'Public and Private Sector Advanced Materials Strategies in the Late 1990s as Illustrated by the Case of Advanced Metals and Ceramics in Greece'

A Thesis Submitted to City University Business School, City University for the Degree of Doctor of Philosophy (PhD) in Strategy and International Business

IOANNIS A. KOTTAKIS
Department of Strategy and Marketing

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ANNEX 1.1: METHODOLOGY

A1.1.1: General Methodology Outlines

Following the preliminary literature review and formulation of the research proposal (and hypothesis contained therein) under the title -

'Public and Private Sector Advanced Materials Strategies in the late 1990s as Illustrated by the Case of Advanced Metals and Ceramics in Greece' -

there were three major requirements to be taken into account:

1. The first was to formulate and build the "codes of practice", in Part I as a bench–marker and working analytical model on the basis of which the thesis hypothesis would be formulated and tested.
2. Having identified the sectors to be examined (see section 1.2 and section 7.4), the second requirement was the need for a balance in the empirical part of the research (field research) ensuring that the views of both the public and the private sector in Greece (and the interactions between them) have been adequately recorded and analysed.
3. The third called for a detailed examination and analysis of the private and public sectors' response to the challenges imposed by the MR.

Consequently, three additional requirements included:

a) The need for a balanced and in-depth analysis of the views of metals and ceramics materials users and materials producers and the interactions between them.

b) An investigation of the role and the views of research institutions, public agencies and universities (in the case of Greece, all of them under public control, or State administration) as a part of the analysis of the Greek public sector response to the materials challenge.

c) The need to involve Greek financial institutions in order to empirical evidence over the issue of financing materials technologies and long-term technological innovation.

According to the above, the first critical question which had to be answered was the following: Which methodology approach is the most suitable for the proposed research?

Based upon the methodology recommendations of Yin (1994), Gill and Johnson (1994), Krull, Sensi and Sotiriou (1991), OECD (The Oslo Manual – 1992) and Lahlou et al (1992), and on examples of previous academics works[1] of similar nature, the study adopted **a triangulation approach**[2] which includes **a combination of desk work and field research**. In more detail:

Part I, includes the identification of the codes of practice and heavily depends on **desk-work** and **secondary sources of data**[3] including literature gathering and review, evaluation, analysis and synthesis of recorded experience and available evidence.

By employing a **combination of deduction and induction methods**[4], the "codes of practice" have been extracted after careful evaluation of the available literature and information sources and serve as a reference point and testing tool (**or variables**) of the study. The 'codes of practice' reflect internationally accepted common patterns of materials strategies, their effective support and their integration with technology and business strategies. This information is also used, to a certain extent, to check the validity of the findings of the field research (see below).

Part II, the field research, tests the codes of practice in the case of Greece, and primarily relies on the analysis and synthesis of qualitative and quantitative results emerging from a triangulation of **primary sources**[5] of information such as data collection and recorded interviews with companies, industrial groups, research organisations and university departments, public and governmental agencies, governmental officials, financial organisations and others. Although the information obtained directly by companies and other organisations is the primary source of

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[1] The study took into account many international experience paradigms and previous approaches to similar problems and tasks (E.g. Hane 1992; Lastres 1993; Planet 1994; Tsipouri 1993 - see also Methodology References further below).

[2] According to Gill and Johnson (1994) the method of **triangulation** includes:

1. The use of different research methods in the same study to collect data so as to check the validity of any findings.
2. The collection of different data upon the same phenomena so as to validate any findings.
3. Collecting data upon the same phenomenon at different times and places within the same study.

[3] That is data gathered by other people and documented in forms such as papers, academic publications, reports, books, consultancy reports, grey literature etc.

[4] According to Gill and Johnson (1994) **deduction** is the deduction of particular instances from general inferences. It entails the development of a conceptual and theoretical structure which is then tested by observation while **induction** is the development of theory (the bench-markers or 'codes of practice' in this instance) from observation of empirical reality. In a general framework, Gill and Johnson (1994) and Yin (1994) suggested that a combination of the two methods has many advantages over single deduction or induction as it provides better opportunities to triangulate the available information. In the present thesis, deduction is employed in the case of published works including studies and conclusions on large populations (such as the NRC (1989) study), while induction is used in the case of published works presenting case studies and conclusions on individual cases (such as the Alcoa-Audi collaboration presented in chapter 4).

[5] Such as interview results, raw data or re-evaluation of published data.

information, it is also supported by secondary sources (a limited number of related publications) in order to provide additional insights into the materials strategies and tendencies in Greece and achieve a better **triangulation** of results and **validation** of findings.

Part II concludes with the final chapter of the thesis which aims to bring together all the findings of the previous parts, derive general conclusions on the basis of the tested hypothesis, formulate strategic proposals (scenarios) and suggest areas of future research (desk work).

The sample of the thesis, including the character and the main activities of each reviewed organisation are summarised further below.

After setting these very general outlines a second set of critical questions had to be answered: Is the task achievable? Are there sufficient data available and are they accessible? Can contacts and links be established with people who can provide valuable information? First of all **the viability and originality** of the research tasks had to be secured.

A1.1.2: Viability of the Task and Originality Verification

Two issues arise here: the availability of literature necessary for Part I and the viability of undertaking field research in Greece.

Availability of literature and data for Part I: From an extensive literature review and investigation of the field[6] it was found that there is an adequate amount of information covering crucial issues in MSE technologies and their interactions with areas such as industrial and technology strategies, R&D strategies, business environment, manufacturing and management practices and others. This sufficient but unorganised information (in the generally accepted form of "codes" of basic strategic practices) includes reports, conference results, "Grey literature" reports, hearings, papers, some academic publications (limited number) and a handful of MPhil/Ph.D. studies. Given that most of the located material (about 70% - 80% according to personal estimate) was accessible[7] over a reasonable time period, the availability of literature and data for Part I was confirmed. In addition there is sufficient and accessible information on

[6] Covering library archives and collections (e.g. the British Library, The Institute of Materials Library in London, Embassy Libraries), electronic literature and documentation databases (e.g. the British Library OPAC system, BIDS, HELECON, CORDIS, OTIS etc.), MPhil and PhD thesis databanks (e.g. UMI) and others.

[7] Using various ways including personal visits to libraries, downloading information from data bases and the internet, interlibrary loans services and others.

supportive literature such as literature on core technological issues, technological innovation, management of technology, technology strategies, R&D organisational structures, technology policies, national systems of innovation, established management practices and financing technological innovation.

Finally, by investigating **databases** regarding Mphil / Ph.D. studies[8] the **originality** of the research was verified.

Viability of Part II: The field research: In order to answer the above questions regarding the viability of the field research *a first preliminary in situ investigation in Greece was undertaken*. The main aims were to obtain and/or to secure access to information and data and to establish contacts with people in industries, universities, government and organisations who have knowledge of the field (managers, directors, academics, advisors, government administrators) and who would be willing to provide interviews and other relevant information.

In order to meet the above targets, the author spent 32 days in Greece between 20/8/1994 - 23/9/1994, where he contacted and visited individuals, institutes, services and organisations located either in Athens or in Patras. In brief, the results of the in situ preliminary investigation were as follows:

I) From extensive Greek literature review using Greek libraries and literature documentation data bases (including MPhil/PhD theses) the author found that there is a considerable amount of information covering key relevant issues and areas such as industrial policies, technology, R&D in Greece, business environment and others, but very limited material with respect to materials technologies and their position in the Greek innovation system (see chapters 7, 8 and 9). This rather limited and unorganised information includes reports, conference results, "Grey literature" reports, hearings, and confidential collections covering mainly the activities of the public sector and not so much the activities of the private sector ; it has usually qualitative, descriptive or executive form. The main location sites of these references are given in ***Table M1*** **.** The author visited in person all the listed locations and verified that the relevant material was in large measure accessible.

II) High quality company information was more difficult to obtain. There was no information apart from sparse case studies. Therefore, interviews and visits to a carefully selected sample of companies was necessary. In order to build up contacts and gain access to the targeted companies and various other institutions the author followed the procedure described below .

[8] Including Greek Mphil / Ph.D studies.

The author visited and thoroughly discussed the research issues with an initial core of "key" people such as:

1) Academic staff from 3 departments in 3 different universities (two chemical engineering and one mechanical engineering department) who cover all the MSE spectrum including processing, machining, design, operational research and finance. These individuals provided very strong and direct links with senior managers in industry, companies, other Universities and Research Institutes.

2) Members of the Administrative Board of the Technical Chamber of Greece. They provided direct links with leading industrialists especially in the construction field.

3) Individuals in the General Secretariat of Research and Technology (GSRT) and in the Ministry of Development (similar authorities to the DTI in the UK). These people manage the technology and research policy issues as well as the research funds allocation and the funds for national and international collaboration and programmes. They provided further contacts with high level public and governmental officials and other public services.

4) Members of staff of the City University Business School provided contacts with the Banking and the Financial services sector.

No	Sources of Information (Locations)
1	National Statistical Service
2	National Research Foundation
3	General Secretariat of Research & Technology (Archives & data banks)
4	National Bank for Industrial Development (Archives and data banks)
5	Professional Associations libraries (Archives and data banks)
6	Technical Chamber of Greece
7	Industrial and Trade Chamber of Greece
8	Ministry of Industry and of Education libraries, archives & data banks
9	The Athens British Council
10	National Documentation Centre
11	European Investment Bank (Greek Branch) archives and data banks
12	Commercial bank of Greece libraries, archives and data banks
13	Centre of Planning and Economic Research
14	Federation of Greek Industries (Libraries and archives)
15	Greek Management Association
16	University Libraries
17	Company / firm information
18	The Athens European Commission Office

Table M1: Sources of Information (Locations) in Greece.

Most of the people contacted clearly stated that they would welcome a further collaboration and that they were willing to assist in every way they could. They also stated that they would prefer or recommend a formal kind of co-operation / assistance (see further below: preparing the interviews). Summarising, both the results of the literature investigation and the results of the *in-situ* investigation in Greece confirmed that the tasks set in the thesis could be achieved.

A1.1.3: Creating Part I and Part II

Part I aims to develop a generally accepted analytical model on the basis of which the thesis hypothesis would be formulated and tested. As such, a set of bench-markers (codes of practice) is identified by drawing inferences after an evaluation and synthesis of the available information and recorded (published) experience. The results provide the analytical basis and reference point for Part II.

Given the inter-disciplinary and in cases exploratory nature of the present research, triangulation is the most recommend methodology for collecting and evaluating information before deriving conclusions (Gill and Johnson 1994, Yin 1994, The Oslo Manual 1992). Moreover, given that:

-- many sources of the available information were designed for specific purposes which are likely to differ from the objectives of the thesis (to build an analytical model in order to analyse and evaluate materials strategies and their strategic implications),

-- that it is possible that the available information may contain intentional or unintentional bias particularly regarding figures of R&D expenditures or strategic choices or corporate financial performance and strategic choices portfolios,

to achieve triangulation during the identification of the codes of practice, a **combination** of both deduction and induction methods during the evaluation and synthesis of the available information was employed[9].

The literature involved in all fields and the two parts of the thesis is no older than 1985 (year of publication). This is for the following reasons:

[9] For example, the extraction of inferences by established theories (e.g. the works of Bleeke and Ernst (1993) and Pavit (1995) on strategic alliances (deduction) are compared and then critically synthesised with inferences derived from empirical case studies (induction) demonstrating materials cases (e.g. the Alcoa-Audi case study analysed by Kaounides (1995)).

Firstly, a clear idea that the MSE field is a unified, coherent and multi-disciplinary field became apparent (and globally accepted) in the late 1980s[10]. Before that we could not safely identify a MR (e.g. Advanced Materials were identified in 1986 in Scientific American by MIT professors) or the MSE field and its main parameters and implications.

Secondly, the formulation of materials policies only began in the late 1980s (apart from Japan where MITI established the Fine Ceramics Office in 1982 and the New Materials Office in 1984).

Thirdly, a typical characteristic of materials technologies and strategies (and technological issues in general) is that the results of their implementation are not always immediately apparent. In many cases considerable time has to pass from the time a project ends until its technological, strategic and financial effects become apparent and become possible to measure, evaluate and record. Therefore, for reasons of keeping pace with current developments, nothing older than the 1985 publication date is employed apart from few exceptions[11].

Hence, every effort was made to deal with ongoing frontier developments, to use sources of outstanding credibility (such as The institute of Materials, London or the DTI, London) and to verify the validity of these sources.

Finally, in Part I some points/issues have been deliberately left out. For reasons of presentation and better exposition some of the parts of the literature review which in practice should belong to Part I are transferred and developed at points where discussion of relevant issues takes place in Part II[12].

Creating Part II. Part II, the field work, took place through a combination of data collection and interviews with advisors, managers, directors, academics, and governmental officials in Greece which recorded the views of corporations (both materials users and producers) public agencies, research organisations (universities and research / technological institutions), professional associations and financial institutions (banks, venture capital companies). In that way, a balanced representation of all the involved parties was achieved. Simultaneously, both the involvement of interrelated organisations different in nature and activities, and the design of the questionnaires (see below) provided original information on the same phenomena

[10] See for example the publication dates of the literature reviewed in section 1.5.

[11] When general theories are involved (e.g. technological innovation, market efficiency etc.) this is not the rule.

[12] For example, literature review regarding the Greek national system of innovation is presented at chapter 7.

(materials strategies and their implementation in Greece) achieving a high level of findings and inferences triangulation.

These findings were further compared or supported by "Grey" literature reviews, internal documents (when possible), and the available data or published literature with respect to technological trends, materials production and consumption, and materials (metals and ceramics mainly) projects and activities.

Finally, information on the same phenomena received during different time periods (see below 4.3: Observations on the sample - observation 7) provided an additional source of triangulation.

The above approach was adopted after careful consideration of the nature of the research field (inter-disciplinary, in many cases exploratory), the relative absence of reliable quantitative information[13], and the accumulated experience in the area of researching management of technology issues (OECD 1992, Tsipouri 1993, Planet 1994) or materials issues (Beauvais 1987, Hane 1992, Lastres 1993).

A1.1.4: The Sample

A1.1.4.1: General Sample Outlines and Sample Selection criteria

As suggested by the general study guidelines, the research sample must be representative, balanced, and homogeneous with respect to the main thesis parameters and requirements. It must also be sufficiently spherical (that is to include the views of all the involved parties) in order to achieve a high quality triangulation and validity of results. As such, in order to achieve sample homogeneity and secure results compatibility and comparability the following sample eligibility criteria were put forward:

The Public sector. Here there was not much freedom of choice. In order to examine national materials policies one has to investigate a rather limited number of institutions and agencies which have the responsibility of designing and implementing these policies. With respect to this principle the research sample reflects the views of some of the public agencies responsible for materials R&D and strategic planning in Greece. Additional selection criteria of which agency is the most appropriate were

[13] The preliminary investigation demonstrated that there are no sufficient quantitative data to support a quantitative approach. The existing data are either patchy, incompatible or extremely fragmented (OECD 1990). There is a similar situation in the case of Greece (see also chapter 7).

based on the findings presented in chapter 4. Some large, State controlled corporations also had to be involved. Private sector eligibility criteria were applied for their selection.

The Private sector (company selection). The private sector mainly includes companies, experts, professional associations and financial institutions. Given that two different major industrial areas and their interrelated sectors are involved, extra attention had to be given so that the sample of the private sector remains representative, balanced and homogeneous with respect to the targeted sectors.

The major selection criterion for the two sectors studied (metals and ceramics including both materials producers and final users) was:

1) To try and contact the market and technology **leading companies**, that is the market leaders and /or the best performing companies in each sector, and,
2) To achieve the highest representation of the domestically produced annual output of each sector.

Having these as starting points and in order to make the findings of different sectors comparable (and compatible), two more major and predominant unstabilising parameters had to be eliminated: **size** of the company and geographical - region related factors.

According to the above, the *regionality* factor *was eliminated* altogether. It does not matter for the present study if all companies are gathered in one region or if they are scattered in a vast geographical region.

Size: The materials strategies and the management response analysed in the following chapters mainly concern large corporations. The "codes of practice" with respect to the private sector (outside of Greece) have also been extracted from the experience of large firms and corporations and can't be expected to be fully met by SMEs[14]. As such SMEs had to be eliminated from the sample.

The sample has thus been selected from data bases including large[15] companies which meet at least 4 out the 5 following criteria:

- Large size: more than 400 employees and to be placed continuously among the 100 largest corporations in Greece in terms of annual sales or turnover during the last 5 years (1990-1994).

[14] There is no sufficient documentation on the issue, hence that parameter would possible involve hidden risks.

[15] Here it has to mentioned that EU criteria for SME involves a number of workers between 100-250. For Greece 100-250 workers is not a SME but a medium - large enterprise.

- Market share: to cover more than 20 % of their specialised markets in terms of domestic production or domestic consumption .
- Continuous profitable performance: that is above average financial results for at least the last 5 years, and/or among the 100 most profitable corporations in Greece during the last 5 years.
- R&D activities: this includes companies which have received national or international R&D subsidies, companies which are known to have R&D units/capabilities, or companies which have a record of participation in national or international collaborative R&D activities. The selection was based on data publicly available.
- Length of industrial presence: The company must be more than 7 years old.

In addition, the **quality of contact** was a predominant factor: that is contacts had to be built with the highest possible management levels in the companies-top management teams or individuals who were likely to be able to provide authoritative information on the requested issues.

The conditions above were applied quite rigorously and they gave a list of 33 individual companies or industrial groups from which 28 were targeted and 21 accepted to participate in the present investigation[16].

Sixteen (16) out of the 21 companies and industrial consortia are big companies with more than 400 employees each and satisfy all the above criteria. The remaining 5 companies (24%) are defined to be SMEs according to EU standards but they are still regarded as large corporations with respect to Greek standards. Apart from this, these companies were involved because they were known to regularly participate in national R&D collaborative schemes, or because they had particularly strong linkages with universities and research institutes, or because **they control significant segments** of the market share (domestic production) of their specialised field.

The financial Institutions. To achieve both public and private sector views the research sample includes the views of two State controlled banks (one commercial and one investment bank), three venture capital companies (all private), one financial agency (public sector) and one independent financial consultancy agency (private sector).

Professional Associations. There is not much freedom of choice here. The two appropriate associations had to be selected: the Technical Chamber of Greece and the

[16] For the rest the last criterion failed: top management contacts were not possible to be made.

Institute of Financial and Industrial Studies (IOBE) agreed to take part in the present research.

In short, all the selected companies are leading companies (with respect to size, annual turnover, profitability, production capacity and market share) in their specialised fields. On many occasions, where the reviewed sectors are dominated by monopolies or oligopolies, the sample covers more than 80% or 100% of the overall domestic capacity and market.

Summarising, in order to meet the above requirements and limitations and secure a better triangulation of results (different points of view), a sample of 49 experts, institutions, companies, industrial groups, financial organisations and public departments / agencies was initially targeted. Forty - two (42) institutes / organisations and agencies accepted to participate and be interviewed by the author. They are described below.

A1.1.4.2: Sample Structure

During a second visit to Greece between 27/7/96 and 5/8/96 (38 days) 42 out of the targeted 49 experts, institutions (21 companies, industrial groups and construction consortia), financial organisations and public departments / agencies accepted to take part in the present investigation. The results of their participation are reflected in 57 interviews and a large volume of documentation and internal information.

The public sector sample involves the views of 5 public and governmental agencies, 5 university departments from 4 different Universities, 3 research and technological institutes (of which one is metals-oriented and one ceramics-oriented) 2 banks under public control, 5 public ownership companies (1 materials producer and 4 materials users (which involves the entire Greek defence manufacturing industry), and one other public financial institution/agency. In total, the public sector is represented with 20 institutions, experts and organisations under the criterion that all of them are ultimately under public or State control.

The private sector sample involves 16 private materials producers or final users (3 construction companies, 1 construction consortium and 12 firms and industrial groups) 3 venture capital companies, 2 professional associations and 1 financial consultancy company. In total the private sector is represented with 22 institutions, industrial groups, experts and organisations.

The **financial institutions** sample includes 2 banks, 3 venture capital companies, one governmental financial agency and one independent financial expert[17]. Seven (7) out of 42 in total.

Finally, the sample involves 4 universities, 2 professional associations, 3 research institutes, 21 companies /industrial groups, 5 governmental agencies and 2 other bodies /experts.

Type of Institution / Organisation		**Private**	**Public**	**Total Number**
Firms / Companies / Industrial Groups[18]	Manufactures & Materials Producers	12	2	14
	Defence Related Companies		3	3
	Construction Companies	3		3
	Construction Consortia [19]	1		1
Research Institutions			3	3
Universities[20]			4	4
Public and / or Governmental Agencies			5	5
Financial Institutions	Banks		2	2
	Venture Capital Companies	3		3
Professional Associations[21]		2		2
Other Bodies / Experts[22]		1	1	2
Total		**22**	**20**	**42**

Table M2: Classification of organisations / industrial groups, construction consortia and experts which have accepted to participate in the research[23].

The research sample (general information about the participants) is summarised in **Tables SA-SC in Annex 1.2** which shows how the 57 interviews were spread across the reviewed sectors. Tables SA-SC in Annex 1.2 also provide more details on the

[17] Until 1994, in Greece 85% of the national banking system was under public - governmental ownership. Apart from two major investment banks all the other major banks are commercial banks. The investment bank of the sample is the only one still enjoying independence of decisions. The commercial bank is a typical large Greek commercial bank. Moreover, in 1994/95 there were 4 major venture capital companies in Greece controlling the venture capital market. The sample includes the views of the three leading, largest venture capital companies. The financial agency (ELKE) is responsible for securing capital and flow of capital for large investments under governmental guarantee. The independent consultancy agency has a large accumulated experience in the financial markets of Greece.

[18] Industrial Groups are those under the codes M5 , MU1, and C2.

[19] The construction consortium under question is the consortium for the Athens Underground.

[20] The number 4 indicates that participants from the Academia come from 4 different Universities.

[21] Technical Chamber of Greece (CONEXP4- 6) and IOBE (FINEXP1) .

[22] ELKE (FINEXP2) and FINEXP3 .

[23] Note that a single institution can include more than one interview (i.e. Technical Chamber of Greece includes 3 interviews).

profile of each participant including its character and nature of activities. For presentation reasons, Tables SA-SC and Annex 1.2 are presented at the end of the current methodology presentation.

Table M2 represents a sector classification of the research sample. As can be seen from Table M2 the total number of financial institutions, public and governmental agencies, universities, research institutions and professional associations account for 21 out of a total of 42 institutions. The materials production and consumption sectors (individual companies, consortia and industrial groups) account for the other 21 institutions. From these 21 companies / industrial groups 11 are materials producers (6 ceramic producers and 5 are metals producers) and 10 are materials users[24] (4 intensive metals users, 3 intensive ceramics users and 3 intensive materials users (both ceramics and metals)). Nine companies / industrial groups have strong emphasis on ceramics (6 producers and 3 users[25]), 9 have strong emphasis on metals (5 producers and 4 users) while 3 companies / industrial groups and consortia have mixed emphasis on both ceramics and metals (1 producer, 2 users).

Firm / Company Type of Ownership and Materials Orientation	**Number**
Under Private Sector Control	16
Under Public Sector Control	5
Under Greek Control	14
Under International Control	4
Under Mixed Control	3
Materials Producers	11
Materials Users	10
Materials Producers & Manufacturing Companies	17
Construction Companies and Consortia	4
Companies with strong emphasis on Ceramics	10*
Companies with strong emphasis on Metals	10*
Mixed Emphasis	3
Total number of Companies / Firms / Industrial Groups	**21**

Table M3: Classification of Companies / Firms / Industrial Groups according to type of ownership and materials orientation. * One technological and research institution corresponds to each category. RI1 for ceramics and RI2 for metals.

Finally 14 out of the 21 companies / industrial groups are under Greek control, 4 are subsidiaries of multinationals and 3 are under mixed control. **Table M3** summarises the above information.

[24] Note that materials producers of say, metals, are intensive users of materials produced by ceramic producers. That means that the real number of materials users is much larger than 10.

[25] In addition, note that all the metals producers are intensive industrial ceramics and refractors users.

A1.1.4.3: Observations on the Research Sample

1) Industrial Groups are those under the codes M5, MU1, and C2 .

M5 is a large conglomerate involving five major metal and metal products production industries (Steel, Aluminium , Copper & Zinc, and Welding Electrodes & materials) and two intensive materials user industries (Wire & Cables and Aluminium Can Industries). This group of industries is under common central control by the same group of owners. The interviews with this group reflect the major views and strategy trends of the conglomerate and not of individual industries within the group. When one of the industries for some reason exhibits strong differentiation from some of the conglomerate's mainstream principles the interview usually records this differentiation along with an explanation why this is the case. Similar conditions apply to the MUI and C2 industrial Groups:

MU1 is a high tech industrial group composed of 3 major industries involved in high tech production of mechanical parts of outstanding precision, electronics and optics. MU1 group is under common central control by the same owners. The group has recently acquired M4ST, a highly specialised small steel and cast products producer, but M4ST retains much of its decision making and strategy autonomy.

C2, now a part of a large multinational, has a large number (about 15) of directly controlled subsidiary companies (SME). They express a strong diversification strategy with respect to materials and products and they also act as new products and market "probes" as the C2 officials have stated. Finally, almost all of the examined industries have a large number of SME under their direct or indirect control.

2) The construction consortium under question is the consortium for the Athens Underground. This project involves more than 50 major Greek and International contractors, and subcontractors. The constructions experts CONEXP1 - 3 due to their position and responsibilities in the project (see Table SA, CONEXP1 - 3) are in a position to provide sound opinions and information based on their experience and information they have on the technological capability and business strategies of almost all the participating companies and to identify clear trends shaping the construction field in Greece today. Professional Associations experts like CONEXP4-6 also provide cumulative sound opinions based on their experience as leading members or their professional associations. Furthermore, these people hold organic positions in strategic sectors of the Greek Public sector, such as Greek National Railways (CONEXP5) and the Greek Ministry of Environment and Civil Works (CONEXP4).

Therefore, the present research includes materials science and engineering, R&D and technology strategy trends of a much larger volume of companies than the total number of materials user and producer industries which were directly interviewed. According to observation (1) the total number of companies and industries rises from 21 to 30 in addition to a large number of inter-dependent SMEs . According to observation (2) the total number of construction companies is considerably larger but cannot be identified with accuracy. In total the sample covers directly or indirectly 30 industries /companies and indirectly a large number of construction companies and SMEs.

3) Among University experts and Academics every effort was made to obtain selective views from different Universities. That is because in Greece there are notable attitude and perspective variations among universities, as well as among members of academia. More importantly, academics have a double role in the present investigation. They not only express their opinion on education, research and R&D issues but they also act as technology and science experts with a wider perspective and point of view.

In Greece, academics are usually much better informed about world wide technological and science developments than industry (this statement will be justified in the following chapters). In many cases they act as technology and science consultants for manufacturing and construction firms or projects and therefore they are in position to know trends and conditions from within. Moreover, academics are the most experienced people with respect to both national and international research and R&D projects. Finally, most of them (especially the professors and readers) have held high posts in Greek manufacturing or services industry. For example, PAC3 and PAC6 were ex - directors of the National Power Company covering a time span of 15 years between them (other directors were appointed between the directorship period of the two). It follows that academics function in the present research in a much more complex role than simply providing information on education and research trends.

4) The public servants and governmental officials participating in the current research hold key positions in the public sector and governmental agencies with respect to the research subject matter. They are placed in positions which receive multiple inputs from both the private and public sector and they have key technology and R&D policy making responsibilities.

5) The Ministry of Development is a large conglomeration of recently combined ministries: The Ministry of Industry, Research and Technology, the Ministry of Trade and the Ministry of Tourism . PA1, PA2, PS5 and GSRT (PS1-3) act under the

authority of the Ministry of Development but they maintain high levels of independence with respect to policy and decision making for issues under their immediate jurisdiction.

6) Some interviews with some experts took place simultaneously –akin to a brainstorming meeting . A typical example is the simultaneous interview with experts RI2, THAC1 and VAC1 or with CONEXP1 and CONEXP2 . Interviews with C2 and CA2 were complementary to each other. Other interviews are presented as a single interview but in fact more than one person was present providing the requested information. Typical is the interview with the M5 industrial Group.

7) Some interviews were double: one off the record preliminary interview during the first contact in summer 1996 and one official during autumn / winter 96-97. Apart from the official interviews a considerable number of discussions with other experts took place to whom the author is indebted for the suggestions and ideas they have provided. In addition, that provided the opportunity to collect information upon the same phenomenon at different times within the same study (Triangulation – Gill and Johnson 1994) and adds to the validity of the results.

8) The number of the interviews (57) is larger that the number of the institutes interviewed (42) because in some cases more than one expert comes from the same institution (for example see PS1 - PS3). But the number of interviews represents a much larger depth and volume of institutions because many of the interviewed experts are in a position to provide information for more than one company (especially in the construction sector) either because these companies belong to the same industrial group (e.g. M5 or CONEXP1-3) and cover many industries / companies, or because they have vast working experience from the area / field and they have the ability to express concentrated experience and sound views (e.g. CONEXP1-3).

9) The names of companies, departments, or individuals may or may not be revealed after the interview in line with a confidentiality agreement made with the interviewed participants. Key identifications will be employed when necessary.

By combining observations 1 - 8 it follows that the 42 interviewed organisations and the 57 interviewed individuals reflect the accumulated views of a much **larger** research sample than appears in the above tables[26].

[26] This is not unusual for research projects with similar aims and methodology. For example, there is an identical case in a 1993 study by Tsipouri (1993) and in a 1994 study by Planet Ltd (1994) – see also methodology references.

A1.1.5: Data Collection

A1.1.5.1: Preparing the ground

In order to select the targeted companies, agencies and institutions, establish contacts and make appointments, a two months preparation period was involved including a second trip to Greece during summer 1997. The procedure of establishing contacts is as follows:

An initial core of people (see Viability of Part II) introduced the author to the director or the manager, or the owner of the agency, company or department.

The author made appointments with these people in order to explain the aims and the tasks of research and ensure future collaboration, that is, to secure further co-operation and a full scale interview. When that was achieved, these people usually directed and introduced the author to new people out of the realm of the initial core; and so on. That procedure enabled the author to build an interlocking network of companies, public agencies, financial bodies, research institutions, universities and professional associations. During the same time location of data took place. In some cases face to face first contact appointments were not possible. In such cases, appropriate material was mailed always to eponymous individuals and never under the label "general manager" or the "director of...".

In all cases the author presented an outline of the research and supporting documentation such as official papers from City University Business School (e.g. Official confidentiality agreements, letters of reference and other documents).

Some participants required to see the interview questions well in advance before the interview. The author sent copies of the interview questionnaire to them at least 15 days in advance of the appointed interview.

A1.1.5.2: Creating the Questionnaires

The questionnaires are based mainly upon the findings of the first six chapters and they test the basic ideas (codes of practice) developed in these chapters in the case of Greece. They were designed to provide the maximum potential when used in interviews run by the author. They are presented in **Appendix 1.3** .

The aim of the questionnaires is to provide group results reflecting general tendencies and not to focus on analysing in detail individual firms. These results can then be compared on a triangulation basis[27]and analysed with respect to the theoretical background provided in chapters 1-6.

The questionnaires (and the interviews) adopt a mixed approach of closed (structured) questions (when applicable) supported by open questions (semi-structured type of questionnaire) where the participant is free to develop his / her views and ideas or to comment on his/her choice in closed questions. Usually an open question follows immediately after a structured question (multiple choice) asking for the reason the participant made a specific choice in the structured question.

The merits of combining semi-structured questions with structured questions have been extensively analysed by Gill and Johnson (1994), Yin (1994), Lahlou et.al. (1992) and the hand-outs of the Survey Methods I & II lectures and the Research Methodology lectures run by the *Social Science Research Unit* (SSRU) at City University, London. The semi-structured questions provide more insight and derive more information whereas the closed questions provide immediate comparison of the value of different variables (Yin 1994, Lahlou et al. 1992). They have been extensively employed by many studies (e.g. Tsipouri 1993, Planet 1994, Beauvais 1987, Hane 1992, Lastres 1993).

Particular effort was expended on both the content[28] (the nature and the way the questions are placed) and the technical design of the questionnaire while the whole structure of the questionnaires can *work as a checking system* for the information obtained from the interview.

In order to ensure that the questionnaires were appropriate, **two pilot case studies** were carried out during the second travel to Greece in summer 1996. Corrections were made and only then the final form of the questionnaires was employed or mailed, approximately 15 - 20 days prior to the interview, to the participants who requested it.

Six major questionnaires were employed. They aim at: (1) materials users and producing firms, (2) construction firms and construction experts, (3) research

[27] The collection of different data upon the same phenomena so as to validate any findings is extensively achieved by the spherical approach of the sample and the structure of the questionnaires: all the involved parts comment on common or interrelated topics put forward by commonly shared questionnaire questions. In most cases convergence of opinion was achieved. Finally, there was a limited collection of data upon the same phenomenon at different times within the same study by combining findings of the pilot studies and the final interviews.

[28] Brief pilot interviews with experts took place during the visits in Greece. The aim was to construct questionnaires close to the Greek environment (also see Chapter 7).

institutions, (4) universities, (5) GSRT and other public agencies (this type includes two variations specially designed to cover special topic interviews (e.g. the patents and standards issues)) and (6) financial institutions.

The six major questionnaires are based upon the findings of the first 5 chapters and in essence test the basic ideas (codes of practice) developed in these chapters in the case of Greece.

The first two questionnaires (materials users and producers and manufacturing and construction firms) largely draw on findings of chapters 1,2,3 and partially of chapter 4 and 5. These two questionnaires are basically similar in terms of structure but they have some small variations in order to be more suitable to the nature of the construction field.

Questionnaires on research institutions, Universities, and especially public agencies mainly draw on chapters 1, 2, 4 and 5 and partially from chapter 3.

The first 5 major questionnaires share many common questions and up to a point, a common basic skeleton and logic: they examine how the selected organisations cope with the materials challenge, what strategies they have in place, what strategies they can put in place, how they integrate materials strategies into technology and business strategies, what supporting infrastructure they have in place and how they (technologically) interact with each other. Given that the questionnaires were designed to collect different data (that is different views) on the same phenomenon (materials strategies and their strategic implications in Greece) a good comparison (triangulation) and validation of findings was achieved.

The sixth questionnaire (financial institutes) has a different structure because its mission is different. It draws on the findings of chapter 5 and partially chapter 4 and 3 and examines whether there is a financial environment which favours the development and implementation of long term, risky technologies such as materials technologies in Greece.

A1.1.5.3: The Interviews

Four types of interviews were used, as shown in **Table M4**. The interviews and the data collection took place during a 3 months period in Greece (16/10/1996 - 16/1/1997). The aim was to achieve face to face direct interviews. This was achieved in 51 out of 57 interviews (see Table M5). A voice recorder was employed during some of the interviews. Most of the time, though, that was not possible because the interview was provided under the condition that a voice recorder or any other recording device would not be employed. The telephone interviews (there were six of them) do not include voice recordings either. In cases like these, the author was allowed to keep detailed notes and therefore a full record of the interviews exists even though this is a second best solution. The full, detailed script of the interviews is subjected to the **confidentiality agreement** made between the researcher and the interviewed participants.

Interpretation Keys	**Type of Interview**	**Number**
Face to Face Full Interview: the interview covered all the length of the appropriate questionnaire in a face to face interview.	FFFI	40
Face to Face Special Topic Interview: the interview covered parts of appropriate questionnaires or special design questionnaires were used (as in the case of PA2 for example).	FFSTI	11
Full length Telephone Interview: the interview covered all the length of the appropriate questionnaire in a telephone based interview.	FLTI	3
Special Topic Telephone Interview: the telephone interview covered parts of appropriate questionnaires or special design questionnaires were used.	STTI	3
	Total	**57**

Table M4: Classification of interviews according to type.

The interview time was 1.5 hours approximately. In some cases it lasted up to 2.5 hours with the initiative of the interviewee. There were cases where the voice recorder was asked to be temporarily or permanently deactivated during the provision of sensitive information. However, a **full record of all the interviews** has been made.

In general, the questionnaires enjoyed very good acceptance. There were only two major problems: in some cases despite the pilot cases, some questions proved to be too sensitive (e.g. how much do you spend / invest) or too demanding (e.g. specify and comment in detail and with figures on R&D expenditure, duration, aim etc.). The second problem was focused on the last part (final general questions including five general questions) section of all the questionnaires (similar in all the questionnaires): it proved too general to be answered at length and those who answered provided a variety of answers.

A1.1.6: Results Analysis

According to the preceding sections, the aim of the thesis **is to provide group results** reflecting general tendencies and not to focus on analysing in detail individual firms or other organisations. As such, the analytical unit from which conclusions are derived, is industrial sectors and national level indicators, not individual firms or case studies. A few individual case studies, presented in brief, were used to support the analysis of the sector findings either because they make excellent trend and strategy examples or because some of the reviewed sub-sectors are monopolies or oligopolies[29].

On this basis, the empirical field results and data were initially subjected to **qualitative and discriminative** analysis[30]. A pattern matching procedure (patterns matching the "codes of practice") was employed which involved several steps including the familiarisation, conceptualisation, recording, cataloguing, and linking - matching of concepts (Lastres 1993). Then, the results **were grouped** on the basis of industrial sectors and subsections (e.g. Metals producers - Ferrous metals producers, the role and the view of universities etc.) in order to provide comparable similarities and differences of the trends prevailing or emerging in each reviewed sector.

Final conclusions were derived on the comparison of the findings between: Public materials strategies and their implementation, metals Vs ceramics materials producers, and materials final users Vs materials producers. Additional observations were made on the basis of the available findings (e.g. the influence of the type of ownership on the characteristics of currently applied MSE strategies). These results assisted in deriving conclusions and creating strategic scenarios in the final chapter of this study.

This process was occasionally supported by the employment of simple statistical analysis and by secondary sources (such as the findings of the Greek technology foresight studies).

Extensive quantitative or numerical analysis such as regressions or even simulations using dummy variables was considered but it was not possible to be applied for the following reasons:

If a linear regression[31] approach was employed, that would involve the utilisation of a dependent and an independent set of variables in the form of:

[29] Nickel and Aluminium production sectors for example are dominated by only one company each.
[30] For the theoretical validation of the method see Yin (1994), Gill and Johnson (1994), Miles and Huberman (1994) and the other methodology references.
[31] Linear regression is the study of a linear relationship between one or many independent variables and a dependent variable (Goldberger 1994).

$$- Y = a + b (X) + E -$$

where (Y) is the dependent variable (or set of variables) and (X) the independent variable or the independent set of variables[32].

In the case of the present research, (Y) would be the quantitative reflection of a collective and cumulative effect of the action of a multi-dimensional and heavily interrelated set of independent variables (Xi) (the 'codes of practice') tested in say, each separate industrial sector. Note that each sector has its own individual characteristics influencing the outcome through correcting factors such as the residual (E). Then the attempted regression would include a set of multi-variant relationships in the form of :

$$- Yi = a + B1(X1) + B2(X2) + B3(X3) + \ldots + E -$$

where

$$(X1) = C1 + D1(Z1), (X2) = C2 + D2(Z2) \text{ etc.}$$

Then, the **statistical inference**, the most crucial part of any linear regression, would have to be performed. A **valid** statistical inference however, requires sufficient sample in terms of numbers of observations[33] (degrees of freedom). It is common practice in econometrics (Goldberger 1994) to require more than 60 observations for a proper regression analysis (especially in the case of structural regressions) and a valid statistical inference.

Given the necessary fragmentation of the research sample, the imposed qualitative requirements (selection mechanisms), the objective lack of sufficient numerical data and the oligopolistic or monopolistic nature of the reviewed sectors, the sample does **not** have the statistically sufficient number of observations with adequate homogeneity to provide consistent and valid statistical results.

Moreover, given that each sector operates under different conditions (i.e. initial or boundary conditions) different models (with respect to inference and correcting factors) would have to be built for each sector. In strictly statistical terms, a solution like that would make the sample even less statistically credible.

[32] Dependent variable: The phenomenon whose variation the researcher is trying to explain or understand; Independent variable: A phenomenon whose variation notionally explains or causes changes in the depended variable (Gill and Johnson, 1994).

[33] According to the central limit theory any distribution approximates the normal distribution for a sample larger than 60 observations (Goldberge1994). When the sample distribution approximates normal distributions, the estimation of statistical inference is more accurate and valid.

A1.1.7: Methodology References

With respect to technical and epistemological aspects, the general outlines (general approach) of the present methodology, the approach method of Part I and II and the development of the questionnaires are based on previously recorded international experience and well established practices, and on valuable advice generously provided by academic staff in City University Business School and by academic staff in Greece.

Unfortunately, verbal advice cannot be recorded. The following is a short list of academic works and previous studies and guides which provided valuable points of reference and inspiration during the design and development of the methodology of the present study :

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In addition tribute should be paid to the experience on building questionnaires and formulating research methodologies derived from the *Survey Methods I & II* Lectures and the *Research Methodology* lectures run by the *Social Science Research Unit* (SSRU) at City University, London.

ANNEX 1.2: General information about the interviewed/reviewed participants

Tables SA-SC present lists of participants in the current research including the employed code names and type of interview.

Code Name	Name of Organisation	Character / Nature of Activity	Type of Interview
C1	Confidential	Cement & Ceramics	FFFI
C2	Confidential	Cement & Refractors	FFFI
C2A	Confidential	Privately own R&D company specialised in Ceramics R&D	FFFI
C3	Confidential	Consumer Ceramics & Tiles	FFFI
C4	Confidential	Consumer Ceramics & House Equipment	FFFI
C5	Confidential	Ceramics & Refractors	FFFI
C6	Confidential	Refractors – Industrial Minerals	FFFI
M1	Confidential	Iron & Steel	FFFI
M2	Confidential	Nickel, Steel, Chromium, Raw materials.	FFFI
M3	Confidential	Alumina, Aluminium, other metals	FFFI
M4St	Confidential	Steel, Iron & Aluminium Castings.	FFFI
M5: M5St, M5Al, M5W, etc.	Industrial consortium under central management and ownership	Aluminium , Cooper, Wires & Cables, Steel, Welding materials Construction materials, metallic products etc.	FFFI
MU1	Industrial consortium under common management and ownership	High precision machinery, optics and electronics; Military equipment.	FFFI
MU2	Confidential	Aerospace materials & aircraft maintenance.	FFFI
MU3	Confidential	Weaponry and Armaments.	FFFI
MU4	Confidential	Explosives & Ammunition / Metal. Constructions	FFFI
MU5	Confidential	Shipbuilding and Repair Railway Equipment	FFFI
MU6	Confidential	Consumer electric appliances & electronics ; Communications Equipment & Cables	STTI
CON1	Confidential	Mech. & Civil Eng. Constructions	FFFI
CON2	Confidential	Civil Eng. Constructions (Foundations)	FFFI
CON3	Confidential	Civil Eng. Constructions (Buildings)	FFFI
CONEXP1 &2	Athens Metro Consortium for the Athens Underground.	Mechanical & Electrical Works Division	FFFI
CONEXP3	Consortium for the Athens Underground	Civil Works / Materials evaluation Laboratory	FFFI
CONEXP4	Technical Chamber of Greece	Professional Engineers Association ; Official to the Greek Government Consultancy Body for Scientific and Technological Issues.	FFFI
CONEXP5	""""	"""""	FFFI
CONEXP6	Technical Chamber of Greece: Section of Continuing Engineering Education	Continuing Education and Consultancy	FFFI

Table SA: Companies and Private sector

Code Name	Name of Organisation	Character / Nature of Activity	Position	Type of Interview
RI1	Technological Institution	Ceramics R&D	Confidential	FFFI
RI2	Technological Institution	Metallurgy , Surface Treatments and Metals R&DT	Confidential	FFFI
RI3	Research Institution	Energy Production, Distribution and Utilisation R&DT	Confidential	FFFI
AAC1	National Technical University of Athens	Chemical Engineering Dpt.	Reader	FFSTI
AAC2	""""	"""""	Senior Lecturer	FFSTI
AAC3	"""""	University Liaison Office	Confidential	FFSTI
PAC1	The of University Patras	Mechanical & Aeronautical Engineering Dpt.	Professor, Lab. Director	FFFI
PAC2	""""	""""	Reader, Lab. Vice Director	FFFI
PAC3	""""	"""""	Professor, Lab. Director	FFFI
PAC4	""""	""""	Senior Lecturer	FFFI
PAC5	""""	"""""	Reader, Division Vice President	FFSTI
PAC6	"""""	Chemical Engineering Dpt.	Professor, Lab. Director	FFSTI
PAC7	"""""	""""	Reader, Lab. Vice Director	FFSTI
PAC8	"""""	""""	Senior Lecturer	FFFI
PAC9	"""""	Div. of Applied Maths & Physics	Professor	FFFI
THAC1	Aristotle's Univ. of Salonika: Mechanical Engineering Dpt.	Division of Physical Metallurgy	Reader - Vice Director	FFFI
VAC1	University of Thessaly	Dpt. of Mechanical and Industrial Engineering	Senior Lecturer	FFFI
PS1	General Secretary of Research and Technology	Public Agency with the mission of Science, R&D, and Technology Planing.	Senior Official	FFFI
PS2	""""	"""""	Senior Official	FFFI
PS3	""""	"""""	Senior Official	FFSTI
PS4	Ministry of Education and Culture	Public Agency responsible for Higher Education.	Senior Official	FFFI
PS5	Ministry of Development: Standards and Attestation Agency	Public Agency responsible for national Standards and attestation policies	Confidential	FFSTI
PA1	Industrial Property Organisation (OBI)	Services with respect to legislation and registration of patents & copyrights	Confidential	FFSTI
PA2	Greek Standards Organisation (ELOT)	Patents & Standards of products, services, materials & processes	Confidential	FFSTI

Table SB: The Public Sector

Code Name	Name of Organisation	Character / Nature of Activity	Position	Type of Interview
F1	Financial & Industrial Research Institute (IOBE)	Research Institute specialised in Industrial and financial analysis and consultancy	Confidential	FFSTI
B1	Investment Bank	Investment Bank	Confidential	FFFI
B2	Commercial Bank	Commercial Bank	Confidential	FLTI
F2	Hellenic Investment Centre (ELKE)	Public Agency managing large investments in Greece	Confidential	STTI
VC1	Confidential	Venture Capital Company	Director	FFFI
VC2	Confidential	""""	Confidential	STTI
VC3	Confidential	""""	Confidential	FLTI
F3	Confidential	Financial Markets Consultancy	Confidential	FLTI

Table SC: The Financial Markets

Interpretation Keys:

Ci: Ceramics company (i)

Mi: Metals producer company (i)

MUi: Materials User Company (i)

CONi: Construction Company (i)

RIi: Research Institute (i)

CONEXPi: Construction Expert (i)

Fi: Finance Expert (i)

AC stands for Academic: AACi is Athens (University) Academic (i), PACi is Patras (University) Academic (i) , THAC is Thessalonica Academic and VAC is Volos Academic.

Bi: Bank (i)

VCi: Venture Capital Company (i)

PSi: Public Service - Servant (i).

Acronyms: St stands for Steel, Al for Aluminium, and Ni for Nickel.

ANNEX 1.3: THE QUESTIONNARES

- FIRMS
- CONSTRUCTION FIRMS
- RESEARCH INSTITUITONS
- UNIVERSITIES
- GSRT / PUBLIC AGENCIES
- BANKS-FINACIAL INSTITUTIONS

STRATEGIES IN ADVANCED MATERIALS IN GREECE

QUESTIONNAIRE - FIRMS

Ioannis (John) A. Kottakis
Autumn 1996

City University Business School
City University

Barbican Centre, London, EC2Y 8HB
Tel: 0171 - 477 8632 - Fax: 0171 - 477 8881

I. TECHNOLOGY AND CORPORATE STRATEGY

1) Does your company have a fully worked out technology strategy ___________?
Do you integrate the technology strategy with business units or the overall corporate strategy ?

2) Your company mainly depends on technologies build in - house or on acquired technologies and technology transfer mechanisms ?
In house ______________ Acquired ______________
What is the case in the materials technologies ?
In house ______________ Acquired ______________

3) When a technology is licensed, transferred or acquired, what mechanisms does exist to diffuse and "digest" this knowledge within the firm ? What is the case in the materials technologies ?

4) If you have organised corporate R&D laboratories describe the R&D portfolio selection mechanism / procedure.

5) How are your R&D efforts and departments organised ? How do they meet short, medium and long run business objectives ?
(i) Central corporate laboratories ____________?
(ii) Decentralised R&D labs attached to business units ____________?
(iii) A combination of the above ____________.

6)Your basic strategic aim is to cover:
Domestic markets ____________%
In international markets ____________%
Both ____________.
Do you intent to have the same aims during the next 5 - 10 years ?

7)Which industrial sectors are your bigger customers ? Please specify using descending importance order:

i)	iv)
ii)	v)
iii)	vi)

II. MATERIALS ACTIVITIES

1) Are your materials R&D efforts and strategies part of your technology strategy ? Is it difficult to combine the two process ____________? Comment on that .

2) Do you have a materials R&D dedicated group ____________? What is its mission ?

3) For how long have you been involved in materials R&D ?

4) Reasons to be involved in materials related R&D:

Reason	Very important	Important	No importance / indifferent.
Company's core strategy			
Group diversification strategy			
Demand from customers			
Create new products / markets			
Trouble – shooting			
Pressure from national competitors			
Pressure from international comp.			
Governmental policies.			
Other - Specify			

5) How large is your In - house R&D activities on materials in terms of:

- Annual expenditure as a percentage of your annual R&D budget: ____________.
- Number of researchers / People involved: ______________ .
- Time horizon: (Average project duration): ______________.
- Number of publications and patents: ______________.

6) Your materials related R&D efforts apply particular emphasis on basic (pre - competitive), applied or near market R&D and what is the average time span for each of these stages ? Comment on average project duration .

Emphasis	Type of Research	Average time span in years
	Basic - pre competitive	
	Applied	
	Near market	

7) In which areas of new or conventional materials does your company conduct R&D?
Specify class of materials (e.g. metals, ceramics, etc.) and application areas (e.g. for offshore applications, construction, functional applications etc.).

8) Do you mainly try to **improve existing** materials and their grades (e.g. steel, aluminium, cement) **OR create new** materials (e.g. new ceramics, new advanced grades of steel, smart materials etc.) ? Can you comment on the reasons ?

9) Do you mainly concentrate your R&D efforts on **structural** materials (e.g. metals for transport and construction, ceramics for construction, composites for structural applications) **OR** on **functional** materials (e.g. ceramics for energy applications - catalysts, photovoltaics, smart materials, semiconductors and others)?

10) Is your company 's R&D in materials involved in materials:

Performance
Properties
Structure & Composition
Synthesis & Processing

Which of the four elements attracts the most attention and why ?

10a) How do you asses S&P in particular with respect to your industrial AND services competencies ?

11) With respect to the following materials classifications which material's element attracts more attention:

Materials:	Properties	Performance	Synthesis & Processing	Structure & Composition
Metals				
Ceramics				
Plastics				
Composites				
Special materials				
New				
Incremental				
Structural				
Functional				
Other - Specify				

12) Your materials related R&D has usually the aim to:

Improving incremental and existing materials		Developing new materials	
Improve products		Improve products	
Produce new products		Produce new products	
Find new applications		Improve technologies	
Improve technologies		Develop new technologies	
Develop new technologies		Support innovative ideas	
Support innovative ideas		Improve manufacturing or S&P technologies	
Improve manufacturing or S&P technologies		Improve Machinery or equipment performance	
Improve Machinery or equipment performance		Other – Specify	
Other – Specify			

Can you provide a percentage (approximately)

13) How do you assess the importance of the following items in the development of these materials:

Item	Very important	Important	No importance / indifferent.
In house R&D			
Collaborative Arrangements			
Licensing agreements			
Acquisitions			
Other - which ?			

14) Which of the following would discourage you to be involved with materials R&D

Reason	Very Discouraging	Discouraging	Indifferent
Lack of skills			
Lack of Information			
Technology Availability			
Lack of Capital			
Other – Specify			

15) State the most outstanding problems you have when involved in materials R&D:

16) What are the major problems when you are trying to commercialise your research?

III. MANAGEMENT TOOLS AND CORE MATERIALS COMPETENCIES

1) Do you employ continuous improvement and Kaizen practices____________?

2) Is Total Quality Control (TQC) synonymous to Kaizen ?

3) Do you employ Simultaneous Engineering practices in product and manufacturing process design ___________?

4) Do you use the concept of team work ___________ ?

5) Comment on level and timing of participation of your suppliers (of materials - equipment) during product / process development

6) Do you have mechanisms for gathering and evaluating current and future customers needs?

7) Your favourite customer is the one who says:
- " I want products and services as cheap as possible and conventional, **OR**
- " I want something special "

Do you keep balance between them_______________?

8) What is your principle priority:
(A) Prise = Cost + Profit OR
(B) Price - Profit = Cost

TECHOLOGICAL CORE COMPETENCIES

9) Do you use the concept of core competency ____________ ?
What do you feature as your company's core competencies ____________?
Which core technologies are you investing in ____________?

10) Does your company see materials technologies and MSE skills, capabilities and know - how (S&P capabilities in particular) as an important, basic core competency or as a strategic asset and as a source of competitive growth in the future?

11) How have you been able to sustain or build these competencies ?

12) Please comment on your firm's patenting strategy and the procedure for publishing papers.

13) How do you evaluate technologies (materials technologies in particular) and how do you decide whether to develop a new technology in - house or acquire it from external sources ?

14) Do you have intelligence gathering mechanisms ? Do you use them in the case of materials technologies ?

15) Do you regularly invest in instrumentation and new machinery ____________ ?

16) Do you have computing, modelling and analysis skills _____________?
Do you apply analysis and modelling techniques in your R&D ______________?

17) Do you use third parties (e.g. universities) in order to carry out materials R&D? If you do, how frequent and how extended is this ?

HUMAN RESOURCES POLICIES

18) For what qualification are you looking for your materials people ?
Previous experience: Absolutely necessary or not ? ______________

19) Do you think the Greek educational system provides people well trained for your requirements or not? ______________.

20) Comment on:
- Technicians: Are they easy to be found?
- "Tacit " knowledge and training..

21) What is the relative balance of power between people with accounting / finance and technology / science / engineering background within your firm ____________? Roughly, what percentage of top managers have technical background __________?

IV. MATERIALS TECHNOLOGY ALLIANCES AND CO-OPERATION

1) How frequent is your company's technical interaction with:

	Frequent	Occasional	Rare or None
Customers			
Materials suppliers			
Equipment suppliers			
Competitors			
R&D Institutions			
Universities			
Others – which			

2) Does your company enter into R&D alliances and co - operation within Greece and / or abroad aiming the development and application of improved or new materials ?

	Greece	Abroad
Companies		
Universities		
Research Institutions		
Governmental Laboratories.		

3) What is the aim of these collaborations:

Aim of collaboration with:	Companies	Universities	Research Institutions	Gov. Labs
Basic Research (Learn)				
Applied research (Apply)				
Commercialisation				
Characterisation - Testing				
Education and training				
Standards				
Manufacturing / production				
Product Improvement				
Product Development				
New technologies				
Reducing cost and /or risk				
Other - Which				

4) What character does this R&D collaboration have, what is its duration and who covers the expenses?

Collaboration with	Companies	Universities	Research Inst.	Gov. Labs
Time Span				

Comments:

5) In **inter - firm** collaboration, please comment on the form and the aims of the collaboration. Do MSE technologies and capabilities have a strategic role?

6) Comment on the main points hampering inter - firm collaboration:

COLLABORATION WITH RESEARCH INSTITUTIONS - UNIVERSITIES.

7) Describe your interaction and relationships with other universities and research institutions in terms of:

Aim of collaboration:	R&D Level:
Programme Duration:	Budget:

8) What forms does this collaboration take ?

Establishment of co-operative agreement
Requesting specific research to be conducted on contract
Donating / investing funds to create a chair or laboratory
Dispatching researchers,
Other.

9) Comment on the main points hampering collaboration between firms, universities and research institutes :

Institutional barriers / Legal Barriers
Obsolescence of University research facilities
Rigidity of Greek university Budget system
Conservatism / Out of date interests and academic curricula.
Economic constrains - specify

10) Which type of organisation / institution do you consider as the most important partner in collaborative arrangements in materials technologies:
In order of importance: 4 = most important, 0 = no importance

Greek Firms	Universities	Research Inst.	Gov. Labs	Foreign Firms

V. INTERACTIONS WITH NATIONAL AND INTERNATIONAL R&D ACTIVITIES

1) Can you state the number of activities / projects developed with and without government support in the following categories (with respect to materials technologies):

Aim of collaboration	With Gov. support	Without Gov. support
Basic Research		
Applied research		
Commercialisation		
Characterisation – testing		
Education and training		
Standards		
Manufacturing / production		
New technologies		
New / Improved Products		
Other – Which		

2) Do you participate in the following collaborative programmes? How many times?

YPER: BRITE / EURAM:
PABE: STRIDE:
EPET: OTHER INTERNATIONAL:
PENED: OTHER NATIONAL:

What materials class and application is involved?

3) Can you comment on you experience from your participation in these programmes?

Advantages	National Program.	International Program.
Access to knowledge and equipment		
Spread of R&D cost and Risk		
Multidisciplinary approach		
Training of personnel		
Assistance in product Dev.		
Assistance in production problems		
New technology implementation		
Other – Which		
Problems		
Bureaucracy / slowness		
hidden high costs		
Distrust / communication problems		
Co-ordination problems		
Clear aims problems		
Agreements on standards		
Transfer of technology		
Others – Specify.		

4) For the National programmes:
Do you estimate that each of the above R&D schemes have a separate materials strategy or there are some general lines throughout all initiatives? Are these initiatives used as arms - instruments of a solid national materials strategy?

5) For BRITE / EURAM and other international programmes:
Comment on your experience from participation to the BRITE / EURAM programmes and other similar international activities.

6) Comment on the use and implementation of the research results of the international programmes with respect to tangible returns such as industrial applications, patents and commercialised products and services. How relevant these programmes were to the materials needs of the Greek industry and economy?

7) Describe your interaction and relationships with GSRT and other public agencies.

8) Does your company see any need for a national materials policy / strategy? If so, what should it comprise?

	Very Important	Important	Not so important
Identify areas of importance			
Provide directions			
Inform for international Developments			
Support basic research			
Support applied research			
Promote industrial networks			
Initiate University / Industry collaborations			
Education / Training (including continuous education)			
Standards			
Research networks and institutions			
Promote international co-operation			
Procurements			
Tax incentives			
Regulations			
Provide low cost capital for high tech investment			
Information diffusion mechanisms			
Intellectual property protection			
Trade regulation			
Collaboration promotion[1]			
Other – specify			

If some of the above are important but they don't happen comment on where the problem is.

[1]Legal and institutional framework for collaboration promotion between firms - universities - research institutions.

VI. FINANCE OF R&D

1) How do you fund your R&D activities (In General - in Materials) ?
Provide (if possible) the percentages

Government: ___________ Own resources: ___________
Domestic Collaborations: ___________ Parent Company: ___________
International collaborations: ___________ Subsidiary Companies: ___________

2)Your R&D expenditures are:
a) Seen as an overhead with the annual budget as a fraction of sales or other performance indication.
b) Dominated by the "net present value " rule, with respect to each individual project
c) Seen as strategic investment and therefore the R&D portfolio is constantly monitored and evaluated .

3) Are technological investments made with **a long term vie**w to develop technological capabilities and financial returns are of secondary importance or are they subject to short - term and medium term financial constraints ?
Does it depend from the technology ? What is the case for materials related technologies ?

4) Comment on your basic problems financing R&D .

5) Describe your relationships with banks and financial institutions.

6) Comment on national and bank policies when you want capital for technology issues.

VII. FINAL GENERAL QUESTIONS:

1) Given that Greece has some excellent pockets of basic research, what do you think is the main reason(S) for obstructing and preventing the development and commercialisation of high technology in Greece ? Do theses reasons apply in the case of materials ?

2) How do you view the prospects of new and advanced materials technologies in the next few years in Greece ? What are the major problems facing their commercialisation in Greece ??

3) What are the key materials and capabilities the Greek industry needs in order to remain or become competitive ?

STRATEGIES IN ADVANCED MATERIALS IN GREECE

QUESTIONNAIRE - CONSTRUCTION FIRMS

Ioannis (John) A. Kottakis
Autumn 1996

City University Business School
City University

Barbican Centre, London, EC2Y 8HB
Tel : 0171 - 477 8632 - Fax : 0171 - 477 8881

I. TECHNOLOGY AND CORPORATE STRATEGY

1) Does your company has a fully worked out technology strategy ___________?
Do you integrate the technology strategy with business unit or the overall corporate strategy?

2) Does your company mainly depend on technologies build in - house or on acquired technologies and technology transfer mechanisms?
In house _____________ Acquired ____________________
What is the case with materials technologies?
In house _____________ Acquired _____________

3) When a technology is licensed, transferred or acquired, what mechanisms does exist to diffuse and "digest" this knowledge within the firm? What is the case with materials technologies?

4) If you have organised corporate R&D laboratories describe the R&D portfolio selection mechanism / procedure. How are your R&D efforts and departments organised?

5) If you don't have organised R&D laboratories how do you cope with near market problems, "on site production" problems, and new technology challenges? Do you plan to create R&D departments and what their mission will be?

6) Your basic strategic aim is to cover:
Domestic markets __________ %
International markets ________ %
Both _________
Do you intent to have the same aims during the next 5 - 10 years?

7) Which industrial sectors are your bigger customers? Please specify using descending importance order:

i)	iv)
ii)	v)
iii)	vi)

II. MATERIALS ACTIVITIES

1) Are your materials R&D efforts and strategies part of your technology strategy?
Is it difficult to combine the two process ___________? Comment on that.

2) Do you have a materials "R&D" or a materials trouble - shooting dedicated group? What is its mission? What are your main materials based problems and needs?

3) For how long have you been involved in materials R&D?

4) Reasons to be involved in materials related R&D:

Reason	Very important	Important	No importance / indifferent.
Company's core strategy			
Group diversification strategy			
Demand from customers			
Create new products / markets			
Trouble – shooting			
Pressure from national competitors			
Pressure from international comp.			
Governmental policies.			
Other – Specify			

5) How large is your In - house R&D activities on materials in terms of:
- Annual expenditure as a percentage of your annual R&D budget: ____________.
- Number of researchers / People involved: __________
- Time horizon: (Average project duration): __________
- Number of publications and patents: ______________.

6) Your materials related R&D efforts apply particular emphasis on basic (pre - competitive), applied or near market R&D and what is the average time span for each of these stages? Comment on average project duration.

Emphasis	Type of Research	Average time span in years
	Basic – pre competitive	
	Applied	
	Near market	

7) In which areas of new or conventional materials does your company conduct R&D? Specify class of materials (e.g. metals, ceramics, etc.) and application areas (e.g. for offshore applications, construction, functional applications etc.).

8) Do you mainly try to **improve existing** materials and their grades (e.g. steel, aluminum, cement) **OR create new** materials (e.g. new ceramics, new advanced grades of steel, smart materials etc.)? Can you comment on the reasons?

9) Do you mainly concentrate your R&D efforts on **structural** materials (e.g. metals for transport and construction, ceramics for construction, composites for structural applications) **OR** on **functional** materials (e.g. ceramics for energy applications - catalysts, photovoltaics, smart materials, semiconductors and others) ?

10) Is your company 's R&D in materials involved in materials:

Performance
Properties
Structure & Composition
Synthesis & Processing

Which of the four elements attracts the most attention and why?

10a) How do you asses S&P and "on site" or fabrication capabilities in particular with respect to your industrial AND services competencies?

11) With respect to the following materials classifications which material's element attracts more attention:

Materials:	Properties	Performance	Synthesis & Processing	Structure & Composition
Metals				
Ceramics				
Plastics				
Composites				
Special materials				
New				
Incremental				
Structural				
Functional				
Other - Specify				

12) Your materials related R&D has usually the aim to:

Improving incremental and existing materials		Developing new materials	
Improve products		Improve products	
Produce new products		Produce new products	
Find new applications		Improve technologies	
Improve technologies		Develop new technologies	
Develop new technologies		Support innovative ideas	
Support innovative ideas		Improve manufacturing or S&P technologies	
Improve manufacturing or S&P technologies		Improve Machinery or equipment performance	
Improve Machinery or equipment performance		Other - Specify	
Other - Specify			

Can you provide a percentage (approximately)

13) How do you assess the importance of the following items in the development of incremental or new materials:

Item	Very important	Important	No importance / indifferent.
In house R&D			
Collaborative Arrangements			
Licensing agreements			
Acquisitions			
Other - which?			

14) Which of the following would discourage you to be involved with materials R&D?

Reason	Very Discouraging	Discouraging	Indifferent
Lack of skills			
Lack of Information			
Technology Availability			
Lack of Capital			
Other - Specify			

15) State the most outstanding problems you have when involved in materials utilisation - application and possibly "R&D " and what are the major problems when you are trying to commercialise your research? (E.g.: Lack of promotion mechanisms)

16) What are the basic problems for the implementation of emerging technologies in the construction field? (e.g. robotics, automation, industrialisation, new materials)

III. MANAGEMENT TOOLS AND CORE COMPETENCIES

1) Do you employ continuous improvement and Kaizen practices___________?

2) Do you employ Simultaneous Engineering practices (simultaneous selection of material - construction method during the construction design) ___________?

3) Do you use the concept of team-work___________ ?

4) Describe your relationships with your basic materials and machinery suppliers. What is the level of their participation during "product" and processes development?

5) Do you provide feed-back for the materials related problems you have to your suppliers? Do they invite you to participate and have a say during the development of new materials and S&P technologies and their manufacturing process?

6) Do you have mechanisms for gathering and evaluating current and future customers needs?

7) Your best customer is the one who says:
1. "I want products and services as cheap as possible and conventional" OR
2. "I want something special "
Do you keep balance between them ___________ ?

8) What is your approach to cost ?
(A) Price (of project) = Cost + Profit, OR
(B) Price - Profit = Cost

TECHOLOGICAL CORE COMPETENCIES

9) Do you use the concept of core competency ____________?
What do you feature as your company's core competencies ____________?
Which core technologies are you investing in ___ _________?

10) Does your company see materials technologies and MSE skills, capabilities and know - how (S&P capabilities in particular) as an important, basic core competency or as a strategic asset and as a source of competitive growth in the future ?

11) How have you been able to sustain or build these competencies?

12) Please comment on your firm's patenting strategy and the procedure for publishing papers.

13) How do you evaluate technologies (materials technologies in particular) and how do you decide whether to develop a new technology / capability in - house or acquire it from external sources?

14) Do you have intelligence gathering mechanisms with respect to new construction technologies? Do you use them in the case of materials technologies?

15) Do you regularly invest in instrumentation and new machinery_________?

16) Do you have computing, modeling and analysis skills ___________ ?

17) Do you use third parts (e.g. universities) in order to carry out materials R&D? If you do, how frequent and how extended is this?

HUMAN RESOURCES POLICIES

18) For what qualification are you looking for your materials people? Is previous experience: Absolutely necessary or not?

19) Do you think the Greek educational system provides people well trained for your requirements or not? ______________.

20) Comment on:

- Technicians: Are they easy to be found?
- "Tacit " knowledge and training..

21) What is the relative balance of power between people with accounting / finance and technology / science / engineering background within your firm ____________?
Roughly, what percentage of CEOs have technical background______________ ?

IV. MATERIALS TECHNOLOGY ALLIANCES AND CO-OPERATIONS

1) How frequent is your company's technical interaction with:

	Frequent	Occasional	Rare or None
Customers			
Materials suppliers			
Equipment suppliers			
Competitors			
R&D Institutions			
Universities			
Others - which			

2) Does your company enter into R&D alliances and co - operation within Greece and / or abroad aiming the development and application of improved or new materials and their on-site processing technologies?

	Greece	Abroad
Companies		
Universities		
Research Institutions		
Governmental Laboratories.		

3) What is the aim of these collaborations:

Aim of collaboration with:	Companies	Universities	Research Institutions	Gov. Labs
Characterisation – Testing				
Education and training				
Standards				
Development of works				
Product Improvement				
Product Development				
New technologies				
Reducing cost and /or commercialisation risks				
Other - Which				

4) What character does this R&D collaboration have, what is its duration and who covers the expenses?

Collaboration with	Companies	Universities	Research Inst.	Gov. Labs
Duration				

Comments:

5) In **inter - firm** collaboration, please comment on the form and the aims of the collaboration. Do MSE technologies and capabilities have a strategic role?

6) Comment on the main points hampering inter - firm collaboration.

COLLABORATIONS WITH RESEARCH INSTITUTIONS - UNIVERSITIES.

7) Describe your interaction and relationships with universities and research institutions in terms of :

Aim of collaboration:	R&D Level:
Programme Duration:	Budget:

8) What forms does this collaboration take?

Establishment of co-operative agreement
Requesting specific research to be conducted on contract
Donating / investing funds to create a chair or laboratory
Dispatching researchers,
Other.

9) Comment on the main points hampering collaboration between firms, universities and research institutes:

Institutional barriers / Legal Barriers
Obsolescence of University research facilities
Rigidity of Greek university Budget system
Conservatism / Out of date interests and academic curricula.
Economic constrains – specify

10) Which type of organisation / institution do you consider as the most important partner in collaborative arrangements in materials technologies:

Greek Firms	Universities	Research Inst.	Gov. Labs	Foreign Firms

In order of importance: 4 = most important, 0 = no importance

V. INTERACTIONS WITH NATIONAL AND INTERNATIONAL R&D ACTIVITIES

1) Can you state the number of activities / projects developed with and without government support in the following categories (with respect to materials technologies):

Aim of collaboration	With Gov. support	Without Gov. support
Basic Research		
Applied research		
Commercialisation		
Characterisation – testing		
Education and training		
Standards		
Manufacturing / production		
New technologies		
New / Improved Products		
Other – Which		

2) Do you participate in the following collaborative programmes? How many times?

YPER:
PABE:
EPET:
PENED:
BRITE / EURAM:
STRIDE:
OTHER INTERNATIONAL:
OTHER NATIONAL:

What materials class and application is involved?

3) Can you comment on you experience from your participation in these programmes?

Advantages	National Program.	International Program.
Access to knowledge and equipment		
Spread of R&D cost and Risk		
Multidisciplinary approach		
Training of personnel		
Assistance in product Dev.		
Assistance in production problems		
New technology implementation		
Other – Which		
Problems		
Bureaucracy / slowness		
hidden high costs		
Distrust / communication problems		
Co-ordination problems		
Clear aims problems		
Agreements on standards		
Transfer of technology		
Others - Specify.		

4) For the National programmes:
Do you estimate that each of the above R&D schemes have a separate materials strategy or there are some general lines throughout all initiatives? Are these initiatives used as arms - instruments of a solid national materials strategy?

5) For BRITE / EURAM and other international programmes:
Comment on your experience from participation to the BRITE / EURAM programmes and other similar international activities.

6) Comment on the use and implementation of the research results of the international programmes with respect to tangible returns such as industrial applications, patents and comerciallised products and services. How relevant these programmes were to the materials needs of the Greek industry and economy?

7) Describe your interaction and relationships with GSRT and other public agencies.

8) Does your company see any need for a national materials policy / strategy? If so, what should it comprise?

	Very Important	Important	Not so important
Identify areas of importance			
Provide directions			
Inform for international Developments			
Support basic research			
Support applied research			
Promote industrial networks			
Initiate University / Industry collaborations			
Education / Training (including continuous education)			
Standards			
Research networks and institutions			
Promote international co-operation			
Procurements			
Tax incentives			
Regulations			
Provide low cost capital for high tech investment			
Information diffusion mechanisms			
Intellectual property protection			
Trade regulation			
Collaboration promotion[1]			
Other – specify			

If some of the above are important but they don't happen comment on where the problem is.

[1]Legal and institutional framework for collaboration promotion between firms - universities - research institutions.

VI. FINANCE OF R&D

1) How do you fund your "R&D" activities (In General - in Materials)?
Provide (if possible) percentages.

Government: ___________ Own resources: ___________
Domestic Collaborations: ___________ Parent Company: ___________
International collaborations: ___________ Subsidiary Companies: ___________

2) Your R&D expenditures are:
a) Seen as an overhead with the annual budget as a fraction of sales or other performance indication,
b) Dominated by the "net present value " rule, with respect to each individual project
c) Seen as strategic investment and therefore the R&D portfolio is constantly monitored and evaluated.

3) Are technological investments made with **a long-term** view to develop technological capabilities and financial returns are of secondary importance or are they subject to short - term and medium term financial constraints? Does it depend from the technology? What is the case for materials related technologies?

4) Comment on your basic problems financing "R&D ".

5) Describe your relationships with banks and financial institutions.

6) Comment on national and bank policies when you want capital for technology issues.

VII. FINAL GENERAL QUESTIONS:

1) Given that Greece has some excellent pockets of basic research, what do you think is the main reason(s) for obstructing and preventing the development and commercialisation of high technology in Greece? Do these reasons apply in the case of materials?

2) How do you view the prospects of new and advanced materials technologies in the next few years in Greece? What are the major problems facing their commercialisation in Greece?

3) What are the key materials and capabilities the Greek industry needs in order to remain or become competitive?

STRATEGIES IN ADVANCED MATERIALS IN GREECE

QUESTIONNAIRE - RESEARCH INSTITUTIONS

Ioannis (John) A. Kottakis
Autumn 1996

City University Business School
City University

Barbican Centre, London, EC2Y 8HB
Tel : 0171 - 477 8632 - Fax : 0171 - 477 8881

I. TECHNOLOGY AND CORPORATE STRATEGY

1) Does your Research Institute have a fully worked out technology strategy_______?
Is it a part of the overall national technology strategy _____________?

2) Describe the R&D portfolio selection mechanism / procedure. Who decides for directions, budgets and duration of projects ?

3) How are your R&D efforts and departments organised ?
How do these meet short, medium and long run R&D objectives ?

4) Do you mainly work on build in - house technologies or on acquired technologies?
In house _____________ Acquired _____________
What is the case with materials technologies ?
In house _____________ Acquired _____________

5) When a technology is licensed, transferred or acquired, what mechanisms does exist to diffuse and "digest" this knowledge within the Institution in order to be able to diffuse it in the industrial base? What is the case in the materials technologies ?

6)Your basic strategic aim is to :
Produce new knowledge ___________
Apply Knowledge ___________
Both ___________
Do you intent to have the same aims during the next 5 - 10 years ?

7) The end users of your research results are :
By market : Greek market ___________% Foreign market ___________ %
By Industrial Sector : Please specify using descending priority order :
i) iv)
ii) v)
iii) vi)
By type of sponsor : Industry ___________% Public sector ___________ %

II. MATERIALS ACTIVITIES

1) Do you have a materials R&D dedicated group ____________? What is its mission?

2) Are your materials activities formed independently of your other research activities?

3) Are your materials R&D efforts and activities a part of a national materials strategy _________ ? Is it difficult to combine the two process____________? Comment on that .

4) For how long has your institute been involved in materials R&D ?

5) Reasons to be involved in materials related R&D :

Reason	Very important	Important	No importance / indifferent.
Research institute 's strategy			
Governmental policies			
Support generic technologies			
Industry Trouble - shooting			
Demand from "customers"			
National Defence/Security			
Other - Specify			

6) How large is your In - house R&D activities on materials in terms of :
Annual expenditure as a percentage of your annual R&D budget: _____________.
Number of researchers / People involved : ______________ .
Time horizon : (Average project duration) : ______________.
Number of publications and patents : ______________.

7) Your materials related R&D efforts apply particular emphasis on basic (pre - competitive), applied or near market R&D and what is the average time span for each of these stages ? Comment on average project duration .

Emphasis	Type of Research	Average time span in years
	Basic - pre competitive	
	Applied	
	Near market	

8) In which areas of new or conventional materials does your Institution conduct R&D
Specify class of materials (e.g. metals, ceramics, etc.) and application areas (e.g. for offshore applications, construction, functional applications etc.).

9) Do you mainly try to **improve existing** materials and their grades (e.g. steel, aluminium, cement) **OR create new** materials (e.g. new ceramics, new advanced grades of steel, smart materials etc.) ? Can you comment on the reasons ?

10) Do you mainly concentrate your R&D efforts on **structural** materials (e.g. metals for transport and construction, ceramics for construction, composites for structural applications) **OR** on **functional** materials (e.g. ceramics for energy applications - catalysts, photovoltaics, smart materials, semiconductors and others) ?

11) Is your Institute's R&D in materials involved in materials :

Performance
Properties
Structure & Composition
Synthesis & Processing

Which of the four elements attracts the most attention and why ?

11a) How do you asses S&P in particular with respect to industrial competencies ?

12) With respect to the following materials classifications which material's element attracts more attention :

Materials :	Properties	Performance	Synthesis & Processing	Structure & Composition
Metals				
Ceramics				
Plastics				
Composites				
Special materials				
New				
Incremental				
Structural				
Functional				
Other - Specify				

13) Your materials related R&D has usually the aim to :

Improving incremental and existing materials		Developing new materials	
Improve products		Improve products	
Produce new products		Produce new products	
Find new applications		Improve technologies	
Improve technologies		Develop new technologies	
Develop new technologies		Support innovative ideas	
Support innovative ideas		Improve manufacturing or S&P technologies	
Improve manufacturing or S&P technologies		Improve Machinery or equipment performance	
Improve Machinery or equipment performance		Support Defence R&D	
Support Defence R&D		Other - Specify	
Other - Specify			

Can you provide a percentage (approximately)

14) How do you assess the importance of the following items in the development of incremental or new materials :

Item	Very important	Important	No importance / indifferent.
In house R&D			
Collaborative Arrangements			
Licensing agreements			
Acquisitions			
Other - which ?			

15) State the most outstanding problems you have when involved in materials R&D.

16) What are the major problems when you are trying to commercialise or diffuse the results of your research ?

Reason	Very Discouraging	Discouraging	Indifferent
Lack of skills			
Lack of domestic market			
Lack of good extrinsic "product" credibility			
Lack of promotion mechanisms			
Lack of Information			
Lack of supporting Technologies			
Legal - Administrative Difficulties			
Lack of Capital			
Other - Specify			

17) Comment on the use and implementation of your research results with respect to industrial applications, governmental programmes, patents and commercialisation.

18) Do you see materials capabilities as a basic core competency upon which Industry can build technology and corporate strategies ____________?

19) Which industrial sectors do you see as the most successful innovators in materials and materials technologies in the 1990's ? Please rank in descending order of importance.

Chemicals & Petrochemicals
Metal producers
Ceramic producers
Machinery producers
Electrical equipment firms
Transportation firms
Constructors (Mechanical works)
Textiles
Plastics producers
Cement producers
Defence industry
Electronics firms
Telecommunications firms
Constructors (Civil works)
Food
Others

III. MANAGEMENT TOOLS AND CORE MATERIALS COMPETENCIES

1) Do you employ continuous improvement and Kaizen practices ___________?

2) Comment on level and timing of participation of your sponsors during the project development .

3) Do you use team work during the development and implementation of a new project or to diffuse new knowledge into the institution ?

4) Do you have mechanisms for gathering and evaluating current and future "customers" needs and technologies ?

5) What is your innovation approach ? Comment on :
Science = Technology ___________ and
Technology = Innovation ___________.

TECHNOLOGICAL CORE COMPETENCIES

6) Do you use the concept of core competency ____________ ?
What do you feature as your Institute's core competencies ____________?

7) How have you been able to sustain or build these competencies?

8) Does your Institute see materials technologies and MSE skills, capabilities and know - how as an important strategic asset and as a source of national competitive growth in the future ____________?

9) Please comment on your Institute' s patenting strategy and the procedure for publishing papers.

10) Do you have technology monitoring and intelligence gathering mechanisms ?
Do you use them in the case of materials technologies ?

11) Do you regularly invest in instrumentation and new machinery____________ ?
Who covers the cost ?

12) Do you have in-house computing, modelling and analysis skills _____________?
Do you apply analysis and modelling techniques in your R&D ? ______________

13) Do you use third parties (e.g. universities) in order to carry out materials R&D? If you do, how frequent and how extended is this ?

HUMAN RESOURCES POLICIES

14) For what qualification are you looking for your materials people ?

15) Do you think the Greek educational system provides people well trained for your requirements or not ? ______________. Comment on that

16) Technicians : Are they easy to be found ?
Comment on 'tacit' knowledge and training.

17) What is the relative balance of power between people with accounting / finance and technology / science / engineering background within your Institution ________? Roughly, what percentage of CEOs have technical background ______________ ?

IV. MATERIALS TECHNOLOGY ALLIANCES AND CO-OPERATION

1) How frequent is your company's technical interaction with :

	Frequent	Occasional	Rare or None
Customers			
Materials suppliers			
Equipment suppliers			
Competitors			
R&D Institutions			
Universities			
Others - which			

2) Does your institute enter into R&D alliances and co - operation within Greece and / or abroad aiming the development and application of improved or new materials ?

	Greece	Abroad
Companies		
Universities		
Research Institutions		
Governmental Laboratories.		

3) What is the aim of these collaborations :

Aim of collaboration with :	Companies	Universities	Research Institutions	Gov. Labs
Basic Research (Learn)				
Applied research (Apply)				
Commercialisation				
Characterisation - Testing				
Education and training				
Standards				
Manufacturing / production				
Product Improvement				
Product Development				
New technologies				
Reducing cost and /or risk				
Other - Which				

4) What character does this R&D collaboration have ?? What is its duration ? Who covers the expenses?

Collaboration with	Companies	Universities	Research Inst.	Gov. Labs
Time Span				

Comments :

LINKS WITH INDUSTRY

5) In collaborations with firms please comment on the form and the aims of the collaboration. What is the average duration and the included budget ?

6) Describe the form your co-operation takes with industry :

Establishment of co-operative agreement
Requesting specific research to be conducted on contract
Donating / investing funds to create a laboratory
Dispatching researchers
Other.

7) Which of the following sectors industrial sectors has the higher participation / contribution to your research programmes (with respect to materials). Prioritise from 1 to 16.

Chemicals & Petrochemicals
Metal producers
Ceramic producers
Machinery producers
Electrical equipment firms
Transportation firms
Constructors (Mechanical works)
Textiles
Plastics producers
Cement producers
Defence industry
Electronics firms
Telecommunications firms
Constructors (Civil works)
Food
Others

8) Comment on the main points hampering Institution - industry collaboration :

Institutional barriers / Legal barriers
Obsolescence of Institution research facilities
Rigidity of Greek Institutional Budget system
Conservatism
Economic constrains from the industry's point of view (e.g. no tax incentives).
Other.

LINKS WITH RESEARCH INSTITUTIONS - UNIVERSITIES.

9) Describe your interaction and relationships with universities and other research institutions.

Aim of collaboration :	R&D Level :
Av. Project Duration :	Budget :

10) What form does this collaboration take ?

Establishment of co-operative agreement
Requesting specific research to be conducted on contract
Dispatching researchers
Other.

11) Comment on the main points hampering inter institution and institution - university collaboration :

Institutional barriers / Legal Barriers
Obsolescence of research facilities
Rigidity of Budget system
Conservatism
Economic constrains – specify
Other – specify

12) To which country do you mainly turn to gain experience and be informed for R&D strategies :

Country	1980 - 1990	1990 - 1995	Now	2000
US				
Japan				
Europe. Which :				
Others. Which :				

13) Which type of organisation / institution do you consider as the most important partner in collaborative arrangements in materials technologies :
In order of importance : 4 = most important , 0 = no importance

Companies	Universities	Research Instit.	Gov. Labs	Foreign Instit. / Firms

V. INTERACTIONS WITH NATIONAL AND INTERNATIONAL R&D ACTIVITIES

1) Can you identify the number of activities / projects developed with and without government support in the following categories (with respect to materials technologies) :

Aim of collaboration	With Gov. support	Without Gov. support
Basic Research		
Applied research		
Commercialisation		
Characterisation – testing		
Education and training		
Standards		
Manufacturing / production		
New technologies		
New / Improved Products		
Other - Which		

2) Do you participate in the following collaborative programmes ?

YPER : BRITE / EURAM :
PABE : STRIDE :
EPET : OTHER INTERNATIONAL :
PENED : OTHER NATIONAL :

What materials class and application are involved ?

3) Can you comment on you experience from your participation in these programmes

Advantages	National Program.	International Program.
Access to knowledge and equipment		
Spread of R&D cost and Risk		
Multidisciplinary approach		
Training of personnel		
Assistance in product Dev.		
Assistance in production problems		
New technology implementation		
Other - Which		
Problems	National Program	International Program
Bureaucracy / slowness		
hidden high costs		
Distrust / communication problems		
Co-ordination problems		
Clear aims problems		
Agreements on standards		
Transfer of technology		
Others - Specify.		

4) For the national programmes :
Does each of the above initiatives have a separate materials strategy or there are some general lines throughout all initiatives ? Are these initiatives used as arms - instruments of a solid national materials strategy ?

5) For BRITE / EURAM and other international programmes
Comment on your experience from participation to the BRITE / EURAM programmes and other similar international activities.

6) Comment on the use and implementation of these programmes research results with respect to industrial applications, governmental programmes, patents and commercialisation in Greece. How relevant these programmes were to the materials needs of the Greek industry and economy ?

7) Describe your interaction and relationships with GSRT and other public agencies.

8) Does your Institution see any need for a national materials policy / strategy ? If so, what should it comprise ?

	Very Important	Important	Not so important
Identify areas of importance			
Provide directions			
Inform for international Developments			
Support basic research			
Support applied research			
Promote industrial networks			
Initiate University / Industry collaborations			
Education / Training			
Standards			
Research networks and institutions			
Promote international co-operation			
Procurements			
Tax incentives			
Regulations			
Provide low cost capital for high tech investment			
Information diffusion mechanisms			
Intellectual property protection			
Trade regulation			
Collaboration promotion[1]			
Other – specify			

If some of the above are important but they don't happen comment on where the problem is.

[1]Legal and institutional framework for collaboration promotion between firms - universities - research institutions.

VI. FINANCE OF R&D

1) How do you fund your R&D activities (In General - in Materials) ?
Provide (if possible) the percentage derived from :
Government : ___________ Own resources : ___________
Domestic Collaborations : ___________ International collaborations : ___________

2) Do you see R&D expenditures as a strategic investment and therefore the R&D portfolio is constantly monitored and evaluated ?

3) Comment on your basic problems financing R&D .

4) Describe your relationships with banks and financial institutions.

5) Comment on financial markets and banking policies when you want capital for technology issues.

6) In general in Greece : Are technological investment made with **a long term view** to develop technological capabilities and financial returns are of secondary importance or are they subject to short - term and medium term financial constraints ? Does it depend from the technology ? What is the case for materials related technologies ?

VII. FINAL GENERAL QUESTIONS

1) Given that Greece has some excellent pockets of basic research, what do you think is the main reason(s) for obstructing and preventing the development and commercialisation of high technology in Greece ? Do theses reasons apply in the case of materials ?

2) How do you view the prospects of new and advanced materials technologies in the next few years in Greece ? What are the major problems facing their commercialisation in Greece ??

3) What are the key materials and capabilities the Greek industry needs in order to remain or become competitive ?

4) What are the key areas in which Greece needs to develop skills in Materials Science and Engineering ? Can you list specific groups of materials or technologies ?

5)What directions a national materials strategy should have and which areas should the government promote and support as part of a national strategy ?

STRATEGIES IN ADVANCED MATERIALS IN GREECE

QUESTIONNAIRE - UNIVERSITIES

Ioannis (John) A. Kottakis
Autumn 1996

City University Business School
City University

Barbican Centre, London, EC2Y 8HB
Tel : 0171 - 477 8632 - Fax : 0171 - 477 8881

I. MATERIALS ACTIVITIES[1]

1) Reasons to be involved in materials related R&D (Apart from teaching) :

Reason	Very important	Important	No importance / indifferent.
University Policy			
Governmental Policy			
Demand from Industry			
Defence R&D			
Economic Reasons			
Other Academic Reasons			
Other - Specify			

2) **Which areas** of new or conventional materials attract most of the university materials related R&D and research activities ? Can you specify (approximately) **class** of materials (e.g. metals, ceramics, etc.) and **application areas** (e.g. for offshore applications, construction, functional applications etc.).

3) University materials related R&D activities have mainly the aim to **improve existing** materials and their grades (e.g. steel, aluminium, cement) **OR create new** materials (e.g. new ceramics, new advanced grades of steel, smart materials etc.) ? Can you comment on the reasons ?

4) Most of the university materials related R&D is concentrated on **structural** materials (e.g. metals for transport and construction, ceramics for construction, composites for structural applications) **OR** on **functional** materials (e.g. ceramics for energy applications - catalysts, photovoltaics, smart materials, semiconductors and others)

5) Most of the university materials related R&D is focused on materials :

Performance
Properties
Structure & Composition
Synthesis & Processing

Which of the four elements attracts the most attention and why ?

5a) How do you asses S&P in particular with respect to industrial AND services competencies?

[1]**Note : Chemicals are not included in the present study**

6) With respect to the following materials classifications which material's element attracts more attention (with respect to university's R&D):

Materials	Properties	Performance	Synthesis & Processing	Structure & Composition
Metals				
Ceramics				
Plastics				
Composites				
Special materials				
New				
Incremental				
Structural				
Functional				
Other - Specify				

7) Academic materials related R&D has usually the aim to :

Improving incremental and existing materials		Developing new materials	
Improve products		Improve products	
Produce new products		Produce new products	
Find new applications		Improve technologies	
Improve technologies		Develop new technologies	
Develop new technologies		Support innovative ideas	
Support innovative ideas		Improve manufacturing or S&P technologies	
Improve manufacturing or S&P technologies		Improve Machinery or equipment performance	
Improve Machinery or equipment performance		Other - Specify	
Other - Specify			

Can you provide a percentage (approximately)

8) University materials related R&D efforts apply particular emphasis on basic (pre - competitive), applied or near market R&D and what is the average time span for each of these stages ? Comment on average project duration .

Type of Research	Average time span in years
Basic - pre competitive	
Applied	
Near market	

9) State the most outstanding problems you have when involved in materials R&D

10) What are the major problems when you are trying to commercialise your research

Reason	Very Discouraging	Discouraging	Indifferent
Lack of domestic market			
Lack of supporting Industry			
Lack of skills			
Lack of domestic market			
Lack of good extrinsic "product" credibility			
Lack of promotion mechanisms			
Lack of Information			
Lack of supporting Technologies			
Legal / Administration difficulties			
Lack of Capital			
Other - Specify			

11) Do you see materials capabilities as a basic core competency upon which Industry can build technology and corporate strategies ___________?

12) The end users of your materials related research results are :
By market : Greek market ___________ % Foreign market ____________ %
By Industrial Sector : Please specify using descending priority order :
i) iv)
ii) v)
iii) vi)

13) Which industrial sectors do you see as the most successful innovators in materials and materials technologies in the 1990's Please rank in descending order of importance.

Chemicals & Petrochemicals
Metal producers
Ceramic producers
Machinery producers
Electrical equipment firms
Transportation firms
Constructors (Mechanical works)
Textiles
Plastics producers
Cement producers
Defence industry
Electronics firms
Telecommunications firms
Constructors (Civil works)
Food
Others

II. LINKS AND TECHNOLOGICAL INTERACTIONS

1) How frequent is university's interaction with :

	Frequent	Occasional	Rare or None
Customers			
Materials suppliers			
Equipment suppliers			
Competitors			
R&D Institutions			
Universities			
Others - which			

2) From your point of view : what is the main aim of collaborations with the following organisations :

Aim of collaboration with :	Companies	Universities	Research Institutions	Gov. Labs
Basic Research				
Applied research				
Near market Research				
Commercialisation				
Characterisation - Testing				
Education and training				
Standards				
Manufacturing / production				
Product Improvement				
Product Development				
New technologies				
Other - Which				

3) What character does this R&D collaboration have, what is its duration and who covers the expenses?

Collaboration with	Companies	Universities	Research Inst.	Gov. Labs
Time Span				

Comments :

LINKS WITH INDUSTRY

5) In collaborations with private or public firms please comment on the form and the aims of the collaboration. What is the average (if any) duration and the included budgets?

6) Describe the form your co-operation takes with industry :

Establishment of co-operative agreement
Requesting specific research to be conducted on contract
Donating / investing funds to create a chair or lab.
Dispatching researchers,
Other.

7) Which of the following sectors industrial sectors has the higher participation / contribution to your research programmes (with respect to materials). Prioritise from 1 to 16.

Chemicals & Petrochemicals
Metal producers
Ceramic producers
Machinery producers
Electrical equipment firms
Transportation firms
Constructors (Mechanical works)
Textiles
Plastics producers
Cement producers
Defence industry
Electronics firms
Telecommunications firms
Constructors (Civil works)
Food
Others

8) Comment on the main points hampering university - industry collaboration :

Institutional barriers / Legal barriers
Obsolescence of University research facilities
Rigidity of Greek university Budget system
Conservatism / Out of date interests and academic curricula.
Economic constrains from the industry's point of view (e.g. no motive such as tax deductions to invest in university projects).

LINKS WITH RESEARCH INSTITUTIONS - UNIVERSITIES.

9) Describe your interaction and relationships with other universities and research institutions. What form does this collaboration take ?

Establishment of co-operative agreement
Requesting specific research to be conducted on contract
Dispatching researchers,
Other.

10) Comment on the main points hampering inter university and research institutes collaboration

Institutional barriers / Legal Barriers
Obsolescence of University research facilities
Rigidity of Greek university Budget system
Conservatism
Economic constrains - specify
Other- specify

11) Which type of organisation / institution do you consider as the most important partner in collaborative arrangements in materials technologies :
In order of importance : 4 = most important , 0 = no importance

Companies	Universities	Research Instit.	Gov. Labs	Foreign Instit. / Firms

III.INTERACTIONS WITH NATIONAL AND INTERNATIONAL R&D ACTIVITIES

1) Do you participate in the following collaborative programmes ?

YPER : BRITE / EURAM :
PABE : STRIDE :
EPET : OTHER INTERNATIONAL :
PENED : OTHER NATIONAL :

What materials class and application are involved ?

2) Can you comment on you experience from your participation in these programmes and in collaborations in general ?

Advantages	National Program.	International Program.
Access to knowledge and equipment		
Spread of R&D cost and risk		
Multidisciplinary approach		
Training of personnel / students		
Assistance in product Dev.		
Assistance in production problems		
New technology implementation		
Other - Which		
Problems	National Program	International Program
Bureaucracy / slowness		
Hidden high costs		
Distrust / communication problems		
Co-ordination problems		
Clear aims problems		
Agreements on standards		
Transfer of technology		
Others - Specify.		

3) For the national programmes :

Does each of the above initiatives have a separate materials strategy or there are some general lines throughout all initiatives ? Are these initiatives used as arms - instruments of a solid national materials strategy ?

4) For BRITE / EURAM and other international programmes

Comment on your experience from participation to the BRITE / EURAM programmes and other similar international activities.

5) Comment on the use and implementation of these programmes research results with respect to industrial applications, governmental programmes, patents and commercialisation in Greece. How relevant these programmes were to the materials needs of the Greek industry and economy ?

6) Describe your interaction and relationships with the government and GSRT programmes

7) Do you see any need for a national materials policy / strategy ? If so, what should it comprise ?

	Very Important	Important	Not so important
Identify areas of importance			
Provide directions			
Inform for international Developments			
Support basic research			
Support applied research			
Promote industrial networks			
Initiate University / Industry collaborations			
Education / Training policies			
Standards			
Research networks and institutions			
Promote international co-operation			
Procurements			
Tax incentives			
Regulations			
Provide low cost capital for high tech investment			
Information diffusion mechanisms			
Intellectual property protection			
Trade regulation			
Collaboration promotion [2]			
Other - specify			

If some of the above are important but they don't happen comment on where the problem is. What directions a national materials strategy should have and which areas should the government promote and support as part of a national strategy ?

IV. GENERAL QUESTIONS ON EDUCATION

1) Do you see education as a "manufacturing process" (Industry = User, Education system = producer, Skilled personnel = product).

2) What are the major problems in materials education in Greece ? Please list them.

[2] Legal and institutional framework for collaboration promotion between firms - universities - research institutions.

3) Do you think that MSE departments should be established or MSE education needs can be covered by modification on the structure and academic curricula of existing departments ?

4) What action should the government take in order to encourage / promote under and post graduate studies in MSE ?

5) Infrastructure needs such as laboratories equipment : State the major problems and obstacles.

V. FINANCE OF R&D

1) R&D funding mechanism : How do you fund your R&D activities (In general - in Materials) ?Provide (if possible) the percentage derived from :

Government : Domestic R&D :
Collaborations : Companies :
International collaborations : Earned by direct university initiative :

2) How financial autonomous are you ? What has changed during the last 5 years ?

3) Are your R&D expenditures seen as strategic investment and therefore the R&D portfolio is constantly monitored and evaluated ?

4) Describe your relationships with banks and financial institutions.

5) Comment of national and bank policies when you want capital for technology issues.

VI. FINAL GENERAL QUESTIONS :

1) Given that Greece has some excellent pockets of basic research, what do you think is the main reason(S) for obstructing and preventing the development and commercialisation of high technology in Greece ? Do theses reasons apply in the case of materials ?

2) How do you view the prospects of new and advanced materials technologies in the next few years in Greece ? What are the major problems facing their commercialisation in Greece ??

3) What are the key materials and capabilities the Greek industry needs in order to remain or become competitive ?

4) What are the key areas in which Greece needs to develop skills in Materials Science and Engineering ? Can you list specific groups of materials or technologies ?

STRATEGIES IN ADVANCED MATERIALS IN GREECE

QUESTIONNAIRE – GSRT / PUBLIC AGENCIES

Ioannis (John) A. Kottakis
Autumn 1996

City University Business School
City University

Barbican Centre, London, EC2Y 8HB
Tel : 0171 - 477 8632 - Fax : 0171 - 477 8881

I . NATIONAL TECHNOLOGY STRATEGY CHARACTERISTICS

1. Does Greece have a fully worked out a national technology strategy ________?
   Is it integrated with the national industrial strategy ___________?
   Is it integrated with the national economy and education strategy _________?

2. The national technology and industrial strategy ' s aim is to support:
   Domestic markets____________ Exports___________ Both____________.
   Do you intend to have the same aims during the next 5 - 10 years ?

3. Have you identified critical industrial sectors to be supported or targeted to be developed?

4. Do use the concept of " picking winners" ? How do you use it and what are your selection criteria ? For industry - For research

5. Describe the national R&D portfolio selection mechanism / procedure. What is the role of materials in this ?

6. Comment on the role and functionality of government laboratories and public research institutions as parts of the national innovation system.

7. Summarise the basic mechanisms for supporting research and the national research infrastructure

8. Please comment on the :
   - National standards
   - Patenting
   - Intellectual property rights protection strategy

9. State and comment on tax incentives used to promote :
   - Basic research
   - Product or technology development and commercialisation.

10. Do you use the concept of government procurements? If you do, what form do they take ?

11. Comment on export - import policies to support industrial activities.

II NATIONAL MATERIALS ACTIVITIES

1) Identify the main factors / parameters which shape or would need to shape the national materials strategy.

2) Are materials R&D efforts and strategies a part of the Greek national technology strategy?

3) Are national technology strategies and materials strategies formed independently of industrial strategies and / or education strategies ? Is it difficult to combine the two process ?

4) Does Greece have special R&D programmes entirely dedicated to materials and materials technologies? If yes, name them .

5) Who decides for the objectives of these programmes ?

6) Are the materials related R&D programmes connected with other R&D programmes? Is there a reciprocal connection between them?

7) How large are the national materials R&D activities in terms of :
Number of researchers / People involved : ______________ .
Time horizon : (Average project duration) : ______________.
Can GSRT provide figures for each materials class and / or applications areas separately ?

9) How much do the programmes on materials and materials technologies represent in terms of the GSRT and the national R&D expenditure ?
GSRT /==/ National R&D expenditure

10) National materials related R&D efforts apply particular emphasis on basic (pre - competitive), applied or near market R&D and what is the average time span for each of these stages ? Comment on average project duration .

Emphasis	Type of Research	Average time span in years
	Basic - pre competitive	
	Applied	
	Near market	

11) The national materials strategy has the **strategic concept of:**

- making up lost ground when a lag has been observed in a sector or particular technology (analysis of situation and requirements)
- creating new technology and technical innovation when it provides substantial business spin - offs (analysis of technical growth and future potential)

B) According to the ***time horizon and nature of target :***

- Application oriented R&D strategies : That is pushing forward and directing R&D in areas and priorities concerning tangible, existing or near future problems or responding to problems originated by competitive pressures and rising performance requirements in technologies and industries.
- Mission oriented R&D strategies : This type mostly concern basic research activities and it usually concerns emerging technologies that show promise of application across several fields. The first task is to identify suitable technologies and explore their potential using inexpensive pilot projects.

12) **Which areas** of new or conventional materials attract most of the national materials related R&D and research activities ? Can you specify (approximately) **class** of materials (e.g. metals, ceramics, etc.) and **application areas** (e.g. for offshore applications, construction, functional applications etc.).

13) The national materials R&D activities have mainly the aim to **improve existing** materials and their grades (e.g. steel, aluminium, cement) OR **create new** materials (e.g. new ceramics, new advanced grades of steel, smart materials etc.). Can you comment on the reasons ?

14) Most of the national materials related R&D is concentrated on **structural** materials (e.g. metals for transport and construction, ceramics for construction, composites for structural applications) **OR** on **functional** materials (e.g. ceramics for energy applications - catalysts, photovoltaics, smart materials, semiconductors and others)?

15) The national R&D efforts mainly concentrate on materials :

Performance
Properties
Structure & Composition
Synthesis & Processing

Which of the four elements attracts the most attention and why ?

16) How does GSRT asses S&P in particular with respect to industrial AND services competencies?

16a) Are materials programmes strongly linked to manufacturing improvements?

17) National materials related R&D has usually the aim to:

Improving incremental and existing materials		Developing new materials	
Improve products		Improve products	
Produce new products		Produce new products	
Find new applications		Improve existing technologies	
Improve existing technologies		Develop new technologies	
Develop new technologies		Support innovative ideas	
Support innovative ideas		Improve manufacturing or S&P technologies	
Improve manufacturing or S&P technologies		Improve Machinery or equipment performance	
Improve Machinery or equipment performance		Other - Specify	
Other – Specify			

Can you provide a percentage (approximately)

18) Which of the following does the national materials strategy comprise ?

	Very Important	Important	Not so important
Identify areas of importance			
Provide directions			
Promotion of industrial research			
Inform for international Developments			
Support basic research			
Support applied research			
Promote industrial networks			
Initiate University / Industry collaborations			
Education / Training			
Standards			
Research networks and institutions			
Promote international co-operation			
Procurements			
Tax incentives			
Regulations			
Provide low cost capital for high tech investment			
Information diffusion mechanisms			
Intellectual property protection			
Trade regulation			
Collaboration promotion			
Other - specify			

Can you provide some brief comments of what has been achieved and what are the major difficulties during the last 10 - 5 years.

19) How is the national materials R&D policy carried out ? Define the roles of:
- Stimulate - encourage industry to do it
- Research institutions
- Universities
- Combinations of the above / other

20) What percentage of the following collaborative programmes is dedicated to materials and materials technologies ?

YPER :	EPET :
PABE :	PENED :

OTHER NATIONAL:
Can you list the classes of materials and relative technologies for each programme ? .

21) Each of the above initiatives has a separate materials strategy or are there some general lines throughout all initiatives ? Are these initiatives used as parts - instruments of a solid national materials strategy ?

22) State the most outstanding problems for shaping and applying a national materials strategy.

23) What are the major problems for the commercialisation of R&D results.

III. CORE MATERIALS COMPETENCIES

1. Do you use the concept of national technological core competencies ? If yes which are they you try to : support or create a critical mass.

2. Do you see materials technologies and MSE capabilities (S&P capabilities in particular) and know - how as an important, basic core competency or as a national strategic asset and as a source of competitive growth for the Greek economy in the future ?

3. How have you been able to sustain or build these competencies ?

4. Do you use the concept of emerging technologies ? Which emerging technologies do you identify as crucial for the needs of the Greek economy ?

5. Do you have global intelligence gathering mechanisms ? Do you use them in the case of emerging and materials technologies ?

6. How do you evaluate technologies and how do you decide whether to develop a new technology or initiate technology transfer mechanisms?

7. Do you think that Greek industry mainly depends on technologies build in - house or on internationally acquired technologies? What is the case in the materials technologies ?

IV. CO - OPERATIONS / INTERACTIONS

1) Comment on mechanisms which stimulate the co-operation / communication between firms / universities / research institutions ?

2) What form these collaboration usually have, what is its duration and who covers the expenses?

3) Describe the relationships between GSRT and other public agencies with universities, research institutions and industry.

4) What is the primary aim of these interactions :

Aim of collaboration with :	Companies	Universities	Research Institutions	Gov. Labs
Basic Research (Learn)				
Applied research (Apply)				
Commercialisation				
Characterisation - Testing				
Education and training				
Standards				
Manufacturing / production				
New or improved products				
New technologies				
Other - Which				

5) How do you assess the importance of the following factors for firm's participation in national and international R&D collaborations (firms want to participate / be supported as a result of) ?

	Very Important	Important	Indifferent
Group formulated strategy			
Group diversification strategy			
Technology fusion intention			
Demand form customers			
Governmental policies			
Response to national competition			
Response to International competition			
Training and knowledge acquisition			
Other - which.			

6) Which of the following sectors industrial sectors has the highest rates of participation / contribution in the national R&D programmes (with respect to materials). Prioritise from 1 to 16.

Chemicals & Petrochemicals
Metal producers
Ceramic producers
Machinery producers
Electrical equipment firms
Transportation firms
Constructors (Mechanical works)
Textiles
Plastics producers
Cement producers
Defence industry
Electronics firms
Telecommunications firms
Constructors (Civil works)
Food
Others

7) Can you comment on the experience and benefits gained for the Greek economy and industry from participation in the national and international R&D programmes ?

Advantages	National Program.	International Program.
Access to knowledge and equipment		
Spread of R&D cost and Risk		
Multidisciplinary approach		
Training of personnel		
Assistance in product Dev.		
Assistance in production problems		
New technology implementation		
Other - Which		
Problems	National Program	International Program
Bureaucracy / slowness		
hidden high costs		
distrust / communication problems		
co-ordination problems		
clear aims problems		
agreements on standards		
transfer of technology		
Others - Specify.		

8) How frequent do you receive feed-back from :

	Frequent	Occasional	Rare or None
Industry			
Universities			
Private Laboratories			
R&D Institutions			
International Org.			
Others - which			

9) In what proportion do the following institutions participate in defining GSRT programmes in materials and in technology policy :

Industry	%	EU strategies	%
Government	%	Universities	%
Research institutions	%	Others – Who	%

10) Comment on your selection criteria .

11) Roughly, what percentage of technology policy makers have technical background and accounting / finance / law background ?____________ %

V. FINANCE OF R&D

1) R&D funding mechanism : How do you fund R&D (In General - in Materials) Provide (if possible) the percentage derived from public funds, industry and international sources.

2)The national Materials R&D expenditures are :

a) Seen as an overhead with the annual budget as a fraction of the GDP or other performance indication,
b) Dominated by the "net present value " rule, with respect to each individual project
c) Seen as strategic investment and therefore the R&D portfolio is constantly monitored and evaluated according to current and future industrial and national needs.

3) Are technological investments made with **a long term view** to develop national technological capabilities and financial returns are of secondary importance or are they subject to short - term and medium term financial constraints ? Does it depend on the technology ? What is the case for materials related technologies ?

4) Comment on the basic problems of financing high tech and R&D in Greece. What is the role of the banks ?

5) Financial regulations : What is their influence for technology development and implementation?

VI. FINAL GENERAL QUESTIONS :

1) Given that Greece has some excellent pockets of basic research, what do you think is the main reason(s) for obstructing or preventing the development and commercialisation of high technology in Greece ? Do theses reasons apply in the case of materials ?

2) How do you view the prospects of new and advanced materials technologies in the next few years in Greece ? What are the key materials and capabilities the Greek industry needs in order to remain or become competitive ?

STRATEGIES IN ADVANCED MATERIALS IN GREECE

QUESTIONNAIRE - FINANCIAL INSTITUTIONS

Ioannis (John) A. Kottakis
Autumn 1996

City University Business School
City University

Barbican Centre, London, EC2Y 8HB
Tel : 0171 - 477 8632 - Fax : 0171 - 477 8881

I. FINANCIAL MARKETS AND TECHNOLOGY INVESTMENTS

1. Comment on national finance and investment schemes to support industrial and technological activities. What is the role of the banks and/or venture capital?

2. Comment on banking (and governmental) policies for financing high technology development and implementation.

3. Do you use the same measures for both public and private investments ?

4. Do you finance governmental programmes on materials technologies ? In other technologies ?

5. Comment on general investment characteristics :

- Cost of capital : ___________________________
- Time horizons : ___________________________
- Interest rates : ___________________________
- Securitisation methods : ___________________________
- Rates of return : ___________________________
- Does the above depend on the technology ___________________________?

6. Have you developed mechanisms for evaluating technology based investment ? Describe your investment decision criteria. Do you give priorities to some technologies ?

7. Are you aware of the financial and strategic importance of the MSE field and materials technologies ?

8. Do you use the concept of "picking winners" when investing in high- tech industries?

9. How do you evaluate risk in high technology investments?

10. How do you define a technology-based firm ?

11. What are the general requirements a proposal must have (e.g. credibility, assets, equity) ?

12. Presume that a firm seeks financial support in order to :

a) Improve or Develop In - House technology or products,
b) Expand in new high tech areas (diversification of activities),
c) Organise and create R&D facilities and departments,
d) Acquire technology,
e) Transfer technology.

For each case please describe your policy including evaluation criteria, cost of capital, time horizons, interest rates, securitisation methods, return rates. Does it depend on the technology ?

13. When you evaluate a proposal, which is the most important :
- Fixed capital investment
- Intangible assets ______________________

14. Which type of risk do you fear the most (e.g. cost, market or technological risk)?

15. How do you monitor - supervise your investment ? What control mechanisms do you have ?

16. Do you use venture capital to finance high technology ? Describe the venture capital markets in Greece (Strengths - Problems).

II. GENERAL ISSUES ON THE FINANCE OF TECHNOLOGICAL INNOVATION

1. Comment on tax incentives used to promote basic research and product or technology development and commercialisation.

2. Comment on export - import policies to support industrial activities.

3. Government Procurements : how are they used, what form do they take ? What is the involvement of financial institutions?

4. Financial regulations : What is their influence for technology development and implementation.

5. Comment on your basic problems during your interactions with industry or research institutions and universities .

i. Bureaucracy:
ii. Government Regulations:
iii. Links with industry:
iv. Other:

III. GENERAL QUESTIONS

1. Given that Greece has some excellent pockets of basic research, what do you think is the main reason(S) for obstructing and preventing the development and commercialisation of high technology in Greece ?

2. What are your contacts - links with them ?

3. What are the key areas in which Greece needs to develop technological skills ? Can you list specific groups of technologies ? Are (or should) materials technologies among them ?

4. What directions a national technology strategy should have and which areas should the financial markets and institutions promote and support as part of a national technology and development strategy ?

ANNEX 2.1: The Materials Definition Issue

A2.1.1: The definition and classification issue.

The following paragraphs make a small contribution by offering comments on previous attempts at materials definitions and by *the provision of detailed justification* for the new definitions employed by the thesis.

A2.1.2: Definitions

Materials can be defined and classified in many ways. This strongly depends on either the approach or the definition criteria employed. It is the definition issue that creates most of the problems to managers / economists and engineers. There is still strong debate of what is "advanced" and what is "conventional" materials or old and new materials. While no definition has been universally accepted, in trying to develop the concept of "advanced", new and "conventional" materials most scholars have tended to define them as those materials developed to satisfy sophisticated or specific needs created by either technological advantage or market evolution. Early definition criteria and subsequent definitions have included:

Descriptive criteria: These employ a fundamental property or group of properties, characteristics, functions, and uses of materials and attempt to combine definition and categorisation simultaneously (e.g. metals, ceramics, plastics, plastics, or electrical materials, magnetic materials etc). This is a very early approach and it produced ambiguous results because it confused definitions and classifications, two entirely different subjects, and it lacked a holistic view and approach.

Market and economic based criteria:

I) Anticipated growth rate of materials consumption: An advanced material would be a material whose anticipated consumption growth rate over the next decade exceeds the average growth rate of the economy (of an advanced industrialised economy). A material is regarded as old or conventional if its anticipated growth is below the average. Cohendet et al.(1988), adapted the theory and defined a growth rate of 3% as the advanced /conventional divide. A similar approach has been proposed by the French Observatoire des Materiaux Nouveaux at Bureau d'Informatics et de Previsions Economiques in 1987 who defined AM as those whose economic growth rate is greater than 6 %.

This approach to define AM is rather blurred and out of focus. They suggest for example, that materials such as Carbon - Carbon composites employed from aerospace with stable or incremental consumption rates or defect free new magnets or beam epitaxy produced thin films for specialised optoelectronic applications are not AM. A new or advanced material can exist and fill either a specific gap or a range of limited applications reaching its marker limits very fast. It can also exist and not be commercialised for numerous reasons. Does that mean it is not a new or an advanced material ?

II) Date of commercialisation criterion: Advanced materials are those which have been employed by industry since a given date, for example the last 25 years (Theulon 1989). As Theulon herself admitted this is a time based criterion and does not include materials under development or materials existing (patented) but not widely employed. Further, not all materials marketed over the last 25 years can be considered as advanced or new.

III) Price per weight criterion: This is a reasonable criterion but with no real power: price is a relative measure and some materials are designed for very limited applications with the effect that their price remains high over a very long period. Price can also be determined by a combination of factors largely irrelevant with the real substance of new or advanced materials. Therefore the criterion can only be employed as an approximation and as a good but not sufficient and enabling indication .

In short, these definition approaches can be combined with other definition criteria but they are not sufficient to define AM by themselves. This inefficiency was soon recognised and a new concept emerged.

The multidisciplinary criteria:

These criteria have been developed recently and recognise the fact that the materials field is so diverse it can not be adequately approached by employing a single view only. It became also apparent that economic approaches and definitions such as the above were not sufficient. The need for multidisciplinary dynamic approaches and definitions encompassing characteristics of both advanced materials (technical and economical) and processes was identified by Japan's MITI 's Basic New Materials study group, (MITI 1989) and by the US Bureau of Mines Activities in Advanced Materials (1987). This approach was also adapted by Lastres (1993), and partially by Kodama (1992). The Bureau of Mines has adopted the following working definition (1987):

> "Advanced materials are those developed over the past 30 years or so, and being developed at present, that exhibit greater strength or specific strength, greater hardness and/or more superior thermal, electrical, optical or chemical properties when compared with traditional materials. Advanced ceramics, metals, composites and polymers offer the promise of decreased energy consumption, better performance at lower cost, and less dependence on imports of strategic and critical materials."

MITI's Basic New Materials study group based its definition on *the value added criterion.* They defined AM as:

> "High value-added materials which have produced totally new epochal characteristics and new social values by driving sophisticated manufacturing processes and technologies and/or commercialisation technology based on metallic, inorganic and organic materials and combinations."

The above definitions are still incomplete because they do not sufficiently clarify the difference between advanced - new and conventional (old) materials. In addition, even though the term AM has prevailed in relation to the term NM, "advanced" is not synonymous to new and conventional to old. Also note that Japan's MITI refers to NM rather than AM and it does not make clear that the term AM includes two main categories of materials: the drastically improved, well - known materials with respect to older generations of the same materials, and completely new materials with superior properties which did not exist before. First of all it is apparent that AM comprise two main categories of materials:

A) Drastically improved well known materials (e.g. HSLA steel, high strength aluminium) for which new applications have been developed or exhibiting superior properties (usually due to S&P improvements) with respect to older generations of the same materials for the same applications (superior performance)[1]. For example St 42 is a well known category of steel. So it is an old or conventional material. The same category of steel under controlled processing gives a "new" material with carefully arranged and calculated micro structure. This new St42 has twofold better properties and thus performance than its predecessor. This has been recently achieved[2]. The new St42 is a conventional but improved material; it is the result of the application of an information-rich and technology-intense procedure on an "old" material. It is an information rich, high value added material with improved performance; it is an advanced material.

B) Completely new materials with superior properties which did not exist before. These can be the result of an effort to meet a particularly demanding application or the result of tailoring new designs from the very beginning. The case of Carbon Fiber Composites (CFC), Metal Matrix Composites (MMC), superconductors and self - assembly materials are typical examples. These categories of materials are new, advanced, and highly sophisticated. The levels of information and technology intensity and high added value they contain are among the highest of all.

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[1] Some call this kind of materials incremental materials because they have large improvement potential.

[2] By controlled continuous casting and temperature/pressure monitoring techniques.

Critical Overall performance: An "advanced material" which substitutes a conventional one for a specific application does not have to exhibit superior properties all-round. One property or a set of properties can be so crucial that it determines the selection of a material. For example, ceramics are inferior to metals in many aspects but they are much more corrosive resistant than any metal. Assume that corrosion resistance is the critical factor and fracture toughness the secondary factor. Until recently, ceramics could not satisfy the secondary factor. They were too brittle. So metals were used, sometimes with poor results. By improving ceramics' fracture toughness to acceptable levels the ceramics were still inferior to metals with respect to many properties but had outstanding corrosion resistance which is the critical factor for the specific application. That enables them to have *superior overall critical performance* and therefore they substituted metals. These particular ceramics are 'advanced' ceramics or 'advanced materials' with respect to the metals they replaced.

Box A2.1: Overall Critical Performance definition criterion. Kottakis 1999.

Moreover it is apparent that the term AM necessarily entails a *relative*, dynamic and multi - dimensional approach. Something is advanced with respect to something similar with inferior property(ies). Therefore, the word "advanced" immediately refers to something improved, to an improved property or properties and thus performance with respect to the one it substitutes. It does not matter what exactly the property(ies) will be. If a material for whatever reason exhibits better performance of any kind (functional, mechanical, economic) for a specific application or range of applications with respect to its predecessors (the material(s) it replaces or has the potential to replace) then it is an advanced material. So, according to the author's opinion, **overall critical performance** is the safest, sufficient and enabling definition criterion which defines AM in general. Further specifications rather lead to classification or description than definition. As such, for the purposes of this research the following *working definitions* are used:

- **Advanced materials** are those usually high value-added, information-rich, probably experience-poor and technology-intensive materials which exhibit superior overall performance (functional, mechanical, economic) for a specific application or range of applications with respect to the performance of their predecessors.
- **New Materials** are those materials which simply did not exist before and / or introduce new or far superior properties or exhibit new phenomena.
- **New Advanced Materials** are those materials which are both new and exhibit a superior overall performance for a specific range of applications.

- **Incremental materials** are existing, known materials which are experience-rich but not information-saturated materials, which have not reached their theoretical limits and which retain a high potential for considerable properties and performance improvements and for employment in increasingly demanding applications (Kaounides 1995, Rolls-Royce 1995).
- **Conventional or old** materials are the experience-rich, information-saturated, and technology-mature materials which exhibit an acceptable but not outstanding overall performance for a specific application or a range of applications. They also have some common and distinctive market characteristics such as low price per weight and long service history.

A2.1.3: Comments on the employed definitions

Based upon the overall critical performance criterion, the above 'categorisation' defines advanced, new, conventional and old materials. A material can be advanced but not new especially when it is an evolution of older materials. It can be both new and advanced (e.g. the CFC, MMC, and superconductors example). It can be new but not advanced (during the efforts to create a high temperature resisting polymer many new polymers were created. Most of them were really new (with different values of properties of all known materials) but had no comparative advantage or offered no significant performance improvement with respect to existing materials). Obviously "advanced" is not synonymous to "new".

On the contrary, the terms conventional and old materials (such as wood, stone, traditional metals, etc) can be the same thing. Surprisingly criteria such as annual growth rate and price per weight can give good definition approximations for the conventional materials which are usually well-known, materials employed for a wide range of conventional and frequently 'bulk' applications. Moreover conventional materials are well known, have good records and reflect gained experience. Experience is the AM's weak point. But it is the strong point of the conventional materials and perhaps the best criterion to define them. Theoretically almost all conventional materials can be substitute by advanced materials but the overall critical performance including cost and experience or simply indispensability (e.g. gasoline and oil) keeps them employed.

In addition, there are many materials which originate from dramatic improvements of previously existing grades of the same basic material but still retain much potential for further improvement in their properties and performance. These materials are called "incremental" materials because even though they are not entirely new, they have high potential for further improvement and employment in increasingly demanding applications. Incremental materials usually inherit the experience in use and applications of their predecessors.

ANNEX 2.2: Additional Working Definitions And Terminology

A) U.S National Science Foundation Definitions:

BASIC RESEARCH

Gain more understanding and knowledge of subject without specific applications in mind.

In Industry: basic research is research that advances scientific knowledge (but with no specific immediate commercial objectives) - however it may be in areas which are of present or potential commercial interest.

OECD: Two types of "basic research":

- "Pure basic research": that is research without limitations or restrictions of any kind.
- "Oriented basic research ": that is basic research without limitations or restrictions of any kind but restricted in one or more specific areas with promising potential.

APPLIED RESEARCH

Gain knowledge or understanding to determine the means by which a specific recognised need may be met. In Industry: Discovering new scientific knowledge which has specific commercial objectives in products, processes or services.

DEVELOPMENT

Knowledge or understanding from research is systematically directed to the production of useful: materials, devices, systems, methods and design / development of prototypes and processes.

TECHNOLOGY TYPES

According to Dussauge, Hart and Ramanantsoa (1987 and 1996):

BASE TECHNOLOGIES

Base technologies are those which are extensively used in a given business. In many cases, skills in base technologies are what enabled firms to enter a business but today they no longer provide competitive advantage; they are readily available and all competitors possess them.

KEY TECHNOLOGIES

Key technologies are those which, for the time being, have the highest competitive impact. In other words, they are a driving force of competition and the strength of competitors in such technologies is reflected in their competitive position.

PACING TECHNOLOGIES

Pacing technologies are those in the development stage which still do not have many applications and whose utilisation in a given business is marginal. However, such technologies would seem to have important potential, and some of them are likely to become key technologies eventually[1].

GENERIC TECHNOLOGIES

A technology is described as generic if - through combinations with other technologies - it is likely to lead to numerous different applications in diverse businesses. Unlike key technologies, generic technologies are not defined with reference to a particular business; the generic nature of a technology is determined by its wide ranging industrial and commercial applications.

TECHNOLOGY CLUSTERS

A technology cluster can be defined as a set of businesses sharing a common technological base. A technology cluster consists of a number of applications relating a core technology to products and markets (GEST 1986).

[1] The US Department of Commerce (DOC 1990) calls these technologies as "Emerging Technologies".

ANNEX 2.3: Examples of the technical and business potential of advanced materials and MSE.

Annex 2.3 provides brief examples of the technical and business potential of advanced material with respect to recent developments in the MSE field and with respect to the links they have with selected industrial sectors or groups of technologies. The following information is of both a technical and management nature and provides (in a very abstractive way), major developments in each surveyed field. The first part of Annex 2.3 is dedicated to materials groups presentation and the second part to the materials interaction / impact with selected industries / technologies.

Part I: Basic materials classes (metals, ceramics, polymers, composites and special materials). Key characteristics and strategic implications.

The following pages are dedicated to a brief presentation of materials groups and their main technical and management aspects. The aim is to provide essential information in order to assist the non -familiar with the MSE field reader in understanding some of the issues raised in other parts of the present study. Each materials group is represented according to specific issue headings described below:

Class of materials: nature and applications: A brief description of the nature and fundamental properties of each group of materials and some application examples.

Major technology elements and underlying science: A listing of the most important technologies, scientific and engineering areas felt to be of critical importance to the development and commercialisation of products based on theses materials. Capabilities in scientific areas such as physics, chemistry, computer science and instrumentation are obviously required for all materials classes.

What is new or better: Examples of improvements with respect to performance, properties, S&C and S&P of each group of materials and of areas which directly benefit from the improvements in the specific group of materials.

Special strengths, strategic implications and limitations: A very brief discussion of those fundamental technical advantages and impediments inherited by the nature of each materials group followed by their basic strategic implications. Identification of some of the basic technical obstacles which have to be eliminated or circumvented before products and / or processes can be marketed or before further progress is made.

Metals and Advanced Metals

Nature and applications: Metallic materials are normally either pure substances or combinations and mixtures of non - interacting metallic elements. They are characterised by the *metallic bond*, that is electrons are not bound to particular atoms. Most of the metals properties are directly attributed to these free electrons and from the fact that, when in mixture, there is (usually) no chemical interaction between them able to destroy the metallic bond[1]. Basic traditional characteristics are: strong but with good formability - that is they can take almost any shape, tough, good conductors of heat, electricity, magnetic fields and sound, variable corrosion resistance, variable hardness and "traditional" magnetic properties. Metals applications include ductile, strong structural materials, high temperature and corrosion resistant alloys (super alloys), and electrical conductors. Advanced metals tailored for specific applications are predominately structural light - weight alloys, advanced steels, and high-temperature resistant, high strength alloys. Other examples are amorphous metals with special electrical and magnetic properties, ultra strong intermetallics, shape memory metals, ceramic coated metals etc.

Major technology elements and underlying science: Metallurgy, fluid dynamics and kinetics, diffusion mechanisms, fracture mechanics, solidification and casting technologies, thermodynamics, hot and cold forming technologies, machining technologies, surface science and surface treatment technologies, crystallography, corrosion/erosion resistance, structure and processing monitoring and processing sensors.

What is new or better: Superior strength combined with no loss of ductility, formability or toughness; new alloys for extreme environments e.g., blades for high temperature turbines, perfection of surface treatments; accurate life - time predictions; better understanding and modelling of the relations between structure and properties such as fatigue and erosion resistance and creep mechanisms; new processing technologies (e.g. rapid solidification, continuous casting) applied even for large sections and reducing cost while achieving controlled structure and properties; monocrystalic alloys and components; new amorphous metallic alloys for electrical and magnetical applications.

Special strengths, strategic implications and limitations: Incremental and advanced metals are mainly structural and on this basis they have many comparative advantages with respect to the other classes of materials: long established experience, relatively

[1] Sometimes intermetallics are formed. The intermetallics still preserve the metallic bond while exhibiting new or improved properties. Most of the super alloys are inter - metallic compounds.

cheap production and processing technologies, high recyclability, and the most important, the way they exhibit their mechanical and natural properties.

Metals are highly *isotropic* materials, that is, they have the same response and the numerical value of their properties is the same no matter from which direction the stimuli come. This *isotropic behaviour* in association with high strength and formability properties, and all the above mentioned parameters make metals extremely attractive choices for many conventional and demanding applications. Light metals compete successfully with composites and plastics and super alloys are still the major choice for aggressive environments.

Engineering and science barriers include the development of rapid and reliable processing methods, the understanding of complex failure mechanisms related to processing and service - produced (that is performance) micro structures.

In conclusion, metals were and will be important for all industries and human activities and especially for structural applications will take a long way before they begin (if ever) to be widely and en-masse substituted by composites, ceramics or bio - mimetic materials.

Ceramics and Advanced Ceramics

Nature and applications: Ceramics include materials made from combinations of metallic and non-metallic minerals and oxides. The atomic bonding in ceramics is either partially or totally ionic; ceramics are rather composed of electrically charged ions instead of atoms. This very strong and stable bond provides isotropic behaviour and is responsible for most of the ceramics advantages - such as light weight, hardness, superior corrosion resistance and superior tolerance to high temperatures - and for most of their disadvantages - such as brittle behaviour to both impacts and thermal shocks, lack of formability, and poor tensile and fatigue resistance. “Traditional ceramics" account for most of clays, glasses, cements, abrasives and refractors in use. Most of them are structural materials. On the other hand, advanced ceramics such as semiconductors, superconductors, optical fibers, high precision monocrystalic ceramic blades, ceramic coatings, piezoelectrics, sensors, photovoltaics and many others are mostly functional and they are set to have a dramatic effect in our lives; electronic, computer, power, communication, aerospace, sensors and a host of other industries rely on their use.

Major technology elements and underlying science: Fracture mechanics; diffusion mechanisms; advanced fabrication technologies such as sintering, beam epitaxy, chemical deposition, beam deposition; crystallography; advanced processing monitoring; casting technologies, quantum physics and solid state physics, nanotechnologies.

What is new or better: For structural ceramics, increased structural accuracy - less defects and voids - achieved through advanced fabrication techniques or through advanced control of existing fabrication techniques leading to increased fracture toughness without loss of hardness or corrosion resistance; increased thermal and impact resistance; conventional and old materials such as cement gain new interest, becoming advanced materials after the introduction of MSE principles in their production. Functional ceramics: new functional ceramics with new properties - i.e. superconductors, optical fibers, piezoelectric and smart structures.

Special strengths, strategic implications and limitations: Ceramics have been always important but the new advanced ceramics have the potential to literally revolutionise our world. Structural ceramics hold the key for high performance combustion engines and for effective turbine based power generation while functional ceramics hold the key for the development of optics technologies, super - computers and, the most important, magnetism and cheap and environmentally friendly power generation (ceramic processing technologies are fundamental for the development of superconductors, the key material for fusion power reactors). It is important to underline that advanced and new ceramics development comes through either the improvement of conventional S&P capabilities or from a fusion of totally new fabrication techniques with deep theoretical understanding of the relation between their structure and properties. The atomic layer by atomic layer build - up or surface treatments or fabrication and processing technologies have been initially developed for functional ceramics for the electronic and computer industry. These S&P capabilities are rapidly spreading to many other materials classes.

Engineering and science barriers are mainly imposed by the rigidity of the ionic bond. Fracture toughness still remains a major problem for structural ceramics, while the fabrication cost for structurally perfect ceramics is still very high. In addition, much theoretical understanding of properties, structures and phenomena is also needed before new advancements are made in a wide range of functional ceramics.

In conclusion, ceramics, as metals, were and will be important for all industries and human activities either due to rejuvenation of properties and applications of conventional ceramics like cement and glass - optical fibers or due to special new ceramics for functional and structural applications.

Polymers and Advanced Polymers

Nature and applications: Polymers include a variety of large molecules consisting of long chains of repeating small organic molecular units. The synthesis can be produced inexpensively, and their structure can be managed to the degree that they exhibit a wide range of properties and applications. Most of the repeating small organic molecular units are hydrocarbons; that is they are composed of hydrogen and carbon connected together with covalent bonds. Furthermore, intermolecular bonds and hydrogen bonds are quite frequent. These kinds of bonds are very "flexible" (in contrast with the ionic bond) and many of the polymers properties originate from this "flexibility". In addition, each carbon atom - the basic element of most polymers - has four electrons that may participate in covalent bonds shared with almost any other element, substance or molecule. These factors provide the opportunity for the creation and development of a literally endless variety of structures, properties and finally applications.

Major technology elements and underlying science: Chemistry and chemical engineering, petroleum related science and technologies, refineries, simulations for structural modelling, advance processing controls, surface science, fluid mechanics and fluid dynamics, casting and thermo - forming technologies, biotechnologies and biomimetics.

What is new or better: Specialised new polymers for advanced applications such as bio - degradable plastics for packaging, high temperature polymers used for aircraft skins, bio - compatible implants, new "smart" textiles for clothing and fabrics, advanced adhesives, impact resisting materials, various coating applications, advanced thermo and sound insulation materials.

Special strengths, strategic implications and limitations: Polymers have the traditional advantage of cheap production. When performance requirements are no more than the conventional, large quantities can be produced using high - production, cheap S&P technologies. Advanced polymers, though, for high performance applications such as pipes for off - shore and chemical industries or protecting coatings for large surfaces require different approaches such cost effective chemical and vapour deposition or continuous casting - a method developed originally for other materials classes. On the other hand, polymers are a characteristic group of materials which constantly provide S&P ideas for the production of other classes of materials and constantly receive ideas from the production of other materials groups. Most polymers were traditionally structural materials with the exception of paints, coatings and adhesives. While structural polymers are constantly improving, keeping a high interest and retaining their market share, the big application and commercial boom comes from the functional materials of the group. Advanced epoxy - based coatings, adhesives, insulation materials, paints, electric materials, packaging materials (bio - degradable, environmental friendly plastics), pseudo - organic substances and new "smart" textiles for clothing and fabrics are expected to create significant new markets and a wide range of new products.

Especially "smart" textiles for clothing and fabrics with adaptable to the environment heat transfer and heat insulation properties or with stain - proof capabilities are already commercialised and they are expected to revolutionise the textiles and fashion industry.

Composites and Advanced Composites

Nature and applications: Composites include combinations of two or more materials, usually reinforced ceramic, metal or organic - matrix (polymer, plastic, or carbon) materials exhibiting a wide range of types of properties and performance. The aim is to combine and take advantage of the most useful properties of each component. Fiberglas is a traditional composite, composed of glass fibers in epoxy or polyester matrices. Advanced composites (AC) have both structural and functional applications and they are mainly used in air and land transport. The most versatile and important group of composites are the fiber - reinforced ones with second most important the structural (laminates and sandwiches) and the finally the particle - reinforced composites. The five most common groups of the fiber reinforced AC being used today are Polymer Matrix Composites (PMC), Carbon - Carbon Composites (CCC), Ceramic Matrix Composites (CMC), Metal Matrix Composites (MMC) and Granulate Composites (GC). While CMC, GC and MMC are rather elite materials with small volume markets, there is a growing tendency to use PMC or CCC and carbon fibers for "bulk" applications in transport, off - shore, marine and particularly large scale civil and mechanical engineering constructions displacing metals or traditional ceramics (i.e. cement) (Kaounides & Kottakis 1997).

Characteristic properties include superior strength and stiffness to density ratio, ability to be tailored after precise loading conditions, saving structural weight, superior corrosion resistance, considerable weight savings, cheap raw materials, dimensional stability, and finally high impact, fatigue and in cases heat resistance.

Applications include frames and structural parts for aircraft, missiles and the transport sector, insulation, structural parts for vehicles, heat or fire insulation layers, and lately structural materials for large scale constructions such as wires and panels for bridges and buildings.

Major technology elements and underlying science: Fluid dynamics, advanced modelling and simulations, advanced processing control, interface and surface science, mechanics, polymer science, fibers and textiles technologies, specialised fabrication technologies (i.e. bag moulding, thermo - forming), textiles principles integrated with petroleum and plastics know - how.

What is new or better: Better understanding and control of the fiber - matrix interface; technologies for controlling internal structure and processing that allows high levels of "design - in" properties; manufacturing and fabrication techniques getting cheaper while volume production is increased; new markets emerge with new performance requirements.

Special strengths, strategic implications and limitations: Composites, contrary to metals and ceramics, are usually *highly anisotropic*. Their response to stimuli varies considerably according to stimulus direction or nature. This is a significant advantage if performance conditions can be safely and accurately predicted or designed but a big disadvantage when this is not possible. Low levels of recyclability and limited formability of finished products (with respect to metals) are also limitations of composites. In addition, Advanced Composites have been developed to meet extremely demanding performance requirements imposed mainly by the aerospace industry. As such, many of these materials are elite materials with limited markets coming out of very expensive low - volume capacity S&P and manufacturing lines.

A major change emerges with the rise of new markets for AC as new final materials users focus their attention on them. If *performance requirements are relaxed*, the combination of high strength to weight ratio, the high corrosion resistance and the high impact and vibration dumping properties of these materials makes them extremely attractive for constructions such as bridges, tunnels, large panels, off - shore structures and others. This trend is combined with increased capabilities to produce high volumes of mainly PMC.

In conclusion AC are and will be important for high performance applications but the next 15 years will witness the gradual but steady commercialisation of some of these materials (mainly the PMC and CCC) for wide scale bulk applications displacing traditional materials such as metals or conventional structural ceramics.

"Smart or Intelligent" Materials

Nature and applications: "Smart" or "intelligent" materials are materials which have energetic response to stimuli and in addition their response - that is their structure and properties - have the ability to adapt to stimuli variations. Typical examples are piezo - electric ceramics, "smart" sensors evaluating damage or other parameters of operating structures, shape memory alloys (metals and some intermetallic compounds[2]), heat and light - sensitive glasses and windows for industrial and building applications, and "smart" fibers and textiles (polymers - see above). Existing and potential applications include actuators and motors that can behave like muscles, sensors that serve as nerves and memory, intelligent communication and computation methods, advanced structure's integrity monitoring against catastrophic failure, and even commodity products like clothing, materials for dental applications (shape memory materials) and relaxation and entertainment products e.g. sound and vibration control.

Smart materials can belong to any class of materials with any kind of structure. Piezo - electrics for example are mostly ceramics and apart from their ability to transform deformation to electrical current and vice - versa at will, have inherited many of the advantages and limitations of the ceramics group. Similarly, shape memory materials are mostly metals with the most prominent among them the family of the nickel - titanium alloys. These metals have unusually high plastic deformation yield points and if deformed below this point at a certain temperature revert back to their original shape.

Major technology elements and underlying science: The entire materials science and engineering field, biomimetics, possibly biotechnologies for some materials, and new manufacturing and design perspectives which will allow the full integration of these materials to products, systems and operations according to application materials case. **What is new or better:** With respect to materials, all these materials classes and their applications are new while their properties and performance are improving with accelerating rate. Engineers are getting more and more able to integrate these materials in *integrated systems* - like an intelligent building for example - able to behave in complex, multi - level ways. As such, design gets the opportunity to be highly flexible and achieve high levels of sophistication and materials and processes integration. S&P techniques and technologies are developed simultaneously with the development and perfection of these materials.

[2] Intermetallic compounds: A combination of two metals that has a distinct chemical formula (e.g. Ti - Al or $CuAl_2$). On a phase diagram it appears as an intermediate phase that exists over a very narrow range of compositions.

Special strengths, strategic implications and limitations: There still many problems of theoretical understanding of the behaviour of many of these materials. In addition, the level of design sophistication these materials enable clearly takes a toll on existing manufacturing processes. Large arrays of actuators, sensors, power sources, control mechanisms and integrated components put together require multi-level interconnections. Such complexity can easily render a smart structure or system too expensive to build.

On the other hand, intelligent systems based on smart materials may not only initiate the next step of the materials revolution but may also lead to the next step in our understanding of complex physical phenomena such as structural change of structures during performance periods and failure mechanisms. Smart materials and systems are in many ways the ideal recording devices. They can sense and adapt to their environments, store detailed information about the state of the material or system over time, and respond to changes by changing structure and properties.

The most lasting influence, however, will be on the philosophy of design. Intelligent materials systems will enable inanimate objects to become more natural and lifelike. Engineers will not have to add mass and cost to ensure structural integrity and safety. We will soon have the chance to ask structures (see for example Constructions section further below), how they feel, where they hurt, if they have been abused (overloaded) recently, even be able to identify the abuser. Intelligent systems and structures will be manifestations of the next engineering revolution - the establishment of new materials age.

Part II: Materials and strategic industrial sectors

The following pages provide a brief presentation of the interaction among materials and selected industrial sectors or emerging technologies. The presentation is arranged on the basis of specific issue headings whose nature is described below. A general observation is that capabilities in basic scientific areas such as physics, chemistry, materials and computer science and engineering are obviously required for all industrial sectors and / or emerging technologies.

The industry / technology: What the industry / technology includes and what are the mainstream products.

Special characteristics of the industry: Trends and characteristics shaping the nature and character of the industry today. A brief listing of special needs and orientation of products and / or technology trends follows.

The materials impact: Where and how materials and materials technologies interact with these industries and technologies. What they offer that is new or what they have to offer and what limitations / obstacles to their introduction exist.

Future prospects and R&D directions: Future prospects and R&D directions and the role of materials in them.

Biotechnology And Bio - Industries

The industry / technology: Production of high value - added products on a commercial scale. Modify the genetic machinery of living cells to produce useful bio - chemicals and bio - substances. The industry includes / relates to bio - processing, drug design, genetic engineering and pharmaceutical products, bio - materials and electronics and sensors. Other emerging areas include the agro - chemicals, intelligent drugs, molecular biology and agro - biology (genetically modified plants).

Special characteristics of the industry: Very strong influence from molecular biology, chemical engineering, bio-chemistry, bio-physics and medicine. Boosted by introduction / coupling with information technologies, new instrumentation and materials. Growing under the wings of the chemical and pharmaceutical industries (NRC 1989). (For recent developments see Ernst &Young. *Annual Report on the Life Sciences* (1997, 1998, 1999)).

The materials impact: Biomaterials and biomolecular materials include diverse materials (from all groups of materials) that are compatible with human tissues and mimic or substitute biological phenomena and / or functions. Applications include bio

- materials for medical applications (lenses, hip replacements, artificial skin, membranes, artificial bones) and a wide variety of many other products such as ultra - tough ceramic tank armour modelled on the molecular structure of abalone shells, and bio - degradable plastics for food packaging. They also provide the basis for many substances and processes (e.g. biological membranes for liquid filtration), and the means to carry out difficult bio - chemical reactions (catalysis) while advanced structural and functional materials enable the building up and creation of new powerful medical and biological instrumentation. Nanotechnologies are also expected to initiate dramatic progress in the biotechnology fields.

Future prospects and materials related R&D directions: Bio - mimetic materials (i.e. artificial muscles), completely bio - compatible artificial organs, smart drugs, bio - sensors and diagnostics, structural materials tailored after natural physical structures, environment friendly chemicals, organic computers, new life forms(?).

The Construction Industry

The industry: The construction industry is a very diverse industry. Its "products" include everything from large scale constructions like bridges, dams, roads, power plants and networks, off - shore oil platforms and other large infrastructure projects to any size of buildings either for business, housing or service provision of any kind, for recreation facilities and for accommodation. Common principles, however, apply to all branches of the industry and technology and ideas transfer from one branch to the other and vice versa is frequent.

Special characteristics of the industry: During the last 20 years, the technological and quality demands of emerging civilian construction applications was constantly rising and becoming more complex, that may take the form of longer bridges or larger, energy conscious and environmental friendly buildings. In addition, construction industries, traditionally regarded as low technology intensity industries, have already begun to feel the pressure originating from globalisation and internationalisation of competition. Simultaneously, the perception that construction projects must be approached as highly interactive systems where all activities (as in manufacturing) are interrelated and therefore must be managed as a manufacturing process and the realisation by the construction sector of their role as final materials and other technologies users, redirects the focus of the traditionally conservative sector to new materials and new technologies and accelerates the diffusion of innovation in the sector.

In parallel with these global tendencies, rapid developments are occurring in the areas of flexible and modular construction (including prefabrication technologies and in situ assembly); house construction from large lightweight single components; intelligent building facilities or structural deformation diagnostics including construction quality assurance; employment of new materials; applications of advanced robotics in dangerous or hazardous construction sites; automation technologies and machinery and advanced project management engineering.

Buildings and other infrastructure facilities (e.g. bridges, dams, airports, transport infrastructure) are being equipped with smart materials and "intelligent systems" such as sensors and data processors to monitor the environment and the structural integrity of the facility and provide security, air quality, thermal, lighting and energy control (buildings) and dynamic structural response (dams, bridges, power plants).

The Materials Impact: New and advanced materials have multiple applications in the construction sector: the entire range of smart or intelligent materials can be integrated into heavy infrastructure constructions to provide structural monitoring and evaluation or to transform a conventional building into a "smart" energy conscious, environment friendly building. Applications include optical fibers, light and heat sensitive glass, special coatings, insulation materials, light sensitive paints, shape memory alloys and piezoelectrics. Advanced composites and especially PMC and CCC as well as carbon and other synthetic fibers are expected to have a major impact in the construction sector. A combination of properties like high strength to weight ratio, high impact resistance, high dumping resistance and superb corrosion resistance make them irresistible for many large scale structural applications such as concrete reinforcement, substitution of structural steel or concrete and active control of structures, vibration control and low maintenance cost.

On the other hand, traditional construction materials fight back: advanced concrete has many times higher tensile strength than the conventional one while being substantially lighter. Other light weight ceramics with built-in heat and sound insulation substitute traditional tiles and bricks. Photovoltaics substitute roof tiles saving structural weight and providing environment friendly energy. Metals are also fighting back: structural steels with superior bonding properties, about 25% lighter than their predecessors and shaped to match design requirement of individual projects have already found their way to the market.

Future prospects and R&D directions: Advanced and new materials play an active role in the transformation of the construction industry from a low technology to a high tech sector. In many cases materials technologies or technological know - how related to them become the enabling tool for these transformation.

Future prospects include intensive R&D in new types of concrete and construction ceramics, ways to integrate intelligence systems into buildings and constructions, AC for construction applications, lightweight structural metals, adhesives, weathering resistant coatings, and new building subsystems such as pipes, wires and cables.

The Energy Sector

The industry: Energy is one of the most strategic assets of a nation. A country which has abundant, cheap and "clean" energy enjoys a high degree of independence. The Energy industry includes technologies which are involved in power generation, utilisation and distribution. Conventional power generation exploits renewable sources of energy (e.g. waterfalls, wind power or solar radiation) and thermal sources (burning of coal, peat, natural gas, oil or nuclear fuel). Future energy sources will possibly exploit the environmentally friendly thermal source of nuclear fusion.

Special characteristics of the industry: As the global population is growing, the need for electrical energy is rising steeply. Simultaneously the production of environmentally "dirty" energy - that is the heavy de - regulated use of thermal and nuclear sources is becoming less and less acceptable. To make things worse, thermal energy sources based on existing technologies and *materials* have almost exhausted their limits while energy production based on environmentally friendly technologies and *materials* exploiting renewable sources has still a long way to go before it becomes capable to substitute the thermal sources. Efforts are concentrated in more efficient energy production using thermal sources which will increase output and decrease fuel consumption and hazardous emissions to the environment, energy savings during energy distribution, energy storage (batteries) and better use of energy.

The Materials Impact: Materials and materials technologies literally hold the key for the future of the energy sector because their role is crucial for both production and utilisation of energy. With respect to conventional energy production using thermal energy sources materials can provide solutions such as: advanced blades of hot steam turbines increasing the operating temperature and efficiency of the turbine; better and more efficient burning theories and higher burning temperatures, increasing the efficiency of the fuel and reducing the production of hazardous substances; better and cheaper filters and emission traps; cheaper and more effective purification and preparation of fuels such as coal and peat. For nuclear power stations examples include new generations of special steels and concrete which can resist successfully to radiation damage. These developments are already under way but the real revolution will come from the introduction of new materials such as superconductors, and advanced photovoltaics in the energy field.

First of all, all technologies for energy production based on renewable sources are materials restrained. Solar power exploitation is still ineffective because there are no photovoltaics yet available to transform efficiently solar power to electric power. Photovoltaics are usually a special grade of ceramics and their further development rests in the abilities of the MSE field and solid state physics. Superconductors, another group of materials with usually ceramic structure, hold the key for the fusion reactors of the future which will produce environmental friendly, cheap and abundant electrical energy. Superconductors, below a specific temperature, have practically zero electrical resistance. Magnetic coils made of superconductors can generate the monstrous magnetic fields necessary to control the plasma chamber in which the fusion reaction takes place. Lower electrical resistance materials (mostly metals or even polymers) will save considerable energy losses during energy distribution and use (it is estimated that more than 10% of the produced energy is lost in the form of heat due to the electrical resistance of wires and cables) and will increase the output of all electric engines and machinery.

Future prospects and R&D directions: The above examples are just indicative of the impact of materials in the energy sector. In the near future, it is expected that the efficiency of thermal power plants will be increased to 60% - 75% from 35% to 50% as of now, including considerable fuel savings and emissions reduction. Materials technologies are mostly behind these developments. R&D efforts include all classes of materials with the aim develop materials operating effectively in high temperature corrosive environments. Intense efforts are also concentrated in materials for renewable energy sources. If fusion reactors and effective solar power cells become a reality, cheap electricity will be used to remove salt from the ocean water and then the Sahara and Gobi deserts will become green again. That means that the Earth mass be able to sustain a larger population without serious environmental damage.

Information Technologies (IT)

The industry / technology: Among many other, the industry includes four major branches corresponding to four major emerging technologies: high performance computing; advanced semiconductors devices and microprocessors; high-density data storage; and, in conjunction with optoelectronics and sensors technologies, artificial intelligence (DOC 1990).

- High - performance computing involves the design and development of architecture and "tools" for rapid and efficient processing, i.e. development of ways to program large systems to perform complex tasks.
- Advanced semiconductors devices and microprocessors incorporates the improvement and development of materials, fabrication techniques and advanced components and devices for use in electronic and computing equipment of all kinds. Computer performance heavily depends on these improvements.
- High - density data storage involves the development or improvement of erasable data storage devices offering several orders of magnitude improvement in information storage density.
- Artificial intelligence brings together electronic and electro - mechanical systems incorporating knowledge - based control systems.

Special characteristics of the industry: Information technologies is one of the two infrastructure, generic and enabling groups of technologies - the second group is materials technologies - upon which progress in any other technological or services sector critically depends. IT applications and products are as diverse as the term "Technology" and the sector enjoys rapid developments and improvements mainly motivated by a fusion of materials technologies and capabilities with advanced architecture and electronic design and engineering. Recent developments include semiconductors and microprocessors operating at higher speeds and frequencies (operating capability is estimated to be doubled every 18 months), reduced size, higher density, multiple functions and lower costs. Consecutive generations of magnetic disks produced with thin - layer technologies - a materials technology - steadily increase information density (doubles about every 3 years) and reduce access time. Magneto - optical disks provide very reliable high information densities combined with reduced danger of contact with storage media while advanced software can address huge problems of numerical and scientific computing reflected to advanced modelling and simulation techniques applied to all scientific principles.

The Materials Impact: Information technologies (the hardware) were developed upon the invention and continuous improvement of the silicon chip. Ever since, IT and its applications are inextricably related to materials technologies and their developments. Advanced semiconductors devices and high - density data storage technologies for example are almost entirely materials technologies, while artificial intelligence is directly related to materials and is expected to make a quantum progress leap by fusion of IT with nanotechnology, a clear materials technology assisted by advanced processing capabilities (sensors, optical technologies based controls). Optical based computers and optoelectronics follow the same pattern. They originate from the introduction of optical fibers, optical sensors and optical circuitry - all of them materials related technologies.

Future prospects and R&D directions: Further miniaturisation and condensation of semiconductors and microprocessors; computational speed; large - volume, low - cost and reliable manufacturing methods; even higher data storage densities; parallel processing and 3 - D microprocessors; size of information cells (domains); error detection; agile response to data storage and retrieval; IRAMs (Intelligent Random Access Memory = a microprocessor with built-in memory and programme); quantum dots and other single - electron devices; molecular computing; nanomechanical logic gates.

Telecommunications & Multi-Media

The industry: The industry is a services based sector. It includes the provision and transmission of sound, image and other data using wire based communication systems, optical networks, wireless networks, and satellites.

Special characteristics of the industry: The industry has become one of the most technology intense industrial sectors both in terms of receiving and transmitting information as well as the provision of products to interpret and present this information (e.g. mobile telephones, liquid crystal televisions and screens, multi - purpose communication equipment). It is mainly a "technology user" industry growing simultaneously with software and hardware information technologies, optoelectronics, satellite developments and recently materials technologies, all of which make significant contributions to further progress of the sector. During the last 15 years the industry has taken a leading role in these supporting technologies with heavy technological and financial investment in materials, optoelectronics and satellite research.

The Materials Impact: The direct materials impact comes mainly from the introduction of the optical fiber and from materials technologies making it compatible with existing systems. Optical fibers have an enormous information - carrying capacity thousands of times greater than conventional copper - based cables and wires. This is because optical fibers use light as an information carrier, (conventional wires use electrons and electricity), and their performance is based upon the low loss of light intensity (that is signal losses) over very long distances (up to five hundred kilometres for the silica based fibers) without the need for re amplification. Furthermore, unlike metallic cables and systems, fiber optical carriers are not affected by electromagnetic disturbances. As such, optical fibers simplify telecommunication systems, bring down their installation and operational cost and multiply their capacity to transfer information bringing into sight high resolution, world-wide TV, "videophone" and computer networks.

Future prospects and R&D directions: New, fluoride based optical fibers which will have 10 times lower light intensity loss than silica based fibers; optical switches and optical sensors, data and image processing, high definition liquid crystal display, integrated optical circuitry and solid state lasers for information transmission (information beams).

Optoelectronics

The industry / technology: The technology employs the use of light (visible, infra-red, or ultra-violet) as the means to transmit, measure, process and store information. Combined with soft and hard core information technologies, optoelectronics provide the branch of digital imaging technology which uses digital technology to store, display, process, analyse and transmit images.

Special characteristics of the industry: Very strong bonds with information technologies (data storage, process and analysis, digital image and sound analysis), materials technologies (optical fibers, optical sensors, integrated optical circuitry) and telecommunications (see above). Growing bonds with electronic engineering, artificial intelligence, high definition systems, telecommunications, data compression and nanotechnologies.

The Materials Impact: Fiber optics and special materials for actuators and sensors. They provide superior to the conventional electronics information handling capacity and signal quality, reduced sensitivity to interference, increased processing speed and data storage capacity and high resolution video display.

Future prospects and R&D directions: Advanced optical sensors; optical computing (thousands of times more effective than today's electronic computing); materials limitations connected with integration of components and compatibility with electronic devices and solid - state lasers for information transmission; effective utilisation of bandwidth; efficient, high - resolution large and flat displays.

Transport

The industry: The industry includes everything that moves or carries something (people or goods) from place A to place B. It includes the automotive industry, the aerospace industry, the aircraft industry, railways, passenger liners, cargo vessels, tankers, the shipbuilding industry and a large section of military technologies (vehicles, aircraft, helicopters). The transport section is closely interrelated with large sections of the construction industry (construction of transport infrastructure – e.g. ports, airports, roads etc.) and it increasingly integrates IT and telecommunications to its final products.

Special characteristics of the industry: Light weight cars and vehicles to minimise emissions and pollution; electric cars and trucks; super fast trains running at more then 300 Km/h (magnetic and levitation trains), larger air - carriers with the capacity to carry more than 500 people at a time; supersonic civilian aircraft; safer and environment conscious oil tankers and bulk carriers are just a few examples of the trends shaping the character of the sector.

The Materials Impact: Light weight materials such as aluminium transform the body of cars and other transport structures; superplasticity gives new dimensions and opportunities to steel to fight back; superconductivity is the foundation of the levitation phenomenon and the levitation -Maglev- trains; new materials make batteries for electric vehicles lighter and more effective; ceramic materials make engines more reliable and able to operate in higher temperatures; advance ceramics and alloys make aircraft more agile or able to carry larger loads; safety in ships is increased and new propulsion systems are under investigation. There is literally no element in the transport sector unaffected by materials and materials technologies.

Future prospects and R&D directions: Maglev trains; solar cars (?) for in-city short routes; fully operational, long distance electric cars; cargo ships using electrical currents as power source; environmental - proof tankers and bulk carriers; large supersonic air-carriers are just some of the most expected and already active directions in the field.

ANNEX 3.1: Recent Progress in Materials (1960 – 1989)

Annex 3.1 summarises some striking examples of recent progress in materials and just a few of their commercial applications and impacts on "products", services and technologies. Note that different references give different information about the discovery/invention of substances, materials and processes. This table includes information confirmed by more than one source and endorsed by official sources. The employed sources are: NRC 1989, Lastres 1994, US Bureau of Mines, US Department of Industry.

Recent progress in materials, 1960-1989

Year	Event
1960	Ethylene vinyl acetate co-polymers introduced Acetal co-polymer used in automobile brake-cable pulley Development of high-impact styrene furniture legs with through-bolt construction accomplished, starting trend to plastic furniture. Glass-ceramic patented Amorphous metal alloys produced Synthetic diamond production begins Aircraft with fibreglass-polyester skin and paper honeycomb core first flown Demonstration of advantages of parallel metal grain boundaries for turbine blades Effects of rapid solidification process first reported
1961	Tape process of forming thin ceramics patented
1962	Polyvinylidene fluoride introduced Transparent polycrystalline alumina patented Nickel-based superalloys using oxide-dispersion strengthening announced Development of gallium arsenide laser diode accomplished First commercial niobium-titanium superconducting wire developed
1963	Polyamide (Polymer) SP^{TM} introduced, increasing the thermal endurance of thermo-plastics to 400^{o}C Low-pressure structural foam processing invented Nomex^{TM} flame-resistant aramid fibre and paper introduced for protective clothing, high-performance hoses, high-temperature electrical uses Float process for making glass patented Sintered alumina abrasive grain patented
1964	Polyphenylene oxide (PPO) components for appliances and electrical connectors produced Surlyn^{TM} ionomer resins introduced, offering clarity or glass and toughness for use in food packaging, sporting goods and automobiles. 'Certi-fired' thick film materials for electronic circuit miniaturisation introduced.

Recent progress in materials, 1960-1989 (Continued)…

1965	Polysulfone (Udel^{TM}) developed and introduced, finds commercial uses in electrical components Glass-reinforced styrene-acrylonitrile (SAN) co-polymers appear in automobiles Clysar^{TM} shrink film used in cold packaging applications Process patented for making dense impregnated, silicon-carbide articles Development of cobalt-rare earth magnets accomplished
1966	Modified PPO introduced as Noryl^{TM}, cheaper and easier to process Machine for high-density polyethylene blow-moulded milk bottle production introduced Acrylonitrile-butadiene-styrene (ABS) used on exterior surfaces of helicopter Polyamide film, Kapton^{TM}, offering resistance to moisture and extreme temperatures, is developed and becomes valuable for aerospace use Development of optical fibres accomplished
1968	Polyphenylene sulphide (PPS) introduced as Ryton^{TM} Chrome plated polypropylene used in automobiles Riston^{TM} photo-polymer films for pri9nted circuit board production Very large-scale integration (VLSI) electronic circuitry commercialised High-toughness ceramics (Al_2O_3+TiC system) developed for cutting tools
1969	Corian^{TM} introduced as a stain, scratch and burn resistant non-porous material
1970	Boron-epoxy horizontal stabiliser on the F-14 represents the first advanced composite part produced that was designed as a composite part and not as a substitute for metal Blow-moulding of PET became popular High-toughness thermet (TiN system) developed for cutting tools
1971	Development of mechanical alloying accomplished Development of metal injection moulding accomplished Zinc oxide varistor patented.
1972	Polyethersulfone, Vitrex^{TM}, used in aerospace and automotive applications Robotics used in the plastics industry as the first high-speed machine mounted, automatic part remover for injection is patented Imron^{TM} polyurethane enamel introduced for automotive applications Development of Sialons accomplished
1973	Kevlar^{TM}, aramid fibres introduced, which, on a weight basis, is five times stronger than steel. Used in sporting goods industrials products, bullet-resistant vests, automobiles aerospace etc Superconductivity demonstrated at 23^{o}K by depositing niobium-germanium on a substrate Using thin-film technology
1974	Carbon-reinforced epoxy upper aft rudders introduced in MacDonnell Douglas DC-10 Acrylic sheet stiffened with reinforced plastic used for all exterior body panels in automobiles Sintered high-speed steels developed for cutting tools
1975	Reaction-injection moulded urethane held in place by a glass-reinforced polypropylene sheet retainer is used as the front end of automobiles
1976	All plastic jet designed Plastic microwave cook-ware becomes available to the consumer market Amorphous silicon solar cell introduced
1977	Commercial production of linear low-density polyethylene (LLDPE) begins Polyphenylsulfone, Radel^{TM}, introduced
1978	Polyetheretherketone (PEEK), a high-temperature resistant material becomes available for aerospace and computer applications Polyacrylates introduced The practical use of optical fibres begins

Recent progress in materials, 1960-1989 (Continued)…

1979	The Gossamer Albatross, made in large part of Mylar^{TM} polyester film, becomes the first human-powered aircraft to cross the English Channel Rynite^{TM}, a very rigid polyethylene terephthalate (PET) introduced for use in electronic components, furniture, lighting fixtures, industrial machines and automobiles Tungsten-fibre-reinforced ferro-chromium-aluminium-ytrium use experimentally for jet engine rotor blades.
1980	Acid-leaching process introduced for producing 99.9% silica fibres that resist devitrification up to 1370^{o}C. Used as insulation for the Space Shuttle
1981	Pyralin^{TM} polyimide coatings used as insulation in semi conductor chips Superconductivity used in magnetic resonance imaging medical equipment
1982	Modified polyimide (polyether-imide) introduced, Ultem^{TM}, for use in high-performance optical fibre components, co-extruded food packaging and advanced composites High-purity polycarbonate resin for manufacture of compact, discs (CDs) introduced Jarvik-7 artificial heart designed, made largely of plastics, supports patient for 112 days
1984	Melt-processible liquid crystal polymers (LCP) introduced as Xydar^{TM} Five ship sets of composite horizontal stabilisers installed on the Boeing 737 Plastic fuel tank for passenger car is blow-moulded and treated with sulfonation process to control hydrocarbon permeability The twin-turboprop Avtek 400^{TM} promotes the art of advanced composites Selar polyamide barrier resins introduced to blow-moulded bottles used for containing chemicals and hydrocarbons Quasi-periodic crystals discovered
1985	Bexloy^{TM} engineering resins introduced for low-weight, high-strength auto body parts to replace metals Alumina-fibre-reinforced aluminium experimental squeeze casting introduced Graphite-fibre-reinforced magnesium vac-assisted investment casting introduced. Electronic discharge machining of metal matrix composites demonstrated
1986	The Voyager, a composite aircraft, flies around the world without refuelling. Superconductivity demonstrated at 39^{0}K with the development of a ceramic compound of lanthanum, strontium, copper oxygen Large billets of both silicon-carbide-particle-reinforced aluminium and silicon-carbon-wire-reinforced aluminium produced Alumina-fibre perform-reinforced aluminium introduced Molten metal oxidation method used to produce net shapes Commercial production of alumina-silica-fibre-reinforced aluminium pistons by squeeze casting begun Boron-bibre-inforced aluminium used in sports equipment Water jet and laser cutting of metal matrix composites demonstrated
1987	Superconductivity demonstrated at 98^{0}K (liquid nitrogen range) with the development of a ceramic compound of yttrium, barium, copper, oxygen Silicon-carbide-particle-reinforced aluminium, optical-grade material developed Discharge welding of silicon-carbide-fibre and wire-reinforced aluminium demonstrated Silicon-carbide-particle-reinforced aluminium formed by standard forming technique
1988	Silicon-carbide-fibre-reinforced titanium and silicon-carbide-fibre-reinforced titanium-aluminium, experimental metal matrix composites developed for temperatures near 2000^{o}F Superconductivity demonstrated at 125^{o}K Development of high-purity, low-defect indium phosphide single crystals, which has high potential for use in space-based solar cell
1989	The first composite business jet, Beech Starship, goes into commercial production Development of high-purity, low-defect indium phosphide single crystals, which has high potential for use in space-based solar cell.

Sources: NRC 1989, Lastres 1994, US Bureau of Mines, US Department of Industry.

ANNEX 7.1: R&D INDICATORS IN GREECE

This Annex provides information on R&D issues in Greece in the form of graphs and tables on basic R&D indicators. The basic sources of information are the OECD Science and Technology Indicators (OECD 1996) and the statistics of GSRT (GSRT 1994, 1995).

One of the basic characteristics of the Greek R&D system is the comparatively small size of its activities and the disproportional participation of industry and services sectors in research activities and R&D expenditure. Budget appropriations for R&D expenditures (GERD) increased appreciably throughout the 1980s from 0.16% of GDP to 0.32% towards the end of the decade (see **Figures A7.1 & A7.2**). During 1994 Greece dedicated 0.46% of the GDP for R&D expenditures while the EU average GERD is 2% of GDP. Moreover, in 1994, the official participation of industry and services in the total R&D expenditure was approximately 25%, **(Figure A7.6a)** while the state is the primary contributor with a share hovering around 75% approximately in 1993 figures. **Figures A7.4 & A7.5** provide the percentage of public expenditure on R&D by source of funds. GSRT, the Ministry of Development and the Ministry of Education and Culture are by far the most important contributors. However, as Figure 6A indicates, the business sector and international sources are steadily increasing their percentage of the GERD. A worrying trend is the rapidly decreasing percentage of the contribution of large public enterprises (such as the National Power Enterprise). The public sector however, (public agency laboratories, research and technological institutes) and the higher education institutions (public universities) are absorbing most of the available GERD (as performing sectors). As can be seen from **Figure A7.6b**, the private sector performed less than 26% of the total R&D activities for 1993 while the performance contribution of other organisations (non-profitable and public enterprises) is negligible. Moreover, the importance of the public sector is also illustrated by **Figure A7.7** which provides the distribution of research personnel in Greece as a percentage of man hours for 1993. This immediately shows the overconcentration of researchers at public universities (46%) and public research institutes (33%) while enterprises do not exceed 20% of the total. The total figures of researchers in 1993 were 0.6% of the working population and 1.25% of the total research population of EU. Finally, **Tables A7.1-7** provide numerical comparisons of the most basic R&D indicators between Greece and the other OECD countries. In the case of Greece however, these figures should be seen with scepticism. Information gathering imperfections and classification / evaluation flaws distort the final picture. In the author's opinion, the existing evidence supports the argument that the real figures of the basic R&D indicators are considerably higher than the official values.

Figure A7.1: Gross Domestic Expenditure on R&D (GERD) as a Percentage of GDP. Source GSRT 1995

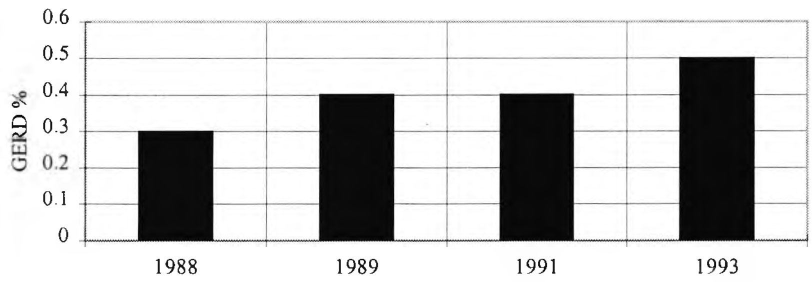


Figure A7.2: Percentage of Gross Expenditure for R&D to the Gross Domestic Product. Source : GSRT 1994

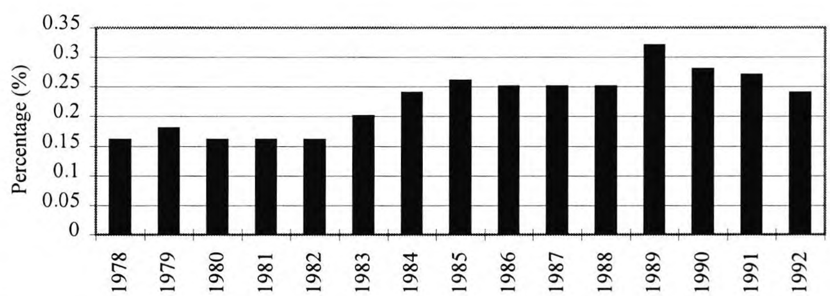


Figure A7.3: Percentage of Public Funding (State Budget) for R&D to the GDP. Source: GSRT 1997

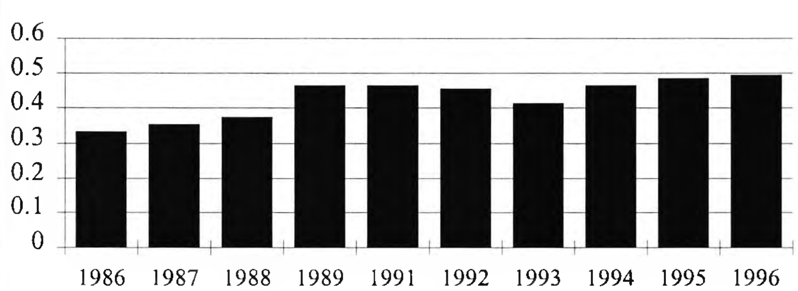


Figure A7.4: Percentage of Public Expenditure on R&D by Source of Funds. Source : GSRT 1995.

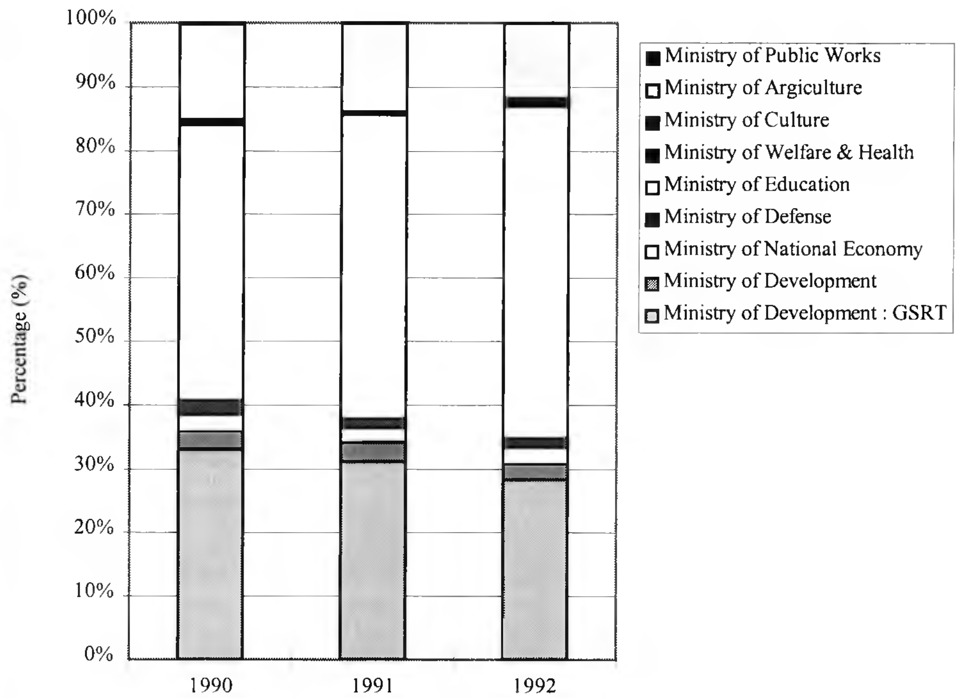


Figure A7.5: Goverment R&D Appropriations Funds provided by GSRT. Source : GSRT 1995

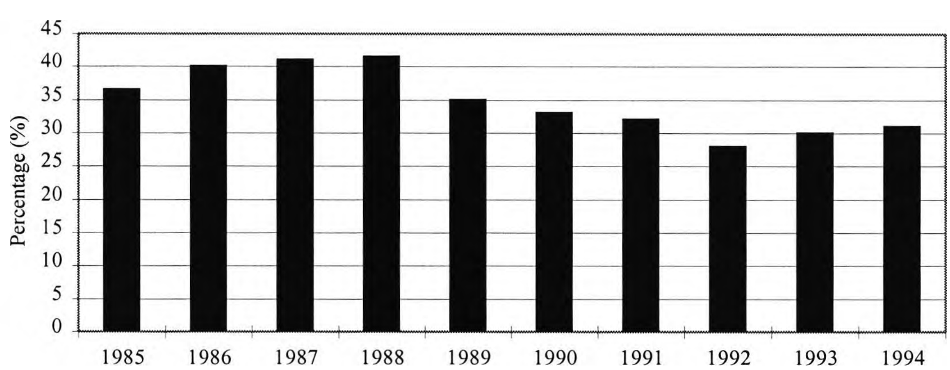


Figure A7.6a: Gross Domestic Expenditure on R&D by Source of Funds. Source : GSRT 1995

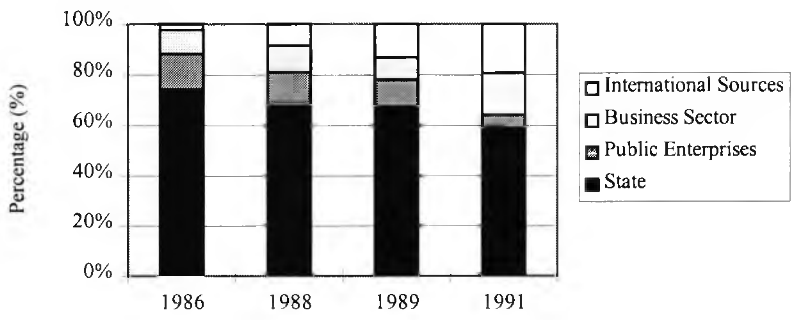


Figure A7.6b: Gross Domestic Expenditure on R&D by Performing Sector. Source : GSRT 1995.

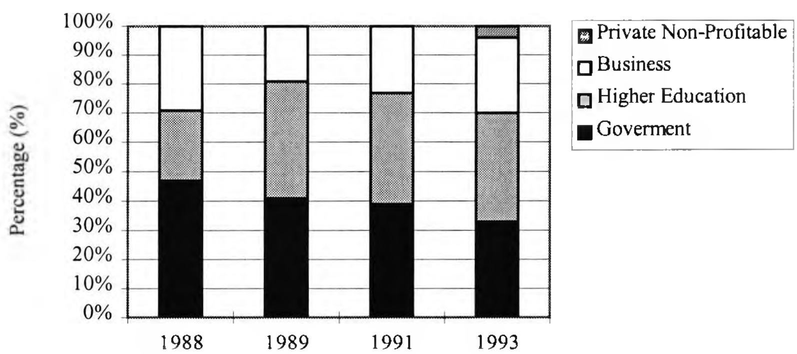
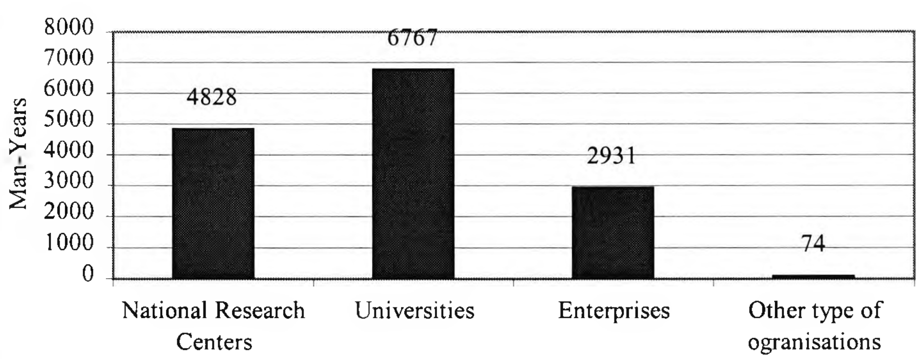


Figure A7.7: Research Personel in Greece (1993). Numbers in man-years. Source: GSRT 1995



ABBREVIATIONS

BE	Business enterprise sector
BEMP	Business enterprise R&D personnel
BERD	Expenditure on R & D in the business enterprise sector
FTE	Full-time equivalent (on R&D)
GBAORD	Government budget appropriations or outlays for R&D
GERD	Gross domestic expenditure on R&D
GUF	General University funds
HE	Higher education
HEMP	Higher education R&D personnel
HERD	Expenditure on R&D in the higher education sector
NEC	Not elsewhere classified
PNP	Private non-profit sector
PPP	Purchasing power parities
R&D	Research and experimental development
RSE	R&D scientists and engineers, researchers
TBP	Technology balance of payment
..	Data not available

STANDARD FOOTNOTES

a) Break in series with previous year for which data is available.
b) Secretariat estimate or projection based on national sources.
c) National estimate or projection adjusted, if necessary, by the Secretarial to meet OECD norms
d) (Note used only for internal OECD data-processing.)
e) National results adjusted by the Secretariat to meet OECD norms.
f) Including R&D in the social sciences and humanities.
g) Excluding R&D in the social sciences and humanities
h) Federal or central government only.
i) Excludes data for the R&D content of general payment to the higher education sector for combined education and research (public GUF).
j) Excludes most or all capital expenditure.
k) Total intramural R&D expenditure instead of current intramural R&D expenditure.
l) Overestimated or based on overestimated data.
m) Underestimated or based on underestimated data.
n) Included elsewhere.
o) Includes other classes.
p) Provisional.
q) At current exchange rate and not at current purchasing power parities.
r) Including international patent applications.
s) Un-revised breakdown not adding to the revised total.
t) Other anomaly.

Source: OECD Science, Technology and Industry Outlook 1996

Table A7.1: GERD as a percentage of GDP

	1975	1981	1985	1990	1991	1992	1993	1994
United States	2.3	2.4	2.9	2.8	2.8[8]	2.8	2.7	2.5
Canada	1.1	1.2	1.4	1.5	1.5	1.5	1.5	1.5
Mexico	..	..	..	..	..	..	0.3	..
Japan (adj.)	1.8	2.1	2.6	2.9	2.9	2.8	2.7	..
Australia[1]	1.0	1.0	1.3	1.4	..	1.6	..	..
New Zealand[2]	0.9	0.9	..	0.9	0.9	..	..	..
Austria	0.9	1.2	1.3	1.4	1.5	1.5	1.5	1.6
Belgium[3]	1.3	..	1.7	1.7[8]	1.7	..	..	..
Czech Republic	..	..	..	..	..	..	..	..
Denmark	1.0	1.1	1.3	1.6	1.7	1.8	1.8	..
Finland	0.9	1.2[8]	1.6	1.9	2.1	2.2	2.2	..
France	1.8	2.0[8]	2.3	2.4	2.4	2.4	2.5	2.4
Germany[4]	2.2	2.4	2.7	2.8	2.6[8]	2.5[8]	2.5	2.4
Greece[5]	..	0.2[8]	0.3	0.5[8]	0.5	..	0.6	..
Iceland	0.8	0.6	0.7	1.0	1.2	1.3	..	..
Ireland	0.8	0.7	0.8	0.9	1.0	1.1	1.2	..
Italy	0.8	0.9	1.1	1.3	1.3	1.3	1.3	1.2
Luxembourg	..	..	..	..	..	..	..	..
Netherlands	2.0	1.9	2.1	2.0	1.9	1.9	1.9	..
Norway[3]	1.3	1.3	1.6	1.9	1.8	..	1.9	..
Portugal[6]	0.3	0.3	0.4	0.5	..	0.6	..	..
Spain	0.4	0.4	0.6	0.9	0.9	0.9[8]	0.9	0.8
Sweden[3]	1.8	2.3[8]	2.9	2.9	2.9	..	3.3	..
Switzerland	2.4	2.3	2.9	2.9[8]	..	2.7	..	..
Turkey	..	..	..	0.3	0.5	0.5	0.5	..
United Kingdom	2.2	2.4[8]	2.3	2.2	2.2	2.2	2.2	..
North America[7]	..	2.3	2.8	2.7	2.6	2.5	2.5	..
EU – 15	..	1.7	1.9	2.0	2.0[8]	2.0	2.0	..
Total OECD[7]	..	2.0	2.3	2.4	2.3	2.3	2.2	..

1. 1976 and 1986.
2. 1979.
3. 1989.
4. Figures for Germany and zone totals from 1991 onwards refer to the whole of Germany
5. 1986 and 1989.
6. 1976, 1982 and 1986
7. Including Mexico from 1991 onwards.

(...) Break in series with previous year for which data is available

Source: OECD Science, Technology and Industry Outlook 1996

Table A7.2: Gross domestic expenditure on R&D (GERD) by sector of performance and source of funds (in million Dr)

	1987	1988	1989	1990	1991	1992	1993
Business enterprise							
Financed by:							
Business enterprise	..	6 137.7	6 890	..	11 484	..	19 063
Direct government	..	876.2	787	..	848	..	1 878
Higher education	..	0	..	..	..	..	..
Private non-profit	..	0	..	..	..	..	..
Funds from abroad	..	725	1 470	..	3 197	..	8 798
Total	..	7 752.2	9 147	..	15 529	..	29 739
Government							
Financed by:							
Business enterprise	..	15.2	181.6	..	238	..	405
Direct government	..	12 440.7	15 354.9	..	17 404	..	21 562
Higher education	..	..	..	..	..	..	..
Private non-profit	..	..	..	..	..	..	..
Funds from abroad	..	684.1	1 829.6	..	6 242	..	10 157
Total	..	13 139.9	17 366.1	..	23 844	..	32 124
Higher Education							
Financed by:							
Business enterprise	..	318	892	..	1 219	..	1 551
Direct government	..	435	1 739.8	1 179	1 311	..	6 426
General university funds	4 4130	4 973.3	10 371.3	11 654	14 761	..	17 744
Sub-total government	..	5 406.3	12 111.1	12 833	16 072	..	24 170
Higher education	..	1.5	36.3	..	426	..	2 4 23
Private non-profit	..	0	..	..	..	..	..
Funds from abroad	..	946.8	1 445.8	..	2 373	..	12 697
Total	..	6 674.6	14 485..2	..	20 090	..	40 841
Private non-profit							
Financed by:							
Business enterprise	..	..	..	..	..	..	54
Direct government	..	..	..	..	..	..	154
Higher education	..	..	..	..	..	..	..
Private non-profit	..	..	..	..	..	..	152
Funds from abroad	..	..	..	..	..	..	211
Total	..	..	..	..	..	..	571
GERD							
Financed by:							
Business enterprise	..	6 509.9	7 963.6	..	12 941	..	21 073
Direct government	11 586.1	13 751.8	17 881.7	..	19 563	..	30 020
General university funds	4 413	4 973.3	10 371.3	11 654	14 761	..	17 744
Sub-total government	15 999.1	18 725.1	28 253.0	..	34 324	..	47 764
Higher education	..	1.5	16.3	..	426	..	2 423
Private non-profit	..	0	0	..	..	..	152
Funds from abroad	..	2 356.2	4 745.5	..	11 812	..	31 863
Total	..	27 589.7	40 998.1	..	59 503	..	103 275
1.2 Million constant $ (1990 prices and ppps)							
Business enterprise							
Financed by:							
Business enterprise	..	59.6	59.1	..	69.4	..	88.3
Direct government	..	8.5	6.8	..	5.1	..	8.7
Higher education	..	0	..	..	..	..	..
Private non-profit	..	0	..	..	..	..	..
Funds from abroad	..	7.0	12.6	..	19.3	..	40.7
Total	..	75.1	78.5	..	93.8	..	137.7
Government							
Financed by:							
Business enterprise	..	01	1.6	..	1.4	..	1.9
Direct government	..	120.1	131.8	..	105.1	..	99.8
Higher education	..	..	..	..	..	..	..
Private non-profit	..	..	..	..	..	..	..
Funds from abroad	..	6.6	15.7	..	37.7	..	47
Total	..	129.6	149.1	..	144.3	..	148.7
Higher Education							
Financed by:							
Business enterprise	..	3.1	7.7	..	7.4	..	7.2
Direct government	..	4.2	14.9	8.4	7.9	..	29.8
General university funds	49.3	48	89	82.8	89.2	..	82.2
Sub-total government	..	52.2	104	91.1	97.1	..	111.9
Higher education	..	0	0.3	..	2.6	..	11.2
Private non-profit	..	0	..	..	..	..	..
Funds from abroad	..	9.1	12.4	..	14.3	..	58.8
Total	..	64.5	124.3	..	121.4	..	189.1
Private non-profit							
Financed by:							
Business enterprise	..	..	..	..	..	..	0.3
Direct government	..	..	..	..	..	..	0.7
Higher education	..	..	..	..	..	..	..
Private non-profit	..	..	..	..	..	..	0.7
Funds from abroad	..	..	..	..	..	..	1.0
Total	..	..	..	..	..	..	2.6
GERD							
Financed by:							
Business enterprise	..	62.8	68.4	..	78.2	..	97.6
Direct government	12 9.3	132.8	153.5	..	118.2	..	139
General university funds	49.3	48	89	82.8	89.2	..	82
Sub-total government	178.6	180.8	242.5	..	207.4	..	211.1
Higher education	..	0	0.3	..	2.6	..	11.2
Private non-profit	..	0	0	..	..	..	0.7
Funds from abroad	..	22.8	40.7	..	71.4	..	147.5
Total	..	266.4	351.9	..	359.5	..	478.2

Source: OECD Science, Technology and Industry Outlook 1996

Table A7.3: Financing of R&D expenditures by source (percentage)

	Business enterprise				Government				Other national sources				Abroad			
	1971	1981	1991	1993	1971	1981	1991	1993	1971	1981	1991	1993	1971	1981	1991	1993
United States	39.3	48.8	57.5	58.7	58.5	49.3	40.5	39.2	2.1	1.9	2..0	2.1	..	..	..	..
Canada	27.0	41.3	41.8	42.3	64.6	50.0	43.4	42.4	6.5	4.9	4.8	4.5	1.9	3.9	10.0	10.0
Mexico	..	..	..	9.3	..	..	..	82.3	..	..	..	7.6	..	..	..	0.7
Japan (adj.)	64.8	67.7	77.4	73.8	26.5	24.9	16.4	19.6	8.5	7.3	6.1	7.0	0.1	0.1	0.1	0.1
Australia[4]	..	20.2	41.4	44.3	..	72.8	54.7	49.9	..	2.1	2.7	3.9	..	1.0	1.3	1.9
New Zealand[1,3]	17.3	15.7	32.9	..	81.8	84.2	65.3	..	0.9	0.1	..	..	0.0	0.0	1.9[9]	..
Austria[4]	50.8	50.2	50.2	47.7	47.7	46.9	46.5	49.1	0.8	0.4	0.3	0.3	0.7	2.5	3.0	2.9
Belgium[3]	45.4	65.8	64.8	..	51.8	31.0	31.3	..	1.2	1.8	0.9[9]	..	1.5	1.4	3.9[9]	..
Czech Republic	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Denmark[4]	44.6	42.5	51.4	50.0	53.9	53.5	39.7	37.7	1.0	2.0	4.6	5.0	0.5	2.1	4.4	7.3
Finland	52.3	54.5	56.3	56.6	44.3	43.4	40.9	39.8	2.5	1.1	1.5	1.8	0.8	1.0	1.3	1.8
France	36.7	40.9	42.5	46.2	58.7	53.4	48.8	44.3	0.9	0.6	0.7	1.3[9]	3.7	5.0	8.0	8.1
Germany[5]	52.0	57.9	61.7	60.2	46.5	40.7	35.8	37.0	0.6	0.4	0.5[9]	0.5[9]	0.8	1.0[9]	1.9[9]	2.3
Greece[5]	..	21.4	21.7	20.1	..	78.6	57.7	47.3	..	..	0.7	2.6	..	..	19.9	30.0
Iceland	7.5	5.7	24.5	24.4	89.8	85.6	69.7	69.8	0.0	5.0	1.7	1.6	2.7	4.3	4.1	4.2
Ireland	40.9	37.7	59.4	63.8	53.1	56.5	28.2	25.3	4.4	1.1	2.1	2.6	1.6	4.8	10.3	8.3
Italy	52.2	50.1	47.8	49.9	41.1	47.2	46.6	45.9	4.8	0.0	..	..	1.9	2.7	5.7	4.2
Luxembourg	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Netherlands	51.3	46.3	51.2	47.3	44.5	47.2	44.9	44.7	0.7	1.3	1.9[9]	2.2	2.7	5.2	2.0	5.7
Norway[4]	37.7	40.1	44.5	44.3	59.4	57.2	49.5	49.1	1.4	1.4	1.3	1.3	1.5	1.4	4.6	5.4
Portugal[2,7]	27.8	26.6	27.0	20.2	65.6	66.8	61.8	59.4	5.2	4.7	6.5	5.4	1.4	1.9	4.6	14.9
Spain[6]	44.1	42.8	48.1	43.7	54.6	56.0	45.7	50.2	0.5	0.1	0.6	0.6	0.8	1.1	5.6	5.5
Sweden[3]	54.4	54.9	61.5	..	40.2	42.3	34.3	..	2.0	1.4	2.7	..	1.0	1.5[9]	1.5	..
Switzerland[6]	73.4	75.1	..	67.4	14.2	24.9	..	28.4	0.5	..	..	2.3[9]	1.5	..	..	1.9
Turkey	..	..	28.5	31.8	..	..	70.1	65.2	..	..	1.3	2.2	..	..	0.2	0.8
United Kingdom[1]	43.5	42.0	50.4	52.1	48.8	48.1	34.2	..	2.3	3.0[9]	3.6[9]	3.9	5.4	6.9[9]	11.8	11.7
North America	..	48.4	56.4	57.4	..	49.3	41.0	39.8	..	2.0	2.1	2.3	..	..	..	..
EU-15	..	48.7	52.5	53.0	..	46.7	40.6	39.6	..	1.1	1.3	1.5	..	3.5	5.6	5.9
Total	..	51.2	58.8	58.6	..	45.0	36.5	36.3	..	2.4	2.6	2.9	..	..	..	..

1. 1972.
2. 1990 and 1992.
3. 1979.
4. 1970.
5. Figures for Germany and zone totals from 19991 onwards refer to the whole of Germany
6. 1992.
7. 1980.
8. Overestimated.
9. Change in survey methods or coverage.

Source: OECD Science, Technology and Industry Outlook 1996

Table A7. 4: Distribution of R&D by sector of performance

	Business enterprise				Government				Higher Education				Private non-profit			
	1971	1981	1991	1993	1971	1981	1991	1993	1971	1981	1991	1993	1971	1981	1991	1993
United States[1]	65.9	70.3	72.8	71.2	15.5	12.1	9.9	10.2	15.3	14.5	14.1[9]	15.2	3.3	3.1	3.3	3.5
Canada	33.4	48.7	53.9	54.4	31.9	23.4	18.7	17.9	33.9	27.0	26.4	26.4	0.8	0.8	1.1	1.3
Mexico	..	..	..	8.0	..	..	..	50.3	..	..	..	41.7	..	..	..	..
Japan (adj.)	64.7[8]	66.0[8]	75.4[8]	71.1[8]	13.8	12.0	8.1	10.0	19.8	17.6	12.1	14.0	1.7	4.5	4.4	4.9
Australia[2]	..	25.0	40.7	44.7	..	45.1	32.2	27.4	..	28.5	25.8	26.6	..	1.4	1.3	
New Zealand[3]	21.8	..	31.7[9]	..	59.5	..	49.3[9]	..	18.0	..	19.0[9]	..	0.7	..	..	..
Austria[1,4]	54.6	55.8	58.6	..	10.2	9.0	7.5	..	33.2	32.8	32.4	..	1.9	2.3	1.6	..
Belgium	51.0	..	66.5	..	14.8	..	6.1[9]	..	33.4	..	26.2[9]	..	0.8	..	1.2[9]	..
Czech Republic	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Denmark[1]	46.9	49.7	58.5	58.3	25.6	22.7	17.7	17.8	26.3	26.7	22.6	22.8	1.2	0.9	1.2	1.0
Finland	54.5	54.7	57.0	58.4	21.6	22.5[9]	20.2[9]	20.5	21.0	22.2[9]	22.1[9]	20.5	3.0	0.6	0.7	0.7
France	56.2	58.9	61.5	61.7[9]	26.9	23.6	22.7	21.2[9]	15.6	16.4[9]	15.1	15.7	1.3	1.1	0.8	1.4[9]
Germany[5]	63.7	70.2[9]	69.3[9]	66.9[9]	14.2	13.7[9]	13.9[9]	14.8[9]	21.6	15.6	16.3[9]	18.1[9]	0.6	0.5	0.4[9]	0.3[9]
Greece	..	22.5	26.1	26.8	..	63.1	40.1	32.0	..	14.5	33.8[9]	40.7	..	..	..	0.3
Iceland[6]	1.1	9.6	21.8	22.0	75.7	60.7	44.5	43.4	22.1	26.0	29.4	30.6	1.2	3.7	4.4	4.1
Ireland	38.9	43.6	62.0	68.7	44.5	39.3	13.7	10.5	13.9	16.0	22.6	19.9	2.7	1.1	1.6	0.8
Italy	55.9	56.4	58.5	58.0	20.8	25.7	21.5	21.5	23.3	17.9	20.1	20.5	..	..	..	..
Luxembourg	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Netherlands	55.2	53.3	53.2	53.0	19.1	20.8	19.6	19.4	23.7	23.2	24.7[9]	24.9	2.0	2.8	2.5[9]	2.7
Norway[1]	45.6	52.9	54.6[9]	53.5	20.4	17.7	18.8[9]	19.2	32.6	29.0	26.7	27.3	1.5	0.5	..	..
Portugal[2,7]	24.7	28.6	26.1	21.7	51.2	47.3	25.4	22.1	18.5	19.9	36.0	43.0	5.6	4.2	12.4	13.1
Spain[6]	43.8	45.5	56.0	48.6	45.7	31.6	21.3	20.8	10.5	22.9[9]	22.2	29.9[9]	..	..	0.5[9]	0.6
Sweden	66.5	63.7	68.2	71.1	8.4	6.1[9]	4.1	4.0	24.9	30.0[9]	27.6	24.7	0.1	0.3[9]	0.1	0.2
Switzerland[4,6]	79.0	74.2	74.9[9]	70.1	5.9	5.9	4.3[9]	3.7	13.3	19.9	19.9[9]	25.0	1.8	..	0.8[9]	1.2
Turkey	..	..	21.1	22.9	..	..	7.9	9.9	..	..	71.1	67.2	..	..	..	..
United Kingdom[3]	62.8	63.0	65.6[9]	65.9	25.8	20.6	14.2[9]	13.8	8.7	13.6[9]	16.3[9]	16.5	2.6	2.8	4.0[9]	3.8
North America	..	69.3	71.3	69.7	..	12.6	10.7	11.0.	..	15.1	14.9	16.0	..	3.0	3.1	3.3
EU-15	..	62.4	63.6	62.6	..	18.9	16.8	16.6	..	17.4	18.3	19.4	..	1.4	1.2	1.3
Total OECD	..	65.8	69.0	67.0	..	15.0	12.4	12.9	..	16.6	15.9	17.3	..	2.6	2.7	2.9

1. 1970.
2. 1990 and 1992.
3. 1972.
4. 1989.
5. Figures for Germany and zone totals from 1991 onwards refer to the whole of Germany.
6. 1992.
7. 1980.
8. Overestimated.
9. Change in survey methods or coverage.

Source: OECD Science, Technology and Industry Outlook 1996

Table A7.5a,b: Total Greek R&D personnel by sector of occupation and by sector of employment and formal qualification (in full-time equivalent)

	1987	1988	1989	1990	1991	1992	1993
Business enterprise							
RSE	..	741	760	..	1 042	..	1 338
Technicians	..	569	561	..	676	..	941
Other	..	456	489	..	526	..	652
Total	..	1766	1 810	..	2 244	..	2 931
Government							
RSE	2 084	..	2 101	..	1 918	..	1 905
Technicians	985	..	955	..	1 008	..	971
Other	1495	..	1 654	..	1 565	..	1 952
Total	4565	..	4 710	..	4 491	..	4 828
Higher Education							
RSE	1 978	..	2 600	..	3 119	..	4773
Technicians	293	..	202	..	722	..	1 350
Other	140	..	264	..	329	..	644
Total	1 511	..	3 066	..	4 170	..	6 767
Private non-profit							
RSE	..	..	..	..	..	..	34
Technicians	..	..	..	..	..	..	12
Other	..	..	..	..	..	..	28
Total	..	..	..	..	..	..	74
TOTAL							
RSE	..	..	5 461	..	6 079	..	8 050
Technicians	..	..	1 718	..	2 406	..	3 275
Other	..	..	2 407	..	2 420	..	3 276
Total	..	..	9 586	..	10 905	..	14 600

Table A7.5a

	1987	1988	1989	1990	1991	1992	1993
Business enterprise							
University PhD level degrees	..	..	..	..	..	..	275
Other university degrees	..	..	..	..	..	..	1 364
Sub-total university degrees	..	866	..	..	1 385	..	1 639
Other post-secondary	..	255	..	..	375	..	501
Other	..	433	..	..	396	..	658
	..	212	..	..	88	..	133
Total	..	1 766	1 810	..	2 244	..	2 931
Government							
University PhD level degrees	..	..	..	..	..	..	892
Other university degrees	..	..	..	..	..	..	1 692
Sub-total university degrees	2 558	..	2 492	..	2 366	..	2 584
Other post-secondary	332	..	222	..	234	..	301
Other	1 008	..	1 106	..	1200	..	1 212
	666	..	890	..	691	..	731
Total	4 564	..	4 710	..	4 491	..	4 828
Higher Education							
University PhD level degrees	..	..	..	..	..	..	3 699
Other university degrees	..	..	..	..	..	..	1 794
Sub-total university degrees	1 321	..	2 734	..	3 529	..	5 493
Other post-secondary	50	..	68	..	112	..	219
Other	140	..	220	..	492	..	978
	..	..	44	..	37	..	77
Total	1511	..	3 066	..	4 170	..	6 767
Private non-profit							
University PhD level degrees	..	..	..	..	..	..	23
Other university degrees	..	..	..	..	..	..	50
Sub-total university degrees	..	..	..	..	..	..	53
Other post-secondary	..	..	..	..	..	..	1
Other	..	..	..	..	..	..	19
	..	..	..	..	..	..	1
Total	..	..	..	..	..	..	74
TOTAL							
University PhD level degrees	..	..	..	..	..	..	4 889
Other university degrees	..	..	..	..	..	..	4 880
Sub-total university degrees	..	..	..	..	7 280	..	9 769
Other post-secondary	..	..	..	..	721	..	1 022
Other	..	..	..	..	2 088	..	2 867
	..	..	..	..	816	..	942
Total	..	..	9 586	..	10 905	..	14 600

Table A7.5b

Source: OECD Science, Technology and Industry Outlook 1996

Table A7.6: Researchers by sector of employment (percentages)

	Business enterprises					Government					Higher education				
	1971	1981	1989	1991	1993	1971	1981	1989	1991	1993	1971	1981	1989	1991	1993
United States	68.5	73.0	79.3	80.8	79.4	12.1	8.7	6.4[8]	6.1	6.2	15.2	14.4	13.3	12.2	13.3
Canada	47.5	36.8	46.4	46.4	..	33.6	17.2	12.0	11.5	..	18.9	45.1	40.9	41.2	..
Mexico	..	..	..	..	10.1	..	..	..	..	..	..	..	..	..	89.9
Japan (adj.)	58.2	62.0	68.6	69.4	69.8	12.8	9.3	6.4	6.0	5.7	27.6	26.2	22.5	21.8	21.8
Australia1	..	14.3	..	29.5	26.9	..	28.1	..	21.1	17.9	..	56.2	..	48.2	54.
New Zealand[2]	..	..	31.4	29.7	..	..	..	29.7	31.5	..	..	..	..	38.8	....
Austria[2]	40.0	43.0	45.7	..	..	10.8	8.1	5.9	..	..	46.5	45.5	45.3	..	..
Belgium[3]	39.6	40.4	47.5	48.3	..	8.5	5.0	4.8	.4.3	..	50.8	51.7	46.8	46.4	..
Czech Republic	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Denmark	31.4	34.4	40.3	.42.8	43.0	29.2	25.9	22.3	21.4	22.0	37.8	38.5	36.1	34.3	33.8
Finland	30.7	..	..	.36.8	35.8	25.2	..	..	23.1	22.8	40.2	..	..	38.9	40.0
France	44.2	41.0	45.1	45.9	..	19.3	18.4	20.1	20.0	..	33.6	38.2	33.0	32.5	..
Germany[3]	62.7	61.8	64.2	58.6	..	13.8	14.3	13.1	15.1	..	22.8	22.8	22.0	25.8	..
Greece[4]	..	1.9	13.9	17.1	16.6	..	49.9	38.5	31.6	23.7	..	48.2	47.6	51.3	59.3
Iceland[5]	2.0	9.8	19.7	24.4	25.1	68.5	50.4	43.3	42.1	40.4	27.5	37.2	26.9	31.3	31.7
Ireland[5]	25.2	28.7	36.8	39.9	40.4	33.5	30.2	12.2	9.9	9.1	37.8	39.1	47.1	46.5	46.7
Italy[5]	41.2	37.4	40.1	39.3	38.3	13.8	15.1	18.4	16.8	17.6	45.0	47.5	41.5	43.9	44.1
Luxembourg	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Netherlands	41.4	43.4	40.2	..	37.7	23.1	23.4	25.3	..	24.1	33.7	31.5	32.1	..	35.3
Norway[2]	43.2	41.8	49.9	50.0	48.4	19.5	18.5	19.9	19.2	19.5	36.8	38.7	30.2	30.9	32.1
Portugal[1 6]	..	14.1	..	7.4	6.3	..	31.4	..	18.5	14.0	..	51.8	..	63.6	67.6
Spain[5]	21.0	16.7	28.5	28.6	27.8	54.5	18.8	17.8	19.9	18.4	24.6	64.4	53.3	51.1	53.2
Sweden[3]	52.4	53.6	48.2	50.2	..	11.0	8.0	6.0	6.5	..	36.5	38.0	45.5	43.1	..
Switzerland[4 5]	50.3	46.2	57.7	..	50.6	7.2	7.1	3.7	..	3.4	41.9	45.3	38.7	..	45.9
Turkey	..	..	..	10.7	11.9	..	..	..	15.9	13.0	..	..	..	73.4	75.1
United Kingdom	..	60.6	63.9	61.1	61.4	..	15.7	11.3	11.5	10.0	..	19.7	20.3	22.1	22.9
North America[7]	..	71.0	77.3	78.1	76.7	..	9.1	6.78	6.4	6.5	..	16.1	15.0	14.7	15.7
EU-15	..	50.0	51.7	50.0	..	..	16.0	15.3	15.8	..	..	32.0	31.1	32.4	..
Total OECD	..	61.2	66.2	65.7	65.3	..	11.8	9.6	9.7	9.6	..	24.2	22.7	23.1	24.7

1. 1990 and 1992.
2. 1970.
3. Figures for Germany and zone totals from 1991 onwards refer to the whole of Germany.
4. 1979.
5. 1992.
6. 1980.
7. Overestimated
8. Break in series

Source: OECD Science, Technology and Industry Outlook 1996

ANNEX 7.2: INSTITUTIONAL CHANGES

This Annex provides information on some important institutional changes introduced into the Greek national innovation system during the 1986-1994 period.

The national Organisation for Industrial Property (OVI)

The intellectual property system has undergone a profound reshuffling since 1987. Patent granting has been modernised, and Greece joined the European Patent Organisation and the Patent Co-operation Treaty. A new independent national Organisation for Industrial Property (OVI) has been created to support patent exploitation and protection administratively.

The National Advisory Council for Research (NARC)

The National Advisory Council for Research (NARC) was established in 1988 by a joint decision of the Minister of National Education and Cults and the Minister of Industry, Energy and Technology (today Minister of Development). It is the supreme State advisory body related to research issues in Greece with the mission to advise the Greek government on principal choices to be made as regards the planning of the national research and technology policy and on all subjects related to research and technology according to the provision of the stature of law 1514/85. More specifically, the NARC is competent on giving advice on issues of the allocation of research funds, the creation of new research institutes, the selection and appointment of directors in research centres, the invitation of Greek scientists from abroad and the appointment of expert scientists as evaluators of the proposals of the Programme of Research and Technology Development. NARC functions in two different sections and it is composed of more than 70 members and deputy members the majority of whom are university professors.

Section A (the major scientific committee) is composed of four sector sub-committees:

1. Exact science and engineering (physics, mathematics, and all of technological sciences) made up of seven members,
2. Agricultural science and biology (including the principles of biology, biotechnology, and agricultural sciences) with five members,
3. Medicinal science with five members, and,
4. Social science and humanities (social, human, and law science) made up of five members.

Section B of the NARC is composed of representatives of various socio-economic institutions some of which are notably, the Technical Chamber of Greece (TCG), the

Association of Greek Industries (SEV), the Economic and Scientific Chamber of Greece, many other technical and scientific associations and chambers, trade unions and others. Each committee has an equal number of deputy members. All members are appointed by the Minister of Development according to the provisions of law 1514/85.

By observing the scientific background of the members of the four sub-committees[1] we can see that there is a strong emphasis on biosciences and biotechnology with 7 out of 10 regular and deputy members specialised on biosciences and biology (sub-section 2) while there is very limited attention on MSE with only 4 out of the 14 regular and deputy members specialised on MSE with strong emphasis on chemistry and chemical engineering (sub-section 1).

According to the unanimous opinion of the interviewed experts (PAC2, PS1, PS3, PS4), until 1992, NARC did not make a significant impact on the formation of priorities of the Greek science and technology policy. However, the Simitis administration put new emphasis on the role of the Council and proceeded in the substitution of many members of the sub-panels of Section (A)[2]. MSE gains more emphasis because 7 out of the 14 regular and deputy members of sub-panel 1 are related to MSE principles (strong emphasis on chemistry remains) while the emphasis on biotechnology *and its applications* is enhanced in sub-panel 2.

The Government Committee for Co-ordination of Research & Technology Modernisation (KYSETE)

The Committee was set up in 1992, and its major responsibilities include suggesting how government should set its priorities regarding the allocation of resources to applied research and technology and to co-ordinate activities so as to avoid duplication of efforts. Until 1996 KYSETE has not met at regular intervals and thus it has not had much impact on the R&D co-ordination and planning problem.

University Liaison Offices

One of the most important points of the Higher Education Act of 1992, was the establishments of University Liaison Offices and the institutionalisation of the capability of universities to provide high quality technology and research services to industry, public agencies, the state and any other kind of EU based "customer". The University Liaison Offices have the mission to market the research capabilities of university, departments, divisions and research teams and integrated these capabilities into the needs

[1] See: *The National Advisory Research Council*. GSRT, 1994.
[2] See GSRT, Information Bulletin, February 1997.

of (primarily) the economy. As such, their basic mission is the promotion and connection of research with industrial and economic needs. Research teams and laboratories, are entitled to provide high standards research services based on invoice bills in the open domestic and EU market. This is a development of tremendous importance for the Greek academic system because it provides the opportunity to any research team to be financially independent from proposals submission in the national or international R&D schemes. As such, if incomes are not entirely project based, the basis for a long - term policy are set.

However, the Higher Education Act and the liberties of the Liaison Offices were not extended as much as it was desirable. The ability to finance technological or research spin-offs (establishment of high technology SME) and the concept of university located (or technological parks related) high technology company incubators has not yet been established and it is not adequately supported by the existing (1996) financial, legal and administration system (see chapter 8).

Measures for financing technological innovation

During the late 1980s and the early 1990s a number of legislation measures aimed to promote, mobilise and institutionalise the financing of technological innovation. The most important are:

- The institutionalisation of the finance of industrial research according to the statutory of the Presidential Decree 558/85 and 434/88,
- The institutionalisation of motives for investments in research (law 1262/82) and for investments in innovation (law 1775/88), and,
- The investment law 1892/90, and its supplements and amendments (law 2234/94) for investments in exceptionally high technology areas and sectors.

The concept of the above laws is to promote venture capital structures and funding for the promotion of the research (1892/90), the use of research findings and the creation of spin-offs by researchers, tax incentives for technology transfer and for R&D expenditure and investment, funding incentives and subsidies for new R&D units in Greek industries, financial backing for high-technology goods and services and the promotion of metrological services, promotion of quality controls and many other secondary measures. The most important elements of these measures receive further attention (with respect to materials technologies) in chapter 8.

ANNEX 7.3: PRESENTATION OF EPET I AND STRIDE-HELLAS[1].

EPET I (1989-1993) with a budget of 21.962 million ECUs and STRIDE (1991-1993) with a budget of 100.686 million ECUs (in 1993 values) were designed primarily to improve the national innovation system's shortcomings, weaknesses and deficiencies and for the 1989-1993 period, they were the main instruments of supporting science and technology infrastructure in Greece. EPET I was the most important of the two projects. Structured in three sub-programmes it aimed to create (or enhance the existing) national R&D infrastructure. Sub-programme 1 (87.44% of the total budget) was dedicated to physical R&D infrastructure, sub- programme 2 (10.11% of the total budget) was dedicated to human resources and education and sub-programme 3 (2.45% of the budget) focused on R&D organisation and administration infrastructure issues. EPET I's objectives are summarised in **Box A7.1a**.

Contrary to the application of the three national R&D programmes (PAVE, PENED, SYN) the majority of the budget of EPET I was allocated in applications subjected to quotas based on specific field priorities. As such, EPET I gave considerable attention to materials technologies through its sub-programme 1, action 1and 4 by the establishment of three materials related technological institutions[2] and considerable support to materials related laboratory equipment.

On the other hand, STRIDE was designed to have a complementary action to EPET I, it was much more basic research oriented (sub-programmes 1&4) and the project distribution of these sub-programmes was very dispersed. However, sub-programme 3, which consumed 67% of the total budget, was field-focused. The objective was the creation or expansion of laboratory infrastructure and research activities in the pre-selected fields of information technologies - microelectronics - telecommunications, *materials - chemical technologies,* agriculture, energy, environment, health, recreation - culture, and, social problems. STRIDE's objectives are summarised in **Box A7.5b**.

[1] Source: GSRT publications 1994-1996.

[2] MIRTEC S.A. (Metals), CERECO S.A. (Ceramics) and the materials related CLOTEFI S.A. (Textiles and fibers).

The first National Programme for Research and Technology (EPET I):

Sub-program 1: Development of tangible (physical) infrastructure.

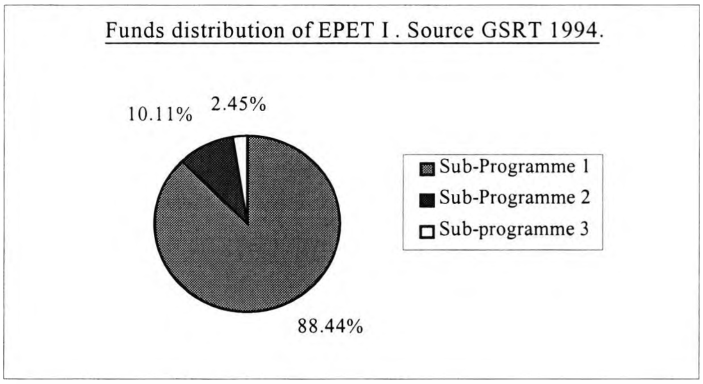
- Action 1: Development of a network of sector technological companies for industrial research and technology
- Action 2: Development of Technological parks, Research institutions and company "incubators"
- Action 3: Transfer and diffusion of research and technology related information
- Action 4: Research infrastructure and facilities.
- Action 5: Support of the research and technology infrastructure in industry.

Sub-Program 2: Human resources / Education

- Action 1: Development and support of the domestic R&D personnel (researchers)
- Action 2: Development and support of the domestic technical personnel
- Action 3: Continuous education and specialisation of private sector employees.

Sub-program 3: Administration and Organisation issues.

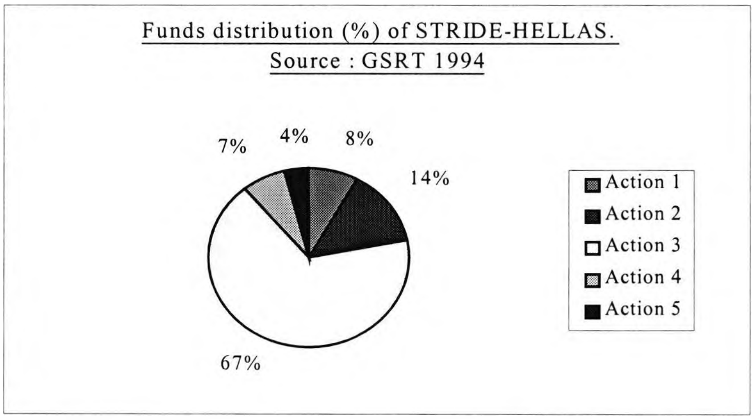
- Action 1&2: R&D administration and organisation issues.



Box A7.1a: The first National Program for Research and Technology (EPET I).

STRIDE - HELLAS: Science and Technology for Regional Innovation and Development

- Action 1: Improvement of the links and co-operation between Greek production and research institutes and their European counterparts.
- Action 2: Improvement of the links between research and production in Greece and support for technological innovation.
- Action 3: Improvement / support of R&D infrastructure
- Action 4: Human resources / Education
- Action 5: R&D projects evaluation measurements .



Box A7.1b: STRIDE-HELLAS: Science and Technology for Regional Innovation and Development

ANNEX 7.4

The second Operational Programme for Science and Technology (EPET II)
Executive summary of its framework, structure and project's evaluation criteria.

The Executive summary is the copy-right of the Greek GSRT and the Ministry of Development. However, the document is included for information reasons only, and most importantly, it is a public document freely available to the general public.

DEVELOPMENT STRATEGY OF RESEARCH AND TECHNOLOGY THROUGH THE NEW CSF[1]

General Information

R & D constitutes an extremely helpful tool for economic development in the present competitive international environment, especially for a country like Greece, which lags considerably behind in the technological renovation of physical capital and the upgrading of human capital. A wider use of R & D and the promotion of innovation in all production process stages constitute the necessary preconditions for the improvement of competitiveness of the Greek economy and, especially, that of the Greek manufacturing.

The main aim of the EPET II is to improve the competitiveness of the Greek industry and economy. This means strengthening the capacity of the country's techno-economic network in order to attract productive investments and produce added value through products and services offered to the international market. In formulating EPET II, the following points have been taken into consideration:

1. Greece is lagging behind the other countries of the European Union in the field of R&D.
2. The new political conditions in the Balkans and the Middle East have forged a new role for Greece in the area.

The Actions foreseen aim at the promotion of the Programme's targets, thus contributing to the completion and the balance of the country's techno-economic network, and the development of innovation. The main policy guidelines are the following:

a. Enhance co-operation between R & D organisations and production units/intermediate organisations in carrying out large projects of high economic interest (i.e. Environment, new materials, information technologies, telecommunications, biotechnology, etc.)
b. Encourage technology transfer from abroad through the following measures:

[1] Second Community Framework

- Licensing, technical assistance, etc
- Technology transfer networks
- Partially covering entrepreneurial risk inherent in the adoption of new technologies, etc

c. Support all stages of the innovative process, through technical support, education, financing, supervision etc.

d. Introduce information and assessment mechanisms regarding the outcome of government funded scientific research, through:

- Information networks, databases, publications and conferences aiming at the dissemination of research results
- Special units established in Universities and Research Centres for the dissemination of scientific results
- Innovation Centres, company 'incubators,' scientific and technological parks, special agencies supplying risk capital, and the provision of know-how and consultation to innovative firms

e. Support and restructure the existing R & D tissue through special initiatives, so that it can face the challenges and the needs of specific sectors presenting comparative advantages (i.e. telecommunications, energy, environment, biotechnology, new materials, economics, administration, social space, culture, sports, etc.)

Given the over concentration of R&D activities in Attica (50-55% of the country's R&D resources), an effort will be made towards the optimisation of the R&D structure, as well as the promotion of regional aspects of R-D policy in regions with special features concerning the position of Greece in Europe, the Balkans and the Mediterranean area.

f. Assessment of the present training needs of Greek human capital, through substantial training programmes in new technologies and techniques. Special incentives will be given for carrying out applied postgraduate research by young researchers.

g. Support the cultural assimilation of new communications, information and expression techniques resulting from technological innovation. At the same time, the importer of innovation, inventiveness and initiative in the field of education will be stressed. These aims will be promoted by special actions that encourage technological culture.

An effort will be made to co-ordinate and partially support the research and technology needs of large projects, that have been included in the Operational Programmes of other areas, i.e. natural gas, power networks, etc. The aim will be to avoid repetitions and overlapping, a phenomenon observed to a great extent in the past.

Special emphasis will be given to the deployment of human resources through promotion and support of special research and technological initiatives that will take into consideration the development of economic relations with the other Balkan and Middle East countries.

The main guidelines and policy directions of the EPET II are described below:

Sub-programme 1

R&D in Selected Areas

The participation of external financing in the R&D system has radically changed over the last years. The participation of foreign funds in the shaping of GERD has gone up from 2% in 1986 to over 20% in 1991, placing Greece first among OECD countries, as far as the level of external financing for R&D is concerned. This rate is even higher in the field of industrial research (23%). Greek R&D policy would benefit from a further increase of this rate, because it would create the conditions for supplying research services to European industry. In such an event, serious changes in the management of the Greek research centres are required, in order to reap the economic benefit from the sales of technology patents.

In accordance with the above target, the Programme will focus the national R&D effort on specific, carefully selected fields of high economic interest.

A study carried out by the GSRT led to the conclusion that the secondary sector has major needs, while the tertiary sector has fewer. The primary sector will be supported by other Operational Programmes within the context of the new CSF. The areas of priority are the following:

- Environmental technology. Also environment-friendly methods of production, more renewable sources of energy, including energy saving.
- Information technologies and applications in product manufacturing and supply of services
- New or improved materials and new production and process methods
- Analysis of the social, economic, administrative and cultural features of development.

This area is developing rapidly and contributes to the timely adjustment of technologies to the social and economic needs and special characteristics of the country, and vice versa. Greece needs to follow this evolution by developing the appropriate infrastructures, institutions, behaviours, and activities

The drive of the First Sub-programme is to enhance activities in the above mentioned areas. These areas are quite general in order to facilitate the concentration of the available resources and the creation of a competitive advantage. The definition of more detailed targets requires special procedures, according to the needs and the particular features of every area. In certain cases, it is possible to define the target at a project level or a special action level, whilst in other cases the Programme sets the general direction.

In order to prevent the fragmentation of the Programme into limited and strategically unimportant actions, a relatively high budget threshold is required for the projects to be selected. The promotion of networking between research and production entities and the desired bridging of research and production require that the financing of projects is widely supported by private production units.

Sub-programme 2

Industrial Research, Technology Transfer, Innovation

The realisation of innovation in the production process of goods and services requires increased capacity of technology transfer, diffusion and absorption. Technology transfer both inside the country, from Universities and Research Centres to the enterprises, as well as from abroad is equally important.

Special attention will be paid to the balanced support of demand and supply of technology.

The aims of the Sub-programme are: to encourage know-how networks and the flow of R&D related of business information, to enhance the creation and updating of data bases and libraries related to the technological subjects and finally, to promote the upgrading of the National Documentation Centre.

One of the most important aims of the Programme is to develop the ability for supplying consultation and technological services to enterprises (like for example, reverse engineering, quality control, technical documentation, technology management, measurements and testing, etc.) These technological services are provided through technology research and development agencies, company incubators, scientific and technology parks, technology transfer parks, quality control and certification labs, and other related entities (ELOT, OBI, EOMMEX, ELKEPA)

Their development requires very careful management, not only by the EPET Programme but also by the respective Operational Programme for Industry (especially as far as the quality control and certification are concerned.) High priority will be given to proposals which create the conditions for the provision of integrated services alongside with the promotion of competition, whilst taking care to prevent the creation of superfluous offices and unnecessary intermediate organisations. Otherwise, there may be an increase in the supply unmatched by a simultaneous increase in the demand for new technology.

In addition to the development of initiatives for the direct promotion of technological innovation to the Greek enterprises, finance services, which help companies to support innovation, will also be supported.

Another policy measure that helps in the creation of the appropriate environment for technology absorption and diffusion, is the close association of research organisations with the industrial activities of the country. This association will be promoted through the following activities:

(a) PAVE (Industrial Research Development Programme). The rationale to these programmes is to encourage industrial initiatives on every scale, outside any predetermined forms of co-operation and operation budget threshold, responding to the particular needs of any industrial unit (bottom-up approach). In this way, complementarily of the concentrated, large-scale actions of the first Sub-programme, which have more of a strategic character (top-down approach) is achieved.

(b) YPER (Scholarships of Oriented Research). This is a novel programme aiming at supporting applied research, geared towards the needs and problems of industrial and other production units. The co-operating parties should consist of a firm, a research organisation and a research student. A concomitant aim of the programme should be the completion of a doctoral thesis on a specific topic of interest both to the firm and the researcher.

(c) SYN (Co-financing Programme). This is a revised follow-up of the Co-financing Programme implemented in the past. It is expected to stimulate, on the one hand, of short-term co-operation initiatives on behalf of research institutions with industrial production units and, on the other hand, to mobilise a number of enterprises to make use of research possibilities and results of other research units, technology institutes and individual researchers.

(d) Liaison Offices. The creation of Liaison Offices between research and industry at Universities, Higher Technological Institutions, and Research centres for the implementation of R&D outcomes results. In addition, the institution of Special Information Bureaus consisting of government organisations and state-run enterprises will be promoted so as to achieve an efficient use and application of the research outcomes obtained under State Procurement Contracts

It should be stressed at this point, that the basic aim of the second Sub-programme is to develop initiatives and structures which will lead to an integrated approach of technology transfer and the diffusion of technological innovation issues, through the promotion and support of all stages involved, i.e. mobilisation/awareness, technical assistance, training, financing, etc.

Wherever necessary, special attention will be paid to the mechanism applied for carrying out certain actions, through feasibility studies. For actions for which there is not enough experience in Greece, a pilot action will at first be applied, in an attempt to solve the technical and institutional difficulties, through the use of expert services from abroad.

Economic growth does not solely depend on the mobilisation of company personnel and the introduction of new techniques; it also constitutes a general cultural phenomenon, whereby the sensitisation of the wider public opinion, familiarisation with technical culture and the establishment of social patterns awarding pioneering work, creativity and inventiveness, all have an important role to play. Special actions, towards this direction, will also be implemented.

Sub-programme 3

Support and restructuring of the national Research Tissue.

The past decade has been a period of intense development of the research structure of the country through the establishment and operation of new Research Centres and sectoral industrial technology companies, and also a massive reorientation of Universities towards research. One of the basic aim of this Sub-programme is to further develop this structure. The general aims of the proposed actions are the strengthening of communication, co-operation and complementarily of the research institutions, the orientation and specialisation of research institutions, the orientation and specialisation of research organisations towards selected technology fields of high economic interest, the regional decentralisation and development of research structure, the harmonisation of research activities with the production needs and the general development perspectives of the country and, finally, the support of the human research capital. More specifically the Sub-programme includes the following:

- The reorientation, restructuring and -eventually- broadening of existing scientific and technological infrastructure (R&D Tissue), aiming at a more rational location of the R&D structures and at their active linking with areas of economic interest. This development will be founded on expert studies, evaluating -among other things- the investment incurred until now in the existing scientific and technological agencies, their perspectives, the contribution to economic and technological upgrading of the country, the international achievements of their research teams, procedures for a systematic assessment of their work, etc.

- The establishment of new R&D organisations, complementary to the existing structure - both at the functional as well as from the regional aspect level-in accordance to fully justified studies, which will examine in detail, both the need for their establishment as well as the qualitative and quantitative prerequisites for a successful operation.

Given that there is over-concentration of institutions in the Attica Prefecture and, therefore, an asymmetric regional distribution of research activities. Consequently, an effort will be made for a more rational expansion of the R&D Tissue into Epirus, Macedonia, and Thraki (Northern Axis), in areas that present an interest not only for these specific regions, but for the country as a whole. These two choices are fully consistent, with the broader development targets and perspectives of the country, in view of the role of Greece in the Balkans and the expected positive developments in the Middle East.

Sub-programme 4

Human Capital

Human Capital constitutes the most important feature of the country's research system. Upgrading and expansion of human capital are substantial aims of an R&D policy. From a quantitative point of view, it is expected that the total number of actions of this Programme will lead to an increase of the research personnel of the country from 2.4 to 3.5 researchers per 1000workers.

Moreover, a fundamental objective of technological modernisation is the substantial increase (by 50-100%) of advanced technical personnel employed by the enterprises and other organisations.

To this effect, a multiple training and qualification programme will be promoted, adjusted to the needs and specificity of every sector. These efforts will focus on the following activities:

- Creation of new research personnel and training/reorientation of older researchers, in view of acquiring new knowledge in the fields of rapidly advancing technologies
- Training of technical personnel, who support R&D activities and participate in technology applications.
- Training of business-qualified personnel in new technologies, especially in those which are of major importance for Greek industrial and services sector
- Training and qualification in the area of R&D and innovation management
- Establishment of human networks between research laboratories in similar scientific areas.
- Encouraging mobility of research personnel between research organisations and industrial units
- Support actions which encourage a better involvement of Greek scientists from abroad, also by designing special measures for distinguished scientists from Central and Eastern Europe. Utilisation of specialised and high-powered scientists from abroad in new areas of research.
- Creation of evaluation mechanisms regarding the proposed training and technical specialisation, as well as performance comparisons of various research groups and centres.

Some of the above mentioned activities will initially be tentative or have a pilot character, until the various technical and practical co-ordination problems between research centres and industrial companies are overcome.

CRITERIA FOR PROPOSAL EVALUATION

The priority guidelines set out in the previous chapters determine to a large extent the contents of the EPET II project proposals. The approved projects should comply with the general and special aims of EPET II.

In order to obtain substantial results, the projects directed towards the creation of R&D structures, should on the one hand combine the active participation of research and industrial organisations and, on the other hand, correspond to a sizeable activity.

Other criteria that will be used for the evaluation of the proposals are the quality, the utility of the project, and the scientific and administrative ability of the proposing bodies.

The main evaluation criteria to be used are described as follows:

(i) Acceptance/rejection criteria, whereby the proposals failing to fulfil the conditions of the Call for Proposals are rejected.

(ii) Evaluation and ranking criteria, whereby the proposals are classified in ranking order, so as to be financed according to funds availability.

Although the criteria will be specialised every time according to the specific stage of the project, the general directions are the following.

(i) **Acceptance/rejection criteria**

If a project proposal does not fulfil the following criteria, it is rejected without any further evaluation.

For all proposals

1. Compatibility with the general aims of EPET II, as these are set out in this Chapter
2. Compatibility with the specific aims of EPET II, that is to comply with out or more measures of the Programme. The maximum number of measures with which it should comply will be determined by the Call for Proposals.
3. A written statement signed by the representatives of all participants should guarantee the Greek financial contribution
4. The submission of the predefined number of copies at the GSRT
5. The presence of a Project Contractor and a Project Co-ordinator
6. The project budget should be within the limits defined by the Call for Proposals
7. The Project should guarantee tangible results within 3 years (requested financing will be for 3 years but the total duration of the project could be longer). If it is estimated that this time limit can differ for certain measures or actions, then this should be explicitly referred in the terms of the Call for Proposals
8. Existence of balance sheets for the last 3 years for enterprises (unless if different time period is mentioned in the call for proposals).

(ii) **Evaluation and ranking criteria**

Proposals which comply to the respective criteria are evaluated and ranked on the following basis.

(a) Credibility of the tenders

1. Professional standing and scientific merit of the participants, previous experience, cohesion and team working spirit of the group, previous participation in European Community and International R&D programmes (the submission of Curriculum Vitae is indispensable).
2. Experience in managing research projects and programmes - both national and international
3. Existing infrastructure related to the subject of the proposal
4. Ability to support the managerial, administrative and economic aspects of the project
5. Attitude and proof of the past experience of the tenders to carry out the project
6. Balance sheets and annual turnovers for production companies
7. Extensive and consistent previous record of the enterprises in innovative activities (own funds for R&D, competitiveness profile, etc).

(b) Project proposal

1. Precision and feasibility of the targets envisaged
2. Clarity, appropriateness and effectiveness of the methodology and the means for carrying out the project (detailed presentation of all work packages and of the respective contribution of each organisation, allocation of tasks to the personal, time schedule, structure of the budget by measure, work package, organisation, year, etc
3. Comprehensible description of deliverables
4. Competence of the project contractor to manage the project.

(c) Expected economic results

1. Ability for product utilisation by the participants or third parties
2. Cost/benefit analysis for all technological, production, commercial and economic aspects
3. Fostering of competitiveness of the enterprise and of the economy in general
4. Expected multiplicative effects on overall economic activity

It is also possible to add special criteria or to modify the above ones, according to specific requirements posed by a Sub-programme, Measure or Special Action.

Eligible for financial support from EPET II are Corporate Entities of a Public or Private character of any nature and structure or Co-operatives between them. Each individual Call for Proposals will specify eventual limits to the above rules, whenever this appears to be necessary.

ANNEX 7.5: National R&D Programmes and Collaborative Schemes

This Annex contains information on the aims, structure and requirements of the most important (in terms of magnitude and spectrum of action) national R&D programmes and collaborative schemes. The included information is derived from GSRT's internal documents and information bulletins (1994-1996).

Programme for the Development of Industrial Research (PAVE)

PAVE was institutionalised in 1985 (launched in 1986) and its primary objective is to promote industrial research and support technological innovation. In more detail the programme aims to:

- Improve productivity of enterprises (operational effectiveness) and develop new or improved production process,
- Development of improved or new products with high - added value and penetration of new markets,
- Transfer and adaptation of high - technology in various traditional industrial sectors.

Specifically, PAVE serves as a means of funding research programmes in *ALL* production sectors including materials (all classes and types), energy, information, electronics, mechanical engineering, agricultural etc. The projects are classified under:

-- Action (A) - development of industrial research or exploitation of research results: support of proposals in activities *in any* industrial sector or field without prior pre-selection of groups or technologies;

-- Action (B) - promotion of technological innovation: study and development of industrial prototypes *by application of existing knowledge*, certification of the reliability of prototypes and standardisation process and finally, organisation of large scale industrial production and market expansion.

The governmental contribution covers between 30-70% of the funding aiming to support inventory costs (e.g. R&D equipment and laboratories equipment) and part of the overall cost such as personnel support, data acquisition expenses and others but the duration of each project can not be longer than 2-3 years. Since 1994, PAVE became a part of the Operational Programme for Research and Technology (EPET II) as part of the EPET II, sub-programme 2, Action 1.

Programme for the Enhancement of Research Manpower (PENED)

PENED was introduced in 1986 and is exclusively dedicated to higher education and training (funding of small academic projects). Its primary objectives are:

- Training and education of new researchers in sectors that lend themselves to the scientific, technological and productive development of the country,
- Retention of high level research staff in the tertiary and technological education establishments and in general any public establishments that have extensive research activities,
- Increase the mobility of experienced researchers between similar scientific sectors and their encouragement to work in emerging technologies of a multi-disciplinary nature,
- Participation of Greek scientists living abroad in research projects, which to a major extent, are carried out in a Greek Public Research Establishment.

Contrary to PAVE whose action is clearly horizontal, PENED, especially after 1994, identifies five research sectors one of which is dedicated to emerging technologies including biotechnology, new materials, information technologies and transport technologies. The programme proceeds even further and in the materials field with a pre-selection of focus *on new materials and composite materials.*

The duration of the projects, however, can not be longer than 2-3 years and the funding does not normally exceed 34,000 ECU. Since 1991, PENED became a part of EPET I[1] and since 1994 is a part of EPET II, sub - programme 4, Action 1.

Co - Financing Programmes (SYN)

The SYN programme covers "cutting - edge" sectors in science and technology. It aims to establish *direct co-operation* between research institutions and the country's social and productive establishments in order to solve problems and satisfy needs they confront. This is done by encouraging exploitation of *already existing* or advanced research results during 2 - 3 years duration projects. The operations entail the participation of at least two types of partners: one research organisation of any type from the public sector (henceforth to be called "institution of research") and a non - research institute from either the public or the private sector able to capitalise the results of the research, in the role of institution - user. SYN (like PAVE) does not pre-select any fields or technologies. However, it is significantly smaller than PAVE as its total budget during the 1986-1990

[1] Due to administrative and institutional framework difficulties the program did not run during 1998 and 1990.

period was only 1/5 of PAVE. Since 1994 SYN is a part of the EPET II, sub-programme 2, Action 2.

Since 1994, and within the framework of EPET II, an additional number of R&D and technology policy programmes with action complementary to the already established, were introduced. They are:

EKVAN: The Programme of Research Consortia for Improving Industrial Competitiveness

EKVAN involves the co-finance of large scale, 3-4 years research projects with an average budget of 1.03 million ECUs per individual project. The initiative's significance rests on the fact that it is the first Greek R&D programme which clearly pre-selects priorities (technological sectors), exploits (and simultaneously improves) the already existing potential of the national - private and public - R&D capabilities and aims to strengthen industrial competitiveness *by strengthening R&D activities in high economic potential sectors*. The programme includes five measures / pre-selected fields (see Table 7.7) aiming to co-ordinate and focus the resources of the projects to the solution of specific, high - priority problems. Measure 1.4 aims to strengthen R&D activities *in the field of new materials and S&P methods*. Since 1994, EKVAN is a part of EPET II, sub-programme 1. Action 4 is entirely dedicated to new materials and occupies 28.5% of sub - programme 1 and 7.42% of the total (directly allocated) EPET II budget.

Programme for Focused Research Scholarships (YPER)

YPER was launched in 1995. The programme covers ALL technological fields without any sectors or group of technologies pre- selection and aims to:

- Increase the flow of doctorate level scientists with applied research experience to public or private enterprises,
- Upgrade firms' scientific staff by promoting studies aimed at obtaining a PhD in applied sciences,
- Enhancement of the perception of company executives of applied research and technological renewal as a basic element in the strategic planning of enterprises and,
- Enhance the communication between research institutions and enterprises.

Precondition: the project proposed must lead to the PhD degree. Since 1995, YPER is a part of EPET II, sub- programme 2, Action 2.

In addition there are a number of technology transfer, industrial design and regional development programmes. Most of them take horizontal measurements in order to strengthen the national industrial and R&D infrastructure, create a set of technology and

R&D services and enhance or create technology and information diffusion mechanisms. The most important of them are:

A) Regional support programmes:

Special Action for Northern Greece: programme with regional character aiming to enhance the local R&D activities and industry. It has pre - selected priorities *and materials priorities focus on mining and natural resources and on the field of construction materials.* The programme is enlisted in EPET II, sub-programme 3, Action 2.

Funding of Scientific Conferences: This programme's higher priority is attached to conferences that take place in the Greek periphery, ensure international participation and their topics *deal with pre- selected fields which include materials technologies* and biotechnologies. The programme is enlisted in EPET II, sub-programme 5, Action 2.

B) Programmes promoting the diffusion of innovation and industrial planning

Technology Brokers: the programme on Technology Brokers aims to:

- on the one hand enhance the flow of technology and technological information from abroad towards economic and social institutions in Greece and,
- on the other hand to encourage the development of a technology market and the profession of technology brokers in Greece[2].

The programme is enlisted in EPET II, sub-programme 2, Action 3 (technology transfer).

Human Science & Technology Knowledge Dissemination Networks: The aim of this special action is the improvement of communications and the facilitation of development of links between Greek researchers and professional staff of enterprises in order to strengthen know-how diffusion towards the countries production sectors and encourage multidisciplinary approaches of specific economic and social problems. The programme is enlisted in EPET II, sub-programme 4, Action 1.

Open Gates: "Open Gates" aims to a dissemination and diffusion of R&D activities of the research and technology establishments supervised by GSRT to the general public and to potential users of R&D projects. The programme is enlisted in EPET II, sub-programme 2, Action 3.

Demonstration Projects - Transfer of Technology (PEPER): The main objective is the application of new, in Greece, technologies and procedures which have been previously applied successfully in other sectors or in / and in other countries. The programme aims at demonstrating the methodology and economic viability of new technologies through

[2] Estimated at 1996 to 2-3 persons employed full time and up to 5 persons employed part-time.

their application on a sufficiently large scale. The programme pre -selects priorities but up to 1996, *materials technologies were not included.* PEPER is enlisted in EPET II, sub-programme 2, Action 3.

Best Practice Benchmarking (PAFOS): The programme focuses only on topics of technological modernisation. It aims at producing awareness within Greek enterprises of the methods now used internationally for this purpose and to their systemic utilisation by various enterprises. Applications / proposals for participation on the project concern *the whole spectrum* of business operations without any priorities pre- selection.

Technology Performance Financing Programme: The programme aims at encouraging Greek industries to adopt new technologies relating to infrastructure and processing methods by reducing the firms' operational risk generated by the rapid introduction of new or disruptive technologies into the established production methods. This is achieved by introducing the idea of financing within Greece on the basis of return -on-investment or third party financing (TPF). The programme does not pre-select priorities but it is the first one that energetically involves the finance and banking sector. The programme is enlisted in EPET II, as sub-programme 2, Action 3.

ANNEX 8.1: Analysis of the Greek national materials priorities and materials selection mechanisms

The detailed analysis of Annex 8.1 provides the findings for testing hypothesis (H8.1). Until 1994, apart from infrastructure issues, Greece had not officially identified specific MSE priorities. Materials priorities were subordinate to the horizontal character (e.g. technology transfers, infrastructure support) of the national science/technology priorities. According to GSRT officials (experts PS1 and PS2), this happened because when the first national R&D programmes were launched (1986-1992 period), the Greek technology policy designers did not have sufficient information with respect to the science and technology needs of industry (there was an almost even dispersion of demand through all materials classes) and they had to cope with the relatively low level of the national R&D infrastructure and the very low level of industrial R&D activities.

The application of the early stages of the national R&D programmes (horizontal measures - see section 7.5), and the launch during 1992 and 1993 of eleven technology forecast studies for the years 2000 and 2010, were designed to deal with these problems and simultaneously accumulate feedback with respect to the science/technology capabilities of the Greek innovation system. The findings of evaluation reports on the results of the application of the early stages of the national and structural R&D programmes, and some early findings of the technology foresight reports (those submitted before the end of 1994) were used as reference points for the identification of materials priorities during the design of the Second Operational Programme for Research and Technology (EPET II).

The results of this period (1986-1993) are analysed below. The analysis is based upon a materials field classification summarised in **Table A8.1**. This classification was developed by Papa[1] (1993) and it has been employed by the thesis in order to provide comments compatible with the results of previous evaluation reports of national R&D programmes. Moreover, the employed classification was developed to provide information on the basis of "domestic demand" for each class of materials and it reflects the way the MSE field is perceived by the Greek public sector.

From Table A8.1 it can be seen that:

- The low to medium technology intensity materials groups are listed under distinctive materials groups (e.g. classes (1), (2), (3), (4), (5)).

[1] Pappa, A. (1993). *The materials sector in the national, structural and international R&D programmes*. GSRT internal document- Unpublished report.

- The medium to high technology intensity materials which are listed under "umbrella" style classes (e.g. class (7) which includes many classes of advanced and new structural materials and their S&P technologies and class (12) which includes many classes of functional materials including smart materials).

No	Description	No	Description
(1)	Ores and raw materials: mining technologies, enrichment technologies. Solid fuels. Basic metallurgy (extraction of metals) and relevant technologies.	(9)	Textiles
(2)	Metals, metallurgy and metallic products (both ferrous and non-ferrous).	(10)	Leather
(3)	Structural ceramics: refractors, commodity ceramics (tiles, bricks, sanitary products), glass.	(11)	Information Technology related applications: simulation and modelling of materials and S&P; applications of CAD/CAM and advanced design techniques.
(4)	Materials for the construction industry: Cement and other relative products.	(12)	Advanced functional materials, Smart materials for optical, magnetic, electric and electronic applications Biomaterials and biomimetics.
(5)	Surface science and surface treatment technologies (e.g. coatings)	(13)	Basic research in materials (e.g. solid state physics, nuclear physics).
(6)	Chemical technologies and chemical industrial processes including: polymers technologies, catalysis, environmental technologies and oil and refineries.	(16)*	Various materials technologies.
(7)	Advanced and new structural materials ; advanced S&P technologies for structural materials ; advanced testing methods (e.g. non-destructive tests)	(17)*	Strength of materials[2]
(8)	Wood and Paper	(18)	Food and agriculture related materials

Table A8.1: Working classification of materials fields in Greece. Source: Papa (1993) as modified by the author. **** Note that in the following analysis (i.e. graphs, figures and tables) categories (16) and (17) are merged and they are represented by the indicator (14).**

In addition, class (6) which is also an "umbrella" class, reveals that many materials sectors (including polymers and plastics) are dominated by the chemistry and chemical processes sector or they are perceived to be a part of the chemical industry. Similarly, class (3) and class (4) are separated to indicate the particular strength of the cement and other construction materials industries.

The analysis of the results of the period 1986-1993 period and the analysis of the 1994-1997 period provide the necessary evidence for testing the first working hypothesis (see section 8.0: Introduction and hypotheses) of chapter 8. In addition,

[2] Applied to the classification of the character of academic and research institutions laboratories.

some of the findings and results can be used to test the fifth working hypothesis of chapter 8.

A8.1.1: Analysis of the 1986-1993 period

The Technology Foresight Reports

During the 1992-1993 period eleven sectoral technology foresight programmes were launched. Three of them were entirely dedicated to materials (metals, ceramics and polymers), five more (the sectors of energy, transport, textiles, construction industry and telecommunications) identified materials as crucial priorities for further technological advancement in Greece and two of them (energy, construction industry) identified materials technologies as one of the most important elements for future competitive advantages.

The most important contribution of the technology foresight sectoral studies was the identification of specific technological priorities in the form of tangible and future industrial needs. The findings of these studies (notably the construction sector and energy sector which were submitted in 1994) had a significant contribution to the formation of EPET II and especially on the materials priority areas of EKVAN (see below). In particular the construction industry report identifies materials priorities *within an integrated producer-user system* and identifies the construction industry as a powerful materials user. The energy sector report highlighted the role of materials during the production, utilisation and storage of electric energy and the telecommunications report highlighted the potential of optical fibers for the Greek cable and wires industry. The three materials dedicated studies were submitted during 1995 and their findings are expected to have a major impact on materials strategies during the late stages of EPET II.

National and International R&D Collaborative Programmes

During the 1986-1993 period, the MSE field received considerable public attention during the execution of the structural programmes EPET I and STRIDE (see chapter 7). During the same period, many materials related industrial sectors were successful in submitting reliable project proposals within the framework of the national R&D collaborative programmes. Thus a considerable percentage (X%) of the budget of the major national R&D collaborative programmes (e.g. PAVE, SYN, PENED) was allocated to materials technologies.

Based on the Table A8.1 classification, **Table A8.2** summarises the **approved** individual projects related to materials technologies for the 1986-1992 period[3]. The figures correspond to projects of the national R&D programmes (e.g. PAVE), structural programmes (EPET I), projects financed under the stature of the 1892/90 investment law (see section 8.6) and the most important materials international R&D programmes[4] (e.g. the Brite/Euram programmes).

The observation of the data of Table A8.2 and the **Figures A8.1A,B** which are based on these data, and the analysis of insights into the outlines of the individual projects (too difficult to be summarised in a thesis) leads to the following deductions:

- Class (1) is by far the most active materials class throughout all the national and international programmes including the structural programmes. The sector attracts high levels of both industrial and academic demand.
- Class (2), ferrous and non-ferrous metals and metallic products is the second largest sector in the national and structural programmes. As shown in Table A8.2, the highest demand comes from industry (PAVE) whereas the sector's participation in international R&D projects and in the SYN (research links) and PENED (human resources) programmes is very limited. These trends indicate that the sector keeps a "distance" from research organisations (e.g. the academic community) or that it has no interest in responding to programmes where research dominates over development.
- Similar conditions apply to class (3) commodity ceramics, glass, structural ceramics, refractors. In class (4), cements and construction materials, there is a notable demand in both national and international programmes which indicates the existence of good links of the sector with research organisations and the ability to undertake and exploit high level R&D activities.
- Class (6) reveals a rather even distribution of demand throughout all R&D programmes. However, by looking into the character of the submitted proposals we can see that the sector is dominated not by chemical industries (as may be expected) but by industries involved in polymer technologies and environmental applications. Research organisations and international collaboration interest is also concentrated on these areas and on catalysis.

[3] Based on information availability during Autumn 1996.
[4] The international programmes receive detailed attention in chapter 10.

Field	National Programmes				Inv.Law	Structural Programmes			International Collaborations (1986-1991)				Total
	PAVE (86-92)	SYN[5] (87-90)	Pened[6] (87-89)	Total	1892/90 (90-92)	EPET I (89-93)	Stride 89-93	Total	Raw Mat.	Brite / Euram	Eureka	Total	
(1)	40	5	18	63	-	-	2	2	16	9	-	25	90
(2)	66	1	1	68	4	1	-	1	5	5	2	12	85
(3)	22	-	-	22	1	1	1	2	-	-	-	-	25
(4)	24	1	1	26	1	-	-	-	-	6	-	6	33
(5)	14	-	1	15	2	-	2	2	-	7	-	7	26
(6)	42[7]	2	1	45	7	3	3	6	-	12	2	14	72
(7)	6	-	7	13	-	-	1	1	-	25	-	25	39
(8)	6	-	-	6	1	2	-	2	-	-	-	-	9
(9)	6	-	-	6	2	2	1	3	-	2	1	3	14
(10)	12	-	-	12	-	1	-	1	-	-	1	1	14
(11)	18[8]	1	-	19	2	1	-	1	-	31	1	32	54
(12)	2	-	6	8	4[9]	-	-	-	-	10	-	10	22
(13)	-	1	15	16	-	2	-	2	-	-	-	-	18
(16)	-	-	4	4	-	1	-	1	-	7	-	7	12
Total	258	11	54	*323*	*24*	14	10	*24*	21	114	7	*142*	**513**

Table A8.2: National and International **approved** individual projects related to materials technologies for the 1986-1992 period.
Source: Author on Papa 1993/1995 and GSRT archives.

[5] The figures in brackets indicate submitted proposals for the 1991-1992 period.
[6] The figures in brackets indicate submitted proposals for 1990. Pened was interrupted and launched again in 1995.
[7] Nineteen (19) projects dedicated to polymers and plastics.
[8] The total number of approved proposals is 122 ; however, only 18 are directly connected to materials (simulation and modelling). The rest are widely distributed over production technologies, automation, robotics, CAD/CAM etc.
[9] Optical fibers, optical fibers cables production.

Figure A8.1A: National & International Approved individual projects related to materials technologies for the 1986-1992 period. Source: Author based on Papa 1993/95 and GSRT Archives.

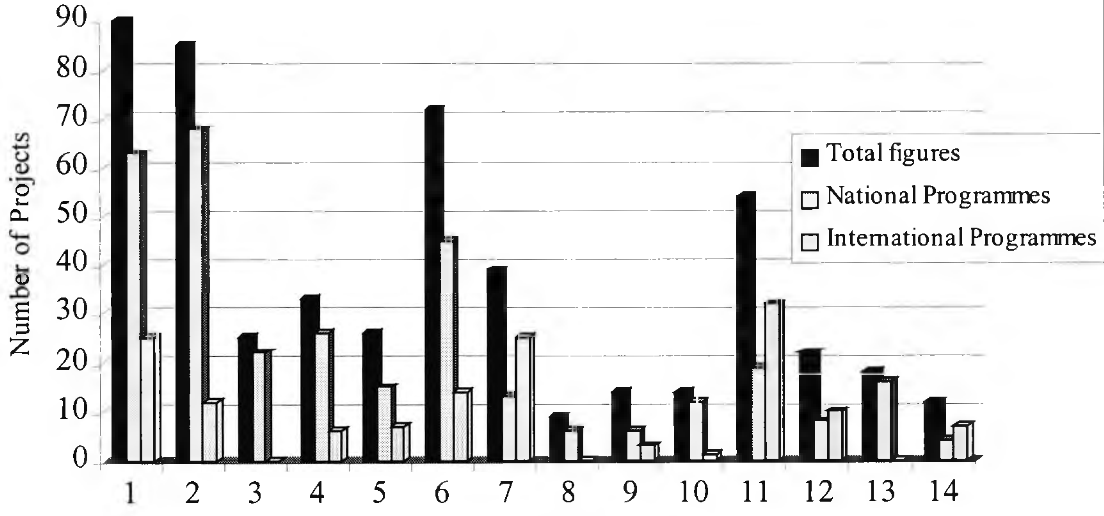
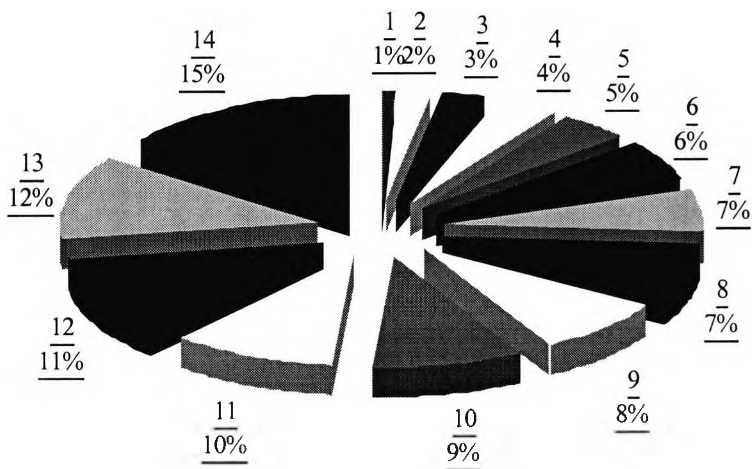


Figure A8.1B: Structural approved individual programmes related to materials technologies for the 1986/1992 period. Source: Table A8.2 Data.



- In contrast with the preceding classes, domestic industrial demand for class (7), advanced structural materials and their S&P technologies, and class (12), advanced functional materials, is very low and usually "rotates" around the interests of the defence industries and a small number of electronics / telecommunication companies (class 12). Classes (7) and (12) concentrate high academic interest and this can be seen by high levels of participation in PENED and in international collaborations. A notable exception is the case of optical fibers. The Greek glass industry has shown no interest but the cables and wires industry has dynamically entered the area. Four large investment schemes under the auspices of the investment law 1892/90 were dedicated to the support of the industrial scale production of optical fibers cables and other products. Class (7) also indicates some limited industrial demand for advanced S&P technologies like powder metallurgy, continuous casting, thermoforming etc. which suggests that there are industrial segments which can take advantage of emerging materials technologies. On the contrary, class (12) is dominated by characterisation, properties and S&C proposals.

- Advanced S&P technologies are clearly represented by class (5) - surface science / treatments. The sector exhibits both industrial and academic interest. Potential industrial users are chemical, food and beverages, oil and refinery, shipbuilding and marine, and metal products industries. Simultaneously, there are academic departments and research institution which active in the field.

- Class (11) is the most popular sector (122 projects on applications of IT for the automation of production processes, design of new products and organisation of production). The sector has the highest concentration in the Brite / Euram programmes which indicates the high potential of the academic sector in the field. However, the number or national projects directly related to materials (modelling and simulation) is very low (only 18 in the national programmes).

- There are classes with very poor results such as class (8) wood and paper, (9) textiles, and (10) leather. Especially in the research oriented programmes (e.g. the international programmes) their participation is extremely low; in addition the lack of participation in SYN (links) proves the relative isolation of the fields.

- Finally, the materials needs of some other industrial sectors are not represented at all. To give an example, expert PS1 stated that "*the food industry for example, contrary to the established perception is a very competitive, technologically speaking sector;*

however, they have started to have an interest in national R&D activities, just after the early 1990s because they realised that they could gain advantages."

A8.1.2: Analysis of the current materials policies and priorities

Based upon the received "feed- back" described above, the Ministry of Development and GSRT proceeded to the formation of materials priorities within the framework of EKVAN, sub-programme 1 of EPET II (see chapter 7 and Annex 7.3). Action 4 of EKVAN is entirely dedicated to materials technologies with a budget of 42,983 million ECUs (in 1994 prices), that is 28.5% of sub-programme 1 or 7.42% of the total EPET II budget (see **Table 7.6).** The national materials priorities are summarised in the next two pages while the materials budget for the 1994-1999 period (direct allocation[10]) is 42,983 million ECUs.

NATIONAL MATERIALS STRATEGY (1994-1999)

Official Declaration of Targets and Priorities

Description of Targets

Action 1.4 (materials technologies) of sub-programme 1 of EPET II, aims to develop and support technological activities in the area of **new and improved materials**. The implementation of the action is expected to create strong foundations which will support the gradual but dynamic re-direction of specific segments of the Greek economy, which have comparative or competitive advantages, towards the production of high - technology products, on par with the products of the technologically advanced nations. By taking into account:

- the current R&D infrastructure of the country,
- the special characteristics of national production systems (industry and services)
- the received feedback from the evaluation of industrial and research organisations participation in the national and international collaborative R&D programmes,

[10] The total budget allocated to materials technologies is much higher but it is not easy to be accurately estimated. Apart from EKVAN's figures materials are indirectly or directly supported by many other activities of EPET II (see Table 7.7). Given that there is no technology pre-selection and no operational budget threshold for specific technological fields in the majority of the other EPET II measures, accurate figures are very difficult to estimate.

- some early results from the technology foresight initiatives (for some of the sectors)

the following materials sections / priorities were chosen:

Materials Priorities

1) Advanced processing, production (manufacturing) and control technologies:

1. Advanced coating technologies: development and application of plasma-spray, laser deposition, chemical deposition, vapour deposition and multi-layers deposition technologies for the treatment and production of metallic, ceramic and composite based products / components performing in aggressive or demanding environments such as corrosive environments, high temperature environments, high friction environments, etc.
2. Development and application of powder metallurgy and advanced casting (continuous casting) technologies for the production of high precision components for various engineering applications.
3. Development and application of CIME, CNC, CAD/CAM, CAFM, robotics and advanced sensors technologies for the automation and quality control of production (manufacturing) processes of machinery and tools.
4. Development and application of non-destructive testing methods (such as acoustic emission and supersonics) for the diagnosis or the prognosis of damage or damage accumulation in structural materials, components or final products.

2) Development of improved or new materials for applications in:

1. *Building, construction and public works* (national infrastructure like roads, underground networks, railways etc.) such as the development of advanced fibers reinforced concrete, prefabricated structural elements, reinforced lightweight building elements, improved or advanced metallic, ceramic and other insulation materials for improved efficiency in heating and sound insulation of buildings and other large scale structures and for reducing construction and maintenance cost.
2. *Telecommunications and information diffusion:* emphasis on opto-electronic materials and optical fibers.
3. *Production, distribution, utilisation and storage of energy.* Emphasis is given on the development of advanced ceramics and refractors such as solid electrodes, semiconductors, and piezoelectrics for energy applications.

4. *Transport and agricultural production;* development of advanced polymeric materials for applications such as watering pipes, greenhouse panels and recreation sea vessels.
5. *Textiles, clothing and shoes*
6. *Wood products*
7. *Medicine*[11]

3) Materials and materials technologies for the protection and restoration of the national heritage and art works.

Development and application of advanced materials technologies in the maintenance, restoration and protection of the national heritage and art works from time damage and environmental pollution. Development of know-how for the employment of advanced materials during the restoration of ancient and traditional buildings and monuments.

4) Improvement of the efficiency of the construction industry with the substitution of "traditional" construction methods by in situ industrial style processes.

The aim of the initiative is the application of advanced building and construction technologies in order to optimise the in-situ construction process (by minimising time, cost and complexity) and in order to take advantage of the opportunities offered by new construction materials, especially the environmental friendly ones.

A8.1.3: Analysis of the 1994-1997 period

According to chapter 7, all the Greek national technology priorities including material priorities are implemented through the national R&D collaborative programmes. During the 1994-1997 period EKVAN allocated **30** projects to the materials field. The distribution of these programmes is summarised in **Table A8.3** (see column EKVAN). The budget for each programme accounted for 1-1.2 million ECUs distributed over a three years period of funding but the duration of the projects can be four years or more. The overall participation is characterised by high university participation: 48% of the

[11] It is not defined what classes of materials are involved ; functional materials is a possible assumption and the chemical industry can have a leading role in these efforts.

participants are industrial units, 45% are university departments and only 7% are research institutions[12].

Field	National Programmes 1994-1997				Structural Programmes 1994-1996			Total
	PAVE 1994	SYN 1996	Total (P+S)	**EKVAN** 1995-97	Tech. Brokers	R&D Infrastr.	Total	
(1)	9	-	9	*4*	-	1	1	14
(2)	11	2	13	-	2	1	3	16
(3)	36	2	38	*2*	-	-	-	40
(4)	21	1	22	*4*	-	1	1	27
(5)	-	1	1	*2*	-	-	-	3
(6)	32[13]	1	33	*4*	3	4	7	44
(7)	-	2	2	*1*	-	-	-	3
(8)	4	-	4	*3*	1	-	1	8
(9)	6	-	6	-	-	-	-	6
(10)	4	-	4	-	-	-	-	4
(11)	3	-	3	*5*	-	-	-	8
(12)	1	-	1	*5*	1	1	2	8
(13)	-	1	1	-	-	1	1	2
(16)	16	-	16	-	-	2	2	18
Total	143	10	153	*30*	7	11	*18*	**201**

Table A8.3: National and International **approved** individual projects related to materials technologies for the 1994-1997 period. Source: Author based on GSRT archives.

In line with the national materials priorities, basic metallurgy, cement and construction materials technologies, polymer technologies, advanced processing technologies, and functional materials such as optical fibers and sensor technologies (with smaller budgets from the previous fields) receive most of the attention. As in the 1986-1993 period projects related to functional materials are characterised by very low company participation (one or two firms as final users per project). On the contrary, structural materials attract higher levels of industrial interest (2-3 companies per average) which reveals that the level of industrial interest for structural and functional materials has not changed during the last 12 years.

Moreover, Table A8.3 provides some additional information of the approved materials projects of EKVAN as compared with the approved materials projects (until 1996) of two new structural programmes (Technology Brokers and national R&D infrastructure support – see Annex 7.4) and the continuation of the most important national R&D

[12] As a percentage of the total number of participants in all projects.
[13] Eighteen of them polymers and plastics.

programmes (PAVE and SYN) programmes. Table A8.3 shows that class (6) and class (3) and (4), ceramics and cements, have almost doubled their percentage in PAVE '94 while the basic metals and raw materials sectors, classes (1) and (2) reveal a considerable reduction of approved proposals. On the other hand, the total number of materials projects of SYN is very low (when compared to PAVE) but the approved projects involve very advanced materials applications.

Field	National Programmes (%)				Other Programmes (86-92)		
	PAVE (86-92)	PAVE 1994	Total (86-92)	**EKVAN** 1995-97	Invest. Laws	Structural Progr.	Inter – national
(1)	15.15	6.3	19.5	*13.3*	-	8.3	17.6
(2)	25.6	7.7	21	-	16.6	4.1	8.4
(3)	8.5	25.2	6.8	*6.6*	4.1	8.3	-
(4)	9.3	14.7	8	*13.3*	4.1	-	4.2
(5)	5.4	-	4.6	*6.6*	8.3	8.3	4.9
(6)	16.3	22.4	13.9	*13.3*	29	25	9.9
(7)	2.3	-	4	*3.3*	-	4.1	17.6
(8)	2.3	2.8	1.85	*10*	4.1	8.3	-
(9)	2.3	4.2	1.85	-	8.3	12.5	2.1
(10)	4.6	2.8	3.7	-	-	4.1	0.7
(11)	6.9	2.0	5.9	*16.6*	8.3	4.1	22.5
(12)	0.8	0.7	2.5	*16.6*	16.6	-	7
(13)	-	-	5	-	-	8.3	-
(16)	-	11.9	1.25	-	-	4.1	4.9
Total	100	100	100	*100*	100	100	100

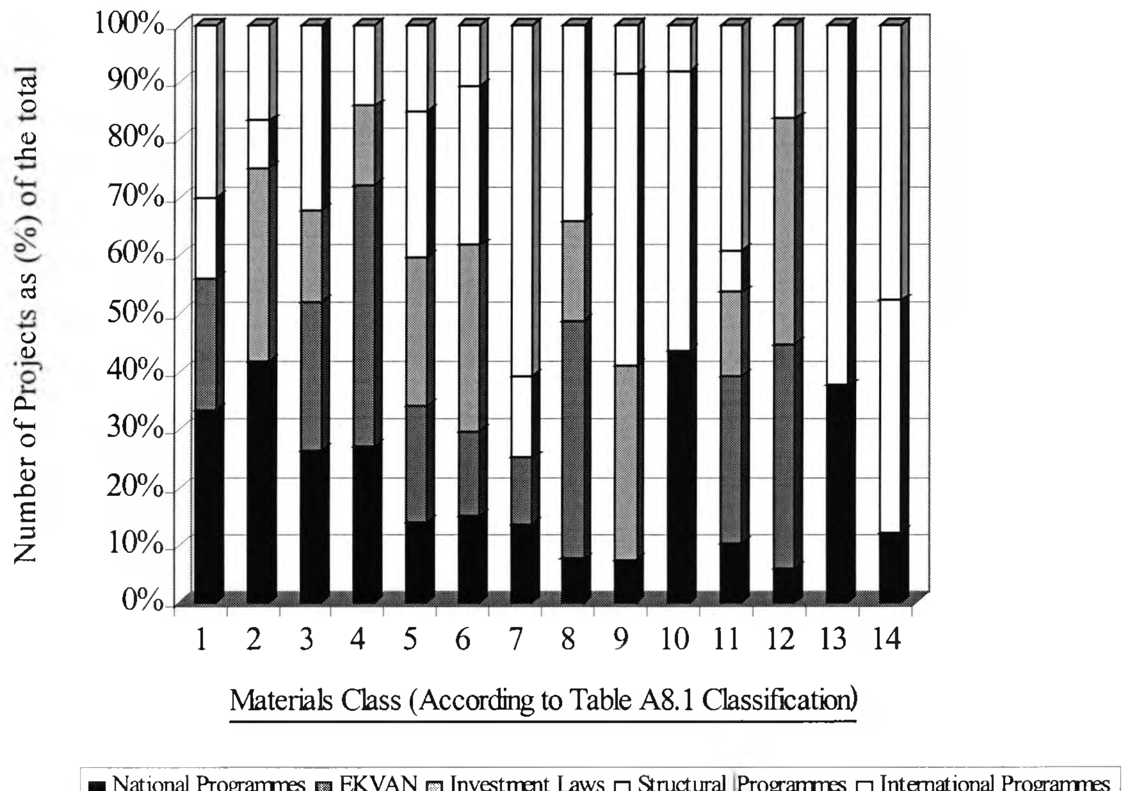
Table A8.4: Comparison between the materials project distribution of EKVAN and the materials project distribution of other programmes on the basis of percentages (X%) of the total number of individual projects per materials field. Source: Author on GSRT archives.

Finally, **Table A8.4** and **Figure A8.2** provide a comparison between the materials project distribution of EKVAN and the other R&D programmes on the basis of the percentages (X%) of the total number of individual projects per materials field[14]. Given that each project absorbs 1-1.2 million ECU the percentage (X%) of projects allocated to each materials field is also an approximation of the percentage (X%) of the budget allocation to each priority area. With respect to the percentage of project distribution we can see that the distribution of EKVAN projects is relatively consistent with the high interest

[14] For example, the total number of EKVAN projects is 30; the percentage of each materials field is given by the: ((number of projects in a given materials class / 30) * 100).

areas of both the national and international R&D programmes but it is not followed-up by the project distribution of the other R&D schemes.

Figure A8.2 : Percentage (%) comparison between the distribution of EKVAN materials projects and the materials project distribution of other R&D programmers.
Source: Table A8.4 Data.



ANNEX 8.2: Supporting the national materials priorities: Detailed analysis

The detailed analysis of Annex 8.2 provides the findings for testing hypothesis (H8.2). Given the extensive restructuring and upgrading of the national R&D infrastructure and of the national system of innovation over the 1986-1994 period, the national MSE strategies/priorities would be effectively and sufficiently supported by a) the national R&D infrastructure, b) patenting and standards policies, and, c) higher education policies and continuous education schemes.

A8.2.1: National Materials priorities and the national materials R&D infrastructure

During the 1986-1993 period, GSRT tried to cover some serious gaps in the national R&D materials infrastructure with the design and application of EPET I and STRIDE. EPET I gave emphasis to supporting the applied R&D infrastructure of "traditional" industrial sectors like the basic metals, ceramics, textiles, wood and paper and leather (see EPET I column in Table A8.2). Six technological organisations dedicated to metals, ceramics, wood, leather, textiles and food technologies were established through individual projects of EPET I. STRIDE on the other hand, was much more chemistry and chemical industrial processes oriented. Apart from two projects dedicated to fuel technologies and one to surface treatments for the ceramic industry, five others were directly (or indirectly) related to class (6). As such, in 1993, the national research infrastructure (dedicated exclusively to materials) consisted of the following:

I) University infrastructure: in Greece there are no independent MSE departments. The MSE field is served by the materials divisions of 8 universities and 7 technological education (T.E.) institutes, including the chemistry, metallurgy and mining, and physics departments, the chemical, mechanical, naval architecture, civil and construction and electric/electronic engineering departments and occasionally the Medical or Biology departments. University research in the MSE field is mainly dedicated to:

- synthesis and composition, characterisation, chemical processing, solid state physics, physical properties, quantum properties – science departments
- mechanical properties, performance, manufacturing, Synthesis and Processing – engineering departments

- magnetic and electric / electronic properties and performance- electrical / electronic engineering and physics departments
- biotechnologies – medical, biology and mechanical engineering departments.

II) Six research institutes:

- The National Centre for Scientific Research *Demokritos* including: a) the Institute of Microelectronics and b) the Institute of *Materials Science.* The Institute of Materials Science is the only national research institute exclusively dedicated to materials and in 1994 it had a man power of 32 researchers and 27 postgraduate students. It specialises in advanced functional materials (due to its strong roots in physics and chemistry) such as superconductors, semiconductors, magnetic materials, thin membranes, amorphous metals, surface technologies (sol-gel) and ceramic Biomaterials.
- The National Hellenic Research Foundation including: a) the Institute of Theoretical Chemistry, b) the Institute of Organic Chemistry oriented to theoretical chemistry.
- The Foundation for Research and Technology with the Institute of Electronic Structures and Lasers specialised in new electronic materials and laser applications.
- The Institute of Chemical Engineering and High Temperature Chemical Processes including teams involved in the area of catalysis.
- The Chemical Processes Engineering Research Institute,
- The Centre for Solid Fuels Technology and Application dedicated to solid fuels technologies and to environmentally friendly fuels.

III) Two dedicated Technological Organisations:

- The Metallurgical Industrial Research and Technological Development Centre (MIRTEC S.A.), and,
- The Ceramics and Refractories Technological Development Company (CERECO S.A.).
- Moreover, four more Technological Organisations (The Marine Technology Development Company, the Clothing, Textile and Fiber Technological Development Company, the Leather Technology Development Company, and the Centre for Renewable Energy Sources) have divisions dedicated to materials technologies.

IV) The Institute of Geological and Mineral Research

V) The Hellenic Centre of Biomaterials with the mission to conduct research and to provide quality control services and certifications to pharmaceutical, biotechnology and medical products.

VI) In addition, governmental agency laboratories and many public enterprises have the capability to be engaged in materials R&D efforts, however, most of their R&D resources are devoted to testing and quality control.

Table A8.5 summarises the number[1] of laboratories dedicated to materials technologies per type of research organisation as classified in the 16 materials classes described in Table A8.1. As shown in Table A8.5 and **Figure A8.3**, one third (1/3) of the total number of the materials related laboratories is dedicated to chemistry or chemistry related sectors. Apart from the chemistry sector there is a relatively even distribution of

university laboratories across all materials classes apart from classes (8), (9), and (10). On the contrary, the distribution of the research institution laboratories is uneven; class (6) chemistry and chemical processes, class (12) functional materials with emphasis on functional materials for electric, electronic, and magnetic applications, and class (13) basic research, prevails.

Field	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(16)	(17)	(18)	Total
(U)	6	5	1	3	1	21	4	-	-	-	2	6	5	-	6	-	60
(T.E)	-	-	-	1	-	2	-	-	-	2	(?)	-	-	1	3	35	9[2]
(R.I.)	2	-	-	-	-	10	1	-	-	-	(?)	14	6	-	-	-	33
Total	8	5	1	4	1	33	5	-	-	2	2	20	11	1	9	35	102

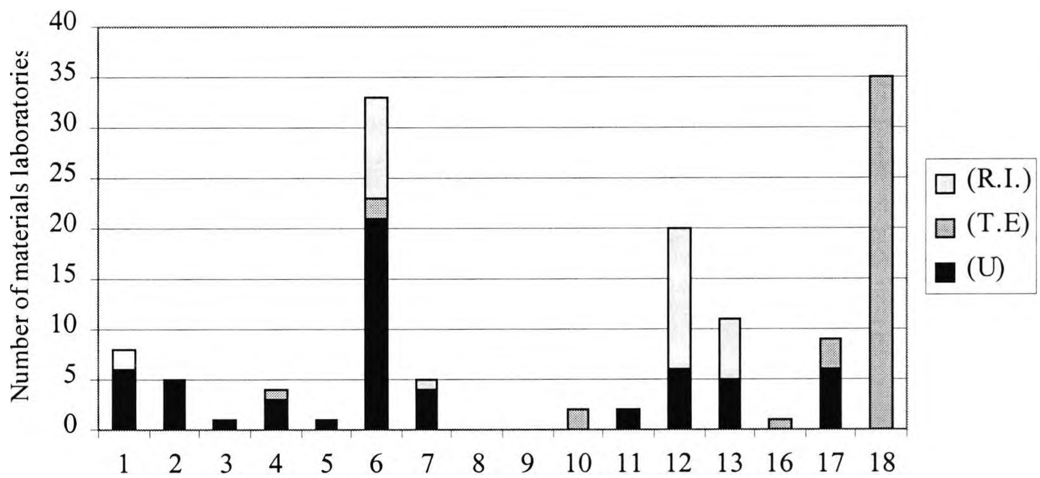
Table A8.5: Public laboratories dedicated to materials technologies per type of research organisation. Source: Author on data provided by GSRT

Abbreviations: (U): University; (T.E.): Technological Education; (R.I): Research Institution - technological institutions and public agency laboratories are not included.

[1] The figures of Table 8.6 are presented with some reservation. As identified by an earlier report (Planet Ltd 1994), until 1994 GSRT had not proceeded in classifying the 445 laboratories according to thematic areas or research objectives. Until December 1996, there was no change of status. As such, the figures in the case of university laboratories and technological education laboratories are only approximations because university laboratories, in particular, have changed thematic areas of research during the last 10 years. The technological organisations are **not** included in Table 8.6.

[2] The 35 laboratories dedicated to food and beverages are not included in the totals.

Figure A8.3: Public materials laboratories according to type of research organization. Source: Table A8.5 Data.



Class of materials (according to the classification of Table A8.1)

A8.2.2: Analysis of Education Policies and Materials Science and Engineering in Greece

MSE and higher (academic) education

Given that in Greece industry has no demand for pure MSE graduates which do not combine MSE principles with another discipline, the MSE field is not fully recognised as an independent science/engineering principle (not even from the Technical Chamber of Greece). As such, the relationships of materials divisions and laboratories with their departments and with other university departments is integrated and complementary. The rationale is that materials education must be always connected with applications and other technologies. Hence, MSE education at both undergraduate and postgraduate level is dispersed in many departments (mainly the mechanical, civil and chemical engineering departments and the chemistry departments), which makes co-ordination of efforts difficult but it has the advantage that the MSE field enjoys multi-disciplinary inputs and materials education or research is directly related with its applications. As a positive side effect, this is one of the main reasons why materials laboratories are the most successful in project proposals and "attraction" of contracts of all university departments.

Therefore, the idea of establishing independent MSE departments *was rejected* both by almost all (7 to 1) of the interviewed academic experts and all industrial experts. Especially the academic experts pointed out that the establishment of independent MSE departments would jeopardise these competitive advantages. Moreover, two of the interviewed experts (PAC7, PAC8) pointed out that the establishment of MSE departments would have serious administration and management problems and since it would be created out of existing divisions (and not from zero basis), it would seriously disrupt the *balance of power* and the existing *Status Quo* of many universities departments. However, there was a unanimous agreement that at postgraduate level it would be much more useful to establish (or support the existing) multi-disciplinary postgraduate studies between many departments which will offer materials specialisation as a response to the national materials priorities and to recorded or anticipated industrial and economic needs. Some postgraduate specialisation studies (MSc, MPhil level) have been introduced since 1992-1993 and many materials divisions have begun to develop materials related specialisation.

For these reasons, the MSE field in Greece does not particularly suffer from the endogenous field-related education problems identified in chapter 5 (because it is not detached from its application fields) but from exogenous factors and a number of general education policy shortcomings summarised under below.

MSE and national higher education policies

Higher education administration problems. Materials divisions, on their own initiative, are among the most active divisions trying to update their undergraduate and post-graduate curricula on the base of international and domestic feed-back. However, as experts THAC1 and VAC1 identified, there are no institutionalised mechanisms, neither in department/university level, nor at national level, which can evaluate the academic curricula on a regular time base (say every 2-3 years) and to suggest or approve proposals for changes. Changes are decided after personal initiatives and then they have to fight for acceptance by the academic establishment.

Orientation of the education policies. The Greek higher education system is a typical "*laissez-faire*" system. While the Ministry of Education and Culture enforces an abstract form of financial control over university authorities, it has not defined any higher education policy directions aligned with the national technology policy aims. On this point, the interviewed academics underlined that from the State's point of view, some "intervention" in the form of identifying and supporting priorities and calling for specific specialisation would be necessary, and from the university's point of view there would be a more rigorous correlation between university curricula and economy/social feed-back with academia responding to current and future needs. On the question of "how MSE studies should be encouraged in Greece" the interviewed participants primarily focused on the issues of supporting the creation of human resources (scholarships), of technical education and of financial support for fundamental research and laboratory equipment (the academics).

Scholarships. With respect to scholarships, all the participants underlined that it is necessary to identify the MSE field as an education priority area, and more funding and *oriented scholarships* in the direction of materials technologies is urgently needed, otherwise, “there would be serious problems in the near future” (PAC1). However, the direction of funds and the support of field-oriented scholarships is a clear issue of managing and developing human resources for current and future economic needs at national policy level[3]. According to expert PAC9 to provide "groups" of scholarships on specific pre-selected technological fields (such as the MSE field) and send groups of people abroad to be trained in centres of education excellence is much more effective and rewarding in technology transfer terms than simply paying technology royalties and training agreements[4].

On this point the Greek education system *fails completely*. **Table A8.6** and **Figure A8.4** provide the distribution of the scholarships awarded by the State Scholarships Foundation[5] (IKY) according to technological area or field. Observe the very low number of materials (and biotechnology) related scholarships as a percentage of the total number

[3] Almost all EU member countries are finding it increasingly necessary and appropriate to concentrate their research efforts and human resources on areas of particular scientific or technological importance (OECD 1994/96). Thus, they direct their scientific base towards the selected orientations largely by education policies.

[4] Taiwan, and South Korea have based a considerable part of their technological success in human resources policies supported by these mechanisms (Lee 1995). In EU, the most spectacular advances have been made by Portugal (a country very similar to Greece). With EU aid (the CIENCIA programme), the Portuguese government has set up 12 research institutes, most of them in collaboration with universities, and *launched a vast training programme* of 3000 scholarships for doctoral students, including 600 for study abroad in centres of excellence. Materials technologies received a top level priority.

[5] The official State scholarships awarding body acting under the auspices of the Ministry of Education and Culture.

of awarded scholarships[6]. In addition, by observing the thematic areas of the scholarships, it is apparent that MSE (and engineering principles in general) do not correspond to the national materials priorities and they are not a national educational priority. On the contrary, humanities, arts, social sciences and medicine have the "lion's share" of the state scholarships.

	Scholarships for Domestic Studies				Scholarships for Studies Abroad			
Academic Period	Materials	Bio/gies	IT	Total	Materials	Bio/gies	IT	Total
1989-90	0	0	3	176	0	0	2	127
1990-91	1	1	1	140	2	0	2	184
1991-92	3	3	4	135	4	3	5	155
1992-93	2	0	1	130	3	3	5	162
1993-94	0	2	6	149	3	1	5	115
1994-95	2	2	5	161	2	0	4	135
1995-96	2	1	3	161	2	2	7	171
Totals	10	9	23	1052	16	8	30	1049

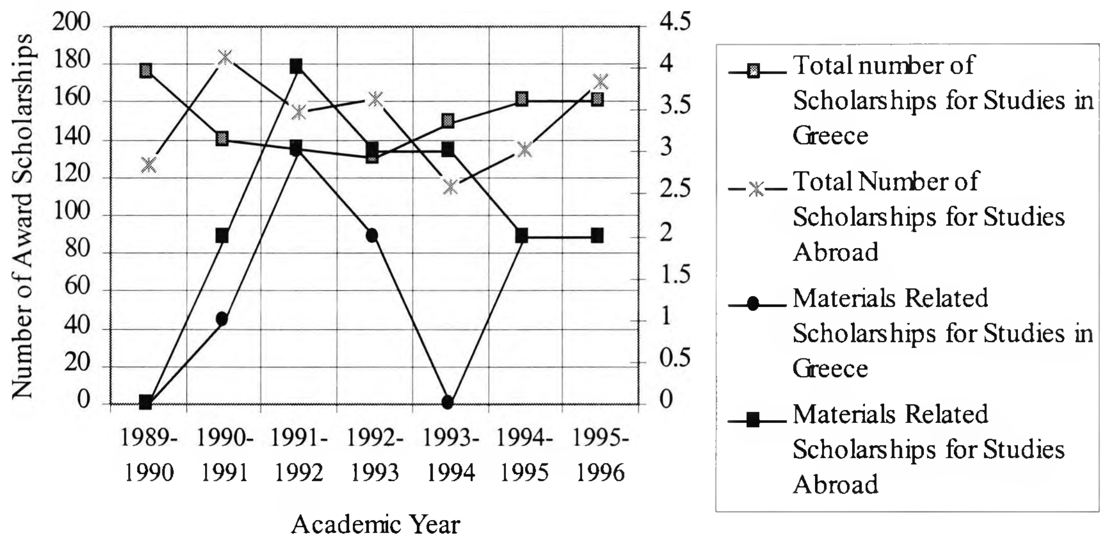
Table A8.6: Distribution of National Scholarships according to technological area. Source: Author on Data provided by IKY

On the other hand, the scholarships awarded through the national R&D programmes (under the auspices of GSRT), reveal a different picture. PENED has recognised the MSE field as a priority field, but its resources are spread over the entire materials field (see Table A8.2). YPER scholarships (an action of EPET II) focus on EKVAN's materials priorities but YPER does not recognise materials as priority areas (in 1997, only 11.8 % of the projects and 17.35% of the budget was allocated to the entire MSE field). However, the scale of the scholarship programmes supervised by GSRT is dwarfed by the budget scale of the scholarships awarded by the State Scholarships Foundation (the totals of the national R&D scholarships make for only 6.25% of the budget of State scholarships (approximation on annual basis).

MSE and technical education. With respect to university graduates, all interviewed sources agreed that due to the integration of materials divisions into engineering departments and the structure of the university education system in Greece the Greek higher education system provides well-qualified graduates.

[6] The total number of scholarships involving MSE aspects is probably higher, but the MSE field received minimal attention over the examined period of time.

Figure A8.4 : Materials related National Scholarships as compare to the total number of National Scholarships. Source : Author based on data provided by the National Scholarships Foundation



However, all interviewed sources (industry and technological institutions in particular), identified that there is a growing shortage of high quality technicians and middle-level technical education personnel. The present system of higher education in Greece has deprived the Greek economy of the output of lower to medium education level graduates who combine technical skills with some academic qualifications.

With respect to lower or semi-empirical education level, the decline of professional apprenticeships has deprived the Greek economy of good technicians with formal education. Middle-level technical/technological education is the mission of the *Technological Education Institutes* (TEI) (organisations similar to the British Polytechnics before they changed status during the early 1990s). Since the late 1980s, the majority of these institutions are trying to rival universities, giving too much emphasis on theoretical issues at the expense of technological education (Technical Chamber of Greece 1995). That development has a detrimental effect on the availability of skilful people in many ceramics and metals related industries (see chapter 9) which has already started to take its toll. Large companies respond by internal training schemes. SMEs however, with limited resources cannot provide sufficient educational compensation and therefore suffer.

Management education and MSE. All reviewed sources (construction industry and technological institutions in particular), identified that there is a severe lack of people able to combine engineering and science skills with management and finance skills. Until very recently, the system of higher education in Greece offered no opportunities for complementary finance- technology - management education neither at undergraduate, nor at postgraduate level.

According to Tsipouri (1993), many shortcomings of the national innovation system are based on problems arising from established perceptions in both public and private sector or management practices flaws during the design and implementation of policies and strategies. This is a verification of Kaounides, Dennis and Chelsom (1994) findings who identified that the severe lack of people with holistic views on the technology-management - finance interactions is a major source of obstacles for materials strategies and their integration in technology and business strategies. To fill this void in Greece, the idea of merging technology, economic/finance and management principles under common education schemes is the subject of very recently (1996-1997) established, pilot postgraduate studies curricula, usually under the co-supervision of engineering and economics departments.

The issue of continuing education. Continuous education has not yet been institutionalised at national or university level. Large companies invest privately in their own continuous education schemes and, after 1992, university departments gained the legal ability to offer continuous education services to firms or public agencies. Otherwise, continuous education is usually the domain of professional associations such as the Technical Chamber of Greece (see chapter 9).

A8.2.3: Patents, Standards and Materials Science and Engineering in Greece

In Greece the areas of patents protection, certification and standardisation are the jurisdiction of the Industrial Property Organisation (OBI), the Hellenic Organisation for Standardisation (ELOT) and the Division of Standards and Certifications in the Ministry of Development. The basic mission and aims of these organisations are summarised in the end of this section.

Patents and Utility Models Certificates[7]

The Industrial Property Organisation (OBI) was established in 1988, it operates under the supervision of GSRT, and on the basis of invoices and fees is the legally qualified institution in Greece for exclusive grant of protection titles such as patents and utility model certificates. OBI's main goals are summarised in the end of this section.

With respect to industrial interest for patents, OBI officials pointed out that there is considerable reservation by both SMEs and large companies to apply for patents despite OBI's marketing campaigns and confidentiality policies[8] in favour of the commercial and technological benefits of patents. According to OBI officials,

> "very few companies have really good patents and in general, industry avoids informing OBI on matters of technology transfer or improvements in their products or manufacturing lines. There is, however, an increasing mobility in the area of utility model certificates which have an immediate commercial effect... (PA1 1996) ".

The majority of Greek industry, OBI continues, do not have patents specialists nor specific patent policies because they are only technology users. In the case of companies which have the ability to produce patents, the established "indifference" is intensified by the absence of horizontal motives (e.g. tax incentives, subsidisation of patenting expenses in the case of research results of public research organisations) for the promotion or support of patenting and standards.

As for patenting research results, OBI identified that there are no special financial or procedural arrangements in practice for patenting research results and in the R&D projects proposals of the national R&D programmes there are **no** distinctive budget

[7] A utility model certificate is the protection title with a duration of 7 years. It is granted to holder of the right for a three-dimensional object with defined shape and form, capable of giving a solution to a technical problem and proposed as novel and industrially applicable.

[8] After the submission of a patent application, OBI offers confidentiality for 18 months.

allowances reserved for the expenses of patenting[9]. Moreover, the interviewed academics identified that up to 1996 there was no official procedure for patenting university research (the establishment of procedures for patenting university research on the archetype of, say, the USA Massachusetts Institute of Technology patent office are still in their embryonic stage), and the majority of the academic society was not informed of the involved costs and procedures. In addition, if these procedures were in place, there are no mechanisms to support the profitable exploitation of patents (e.g. spin-off business, start-up venture capital – see section 8.6)[10].

OBI cannot have any direct involvement in the design of constitutional mechanisms which would further support the patenting procedure of research results. OBI however, has consultation role to the Ministry of Development for the improvement or introduction of the necessary institutional mechanisms.

OBI and MSE

During the 1988 - 1995 period there were 3033 patent applications of Greek origin and 2303 patent applications of foreign origin. For the same time period, OBI granted 2100 patents and 1731 utility model certificates of both Greek and international origin (OBI 1996). Unfortunately, there are no official sector statistics and thus there is no official information on how many of these utility model certificates and patents concern materials and materials technologies.

Given the focus of Greek industry on structural incremental materials and the nature of the utility model certificates, it can be *presumed* that a considerable percentage of the granted utility model certificates were or would be predetermined for S&P applications. But chapter 5 argued that in the case of incremental improvements of structural materials, isolated patents are rarely effective. As such, incremental improvements in structural materials are usually kept secret until a significant change is fully incorporated into a new or radically improved final product.

[9] From the author's perspective this is a serious policy inconsistency: on one hand, all national R&D programmes (apart from PENED) target applied or near market research which is most likely to lead to patents and pursue heavy involvement of university teams and research institutions. On the other hand, there is no budget allowance for patents and utility certificates. As such, small university teams and research institutions have to finance patenting procedures as an overhead for both national and especially international, more expensive, patents.

[10] Expert VAC1 characteristically stated: "it is sad to have the potential to create valuable patents in materials technologies and having this potential destroyed by lack of procedures or insufficiency of specific services" (VAC1 1996).

The interviews and case studies with Greek materials industries verified these trends. All the Greek companies involved with the production or use of low-medium technology intensity, incremental structural materials rarely produce patents and these patents notify a significant achievement (see the case of the new structural St4 steel produced by M5, in chapter 9). Given that the majority of the Greek materials industry is related to incremental structural materials, it is not surprising that even big companies are "reluctant" to patent their R&D activities on a regular basis[11].

Furthermore, RI1 underlined that patenting research results in materials (and any other) technologies is becoming increasingly difficult in Greece: even though it is in the strong interest of research organisations to produce publications and patents, the applied or near-market nature of the research projects prohibits that in order to protect the interests of the financial sponsor. The sponsoring company controls the results and their availability and usually it is against the company's interest to patent near market research results. This trend, in connection with the previous reasons creates a disincentive for patenting and publications.

However, OBI admitted that there were no special arrangements to promote materials related patents and that they (OBI) do not differentiate their approach according to the characteristics of each individual industrial or materials sector. What is applied in any technological field also applies in the case of materials technologies.

Standards in Greece

Standards is a crucial issue for the Greek innovation system. During the 1970s and up to the late 1980s, standards, quality assurance and quality control issues were the number one priority of Greek industry during its struggle to achieve operational effectiveness and international product and services credibility. Many efforts and much capital have been consumed in the directions of standards and quality control until international standards were reached. Today, the majority of Greek manufacturing and services industry and the Greek research organisations operate under the ISO9000 and ISO9001or ISO9002 certification which accredits a standard level of practices to assist delivery of products or services without quality volatility.

During the last 10 years, one of the invisible but crucial benefits of the national R&D programmes is that they promoted the application and enforcement of standards (ISO).

[11] These tendencies are enhanced by a strong dependence on technology transfers and on the fact that many large companies in Greece are still parts of multinationals which prefer to patent on their country of origin and not in Greece.

Many companies would never move alone to obtain ISO9000 or ISO9001 if they did not have the motive to participate in these programmes.

Today, industry and research organisations (e.g. universities) are committed to achieve the EN45000 certification of high quality products and services provision. This certification is the next stage from the ISO 9000 or ISO 9002 which simply certified a standard level of consistent adherence to good practices. To get the EN45000 certificate is absolutely crucial for university materials laboratories. As experts PAC8 and PAC2 explained, this certification is a guarantee that the specific laboratory produces a standard level of high quality research results by employing indisputable experimental methods; thus the research results are compatible with international standards, can be used with safety and bear credibility. It is paramount for the survival of the technology and science oriented Greek laboratories and for industrial R&D departments because, in the near future, the EN45000 certificate will be one of the basic requirements for participation in any international or national R&D collaborative programmes.

The Hellenic Organisation for Standardisation (ELOT)

The Hellenic Organisation for Standardisation (ELOT) was established in 1976, is funded by the state and operates under the supervision of the Ministry of Development - Division of Certifications and Standards. The aim of ELOT is to promote and implement Standardisation in Greece (see below).

The strategy of ELOT

ELOT is fully aware of both the technological and economic strategic importance of standards. However, ELOT does not have an autonomous strategy on standards and certificates activities. The policy directions are determined by a combination of Greek directives and EU directives. The Greek directives are addressed by the Ministry of Development's Division of Certifications and Standards on the basis of industrial sectors priorities and **not** on the basis of technological priorities. Up to January 1997, there was no tangible evidence that standards policies were either among the national technology policy priorities or among the national materials technology priorities.

As such, emphasis on materials technologies is circumstantial (it is a consequence of the fact that many industrial sectors are materials dominated) rather than deliberate. Moreover, emphasis is placed on commodity and low-to-medium technology intensity materials technologies (as a direct consequence of the characteristics of the Greek materials industrial sectors). Very little attention is given on advanced materials and new materials technologies. It is characteristic that during the time of the interview (December

1996), ELOT was not aware of the existence of the VAMAS initiative. Further, all the interviewed experts highlighted that emphasis is placed primarily on the production and not on the utilisation of materials. That neglects the interests of final materials users such as the construction industry.

The EU directives are addressed on the basis of the decisions of the EU General Secretariat of Standards in which ELOT participates as a full, coequal member. As a full member ELOT protects Greek technological interests when it has the opportunity and the technological means to do so. For example, ELOT has succeeded in establishing Greek technological standards as EU standards in the case of solar power boiler technologies for domestic applications[12] where Greece has achieved a technological head-start over EU competitors. As ELOT officials explained, there are many emerging technologies opportunities where similar accomplishments can be achieved; the problems begin in "closed areas" that is areas where standards have been already enforced by others.

ELOT's activities are hampered by the relatively small size of the organisation and its limited financial and human resources. ELOT has a serious and chronic problem of human resources which blocks its efforts to systematically pursue the development and standardisation of emerging technologies in Greece. Moreover, ELOT entirely depends on state funds for its operation. Contrary to international experience, industry does not have any financial contribution to ELOT's activities and only recently ELOT gained legal permission to "market" its certification abilities on the basis of invoices or to participate in national R&D programmes. Expert PA2 pointed that it is essential for Greece to recognise standards (materials standards in particular) as a national technology priority and, in co-operation with ELOT, to launch large scale R&D programmes with the mission to establish and standardise technologies - not only isolated products.

These conditions can become a serious drawback for the efficient support of the national materials priorities - especially when advanced materials and S&P technologies are targeted.

Ministry of Development - Division of Certifications and Standards

The Division of Certifications and Standards is the legally qualified public agency in Greece for the exclusive grant of certification stamps to other institutions and for the formation of the national standards and certifications directions. The division is supervised by the leadership of the Ministry of Development and operates along the lines of four sections:

[12] Including materials standards.

- The section of certifications, standards and prototypes which defines the national standards and certifications policies and directions,
- The certification stamps accrediting section which grants quality certification stamps to other institutions (e.g. Mirtec and Cereco in the materials case),
- The metrology section which certifies the calibration and correct operation of scientific instruments and experimental apparatus, and,
- The standards monitoring section with the aim to supervise and block uncontrollable imports of goods or materials of low or no standards.

The Division of Certifications and Standards provide standards and certification directives on the basis of industrial priorities[13] and **not** on the basis of identification of technological priorities. However, the division does not pre-determine any industrial priorities. It depends on market-driven, "bottom-up" approaches where priorities emerge in the form of established needs of specific industrial sectors and *"supports only the areas which call for support"* (PS5 1996). It then moves either to support these needs or support any visible potential as happened in the case of solar power boiler technologies. If materials cases emerge, then for the needs of each materials case, occasional consultation is received by four other Ministry of Development industrial administration divisions:

1. The Division of Non-Metallic Materials and Products (cement, ceramics, polymers, and chemicals),
2. The Division of Natural Fibers (textiles, wood, paper, and leather),
3. The Division of Basic Metallurgy (mining and production of steel, aluminium, etc.),
4. The Division of Metal Products (tools, machinery, transport equipment, electric equipment etc.)

These industrial administration divisions are still organised on the basis of the old OECD classification of industrial sectors presented in Table 7.2. and they gather and evaluate information on the basis of old classification systems on the basis of industrial sectors and not technological fields which creates additional understanding and evaluation problems.

[13] Under the criterion of which industrial sectors are regarded as "sensitive" for the Greek economy. This concept was developed during the 1970s and early 1980s (see chapter 7) and albeit GSRT has been detached from it, many public sectors still operate on the basis of this concept.

Public Agencies Profiles

A) Patents and Utility Models Certificates

The Industrial Property Organisation (OBI) was established in 1988, it operates under the supervision of GSRT, and is the legally qualified institution in Greece for exclusive grant of protection titles such as patents and utility model certificates. As such, on the basis of invoices and fees, the main goals of OBI are:

- to grant patents following the drawing-up of a full search report on the novelty of the invention on national and international level[14],
- to assist in the dissemination of world-wide technological knowledge (technology transfer services) to those interested, such as enterprises, public organisations, research organisations, industries and teams or individual researchers.

OBI operates along the guidelines of international archetypes and is connected with similar international organisations. OBI has also established regular co-operations (on the basis of invoices and fees) with some of the national research organisations (e.g. Mirtec) but it has not established (until 1997) formal information exchange networks with other information gathering organisations in Greece[15] (such as the National Documentation Centre).

B) The Hellenic Organisation for Standardisation (ELOT)

The Hellenic Organisation for Standardisation (ELOT) was established in 1976, is funded by the state and operates under the supervision of the Ministry of Development - Division of Certifications and Standards. The aim of ELOT is to promote and implement Standardisation in Greece (see also Annex 8.2). The procedures for standardisation are defined in the:

- rules and regulations for the operation of technical committees for standardisation,
- rules and regulations for compiling and publishing Greek standards.

In addition, ELOT applies *Certification* systems and procedures consistent with the International Organisation for Standardisation (ISO) and the Standards of the European Committee for Standardisation (CEN). The marks and certificates of conformity for quality assurance systems awarded in accordance with the requirements of the Greek

[14] OBI has access to archives containing inventions form most of the world's sources including European, American and Japanese archives.

[15] That includes "free-of-charge" services on the provision of technological information. That means that an individual or company can request information on specific issues so multiplication of efforts on the same subject can be avoided. This service is complementary with the National Documentation Centre service of providing information on national and international research but the two facilities are not yet connected.

standards, European Standards (EN), Experimental European Standards (ENV) and Harmonisation Documents (HD), are the Hellenic Marks of Conformity (Quality). With respect to Quality assurance, ELOT complies with the requirements of the European Standard EN 45012, has been assessed successfully and become a coequal member of the European Network for Quality System Assessment and Certification (EQNet)[16] and has developed certification activities in accordance with the standards ISO 9000, ISO 9001 and ISO 9002 and ELOT EN 29000 and very recently EN45000 and EN45001. ELOT also operates libraries, information centres and Testing Laboratories.

[16] A product or service is certified or standardised by one of participating members, then it is automatically certified for all the participating members.

ANNEX 8.3: The role of Universities and research/technological institutions in supporting Materials Science and Engineering strategies in Greece

The aim of the following sections is to analyse and test hypothesis **H8.3**. Hypothesis H8.3 states that given that all of the national collaborative R&D programmes require the direct involvement of research organisations it is hypothesised that both universities and research/technological institutions would be performing a key role in the development and implementation of the national MSE priorities within the Greek national system of innovation.

A8.3.1: The role of Universities in supporting Materials Science and Engineering strategies in Greece

Section 7.5.6 argued that universities hold a key role for the design and implementation of the national technology in the Greek national system of innovation. The contribution of university departments to the MSE field takes place directly through university participation in the national R&D collaborative programmes and through their role as education institutes.

The synthesis of the findings of the previous sections of chapter 8 pointed out that universities and research/technological institutions hold a key role for the design and implementation of national materials strategies for a number of reasons summarised in the beginning of the chapter, in section 8.1.3

The following paragraphs examine in detail the MSE activities of university materials divisions and research/institutions within the frame of the national (and international) R&D collaborations.

Universities And Materials Activities

From the six surveyed materials laboratories (covering a span of five departments in five universities), four of them were focused to structural metals and ceramics, one in functional ceramics and one in both functional and structural materials.

It is indicative that when the interviewed experts were asked to identify the reasons for being involved in materials related R&D (apart from teaching), invariably the answer was "*personal choice*". University or governmental policies were not considered as important reasons to be specialised in the MSE field. However, more detailed answers revealed that apart from personal scientific interest, the choice was also the outcome of serious strategic consideration: PAC1 and PAC2 endorse the argument that "*he who controls materials, controls technology*"; PAC8 identified that even for a university division, materials offer many scientific and technological challenges as well as many financial rewards due to long-term registered industrial demand and international interest.

University research activities in the MSE field are almost exclusively circulated within participation in national and international R&D collaborations. The forms these collaborations or co-operations take are summarised in **Table A8.7**. There are no special arrangements in favour of the specific needs of the MSE field. What is applied in any other field is also applied in the MSE field.

Participation in collaborative projects:	(5)
Establishment of co-operative agreement:	(2)
Requesting specific research to be conducted on contract:	(4)
Donating / investing funds to create a chair or laboratory:	(0)
Dispatching researchers:	(1)

Table A8.7: Forms of materials co-operations between universities and industry in descending order of frequency - (5) is the most frequent form. Source: Empirical research results.

After 1992, and according to the provisions of the Higher Education Act, academic departments and individual laboratories gained the ability to "market" their research expertise in the open market. Ever since, requesting specific research to be conducted on contract (in the form of research and technology services provision) became the second most important form of collaboration between research organisations and industry. The establishment of co-operative agreements (that is long-term co-operations between university laboratories and industrial firms) is circumstantial and not yet fully institutionalised, while despatching researchers is rare. Exchanging researchers is a form of co-operation more frequent among inter-university international collaborations or through a limited number of multidisciplinary PhDs in the materials field.

Aims and characteristics of university-industry materials collaborations

The aim of materials collaborations with universities is strongly project or contract connected. The most frequent aims of collaboration are summarised in **Table A8.8**. Usually universities are "forced" to adjust their field of interest to domestic or international demand as expressed though the objectives and characteristics of the national R&D collaborative programmes or the interests of the industrial partner/participant in the case of joint project proposals submission. However, they have the freedom to choose the specialisation area[1]. As such, and with respect to the character of the final user of the research, no general trends could be identified because this is subjected to the market specialisation of each laboratory. Notably, the laboratories which have a high degree of domestic collaborations are mainly involved with the improvement of existing structural metals and ceramics and their S&P technologies and the final users of their research results are by origin approximately 50% Greek and 50% EU, while the laboratories where international participation dominates, are advanced structural materials oriented (class (7)) and the final users of their research results are approximately by origin, 10% Greek and 90% foreign[2] (EU).

Aim of collaboration with:	Companies	Universities	Research Institutions	Gov. Labs
Basic Research	-	X	X	-
Applied research	X	X	X	-
Near market Research	-	-	-	-
Characterisation – Testing	X	X	X	X
Education and training	X	X	X	X
Standards	-	-	-	-
Production improvements	-	-	X[3]	-
Product Improvement	X	-	-	-
Product Development	X	-	-	-
New technologies	X	-	-	-

Table A8.8: The most frequent aims of materials collaborations. Source: interviews and GRST archives.

In short, all the interviewed academics verified that domestic collaborations are mainly connected with the improvement of incremental materials while most of the international collaborations involve the testing or development of new materials. In addition they verified that there is a limited domestic industrial demand for advanced functional materials and that this demand is dominated by research institutions participation, whereas there is a growing domestic demand for advanced structural metals and ceramics for the needs of a wide span of industries[4].

[1]For example, the laboratory of experts PAC1 and PAC2 is specialised in metals for advanced aerospace and other transport applications and the laboratory of experts PAC3 and PAC4 is specialised in advanced composites for advanced aerospace and other transport applications.

[2] Experts VAC1 and THAC1 added that, notably the foreign markets were more effective in applying and taking advantage of the research results.

[3] With the technological institutions.

[4] From chemical industries to food and cement industries.

The research results are used over a wide spectrum of applications (no predominant tendency was identified) from product and process improvement up to new technology development. Notably, there were no collaborations related to improvement of machinery or equipment performance or with the aim to promote standards and measuring technologies in advanced materials and processes. Basic materials research was limited only between research organisations and the participation of governmental laboratories (e.g. the laboratories of the Ministry of Defence) is almost non-existent.

University research and the materials tetrahedron

Contrary to the USA universities, the interviewed experts identified that in Greece there is no concept-based academic reservation to be involved in S&P - the reservations are clearly demand originated (see below). Moreover, with regard to perceptions and concepts, two of the six interviewed laboratories identified that the materials tetrahedron and its interconnections and implications is the first thing they teach their students and this tendency is spreading through out all materials divisions in Greek Universities.

With respect to the materials tetrahedron, academic research focuses on properties and performance studies (mechanical, civil engineering departments), and properties, chemical processes and structure and composition studies[5] (chemical engineering and physics departments). Similar to the findings of the NRC study (1989) for American Universities, S&P does not attract much attention but for very different reasons. From the six participating laboratories only two had research projects on S&P but these projects were a small fraction of their total materials activities.

This was just a reflection of a general trend in Greece, summarised by **Tables A8.10** and **Figures A8.5A,B**. Table A8.9 and Figure A8.5A provide a comparison between the total number of PhDs in three engineering departments[6] and one science department and the total number of materials related PhDs as they have been recorded by the National Documentation Centre (NDC) for the 1988-1995 period[7].

[5] Similar conditions apply with the research institutions materials research.

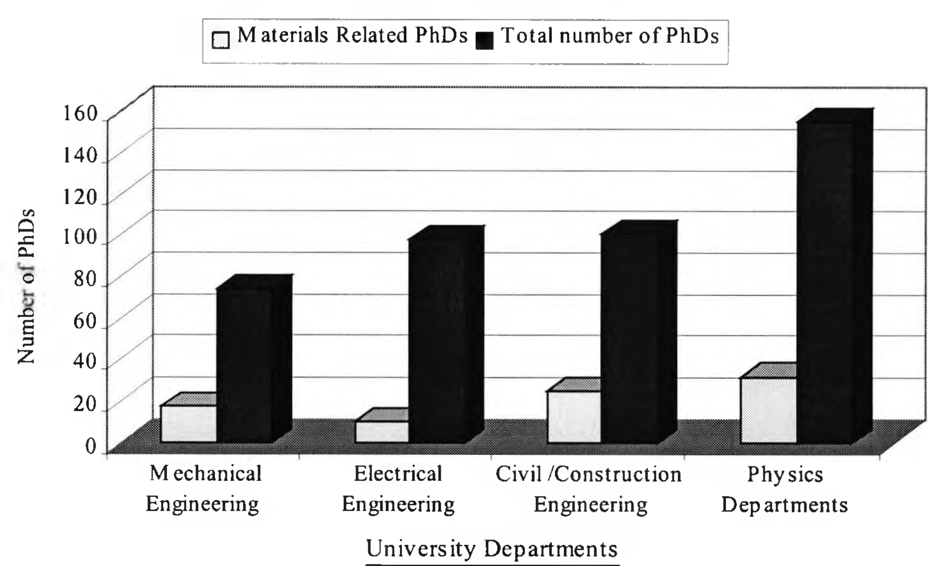
[6] Including **all** Greek universities. Chemical engineering and chemistry departments are not included because it is very difficult to distinguish between MSE and pure chemistry or chemical processes projects. However, there is a strong emphasis on characterisations, structure and composition, properties, and in some departments, industrial processes and catalysis.

[7] Figures are presented and used with some reservation: the NRC does not have complete records of the all PhD titles for this period of time. Until 1996, it was the responsibility of each individual laboratory to inform NRC; only after 1996, and in co-operation with GSRT, university departments' administration have the duty to keep NRC informed.

	Mechanical Engineering	Electrical Engineering	Construction / Civil Engineering	Physics Departments	Total Num. of Materials PhDs
Performance	0	0	8	1	9
Properties	12	4	11	14	41
Structure & Composition	0	1	1	11	13
Synthesis & Processing	3	0	0	1	4
Combination*	3	5	5	5	18
Totals	18	10	25	32	**85**
Total Num. of PhDs	74	98	101	155	428

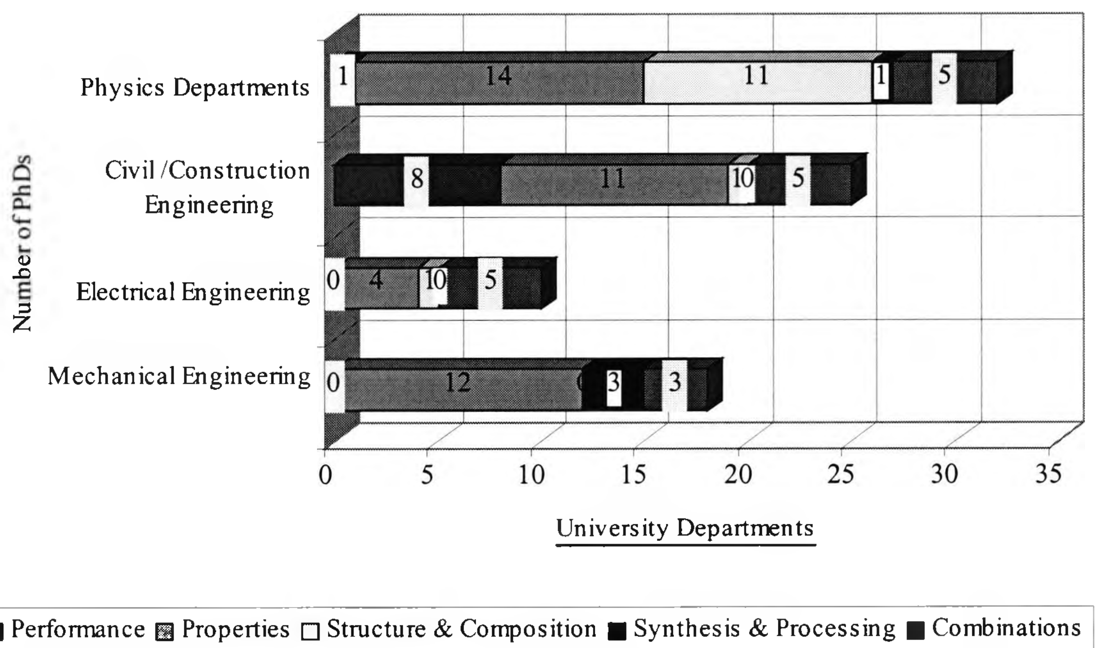
Table A8.9: Distribution of Engineering Departments PhDs according to the four elements of the materials Tetrahedron (1989-1995 period). Source: Author on data provided by the National Documentation Centre archives. * Combinations of Properties and Structure and Composition dominate.

Figure A8.5A : Materials related and total numbers of PHDs as recorded by NDC (1996) : Engineering and Physics Departments (1988-1995).



In absolute numbers, the MSE field attracts more attention in civil and mechanical engineering departments (24.7% and 24.3 %) and less in physics and electrical engineering departments (20.6% and 10.2%). Table A8.9 and Figure A8.5B provides a distribution of materials related PhDs with respect to the four elements of the materials tetrahedron for the reviewed academic departments and over the same period of time. There are 41 recorded properties related PhDs and only four S&P related PhDs.

Figure A8.5B: Distribution of materials related PhDs with respect to the four elements of the materials tetrahedron.
Source: Author based on data provided by NDC (1996).



According to experts PAC2 and VAC1 this picture is justified because it reflects the demand by the domestic industry. The character of Greek industry does not incorporate very advanced S&P technologies. The majority of companies pay large royalties for their S&P technologies and since they have no interest (or ability) to further develop them, they prefer to keep buying instead of developing[8]; thus they have no interest in supporting S&P research but they are primarily interested in properties, performance and characterisation.

On the other hand, a limited number of large companies which have developed their own S&P technologies, regard information on these areas as too sensitive to be shared with a

[8] Expert PAC2 suggested that the majority of the Greek industry does not use advanced S&P technologies like, say, the semiconductors industry. Industrial firms cover their every day problems through manuals and international technical assistance.

university which can act as an information diffusion link with other companies or industries. As such, they prefer to develop and improve S&P technologies either on their own or through well - trusted technology alliances with foreign companies (see findings of chapter 9). As VAC1put it, research in S&P in Greece would be practically un-marketable.

However, that is *not* the case when technological institutions are involved because their mission is to provide integrated technological solutions to specific problems and not just explain, estimate or evaluate a problem. Moreover, all experts pointed out that there is a growing industrial tendency to introduce advanced S&P technologies even in commodity industries expected to make an impact on materials academic research.

University - industry materials collaborations and pre-competitive research

Since the majority of collaborations in which universities participate are project or contract related, the involved research is application or market oriented with 2-3 years duration of funding. As such, (and contrary to an old perception), fundamental or pre-competitive research is currently sparse in the project driven Greek materials departments and it has a tendency to become sparse even in the national research centres. As all academic experts identified, there are no large scale, mission - oriented R&D programmes in Greece and as such there are no funds available for long-term pre-competitive research. Subsidies from the ministry of Education and Culture barely cover the basic inventory costs and they are not allocated on the basis of specific research projects as in USA, Germany, Portugal, Switzerland etc. Some laboratories engaged in pre-competitive research, finance it with the money "left -overs" (PAC1 1996) from the application oriented projects or contacts.

These developments have caused some reasonable frustration in the academic community: PAC9 identified that basic research has been deserted, and when it is not, contrary to international practice, it is the "blue skies" and not the "mission oriented" type. VAC1, THAC1 and PAC8 identified that if these conditions are prolonged over a long period of time, one of the main missions of the university, that is the commitment to fundamental or mission oriented but pre-competitive research, is under jeopardy endangering the future scientific and technological capabilities of the country. The findings indicate that there is a visible danger of a serious erosion of the Greek abilities in pre-competitive materials research, in many materials fields which can deprive the country of the ability to design and apply mission oriented, long-term R&D strategies in the future.

A8.3.2: The role of research and technological institutions

Two technological institutes entirely dedicated to materials technologies and one research institute dedicated to renewable energy sources are reviewed.

Materials-dedicated Technological Organisations

The two reviewed technological institutions entirely dedicated to materials technologies are the Metallurgical Industrial Research and Technological Development Centre (MIRTEC S.A. - RI1), and the Ceramics and Refractories Technological Development Company (CERECO S.A.- RI2). They were established in 1986-1988 and they are the only Greek research organisations dealing exclusively with R&D in the field of metals & metallurgical processing and ceramics & refractory materials.

Mirtec has the mission to assist Greek companies in terms of technology transfer for the development of new products and processes and to provide scientific and technological services and expertise to the sectors of basic metallurgy and metals, metal products, casting technologies and heat treatments. In addition, Mirtec has the mission to certify quality controls and inspections for the Greek metals industry. Cereco has the mission to provide scientific and technological services such as technology transfer assistance to large companies and SMEs involved with the production or use of structural ceramics, glass products and technologies, commodity ceramics, refractors, and cement technologies. In addition, Cereco has the ability to provide quality control certifications to the Greek ceramic and cement industry.

The strategic aims of both Mirtec and Cereco were designed as an integrated part of the national technology policy priorities with the aim to cover the field of metals and ceramics. Apart from the certification, quality assurance and standardisation roles, Mirtec and Cereco are trying to identify the needs of Greek industry (especially SMEs) and either develop or transfer technology in order to respond to these needs. Thus, both Mirtec and Cereco frequently act as catalysts between other Greek research organisations and industry, bridging the gap between research and industrial activities. What differentiates them from typical research institutions is that their mission is to deliver *integrated technological services*, that is find the source of the problem, and then provide complete technology and methodology solutions for the problem.

R&D portfolios and materials activities

Cereco and Mirtec do not have the legal and administrative ability or the financial resources to design and implement their own R&D portfolios pursuing the development of materials technologies tailored after the common needs of multiple industrial sectors. As such, the R&D portfolio of both companies is clearly market or project oriented with emphasis given to domestic markets (65-70% Greek companies and 35-30% foreign companies in the case of Cereco and 90% Greek companies and 10% foreign companies in the case of Mirtec). However, both companies, Cereco in particular, are trying to strategically design their projects portfolio in an effort to enter projects which will offer multiple benefits for the entire sector in which they operate.

Within this framework, materials activities take the following forms:

* Structural, incremental materials account for the majority of activities in both companies[9], while functional materials (ceramics such as catalysis and electrolytes) account for 15-20% of Cereco's activities mainly due to materials based diversification / rejuvenation efforts of some ceramic and cement producers (see also chapter 9).

* The R&D portfolio of both companies is oriented to serve the specific interests of individual companies and not entire sectors. Usually, these interests, take the form of short - to medium term projects or contracts (a few months to 3 years, at best[10]) involving applied or near market research tailored after the individual needs of the project's sponsor. Mirtec has the greatest proportion of short-term contracts or projects which regularly take the form of trouble-shooting rather than real R&D[11]. On this point, Cereco follows a more aggressive materials policy by trying to advise companies[12] to get involved in longer - term materials R&D through entering (or creating) projects and collaborations which will serve the concept of the development of base materials technologies useful for many potential industrial users. Similar Mirtec's efforts are hampered by the nature and characteristics of their immediate industrial environment such as the lack of long-term

[9] As RI2 put it "if we research new materials it is very difficult to find a "customer" for them".
[10] Only EU collaborations extend to 48 months.
[11] Both companies, and especially Mirtec reflecting the prevailing conditions in the metals sector, identified that they have to accept this type of projects for financial reasons (see below and section 8.6 financing innovation).
[12] Cereco identifies areas of high technological and commercial potential and after discussions with potential user companies, if an agreement is reached, they formulate an R&D project proposal.

R&D planning of the metal sector companies[13] or other heavy metals users such as construction companies.

* Collaborations take the form of participation in national and international R&D schemes or the form of contracts on the basis of invoices or special agreements. However, collaborative research is industrial application oriented and regularly has to deal with production and processing problems. Therefore, the technological institutions research is strongly connected to S&P applications and all four elements of the materials tetrahedron receive equal attention. Moreover, S&P technologies such as surface treatments (Mirtec) and ceramic coatings (Cereco) are two successful cases which enabled the two companies to provide technological services to the chemicals, food, oil & refineries and agricultural industrial sectors. It is the view of both companies (especially Cereco's) that business diversification or rejuvenation efforts can be boosted by materials diversification strategies (see chapter 3) and this is the message they are trying to pass to their immediate industrial vicinity.

Limitations of the materials oriented technological institutions

The above information shows that Mirtec and Cereco have similar structures and their strategic mission is differentiated only by the nature of the industrial sectors they are designed to serve. As such, the existing limitations have their origins in a combination of shortcomings imposed by their operational specifications, their special ownership character and the characteristics of the industrial fields they interact with.

The most important is the operational specifications of these institutes: they were designed to operate as private enterprises (S.As) and not as a typical public research institutions; the Greek state, however, is still their primary share-holder (absolute majority) and their operation *mondus vivandi* is narrow and strictly monitored.

Then, there is the issue of financial support of these institutions: following their establishment, which was financed by heavy Greek and EU subsidies, the Greek state only partially subsidises inventory and laboratory equipment costs[14]. Both institutions have to rely heavily on market driven contracts or collaborations. As such, they are fully "exposed" to the specificity of the sector they were designed to serve and to R&D markets which are largely unprepared, unable or unwilling to use their "products".

[13] Expert RI2 underlined that in general terms, the metals industry suffers from a lack of medium to long-term technological planning capabilities. This point was verified by the findings of chapter 9.
[14] For comments see section 8.1: financing innovation.

Mirtec (metals) has definitely less influence over the metals sector; as chapter 9 argues the sector is much larger in volume, more "primitive" and conservative in terms of technology and management of technology issues and largely influenced by the "high-inertia" public sector. In short, the sector has very few demanding technology users who are willing to seek Mirtec's services. On the other hand, Cereco has to deal with a sector which is dominated by private enterprises, it is strongly influenced by the advanced (in terms of technology and management) cement sector and enjoys high levels of industrial interconnections. As such, Cereco has a different and more fertile ground to step on, and can formulate a more strategic operational approach compared to the rather services provision, commerce oriented, Mirtec approach.

According to the above, the two institutes have limited capabilities to influence the market forces in which they operate, because they have neither the autonomy nor the operational capabilities to design and implement large scale, mission-oriented R&D activities in generic technologies which could be beneficial to several industries.

The case of the Centre for Renewable Energy Sources (CRES)

The Centre for Renewable Energy Sources is reviewed in connection with materials technologies because apart from the Centre for Solid Fuels Technology and Applications it is the only research organisation dedicated to energy production, storage, distribution and utilisation in Greece. Energy issues and materials technologies are of paramount importance in Greece for the following complementary reasons:

- Energy production is in deficit and energy is regularly imported for other countries;
- Energy production is based on the consumption of solid fuels (lignite), crude oil (imported) or natural gas (imported); apart from being environmentally unfriendly the imported sources of energy contribute significantly on the trade deficit of the country.
- Greece has a vast potential for renewable energy sources (sunlight, wind power);
- The Greek Energy technology foresight panel highlighted materials technologies as one of the most important technologies for further advancement in both conventional and renewable energy production and for energy storage, distribution and utilisation;

- International studies[15] have also identified the crucial role of materials in energy production and utilisation.

The Role of CRES with respect to materials technologies

The technology and operational strategy of CRES is defined by its establishment specifications. But since 1997, CRES is in a transition process moving its fundamental orientation from being committed to national and international *research or pilot* R&D programmes and collaborations, to the provision of high-technology services, projects and "products" on the basis of IEN45001 specifications targeting both the domestic and the international energy markets.

CRES is a typical example of the new generation research institutions in Greece (established during the late 1980s) in both organisational and operational terms[16]. CRES is structured into 9 divisions: the divisions of energy generation through sunlight, wind power, geothermal, passive and hybrid systems (including fuel cells), small scale hydrodynamics, biomaze and alternative fuels, photovoltaics, the division of rational use of energy and the division of testing and certifications.

However, CRES does not have the ability to design top-down mission oriented strategies in the energy field (and thus, design large scale materials programmes for energy applications), and according to the provided information (January 1997) there were no plans for change.

In a manner similar to technological institutions, the R&D portfolio of CRES is "bottom-up" project or contract oriented. Strategic considerations apply only in identifying the areas in which each of the CRES's individual departments submits proposals or seeks co-operation. These considerations are subjected to the discretion of each department but they must have the approval of the administration board of CRES.

While CRES projects usually include materials related activities, there are no materials priorities or materials dedicated programmes at CRES. As expert RI3 explained, even

[15] E.g.: The Institute of Materials (1994). Materials Strategy Commission - Technology Foresight Programme: *Draft Report on the Power Generation Industry*. London.; European Commission: *JOULE - R&D actions in the Field of Non-Nuclear Energy*. Work Programme 1994-1998.; Department of Energy (1995). *Sustainable Energy Strategy: Clean and Secure Energy for a Competitive Economy*. Government Printing office, Washington D.C.

[16] Moreover, CRES is a very good example of growth and expansion: CRES is by far the largest and most successful of the research and technological institution established during the late 1980s. It was established in 1987 with a manpower of 22 scientists and researchers and in 1997 occupies 115 specialised scientists and researchers. Its growth was primarily financed by successful project proposals, by research collaborations and by contracts accounting for approximately 65million ECUs (source: CRES 1997).

though there are many projects which involve materials technologies, CRES receives the role of materials[17] as granted (as given) input and then tries to optimise the use of these materials or, occasionally, materials systems in order to optimise production or utilisation energy systems. Emphasis is not placed on the improvement of the materials per se but on the testing of the material and the improvement or optimisation of its performance through better design, control, simulation and modelling techniques for the benefit of energy related applications. A secondary task of CRES related to materials technologies is the testing and certification provision of both existing and experimental materials for energy applications (such as the testing of the properties and performance of new light-weight bricks with build-in heating insulation).

[17] That is their properties, their performance and their structure and composition.

ANNEX 8.4: Materials Science and Engineering and the implementation of the National Collaborative R&D Programmes [1] (NCRDP)

Section 7.5.4 pointed out that the implementation of the national science and technology priorities takes place through the design and implementation of a set of national collaborative R&D programmes (*NCRDP*) with complementary but horizontal targets. As can be seen from Annex 7.3, there are no special arrangements on the basis of the specific character of individual technologies. The general settings also apply without any modifications in the MSE field.

According to evaluation reports examining the 1986-1994 period (Giannitsis 1994, Planet 1994, Technical Chamber of Greece 1992, Fokas 1994, Pappa 1993- 1995, GSRT 1994b-1995b) the national collaboration settings had many positive effects on the national innovation system of Greece from which the MSE field has also benefited:

- They have created links between research organisations and industry, some of which took the form of unofficial but long-term, regular technological collaborations[2],
- They have provided capital for materials R&D which otherwise would have been allocated to other activities,
- They have financed the infrastructure (experimental apparatus, machinery, etc) of many materials laboratories,
- They have created a substantial "pool" of specialised human resources and have familiarised R&D personnel with international experience and the performance requirements of high-standards of research.

However, the same evaluation reports concluded that the public-private collaboration-based R&D programmes gave poor tangible results[3] in most technological fields. As section 7.6 argued, this documented "inefficiency" has its origins primarily in shortcomings created by the application of the national collaboration-based R&D programmes *per se* and to some enduring shortcomings of the national innovation system. By using the MSE field as an illustration, the following limitations were identified:

[1] Inter-firm collaborations and technology-based alliances are analysed in chapter 9.
[2] Usually, a firm (or a group of firms under common management) use as research partner the same university or research institution division or laboratory on a regular basis over a long period of time and for many project proposals.
[3] Such as commercialised products and services, patents, new technologies, standards etc.

1. The non-discriminative, competition-based implementation of the national R&D collaborative programmes does not take into account the special nature and needs of the MSE field. Given that there are no budget thresholds for every one of the national materials priorities (not even in EKVAN) funds are allocated on the basis of non-discriminative evaluation of submitted project proposals as in any other technological field.

2. The analysis of both the early materials activities during the 1986-1993 period and the 1994-1996 period verifies the argument that the implementation of national R&D collaborative programmes creates problems of thematic and technological consistency and diffusion of results to the MSE field[4] (and most likely to all technological fields).

3. The short-term, competition-based characteristics of the national collaboration-based R&D programmes has a number of negative side effects:

- The NCRDP have created links between research organisations and industry but they do not provide the framework for the creation of technology-based consortiums, industry-to-industry links, the formation of industrial consortia and the formation of long-term technology-based alliances with complementary targets (such as the Alcoa-Audi alliance) (PS4 & PS3, 1997). As such, in the majority of cases, the primary aim of the participants is to satisfy separate, individual needs of circumstantial and not strategic complementarity; hence the common project proposal. On the other hand, in the few cases where research organisations-industry links take the form of long-term collaborations, then there is strategic complementarily and usually the undertaken projects lead to substantial tangible results[5]. However, these cases are the outcome of the management choices of the participants and they have not taken the form of official research consortia; they exist as long as the national R&D collaborative programmes exist.
- All the interviewed academic and research institutions experts underlined that the open competition character and the focus on competitive research of the NCRDP, practically "enforce" all potential participants to compete for the same stages of R&D. Given that participation in the NCRDP is a matter of crucial financial importance for many Greek research and technological organisations, they have to

[4] As shown in Table A8.2 and Table A8.4, the number of materials-related industrial R&D projects (PAVE) is disproportional (much larger) and more dispersed compared to the number of the materials projects of the other two programmes (SYN - links and PENED - human resources). Insights of the outlines of individual projects for the same period of time verified the argument.

[5] Examples of this tendency in the MSE field include S&P R&D on mining and basic metallurgy and functional materials for electromagnetic and telecommunication applications.

adjust their research focus accordingly. Hence, the *R&D division of labour* within the Greek system of innovation is *de facto* disrupted.

- The relatively low-budget and short-term character of the NCRDP *deter* the submission of proposals targeting pre-competitive research or the development of new materials. With respect to R&D activities in general, all the interviewed academics and research institutions pointed out that pre-competitive and fundamental research has become almost extinct from the Greek innovation system. With respect to materials activities, our findings show that the present implementation arrangements favour the improvement of incremental materials, simulation and modelling activities, software developments, and S&P efficiency improvements despite the effort of the national materials priorities to put equal emphasis to radical materials improvement, new materials and the developments of new S&P technologies[6].

4. With respect to the materials *tetrahedron*, the application of the national programmes (apart from PENED) and the implementation of the materials priorities (EKVAN) encompass **all four** elements of the materials tetrahedron. This has been verified by the empirical results of the interviewed companies and by evidence from completed R&D projects. With respect to projects with industrial participation, the element of S&P attracts particular attention (in terms of effectiveness, cost reduction, standardisation, quality control, operational improvements, and simulation and modelling). However, academic and research institutions (not technological institutions) research does not follow these patterns. Especially in the university related research projects, the element of S&P (apart from simulation and modelling topics) does not attract the required attention (see previous sections) and the overwhelming majority of the projects concentrate on the elements of properties evaluation and structure and composition.

5. Since the NCRDP have failed to create strong inter-firm links, a negative side effect is that the majority of the approved projects include only one or two industrial participants. Given that the aims of the collaborative project are largely dictated by the industrial party, the dissemination of research results are restricted by the single participating firm.

[6] Indeed, the majority of the interviewed companies indicated that they prefer **not** to use the NCRDP when they are involved in new materials or technology development efforts because the competitive, sort-term character of the programmes is inappropriate for such activities. However, they prefer to use the NCRDP for near market research targeting materials, products or S&P incremental improvements. The tangible results though, are the property of the sponsoring firm which participates with contributions of its own capital, and since they are small incremental improvements of established products, materials and technologies, they are rarely patented or published.

Hence, individual firms benefit but the development of generic technologies is inhibited and no wide and substantial technology transfers, spill-overs or spin-offs can be expected outside individual corporate level.

6. The case of CRES indicates that after 10 years of application of R&D collaborative programmes, research in materials technologies has become multi-organisational but not inter-disciplinary (or multi-disciplinary). Co-operative programmes have brought together industry and public research organisations but they have not achieved the bringing and mixing of organisations of different disciplines and fields together[7]. Under these circumstances the interdisciplinary potential of many research organisations and technology fusion opportunities are wasted. However, this is a consequence and not a cause. The national collaborative R&D programmes are totally deprived of the concepts of promoting or supporting materials based rejuvenation, diversification and especially technology fusion strategies and activities. And if they were not deprived, their implementation arrangements would inhibit the development and application of such concepts.

Reason	Very Discouraging	Discouraging	Indifferent
Lack of domestic market	X		
Lack of supporting Industry	X		
Lack of marketing skills	X	X	
Lack of promotion mechanisms	X		X
Lack of supporting technologies		X	
Lack of information on legal / administration issues		X	
Legal / administration issues	X		
Lack of Capital	X	X	

Table A8.10: Institutional obstacles hindering the effectiveness of public-private R&D collaborations. Source: Empirical research results.

Moreover, there are some additional obstacles hindering the effectiveness of public-private R&D collaborations related to national system of innovation shortcomings, industrial attitudes and inadequate institutional arrangements. The most discouraging factors are summarised in **Table A8.10**. The double point (X) in two or more columns of Table 8.10 indicates that on the specific issue there was an opinion variation among the

[7] E.g. a ceramics producer in co-operation with CRES in order to develop a new ceramic material for energy applications; the Marine Technology Development Company in co-operation with a steel or aluminium producer to develop advanced materials for off-shore applications; chemical industries with textile industries in order to develop advanced fiber technologies etc.

research participants. **Box A8.1** provides the most pertinent answers explaining the (X) points.

** *Lack of domestic market:* " the domestic market size is small or can not follow the university R&D capabilities".
** *Lack of supporting Industry:* "the majority of industry discover their needs only when it is too late" ; "industrial needs are low technology intensity".
** *Lack of marketing skills and promotion mechanisms:* a major problem; the establishment of "liaison offices" with the aim to promote and market academic expertise is expected to fill many gaps in this field.
** *Lack of supporting technologies:* "very big obstacle in the case of new materials; there are no technological clusters to take advantage; better networking within EU can provide better results."
** *Lack of information on legal / administration issues :* one more role for the Liaison Offices.
** *Legal / administration issues:* "The legal framework allows co-operations and research contracts but still imposes many barriers and controls. Need for further liberalisation".
** *Lack of Capital:* Here the sample was strongly biased ; each expert gave an answer reflecting his personal experience. However, there was a unanimous agreement that :

a) industry is reluctant (even large units) to take higher risks and invest in large scale R&D activities,
b) there is no legal framework or capital available to support technological spin-offs, infant industries and company incubators,
c) the financial markets have very little to do with the financing of technological innovation.

Box A8.1: Explanation remarks on Table A8.10. Source: Empirical research results.

In addition, old-fashioned management practices, industrial isolation and lack of economic motives (e.g. substantial tax reductions or market securitisation mechanisms) were identified as additional obstacles hampering further research organisations - industry R&D collaborations. Legal and institutional barriers were the only serious problem hampering inter-university collaborations or the formation of university research consortia and alliances[8].

[8] As PAC3 put it "*there are no particular problems in these collaborations because academics speak the same language*" However, all parts identified that university collaborations are largely dependent on personal contacts and relationships.

ANNEX 8.5: Supporting governmental policies

Monitoring and supervision mechanisms: GSRT is the public agency responsible for the monitoring and supervision of the execution of the national R&D programmes and for the operation of all research related organisations in Greece apart from universities and other public agency (e.g. Ministry of Agriculture) institutions.

With respect to the overall supervision and co-ordination of national R&D activities, GSRT has not met the desirable level of co-ordination mainly due to administration and co-ordination imperfections beyond GSRT's jurisdictions (see section 7.5).

However, the supervision of the execution of the national R&D programmes is under GSRT's jurisdiction. In principle, GSRT has established supervision - monitoring committees (with a mixed composition of public agents, members of the academia, industry representatives and auditing specialists) with the jurisdiction of in situ inspection and auditing surveys during the development of the programme. If a project fails, then the failure must be objective and well documented, otherwise the project contractors are held responsible. According to expert PS3, this scheme met successfully its tasks for EPET I and STRIDE mainly due the limited and specialised number of projects. For EPET II, however, and until the day of the interview (January 1997) the supervision of EPET Id's projects was restricted to financial auditing only. GSRT's can not any longer sustain substantial supervision of the projects mainly due to lack of human resources and/or expertise[1]. The included volume of work frequently forces GSRT to outsourcing of experts frequently from the international arena. Outsourcing has the advantage of bringing-in evaluations of high scientific and technological caliber but the external evaluators are usually distant from Greek conditions.

Further, as a participant in the NCRDP, the Greek State directly subsidies industrial R&D activities in the form of direct capital flows to individual companies. With respect to international experience this is a rather unusual case. As chapters 4 and 5 identified, industry has the responsibility to invest in R&D. One of roles of the government is to indirectly subsidise R&D activities through tax incentives, procurements, 'market securitisation' and other supporting policies. The direct allocation of funds can create serious monitoring and supervision inefficiencies as there is no real guarantee (apart from good will) that the capital will be allocated as requested.

[1] The wide thematic distribution of the submitted proposals (all fields - all principles) creates problems with respect to the evaluation and monitoring of the proposals.

The concept of "picking winners" and creating national champions: The Greek national innovation system is designed to create R&D winners. To begin with, at the *infrastructure level,* the budget allocation of EPET I (structural programmes) was allocated according to specific sector budget thresholds (see Table A8.2). This activity is followed-up by sub-programme 3 of EPET II. With this programme, 51 university, research institutions and technological education laboratories were subsidised on the basis of criteria of excellence[2]. Each laboratory received a 100,000 - 350,000 ECUs subsidy to support its "physical R&D infrastructure" with the mission to update or enhance its capabilities to provide high standards R&D services to domestic and international industry. Eight projects were allocated to materials laboratories: one in fuel technologies, one in polymer technologies, two in functional materials (lasers and optical fibers), one metallurgical and two strength of materials laboratories.

At *corporate level,* the system of directly allocating R&D funds on the basis of projects competition provides a big bonus to competition winners. The system uses a combination of the market forces and the imposed evaluation criteria as a mechanism of "natural selection" to pick (or create) R&D champions. Companies with the best projects become better and thus more successful in future project applications. Given the near market or applied character of research, individual companies (and not industrial sectors) gain all the technological benefit while accumulating additional competitive advantages. Many individual materials companies[3] took advantage of the system and they have been established as the R&D corporate "national champions" of their field. A weakness, however, of the system is that many companies (or even entire sectors[4]) lost out during the early stages of the competition and were thus excluded from the national R&D programmes[5].

Evaluation and diffusion of technological information: A serious deficiency of the Greek innovation system is the way in which R&D data (and other technological information) are collected, recorded and evaluated. First of all, R&D data are mainly collected and evaluated by the GSRT but many other institutions and agencies are also responsible for collection of R&D indicators which adds confusion and creates data incompatibilities due to significant differences between the methods of collection,

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[2] Such as, participation in national and international R&D collaborations, publications, organisation of international activities etc.

[3] Active in classes (1), (2), (3), (4), (6- polymers) , and (11).

[4] However, some other sectors, due to their weak connections with the academia which has vast experience in applying for funds, failed to have their proposals approved.

[5] A sort-lived attempt to compromise the particular weakness of the system ended-up in reducing the effectiveness of the system by excluding repeatedly successful applicants in favour of first comers.

classification and presentation of the data[6]. Apart from the incompatibility issue of the total figures, there is the additional problem of a significant time-lag between the time of data collection and data availability which is usually three to four years. Moreover, figures of R&D indicators are collected according to traditional OECD classifications of industrial sectors and not on the basis of modern technological sectors or groups of technologies[7]. Therefore, both the public and the private sector have difficulties in obtaining a clear picture and proceed further in technology policy evaluation and strategy design measurements while all of the Greek R&D activities (in terms of expenditure, investment, number of researchers, laboratory equipment) are significantly underestimated. In addition, private companies are reluctant to release data on their R&D activities mostly for taxation reasons

Within this frame, GSRT and the National Documentation Centre (NDC) have developed mechanisms to monitor global technological developments. However, there are no units specialised in materials technologies (or any other technologies). In addition, there is no institutionalised mechanism to evaluate the received inputs and pass the results to industrial and other potential users. The received information is mainly used internally to assist the mission of the R&D evaluation committees and it is not distributed in the form of, say, technological reviews to the general public. On the other hand, the NDC is mainly responsible for information gathering in the form of data and data banks creation and support. Individuals, academic and research institutions, industry and public agencies have information access on the basis of services provision invoices. Materials specialised data - bases are under creation but a specialised agency dedicated to the monitoring and evaluation of materials technologies like the, say, The Institute of Materials in London, UK, does not yet exist.

Export policies and commercial networks: Exports promotion mechanisms were specialised according to the aim of providing assistance to traditional industrial sectors and not according to technological fields. They usually took the form of export - import tariffs and subsidies which during the 1970s and up to the middle 1980s were designed to support consumers goods (such as food, tobacco and textiles) and to "punish" capital and

[6] For example, the Bank of Greece uses settlements data denominated in USA dollars. They record only the value or price of goods (e.g. laboratory equipment) or activities when they pass as invoices through the banking system. The National Statistical Service (NSS) uses denominations in drachmas. GSRT also collects data in drachma denominations but serious problems for the accuracy of figures are under question due to the application and collection of VAT tax on R&D activities.

[7] Take the non-metallic minerals sector for example. This general term includes practically all the structural ceramics R&D activities and most of the functional ceramics R&D activities covering a diverse band of technologies from cement to photovoltaics and ceramic coatings.

technology intensive goods (such as steel, machinery, electric equipment etc.) (PS4, Patsouratis 1993).

As for the issue of supporting commercial networks, there was *a unanimous* agreement that one of the most fundamental problems for technology innovation in Greece *is the lack of promotion networks*. The problem is intensified when "hard" international markets are targeted. It is not the aim of the present study to analyse this issue in depth. However, the creation of international promotion mechanisms is an issue which needs the long-term government's attention and according to international experience (e.g. USA, Britain, France, Japan etc.) the creation of networks is usually supported by long-term commitments including diplomatic efforts.

ANNEX 8.6: Financing Technological Innovation in Greece

A8.6.1: The role of the Government

Direct capital allocation. Direct public R&D expenditure accounts for approximately 70% of the R&D expenditure in Greece (see section 7.5 and Annex 7.1). However, the criteria behind budget allocation for R&D activities (such as the State participation in national R&D programmes) and for long-term investments such as the financing of R&D infrastructure, are different.

Until 1994, the direct budget allocation for R&D activities (e.g. the funds allocated to national programmes such as PAVE, EKVAN, PENED etc.) was dominated by the "net present value" concept and it was predetermined and justified according to the needs of each individual project or according to each individual national technology policy priority. With EPET II, however, the concept behind the direct budget allocation for R&D activities is somewhere in between the "net present value" concept and the "strategic investment" concept where the R&D portfolio is constantly monitored and evaluated. EPET Id's programmes and actions (see Table 7.7) cover a 5 years funding period where the budget allocation is predetermined (+/- 20%), but the budget distribution to specific actions is flexible and subjected to BI-annual feed-back evaluations of progress.

The financing of R&D infrastructure, however, has always been dominated by the strategic investment concept aiming to develop the technological and science capabilities of the country, and not to generate immediate financial returns. As a direct side effect, during the 1970-1994 period, Greek policies such as tax incentives, subsidies and other supporting measures provided emphasis on the acquisition or updating of R&D equipment, or the development of "physical" R&D facilities such as R&D laboratories. But according to the findings of chapter 6, to subsidise the acquisition or updating of equipment is effective for any one organisation every, say, 3-5 years. To use the equipment involves ongoing expenditures. This kind of R&D expenditure (including intangible expenditures such as human resources, organisation expenditures, formation of information networks etc.) was not subsidised in Greece.

Finance of University and Research/ Technological Institutions

A tangible example in support of the preceding argument is the financial support allocated for R&D in Universities research / technological institutions. The reviewed technological institutions were established during the 1986-1992 period on the deployment of considerable EU and Greek funds. That investment covered the creation of buildings, laboratory equipment, machinery, experimental apparatus and other "physical R&D infrastructure". At that point State subsidies stopped. The research and technological institutions still receive subsidies for the updating of equipment but nothing else. So, they have to survive on their own ability and thereby they are totally dependent on projects and short-term contracts.

The University laboratories case is similar. The annual funds allocated by the Ministry of Education and Culture for R&D are unanimously regarded as insufficient and they barely cover basic salaries, administration and "inventory" costs. However, during the last 10 years many materials divisions, on the basis of participation in R&D collaborative projects and services provision, have managed to become financially autonomous and reach annual budgets of more than 1 million ECUs. To do so, university laboratories were "forced" to adopt corporate management practices; as experts, PAC2 and PAC3 explained, university laboratories live out of competitive programmes, but the choice of which area of competition to enter is a strategic choice constantly monitored and re-evaluated on the basis of "market" demand evaluations and the laboratory's core expertise. In many cases, research activities are almost exclusively aligned or integrated to EU needs. This has already occurred with two of the reviewed laboratories.

Indirect measures

According to the findings of chapters 5 and 6, governments can support the financing of technological innovation with a set of indirect but equally effective measures such as "market securitisation", the concept of infant industries and tax incentives. Complex and sophisticated technologies such as materials technologies are in particular need of this type of support. In more detail:

Tax incentives: according to Karageorgiou (1996), Patsouratis (1995) and experts PS1, PS4 and F1(1996), apart from law 1731/87 which provided substantial support for R&D industrial expenditures, there are no other tax incentives (in the form reviewed in chapter 6), for the support of basic and applied industrial research. According to expert PS1, the Greek State views industrial R&D expenditures as an effort for tax evasion[1] which fits with the findings of Karageorgiou (1996-see section 7.5) that companies hide their R&D activities to avoid taxation problems. This tendency was also verified by the present study because 80% of the interviewed companies were reluctant to provide figures for their R&D expenditures. Taking this

[1] Given the low technological abilities of Greek industry and the very low industrial R&D activities until the early 1980s, this attitude had some rationale behind it. But according to F1, the relative legislation has not adapted to evolving conditions.

point, expert PS4 argued that since most of industrial R&D expenditures not related to the national and international collaboration programmes have been forced to entered the domains of "black economy", the effectiveness of tax incentives for R&D activities like those in USA or Canada would be very limited until an environment of "trust" is created. In the place of tax incentives, there are capital subsidies (law 1892/90 and its supplementary modifications) but only in the form of industrial development support (see below) and on the basis of supporting the application of existing knowledge in order to produce tangible products and services.

Government Procurements and "market securitisation"

According to experts PS1, PS2 and PS4 (1996), until the early 1990s public contracts and procurements were **not** consciously perceived as tools for technological development. That confirms the findings of earlier studies which argue that public, contracts, subsidies and procurements usually take the form of industrial or regional support and not the form of supporting technological development (Kalogirou 1991/92, Zorbala 1992). The Greek State, either directly, through a public agency (e.g. the Ministry of Defence) or indirectly through "public goods" companies subsidises large companies and industrial activities in the form of procurements for products or services. It is common for these industrial activities to involve highly sophisticated and technologically advanced products and service. However, when these services or products became the output of domestic production in Greece, they involved mature and well-established technologies designed to meet the requested, average, performance requirements[2]. Moreover that kind of procurement does not take the form of long-term "market securitisation" as happens in, say, Sweden and Canada where "market securitisation" policies take the form of 10-15 years contracts[3]. As PS4 and PS3 pointed out, until 1997 there was no legal framework for similar activities in Greece and the measure of government procurement policies for high technology products and services was *not yet* institutionalised[4].

Public contracts and procurements take the form of one-off contracts[5] for products and services usually appointed after competition on the basis of performance and cost requirements (cost considerations usually prevail). These arrangements provide

[2] According to Kalogirou (1991), due to cost considerations of the "investment of the public money" the contracts or orders of the Greek State to domestic enterprises usually concern cheap or average performance products while for high performance products or specialised products the Greek State gives the contracts to importers or foreign markets.

[3] Doutriaux (1991) pointed out that in the case of Canada and Sweden, long-term government contracts for goods and services are more important for competitive growth than contracts for R&D and other R&D support mechanisms.

[4] According to expert PS4 and Tsipouri (1993), the main reason against the institutionalisation of "market securitisation" is the " invented elsewhere" syndrome (why should we make if we can buy).

[5] When the product or service is delivered the contract terminates.

significant cash-boosts but no real security for continuous, consistent efforts. As a direct side effect, the concept of supporting *infant and/or high-technology industries* by exploiting the vast financial potential of the Greek public sector, is in practice, in its early infancy[6]. Thus, the existing situation has a multiple negative impact on the Greek innovation system by degrading the vast (in terms of sources of funding) technological innovation capabilities of the Greek public sector.

A8.6.2: The investment law 1892/90 and its supplements and amendments

The investment 1892/90 law (and its later modifications and supplements[7]) is primarily an instrument of industrial and regional development policy designed to support large scale, high-technology, product, process or services projects with a time horizon of 2-5 years and budgets in the range of 3.5 - 10 million ECUs. However, it is reviewed in detail because it is the first *industrial development* law which, in spirit, introduces the concept of technological development in parallel with the concept of industrial development in Greece, and because it provides evaluation insights to banks and venture capital companies when they have to evaluate investment proposals related to technological innovation.

The investment law has a strong regional and imports substitution character and it subsidises either the initial cost of tax-free capital (deposits) for the investment or the granting of loans. The level of subsidy can reach up to 55% of the required capital and it is adjusted according to category of investment and geographical region of the investment. There are eighteen categories of investments and five geographical regions as defined by article 9 of the investment law. **Table A8.11** summarises the level of grants (%) by category of investment, undertaking and geographical area as defined by article 9 of the investment law.

As shown in Table A8.11, Thrace is the highest subsidised zone (grants up to 55% of capital) and zones A and B (where notably most of industry, universities and high technology activities are concentrated) are the lowest zones. Simultaneously, the tax allowances are up to 100% for Thrace and less than 60% for zones A and B. If an investment proposal is to be subsidised in zone A or B it has to be of exceptional high – technology content (for Greece).

[6] The National Power Company pioneers this type of R&D subsidy by supporting the formation of industrial consortia based on contacts agreements to develop and deliver a specific range of products or services. But when the product or service is delivered the contract terminates.

[7] The articles 23a and 23b on investments for exceptionally high technology , the codification of the 456/95 Presidential decree and the amendments and supplements of law 2234/94.

	AREA									
CATERGORY OF INVESTMENT[1] AND UNDERTAKING[1]	A		B		C		D		THRACE	
	Up to 5 Bil. Dr. For all underta-king	**5-25 Bil. Dr.** Proce-ssing only	**Up to 5 Bil. Dr.** For all under-taking	**5-25 Bil. Dr.** Proce-ssing only	**Up to 5 Bil. Dr.** For all under-taking	**5-25 Bil. Dr.** Proce-ssing only	**Up to 5 Bil. Dr.** For all undert aking	**5-25 Bil. Dr.** Proce -ssing only	**Up to 5 Bil. Dr.** For all under-taking	**5-25 Bil. Dr.** Proce-ssing only
1. Protection and restoration of the environment, Reduction of pollution recycling of water	40	30	40	30	40	30	45	30	55	40
2. Exploitation, substitution. Conservation of energy	40	30	40	30	40	30	45	30	55	40
3. Establishment or expansion of laboratories engaged in applied industrial, energy or mineral research by the productive units of article 2, paragraph 1	40	30	40	30	40	30	45	30	55	40
4. Production of "new" products. Products, services and equipment characterised by highly advanced technology	40	30	40	30	40	30	45	30	55	40
5. Special institutions and workshops for the rehabilitation of persons with special needs and undertakings employing such persons.	40	30	40	30	40	30	45	30	55	40
6. Independent laboratories engaged in applied industrial, energy and mineral research and investments by undertakings developing technologies and software	40	30	40	30	40	30	45	30	55	40
7. Agricultural, forestry, livestock and fishery (aquaculture) undertakings using modern technology	15		15		35		35		50	
8. Investments by construction companies involving the modernisation or replacement of machinery.	-		30		15		15		15	
9. Conversion of listed or traditional buildings into guest houses or hotel undertakings	15		25		30		30		35	
10. Technical assistance and joint business action centres (see 1.4. or par. 1. Article 2 [2]	25		35		25		35		50	
11. Undertakings carrying out investments aimed at exploiting industrial minerals as listed in article 9	-		35		35		35		35	
12. Undertaking s exploiting agricultural, industrial and urban refuse and waste	-		35		35		35		50	
13. Undertakings of agricultural or agro-industrial co-operatives for investments in sowing. Cultivation and harvesting machinery	-		25		35		35		50	
14. Investments by mining and quarrying undertakings	-		25		25		35		50	
15. Publishing or printing undertakings of the Athens and Thessaloniki daily press and daily provincial newspapers	25		25		25		35		50	
16. Treatment and rehabilitation centres and undertakings providing living accommodation to persons with special needs	25		25		25		35		50	
17. Independent undertakings or hotel enterprises operating a) Marinas b) Conference centres c) Golf courses d) Health spas e) Winter tourism centres	25		35		25		35		35	
18. Undertaking constructing and operating car parks, garages for public use.	300,000 Dr. per parking place									

Table A8.11: Table of grants (%) by category of investment Undertaking and area pursuant to article 9. Source: ETVA 1996

(1) For Film Companies, see Law 1597/86 (Government Gazette 68/A/86) which is currently force

(2) For Expenditure Abroad, The Grant Is 25%

Table A8.12 shows the type of undertaking and the minimum size of productive investment required for a proposal to be made eligible for the provision of investment grants and interest subsidies as defined by articles 23a and 23b of the investment law.

As shown in Table A8.12, the investment law gives equal emphasis on new establishments, expansions, and modernisation. It identifies industrial sectors (e.g. agricultural industry, information technology industries) but it does not pre-select any particular technological field or technology.

This becomes more apparent after reviewing the evaluation processes of the submitted proposals. The evaluation starts from the characterisation of the proposal as an exceptionally high technology proposal. Evaluation committees in the Ministry of Development or GSRT proceed into evaluations according to criteria summarised with **Table A8.13**. Similar evaluation criteria apply for exceptionally high technology products and services, and for exceptionally high technology apparatus and equipment investment.

Table A8.13 shows that the evaluation criteria do not include any technological pre-selection and they do not take into account the different potential and peculiarities imposed by the nature of each technology. The second evaluation stage includes the evaluation of the financial feasibility of the proposal based on credibility, assets, cash-flows, market and cost of investment criteria.

Investment Laws and Materials Activities

During the first three years of the application of the investment law, forty seven projects related to materials technologies were approved (see **Table A8.14 and Figure A8.6**). The metals sector (steel and aluminium industry) was subsidised with 8 projects in the range of 7-10 million ECUs. The chemical industry was subsidised with 18 projects with much smaller budgets. The functional materials field was monopolised by projects allocated to the cables and wires industry investing in optical fiber technologies (4 projects). The investment proposals were submitted by large corporations focusing on processing technologies and processing improvements. There was no participation from SMEs.

TYPE OF UNDERTAKING	TYPE OF PRODUCTIVE INVESTMENT	Minimum size of productive investment in mil. Dr.
Undertaking exclusively providing services involving highly advanced technology	Modernisation Establishment – expansion	2 5
Laboratories engaged in applied industrial energy and mineral research	Modernisation Establishment – expansion	2 5
Undertakings engaged in the development of technologies and software	Modernisation – expansion Establishment – expansion	2 5
All other undertakings except the above	Modernisation	10
Listed houses or buildings or traditional workshops producing traditional craft industry products or handcrafts	Repair, restoration, conversion of listed traditional houses or buildings into guest houses, hotels or workshops producing of agricultural products (establishment or expansion)	15
	Increased to 25m. dr. by Min. Dec. 43500/94	
Agricultural, forestry, livestock and fishery undertakings using modern technology	Establishment or expansion	30
Undertakings of agricultural or agro-industrial co-operatives	Investments in mechanical means of sowing, cultivating, irrigation installations and systems, harvesting and packing of agricultural products (establishment or expansion	30
Undertakings engaged in the drying, freezing or dehydration of agricultural, livestock or fish products	Establishment or expansion	30
Undertakings producing biomass from annual or perennial plants for the production of energy	Establishment or expansion	30
Craft industry and handicraft undertakings	Establishment or expansion	30
All other undertaking except the above	Establishment or expansion	45
Existing industrial processing undertakings	Business plans of 2 - 5 years	1,000 (1 bil. Dr)
Existing software companies	Business plans of 2 - 5 years	500
Industrial processing undertakings or undertakings providing quality services	Expenditures for studies, equipment, installations and the operation of the necessary infrastructures and procedures, expenditures incurred for the certification of product quality.	50
	Expenditures for conversion aimed at making units more flexible	50
	Expenditures for importing environment-friendly technology	50
	Expenditures for the production of innovative products, the introduction of innovations in the production process, the award of patents for inventions and prototypes.	50
	Expenditures for the expansion of laboratories providing quality services	50
	Expenditures for the establishment of laboratories providing quality services	250
	Expenditures for the establishment of industrial units for the ecological dismantling/breaking up and use of products consumed in Greece	250

Table A8.12: Table showing type of undertaking and minimum size of productive investment required in order to be made eligible for the provisions on investment grants (1) and interest subsidies (of article 1, par. 3 and articles 23a and 23b). Source: ETVA 1996.

Criteria	Evaluation Scale**			
Group A : Status of the Technology				
Age of technology	Emerging (6)	Critical (3)	Base (0)	-
International implementation of technology	Small (4)	Average (2)	Wide (0)	-
How sufficiently the technology is supported in Greece	Well supported 4)	Sufficient (2)	Little support (0)	-
Demand for new materials	High (3)	Significant (1)	Small (0)	-
Demand for specialised high technology equipment	High (3)	Significant (2)	Small (0)	-
Group B: Infrastructure demands and conditions for the successful adaptation and "digestion" of the technology by the company				
Employment of qualified human resources	Substantial (8)	Satisfactory (5)	Insignificant (0)	-
R&D laboratories	Modern (5)	Elementary (2)	Non-existent (0)	Not necessary (3)
Quality control and certification laboratories	Modern (5)	Elementary (2)	Non-existent (0)	Not necessary (3)
Technology transfer agreements	Secured (2)	Planned (1)	Non-existent (0)	Not necessary (2)
Group C: Technological characteristics of the product				
Creation of technological competitive advantage	Substantial (8)	Average (4)	Insignificant (0)	-
Success prospects of the product in the Greek market	Substantial (6)	Average (3)	Insignificant (0)	-
Technological risks for the acceptance of the product from the market	Substantial (3)	Average (2)	Insignificant (0)	-
Technological risks for the production of the product	Substantial (3)	Average (1)	Acceptable (0)	-

Table A8.13: Evaluation criteria for the characterisation of exceptionally high technology products in Greece. Source: GSRT 1996

** Proposal approval conditions : Partial Totals : A>7, B>7, C>7 ; S >10. Total (S) : S = ((0.5 x A) + (0.3 x B) + (0.2 x C))

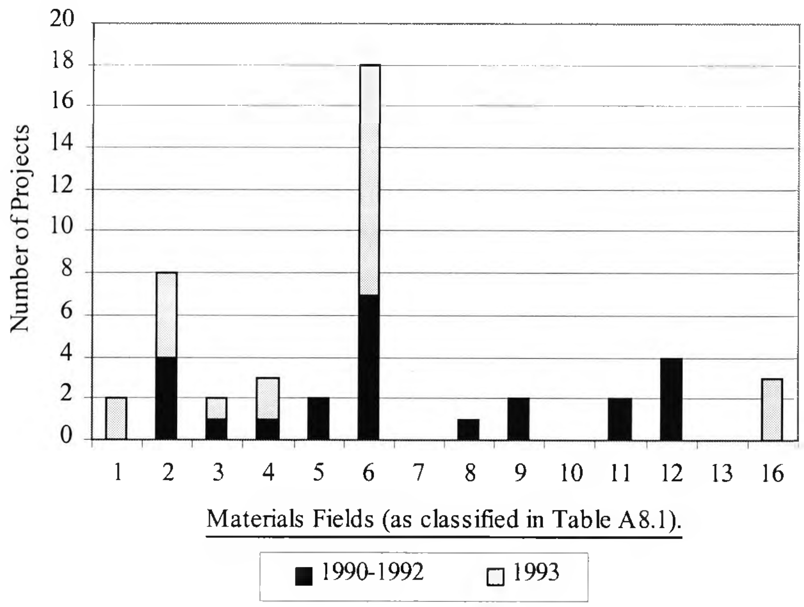
Field / Year	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(16)	Total
1990-1992	-	4	1	1	2	7	-	1	2	-	2	4[8]	-	-	24
1993	2	4	1	2	-	11[9]	-	-	-	-	-	-	-	3	23
Total	2	8	2	3	2	18	-	1	2	-	2	4	-	3	47

Table A8.14: The application of the investment law (1990-1993) in the MSE field. Source: Polyzakis 1995 and Pappa 1993.

[8] Optical fibers, optical fibers cables production.

[9] Polymers: 7 ; other chemicals: 4.

Figure A8.6: The application of the Investment law in the MSE field. Source: Table A8.14 data.



Comments on the application of the law, its strengths and its weaknesses

The 1892/90 investment law and its amendments substituted the older industrial development law 1262/82. There are two positive developments:

- The focus on the importance of technology and the linking of the issue of industrial development with the issue of technological competence, and,
- The introduction of the concept of technology adaptation and reverse engineering; reverse engineering capabilities are an important determinant for the successful evaluation of a proposal (Group B in Table A8.13).

However, the spirit and the application of the law has four serious drawbacks:

1. The first serious drawback is the strong emphasis on regional development. As expert F1 identified the investment law "*gave everything to regionality*". Indeed, the investment law heavily subsidises proposals connected to regions which have neither the human resources nor the basic infrastructure (e.g. proximity with universities and other centres of research excellence, information and modern telecommunication networks etc.) to support large scale, high technology investments and industries. On the contrary, the spirit and design of the law, "punishes" regions (A) and (B[10]) by giving no or very low incentives. Given that the incentives of the investment law are **not** supported by a parallel stream of incentives or measures targeting the infrastructure development of the heavily subsidised by the investment law regions, this is a serious policy inconsistency because it is in these areas where human resources, universities, centres of research expertise and basic infrastructure are most needed. On the other hand, the "punished" areas have the highest participation in the national and international R&D collaborations, and it is in these regions where the Greek State has heavily subsidised the development of the six technological companies (such as Mirtec and Cereco) and the development of technological and industrial parks. As identified in chapter 7, the Greek State insists on providing priority to regional development strategies rather than industrial and technology strategies.

2. The investment law shifted attention from exports to imports substitution[11]. As identified in chapter 7, that concept is responsible for many of the existing weaknesses of the Greek economy. In global terms, Greece's small internal market is insufficient to support high scale production (unless it is commodities such as food and beverages). Contrary to international experience (e.g. Japan, Sweden, South Korea, Taiwan which clearly sponsor *export - oriented* high - technology industries based on the development of new technologies), the 1892/90 law gives priority to high technology import substitution and high value products produced by established technologies.

3. With respect to technological issues, the investment law focuses on transfer and small development/evolution of established technologies for production (and primarily import substitution) of high technology products or services. Thus, the concept of creating intelligent users and not technology producers is by default in the spirit of the law. Moreover, the law does not include the element of technology strategy because it does not differentiate between technologies. And finally,

4. The incentives of the 1892/90 law focus on generic measures designed to support industrial sectors or wide technological fields. According to the findings of chapter 6 (section 6.3) these horizontal character arrangements are necessary for the creating a supportive environment for all technological fields but they cannot efficiently support specific technological or industrial fields. Moreover, the incentives

[10] Industrial zones of Athens, Thessaloniki, Patras, Volos, Korinth, Chalkis and Lagatha which concentrate most the majority of research and industrial activities **including more than 90%** of the metals, ceramics, cement and polymers sectors.

[11] On this point, law 1262/82 is the best investment law because it put exports in first priority.

of the 1892/90 are clearly designed to support large-scale industrial production. They are not designed to support R&D spin-offs or high technology start-ups.

A8.6.3: The role of the financial markets in Greece

The role of Banks. The key characteristics and the role of banks in financing industrial development in Greece has been reviewed in section 7.3. The present section reviews the role of banks in financing technological innovation since the middle 1980s up to the end of 1997. Two banks[12] are reviewed: a large, State controlled investment bank (B1) and a large State controlled commercial bank (B2).

Financing within the statute of the investment laws

For investments in high-technology areas subject to the statute of the 1892/90 investment law (and its later modifications) the State controlled banks operate within the directives of the investment law. When high technology investment proposals are under evaluation, as in any other case, a feasibility study is launched. For banks, the business characteristics of the proposal, financial sizes, market conditions and credibility issues are the basic evaluation points of the proposal. Technology evaluations are usually received by the high - technology evaluation committees of the Ministry of Development. When an investment proposal is approved, banks are obliged to provide loans or investments under better terms[13] but it is up to their discretion to decide on insurance measurements and exit mechanisms.

Free will investments

The State controlled banks (especially after the liberalisation of the financial markets) have the autonomy to finance high technology projects or corporations of their selection. Until 1997, however, they did not have in place specific policies for financing technological innovation portfolios. The reviewed banks (the commercial ones in particular), admitted that they were not aware of the strategic and financial potential of many technologies including materials technologies. As such, for a number of reasons, banks were from very cautious to indifferent to the finance of technological innovation apart from a limited number of promising technological areas offering short-term tangible returns (such as telecommunication technologies and Information Technology applications).

[12] B1 is the only investment bank with relative policy making autonomy. B2 is a typical commercial bank under public control; the practices applied by B2 are largely common for all the State controlled banks.

[13] With respect to free-market investment proposals.

The first reason for this behaviour is that the public commercial banks can not afford to take high risks because they operate under very small profit margins (3-4% for 1995[14]). Moreover, for investments in high-technology areas not related to the investment laws, banks do not have the privilege of the technology evaluation services of the Ministry of Development evaluation committees. As experts B1, F1, F2, F3 and PS4 identified (1996), banks do not have their own mechanisms to effectively understand and evaluate technology based projects[15]. When a need emerges, they depend for "the basics" on limited human resources and foreign consultancy. Thus, banks, (especially the commercial ones) do not (or can not) see the financing of technological innovation as something special and "*whatever banks do not understand, they avoid*" (PS3, F1, F3 1996). However, both the investment and the commercial banks have been involved in the financing of projects[16] which involve high technology elements on the basis of the applicants financial credibility. But given that banks have not yet developed internal mechanisms to select and evaluate technologies, they neither give priority to any particular field nor to pre-selected technological fields and each proposal gets the same evaluation "handling" as any other project.

Evaluation criteria for corporate / project finance

Banks, (commercial banks in particular) evaluate even the financing of technological innovation only on the basis of financial, market, business plans and company credibility issues. Technological issues and the characteristics of the technology come last[17]. However, a distinction between project financing and corporate financing has to be made.

For corporate financing, during the evaluation of a proposal, fixed capital and tangible assets are the most important parameters. For project financing, the company has to guarantee the investment with its assets. On these lines, the evaluation criteria (in order of importance) used by investment and commercial banks are summarised in **Table A8.15**.

This shows that commercial banks are more "rigid", giving priority to financial magnitudes while investment banks are more relaxed, giving priority to the evaluation of the credibility of the idea and the applicant which involves more strategic and intangible elements than economic elements. However, both B1 and B2 underlined that the risk they fear the most is to make the wrong decision about the credibility of

[14] Source: National Bank of Greece 1996.
[15] Bankers, particularly middle managers in the public sector, are still on a steep upward learning curve (Industrial Review 1996).
[16] Mainly in the form of loan and capital provisions.
[17] Occasionally they receive consultancy reports from external experts.

the applicant or on false information on market conditions and allocate funds to applicants which are unfit to carry out the project. Both banks agreed that they have the biggest evaluation problems and face the biggest decision dilemmas in the case of SMEs who attempt to introduce new technologies and new high technology products or service. Usually the dilemma is resolved with the rejection of the proposal[18].

Moreover, the terms of the investment are not differentiated in the case of financing technology based proposals: the cost of capital is not subsidised, the investment time horizons vary from 4-10 years for investment banks and 2-5 years for commercial banks and the rates of return were 15-16% in 1996-1997 values. Small variations depend on the nature of the investment scheme and not on the nature of the involved technology (if any).

Financing Technological Innovation		
No.	Investment Banks	Commercial Banks
1	Validation of business plans and "credibility" of the idea	Market conditions - commercial networks – product or service distribution networks.
2	Credibility of the applicant (in financial and management terms)	Involved costs and cash flow issues / financial indicators: assets, fixed capital, turn-over etc.
3	Financial indicators: assets, fixed capital, turn-over etc.	Credibility of the applicant (in financial and management terms)
4	Market conditions – commercial networks – product or service distribution networks.	"Exit" Issues

Table A8.15: Evaluation Criteria of Financing Technological Innovation; Commercial Vs Investment Banks. Source: Interviews results.

Supervision of the investment is exercised by regular techno - economic auditing and capital is gradually released on the basis of the evaluation reports. In the case of large investments, a bank manager is assigned to the management board of the beneficiary company. However, B1 admitted that bank managers make day to day controls and for high-technology, highly sophisticated projects it is relatively easy to disorient the appointed managers.

Finally, if a technology related investment is approved, it usually involves technology or product improvements, new plants, expansions, introduction of new products or services produced by established technologies and technology transfers or acquisitions. Banks prefer this type of project because they are low risk when

[18] Note, that SMEs are also unable to take advantage (they can not even be considered) of the investment laws due to their small size and small initial budget.

compared with new technology developments or substantial innovations, they do not require the investment of too much capital and because many of these activities are or can be subsidised by the Greek State (see investment laws). Technology based diversification and technology fusion are avoided because they require a lot of capital, they are not subsidised by the State and they are long-term investments.

Moreover, all the financial markets experts (banks and venture capital companies) confirmed that banks have no participation in the national R&D programmes, and that they have very little or no communication at all with "pockets of research excellence" or with the university and research institutions.

Venture Capital In Greece

There are four venture capital (VC) companies in Greece. Three of them, VC1, VC2 and VC3, are among the thesis sample.

Until 1988, there were no VC in Greece. Venture capital was initially conceived as *a means of promoting high technology* developments. Legislation introduced in 1988 (law 1775/88) provided generous government subsidies in the form of grant aid for companies prepared to finance such ventures. But the law was so rigorously defined that virtually no business was done under its terms. The legislation was modified in 1993 and again in 1995 to extend incentives to all VC companies. Law 2367/95 provides generous tax relief, allowing qualifying firms to consign all non-distributed profits to tax-free reserves for further investment and taxing distributed profits at just 15% as opposed to the standard corporate rate of 35% (in 1996). The State still offers 20% grants towards investment participation deemed by the Ministry of Development and GSRT[19] to be high technology. The preferred time horizon of VC investments is between 3-5 years. Under special conditions, the time horizon is eight years extended to ten years if necessary, for orderly divestment[20]. As their international colleges, VC companies in Greece prefer to exit by taking the company public.

Venture Capital and high technology

According to the interviewed experts, the Greek VC companies have better abilities to handle high technology investments and better ability to evaluate intangible assets than banks (especially the public sector commercial banks). However, they do not focus on specific technologies (thus no materials technologies preference), and they

[19] A committee evaluates the proposals on criteria very similar to the criteria used for the evaluation of the proposals of the 1892/90 law.

[20] Two of the three VC manage funds designed to promote investment in the Balkans (the Danube and the Euromerchant Balkan Fund).

admitted that they have serious problems (similar to the banking sector) in evaluating the potential of each technological field[21].

The philosophy behind VC companies evaluation criteria is as follows: "... *we presume that the applicants have the technological expertise. They do not have to convince us on this issue. However, they have to convince us that they are reliable on the following issues*":

1. The reliability and credibility of the business plan.
2. Market research and establishment (or existence) of commercial networks (that is "securitisation" of markets - market feasibility studies: VC companies are keen on being convinced that the applicant has worked out the way to place his product in the market.
3. Management skills and Organisation issues including, degree of commitment, organisational structure, human resources, management practices, what is the bonding of employees with the company etc. .
4. Real assets and credibility of the company (large and established companies are preferred over new entries and start-ups).
5. Technological potential, that is technology assessment and evaluation. On this point, the Greek VC companies have serious weakness and they regularly employ external expertise.

The order of importance varies between the interviewed VC companies[22], but as VC2 and VC3 identified, all the criteria are of more or less of equal importance. Under these conditions, materials technologies are not perceived as promising areas, even though, 18,3% (on average) of the investment portfolios of the reviewed VC companies are invested in materials related sectors[23].

There are considerations however, for VC companies to move, as the banks, into portfolios of IT, telecommunication and services provision companies, motivated by international experience examples and by the high annual growth of these industrial sectors. Industries based on materials technologies have no been identified as high-growth areas.

[21] For that they heavily rely on the Ministry of Development or GSRT's evaluation committees or on external consultancies.
[22] VC1 puts no.3 as the most important criterion, while VC2 and VC3 puts no.2 as the most important criterion.
[23] However, this is rather circumstantial because the participating companies seek expansion of their activities and they are, in all cases, large, well-established materials companies with high market credibility, experience and commercial networks.

Moreover, VC companies in Greece, like their EU counterparts[24], prefer to focus on new product introduction, product or process improvements, expansions, growth and diversification projects which involve high technology elements and are supported by established and well- asserted companies.

Financing high-technology start-ups: VC1 is established on American prototypes and is the only VC company specialising in high technology *start-ups*. However, VC1 is **not** a typical venture capital company because one of the basic share holders[25] is the Ministry of National Economy which regularly subsidises its activities. VC1 objectives are to provide near and long-term direct and substantial benefits to the Greek industry and economy and improve the balance of payments. VC1 meets these objectives by utilising its funds on foreign currency generating business development projects involving high technology joint ventures, equity-investments, technology transfers, and technical and marketing assistance to high technology companies. VC1, commenced activities with a capital of $ 50 million in 1988. As such, VC1 is rather a financing innovation body such as the SWORD activity mentioned in chapter 6, but it operates under procedures, methodologies and investment selection mechanisms almost identical with the rest of the VC companies in Greece. However, VC1 does not specialise in any technological field; the range of its investment portfolio spans from food to defence and military equipment companies.

Moreover, all the interviewees (academics, technological institutions, banks, VC companies), verified that there are no official communication channels between the science and technology base and the financial markets of Greece. Even in the case of VC companies, communication is occasional and circumstantial and until 1997, apart from a couple of isolated and not very successful efforts, there was not a single example of a company which has been established as a spin-off of R&D results. All parties identified that there is "a wall to be broken" between the two worlds[26].

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[24] See Murray, G. and Lott, J. (1995). *Have UK Venture Capitalists a Bias Against Investment in New Technology-Based Firms ?* Research Policy, Vol.24, No.2, pp.283-299. Moreover, the Greek VC companies have particularly strong bonds with British VC companies and Banks because the majority of their leadership has British education and/or background.

[25] The other three basic share holders are foreign multinational companies.

[26] There is a real communication "wall" here: the VC companies and the banks complained of the lack of, or the difficulties to locate, R&D which can be commercialised outside the national and international R&D programmes. That is largely true because the applied character of these programmes leaves no room for spin-offs and the potential spin-offs are restricted by the sponsoring company. On the other hand, the academics and the technological institutions insist that there is absolutely no interest from banks and VC companies for financing the commercialisation of R&D results. On the question - what is your level of co-operation with banks and VC companies - the answer was "none". Given that VC companies and investment banks are risk averse and there are no start-up specialists, this view is also justified.

To summarise, there is no VC company which specialises in high technology start-ups on the lines of USA VC companies (apart from VC1 which is not a typical VC company – see Annex 8.6) and there are no official links between science and technology and financial markets in Greece. As such, concepts such as high technology company "*incubators*" can not be successfully supported before these links get created and before the concept of VC companies in Greece gets strengthened. *The findings identify these gaps as serious weaknesses of the Greek innovation system.*

Capital and Investment provision Agencies

The Hellenic Centre for Investment (ELKE) was established in 1995 by the Greek government and is supported by the EU to assist investment in Greece. Its mandate is to attract foreign investment and promote international alliances with Greek companies. It is funded jointly by the EU and the Greek government and provides advice and assistance to investors through all phases of the investment process without charge. This includes assistance in securing necessary licences and support during all stages of the administrative process. Under the investment incentives of the investment law 1892/90, ELKE is empowered to receive and handle applications for projects with total cost exceeding 10 million ECUs or 3.5 million ECUs if at least 50% of the equity is in foreign capital. ELKE is also vested with the authority to make specific recommendations for changes to the legal and institutional framework affecting investment. ELKE has been heavily involved in the financing of many high technology projects in the area of telecommunications, energy and energy resources, mining, shipping, food and beverages, tourism, and banking and insurance. However, F2 identified that ELKE is primarily a one-stop-shop for the support of industrial investment and not for financing technological innovation. Due to the influence of the investment law (see above) high-technology investment is a favourable priority (especially in the telecommunications field and in the field of packaging materials) but it heavily involves the application and use of existing technologies and not the development of new technologies. ELKE is not involved in the support of R&D spin-offs or in the financing of high technology SMEs.

Moreover, ELKE's strategies for the attraction of foreign investment are mainly based on the effective marketing of "traditional" advantages such as geographical position of Greece, cheap industrial labour costs[27], and the concept of emerging markets which has attracted particular international interest in the banking and telecommunication sectors. However, since there is no visible public strategy to create new investment-

[27] In 1992 prices, the second cheapest in EU after Portugal. However, Greece can not compete with East Europe labour costs.

attractive advantages, many of these traditional advantages already have (or will soon) hit ceilings and their efficiency in attracting foreign capital will be reduced.

Constraints on financing materials technologies in Greece

According to the above, financial markets in Greece are in principle uninterested or very cautious in becoming involved in the financing of technological innovation because they are either unaware or unprepared to cope, or because they still "suffer" from burdens inherited from their past and can not yet afford the involved risks. However, the gradual liberalisation and reform of the Greek financial markets is expected to create large banking groups with more "adventurous" management and higher risk undertaking capabilities which can direct investment in technological innovation projects. Indeed, since early 1997, both investment and commercial banks pointed out they were in the process of identifying suitable high-technology sectors for investment. B1 in particular, mentioned that telecommunications, IT applications and high-technology services were under serious consideration for future strategic investment portfolios. However, B2 and F2 identified that the choice to move into these technology directions is rather "instinctive" and motivated by the concept of emerging markets in Greece (the telecommunications sector is a booming sector in Greece) and by the need to achieve short-term capital growth and income returns.

ANNEX 9.1: Detailed Analysis of The Cement Industry

General characteristics of the Industry

The products of the cement industry (e.g. cement, concrete and other ceramic based construction materials) are commodity materials produced in "bulk" quantities, subjected to very strict *regulations and standards* because they are materials directly related to the safety and hygiene of populations. Structures made of these materials are expected to be healthy and safe for living and/or use for very long periods of time. As such, the pace of innovation is very slow because experience is valuable, risks have to be minimal and standards (international) are difficult and slow to change. Only very large corporations or industrial conglomerates have the corporate muscle and the financial depth to enforce the modification of standards or the employment of new specifications (C1, C2 1996). Given however, that the cement production industry is a capital and energy intensive industry, processes (S&P) and production related innovations targeting cost or production efficiency and reductions of hazardous emission are more frequent. Thus, it is usually very large production groups which focus on both product (new and advanced materials) and process innovation while smaller size and capacity groups usually focus on process innovations and products incremental improvements. In addition, cement and other commodity and consumer ceramics industries are by tradition domestic or local range industries because the barrier to international trade is transport cost[1]. Long-distance profitable international trade has to be traded by sea. Thus, the average international export percentage is only 6% of the domestic production (Industrial Review, Special Issue, 1996).

However, the application of modern MSE principles has the potential to slowly but gradually revolutionise the industry through both process and product innovations. New materials and simulation and modelling techniques dramatically improve cost and production efficiency while new grades of advanced cement and other cement light-weight by-products provide new commercial and exporting opportunities.

Profile and structure of the Greek cement industry. The Greek cement industry is an oligopolistic sector including four industrial groups producing cement and other related construction and structural materials (of mainly ceramic nature) and many secondary ready concrete[2] suppliers who directly buy cement from the four major

[1] It is generally considered un-economical to transport cement by land for distances longer than 350Km.

[2] "Wet" concrete, ready for casting and shaping on the construction site or pre-fabricated concrete / cement products such as reinforced concrete slabs and panels of various sizes and shapes.

cement producers. It is notable that large construction companies and construction consortia prepare their own concrete and buy cement and other materials directly from the cement producers. The industry is a mature sector with most of its units established at the beginning of the century and until 1989 all the major corporations of the sector were operating under Greek ownership and leadership. Since the early 1990's only one remains in Greek ownership.

Market orientations of the industry. The Greek cement industry is the fifth largest producer of cement in Europe but its biggest exporter (Industrial Review 1997). The annual cement production of the Greek industry for 1995 was 14,6 million tons but world-wide, Greece is the third largest cement and cement products exporter after China and Japan. Contrary to the international average, the Greek cement industry exports approximately *half* its annual production in EU and other countries which accounted for 7.4 million tons in 1995. The reviewed cement producers (C1 and C2) have a similar market balance by exporting approximately 50% of their production and they stated that it is their intention to maintain this balance for the next 5-10 years. Greek cement producers can compete successfully in international markets (despite the low profit margins of exporting cement and other commodity ceramics) because they own vertically integrated distribution networks including their own ports, dedicated cargo fleets and floating silos. Cement and other relative materials imports are limited and they are restricted to special properties cements or special cement additions (mainly chemical supplied by chemical industries). Since the early 1990's the industry is subjected to strong domestic and international exports competition from multinationals which have established trading companies and buy product from low cost producers (e.g. Romania, Turkey etc.) to trade into price sensitive markets.

Corporate Strategies and Materials Activities

The thesis reviews the two leading companies (C1 and C2) of the sector producing more than 80% of the annual domestic cement production and the more than 85% of its by-products.

With respect to their technology, business and materials strategies the two companies share many similarities and significant differences mainly originating from objective limitations imposed to one of them (C1) rather than deliberate strategy choices.

With respect to *production and manufacturing* technologies both companies place emphasis in the strategic acquisition and transfer of state of the art technology from international sources (*intelligent users of advanced technology*). Both companies have reverse engineering and technology adaptation capabilities dedicated to integration and/or improvement of the externally acquired technologies.

With respect to *materials and business strategies* however, the two companies follow different approaches.

C1 is a medium size corporation when compared to its international competitors. Therefore, the company, due to size and hence financial limitations, cannot afford to develop new technologies from scratch or *develop and enforce* the standardisation of totally new materials. Thus, the company's technology strategy focus to keep the company at the forefront of international technological developments while its materials strategy focuses on the improvement of existing materials (as products or as enabling tools for S&P improvements) or the introduction of new but established materials into demanding (but established) markets. In order to support its strategic choices, C1 established in 1991 a MSE oriented R&D division by putting forward an investment of approximately 1.2 million ECUs and with an annual turn over of approximately 0.5 million ECUs. The division has a man-power of 14 researchers, technicians and administration personnel. The basic aims of this division are:

- The development and application of solutions of product quality control and processing (S&P) related problems ,
- The provision of technical and technological consulting and services to customers as well as the technological communication with the company's customers,
- Improvement of existing products and materials, technology transfers and the integration of new or advanced materials in the company's production capabilities or/and the incremental improvement of existing materials, and,
- The establishment of links with the domestic research community and the participation in national and international R&D collaborations.

Materials research mainly focuses on S&C and properties improvements of incremental materials (structural ceramics) and on practical S&P problems such as the integration of new or improved materials into the company's production capabilities. Another secondary stream of activities targets the improvement of S&P capabilities, and recently the modelling and simulation of S&P and the improvement of production lines, machinery and equipment performance. These activities include real scale performance testing of materials in order to establish which material is best for specific production applications[3]. Apart from the performance testing, however, the average R&D project duration is no longer than 1-2 years which is a reflection of the objective limitations found by the company.

[3] A typical example is the testing of performance of refractors in the production kilns. The best refractor (and hence supplier) is chosen after long-term, real production conditions experimentation.

Given that C1's R&D activities are almost exclusively financed by the company's resources, C1 took the strategic decision *not to* allow the overgrowth of the company's R&D division under the concept that "*...a big R&D department is a significant investment in human resources and infrastructure. In times of hardship we would have to restrict its facilities which would be a waste. We prefer to be able to sustain R&D facilities even during difficult times rather than risking the interruption of our R&D efforts.*"

C2 is a large cement and other construction materials producer and since the early 1990's operates as a major unit of an international giant specialised in the production of structural and construction materials. Therefore C2 is not subjected to the size, technological influence and financial limitations in which C1 is subjected and is able to pursue more "aggressive" materials and business strategies which consist of three parallel (and complementary) streams of action:

** *Materials strategies:* At present (1997) 90% of the technological, R&D and operational activities of the company are focused on its main products – that is cement and cement products- and 10% on other ceramic based structural materials for construction applications. Within this balance C2 simultaneously pursues *both* the improvement of incremental materials and technologies and the development of totally new materials (structural ceramics) in order to support product and technological innovations such as processing and other S&P innovations. Given that C2 foresees in the long-term future (40-50 years) a significant decline in cement markets due to the gradual replacement of cement by other new structural materials in the building and housing industries, the gradual shift from cement to other structural ceramics is expected to slowly accelerate.

** *Diversification strategies:* As C2 put it "*... the company's core business is and will be for the foreseeable future the production and utilisation of materials (cement and other ceramic based structural materials).*" Since the early 1990s, C2 aims to create new markets and business based on new materials and MSE competencies. As such, C2 pursues a technology and materials based diversification strategy implemented by the establishment of a number of subsidiary SMEs specialising in the production of new (and advanced) ceramic materials for construction applications. Each subsidiary targets niche markets and applications and has the freedom to develop its own business, technology and marketing strategies. C2 supports these companies by R&D infrastructure and know-how backing and by its distribution and operational support networks. If a company is proved to be successful (and hence its products / new materials) then C2 allocates more resources in its area; if not then the company is re-absorbed by C2.

** *Vertical integration strategies:* Simultaneously with its diversification strategies C2 pursues a vertical integration strategy. Until the late 1980s C2 had created an intricate network of subsidiary companies aiming to vertically integrate and support the production and distribution of its primary products (cement products). Since the early 1990s C2 targets not only an operational but a MSE based technological and product vertical integration including raw materials production (used for cement and other products) and the acquisition of construction companies employed in the commercialisation of new products and materials.

In order to support its materials and business activities C2 established in 1979 an R&D division (C2A) which operates today as a subsidiary of C2. C2A employs 10 full-time researchers and 10 technicians and administrative staff. The basic targets of C2A are:

- Activities which promote immediate solutions to cement S&P problems, or alternatively, those which realise customer needs in the sense of after sales support;
- Activities devoted to the optimisation (including cost reduction and productivity increase) of the S&P and production process of cement and other materials;
- The evaluation of propositions for application and transfer of modern technology in cement production;
- Activities which assist in development of *new cement types and other materials* for new or existing markets. In context with the development of new materials and the amelioration of relevant market products, C2A also targets the employment of native industrial by-products and raw materials for various uses;
- Activities targeting the optimisation of fuel consumption and evaluation and the optimisation of combustion and grinding processes.

In addition, some of the subsidiary companies of C2 also have limited R&D capabilities and they contribute their participation in a collective accumulation of know-how.

Materials R&D focuses *equally on all four* of the materials tetrahedron elements and it is extensively supported by simulation and modelling techniques. Clearly emphasis is provided in structural materials. *Functional* materials are also evaluated and considered as a secondary option but always within joint venture schemes. The average R&D project duration however, is no longer than 2-3 years which is a reflection of the time constraints found by the company.

Management Practices

Both companies stated that they are consciously committed to the concept of Kaizen. This is also demonstrated by the apparent efforts of both companies to optimise the interaction between their R&D departments and their business units and by the way they have structured and designed their R&D portfolio tailored to their business objectives. In addition, while the industry only occasionally employs some Kaizen elements (e.g. SE during the design of their technology and business portfolio), it has been the Greek pioneer of some others (e.g. team-work and human resources policies). In all cases, both companies are committed to continuous improvement principles over the long-term.

Core Competencies

The views of C1 and C2 on the concept of core competencies were almost identical. Both companies identified as their number one core competency their product and market *credibility* (brand-name / trade mark) and their ability to technologically support this credibility over long periods of time. As C1 explained,

"*... we are considered to be premium producers and we are internationally noted for the high standards of quality and reliability of both our products and supporting services. If price is not the only criterion, our credibility and reliability provides significant added-value leverages and enable us to successfully compete in both demanding and conventional markets.*"

C2 verified these views and added that a second but equally important core competency of the company is the technological strengths of its core business (cement and other structural ceramics) and the ability to diversify its activities on the basis of these technological strengths. Both companies pointed out that they have been able to create and sustain these competencies through long-term accumulated experience, their human resources policies, the vision of their leadership (C2) and long-term stability of ownership (C1).

Other Technological Core Competencies.

As in case of core competencies the Greek cement sector follows converging approaches in a number of supportive technological competencies:

* Both companies have *technological information gathering mechanisms*. In the C1 case, emphasis is given to close co-operation and exchange of information between C1 and other international materials producers while in the case of C2 they take the form of dedicated groups with the task to identify technological and product trends, evaluate them and provide the "green light" for investments in new

technologies and materials. Moreover, C2 frequently uses its subsidiaries as market and technology information "probes" to get feed-back on niche technological areas.

* Both companies have established constant communication links between their information gathering/evaluation units and their R&D divisions. Such feed-back is a key element to achieve a science push/market pull combination.

* Both companies heavily and regularly *invest in new machinery and instrumentation.* These investments are perceived as long-term strategic investments upon which the long- term competitiveness of the company depends, they are not dominated by the net-present value principle and they are designed simultaneously with the business and technology strategies of each company.

* Both companies have groups dedicated to receive and evaluate feed-back received from their customers and, in co-operation with the information gathering units, to evaluate future customers needs.

* C2 has internal teams dedicated to the *simulation and modelling* of processes, products, materials and distribution / supply systems. C1 has just started to develop these skills in connection with the company's participation in R&D collaborative schemes.

* Both companies have no patenting strategies. C1 stated that the company has no patents because the research they are engaged is very competitive and easily transferable. C2 stated that the company has some patents but no specific patenting strategy. Both companies underline that patenting is rare in the industry and mainly concerns new products, thus new materials. The question is how effective is the patent and if the company has the power to enforce its international standardisation (see also patents and standards in chapters 5 and 8).

Human Resources Policies

A fundamental strength of the reviewed companies is their human resources policies. Both companies have created internal education and training mechanisms (something like corporate schools) and they heavily invest in the training and continuous education of both their scientific / engineering and their technical / labour force. Moreover, both companies put particular emphasis on long-term employment and position stability especially in the middle management levels. Both companies believe that the combination of these policies provides the basis for the constant technological adaptation of the companies without problems originating from the inability of the working force to adapt to innovation and constant change.

Both companies however, underlined the serious lack of well- trained and qualified technicians (thus much of the internal training) and the decline of the traditional craft apprenticeships. Both companies believe that the decline of professional apprenticeships and the severe lack of skilled workforce are two fundamental reasons inhibiting the development of many materials-related and other Greek industrial sectors.

Technological Interactions, Co-Operations and Alliances

Both C1 and C2 have a long record of technological interactions and collaborations with other structural materials producers, materials and machinery suppliers, research organisations and customers (construction industry). As the two companies stated, the formation of technological co-operations is a basic element of their technology strategy because both companies believe that learning-by-interacting creates strong industrial and human networks and *multi-dimensional R&D clusters* with complementary powers. Technological collaborations are in many cases perceived as the key for successful technology transfers, introduction of new materials into demanding markets, materials or products development or improvement, processing improvements, manufacturing optimisations, training and education of human resources, etc. Thus, the targets of the collaborations are multi-dimensional and they simultaneously address many complementary issues. As C2 put it "*... the company does not only try to enter technological collaborations tailored to our technological needs but to continuously optimise them.*"

Inter-firm collaborations. Under the preceding concepts, both companies provide emphasis to technology transfers (international collaborations with machinery suppliers and other international structural materials producers). Domestic inter-firm collaborations are rare since the two companies are rivals sharing comparable technological capabilities. C2, however, regularly enters "collaborations" with domestic or international SMEs: when C2 identifies a technological or materials opportunity, the company directly channels capital and scientific / technological expertise to the SME. It is the responsibility of the SME to take the risk, "probe" the markets and see the project through. As a return for its "investment" C2 co-owns the results or gets a share of the profits.

Interaction with materials supplier and user industries. Both companies have developed strong technological and commercial ties with their materials suppliers (not to be confused with raw materials). The best example comes from the collaboration of the cement industry with the refractory industry. The cement companies are the final, technologically and performance demanding, users of their products.

On the other hand, both companies are committed in efforts to increase the technological awareness (not just the commercial) of the final users of their products, that is the construction industry[4]. Both companies (C1 in particular) have taken the initiative to inform the construction industry of new materials and process through private and public information seminars. Given that many large construction companies and construction consortia buy cement and other structural materials directly from C1 and C2, C1 and C2 "grasp" the opportunity to technologically "enlighten" their customer and simultaneously receive feed-back for the performance of their products. Even though the direct technological collaboration between the Greek construction industry and large materials suppliers is still in elementary stages, it has vast technological and commercial potential for new materials and advanced materials technologies. Under this concept C2 adopts a more aggressive view:

"*In order to have considerable technological upgrading, they (construction companies) must be able to play their role as sophisticated advanced materials users. Under present conditions most of the existing construction companies are yet unable to play this role, hence our own vertical integration efforts in the construction sector.*"

Interactions with research organisations. When necessary C1 and C2 proceed in collaborations with universities and research institutions. These collaborations (or outsourcing of R&D activities in the case of C1) take the form of participation in national and occasionally international R&D programmes where C1 and C2 keep the role of the final user of the R&D results. Simulation and modelling of S&P, reduction of pollutants, testing of new products for new applications[5], S&C characterisations and manufacturing improvements are the most frequent aims of these collaborations. The collaborations usually include the direct dispatching or exchange of researchers and in some cases is the donation or investment of funds to universities or research institutions for the creation of a chair or a specialised laboratory tailored to the needs of the industry[6]. RI1 (reviewed in chapter 8) is the first technological/research organisation to benefit from the emerging trend.

However, both companies pointed out that until the early 1990s the research capabilities the Greek research organisations (universities in particular) and the established perceptions of the majority of Greek academics were prohibiting extensive collaborations between the cement industry and Greek research organisations. Both companies identified that since the early 1990s the collaborations are increasing as a direct consequence of the application of the national R&D programmes which has

[4] As C2 put it " *We are looking for them – they are not looking for us*."
[5] E.g. RI3 test the energy efficiency of new bricks with heat-insulating properties and other new structural materials for C1.
[6] This is an almost unique innovation in Greece.

updated the research capabilities of Greek universities and has re-focused the research interests of Greek academics.

Interactions with national and international R&D activities. Both companies have a rich record of participation in the national and international R&D collaborative schemes. They underlined that only the early stages of the national R&D programmes offered substantial financial incentives for participation because they subsidised the acquisition and deployment of R&D laboratories and research equipment (R&D physical infrastructure). During later stages, the financial incentives offered were not the leading motive for participation (small budgets when compared to the internal annual R&D expenditure of the two companies). However, both companies continue to participate because *they benefit from the participation per se,* that is the *interactions* with other companies and research organisations, the *creation of human networks* and the *exchange* of ideas and information. According to C1, the Greek technology policy makers have completely missed that point.

Additional comments on the national R&D programmes focused on the selection criteria of the submitted proposals, the lack of strategic directions (apart from EKVAN) and the lack of supervision mechanisms after the allocation of resources. According to C1, a real source of concern are participations which are an issue of financial "*life or death*" for the participant. These participations use R&D proposals to supplement the finance of their operations and hence the R&D results are questionable.

On the other hand, participation in international R&D collaborations such as the Brite/Euram programmes has been successful and fruitful for the cement industry. As C1 put it "*... the results of Brite/Euram programmes are relative to the needs of Greek industry if Greek industry participates as a primary participant. In our case, this is the case.*"

Interactions with public agencies. Both companies pointed out that there are no institutionalised mechanisms for direct interactions with GSRT or other relative agencies. Interactions take the form of occasional submission of industrial or technology policy proposals and occasional direct interaction with GSRT or Ministry of Development officials (participation in committees) for the design of the directions of the national technology policy priorities. When the two companies were asked to provide comments on the need and the elements of a national materials strategy, their views converged at the following points:

- The need to provide national technology priorities (e.g. the national materials priorities) and effectively support them with specialised actions. As both companies identified Greece has traditional strengths in production, utilisation and *export* of cement and other ceramic-based structural materials.

- The urgent need for effective standardisation and certification mechanisms for products and equipment. As both companies explained ELOT is unable to respond to the needs of the sector due to insufficient infrastructure and severe vacancies of specialised personnel.
- Effective supervision and survey mechanisms on the application of standards and construction specifications and enforcement of the relative legislation.
- Trade regulations, that is the blockade of the unregulated imports and utilisation of dubious quality but cheap construction materials from non-EU countries[7].
- Creation of national R&D infrastructure facilities tailored to the needs of the sector. C1 in particular stated that the company took the strategic decision to establish its R&D division because outsourcing of R&D in Greece is unable to meet the company's needs.

It is notable that many of these "requests" are common among all the reviewed materials producing sectors.

Financing Technological Innovation and R&D

Both companies finance their technological and R&D activities primarily using their own resources because they perceive technological and R&D investments as an absolutely necessary strategic investment. C2 stated that *"you must think and invest as you are about to live 200 years"*. C1 explained that

> *"... only with this attitude the company can secure its long-term survival. Innovation in the cement industry is slow; it has however significant long-term impacts on the production efficiency in terms of quality and cost reductions. If you do not invest in the most recent developments -even though immediate financial returns do not justify it- you will certainly miss a technological wave and hence your market position weakens."*

CA2 R&D activities are constantly monitored and evaluated and they are almost exclusively financed by C2's own resources. On the contrary the R&D activities of the subsidiary companies are financed by a 50-50% participation in national and international R&D collaborations.

It is notable that the dominant shareholders of C1 (and until the early 1990s of C2) are individuals and until today (1997) the stability and concentration of ownership for both companies is high. According to the findings of chapter 6, these conditions favour the development of strategic controls over financial controls and hence favour the decision to support long-term technological investments.

[7] That point was unanimously picked-up by all materials producers.

Interaction with banks and financial markets. Both companies enjoy very good relationships with both commercial and investment banks due to their size and especially their credibility. This credibility has also assisted the reviewed companies to take advantage of the 18992/90 investment law in order to support their technological activities and their infrastructure. According to C2,

> "*..this (credibility) is all that counts; banks (Greek banks) do not have the mechanisms to evaluate technological information or anything related to the financial potential of technological know-how. As for the future the company is pessimistic; the de-regulation of the Greek banking system has increased the pressures for short-to-medium term profits and returns. Long-term investments in our sector do not support these choices.*"

Note that B1 and B2 verified these arguments by stating that the Greek banking sector is rapidly developing an interest in the electronics and telecommunications sectors which promise fast returns and not for materials related sectors.

ANNEX 9.2: Detailed Analysis of The Refractories & Commodity Ceramics Industry

Profile and market orientations of the industry

Refractors: The refractories industry is probably one of the very few industrial sectors in Greece which both supports and simultaneously relies upon the operation of capital intensive and energy intensive industries such as basic metals and cement production, consumer ceramics production, energy production, chemical industry branches (e.g. fertilisers) and other high temperature industries. In Greece the sector is a very specialised (technologically) sector consisting (in 1995) of five production units, most of them SMEs (less that 250 workers) when compared with their EU counterparts. That poses imposes profits limitations and hence capital limitations available for R&D expenditures. Nevertheless, the sector supplies all the previously mentioned industrial sectors and has a good record of exports. The most important domestic consumers of the sector's products are the metallurgical industry, the cement and consumer ceramics industries (the most technologically demanding sectors) and the energy production sector (that is the National Power company using refractors for its geothermal energy production sites). The industry exports approximately 50% of its output supplying both "easy" and technologically demanding markets. It is the strategic target of the two reviewed companies to increase their exports within the next seven years and simultaneously enter new, technologically demanding markets. These business strategies are supported by the improvement of existing materials and the development of new advanced refractories able to resist higher temperatures and wear more effectively. Moreover, it is estimated (Cereco 1995) that the sector is gradually entering niche technological fields, that is the production of very specialised high-value added advanced refractories tailored to specific applications or tailored to specific requests[1].

Commodity and Consumer ceramics: The consumer ceramics sector, excluding the production of bricks, is an oligopolistic sector. The sector includes five large companies out of which only C3 and C4 have established R&D activities. One more out of the five companies operates as a subsidiary of C1 and has very similar technology and materials strategies with C1 (reviewed in the previous section). The sector also includes many local producers which serve very low performance requirements local needs. The tiles subsector is a very specialised sector with a relatively narrow range of products (tiles for any application and other relative

[1] The two reviewed companies (C5 and C6) verified this.

materials / products such as adhesives). The sanitary ware subsector is more materials diversified as it includes ceramics (glazed porcelain), cast iron products, plastic products (acrylics) and recently non-ferrous metals based products. Given that cast iron sanitary ware products are rapidly replaced by acrylic – based products, C4 provides emphasis on ceramics and acrylics polymers.

The special character of the sector's products provides difficulties associated with the transportation of bulky and brittle materials over large distances. Paradoxically, the large building materials suppliers (such as the cement and the consumer ceramics industries in Greece) have been among the first to become more international through a strategy of ownership in other countries rather than by exporting materials and that is demonstrated by the ownership conditions of C3, C4 and C5. Given that the Greek consumer ceramics sector does not have the vertical integration of the cement sector (ports, cargo ships etc), the sector exports only 15-20% of its output supplying both "easy" and performance demanding markets while the remaining output is absorbed by domestic markets (primarily *the construction sector*). However, the reviewed companies opt to increase their exports output by taking advantage of their special ownership conditions (and hence the international distribution networks) and by opportunities clearly based on MSE strategies such as the development of "advanced commodities" such as advanced tiles tailored to the needs of the individual customers and durable and light-weight sanitary ware equipment.

Technology And Materials Strategies

For all the reviewed companies the term 'technology strategies' is almost synonymous to the term 'materials strategies'. In particular, the refractors companies underlined that they are specialised ceramic materials producers and hence all their technological considerations rotate around their specialised materials-products and their processing / production technologies which are in effect S&P technologies. The consumer ceramics producers verified the argument even though they gave it a broader meaning because they are involved in a broader spectrum of products and hence processes and manufacturing technologies.

With respect to the latter, (manufacturing technologies, i.e. production lines, and manufacturing equipment), all four companies depend upon internationally acquired know-how (mainly from Germany in the case of C5 and C3) which is integrated to the capabilities and needs of each company through specialised internal mechanisms. Due to the special ownership status of C3, C4 and C5, technologies transfers do not take the form of royalties but exchange of technological information, equipment and know-how.

On the contrary, materials and products know-how has been developed internally (in-house), and, apart from the special case of C4, materials innovations are mainly the result of internal organised R&D efforts. As **Table A9.1** demonstrates, all the reviewed companies (including C4) are strongly committed to MSE strategies because they perceive materials competencies, and hence materials R&D activities, as crucial determinants of their business competitiveness.

Reason	Very important	Important	Indifferent.
Company's core strategy	C3,4,5,6		
Group diversification strategy	C3	C4	
Demand from customers	C3,5,6	C4	
Create new products / markets	C3,5,6		
Trouble – shooting	C5	C6	C3
Pressure from national competitors			C3, 5, 6
Pressure from international comp.	C3, 5	C6	
Governmental policies			**None-Unanimous**

Table A9.1: Reasons to be involved in materials related R&D. The refractories and consumers ceramics view. Source: Interviews results.

However, the way these concepts are implemented varies considerably from company to company due to size and type of ownership variations and management perceptions. In more detail:

The refractory sector: C5 and C6 focus their technological and R&D activities almost exclusively on refractories and other ceramics (tiles) for high temperature applications. Currently, there are no diversification efforts into functional ceramics or into ceramics for non-high temperature applications. Each company has a small[2] MSE dedicated R&D laboratory located at, or very close to its production site. The R&D portfolio of both companies is tailored to the company's business strategies and mainly provides emphasis on the improvement of incremental structural materials (C6), the development of new structural materials able to be synthesised and processed by existing S&P capabilities in order to enter new markets (C5), and, incremental S&P improvements and emerging quality and production efficiency problems (both companies). However, only C5 provides extensive emphasis to pre-competitive research by allocating approximately 30% of its resources to the development and production of advanced refractors and other related products. Advanced spinells, Silicon Carbides and advanced Zirconia are among C5's research portfolio. On the contrary, C6 clearly focuses on applied and competitive materials research. In the case of C6, the relationship between improving materials and

[2] Which includes 3-4 full time researchers.

developing new materials is 90-10% in favour of improving incremental materials. Both companies provide emphasis on all four elements of the materials tetrahedron giving particular emphasis to the element of S&P. The R&D and production research units of each company receive extensive support and feed-back from many other related units such as information gathering and evaluation units, technology transfer units, etc. In addition, each company (C5 in particular) receives extensive R&D support from external partners, that is outsourcing of R&D activities non-crucial for the competitiveness of the company.

The consumer ceramics sector: C3 and C4 follow more aggressive business policies by pursuing a simultaneous materials- based vertical integration and diversification of their activities by entering and controlling raw materials production and supply and a supportive network of products and services relative to their mainstream products. Both companies have a small MSE dedicated R&D group[3] located at, or very close to their major production sites.

With respect to materials related research, C3 has a balanced R&D portfolio between improvement of existing structural materials and *on the design* and the economic production of new products (e.g. the production and commercialisation of holographic tiles) based on improved or advanced S&P techniques. C3 has pioneered the development of real scale pilot production lines dedicated to real production conditions testing new products or R&D results. Thus, the company ensures that R&D efforts and results are always compatible with the existing (or scheduled) production and S&P capabilities. The same approach has been recently adopted by C5 and C4.

The R&D portfolio of C4 directly follows the strategic concepts and directions provided by the parent company. As C4 explained:

> "... in order to be competitive our industry needs an optimum combination of technological competencies and cheap production and distribution of products. Hence, the parent company has established many subsidiaries to optimise the geographic production and distribution of its products. Thus it is the core strategy of the parent company to keep the key technological competencies only for the disposal of the parent company (and gradually, when conditions permit, diffusing them to selected subsidiaries). New and advanced materials know-how is regarded as one of the most important core competencies; hence the parent company has committed itself to strategic materials research while the subsidiaries are committed to competitive research and in research supporting the parent company's research."

Thus the R&D portfolio of C4 provides particular emphasis on the improvement of the efficiency of production and S&P technologies (including materials research which improves the performance of machinery and instrumentation) and on materials

[3] Including research teams of 7-8 full time researchers.

substitution in order to increase the competitiveness of existing products (e.g. the substitution of porcelain by other existing materials such as acrylics (plastics) in many sanitary ware applications). As such the in-house materials research is purely macroscopic and focuses on materials performance and S&P issues. The results are distributed within the network of subsidiaries and parent companies[4]. C4, being one of the most successful subsidiaries, has also the freedom to be involved in relatively limited advanced materials research. The performance improvement of incremental materials such as commodity ceramics attracts little attention (because *"... the parent company thinks that china and porcelain have reached their performance limits within the existing production cost limitations"*). C4, however dedicates approximately 15% of its R&D resources in new materials research and contrary to the other three reviewed companies, its portfolio includes research on *advanced functional ceramics* such as ceramic-based catalysts for energy and pollution control applications. As C4 explained:

"... we have entered research related to functional ceramics (catalysis) because we see it as a 'low risk adventure'. If this adventure provides promising results then we will enter the field in large scale."

These activities are usually supported by R&D collaborations with Greek and international research organisations within the framework of national and international R&D collaborative schemes.

Finally, as in the case of C5 and C6, the R&D activities of each company receive extensive support and feed-back from all the other related units of each company such as technological information gathering and evaluation units, technology transfer units, etc. In addition, both companies receive extensive R&D support from external partners, that is outsourcing of non-crucial R&D activities.

Management Practices

Over the last 10 years, both subsectors have benefited from the adaptation and implementation of Kaizen management practices including the introduction of automation, team-work concepts, product and process optimisation cycles, and SE approaches by achieving constant improvements in product quality and production efficiency including significant production cost reductions[5]. Simultaneous Engineering practices are usually employed during the design and/or optimisation of the manufacturing outline or the R&D portfolio of each company. In addition,

[4] The case of C4 in Greece is not an isolated case. Note in the next section the identical case of M3, a large aluminium producer operating as the subsidiary of a multinational aluminium giant.
[5] For example, through the introduction of Kaizen practices and management perceptions, C4 managed to achieve a 35-40% production cost reduction within five years (1990-1995) (CERECO 1996).

continuous improvement practices have just started to reveal their potential. As C3 underlined, "*... the concept of cost reduction taking place simultaneously with the concept of product improvement has just started to emerge in Greece.*" SE practices could also be employed during the design of new product and materials development including direct technological involvement of final materials users ("Open SE" – see chapter 4). But as all four companies pointed out, the most commercially important customers - the metallurgical sector and the construction sector – are not effectively involved in such commitments because they provide emphasis to cost considerations, "the cheaper, the better", rather than technological performance.

Core Competencies

The reviewed *refractories* companies believe that the concept of core competencies is clearly related to each company's MSE capabilities and to its ability to optimally couple them with their production capabilities. As C5 put it "*...our core competency is our ability to apply materials know-how into real products – that is our ability to improve or create new materials compatible with our S&P and production capabilities- and our company's credibility*[6]." C6 pointed to the same directions apart from the concept of credibility: "*... we are a relatively new company and our name is not yet widely known.*" As both companies pointed out, these core competencies have been created through accumulated experience and expertise. However, they are not supported by formulated patenting strategies. In fact, both companies underlined that they do not have any specific patenting strategies or recent patents. On this issue, the consumer ceramics subsector provides some additional insights:

The reviewed *consumer ceramics* companies define their core competencies in a different way:

- C4: "our core competency is the combination of our consistent product quality, our product design and our competitive prices. We have been able to create and sustain these competencies, through our own choices and through the support we receive from our parent and sister companies."
- C3: "Our core competencies are the know-how of our products (MSE strengths) and our customer services: we have been among the first and we are still the only company globally which has its own demonstration services exclusively dedicated to the needs and requests of our customers. However, I have to add that the concept of core competency for our products is a bad investment. We are a price dominated industry. When we come to price no core competency counts."

[6] In similar manners as the cement industry.

C4 clearly derives much of its strengths from its parent companies and from the network of its sister companies while C3 reveals a fundament weakness of the sector directly related to the demand of the final customer of the companies products. However, the views of both companies converged on the issue of patenting strategies. C4 identified that materials related and other technological patents are the responsibility of the parent company (because it has the power to enforce them internationally). C3 which does not have a parent company pointed out that "everything remains secret" because "... the Greek patenting infrastructure is weak, easily infiltrated and without effective supervision mechanisms". Thus, C3 - as many others- prefer to keep a "low profile".

Supportive technological competencies

All four companies support their R&D and their operational activities with institutionalised internal mechanisms which include:

- Organised technology intelligence gathering mechanisms. In the case of C4 that takes the form of information exchange within the international network of sister companies.
- Internal simulation and modelling skills: C5 and C4 apply these skills in "everything", C6 employs simulation and modelling only for manufacturing improvements and not in R&D activities and C3 is currently outsourcing its needs but it is in the stage of developing internal skills.
- Regular investments and updating of machinery and instrumentation which is seen as fundamental long-term strategic investment by all the reviewed companies.
- Customers needs evaluation mechanisms including extensive and constantly updated customer data banks.

Human Resources Policies

According to the views of the reviewed companies, the Greek educational system provides flexible and versatile graduates with good science/engineering background but with no specialisation related to either sector's needs. In addition all four companies provide particular emphasis on long-term employment stability and on smooth transition of knowledge and experience between incoming and retiring human resources. Thus, all companies (especially the large ones) invest in people by employing graduates of relative principles (e.g. metallurgists, chemists) and internally training them. Internal education schemes include exchanges of students, international seminars and continuous education schemes.

With respect to the availability of skilled and well trained technicians, the refractors and consumer ceramics sectors face the same problems applied to any other sector in Greece: well-trained, reliable technicians are difficult to find. Thus, companies have to "create" them from the very beginning by investing in their training and education through schemes similar to those applied in the case of their scientific/engineering personnel.

Technological Interactions, Collaborations And Alliances

The reviewed ceramics producers frequently interact with their customers (e.g. metallurgical industry, cement and consumer ceramics industry, energy production industry), their machinery suppliers, and with research organisations such as universities and research institutions. While the refractories companies have some opportunities for substantial technological interaction between them and their customers, the consumer ceramics sector interact with their customers only on a commercial basis because they (primarily the Greek construction sector) perceive the products of the sector as commodities and thus they give priority to commercial and cost considerations. Inter-firm technological alliances among similar companies (not belonging in the same group or family of companies) are rare because "*... there are strong conflicts of interest*" (C6) or unofficial (C3). The sector however, has recognised the value of exchanging information ideas on emerging markets and technological trends. As such, the sector has established the Greek Ceramic Association whose mission (among others) is the promotion of collaborations between the companies of the sector, the diffusion of information and ideas and the support of complementary industrial clusters and industrial networks. Nevertheless, complementary collaborations on the basis of the materials user -producer relationship described in the Alcoa-Audi case study are also rare because the final users of the sector's products are unable to respond to the sector's technological standards. Finally there is a strong and steady exchange of technological information between ceramic producers and international machinery and equipment suppliers as the Greek ceramic producers perform the final users role for their machinery suppliers.

Interactions with customers – users industries. With respect to the *refractories* sector, the most commercially important customer of the reviewed companies is the metal production and basic metallurgical industry. The second most important is the cement and consumer ceramics sector and then come all the other sectors. Still, only the cement and consumer ceramics sectors impose technologically demanding requests to their refractories providers and they are willing to contribute their "user" experience in technological collaborations. In any other case, "*... customers never come to us looking for materials innovations; we always go to them trying to trigger their interest* *at least as final customers*" (C5). According to C5, this is the result of both attitude and relationships and lack of the required level of MSE expertise or technological sophistication to support MSE based technological collaborations.

The consumer ceramics industries face similar if not worse problems as the final customer of their products is the buildings and housing construction sector where cost considerations almost always dominate. Construction companies hesitate to employ entirely new materials they do not provide purchasing guarantees and they rarely enter any form of R&D collaboration for reasons explained in section 9.3.

The only exception to the rule is *commercial* collaborations with major distribution companies or regular customers such as large building construction companies aiming at the improvement of the design and appearance of the product. Collaborations targeting commercial designs are regular but they are usually enlisted under the concept of "*evaluating current and future customers needs*".

This lack of sufficient technological and market pull from the primary customers of the consumer ceramics and refractories sector is unanimously regarded as the main obstacle for expanding the R&D activities of the sector and developing en masse advanced refractories, high temperature ceramics and advanced consumer ceramics for industrial and every day applications. Thus, the reviewed companies are cautious to develop specialised products and they do so only when high volumes are requested.

Interactions and collaborations with research institutions. The sector frequently interacts with research organisations such as universities and technological institutes by outsourcing many of its R&D activities. C5 for example, apart from participation in collaborative R&D schemes, collaborates on a regular and stable basis with the same university division since 1976 and with RI1 since 1988[7]. The aim of these collaborations is the optimisation of products (materials) and processes, characterisation and analysis of structure, composition and properties of new materials (that is outsourcing of pre-competitive research) and standardisation / quality control technologies. In the case of C6 and C3 all research projects, apart from those related to S&P or production research, involve the participation of external partners, that is universities or research institutions. Collaborations usually involve the establishment of co-operative agreements or the submission of common research proposals and participation in R&D collaborative projects. There are, however, some obstacles still to be resolved. As C4 put it "*... these are mainly mentality related problems. Many academics still concentrate their attention on machinery and laboratory equipment*

[7] C5 is the pioneer of that concept. Through the years C5 has un-officially but practically established its position in the specific university laboratory / division and has acquired (by outsourcing its R&D activities) regular, reliable, high-quality and relatively cheap R&D services.

acquisition and publication of papers and fail to see the commercial part of research. I hope that will rapidly change in the future."

Interactions with National R&D Activities and Public Agencies. The ceramic producer sectors including cement industries took the lead in the establishment of RI1, the only dedicated ceramics research and technological institution in Greece[8]. Since its establishment in 1986 ceramic producers are among the basic supporters of RI1, they have a long record of common research projects and common participation in national and international R&D collaborative schemes and they constantly persist in the expansion of RI1's activities and services. Moreover, both the refractories and the consumer ceramics sector have extensive experience from participation in the national and international collaborative schemes.

Their views are summarised by C3's statement: "*If a company wants to benefit from national R&D collaborative schemes, then the opportunity is there. Even though we do not see a specific materials strategy cutting through these schemes, many good things can come out of this participation.*" Examples include education / training of human resources, applied research support (facilities and infrastructure), subsidies for experimental apparatus and laboratory equipment and most importantly the initiation of collaborations per se[9]. C6 and C4 took the issue one step ahead and revealed that the horizontal character of the national R&D collaborative schemes, despite their implementation weakness can be flexibly used by participating companies in order to subsidise their immediate R&D needs. As C4 explained: "... *if we have an emerging local problem which is not related to cutting edge technologies or materials research , the parent company will (most likely) not finance it. Thus we have to cope with it on our own and hence we try to utilise the support we receive from participation in the national collaborative schemes.*"

Given that two of the national materials priorities as implemented with EKVAN, include commodity and structural ceramics technologies which are compatible with the needs and characteristics of the sector and its products the reviewed companies focused their comments on the need and the elements of a national materials strategy on the following points:

- The identification of materials priorities, the consistent support of these priorities over long periods of time and the provision of information about international trends and developments,

[8] Reviewed in section 8.... .
[9] The cement sector also picked this as the most important benefit.

- The promotion and support of industrial networks between complementary sectors or industries, something which the sector has taken the initiative to create without any substantial state support,
- The expansion of the currently available national R&D infrastructure facilities including the strengthening of RI1,
- The provision of effective tax incentives for R&D and the provision of low cost capital for R&D investments. Note that these two points are invariably picked up by all the reviewed companies and verify the argument (see chapter 8) that Greece has not established sufficient mechanisms for the financial support of technological innovation,
- The enforcement of effective quality control regulations not only on materials producers but on materials users as well,
- The enforcement of effective standards and imports controls and supervision mechanisms,
- The blockade of cheap but dubious quality and uncertified products from non-EU countries.

Most of these points invariably feature in all the reviewed materials producers and by many materials users (also see the review of the construction sector). Also note that as in the case of the cement sector, criticism of the consumer ceramics and refractories sectors focuses on monitoring and supervision mechanisms issues such as standards and trade regulations. Given their size and international connections most of the reviewed companies have developed their own means to compensate for the weaknesses of the national innovation system (e.g. education policies and support for competitive research). They can not compensate however, for national institutional arrangements and procedures.

Financing of R&D and Technological Innovation

The sources of funding of R&D activities, as well as the concepts behind capital allocation to R&D expenditures vary considerably among the reviewed companies. C4 has the most complex system of capital raising for the finance of its R&D activities:

> "The *parent* company provides the required funding for R&D targeting emerging technologies or advanced materials. That is however limited because as you know our R&D portfolio mainly targets the improvement of mature technologies and materials. That part of our R&D portfolio is financed by our own resources supported when necessary from external resources such as participation in national and international R&D collaborations. As such, our R&D expenditures are dominated by the "net present value"

rule subjected to each individual project .... while the *parent* company sees R&D expenditures clearly as a strategic investment."

C3 and C5 finance their R&D activities almost exclusively out of their own resources. A small percentage of the available finance is contributed by external sources, that is participation in national R&D collaborative schemes. In the case of C5, R&D expenditures are dominated by "net present value " rule, with respect to the emergence and utility of each individual project but as C5 stated "... *technology infrastructure investments are definitely seen as strategic investments; we hope that in the next year we will have the capability to follow similar approaches for our R&D investments*."

On the contrary, C3 and C6 have similar views for technology infrastructure investments but due to capital raising limitations R&D expenditures are seen as an overhead with the annual allocated budget as a fraction of annual profits (something similar to 2nd generation R&D) . Moreover, in the case of C6 which is the weakest of the reviewed companies, approximately 40% of the annual R&D expenditures are covered by external resources – that is participation in R&D collaborative schemes. Hence C6's R&D portfolio is strongly dependent on the approval of R&D collaborative proposals in which the company is a participant[10].

According to the preceding information these variations originate from objective limitations (such as size of the company and capability to secure patient capital) rather than management perceptions. C6 and C3 try to achieve the best they can with the resources they have, even though they know that the present conditions make their R&D and technological efforts "vulnerable" and increase the risks the two companies take.

Interactions with banks and financial markets. All the reviewed companies identified that the Greek financial markets have not developed efficient mechanisms for the provision of patient capital or the financing of technological innovation. As C4 and C5 underlined, banks place priority on the evaluation of market, assets and size and name credibility criteria of the company while venture capital is not yet fully developed in Greece. Thus, high technology SMEs face serious difficulties in their efforts to secure capital from the Greek financial markets. Note, the banking sector reviewed in chapter 8 verified these views.

[10] Note that MU2 and MU5 has similar limitations and they have adopted similar approaches.

ANNEX 9.3: Detailed Analysis of The Ferrous Metals Producers

General Introduction

In general, the global steel industry is a technologically mature sector which was in decline during the late 1970s and the early 1980s. The industry however, managed to exploit the opportunities offered by the materials revolution and make an impressive recovery on the basis of rejuvenation and diversification strategies based upon MSE strengths, competencies and business opportunities. The industry achieved either the dramatic improvement of incremental materials (most of them commodities produced in bulk quantities) and / or the development of new advanced materials such as specialised steels and superalloys simultaneously with impressive production cost reductions and efficiency improvements[1].

Profile and structure of the industry

In Greece, since the early 1990s the Greek steel sector is going through a serious crisis. The industry faces increasing production cost pressures from rising energy prices and wages prices. Moreover, the EU integration (single market since January 1st 1993) lifted trade barriers and permitted an "invasion" of massive imports of Italian and Spanish steel at competitive prices[2] directly competing with the domestic products. In addition, it is alleged that due to slow and bureaucratic supervision mechanisms, cheap steel products are "dumped" into Greece from Eastern European countries. In brief, the Greek steel industry, protected by trade regulations and governmental subsidies until 1992, is subjected to increasing competition pressures identical with those faced by its international counterparts during the late 1970s and in the 1980s.

The Greek *steel industry* is an oligopolistic sector, including four major production and re-rolling companies each having a single production plan. All of them use electric arc furnaces (mini-mills) and continuous casting techniques employing scrap as input (raw) material. In addition, there is a fifth company, Hellenic Steel, which is not a primary producer but a large re-roller, producing flat products from imported hot rolled coil. According to a 1990 study[3], in the late 1980s all production plants had relatively modern equipment comparable to EU standards. In addition, the industry

[1] For rejuvenation and diversification examples see the case studies of Nippon Steel and British Steel in chapter 3.

[2] Imported rebars were reported to have covered 20-30% of demand in 1992-1993 despite the transport cost. That proves that the Greek steel industry didn't take the appropriate measures to cut down production cost before the lifting of trade barriers.

[3] See: Mantzavinos, V. (1990). '*British Steel plc vis-à-vis the Greek steel market*'. MBA Thesis. City University Business School, London.

includes a small number of specialised casting companies (e.g. M4) and one large nickel producer (M2 - a monopoly in Greece) producing and exporting 100% of the annual Greek production of nickel and ferronickel.

Market orientation of the industry. Given that all four steel producers in Greece produced steel by recycling scrap, none of them has the financially affordable[4] capability to produce stainless steel, HSLA steels or other specialised steels. Moreover, the industry made the strategic mistake to tailor most of its activities on domestic demand. Thus, output is focused on low to medium technology intensity products mainly targeting the low to medium technology intensity *construction* industry and the low to medium technology intensity segments of the transport industry[5] (shipbuilding and railway infrastructure equipment). Steel profiles are usually produced by smaller manufacturers who make them from imported steel coils. M5St is the only large manufacturer producing light steel profiles. Finally, M4 is an almost unique casting company specialised in high precision castings and technologically demanding products.

The Case Of M1

Technological considerations and materials activities

M1operates on the basis of international standards. As such, it provides particular emphasis to the quality control and certification of all its products. M1's mainstream products target the domestic and international construction industry (rebars, concrete reinforcing bars and mesh, wires, and billets or slabs for re-rolling). For the production of these products, M1 depends upon internationally acquired, mature steel production technologies (mini mills and electric arcs) which the company has "... *simply learnt to use..*" (M1 October 1996). Until 1981, M1 was the only steel production unit in Greece able to produce pure iron by smelting iron ores in blast furnaces. Since 1981 however, M1 terminated the operation of their blast furnaces on the basis of cost considerations. As a result, M1 abolished the opportunity to produce pure iron from iron ores which would enable the company to diversify its products into high performance steels for technologically demanding applications as other steel industries in Japan, USA and EU did. Ever since, M1 is constantly exposed to

[4] Steel produced by scrap is rich in impurities. To produce high performance steels, un-purified steel must first be purified to pure iron and then the necessary additions must be added. That procedure evaporates the cost benefits of the mini - mill technologies.

[5] Domestic production includes concrete reinforcing bars (rebars), concrete reinforcing mesh, billets, slabs, hot rolled plates and coils, cold rolled coils and strips, cold rolled sheets including galvanised sheets, various wires, netting, steel plates for bridge decking and shipbuilding and cast iron secondary products such as radiators and boilers.

competitors with the same range of products produced with low wages and energy costs (e.g. Brazil, Turkey, and Spain).

Despite the gradual intensification of competition, M1 appears to be "*technologically compromised*". The company has not invested in the development of R&D strengths including reverse engineering activities and capabilities and stated that the company's best customer is someone who needs "something cheap and conventional" and not something expensive but special[6]. The company has not developed R&D activities even though it has well equipped laboratories whose activities are exhausted on quality controls and certifications of products or processes and the resolution of day to day problems arising during the operation of the company.

As such, M1 responded to rising competition by solemnly *attempting to constantly compress production costs and increase production efficiencies*. As M1 put it, "*... we are focused on really basic technologies and products. Thus we focus only on small but* ***continuous*** *processing improvements.*" Given that M1 has no R&D capabilities or reverse engineering experience this choice can not be supported by the simultaneous improvement of incremental products or the introduction / development of new materials. Any materials related activities are connected either to properties or performance certification of standardised products or to efforts to improve the S&P of standardised products without compromising their standard performance.

Thus, in order to achieve its goals, the company has to rely on some internal competencies (see below) and on external (international) sources and new technology transfers from international technology producers.

Management Practices

Given the technology strategies pursued by M1, the management practices the company employs come as a mild surprise. The company is not committed to R&D but it is committed to continuous improvement practices in order to optimise the implementation of its strategic decisions and to maximise the efficiency of its operations. Even though the continuous improvement practices are not supported by other concepts such as team-work (M1 has adopted a vertical, hierarchical management and organisational structure) their efficiency is reflected by the constant small but incremental cost reduction and production efficiency improvements in the production of steel, without compromising quality, which has permitted the company to remain afloat during the late 1980s and early 1990s despite the regular experience of heavy losses.

[6] Even though M1 is relatively elastic on this issue.

As M1 explained, this achievement is in effect the result of Kaizen management practices because it has been achieved through the simultaneous convergence of many complementary improvements within the company including the improvement of human skills, the improvement of machinery, the increased efficiency of the output of internal supportive facilities such as simulation and modelling practices etc. There is no doubt that if M1 had chosen to develop sophisticated materials strategies, these strategies would be effectively supported by similar management practices.

Technological Core competencies. Given that M1 does not have any significant technological or materials differentiation from its rivals, it identifies its core competencies as a direct correlation (more accurately as a derivative) of the company's size and management practices. Thus M1 identified as its basic competency, "*... our ability to constantly compress production costs and improve production efficiency over long periods of time without compromising quality*". According to M1 officials, it was the company's size that provided the necessary depth and resources to the company to transfer international experience, learn-by-doing and most importantly dedicated resources to the development and optimisation of a number of supportive technological competencies and internal organisational structures.

Supportive technological competencies

M1 has developed a number of supportive technological competencies whose function is tailored strictly after the central objective of M1's technology strategy: to compress cost and increase production efficiency. These include:

* S&P, production and quality control simulation and modelling techniques developed and applied by in-house groups,

* Technological information gathering mechanisms with the tasks to identify opportunities for cost reductions (e.g. advanced machinery) or locate new methods for producing new products ("new" with respect to the current product portfolio of the company) with existing production arrangements;

* Flexible customers services mechanisms including reciprocal information exchange mechanisms,

* Investments in technological infrastructure such as new machinery and instrumentation are dominated by the "net present value" rule and they are done "*... only when absolutely necessary*".

* Human resources policies: M1 provides particular emphasis to long-term employment and on internal training of both scientific and labour personnel. For that M1 has developed internal training schemes and continuous education mechanisms.

Technological Interactions and Collaborations

Interactions with companies. M1 (and the Greek steel sector in general) has developed closed technological ties only with its machinery and technology suppliers. The relationship includes exchange of information on machinery performance and new machinery availability. M1 does not support R&D on new materials targeting the improvement of machinery as, say, C4, M2 and M3 do. In every other case M1 interacts on a purely commercial basis. The only exception is the case of bulk customers with a special performance request. In that case M1 tries to meet the imposed requirement after it receives the appropriate specifications. But there are close collaborations even with complementary companies such as the Greek shipbuilding companies.

Interactions with research organisations. Since 1992, M1 has no interactions with universities or research institutions (apart for quality control and standardisation issues) and hence is deprived from the benefits of the interaction, cherished by other sectors (e.g. ceramic and cement producers). Similarly, the participation of M1 in national and international R&D programmes, which requires participation of more than one company or research organisation, is very low (two participation in PAVE which provided supportive capital for the acquisition of quality control equipment). M1 explained that the interests of the company are very "practical" and they can not support the submission of an R&D proposal. The interviewed academics however, pointed out that common ground could be found if M1 and the other companies of the sector were less secretive and aloof. Given that M2, M4 and M3 have adopted exactly the opposite policy (see below), it seems that the academics have a point.

The Case Of M5St

M5St was the only Greek steel producer with the capability to produce light structural steel profiles for construction applications. Otherwise, until the early 1990s the case of M5St was very similar to the case of M1. M5St, a rather small, Greek owned, electric arc steel producer, produced a similar portfolio of products, targeting similar markets and faced similar competitive pressures. As in the M1's case, the technology strategy of the company provided priority to cost reductions and production efficiency improvements of steel commodities. M5St had neither R&D capabilities (only quality control facilities) nor reverse engineering mechanisms.

Since 1991, however, M5St became a part (acquired) of the M5 conglomerate and developed more aggressive and complex materials and technologies strategies reflecting the views and strategies of its new leadership (reviewed in detail in the next section).

The new leadership retained the concept of cost reduction and production efficiency improvement but it coupled it with the simultaneous introduction of incremental product improvements and the introduction of new products (internationally established but new in Greece – a concept also applied by C1) such as advanced structural steels with significantly improved properties.

According to the interviewed officials, these are the first stages of the gradual transformation of M5St from a commodity producer into a producer of high quality, advanced performance steel tailored after specialised, high-added value applications and markets. The next stage of this strategy took place in 1996-1997 when M5 merged M5St with a smaller member of the M5 family, a company specialised in the production of welding rods and adhesive materials, creating a company able to produce a vertically integrated range of complementary products (structural steels with superior welding capabilities and specialised welding rods).

In order to support these changes M5 made significant changes in the internal structure and organisation of M5St:

- They added R&D duties to the quality control duties of the quality control laboratories of M5St and invested in the strengthening of their R&D capabilities. As M5 put it, "*we took advantage of the existing infrastructure and experience, we strengthened it and we expanded the portfolio of its duties*",
- They enforced Kaizen management principles (see the analysis of M5, further below),
- They restructured the distribution network of M5St,
- They developed internal supportive competencies (such as intelligence gathering units, simulation and modelling departments, etc.),
- They increased the level and the quality of technological interactions of M5St with its environment and with other companies and industrial networks.

In brief, under the supervision of M5, M5St is gradually transforming from a commodity producer full of competitiveness troubles, into an intelligent materials producer by capitalising on the technological and commercial opportunities offered by advanced materials and MSE related technologies.

The Case Study Of M4

Technological considerations and materials activities

M4 is a casting company specialised in high precision products for technologically demanding applications. Its output is mainly absorbed by international markets[7] while it is in the intention of M4 to increase its penetration into international markets.

For M4 the term materials strategies is almost synonymous with the term technology strategies and M4 has built its business orientations and operational capabilities around its materials-technological capabilities. The company has made the strategic choice to gradually enter the production of specialised advanced casting products (including both ferrous and non-ferrous (aluminium) castings) by capitalising on investments in emerging casting technologies and its in-house expertise.

In order to support these strategies the company has a fully equipped, MSE dedicated R&D laboratory located "next door" to the company's production plant. The lab is able to carry out complex R&D tasks but the average project duration is no longer than 2 or 3 years. That is because the company does not aim to develop a new range of materials. Focus is provided on the ability of the company to implement advanced but existing materials[8] in order to produce high- added value products. Only occasionally the company takes the initiative to experiment with new materials such as experimental mixtures of zinc and aluminium. As such, in-house research emphasises on all four elements of the materials tetrahedron providing particular emphasis on Structure and Composition, and S&P issues. S&P research includes three sub-areas: casting control (the company is in the stage of introducing simulation and modelling methods and numerical control techniques), machining and surface finish of semi-finished components.

Management Practices

M4 has adopted Kaizen and SE management practices. Given that M4 supplies components to industries such as the transport industry and the food industry it has the opportunity to really participate in the design and development of new systems providing the materials (components) point of view. According to M4, the gradually emerging ability of the company to provide sophisticated services to its customers through SE practices is expected to become an additional competitive advantage of the company. In addition, the company has developed Just-In-Time capabilities, it is in the stage of developing team work and job rotation practices and runs regular

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[7] The bigger customers of M4 are the food and chemical industry, the defence sector, the structural industry (machinery and electrical equipment) and the buildings industry.

[8] Such as hybrid metals, nitrogen rich steels and aluminium castings.

product and process optimisation loops targeting the simultaneous improvement of products-processes- and human skills.

Core competencies

M4 defined as it basic core competencies a combination of:

- The in-house developed know-how on dies and stamps calibration and adjustment techniques,
- The Just-in-Time production and delivery capabilities of the company,
- The customer services including long-term technological feedback, and,
- Competitive prices (when compared to EU competitors).

According to M4, the first competency was created accidentally during the stage of the initial design of the company and it has been adopted and developed ever since, while the other three are clearly the result of long-term consistent efforts.

In addition M4 is at the stage of developing simulation and modelling skills and it has already installed intelligence gathering mechanisms integrated with the mechanisms responsible for the evaluation of current and future customer needs.

Human resources policies

As M5St, M4 endorses long-term employment schemes but it has not developed extensive internal education mechanisms. Its internal education mechanisms are primarily focused on the technical and labour force (especially workers involved with dies fabrication and the casting of metal into the dies). Given that casting and die preparation is not yet fully automated, M4 admitted that the biggest current production problem is quality fluctuations originating from fluctuations in the performance of each individual worker. That is the main motive behind the company's efforts to introduce automation and numerical control techniques into the casting process.

Technological Interactions and Collaborations

Interactions with companies. M4 has regular technological interactions and collaborations with both domestic and international firms with the aim of exchanging technological information and product ideas. It also has regular interactions with the final users of its products which frequently take the form of materials producer-user collaborations. Given however, that the maximum duration of any research programme is no more than three years (due to time and resources limitations), these collaborations cannot have the depth and the extension of the Alcoa-Audi collaboration.

Interactions with research organisations. Contrary to the case of M1 and M5St which tend to be aloof from participation in R&D collaborative schemes, M4 regularly participates in both national and international R&D collaborative schemes in order to supplement its R&D resources and benefit from "fresh ideas" as M4 put it. M4 underlined that the company always interacts with research organisations only through this route. "*Dispatching researchers or directly allocating funds is among our intentions but it hasn't happened yet*", M4 added.

Nickel Producers: The Case Of M2

Technological considerations and materials activities.

M2, a large public enterprise, is the only Greek Nickel producer producing *ferronickel* in grains and other secondary products based upon recycling of nickel production by-products. Until 1966 the company produced pure Nickel by using electrolysis techniques. Since 1967 however, the company produces ferronickel by using unique in the world technologies (pyrometalurgical methods developed by the company) which enable the exploitation of very poor nickel ores (1.1-1.5% Ni). The company is profitable, it is **not** subsidised by the Greek state (despite the high energy costs), and given that there is no stainless steel industry in Greece to vertically integrate and capitalise on its products, it exports 100% of its annual ferronickel output to EU and other countries.

As M2 explained the company operates under very specific and rigid conditions:

* First of all, the company operates in a globally inflexible market, with very low profit margins and high production costs (the sector is both capital and energy intensive). Thus, the company always operates under the pressure of constantly reducing production costs.

* Secondly, the company (and in general the entire nickel production sector) is subjected to constantly rising EU environmental regulations and costs related to the environmental disposal of its processing by-products.

* Thirdly, the mainstream products of the company (nickel and ferronickel) are primary products which have reached their improvement ceilings[9]. Thus, they can't be further improved or altered.

Thus, the entire operational, technology and materials strategy of M2 is directly related to these restrictions and its defined by three parallel streams of action:

[9] M2 has long exhausted the quality limits of its mainstream products (hence their acceptance by international, quality demanding markets).

- The simultaneous improvement of production efficiency and production cost compression;
- Diversification of activities / generation of new activities by exploiting the technological and commercial opportunities of the nickel processing by-products;
- Entering new markets and creating new products as spin-off results of the two previous activities.

The R&D portfolio of the company is tailored to support these three streams of action:

<u>I) Reduction of production cost and increase of production efficiency:</u> Contrary to M1 which attempts to achieve these targets through technology and machinery transfers from external resources, M2 follows an aggressive materials strategy by directly supporting materials R&D targeting the improvement or the development of materials which can improve the S&P procedures and the operational activities of the company. Research targets materials with the potential to increase machinery performance (e.g. high temperature alloys) or the production yield of chemical processes (e.g. catalysis). As M2 pointed out, these activities take place *always* in co-operation with the company's materials and machinery suppliers. As M2 put it ".. *it is not our job to produce these materials. We are merely the final users... But we help them to help us.*"

A second stream of R&D activities in this area is covered by the reverse engineering and technology transfer capabilities of the company. Supportive technologies are usually transferred to the company and then they are modified to the existing needs[10].

<u>II) Diversification activities:</u> M2 vigorously supports R&D in new materials and processes which will enable the company to commercially exploit its processing by-products and simultaneously satisfy the constantly rising EU environmental regulations. As M2 explained,

> "The ideas we are working on are old hat but we are trying to rejuvenate them by making them commercially viable. An example is the production of Aluminium rich cement from our processing scrap and by-products. Another example is our efforts to diversify into **consumer ceramics** in order to exploit ceramic nature by- products such as ceramic based debris. In all diversification cases we seek assistance from domestic and international research organisations and we have long established ties with specific academic departments."

<u>III) Entering new markets and developing new products:</u> Simultaneously with the materials and products R&D, M2 is committed to market research in order to secure distribution networks for the new products. The difference from established

[10] For example, M2 was the first metallurgical company to expand the application of fuzzy logic controls in the metals production industry. This technique has been developed by the cement industry and was acquired by a cement company.

procedures is that the received feed-back is directly channelled to the development stage and corrections are made before the product enters the production stage.

In order to achieve its R&D goals M2 follows a de-centralised R&D organisational approach where each department has its own R&D capabilities. In administration terms however, the company has a small division dedicated to the monitoring, supervision and co-ordination of the entire R&D activities of the company. There is also a large MSE dedicated laboratory with the mission to support all the peripheral activities of the company and provide feed-back and services on common issues and needs.

Management Tools and Core Competencies.

M2 admitted that the company has sub-consciously adopted Kaizen management techniques and stated that "*We follow what we see as best practice and what appears to be common sense.*" Given the close one-to-one correspondence between business objectives and the company's R&D portfolio, the regular optimisation loops, the commitment to continuous improvement and learn by interacting practices, all indicate that the company applies successfully Kaizen management methodologies.

Technological core competencies.

M2 defined as its basic core competencies a combination of:

- The in-house developed and globally unique ability of the company to successfully and profitably exploit very poor nickel ores and, currently,
- The ability of the company to gradually diversify-enrich its activities on the basis of MSE expertise.

According to M2, both competencies were the result of long-term patient and persistent efforts and the long-term commitment and dedication of the company's human resources.

Supportive technological competencies

* Simulation and modelling: M2 provides particular emphasis on automation and modelling techniques and during the time of the interview the company was en-route to quantify and integrate all its basic activities on the basis of advanced models and numerical techniques. The company has its own S&M capabilities but it also outsources many of its interests to Greek universities and research institutions.

* The company does not have an organised intelligence gathering division. Each business unit is responsible for gathering information related to its activities.

* M2 regularly invests in new machinery and R&D instrumentation (perceived as strategic investment). The investment intensity however, is subjected to financial constraints.

* Patenting and publishing strategies. The company regularly participates in academic or business publications which provide publicity for R&D results obtained during participation in national and international R&D collaborations. It avoids however, publications or patenting which are the outcome of internal R&D or of private collaborations. M2 explained that: "*..we do that because i) our interests are very specialised, thus of no significant commercial interest apart from ourselves and ii) because we cannot supervise the patent.*"

* Human resources policies. As all the other metallurgical companies M2 endorses long-term employment schemes and took advantage of the low mobility of human resources in its sector. M2 also invests in internal training schemes and continuous education schemes.

Technological Interactions and Collaborations

It is the strategy of the company to form *technologically complementary* co-operations with machinery and equipment suppliers and with research organisations. As M2 explained 90% of the company's research has a co-operative nature. The aim of the collaborations is to address common or complementary problems but always under the condition that the company does not compromise its secrets. As such, M2 was among the first Greek companies to participate in the national R&D collaborative schemes and among the first companies to form closed ties with specific academic departments and laboratories. M2 underlined that many of the current technological competencies have originated from collaborations with academic institutions.

Ferrous Metals: Common Findings

Interactions with national and international R&D activities

M1 and M5St have a very poor participation record in national and international collaborative schemes consistent with their relative isolation and their aloofness from the national R&D infrastructure. Moreover, given that both companies have not developed close ties with academic institutions or research organisations, they have difficulties in getting aligned with the prerequisites of the national collaborative schemes. On the contrary, M2 and M4 have regular participation in almost all the national R&D collaborative schemes and the Brite/ Euram programmes. Both companies identified that the best benefit of these programmes is the participation per se, that is the exchange of ideas, knowledge-creation and the interactions and networks they generate[11] .

The views of M1, M5St, M4 and M2 on national materials strategies

While providing comments on the need and the elements of the national materials strategy the reviewed companies provided a more general view focusing on generic technology policy issues rather than materials issues:

** The need for trade regulations and the enforcement of quality standards. That is a logical request particularly when it comes from M1 and M5St. The mainstream products of these companies are steel commodities which have been hit hard from the unregulated importation of low quality materials from East European countries.

** The promotion / support of industrial clusters and industrial networks: all companies identified that the current arrangements of the national innovation system (e.g. R&D collaborative schemes, and their implementation, financial arrangements such the law 1892/90 etc.) favour individuals and not complementary industrial sectors and technologies.

** Tax incentives and the provision of low cost capital for technological innovation. M2 pointed out that there are some incentives but the bureaucracy is immense. That inhibits any non-public sector company from seeking financial assistance from public sources.

** Information mechanisms for international developments and technological information diffusion mechanisms (M4, M2).

Sources of Capital for R&D and technological innovation

M1 and M5St rely entirely on their own resources for any R&D activities they have. M5St also receives substantial support from M5, the parent conglomerate. M4 and M2 keep a balance between their own resources allocated to R&D and external resources such as support their receive from their participation in collaborative R&D schemes. M2 stated that "*... the company has an internal system to prioritise our needs. Only urgent or very sensitive projects are financed exclusively through our own resources.*". Only M5St (after it became a member of the M5 family) perceives technological investments (technological infrastructure) as a long-term strategic investment while R&D is justified under the "net present value" rule on the basis of individual projects. Likewise, both M2 and M4 use the "net present value" rule (M4 mainly due to financial constraints related to the size of the company and M2 due to its internal

[11] Note the similarity of opinion with the cement and consumer ceramics sectors.

prioritisation system), while M1 clearly perceives any technological investment as an annual overhead to be made "*...only when absolutely necessary*".

Interactions with Banks and financial markets. All companies verified that the Greek financial markets have not yet developed the necessary mechanisms to deal with the financing of technological innovation and thus they prefer to avoid the issue or provide priority to credibility issues such as the size and the assets of the company. As such, M4 the smallest of all the reviewed companies avoids financial markets as much as possible, while the other three companies, if they ever need capital, secure it through their assets and size credibility.

ANNEX 9.4: Detailed Analysis The Non-Ferrous Metals Producers

General characteristics of the industry

Recent technological developments in aluminium and other non-ferrous metals provide some of the best examples of how advanced light-weight structural materials can revolutionise entire industries or create competitive advantages and new business opportunities (for examples see chapters 3 and 4). Moreover the application diversity of these materials is constantly increasing, simultaneously increasing their strategic economic importance.

Profile and market orientations of the industry. In Greece the non-ferrous metals industry is a dynamic exports-oriented sector dominated by a single aluminium producer and an aluminium products industry built entirely upon its output. In 1994 for example, Greece shipped 290,400 tons of Alumina exclusively produced by one smelter: (M3). M3, a subsidiary of large European aluminium producer, produces Alumina and aluminium from local rich bauxite ores and approximately exports 50-65% of its annual alumina production to its parent company or to other international markets. The remaining alumina (35-50%) is locally consumed for the domestic production of aluminium castings, billets and slabs which find their way into domestic aluminium markets such as packaging (36%), construction applications (23%) and housing - building equipment (20%). Only 6% is absorbed by high added value sectors such as transport (1%), machinery (2%) and electric/electronic equipment (3%). The case of M3 is a good example of Kindis (1982, 1995) arguments for the need of vertically integrated large industrial units/sectors in order to provide the necessary push for smaller secondary industries because the entire aluminium transformation industry has grown on the back of M3's output. For example, 21 extrusion companies have grown up producing components such as window frames, panels, wires, rolling shutters, false ceilings etc. for the construction industry. In addition, the rolled semi-products market (dominated by M5Al and other companies of the M5 group) includes products such as cans, foils, corrugated sheets and cladding and rolled sheets for specialised construction applications. There is also a limited but growing production of aluminium cables and aluminium castings pioneered by M4 and the M5 group. In addition there is a plethora of small manufacturers which has made it almost impossible for foreign products / firms to penetrate the Greek market. But for the same reason exports of the sector have never reached their full potential.

The Case Study Of M3

Technological and Materials activities

M3 is a subsidiary company operating under the direct supervision of its parent company, the largest EU Aluminium and Alumina producer. As such, the operational, technology and materials strategies of M3 are largely defined by the parent company in a way resembling the case study of C4 (see the consumer ceramics section). As M3 explained, "Approximately 90% of the crucial decisions on any issue related to the operation of the company are taken by the parent company. We receive operational guidelines and its up to us to see them through."

With respect to technology and materials policy issues, M3 operates under a framework very similar to that of C4. M3 explains:

> "We are not supposed to engage in emerging technologies or advanced materials research nor to alter the properties, quality or performance of our final **mainstream** products. These are the mission of the parent company. We have the duty however, to engaged in R&D which reduces production costs and / or increases production efficiency without compromising our final mainstream products quality. We also have the choice to be engaged in R&D targeting secondary products or R&D targeting supporting technologies or secondary areas (e.g. recycling of by-products, simulation and modelling skills) from which the entire network of sister companies can benefit. "

Under these arrangements, M3 belongs to a large "family" of companies with which it constantly interacts and exchanges technological know-how and information. When it comes to R&D arrangements the company has a centrally located R&D laboratory almost exclusively dedicated to S&P and production issues. Given the research limitations imposed by the parent company, *materials related R&D* has primarily the mission to improve S&P efficiency (including cost reductions) and very recently to provide solutions on recycling and environmental problems.

With respect to the first issue, M3 who is the final user, enters long-term R&D collaborations with machinery and other equipment suppliers. The aim is the development of advanced materials which improve machinery performance and hence improve M3's production efficiency (for a characteristic example see further below: technological interactions). M3 however, never contributes to the production of these materials. Its contribution goes as far as the development and testing stages. As M3 characteristically put it "... *We help them to help us*.".

An additional stream of R&D involves research on supportive technologies such as the application of automation and simulation and modelling during all S&P stages. M3, for example has recently completed a large simulation and modelling project which enabled the full automation and numerical control of the M3's kilns. By employing specially adjusted intelligent (expert) systems, the developed technique has managed to quantify 10-30 years empirical experience and half the required operational man-hours. It was developed in close co-operation with Greek academic institutions within the frame of a national R&D collaborative scheme.

Core Competencies

M3 identified as its basic core competencies i) the ability to produce high quality materials at constantly competitive prices, ii) to a network of loyal customers. The first competency was gradually generated by local learn-as-you- go and learn-by-interaction processes and the second was the result of persistent information campaigns which achieved to convince the company's customers for the advantages of M3's products. Definitely the size of the company and especially its monopolistic presence in Greece has also assisted this campaign.

Supportive competencies

- Simulation and modelling skills: M3 has extensive internal capabilities in this field and also invests in the expansion of these skills. When necessary, outsourcing in the form of R&D collaborations with universities or research institutions take place.
- Information gathering mechanisms: These mechanism are mainly controlled by the parent company which then distributes the results in the subsidiaries. Subsidiary companies such as M3 focus on specialised issues such as S&P related technologies.
- Investment in new machinery and instrumentation: They take place in regular time intervals and they are perceived as strategic investment. When M3 is "short of capital" the parent company subsidises investments directed to sensitive and urgent equipment.
- Patenting and publishing strategies: As M3 explained, this is mainly the responsibility of the parent company. If a subsidiary such as M3, has something significant to be patented then this knowledge is passed into the parent company which has the capabilities to patent it on a global basis (similar approach with C4). The company publishes R&D results only if they are the outcome of participation in national collaborative schemes.
- Human resources policies: M3 endorses long-term employment schemes and was among the first companies in Greece (the first basic metals producer) to develop extensive internal education mechanisms including continuous education schemes and dispatching of personnel and research in other companies and research organisations. As all the reviewed sectors identified, there is a serious problem to find well trained technicians and technical managers with holistic views (combining both technical and interpersonal / management skills). M3 identified this vacancy as the most serious education problem in Greece.

Management Practices

M3 vigorously applies Kaizen management and production tools. The company has a long-standing continuous improvement record, it applies the concept of team work and job rotation as an every day practice, it has developed automation and numerical control production methodologies and is en route to develop Just-In-Time production capabilities in order to minimise storage costs and accelerate deliveries. In addition, Simultaneous Engineering practices are employed during R&D collaborations, especially when large machinery suppliers are involved in order to optimise the collaboration and its results.

Technological Interactions and Collaborations

Interactions with firms: M3 has an almost unique in Greece record of long-term technological collaborations with its international machinery and materials suppliers resembling the complementary technological alliance between Alcoa and Audi. The aim of the collaboration is to assist these companies to improve their materials employed by the production process of M3. The following case is a characteristic example: Greek bauxite is very rich in aluminium but at the same time is one of the hardest and most corrosive ores on earth[1]. Thus, if a material has an acceptable performance (including useful operational life) during the cutting and grinding process of Greek bauxite, then simultaneously it is able to cope successfully with any other ore in the world. Four international producers of cutting and grinding machinery approached M3 and an international long-term R&D collaboration was established. M3 contributed its experience, and as the final user of these materials carried out performance tests including full industrial and production scale tests. When the new machinery, based on advanced materials entered the production stage, M3 was the first company in the world to take advantage including updates priority and significant know-how.

M3 has also attempted to establish similar collaborations with large domestic users of its aluminium output (notably with the M5 group). Even though these collaborations have created some new products (with respect to Greek markets), until today they have not taken the depth and the extension of the previously described example. M3 declined to provide further information on the issue.

Interactions with research organisations: M3 interacts with universities and research organisations "... *on a rather occasional basis*". M3 initiates a collaboration with an academic research team or with a research institution as a form of outsourcing part(s) of its R&D activities or in order to supplement its R&D portfolio. Over the years the

[1] Even harder than uranium ores.

company has developed some unofficial but strong links with specific research teams which are regularly employed by M3. The co-operation takes either form of requesting research on contract or more frequently the participation in a common national R&D collaborative programme where M3 is the industrial user. M3 would like to increase the frequency and number of these collaborations but *"... in most cases our needs do not match academic expectations... I see that as a major inhibitor for increasing the frequency of these collaborations"* M3 said.

The Case Study Of M5

Technology strategies and materials activities.

As the M5 officials explained, all the mainstream products of the group target internationally standardised commodity or bulk applications and they are the output of internationally mature (base) technologies. As such, the pace of technological change is slow, competition is high and the profit margins are low. The combination of these inflexibilites combined with the fact that M5 does not have the required size to be a global technology leader, inhibit the group from engaging in large scale R&D targeting entirely new manufacturing technologies or new materials[2]. In addition, M5 has taken the deliberate decision, not to enter emerging aluminium markets (e.g. transport industry) until the beginning of the next century. As the officials of the group explained *"...by insisting on established markets until the beginning of the century we take a deliberate risk. Our strategy however, is to gradually and slowly enter these markets, once they become more stable."*

As such, with respect to mainstream products, the technology strategy of M5 is the *intelligent reclamation and implementation of mature technologies* which enables the group to be on the leading edge of the available but established technologies and products. Examples of this strategy are illustrated by the case study of M5St (see above) and by the case of M5C (a large wires and cables manufacturer) which was among the first EU cable companies to enter the production of optical fiber cables[3] by intelligently modifying and exploiting existing technologies and production capabilities.

M5 follows more aggressive strategies (supported by proportional R&D activities) in niche markets and specialised products. This is demonstrated by the case of M5WR, a welding rods company which has developed a new rod tailored after the superior

[2] According to M5, an additional problem for the development of advanced structural materials is the indifference, hesitation or reluctance of the construction industry to use them.
[3] The optical fibers are imported.

welding abilities of St4 (produced by M5St) and the case of specialised aluminium products such as very thin aluminium foils or aluminium membranes. M5 believes that these activities will eventually become the diversification vehicle of the group to enter high technology markets such as electronics and telecommunications.

The R&D activities of the group are tailored to support the technology and business choices of the group. The R&D portfolio includes:

- R&D targeting S&P and production including reduction of processing cost and increase in production efficiency. On this point M5 has a very similar strategy to M2 and M3 and actively supports research on materials which will indirectly but ultimately improve the operational and production capabilities of the group.
- Small incremental improvements of structural materials (the mainstream products of the company) when a long-term contract for major quantities is secured.
- R&D targeting problems originating from customers' requests.
- R&D focused on materials for specialised or niche applications (structural materials and a few cases of structural/functional materials). This stream of action frequently involves pre-competitive research.
- The tackling of every day production or services problems.

The group has a decentralised R&D approach where each production unit has developed and is responsible for its own R&D portfolio on the basis of the above described targets. The R&D divisions trace their origins to the quality control divisions of each member of the group. These divisions include a hard core of researchers and a flexible number of additional production or services scientists and engineers which contracts or expands on the basis of the needs of each individual project. With the completion of the project the temporarily allocated people return to their posts transferring the acquired experience into their groups and production units.

Core Competencies

M5 believes that the group does not have any significant technological differentiation from its international competitors because the group's production units utilise well established, base technologies. Thus, the core competencies of the group originate from a combination of the following attributes:

- The excellent follow-up services and other client services the group offers to their customers (similar to C3);
- The ability to apply materials and find new applications through theoretically exhausted technologies,

- The extensive files and case study records of the group (similar to MU3),
- The capability to adjust the production lines of the group in order to be able to respond to many major standard systems such as DIN (Germany- Central Europe), JIS (Japan), BS (Britain) and ASTM (International- USA). That ability enables the company to be a global supplier of materials, products and components and it provides the opportunity for agile reactions to rapid shifts of demand.

In addition M5 has an extensive network of supportive competencies such as:

- Simulation and modelling skills: they are primarily applied in the numerical control of production rather than for R&D.
- Regular investment in machinery and new instrumentation: it is done on an annual basis and absorbs the largest part of the annual capital budgets.
- Integrated technological information gathering mechanisms and customer service mechanisms.

The group however, does not have any specific patents policy and in general avoids to announce or publish its achievements.

Management Practices

M5 has adopted a linear management structure involving only five management levels: Shop floor – division supervisor – production manager – general manager of each individual company/production unit – the principles of the group/conglomerate. Moreover, each "member of the family" is committed to continuous improvement techniques and operates under TQC and Just-In-Time production and delivery methodologies. Team work and SE practices are not that common because "... we are not an integrated manufacturer such as a car manufacturer... we simply deliver out products and that's it. We try, however to apply these principles as much as possible and we have some good opportunities during the design or the implementation of our R&D activities".

Technological Interactions And Collaborations.

M5 provides emphasis on collaborations with international companies which develop technological know-how crucial for the operation of the group. These usually take the form of imported technological assistance or of licensing agreements. Interactions with similar materials producers are rare because *"... there is a strong conflict of interest."* Interactions with machinery suppliers take a more organised form. As M5 explained, *"usually they come after us and we respond as the final user of their products."* By combing in-house expertise and the experience gained by these interactions M5 has developed the in-house ability to improve the performance of existing machinery or even proceed in radical improvements of machinery and equipment.

On the other hand, technological interactions and collaborations with universities and research institutions are rare. M5 justified that on the basis of difference of interests between the group and the research community: "*since the group is not committed to pre-competitive research there are not many common grounds*". This attitude is identical with the case of M1 and comes as a surprise from M5. In any case it verifies that significant segments of the metals sector in Greece still insist on being isolated from the national research infrastructure for reasons not yet entirely clear (no further comments were provided).

Non-Ferrous Metals Producers: Common Topics

Interactions with national and international R&D activities

Only M3 has extensive participation in the national and international R&D programmes. M5 has a very low participation record and didn't provide any further comments on the national R&D collaborative schemes. According the M3's opinion the implementation of the programmes has created notable R&D leverage in terms of spreading risks and R&D expenses, training and education of human resources, and subsidisation of R&D infrastructure. The main disadvantage of the programmes (according to M3) is their implementation which does not provide any technological priorities and does not favour the development of industrial networks or clusters because the participation requirements do not pre-require them. Usually one industrial user is sufficient to support a successful application.

Interactions with public agencies.

Both M3 and M5 have access to GSRT through participation in scientific and industrial / technology policy committees. As M5 put it, "*sometimes they listen to what we have to say, sometimes they don't*". In addition, some of the reviewed companies (e.g. M3, M2, M5) have actively participated in the establishment of RI2, the only Greek research and technological institution dedicated to metals and metals and their technologies[4]. Since its establishment in 1986, the basic metals producers are among the basic supporters of RI2. However, the industry perceives the institute mainly as a technological services provider rather than a R&D partner[5]. Thus, the record of common R&D projects or common participations in collaborative R&D schemes is low and RI2, originally designed to technologically assist the sector, has limited technological influence over the very conservative or technologically compromised basic metals sector.

[4] Reviewed in section 8.... .

[5] Also see chapter 8 and note the considerable contrast with the RI1 (ceramics) case.

The views of the sector on national materials strategies

The M3 and M5 verified the steel producers' views. Criticism was focused on:

- Enforcement of quality controls and standards as a trade barrier to importation of dubious materials,
- Promotion and support of industrial networks and complementary industrial clusters,
- Provision of low cost capital for technological information and tax incentives for R&D expenditures.

It is notable that neither of the two metals sectors has requested the strengthening of the existing national research infrastructure and the promotion of research networks and institutions. This is in direct contrast to the cement and consumer ceramics sectors and demonstrates the aloofness of the sector (or the distrust) from the national research infrastructure.

Sources of Capital for R&D and technological innovation

M5 relies entirely on its own resources for the financing of its R&D. M3 mainly relies on its own resources, subsidies from the parent company and some small supplements from participation in the national or international R&D programmes. Only M3 perceives both technological (machinery, technological infrastructure) and R&D investments as a long-term strategic investment. M5 perceives only the technological infrastructure investments as a strategic investment while for R&D investments it uses the "net present value" rule to justify cash flows in each individual project.

Interactions with Banks and financial markets.

Both companies verified that the Greek financial markets have not yet developed the necessary mechanisms to deal with the financing of technological innovation. Moreover M3 prefers to raise capital from the internal network of companies it belongs to while M5, if in need, prefers international financial markets (likewise M1).

ANNEX 9.5: Detailed Analysis of The Defence Sector

General Characteristics Of The Industry

Profile and structure of the industry. Greece dedicates approximately 4-5% of its annual GDP for defence expenditures. A major fraction of these expenditures is absorbed by the domestic defence industry which is an intensive advanced materials user (mostly metals and plastics/composites). The industry includes six major production or assembly units of advanced military equipment (MU1), military aircraft support and maintenance (MU2), weaponry and armaments (MU3), ammunition and explosives (MU4) vessels and shipbuilding (MU5) and military and civilian vehicles (ELVO- not included in the thesis sample). The industry operates under the authority (or the influence) of the Greek Ministry of Defence (MOD) which defines and supervises the basic operational parameters and budgets of four out of the six major production units of the sector.

MU2, MU3, MU4 and ELVO are public enterprises operating under the direct supervision of MOD. MU5 is a large shipbuilding company established by private initiative. In the late 1980s it moved to public control and until today its production output includes a mixed portfolio of assembly, construction and maintenance of both civilian and military vessels and equipment (e.g. railway equipment). MU1 is a group of companies operating under common private ownership, and it includes four major production units of military equipment, one construction unit for civilian structures and one materials producer (steel castings). It is reviewed in this section of the thesis because 70-90% of its production output is absorbed by the Greek defence sector and the Greek army. In addition, the industry includes numerous interdependent specialised SMEs which act as equipment or military systems (e.g. electronics) suppliers to the six major production units.

Market orientation of the industry. The primary mission of the Greek defence industry is to support the operational capabilities of the Greek army and substitute imports of military equipment, weaponry and ammunition with high-quality domestic products. This remains the primary mission of MU3, MU2 and MU1. Exporting activities are supplementary to the supply of the domestic markets. Given that during the last seven years, the sector regularly operates under heavy losses and its production units are the primary contributors to the payments deficit of the sectors where they are enlisted (ICAP Statistics 1990-1996), MU4, MU2 and MU1 have established divisions targeting civilian markets. MU4 has established a construction branch[62] with the aim to construct large specialised metallic structures for the needs of the domestic industry and public enterprises (in particular). MU2 provides maintenance and repair services to civilian aircraft and aviation companies and MU1 has moved to develop high precision components, explosives, electronics and optics equipment (e.g. lenses) for civilian applications. In the case of MU5, the Greek government subsidised its civilian operations by allocating defence contracts (assembly of military vessels for the Greek navy) and railway equipment for the Greek railways (public enterprise).

In all cases the Greek State totally dominates the defence sector both as the primary final (and in many cases the only) customer of the output and as the final decision maker for the four major production units of the sector.

Technological Considerations

Apart from MU1 and MU5 which operate under civilian leadership, the fundamental business objectives of the other three companies are clearly defined by the leadership of the Greek MOD. The companies' leadership implements the basic guidelines and suggest business strategies which, however, are ultimately approved by the MOD leadership. The three companies were designed to primarily serve the needs of Greek military forces while exports were identified as a secondary, complementary activity. That immediately imposed production and corporate size limitations to the Greek defence sector as the "products" and military systems absorbing capacity of the Greek military is limited with respect to international standards. Given that the Greek military also absorbs approximately 70-90% of the domestic production of the private companies, the market limitations of the sector are also imposed upon the private units of the sector (e.g. MU1 and MU5).

On that operational basis the technology strategy of the four major production units of the sector (MU1-4) has the objective to keep the technological capabilities of the companies constantly updated and in touch with international developments - *that is to remain technology-intelligent users* - in order to be able to sustain the position of the companies as major suppliers of high quality products of the Greek military forces[63]. MU1 follows a more aggressive approach based on recent acquisitions of a couple of small materials producing companies (steel mills and metals casting companies). By these acquisitions MU1 attempts to achieve an internal vertical

[62] 75-90% of the annual sales of MU4 correspond to ammunition and explosives sales. The rest is allocated to civilian applications such as metallic components and large scale structures for large industrial users such as the national Power Company.

[63] Moreover, a diversification strategy of MU3 attempts to direct the technological and a part of the production capabilities of the company to the establishment of a division able to produce smart bombs, weapons and explosives.

integration of materials production and final processing in order to support its export activities and its product diversification strategies. The technological capabilities of the civilian divisions of MU4, MU2 and MU1 are perceived as a natural outcome of the established technological capabilities of their parent companies. Finally, MU5, at the time of the interview (January 1997), was at the stage of reorganisation and strategy redefinition under new leadership which was expected to affect all the civil (but not the military) activities of the company including its future technology strategies and organisational structures.

To achieve their goals the Greek defence sector *heavily rely on technology transfers and external technology acquisitions* for updating and sustaining their technological capabilities. These technologies are transferred with the aim to be absorbed and fully integrated into each company's infrastructure in order to support its production capabilities. In some cases imported technologies have been further developed providing the basis for the development of technological competencies in niche markets applications (e.g. the case of MU2 where the company has reached the level to export services and know-how in the area of aircraft repair and maintenance). An exception to the rule is MU1 which follows a mixed portfolio: for some products technology is internationally acquired and then it is internally further developed by institutionalised reverse engineering activities. For some other products the company depends on in-house expertise acquired through long-term experience. All companies apart from MU5 underlined that *materials* know-how is an integrated part of this process. In the case of MU5, technology transfers do not include materials know-how; only performance and properties specifications.

<u>R&D Activities</u>

As MU1-4 pointed out, the primary mission of their R&D divisions is technology transfer in the fields of product design and manufacturing technologies/techniques. MU5 has technology transfer mechanisms similar to those of large construction companies based upon human interactions and collective experience of senior engineers rather than organised technology transfer mechanisms fully dedicated to the task. In more detail:

** MU1 allocates 10-25% of its annual profits to R&D expenditures and has two centrally located R&D laboratories dedicated to the development and testing of new products and the improvement of existing products. The R&D divisions are also functioning as the connecting link of the group with other companies, research organisations and government agencies as they have the duty to suggest, design and implement the technological and scientific interactions of the group with other organisations. MU1 has a small pre-competitive research portfolio but it provides emphasis to applied research (average project duration 3-5 years) for new product development or new product improvement and near market research (average project duration 1-2 years) for continuous improvement reasons.

** Similar is the structure and mission of the R&D divisions of MU2 which has a manpower of approximately 50 researchers and supporting personnel. MU2 has a portfolio of 30-70% applied to near market research activities with average project duration similar to MU1 for each category of activities.

** MU3 has a research manpower of 40 researchers and three corporate R&D laboratories allocated to the three major production units of the company (geographically decentralised structure). However, all three divisions operate under central control and supervision. One out of the three laboratories is dedicated to the analysis and understanding of advanced technologies materials and systems and the other two are more "crude" and they are dedicated to product design and development, production and manufacturing research and problems. MU3 declined to provide further information and details for the company's R&D portfolio.

** MU4 has two centrally located R&D groups (product design and manufacturing) with approximately 60 researchers and other supporting staff with the aim to analyse and absorb incoming technology for military applications. In some cases these groups proceed in reverse engineering activities and achieve small modifications or improvements of the imported technologies. According to MU4, theses laboratories have probably the best metallurgical experimental equipment in Greece. MU4 provides emphasis to applied and near market research with 3 years maximum project duration.

** MU5 has no corporate R&D facilities. The company has very well equipped materials and structures quality control laboratories able to diagnose the quality and integrity of materials and structures by employing mechanical and/or non-destructive tests (ultrasonic) and it has been recently committed to applied materials research (on S&P issues) by outsourcing activities to universities and research institutions. The outsourced projects are focused on near market, competitive research with a maximum duration of 2-3 years.

In all cases materials considerations are regarded to be totally integrated to the activity they support and even though the reviewed companies recognise their value they do not allocate resources exclusively for MSE issues.

Materials Activities

Table A9.2 summarises the main reasons motivating companies in the Greek defence sector to be involved with or develop advanced materials strategies and R&D activities. Two major trends emerge:

* The Greek defence sector perceives advanced materials technologies as supporting technologies in a complementary role to its activities and not as a crucial element for building competitive advantages[64]. The reasons behind this concept are analysed below.

* The level of involvement in materials technologies and the level of sophistication of materials strategies varies considerably from company to company with MU5 and the civil division of MU4 the most elementary and the strategies and activities of MU2 the most sophisticated.

Reason	Very important	Important	No importance / indifferent.
Company's core strategy	MU2	MU1,3,4	
Group diversification strategy	MU1		MU2
Demand from customers	MU1,MU2	MU3	
Create new products / markets	MU1, MU2	MU3	
Trouble – shooting	MU2, MU3,5	MU1,3	
Pressure from national competitors			MU2,3
Pressure from international competition		MU1, 2, 3	
Government policies		MU3,2	

Table A9.2: Motives to develop advanced materials activities.

MU2 is the only one out of the five reviewed companies which has R&D facilities exclusively dedicated to MSE and materials technologies. The primary mission of the division is to transfer and absorb advanced materials know-how in order to make the company more independent from advanced materials suppliers. The secondary mission is to improve or develop a range of specific structural and functional materials used in maintenance and repair of aircraft - the strategic objective of the company. R&D facilities include mechanical and non-destructive tests equipment and experimental processing machinery (e.g. autoclaves for composites).

In the case of MU3, materials technologies and materials "strategies" simply support the technology and business strategies of the company. Materials strategies do not

[64] Apart from MU2 and recently MU1 who sees materials technologies as a fundamental element for building future competencies and supporting diversification strategies.

play an active role in the formation of either the technology or business strategy of the company. As MU3 pointed out, the company is a final materials users of a relative small size compared to its international competitors and it operates in a field which demands the most advanced materials performance and the most strict standards and specifications. Thus the company cannot afford to be involved in advanced materials research and development[65], and invests only in knowing what materials can do and how they can do it. Materials related R&D is integrated with the R&D divisions of product and processes development and takes the form of product and processes improvement and support.

Similar is the approach of MU1. Even though the MU1 group is involved in materials activities and R&D for the last 20 years it does not have a specialised full time dedicated materials R&D division. Materials R&D has always been integrated with the other R&D activities as an important parameter and many times it has been outsourced to universities and research institutions. However, MSE is rapidly gaining importance in MU1's activities and the group intents to establish specialised materials R&D departments in order to support its materials producing units and its diversification strategies.

MU4's materials strategy "*...is to be able to use as advanced materials as possible and be able to process them with our own resources and capabilities. Thus whenever we introduce a new material we insist on learning what the material can do and on acquiring S&P know-how in order to be able to process the material within our own facilities.*"

Materials related R&D activities are connected to technology introduction and improvement of cost and efficiency of production. Thus, MU4 does not have specialised materials R&D divisions because "*... MSE is entirely integrated with product design and manufacturing problems*". The design department absorbs the know-how of the materials as related to targeted products and the manufacturing division makes S&P modifications and applies it to MU4's production lines.

Finally MU5 is the least sophisticated in terms of materials technologies. MU5 explains:

> "With respect to military applications (vessels) we are restricted by international standards and very strict materials specifications already imposed by the foreign manufactures who have subcontracted the assembly job to us. Thus we are not allowed to change the materials because all the outcome will change. With respect to civilian applications we try

[65] MU3 explained that the certification of new products based on novel, non-certified materials is a very expensive procedure. For example, suppose that the company wants to certify a new cannon barrel. That would require an expenditure of approximately 185000 ECUs just for certification and standardisation expenses.

to employ established materials certified according to international specifications (e.g. ASTM) or marine classification societies (e.g. Lloyds Register of Shipping) standards."

The only original materials research MU5 are committed to is research related to the improvement of S&P of given materials such as welding technologies and surface science (coatings technologies). These activities have been recently developed and they are outsourced to various research organisations. Apart from that all MU5's materials "R&D" activities are concentrated on quality controls and specifications carried out by fracture and other non-destructive tests (ultrasonic) in a recently established quality control laboratory. But the mission of this laboratory is to certify the quality and integrity of finished structures (e.g. the strength and integrity of welding) and not to certify individual materials and comment on the findings as, say, CONEXP4.

The *class of materials* attracting the interest of each reviewed company varies considerably in accordance to the specialisation field of each company (see **Table A9.3)**. However, all companies are trying exclusively to *improve* (in the best case) *incremental* materials and *focus primarily on structural and a few mixed function materials* (e.g. MU1: materials for lenses, MU2: adhesives).

Company	Class of Materials
MU1	Advanced metals and ceramics (optics) and explosives
MU2	Advanced composites, materials for electronic applications and adhesives
MU3	Advanced metals, advanced ceramics (e.g. grain reinforced glass), advanced plastics and light structural alloys
MU4	Advanced metals and explosives
MU5	Structural metals and welding technologies

Table A9.3: The materials interests of the Greek Defence industry.

In addition, MU1 and MU4 focus on chemicals and explosives while smart materials are gaining interest with MU3 and MU2. With respect to *the materials tetrahedron* all the reviewed companies focus almost exclusively on the performance of the materials and on S&P technologies. Only the military division of MU4 and MU1 have developed S&C interests which try to improve the structure of the materials they focus on. As such, S&P skills and understanding of existing materials is assessed to be a primary competitive advantage by invariably all the interviewed companies.

Management Practices And Core Competencies

This section reviews the current management concepts employed by the Greek defence sector, and, having the analysis and findings of chapter 4 as a reference point it examines if the current conditions can efficiently support complex materials and technology strategies.

Management Tools. The level of awareness of the concept of Kaizen varies considerably between the reviewed companies. MU1, (under private management) consciously employs continuous improvement practices and many of the Kaizen umbrella elements. It is characteristic that much of the near market R&D of MU1 is committed to continuous improvement missions. MU1, however, is a rather isolated case. MU3 applies "*common logic practices*" and declined the request for future information while MU2, MU4 and MU5 clearly identified that they do not employ Kaizen practices or that they are not in position to employ them successfully because they are "*public enterprises*" (MU4, MU5)[66].

Simultaneous Engineering practices in manufacturing and process design are employed only by MU1[67]. MU2, and MU3 also stated that they employ SE practices, however they admitted that the participation of their materials suppliers was negligible apart from the provision of technological specifications and properties and performance descriptions. In addition MU2 and MU3 employ elements of team work only in their R&D departments but not on their manufacturing floor. Finally, MU5 and MU4 pointed out that ".... *it has a meaning to speak for SE practices only during the stage of trouble-shooting where experts from different fields contribute to the solution of the problem.*" As MU4 continued "*...according to my experience SE takes place only during the design of the assembly or the manufacturing process .... but again this is an internal process ; it does not include the constant involvement of, say, materials suppliers.*"

This last statement suggests that materials suppliers do not have an active technological role in the Greek defence sector, and that the users do not fully practice SE.

Core Competencies. The views of the five reviewed companies on the concept of core technological competencies vary considerably:

- MU1: " Our core competency is our manufacturing capabilities ; our ability to produce difficult and sophisticated products with our own know-how.
- MU2: "Our ability to produce high quality services with competitive advantages".

[66] Similar indications for the public sector have been identified by Giannakos (1994) in "*Inquiry into the applicability of Kaizen and the learning organisation to a small business in Greece*". MBA thesis. City University Business School, City University, London.

[67] MU1 provided a couple of examples of the design and production of components for tanks in common co-operation with their German materials and design suppliers.

- MU3: " The commercial one is good quality at competitive prices. The essential one are: a) our ability *to apply existing materials* successfully and b) our files and data banks on our products."
- MU4: " It is *100% our ability to apply materials* for our customers needs and our ability to quickly adopt new materials and integrate them successfully in our products and production lines."
- MU5: "The essential one is the protection and subsidies we receive from the Greek state."

According to the interviewed officials, materials technologies (S&P in particular) are seen as strategic technological competencies only by two companies: MU3 and MU4. MU1 has just started (over the last 5 years) to identify materials not only as supporting technologies but as basic core competencies. These "competencies" were created and sustained through a continuous improvement process (learning -by-doing) over the last 30-40 years, and by building and sustaining a strategic core of human resources over a long period of time[68]. These competencies however, are not supported by a solid patenting and publications strategy. All the interviewed companies admitted that they have not attempted to develop a patenting strategy because

a) their research is very applied and thus easily copied so "*patenting is almost meaningless* (MU1)"

b) because reverse engineering R&D "*does not produce anything new* (MU4)", and,

c) reasons of national security (MU3 and MU2).

Only MU5 in the field of welding technologies sees a future opportunity for some limited patenting[69].

From these conditions it can be presumed that the concept of technological core competencies has been insufficiently addressed by the Greek defence sector probably because the sector does not operate in real and open competition conditions (see the sincere statement of MU5 for example). As a result, some of the reviewed companies appear to confuse the concept of commercial competencies with the concept of technological core competencies (e.g. MU2) or the concept of manufacturing competencies with technological competencies (MU1).

Supportive competencies. The companies of the Greek defence sector follow converging approaches in a number of supportive technological competencies.

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[68] Note the contrast with the construction industry on this particular point.

[69] In addition, publications and patenting involves issues which need the existence of a coherent R&D and Industrial Public Relationships management strategy.

Intelligence gathering and customer's needs evaluation mechanisms. Apart from MU5, all the reviewed companies have business unit or division based institutionalised technology intelligence gathering mechanisms. These mechanisms involve teams of experts full-time allocated to the technology information gathering task by employing extensive library and databases networks. For MU4 these teams are an integrated part of MU4's R&D divisions. In the case of MU3, the technology intelligence gathering mechanisms are partially integrated with the marketing department assisting in the evaluation of future customer needs. In all cases, collective experience of senior engineers plays an important role in the evaluation of the collected data. Even though there are no MSE specialised divisions within these teams, MSE materials considerations always play an important role in the evaluation of technologies and especially in terms of what advanced materials are available in the international market, what properties / performance they have and if they can be integrated successfully into the company's products and processing capabilities.

MU1 and MU3 have also organised teams dedicated to the task of evaluating future customers' needs. Their action is partially integrated to their technology intelligence gathering mechanisms. On the contrary MU2 and MU4 have applied "sporadic but unorganised efforts" to this direction. MU5, finally, employs the method of "collective experience" based on expertise of senior engineers and scientists for both customer's needs evaluation and intelligence gathering needs. This approach resembles the approach adopted by the construction sector reviewed in section 9.3. MU5 declared that it is the intention of the new leadership of the company to established institutionalised teams and replace the "collective experience" approach of the company in the immediate future.

Instrumentation and new machinery investments. MU1 and MU2 operate on the basis of 5 years investment plans including heavy investment of the updating or continuous replacement of instrumentation and equipment of both their R&D divisions and of their manufacturing floor. MU3 follows similar approaches but the investment / replacement rate is subjected to product and market related evaluations. MU4 regularly invests only for the updating of the R&D divisions instrumentation and not for the machinery of the manufacturing floor, while MU5 just entered the stage of updating after many years of neglect.

Simulation and modelling skills. Contrary to the construction sector which prefers the solution of outsourcing when it comes to simulation and modelling issues, the defence sector is keen on developing and sustaining these skills internally. MU1, MU2, and MU3 have developed these skills from the early 1980s mainly dedicated to production and production design issues and R&D problems. Future plans involve the strengthening of the simulation and modelling divisions. On the contrary, MU4 has developed these skills only for the military divisions of the company, while MU5 does not have in-house simulation and modelling units even though it employs CAD/CAM and CNC based manufacturing systems.

Human Resources Policies. According to interview results, the companies of the Greek defence sector have converging views and human resources policies with respect to both engineering and scientific personnel and unskilled labour force or technicians.

To begin with, the mobility of senior, experienced engineers in the sector is very low (as contrasted to the mobility of senior engineers in the construction sector). That is because all the reviewed companies invariably invest in the gradual improvement and internal education of their engineers, scientists and specialised technicians. This policy applies for all, including MSE people. New-comers with previous experience are preferred but since well-qualified people with specialised knowledge are rare, graduates used to be employed and internally trained. Greek universities are considered to provide scientists and engineers with a good general background which is, however, rarely sufficient for the needs of the industry. The problem is more intense with technicians because when they enter the field they are of very low quality and usually without formal technical education. Thus all the companies have to invest in internal training and re-training schemes.

But MU2-MU5 (all of them public enterprises) face an unprecedented challenge imposed by the Greek state: from 1989 the Greek state has frozen the employment of new personnel (including scientist and engineers) in all public enterprises including the enterprises of the defence sector. Until February 1997 this situation was holding strong. MU2 and MU3 are trying to temporarily overcome this difficulty with seasonal or project based contracts and the occasional appointment of researchers from universities and other research institutions or other companies. As MU4 put it,

> "... that situation has already taken a heavy toll on the technological and R&D capabilities of the four major defence production units and if the condition is not reversed until 2001 it will have a detrimental effect for both the R&D and the operational capabilities of MU4 and many other public enterprises."

This situation has already disrupted accumulation of knowledge - tacit knowledge in particular - of all public enterprises and has already stopped the introduction of new ideas and skills by new people .

Finally the majority of the board of directors of all five reviewed companies have an engineering (mostly) or science educational background. This, however, has not been identified as a handicap when it comes to innovation policies and practices; according to all the interviewed officials innovation is halted by external parameters such as the size of the companies, the conservatism of the Greek MOD, the employment condition and others and not by leadership perceptions.

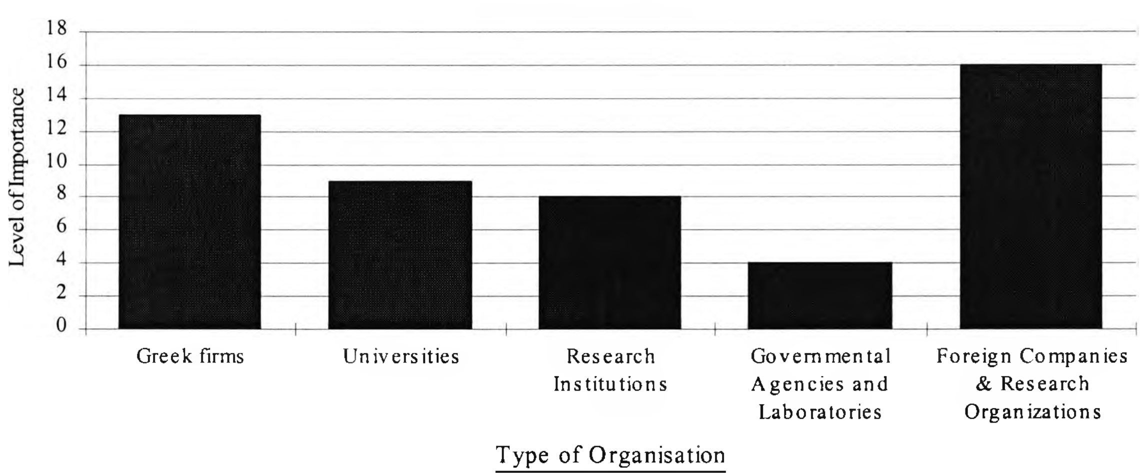
Technology Interactions, Collaborations And Alliances

According to the findings of **Table A9.4** only MU1 and MU2 have established frequent technological interactions with both corporations and research organisations in Greece and abroad. The other three companies provide emphasis to interactions with companies (mainly international companies) while they appear somehow isolated from interaction with universities and research institutions in particular. This is also reflected with **Figure A9.1** which illustrates which organisation Greek defence companies consider as their most valuable technological partner in materials and other related technologies. Clearly, domestic and especially international companies are top of the list while national research organisations and governmental agencies are the last of the list.

	Frequent	Occasional	Rare or None
Customers	MU1,2,3		MU4, MU5
Materials suppliers	MU1,2	MU4, MU3	MU5
Equipment suppliers	MU1,2	MU3, MU4	MU5
Similar Companies	MU1,2,3	MU4	MU5
R&D Institutions	MU1,2	MU3	MU4, MU5
Universities	MU1,2	MU3, MU5, MU4	

Table A9.4: Frequency of technological interactions of defence companies with other organisations.

Figure A9.1: The most valuable partner with respect to in-coming knowledge transfer: The defence companies view. Source : Author based on interviews data.



Interactions with national and international manufacturing firms. The Greek defence companies prefer to enter short to medium term collaborations with mainly international manufacturing companies rather than forming long-term complementary technological alliances with manufacturing companies or materials / equipment suppliers. As all companies explained, this is a deliberate choice because the present size and the organisational and R&D structure of the interviewed companies does not allow the formation of such alliances. As such, the interviewed companies opt for short to medium term technological collaborations with the aim to learn and transfer established know-how rather than produce new know-how which can ultimately be transformed into new products and markets.

The interactions take place through each company's R&D divisions usually through direct interaction and occasionally through participation in collaborative projects[70] with the aim to transfer or digest knowledge which can be translated into products, manufacturing techniques or processes improvements as soon as possible. In some cases the aim of the collaboration is to reduce costs and risks of entering new markets (MU1) or providing access to markets (MU4) or exchange human resources and creating human networks (MU2). It is characteristic that until 1994, MU5 and the civilian division of MU4 did not even enter this type of collaboration. Commercial and product / process description information exchange was all that took place. MU1-MU4 declined to provide further detailed information on their collaborations with to respect project or collaboration duration and budget.

Interactions with materials and machinery suppliers. The materials suppliers (mainly metals) of the Greek defence sector are both Greek and international materials producers. There is, however, a distinctive difference: Greek materials producers mainly supply the conventional, structural metals employed by the civil divisions of the reviewed companies. All the "special" and advanced materials are imported because Greek producers either do not or cannot produce them. To make things worse, MU5 and MU2 identified that the imported "special" materials are rarely accompanied with full technological and scientific records and descriptions[71]. Similar are the conditions with the machinery suppliers with the difference that they are almost exclusively international companies.

Commenting on the level and timing and substance of participation of materials and equipment / machinery suppliers during product / process development, only MU1 stated that they have managed to achieve a very good level of both commercial and

[70] Almost exclusively in the case of MU2.

[71] That situation has enforced MU2 to develop materials R&D activities in order to reduce the technological dependence of the company from some of its materials suppliers and is one of the reasons behind the acquisition of materials producer (casting company) by MU1.

technological co-operation under the form of "*...we teach them and they teach us*" (MU1 1996). MU2, MU3 and MU4 pointed out that there is a strong reciprocal relationship with regular materials suppliers but they admitted that the co-operation has a clearly commercial and information exchange character (description of new products, properties and performance) rather than real participation of the materials suppliers in product and process design. MU5 has not even steady materials suppliers[72] apart from the specialised parts which require special performance materials. It is characteristic that only MU5 and the civilian division of MU4 are regular, "bulk" customers of the Greek materials producers (steel, aluminium) and that is only for conventional applications. Note that with respect to metals the construction industry gave a very similar picture of who provides what in the Greek construction sector.

Interactions with research institutions – universities. The interactions of the Greek defence sector with universities and research institutions goes mainly through common participation in national and international R&D collaborative projects. Nevertheless, the level of participation of the reviewed companies varies considerably: While MU1 frequently participates in both national and international collaborative projects and MU2 stated that all of its R&D portfolio is collaborative R&D, MU3 and MU4 pointed out that they have no particular interest in these activities because early participation in collaborative projects did not provide the expected results. However, the civilian division of MU4 and MU5 demonstrate a growing interest in creating links with research organisations and participate in R&D collaborations.

Occasionally the interaction between defence companies and research organisations takes the form of dispatching researchers or of outsourcing R&D activities on the basis of establishing co-operative agreements or requesting specific research. MU5 in particular almost entirely relies on universities and research institutions for its recently established R&D activities[73].

The aim of these collaborations is invariably the improvement of products or processes, modelling and simulation of experiments and designs, and in a few cases the development of new products or technological solutions by exploiting existing

[72] MU2, MU3 and MU4 had to develop at least a close commercial relationship with their materials suppliers because they depend on regular supplies of relatively limited quantity materials of high standards and performance specifications. On the contrary, MU5, for its civilian applications employs more conventional materials and is subjected to more "relaxed" specification which many materials suppliers can match.

[73] Examples include welding and advanced processing of steels with laser technologies and electron beams, advanced surface treatments , welding technologies and non-destructive tests and diagnostic methods for welding and cracks.

capabilities. Education motives and human resources policies are also a top priority of these collaborations.

Even though there are no special arrangements for materials technologies, many of the collaborations are materials related. The aim is the evaluation of performance and properties and design of processing on the basis of the results (this is on the part of the firms). The duration of these projects however, rarely exceeds 48 months and the budget of 135000-165000 ECUs (in the case of MU2 which has the most extensive participation in R&D collaborative projects).

Commenting on the question of which are the main points hampering further collaboration between the military divisions of defence firms and research organisations MU1 and MU3 suggested that "... *according to our experience domestic universities do not have the required experience or the supporting infrastructure and equipment to support our specialised needs. However we allocate design studies in engineering schools when we regard them as the best choice*." Overspecialisation of the sector and legal barriers were also mentioned as main obstacles for further co-operation between the military division and the Greek civilian R&D infrastructure.

All the proceeding evidence suggests that the military divisions of the public enterprises of the sector (apart form MU2) are aloof (with their own choice) from the research infrastructure of the country. This comes as a surprise if one considers the benefits originating from the strong bonds between the military industries of the, say, USA, UK, and Israel and the research organisations of these countries. Given that all companies provided limited information on the exact nature of their technological interactions, it is not clear if these conditions have been imposed by objective reasons (e.g. the current technological and R&D structure and capabilities of the companies) or by a deliberate choice of the leadership of the companies or the Greek MOD. Commenting on the issue, academics PAC1 and PAC2 suggested that the Greek defence related companies are trying to do everything on their own because they either do not know exactly what their technological competencies are or they have problems managing them and protecting them. In any case, huge technological and business opportunities are wasted.

Interactions with national and international R&D activities. The participation of the defence sector (military divisions) in national and international R&D activities was limited and since 1994 it has further declined. With the exception of MU2 which is the only one of the public enterprises which has a formulated participation strategy because it uses the collaborative projects as a major source of income for its R&D

activities[74], the other two public enterprises of the sector have become aloof from participation in the national R&D collaborative schemes because "*we didn't receive the expected results*" as they put it. MU5 has never participated because it lost out in the proposals competition. Moreover, MU2 and MU1 are the only companies of the sector which have extensive experience from international programmes (e.g. Brite/Euram). The civilian departments of MU4 and MU5 have just started to participate (since 1994) and they have limited experience from both national and international R&D activities.

When the companies of the sector were asked to comment on the national and international R&D programmes and the participation of the sector, they quoted that the national programmes are of horizontal and not of strategic character (identical view with the construction sector). Moreover, MU2 and MU1 questioned the evaluation and supervision mechanisms of the national R&D schemes as insufficient and MU5 pointed out that the *application* of the national R&D schemes has in practice excluded not only MU5 but the entire shipbuilding sector from participation. This is the **second** important industrial sector (after the construction sector) which has been excluded from state R&D subsidies and R&D supportive schemes.

Interactions with pubic agencies. GSRT and the Ministry of Development retain no direct contact with the Greek defence sector. The sector is entirely subjected to the control and jurisdiction of the Greek MOD for both R&D issues and technology and business strategies. MU1 is not a public enterprise but given that the Greek MOD is the main (and in cases the only) customer of the group's products, MU1 has been aligned with the sector and the group's interactions are also limited and indirect passing through collaborations in GSRT R&D programmes. This situation proves an argument of chapter 7 and chapter 8 that the Greek state has not yet managed to co-ordinate the R&D and technological activities of all its agencies and GSRT has no jurisdiction on major sectors which are or have the potential to become R&D intensive.

Given the direct control of the sector from MOD and the limited technological experience of the sector with MSE technologies, the interviewed officials were very cautious on providing comments on the need and the elements of a national materials and technology strategy. In fact, they focused on general national technology strategy issues rather than MSE issues.

** MU1 and MU2 gave particular emphasis to the issue of providing technological directions and identifying areas of importance in both materials and

[74] MU2 is the "champion" of the sector with a total number of eleven national and international collaborations during the 1989-1996 period.

other technologies and pointed out that the national materials selections are efficient only if they address sectional needs and not individual cases[75].

** MU4 focused on the need for co-ordination and long-term planning of all the national R&D and technology activities. MU4 suggested that " .... *attention should be focused on the technological (and materials) needs of sectors which can survive without constant commercial subsidisation from the Greek state.*"

** MU5 underlined the immediate need for a national strategy in shipping and shipbuilding and the creation of a relative and specialised supporting infrastructure. As MU5 explained,

> "Greece has the potential for developing many advanced offshore materials because it has both the production units and the climate advantage for the processing of materials which other countries (e.g. Norway) do not have. But there is a lack of strategic decision at national level to support R&D in materials for offshore and marine applications. Isolated companies, however, can not go far on their own."

The opinion of all companies converged on the following issues:

- The provision of long-term planning in state procurements[76],
- The promotion of industrial and commercial networks, and,
- The provision of patient capital for high technology and R&D investments.

The same issues are also perceived as the main obstacles orbiting the sector to develop more intensive R&D activities and commercialise its results. The last request in particular (long-term capital for R&D investments and "the way the existing capital is administrated" (MU3)) is regarded as the number one obstacle for further development of R&D in both materials and many other technologies.

Financial Constraints For Long-term R&D

Given the constant subsidisation of the sector by the Greek state, the remark that financial constraints and lack of capital are the major obstacle inhibiting the development of further R&D activities comes as a major surprise. It also explains why the R&D capabilities of the sector are limited and why the technology and R&D portfolio of the sector has a technology transfer and a short to medium term products and processes improvement character rather that a balanced portfolio of both technology transfers and new knowledge and products development. Simply, the

[75] According to the findings of chapter 8, the national materials priorities have partially complied with this industrial request.

[76] Similar to the request of the construction industry for long-term planning of public works announcements.

companies of the sector cannot afford to be exposed in long-term, complex and expensive R&D activities such as materials R&D activities.

As MU3 and MU2 explained, the Greek state subsidises the sector (which operates under heavy deficits for the last eight years) either by allocating directly public funds or by using the MOD budgets. The available funds aim: a) to cover the operational costs and the annual losses of the sector and b) purchase the production of the sector at cost prices - thus much of the trade deficit of the sector. As such, the sector does not have substantial profits to re-invest in R&D activities. Moreover, MOD does not directly subsidise the R&D activities of the sector apart from the case of physical investments (equipment and infrastructure) and the case of MU3 and MU4 which receive a small but certain subsidy for maintaining the existing level of their R&D activities. On the contrary MU2 pointed out that the company does not receive any public R&D subsidy and has to rely almost entirely for the finance of its R&D activities on participation in national and international collaborative R&D projects[77].

Under these circumstances the R&D expenditures of MU2, MU3 and MU4 are dominated by the "net present value" rule, with respect to each individual project's value and urgency. Only R&D infrastructure expenditures are made with a long term view and only if an MOD subsidy has been secured. Apart from selected S&P technologies, MSE technologies receive no special treatment or priority. It is notable, however, that all the interviewed officials underlined that the R&D expenditures should be seen as a strategic investment but the inability to secure stable cash flows over a long period of time prohibits this particular strategic choice.

Interactions with banks and financial markets. All the interviewed officials pointed out that the Greek defence sector has not developed any substantial links with Greek banks and financial markets. In the 1980s public banks had provided loans with the Greek state providing capital and interest guarantees. Apart from that, there was a unanimous agreement that the Greek financial markets do not support technological innovation either due to lack of patient capital or due to lack of evaluation / supervision of the investment capabilities[78]. In addition the interviewed officials underlined the lack of established and institutionalised spin-off mechanisms which would have the potential to diffuse military R&D into civilian applications and provide considerable financial returns (as in the USA) to the Greek defence sector.

[77] That is why MU2 has a well-defined collaboration strategy.
[78] Something which has been identified by the banking sector in chapter 8.

Annex 9.6: Detailed Analysis and Review of the Construction Industry

General Introduction

The construction industry is an intensive materials using sector which provides one-off tangible services on request. The sector, however, is distinct from the services sectors because it provides tangible "products" and it entails the transformation of materials and components on site. It may also be distinguished from manufacturing because the final product is unique and is built on request at a fixed location where it is to be used (Gann 1990). For these reasons, the labour, *materials* and equipment required in the construction process are highly mobile. Moreover, construction markets are highly cyclical subjected to many macro-economic and /or national government and EU policy factors[1]. During the last 20 years, shifts in the nature of demand[2] together with technological and organisational innovations in the construction process are leading to radical changes in EU and other national construction industries (Gann 1990). The transition from craft-based processes towards integrated solutions tailored to specific applications, including the use of integrated systems of advanced technologies and materials (e.g. assembly technologies, robotics, automation, advanced construction materials) is increasingly evident (Gann 1991, Kaounides and Kottakis 1997). As such, many construction companies are gradually realising their potential as both developers and users of advanced technologies and materials and they are transforming into high technology companies widening the gap between them and construction companies employing conventional construction methods and materials (Gann 1991). These factors define both the "environment" in which the sector operates and many of the organisational and operational parameters of the sector.

General Characteristics Of The Industry

Structure of the industry. The Greek construction sector is entirely controlled by private enterprises operating under fierce competitive conditions. Until recently, the industry was very fragmented and was characterised by a large number of SMEs and a relatively small group of non-specialised large construction companies. Recent trends have seen the emergence of a small group of *large specialised* construction companies while the entire sector has undergone a major re-classification of public works contractors

[1] For example, the EU framework programmes heavily invest in infrastructure from which countries like Greece have extensively benefited (see chapter 7, section 7.4).

[2] Such as ecological buildings, earthquake resistant structures and large scale infrastructure projects.

in order to facilitate the major CSF II (EU supported) infrastructure projects[3]. The 39 large construction companies which emerged from this re-classification, are among the lead bidders in most projects and have begun forming consortia among themselves to participate in the largest projects. Frequently it is the same companies grouping and regrouping and some commentators (see Industrial Review: Special Issue 1996) believe that it is only a matter of time until there are mergers leading to the creation of internationally sized Greek construction companies which could be eventually able to export en-masse their services - particularly in the Balkans and Eastern Europe.

Market orientation of the industry. Traditionally, and until today, the sector is primarily domestic market oriented. That is because the majority of Greek construction companies do not have the organisation and management capability or the experience and the required support to go after demanding international markets (CONEXP1,2,4,5 1996/97). Moreover, early internationalisation attempts during the late 1970s and early 1980s in the Middle East and North Africa regions led to very painful financial disasters. Given that neither the Greek State nor the Greek banks (State-controlled in their majority) supported the involved construction companies (in similar ways such as, say, the British and French governments), the Greek construction sector is very hesitant to repeat en-masse the internationalisation adventure[4].

Characteristics of the Greek domestic construction market. The Greek construction markets have been developed in an environment well protected from international competition. Until the late 1980s, the Greek private sector has mainly financed the development of the buildings and housing industry. The Greek State and the Greek public sector[5], however, was and still is the main client of the sector with the large scale infrastructure, public works and public agency building projects. Given that the

[3] Until 1994, public works contractors were categorised in classifications1-7 (Alpha to Zeta) which reflected the size of their assets, equipment, personnel and specialist expertise. Invitations to tender are issued only to companies whose skills are appropriate to the scale of the job. In order to ensure solvency companies are limited to the size of jobs on which they can bid. For larger projects they have to enter joint ventures. To facilitate the major CSF II (EU supported) infrastructure projects, the authorities created in 1994 a new top category (**ITA or 8**) which allows construction companies with own capital of 1.8billion Drachma (or 6 million ECUs) and fixed assets up to 2.4 million ECUs to bid individually on projects up to 40 million ECUs. They can bid individually up to three times their net worth (to a ceiling of 8 million ECUs) but must enter consortia to undertake work. To qualify, 22 construction companies (some of them specialised) jointed the stock exchange in 1994-1995 and in December of 1995 there were 39 ITA (8) class companies.

[4] Even the three large specialised construction companies of the sample stated that their international activities rarely exceeds 15% of their annual turnover and future internationalisation plans are subjected to the crucial influence of many exogenous macro-economic parameters such as governmental support, volatility of regional construction markets, banking policies etc.

[5] Including "public goods" enterprises such as the National Power Company.

construction industry is an industry which provides one-off tangible services at request, it follows that it is primarily *the customer* (be that an individual, a firm, or the Greek public sector) *who enforces the utility performance* and *cost specifications* of the finished "product" to the contractor. In other words the constructor is frequently bound by rigid requirements but it is the task of the contractor or the consultant / design engineers to decide with which technologies, materials and construction processes the set described requirements are to be met.

The private sector as customer is very fragmented, it puts cost considerations first, and, as all the interviewed experts pointed out, *is uninformed* about the advantages (including long-term cost advantages) offered by the employment of new technologies and materials in the building and housing industry. Thus a private client does not ask for the application of new materials or technologies and given that there are not tax or other subsidy motives for the contractor to use them, the concept of "*why should we innovate when conventionality does it*" dominates the industry.

On the other hand, for the large scale national infrastructure projects, the client is the Greek State and/or the large "public goods" national enterprises. During the allocation of projects the Greek State has the opportunity to subsidise and even ask for the employment or introduction of innovative construction technologies and new materials. But as identified by Kalogirou (1991), Kalogeras (1996) and all the interviewed experts the Greek State *has never seen* construction projects as an opportunity for new materials and technology development or transfer. Apart from the basic performance specifications, short-term cost considerations are the first priority (under the concept of protecting the tax-payers public money) and no advanced technological specifications are imposed. However, given the demanding technological nature of many large infrastructure projects, Greek construction companies have to achieve an optimisation between *the readily available state of the art* technological solutions and the imposed cost considerations.

In addition, the Greek State announces and auctions infrastructure projects on an irregular basis. These conditions maximise long-term operational risks and have a negative influence on the development of long-term technology and business strategies of the Greek construction companies. As such, very few companies dare to prepare technologically prior to the announcement of a specific project or even prior to the securitisation of contracts. After they secure contracts construction companies investigate all the available technological solutions[6].

Given the described pressures imposed by their immediate operational environment, Greek construction companies have adopted a flexible organisational approach which allows them to operate with minimal fixed capital, own resources and inventory costs during periods of hardship. Even the largest of them are based upon a minimal basis of technical and engineering man-power and inventory equipment (some of them do not even own the buildings in which they are based) and then they expand according to the load and the number of projects they secure. To achieve that, construction companies are forced to adopt an "**accordion**" - style operational approach which constricts to a minimal basis of personnel and inventory in times of hardship and expands by contract-based remuneration of human resources, inventory and machinery to meet peaks of demand. This approach has the obvious advantage of minimising risk and some not so obvious disadvantages: according to CONEXP4 the great majority of Greek construction companies which have adopted the "accordion" organisational approach, as organisational entities have a completely elementary form and structure and according to CONEXP1and 2 they retain a strong personal or family enterprise character rather than a real corporate character. In addition, CONEXP4, continues, "... the majority of Greek construction companies, despite their size, are *not* capital intensive companies. Only the companies of the Ita - (8) class created after 1994 (see above), and some specialised construction companies can be called capital intensive."

Box A9.1: The "accordion" structure of the average Greek construction company.

Organisational structure of the Greek construction companies. This very nature of the construction market in Greece has forced the majority of even large and specialised construction companies to adopt an idiomorphic organisational structure assimilating the "accordion" structure and function summarised in **Box A9.1**.

These conditions were radically challenged with the implementation of the EU support framework programmes (CSF II). The Greek State still contributes a significant percentage of the funds and through its agencies and project allocation mechanisms still controls much of the projects distribution for large infrastructure contacts. The projects allocation timing, however, became more "predictable" (hence companies can proceed in long-term planning) while the technological implementation of the projects per se enforced the entrance of many high technology international construction giants and

[6]This situation is very well summarised by CON2: "To prepare ex-ante technologically involves high risks: the one who is ex-ante prepared has made an investment and expects returns; thus he is most certainly more expensive. However, in order to secure public works contacts you have to be as cheap as possible because (unfortunately) that is the only crucial criterion. Thus, if you are ex-ante technologically prepared you know exactly what is involved and you appear to be expensive. On the contrary someone who is unprepared is unaware of what exactly is involved and appears to be cheaper. If he gets the job it is questionable if he will deliver or exit."

ended the protectionism conditions in which the domestic industry grew by imposing new technology based competition challenges.

Technological Considerations And Materials Activities

Construction companies and technological considerations. All the interviewed experts pointed out that the Greek construction sector is highly innovative in terms of adopting new but established technologies and materials. The development, however, of strong technological competencies based on long-term strategic planning is inhibited by some negative influences such as:

- The "accordion" organisational structure of many construction companies,
- The lack of innovation mentality of the leadership of many construction companies,
- The lack of long-term programming in the announcement of public works contacts,
- The high mobility of senior engineers within the sector (see human resources policies),
- The lack of business or field specialisation of the majority of the construction companies,
- The lack of innovation spirit from the leadership of many construction and engineering design or engineering consultancy agencies[7], and,
- The relatively small size of the Greek construction companies (when compared with the international EU construction giants.

According to CONEXP1,2 and 4, there is only a handful of Greek construction companies which have managed to compromise the objective difficulties and base their operational and business strategy on their technological capabilities. With respect to those who have, the phenomenon is more frequent among the large specialised companies and among the large Ita - (8) class companies[8]. According to CONEXP3 and 5 these companies have technology and business strategies of equal levels of sophistication with their international counterparts.

[7] CONEXP1,2,4,5 and 6 revealed that even the large construction companies listed in the Athens stock market retain a strong personal or family controlled character. As such the mentality of each individual leadership can make a significant difference. As CONEXP1 put it, "*change in the Greek construction sector passes through people and not through institutionalised mechanisms ; thus innovation must be in the people's minds...*".

[8] These points were verified by CON1 and CON2; CON3 admitted that they had not yet (December 1996) fully integrated business strategies and technology strategies.

Within these objective limitations, the technology strategy of almost invariably all construction companies, which have put one in place, **is to consciously remain intelligent technology (and materials) users** and keep at the forefront of the national and (as much as possible) international technological and materials developments.

Acquired or transferred construction technologies and methodologies and frequently materials know-how are usually exploited to the very limits but in technological terms they are absorbed up to the point of developing effective and economical application capabilities and not down to their very basics (CON1, CONEXP6, PAC2). As such, many construction firms are frequently among the first to apply innovative ideas or construction methods which have just become (internationally) available. But cost considerations are a serious drawback: if an innovation does not include significant cost elevations, it is rapidly adopted. If it does or when it involves long-term returns it is usually rejected. As CONEXP3 put it "*companies invest in in-depth technology absorption and reverse engineering only if their leadership identifies visible and immediate economic returns and in very rare occasions (e.g. CON2) strategic returns*." In some rare cases Greek construction companies were able to further develop the acquired technologies turning them into essential core competencies. That is usually the case of in-situ construction techniques and occasionally of design and engineering methodologies. Notably, this approach is more frequent among the field and/or technology specialised companies, such as CON1 and CON2.

In the *case of materials,* CONEXP3, CON1 and CON3 explained that construction companies, as typical materials users, are particularly keen on knowing in depth the materials properties and performance specifications. For this however, they almost exclusively rely on information provided by their materials suppliers and to certified quality controls. They **do not** have extensive materials R&D laboratories like, say, Nissan (see chapter 4) dedicated to materials knowledge "digestion". According to the findings of chapter 3 and 4 this method has limited effectiveness because materials users still need to develop in-house R&D materials activities in order to be able to judge and fully understand their materials suppliers.

R&D Activities

Construction companies **have no organised** corporate R&D laboratories as those described in chapters 2, 3 and 4 because, as the interviewed experts explained, the necessity for corporate R&D laboratories has just begun to emerge. Given that construction companies are basically intelligent technology and materials users and didn't develop new materials or new technologies, and given the objective problems obstructing long-term planning, there was a very small margin for the establishment of organised corporate R&D laboratories. Emerging problems were related with on site materials processing or construction methodologies which were faced either by internal ingenious improvisations or by extensive outsourcing, such as engineering consultancy, materials suppliers consultancy, outsourcing of R&D etc.

Technology and know-how transfer (including materials know-how) is mainly **achieved through personal human interactions** which take place within the frame of construction consortia and not through institutionalised procedures. The mechanism is effectively summarised by CON3:

> "For advanced technological applications we do not enter a consortium co-operation if we do not ensure that our people (senior designers and engineers) will be involved in all the stages of the design, development and execution of the project. We literally stick on foreigner experts and we absorb as much as we can. We have the ability to do that because the nature of the construction sector necessitates direct human interaction through all stages of a project."

However, both CON3 and all the other experts admitted that these technology transfer mechanisms are not organised "*as the Japanese would do it*". There are no special units dedicated exclusively to the job, nor there are reverse engineering R&D laboratories. All this is a part of the tacit knowledge and expertise of each company and the effectiveness varies considerably.

Nevertheless, some Ita-(8) class construction companies have recently established structural materials quality control laboratories equipped with testing machinery able to deliver far more complex tasks. Moreover, a handful of large specialised construction companies (e.g. CON2 and 2-3 others) have established small corporate R&D laboratories and allocated resources, R&D equipment and small groups of engineers for exclusive R&D duties. CON2 identified that the main aim of their R&D team is to solve problems which can not be solved by outsourcing. CON2 and other participants refused to provide further information on the current and future portfolio of these small dedicated R&D groups.

Materials Activities

Greek construction companies put a lot of emphasis on materials and they are fully aware of their importance for the construction industry. However, according to the interviewed companies and experts, construction companies **do not have** materials strategies or materials R&D departments as those described in chapters 2, 3 and 4 because serious problems originating from the utilisation of well-established materials are rare (CONEXP3). As CON2 pointed out,

"...the construction sector is primarily a services sector ; thus it is mainly interested in the process rather than the materials. Thus, we use established specifications and standards materials and only when a massive order of materials does not fulfil our requirements then we demand for a materials improvement from our suppliers or materials producers".

That is because the m*aterials selection* is based on established standardisation and pre-determined specifications which have been defined during the study and design stage of the project. Exactly at this stage, and under the condition that materials specifications have not already been defined by the client, construction companies have the opportunity to require, or suggest the employment of advanced or new materials. In many cases the construction contractor is responsible for both the design studies and the implementation of the project and has more freedom to employ innovative materials and technical solutions. That is usually the case of the building and housing industry where Greek construction companies regularly take the initiative to apply both new functional and structural materials.

This, however, is rarely the case with large scale infrastructure projects (public works). Here the construction company usually executes design and construction studies conducted by Greek and in many cases international[9] engineering consultancy firms. Lack of information and conservatism regularly inhibits the application of new construction materials. The construction companies however, have the opportunity to provide feed-back on the materials selection through the outcome of the in situ materials performance and on properties quality controls.

As such, materials R&D activities and materials dedicated groups are rare, but innovative construction companies are regularly and consciously investing in knowing what is new and available and what new advanced construction materials can do, and they are among the first to employ them (or press for their employment) internationally. In the Athens Underground project for example, it was Greek construction companies which have insisted and finally "enforced" the application of many integrated processing and construction technology systems based on new construction materials[10].

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[9] This is the case of many high technology intensive infrastructure projects like the Athens Underground and the Rion - Antirion 2.5Km suspension bridge.

[10] For example :

** A special cement addition delays the cementation process for about 72 hours. That enables liquid cement or concrete to be transferred in the tunnels over long distances and applied in situ by liquid ejection systems. That has accelerate the construction process by providing just-in -time readily applied materials

A new trend has started to emerge during the last 10 years, when strict materials regulations and new technological challenges imposed by the implementation of large, EU supported, infrastructure or energy related projects, have enforced increased technological demands on the Greek construction companies. In order to respond to the onset challenges, many Ita class construction companies refocused their attention on new and advanced construction materials and they have launched or they are about to develop formulated R&D materials activities. **Table A9.5** summarises the most important motives behind the existing interest in advanced construction materials and especially the motives behind the intention to be involved in more vigorous materials R&D activities in the near future.

Reason	Very important	Important	No importance / indifferent.
Company's core strategy	CON1, CON2		
Group diversification strategy		CON3	
Demand from customers	CONEXP3, CON1	CONEXP1,2 CON2	CONEXP4, CON3 : Not informed (especially the private sector).
Create new products / markets		CON3	
Trouble - shooting	CONEXP1,2,3,4	CON3	
Pressure from national competitors			CON3
Pressure from international comp.			
Governmental policies.			**All respondents**

Table **A9.5:** Construction Companies: Reasons for becoming involved in advanced materials technological activities.

Table A9.5 verifies the argument that demand from customers is important only for large scale construction projects (public works contractors) while the private industry (mainly buildings and housing) represented by CON3 and CONEXP4 identified that customers are not informed about the benefits of new materials and they do not ask for them. Moreover, it is verified that specialised companies regard materials as important for the company's core strategies while non- specialised large construction companies face (so far) the materials challenge only circumstantially (trouble-shooting). Note that governmental policies are indifferent to the materials strategic planning of construction companies.

and eliminate the hazardous side effects (dust) of transferring powdered cement and water making concrete in the tunnel. The special addition is the product of an international chemical industry.

** A new water absorbing plastic material is used for water-proofing the joints between construction panels: The material initially absorbs water and expands to 3 times its initial volume. When it reaches saturation point it completely locks additional water and moisture out of the joints.

The first elementary materials "R&D" activities were focused on materials properties and performance quality controls and evaluations enforced[11] by the high technological specifications of national infrastructure projects and by the "code of operational practice" of foreign companies participating in these projects. For example, CON1 heavily involved with metallic structures, has developed laboratories of quality control and certifications testing of properties and performance of mainly structural metals according to the ISO 9002 specifications. CON1 also employs advanced non-destructive tests. Even though these activities can not be characterised as R&D activities, the instrumentation, equipment and gained experience can act as a nucleus of future real R&D activities. Other companies resolve the quality issue by outsourcing.

A very limited number of specialised construction companies (e.g. CON2 and 2-3 others) have advanced towards more organised materials and R&D efforts. Currently, these activities are very small involving small teams of 3-10 researchers. R&D portfolios are strictly project oriented and the materials related R&D efforts are clearly applied and near market stage R&D. The most frequent aims are the support of innovative construction ideas, the improvement of in-situ S&P techniques or methodologies and materials quality certifications or assessments. As such, emphasis in given to properties and performance evaluations of structural materials and in particular on the **implementation** and the **in - situ S&P** of new and advanced **existing** materials. According to CONEXP3, the on-site processing of materials offers significant opportunities for research with very rewarding results because the area until today is dominated by empiricism. Both Greek and EU materials supplier (e.g. structural steel and cement companies) and construction companies can be simultaneously involved in future projects.

Management Practices and Core Competencies

Management Practices. To begin with, construction companies are not consciously aware of the concept of Kaizen (see chapter 4). However, instinctively, sub-consciously or under the concept of common logic the interviewed construction companies in practice employ many Kaizen elements such as Simultaneous Engineering, learning by doing, learning by interaction (an element which they have developed to perfection), team work and seeking to satisfy technologically demanding customers.

[11] For example a significant collective effort is the materials quality control and certification laboratory established after foreign demand for certifying the quality and the properties/performance specifications of materials and structures utilised by the Athens underground project. Similar actions are expected for the Rion - Antirion suspension bridge.

For example, Simultaneous Engineering practices (simultaneous selection of materials - construction method) are employed on a regular basis during the design stage of the construction. The concept of team-work is extensively used during the design of the execution of a project and on a regular basis on the construction site and during the project's construction. However, there are no specific operational models and much depends on the communication abilities of the construction site engineers. Moreover, technologically specialised companies (such as CON1, CON2, and CON3) aim to balance their projects portfolio between projects of conventional technological (and materials) requirements and technologically demanding projects showing a clear preference to technologically demanding projects[12]. But as CONEXP1,2,4 and 5 pointed out, all management procedures and methodologies employed by even the large construction firms are based on experience, they are not institutionalised and are strongly based upon the attitude or the mentality of the leadership of each company.

Core competencies. An additional general disadvantage of the sector originates from the ways construction companies address and manage their technological core competencies. According to CONEXP4 and 5, most construction companies have not invested in technological core competencies because i) they are not specialised construction companies and ii) their leadership did not see immediate returns from that particular investment. This type of company is usually overdiversified on the basis of an opportunistic way and that inhibits the specialisation in specific fields and the development of technology-based core competencies. As such, they give a different substance to the concept of core competency such as commercial advantage (CONEXP6) or ability to secure contracts through effective marketing, "public relationships" and interpersonal connections (CONEXP4,5).

A totally different view emerged from the large, technologically specialised construction companies. The reviewed companies have identified their core competencies as technological ones:

- CON1: "Our core competencies are our systematic and long-term investment in updating of equipment and machinery, in acquisition and employment of new

[12] As CON1 identified, some companies are expensive but they get the contracts because they have managed to establish a reputation of reliability for difficult cases. Once a construction company achieves that, then it has no other option but to systematically pursue technologically demanding projects which provide a challenge and pay better. "Easy" projects are auctioned to low technology intensity companies able to bid at very low prices.

technologies and our strengths *in applying construction technologies and materials*[13]*"*.

- CON2: "Our technological relationships and the technology based alliances with our equipment and machinery suppliers which provides a constant stream of state of the art machinery and equipment, the fact that our company is active in a specialised technological field which we know VERY well and we keep it that way, and the fact that we pay particular attention to managing and protecting our core competencies and never subcontracting them."
- CON3: "Our perfect technological background and our ex-ante technological preparation when we give an offer for a project and our innovative abilities to *apply new construction materials*."

These brief statements indicate that at least some of the specialised construction companies *have identified as paramount core competency their ability to handle, apply and process in-situ conventional and new construction materials*.

Moreover, CONEXP3 highlighted that today's core competencies are originating by the in situ (or on site) S&P capabilities of companies and differentiate the competitive from the uncompetitive construction companies. However, all this knowledge, CONEXP3 stated, is the product of empirical experience and as it remains "in the heads of the engineers of each company" is strictly **tacit** knowledge bounded to specific individuals. There are no case study records, CONEXP3 continues, and the produced knowledge is not codified and especially not patented. As such it is very sensitive to human mobility and in an industry which primarily learns by interaction is very difficult to be efficiently protected. CON3 verified CONEXP3's opinion by illustrating a case where weaknesses in the management of core competencies of the company led to the creation of a powerful current competitor.

[13] For example, CON1 stated that one of the main technical / technological strengths of the company is the accumulated know-how of applying and in-situ processing materials and speaking for structural metals, the company strength is in the welding and bonding processes (which is an emerging technologies field).

Supportive competencies

Construction companies follow converging approaches in a number of supporting technological core competencies.

Equipment and new machinery. First of all, the specialised companies regularly invest in equipment and new machinery. CON1, CON3 and especially CON2 identified it as their main source of competitive advantage. CONEXP3 explains the reasons behind this attitude: "*...in general, advanced machinery reduces the dependence on human labour especially when we speak about utilisation of new materials where human labour is difficult to be retrained*". In Greece companies with sufficient capital seek for the best available solutions and pick the most competitive. CONEXP2 added that "...in Japan the insufficiency of skilled human labour combined with high salaries has become a basic motive for the introduction of advanced machinery and advanced technologies such as construction robotics into the construction sector which simultaneously reduces the dependence on human resources and enables the utilisation of new materials and processes. In Greece, construction companies are today restricted to introduction of new machinery and not new construction high-technology based systems because the labour cost is still affordable."

Simulation and modelling skills. Even the large specialised companies prefer the solution of extensive outsourcing when it comes to simulation and modelling skills. They take advantage of the abundance of the cheap and high quality software and modelling companies offered by the Greek domestic market. Only CON2 has plans to develop an internal simulation and modelling department to deal with "sensitive" projects.

Patenting and papers publishing strategies. Given that new knowledge creation related to both materials and construction processes is of extremely competitive nature and given that most of this knowledge is tacit knowledge, construction companies deliberately avoid to patent or publish papers. All innovations and ingenious solutions are kept strictly inside the company and in the heads of company's engineers (Unanimous attitude). That attitude transforms senior engineers into highly tradable assets. Moreover, CON3 acknowledged that that there is a problem of know-how management and codification of knowledge but CON3 is the only company (at the time of the interviews) which has taken action to resolve the problem.

Intelligence gathering mechanisms. Greek construction companies have no institutionalised technology intelligence gathering mechanisms as those described in chapter 4. Technology intelligence gathering (including materials technologies) is rather project related and it is carried out through experienced senior engineers appointed for a specific period of time to the task of gathering technological and materials information for new but established materials and technologies ; not for emerging technologies or experimental materials (CONEXP3). CON3 and CON2 has a collective approach where each senior engineer is responsible to collect information for the area of his authority and specialisation.

Customer's needs evaluation mechanisms. CON1 and CON2 have organised mechanisms for gathering and evaluating current and future customers needs in order to be able to prepare technologically prior to the emergence of the need. However, as CONEXP1,3,4,5 identified this is the exception and not the rule. General orientation construction companies, due to domestic markets volatility prefer to ".. *simply, play it by ear*."

Human Resources Policies

According to the preceding information senior and experienced engineers have the responsibility to keep in touch with national and international developments and to make proposals on innovative construction methods and materials. Therefore, it is of paramount importance to secure the employment of experienced and well educated people over a long period of time. However, according to the interviewed construction experts the overwhelming majority of the Greek construction companies have no specific or formulated human resources policies for senior or executive level employees. Given that experienced people are in high demand, that explains *the high mobility* of senior and experienced engineers in the sector. Given that many corporate competitiveness and innovation characteristics are based on the skills and the mentality / education background of these people, the high mobility of senior engineers and executives has a detrimental effect on the design and implementation of long-term strategic planning and the management and protection of essential core competencies[14].

With respect to the employment of inexperienced graduates, Greek universities are viewed as suppliers of scientists and engineers with a good general background which is, however, rarely sufficient for the real needs of the sector. Mechanical engineers are preferred to be employed as materials specialists because they have a more rounded education background in MSE. Recruitment is carried through the individual divisions and not through central administration. The system has the advantage of hiring people with the best possible technological / scientific skills but it usually excludes the

[14] CON3 stated that past inability to keep crucial people in the company has led to the creation of new competitors while CON1 and CON2 pointed out that much of their technological and business progress is based *on a stable* nucleus of experienced people employed for many years in the company.

recruitment of people with combined skills. Recruitment is followed by in - house training and job rotation programmes but as CONEXP4, and 5 pointed out, very few companies make the effort to inform and re-educate their people. That has a direct effect on the productivity and innovation capability of the firms.

The innovation capabilities of construction firms (the application of new or advanced materials and integrated construction systems based upon them in particular), are also affected by the capabilities and skills of the employed technicians and labour force. On that point, specialised construction companies (such as CON1) make every effort to have a permanent core of skilled technicians and labour workers. Even though this is not the case for the average Greek construction company, CONEXP1,2 and 3 identified that, at present, both experienced people and new-comers are in general "open" to technological change and they are willing to learn new skills. But as CONEXP1,2 and 3 put it "*the successful introduction of technological change on the works site mainly depends on the personality and capabilities of the supervisor of works and the respect the labour force have for him.*" Moreover, the quality of training has been eroded by the casualisation of employment[15], and the decline of the number (or even purging) of traditional craft apprenticeships[16]. In addition, the large scale employment of (mostly illegal) immigrants with very low or non-existent education qualifications poses serious threats for the long term technological future of the Greek construction sector.

The prevailing human resources trends can endanger the future competitiveness of the Greek construction sector as has already happened with their international counterparts. In Japan, similar problems enforced the introduction and rapid diffusion of advanced construction technologies (such as construction robotics, automation etc), many of them based on opportunities provided by advanced materials technologies. In Greece, there is no adequate evidence that a similar response is under way. On the contrary, the present evidence suggests that both the construction sector (apart from isolated exceptions) and the Greek State have not taken steps to balance the trends.

Finally there is the issue of the educational background of the leadership of the Greek construction companies. All interviewed experts and companies admitted that 80-100% of the CEOs of the sector have technical, science and engineering backgrounds. The most innovative firms are those who have leadership with long-term vision and innovative

[15] In the case of Greece the "accordion" organisational style of many construction companies is directly responsible for this.
[16] While no clearly identifiable and workable approach to training has replaced them.

mentality (CONEXP1,2) or a holistic management attitude towards construction and its "environment".

Technological Interactions, Collaborations and Alliances

According to the findings of **Table A9.6** construction firms interact frequently with other construction firms within common participation in construction consortia, frequently or occasionally with materials and equipment suppliers and occasionally or rarely with research institutions or universities[17]. This is also reflected in **Figure A9.2** which depicts which organisation Greek construction companies consider as their most valuable technological partner in both construction and materials technologies. Clearly domestic and international companies are first in the list while the national research organisations and governmental agencies are the lowest in the list.

	Frequent	Occasional	Rare or None
Materials suppliers	CONEX1,2,3, CON3	CON1, CON2	
Equipment suppliers	CONEX1,2,3, CON1, CON2, CON3	CONEXP4,5,6	
Other construction companies	CON1, CON3	CONEX1,2,3,4,5, CON2	
Research Institutions & Universities		CONEXP3, CON2	CONEX1,2,4 CON3

Table A9.6: Frequency of technological interaction of construction companies with other organisations.

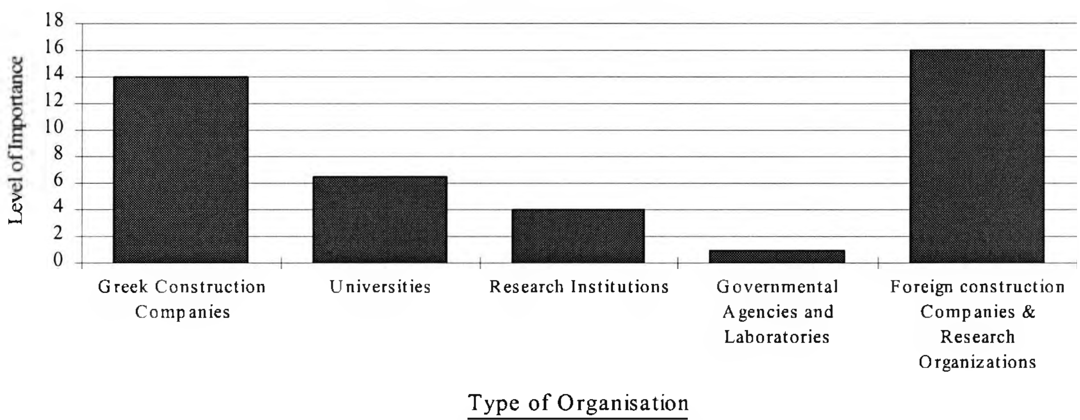
The nature and the characteristics of these interactions rather than technological collaborations or alliances are summarised in the lines below.

Technological interaction with national and international construction firms. As all the interviewed experts explained, the nature of the construction industry in Greece does not allow the formation of complementary long-term technology - based alliances among construction companies. The very competitive nature of the industry, the fact that problems call for immediate solutions and the very competitive nature of any R&D activities inhibit the formation of technologically complementary alliances between construction firms. However, the constant interaction of many large construction firms within large construction consortia during the design, development and execution stage of large infrastructure projects and the high mobility of senior engineers, replace much of

[17] Interaction with universities is frequent but only on the level of seeking consultation or involving academics in advanced studies of difficult projects.

the benefits of formal technological interactions as experience and know-how is at senior levels. Moreover, when international firms participate in a consortium, Greek companies take the opportunity and deliberately enforce links with the foreign companies in order to achieve technology transfers and know-how. Greek engineers have accumulated expertise in absorbing technological know-how through their interactions with international companies and given the opportunity, they soon adopt the technology and further develop it[18].

Figure A9.2: The most valuable partner with respect to in-coming knowledge transfer: The construction companies view.
Source: Author based on interviews data.



Interaction with materials suppliers. The materials suppliers of the Greek construction sector are both Greek and international materials producers. For technologically demanding applications the majority of the employed materials are imported (CONEXP3). For conventional applications most of the *ceramic materials, cements* and *aluminium alloys* and structures are produced in Greece while most of the employed *ferrous structural metals* and specialised advanced construction materials are imported or produced in Greece under licence agreement because Greek producers regularly fail to meet engineering performance specifications or cost considerations[19]. As CON1, an intensive ferrous metals user, pointed out, the company is very demanding in terms of materials properties and performance and unfortunately the majority of Greek materials

[18] A typical example comes from the Athens underground project: special technology foundations have been constructed under close supervision of French companies; in a few months Greek engineers and Greek construction companies have managed to replace the French completely.
[19] That does not apply for advanced cements and advanced consumer ceramics.

suppliers can not match the company's specifications or they do not pass the quality controls standards. These findings *verify* the poor condition of the majority of the ferrous metals industry in Greece as contrasted to the condition of the cement and ceramics industries, identified in previous sections of chapter 9.

The establishment of close technological co-operations and alliances between materials suppliers and construction companies in Greece is rare to non-existent. The interaction between the two industries is a commercial one and it is described by frequent (in the best case) exchange of technological information concerning specifications and data on the properties, performance and standards of the available materials. That is because the construction materials in Greece are mainly distributed by intermediate traders who have strictly commercial interests, and no technological qualifications. If a materials producer wants to receive technological feed-back on the introduction and application of new materials he must appoint his materials experts at the site of works or he should sell his products directly to the construction company without the use of intermediates.

According to CONEXP1 and 2 it should be the responsibility of materials producers to take the initiative and create closer links with construction companies and engineering consultancy offices which produce the designs and the materials selections of most of the large construction projects. A good example of the argument in Greece is the case of the aluminium components industry which managed to establish its position as a current major materials supplier of the construction industry through a vigorous and persistent information campaign for the advantages of aluminium frames for doors, windows and other structures. A second and very recent example is the case of MU5 (see section 9.1) which has managed to develop and successfully market an advanced structural steel with superior welding properties tailored to the needs of both domestic and international structural industry.

Moreover, a positive trend has started to emerge as some powerful materials suppliers (including C1, C2 and MU5 of the sample) have started to regularly visit the sites of works and discuss the behaviour of materials with site and construction company engineers. Both construction experts and the representatives of materials suppliers believe that there is a lot of potential for future closer technological co-operation between construction materials suppliers and construction companies in Greece. In addition, regular co-operation in common projects opens the way for mergers and acquisitions in the construction industry. The emergence of larger construction companies is expected to tighten the links between construction materials suppliers and construction companies and has the potential to lead to the formation of long-term technological and commercial co-operations.

Interactions with machinery suppliers. The interactions of construction companies with machinery suppliers is frequent but its nature is purely commercial apart from the exceptional case of CON2. CON2 are pioneers in the use of new machinery and technology and this is acknowledged to be one of the main core competencies of the company. This is achieved because CON2 has established complementary technological alliances with their heavy machinery international suppliers: CON2 is the first construction company which exclusively tests completely new and innovative machinery in real working conditions. In return, CON2 provides to its machinery manufacturers real operational performance feed-back including significant operational and technological information. In return, CON2 get the advantage to be the first company to employ state of the art equipment gaining a significant head-start from all its competitors. This is a very good example of complementary technology based alliance. Note that this is the second case where a Greek company has such an achievement. The first and very similar case was the case of M2Cr and M3Al presented in section 9.1.

Interactions and collaboration with research institutions - universities. There are no significant technological or R&D collaborations between construction companies and universities or research institutions. "The correct term is interactions not collaborations" as CON3 put it. These interactions usually take the form of requesting specific "research" to be conducted on contract. The contracts usually involve individuals (experienced academics) or small study groups concentrated around an experienced academic, appointed to the study of a difficult project or appointed to evaluate the mechanical properties and the performance of new construction materials. These contracts regularly take the form of engineering consultancy or trouble-shooting and their duration is as long as the construction project. Given that, some specialised construction companies increasingly find these services insufficient for their needs and are moving to establish their own research teams.

On the question of which are the main points hampering collaboration between construction firms and research organisations, there were as many answers as participants:

- CONEXP1,2,4,5: Conservatism of the academic environment ; construction technologies research is not regarded as high profile academic research .

- CON3, CON1: Insufficiency of research facilities for very specialised cases or problems.
- CON2: There is a completely different approach between construction sector and academia ; we are perceived as too applied to justify a large scale university or research institution involvement.
- CONEXP3: Universities and research institutions are not informed of the services they can offer and the emerging research opportunities.

As for interactions with research and technological institutions, currently there are no interactions because:

a) the established research institutions are dedicated to functional materials and completely different areas of research (except from CRES - see chapter 8), and,

b) there are **no** construction technologies and construction materials dedicated research or technological institutions despite the crucial economic and technological significance of the sector.

The only exception is the case of CONEXP3. CONEXP3 is primarily a temporary construction materials organisation dedicated to testing and certification of quality, properties and performance of mainly structural construction materials and structural components (e.g. pre-fabricated concrete panels) aimed to be utilised in the Athens Underground project. The formation of CONEXP3 was enforced by the international construction companies participating in the Athens Underground construction consortium and it is jointly funded by all the participants and the budget of the project. It employees 15 full time researchers with an annual budget of approximately 0.5 million ECUs for research expenditures only. CONEXP3 has managed not only to provide high quality services on the lines of its deigned mission but it achieved to expand its activities and provided significant information in testing new materials, participating in the improvement of existing incremental materials and by providing direct feed-back to their producers. Moreover it has identified new areas calling for urgent research of significant economic importance[20] and has demonstrated its value as a nexus point initiating and enabling technological collaborations between materials producers, the construction industry and selective academic departments.

[20] For example, cement companies and concrete producers have not realised the significant change of properties and performance (ageing) of pre-fabricated concrete panels which occurs during the storage time of the panel between its production and its utilisation in the site of works. Moreover, CONEXP3 pointed out that almost nobody takes into account the influence of the in- situ processing of materials on their final properties and performance.

However, CONEXP3 is not officially institutionalised. It operates on a temporary basis and officially it exists only as long as the Athens Underground project (and possibly the Rion - Antirion suspension bridge project) exist.

Interactions with national and international R&D activities. Figure A9.2 also provides an insight to the participation of construction companies in the national and international R&D programmes. Given that most construction companies do not have R&D activities and given that they do not substantially interact with research organisations it is expected to have very low participation in the national and international R&D projects. Indeed, the interviewed participants verified that the participation of the construction sector in these activities is very low, especially when it comes to the participation of general orientation construction companies. Any participation comes from large specialised companies such as CON1, CON2 and CON3:

- CON1:"Our participation proposal in STRIDE was rejected, we participated twice in PAVE and we really benefited by our participation in RETEX" (international programme - see chapter 10).
- CON2: "We have participated in PAVE and Brite/Euram with good results".
- CON3: "We have no participation strategy; however we are en route to develop one because we acknowledge the value of especially the international programmes".

Advantages	National Programmes	International Programmes
Access to knowledge and equipment	CON1	CON1, CON2
Spread of R&D cost and risk	CON2	CON2
Training of personnel	CON2	CON2
New technology implementation	CON2	CON1, CON2
Problems	National Programmes	International Programmes
Bureaucracy / slowness	CON2	CON2
Co-ordination problems	CON2	

Table A9.7: Benefits and problems of national and international R&D collaborations: The construction industry view.

Commenting on their participation in the national and international R&D programmes, CON1 and CON2 identified that their individual participation was substantial because they had the chance to develop and acquire knowledge and to enter markets which would be inaccessible without this participation (see **Table A9.7**). These participations were not continued because they required special resources and contacts which are currently unavailable. As for the participation of Greek construction companies in EU R&D programmes there are only 4-5 entries in Brite/Euram programmes. The competitive nature of the sector, the lack of R&D activities and the poor connections of the sector with the domestic and EU academic / research community have inhibited the participation of the sector in these pre-competitive research programmes.

Interactions with public agencies. According to the interviewed construction experts, the national R&D programmes are clearly of horizontal and not strategic character and their application has in effect excluded the participation of the construction sector. This is precisely a major point identified in chapter 8: The Greek State has heavily invested in creating a sufficient technological and R&D level in many Greek industrial sectors. However, chapter 8 identified that many sectors, due to their special characteristics, would not be in position to enjoy the beneficiary but horizontal action of the national R&D programmes, no matter what their strategic importance. The very poor participation of the construction sector verifies the argument. The sector, despite its economic and technological importance, has been practically omitted from the national R&D programmes and has missed the opportunity to develop R&D activities and capabilities as other sectors have done.

In addition, all the interviewed experts expressed their concern for the total break of communication for technological issues between the construction sector and the Ministry of Development. Apart from two 1994 technology foresight reports dedicated to the sector, there is no GSRT or Ministry of Development division dedicated to the needs and the technologies of the construction sector. According to CONEXP3,4 and 5, even the Ministry of Public Works has insufficient contacts with construction companies and it does not have a specialised agency dedicated to the technological support of construction companies nor with the promotion of the internationalisation of the Greek construction sector. To make things worse, the investment specifications of the development law 1892/90 (see chapter 8) totally ignore the special needs and requirements of the sector and in effect the application of the law excludes the construction sector and its technologies from its funding merits.

According to CONEXP4, this situation has been created because the Greek State sees the construction sector as a labour intensive sector and not as a technology intensive sector and it does not realise its technological potential. Thus, given that the Greek State does not exploit the opportunity to demand the application of new technologies and materials during the implementation of public contracts, the great potential of the sector is wasted, critically affecting the future internationalisation efforts of the sector and its future abilities to compete successfully with international competitors even in domestic markets.

In view of the above, the interviewed construction experts commented on the elements and the need for a national materials (and construction technologies) policy / strategy. Their views are summarised with **Table A9.8**. They particularly focused on the following issues:

	Very Important	Important	Not so important
Identify areas of importance	CON1, 2, 3		
Provide directions	CON1, 3		
Inform for international developments/ information diffusion mechanisms	CONEX1,2,4,5 CON2	CON3	
Support basic research		CON3	
Support applied research	CON3		
Promote industrial networks	CONEXP4,3,5	CONEX1,2	
Initiate University / Industry collaborations		CONEX1,2	
Education / Training (including continuous education)	CONEXP4,6	CON3	
Standards	CON3, CONEXP1,23		
Research networks and institutions		CON3	
Promote international co-operation		CON3	
Procurements	CON1,3		
Tax incentives	CONEXP4, CON2,3		
Construction and trade regulations	CONEX1,2,4,3,5 CON3		
Provide low cost capital for high tech investment	CONEX1,2,4, CON2,3		
Intellectual property protection	CON2	CON3	
Collaboration promotion[21]	CONEX1,2		

Table A9.8: Comments on the need and the elements of a national materials policy / strategy: The construction industry view.

- The first issue to be picked was the identification of priorities and the information on international developments in construction materials technologies. As all experts identified there is absolutely no official information and information diffusion mechanism for new and advanced materials and what they can do.

[21]Legal and institutional framework for collaboration promotion between firms - universities - research institutions.

- The second issue is the issue of regulations and standards. According to CONEXP3, ELOT (see chapter 8) has done remarkable work in the certification of manufacturing, tangible products and mechanical engineering works. However, in civil engineering works, ELOT's involvement is still inefficient or elementary and standardisation is in its beginning. The weakest point is the certification of quality of works and constructions and this gap is covered for the Athens Underground project by the missions of the CONEXP3 laboratory.
- The third issue concerns the establishment of a national Construction Technologies Institute as an extension and institutionalisation of the CONEXP3 laboratory which many companies would be willing to support (even financially) and the final most common issue picked up by the construction companies is the provision of low cost capital for high technology investments.

Financing R&D and Technological Innovation

The provision of low cost capital for high technology investments has been picked invariably by all the reviewed sectors. In the construction sector, those vigorously supporting the concept are the large specialised construction companies. So far, all the research activities of the reviewed companies have been exclusively financed through corporate resources apart from the sparse cases of participation in national / international R&D programmes). These expenditures are invariably seen as strategic investment and therefore they are constantly monitored and evaluated.

This is not the case, however, with the majority of the Greek construction sector. Most companies see investments in technology as "necessary evil" and they invest only when they have reached a critical point (CONEXP4,6). When they do so, they invest under the concept of the "net present value" rule, and always with respect to the needs of each individual project (CONEXP1,2,3). Given the past and present operational conditions of the sector, this investment attitude is justified. In the face of increasing international competitions however, the "net present value" attitude can have limited returns (see chapter 4 and 6).

Interactions with banks and financial markets. Venture Capital companies "don't even know the construction sector". The banking sector on the other hand has a strong interest to be involved with the construction sector but according to the interviewed experts they do not exhibit any understanding for the special needs and characteristics of the sector[22]. Moreover, there is a climate of distrust between the two sectors because the banking sector did not support construction companies when they needed them the most. As such, the construction sector is not supported by the banking sector which creates additional problems to the development of long-term business strategies based upon long-term technology strategies.

[22] CON1: " Banks do not take risks and they do not differentiate between sectors"; CON2: " so far we have avoided the need for financial investors..." ; CON3: ".. the only thing banks examine is your credibility and your pay-back ability". These lines were verified by the banking sector : see section 8.6.

Annex 10.1: The first three EU Framework Programmes: A brief overview.

The *first Framework Programme* (1984-1987) gave priority to the improvement of the technological competitiveness of European industry by making the first attempt to identify fields of technological priority crucial for long-term competitiveness. Information technologies, materials technologies and biotechnologies were identified as top priorities and special actions were tailored in support of these technological groups (e.g. RACE for Information Technologies and BRITE for materials). The first Framework programme absorbed 2 billion ECUs or approximately, 2.6% of the EU budget.

The *second Framework Programme* (1987-1991) coincided with the signing of the European Union Act (1987) which enabled the EU, through basic or pre-competitive R&D programmes, to develop a coherent basis of R&D actions for supporting the competitiveness of EU industry. As such, the second Framework Programme was designed to support the competitiveness of European technology primarily against the challenges posed by the USA and Japan. It included 32 specialised actions and a budget of 5 billion ECUs. Sixty percent (60%) of the budget was allocated to industrial research and the introduction of new technologies in "traditional" industrial sectors such as automotive industries, basic metallurgy, commodities manufacturing etc. Significant attention was given to environmental technologies, materials technologies and biotechnologies.

The *third Framework Programme* (1990-1994) deliberately overlapped with the last two years of the second Framework Programme and, in parallel with the support of the international competitiveness of EU industry, placing particular emphasis on:

- The increase of the competitiveness of the European industry in the face of strong international competition, particularly in strategic sectors of advanced technology;
- The strengthening of European economic and social cohesion consistent with the pursuit of scientific and technological excellence.

A number of additional strategic aims complemented the overall objectives of the programme:

- Increase SME's involvement in advanced technologies and manufacturing,
- Encourage diversity and training of human resources,

- Increase the social consideration of the impact of new technologies,
- Diffuse and exploit the results of the individual projects.

In addition, the programme introduced the elements of flexible design of actions and of effective monitoring and supervision of the supported R&D actives. The third framework programme had a budget of 5.7 billion ECUs and in 1994 was followed by the fourth Framework Programme (1994-1998) - the current framework programme - with a 5 year duration and a budget of 12.3 billion ECUs.

Annex 10.2: The CRAFT and COST collaborative programmes

The CRAFT programme: Co-operative research "CRAFT" is designed to provide enterprises, especially SMEs not having their own research facilities, with the possibility to *contract* outside research institutes (or other undertakings in the form of research outsourcing) to carry out research on their behalf. Co-operative research Projects resemble a typical "multi-client" activity.

The COST programme: For the last 20 years there are European concerted materials actions in the framework of COST. The flexibility in selecting appropriate topics of scientific and industrial relevance and the inclusion of research laboratories in mid and eastern European non-member states make COST *materials actions* still very attractive besides the EUREKA initiative and the Brite-Euram programmes. Metal alloys development and design and processing of components stood in the foreground of COST materials actions in the past. The Technical Committee on Materials discussed and prepared in the last three years the implementation of several new COST Materials Actions setting priorities on the basis of a dialogue with experts from industry. These new actions include as well ceramics, polymers, composites and surface modified materials. Thus, they will contribute to all the important industrial key technologies i.e. information technologies, communications, energy, environmental, medicine and biotechnologies. By proper co-ordination of the current and proposed COST Materials Actions and by taking synergism with complimentary activities within the framework of CEC program and Eureka initiative into account, the competitiveness of European industry is expected to be strengthened.