CHAPTER 4

SCENARIOS OF SUSTAINABLE DEVELOPMENT AND ADVANCED MATERIALS: NATIONAL CAPABILITIES AND OPPORTUNITIES FOR BRAZIL

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CAPABILITY VERSUS DEMAND AND OPPORTUNITIES FOR BRAZIL

This chapter is a final analytical summary of the partial conclusions reached in the course of the project. Basically, it aims to tabulate the most important information from the studies by sector, relating to future demand for materials and present capabilities for meeting it in the two scenarios proposed. The chapter thus falls into three main blocks: 1. Forecasts of Brazil's Demands for Advanced Materials in Scenarios I and II; 2. Analysis of Brazil's Capability in Advanced Materials; 3. Matrices for Correlating Capabilities with Demand Opportunities. The criteria and methodologies used in drawing up the tables and analyses are described in each of the blocks.

Overview of demand in the scenarios

The starting point for the exercise were the relative positions of demands in each segment of the sectors studied, in the light of the conditions established by Scenarios I and II. Results set in the previous chapter for Energy, Transport, Microelectronics and Telecommunications sectors are shown in Chart IV.1. Chart IV.2 relates the sector and their segments to the main technologies and their positions in Scenarios I and II.This position is given by matching Chart IV.1 against the corresponding demanded technologies. Chart IV.3 shows the order of the segments of the various sectors in the scenarios, and correlates them with the materials on the basis of the technologies presented in the foregoing table. One thus obtains a grading of demand for materials in the scenarios. This grading comprises three concepts: STRONG, MODERATE and WEAK, which.are assigned by correlating the material with the segment's position in the respective scenario. One possible interpretation of these tables reveals the growth prospects of markets for technologies related to the various segments and, thus, for the advanced materials that already are, or will come to be, incorporated by these technologies. In summary, for each sector analyzed in the alternative scenarios, a future demand panorama was obtained for the materials that are or will be essential to them.

Brazilian Demand for Advanced Materials in Scenarios I and II

Chart IV.1 - Position of Sub-Sectors in Scenarios 1995-2015

DEGREE OF IMPORTANCE IN THE SCENARIOS	SCENARIO I	SCENARIO II
SECTOR ENERGY(*)		
STRONG	1. HYDROELECTRICITY 2. OIL	1. HYDROELECTRICITY 2. BIOMASS
MODERATE	3. BIOMASS 4. NATURAL GAS	3. OIL 4. NATURAL GAS
WEAK	5. COAL 6. OTHER RENEWABLES	5. OTHER RENEWABLES 6. COAL
SECTOR TRANSPORT(**)		
STRONG	1. ROAD	1. RAIL
MODERATE	2. AIR 3. RAIL	2. WATER 3. ROAD
WEAK	4. WATER	4. AIR
SECTOR MICROELECTRONICS (***)		
STRONG	1. INFORMATICS 2. CONSUMER	1. TELECOMMUNICATIONS 2. INFORMATICS
MODERATE	3. TELECOMMUNICATIONS 4. AUTOMOTIVE ELECTRONICS	3. CONSUMER 4. INDUSTRIAL ELECTRONICS
WEAK	5. INDUSTRIAL ELECTRONICS	5. AUTOMOTIVE ELECTRONICS

(*) Position of energy sources in terms of each one's share in the projected energy matrix. (**) Position of means of transport in terms of their accumulated growth rates over the period. (***) Position of microelectronics inputs demanding sub-sectors in terms of their accumulated growth rates over the period.

Chart IV.2 - Advanced Materials Technologies by Sector and Their Importance in the Scenarios

SUB-SECTORS	MATERIALS TECHNOLOGIES	DEGREE of IMPORTANCE	
ENERGY		**SCENARIO I**	**SCENARIO II**
HYDROELECTRICITY	technology for insulating and contact materials; superconductors for transmission and generation; technologies for materials for more efficient, durable turbines; technology for materials for energystorage.	STRONG	STRONG
OIL	Technologies for materials for use in drilling equipment (more resistant to wear and high temperatures); materials with high resistance to fatigue for drilling columns; materials for flexible risers; technologies for materials more resistant to hydrogen cracking; materials for linings and tubing resistant to corrosive environments; materials for subsea welding; technologies for electrical and electromechanical devices for subsea vehicles and equipment, technologies for materials for floating and refrigerated tanks.	STRONG	MODERATE
NATURAL GAS	Technologies for lighter, safer storage and transportation cylinders and for use in vehicles; technologies for materials for thermal electric generator units; technologies for materials for drilling similar to those for oil.	MODERATE	MODERATE
BIOMASS	Materials more resistant to exhaust gases and steam for cogeneration; materials for gasifiers and gas turbines designed for the combined cycle; technologies for polymer membranes for green fuel production processes; technologies to increase resistance to corrosion in materials for alcohol distilleries; technologies for materials for green fuel combustion enginees .	MODERATE	STRONG
COAL	Technologies for lining materials resistant to wear, corrosion and higher temperatures for thermal electric generation (steam or combined cycles).	WEAK	WEAK
OTHER RENEWABLES	Development of solar panels, especially with silicon - based semiconductors and with composite semiconductor films; durable, light and more compact batteries with greater storage capacity; materials for lighter, more efficient fuel cells.	WEAK	WEAK

SUB-SECTORS	MATERIALS TECHNOLOGIES	DEGREE of IMPORTANCE	
TRANSPORT			
ROAD	Technologies for new materials for car bodies: better strenght/weight ratio, resistance to corrosion, forming(including lower tool and machinery costs), quality of finish and ease of repair, besides meeting more rigorous recyclability standards; technologies for materials for alternative propulsion devices with low environmental impact: materials for high capacity storagebatteries, materials for lighter, more efficient fuel cells, materials for fuel gas storage tanks, materials and linings resistant to corrosion by green fuels; lighter materials more resitant to higher working temperatures in internal combustion motors.	STRONG	MODERATE
RAIL	Technologies for materials for lighter, faster trains; materials for new forms of propulsion (new magnetic materials, superconductors for supermagnets).	MODERATE	STRONG
AIR	Technologies for structural materials for more economical planes with greater capacity; technologies for materials for more efficient, silent turbines.	STRONG	WEAK
WATER WAYS	Materials for alternative propulsion technologies (magneto-hydrodynamics, wind propulsion).	WEAK	STRONG
MICROELECTRONICS			
INFORMATICS	Materials for continued expansion of silicon-based microelectronics (integration and miniaturization); opto-electronics materials for integration with communications area; new semiconductors.	STRONG	STRONG
CONSUMER	Materials for continued expansion of silicon-based microelectronics (integration and miniaturization); and materials for components for communications appliances (audio and video); materials for use interfaces (microphones, sensors, lenses, speakers, etc.).	STRONG	MODERATE
TELECOMMUNICATIONS	Materials for continued expansion of silicon based microelectronics (integration and miniaturization); materials for components for communications appliances (audio and video) with emphasis on optoelectronics and radio transmission and broadcasting systems (mobile telephony, satellites).	MODERATE	STRONG
AUTOMOTIVE ELECTRONICS	Materials for continued expansion of silicon-based microelectronics (integration and miniaturization); materials for components for communications appliances (audio and video) with emphasis on optoelectronics and radio transmission and broadcasting systems (mobile telephony, satellites); materials for sensors.	MODERATE	MODERATE
INDUSTRIAL ELECTRONICS	Materials for continued expansion of silicon-based microelectronics (integration and miniaturization); development of materials for mechatronics (sensors.)	WEAK	WEAK

Chart IV.3 - Demand for Advanced Materials in Brazil in the Scenarios I and II

Sectors	Materials	SCENARIO I	SCENARIO II
Energy	Martensitic Stainless Steels	STRONG	STRONG
	Ferritic and Austenitic Stainless Steels	STRONG	STRONG
	Refractory Ceramics	MODERATE	STRONG
	Superalloys	MODERATE	MODERATE
	Electronics Grade Silicon	WEAK	WEAK
	Amorphous Silicon	WEAK	WEAK
	Composite Semiconductors	WEAK	WEAK
	Polymers and Polymer Concretes	STRONG	STRONG
	Nb/Ti metal-alloys (superconductors)	STRONG	STRONG
	Superconductor Ceramics	STRONG	STRONG
	Polymer Membranes	STRONG	STRONG
	Ni/Ti, Cu/Al/Zn Metal Alloys	STRONG	STRONG
	Ni/Cd and Rare Earth Alloys	STRONG	STRONG
	Fe/Ti, Mg/Ti and Ni/Rare Earth Metal Alloys	STRONG	STRONG
	Corrosion Resistant Metal Alloys	MODERATE	STRONG
	Coated Metal Alloys	MODERATE	STRONG
	Polymers (resistant to degration)	MODERATE	STRONG
	Structural Steels	STRONG	MODERATE
	Alloys Resistant to Marine Corrosion	STRONG	MODERATE
	Polymer Matrix Composites	STRONG	MODERATE
	Steels and Polymers (tubing /pipes)	STRONG	MODERATE
Transport	Thermoset Polymer Matrix Composites	MODERATE	WEAK
	Al/Li Alloys	MODERATE	WEAK
	Nickel-based Superalloys	MODERATE	WEAK
	Special Steels (UART)	MODERATE	STRONG
	Low-Alloy, High-Strength Steels	STRONG	STRONG
	Engineering Thermoplastics	STRONG	MODERATE
	Structural Ceramics	STRONG	MODERATE
	Treated Surface Steels	STRONG	MODERATE
Microelectronics and Telecommunications	Electronics Grade Silicon	STRONG	STRONG
	Covalent Ceramics and Alumina	STRONG	STRONG
	Thermoset Resins	STRONG	STRONG
	Al, Au, Cu (pure metals and alloys)	STRONG	STRONG
	Composite Semiconductors	MODERATE	STRONG
	Fused Quartz for optical fiber	MODERATE	STRONG
	Cultivated Quartz for oscillators	MODERATE	STRONG

Panorama of Brazil's Capability in Advanced Materials

In order to make it possible to establish present situation of the materials in question, an assessment was made of the level of Brazil's capability in the materials related to the technologies highlighted by segment in the sectorial analyses. This assessment was performed using defined criteria, using a homogeneous method for all sectors, with differentiated weightings and concepts that could be related to a numerical expression, so as to permit comparison among the materials and generate a capability position by sector for each material. The result is shown in the Tables IV.1, IV.2, IV.3 and, aggregated by material, in Table IV.4 (see the next pages).

Correlating Demand with Capability

The final exercise in this chapter is to correlate the final demand position (Chart IV.3), obtained by the sectoral analyses in each scenario, with that of Brazil's Advanced Material Supply Capability (Table IV.4). The result is a panorama of future prospects for advanced materials in Brazil in the scenarios considered, the related opportunities and threats were ranked, conceived by a qualitative assessment which classifies each material in terms of nine alternatives stipulated for the matching of supply capability with demand. Each of these alternatives was denominated in such a way as to express the result of the correlation. The ideas used are those expressed by the terms **opportunity** and **threat**. The nine alternatives incorporate these terms in an individual or aggregate form (opportunity with weak threat, strong threat, moderate opportunity, etc.). The adjectives "strong", "moderate" and "weak" were used to introduce differentiation which would assist in studying strategies for the materials. This analysis aims to offer concrete elements for formulating differentiated strategies appropriate to the advanced materials grouped according to the classification they received in the matching of supply and demand. This will make it possible to draw up a Brazilian Agenda of Technological and Industrial Research and Development for these materials. Naturally, the whole methodology developed here opens the way to specific studies on each material, which would then make it possible to define, with a high degree of reliability, the policies and measures which should be formulated and carried out by interested agents.

Analysis of Brazil's Capability in Advanced Materials

A) Explanation of the Concepts and Weightings of Criteria Used to Determine the Level of Capability

Three criteria were adopted for drawing up the capability table: **availability of raw materials, R&D capability and industrial capability** - all referring to the situation in Brazil today. Here, raw materials were assessed in terms of their existence and availability, and the materials originating from them were classified according to the level of R&D capability and industrial capability (good, moderate or deficient). The descriptions below are designed to clarify the parameters that guided these qualitative definitions and analyses used in criteria weightings and in the concepts expressed by each criteria.

Criterion Weightings

Industrial Capability: weighting = 3

The most important criterion is that of industrial capability since, in most cases, it portrays whether there exists technical and managerial competence for production in the segment. Many of the materials or products being analyzed here are probably not yet being produced domestically, but nonetheless this criterion can be gauged indirectly in terms of what is now being developed and manufactured, which demonstrates the capability of companies in the segment to deal with highly complex products. No account will be taken of the origin of the capital of the leading companies in any segment or the origin of the technology they use. What is important is to determine whether this criterion adds much, little or nothing to the level of capability installed in Brazil.

R&D capability: weighting = 2

The R&D capability criterion seeks to assess, from existing information[116] , the capacity of the present technical and human resources in Brazil, located in universities and public or private research centers. Sensitivity to this criterion is based on an evaluation of the level of technological knowledge already performed in the segment. In certain cases, it is considered that technical quality, capacity for initiative and other favorable circumstances, such as productive alliances in Brazil and abroad, are indicators of reliability and of good expectations for R&D in the segment. It is not reasonable, for instance, to judge this capability by comparing it with that of other more developed countries. This assessment also does not attempt to determine relative positions or capacity of innovation. We sought to make good use of the knowledge acquired in earlier surveys of capability in Brazil in order to perform an exercise which seeks to assess whether or not the know-how assimilated and applied in R&D gives ground for expectations, whether or not it requires greater attention to a specific subject under consideration.

Availability of raw materials (and inputs): weighting = 1

In most cases it can be seen that raw material can no longer be considered the principal strategic factor in the materials industry. On the contrary, as discussed here, one of the main functions of advanced materials is to offer alternatives to replace other materials which depend on inputs which are scarce and/or supply of which on the world market is in some way threatened. Moreover, the "dematerialization" of production - that is, the reduction in the material content in

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[116] This assessment is based on the documental information of the data base "Novos Materiais: Capacitação e Potencialidades Nacionais", prepared by the Núcleo de Estudos em Novos Materiais/INT, in 1988, and on information obtained directly in the interviews with specialists.

products - is tending to stabilize or even reverse the direction of growth of the quantities of materials used in manufacturing products worldwide. In any case, this criterion should be taken into consideration, given that it is better to have raw material available than nothing.

B) Assessment of Criteria: Concepts and Value Analysis for Determining Level of Capability

Availability of raw materials and inputs

– **Exist** (VALUE = +): in this case the starting raw material exists in Brazil and can be supplied directly or be developed into the appropriate form or formulation for obtaining the final material.

– **Available** (VALUE = 0): means that the raw materials/main inputs can be acquired on the international market, but nothing guarantees future supplies due to the interference of manufacturers' possible strategic interests and/or protectionist policies on the part of countries holding the raw materials or technology for processing them.

– **Deficient** (VALUE = -): essential starting inputs for the process of manufacturing the material are not available or severe restrictions are already known to exist on their sale.

R&D Capability

– **Good** (VALUE = +): there exists a capability at a good level and with experience sufficient for local development or direct assimilation of techniques and technology for processing the material.

– **Moderate** (VALUE = 0): existing capability is limited, although of good quality. If encouraged, the necessary know-how could be acquired in the medium to long term.

– **Deficient** (VALUE = **-**): the existing capability is not considered to be up to initiating the process of acquiring know-how and thus need major incentive and investment at the basic stages, such as formation of human resources and laboratory infrastructure for basic and applied research.

Industrial Capability

– **Good** (VALUE = +): in this case, capability is considered to exist and be available in Brazil for manufacturing the material. It is taken into account that companies have already acquired sufficient know-how, already manufacture or manufactured the material and thus understand the fundamental of the process technologies. Mastery of all stages of processing is not considered necessary, since the most important of them have been assimilated.

– **Moderate** (VALUE = 0): moderate industrial capability means that companies in the segment are able to assimilate the manufacturing techniques by way of technology transfer and equipment purchases and/or by way of R&D programs pursued jointly with Brazilian or foreign organizations. It is assumed that companies can draw on previous successful experiences and/or similarities with products already marketed.

– **Deficient** (VALUE = -): here opportunities for manufacturing in Brazil are considered to be very limited owing to the lack of companies with mastery of the basic processing technologies. Other market restrictions may also bear upon this concept, such as it being unfeasible to acquire technology or raw material, creating huge obstacles for development to local firms.

On the next pages, tables IV.1, IV.2 e IV.3 show capabilities evaluations, made according this methodology, and final results for each material are set on column Degree of Capability.

Table IV.1- Brazil's Advanced Materials Capability for the Energy Sector

			Availability of	Capability		Degree of
Field of Application	Characteristics	Material	Raw Material	R & D	Industrial	Capability
Energy Generation **- hydroelectric**	resistance to creep (turbine vanes)	- martensitic stainless steels	available (0)	good (+)	good (+)	(+5)
- thermal electric	resistance to higher temperatures under the action of combustion gases and steam	- ferritic and austenitic stainless steels	available (0)	good (+)	good (+)	(+5)
		- ceramics: refractory specialties	exists (+)	good (+)	good (+)	(+6)
	resistance to creep and high temperatures (gas turbines)	- super-alloys	available (0)	moderate (0)	moderate (0)	(0)
- alternative	semiconductivity (photovoltaic generation)	- electronics grade silicon	exists (+)	good (+)	moderate(0)	(+3)
		- amorphous silicon	exists (+)	good (+)	moderate (0)	(+3)
		- composite semiconductors	available (0)	good (+)	moderate (0)	(+2)
Power Transmission	electric insulator	- polymers	exists (+)	good (+)	good (+)	(+6)
		- polymer concretes	exists (+)	good (+)	good (+)	(+6)
	superconductivity	- Nb/Ti alloy	exists (+)	modetated (0)	moderate (0)	(+1)
		-superconductor ceramics	available (0)	moderate (0)	deficient (-)	(-3)
Energy Conservation	selectivity	- polymer membranes	available (0)	moderate (0)	deficient (-)	(-3)
	shape memory	-Cu/Al/Zn metal alloys	exists (+)	good (+)	moderate (0)	(+3)

Energy Storage	energy accumulation (high-capacity batteries)	- Ni/Cd - Rare Earth alloys	available (0) exists (+)	moderate (0) moderate (0)	moderate (0) moderate (0)	(0) (+1)
	storage of hydrogen	- Fe/Ti, Mg/Ti, Ni/Rare Earths metal alloys	available (0)	good (+)	moderate (0)	(+2)
Transport	resistance to corrosion by alternative fuels	- metal alloys - coated metal alloys - polymers	exists (+) available(0) exists (+)	good (+) moderate(0) good (+)	good (+) moderate(0) moderate (0)	(+6) (0) (+2)
Oil Industry - prospecting and production	resistance to hydrogen cracking	metal: stainless steels	exists (+)	good (+)	good (+)	(+6)
- off-shore platforms	resistance to fatigue	metal: steels	exists (+)	good (+)	good (+)	(+6)
	resistance to marine corrosion	- structural steels low alloys steels - stainless steels and nickel alloys	exists (+) available (0)	good (+) good (+)	good (+) good (+)	(+6) (+5)
	low density and high mechanical strength	- polymer matrix composites (resins/reinforcing fibers)	available (0)	good (+)	good (+)	(+5)
- transport of fluids	flexibility	- steels and polymers	available (0)	good (+)	moderate (0)	(+2)

Note: table prepared with collaboration from Heitor Luz Neto, INT- Instituto Nacional de Tecnologia, and with suggestions from Carlos Camerine, CENPES- Centro de Pesquisas da Petrobrás.

Comments on Table IV.1

In order to justify the assessments set out in the table above, some comments must be made on the main areas where advanced materials are applied in the energy sector.

Hydroelectric Generation

Brazil's great hydroelectric generation installations are attended by a considerable equipment supply sector, where large foreign companies, including Siemens and Asea-Brown-Bovery, are a major presence. It is they who are responsible for bringing into Brazil, for instance, the advanced technology for direct current transmission of power generated at the Itaipu plant. Innovations in the materials field are incorporated in more modern equipment like turbines and generators, which does not mean that suppliers necessarily develop them in Brazil, although the competence may be there. On the other hand, Eletrobrás has an important research center in Rio de Janeiro (CEPEL), with capability for assessing the performance of materials for the sector and even develop them if necessary.

Thermal Electric Generation

Brazil's capability in the technology of thermal electric generation is limited when compared with that for hydroelectric generation. Large-scale utilization of biomass is restricted to the use of sugarcane bagasse in the sugar-alcohol industry. The coal burnt in generating plants in the south of Brazil has a high ash and sulfur content and still causes environmental problems, from when it is mined through to when it is burnt at the plants. Development is beginning on a prototype combined cycle unit, in line with a new world trend, but assimilation of this technology does not presuppose local development of the most important related materials, especially the superalloys. For the materials used in traditional turbines, there already exists capability installed in companies like Aços Villares and Eletrometal, as well as refractories industries with broad experience in supplying the thermal electric power generation and iron and steel sectors, outstanding among them being Magnesita and Carborundum.

Generation by alternative sources: solar

Development of photovoltaic energy based on semiconductor silicon is of great interest to Brazil, which produces significant quantities of metallurgical grade silicon, the starting input for production of semiconductor silicon, and has already assimilated the know-how and basic techniques necessary for its research institutions to produce it. There is also a Brazilian company producing photovoltaic panels. As for composite semiconductors, some competency has been developed in using them in optoelectronic communications, but without any significant repercussions in the photovoltaic field. Thermal electric solar generation is further than the others from becoming a reality, since it is viable only on larger scales than its wind and photovoltaic counterparts. At present, only thermal water-heater panels have found growing demand, but these do not require special materials.

Power Transmission

Difficulties are not expected in the power transmission field as concerns assimilation of new materials for traditional systems, due to the presence of large international companies like Pirelli and Furukawa. Development of superconductivity in metallic materials has achieved a good level, despite being centered in only one research center which for some time received investments from large companies. Note that Brazil holds the world's largest reserves of niobium, as well as having the largest niobium mining and intermediate products manufacturing company. Development of niobium-titanium type alloys and their applications would thus make this metal immensely valuable. The emergence of ceramic superconductors - although they are not yet competitors for uses requiring high levels of current density - seems, nonetheless, to have inhibited these initiatives. Inexplicably, after a few months of enthusiasm among the Brazilian scientific community, research into these materials at the most important centers practically ceased. So one of the rare chances to accompany development of this novelty more closely was missed.

Energy Conservation

In this area, advanced materials can make an immense contribution as in the examples described. Polymer membranes open the way to gas and liquid separation technologies that compete with those requiring phase changes, which are thus great energy consumers. Major industrial segments already using membrane separation include the fruit juice and dairy industries, and this can expand to the sugar-alcohol and chemicals sectors. Research groups with relevant experience do exist in Brazil and various niches opened up by these technologies can be exploited. Shape-memory alloys also find certain applications in the electric sector which contribute to energy savings.

Energy Storage

Trends regarding energy storage technologies will be dictated by renewable sources advance, especially solar and wind energy, due to the natural intermittence of its generation. As interest in these sources on the part of the main protagonists in the Brazilian electric system is still restricted, little has been done in terms of R&D in this country. In any case, a good number of the raw materials used in high-capacity accumulator batteries exist in Brazil, along with a reasonable amount of processing know-how. International companies, such as Delco, are already introducing innovations into their products. The use of hydrogen, both as storage medium and its application in, for instance, fuel cells, is still an academic curiosity, while there is some research into prototypes for automotive use. In this area, development of materials is essential for commercial feasibility.

Transports

Alternative fuels, especially those derived from biomass, may require development of appropriate materials or special techniques for protection against corrosion. Brazil is well situated in this field with the experience acquired in developing hydrated alcohol driven motors, but a whole series of material coating techniques have yet to be fully mastered.

Oil and Gas Prospecting and Production

Brazil's capability in this area is internationally acknowledged, so that its needs in terms of materials technologies in response to new challenges - especially as concerns deepwater wells - tend to be confronted and overcome with competence. Petrobrás has a highly efficient research center and makes routine use of other capabilities, both in Brazil and from abroad, even carrying out more burdensome R&D programs by partnering with other major groups interested. It is thus to be imagined that all the specialties in materials described here represent interesting opportunities, in view of the technical and managerial competence already attained.

Table IV.2 - Brazil's Capability in Advanced Materials for the Transports Sector

			AVAILABILITY OF RAW MATERIALS	CAPABILITY		DEGREE OF CAPABILITY
FIELD OF APPLICATION	**CHARACTERISTICS**	**MATERIAL**		**R & D**	**INDUSTRIAL**	
1. Air Transport -structural parts of aircraft	lower weight without forfeiting strength	thermoset polymer matrix composites	available (0)	moderate (0)	good (+)	(+3)
		aluminum-lithium alloys	available (0)	moderate (0)	deficient (-)	(-3)
- aircraft turbine vanes	high strength at high temperatures	nickel-based superalloys	exists(+)	deficient (-)	moderate (0)	(-1)
-turbine parts and certain structural parts of aircraft	high resistance to corrosion and high strength/weight ratio	titanium and some of its alloys	exists (+)	moderate (0)	moderate (0)	(+1)
-parts of aircraft landing gear and suspension	ultra high strength	special, high-strength steels	exists (+)	good (+)	good (+)	(+5)
2. Road Transport - structural parts of land transport vehicles	better strength/weight ratio than common steels	high-strength, low-alloy steels	exists (+)	good (+)	good (+)	(+6)
- parts and external portions of automobile bodywork	mechanical strength, lower weight, good resistance to corrosion	engineering thermoplastics	available (0)	moderate (0)	moderate (0)	(0)
- internal parts of internal combustion motors	high resistance to wear and to corrosion at high temperatures	structural ceramics	available (0)	moderate (0)	moderate (0)	(0)
- panels for external portions of automobiles	good stiffiness and corrosion resistance	surface coated steels	exists (+)	good (+)	good (+)	(+6)

Comments on Table IV.2

Air Transports

Brazil's capability in materials technology for use in aviation can be considered highly developed. In relation to polymer matrix composite materials, both the design and manufacture of wing and fuselage parts are processes familiar to Embraer and its numerous specialized suppliers. The limited scale of demand has not made it feasible to develop the manufacture of basic aircraft construction materials, however, including the special thermoset polymer resins or even reinforcements fillers, like carbon fiber. Pilot production of the latter has been started by the company Copene in Bahia with support from the CTA (Centro Tecnológico de Aeronáutica) but, although technically successful, the initiative did not go beyond that stage. As concerns manufacture of thermoset resins and pre-impregnated sheets, the German company BASF considered the possibility of setting up a specialized plant in Brazil , but withdrew - as far as is known - because of the recession on both Brazilian and international aircraft markets. No obstacles for these materials importation are known to exist. Restrictions on access to innovations are always possible, however, especially if one considers Embraer's fine international performance in certain niches, such as military trainer aircraft and regional transport aircraft, where it is competing on the same level with large companies like Fokker and Saab.

The aluminum-lithium alloys continue to constitute an promising option for applications in the aviation field. Their prices are still not attractive because of the sophisticated processing involved, but they may be very useful for future supersonic aircraft, which are beginning to be reconsidered. At present, Al-Li alloys are seen as materials which are still "looking for applications". International companies in the aluminum field installed in Brazil have already mastered the manufacturing technology, but have limited investment in this specialty, even at their central facilities. Having or not having technology in these materials does not constitute a threat at the moment.

In the field of materials used in propulsion equipment, such as jet turbines, there is a deficiency, especially given the great advances represented by new technologies for manufacturing monocrystalline or oriented crystal-grain superalloy vanes, which have not yet been totally mastered in Brazil. This fact must be credited more to lack of opportunity than to lack of industrial competence, since companies like Eletrometal produce these basic materials, the flight operator Varig has the largest maintenance installations in Latin America and the company Celma, recently purchased from the government by General Electric, has maintained and repaired propeller systems for years. It is reasonable to imagine that, should there be demand for turbines for use in thermal electric generation using the combined cycle process - the technology for which is covered in the section of this study devoted to the energy sector - this could constitute a decisive incentive to assimilation of the sophisticated techniques for processing superalloys. The greatest deficiency in this segment lies in the R&D area, where there is no significant activity in Brazil.

The situation regarding composite materials is repeated in the case of development of titanium and its alloys; that is, there are no great problems as to specification of material and design of parts, but the aviation market has not offered any major opportunities for these materials, which more recently have been directed to the armaments area. For several years, the CTA (Centro Tecnológico da Aeronáutica) carried out research into obtaining and manufacturing these materials and, at present, certain aviation alloys, such as Ti-Al-V (used also in medical devices) are being produced in Brazil, albeit on a minute scale. Meanwhile, Brazil has considerable reserves of titanium ores and it would be in its interest to develop the technology and domestic market for products to encourage their use.

In relation to high-strength steels for aviation applications, a high level of technical know-how is available at specialized steelworks, at least one of which is an accredited supplier to North American and European aircraft construction companies. Demand for these materials could also be stimulated by a resumption of railway equipment construction. At present, it is the processing of these steels that has effectively caused the technological improvements. As long as the sophisticated equipment responsible for these improvements are available for purchase from suppliers located in the more developed countries, Brazilian companies need not worry, since they have already demonstrated their good technical and managerial capacity. What should be assessed, is whether or not difficulties will arise in the future over this kind of technology transfer, given that in the central countries the sector has opted for the specialties, leaving the traditional iron and steel segment to the peripheral countries.

Land Transports

High-strength, low-alloy steels, especially with niobium, have been developed to quite a high degree in Brazil because of to their structural applications in offshore platforms for oil and gas exploration and production. These, along with other varieties alloyed with molybdenum, have an important function in reducing the weight and increasing the strength and safety of vehicles. With the modernization of vehicle models produced in Brazil by foreign manufacturers, it is expected that these materials will be assimilated on a steadily greater scale, in that safety regulations are also working to encourage these improvements. To summarize, Brazil has quite a high level capability for developing these steels at present.

Countless polymers have also found structural applications in vehicles for land transport. Outstanding among these are the engineering thermoplastics, like the polyamides (Nylon), polycarbonates and polyethylene terephtalates (PET and PBT), which are already considered commodities on the market, and others less well known, like the polysulfones, the aromatic polyamides (e.g., Kevlar), the polyimides, etc. These resins throw open countless possible options for the same applications. This is due to the development of innumerable grades for each one, to the use of fillers and reinforcing fibers put together with them and to the development of the so-called polymer alloys. The laters seek to combine the best qualities of two or more resins to generate intermediate gradeproducts with a combination of properties which, compared with the starting resins, are more suited to the proposed use and cost less. Most of the basic commodity resins are already being produced in Brazil, as well as the most usual fillers and reinforcing fillers. Certain polymer alloys especially designed for the automobile sector are being produced by the company Coplen, a joint venture of Nitriflex with GE Plastics. Access to more sophisticated resins on the external market has not been a problem since most of the major international petrochemicals groups have plants or shares in firms in Brazil, which in turn are responsible for introducing these products onto the domestic market. There is, however, an enormous deficiency in R&D into new formulations or to develop successors not covered by international patents. The only significant case known is development by the Petrobrás Research Center (CENPES) of catalysts that permit production of ultra-high molecular weight polyethylene (UHMWPE). In general terms, Brazilian petrochemicals groups prefer to associate with their foreign counterparts to bring in new know-how, rather than investing in development in Brazil to produce innovations. Meanwhile, if one considers expenditure in technology transfer, this is the sector of industry that historically has invested most in R&D.

There is considerable technological research into structural ceramics, centered on the Universidade Federal de São Carlos (São Paulo), at technology centers like IPEN (São Paulo) and, on a smaller scale, at INT (Rio de Janeiro) and CDTN (Minas Gerais). Other centers like CETEM and Cemar-Lorena aim to produce precursors (starting materials for these ceramics). There are no reports of more complete packages of advanced structural ceramics technology being transferred to Brazilian industry, either by Brazilian research groups or by leading international firms which, like Japan's NGK, have operated in Brazil for years. Some initiatives have been taken by Metaleve towards using certain ceramics, in the form of composites, in piston and valve parts. Catalyst materials for vehicle exhaust emissions also continue to be imported.

Surface treated, and especially galvanized, steels for vehicle bodywork panels are already produced in Brazil by more advanced methods such as electrogalvanizing, recently inaugurated at Usiminas. Other, more sophisticated processes have not yet been requested by the vehicle assembly plants. In any case, the tendency is for possible new processes to be incorporated by direct purchase of equipment from abroad, despite there being a good corrosion R&D capability in Brazil.

Table IV.3 - Brazil's Capability in Advanced Materials for Microelectronics and Telecommunications

FIELD OF APPLICATION	CHARACTERISTICS	MATERIAL	AVAILABILITY OF RAW MATERIAL	CAPABILITY		DEGREE CAPABILITY
				R & D	INDUSTRIAL	
Microelectronics in General (ntegrated circuits)	-Semiconductivity	- Silicon	Exists (+)	Good (+)	Moderate(0)	(+3)
	- Thermal and electrical insulation (encapsulation)	- Ceramics (alumina and covalents)	Exists (+)	Good (+)	Deficient(-)	(0)
		-Thermoset Resins	Available (0)	Good (+)	Moderate(0)	(+ 2)
- Integrated and Printed Circuits	- Electrical Conductivity	- Al, Au, Cu (Pure Metals and Alloys)	Exists (+)	Good (+)	Moderate(0)	(+3)
Microelectronics and Optoelectronics Specialties	Semiconductivity	Composite Semiconductors	Available (0)	Good (+)	Moderate (0)	(+2)
Opto-eletronic forTele-communications	Electromagnetic Radiation Conduction	Fused Quartz for optical fiber	Exists (+)	Good (+)	Deficient(-)	(0)
Telecommunications and Consumer Electronics	Piezoelectricity	Cultivated Quartz for Oscillators	Exists (+)	Good (+)	Good (+)	(+6)

Comments on Table IV.3

Microelectronics in general

With the incorporation of integrated circuits into consumer electronics and telecommunications final products, microelectronics in Brazil has followed a course similar to that for electricity generation equipment, with major multinational enterprises setting up here (in the 1960s) for final assembly of finished parts and products. R&D began a decade later and, despite the excellence of the research teams and good laboratory results, there was no effective transfer of this acquired technological knowledge to the industrial structure. This was due, in large part, to the oligopolitic, pattern of this market, evident in the demand table for the sector. Brazilian companies never showed an interest in producing basic inputs or materials for microelectronics, alleging that the domestic market was small and that the related costs were insignificant in relation to the total value of production by the sector. The opportunity for triggering the multiplier effect upstream from the production chain was lost, and this for a sector that, at the end of the 1980s, was supplying a US$ 394-million market in semiconductors, where imports totaled US$ 210 million, without counting inputs destined for domestic production.

Microelectronics and Optoelectronics Specialties

Outstanding here were semiconductor materials, especially composite semiconductors, designed for applications in microelectronics (e.g., supercomputers) and optoelectronics (emission and detection of light spectra for optical communications). Since 1982, R&D into applications for these materials in telecommunications devices is being led by the Telebrás Research Center (CPqD). After successfully developing and transfering technology for manufacture of optical fibers, recently engaged three companies - Elebra, 1987; AsGa, 1989; and Avibrás, 1993 - in the process of laser assembly technology transfer, and continues to invest in special niches for Brazil's interests. Note however that the deficiency in the composite semiconductor production chain resides at the stage of research and development into basic inputs, such as the preparation of pure elements for fine film deposit processes for thin layers deposition.

Optoelectronic Telecommunications

In the optoelectronics field, Brazil achieved important initial successes, being the first developing country to master optical transmission technology, after nationalizing manufacture of most of the related components. The greatest gap in this chain results from with a lack of success in mastering the technique of manufacturing the pre-form (quartz tube) from which the optical fiber is drawn. Thus, the advantage in terms of the excellent quality and large volume of the mineral quartz deposits in Brazilian territory, was not realized via this product which continues to be dominated by only a few companies in Germany, France and the United States. This quartz tube production process can add in the order of 1,000 times its value to the raw quartz. Development of new materials for the fibers (e.g., fluorineted glass) constitutes another threat.

Telecommunications and Consumer Electronics

As this is a simpler and more mature segment than the others, the materials applied to telecommunications and consumer electronics (radio-telephony, radio, audio and video appliances) are the most complete in Brazil's capability chain.However they do not offer significant development opportunities, as a result of the same broad characteristics of fusion and technological dominance by large international groups. It should be remembered that many of the Brazilian assemblers of these types of equipment disappeared or were bought out in the 1970s.

C) Concepts Applied in Awarding Points in the Assessment of Brazil's Advanced Materials Capability

After analyzing the situation of the materials selected through the studies by sector, in accordance with the three criteria (availability of raw material and inputs, R&D capability and industrial capability), the individualized points described in the column Degree of Capability were obtained. The numerical values recorded, which range from -6 to +6, are designed to clarify the potential of **domestic supply** of those materials, thus permitting greater precision for comparative analysis within the sample studied. Nonetheless, the degree of precision achieved should be used with some caution, because the levels (values) close together portray conditions which are almost similar for our practical purposes.

So, the following intervals seem to be more adequated.

Description of Aggregate Degree of Capability

POINTS RANGE	DEGREE OF CAPABILITY	DESCRIPTION OF ATTRIBUTES
between +6 and +5	high capability	excellent situation in terms of all the criteria; any new demand to appear can be met or assimilated by the local technical and managerial chain; good level of technological knowledge
between +2 and +4	good capability	obstacles exist for local development of these materials and related technologies, but can be surmounted by objective initiatives in problematical areas; good level of technological knowledge at essential stages.
between -1 and +1	moderate capability	deficient links exist in the chain of technical know-how or availability of inputs for the given material; requires planned, joint action to master the technology and/or to enter the market
between -2 and -4	capability deficient	most links in the input/R&D/industrialization chain exist in a precarious or emergent form, distant from the current state-of-the-art know-how required.
between -6 and -5	capability non-existent	activities in these materials are practically non-existent or at a very preliminary stage; great efforts must be made to coordinate and plan among the intervening agents if these need to be levered.

Thus, according to the criteria used and justified above, the degree of capability will indicate, for the present, the domestic supply capacity for each of the materials. Chart IV.4 below summarizes the results represented by the attributes recorded for each material, by sector, in Tables IV.1, IV.2 e IV.3.

Chart IV.4: Brazil's Capability in Advanced Materials by Aggregate Levels

SECTORS	MATERIALS	DEGREE OF CAPABILITY
ENERGY	Stainless Martensitic Steels	High
	Stainless Ferritic and Austenitic Steels	High
	Refractory Ceramics	High
	Superalloys	Moderate
	Electronics Grade Silicon	Good
	Amorphous Silicon	Good
	Composite Semiconductors	Good
	Polymers and Polymer Concretes	High
	Nb/Ti Alloy	Moderated
	Superconducting Ceramics	Deficient
	Polymer Membranes	Deficient
	Cu/Al/Zn Metal Alloys	High
	Ni/Cd and Rare Earth Alloys	Moderate
	Fe/Ti, Mg/Ti and Ni/Rare Earth Metal Alloys	Moderate
	Corrosion Resistant Metal Alloys	High
	Coated Metal Alloys	Moderate
	Polymers resistant to degradation	Good
	Structural Steels	High
	Alloys Resistant to Marine Corrosion	High
	Polymer Matrix Composites	High
	Steels and Polymers	Good
TRANSPORT	Thermoset Polymer Matrix Composites	Good
	Al/Li Alloys	Deficient
	Titaniun alloys	Moderate
	Nickel-based Superalloys	Moderate
	Special Steels (UHS)	High
	High-Strength, Low-Alloy Steels	High
	Engineering Thermoplastics	Moderate
	Structural Ceramics	Moderate
	Surface Coated Steels	High
MICROELECTRONICS AND TELECOMMUNICATIONS	Electronics Grade Silicon	Good
	Covalent Ceramics and Alumina	Moderate
	Thermoset Resins	Good
	Al, Au, Cu (pure metals and alloys)	Good
	Composite Semiconductors	Good
	Fused Quartz for optical fiber	Moderate
	Cultivated Quartz for oscillators	High

THE FUTURE OF ADVANCED MATERIALS IN BRAZIL IN THE SCENARIOS FOR SUSTAINABLE DEVELOPMENT

Methodology used for Correlating Degree of Capability with Demand Expectation

The exercises performed previously sought to define the levels of two variables for each material or family of materials. These are:

- present level of Brazil's capability in advanced materials;
- level of expectation as to the importance that these materials will come to assume in the scenarios projected, by virtue of the technologies that use them.

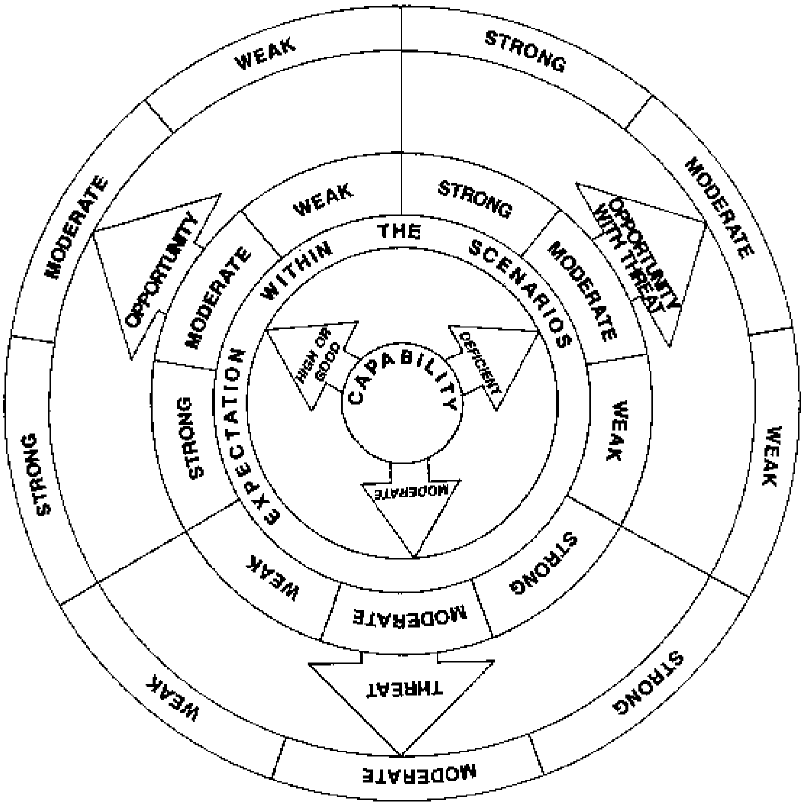
By correlating these two variables, one can foresee the possibilities for each material in terms of situations classified in this study as OPPORTUNITY and/or THREAT for Brazil. The level of detail achieved by the exercises permits nine different possible correlations to be established among these variables, as illustrated in the diagram.

The methodology chosen for determining the levels of opportunity and threat was as follows:

- the starting principle is that one should look at the future prospects indicated by the scenarios from the point of view of the present situation of Brazil's capability, since any strategies that may be required should be formulated now so as to lead that capability to a suitable future situation. Thus, in assessing opportunities and threats, the evaluator is located at each material's present situation and is looking, via the panorama opened up by the scenarios, towards the future importance of the same material and seeking, finally, to plot the most appropriate path (strategy) to achieve the desired capability.

The level of detail obtained, both for degree of capability and for expectations within the scenarios, enabled the materials to be framed in nine different gradings, as illustrated in the diagram, and which should be understood as below.

Figure IV.1 - Capability and Opportunity Circle



Sustainable Development Scenarios: a Forecasting Exercise for Advanced Materials in Brazil

This section presents the conceptual details of the above circle diagram, which are explained on Charts IV.5-7. The analysis and assessment of opportunities and threats is described on Charts IV.8 and 9, which show materials grouped after the capability vs. demanded expectation positioning. Finaly, Chart IV.10 lists the combination of both attributes and the final result.

Chart IV.5 - First Quadrant of the Capability - Opportunity Circle

LEVEL OF CAPACITATION	CORRELATION WITH EXPECTATION TYPE	EXPLANATION
High or Good	**strong**	**strong opportunity:** present conditions are extremely favorable to taking of significant future opportunity
	moderate	**moderate opportunity:** favorable conditions for taking less significant opportunity
	weak	**weak opportunity:** favorable conditions for the lesser important opportunities

Chart IV.6 - Second Quadrant of the Capability - Opportunity Circle

LEVEL OF CAPACITATION	CORRELATION WITH EXPECTATION TYPE:	EXPLANATION
Moderate	**strong**	**opportunity with strong threat:** present conditions reasonable but do not guarantee taking of highly significant opportunity
	moderate	**opportunity with moderate threat:** present conditions reasonable but do not guarantee taking of less significant opportunity
	weak	**opportunity with weak threat:** present conditions reasonable for an lesser important opportunities

Chart IV.7 - Third Quadrant of the Capability - Opportunity Circle

DEGREE OF CAPABILITY	CORRELATION WITH EXPECTATION TYPE:	EXPLANATION
Weak	**strong**	**strong threat:** conditions deficient for taking opportunity of great significance
	moderate	**moderate threat:** conditions deficient for taking less important opportunity
	weak	**weak threat:** conditions deficient and opportunity unimportant

Chart IV.8 - Materials Position According to Scenario I vs Capability Analysis

LEVEL OF CAPABILITY

HIGH OR GOOD	• Solar grade silicon (electronic grade and amorphous) • Solar grade composite semiconductor	• Refractory ceramics • Alloys resistant to corrosion (green fuels) • Polymers (resistant to degradation) • Thermoset polymer matrix composites • Special steels (ultra high strenght) • Composite semiconductor • Cultivated quartz	• Martensitc stainless steels • Ferritic and austensitic stainless steels • Polymers and concretes (transmission) • Shape memory alloys • Structural steels (HSLA) • Marine corrosion resistant alloys • Polymers matrix composites (use in off-shore platforms) • High strength, low-alloy steels • Surface coated steels (transport) • Eletronics grade silicon • Thermoset resins (eletronics) • Pure metals and alloys (eletronics)
MODERATE		• Superalloys (energy, transport) • Coated alloys (green fuels) • Titanium alloys • Fused Quartz (optical fibers)	• Metalic superconductors • Special alloys for batteries • Hidrogen storage alloys • Steels and polymers for flexible pipes • Engineering plastics (automotive) • Structural ceramics (transport) • Covalent ceramics and alumina (eletronics)
DEFICIENT		• Aluminium-litium alloy	• Superconducting ceramics • Polymer membranes
	WEAK	MODERATE	STRONG

DEMAND EXPECTATION

Chart IV.9 - Materials Position According to Scenario II vs Capability Analysis

LEVEL OF CAPABILITY

HIGH OR GOOD	• Solar grade silicon (eletronic grade and amorphous) • Solar grade composite semiconductor • Thermoset polymer matrix composite (transports)	• Structural Steels (microalloys) • Marine corrosion resistant alloys • Polymer matrix composite (use in platforms) • Surface coated steels (transport)	• Martensitc stainless steels • Ferritic and austensitic stainless steels • Refractory ceramics • Polymers and concretes • Metalic superconductors • Shape memory alloys • Alloys resistant to corrosion (green fuels) • Polymers resistant to degradation • Special Steel (UHS) • High strength, low-alloy steels • Eletronics grade silicon • Thermoset resins (electronics) • Pure metals and alloys (elect.) • Composite semiconductor • Cultivated Quartz for oscilators
MODERATE	• Titanium Alloys • Nickel-based Superalloys (transport)	• Superalloys (energy, transport) • Steels and polymers (for flexible pipes) • Engineering thermoplastics (automotive) • Structural ceramics (transports)	• Special alloys for batteries • Fe/Ti, Mg/Ti metals alloys and Ni/rare earth. • Covalent ceramics and alumina (eletronics) • Fused Quartz (optical fibers) Coated metals and alloys (green fuels)
DEFICIENT	• Aluminium-litium alloys		• Superconducting ceramics • Polymer membranes
	WEAK	MODERATE	STRONG

DEMAND EXPECTATION

Chart IV.10 - The Future of the Advanced Materials in Brazil in the Scenarios for Sustainable Development

SCENÁRIO I - ENERGY SECTOR

MATERIALS	CAPABILITY	DEMAND EXPECTATION	FINAL RESULT (THREAT AND OPPORTUNITY)
Martensitic stainless steels	HIGH	STRONG	STRONG OPPORTUNITY
Ferritic and Austenitic Stainless Steels(*)	HIGH	STRONG	STRONG OPPORTUNITY
Refractory Ceramics (*)	HIGH	MODERATE	MODERATE OPPORTUNITY
Superalloys (*)	MODERATE	MODERATE	OPPORTUNITY WITH MODERATE THREAT
Electronics Grade Silicon	GOOD	WEAK	WEAK OPPORTUNITY
Amorphous Silicon	GOOD	WEAK	WEAK OPPORTUNITY
Composite Semiconductors	GOOD	WEAK	WEAK OPPORTUNITY
Polymers and Polymer Concretes (**)	HIGH	STRONG	STRONG OPPORTUNITY
Nb/Ti Metal-alloy (superconductors)	MODERATE	STRONG	OPPORTUNITYWITH STRONG THREAT
Superconducting Ceramics	DEFICIENT	STRONG	STRONG THREAT
Polymer Membranes (**)	DEFICIENT	STRONG	STRONG THREAT
Ni/Ti, Cu/Al/Zn Metal Alloys (shape memory)(**)	HIGH	STRONG	STRONG OPPORTUNITY
Ni/Cd and Rare Earth Alloys (batteries)(**)	MODERATE	STRONG	OPPORTUNITY WITH STRONG THREAT
Metal Alloys for hidrogen storage(Fe/Ti, Mg/Ti and Ni/Rare Earth)	MODERATE	STRONG	OPPORTUNITY WITH STRONG THREAT
Metal Alloys (resistant to corrosion by green fuels)	HIGH	MODERATE	MODERATE OPPORTUNITY
Coated metal alloys and steels (Corrosion resistant)	MODERATE	MODERATE	OPPORTUNITY WITH MODERATE THREAT
Polymers (Degradation Resistant)	GOOD	MODERATE	MODERATE OPPORTUNITY
Structural Steels (HSLA)	HIGH	STRONG	STRONG OPPORTUNITY
Marine CorrosionResistant Alloys	HIGH	STRONG	STRONG OPPORTUNITY
Polymer Matrix Composites (Use in Platforms)	HIGH	STRONG	STRONG OPPORTUNITY
Steels and Polymers (for flexible pipes)	MODERATE	STRONG	OPPORTUNITY WITH STRONG THREAT
SCENARIO I -TRANSPORT SECTOR			
Thermoset Polymer Matrix Composites	GOOD	MODERATE	MODERATE OPPORTUNITY
Al/Li Alloys	DEFICIENT	MODERATE	MODERATE THREAT
Titanium alloys	MODERATE	MODERATE	OPPORTUNITY W/MODERATE THREAT
Nickel-based Superalloys	MODERATE	MODERATE	OPPORTUNITY WITH MODERATE THREAT
Special Steels (UHS)	HIGH	MODERATE	MODERATE OPPORTUNITY
High Strength, Low-Alloy Steels (HSLA)	HIGH	STRONG	STRONG OPPORTUNITY
Engineering Thermoplastics	MODERATE	STRONG	OPPORTUNITY WITH STRONG THREAT
Structural Ceramics	MODERATE	STRONG	OPPORTUNITY WITH STRONG THREAT
Surface coated Steels	HIGH	STRONG	STRONG OPPORTUNITY

continue next page

SCENARIO I
MICROELECTRONICS /TELECOMMUNICATIONS SECTORS

Electronics Grade Silicon	GOOD	STRONG	STRONG OPPORTUNITY
Covalent Ceramics and Alumina	MODERATE	STRONG	OPPORTUNITY WITH STRONG THREAT
Thermoset Resins	GOOD	STRONG	STRONG OPPORTUNITY
Al, Au, Cu (Pure Metals and Alloys)	GOOD	STRONG	STRONG OPPORTUNITY
Composite Semiconductors	GOOD	MODERATE	MODERATE OPPORTUNITY
Fused Quartz for Optical Fiber	MODERATE	MODERATE	OPPORTUNITY WITH MODERATE THREAT
Cultivated Quartz for Oscillators	HIGH	MODERATE	MODERATE OPPORTUNITY

(*) material used in technology applied to more than one energy source.

(**) materials designed for energy transmission, conservation and storage, covering several subsectors.

SCENARIO II - ENERGY SECTOR

Materials	Capability	Demand Expectation	Final Result (threat and opportunity)
Martensitic stainless steels	HIGH	STRONG	STRONG OPPORTUNITY
Ferritic and Austenitic stainless steels	HIGH	STRONG	STRONG OPPORTUNITY
Refractory Ceramics	HIGH	STRONG	STRONG OPPORTUNITY
Superalloys	MODERATE	MODERATE	OPPORTUNITY WITH MODERATE THREAT
Electronics Grade Silicon	GOOD	WEAK	OPPORTUNITY W/WEAK THREAT
Amorphous Silicon	GOOD	WEAK	OPPORTUNITY W/WEAK THREAT
Composite Semiconductors	GOOD	WEAK	OPPORTUNITY W/WEAK THREAT
Polymers and Polymer Concretes	HIGH	STRONG	STRONG OPPORTUNITY
Nb/Ti Metal-alloy (superconductors)	GOOD	STRONG	STRONG OPPORTUNITY
Superconducting Ceramics	DEFICIENT	STRONG	STRONG THREAT
Polymer Membranes	DEFICIENT	STRONG	STRONG THREAT
Ni/Ti, Cu/Al/Zn Metal Alloys (shape memory)	HIGH	STRONG	STRONG OPPORTUNITY
Ni/Cd and Rare Earth Alloys (batteries)	MODERATE	STRONG	OPPORTUNITY W/ STRONG THREAT
Hidrogen storage (Fe/Ti, Mg/Ti Metal Alloys and Ni/Rare Earth)	MODERATE	STRONG	OPPORTUNITY W/STRONG THREAT
Metal Alloys (resistant to corrosion by green fuels)	HIGH	STRONG	STRONG OPPORTUNITY
Coated Metal Alloys (Resistant to Corrosion by green fuels)	MODERATE	STRONG	OPPORTUNITY W/STRONG THREAT
Polymers (Degradation Resistant)	GOOD	STRONG	STRONG OPPORTUNITY
Structural Steels (HSLA)	HIGH	MODERATE	MODERATE OPPORTUNITY
Marine Corrosion-Resistant Stainless and Nickel Alloys	HIGH	MODERATE	MODERATE OPPORTUNITY
Polymer Matrix Composites (Use in Platforms)	HIGH	MODERATE	MODERATE OPPORTUNITY
Steels and Polymers (for Flexible pipes)	MODERATE	MODERATE	OPPORTUNITY W/MODERATE THREAT

continue next page

SCENARIO II - TRANSPORT SECTOR

Thermoset Polymer Matrix Composites	GOOD	WEAK	WEAK OPPORTUNITY
Al/Li Alloys	DEFICIENT	WEAK	WEAK THREAT
Titanium Alloys	MODERATE	WEAK	OPPORTUNITY WITH WEAK TREATH
Nickel-based Superalloys	MODERATE	WEAK	OPPORTUNITY WITH WEAK THREAT
Special Steels (UHS)	HIGH	STRONG	STRONG OPPORTUNITY
High Strength, Low-Alloy Steels(HSLA)	HIGH	STRONG	STRONG OPPORTUNITY
Engineering Thermoplastics	MODERATE	MODERATE	OPPORTUNITY WITH MODERATE THREAT
Structural Ceramics	MODERATE	MODERATE	OPPORTUNITY WITH MODERATE THREAT
Surface coated Steels	HIGH	MODERATE	MODERATE OPPORTUNITY

SCENARIO II

MICROELECTRONICS/TELECOMMUNICATIONS SECTOR

Electronics Grade Silicon	GOOD	STRONG	STRONG OPPORTUNITY
Covalent Ceramics and Alumina	MODERATE	STRONG	OPPORTUNITY WITH STRONG THREAT
Thermoset Resins	GOOD	STRONG	STRONG OPPORTUNITY
Al, Au, Cu (Pure Metals and Alloys)	GOOD	STRONG	STRONG OPPORTUNITY
Composite Semiconductors	GOOD	STRONG	STRONG OPPORTUNITY
Fused Quartz for Optical Fiber	MODERATE	STRONG	OPPORTUNITY WITH STRONG THREAT
Cultivated Quartz for Oscillators	HIGH	STRONG	STRONG OPPORTUNITY

(*) the same observations apply as for the Scenario I table

Generic Strategies Applied to the Groups of Materials

The following text was prepared for the purpose of introducing the debate over strategies for Brazil in the field of advanced materials. The methodology used permitted the materials analyzed to be grouped according to the prospects offered to them in the scenarios by the level of capacitation presently existing in Brazil. This should certainly be the point of departure for building the future in the light of the challenges that both scenarios raise for such an undertaking. On this premise, some more generic strategies can be traced immediately, while more specific proposals for each material lie beyond the scope of this project and will have to be worked out in specific forums.

The set of generic strategies, or macro-strategies, should be appropriate to the results of the above exercise in correlation and differentiated according to a logical prioritization. This leads to certain sets of base-ideas which are designed to favour discussion with the economic, political and technical agents who are the effective clients of this forecast study.

The issue of raw materials and inputs may become of crucial importance for several of the materials considered here, besides being of great importance to

Brazil's political and economic interests, given its mining potential. With appropriate weighting (and adjustments to the methodology), this component could modify some of the positions of materials in this study. The generic strategies for each group of materials are described below.

Opportunity Quadrant

The quadrant of opportunities (strong, moderate and weak) shows where Brazil's capacitation is such that the nation's aims as set out by sector in the scenarios are more likely to be achieved. The groups of materials covered here should be read as follows:

Strong opportunity: requires that the level of capacitation achieved be maintained by way of the instruments that are already ensuring good performance by the segment. Continued support for those R&D programs that are the main guarantee of progress thus far will be decisive. There should be (continued) monitoring of performance indicators for Brazil's production segments and for domestic and foreign markets, as well as of performance indicators for Brazilian R&D, and monitoring of innovations and alterations in international transfers of technology and industrial property. All these measures are designed to enable intervening agents to organize and to act quickly.

Moderate opportunity: these should be seen as complementary to the above and, given the good level of capacitation acquired, they should involved the same kind of monitoring as proposed above. Part of this capacitation could be transferred to support strong opportunities which are more important, without however failing to support initiatives in the segments defined here.

Weak opportunity: in many cases, the capability acquired may be excessive given the lesser importance that the segment assumes in the scenario. It is thus considered wise to transfer it judiciously to other higher-priority areas, while encouraging only limited number of groups of excellence and continuing to monitor the evolution of these materials.

Quadrant of Opportunity with Threat

Characteristically, in this quadrant, some capability exists but stills needs reinforcing in order to attain levels favorable to taking the opportunities indicated in the scenarios.

Opportunity with Strong Threat: efforts should be made to strengthen the segments as part of a medium-term capacitation plan (between eight and ten years). It should then immediately be determined whether this plan achieved indicators compatible with the "Strong Opportunity". For this purpose, it is of fundamental importance to guarantee that the incentives continue throughout this period, this being the main reason that so many good programs fail in Brazil. One way is to link these incentive instruments to participation by companies and/or to international funding or partnering which would guarantee their continuance against policy shifts.

Opportunity with Moderate Threat: in this case, the strategy for capacitation can follow the lines indicated above, while bearing in mind, however, that this is not the highest-priority group of materials. Should they come to acquire greater importance, as shown by monitoring of the indicators or as a result of changes not foreseen in the scenarios, they could be reinforced.

Opportunity with Weak Threat: part of the scientific and technological capacitation can be transferred judiciously to segments with "Opportunity With Strong Threat". There is little likelihood of their becoming more attractive.

Quadrant of Threats

This quadrant contains the segments that require greater attention due to the lack of technical-scientific and industrial-commercial capability. The materials specified under "Strong Threat" and "Moderate Threat" call for vigorous treatment if they are judged to be of strategic importance after case-by-case study.

Strong Threat: the materials specified here should be assessed in detail as to their importance for the technologies that employ them. Presently deficiency capacitation may have any number of causes that need to be understood and assessed before any action is taken to raise them to appropriate standards. The costs of such initiatives could also be very high owing to the intervening scientific and technological lag, making it a precondition that there be cost-benefit analysis and real possibilities of capacitation in relation the materials in question

Moderate Threat: the same treatment as described above, with more rigorous cost-benefit analysis.

Weak Threat: this is the lowest-priority group and no planned effort is recommended, besides monitoring its evolution internationally.

CHAPTER 5

SUSTAINABLE DEVELOPMENT AND ADVANCED MATERIALS: CHALLENGES FOR BRAZIL

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5. SUSTAINABLE DEVELOPMENT AND ADVANCED MATERIALS: CHALLENGES FOR BRAZIL

5.1 OPPORTUNITIES AND THREATS FOR BRAZILIAN MINERAL INDUSTRY

The mineral industry has been affected, along the years, by a progressive introduction of advanced materials in products. Those impacts are effects of diferent origins, sometimes crossed, and can be pointed as follows:

At the first place, we have the product's loss of materials , which means that products, along the years, are been produced with less raw materials, due to design improvements, as well as, by materials' properties improvements , that can, therefore, perform more functions on the same product. The products have less material and this has a direct effect on the raw materials consumption.

Another important impact is the consequence of the *hiperchoice* of materials, which means the availability of a certain number of materials able to meet the needed requirements. It increased the competition among the different materials. At the present moment, it can be clearly seen at the structural materials market, as example, on the strong competition on the automobilistic industry between plastics (polymers) and metals, specially steels and aluminium.

Besides the facts above, other important events to be considerd are the outstanding growth of the recycling industry, due to the increase on the enviromental restrictions, as well as the decrease of production discarded materials and scrap by the improvement of production standars related to new tools for manufacturing organization .

It's necessary to keep in mind, that the high rate of technological innovation is replacing materials on several products. However, such a replacement for new materials, is not happening so widely, since many tradicional materials had also suffered the benefits of the improvement of materials technology. They are presenting an evolution capable to face the new materials competition, sometimes with better results. As an example, later in this chapter, the case of success of new technologies and joint ventures on the aluminum industry is presented making feasible production of automobile cars almost in aluminum.

Specifically, with regard to the impact on the brazilian mineral resources, a forecast exercise was made, based on the perspective that such advanced materials represent to Brazi as a result from the capability vs. demand analysis, already presented in chapter 4.

The analysis will be limited to materials classed as **strong opportunity and opportunity under(with) strong threat** since they are the main groups of interest for private and government sectors according to the methodology that was developed. For instance, the analysis of the results for a government strategy to foster materials S&T, will show that the group needing more attention is the **opportunity with strong threat** ,as it shows excellent expectations within the scenarios, but it will need specific policy, planning and financing in order to upgrade it to the strong opportunity situation in the future. The **strong threat group** needs also attention but will certainly require more investments and will take longer period of time to reach the same status, involving much more risks.

On the other hand, if the private industrial sector is looking for future investment opportunities using domestic capabilities , **strong opportunity** should be the choice for specific market studies. The following Charts 5.1 and 5.2 show these materials and their main mineral or elemental inputs.

Chart V.1 : Strong Opportunities for Advanced Materials by Sector in the Two Scenarios

MATERIALS BY SECTOR	SCENARIO I	SCENARIO II	Main Elemental or Minerals Inputs
ENERGY			
Martensitic Stainless Steels	●	●	*Cr*
Ferritic and Austenitic Steels	●	●	*Cr,Ni e Mo*
Refractory Ceramics		●	*Alumina,* *Magnesite,* *Graphite Chromite*
Polymers and Polymer Concretes	●	●	*Mineral fillers*
Nb/Ti Metal-Alloy	●	●	*Nb,Ti*
Ni/Ti, Cu/Al/Zn Metal Alloys	●	●	*Ni, Ti, Cu, Al, Zn*
Metal Alloys Resistant to Corrosion by Green Fuels		●	*Ni, Cr, Mo*
Polymers (degrad.resist.)		●	*Mineral fillers*
Structural Steels (HSLA)	●		*Nb, Mo*
Marine Corrosion-Resistant Stainless and Nickel Alloys	●		*Ni, Cr*
Polymer Matrix Composites	●		*Mineral fillers*

MATERIALS BY SECTOR	SCENARIO I	SCENARIO II	Main Elemental or Minerals Inputs

TRANSPORT			
Special Steels (mech.constr.)		●	*Mn, Cr, Ni, Mo, Si*
High-Strength, Low-Alloy Steels	●	●	*Nb, Mo*
Surface Treated steels	●		*Zn, Cu, Sn, P*
MICROELECTRONICS & TELECOMMUNICATIONS			
Electronics-Grade Silicon	●	●	*Quartz*
Thermoset Resins	●	●	*Mineral fillers*
Al, Au, Cu (Pure Metals and Alloys)	●	●	*Al, Au, Cu*
Composite Semiconductors		●	*As, Ga, I, P*
Cultivated Quartz for Oscillators		●	*Quartz*

Chart V.2: Opportunity under Strong Threat for Advanced Materials by Sector in the Two Scenarios

MATERIALS BY SECTOR	**SCENARIO I**	**SCENARIO II**	**Main Elemental or Minerals Inputs**
ENERGY			
Ni/Cd and Rare Earth Alloys	●	●	*Ni, Cd, R. Earths*
Fe/Ti, Mg/Ti and Ni/Rare Earth Metal Alloys	●	●	*Fe, Ti, Mg, Ni, R.Earths*
Coated Metal Alloys		●	*Cu, Sn, Zn, P*
Steels and Polymers	●		*Mineral Fillers*
TRANSPORT			
Engineering Thermoplastics	●		*Mineral Fillers*
Structural Ceramics	●		*Alumina, Zirconia, Boron*
MICROELECTRONICS & TELECOMMUNICATIONS			
Covalent Ceramics and Alumina	●	●	*Alumina*
Fused Quartz for Optical Fiber		●	*Quartz*

Steels, special alloys, ceramics and semiconductors are materials depending intrinsically on mineral inputs. Polymers use mineral fillers, that play an important role in them, as well as in their catalysts. The following shall be considered, in case the objective is to set a list of priorities for minerals opportunities, accordingly to the importance they have for advanced materials:

a) The number of alternative uses for these inputs in different materials. To some extent, this will show the variety of consumer markets the specific input can achieve;

b) as a low risk criteria, the number of times a specific material, and its inputs, appear simultaneously in both scenarios

The following statistics have been drawn from the first criterion (a):

In the strong opportunity group

- Cr, Ni and Mo, 5 times
- Nb, and Mineral fillers, 3 times
- Ti, Cu, Al, mineral fillers and quartz, 2 times
- Alumina, Magnesite, Graphite,Chromite Zn, Mn, Si, Au, As, Ga, In, P, one time each

In the opportunity with great threat group

- Rare Earths, Alumina and mineral fillers, 2 times
- Zirconia, Ni, Magnesite, Ti, Cu, Zn, Quartz, Sn, P, Cd, one time each

This can be considered as a first priority broad list of raw materials that should receive more attention from the private sector and the government alternatively. Howewer , if the second criteria is folowed, only materials (and inputs) that appear in both scenarios simultaneously will be selected:

In the strong opportunity group:

-Cr, Ni, Mo, Nb, Ti, Cu, Al, 2 times each
- others, one time each

In the opportunity under great threat group:

- Ni and Rare Earths, 2 times
- others ,one time each

With such a long-range forecast exercise, some conclusions can be drawn as whether advanced materials should be taken as emerging opportunities for the Brazilian mineral sector:

1. In fact, the list of minerals which should retain major importance for the country, and are used in advanced materials regarding the analysed sectors, is limited.
2. For most of those minerals, there are comfortably high reserves available in the country.

However, if Brazil expects to make its natural available resources into a competitive advantage, it is essential to broaden such a list. This depends on the development of technological and enterpreneurial skills in specialty materials and high-tech final goods manufacturing, which still are the main voids in the Brazilian production chain. So, an improvement in the national system of innovation is essential. On the other hand, the private sector, including the mineral-metallurgical, has to foster co-operative initiatives together with costumers and supliers, reinforcing relationships to turn great threats into strong opportunities, which is only achievable through the improvement of domestic R&D and industrial capabilities.

5.2 MINERALS AND ADVANCED MATERIALS REQUIREMENTS UNDER PROJECTED SCENARIOS: THE ALUMINIUM CASE

The impact of the two Scenarios on key materials requirements (and hence mineral inputs) and possibilities in three selected industrial sectors in Brazil has been extensively discussed in Chapters 3 and 4. Here, we briefly examine the complex forces at work in the case of materials selection in the transport sector. Aluminium has enormous potential for growth in packaging, construction and, importantly, in different modes of transport where it can provide solutions to pressing environmental, energy and social needs. If this potential is realised then it will clearly have an impact on Brazilian aluminium and steel production and consumption and on bauxite and iron ore production. However, for aluminium to penetrate further into these markets certain preconditions have to be met. We discuss the complexity of the forces at work in just one material below, but clearly similar considerations apply to the rest of the materials in the three sectors under the two scenarios.

The growth in the demand for aluminium between 1993 and the year 2000 is forecast by Alcan to be higher than that experienced in the precious seven years. On the other hand the growth in the demand for primary aluminium will be the same as during 1986-1993. This is due to the increasing importance of recycling, especially in cans and cars, as a source of metal in the future. Asia, including Japan, is expected to be more than double that of the maturing North America. Growth is South America and Europe is also expected to be rapid. North America, however, will remain the largest single market for several more years. The aluminium demand growth by world regions from 1993 to 2000 compared to the past growth rates from 1986 to 1993 are shown in the table V.1.

Alcan expects the demand for aluminium in cars to grow at 6.5% per annum until the turn of the century. Much of this will come from greater use of castings, which already constitute 70-80% of the aluminium weight in cars. After the year 2,000 the mass production of aluminium body structures for cars will stimulate further substantial growth in aluminium demand.

Table V.1
AVARAGE ANNUAL ALUMINIUM DEMAND GROWTH
(per cent)

	1993 - 2000	1986 - 1993
By Region		
North America	1.9	1.4

South America	5.8	2.1
Asia	5.3	6.5
Europe	4.0	2.5
Western World		
Total	3.9	2.9
Primary	2.6	2.6
By End-Use		
Building	2.7	2.5
Cars	3.6	4.3
Transport	4.5	3.9

Source: Alcan

In terms of trends and requiremens in materials science and technology in **Scenario I** Brazilian manufacturing and mineral-metallurgical industries will need to offer technological and organisation responses in order to remain competitive under the coercion of world market trends. On the other hand, in Scenario II Brazilian private and public organisations will need to direct R&D in order to meet priority domestic socio-economic and distributional objectives utilising local resources in the context of sustainable development. In both cases, Brazil, or any other Latin American economy, will be required to progressively master critical developments[117] under way in the materials field, some of which are highlighted below:

A) Fundamental Understanding and Application

A first priority is to continue to build up fundamental understanding of materials behaviour and its application in order to meet the emerging paradigm in the materials field by the late 1990's and early part of the next century. Firms in aluminium, steel, nickel, manganese and so on, in collaboration with public and academic research organisations at home and abroad, must develop capabilities to understand and quantitatively define and control the microstructure of a material and its relationship to the processing path and performance. These capabilities must then be applied to the integrated design of a material, the product or component and the fabrication process. Here mathematical modelling and simulation skills together with testing, evaluation and characterisation skills, in-house and across the technology infrastructure are crucial. The totality of these cumulatively acquired core skills in materials science and engineering will progressively enable materials producers to meet the performance needs of user industries through the development of greatly improved existing and conventional materials or entirely new materials tailored for specific applications. It is possible today to push conventional materials and alloy systems to their theoretically predicted limits, incrementally over the

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[117] See L. Kaounides, (Spring 1995), "Advanced Materials: Management and Government Strategies in the 1990's", Financial Times Management Report, Vol. I, London.

medium run. Or create entirely new materials to go beyond such limits and meet new performance and functional criteria in user-industries.

B) Producer-User Collaboration for Net-Shape Material Systems Solutions

The second priority, is the need for materials producers to get close to customers in order to provide materials systems in functional and structural applications which are environmentally friendly, ecologically sustainable and meet the final product and manufacturing needs of these users. That is, materials producers in Brazil must understand the needs of user industries (eg., in automobiles, aerospace, machinery, micro- and opto-electronics and so on) in terms of performance and manufacturing (eg. in joining, forming or assembly techniques), both within Brazil and abroad. In structural applications, there is a trend for ever greater part complexity in near net shape materials systems which are tailored for high performance applications and designed so as to meet the needs of final assemblers for package solutions. These developments imply increasing importance for net shape processing and fabrication technologies across the materials industries.

C) Understanding and Building Matter at the Atomic and Molecular Level

However, a distinct trend in materials research is the progressive move to the atomic scale. Over the next 20 year materials producers will become increasingly capable of designing and creating customised materials from the manipulation and control of atoms and groups of atoms. As fundamental understanding, computational skills and simulations continue to make rapid progress, known materials will be greatly improved in terms of performance and the R&D cycle will be dramatically cut. Moreover, new materials will be created from quantitative, physics-based approaches. The 2010's - 2020's will see the era of nano-phase materials and nanophase processing technologies (leading to nano-devices such as sensors, robots, electronic devices and computers).

5.2.1 The Environment,the Transport Sector and Mineral and Metal Requirements: The case of long-run R&D strategies by aluminium producers

Environmental issues have now acquired critical importance in the transport industry: Solid waste management and disposal; air quality; global warming effects and the ozone layer; energy conservation; minimisation of natural resource use. These considerations have become social and political priorities and have been followed by the coming into force of stringent regulations in order to protect the environment and the quality of life. Lower emission, greater fuel efficiency and greater levels of recycling are now mandatory areas of research and development in the transport sector. Aluminium, in these circumstances, offers distinct advantages in terms of high performance, light weight and full recyclability in the design of transport vehicles. As Alcoa, the worlds largest aluminium producer, puts it **"if it moves, it ought to be aluminium"**. However, to capture and expand aluminium's share in these growing markets, firms and nations must invest considerable intellectual and financial resources over a long period of time to develop the key materials and fabrication technologies in alliance with users in the major markets. The final outcome of this ongoing and fierce competitive struggle between materials in the transport sector depends on the collaborative R&D efforts of international groups in steel, magnesium, polymer composite systems and so on. This makes precise predictions regarding material, and mineral, use in the two Scenarios by the next century very difficult. At best we can identify trends and opportunities or threats.

Over the next quarter of a century total demand for travel is projected to double, and it is likely that air passenger miles may actually double in the next 10-12 years according to projections from aircraft manufacturers. However, the rapidly rising demand for passenger travel and shipping of goods is already straining the limits of the infrastructure in terms of motorways, bridges, modes of public transit, terminal facilities, ports, air traffic controls, airport runways and putting tremendous pressure on the environment in certain high-density parts of North America, Europe and Asia. Such limits are likely to be superseded as we head for the next century by a range of technological responses and the development of new means of transport. For example, mass transit systems will gain increasing importance. In addition intermodal transportation will allow the flow of containerised goods across seaports and airports linked to railway and trucking services. At the same time high-speed rail passenger services will lead to decongestion of motorway and air travel.

These market, technology and environmental developments present large opportunities for aluminium. All types of surface, air and seaborne vehicles and vessels have to be lighter, burn fuel more cleanly, and efficiently, and be safe and recyclable. Some of the trends, which will inevitably affect Brazilian transport and materials use under the two Scenarios are briefly discussed below.

Aerospace

The average longterm growth in revenue passenger miles is around 5-6% per annum, and in some regions it is double this, despite the recent deep recession. Moreover, much of the world's aircraft fleet will need to be replaced by the end of this decade. This means that growth rates will accelerate beyond this point. In general, the long term growth trends for the aerospace industry as a whole are quite favourable. In terms of aerospace materials capabilities it is important to note the leadership position established by Alcoa in both manufacturing capabilities and technology which enables it to fully participate in these growth prospects. Every single aluminium structural alloy that is in flight today has been developed by Alcoa. Moreover, the company has build a global distribution system to deliver materials to airframe builders and their sub-contractors anywhere in the world. The aerospace industry has now become international moving away from the earlier concentration in the US and Europe. A key feature is the fragmentation and global dispersion of subcontractors, as purchasers of aircraft now demand that a large proportion of parts is produced domestically. Hence, new aerospace suppliers have sprung up in Japan, China, South Korea, Singapore, Israel, Italy, Spain, Indonesia and elsewhere, with airframe builders in the US and Europe outsourcing parts globally.

Cost considerations have now risen to primary importance in the aerospace industry. Until now developments in aerospace technology (and hence of materials) were performance driven. However, airlines have now become very cost conscious, and the critical consideration is whether new aircraft will be affordable. Large aircraft makers such as Boeing and Airbus have launched major cost cutting programmes in order to reduce development times and production lead times (Eg. Boeing will want to deliver an aircraft in 6 rather than 12 months). The drive to cost reduction is necessarily having an impact on materials development and application. Here the technology focus is shifting from performance to cost/benefit. Although performance criteria such as lighter weight and greater fuel efficiency retain their importance, new materials will have to be scrutinised very closely in terms of being affordable and offering an acceptable return on investment. Materials and part supplied must assist customers to reduce assembly costs, reduce maintenance costs, increase aircraft durability and reliability and so on. Hence materials producers have to invest in facilities that improve the quality and manufacturability of large sections, for example, in order to enable assemblers to reduce time and cost.

Aircraft Materials

Aircraft manufacturing is now subject to fierce international competion, and intensifying competition between materials. Advanced composite systems have made substantial gains. In lightweight materials, progress continues in aluminium-lithium alloys, which are 8% lighter than conventional aluminium, and in fiber metal laminates (eg Arall) which comprise of aluminium and fiber-reinforced epoxy layers which enable weight reduction while improving damage tolerance. The latest commercial development in the form of the Boeing 777 comprises of 75% aluminium in its structural components. Most of this is made of Alcoa's new aluminium alloys. New materials with improved properties in terms of strength, fatigue and corrosion will continue to be development by the major producers but the emphasis will be on whether the new materials can pay for themselves:

New metal alloys development which integrates design, processing and manufacturing technologies to reduce weight, cost of assembly, number and cost of parts and maintenance while meeting environmental goals, including recycling. Advances in new ultra light, low cost, corrosion resistant alloys which can be used in new structural designs together with new fabrication methods can lead to innovative designs and the doubling of passenger capacity without added cost penalties to airframe manufacturer or operator. Existing skills and equipment application of new advanced metallic alloys in the context of simultaneous engineering to improve the competitiveness of Brazilian aerospace industries. In addition, the design, processing and manufacturing methods in new metallic alloys can be synergistically combined with those developed in advanced composites for aerospace applications and then diffused to other Brazilian sectors. Materials to be investigated, selected and promoted in the context of a private-public sector alliance and national R&D plan include, aluminium - lithium, magnesium - aluminium - lithium - beryllium, aluminium - iron - x.

Aeroengine Materials

The driving forces in aeroengine materials development are the need to raise temperatures and pressures ever higher while continuing to make engines lighter. Steel use has fallen from 60% in 1960 to 15% today, and is falling. Nickel use has peaked at around 45% and will probably decline in the future. Conventional materials will continue to be important over the next 20-30 years. Titanium will be used in cooler parts of the engine and nickel will continue to be used in interior parts. Both alloy systems will continue to be incrementally improved towards their theoretical limit through the use of materials science and engineering.

New materials such as composites and titanium aluminides are important and will be developed for niche applications in the engine, where they will exceed the performance limits of conventional materials and superalloys. CMC's may eliminate the cooling systems now in existence. MMC's will capture only a small percentage of engine weight in the medium run. In intermetallics, monoliths will substitute superalloys in the medium run at low temperature (around 700¡C), while nickel aluminides will be used for higher temperatures in the long run. Titanium aluminides reinforced with ceramics may be used for some rotating parts in the long run.

Space Planes

High Speed Civil Transport Planes (HSTC) which will fly faster and further than Concorde, and carry more passengers, but with less noise and pollution. New aluminium alloys could play an important role in such systems coming in around 2010. Even further in the future is the development of spaceplanes which will combine aircraft and rocket characteristics. Such systems are already under serious development in Japan, the USA (The National Aerospace Plane) and Europe.

High Speed Rail

Super trains on test in France and Japan have exceeded 300mph. In the U.S.A. Amtrak trains reach 130mph, and Japanese bullet trains exceed 170mph, a speed also exceed by French TGV trains.

Magnetic Levitation Trains (Maglev) are being developed for use in several US. cities, where a 1989 Center for Transportation Research study recommended that a 2,000 mile network of Maglev rail systems be set up radiating from major airports. Maglev trains using Low Temperature Superconductivity (LTS) are also on test runs in Germany and Japan. The systems developed will subsequently be improved with the commercial application of High Temperature Superconductivity (HTS). It should be noted that Brazil has an interest in the application of LTS systems (niobium).

In all these systems, aluminium can find increasing markets in terms of minimising the weight of the car to achieve high performance and in guideways. Although emphasis is commonly placed on the development of superconducting materials for highspeed transport systems, it is not often realised that an equally important consideration is the development of conventional materials which provide the supporting structures for LTS (and eventually HTS) superconductive Maglev trains.

Automobiles

Environmental issues are key drivers in automobile design today. Aluminium can provide design engineers with the capability to reduce car weight, save fuel, reduce emissions and conserve resources through recycling, without sacrificing size, safety, space, comfort, acceleration or handling. That is with the ability to meet both higher performance demands and environmental concerns and regulations. These issues are discussed in detail in the Alcoa-Audi R&D alliance below. A large number of considerations are involved in expanding the use of aluminium in the world car industry and hence the role of Brazilian aluminium producers could play in the domestic, regional and global automobile industry under Scenario I. Scenario II would call upon a similar set of scientific and technological capabilities in the materials sector to provide cost-effective, ecologically sustainable solutions in transport systems to meet socio-economic objectives. Similar considerations apply to the Brazilian steel industry which would be fighting the challenge from aluminium and expand the role of steel in transport in the two Scenarios.

Finally, the whole of the transport sector is beginning to be permeated by information technologies (electronic sensing, guidance, communications and computers) for safety systems, scheduling, maintenance, freight management and CAD/CAM applications in the design and production of transport equipment. Materials producers must therefore be able to combine materials and opto-electronic systems for application across the transport sector, including automobiles. There is large scope for synergy in the development of materials for transport and materials for information technologies in the two Scenarios, within Brazil.

5.2.2 Long-Run R&D in Aluminium Automotive Applications:

The Alcoa-Audi Allinace in Lightweight Car Body Structures[118]

A long-run partnership between Audi and Alcoa, beginning in 1982, for the development of an aluminium-intensive vehicle. The result has been a quantum leap in weight reduction technology and automotive structural manufacturing. This revolution is embodied in the development of the aluminium space frame (ASF) and in the ability to integrate the design of the material, the product and the manufacturing process. The ASF concept breaks away form design and manufacturing mindsets and requirements associated with steel monocoque car body structures. Moreover, the aluminium-intensive vehicle introduced by Audi in 1994 represents a significant first step towards the development of a "green" car which is cost effective, high-performance, low emission and recyclable. Lower weight facilitates greater fuel efficiency and the reduction of carbon dioxide emissions while at the same time increasing stiffness and passenger safety. Both companies have identified the growing importance of ecological sustainability, including fuel efficiency and closed-coop recycling, in materials development and application in the materials-intensive car industry which is very sensitive to social, political and environmental trends.

The Manufacturing Solution to Achieving a Quantum Leap in Lightweighting

The fact that aluminium provided large potential in lightweigting technologies led to and sustained the R&D partnership between Audi and Alcoa, which possesses a vast expertise in the development of aluminium alloys, in processing capabilities, in manufacturing and in structural design.

The two companies realised early on that simply substituting aluminium for steel in the body structure prevented them from taking full advantage of aluminium's unique properties and product forms. This led to a joint development of a revolutionary new concept in body structure, the aluminium space frame. The ASF is formed by high-strength straight and curved extruded sections which are joined by complex vacuum die cast modes or junctions at key intersection and connection points. The extrusions are located in areas which are vulnerable to collision damage. These tight tolerance, thin-walled, hollow extrusions are heat-treated in order to induce ductile, energy absorbing behaviour and possess the necessary degree of formability so that they can be bent into complex shapes. The space frame is stiffened by the highly ductile deformable castings which act as the joints of the structure and as distribution points for forces entering it. Both these aluminium product forms are engineered so as to be able to meet individual performance requirements optimally. Because the spaceframe contains fewer redundant parts, we

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[118] The information here is based on Lakis C. Kaounides, Advanced Materials: Management and Government Strategies in the 1990's, Financial Times Management Report, London 1995. The FT retains copyright over this material.

can more easily identify points which require that energy absorption, strength or local rigidity must be designed-in in order to increase stiffness for better handling or comfort or to optimize crash protection. In turn, these custom made and very complex part geometries required highly sophisticated die and tooling design on the part of Alcoa.

In terms of process design the three major areas of development were vacuum die casting, extruding and part forming. All these processes required higher levels of process control and monitoring techniques and the development of new thermal methods, quenching systems and aging practices. The ASF is giving rise to a whole range of new manufacturing demands. These comprise, in the main, of five crucial issues, namely joining techniques, surface treatment, dimensional accuracy and tolerances, speed and cost of production. A major concern at present is the scaling up of lab-scale processes to achieve cost-effective volume output.

Despite a minimum 40% reduction in weight in the spaceframe, it is an extremely strong structure -the stiffest car in the world today- and provides exceptional safety for the car occupants. Aluminium absorbs more energy, on a weigh basis, than steel. The aluminium body structure absorbs more energy in a collision than todays' steel monocoque body structures. Audi claims that the standard of safety and crashworthiness offered by the ASF has not been seen before in conventional cars.

Scientific and Engineering Capabilities to Deliver Ecologically Sustainable Materials Systems

In order to be able to revolutionise carbody construction using aluminium Alcoa had to meet certain preconditions. The company got close to the customer, understood the problems at hand and persisted in its R&D programmes over the longrun even when the technical problems were difficult and commercialisation a distant prospect. However, the key determinants of the ability to display technological leadership and competitive dominance in the materials market lie in the accumulation of materials science and engineering competences since the early 1980's. All companies that want to survive as world class materials producers in the late 90's and the next century must address a similar set of challenges.

The company identified the key MSE competencies which it considered indispensable for dominance in materials technologies, and then systematically began to acquire them. Of central importance is the ability to understand, define and control the relationship between a materials microstructure, its processing path and performance, and then apply it to integrate materials, product and process design together with accompanying skills in testing, evaluation and characterisation in order to provide ecologically sustainable materials systems to meet customer needs. These solutions include new alloys tailored for strength, energy absorption, high formability, corrosion resistance, surface quality and closed-loop recyclability requirements, and the development of new manufacturing processes and joining and assembly techniques.

A key factor in the ASF development was the ability to measure, test, evaluate and characterise materials in product forms, by themselves or component joints or subassemblies. The integration of data acquisition with feedback procedures and changes in materials, design and processing variables proved crucial in the selection of specific alloys and of the processing and manufacturing paths.

Alcoa has been able to seize this commercial opportunity by being able to design and produce parts which minimise weight while meeting specific performance requirements. This is a result of Alcoa's capacity to design-in energy absorption or stiffness or strength precisely where they are required in terms of thickness, shape and intersections in the spaceframe. In turn this ability is a result of Alcoa's ability to conduct Finite Element Analysis in order to evaluate the performance of a part during the design process.

The science base underpinning the set of skills above, reside in mathematical models and simulations of complex sheet and extrusion forming, and extruding and casting processes that can integrate descriptions of the constitution of a material with the design of the product and with process analyses. These skills increasingly enable Alcoa to design and process products (eg. sheet) to meet exact performance requirements. Firms which are unable to master such capabilities will be eliminated in the competition between materials producers to provide cost-effective solutions to meet customers performance criteria, manufacturing and assembly needs and ecological sustainability requirements.

The ASF is only the first generation of aluminium spaceframe automobiles. By the early years of the next century, it will be substantially lighter and more functional than today. Alcoa is already working on second-generation alloys which will facilitate cost reduction in manufacturing, on new processing and assembly paths to simplify the manufacture of the spaceframe and on new design which will consolidate parts, eliminate steps in manufacturing and reduce costs to an even greater extent than at present.

Alcoa also aims to achieve closed-loop recyclability in automotive systems. The alloys developed for the ASF have been designed for recyclability. Moreover, attention has focused also on issues of disassembly and subsequent scrap separation.

Further environmental considerations involve attempts to eliminate toxic materials in spaceframe manufacturing processes. This includes the development of surface treatment which can be considered an environmentally acceptable.

5.2.3 Aluminium and Ecological Sustainability

Cars and trucks today consume over 40% of global oil production and produce around 15% of global carbon dioxide emissions arising from the burning of fossil fuel. Each gallon of petrol burned produces about 21-5 pounds of carbon dioxide plus emission in the form of nitrogen compounds, sulphuric acid and particulates. These emissions therefore depend on fuel consumption. And fuel consumption falls with lighter cars. Therefore less weight leads to lower level of emissions. One estimate indicates that if each car sold in the US in 1991 made use of currently available aluminium lightweighting parts, total savings of 7 billion gallons of petrol and associated emissions would be made during the operational life of these cars. If all cars made use of these weight savings, then the annual carbon dioxide emissions from fossil fuels would be reduced by 98 million tons. However the full potential of lightweighting in order to reduce fuel consumption and emissions while maintaining safety, comfort and performance is yet to be realised. Several car producers are engaged, therefore, in R&D programmes to dramatically increase the use of aluminium in the primary car body structure, an example of which is the Alcoa-Audi alliance in the ASF discussed above.

Ecological sustainability from the point of view of Audi is examined in terms of the conservation of natural resources and total energy consumption. Two independent academic studies commissioned by Audi show that when compared to steel the break even point for the total energy consumed, including the energy needed in aluminium smelting, in manufacturing and operating the Audi ASF is reached between 55,000 and 79,000 kilometres (depending on the assumptions made by the two universities). For the second generation of aluminium spaceframe cars, Audi demonstrates a reduction in energy consumption when using recycled metal at the first kilometre. Similar comparisons between steel and aluminium in terms of carbon dioxide emissions show net savings at 90,000 kilometres in the case of virgin metal, and before the car leaves the showroom when using recycled metal.

Life-Cycle Reductions in Energy Consumption and Emissions

A recent study by Alcoa shows that when aluminium is used extensively in an automobile structure it results in important lifecycle reductions in energy and emissions, from the manufacturing of parts right through to the amount of fuel needed to drive the car. The study compares aluminium and steel in car body structures in several important areas:

1. Weight of the aluminium system compared to its steel counterpart.

Using aluminium can save between 25 to 65% of the weight of a car part as compared to steel. If we focus attention on the car body structure, the use of aluminium can reduce the weight of this body in a family sized car by 300 pounds or 40%. Taking advantage of the lightweight body structure can lead to significant secondary weight savings through the redesign of the engine, transmission system, suspension, wheels, tires, brakes, and energy absorption systems. These can be downsized and lightweighted. If these secondary weight savings are fully realised, and other systems in the car also use aluminium, the total weight of the car can be reduced by as much as 25%.

2. The Energy consumed in the Production of the Body structure.

Under the assumptions made as to source of power consumed, rates of recycling and manufacturing routes, an aluminium body requires 1.6 times the energy needed to produce an aluminium body. As the percentage of recycling increases, aluminium gains an increasing energy advantage, however.

3. The Amount of Fuel Energy Saved over a Fixed Distance.

A typical car today will use about 1.35 gallons of petrol per pound of weight over an assumed life of 100,000 miles. Fuel saving will depend on the amount of weight saved through weight reduction and on the associated downsizing of the powertrain. If resizing of the latter accompanies weight reduction then for most cars the fuel saved amounts to 0.88 gallons per pound saved in 100,000 miles.

If we compare the fuel energy consumed over the service of an aluminium body passenger car as compared to a steel equivalent, the aluminium body reduces fuel consumption by 260 gallons. Over a 100,00 lifetime, the steel body will use 146 million Btu of petrol, compared to 38 million Btu less for an aluminium body.

4. Life-Cycle Energy Consumption

When we combine the energy consumption in production with that in fuel consumption we can compare life-cycle energy consumption between aluminium and steel bodies. Aluminium gains a life-cycle advantage after 20,000 miles of service, and over an average lifetime of 100,000 miles, it accumulates an advantage of 31 million Btu or over 210 gallons of petrol in comparison to steel. If there is no recycling, aluminium retains a higher energy efficiency, but the breakeven point is 75,000 miles

If secondary weight savings are added to an aluminium body, then lifecycle energy requirements for the aluminium system are 25% less than steel (assuming a conservative secondary weight reduction of only 25%). Under these assumptions the aluminium system will break-even after only 14,000 miles of service. If the potential secondary savings are all fully utilised, aluminium body structures gain an energy advantage as compared to steel before the car leaves the showroom.

Moreover, as the percentage of aluminium in cars increases and is recycled, then the lifecycle energy advantage of aluminium in comparison to steel will rise even further, and the break even distances will become shorter.

5. Carbon Dioxide Emissions

The use of aluminium can lead to a net reduction of greenhouse carbon dioxide emissions even though in its manufacturing process the aluminium carbody generates more carbon dioxide than the equivalent process for a steel body. The aluminium body together with a conservatively estimated 25% secondary weight saving can reduce total lifecycle emissions of carbon dioxide by 6,600 pounds compared to a steel body. The aluminium system can lead to a net reduction of carbon dioxide, as compared to the steel system, after only 6,000 miles of driving. Two further results are interesting. As more and more aluminium is recycled, less and less carbon dioxide is generated, thus further adding to its advantage. And, it should be noted that the fuel savings resulting from lightweighting through aluminum also lead to a reduction in the emissions of other fuel-burning pollutants to the atmosphere.

5.2.4 Sustainable Development and Materials Producers

Ecological Challenges and Alcoa's Response

Materials producers have long been involved in environmental issues. In aluminium, Alcoa has had to respond to the ecological challenge across several fronts: Land management (bauxite mining/residues); air pollutants (carbon dioxide and fluorides from smelting to fabricating and finishing); industrial wastes (spent potlines, casting furnaces, skim and dross); and, energy conservation. The responses have been multifaceted involving: Process improvement and control; materials substitution; process elimination; land restoration; recycling and reprocessing; and, waste and effluent minimisation programmes. There are, at present five programmes underway which involve (1) the reduction of energy consumption in smelting (kwh/pound) by 20% (2) the elimination of $C0_2$, CF_4 emissions, (3) the reduction of energy consumption in the Bayer process for alumina production, (4) spray form sheet and (5) salt cake recycling.

Issues of ecological sustainability are now combining with performance and cost-effective processing to act as key drivers for materials development, production and use. Over the last decade Alcoa, has been building fundamental materials understanding, and integrating it to materials, product and process design, to testing and evaluation and to the ability to provide ecologically sustainable materials systems. That is the ability to deliver cost effective performance and protect the ecosystem, in order to meet market pressures, technology trends and social-environmental demands and increasingly stringent regulations in the 1990's and the next century.

Materials Development Must Become Part of Sustainable Development

However, materials producers need and ought to become involved in a wider set of issues involving sustainable development in terms of meeting human needs and in particular those of the poor for food, shelter, clothes, warmth and education. Inevitably materials producers will become involved in meeting development needs across the infrastructure, electricity generation and transmission, building and construction materials, transportation and food and drug packaging. Alcoa sees potential for aluminium use to meet all such needs. It is interesting to note that the concerns identified in Scenario I and Scenario II of this Project have already began to influence the strategies of international materials corporations.

5.3 PROJECTED SCENARIOS, SECTORAL STUDIES AND SPECIFIC MATERIALS SELECTION TO ACHIEVE SOCIO-ECONOMIC AND ENVIRONMENTAL OBJECTIVES

How and by Whom will New Technology and Standards be Developed?

The Recommendations in chapter 2/part I are of a general nature. However, they integrate the global trends in science, technology and industry to the specific opportunities, weakness and conditions prevailing in the set of institutions and mechanisms that constitute the Brazilian National Innovative System in the mid-1990's. It is true to say that, unless present weakness are improved and existing strengths build upon, then any materials selection exercise will simply fail to deliver. That is, reform of the R&D system and the institutional structures that support it is an essential pre-requisite to the successful execution of specific materials and industrial objectives. Secondly, an important lesson from corporate and country analyses ,in recent years, is that many technical and organisational issues and constraints remain to be resolved before the full development and diffusion of several advanced materials technologies by the first two decades of the next century. A common observation is that what is required is a long run, committed, and persistent R&D effort across the development of new materials, processing techniques and standards. A number of leading corporations are taking the long term view and are committing substantial resources on a long run basis to achieve next generation technologies with a pay-off longer than 10 or even 15 years (e.g. in materials and processes beyond 1 Gb and the development of quantum devices in microelectronics, blue lasers in optoelectronics, high Tc and low Tc superconductive devices and so on). Many such technologies are too complex and expensive requiring a fusion of expertise and a range of converging or complimentary technologies. They, therefore, are leading to the formation of inter-firm alliances. And, in many cases such technologies may never be developed if left to market forces alone. Here, many governments around the world are taking the view that they must perform a catalytic and organisational rule in initiating, promoting, coordinating and directing financial and intellectual resources towards the achievement of specific technology and industry objectives in the long run. Therefore public-private sector R&D alliances are beginning to be seen as a necessary tool to achieve techno-economic and materials-related objectives in the 1990's and into the next century, in countries as diverse as the USA, the European Union and Japan. Several governments around the world have published similar lists of emerging and critical technologies upon which industrial competitiveness, and the solution to energy, environment and social needs will depend in the late 90's and beyond. Identifying critical, core technologies, many of which are materials related, and then waiting for the market to develop them, especially in societies where the R&D infrastructure and institutional linkages are not fully in place, can prove disastrous in the 1990's.

A crucial issue therefore for Brazil (and this Project) is not simply the methodology of selecting strategic sectors and associated critical materials technologies that are required to meet the objectives of the sectors but who will develop these technologies, how, who will pay for the R&D effort and over what time horizon will this take place? What institutions and policies will be organised and mobilized to achieve the technological and social-environmental objectives? If Brazil identifies the need to develop a better infrastructure, irrigation system energy generation and distribution, medical and health care system, improved housing and less pollution-intensive technologies, who will be the agents that will conduct the relevant R&D, technology development and transfer to meet these social and environmental objectives? What is the role of the government in the development of technologies to resolve pressing social, health, energy and environmental needs in the next century? And, on the other hand, if certain technologies can be identified as having a large potential for a wide-range of industries, including energy and the environment (e.g. superconductivity), but are too complex and risky for the private sector alone, what should be the role of the public sector and academia? And how will public sector R&D be linked to or transmitted to private industry's needs?

Brazil possesses an ability to conduct R&D, with around 40 state funded laboratories and over 60 business - related laboratories. Not only do research facilities exist but linkages between the research base and private industry also exist in the most developed sectors of the economy (in microelectronics, informatics, aeronautics, civil engineering). These linkages though need to be improved and extended to other sectors. The materials-based sector comprises of 30% of GDP and advanced materials are valued over $2 billion (out of $180 billion worth of materials output). About ten of the major companies in this sector have research laboratories.

Materials R&D to Create and Grasp Market Opportunities

A second set of issues relevant to new studies that, eventually, follows this present one, concerns the development of core competences within Brazilian private and public sector research institutes which will facilitate the design, synthesis and processing of materials to meet specific performance characteristics in specific applications in aerospace, housing, construction, energy, automobiles, electronics and optoelectronics, mechatronics and so on by the end of the decade. This set of core competences would include physics, chemistry, mathematical modelling, surface science, sensor technologies and intelligent processing and so on. This is essential in order to meet the material needs of sectors competing in the worked market but also social objectives in medicine, health care, housing, environmentally clean technologies and energy. But more than this, a major conclusion of this Report is that we cannot simply plan and select materials for intensive R&D on the basis of simple extrapolations of the demand for particular materials and rate of growth of specific sectors. Materials producers today can and must engage in materials R&D and the development of fabrication technologies in order to create new market opportunities and/or capture existing ones. The ongoing battle between steel and aluminium for the vast automotive market in order to meet formability, low cost and environmental criteria is indicative of the trends under way, to which Brazilian steel and aluminium producers must respond in the coming years. Predictions as to market share for either of these materials by the end of the decade are at present unreliable and will be shaped by the R&D effort of materials producers in close alliance with users.

Brazil at the Forefront of Social, Environmental and Industrial Strategies in the 1990's

Brazil is currently conducting a unique and pioneering study placing it at the forefront of countries which attempt to devise appropriate strategies for the next century with explicit reference to social and ecological sustainability criteria. The Project brings together, probably for the first time, a methodology and a comprehensive, in-depth analysis of the global trends in advanced materials science and technology, developments in the mineral-metallurgical sector and key issues in the environment and sustainability. Of all the other countries in the world, only Japan has recently built-in explicitly social and environmental issues into R&D, science and technology strategies in the coming decades, although some elements go back many years ago (e.g. the Moonlight and Sunshine Programmes). The present Project and the methodological and policy implications accruing from it will be of relevance to many countries across Latin America, the rest of the developing world, several former communist countries and industrially developed or industrialising economies.

Brazil an integral part of the world trading system

In what follows we assume that Brazil will continue to participate in the world trading system while further liberalising its domestic market and foreign trade regime. This implies that an increasing number of Brazilian industries and firms will need to meet the standards set by world class competitors in the world market. At the same time environmental considerations are becoming a rapidly increasing concern across all industries and will begin to influence competitiveness in the market place. It is likely that environmentally safe, 'green' products and businesses will be preferred by consumers in the developing world. Environmental issues have hitherto evaded GATT but will be part of the next round, where trade issues and their environmental consequences will have to be considered as one.

Local Materials to meet Basic Needs: Brazil can Provide a World Leadership Role: Scenario 2

The large and increasing basic needs of developing economies in housing, transportation, food packaging, water and energy distribution and health care can be met through more efficient utilisation and upgrading of domestically or regionally available natural resources, using scientific insight and new and improved technologies. The materials revolution affords opportunities to developing economies to make fuller use of domestic materials, while minimising energy requirements and environmental disruption. Included in this is the development of advanced materials designed to meet needs and conditions in developing countries. That is, advanced materials must be tailored to meet needs and specific requirements of industry and infrastructure in developing countries.

The new materials science and engineering base must be mobilised, internationally and within the Developing World, to meet the needs of development in the coming decades. Brazil can give a crucial and vitally important world lead in this direction. For although the science base of the new materials is common throughout the world, the direction of application and problem orientated R&D cannot exclude the pressing needs and available resources of developing economies. Un that sense materials should be "... small, lighter, longer lasting, low cost, low energy and recyclable based on abundant and renewable resources which can be locally processed using simple and employment generating non-polluting technologies".

In housing, MSE can examine alumina silicates, earth, stone laterite and clay based products, which are readily available, and improve brick performance. In addition, modern materials science can also focus attention on renewable resources such as plant based construction materials (eg bamboo, sisal, grasses, and wheat straw), and improve their performance for housing.

In the area of bio-processing of materials, advanced genetic engineering may lead to a strengthening of wood and fibres, microbiological processes can be used to extract metals, and yet other microbiological technologies can be used to extract fibres and ultrafine powders of silica from plant based materials to make advanced ceramics and composites.

Moreover, new advanced materials and inexpensive membranes and filters can be developed to purify and desalinate water, as well as meet the needs for the production, transportation and storage of food. It is worth noting that the US based aluminum producer Alcoa is currently researching into new advanced packaging materials for food and post-harvest products of great relevance to developing economies.

Traditional Materials Fight Back and Create High Growth Market Niches: Scenario I

It must be noted that many metals industries (eg nickel, zinc, steel, aluminium) have been fighting back by utilising MSE insights to improve properties and processing techniques and forging close links with customers in user industries (eg steel-auto or aluminium-auto partnerships). These developments are of vital importance to metals producers in the developing world, not least to the steel and aluminum industries, of Brazil. The battle between steel and aluminium is not resolved yet and Brazil must develop a national strategy in terms of the development and application of these metals in end-use industries domestically and regionally. Simply possessing steel and aluminium domestic production capacity will not automatically qualify Brazil to a share of potential markets at the high-value, fabricated end. The Brazilian public and private sectors can protect existing markets and create new market growth segments in specific materials. The analysis points to the dual need to combine materials design , synthesis and processing skills with the escalating performance requirements and fabrication/manufacturing and assembly needs in user industries. This constitutes an entirely new circumstance in materials R&D and selection with far-reaching implications for materials producing industries and economies by the end of the 1990s.

APPENDIX 1: COMPLEMENT OF CHAPTERS 4 AND 5

AGGREGATION BY LEVELS OF OPPORTUNITY AND THREAT

1 - Strong opportunities for Advanced Materials by Sector in the Two Scenarios

MATERIALS	SCENARIO I	SCENARIO II
	ENERGY	
Martensitic Stainless Steels	●	●
Ferritic and Austenitic Steels	●	
Refractory Ceramics		●
Polymers and Polymer Concretes	●	●
Nb/Ti Metal-Alloy	●	●
Ni/Ti, Cu/Al/Zn Metal Alloys	●	●
Metal Alloys Resistant to Corrosion by Green Fuels		●
Polymers		●
Structural Steels (microalloys)	●	
Marine Corrosion-Resistant Stainless and Nickel Alloys	●	
Polymer Matrix Composites	●	
	TRANSPORT	
Special Steels		●
High-Strength, Low-Alloy Steels	●	●
Surface-Treated Steels	●	
	MICROELECTRONICS/TELECOMMUNICATIONS	
Electronics-Grade Silicon	●	●
Thermoset Resins	●	●
Al, Au, Cu (Pure Metals and Alloys)	●	●
Composite Semiconductors		●
Cultivated Quartz for Oscillators		●

2 - Moderate Opportunities for Advanced Materials by Sector in the Two Scenarios

MATERIALS	SCENARIO I	SCENARIO II
	ENERGY	
Ferritic and Austenitic Stainless Steels	NONE	NONE
Refractory Ceramics	●	
Metal Alloys Resistant to Corrosion by Green Fuels	●	
Polymers	●	
Structural Steels (microalloys)		●
Marine Corrosion-Resistant Stainless and Nickel Alloys		●
Polymer Matrix Composites		●
	TRANSPORT	
Thermoset Polymer Matrix Composites	●	
Titaniun and its Alloys	NONE	NONE
Special Steels	●	
Surface-Treated Steels		●
	MICROELECTRONICS/TELECOMMUNICATIONS	
Composite Semiconductors	●	
Cultivated Quartz for Oscillators	●	

3 - Weak Opportunities for Advanced Materials by Sector in the Two Scenarios

MATERIALS	SCENARIO I	SCENARIO II
	ENERGY	
Electronics-Grade Silicon	●	
Amorphous Silicon	●	
Composite Semiconductors	●	
	TRANSPORT	
Thermoset Polymer Matrix Composites		●
	MICROELECTRONICS/TELECOMMUNICATIONS	
NONE	NONE	NONE

4 - Opportunity with Weak Threat for Advanced Materials by Sector in the Two Scenarios

MATERIALS	SCENARIO I	SCENARIO II
	ENERGY	
Electronics-Grade Silicon		●
Amorphous Silicon		●
Composite Semiconductors		●
	TRANSPORT	
Titaniun Alloys Nickel-Based Superalloys		● ●
	MICROELECTRONICS/TELECOMMUNICATIONS	

NONE	NONE	NONE

5 - Opportunity with Moderate Threat for Advanced Materials by Sector in the Two Scenarios

MATERIALS	SCENARIO I	SCENARIO II
	ENERGY	
Superalloys	●	●
Coated Metal Alloys	●	
Steels and Polymers		●
	TRANSPORT	
Nickel-Based Superalloys	●	
Engineering Thermoplastics	NONE	●
Structural Ceramics	NONE	●
Titanium Alloys	●	NONE
	MICROELECTRONICS/TELECOMMUNICATIONS	
Fused Quartz for Optical Fiber	●	

6 - Opportunity with Strong Threat for Advanced Materials by Sector in the Two Scenarios

MATERIALS	SCENARIO I	SCENARIO II
	ENERGY	
Ni/Cd and Rare Earth Alloys	●	●
Fe/Ti, Mg/Ti and Ni/Rare Earth Metal Alloys	●	●
Coated Metal Alloys		●
Steels and Polymers	●	
	TRANSPORT	
Engineering Thermoplastics	●	
Structural Ceramics	●	
	MICROELECTRONICS/	**TELECOMMUNICATIONS**
Covalent Ceramics and Alumina	●	●
Fused Quartz for Optical Fiber		●

7 - Weak Threat for Advanced Materials by Sector in the Two Scenarios

MATERIALS	SCENARIO I	SCENARIO II
	ENERGY	
NONE	NONE	NONE
	TRANSPORT	
Al/Li Alloys		●
	MICROELECTRONICS/TELECOMMUNICATIONS	
NONE	NONE	NONE

8 - Moderate Threat for Advanced Materials by Sector in the Two Scenarios

MATERIALS	SCENARIO I	SCENARIO II
	ENERGY	
NONE	NONE	NONE
	TRANSPORT	
Al/Li Alloys	●	
	MICROELECTRONICS/TELECOMMUNICATIONS	
NONE	NONE	NONE

9 - Strong Threat for Advanced Materials by Sector in the Two Scenarios

MATERIALS	SCENARIO I	SCENARIO II
	ENERGY	
Superconducting Ceramics	●	●
Polymer Membranes	●	●
	TRANSPORT	
NONE	NONE	NONE
	MICROELECTRONICS/TELECOMMUNICATIONS	
NONE	NONE	NONE

APPENDIX 2: WORKSHOPS PROGRAMMER AND PARTICIPANTS

II Workshop

CETEM - Centro de Tecnologia Mineral - Rio de Janeiro, December 08 e 09, 1994

Participants

Nome/Name	**Empresa/Institution**
Alberto Wester	CNPq/CETEM-Centro de Tecnologia Mineral - Rio de Janeiro
Alfonso Maldonado C	Universidad Industrial de Santander - Bucaramanga - Colombia
Almir de Carvalho	Metal Leve S/A - São Paulo
Anna Cristina Marinho	CNPq/CETEM - Centro de Tecnologia Mineral - Rio de Janeiro
Anne Marie Maculan	COPPE/UFRJ - Rio de Janeiro
Antonio Rodrigues Campos	CNPq/CETEM- Centro de Tecnologia Mineral - Rio de Janeiro
Benjamin Gilbert	Fundação Oswaldo Cruz - Rio de Janeiro
Biamonte Emílio	BATTELLE - EUROPE - Suisse
Bruce B. Johnson	USP - São Paulo
Carlos Adalpho M. Baltar	Universidade Federal de Pernambuco
Carlos Cavallari Netto	DNCM - ABIMAQ - São Paulo
Carlos Cesar Peiter	CNPq-CETEM - Centro de Tecnologia Mineral - Rio de Janeiro
Carlos K. Suzuki	UNICAMP - Campinas/SP
Celso de Oliveira Santos	CNPq/CETEM - Centro de Tecnologia Mineral - Rio de Janeiro
Claudia Cristina das Neves	CNPq/CETEM - Centro de Tecnologia Mineral - Rio de Janeiro
Claudio de Almeida Loural	TELEBRÁS - Campinas/SP
Cyro Alves Borges	COPPE/UFRJ - Rio de Janeiro
Diara Kirch	Metal Buvetir - Rio de Janeiro
Eduardo Torres Serra	CEPEL - Centro de Pesquisa de Energia Elétrica - Rio de Janeiro
Eduardo Vale G. da Silva	Bamburra- Planejamento e Economia Mineral Ltda. - Rio de Janeiro
Frank P. Missel	IFUSP- São Paulo
Heloisa V. de Medina	CNPq/CETEM - Centro de Tecnologia Mineral - Rio de Janeiro
Hoberg, Heinz	RWTH Hachen - Instituf fur Aufberlitung - Germany
Irene Cristina M.Portela	CNPq/CETEM - Centro de Tecnologia Mineral - Rio de Janeiro
Ivan da Costa Marques	UFRJ - Universidade Federal do Rio de Janeiro
Joel Weisz	FINEP - Financiadora de Estudos e Projetos - Rio de Janeiro
José Ellis Ripper Filho	Asga Microeletrônica - Paulinia/SP
José Farias de Oliveira	COPPE/UFRJ - Rio de Janeiro
José R.C. Guimarães	CBMM - São Paulo
Julio E. Pedraza	Universidad Industrial de Santander - Bucaramanga - Colombia
Lakis C. Kaounides	City University Business School - London

Luiz Francisco G.D'Assumpção	CVRD - Companhia Vale do Rio Doce - Minas Gerais
Luiz Gonzaga S. Sobral	CNPq/CETEM - Centro de Tecnologia Mineral - Rio de Janeiro
Luiz Otávio Pinheiro	FINEP - Financiadora de Estudos e Projetos - Rio de Janeiro
Maria Laura Barreto	CNPq/CETEM - Centro de Tecnologia Mineral - Rio de Janeiro
Maria Luiza W. Whitehurst	CNPq/CETEM - Centro de Tecnologia Mineral - Rio de Janeiro
Martha T. Arias	Universidad Industrial de Santander - Bucaramanga - Colombia
Milton Rodrigues Finza	CVRD - Companhia Vale do Rio Doce - Minas Gerais
Peter Rudolf Seidl	CNPq/CETEM - Centro de Tecnologia Mineral - Rio de Janeiro
Roberto C. Villas Bôas	CNPq/CETEM - Centro de Tecnologia Mineral - Rio de Janeiro
Roberto Rodrigues Coelho	CNPq/CETEM - Centro de Tecnologia Mineral - Rio de Janeiro
Ronaldo Luiz C. dos Santos	CNPq/CETEM - Centro de Tecnologia Mineral - Rio de Janeiro
Sarita Albagli	CNPq/CETEM - Centro de Tecnologia Mineral - Rio de Janeiro
Saul B. Suslick	UNICAMP - Campinas/SP
Teresinha Rodrigues	CNPq/CETEM - Centro de Tecnologia Mineral - Rio de Janeiro
Vanda Regina T. Scartezini	SID/VERTICE/ABIMI - Campinas/SP
Walter A. Mannheimer	UFRJ - Universidade Federal do Rio de Janeiro
Willinger Marc	BETA/ULP - France
Yusley Ferreira Neto	Fosfertil - Fertilizantes Fosfatados S/A - Minas Gerais

PROGRAM

DECEMBER 8/94 - THURSDAY

9:30 h Opening remarks and setting of objectives (Villas Bôas, CETEM).

9:50 h Sustainability: history and concepts (Barreto, CETEM)

10:20 h Coffe Break

10:35 h Scenarios of sustainable development (CostaMarques/CETEM,Bruce/USP)

11:35 h Suggested discussions

12:20 h Lunch

13:40 h Advanced materials overview(Lakis, C.U.; Villas Bôas, CETEM)

14:20 h Coffee Break

14:30 h Scenarios and advanced materials: selected case studies (Peiter/INT; Costa Marques, Barreto, Medina, Albagli and Rodrigues, CETEM).

15:30 h Suggested discussions

16:15 h Opportunities for Brazil (Peiter/INT; Bruce/USP; Barreto, Costa Marques, Medina, Albagli, Rodrigues and Villas Bôas (CETEM).

17:15 h Suggested discussions

DECEMBER 9/94 - FRIDAY

9:30 h /10:00 h Formation of the working groups and working groups discussions

12:30 h Lunch

13:30 h/17:00 h Resuming of the working groups conclusions and Final report drawings

I WORKSHOP ON METHODOLOGY

IDRC - CETEM- Centro de Tecnologia Mineral- Rio de janeiro, November 17/19, 1992

Participants

Name	**Institution**
Brent Herbert-Copley	IDRC
Bruce Baner Johnson	Fundação Inst. Adm.-Fac.Econ.Adm.USP
Cesar das Neves	Escola de Engenharia da UFRJ
Carlos Cesar Peiter	Instituto Nacional de Tecnologia - INT
Clarice Dora Gandelman	Centro de Tecnologia Mineral - CETEM
Cyro Borges	Centro de Tecnologia Mineral - CETEM
Prof. Ganapathy, R.S.	ACME, Tecnology Management Group
Gustavo Lagos	CESCO
Heloisa de Medina	Centro de Tecnologia Mineral - CETEM
Igor Abreu e Lima	UFRJ - Escola de Engenharia
Jamil Duailibi Fh.	Instituto Nacional de Tecnologia - INT
José Maldonado	Instituto Nacional de Tecnologia - INT
Jürgen Lexon	BAN -Bundesanstalt für Material forschung uud-prüfung
Lakis C. Kaounides	City University Business School
Luis Alberto Almeida Reis	Centro de Tecnologia Mineral - CETEM
Lelio Fellows Filho	Ministério de Ciência e Tecnologia - Brasil
Mammo Muchie	MIDDLESEX University, Environmental Sciences
Maria Laura T.da M.G.C. Barreto	Centro de Tecnologia Mineral - CETEM
Renato Dagnino	Instituto de Geociências
Roberto C. Villas Bôas	Centro de Tecnologia Mineral - CETEM
Sarita Albagli	Centro de Tecnologia Mineral - CETEM
Saul B. Suslick	UNICAMP
Teresinha Rodrigues	Centro de Tecnologia Mineral - CETEM

PROGRAM

NOV 17

09:00 h - Operning remarks addressing the objectives of the IDRC-CETEM project, the subjects to be covered in these three days and the format of the Workshop. On belive of Prof. Dr. Roberto C. Villas Bôas (CETEM) and Dr. Brent Herbert-Copley (IDRC).

09:45h - The Proposed Methodology. Conducted by Prof. Dr. Cesar das Neves (OPPE/UFRJ, Consultant to the Project).

11:00 h - Coffe break
11:15 h - Discussion on the Methodology
12:15h - Interval for lunch
13:30 h - Conducted by Dr. Lakis Kaounides (City University, Consultant to the Project: "Advanced Materials Technology and Strategies for Brazil into the 21st Century").
14:30 h - Coffee break
14:45 h - Discussions
15:45 h - Case Studies: The Transport Industries
- Automobil
- Aeronautics

Conducted by Ing. M.Sc. Cesar Peiter (INT, Consultant to the Project, and Ing. Cyro Alves Borges Jr., CETEM).
16:30 h - Coffee break
16:45 h - Discussions
18:00 h - End of the day; return to hotel.

NOV 18
09:00 h - The Economical Framework, conducted by Econ. Heloisa Medina, CETEM.
09:40 h - The Legal Framework, conducted by Adv., MSC. Maria Laura Barreto, CETEM.
10:20 h - Coffee break
10:35 h - Discussions on the aforementhioned papers.
11:25 h - The Environmental Framework, conducted by Ing. M.Sc. Teresinha Rodrigues, CETEM.
12.05h - The Socio-Political Framework, conducting by Soc. M.SC. Sarita Albagli, CETEM.
12:45 h - Interval for lunch.
14:00 h - Discussions on the aforementhioned papers.
14:40 h - Coffee break
14:55 h - Working in Subgroups
18:15 h - End of the day; return to the hotel.

NOV 19
09:00 h - Working in Subgroups.
12:30 h - Interval for lunch
13:45 h - Rejoing the Subgroups and presentation of their "Working reports".
18:00 h - End of the day; return to hotel.

SUBGROUP 1: TECHNOLOGY ISSUES

COORDINATOR: FERNANDO RIZZO, PUC/RJ

MEMBERS : FRANK R. FIELD, III - M.I.T.
CESAR PEITER, INT
CYRO ALVES BORGES JÚNIOR, CETEM
RICARDO NAVEIRO, COPPE/UFRJ

SUBGROUP 2: LEGAL ISSUES

COORDINATOR: RENATO DAGNINO, UNICAMP

MEMBERS: JURGEN LEXOW, BAM
MARIA LAURA BARRETO, CETEM

SUBGROUP 3: ECONOMICAL ISSUES

COORDINATOR: SAUL BARISNICK SUSLICK, UNICAMP

MEMBERS: GUSTAVO LAGOS, CESCO
HELOISA MEDINA, CETEM

SUBGROUP 4: SOCIO-POLITICAL ISSUES

COORDINATOR: LÉLIO FELLOWS FILHO, MCT

MEMBERS: MAMMO MUCHIE, MDSU
SARITA ALBAGLI, CETEM

SUBGROUP 5: ENVIRONMENTAL ISSUES

MEMBERS: LAKIS KAOUNIDES, CUBS
TERESINHA RODRIGUES, CETEM

SUBGROUP 6: METHODOLOGY

COORDINATOR: BRUCE JOHNSON, USP

MEMBERS: R. S. GANAPATHY, ACME
CESAR DAS NEVES, COPPE/UFRJ

APPENDIX 3: STANDARD SCRIPT FOR SPECIALISTS' INTERVIEWS

Projeto IDRC/CETEM "Materiais Avançados e Desenvolvimento Sustentável: Estratégias para o Brasil"

ROTEIRO PARA ANÁLISE POR SETOR

I) Estrutura do resultado final

1. O que são os materiais avançados e o setor mínero-metalúrgico.

2. Quais as tendências históricas de sua evolução nos últimos 10 anos (quantitativas e qualitativas).

3. Por quê dessas tendências (fatores restritivos e impulsionadores do desenvolvimento dos materiais avançados).

4. Impactos dos cenários 1 e 2 (representações de estruturas de valores distintos) sobre o os fatores considerados.

5. Projeção das tendências (10 anos).

6. Considerações finais.

II) Documento a ser enviado previamente aos entrevistados (3 a 4 páginas):

1. Os materiais avançados e o setor mineral (definições gerais).

2. Evolução nos últimos 10 anos

3. Cenários 1 e 2.

III) Setores a serem entrevistados em uma primeira etapa:

Energia, Transportes, e Microeletrônica e Telecomunicações

ROTEIRO DE ENTREVISTA DOS ESPECIALISTAS DOS SETORES

1. Entrevistador faz uma síntese dos itens 1 e 2(o que são os materiais avançados e o setor mínero-metalúrgico, tendências nos últimos 10 anos).

2. Perguntas:

2.1. Quais as tendências do setor em questão nos últimos dez anos em termos de:
- produtos e processos?
- evolução tecnológica?

2.2. O que motivou essas tendências (restrições e condicionantes)?

2.3. Quais os impactos dessas tendências sobre o uso de materiais (considerando-se as mudanças no perfil do setor e/ou nas tecnologias empregadas)?

3. Entrevistador apresenta a síntese dos cenários 1 e 2.

4. Perguntas:

4.1. Ocorrendo o cenário 1:

- qual o impacto do cenário sobre as tendências futuras do setor (em termos de perfil e de tecnologias empregadas)?
- considerando esse impacto, qual sua expectativa e projeção futura (quantitativa e qualitativa) no uso de materiais?

4.2. Ocorrendo o cenário 2: idem

MATERIAIS AVANÇADOS	**FUNÇÕES**
POLÍMEROS DE ENGENHARIA Resistência mecânica e térmica próxima a dos metais. Têm mais funções do que os polímeros tradicionais.	Mecânica Elétrica Ótica Biológica Química
CERÂMICAS AVANÇADAS Apresentam usos específicos em função de suas propriedades. Elevados níveis de desempenho são garantidos por processos rigorosos de fabricação.	Mecânica Térmica Elétrica Ótica Magnética Biológica Química
NOVOS METAIS E SUAS LIGAS Diferentemente dos tradicionais, possuem expansão e contração como a borracha e memória de formas, reguladas por variações de temperatura (ligas- amorfas, Supercondutores)	Mecânica Térmica Elétrica Magnética
COMPÓSITOS Têm funções derivadas da combinação de dois ou mais materiais de naturezas diversas (Cerâmica-Metal, Polímero-Metal)	Mecânica Térmica

SCENARIO 1

GENERAL ELEMENTS	SPECIFICS ON MATERIALS
Social dimension: social aspects are not stressed; growing inequalities of income and consumption among individuals and nations.	Technological development of materials applied to increasingly selective and sophisticated markets.
Economic dimension: Emphasis on international competitiveness imposed by the technical standards of production in the developed world.	Emphasis on materials that will enhance competitiveness in exports.
Ecological dimension: Emphasis on preservation and recuperation of the physical environment through technology. Environmental cost penetrates the decision criteria.	Emphasis on substitution of new materials and processes for those that are not renewable and/or polluting.
Political-institutional dimension: "Global commitment" is imposed by the proposals, rules, and institutional models of the developed world.	Control of the technology and of the diffusion of advanced materials by the developed world.
Cultural dimension: The consumption standards in the developed world are substantially maintained, notwithstanding the modifications in way of life caused by environmental factors. Third world countries keep the standards of the developed world as references for development.	Materials based on the standards of consumption that are being established in the process of globalization.

SCENARIO 2

GENERAL ELEMENTS	SPECIFICS ON MATERIALS
Social dimension: more equality in the distribution of income and property.	Emphasis on materials applied to the fulfillment of social needs.
Economic dimension: macro-social factors overcome micro-economic rentability in the construction of rational decision criteria.	Emphasis on strategies of use of materials that will generate positive consequences on employment and income distribution.
Ecological dimension: - creative use of each ecosystem's potential; - rational use/conservation of energy and natural resources; - reduction of the volume of discards and pollution.	- Materials based on renewable and/or abundant resources. - Materials that require less energy (improved performance and durability of products). - Recyclable materials. - Non-polluting technologies.
Political-institutional dimension: new contract among domestic and international agents.	- Coordination of strategies among government, material producers, universities, R&D institutions, and consumers. - International cooperation in the field of materials.
Cultural dimension: increasing importance of local conditions.	- Materials based on the endogenous natural and mineral reality. - Materials based on the endogenous entrepreneurial and R&D experiences and capacities. - Materials applied to the standards of local consumption.