrating this market, was quite pessimistic: "the auto-parts industry, the main source of demand in the sector, is in the hands of foreign capital and has shown a complete lack of interest in investing in this area." When interviewed for this project, Scartezini seemed to have hopes for moving from supplying Brazilian industry to becoming a supplier to the North American Ford, a move on which another interview, José Ripper, was quite skeptical.

### ***Trends***

– In recent years, Brazil has not concentrated efforts on building up a capability and entering more firmly into the microelectronics sector. One cannot see a multiplication of agreements with major companies, universities and research centers;

– Brazil should come to participate in a minor way and with difficulties, both as concerns competing on the international market and in meeting domestic demand;

– The trend towards replacing discrete components by ICs and analog by digital technology should be seen on the domestic market, although with lesser intensity, as a result of the backwardness of final products from electronics complex;

– The opportunities for Brazil to operate in the commodities area would arise through products matured technologically on the world market, although even in these areas it would be necessary to use external technology which, in turn, would have to be made more accessible. and this seems to run counter to present trends;

– ASICs are considered the more feasible route for the future of microelectronics.

In terms of market, the automotive and electrical appliance sectors seem to be the most promising, providing the companies have the appropriate design engineering capability.

– The use of telecommunications as a possible niche for certain products of the microelectronics industry will depend on the direction taken by telecommunications sector policy, which is difficult to predict, despite the investments already made in the CPqD.

## ***INTERNATIONAL TECHNOLOGY TRENDS AND ALTERNATIVE SCENARIOS FOR BRAZIL***

### ***A) International Trends***

On the one hand, the microelectronics sector works closely with trends towards universality and unity, since its products and processes can only achieve economies of scale and scope by adopting techniques and quality standards that are uniform the world over. On the other hand, it is precisely the marriage of microelectronics and linguistics that makes it possible to take account more and more of specifics and of differences. This alliance provides a basis for organizing production (embracing personnel, machines and inputs) which, unlike Fordism, is flexible in a way that permits mass production of numerous different products. For example, automatic machines and robots permit production on a large scale and simultaneously in small batches of differentiated goods because their functions can be altered and adapted very quickly by modifying their software.

As in other high-tech sectors, competition operates by way of a process of technological innovation at a rate and on a scale without precedent in the world

industrialization history. At the local level, however, the rhythm of these changes, even in line with trends that are global, varies according to the possibilities and capacities of each country.

It has already been stressed that the microelectronics sector is dominated by large enterprises of what today are called the world leader countries: Japan, USA, Germany and France. Focusing on the role of the electro-electronic complex in the new model for industry and in the ongoing process of globalization, Medina H.V. and Reis L.A.A. emphasize that this complex today has a market that is increasingly internationalized and intensely competitive built on the basis of mature technology and in which leading edge technology levers industrial economic growth, in turn expressed in terms of market shares and even more sophisticated consumer standards. The typical example is Japan which, at the end of the 1980s, reduced the North American computer and electro-electronics industry's level of international penetration to 50% of its former (1982) value. Figures of the OECD (Organization for Economic Cooperation and Development) show this displacement through the "Export/Import Rate". Between 1982 and 1987, the rate for office machinery and computers fell from 2.63% to 1.04% for the USA, while swelling from 3.18% to 6.53% for Japan. In the electrical-electronic complex as a whole, growth rates in Japan were between 9 and 10% percent for the entire period, while rates in the USA were between 1.5 and 1%. At the time, these figures, taken together with investments in advanced ceramics applications, already indicated the trend towards Japanese domination, since Japan's investments in ceramics for the electronics sector were 40% higher than the United States' in the same period<sup>85</sup>.

In terms of materials, the trends described by Scartezini (1990) clearly indicated that ceramics and metals were being replaced by plastics. The author estimated that, in 1993, 89% of the products (microelectronic components) would have plastic packing against 10% with ceramic material and only 1% metallic<sup>86</sup>. In a special interview for this project on December 13, 1993, Scartezini confirmed these trends and projections as well as their validity for Brazil today. She nonetheless observed that in the last decade there were expectations for the expanding use of gallium arsenide to threaten the dominance of silicon in microelectronics - which never came about. The main reason that gallium arsenide use did not continue to spread as expected was its high cost.

As for more recent forecasts, Scartezini declared that BICMOS technology should grow by 64% over the next 5 years against an average of 18% growth by the others.

---

<sup>85</sup> Medina H.V. and Reis L.A.A. "Minerais e Materiais Avançados Implicações Econômicas do Novo Paradigma" Relatório Técnico CETEM No. 031/92

<sup>86</sup> Scartezini, Vanda op.cit.

The major technological trends in the world and their shares of the world market, described by Vanda in her paper "Microeletrônica-Silício" (IPT/FECAMP 1990), are summarized in chart III.12 and table III.32.

**Chart III.12 - Technological Trends in Microelectronics Industry Worldwide**

RISING	DECLINING	STABLE
CMOS*	TTL**	BIPOLAR
BICMOS	NMOS***	
ECL		

\* **Complementary metal oxide semiconductor** - a development from MOS technology which today dominates the gate array ICs and especially ASICs.

\*\* Although using Bipolar technology (TTL/PLD), this type of IC does not permit reprogramming and cannot be tested 100%.

\*\*\* **N-channel metal oxide semiconductor.**

**Table III.32 - The Main Technologies in Microelectronics on the World Market in 1993**

TECHNOLOGIES	SHARE %
CMOS	61%
BIPOLAR	16%
ECL	5%
BICMOS	3%

Source: Scartezini, 1990 (projections), op. cit.

### ***B) Technology Trends and Alternative Scenarios***

Carlos Ignácio Mammana of CTI (Centro Tecnológico de Informática), sees current international trends and the directions taken by microelectronics reinforcing the dominance described in Scenario I. For him, Brazil's strategy for this sector should be to seek niches where it can be competitive since, as in any high-tech industry, in microelectronics it is not possible to adopt a strategy of follow-the-leader without falling behind in technology. One example given by Mammana was that of the specialized liquid crystal that CTI's endeavors are directed to producing<sup>87</sup>. One difference that Mammana notes between the two scenarios is that, in Scenario II, there is more demand for basic informatics services for society, whereas in Scenario I, it is individualized products that would grow and diversify to a high degree.

For José Elias Ripper Filho, director-president of AsGa Microeletrônica, in the limiting case in Scenario I, there would be no microelectronics industry in Brazil. The entire market would be met by importation of kits. In Scenario II, he feels, there should be a microelectronics industry as substantial as the production equipment area.

<sup>87</sup> CTI is meeting an initial monthly demand of 30 liquid crystal displays.

Scartezini considers that Scenario II would be more favorable to the Brazilian microelectronics industry in that growth of the final goods market and of the information society - that is, the domestic market - would be sufficient to sustain growth of microelectronics in the country. Besides this, she adds, one would be working with a market that is familiar, close at hand and not very demanding of innovations, "which is very important in this area where interaction with the customer is fundamental and increasing".

Meanwhile, Vanda considers that Scenario I would require constant change of Brazilian microelectronics, which when incorporated into production, would in turn demand that it go beyond the relatively small vegetative growth of the domestic market. Microelectronics sector would have to quickly expand its market beyond its national frontiers, in part because of the profile of users of these more advanced products, who are not to be found here or at least not in numbers sufficient to justify the investments in research and industrial production. For her, in Scenario I, the limitations on the sector's success would be linked precisely to its most important driving force; that is, the foreign market. Difficulties of access to this market would be the greatest offset to the microelectronics industry's growth in Brazil.

In short, according to Scartezini, Scenario II would be more sustainable for the sector because it would offer a greater range of options for marketing products that were mature (and even saturated) technologically, at the international level, at great profit, which would permit it to finance a small portion - perhaps 1% - of more advanced products. In any case, maintaining this market would depend on increasing income levels in Brazil.

As has been seen, today the domestic microelectronics sector is small and features a strong presence by multinational electrical-electronics enterprises of two types: those which produce and those which merely trade. It is also eminently an importer of components and materials and the degree of verticalization is low, being restricted to the final stage of production, packing. Besides this, it is the older, more stable technologies like MOS and Bipolar that predominate in Brazil. It is thus necessary and recommendable that opportunity niches be identified for microelectronics products and that alliances be promoted between state agencies and companies for undertaking R&D in the sector.

Brazil's advantages in the sector are: 1) technological capacitation and training of human resources already partially achieved; 2) the low cost of skilled labor, in engineering for example; and 3) availability of raw materials for production of basic inputs for microelectronics, such as silicon, gold, aluminum, quartz, as well as materials for metallization and substrates for ICs, hybrids, alumina, quartz, etc.

Raw materials are a necessary but not, however, a sufficient condition for supply of inputs to the sector. There is a need for both technological development and refinements in the processing of these materials for them to acquire the characteristics required for industrial use in microelectronics. This is where the bottleneck lies in Brazil. This being the case, the high degree of purity required by

the semiconductor industry becomes a limiting factor on production of these materials. This goes for both silicon and for aluminum and gold. Another bottleneck on microelectronics inputs is the lack of a fine chemicals industry in Brazil, leading to the importation of electronics grade chemicals for manufacture of semiconductors.

From the interviews, it can be said that there is a consensus among microelectronics sector specialists that the trends as regards technology and materials would not be very different in the two scenarios considered by this project. It was also clear that, at the international level, the new materials in microelectronics do not constitute a bottleneck or a limiting factor on development in the sector.

The chart III.13 summarizes the market, technology and production trends in microelectronics in Brazil in the light of the two scenarios.

**Chart III.13 - Trends in Microelectronics: Two Alternative Scenarios**

	MARKET	TECHNOLOGY	PRODUCTION
SCENARIO I	International, sophisticated, demanding and high income.	More advanced, constantly evolving, competitiveness based on innovation.	High quality, personalized, diversified and with customer interaction.
SCENARIO II	Domestic, familiar, undemanding, low income sophistication in small niches	Mature, dominated, diffusion/ expansion of capacitacion already acquired, R&D in strategic areas.	Vegetative growth by mature products and simple interaction with customers; niches for sophisticated products

### ***C) Demands for Technology and Materials***

As microelectronics is a sector shaped by the most recent advances in science and technology, its frontiers - in both materials and engineering - are fluid and constantly moving along a trajectory of increasing innovation.

The sector is one where technology is generated, incorporated and spread quickly; where new materials, new products and new uses are part of a process of continuous improvement; a sector which is at one and the same time the fruit of and the driving force behind the process of accumulation by technological innovation. This is why here all the materials used by microelectronics can be considered as "new", since they are the results of recent advances for specific purposes, even though many of them come from traditional sectors, as is the case with steels, aluminum and alloys for electronic uses produced by the iron and steel sector.

R&D activities directed to microelectronics and its materials date from the early 1960s. More precisely, they began with the CTA (Centro Tecnológico da Aeronáutica) with research into semiconductors. At present, there are 12 institutions (6 university institutes, 4 government research centers and 2 linked to

companies) with capability for researching new materials in Brazil<sup>88</sup>. Even today, however, we are visibly and increasingly falling behind in industrial technology, which seriously jeopardizes Brazil's competitiveness in the sector. The situation can be visualized better by analyzing the microelectronics industry by sector for design capability or for the technology used in production.

As regards ASICs design capability, there is mastery of design techniques using Bipolar and MOS technology, especially in the case of the company SID-Vértice, which is exploring this segment quite significantly.

As for technological capability properly speaking, Brazil uses established technologies, in industrial facilities that are old and out-of-date, and it produces unsophisticated products, as is the case with use of Bipolar technology. Regarding CMOS, there is insufficient capacitation, which hinders the creation and launching of competitive products. With more sophisticated technology, like ECL, and the use of gallium arsenide, the field is restricted to the Telebrás R&D department.

In addition these problems resulting from the lack of development and mastery of technology, are accumulated in the sector structure of production, right from the inputs and equipment supply base. Thus, one other limitation on growth by the microelectronics sector in Brazil is, as has already been said, its inability to produce inputs and equipment according to the specifications demanded by this industry.

The situation of the quartz-silicon segment is a good illustration. Brazil possesses the largest, highest-quality reserves of quartz in the world, but this natural advantage is only exploited by the country up to the production of quartz flakes to supply almost the entire world market. The exported raw quartz is worth from 50 to 1,000 times less than cultivated or fused quartz and related final products<sup>89</sup>, which are even imported by Brazil's microelectronics industry. Only one company in Brazil, ABC-XTAL, produces cultivated quartz, and then only in small quantities.

According to figures from Brazil's Departamento de Produção Mineral (DNPM), in 1990 the country's known quartz reserves totaled 78,100,555 metric tonnes and were exploited by 11 companies. The same year, the total value of production was US\$4,958,000, of which US\$4,233,000 was export billing. Almost all Brazil's exports of primary and semi-finished goods (75%) go to Japan, USA and Germany, which are the world's main producers in the electronics complex (see Tables 1, 2 and 3). Of its manufactured goods, like quartz or fused silicon tubes, 78% goes to Colombia, Mexico, Venezuela, Chile and Peru. Another characteristic of Brazilian quartz products exports is the difference between the value of foreign purchases and sales. In 1990, imports of quartz tubes, mounted piezo-electric

---

<sup>88</sup>Information contained in the publication "Novos Materiais: Desafio e Oportunidades" by the INT (Instituto Nacional de Tecnologia) 1992.

<sup>89</sup>Data in the paper by Lastres H. and Lemos C. entitled: "Quartzo e Silício: Diagnóstico do Segmento", mimeo, INT/MCT, January 1988.

crystals and mounted piezo-electric crystal parts alone totaled US\$9,832,000, almost double the total billing by the segment in Brazil, as shown in Tables III.33 and III.34 below.

**Table III.33 - Production of Quartz in Brazil in 1990\***

	Value (*)	Volume (t)
Total Production	4,958	525,000
Exports	8080	6,210
Imports (quartz tubes, mounted piezo-electric crystals and mounted piezo-electric crystal parts)	9,832	141

\* (US\$ thousand)

Source: Anuário Mineral Brasileiro 1991, DNPM / Ministério das Minas e Energia.

**Table III.34 - Volume and Destination of Brazilian Quartz Exports - 1990**

Products	Volume(t)	Share	Country	Volume(t)
Primary Goods raw quartz incl. flakes.	2.254	29 % 19 % 10 %	Japan Germany Holland	2.759
Semi-finisheds raw piezo-electric quartz.	148	46 % 22 % 10 %	Japan USA Germany	1.088
Manufactureds Tubes: Quartz or Fused Silicon and Fused Quartz	3.808	22 % 19 % 17 % 10 % 7 %	Colombia Mexico Venezuela Chile Peru	4.233

Source: Anuário Mineral Brasileiro 1991, DNPM/ Ministério das Minas e Energia.

Brazil, however, even though not in a position to produce high purity inputs for optical and electronic purposes, could be one of the world's largest markets for final products, as in the case of quartz tubes for the optical fibers used in telecommunications. Planning by the Brazilian state telecommunications enterprise EMBRATEL (Empresa Brasileira de Telecomunicações) provides for installation of 16,000 km of optical fiber cables by the end of this century. The first stage, linking São Paulo-Rio de Janeiro-Belo Horizonte, is to be concluded in 1995, and should cover 7,700 km and the second, to be completed by the year 2000, and interlinking the remaining state capitals, should total more than 8,000 km<sup>90</sup>.

<sup>90</sup>Cities which today have optical fiber cables installed: Campinas, Caxias do Sul, Joinville, Ribeirão Preto and Uberlândia, besides the state capitals: São Paulo, Belo Horizonte, Porto Alegre, Salvador, Florianópolis, Recife, Campo Grande, Goiânia and Brasília. This information was published in the February 1994 issue of the journal Revista Brasileira de Construção para o Brasil e a Argentina, "O empreiteiro", in an article entitled: "O Brasil na Rota dos Cabos Óticos".

The same situation is repeated in relation to silicon, the major application for which is the semiconductor industry. Brazilian silicon production is restricted to metallurgical grade silicon and the ferro-silicon alloys that are the basic inputs for materials used in microelectronics. Production of electronics grade silicon is, in fact, quite concentrated in world terms; according to Lastres H. (op. cit), there are 13 companies belonging to groups in the electronics and chemicals industries. According to figures from the same paper, Brazil is one of the largest world producers of metallurgical grade silicon and of Fe-Si alloys, with around 18 companies, which in 1986 exported nearly 72% of Brazil's total production of Si-GM and 53% of its Fe-Si. These proportions persisted until the end of the decade.

Meanwhile, the sector depends fundamentally on imports of equipment and support materials (photo-masks, quartz tubes and potting material). In general terms, if one considers the entire universe of materials involved in the microelectronics and telecommunications industries, classified into 4 major groups, according to the production process in these sectors, Brazil's strengths and weaknesses are distributed as shown in chart III.14.

**Chart III.14 - Materials and Inputs Used in Microelectronics by Stages of the Production Process**

Basic Inputs	Silicon, Materials for/ Metallization, Semi-Conductors and Hybrid Devices.	STRONG in raw materials: Si, Ge, Al, Au, Ni, Cr, Ti, Ge, Gallium Arsenide, Alumina and Quartz.*	WEAK in electronics grade silicon and in high purity quartz.
Materials for Chemical Processing	High Purity Gases, Solvents and Acids, Photoresistors and Photomasks.		WEAK due to shortcomings in the production chain of the chemicals industry installed in Brazil.
Auxiliary Materials	Abrasives, Teflon and Quartz Tubes, High Purity Graphite, Special Ceramics.		WEAK: lacks industrial scale production in all segments.
Materials for Packing	Wires for micro-soldering, Metallic Alloys, Resins and Metal or Plastic Pots.	STRONG in materials for metal alloys for LEDs, and soldering wires (Al-Si, Cu-Zn).**	WEAK in new materials, like thermoplastics.

\* Eletrometal is Brazil's largest producer of alloys for LEDs and Fe-Si alloys.

\*\* Produced by large Brazilian state and private enterprises in the mining-metallurgical sector, like CVRD, USIMINAS, Villares, Metal-Leve, A.F. Piratini and Eletrometal.

In fact, though, Brazil cannot meet its supply needs for these materials from domestic sources, despite its having abundant reserves of mineral raw materials, because of deficiencies in its industrial structure. On the supply side, there is a strong, but traditional domestic mining and metallurgical sector and an incomplete chemicals industry, strong only in petrochemicals and basic chemicals. On the demand side, the electronics sector is internationalized (Siemens, Philips, Mitsubishi, National etc.) with its decision making centers outside Brazil, as is the case with the automobile industry, which could be an important user of electronics.

One study carried out by professors at São Paulo University linked to the area of microelectronics acknowledged, already in 1979, that: "In countries where microelectronics is developed there is concomitant development of the input supply capability. In general, this development was financed by government agencies by way of specific contracts with companies operating in segments with related technology and the necessary products. Thus, on the basis of these needs, the incentive arrangements and the chemicals industry of the time, there emerged in the USA the Electronics Grade Products Chemical Industry." It also pointed out that, given conditions in Brazil, the inputs with the best chances of industrialization with technologies established on a pilot scale included monocrystalline silicon, photomasks, gold and aluminum soldering wires, high-purity acids and solvents, high-purity quartz. These opportunities were not taken in the last decade though, and the best moment for taking them has passed. Today, in the 1990s, production of these materials is being irreversibly concentrated in developed countries like the USA, Japan and Germany. Despite its having acquired the technological capability and its considerable business structure in the mining and metallurgical sector, Brazil was not able to transform its great reserves of mineral inputs (Zirconium, Aluminum, Niobium, Titanium, Rare Earths, etc.) - of strategic importance for electronics and other high-tech applications - into competitive advantages for a complete chain of production.

To summarize, although necessary, neither the natural advantages nor the technological developments achieved here was sufficient to modify Brazil's position as a supplier of mineral raw materials and basic chemicals and metallurgical inputs that has been Brazil's role since it began to industrialize. Moreover, most of the world leader companies in this advanced sector of the electro-electronics complex are installed in Brazil, but there they concern themselves with a line of more mature products that neither require nor generate any great effort in technological development. In Brazil's microelectronics, as in the rest of its industry, innovation is not the basis for a process of competitive production, as is the case of the industrial technological development which commands the new model of economy and production in developed countries.

### ***MICROELECTRONICS AND OPPORTUNITIES FOR NEW MATERIALS IN BRAZIL***

The development of microelectronics in Brazil and its international competitiveness depends on the technological innovation capability, which now is

concentrated in ICs. As microelectronics permeates and affects most segments of industry, as it alters the very pre-conditions for its own development, it is deciding how Brazil's industry can be competitive at a world level.

The opportunities for Brazil may be analyzed, sought and/or created, by taking as pre-conditions the world trends: 1) for competition and exclusion to increase, 2) for economic activity to become increasingly scientific, and 3) for the so-called Fordist model of production to become exhausted, at least partially, and be replaced by more distributed control processes and flexible accumulation.

We have seen that competition in microelectronics occurs differently as regards standard components and those for specific applications. In the case of commodities, price predominates in determining markets. In the case of ASICs, it is interaction, principally with customer engineering (the manufacturers of equipment in which the ASICs are to be mounted), that predominates, as indicated by language proximity, intimacy with and knowledge of the product system, exchange of information, mutual trust, etc. - conditions which Scartezini calls "environment".

As an industry, microelectronics is inseparable from the tendency for economic activity to become increasingly scientific. With the exception of the software and pure service industries, it is perhaps the most abstract of industries in that it uses little material. There is very little relationship between the costs and prices of its raw materials and basic inputs (like energy) and the cost and prices of its final products.

In relation to the exhaustion of Fordism, when the microelectronics industry came into being, certain basic tenets of Fordism were beginning to be called into question, like the rigid separation between planning and execution (office and factory, intellectual and manual labor).

The interviews and the study were designed to identify situations and opportunities for Brazil<sup>91</sup> in the two scenarios - that is, on the two hypothetical contexts for seeking sustainable development. The study did not endeavor to analyze specific company opportunities, so that the study does not take account of specific conditions that could make it possible for one or another company to operate in the microelectronics field, in either scenario, as a result of some singular characteristic. We do not analyze, for instance, Scartezini's conviction that particularly Vértice has the conditions necessary for business survival in both scenarios.

Thus, considering the opportunities for Brazil, the interviews and the data available for the microelectronics sector indicate that, in both scenarios, one of the fundamental points in formulating a microelectronics policy is the need to confront the problem of Brazil's lack of engineering capability.

---

<sup>91</sup> Nation according to Benedict Anderson's concept of an "imagined community". See "Nação e Consciência Nacional" São Paulo, Editora Ática, 1989. Translation of the original "Imagined Communities - Reflections on the Origin and Spread of Nationalism" Nova York, Verso, 1983.

To develop new products requires innovation at the system level and innovation at the component level. System level innovation requires knowledge of product and market. This knowledge is to be found in the engineering of final product manufacturers in each segment of the microelectronics industry. If the engineering capability is poor, there is no way to innovate. Today, innovation at the component level is preceded by innovation at the system level.

Microelectronics technology comprises the specific techniques involved in various segments:

- the production of electronics grade inputs;
- production of manufacturing equipment;
- manufacture of microcircuits, including the various processes (for example, diffusion, oxidation, metallization, ion implantation, corrosion) and stages (for example, stamping and packing) in constructing a workable device.
- design (for example, of ASICs and programmable devices);
- design support software.

Among these, the best opportunities for development in Brazil seem to be concentrated in the area of design of ASICs and programmable devices, such as transistors and pre-diffused logical gates<sup>92</sup>, interconnection of which can be programmed in low cost laboratories (in the tens of thousands of dollars range).

### ***Scenario I:***

In this scenario, it is unlikely that the conditions necessary for microelectronics to develop would be created in Brazil. Barriers to entry into basic processes for obtaining material substrates (the silicon processing and the impurities diffusion process to produce the desirable functional electrical behavior for incorporation into the equipment) are already too great. The diffusion process calls for investment that can run to one billion dollars. Opportunities for entry by third world countries appeared in the 1970s and 80s, and were taken by South Korea.

What would be possible, now in the 1990s - and it would be no small thing in terms of aggregate value opportunity - would be design of application specific integrated circuits (ASICs), as in the case of the dishwasher controller chip described by Scartezini. In Scenario I, it is difficult to discover conditions for Brazil as a nation to turn this ASIC design opportunity to significant good account.

This is because, unlike Fordism, flexible accumulation demands constant interaction, a kind of continuous flows, among the several stages or activities necessary to obtain the final product. Research, conception, design and development come to be inseparable at the production system as an integrated process. This results in a condition stressed by all the interviewees: microelectronics has to stick close to

---

<sup>92</sup> The opportunity offered by transistors and portas lógicas pre-difundidas\*preset logical ports, due to the low implementation cost for companies exploiting this market, has been highlighted by Professor Julio Salek Aude of the NCE/UFRJ.

whoever is designing the equipment. However, Brazil recently opted for the opposite way of minimizing costs in the short term by importing systems as closed packages (black-boxes).

One alternative way -an alternative consecrated in the classic import substitution process- would be to capacitate component development staffs to develop components which, without innovation at the system level, would perform the functions necessary to the new product.

This course, although it may yield some positive results in terms of technical capacitation, is too restricted and slow in identifying new opportunities.

It is also clear that, without drawing on innovations on foreign markets, export-based development is an even more remote possibility.

To conclude, in Scenario I and to the time horizon considered by the project, there is very little probability of Brazil's playing any role in the microelectronics industry, except that of supplier of raw material, as in the case of silicon.

### ***Scenario II:***

The interviewees all foresaw that, because of the distribution of income (and of economic and cultural capital) that it presupposes, Scenario II would transform into opportunities the diversity generated by the incorporation into the sustainable development process of those who today are socially marginal.

It should be said that the three interviewees felt that, as it progressed, Scenario II would lead to greater numbers of equipment and systems being conceived and designed in the search for solutions to specific problems in Brazil's economic, social, cultural and geographical environment. From there, opportunities for local microelectronics - chiefly as concerns design of ASICs and pre-diffused gates - would increase significantly, beginning with less sophisticated processes and products, for which there existed a specific demand not yet exploited by the international competition.

It is stressed, however, that in order to make use of these potential opportunities - and even for them to exist - broad sections of Brazil's population would have to obtain the skills necessary for flexible accumulation, especially the workforce involved with microelectronics (but also, as emphasized by the interviewees, including the customers of microelectronics companies).

In other words, there would be a need for massive and well-done investment in education for acquisition of the linguistic, educational and professional skills seen as necessary to a society for it to be self-sustaining in the modern world (or in post-modern conditions). The start of this process - in large measure indistinguishable from a preparation, at least, for Scenario II - does not appear to be in sight.

## ***GLOSSARY***

### **Microelectronics Glossary**

To assist comprehension of the text, certain concepts should be defined:

**Electronics Complex (EC):** Formed by the following sectors: Informatics, Consumer Electronics, Industrial Automation, Automotive Electronics, Telecommunications and Microelectronics.

**Segments of Informatics:** Mainframe; Mini-computers; Micro-computers; Peripherals; Software.

**Segments of Consumer Electronics:** Consumer Equipment (Audio and Video) and Personal Consumption Products.

**Segments of Industrial Automation:** includes On-board Electronics, Computerized Numerical Command (NC), Programmable Logical Command and Digital Distributed Control Systems (PLC and DDCS); CAD/CAM; Robotics; Flexible Cells and Systems.

**Segments of Telecommunications:** Terminal Equipment, Public Commutation Equipment and Transmission and External Network Equipment.

**Segments of Microelectronics:** Integrated Circuits (ICs), which may be Standard, Customized, Semi-customized and Discrete Components.

**Microelectronics:** Is defined as the industry producing miniaturized electronic devices based on semiconductor materials. The components produced may be Discrete Semiconductors, Integrated Circuits (ICs) and even Opto-electronics circuits. The latter include light-emitting diodes (LEDs), photo-diodes, photo-transistors, solar cells and liquid crystal displays.

**Discrete Semiconductors:** These, by their technical characteristics, constitute a series of products, including transistors, diodes and thyristors, when constituted as individualized electronic parts. Very often, however, these functions are being incorporated into ICs.

**Integrated Circuits(ICs):** The most important in the microelectronics industry, by virtue of the volume of their market and the high technological content. Integrated Circuits also constitute a series of products and are classified according to their functions. They comprise Standards and ASICs. Standards, in turn, comprise volatile and non-volatile memories, microdevices (divided into micro-controllers, micro-processors and micro-peripherals) and Logical Standards. Besides being standard circuits, ASICs can be semi-customized (configured as gate array or linear array), customized (standard cell and full custom) or programmable logic devices (PLDs).

**Standard ICs:** These are used as off-the-shelf products or commodities, on a large scale in a wide variety of applications. Their characteristics are low production cost, smaller profit margins and manufacturers are generally large enterprises.

**Logical Standards:** These perform logical functions. They are classified as IC's, TTL ECL and MOS, according to the technology or physical principles involved in their manufacture and functioning.

**ASICs:** These are produced to order for specific applications. They can be totally designed or adapted from basic circuits developed previously, as in the case of gate array ICs. They are also denominated Semi-Custom or Semi-Customized ICs. This group also includes linear arrays, which represent 2% of the ASIC market. At the opposite extreme are the full customs, which are totally designed and specified to meet a pre-defined need. This characteristic makes it possible to optimize their design and operation. Standard Cells are ASICs developed totally from structures of pre-defined circuits or standard cells. There are also PLDs, which are ASICs with logic based on memory cells which can be programmed and reprogrammed by the user.

Another important concept is the digital IC which assumes different characteristics and commands different markets, according to the technology utilized (Bipolar or CMOS). Bipolar technology permits gains in speed, energy consumption and resistance to the environment. The main users are the consumer goods and telecommunications equipment segments. CMOS technology permits greater circuit density and lower production costs, the main application being in professional electronics, in memories and micro-processors. Thus there is:

**Digital ICs:** Circuits which perform functions that are totally digital, and which may be conceived using CMOS (complementary metal oxide semiconductor) or bipolar technology;

**Analog ICs:** Circuits which perform both analog and digital functions in a single device, more commonly conceived using bipolar technology;

**ASICs:** Circuits developed for set applications, and which may be for exclusive use by one or more customers. May be classified as:

**Semi-dedicateds:** Monolithic circuits having one or more masks - but not all of them - exclusively designed. These, in turn, may be subdivided into:

**Gate Array:** Monolithic circuits composed of a matrix of transistors organized into gates, where one or more layers of metal may be designed for dedicated interconnections among the gates;

**Linear Array:** an arrangement of transistors and resistors interconnected in such a manner as to customize the function and perform the functions of a variety of Linear ICs and Discrete Devices;

**Dedicateds:** Monolithic circuits customization of which requires that all the masks be designed. These are subdivided into:

**Standard Cell:** Circuit Designed using a library of basic pre-defined cells;

**Full Custom:** Monolithic circuit with all the masks designed according to the specific application. The layout is executed manually with the devices designed polygon by polygon;

**Programmables:** (PLDs - programmable logic devices) Monolithic circuits built from basic memory cells which can be programmed and reprogrammed by the user.

### ***REFERENCES***

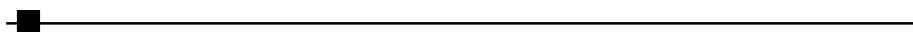
- 1) SCARTEZINI, Vanda: "Microeletrônica - Silício" mimeo, sector report of IPT/FECAMP project "Desenvolvimento Tecnológico da Indústria e a Constituição de um Sistema Nacional de Inovação", 1990.
- 2) USP/ANDRADE, Carlos Américo Morato et alli, "A Microeletrônica no Brasil", 1979.
- 3) LASTRES, Helena and LEMOS, Cristina: "Quartzo Silício: Dignóstico do Segmento" mimeo, 1988. INT (Instituto Nacional de Tecnologia)
- 4) INT: "Novos Materiais: Desafio e Oportunidade" (Parte 1- Novos Materiais Metálicos)
- 5) BNDES - "Microeletrônica e Informática: Uma Abordagem sobre o Enfoque do Complexo Eletrônico", 1990.
- 6) BNDES - "Telecomunicações Via Satélite", Textos para Discussão No. 12, DEEST - Departamento de Estudos Setoriais, September, 1993.
- 7) NORDWORSKI, D. "Nuovi Scenari Neri Business Per lo Sviluppo delle Comunicazioni via Satélite", annals of the "Convegno Internazionale de SAM", 31 March to 2 June, 1989, in Milan, Italy.
- 8) UEHARA, M.J. "Cenários de Telecomunicações", Journal: São Paulo em Perspectiva, 7 (4):59-74, October-December, 1993.
- 9) VALLACE, SIR IAIN, "Customers Must be the Industry's Driving Force", section: "Telecommunications in the 21st century", British Telecommunications Engineering, vol.13: pp 3-7, April, 1994.
- 10) CROCHRANE, PETER; "Copper Mind-Sets", section: "Telecommunications in the 21st century", British Telecommunications Engineering, vol 13: pp 10-16, April, 1994
- 11) DUTTA-ROY, A. "O Fantástico Mundo das Redes Internet", Revista Nacional de Telecomunicações- RNT, pp 54, March, 1994.

# CHAPTER 3

---

*PART V*  
***THE TELECOMMUNICATIONS SECTOR: THE  
SCENARIOS AND THE ADVANCED MATERIALS  
IN BRAZIL***

*Heloisa V. Medina, Ivan C. Marques e Maria Laura Barreto*  
*CETEM/CNPq*



### ***3.V THE TELECOMMUNICATIONS SECTOR: THE SCENARIOS AND THE ADVANCED MATERIALS IN BRAZIL***

#### ***THE RECENT EVOLUTION AND PRESENT SITUATION OF TELECOMMUNICATIONS IN THE WORLD AND IN BRAZIL***

##### ***A) Telecommunications in the World***

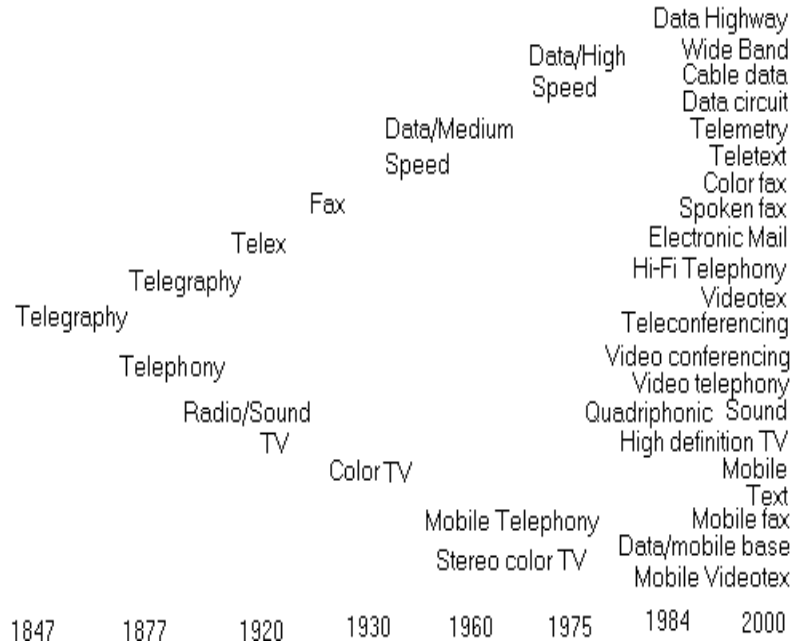
Used at first only for telephony, the fast development of satellite telecommunications, in a little over a decade, as from the 60s, made a wide range of information services available to society. These services today conduct the world of business, academic research and public communications in general. However, it was in the 80s, after incorporating development of other advanced sectors, such as the aerospace and microelectronics sectors, that telecommunications gained power and a global standard, attaining limits known today and projected internationally to the threshold of the next century.

The following scheme<sup>93</sup> shows the evolution of the sector, in the order of the arrival of its main products and services.

---

<sup>93</sup> Adapted from the text of the Danish author David Nowdowski and entitled: "Nuovi Scenari Neri Business per lo Sviluppo delle Comunicazioni via Satelite", presented at the "Convegno Internazionale de SAM": Sistemi Avanzati di Management, "on the subject "Innovazione Tecnologiche: Nuove Opportunità per gli Anni 90, Milan, May 31 to June 2, 1989.

### Telecommunications: Forecasts for the year 2000



In slightly more than 100 years, technological developments in communications systems have taken us from the telegraph to the fax, from the telephone to mobile and cellular telephony, from radio and sound equipment to color television and stereo sound. Now, in this last decade, the telecommunications sector has been leading us, through advances in microelectronics, to a mix of products and services that interweaves this sector's traditional businesses in a complex and synergetic manner. The results of these blends are video telephony, teletext, electronic mail, data lines for public or private circuits, etc...

From the point of view of the electronics complex, a recent report of the BNDES<sup>94</sup> classifies the telecommunications industry, according to its functions, into four large groups: Terminals Equipment, Public Switching and Private Switching Equipment, and Transmission Equipment (overland or via satellite).

Terminals Equipment includes telephones, videotex terminals, telex, fax and is extended to other segments, such as information technology in the case of data processors.

Public Switching Equipment is similar to mainframe computers and is extremely software intensive. This is what is known as digital electronic exchanges whose capacity is 10 times greater than that of the electromechanical exchanges that preceded them.

<sup>94</sup>BNDES (National Bank for Social Development) (1990), Op. cit.

Private Switching is the connection made inside institutions in general through a PABX, PAX or KS. It consists of internal branch systems connected by a single trunk to the public (external) network.

Transmission equipment sends information along a telecommunications network. In this segment, antennas, towers and waveguides use microelectronic devices mounted on printed circuit boards. Among the more important products are multiplexers, modems and those that have electro-optical interfaces.

Satellites are the most sophisticated kind of transmission equipment and incorporate technologies that are both electronic and aerospace. They are being competed with by optical cables, which are both cheaper and more durable. Nonetheless, in low population density regions, where the volume of traffic does not justify fiber optics, satellites are still the most used system. And, lastly, the systems are interconnected in an external network by equipment which consists of the physical means through which the information runs like an electric current. Copper wire is its principal material, although it is now being replaced by optical fiber which carries the information through luminous signals.

According to the nature of the services provided in the telecommunications market, the above-mentioned BNDES report mentions that the largest segment is public switching, in spite of the big growth of private switching since the latter part of the 80s.

In the global market of equipment for telecommunications, the world's leading manufacturers are: AT&T (USA), NEC (Japan), Siemens (Germany), as well as Ericsson and Alcatel, just to mention the largest. Table III.35 below shows, according to Siemens data, the size and growth of the world telecommunications terminals market, including multimedia services such as data terminals coupled to telephones or videos for tele- or video conferencing.

**Table III.35 - Telecommunications Growth in the World Number of Terminals**

Terminals*	1980	1985	1990	2000 (forecast)
Telephones	524 000	660 000	820 000	1 200 000
Mobile Telephones**	4 000	14 000	50 000	300 000
Data terminals	2 000	7 000	50 000	200 000
Fax	1 500	2 500	17 000	80 000

\* in 1,000 units

\*\* 1/3 mobile telephones and 2/3 wireless telephones (cellular)

Source: Siemens, taken from *Electronics*, April, 1994, p. 35.

As one of the largest suppliers of telecommunications equipment, Siemens reckons that this world market in the year 2000 will be worth close to US\$170

billion, compared with US\$121 billion in 1993<sup>95</sup>. The same company also estimates that the share of public communication systems will drop to 55% in the year 2000 from the 60% that it represented in 1990, giving way to mobile and data terminals, and other private communication systems equipment, which today are the most dynamic segments.

On the other hand, the Electronics Journal of July 11, 1994, shows that it is expected that there will be a slight tendency toward deconcentration of that market in 1995. It is forecast that the share of the Asian market and of the rest of the world will grow in terms of the number of subscribers in the cellular telephone market, reflecting the recent introduction of this service in a number of developing countries, such as Brazil (1992), as shown in Table III.36 below.

**Table III.36 - World Cellular Telephone Market**

Percentage Distribution of the Number of Subscribers		
Region	1992	1995
North America	52.6%	46%
Europe	26.2%	26.4%
Asia	15.4%	17.4%
Others	5.8%	10.2%

Source: Electronics Journal, July 11, 1994, p. 14.

Also worth mentioning is that the demand for switching equipment and other public network products is generated worldwide by public corporations that have a monopoly of the telecommunications systems in each country. The exceptions are the USA, where AT&T had a private monopoly until 1984, Canada, Japan and England, which privatized their systems recently.

According to the BNDES (op. cit.), the terminals equipment market is going through a process of growing digitization, incorporating what are called teleinformatics equipment, such as: fax, local data networks, videotex, digital, wireless and cellular telephones, making it a strong contender for acquiring microelectronics products within the electronics complex.

The last segment - Transmission Equipment - owes its dynamism to the expansion of fiber optics networks. This market is controlled by AT&T, Siecor (Siemens/Corning) and Alcatel, which together hold 80% of the North American market which, in its turn, represents 45% of the world demand for optical fibers.

Besides this classification by industrial segment, related to the production of equipment for the sector, telecommunications and their technologies can also be analyzed through the nature of the services they render to society. According to Nowdowski (op.cit.), the sector uses two basic information transmission

<sup>95</sup> The forecast for 1994 at world level, is 126 billion dollars growth, led by the USA which alone should be responsible for 50% of this increase, of about US\$3 billion. *Electronics*, July 11, 1994, p. 14.

technologies: overland (cable or radio) and satellite, and attends two groups of users: public and private, as shown in the following chart:

SERVICES	ORVERLAND	VIA SATELLITE
Public	Telex/Telephone/Telefax Video conferencing, and dedicated data lines	Telephone/Telex/Telefax Video conferencing and Data Network
Private	Cable TV network, fax, wide band data network and dedicated lines	VSAT Network (private satellite services network)

Historically, the telex was the pioneer and telephony the most disseminated means used in the telecommunications system, although data transmission via satellite or cable is the segment that has been growing most in the past 30 years. The video conference and the datacast are the best examples of fast-expanding multiple services. The first service is a mix which uses image and sound transmission systems, allowing remote participation in meetings. The second consists of information transmitted (image and written-teletex) through radio (radio-teletex) or TV channels. Access is through personal computers (PCs) and it is used worldwide for transmitting information on weather conditions, roads, news, the financial market, etc...

The satellite, as a means of transmission, has the great advantage of uniting a large geographical area, even though dispersed in terms of population, in entirely digital and integrated communications networks, carrying at the same time: voice, data and images.

As to the directions being followed by telecommunications development in the world, two major routes can be clearly identified: The first through the modernization of appliances, equipment and materials, and the second is represented by new uses of all the physical devices in the form of diversification of services.

One important aspect resulting from these two routes, is the reduction of communication costs which the technological advances are offering, meaning that in the developed countries, such services are gradually becoming more popular. This, however, has not meant more modest billing for the sector. On the contrary, just the optoelectronics market, with regard to telecommunications, in 1993 had a turnover of about US\$2.42 billion in the USA, according to a study made by ElectroniCast Corporation<sup>96</sup>. The same study projects a moderate growth of this sector's billing of 15% per year, for the next 5 years, reaching 4.83 billion dollars in 1998. This data underscores the tendency mentioned above that telecommunications products and services will become more popular, because the study considers that, in fact, the

<sup>96</sup> Data quoted by the National Telecommunications Magazine (RNT), March, 1994, p. 6.

volume of components sold will grow significantly and this will not be reflected in the same proportion in the value in money due to the reduction of average prices. For the next period until the year 2003, the same source predicts higher average annual growth of about 21% per year.

### ***B) Telecommunications in Brazil***

In Brazil, like in most other countries, telecommunications are a federal government monopoly<sup>97</sup>, although in fact there is a joint partnership between the public and private sectors. The Brazilian Telecommunications System is formed of local companies, public utility telecommunications services concessionaires, and by the public corporation EMBRATEL - Empresa Brasileira de Telecomunicações - all controlled by TELEBRÁS (holding company of state government and private concessionaires), and also by local and foreign manufacturers of materials and equipment for the sector.

Brazil and the rest of the world has a telecommunication industrial structure highly concentrated in a few large producers. So NEC, AT&T, Ericsson and Alcatel, among those that have the highest billing, control 88% of the Brazilian market, as the following table III.37 shows:

**Table III.37 - Leading Telecommunications Equipment Manufacturers in Brazil**

Companies	Net Billing (US\$ Millions)
Ericsson	260.0
NEC	115.0
Elebra	88.2
Equitel	83.6

Source: BNDES (op.cit. 1990)

TELEBRAS is mainly responsible for the equipment demand in this sector, representing about 80% of this market. According to TELEBRAS data, through this system Brazil today (1994) has 13 million terminals installed, more than 300 thousand cellular telephones operating and almost 300 thousand public telephones, of which 25 thousand are card-operated, an advanced technology entirely developed here. The largest private concessionaire company operating is CTBC (Companhia de Telefones do Brasil Central) which has been attending rural areas and smaller cities in the states of Minas Gerais, São Paulo, Goiás and Mato Grosso do Sul since 1954. This complementary system has approximately 300 thousand terminals in a density of 13 lines per 100 inhabitants, in a high rural and agroindustrial income region.<sup>98</sup>

<sup>97</sup> The Federal Government's monopoly of telecommunications services in Brazil is provided for in the 1988 Federal Constitution, in Art. 21, XI and XII.

<sup>98</sup> National Telecommunications Magazine (RNT), March, 1994.

Brazil's average telephone density is, however, one of the world's lowest, at around 7 terminals per 100 inhabitants, in 1993<sup>99</sup>, while this ratio in countries with a similar degree of development is about 20 terminals per 100 inhabitants<sup>100</sup> and among the First World countries this average rises to levels between 40 and 80/100.<sup>101</sup>

The sector's only technological research center is TELEBRÁS's Research Center (CPqD). Hence, in the case of companies whose capital is local, which produce equipment and materials, the technological standard is set by the CPqD and the multinationals and joint ventures have their technologies developed at their headquarters. This is very serious, because in this industry the competition is increasingly technological, that is, highly intensive in investments in R&D. The opening of the CPqD in 1976, to develop digital technology products, allowed local companies to join the sector, taking advantage of a moment of change in the technological base, which represented the start of new equipment and materials production

Among the more important projects developed by this Center, in the public switching area, is the "Tropico Switching Exchange" which will be improved and introduced by local companies. This is a project for developing and designing medium and large digital exchanges. Companies accredited by TELEBRÁS to produce these exchanges are ELEBRA, PHT, SESA, SID Telecom and ABC-Teleinformática. The following chart III.15 lists the leading manufacturers of Switching Exchanges and the origin of their technologies:

**Chart III.15 - Brazil: Leading manufacturers of Switching Exchanges**

Company	Group	Technology
Large Exchanges		
Ericsson NEC	Monteiro Aranha and Ericsson NEC and Commar (Roberto Marinho)	Ericsson NEC
Equitel	Mangels	Siemens
Medium Exchanges		
SESA ELEBRA PHT SID Telecom ABC	Reserva Reserva and Multitel Promon Matias Machline/Itaú ABC ALGAR	CPqD CPqD CPqD CPqD CPqD

Source: BNDES study (op.cit.)

<sup>99</sup> Idem.

<sup>100</sup> BNDES (op.cit.)

<sup>101</sup> According to data in an article by José Uehara, a CPqD researcher, quoted below: the average in Spain is 32/100, in Portugal, 25/100, in Uruguay, 14/100 and in Argentina, 12/100.

According to the aboved mentioned BNDES report there are regional monopolies that have arisen from TELEBRÁS's own purchasing policy, which reserves São Paulo for Ericsson, Rio for NEC and Paraná state for Equitel.

Transmission Equipment, as well as being the leading segment in the demand for microelectronic components, also offers the most opportunities for Brazil because there are less technological barriers. The first effect of this is greater diversification of the productive structure which even in 1987 had 21 companies listed at TELEBRÁS, of which 5 were large (NEC, Equitel, Sul América, ABC Teleinformática and Multitel) 13 medium and 3 small.

The big revolution in the transmission area is occurring not only in the equipment, because of the growing informatization, but also through developments in the means of transmission, through optical fibers. Since the mid-80s, this new material has been transforming telecommunications and data networks, enormously increasing the capacity for transmitting remote digitized information. Besides the advantages of their very small size and high capacity, optical fibers are free from magnetic interference.

In Brazil, optical fibers were developed by the CPqD jointly with ABC-Xtal, which until 1989 was TELEBRÁS's sole supplier. The main historical milestones attained by the CPqD show the record of other partnerships:

**1978** - Start of the Optical Fibers Project.

**1980** - The Optoelectronic Devices Group is set up.

**1982** - 1st optical communications test, with the installation of ELO-34/Multimode Fiber/ GaAs Laser.

**1985** - Laser produced with reliability of more than 100,000 hours.

**1987** - Elebra Microeletrônica engaged in the transfer of GaAs laser technology.

**1989** - Engagement of AsGa Microeletrônica in the transfer of Indium Phosphide Optoelectronic Devices (laser, LED and 1550 nm optical receiver).

**1990** - Prototype of InPh/1300 nm laser and InGaAs/1300-1500 nm photodetector.

**1992** - Transfer of technology of the complete cycle of the family of InPh components to the 1300 nm window.

**1993** - First prototypes of 1480 nm bombardment lasers for fiber optical amplifiers and transfer of technology to Avibrás Fibras Óticas.

**1994** - First field test of a fiber optic amplifier prototype with a CPqD design and components.

At present, projects for introducing and using these optical fiber cable networks are entrusted to EMBRATEL which, by the end of 1995, expects to conclude optical cable connections between the state capitals and main cities of the southern, southeastern and northeastern regions of Brazil, in a total distance of 16 thousand km. At the same time, EMBRATEL is also developing two other

international projects which will link Brazil to the USA, Europe, Asia and the Mercosul countries. In South America, connections on Brazilian territory will be interconnected with the Unisur cable. This project is being developed by AT&T, SSI, Pirelli and Alcatel, although operated by Embratel, Telintar (Argentina) and Antel (Uruguay). Both the Brazilian and international networks will be used at first for providing public services such as voice, data and fax transmissions. However, one of the great advantages of this system is that it offers the possibility, due to its great capacity, of its being used for new services with a wide range of data transmission. Furthermore, the generalized use of high definition television in the future, for example, will depend upon a good optical fiber network.<sup>102</sup> Even nowadays, television is already expanding significantly within this optical cable system. Cable television is big business for the sector's private companies.

In Brazil today there are 3,189 radio or TV broadcasting stations operating under concessions granted by the public authority since 1964.<sup>103</sup> At the same time as the arrival of cable and pay-TV in Brazil, between 1985 and 1988 1,028 radio and TV channels were granted, of which more than half in 1988. In February, 1988, a federal decree regulated the pay-TV system, called DISTV-TV Signals Distributors. Although Article 223 of Brazil's Constitution provides that the Congress must review all concessions and renewals of "sound and sound and image radio broadcasting services" granted by the Executive Branch<sup>104</sup>, the government understood that as the DISTV, a new technology, is a closed service of a private nature, it was not necessary for it to be examined by the Congress. In that year alone, 101 entrepreneurs throughout Brazil were granted concessions for operating radio and TV channels under this system.

EMBRATEL also operates, on an exclusive basis, in satellite transmissions using its own satellites, such as BRASILSAT, and as a member of international consortiums such as INTELSAT and INMARSAT.

BRASILSAT, which was launched in 1985, is part of what is called SBTS - Brazilian Satellite Telecommunications System - "One of the reasons for using satellite technology in Brazil's telephonic communications was the possibility of making connections to sparsely occupied and remote parts of our territory." For this reason the satellite was focused on the Amazon region. Through it, EMBRATEL provides domestic telephone services to the regional telephone companies. "Although it may be a domestic satellite, the neighboring countries also receive BRASILSAT's signals, whose second generation is already planned for covering the South Cone."<sup>105</sup>

---

<sup>102</sup> Brazilian Construction Magazine for Brazil and Latin America, "O Empreiteiro", March/94. P. 26.

<sup>103</sup> Constitution of Brazil, Art. 223. "The Executive Branch has authority to grant and renew concessions, permissions and authorizations for the sound and sound and image radio broadcasting service, respecting the principle of the complementariness of the private, public and state-controlled systems."

<sup>104</sup> Source: Jornal do Brasil, 8/5/94, page 14.

<sup>105</sup> BNDES "Satellite Telecommunications" - Texts for Discussion No. 12, DEEST-Department of Sector Studies, September, 1993, preliminary version.

In the international area, the INTELSAT system is the oldest. Inaugurated in 1964, today it houses a 128-member consortium, whose leader is the United States. The other signatories are mostly companies with monopolies, such as EMBRATEL in Brazil, and public corporations in the European countries which are, at the same time, the system's customers and owners. With its 19 satellites, INTELSAT is used by EMBRATEL for telephony and international transmission of voice, image and data, such as Digisat and Interdata.<sup>106</sup>

Brazil has participated in INMARSAT (International Maritime Satellite Organization), since it was founded in 1979. This system, which has its headquarters in London, currently operates an international mobile land, sea and air communications network which has more than 33 thousand terminals installed in 165 countries.<sup>107</sup> INMARSAT's services range from telephony, telex, fax and data, either analog or digital, to mobile telephony services and transportable data transmission (electronic equipment the size of a briefcase with a phone and antenna) and then on to the global cellular telephone market, all in a portable system.<sup>108</sup>

## ***THE TECHNOLOGICAL TENDENCIES IN TELECOMMUNICATIONS AND THE SCENARIOS***

### ***A) International Tendencies***

The most striking and far-reaching of the general tendencies in telecommunications in the world today is the growing informatization of its services, made possible by the digitization of systems and equipment. This has resulted not only in a reduction of communication times but, principally, in a greater volume of information transmitted. It is in this context that the mixes of products and services as increasingly diversified options are available, providing access to information that is spoken, written or in pictures, as part of a complex of international networks and systems. The result of this process is the creation and regeneration of global markets where producers, suppliers, consumers, investors and researchers of different countries, that is, the different world socioeconomic agents, are connected through a complex of interactive computerized networks.

With the growing digitization of systems, telecommunications services are increasingly basing themselves less on the public networks and shifting to integrated telephony terminals and intelligent computing. What is, today and in the future, a very technologically complex market, therefore requires increasingly larger investments in R&D to modernize itself.

---

<sup>106</sup> BNDES, 1993 (Op.cit.)

<sup>107</sup> National Telecommunications Magazine (RNT), March, 1994, p. 6.

<sup>108</sup> BNDES, 1993 (Op.cit.)

Computing networks were designed in the 70s in the USA to connect the big research laboratories working on military projects for the US Government's strategic departments. Their main purpose was to research basic architecture and the technology of a computing network that could survive any catastrophe that might threaten other communications connections. It was only in the early 80s that the *Internet* took general shape through a protocol which established a common language between the various manufacturers' computers. As from 1985, the number of networks connected to the Internet rose considerably and it evolved to the configuration it has today. Early in 1993 there were 10 thousand networks connected to the Internet, serving more than 10 million host computers. It is estimated that by the end of 1995 there will be 100 thousand networks and 100 million users, indicating an incredible growth of 10% to 15% per month.<sup>109</sup>

This tendency strengthens ties between such sectors as microelectronics and telecommunications. Consequently, communication systems become not only customers for electronic components, but also microelectronics itself becomes part of the complementary systems organization and even substitutes the conventional means of communication. In the opinion of Claudio A. Loral, a CPqD researcher interviewed by the project, "microelectronics allied to semiconductor materials and to optical fibers have made it possible to digitize the telecommunications systems. As a result, optoelectronics with microelectronics became the tripod supporting the telecommunications take-off, which had software as its third leg."

The number of microcomputers connected in networks will represent 65% of the installed microcomputers complex all over the world by 1997, while the evolution of the participation of equipment connected through networks rose from 31% in 1991, to 38% in 1992 and reached 44% in 1993.<sup>110</sup>

Another world tendency in this sector, also deriving from technological developments and from the expansion and diversification of services, is the lowering of costs of such networks for their users. In Brazil the National Packet Switching Data Communication Network (RENPAQ) has become cheaper since February this year (1994). Embratel is reducing its charges for its users on account of the increased volume of traffic, which applies to telex, telephone or dedicated lines.<sup>111</sup>

Another item worth mentioning, as an indicator of world trends in the telecommunications sector, with regard to transmission facilities, is that the television and telephone segments are changing positions as this century ends in comparison with their profile in the 80s. This means to say that optical cable

---

<sup>109</sup>Dutta-Roy, A. "The Fantastic and Complex World of the Internet Network", National Telecommunications Magazine (RNT), March, 1994. P. 54.

<sup>110</sup> These figures are part of a study of *International Data Corporation (IDC)* published in the National Telecommunications Magazine (RNT), March, 1994, p.50.

<sup>111</sup> RNT (idem) p.8: The table of discounts is as follows: for monthly traffic of 20 to 60 million segments (each segment is equivalent to 64 characters), 20%; from 60 to 100, 30%; from 100 to 145, 40%, from 145 to 200, 45%, and above 200 million segments per month, 50%.

transmission, which had its initial thrust in telephony, is being increasingly used by the radio and television segment, while satellites, which had their biggest civil utilization in long-distance and international TV transmissions, are now more intensively serving telephone exchanges and are used for transmitting information in multiple systems (networked voice, sound and image).

### ***B) Technological Tendencies and the Alternative Scenarios***

The technologies which today command the development of the telecommunications sector derive from the aerospace, optico-electronic and, principally, the microelectronics sectors, as well as from all advances and improvements achieved in the field of materials used in such sectors. This makes this sector highly intensive in technology, both because of its nature and because of its industrial interface and R&D with this group's other sectors.

If the two criteria used in the sector's presentation are integrated: both regarding the means of transmission and the nature of the services provided, distinct routes can be seen for expanding telecommunications in Brazil in the two scenarios adopted, illustrated by the following chart III.16:

**Chart III.16 - Alternative Scenarios: The Transmission Technologies and the Telecommunications Services**

Scenarios	Transmission Technologies	Nature of Services
Scenario I	Air: by satellite	Long-distance and cellular telephony, international information networks
	Land: by optical cable	TV and private data networks and dedicated lines
Scenario II	Air: by satellite	Public telephone network for national and cellular integration in large center, radio and TV channels.
	Land: by optical cable	Public network telephony private TV for large urban centers.

If **Scenario I** were to occur in Brazil, the most prominent international tendencies are both cellular telephony and the cable TV segment, with information networks coupled to them. Priority would be given to private systems, private channels and dedicated data transmission networks, for a selected more informatized and "modern" clientele, such as banks. These more demanding clients would then need new technologies, which would then impel and direct the system's modernization. This means that the Brazil of **Scenario I** would follow the tendency of maximum sophistication up to the limit that its market is capable of consuming or to the extent that its products manage to place themselves in the foreign market. The logic of this market is to continue growing until it reaches the saturation point of its own use of electronic technology.

If **Scenario II** were to predominate, local priorities would prevail over global tendencies. It is hoped that there would some coexistence between the expansion of

the private network services with those of the public network, whose expansion is supposed to attend the broader strata of the population. In this scenario, the present situation would have to be reversed. A situation which José M. Uehara, CPqD researcher, says "is distinguished by the absolute lack of telecommunications facilities available to people who have less purchasing power and are farther away from the large centers. In spite of the enormous effort spent on attending .... today about 85% of families (those which have a monthly family income of less than US\$1,000) continue without access to an individualized telephone service." ... "The development of telecommunications for this segment will not actually be brought about by pressure of demand ... action in this segment will come more as a result of a governmental effort to provide the less attended population strata with the same services as the more developed segments of Brazilian society."<sup>112</sup>

Also, according to Uehara, "a desirable scenario for a horizon of about 15 years (year 2010) would be that of about 60% of families (family income higher than US\$300) having individual telephone terminals, reaching a terminals density of around 25 terminals/100 inhabitants (compared with the present 6.5/100). This would mean triplicating the installed plant of telephone terminals (today slightly over 10 million). This scenario would be completed by the large-scale use of community solutions (public pay phones, community teleservice centers, etc.) and by the concept of the virtual telephone (voice mail), which would be extended to the rest of the population."<sup>113</sup>

Certainly the sector has challenges to overcome in either scenario and there are major shortcomings to be made up for, such as:

- more terminals per number of inhabitants;
- digital systems instead of analog exchanges;
- expansion of the capacity of the present systems, substituting copper conductors with optical fibers and launching new satellites;
- integration of systems in informatized networks, among others.

There is no doubt that the intensity and the rate of the sector's developments for supplying these demands will be strongly influenced by the occurrence of conditions forecast for one or the other scenario. This means that, in the first scenario, the international tendencies carry more weight, while in the second, the specific local features share the space with tendencies prevailing in the world which, in their turn, go through a process of selection according to regional possibilities and demands actually identified. Briefly, the so-called private or individualized services would be attended according to their profitability, because the costs are borne

---

<sup>112</sup> Uehara, M. José. Article entitled "Telecommunications Scenarios" published in the magazine *São Paulo em Perspectiva*, 7 (4):59-74, October/December, 1993.

<sup>113</sup> Uehara: idem.

directly by the users, and the public services according to the social criterion and always seeking to cut costs to a minimum.<sup>114</sup>

Accordingly, the conditions of **Scenario II** would be added to ongoing efforts included in TELEBRÁS's strategy and in research under way in the CPqD. The telephone exchange of the CPqD's above-mentioned Tropic RA project is an example of how products developed by this Center can reduce TELEBRÁS's expenses.

### ***C) Technological and Materials Demands***

According to the same approach to tendencies, the technological demands regarding materials can also be related according to the means of transmission considered and according to the nature of the services offered. Furthermore, the demands resulting from the microelectronics sector's production can also be added to these direct demands, in that their products and components are used in the informatization of telecommunications services. These two segments of the electronics complex show much synergy in their technological developments and in the field of materials, whose bases derive from the importance of quartz-silicon as a common raw material.

Again quoting Loural's opinion "regarding materials, in connection with telecommunications and microelectronics, what will predominate is the massive use of silicon for chips and silica for optical fibers. More scientific base will be required from the use until the final discarding of the material, that is, completing the material's life cycle in terms of scientific knowledge."

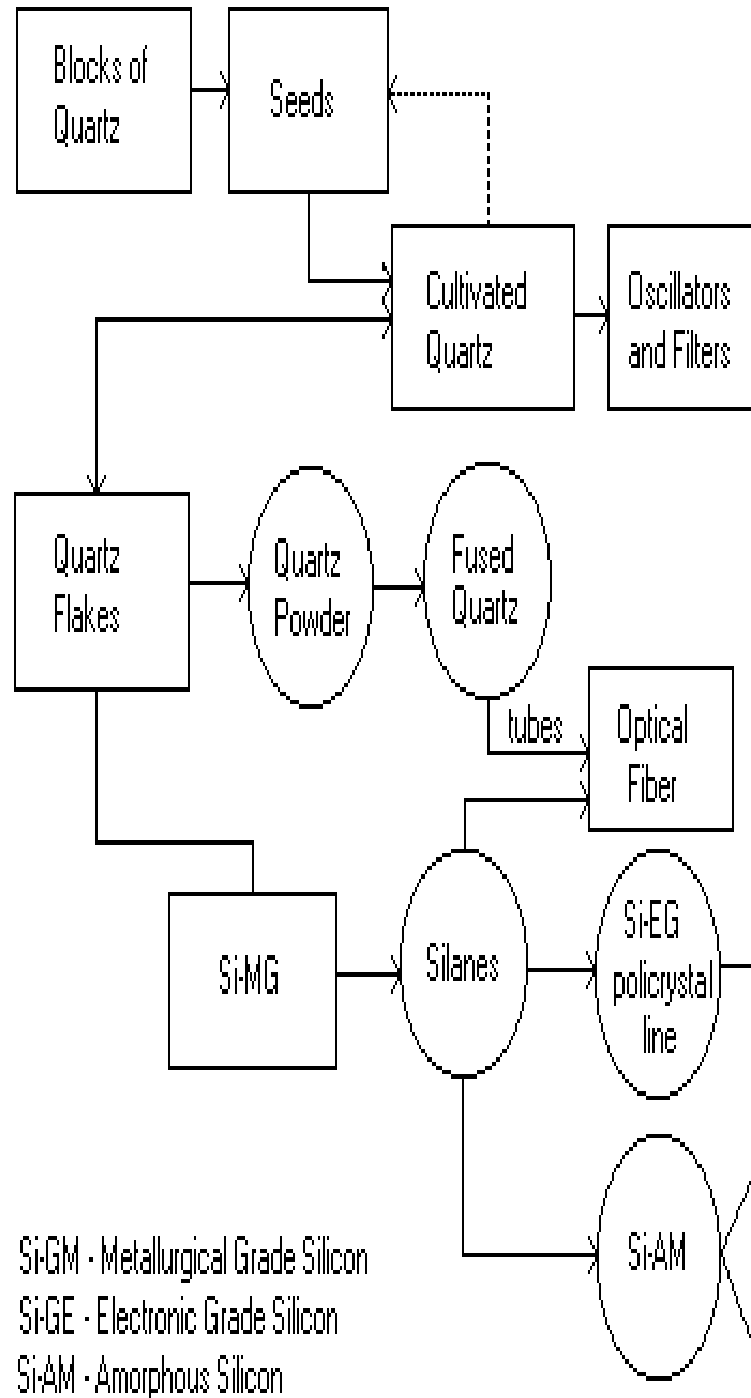
Elydio Adler Pereira of Embratel holds the same view, when he mentions microelectronics taking the place of the relays and cabling industry, and the increase of communications capacity through the use of optical fiber systems technology, as the strongest tendencies of the telecommunications sector.

One can therefore get a clearer idea of the integrated scheme of these two segments - microelectronics and telecommunications -, by studying the elementary production stages of quartz and silicon, which are the basic input used in optoelectronic components. The following flowchart was taken from a recent report by the INT (National Technology Institute), "New Materials: Challenge and Opportunity" - Part 3, Sept. 1992, which illustrates well this interrelationship.

---

<sup>114</sup>The technology of card-operated public telephone exchanges, which was developed by the CPqD, costs half what its foreign similar services cost - US\$570 compared with US\$1300. This is due to its own development of chips and other microelectronic components, according to information from TELEBRAS published in the *Jornal do Brasil* newspaper on 20/5/94.

Flowchart - Production stages of quartz and silicon in Brazil (1988)



This scheme shows that the productive chain of materials derived from quartz and silicon is not complete in Brazil and leaves gaps both for the manufacturing of optical fibers and in the basic materials of the semiconductors and solar cells, as in the case of Electronic Grade Silicon.

The same INT report also says: "New semiconductors made from gallium arsenide, indium phosphide, cadmium telluride and other compounds of these groups, are already being developed. These new semiconductors do not represent more than 5% of the world market, and the projections do not go further than 8% until 1995. ... hence, when discussing semiconductors, in any new materials program, even in advanced countries, the preponderance of silicon is clear." This report also says that there is a need for an industrial policy for EG Si in Brazil and mentions, in this respect, the opinion of the Brazilian Physics Society (SBP): "Brazil wants to develop a highly autonomous national industry of information technology products. Little progress has been made in the area of components development. It is necessary to heed the requirements of SID Microeletrônica, Elebra and Itaucom which want to produce integrated MOS circuits from silicon and to try to help those companies. The MOS silicon circuits are still the most important item in microelectronics, in economic terms, and there is still plenty of time left before GaAs-AlGaAs-based devices take the place of the Si-MOS in economic importance. It is imperative that the gap in Brazil be filled in basic research into Si-MOS systems. (...) we have found that (...) the incipient stage of research into Si-MOS materials and devices in Brazil is keenly felt."<sup>115</sup>

Rounding out this situation of national capability requirements that would be desirable for mastering the technologies necessary for the sector to advance, Elydio A. Pereira of Embratel, emphasized the importance of a "very intensive study of the use of materials for lasers, and also to improve the characteristics of optical fibers through doping, of materials for covering and lining the ducts ... and our participation in this is very small."

To this end, Loural stresses that it is important to pay attention to the choice of wrapping materials, e.g. sheaths and cables for optical fibers, coating polymers, etc... which may not seem so significant, but they have their importance and also have to be looked at from the point of view of environmental impact.

On the telecommunications services side (multimedia), there is also a need to train personnel to cope with the constant changes of the technological innovations cycle and who need to know, according to Sampaio, a director of Embratel, the rudiments of quantic electrodynamics and materials, besides notions of cultural change.

Finally, before discussing opportunities for Brazil, it should be emphasized that, similar to microelectronics, the most important aspect of the advanced

---

<sup>115</sup>Taken from page 45 of the INT publication "New materials: Challenge and Opportunity", Part 3.

materials is their high technological content, that is, capability in the field of these materials means technological mastery of the complete production process of components and equipment that will make it possible to introduce different telecommunications services systems.

### ***TELECOMMUNICATIONS SECTOR AND OPPORTUNITIES FOR ADVANCED MATERIALS IN BRAZIL***

The opportunities for Brazil in the field of research and development of national capability in advanced materials for the sector must be considered as much from the side of industrial requirements - production capacity - as from the side of demand for the most modern telecommunications services, which is intensifying.

As this involves future opportunities within the two scenarios considered, the main points mentioned in this part were taken from interviews with specialists, who were encouraged to carry out a prospective exercise on the subject.

By and large, the persons interviewed consider that the development of research in this sector will depend upon the country's industrial policy and even on decisions on the importation of products and components, which may have similar national products.

A very important role that national capability may seek is, in Loural's opinion, that of accrediting and certifying, and not just producing. To do so, the knowledge produced by research is necessary. To quote him, "the ordinary citizen only sees research when it produces a product and not when it produces regulatory knowledge. This is very important in a market in which you do not fully participate, but to which you must have access... to slow down the tendency of **Scenario II**, you must be capable of reverting this (the general internationalization process) and of talking to the supplier as an equal."

Still making general comments, Sampaio, Embratel's director, said he was skeptical about forecasts because, he said, "they are made in terms of the present paradigm which may not be hegemonic in the future, thereby leading to the failure of forecasts however tendential they may have been when the projection was made".

In line with this viewpoint, Loural, of the CPqD, also expressed his concern about the paradigmatic change. He said: "Personally, I am already beginning to see some saturation in these markets, such as for example, the microelectronics market. On the other hand, fiber optics are not opening up because there is not yet anyone using them although, oddly enough, it is us who will change the paradigm. Over the next 25 years the electronic paradigm, which has sustained these developments, will give way to the biotechnological paradigm. This is because there will be a

saturation of what electronic technology can do, just as there was saturation of metal-mechanical technology."

The consensus reached among the persons interviewed is that the technologies and the materials will not vary according to the scenarios. What will differ in each case is the mix of services and their target public.

To this end the points in common between the two scenarios seem to be the expansion of cellular telephony and the more or less extensive dissemination of the data transmission services, known as multimedia, which in **Scenario I** would be dynamized by the private data networks and in **Scenario II** would be strengthened by the informatization of public access networks, such as schools and libraries, for example.

In Loural's opinion, "**Scenario I** is easier to visualize. You can see that the tendency is toward more sophisticated services and equipment based on the tripod: fiber optics, microelectronics and software, up to the maximum that the market is capable of consuming." ... "In **Scenario II** clever solutions will be necessary to permit the reduction of service costs to attend larger portions of the population, such as for example, basic telephony." In this respect, Elydio points out that cellular telephony is a way of lowering the cost of expanding the telephone system, besides meeting a natural desire of people to have a mobile way of communicating with each other.

## ***REFERENCES***

- 1) DAVID, NOWDWORSKI: "Nuovi Scenari Nery Business per lo Sviluppo delle Comunicazioni via Satélite", Annais "Convegno Internazionale de SAM": Sistemi Avanzati di Management, "Innovazione Tecnologiche: Nuove Opportunità per gli Anni 90, Milano, em 31 de maio a 2 de junho de 1989.
- 2) UEHARA, M. JOSÉ, "Cenários de Telecomunicações" Revista São Paulo em Perspectiva, 7(4):59-74, out/dez 1993.
- 3) RNT: Revista Nacional de Telecomunicações, março de 1994.
- 4) ELECTRONICS JOURNAL, 11 July, 1994, pp. 14.
- 5) BNDES "Telecomunicações Via Satélite "Textos para Discussão No 12, DEEST - Departamento de Estudos Setoriais, st. 1993, versão preliminar.
- 6) Revista Brasileira de Construção para o Brasil e América Latina, "O Empreiteiro", março/94.
- 7) USP/ANDRADE, Carlos Amério Morato et alli "A Microeletrônica no Brasil" 1979.

- 8) LASTRES, HELENA E LEMOS, CRISTINA: "Quartzo Silício: Diagnóstico do Segmento" mimeo 1988. INT (Instituto Nacional de Tecnologia).
- 9) INT: "Novos Materiais: Desafio e Oportunidade" (Parte 1 - Novos Materiais Metálicos)