TECHNION — ISRAEL INSTITUTE OF TECHNOLOGY
THE S. NEAMAN INSTITUTE
FOR ADVANCED STUDIES IN SCIENCE & TECHNOLOGY

הטכניון - מכון טכנולוגי לישראל
מוסד שמואל נאמן
למחקר מתקדם במדע ובטכנולוגיה

The Chemical Industry 2000

Phase B

Potential for future growth

By
Ephraim Kehat
and
Reuven Wachs

With support from

The Ministry of Industry and Trade, Chemicals and Mineral Administration
The Manufacturers Association of Israel, Chemicals and Pharmaceuticals Div.

November 1994

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1. New directions and strategies of the chemical industry

1.1 Introduction

By an analysis of performance data for the past two decades of the Western chemical industry, we have shown in the report on part A of this study (68) that the chemical industry has been stagnating in the past decade. This was caused by a structural stagnation typical of a mature industry with slowly growing markets. The few companies that continued steady growth, had a good mix of products and a continuing presence in emerging markets.

The chemical industry in some developing countries, particularly in the Far East has grown more rapidly than the chemical industry in Western countries, due to expanding local markets, and no commitments to old technologies and equipment.

The growth of the chemical industry in Israel was intermediate between that of the Western countries and that of the Far East. However, the added value of the chemical industry in Israel is relatively low, due to a low degree of vertical integration.

The total sales of the chemical industry in Israel in 1992 were over $4 billions of which over $2 billions was exported, This amounted to a little over 20% of the Israeli industrial exports (excluding diamonds) (68). The total sales of the chemical industry in Israel in 1993 were $4.85 billions of which $2.2 were exported. The chemical industry in 1993 was comprised of 120 manufacturers, employing 21,800 people (127). The productivity per worker was about $ 222,500, more than for most Hi Tech industries.

The main internal markets for locally produced chemicals were : Energy, drugs, industrial (mainly intermediates for other chemical producers), agricultural, building and plastics. However, 50% of the exports go into the agricultural markets and another 27% into the intermediates and energy markets, with considerable sensitivity to fluctuations in these markets.

This report of part B of this study will try to propose strategies for the further development of the Israeli chemical industry.

1.2 New directions of the U.S. chemical industry

Due to the globalization of the chemical industry, and to the more available information on the strategies of the U.S. chemical industry, the U.S. chemical industry will serve here as an example of the international chemical industry.

The MIT commission on Industrial productivity (67) described the transformation of the U.S. chemicals industry in the 80s, as follows:

Over the last century, the major driving force behind the industry's phenomenal growth has been a steady stream of technological innovations, encompassing the introduction of both new products and new process technologies.

The growth slowed by lessening opportunities for materials substitution in various end markets, structural changes in key consumer industries, rising competition from abroad, higher energy prices, lower productivity, decline in R&D intensity, sharp fluctuations in foreign exchange rates, growing overcapacity in commodity chemicals, and the growing array of environmental, health and safety regulations.

Industry's response was to shed off excess capacity, by shutting down, trading plants, or selling plants, the withdrawal from a strong position in the European chemical industry (while the non-US industry now controls more than 25% of the U.S. chemical industry), active diversification into specialty chemicals, pharmaceuticals, biotechnology, advanced materials, reduction in manpower

However, after a short optimistic interlude at the end of the 80s, the chemical industry in general failed to recognize that the hallmarks of today's global economic environment are diversity and change - and sometimes uncertainty and chaos. (R.J. Mahoney, chairman and CEO of Monsanto (2)).

F.P. Popoff, chairman and CEO of Dow, reviewed some of the mistakes made by the chemical industry (2): "The industry has long been guilty of operating with a market share mentality, investing in capacity expansions in advance of demand. We spend without any real attention to marketing fundamentals, exacerbating the ups and downs of a cycle, rather than trying to shave the peaks and fill in the valleys, we swing ourselves through these gargantuan cycles. This habit jeopardizes, among other things, the globalization that is essential to the chemical business. If you are at the bottom of a cycle, it is hard to be forward thinking in doing what is right in a global context. You tend to cut your losses and do things as you have traditionally done them because there is less risk and there is perhaps more short-term reward. I think economic volatility pulls your horizon closer, while success, profitability, and prosperity allow you to make the longer term investments that are fundamental to a global business."

The unprecedented challenges facing the chemical industry include (3) intensified international competition, escalating customer expectations, maturing markets, growing requirements for environmental stewardship and social responsibility, and potential costs of universal health coverage.

The approaches used by chemical companies to improve the bottom line, as detailed in part A of this study (68) were: Cost cutting, staff reductions, divestitures, leveraged buy-outs, mergers and acquisitions, strengthening existing production, move into higher added-value products, foreign trade and production, diversification, demerger, and reengineering.

The divestitures employed by American Cyanamid, Ethyl and Eastman Kodak (4) were to spin off chemical units and to focus on what they think they do best: drugs, petroleum additives, and imaging products respectively.

Middle management people in chemical companies were subjected to a multitude of new 3 or 4 letter subjects, invented by business schools, such as : BMK, BPS, CFM, D&RA, HPWS, IWCT, PACE, MST, QFD, SCM, SDP, SVP, TQM, etc., in the futile hope that new management approaches would help managers control operations and reduce costs.

National commissions were set up to study and make recommendations.

The office of science and technology at the U.S. White House has identified 22 national critical technologies (6). These technologies fall into 6 broad areas, of which 4 are relevant to the chemical industry:

1. Materials with properties that promise significant improvements in the performance of items produced and used by virtually every sector of the economy. (Such as electronic and photonic materials, ceramics, and composites.)

2. Manufacturing processes and technologies that can provide the basis for industry to bring a stream of innovative, cost-competitive, high - quality products into the marketplace.

3. Biotechnology and Life Sciences advances that will permit unconventional approaches to major problems in such diverse fields as medicine, agriculture, manufacturing, and the environment.

4. Energy and Environment related technologies which have the potential to provide a safe, secure, and enduring sources of energy and ensure that a healthy environment is preserved for the use of future generations.

The U.S. National Academy of Engineering has come up with a new technology policy for national economic performance (7), which is summarized in Appendix I of this report.

The new White House policy unveiled recently (11) is:

A. **Declarations**:

1. Basic research is a national need.

2. The work of the scientific community must be more clearly relevant to human concerns.

3. The community should think in more creative multimedia ways of popularizing science.

B. **Specific policies**:

1. Review of Federal research programs to ensure that they relate adequately to national needs.

2. Raising combined public-private R&D spending from 2.6% of the GNP to 3%.

3. Stronger emphasis on multinational funding of large scale scientific projects.

4. Increase private sector involvement in improving academic research facilities and instrumentation.

5. Renewed emphasis on the already strong efforts to develop scientists and engineers among minority groups.

6. Making permanent the tax credit for research and experimentation in industry.

The American Chemical community realized that this policy may kill many sacred cows and rushed to put forward its own recommendations (12), which are summarized in Appendix II of this report.

The chemical industry, in general, is aware of the need for new strategies in order to provide business value and gain or maintain a market leadership position, such as (1):

1. Build core competencies that result in unanticipated products to satisfy real customer needs. These competencies must be built with more speed and agility than do competitors.

2. Invent and reinvent. Continually look for ways to breath new life and functionality into existing products, even in supposedly mature products.

3. Keep an open mind, not blind faith in past practices.

4. Support continued learning and reward people for building core competencies. A company's ability to improve existing skills and learn new ones before the competition is the most defensible competitive advantage of all.

5. Seek new opportunities. Real strategists won't look for a niche within an existing industry space. Instead, they will try to create a totally new space, not one yet filled

> by other players, that is uniquely suited to their core competencies, and provides value to the company and to its customer base.

Dow's chief suggests (2) that to compete, chemical companies need to seek out the location of the least expensive raw materials. They need to make the intermediates and the products where there is talented labor and proximity to markets, and to carry out technical service as close to the customer as possible. Companies have to look beyond their own internal goals and objectives. The industry should not ignore the external issues, such as competitiveness, trade, education, environment, technology, and corporate credibility that will determine the future performance. Industries need to grow in order to survive but development should not come at the expense of environment destruction.

Air Products (8) has shifted their strategic planning from business as usual to what are they doing to promote profitable growth. They are successful with products that apply proprietary technology. In many instances, their technological advantages do not come from basic scientific discoveries or strong patent positions, but from applied engineering that develops incremental advantages that can be moved quickly into the marketplace. They prefer products that are conducive to systems selling. They help customers improve their quality and productivity, and give them advantages that they can take into their markets.

A more international view was suggested by Porter (69): When firms from different nations form alliances, those firms based on nations which support true competitive advantage eventually emerge as the unambiguous leaders.

Competitive advantage is created and sustained through a highly localized process. Differences in national economic structures, values, cultures, institutions, and histories contribute profoundly to competitive success.

The main competitive forces are: The threat of new entrants, the threat of substitute products or services, the bargaining power of suppliers, the bargaining power of buyers and the rivalry among the existing competitors.

There are two basic types of competitive advantages:

1. Lower cost: The ability of the firm to design, produce and market a comparable product more efficiently than its competitors.
2. Differentiation: The ability to provide unique and superior value to the buyer in terms of product quality, special features, or after sale service.

An important variable in positioning is competitive scope. A firm must choose the range of product varieties it will produce, the distribution channels it will employ, the types of buyers it will serve, the geographic areas in which it will sell, and the array of related industries in which it will also compete.

Innovations shift competitive advantages, Such innovations may be : New technologies, anticipating new or shifted buyer needs, perceiving the emergence of a new industrial segment, using a shift in input costs, or raw materials, energy or transportation availability, and adjusting to new government regulations.

In a recent interview during a visit to Israel Porter added (70): "The basis of national competitiveness nowadays is not local raw materials, number of workers, exchange rates or interest rates, but the ability of its business segment to innovate, to improve, to be efficient, to develop knowhow, and to utilize any knowhow.

The government should invest in education and infrastructure, to set standards for quality and for the environment, to encourage R&D by tax reductions, to subsidize the professional training of workers in industry, to be a wise, quality demanding, and leading buyer of local products and services, to legislate against and fight monopolies, and to help develop clusters with competitive advantages."

None of these concepts is new, and most firms are cognizant of their effectiveness, and pay lip service to them.

What has happened to innovations in the chemical industry? Ralph Landau summarized the number of major postwar commercial chemical developments (66):

In the 50s - 9.
In the 60s - 14.
In the 70s - 13.

In the 80s - 3.

Other estimates (9) were that the number of major product innovations declined from a peak of 22 in the decade of the 1940 to only two in the seventies (and the eighties).

The most important development in the chemical industry in the past decade is the production of polyolefins by metallocene single site catalysis. The products can have a narrow molecular weight distribution, and also makes possible control of long chain branching. Perhaps the invention of superabsorbent polyacrylate polymers can also be counted as a major development.

It has been suggested that the decline in major inventions a function of cost (10). The development of nylon cost $10 millions (1939 dollars), whereas the development of Kevlar by, the same company, cost $500 millions (in 1971 dollars).

1.3 Potential for growth of the Israeli chemical industry

Table 1 presents overall views of the economies and chemical production and added value for Israel, 5 developed countries and 2 developing countries. Each of the lines "Relative to Israel" was calculated from the line above it.

Table 1: **The national chemical potential in 1992** (68,72)

Country		Israel	USA	Germany	Japan	Netherland	Switzerrland	China	S. Korea
Population	MM	5	250	79	124	15	7	1134	43
GNP	$MMM	51	5445	1411	3141	259	219	416	231
GNP per capita	$MMM	9808	21700	22730	25430	17330	32790	370	5400
Relative to Israel		2.21	2.32	2.59	1.77	3.34	0.04	0.55	
Added value	$MMM	9	1308	427	872	54	57	111	66
Added value/capita	$MMM	1731	5232	5405	7032	3600	8143	98	1535
Relative to Israel			3.02	3.12	4.06	2.08	4.70	0.06	0.89
Chem sales	$MMM	4	288	100	180	24	15	40	20
Chem sales/capita	$MM	769	1152	1266	1452	1600	2143	35	465
Relative to Israel			1.50	1.65	1.89	2.08	2.79	0.05	0.60
Chem added value	$MMM	1	156	56	87	7	9	14	6

Chem a.v./capita	$MM	192	624	709	702	467	1286	12	140
Relative to Israel		3.24	3.69	3.65	2.43	6.69	0.06	0.73	

The comparison with Israel in the four "Relative to Israel" lines indicates that in order to reach the level of the developed countries per capita, the Israel chemical industry should grow by at least 50% and the chemical added value should grow by at least 200%.

The largest Israeli chemical corporation, Israel Chemicals, has announced its plans for the year 2000 to sell $400 millions in pharmaceuticals and $300 millions in advanced materials, which, if successful, would increase its sales by about 50% and its chemical added value by over 100%. Similar quantitative goals should be set by other companies. Achieving such goals requires fast action to take advantage of opportunities.

1.4 Opportunities and advantages

We live in a period of rapid change. The fall of communism has opened up both new markets and new competition. The peace process with our Arab neighbors, and the termination of the Arab boycott will make possible the purchase of knowhow that was previously unavailable to us at a reasonable price.

The traditional sources of competitive advantage, such as technology, capital and information can be obtained by anyone in the open market today.

Competitive advantage today depends (69) on the speed of getting a new or an improved product to market at a competitive price, on the quality of the product and on the speed of response to customers' needs. Customers value product quality and timely delivery.

Specific advantages of the Israeli chemical industry are:

High quality technical manpower.
A national characteristic: The ability to improvise and react quickly.
A growing number of experienced design and construction companies.
Increasing familiarity with the world markets.
Some relaxation of import restrictions in a few important markets.
Available internal and international credit.
Under-utilized research facilities in the country.
Government support of R&D.

Low interest loans and subsidies for plant construction.

Specific disadvantages of the Israeli chemical industry are:

Government control of most of the chemical industry.
Government control of the economy.
Very little R&D by most chemical companies.

These can be overcome.

1.5 New approaches

We do not presume to know better than the management of chemical companies what is the best strategy and direction of growth of their specific companies.

In the above sections we have tried to show the viable strategies used by chemical companies. We have also shown that there is potential for growth on a relative basis, and that there is potential to increase the added value.

In the next three chapters we present 3 groups of potential areas for growth for the Israeli chemical industry:

Families of intermediates
Specialties.
New technologies.

We have attempted to show that opportunities in these areas exist, and it is up to the chemical companies to utilize the opportunities that fit their potential.

2. Identification of promising intermediate families

2.1 Introduction

The most attractive intermediates and chemicals products would be the chemicals with outstanding market growth rate. In order to avoid the cyclic nature of the market of many chemicals, we present here only those products, that have managed in 1993 (which was relatively a poor year for growth of chemical markets) or during the past 10 years, at least a 6% annual growth, in the U.S.

Table 2 shows the annual growth rate of those chemicals that had higher than 6% average growth rate over the past 10 years or in 1993 in the U.S.

Table 2: **The annual growth rate for specific chemicals in the U.S.** (71)

Organic Chemicals	Bisphenol A	Ethanol dichloride	Ethylene	2-Ethyl hexanol	Methanol	MTBE
1992-1993	7	6	18	-1	30	121
1983-93	7	-4	5	6	3	40

Organic Chemicals	Methyl chloride	MEK	Propylene glycol	Toluene	Vinyl acetate
1992-1993	-12	16	74	6	6
1983-93	8	1	6	1	4

Inorganic Chemicals	Ammonium Nitrate	Hydrogen	Nitric Acid	Nitrogen gas	Sodium Silicate
1992-1993	7	11	6	8	8
1983-1993	3	6	2	5	3

Minerals	Lithium
1992-1993	12
1983-1993	2

Plastics	Epoxy	Mela mine	Poly ester	Poly amide	Poly propylene	Polyethy lene HD
1992-1993	12	16	8	15	2	2
1983-1993	4	4	2	9	7	6

Synthetic Rubber	ABS etc.	Ethylene-Propylene
1992-1993	12	10
1983-1993	4	4

Misc.	Household products	Food products
1992-1993	6	8
1983-1993	2	-4

Agro-chemicals	Herbicides	Ammonium Nitrate	Ammonium phosphate
1992-1993	6	9	15
1983-1993	-1	-2	7

Following are some details of eight intermediates and their derivatives, which we have identified as having a good fit with the Israeli chemical industry and with a potential for growth.

These eight intermediate families are synthesis gas, methanol and its derivatives, sulfur derivatives, ethylene and derivatives, propylene and its derivatives, butanes and their derivatives, benzene and its derivatives, xylenes and their derivatives, and chlorine and its derivatives

The recent consolidation of most of the petrochemicals industry in Israel into one group makes possible a faster growth of the petrochemicals industry which involves six of these eight intermediate families.

Table 3 shows the production capacity of 10 commodity intermediates, including many of the intermediates discussed in this chapter, by the producing companies (101-105).

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Table 3

The capacity of selected chemicals in '000 tpy - 1992

	Styrene	MTBE	Ethylene glycol	Acrylonitrile	Acrylic acid	Terephth. acid	Titanium dioxide	Acetic acid	Butadiene	Methanol
Air Products										225
Amoco						3035			75	
Asahi				260	18					
Ashland										475
BASF	550			220	682			40	180	240
Bayer							125		120	
Beaumont										1000
Borden										840
BP	275			500				450		
Buna	100		654						120	
Cape Horn										750
China-American						1100				
Cytec				160						
Dow									170	
DSM				170					110	
DuPont				170		590	840			
Eastman						250		545		200
Elf					220				110	
EniChem	60			180		90		70	365	
Enron										450
Erdol			150	280					250	
Exxon		40							375	
Formosa					55			150		
Fortier										570
Georgia Gulf										500
Hankook							36			
Hoechst			100	100	170			1240		2000
Huels	300	150			60			40		
ICI			85			550				500
Idemitsu					50					
Intercontinental						200				
Ishihara							200			
Kemira							280			
Kerr-McGee							100			
Kronos							401			
Leuna										650
Lindsey		100								
Lucky					65					
Lyondell									295	800
Methanor										760
Mitsubishi				115	110	870				
Mitsui				60		550				
Mizushima						155				
Monsanto				225						
Nanjing				170		450				
Naphtachimie									70	
Nippon Shokubai					150					
Nitto				90				380		
Novacor										900
Oita					60					
OMW/DEA		80							47	
Oxychem									165	
PCK				70						
Pemex				150					83	
Pequiven										1440
Pertamina						225				
Petkim						70				
Petrocel						440				
Quantum								410		725
Quantum										
Reliance Ind.						230				
Rhone-Poulenc							125	470		
Rohm and Haas					275					
ROW	420									200
Sachtleben							80			
Samnam						280	55			
Samsung						610		150		
Saudi Methanol										2070
SCM							450			
Shanghai						260				
Shell									200	
Showa Denko				50				260		
Sterling				330				275		
Sumitomo				50	48					
Sunkyong						250				
Texaco									270	
Texaco Olefins									508	
Ti-West							54			
Tioxide							484			
Toray						170				
Union Carbide					85			165		
Total	1705	370	989	2920	1915	9945	2692	3945	2735	15295
	partial	partial	partial							partial
Price $ per ton				625	1600	600	1750	450	300	400
Total value $ bill.				2	3	6	5.5	2	1	8

2.2 Specific intermediates families

2.2.1 Synthesis gas, methanol and its derivatives (73-77).

The production of some of these compounds in Israel is based on relatively expensive naphtha reforming. However, if natural gas from Egypt, or the Gulf states becomes available at competitive prices, derivatives based on synthesis gas will be competitive in the world markets.

The world production of methanol in 1993 was over 21.5 million tons, with high capacity utilization of the plants due to the sharp increased demand for MTBE, which may soon pass the production capacity of formaldehyde and acetic acid, the current main derivatives of methanol.

Methanol and MTBE are produced in Israel, mainly for local consumption, but acetic acid is not produced. The bottleneck for more MTBE production in Israel is the limited availability of butylene and not of methanol. However, for a large MTBE plant there will be justification to produce butylene from butane.

Acetic acid is attractive as an intermediate, since it can lead to families of derivatives.

A complex of such intermediates was studied recently by a company in Israel, with reasonable preliminary results. The complex was based on the following items:

15,000 tpy polyvinyl acetate
5,000 tpy polyvinyl alcohol
2,500 tpy polyvinyl butyral
1,250 tpy ethyl acetate
10,000 tpy cellulose acetate

Additional derivatives of acetic acid include:

Chloroacetic acids
Acetyl chloride
Amino acids (by fermentation)
Acetic and acetoacetic esters
Sodium and ammonium acetate
Cellulose propionate and acetate-butyrate
Carboxymethyl cellulose

Acetamide and dimethylacetamide (DMAC)
Salicylic acid

An important outlet for acetic acid is for the production of terephthalic acid (TPA), where it serves as a liquid-phase oxidation solvent.

Other compounds based on CO and methanol include formic acid and its derivatives, formamid and dimethyl formamide. Formic acid is used in the metal, textile and leather industries. Formamide is an important intermediate, made from CO and ammonia. It is used for the production of cyanides, imidazols, triazins and pyrimidine, and also as a solvent for spinning various polymer fibers.

Dimethylformamide is produced from CO and dimethylamine. It is a versatile apriotic solvent used in textiles, polymers casting, aromatic extraction, solvent for gases and electrolytes in galvanization baths, paint remover and cleaner. Its major use is as solvent for acrylic fibers and polyurethanes. The world market in early eighties for dimethylformamide was about 250,000 tpy (73).

2.2.2 Sulfur Derivatives (95)

The leaders in this market are still companies that have developed the process technology. For example, BASF, the developer of the vanadium catalyst for the contact process, is a major producer of sophisticated organic sulfur products, such as 4-amino sulfanilanilide or 3-amino-2-hydroxy-5-nitrobenzenesulfonic acid.

Sulfuric acid production, which represents 75% of the sulfur used by the chemical industry, is dominated by the fertilizer industry.

The availability of sulfur in Israel as a by-product of the refineries or as imported on a large scale by the fertilizer industry presents an opportunity to produce sulfur derivatives.

In the world, only 3 - 5% of the sulfur compounds (by weight) is consumed by the dyes and pigments industry, but these represent sales of sophisticated products with a total products value value close to that of the much larger fertilizer industry.

As an illustration of what a single company can achieve in this area, we can take the Swiss company Saurefabrik Schweizerhall palette of sulfur products:

Inorganics:

- Thionyl chloride
- Sulfuryl chloride
- Chlorosulfonic acid
- Sulfur dioxide
- Oleum
- Sodium hydrogen sulfite

Organics

- Dimethyl sulfate
- Toluenesulfonic acid methyl ester
- 3-Chloro-4-methyl-benzenesulfonyl chloride
- N,N-Dimethylethylamine sulfur trioxide complex
- Pyridine sulfur trioxide complex
- N,N-Dimethylthiocarbamoyl chloride
- 2-Aminoethyl-2-hydroxyethyl sulfide

Another example is the range of fine sulfur chemicals produced in Japan by Sumitomo Seika:

- Thiols
- Thiophenol
- Thioanisole
- Tribromomethyl phenyl sulfone
- Diphenyl sulfide
- Diphenyl disulfide
- p-tert-Butylthiophenol
- 4-Chlorothiophenol
- Thiodiphenols
- 4,4-Thiodiphenol
- Bis (4-hydroxy-3-methylphenyl)sulfide
- Thiophenes
- 2,5-Bis(5-tert-butyl-2-benzoxazolyl)thiophene

Aliphatic sulfur compounds
Methyl mercaptan
2-(Methylsulfonyl)ethanol
Sulfolane
3-Sulfolene

2.2.3 Ethylene and derivatives (71,86,87)

The major derivatives of ethylene, polyethylene and ethylene dichloride, are manufactured in Israel. The production of the third important derivative, ethylene oxide, accounting in the U.S. for about 15% of the ethylene demand, is rather stagnant, due to the decrease in demand of its main downstream product, ethylene glycol antifreeze. Ethylene glycol may be of interest only if a large plant for the production of polyethylene terephthalate is considered. Ethyl benzene is discussed in the section on benzene derivatives.

Ethylene dibromide was an important commodity chemical produced in Israel till the ban on its use due to its carcinogenous properties closed its markets.

There could be a commercial opportunity to build. next to the ethylene plant, plants for a few of the smaller scale derivatives of ethylene, such as:

Vinyl acetate	2 % of world ethylene demand
Ethylene-propylene rubber	1 % of world ethylene demand

The derivatives of vinyl acetate are polyvinyl acetate, polyvinylbutyral, and polyvinyl alcohol.

Ethylene-propylene rubber is used mostly for automotive applications, wire and cable jacketing, and impact modifiers for plastics.

Although considered a mature product, ethylene-propylene rubber has grown fast last year (Table 2.)

Smaller scale derivatives of ethylene are:

Ethylenediamine	used for fungicides and as a chelating agent.
Ethyl and vinyl toluene	used for unsaturated polyesters.
Ethyl anilines	used for dyes, pharmaceuticals, and pesticides.
1,4-hexadiene	used for ethylene-propylene terpolymers.
Aluminum alkyls	used for initiators and catalysts.
Ethyl amines	used for rubber chemicals and as inhibitor.
Ethyl ether	used for pharmaceuticals and as a solvent.
Propionaldehyde	used for cellulose plastics or as grain preservatives.
Propionic acid	used for cellulose plastics or as grain preservatives.

2.2.4 Propylene and its derivatives (88-91)

Currently, all the propylene production in Israel, is dedicated to polypropylene production, and if more propylene were available, it would probably be used for the same purpose.

In the leading industrialized countries 50 to 60% of the propylene is used for acrylonitrile, propylene oxide and propylene glycol, cumene (leading to phenol and acetone), isopropanol, oxo alcohols and acrylic acid.

Acrylonitrile production is driven mainly by the textile and polymer industries. Propylene glycol and phenol are used for thermosetting resins (which are produced in Israel). The other ethylene derivatives products are intermediates, directed to different branches of chemical industry.

The most promising propylene derivative is acrylic acid. It has one of the highest growth rates, both in the West and in the East, and continued to grow about 7% a year for several decades. Water based acrylates are replacing other solvent based esters. The high water absorbing polyacrylates for diapers are one of the best inventions of the past decade.

Acrylic acid is produced currently by oxidation of propylene in two stages, with acrolein, the allyl aldehyde, as an intermediate. Each stage employs a different catalyst and with different operating conditions.

The U.S. market for acrylic acid represents today about 40% of the global capacity, its development over last three decades is shown in table 4.

Table 4: **The development of the U.S. market and price for acrylic acid.**

year		1963	1973	1983	1993
market	M tons	11	60	333	600
price	$/ton	880	528	1300	1600

Due to its attractive market, overcapacity in production facilities for acrylic acid followed and is predicted to persist till 1996.

The production of acrylic acid and its derivatives is limited to a very few countries, probably because of the need for integration. Most major producers of acrylic acid and its derivatives in the Western hemisphere such as BASF, Hoechst-Celanese, Elf-Atochem, and Rohm & Haas have their own in-house propylene.

In Israel the top level - propylene. and the bottom levels - diaper production, and acrylic coatings exist. It may be worthwhile to fill the intermediate stages.

2.2.5 Butanes and their derivatives (80,87 106-108).

The C4 stream in refineries is composed of butanes, butenes and butadiene. Each of these species can be converted to the other if market and economic conditions justify it.

Butane is used as a fuel for homes, and occasionally, as a feedstock for synthesis gas. The main chemical use of butane used to be dehydrogenation to butadiene. However butadiene obtained as a by-product of olefins production has replaced most of the demand for dehydrogenation. Liquid phase oxidation of butane to acetic acid is still used in a few old plants.

An important use of butane is for the vapor phase oxidation to maleic anhydride and maleic acid, which has replaced the older route, using benzene as the raw material. A plant for

10,000 tpy of maleic acid was planned in Israel, but was not built.

The isomers of butene are: 1-butene, cis-2-butene, trans-2-butene, and Isobutylene (2-methyl propene). The most important derivative of butenes and the fastest growing is MTBE from isobutylene and methanol. MTBE is also manufactured in Israel, but its production is limited by the current availability of isobutylene.

The most important derivatives of mixed butenes are: sec-butyl alcohol, which is easily converted to methyl-ethyl ketone (MEK), butyl elastomers (including butyl rubber) and polybutenes. Minor derivatives are: Butylated phenols and cresols (antioxidants), Tert-butylamine, tert-butyl alcohol, tert-butyl mercaptan, di- and tri-isobutylaluminums, butylene oxide, p-tert-butyltoluene, pivalic acid and methallyl chloride.

Most of the demand for butadiene (85% in 1986) was for synthetic rubber. The global synthetic resin capacity was 9.5 million tons in 1993, The distribution of the synthetic rubber production is shown in Table 5.

Table 5: **Synthetic rubbers production in percent of the market share in 1993**

Styrene-butadiene	57
Polybutadiene	16
Butyl-polyisoprene	9
Ethylene-propylene	9
Nitrile	5
Polychloroprene	4

Butadiene is a component of 73% of the market for synthetic rubber. Synthetic rubber takes 60% of the total market for rubber.

The main non-rubber use of butadiene is for adiponitrile, which in turn is used for the production of hexamethylenediamine, one of the two precursors of nylon 6,6. Adipic acid, the second precursor of nylon 6,6 can also be made from adiponitrile, although this route is rarely used currently. Adiponitrile can also be made from acrylonitrile (A Monsanto process).

A new process for butadiene to vinyl cyclohexene to styrene has been piloted by Dow, and will soon be offered for licensing.

A plant for maleic anhydride, maleic, malic and fumaric acids, is a good fit with the current petrochemical industry in Israel. Increasing isobutylene and MTBE production are inevitable. MEK production may also be attractive. If the capacity of cracking to olefins is increased, there will be an economic justification to separate the butadiene (Currently it is hydrogenized), and use it for downstream products, such as Nylon 6,6.

2.2.6 Benzene and its derivatives (71, 78-80)

Heavy downstream demand for styrene and other derivatives and supply problems upstream have recently driven benzene prices up by over 10%. The supply situation of benzene was always associated with the demand for aromatics for the gasoline pool and to the most recent estimates of its toxicity. World capacity production location is shifting. Asia/Pacific accounts for 24% of the world production capacity, about the same as for Western Europe. The main recent capacity increases have been in Korea, Taiwan, Thailand and Singapore.

The present distribution of the 1993 total world production of 22.7 million tons of benzene is shown in Table 6.

Table 6: **The distribution of the world production of benzene by markets.**

Product	Market Share (%)	Used for
Ethylbenzene	53	styrene, polystyrene, ABS, SAN, rubbers.
Cumene	17	phenol, phenolic resins, acetone.
Cyclohexane	15	caprolactam, nylon 6.
Nitrobenzenes	5	aniline, dyes, drugs.
Alkyl benzene	4	detergents.
Chlorobenzenes	2	dyes, solvents, pesticides.
Maleic anhydride	1	polyesters, alkyd resins.

The best fit with the current Israeli chemical industry would be cumene, cyclohexane and chlorine derivatives.

Phenol and acetone can be produced from cumene. Phenol is used in Israel with formaldehyde and melamine for phenolic plastics. Phenol and acetone are used for the production of bisphenol A, for which the demand in Israel has risen. It leads to epichlorhydrine and to fast growing epoxy resins.

Cyclohexane, is used to produce caprolactam, a precursor of Nylon 6.

Chlorobenzene derivatives include:

Chloronitrobenzenes	Intermediates for dyes and herbicides.
3,4 dichloroaniline	Intermediates for dyes and herbicides.
Dichlorobenzenes	Intermediates and disinfectants.
Trichlorobenzenes	Dye carrier.
1,2,4,5-Tetrachlorobenzene	Intermediates, bactericides.

2.2.7 Xylenes and their derivatives (80, 92-94)

The fast growth rate of the demand for saturated polyesters in the Far East caused an acceleration of all the production chain of p-xylene to terephthalic acid to saturated polyesters. 68% of all the world demand for the terephthalic acid are concentrated in the Far East and while the average world growth rate is about 7%, it is higher in Asia. The annual growth rate of p-xylene is 5.5%, the highest of all common monomers. Since only 45% of the world p-xylene production is in the Far East, significant amounts are imported.

Gadot Petrochemicals (Now Gadiv) produces about 60,000 tpy of xylenes, but only 15,000 tpy of o-xylene is converted to chemical products (mainly phthalic anhydride). The remainder is exported.

The production of terephthalic acid with polyethylene terephthalate was considered in Israel several times but was rejected, mainly because of the consideration of inadequate supply of raw materials.

A terephthalates plant will require large quantities of acetic acid as solvent and can motivate a decision to produce acetic acid.

2.2.8 Chlorine and its derivatives (81-84)

Despite recent attacks on chlorine by environmentalists, its global production continued to grow.

The main demand is in the following markets:

Polyvinyl chloride.
Pulp and paper bleaching.
Water treatment.
Chlorinated solvents.
As a synthesis and oxidation intermediate.
Production of bromine.

Table 7 shows the main chlorine derivatives, the production capacity for many of the derivatives in the U.S. and in Japan, and which derivative is manufactured in Israel.

Table 7 : **The production of chlorine and its derivatives in the U.S.,Japan and Israel.**

	Chlorine derivatives in thousand tons/year		Produced in Israel
	USA 1992	Japan 1993	
Chlorine gas	5000	4000	+
Allyl chloride			
Amyl chloride			
Carbon tetrachloride	180	45	
Chlorinated isocyanurates			
Chloroanilines			
Chloroantraquinone			
Chlorofluoro hydrocarbons			
Chloroform	230		
Chloroprene		70	
Chlorosulfonic acid			
Dichloropropane			

Dichloropropenes			
Epichlorhydrine		100	
Ethyl chloride	50		
Ethylene dichloride	7000	2300	+
Methyl chloride	390	110	
Methyl chloroform	320		
Methylene chloride	160	90	
Methallyl chloride			
Perchloroethylene	110	45	
Phosgene			+
Trichloroethane		40	
Trichloroethylene		50	
Aluminum chloride		60	
Antimony pentachloride			
Antimony trichloride			
Arsenic trichloride			
Bismuth trichloride			
Chlorine trifluoride			
Ferric chloride			
Hydrochloric acid	1300	700	+
Hypochlorous acid			+
Iodine trichloride			
Iodine monochloride			
Mercuric chloride			
Mercurous chloride			
Molybdenum pentachloride			
Phosphorus oxychloride			
Phosphorus pentachloride			
Phosphorus trichloride		15	
Sodium chlorate	250	30	+
Sodium chlorite		3	
Stannous chloride			
Sulfur dichloride			
Sulfur monochloride			
Sulfuryl chloride			
Titanium dioxide		570	
Titanium trichloride			
Silicon tetrachloride			
Zinc chloride		12	

Ethylene dichloride is by far the dominant intermediate produced from chlorine, leading to PVC. The growth rate of the use of this polymer in developing countries is high.

Due to environmental pressure, a shift has begun from the use of chlorine for bleaching and water treatment to chlorine dioxide, changing little the overall demand, with minor use of hydrogen peroxide as a more environmental benign chemical.

In Israel, three companies erected, in the early fifties, chlorine plants dedicated to the production of bromine, EDC and DDT respectively. The first two have been expanded and modernized and still serve their original purpose. The new magnesium plant, under construction at the Dead Sea, will more than double the current production of chlorine.

There is a good technological base to expand the chlorine chemistry to more sophisticated intermediates and to reach the downstream consumers. This has been done to some extent in the field of pesticides, but not in other potential areas, such as pharmaceuticals, polymers (other than PVC), ceramic and electronic chemicals, metallurgy, paints, etc.

The only outlet large enough for the potential excess chlorine is titanium chloride/ titanium dioxide. If the HCl byproduct could be used in Israel for phosphoric acid production, a process in which Israel is the world leader, a world scale titanium dioxide plant can be competitive.

Of the organic chlorine derivatives, the more promising intermediates are those used as polymer intermediates, such as epichlorhydrine, and chlorinated isocyanurates, and also silicon tetrachloride, and perhaps chloroprene.

The production capacity of sodium chlorite, which was considered in Israel by two companies is increasing in the world, and sodium chlorite is another prospective derivative.

3. Specialties

3.1 Introduction

Specialties represent low volume, high value-added products for pharmaceutical, foods, processing semiconductors or treating cooling water and a variety of other markets (46,47). Moving into this niche requires a highly responsive research staff. Company strength should be in marketing rather than in production. Strategic business units best suited for specialties are small, entrepreneurial, and market oriented. Large firms moving into specialties had to decentralize at least part of their hierarchy in order to succeed in this business. Profits may be substantial, but so are the risks.

True specialties make up only one sixth of the world market for industrial chemicals (47) - far too little to accommodate all the would be entrants. Advanced companies are therefore moving beyond chemicals into specialty materials, into instruments, complete systems of product plus equipment, and fabricated products and even services.

The downstream era will require a new breed of chemists and chemical engineers. They will have a broader view of science and technology than their predecessors and wider interests. There will be fewer specialists and more generalists, preferably with interdisciplanry experience (47).

The term differentiated products is occasionally used instead of specialties. Differentiated products are defined as (45):

1. Generally impossible to characterize by chemical formulas, or a statement of chemical content or origin alone.

2. Produced with real differences between suppliers, or marketed with imputed differences, such as the supplier's' reputation.

3. Often used only in a few applications.

4. Sold to performance specifications for what they do.

Regardless of the product line, the characteristics of the chemical specialties company are (43):

Hundreds of products - each with its own basket of different ingredients, each sold on the basis of performance rather than on formula or physical characteristics.

A myriad of low volume applications, sometimes called niches, that change as the customer's technology and manufacturing process changes. Product life cycle are less than five years.

High dependence on the relationship between sales staff and customer, and high reliance on speed and flexibility to satisfy customer problems.

Another view of the characteristics of specialized chemicals companies is (44):

Dominant companies but not in the public, anti-big-business eye.

Outward-looking and customer-need-oriented, enabling these firms to be in tune with the times.

Low capital investment.

Low factory labor cost.

Chemicals' cost is a small percentage of end system cost.

Multifunctional (flexible) manufacturing facilities - usually batch type.

Concentration on one type of product or market, allowing top management to have an intimate knowledge of its business.

Cumbersome EPA and TOSCA regulations which make it more difficult for smaller competitors and often poses product opportunity.

A specialty chemicals business must invest in technology, in people and in time (42)." Only when we understand our customers' business as well or better than they do are we likely to succeed. Developing a successful specialty chemicals business comes at a cost. We largely forego economics of scale, and the skilled, dedicated people needed to understand the markets in depth and to service our customers are expensive."

Sartomer Co, a unit of ARCO Chemical Co, in west Chester, Pa, is an example of a small company with a highly specialized line of chemicals (41). It manufactures functional acrylic monomers and oligomers which are used to modify formulas in coatings and other products which utilize polymeric components. Their line has 300 items, and some may be produced in as many as 30 different grades according to the end use. the grades can vary in purity and in the amount of inhibitor present. When Sartomer is presented with a new set of specs by a customer, it often produces a customized specialty and supplies it so rapidly that the customer, unaware of the research involved in filling his order thinks that he is purchasing off the shelf.

Potentially new products beyond conventional chemicals are (9):

Agriculture and food: Animal growth hormones, Food preservation, Integrated pest management services, Seeds and cloned plants.

Ceramics: Advanced glasses, High temperature fibers, Magnetic materials, optical fibers, piezo- and ferro-electrics, sensors, shock resistant structural parts.

Composites: Carbon-polymer, ceramic-ceramic. ceramic-metal, metal-polymer. Electronics: Electrochromics, liquid crystals, light emitting diodes, plasma systems, injection molded circuit boards, photovoltaics materials, radiation shielding, non-silicon substrates.

Energy production and storage: Advanced batteries, fuel cells, hydrogen production from water, imaging materials, solar energy materials, superconductors.

Health care: Artificial blood, artificial organs, medical and diagnostic instruments, prostheses, tissue culture processes.

Metals: Amorphous, clad, magnetic, superconducting, memory alloy.

Military and space: Composites and advanced materials, radiation resistant materials, stealth materials.

Surface modification: Intercalation, Ion implantation, stealth coating, synthetic diamond coating, vapor deposition.

Miscellaneous: Artificial intelligence systems, biosensors, toxic waste management.

Fast growing specialties are (38) electronic chemicals and diagnostic aids, reprographic chemicals, plastic additives and high performance adhesives. Electronic chemicals generally are specified in ultra high purities and require close coordination with the customers.

Analyst Enrico T. Polastro of ADL Brussels estimates the value of worldwide fine chemical sales in the range of $26 billions to $34 billions (40). This includes bulk active ingredients as well as intermediates for end uses such as drugs and pesticides.

Table 8 shows a summary of the estimated markets for a number of specialties of interest, and table 9 shows the 1993 sales of specialties in the U.S.

Table 8: **Estimated markets for a number of specialties**

Subject	Market	Year	$MMM	Ref.
Biochemicals	World	1992	5.9	(36)
Catalysts	U.S.	1985	0.995	(55)
Catalysts	U.S.	1990	1.12	(55)
Catalysts	U.S.	1990	2.11	(57)
Catalysts	World	1990	5.984	(57)
Catalysts	World	1993	8	(58)
Catalysts	World	1994	5.5	(59)
Catalyst	World	1994	7.9	(60)
Catalysts	World	1995	7.888	(57)
Catalysts	World	1998	10.7	(58)
Controlled Release Fertilizers	U.S.	1990	0.175	(39)
Custom Mfg	World	1993	26-34	(63)

Drugs	World	1993	15-17	(40)
Environment	World	1990	200	(28)
Environment	World	1991	270	(27)
Environment	World	1995	300	(26)
Environment	World	1996	399	(27)
Environment	World	2000	300	(28)
Fine Chemicals	World	1993	26-34	(40)
Flavors	World	1993	4	(65)
Fragnaces	World	1993	5	(65)
Membranes	World	1991	2	(51)
Superconductors	World	1992	1.5	(29)
Superconductors	World	1993	1.5	(28)
Superconductors	World	2000	8-12	(28)
Superconductors	World	2010	60-90	(28)
Superconductors	World	2020	150	(29)
Superconductors	World	2020	150-200	(28)

Table 9: **The U.S. sales of specialty chemicals** (116).

Category	1993 sales $MM	Profitability	Projected annual growth %
Pesticides	6,200	Average	2
Industrial coatings	5,780	Average	3
Industrial cleaners	5,300	Average	2
Electronic chemicals	4,700	High	7
Plastics additives	2,900	Average	5
Food additives	2,840	Average	5
Water management	1,900	High	5
Adhesives	1,800	High	7
Catalysts	1,800	Average	3
Flavors & fragrances	1,750	High	5
Photographic chemicals	1,500	High	6
Lubricants	1,300	High	8
Dyes	1,200	Low	4
Pigments	1,200	Average	3
Biocides	800	Average	4
Oil-field chemicals	800	Average	4
Paper additives	700	Average	4
Specialty surfactants	600	Average	5
Total	66,695		6

In Israel several companies have long term experience with specialties. Some, such as the pesticides manufacturers have been active in the international market. However, pesticides, herbicides and fungicides are expected to grow slowly (37). A few Israeli companies, such as paints and detergent manufacturers, have been producing mainly for the local market. Many young chemical companies in Israel have started in the specialty markets. In the next sections we would like to highlight a few specialty areas that have potential for the Israeli chemical industry.

3.2 Promising specialty families

3.2.1 Flame retardants (114,115)

Flame retardants are plastic additives. Plastic additives have a $10 billion world market (including about $3 billion in the U.S.). Half of that market is bulk additives, such as PVC plasticizers and stabilizers, mineral fillers, etc. The rest are true specialties.

The U.S. plastic additives market, excluding fillers, in 1993, is shown in table 10.

Table 10: **The major U.S. plastic additives markets in 1993** (in $MM) (109-111)

Type of additive	Value $MM
Specialty flame retardants	350
Lubricants	290
Specialty plasticizers	270
Reactive additives	190
Antioxidants	145
Mold-release agents	90
Ultraviolet stabilizers	55
Coupling agents	45
Antistats	25
Antifogs	7
Compatibilizers	6
Antimicrobials	5
Total	1,478

Flame retardants, obviously, are the most important group.

Flame retardants can be classified as halogen-based, phosphorus-based, and inorganic chemicals. Halogen-based bromine products and aluminum hydroxide have the largest shares in terms of quantity. The major bromine- based products by volume are tetrabromobisphenol-A (TBBA), decabromodiphenyl oxide (DBDPO) and TBA epoxy oligomer-polymer. In 1992 the DBDPO retardant was attacked on environmental grounds in Europe, and the demand for low toxicity flame retardants has expanded. Alternative candidates for DBDPO are brominated epoxies, TBA epoxy oligomer-polymer, TBA polycarbonate oligomer, etc.

Contradictory opinions about the safety of brominated flame retardants were voiced by Lonza and by Ethyl Corp. Lonza started in 1992 a facility in Austria to produce a new magnesium hydroxide product called Magnifin (112). Its flame-retarding reaction is based on the endothermic decomposition to oxides and water, supposedly without any corrosive or toxic by-products. Two of Israel Chemicals' subsidiaries, Dead Sea Periclase and Bromine Compounds, will jointly build a plant producing flame retardants based on magnesium hydroxide (113).

Bromine Compounds also made a deal with Great Lakes Corp. for joint production of TBBA, currently produced by both companies (111).

EniChem is close to introducing a new glycol terephthalo phosphinic copolymer, and DuPont's subsidiary M-Cap is developing microencapsulated formulations.

Bromine Compounds, which has been active in this field for many years, can become a world leader in flame retardants if it pursues an aggressive R&D operation in this field.

3.2.2 Catalysts

Most catalysts can be considered as specialty inorganic chemicals.

It was estimated (61) that in the U.S. the total value of products requiring catalysis in their manufacture is about $900 billions per year. (About 17% of the GNP), of which the chemical and the refining industries produce about $150 billion of goods.

The global catalyst market is estimated at \$5.5-\$7.9 billion (59,60), and is expected to reach \$10.7 billion by 1998 (58).

Currently (58) the main catalyst markets are: \$3 billion for chemical processes, of which the 1994 polymerization catalyst market was estimated (85) at \$1.15 billion, \$3 billion for environment and \$1.9 billion for refining. The fastest expected growth is for the environment market.

The highest value catalysts are a variety of zeolite based catalysts for FCC. (57) The major producers are: Davison Chemicals (40% market share), Akzo, Engelhard and Katalystics.

Estimates of sales of catalysts are occasionally correct. U.S. sales of process catalysts, used in refineries and chemical processes, reached 4.86 billions lb in 1985, valued at \$955 millions, and was expected in 1986 to reach \$1.12 billion in 1990 (55). The largest volume was for alkylation (4.265 billions lb in 1985 (mostly acids)) with catalytic cracking at 370 million pounds in second place. The largest values were for catalytic cracking (\$250 million in 1985 and estimates of \$275 millions in 1990, and actual sales of \$280 millions (56)), and alkylation (\$160 million in 1985 and estimates of \$177 million in 1990, but the actual sales in 1990 of sulfuric acid for alkylation reached \$220 millions (56)). Polymerization catalysts were expected to reach \$220 millions in 1990.

The most successful new catalysts are the metallocenes. It is expected that new and expanded uses will be developed for metallocenes (85) and it is estimated that the sales of metallocene based polymers in 2000 will reach \$21.6 billion. Although production costs are the same as for the old technology, Dow plans to sell the new narrow size distribution polyolefins at 2-3 times the price of the current products (54).

Another conventional new process is the manufacture of tert-butyl alcohol by a one step hydration of isobutene in mixed butenes, using the heteropoly acid H3PMo12O40 as the catalyst (61)

Microbial enzymes are suggested as important future catalysts, but the only commercial process developed so far is for acrylamide (61). Recently (53) biocatalysis has produced commercial qualities of muconic acid for \$3-5 \$/lb vers \$30/gram in lab quantities by chemical synthesis.

The demand for higher product yields, waste minimization, and environmentally safe raw materials and intermediates (53) is prompting research to develop new routes to old chemicals, but catalyst research and development is not keeping pace with the needs of industrial production, environmental protection, and social demands (61).

It is expected that customer linked commercialization is the key change in catalysts in the 90s (58)

There is a need for new catalysts for emissions from lean-burn gasoline engines, for odor control of living space,for catalyst that can withstand sulfur in refinery operations, for catalysts for intense hydrocracking, for catalysts that can be regenerated, for oxidizing SO2 to SO3 at lower temperatures (and more favorable thermodynamic equilibrium) that in use today, for reducing NOx to N2 in cars exhaust, for the direct oxidation of benzene to phenol, for coupling acetic acid and ethane to make vinyl acetate (61).

Catalysts have been developed in Israel in universities, by Israel Chemicals, and by Makhteshim, but only the latter has used Israeli developed catalysts. The largest quantitative demand for a catalyst is for FCC cracking catalysts by the refineries.

A catalyst manufacturer in Israel should start by producing conventional catalysts, such as cracking or oxidation catalysts for the local market, and continue with a few new proprietary catalysts after tests of their use by prospective clients. Quality assurance and close contact with customers are prerequisites for this business.

3.2.3 Food additives

Food additives suffer less than other specialties from cycles in demand, but are more sensitive to government regulations, and require Good Manufacturing Practice in order to market them world wide.

Tables 11-13 show the food additives markets in the U.S. by category, by specific chemicals and by targets.

Table 11: **Sales of food additives in the U.S. in 1990** (117,118)..

Category	1990 $MM	1995 forecast $MM	Projected growth %
Sweeteners	1000	1310	5.5
Thickeners	884	1100	4.5
Flavors/enhancers	600	785	5.5
Emulsifiers	460	515	2.3
Acidulants	246	287	3.1
Colors	220	272	4.3
Vitamins/nutrients	157	177	2.4
Enzymes	143	169	3.4
Preservatives	83	92	2.1
Other	500	585	3.2
Total	4317	5319	4.3

The worldwide market for fragnaces in 1993 was estimated at $4 billions and at $5 billions for flavors. The growth rate is estimated at 3-5% for fragnaces and slightly higher for flavors (65).

Table 12: **Sales of specific food additives in the U.S. in 1990** (117,118).

Product	Sales $MM	Function
Aspartame	750	Sweetener
Vanillin	160	Flavoring
Citric acid	160	Acidulant
Monosodium glutamate	75	Enhancer
Xanthan gum	50	Thickener
Sorbates	55	Preservative
Carrageenan	45	Thickener
Caramel	40	Colorant
Total	1335	

Table 13: **Sales of food additives by market in the U.S. in 1989** (117,118).

Food additives market	sales 1989 $MM	projected sales 1994 $MM	change 89 - 94 %
Soft drinks	728	1170	10.0
Sauces, dressings	432	675	9.3
Meat, seafood	330	455	6.6
Dairy products	285	415	7.8
Baked goods	273	395	7.7
Frozen foods	148	220	8.3
Grain mill products	108	150	6.8
Alcoholic drinks	53	70	5.7
Other	206	350	11.2
Total	2563	3900	8.8

Significantly most food additives are projected to have a high growth rate, soft drinks are the largest target market for food additives, and sweeteners, particularly aspartame have the greatest sales.

The Israeli chemical industry has long been active in the food additives market, from natural raw materials and by synthesis. It has the potential to increase greatly its activity in this field.

3.2.4 Advanced ceramics

The world production of ceramics in 1991 is estimated at $15.3 billions, of which the U.S. and Japan each account for about a quarter (21)

The more pedestrian uses of engineering ceramics grew from $350 million in 1975 (1983 dollars) to more than $1 billion in 1983 in the U.S. (23).

The world market for advanced materials was estimated in 1986 (24) to include $5.1 billions for ceramics.

The advanced ceramic structural ceramics market in the U.S. was estimated in 1987 at $171 millions, and was expected to grow to $1.16 billion in 1995 and $2.6 billion in 2000 (22). The specific markets in order of size are: Automotive/heat engines, wear parts, Aerospace, Cutting tools, bearings, heat exchangers and bioceramics (21).

New advanced structural ceramics, ceramic coatings, electronic ceramics provide high performance under extreme mechanical, electrical or environmental conditions (24):

The demand for new materials follows closely the advance of technologies in areas such as machinery, plant equipment, transportation, and aerospace (19).

The development of new materials and technologies such as amorphous metals, metallic alloys, diamond films, photovoltaics, rechargeable batteries, high temperature superconductors, and metal and plastic composites will continue to grow, despite the cutbacks in military spending (19).

The most common monolithic advanced structural ceramics are alumina, silicon carbide, silicon nitride and zirconia. Ceramic composites contain fibers that are added to the monolithic ceramics in order to improve toughness. Advanced structural ceramics are currently used for wear parts, cutting tools, bearings, heat exchangers, aerospace applications (21)

The added value in advanced ceramics is high. The main requirement for success in this field are innovation, and understanding the market needs.

Israel is already a leader in high quality periclase, and has considerable research activity in advanced ceramics. The Israeli chemical industry can and should increase its activity in this field.

3.2.5 Advanced polymers

The world market for advanced materials was estimated in 1986 to include $1.2 billion for polymers (24).

The demand for new materials follows closely the advance of technologies and encourages the trend for lighter weight plastic composites (19).

The market growth rate of high performance thermoplastics have slowed due to the decrease in military spending. Civilian customers are not willing to pay as much for slightly improved properties. In order to succeed in this still fast growing market it is necessary to develop low cost production methods of the monomers, and have a critical mass of a portfolio of high performance polymers in order to serve a high variety of customer needs (20). These products include: Liquid crystal polymers (LPCs), Polyamide-imides (PAI), Polyarylates, Polybenzimidazole, Polyetherimide (PEI), Polyethersulfone (PES), Polyimide(PI), Polyketones, Polyphenyl ether (PPE), Polyphenylene sulfide (PPS), Polyphenyl sulfone, Polyphthalamide (PPA), Polysulphone (PS).

The Israeli chemical industry manufactures mainly basic polymers, such as polyethylene, polypropylene, polystyrene, some polyesters and nylon, but has not, so far, gotten into the advanced polymers field. Some research in this field is done at universities. Entrance into this market requires advances in chemistry and understanding the markets, but the return is likely to be high.

3.2.6 Composites

The world market for advanced composites was estimated in 1986 to be $1.7 billion (24).

The worldwide composite use in 1990 is shown in table 14.

Table 14: **The worldwide composite use in 1990.**

Market	$MMM
Aircraft/aerospace	2.3
Industrial	1.0
Recreational	0.6
Total	3.9

The growth rate for the 90s was projected at 10%. The forecast for the total composites market was for $MMM 5.5 in 1995, and $MMM 8.5 for 2000.

Another forecast by the U.S. Department of Commerce (121) projected the total advanced materials at $MMM 400 billion for 2000, without specifying what fraction will be for composites.

The demand for new materials follows closely the advance of technologies in areas such as machinery, plant equipment, transportation, and aerospace. Demand for new materials and technologies is generated by trends that encourage energy conservation and efficiency, more powerful personal computers and workstations with increased portability, higher performing and lighter weight metals, ceramics and plastic composites (19).

New advanced materials that provide high performance under extreme mechanical, electrical or environmental conditions (24) include advanced polymer composites. One definition of polymer composites is: Polymer composites consist of high-strength or high modulus fibers embedded in and bonded to a continuous polymer matrix. Analogous definitions may be made for ceramic and metal composites, and their combinations. The fibers may have a variety of dimensions, geometric arrangements, and continuity, and the matrix may give a verity of mechanical, chemical, optical, electrical etc. properties. The total number of combinations is large, and the complexity of the resultant structures is high (121,122).

The macroscopic arrangements of these materials depend on the microscopic structures and requires consistent methods of preparation. Nanocomposites consist of very small particles of a guest material (nanoclusters having a diameter less than 100 nm) in a host matrix. Their photonic activity may make them suitable for optical computers.(124)

A clear trend in composites is towards a microstructure, in which the reinforcement is not necessarily composed of fibers. Composite structures may enter the molecules. Dendrimers are layered spherical molecules. They are able to change polymer properties and may allow processors to injection-mold plastics, previously limited to thermoforming (123).

In Israel the fiberglass reinforced unsaturated polyesters have been manufactured since the 60s, and polyester resins were produced here for this purpose. The local fiberglass production was only of insulation and not of composite quality. There was no production of more advanced resins, such as epoxy or polyimides. There is no production outside of the armament industry of advanced composites, but some research has been going on for a long time at universities. there is potential here for entry into this field that will develop into a major field in the future.

3.2.7 Drugs

Analyst Enrico T. Polastro of ADL Brussels estimates the value of worldwide chemicals used as drugs at $MMM 15-17 billions (40).

Within the drug market, dollar sales for single enantiomers of chiral drugs are likely to grow at the expense of racemates. In the coming age of managed health care, the big winners will be companies that make chiral drugs and seven days adhesive plastic film patches formulated with single isomers of chiral drugs (126).

The world sales of chiral drugs were estimated at $MMM 35.6 (Table 15), a growth of 22% over 1992, and is expected to grow to over $MMM 40 in 1997.

Table 15: **World sales of enantiopure drugs in 1993** (126).

Type	Sales $MMM
Cardiovascular	11.3
Antibiotics	10.8
Hormones	4.5
Central nervous system	2.0
Anti inflammatory	1.5
Anticancer	1.0
Other	4.5
Total	35.6

There is also a potential for chiral compounds in the food, feed additives and fragnances markets.

A variety of new syntheses of stereospecific compounds have been developed (13,14,126). This field is young and there is lots of room for innovations.

The difference of price for the same chemical between its manufactured cost as a chemical, and its cost as a packaged drug is a factor of 10 to 100.

The Israeli drug industry (Mainly Teva and Taro) has been successful in getting early to the market with generic drugs, and has been not been as successful in the introduction of new drugs. The entry fee for a new drug is too expensive for the Israeli industry, and is best achieved in a partnership with one of the large world companies. The entrance fee for an enantiopure isomer of an existing drug is likely to be cheaper and within the reach of the Israeli chemical industry.

3.2.8 Detergents

The major components of detergents are not the surfactants but the builders. The most cost effective builders are polyphosphates (generally STPP), but their use is being phased out, since they encourage growth of algae and plant growth when they end up in streams and lakes. The common substitutes are zeolites for powdered detergents and citrates. Other substitutes are: carbonate and soluble silicates with polyacrylate dispersants used for liquid detergents. The 1993 world production of STPP is around 2.5 million tons (of which about 420,000 tons in the U.S.). The production of anhydrous zeolites in the U.S. for builder use was about 300,000 tons in 1993 (48).

None of the STPP substitute is even close in cost effectiveness to STPP.

The new popular formulation of detergents is based on alcohol sulfates, and a more efficient zeolite builder that does not require a polycarboxylic acid as a co-builder (49).

Unilever uses a family of organomanganse complexes that catalyze hydrogen peroxide bleaching at about 20 C. These catalysts can be used at low concentrations, as low as 0.1% of the detergent formulation. One of these catalysts, known as Accelerator, is an ingredient of a controversial new detergent formulation, called Persil Power in the UK and Omo Power in the Nederlands. Rival manufacturer Proctor & Gamble charges that the product damages clothes. Unilever has, at least temporarily, modified its formulation (49,50).

If Unilever overcomes the machinations of its rivals, it will revolutionize the detergent industry, since it will make it possible to get good cleaning and bleaching action at low temperatures, and will increase the market for the peroxides that are used in detergent formulations.

In Israel, most of the detergent formulations still use the classic linear sulfonates and polyphosphates. The entry of imported detergents into the Israeli market has so far not awakened the detergent producers to the competition.

The state of flux of the world detergent industry is a good opportunity for new innovated components and formulations to be developed by the Israeli chemical industry.

4. Technologies, systems and services

4.1 Introduction

The boundaries between specialties and chemical technologies are not sharp. However, we have bundled in this chapter, a number of technologies, that in general involve more than one defined market.

Some of these technologies, such as membranes, or superconductors are technologies per se. Some such as ozone or cyanides involve special chemistry.

A few of these technologies are not new, but were chosen because they show great promise today.

A few technologies (cyanides, or phosgene based) may be inherently dangerous, or require special equipment, but usable with the proper know-how. All these technologies demand innovation, special technical expertise and familiarity with their markets.

4.2 Promising technologies

4.2.1 Environment Control

The world environment control industry is estimated at $270 billions in 1991 (27), $300 billion in 1994 (26), and is expected to grow to $399 billions by 1996. Solid waste management is the largest industrial segment and the most mature. Resource recovery and recycling is the second largest industrial segment.

Other estimates of the world market of the environmental control industry are $200 billions in 1990, and $300 billions in 2000 (28).

It is very attractive to the chemical industry that had been a major pollutant, and had and is spending large sums to control pollution and to abate old pollution sites, to be in the business of controlling pollution of any type from any source. The potential market is large and will grow. The technologies are still under development, and it is a proper time for the Israeli chemical industry to utilize its experience and innovation skills and get into this business.

4.2.2 Controlled release

The main thrust of controlled release is for medical purposes. However, there is a growing market for controlled release fertilizers.

The wholesale value of the U.S. controlled release fertilizer was estimated to be $175 millions in 1990. The farm use is for strawberry, citrus, vegetable and melon producers. The cost varies from $250/ton for sulfur coated urea to $1200/ton for polymer coated fertilizers. (compared with $146/ton for non coated urea). Erratic release rates result in plant damage, and product liability risks are considerable (39).

Much research has been conducted in Israel in this field, and some implementations for medical purposes. The Israeli chemical industry, that is strong in the fertilizer market, should also get into more sophisticated controlled release fertilizers.

4.2.3 Superconductors

The global market for high and low temperature superconductors is expected to rise from $1.5 billions in 1992 to $150 billions by 2020 (29).

Another superconductor world market forecast is (28): $MMM 1.5 in 1993, $MMM 8-12 in 2000, $MMM 60-90 in 2010 and $MMM150-200 in 2020.

Chemical compounds supplied to the electronic field are subject to rapid change and market fluctuations, more so than in other industry. They require close cooperation with the electronic industry (30).

Even if the above optimistic market estimates are not achieved, superconductors are going to be an important technology. Much research, some of which is applied research is undertaken in the universities in Israel. The Israeli chemical industry, should get involved.

4.2.4 Membranes

World sales of membrane filters and elements were expected to top $2 billion in 1991 (51). Assymetric membranes for the separation of nitrogen from air are expected to rise fast.

Main uses of membrane technology are (52):

Large scale membrane gas separators are used for hydrogen recovery in petroleum refineries, and for production of carbon dioxide for enhanced oil recovery, and in methanol production and for reverse osmosis and nanofiltration.

Small scale applications are the preservation of food during transportation by nitrogen blanketing, the generation of inert gases for safety purposes, and the dehydration of gases.

For oxygen-nitrogen separation, the membranes of choice are usually from polypyrrolone, polytriazole and polyaniline.

A new promising membrane is a nanoporous carbon membrane that is particularly effective for separating hydrocarbons from hydrogen in low pressure gas streams.

Future membranes include membranes with high selectivity for a given pair of gases, novel new composite membranes, and the ability to alter membrane characteristics after manufacture in order to increase their adaptability.

Some new uses for membranes are: the recovery of chlorinated hydrocarbons (98), the dewatering of azeotropic mixtures by pervaporation (99), and the recovery of VOC from gas streams (100).

In Israel membranes are used for reverse osmosis, and for the electro-chemical production of chlorine and caustic.

Nanofiltration membranes made by a local producer (97) are mostly exported.

The potential of this technology is obvious, and should be targeted by the Israeli chemical industry.

4.2.5 Biotechnology

Biotechnology, the golden promise of the past decade has drawn a great amount of risk funds, and has generated meager profits and great losses.

There are 1050-1100 specialist biotechnology companies worldwide, and another 625-725 with an interest in biotechnology. 12 companies had at least one year profit. There are two companies with overall profitability. World sales of biochemicals equipment and consumables are around $2.0-2.5 billions. World sales of biochemicals have been estimated at $5.9 in 1992. The biotechnology sector employs 70,000-80,000 people. Biotechnology R&D expenditure is estimated as $4.9 billions in 1992 (about the same as the combined R&D of Bayer, Hoechst and Ciba). The current values of sales of biotechnology products in the agriculture market is about $184.5 millions. (36)

In the U.S. the total number of genetically engineered drugs receiving approval by the U.S. FDA in 1982 to 1992 was 17, (3 in 1992). The approved drugs have enjoyed extremely lucrative sales. However, only 3 of the 24 largest biotechnology firms in the U.S. have reported profits in 1992. Agricultural genetically engineering products have had small sales volumes and no profits in 1992 (31). Four of the larger 26 biotechnology companies in the U.S. showed profit in 1993 and three new products received FDA approval (32). Only four of the 20 larger U.S. biotechnology companies showed profit in the first half of 1994 (33).

The most active area, where more profits were anticipated was in drugs and diagnostics. There were more successes in diagnostics than in drugs.

The less exotic plant genetics area is more promising. Genetically engineering of plants to accept genes from certain bacteria in order that the plants may protect themselves against certain insects, which reduces the need for chemical insecticides. Bio-pesticides of interest are non toxic, biodegradable and are effective in killing insect in their immature stage (34). Efforts are underway to create plants that produce their own pesticides, that are more resistant to herbicides and to frost, disease and drought, that contain more starch or a different mix of proteins (35).

The classic biotechnology that has long been part of the chemical and food industries is fermentation. Of the about 200 commercial fermentation products only three (ethanol, mono sodium glutamate and citric acid) can be considered as commodities. Other commodities produced by fermentation in the past, such as glycerol, acetone and butanol, are no longer produced by fermentation. However, antibiotics lead in the value of the products, and the new genetically engineered products lead in unit prices (64). The main changes in this industry are that more antibiotics are produced, and a few genetically engineered RDNA proteins have reached the market. The current research trend is for high value genetically engineered products and not to bulk chemicals (64). Indeed, the past expectations that biotechnology will change the face of the chemical industry have disappeared.

In Israel, there is much academic research and some applied research in all areas of biotechnology. Many small companies were formed, and a few, that have developed new diagnostic tools are expected to grow. The one biotechnological company that was one of the first companies in the world to develop marketable drugs, was taken over by a U.S. company, and stripped of its knowhow.

Genetic engineering of plants and medical sensors are recommended to the Israeli chemical industry. These areas least likely to lead to catastrophic failures, and are assured of good world markets.

4.2.6 Custom manufacture

Large companies do not want to mess around with pesky little chemicals, even when there are market quantities involved, and find an advantage in contracting out the chemical manufacturing, commonly supplying the raw materials and taking the product (62). Smaller companies are more flexible, and have faster start ups. Much of the contracting out crosses borders, since when expensive chemicals are involved, the shipping costs are not a factor.

Consortia of fine chemical firms in the UK, Eastern Europe and former USSR are focusing on obtaining custom processing projects by U.S. firms, particularly in the drug industry. This is particularly useful in cases of in house manufacturing inefficiencies (63). The cost of R&D a new drug is about the same as for a me-too product, which will have greater competition in the market.

One estimate of the worldwide value of custom chemical production is $M12.5 billions. About 600 producers (400 in the U.S.) employ about 45,000 people. Other estimates put the market in the range of $26-34 billions (63).

Israeli chemical companies can, now that the Arab boycott was practically lifted to get into this market.

4.2.7 Ozone

Ozone is expensive, relative to oxygen, as an oxidation agent, but is more powerful, and can lead to products that are more difficult to obtain by conventional oxidation.

As an example of the use of ozone is the generation of an exclusive range of products by the technology developed by Chemie Linz. It is based on the oxidation of a double bond by ozone, with subsequent reduction. This leads to an aldehyde, which may then be converted to acid or alcohol. The versatility of this reaction is remarkable.

The compounds produced by this method in commercial quantities are:
o-Phthalaldehyde
dimethoxytetrafydrofurane
Pyruvic acid methyl ester
Succinic dialdehyde
Phthalazine
Pyruvic acid ethyl ester

All these compounds have commercial applications and ton lots are available.

This was an example of what strength in a particular chemistry can achieve. However, the potential for other interesting oxygenates is good, and should be viewed as such by the Israeli chemical industry.

4.2.8 Halogenation

Israel is a leader in bromine compounds, and Chlorination was discussed in Chapter 2. A field in which Israeli companies have not been active much is fluorides, except for some research on the recovery of HF from the phosphoric acid plants.

The more interesting market for fluoride technology is for non ozone depleting refrigerants, electronic cleaning solutions and fire fighting compounds (Halons).

The development of these new compounds was driven by a rush to replace the old CFCs by HFCs, without too much consideration for the customers.

For instance (25), Allied Signal has started full scale production of its non-ozone-depleting refrigerant, Genetron AZ-50. It is a patented proprietary azeotropic mixture of HFC-125+ HFC-143a, and has been endorsed by refrigeration system makers, compressor manufacturers and valve manufacturers. It is expected to replace R-502 and HCFC-22 in low and medium temperature commercial refrigeration equipment. DuPont's bid for the R-502 market, Suva HP 62 is an non azeotropic blend of HFC-125, 143a and 134a. These new refrigerants require replacements of seals, redesign of compressors, heat exchangers and valves, that make manufacturers of this equipment happy, and leave the customers frustrated.

There is an opportunity for anyone who develops HFC combinations (probably azeotropic mixtures of more than 2 components) that will match closely the properties of existing refrigerants, to obtain a significant advantage over the large companies which have committed large development and construction capital to less favorable compounds.

4.2.9 Cyanide chemistry

The commercial use of cyanides requires careful handling, and considerable safety consciousness. Hydrogen cyanide is a by-product in the production of acrylonitrile, a widespread intermediate, and is used as a reagent by many companies.

As an example of what can be manufactured with hydrogen cyanide is the range of chemicals produced by Hampshire Chemical Corporation, formerly a division of W.R. Grace:

Synthetic amino acids
Nitriles
Amino nitriles
Cyanohydrins
a-Hydroxy acids
Hydantoins

This is another example of what good chemistry plus the technology of handling a dangerous compounds may accomplish.

4.2.10 Supercritical technology

The first commercial uses of the supercritical fluids were in the field of extraction, mainly in the food industry (96). However, supercritical extraction is unlikely to replace ordinary extraction. The advantage of supercritical extraction is the easy separation of the solvent and the low quantities of solvent left in the product, and hence its applications in the food industry.

Recently, promising additional techniques emerged:

Supercritical medium for polymerization.

Supercritical water oxidation replacing incineration (125).

Supercritical reactions such as the supercritical CO2 route to formic acid or the biocatalysis of polyesters in supercritical fluids.

These applications require special equipment and special skills which hardly exist in Israel. Research in the use of supercritical separation techniques had been conducted by the Israeli chemical industry, and some skill in handling has been obtained.

The use of supercritical media for reactions and oxidations should be reviewed by the Israeli chemical industry.

5. Recommendations

5.1 General strategy

As stated in chapter 1, The key terms in all the strategies for success are: innovation, internationalization, efficiency, service, and open minds.

Innovations shift competitive advantages, by developing new technologies, anticipating new or shifted buyer needs, perceiving the emergence of a new industrial segment, using a shift in input costs, or raw materials, energy or transportation availability, and adjusting to new government regulations (69).

Internationalization of the chemical industry is inevitable. The Israeli chemical industry has a number of production facilities and part ownerships abroad, and a few Israeli companies are owned by non Israeli groups. This trend in both directions should be encouraged, when a specific case has an economic or market advantage.

Efficiency requires professionalism of all employees and managers, which in turn require good training facilities.

Service requires good understanding of the markets, and some presence near the clients. However, when a good information highway is developed, some of this presence may be virtual.

Open minds of the leaders of the industry requires a special rare breed of persons that should be selected and developed.

5.2 Specific areas

5.2.1 Adding value to current products

Much of the growth in production and exports of the Israeli chemical industry has been in large quantities, low value, beneficiated raw materials, such as phosphates and potash, and first layer chemicals, such as technical phosphoric acid, fertilizers, distillates and petrochemicals.

The growth of the chemical industry should be directed to higher value chemicals based on the few available raw materials from the Dead Sea, the phosphates field and the small petrochemical industry, and on imported intermediates. This has been the strategy of a few Israeli chemical companies.

Integration downstream, as close as possible to the final customer, has the prospects of highest returns and should be pursued.

5.2.2 Joint ventures and new foreign markets

Joint ventures are becoming very common in the chemical industry, where each partner brings some of the required elements for the venture: Capital, knowhow, skilled designers, experienced operators, environment and market savvy. In the case of a joint venture in another country the local company brings its familiarity with local laws, bribery, getting approvals, subsidies and guarantees.

In tripartite joint ventures, the inputs come from three companies, usually from three different countries, and again, the capital, design, knowhow, and skilled people comes mostly from the non local companies.

Israeli chemical companies can be partners in bipartite or tripartite joint ventures, and can supply knowhow, initial management skills, engineering, training and some of the capital. In the case of implementation in Israel, they can supply all the above mentioned local inputs.

For Eastern block countries, Israel has large numbers of people who speak the local languages, which can expedite communications when a plant is constructed.

5.2.3 Special niches and opportunities.

The Israeli chemical industry has carved for itself a small number of special niches: Potassium nitrate, clean phosphoric acids, bromides, and high quality periclase. Each success carries with it the risk of competition, and of the loss of the dominant position in the niche, if we do not continue to improve the product and give good service to the customers.

The Israeli chemical industry can enter existing niches of specialty chemicals and technology, dominated currently by other countries, if it aggressively pursues R&D in these areas.

Examples of special opportunities that had been pursued by the Israeli chemical industry are the export of distillates by the refineries in the years when the dominant local market was for heavy fuel oil, the use of grain shipping to Israel to carry bulk fertilizers on the return trip, and the use of bulk liquid import ships to export the products of the starting petrochemical industry.

Chemical companies should always be on the look for similar special opportunities.

5.3 National policy and organizations

5.3.1 Introduction

The national goals are not always in line with the goals of an industry. For instance, an important national goal is high employment rate, but an equally important goal of industry is to obtain higher productivity. Both goals will coincide, only if the increased production rate is high.

It is up the government to see that its and industry's goals coincide. In the past the government saw to that by owning most of the chemical industry. Those times have gone, and the government will finish selling off its share in the chemical industry in a few years.

The tendency in Israel used to be government control of every aspect of the economy. This, too, is changing. Here, again, the government can direct industry to national goals by inducements and encouragements and not by rules and controls.

Such inducements should serve national goals of increasing production, exports and jobs. It has been easy to abuse government inducements by unscrupulous people, who used government grants and subsidies to line their own pockets and disappeared, or in rare cases landed in prison.

In no case should the government support a project that will be uneconomical without massive government subsidies. Such projects, such as the Lavie project, or the idealistic sea to sea channel, usually end in uncontrollable losses.

In its eagerness to attract investment the government had the Knesset approve laws that were used for the benefit of single companies, although on occasion other companies found loopholes and took advantage of these laws.

Occasionally a minister decided to give extra large inducement to one company which caused a rush of other companies to request the same benefits.

A few specific recommendations follow:

5.3.2 Indirect support

The direct grants and loans to companies should be eliminated gradually.

Instead the government should support industry indirectly by financing the infrastructure: good roads, railroad lines, communication lines, and services (Water, sewage, electricity) connections to industrial sections.

An emerging important service is the proliferation of databases for every field of endeavor. This service should also be considered as part of the infrastructure to be supported by the government, in order to make available all important technical, patent, and business databases at a reasonable cost to industry, by networking from a central up-to-date and continuously updated repository.

Another important indirect support is for training skilled people at all levels. This can be achieved by government subsidies of good technical schools and technical higher studies, or of students in such schools, that take up a career in industry.

A new popular business in Israel is training courses. An employee receives a special raise every few years if he takes a prescribed number of hours of study of subjects, useful for his/her career. This objective is often abused, by low level courses, and 3 hour sessions that count as 8 hours of study. Industry, that eventually pays the employees, should be involved in seeing that the employee gets real professional benefits from such studies.

Similarly abused is the professional development fund (2.5% of the salary by the employee and up to 7.5% by the employer). A fraction of that sum goes to the union that uses it indiscriminately. An employee in many cases can take a vacation abroad under the guise of technical visits. These funds should be used for the original purpose of professional training.

5.3.3 Direct support

Important direct support employed in many countries, including by Israel, are tax inducements, such as accelerated depreciation and/or income tax in the first years of operation. Such inducements have proved their usefulness for the success of new projects.

Another important direct support is for R&D. It can be in the form of recognition as expenses of R&D supported or run by the company at research institutes or at universities. In Israel, the government supports R&D in established and in young companies by covering part or all of the R&D costs of specific projects. If the project is successful, the company is supposed to pay the government a royalty, and in rare cases, the government receives back its investment in the company R&D. The natural result is an inducement for the companies to request support for the high risk projects and not for the sure things.

This loophole can be closed, if the companies are required to pay the government back a fraction, say 50%, of the government support of unsuccessful projects. This will lead to early elimination of worthless projects, and for developing a growing fund for support of deserving projects.

5.4 Manpower requirements

The key to a successful industry is professionalism at all levels; i.e. highly trained people who know how to perform their jobs well, wish to perform well, and are proud of their contributions to the production. Unlike employees with the only qualifications of belonging to the right party, or having good connections, or as "deserving" persons.

Quantitative assessment of the manpower requirements of the chemical industry are not necessary. The chemical industry is capital and not labor intensive.

In the past, when technical manpower was scarce the industry solved the need by hiring unemployed seamen, with technical experience or by setting up their own technical schools. When chemical engineers were scarce, mechanical engineers were hired and trained on the job. When there was a surplus of chemical engineers some of them were employed as shift foremen. In short, the industry can fill its manpower needs by inducements, training and retraining, and has no need of external support, except for the above recommendations in section 5.3.2.

Appendix I

Summary of the recommendations of the U.S. National Academy of Engineering (7)

The competitive environment for U.S. based companies is being recast by a number of powerful trends:

1. The technical intensity of most manufacturing and service industries will continue to grow at an accelerating pace, and commercial technology will become increasingly science-based and interdisciplinary.

2. National security claims on the U.S. technical base will continue to diminish, and national defense capability will become increasingly dependent on technologies developed and applied first in the commercial sphere.

3. The current revolution in production systems will continue to transform product and service companies and bring a new level of attention to the optimal use of human talents in the workplace.

4. International competition will continue to intensify as world industrial and technological capability becomes increasingly distributed among industrialized nations.

5. Local and regional clusters of industrial activity - and their associated human, material and institutional capabilities - will continue to play a major role in national economic performance and exert a counterprevailing force to rapid internationalization.

6. Internationalization of economic and technological activity will, however, continue, deepening the interdependence of national economies and blurring the distinction between the domestic and foreign policies of nations.

These trends reveal weaknesses in the U.S. technology enterprise that compromise the nation's ability to develop, acquire, and use technology to economic advantage. The most important of these weaknesses are:

1. Outmoded public and private sector management philosophies, organizational frameworks, and human resource strategies.
2. Insufficient investment in, and poor quality of, U.S. workforce training and continued education, particularly at the non supervisory level.
3. Inadequate investment by U.S. based companies in competitive production processes, plant and equipment.
4. Low civilian R&D intensity of U.S. economic activity and insufficient breadth of the nation's civilian R&D portfolio, including underinvestment in growth and productivity enhancing technologies that are high-risk or whose benefits are difficult for individual investors to appropriate.
5. Insufficient awareness of, and interest in, technology originating outside their institutional boundaries on the part of many U.S. companies and federal laboratories.
6. Lack of a strong institutional structure for federal technology policy in support of economic development and the segregation of technological policyfrom domestic and foreign economic policy at the federal level.

Goals and policy recommendations:

Goals:

A. Foster the timely adoption and effective use of commercially valuable technology throughout the U.S. economy.

B. Increase civilian R&D investment in the U.S. economy and close emerging gaps in the nation's civilian technology portfolio.

C. Access and exploit foreign technology and high-tech markets more effectively to advance the interests of U.S. citizens.

D. Create a strong institutional framework for federal technology policy in support of national economic development, and integrate the planning and implementation of federal technology policy with that of national domestic and foreign economic policy.

Specific recommendations (The letter following the recommendation number is the specific goal number:

1(A). Catalyze the development of a dense national network of public and private providers of industrial modernization services that is capable of meeting the diverse needs, including training, of 20-25 percent of the nation's small and medium sized manufacturing companies by the year 2000. Expand the National Institute of Standards and technology's Manufacturing Technology Centers programs and State Technology Extension Program as a first step towards this objective.

2(A). Support experimentation with a wide range of public and private initiatives at the federal, state and local levels to increase the quantity and improve the quality of school-to-work transition programs and of job related training and continuing education for the nation's nonsupervisory work force.

3(a). Establish a high prestige national fellowship program, to be administered by the National Science Foundation, for advanced study of the technical and organizational aspects of manufacturing. Structure then program not only for university graduate students and faculty but also for practitioners from industry.

4(B). Replace the incremental Research and Experimentation (R&E) Tax Credit with a permanent tax credit on the total annual R&D expenditures of a company. Extend the R&E tax credit to cover industry sponsored R&D in universities and other institutions, and the industrial contribution to R&D performed as part of a consortium that involves government laboratories.

5(B). Use public procurement, tax credits, accelerated depreciation schedules, regulation, and other demand oriented policy instruments to pull innovation and increased private sector investments in technologies expected to yield particularly high returns to U.S. society as a whole. These include technologies that produce environmentally benign and energy efficient products and services and technologies that reduce the cost of health care delivery.

6(B). Experiment aggressively with options for direct federal support of the development and diffusion of a broad portfolio of commercially relevant or promising "infrastructural" and "pathbreaking" technologies. rely on industry leadership and involvement in project initiation and design, and on significant private sector cost sharing to ensure commercial relevance. Options include expansion of the Advanced Technology Program and the Small Business Innovation research program, support of additional private sector managed industrial consortia like SEMATECH, creation of an independent federal Civilian Technology Corporation, and expansion of the measurement, standards, and testing activities of the National Institute of standards and technology.

7(C). Stimulate the expansion and institutionalization of U.S. public and private sector capabilities for global technological scanning and benchmarking. Most of these activities should be carried out by industry associations or industrial consortia with some sharing of costs and planning responsibility with federal government agencies.

8(C). Develop a capacity within the federal government for seeding and stimulating international R&D consortia (private sector, public sector, or mixed) in areas of recognized foreign technological strength where gains to US participants are expected to be substantial. This is an important subset of the options for direct federal support of commercially promising "infrastructure" and "pathbreaking" technologies recommended above.

9(C). Improve coordination and cooperation between federal agencies with lead responsibility for science and technology policy by (1) rotating high-quality midlevel staff between these agencies, (2) establishing a technology and trade committee of the federal Coordinating Council for Science, Engineering, and Technology, and (3) making the integration of technology policy with domestic and foreign economic policy an explicit objective of the newly created National economic Council.

10(D). Establish an institutional focus within the federal government to monitor, harness, and supplement the many existing federal programs and capabilities that currently support or could support, more effective development, use, and diffusion of technology throughout the U.S. economy. This institutional focus should work for the early incorporation of technological considerations into the formulation and implementation of U.S. economic policy.

Appendix II

Summary of the ACS Interactive Presidential Colloquium: Shaping the future, The Chemical research Environment in the Next Century (12)

The main recommendations were:

1. Government, industry and university researchers should identify and enhance complementary areas of research to create synergy, to increase the overall productivity and effectiveness of the research enterprise, and to avoid competition for increasingly scarce research support.

2. Mechanisms must be enhanced to achieve personnel exchange among the academic, industrial and government sectors. Transfers, temporary and permanent, between sectors should become the norm.

3. Agreements and contracts defining the terms of alliances must be simplified, streamlined and, to the extent possible, standardized. A time-effective process must be developed to arrive at mutually beneficial agreements for the allocation and utilization of intellectual property resulting from the alliances. The feasibility of umbrella agreements between all government agencies and the other sectors should be examined so that specific agreements can be readily negotiated within the established context.

4. A process must be developed and responsible parties assigned to identify the new products and processes resulting from alliances. The process should include the means to communicate these results to the chemical community, the larger public and the decision makers.

5. A forum should be created to address and resolve issues that may result from alliance activities. Mechanisms should be established to ensure communication of forum issues and their incorporation in subsequent agreements.

6. Graduate programs (in Chemistry) must provide a broader exposure to chemistry and appropriate related subjects, if necessary at the expense of some time in thesis research. More frequent use of the minor in graduate school should be considered, and students should be encouraged to attend courses and seminars outside their immediate specialties.

7. Federal funding agencies should grant more fellowships directly to students, providing some decoupling of financial support from the research process while maintaining the necessary core competencies in specific research areas important to the nation. With limited budgets this change could reduce direct funding of faculty, but should not alter the overall support of departments.

8. Government and industry should fund at a substantially increased level, separately or jointly, positions at universities and industry to facilitate personnel interchanges. Fellowships for senior scholars, internships, and co-op programs are possible mechanisms for such exchanges.

9. All colleges and universities, and especially those heavily involved in research, must rededicate themselves to providing the highest quality educational experience for all students. Chemical science and engineering faculty must be committed to offering outstanding educational opportunities to their students, on par with their commitment to the research and public service functions of higher education institutes.

10. Chemist and chemical engineers must adopt a sense of urgency in responding to the demands of the public and political leaders to refocus our scientific and technical effort on important national problems. It is not appropriate, nor will it be successful, for scientists to claim that their work has no direct relevance to practical ends or that it should not have such relevance.

11. The scientific establishment should recognize and appropriately reward the activities of individual scientists who convey a sense of both the wonder of science and its many contributions to the public welfare. Scientists who by virtue of major accomplishments, special opportunity, or unique gifts of effective communication achieve widespread public acclaim should be valued for their important work.

12. The chemical community must recognize the diverse audience to whom a strong case for the importance of the chemical sciences and technology to modern life must be made. Appropriate strategies and approaches are needed to reach these different segments of the public.

13. The American Chemical Society along with the scientific and engineering community, must redouble its efforts to communicate both the nature and substance of chemical sciences and technology to all sectors of the public, through such mechanisms as the print media, television programs, programs of individual outreach, and "hands-on" experiences such as museum installations. Although the print media are important to the overall success of such efforts, we must explore other avenues to communicate with the public, including computer technologies.

14. The universities working in conjunction with industry, need to determine the type and level of basic knowledge required to advance industrial goals and to establish a mechanism to channel research results to the appropriate parties as quickly and as effectively as possible. Similarly, the university community must help the federal agencies that fund basic research by identifying and specifying the relationship of their research to established national objectives wherever possible.

15. In order to preserve the health of the scientific base that supports the chemical and allied industries and to use that base to expand into new competencies, industry must recruit the best scientific and engineering staffs capable of utilizing the knowledge generated from any sector. In addition, industry must better communicate the value of basic research to its own management and stockholders.

16. The federal government must sustain investment in basic research by its mission-oriented agencies, and preserve the mandate of the National Science Foundation and the National Institute of General Medical Sciences to support fundamental research.

Additional recommendations deal with graduate programs in Chemistry, and the encouragement of minorities.

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