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Characterization and Assessment of Potential European and Japanese Competition in Photovoltaics

Science Applications, Inc.
McLean, Virginia

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A Division of Midwest Research Institute

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MASTER

CHARACTERIZATION AND ASSESSMENT OF POTENTIAL EUROPEAN AND JAPANESE COMPETITION IN PHOTOVOLTAICS

SCIENCE APPLICATIONS, INC.
MCLEAN, VIRGINIA

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FOREWORD

An important influence on the success of U.S. companies in international markets is the strength of foreign competition. This report summarizes the status of the photovoltaic industry in other countries, particularly Japan, Germany, and France. It addresses both technical and market positions of foreign companies in the international market. Foreign governments' support of marketing activities was considered both to determine the relative market positions of U.S. companies and to suggest possible U.S. government programs.

This study was originally prepared to provide information for the International Photovoltaic Program Plan (SERI Task No. 5224). Because of its relevance to those interested in photovoltaics, we are publishing the foreign competition study as a separate report. The efforts of Tom Jaras of Science Applications, Inc. in preparing this report are greatly appreciated.

Approved for:

SOLAR ENERGY RESEARCH INSTITUTE

Dennis Costello, Chief
Economic Analysis Branch

FINAL REPORT

Characterization and Assessment of
Potential European and Japanese Competition
in Photovoltaics

September 1979

Prepared by:

Science Applications, Inc.
8400 Westpark Drive
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PREFACE

This study was performed by Science Applications, Inc. under Contract #8251-1 for the Solar Energy Research Institute, Golden, Colorado. The project was in support of the development of the International Photovoltaic Program Plan for the Department of Energy. Much of the information on Japanese competition was based on previous work performed under subcontract number B56761-A-P to the Pacific Northwest Laboratories for the Office of Conservation and Solar Applications, U.S. Department of Energy. Contributors to this report were Dr. T.M. Knasel, Dr. T. Jaras, Dr. R. Moyle, Ms. P. Parsons and Mr. Robert Rennach. This study represents a three person month effort.

SUMMARY

The objective of this study is an assessment of the potential of European and Japanese firms to produce and market photovoltaic (PV) power systems internationally in competition with firms in the United States. The work was performed by Science Applications, Inc. for the Solar Energy Research Institute in support of the development of the International Photovoltaic Program Plan for the U.S. Department of Energy.

The study consists of three distinct parts: (1) an overview of worldwide export activity which describes the general posture of selected European countries and Japan; (2) an assessment of European competition focusing on Germany, France and the United Kingdom; and (3) an assessment of Japanese competition. This last section on the Japanese competitive position was based on a previous study by Science Applications, Inc. prepared for the Department of Energy, (Export Potential for Photovoltaic Systems, Preliminary Report, April 1979).

The study is limited in scope to an evaluation of existing literature in photovoltaic technology and international marketing trends. Data on specific Japanese and European marketing plans were not available for analysis during the study period. Within this framework, trends in worldwide competition are discussed, drawing as much on historical perspectives in allied fields as on market projections of PV systems. All research was conducted within the United States. Sources of data included published reports in the scientific, trade, and business press, firm's annual reports, telephone interviews with representatives of European and Japanese firms, and a review of the findings of three U.S. groups that

had recently toured Japanese photovoltaic firms. European and Japanese government representatives were also interviewed and government program descriptions evaluated.

Overview of Worldwide Export Activities (Section 2.0)

The approach used to analyze the European marketing position throughout the world involved looking at two levels of competition. First, the world involved was divided into four major regions, Asia, Africa, the Middle East, and Latin America, and the competitors within each region were studied in terms of all imports. With the exception of Australia and New Zealand, the emphasis was on developing countries. This reflects the current view that the most promising applications of photovoltaics are in developing countries, where there is often a strong demand for off-grid electric power.

Within each region, the import markets were analyzed for three product areas: (1) telecommunication equipment - telephone, telegraph equipment, non-broadcast radio and television, data communications equipment, microwave systems, and communications test equipment; (2) electric power equipment - diesel generators and other generation equipment and cables, transformers, and other transmission and distribution equipment, and (3) agricultural equipment. Of the available product areas, these were believed to be most closely related to the photovoltaic power systems markets.

Together the top three European exporters, Germany, United Kingdom and France exported \$241 billion of goods in 1977, which amounted to 35.5% of the exports of all industrialized countries. In 1977 Germany, the world's second largest exporter, totaled \$118 billion in exports.

For the past twenty years, Japan has been one of the leading world exporters. In 1977, Japan exported \$81.125 billion, which was 11.9% of the \$677 billion exported by all industrialized countries. Only two countries, the United States (\$120 billion) and West Germany, exported more than Japan in 1977. France and the United Kingdom were fourth and fifth, respectively. All five of these countries sold more than half of their exports in industrialized countries or oil exporting nations. Of these five countries, Japan had the largest share of exports, 45.1%, to countries outside these two categories. This suggests that all five countries devote roughly the same amount of attention to the same markets.

Japan is successfully exporting to all regions of the world and retains the strongest marketing position in Asia, where it supplies a large fraction of the imports of Australia, New Zealand and Southeast Asia. Although Japan has a special advantage in this region due to its proximity, it faces strong competition from other major exporting nations. The Middle East and Latin America are not Japanese strongholds, but the Japanese provide a significant share of the total imports. Japan is not very active in Africa, particularly Francophone Africa.

Japan is a serious competitor in the markets for telecommunications equipment and electric power equipment worldwide. Japan is often strong in radio and television equipment, but in both product categories, its strength varies considerably from country to country. In both products, Japan usually faces strong competition from the United States and West Germany while France and the United Kingdom provide competition only in select regions. Japan is not prominent in the markets for agricultural equipment with the exception of Asia. However, recent expansion of their market share in

Australia, the Philippines, and Mexico illustrate Japan's ability to move from a relatively minor position to a dominant position very quickly in relevant product lines.

Germany, the most successful European exporter, is not the leading supplier to any of the thirty-three countries examined. However, Germany is among the top three suppliers to twenty-three of those nations, and is frequently the second largest supplier, such as Latin America or North and West Africa. Germany is a strong competitor in the markets for telecommunications equipment and electric power equipment, two of the product markets examined in this study. Germany is particularly successful in selling at least one of these products in countries having subsidiaries of Siemens (the major German electric and electronic equipment firm).

The United Kingdom is a less successful exporter on the world market. Although a strong supplier of imports to former colonies, the United Kingdom is one of the top three suppliers to only eleven of the thirty-three nations studied. The United Kingdom is a major exporter of telecommunications, electric power, and agricultural equipment to Africa, but is much less successful than Germany in selling telecommunications and electric power equipment to other regions of the world.

French exports focus on former colonial areas in North and West Africa. Overall, France is the least important of the three European countries in the other regions of the world. Excluding North and West Africa, France is one of the top three suppliers to only one nation of the thirty-three countries studied. France is rarely a major supplier of any of the three products examined in this study (telecommunications equipment, electric power equipment, and agricultural equipment).

European Competition (Section 3.0)

European competition is addressed in three distinct areas: the characterization of the PV industry, the current and potential marketing activity and the status of PV and related technological developments. In characterizing the PV industry in Europe, the focus is on a description of the firms currently active in photovoltaics. The firms addressed include: AEG Telefunken, Wacker-Chemie GmbH, Philips, RTC, LEP, France-Photon, Photowatt International, Ferranti and Montedison. The European PV industry is comprised of a few large multinational corporations most of which are active in electrical and electronic equipment and telecommunications equipment. A few are major firms with impressive capabilities in silicon materials. All support internal R&D programs.

Also addressed are the recent links between the U.S. photovoltaic industry and European firms particularly the activity with French corporations. Joint ventures with U.S. PV manufacturers provide European firms with advanced PV manufacturing capabilities, a proven PV product, and access to U.S. R&D results. In turn, U.S. manufacturers benefit from capitalization, improved market position and access to European R&D.

Today U.S. manufacturers dominate the world market with European production representing about 18 percent of the world total for 1979. Only Philips is currently a major competitor although Telefunken and Japanese firms could be major competitors in the next few years. The European presence in the world photovoltaics market is closely linked with national government development funding. French development assistance is largely responsible for the attention West Africa is receiving today as a major potential market.

There are about ten companies in Japan which are actively involved in photovoltaic production, or which have the potential, based upon similar product lines, to enter the field quickly. These firms are very large, having annual total sales in the range of 1 to 10 billion dollars. Semiconductor sales and in particular, photovoltaic sales comprised a small fraction of the total sales. This situation appears to be typical of most Japanese PV manufacturers. Extensive exporting of numerous products has allowed the seven major companies combined to establish affiliate companies in 22 countries, subsidiary companies in 9 countries, and branch offices in 51 countries. The sales and distribution networks of these companies are prepared for increased marketing and export of photovoltaic devices.

Total Japanese sales are estimated to range between 30 and 50 KWp in 1978 and maximum Japanese production today is between 40 and 80 KWp. Two general observations can be made; domestic sales are small and depend mainly on government purchases. Secondly, foreign sales are limited and the module prices high. The Japanese domestic market is not impressive. It is expected to develop slowly and perhaps reach 200-400 KWp annual sales in 1985. A small potential market exists because the country has a highly developed central utility grid and few undeveloped regions.

In the area of foreign sales, Japanese export activities can be summed up as exploratory. Japan exports PV systems to a wide range of countries in Africa, South America and Asia. Australia is considered a leading market area. Most U.S. PV companies state that they rarely compete with Japanese products. A partial reason for this is that the world PV market is extremely fragmented today. This is characterized by small volume sales over broad geographical

regions. It is not uncommon to meet a few competitors except where the potential sales are of significant size and frequency.

"Project Sunshine", the broad Japanese government R&D program in solar energy, includes work on photovoltaics; the program emphasis is on cell fabrication techniques, especially those related to mass production. All major cell technologies are represented, including several on edge defined film feed, plasma and chemical vapor thin film deposition, ion beam and conventional epitaxial thin film growth, and polysilicon production.

Photovoltaic R&D outside of "Project Sunshine" is underway at several universities and private companies. This includes work on emerging materials and amorphous silicon. There is little detailed published information available on most of the research efforts, but that which is available indicates that the Japanese are no more than a year or two behind the United States' effort in the areas they actively pursue. The Japanese R&D program allows researchers in Japan to keep abreast of the developments throughout the world, but the limited funding and broad program scope restricts the researchers' role from leading technological developments.

The Japanese R&D effort in photovoltaics reflects an interest to keep up with worldwide technological developments, but little emphasis is placed on market stimulation or systems development specifically for photovoltaics. This posture will allow Japanese industry to exploit breakthrough or technological developments made in photovoltaics, but minimizes the risk involved.

At present, Japan is not a major factor in the photovoltaic power system market; the United States is.

Despite this fact the authors believe that Japanese firms have the potential to capture the major share of the world market in a time frame of about twenty years. This will become true if several assumptions are valid concerning the probability of technical and manufacturing breakthroughs in photovoltaic power, growth of market demand, a determined national push by Japan, and a lack of concerted effort to promote U.S. PV exporters.

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The subject of this study is an assessment of the potential of Japanese and European firms to produce and market photovoltaic (PV) power systems internationally in competition with firms in the United States. To this end a description of Japanese and European firms currently or potentially active in the market, and their business environment is given. Included is a brief review of PV technology and R&D in both Japan and Europe and this is compared with the U.S. R&D activity. Preceding the sections on Europe and Japan is an overview of worldwide report activity which describes the general posture of Europe and Japan in the international market place.

1.1 Purpose and Scope

At present the Department of Energy is actively supporting U.S. firms in the development of photovoltaic power systems. One leading market for this is international sales. This report was written to appraise U.S. decision makers of potential foreign competition in export sales of terrestrial photovoltaic (PV) systems. Of necessity it is limited in scope to an evaluation of readily available literature in photovoltaic technology and international marketing trends. Data on specific European and Japanese marketing plans were not available for analysis during the study period. Moreover, detailed descriptions of national R&D and other related programs were not always available. Within this framework an attempt is made to point out what is currently the situation in the photovoltaic export area based on interviews with representatives of the companies involved and with relevant European government offices.

There are at least two additional areas which could contribute to the study but were not addressed because of the limited scope of this undertaking. They are government development financing programs and the relationship of multinational corporate activities to U.S. exports. Development financing is a common approach today to support the early market penetration of PV products in developing countries. An analysis of the relevant European and Japanese development programs supporting PV sales is a study in its own right and therefore not attempted here. The multinational characteristics of the corporations involved in PV manufacturing and the necessity to eventually manufacture overseas to penetrate foreign markets suggest that a determination of the value of photovoltaics as a U.S. export product cannot be meaningfully addressed here.

1.2 Organization and Approach

The premise of the study is that potential for future competition is based on two sets of factors, technological and economic. The approach involved primarily a review of literature in several key areas with particular reference to Europe and Japan or the U.S. when appropriate. The European and Japanese photovoltaic industries are examined and compared to the U.S. industry. Technological factors as well as economic and institutional factors were examined. These included government sponsored R&D, national export policies, current market activities and corporate strategies. Current knowledge about the semi-conductor industry in Japan was relied upon partially because of the limited information available in the Japanese PV industry.

Sources of data included published reports in the scientific, trade, and business press, firm's annual reports,

telephone interviews with representatives of European and Japanese PV firms and governments, and European and Japanese government program descriptions. The information on market activity was evaluated within the context of the current R&D efforts. The information in the Japanese section was reviewed by an electronics engineer and an economist, both of whom have backgrounds in energy systems. Interpretations of the meaning of the data in terms of long range export potential was based on two major factors. The first involved a net assessment of current Japan and U.S. photovoltaic production. The second reviewed analogous areas of proven export competition. These were examined in a historic context and through a review of the influencing factors that affect exports. These two views were combined to form the study conclusions for the Japan analysis.

Our approach includes several distinct efforts:

- First an overview of European and Japanese world trade is presented with the focus being on developing country imports. The intent is to identify areas of the world where British, French, German and Japanese firms compete most successfully.
- The next section describes and assesses the European PV industry. The private firms active in the European PV industry are briefly described and existing or anticipated corporate links with U.S. PV companies are identified. Then a preliminary analysis is made of the relationship between U.S. and European firms. Today's marketing activity by European firms is discussed in relation to the total world market. Current prices, government marketing activities and philosophical difference between government and industry are discussed. Care is taken to emphasize that the activities being described are part of a transitional market. This point is best emphasized in the next section which addresses the status of European R&D programs. The European R&D efforts are described and then compared with the U.S. program. The above individual descriptions and analysis are integrated and summarized in the conclusions.

- The final section addresses the Japanese PV industry. Included is a characterization of the PV and semiconductor industries in Japan and a description of current markets. A comparison is made between the U.S. and Japanese R&D programs followed by a discussion of the overall Japanese marketing posture in a historic context.

1.3 Key Conclusions

The most important findings of the study are summarized as follows:

- Europe trails behind the U.S. in both technology development and PV product sales. U.S. manufacturers dominate the world market today. The U.S. is also in a lead position in most areas of European R&D activity. The notable exception is the cast ingot polycrystalline effort in Germany.
- European firms are more active in the development of total systems for developing country markets. U.S. manufacturers supply the bulk of the PV cells and modules but European firms are instrumental in developing the markets.
- Europeans view PV systems primarily for developing country markets. French development funding over the last few years is responsible for the current Francophone Africa market activity. Results of this development funding include: broad French corporate interest in PV systems, the rising importance of the African market to PV manufacturers, and increasing joint ventures between U.S. PV manufacturers and French firms to tap this market.
- Europeans are capable of rapidly developing U.S. cell technology "break throughs" but only in select countries where applicable R&D activity exists. In contrast, the U.S. program is broad enough to follow European "break throughs" across the spectrum of PV R&D activities.
- The PV industry is largely comprised of multinational corporations which do not readily fit into the mold of being supportive of national export initiatives. Joint ventures with foreign firms, manufacturing overseas and shared R&D results are realistic business strategies which will become increasingly common as the foreign market develops.

At present Japan is not a major factor in the photovoltaic power system market; the United States is. Despite this fact the authors believe that Japanese firms have the potential to capture the major share of the world market. This will become true if several assumptions are valid concerning the probability of technical and manufacturing breakthroughs in photovoltaic power, growth of market demand, a determined national push by Japan, and a lack of concerted effort to promote U.S. PV exporters. The most likely outcome that can be projected today is that Japan has the potential to capture a significant share of the international photovoltaic power market in about twenty years.

This conclusion is based on the following factors:

- **THE INTERNATIONAL PHOTOVOLTAIC POWER MARKET:** Present R&D in photovoltaic cell technology is directed primarily at lower cost arrays, through many parallel paths. It is necessary for only one of these paths to be fruitful for cell prices to drop dramatically. Most U.S. research is government sponsored, unclassified and available to all firms worldwide. Japan's R&D is adequate to allow their firms to exploit any U.S. breakthrough with minimal time lag even if they produce no independent breakthrough.

Balance of system items, such as cell integration into modules, module and array supports, and power conditioning equipment, represent more difficult areas to reduce costs. Large-scale mass production, reduction of labor content, standardization of units, and related factors all play a role in cost-effectiveness. There is inadequate activity in these balance of system issues at present, but as cell costs decrease attention will be turned to these. They are probably only solvable by practical measures taken under the pressure to reach mass production.

- **RELATIVE CELL MANUFACTURING AND R&D TECHNOLOGY:** Currently Japan's PV industry lags behind that of the United States; substantially in accumulated cell volume, and slightly in cell technology and R&D scope and expenditure. Based on a review of the technical literature, the United States has most of the records for technology milestones; such as highest demonstrated photovoltaic cell efficiency (approximately 27 percent for two-color cells) and highest efficiency for flat panel production cells (approximately 13 percent). The U.S. leads in production volume and is the leader in all major areas of photovoltaic power research; exploring many options as to substrate material, cell configuration (e.g., concentrating or flat plate), and a balance of systems aspects. The U.S. is engaged in a large unique demonstration program for photovoltaic power. While current PV production is fragmented and not automated, the U.S. production base in semiconductors is at least twice the size of the next largest country (Japan). Further, the U.S. leads or is competitive in all aspects of semiconductor production including: design and construction of automated production lines, diffusion and ion implantation, plasma and chemical vapor deposition, lithography, and test and inspection devices. On the other hand Japan has taken the lead from the U.S. in electronics production, for example in color and black and white television, CB radio, and audio equipment. Japan is beginning to challenge the U.S. in computer production.
- **THE JAPANESE MARKETING POTENTIAL:** The Japanese marketing potential in worldwide sales of photovoltaic power exceeds that of the United States. Japan has a well integrated field marketing capability and in addition offshore manufacturing capability in many countries. This organization is experienced with the sales of high technology products; skilled in adapting to local conditions; and often employs local labor in manufacturing and assembly activities. Sales are often conducted on a government-to-government basis with a package of benefits to the client country concerning establishment of indigenous manufacturing capabilities. This network is especially strong in Third World countries where electric power costs are often higher by an order of magnitude than in the U.S. These countries have been identified as a prime near-term market for photovoltaic power and Japan has proven capability of successfully marketing other products in these countries.

Japan has been able historically to penetrate markets in advanced countries with low cost - high quality products - even when there is a strongly entrenched domestic manufacturing capability. Witness the sales of Japanese autos and microwave ovens in the United States.

- **GOVERNMENT INCENTIVES:** U.S. Government incentives directed specifically to photovoltaic manufacturers are superior to those offered to Japanese firms considering R&D funding and government purchase policies. However, Japanese Government incentives to manufacturers in general are superior to those available to U.S. firms. This conclusion is drawn from a net assessment of government R&D policy, tax and energy policy, export and trade incentives, and antitrust and tax provisions of law. While the amount of photovoltaic related R&D performed in the U.S. is clearly superior, the one way flow of ideas does much to neutralize any advantage the U.S. may have obtained through R&D results. Japanese tax and export policy favors firms that increase international sales. Japanese firms are allowed to price export goods below cost and/or domestic price. Trade groupings, both domestic and export, are a carry over from pre-war Japan and expedite sales. Japan encourages exportation of finished goods as a matter of government policy to compensate in the balance of trade for its vast import requirements for raw material. United States incentives for export are sizable, but fragmented when compared with the Japanese incentives. These include trade missions and shows, and assistance by trade representations in the U.S. embassies abroad. Foreign sales of defense related materials may be used also in this regard. As members of CoCom the U.S. does not restrict export of key manufacturing equipment to Japan.

2.0 OVERVIEW OF WORLDWIDE EXPORT ACTIVITIES

2.1 Overview and Findings

The purpose of this section is to provide an overview of the marketing position of the top three European exporters, Germany, United Kingdom, and France, and Japan in select regions of the world. Together these three European countries exported \$241 billion of goods in 1977, which amounted to 35.5% of the exports of all industrialized countries. In 1977 Germany, the world's second largest exporter, totalled \$118 billion in exports.

For the past twenty years, Japan has been one of the leading world exporters. In 1977, Japan exported \$81.125 billion, which was 11.9% of the \$677 billion exported by all industrialized countries. Only two countries, the United States (120 billion) and West Germany exported more than Japan in 1977. France and the United Kingdom were fourth and fifth, respectively. All five of these countries sold more than half of their exports to industrialized countries or oil exporting nations. Of these five countries, Japan had the largest share of exports, 45.1%, to countries outside these two categories. This suggests that all five countries devote roughly the same amount of attention to the same markets.

A summary of this overview of worldwide marketing position is as follows:

- Japan is successfully exporting to all regions of the world. Japan's strongest marketing position is in Asia, where it supplies a large fraction of the imports of Australia, New Zealand and Southeast Asia. Although Japan has a special advantage in this region due to its proximity, it faces strong competition from other major exporting nations. The

Middle East and Latin America are not Japanese strongholds, but the Japanese provide a significant share of the total imports. Japan is not very active in Africa, particularly Francophone Africa.

- Japan is a serious competitor in the markets for telecommunications equipment and electric power equipment worldwide. Japan is often strong in radio and television equipment, but in both product categories, its strength varies considerably from country to country. In both products, Japan usually faces strong competition from the United States and West Germany. France and the United Kingdom provide competition in certain regions of the world. Japan is not prominent in the markets for agricultural equipment with the exception of Asia.
- Recent expansion of their market share in Australia, Phillippines, and Mexico illustrate Japan's ability to move from a relatively minor position to a dominant position very quickly in relevant product lines.
- Germany, the most successful European exporter, is not the leading supplier to any of the thirty-three countries examined. However, Germany is among the top three suppliers to twenty-three of those nations, and is frequently the second largest supplier in regions where imports are dominated by one country, such as Latin America or North and West Africa. Germany is a strong competitor in the markets for telecommunications equipment and electric power equipment, two of the product markets examined in this study. Germany is particularly successful in selling at least one of these products in countries having subsidiaries of Siemens (the major German electric and electronic equipment firm).
- The United Kingdom is a less successful exporter on the world market. Although a strong supplier of imports to former colonies, the UK is one of the top three suppliers to only eleven of the thirty-three nations studied. The UK is a major exporter of telecommunications, electric power, and agricultural equipment to Africa, but is much less successful than Germany in selling telecommunications and electric power equipment to other regions of the world.
- French exports focus on former colonial areas in North and West Africa. Overall, France is the least important of the three European countries in the other regions of the world. Excluding North and

West Africa, France is one of the top three suppliers to only one nation of the thirty-three countries studied. France is rarely a major supplier of any of the three products examined in this study (telecommunications equipment, electric power equipment and agricultural equipment).

2.2 Approach

To analyze the European and Japanese marketing position throughout the world it is necessary to go beyond these aggregate statistics. The approach used involved looking at two levels of competition. First, the world was divided into four major regions, Asia, Africa, the Middle East, and Latin America, and the competitors within each region were studied in terms of all imports. With the exception of Australia and New Zealand, the emphasis was on developing countries. This reflects the current view that the most promising applications of photovoltaics are in developing countries, where there is often a strong demand for off-grid electric power.

Asia contains three subregions, Australia and New Zealand, Southeast Asia, and the Indian subcontinent. Africa is separated into African countries with a strong French presence and all others. Figure 2-1 lists the countries selected as being representative of each region. The countries were chosen on the basis of the availability of market data and their import market size.

Within each region, the import markets were analyzed for three product areas: 1) telecommunication equipment - telephone, telegraph equipment, non-broadcast and broadcast radio and television, data communications equipment, microwave systems, and communications test equipment; 2) electric power equipment - diesel generators and other generation equipment

and cables, transformers, and other transmission and distribution equipment, and 3) agricultural equipment. Of the available product areas, these were believed to be most closely related to the photovoltaic power systems markets.

ASIA	MIDDLE EAST	LATIN AMERICA	AFRICA
Indonesia	Saudi Arabia	Mexico	Algeria
Malaysia	Israel	Brazil	Morocco
Singapore	Iraq	Colombia	Tunisia
Thailand	Egypt	Venezuela	Ivory Coast
South Korea		Argentina	Gabon
Phillipines		Chile	Cameroon
Taiwan			Sudan
China, mainland			Kenya
Australia			Nigeria
New Zealand			Zaire
India			South Africa

Figure 2-1 Regions and Countries Addressed in Defining Worldwide Marketing Positions

The information was obtained from four sources:

1) Department of Commerce marketing reports on each country. Each report describes the economy, trade regulation and importing procedures in that country; 2) global market studies on communication equipment and electric energy systems, 3) analyses of the best prospects for U.S. exporters written by American embassies, and 4) personal interviews. In general, the information was current and detailed for countries that are important markets for American exporters. For other countries, the information tended to be out of date or incomplete. Thus, a conclusion that Japan, Germany, France or the United Kingdom are stronger competitors in one region than

in another may partially reflect the regional variation in the quality of information available.

Another limiting factor of the analysis is the focus on import markets. Many firms have subsidiaries or licensees that manufacture or assemble the product locally. This dimension is not reflected in import data. In many instances, a subsidiary imports good from the country of its parent company. For example, in Mexico, a subsidiary of Ericsson, a Swedish firm, controls local production of telephone and telegraph equipment, and Sweden accounts for approximately 60 percent of Mexico's imports of telephone and telegraph equipment. This is not always the case, but where the data is available mention is made as to which exporting nations produce locally as well.

2.3 African Market

2.3.1 Overview

Of the four regions, Africa receives the largest share of the exports of the three European countries. Their combined exports to Africa amount to \$19.1 billion in 1977 or 7.9% of their combined exports for that year. France's exports to the region in 1977 totalled \$8.7 billion and were larger than the regional exports of either Germany or the United Kingdom. German exports amounted to \$5.5 billion to Africa, and the United Kingdom's were \$4.9 billion. More than half of France's exports to Africa in 1977 were to Algeria, Morocco, Tunisia, Ivory Coast and Senegal. German exports to the same countries were 28% their total African exports in 1977, while the United Kingdom provided less than one-tenth of its African exports to these countries.

Africa received the smallest percentage of Japan's exports in 1977, only four percent. Yet only France and the

United Kingdom sold higher percentages of their total exports to Africa in 1977. France accounted for 13% of its exports in Africa and the United Kingdom, 7%. Over half of France's exports went to Algeria, Tunisia, Morocco, Ivory Coast and Senegal while only a fifth of Japan's exports went to these nations. Africa can be divided into two regions: African countries with a strong French presence, and the rest of Africa.

2.3.2 Francophone Africa

France is the dominant foreign economic power in North and West Africa. Most of these countries were French colonies and retain aspects of this association: In Algeria, Morocco, Ivory Coast, and Senegal, French is the official language. The trade regulations of these four countries allow special preference for French imports. Also, France provides much of this region's development aid. This French dominance extends into the import market. Figure 2-2 lists the import shares of the major exporters to Algeria, Morocco, Ivory Coast, Senegal, Gabon, Cameroon, and Tunisia. The French share ranges from 25% in Morocco to 69% in Gabon. The Japanese account for roughly one to two percent of the imports. Cameroon is an exception; Japan supplied 6% of its imports in 1976. No nation other than France accounted for more than 15% of the imports in any of these countries.

Japan's performance in the import market in telecommunications equipment is slightly better than its record in the market for all imports, but because of the lack of data on these product markets any conclusion is tentative. Information is available for the Ivory Coast where in 1975, Japan was the leading supplier of radio and television equipment, providing 43% of these imports. France was the next largest supplier with 37%. This was Japan's only significant share of a market for telecommunications imports. Japan supplied no more than 2%

IMPORTING COUNTRY (AFRICA)	YEAR	EXPORTING COUNTRY								TOTAL (\$ billions)
		Japan	U.K.	U.S.	France	W. Ger.	Italy	China	Belgium	
Morocco ^a	1977	2.0	1.0	4.0	25.0	11.0	6.0			3.4
Senegal	1975	1.0 ^a	6.6 ^b	6.0 ^a	42.7 ^b	5.5 ^b	3.0 ^b			.58
Tunisia ^b	1977		1.0		31.2	11.0	10.0			1.9
Algeria	1975	1.0 ^a	11.0 ^b	4.0 ^a	30.0 ^b	12.0 ^b	8.0 ^b			5.1
Ivory Coast	1975	2.0 ^a	8.0 ^a	2.0 ^a	29.0 ^b	6.0 ^b	7.0 ^a			1.0 ^b
Gabon ^b	1976		6.0	3.0	69.0	4.0				.48 ('75)
Cameroon ^b	1976	6.0	8.0		44.0	7.0				.61
Sudan	1975	10.1 ^a	12.6 ^b	11.2 ^b	2.3 ^a	7.0 ^b		12.6 ^b		.81 ^b
Kenya	1975	7.6 ^b	7.1 ^b	19.9 ^b	2.7 ^a	7.7 ^b	2.6 ^b			.83 ^b
Zaire ^b	1974	9.0	16.0	4.0	7.0	10.0				.91
Nigeria	1975	9.8 ^a	11.0 ^b	23.0 ^b	8.3 ^a	14.6 ^b				5.5 ^b
So. Africa	1976	10.0 ^a	22.0 ^b	18.0 ^b	4.3 ^a	18.0 ^b				6.8 ^b

a Source: IMF Directions of Trade 1971-1977

b Source: Commerce Department Overseas Business Reports

Figure 2-2 Percentage of Exports to Select African Countries by Major Exporting Countries

of Ivory Coast imports of telephone equipment and accounted for 7% of Morocco's imports of telecommunications equipment in 1976. France was the leader with 77% of telephone imports to the Ivory Coast and 65% of Morocco's imports of communications equipment.

France also supplies most of this region's electric power equipment accounting for the largest share of imports in Algeria, Senegal, and the Ivory Coast. The United States and Germany compete in these markets, but each is a major supplier to only one country in North and West Africa. In 1975, the United States supplied 21% of the electric power generators and electric motors imported to the Ivory Coast while France accounted for 47%. Germany is reported to provide a significant amount of Algeria's imports of electric power equipment, but exact figures were not available. There is no indication of important Japanese electric power equipment exports to the area.

France faces stronger competition in the import markets for agricultural equipment. Due to the paucity of data on North and West African imports of agricultural equipment, this inference is based on data on import shares for various categories of agricultural equipment in two countries, Ivory Coast and Morocco. France supplies most of the region's irrigation pumps, but the United Kingdom, Germany, and the Benelux nations have import shares of about ten to twenty percent. In other agricultural equipment categories, France faces stiff competition. For example, France accounted for 26% of Morocco's non-tractor imports while West Germany and United Kingdom supplied 25% and 20% respectively in 1976. Again there is no indication of Japan being an important supplier of agricultural equipment to the area.

2.3.3 Non-Francophone Africa

Roughly four-fifths of Japan's exports to Africa in 1977 went to non-Francophone countries. Figure 2-2 lists the import shares of major exporting nations for Sudan, Kenya, Zaire, Nigeria, and South Africa. No one exporting nation accounts for more than 25% of the imports of any country. Kenya, Sudan, and Nigeria are former British colonies and the United Kingdom retains the largest import share in Kenya (19.9%) and Nigeria (23%). Two nations, the United States and the Peoples Republic of China, supply more of Sudan's imports than the United Kingdom. Japan is a major supplier to all five countries, its market ranging from 7.6% in Kenya to 10.1% in Sudan. In all five countries, Japan has the third largest market share of the five major exporting countries.

In 1974, Belgium supplied 22% of the imports of Zaire, a former Belgian colony. The import shares of Britain and Belgium reflect the importance of former colonial ties but political change ensures that these figures are not to be relied upon as representative of future market trends. Germany has relatively large shares of the imports of all five countries ranging from 7% in Sudan to 18% in South Africa. France's share is lower in this region of Africa, ranging from 2.3% in Sudan to 8.3% in Nigeria.

In the three product categories, no exporting country dominates the market, but the incompleteness of the data make this conclusion tentative. West Germany and the United Kingdom supply more telecommunications equipment to this region than France, but exact figures were not available. West Germany and the United Kingdom are the major suppliers to Nigeria, Sudan, and Kenya. France has a significant share of Kenyan telecommunications imports. Other important suppliers include the United States and Japan.

In electric power equipment, Japan is strongest in Kenya, where it is the leading supplier and the United Kingdom and France are the major competitors. Japan is not a major supplier to Sudan or Nigeria. Japan also is not a significant exporter of agricultural equipment. In Nigeria and Zaire the major suppliers in 1976 were the United States, United Kingdom, Italy, and Germany. Belgium was an important supplier to Zaire. With the exception of Kenya's markets for communications and electric power equipment, Japan accounts for a very small market share for all three products in this region.

2.4 Middle East

The Middle East receives the next largest share of the exports from the United Kingdom, Germany and France (the four regions considered are Asia, Africa, the Middle East, and Latin America). Of their combined exports in 1977, 6.9% were to the Middle East. In this region in 1977, Germany's \$7.8 billion of exports were over \$2 billion more than the \$5.6 billion exported by the United Kingdom and more than twice the \$3.3 billion exported by France. German exports to the Middle East in 1977 were secondary to those of the United States, which exported \$11 billion to the region and Japan which exported \$8.5 billion.

Outside of the industrialized nations and Asia and the oil exporting countries, Japan's strongest market is the Middle East. In 1977, Japan imported roughly \$20 billion worth of oil from the Arab oil exporting nations, and in an attempt to keep its trade deficit to a minimum, Japan exported roughly \$7.6 billion of goods to the Arab oil exporters or the equivalent of 9.4% of Japan's exports. Overall, 10.4% of Japan's exports in 1977 went to the Middle East. Both the United States and Germany supplied more than Japan did to this region, but of the five major exporting countries, Japan

supplied the highest percentage of its total exports to the Middle East.

Although the United States and Japan are the leading exporters to this region, data on import market shares indicate that the European exporters, Germany in particular, are important suppliers to certain Middle Eastern countries. Figure 2-3 lists the import shares of the major exporters to Israel, Saudi Arabia, Egypt and Iraq. The United States is the leading supplier to Israel, Saudi Arabia, and Egypt, but Japan has the largest share of Iraq's imports. Germany is the second largest supplier to Iraq. The United Kingdom is the second largest supplier to Israel and its shares range from 5.7% in Egypt to 11.2% in Israel. France has the poorest record of the major exporting countries in that its import shares do not exceed 7% (its lowest share is 3.2%) for the countries examined.

Telecommunications: This basic pattern among the European exporters also applies to the specific import markets for telecommunications, electric power and agricultural equipment. Germany is the most successful exporter of telecommunications equipment to the Middle East. In 1974, Germany supplied 28% of Saudi Arabia's imports of telecommunications and 40% of the imports of electrical line, telephone and telegraph equipment. Germany was second only to Japan which has a 50% share. This share was partly due to the Japanese firm, Mitsubishi, building two permanent earth satellite stations in Saudi Arabia. The United States and Britain were far behind, with 13% and 3.3% import shares respectively. Japan is also the leading supplier to Iraq, which received 25% of its imports of communications equipment in 1976 from Japan. The Japanese have recently dominated the market for telephone exchanges and wireless networks. Japan ranked behind the United States, West Germany, Sweden, and France in the Egyptian

IMPORTING COUNTRY (MIDDLE EAST)	YEAR	EXPORTING COUNTRY						TOTAL
		Japan	U.K.	U.S.	W. Ger.	France	Italy	(\$ billions)
Saudi Arabia ^a	1977	15.4	6.5	23.0	11.1	4.0		16.8
Israel ^a	1977	1.5	11.2	16.3	7.8	3.2		5.7
Egypt ^b	1977	5.2	5.8	16.4	10.7	6.3	8.9	5.4
Iraq ^a	1977	18.5	4.0	6.5	16.9	6.7		3.7

a Source: IMF Directions of Trade 1971-1977

b Source: Commerce Department Overseas Business Reports.

Figure 2-3 Percentage of Exports to Select Middle East Countries by Major Exporting Countries

market in 1976, reportedly having a share that was significant but less than 12%. Overall, France and the United Kingdom provided minimal imports in the telecommunications equipment to the region.

Electric power equipment: West Germany is also prominent in this import market for electric power equipment. Although the United States is the largest supplier of electric power equipment to the Middle East, Germany is a major supplier to Egypt, Israel and Saudi Arabia. Germany supplied about 13.5% of Egypt's imports while the United States provided approximately 22.9%. The United Kingdom is also active in this market, accounting for a significant share of Israel's and Saudi Arabia's needs in electric power equipment.

Japan is less successful in supplying electric energy systems to the Middle East than it has been in the communications equipment market. However, any conclusion is tentative because the information on imports of electric power equipment to the Middle East is much less detailed than the information on communications equipment. It is reported that Japan sells electric power equipment to Saudi Arabia, but Japan's exact share of imports is uncertain. The Israeli import market is dominated by the United States, West Germany, United Kingdom, and Switzerland who compete in sales of large generators. Finally, Japan was not among the top four suppliers to Egypt in 1977.

Agricultural equipment: West Germany and the United Kingdom are important suppliers of agricultural equipment to the Middle East. In 1976, 31% of Iraq's imports of agricultural equipment were from Germany and 12.25% from the United Kingdom. The United States was third with a 9% share. While the United Kingdom and Germany are important suppliers to Saudi Arabia, neither is very active in Egypt. The United Kingdom is not

reported as a leading supplier to Egypt and Germany's share was only 3.4% in 1977. There is no indication that Japan supplies agricultural equipment to the Middle East, but because of the lack of data, this observation is little more than speculation.

2.5 Asian Markets

Japan's best export market in the Third World is Asia. In 1977, 28% of Japan's exports were to Asia, the primary areas being Australia, New Zealand and Southeast Asia. Only a small fraction of Japan's exports, 1% go to India. The next largest supplier to Asia in 1977 was the United States, which sold \$13.7 billion, or 11%, of its exports to this region. Together the United States and Japan accounted for 38% of this region's imports of \$99.9 billion worth of goods.

Together United Kingdom, Germany and France exports totalled \$11.2 billion to Asian markets in 1977. West Germany and the United Kingdom each export approximately \$4.7 billion to the region. The United Kingdom's share represent a large percentage of Britain's total exports. A substantial fraction of both these countries Asian exports go to Australia, New Zealand, and India. These latter three countries bought 49% of Britain's Asian exports and 31% of Germany's Asian exports. France exported only \$2 billion to Asia in 1977, and one-fifth of this amount went to Australia, New Zealand, and India.

Figure 2-4 lists the percentage of the imports of 11 Asian nations accounted for by Japan, the United States, the United Kingdom, West Germany, France, and several other nations. Japan's share of Asian imports ranges from 32.4% in Thailand to 9.1% in India, and with the exception of Australia, New Zealand and India, it has the largest share of any exporting country. In Australia, New Zealand, and India, Japan is a close second in having the largest share of imports.

IMPORTING COUNTRY (ASIA)	YEAR	EXPORTING COUNTRY							TOTAL (\$ billions)
		Japan	U.K.	U.S.	W. Ger.	France	Neth	Austr	
Australia	1976	19.6 ^b	13.5 ^b	20.5 ^b	6.5 ^a	1.5 ^a			11.1 ^b
New Zealand ^a	1976	14.6	16.4	13.6	4.2	1.2		19.8	3.3
Taiwan ^a	1976	32.2	2.2	24.0	4.6	.7		1.5	7.6
Phillippines ^a	1977	25.0	3.7	20.6	3.3	2.0			4.3
South Korea ^a	1977	36.0	1.3	22.0	3.2	1.6		8.0	10.0
China ^a	1977	33.9	1.8	2.9	8.7	1.6		4.7	4.0
Thailand ^a	1977	32.4	4.0	12.3	5.5	1.3			4.6
Singapore	1977	17.5	3.7	12.6	3.4	1.2			10.5
Indonesia	1975	31.0 ^b	3.4 ^a	14.0 ^b	7.6 ^a	1.8 ^a	2.7 ^a		4.7 ^b
India ^a	1977	9.1	8.4	14.0	8.5	2.8			6.4
Malaysia ^a	1974	21.2	9.7	9.3					4.3

a Source: IMF Directions of Trade 1971-1977

b Source: Commerce Department Overseas Business Reports.

Figure 2-4 Percentage of Exports to Select Asian Countries by Major Exporting Countries

For example, 20.5% of Australia's imports in 1976 came from the United States and 19.6% came from Japan. Japan receives stiff competition from the United States in South Korea, the Phillipines, and Taiwan. In Taiwan in 1976, Japan provided 32.3% of Taiwan's imports and the United States accounted for 24%. In the Phillipines and South Korea, in 1977, Japan supplied 25% respectively. In the remaining Asian countries, Malaysia, Indonesia, People's Republic of China, Thailand, and Singapore, Japan's share is at least 7 to 10 percentage points higher than the share of the closest competitor, and none of the closest competitors have shares greater than 15%. Clearly Japan faces its strongest competition in countries with close ties to the British Commonwealth or the United States. There are fairly clear reasons for this competition. All British imports to Australia and New Zealand had received until recently reduced tariffs. The United States has supplied military and economic aid to South Korea and Taiwan as part of its foreign policy.

The United Kingdom, Germany and France tend to have relatively small shares in the imports to this region. The United Kingdom has the largest share in New Zealand, but only 1.8% more than Japan's share. The United Kingdom is the third largest supplier to Australia and India. Britain accounts for less than 5% of the imports of every nation on the Asian Continent with the exception of India. Germany's share is never greater than 9% in any country while France's shares are less than 3% in all countries. Clearly most of the competition for foreign trade with Asia is between Japan and the United States.

Telecommunications: Although its market position is strong in Asia, Japan often faces stiff competition from the United States, in communications equipment. In 1976, \$939 million worth of communications equipment was sold in the

Phillippines. Most of the equipment sold was Japanese. Nonetheless, 50% of this \$27.5 million of equipment was imported from the United States. Japan and the United States are also strong competitors for sales of communications equipment in Taiwan. In 1974, Japan supplied 50 percent of Taiwan's imports, and the two largest domestic producers were licensees of Japanese firms. The United States supplied 40% of Taiwan's imports and dominates the imports of certain types of communications equipment that were not locally produced. The United States provided all the imports of microwave components and communications test equipment and three times the amount of non-broadcast radio and television equipment Taiwan imported from Japan. The United States' strength is partly due to a policy of the Taiwanese government to limit imports from Japan in order to reduce its trade deficit with Japan.

In Southeast Asia and Australia, Japan encounters competition from European countries in addition to competition from the United States. The Indonesian telecommunications market is a good example. In 1975, Indonesia received 22% of its imports of communications equipment from Japan, but Japan's imports were concentrated in consumer radio and television and communications test equipment. In 1975, Japan supplied 64% of the imports of consumer radio and television and 48% of imports of test and control equipment. The Dutch and West Germans accounted for 47% and 28% respectively of the imports of landline communications equipment in 1975. Also, United States' firms won a contract to build a domestic communications satellite system in 1975, and the United States has provided most of Indonesia's imports of telecommunications equipment since then.

In addition to illustrating the competition among the major exporters, the Australian communications market

demonstrates the ability of the Japanese to increase their import share very quickly. In 1974, Australia received 25% of its imports from the United States, 23% from Germany, 17% from Japan, and 9.5% from the United Kingdom. By 1977, Japan had become the leader with 31.6% of the imports coming from Japan, 21.8% from the United States, and 13.7% from West Germany.

The competition in the Asian telecommunications market is primarily between the United States and Japan, but European countries provide additional competition in Southeast Asia and Australia. Within a country's market, each exporter has a particular strength, but an exporter's strength is not necessarily the same in each country. A Japanese firm built the satellite communications system in Taiwan, but American firms built the Indonesian satellite system. American imports are the only source of communications test equipment in Taiwan, but Japan supplies the largest share of test equipment imports to Indonesia. Japanese exporters and subsidiaries are consistently strong in PBX equipment.

The European countries are most active in Southeast Asia and Australia. In Indonesia, Germany supplies a substantial part of the sales of central office telecommunications equipment. The United Kingdom, Germany and France sell very little telecommunications equipment to Philippines and Taiwan, whose markets are dominated by Japan and the United States. However, Germany is the major supplier of telecommunications equipment to Southeast Asia and Australia. Neither the United Kingdom or France are as active as Germany is in this market. In Indonesia, Germany supplied 28% of the imports of landline communications equipment in 1975, their share of the product market being second to the Dutch share of 47%. Also, the German firm, Siemens, and its Indonesian subsidiary account for 50% of sales of central office communications equipment in Indonesia. A few French and British

firms participate in the Indonesian market, but they have relatively small shares of the imports and production. In Malaysia, Siemens and Plessey (British firm) are major suppliers of central office exchanges.

Electric Power Requirement: The market for electric power shows a pattern similar to the telecommunications market. The United States and Japan are the major competitors in Taiwan and the Philippines. In South Korea, Australia, Indonesia, and Malaysia, European countries are also active in the market. Neither the United States nor Japan is consistently strong in all countries in a single particular specialty.

Taiwan imports most of its electric power equipment, and the United States accounted for 85% of those imports in 1978 while Japan supplied only 10%. America dominated the market for generation equipment, providing 90% of the imports except for switchgear equipment. Japan was the leading supplier of transmission and distribution equipment, supplying 47% of Taiwan imports in 1978. West Germany has been a major seller of transformers and power circuit breakers. Both the United States and Japan have excellent reputations for quality in their specialties. Also, the American generation equipment is consistent with Taiwanese standards. The Japanese are known for excellent after sales service and modifying their products to fit their customer's needs.

The market for electric power equipment in the Philippines is the scene of intense competition between the Japanese and the Americans, but unlike Taiwan, their market shares have changed significantly in the last seven years. Since 1972, the Japanese have moved from a distant second place to a strong lead in the Philippine import market. In 1972, the United States supplied 46% of the imports and Japan provided 23%. In 1977, Japan led the United States with 40%

of the imports while the United States share had dropped to 29%. This shift is reportedly due to Japan's prices and financing terms.

In the Korean, Australian, Indonesian, and Malaysian markets, European suppliers compete with the Americans and the Japanese. South Korean buyers consider financing terms a major factor in selecting a seller, and this permits the Europeans to have a significant share of the market. In 1974, 26% of Korea's imports came from the United States, 24% from the United Kingdom, and 20% from Japan.

In Australia, Japanese have taken advantage of the phasing out of preferences for British imports and have increased their share from 8.5% of imports of power generation and distribution products in 1975 to 31.6% in 1977. The British share has dropped from 35.2% in 1975 to 12.7% in 1977. West Germany's share has also fallen from 15.9% in 1975 to 6.9% in 1977, while the American share has been steady at approximately 18%. In contrast in Taiwan, the Japanese compete with the Americans in the power generation market.

The Japanese also compete with the United States in the generation equipment market in Indonesia. In 1975, 23% of Indonesia's imports of generation equipment came from Japan, 28% from the United States, and 24% from West Germany. Imports of distribution and transmission equipment show a similar pattern. In 1975, Japan supplied 25%, United States 21%, and West Germany 11%. Also, it is important to note that two Japanese firms, Yaumar and Kyoto, assemble small diesel engines in Indonesia.

Agricultural equipment: The United Kingdom and Germany compete in the Asian agricultural equipment market, but they usually represent smaller market shares than the

United States and Japanese exports. The lack of data on imports of agricultural equipment in Asia, necessitates that this conclusion be based on information from only two countries, Indonesia and Australia. In 1975, the Japanese and Americans supplied the bulk of Indonesia's imports of agricultural equipment. For example, Japan supplied 57% of Indonesia's imports of cultivating machinery and the United States supplied 26%. The United Kingdom and Germany has very small shares, 9% and 4% respectively. In Australia, the United States supplied 48.2% of the agricultural equipment imported in 1977. The United Kingdom and Germany were the other two major suppliers accounting for 16.9% and 12.4% respectively.

In summation, European exports generally have a weaker position in the Asian market than Japan or the United States products. The Europeans provide limited competition in Southeast Asia and Australia in the three product markets addressed here. Germany is the most competitive of the three European exporters: it is a major supplier of communications equipment to Indonesia, Malaysia and Australia. It supplies a significant share of electric power equipment imports to Indonesia and Australia. Germany is also active in the market of agricultural equipment. The United Kingdom is not a major supplier of telecommunications equipment in Asia, but it accounts for a significant share of the electric power equipment imports of Korea and Australia. Britain also sells agricultural equipment in this region. France is not mentioned as a major supplier of any of these selected products markets.

Overall, the Japanese marketing position in Asia is strong, representing the largest share of the region's imports. Nonetheless, there is strong competition with the United States, and, in some cases, with Europe. Japan is not always the leading supplier of communications and electric power equipment, and within each product category, its strength is

not necessarily the same in each country. Of the three products, Japan has the weakest position in agricultural equipment. However, Japan is a significant threat in most market areas because they have demonstrated the ability to substantially increase their market share rapidly.

2.6 Latin American Market

The United States is a dominant foreign economic power in Latin America. Fourteen percent of the total United States' exports, \$17.9 billion, were to Latin America in 1977. The next largest supplier was Japan, with \$5.7 billion of exports in 1977. German exports totalled \$4.6 billion, the United Kingdom \$2.2 billion, and France \$2.1 billion.

The import market shares of exporters to Latin America reflects the dominance of the United States. Figure 2-5 lists the import market shares of exporters to Argentina, Brazil, Chile, Colombia, Mexico, and Venezuela. Japan's share of imports is between 5 and 10%, except for Chile in 1977 when its share was 11%. In Mexico, Venezuela, and Colombia, the United States supplied 63.6%, 47.5%, and 33.9% of all imports, respectively. In Mexico and Venezuela, the United States' share was at least 35 percentage points larger than the share of the next largest supplier. In Columbia, this difference was 24%. Japan and West Germany have the next largest shares. Japan's share is the second largest in Venezuela and Chile and West Germany's share is the second largest in Mexico, Colombia, and Argentina. Excluding Brazilian imports from Saudi Arabia and Iraq, West Germany is the second largest supplier to Brazil. In all of these countries, the Japanese and West German shares differ by no more than 3 percentage points.

In one sense, the Latin American market parallels the Asian market. Each market has one supplier that usually

IMPORTING COUNTRY (LATIN AMERICA)	YEAR	EXPORTING COUNTRY						TOTAL
		Japan	U.S.	U.K.	W. Ger.	France	Italy	(\$ billions)
Mexico	1977	5.2 ^b	63.6 ^b	2.3 ^a	5.7 ^b	2.8 ^a		5.48 ^a
Brazil ^a	1977	7.1	19.7	2.1	8.6	2.9		13.1
Colombia	1977	7.7 ^b	33.90 ^b	3.4 ^a	9.2 ^b	5.7 ^a	4.4 ^b	2.6 ^b
Venezuela	1974	9.5 ^b	47.5 ^b	3.1 ^b	9.0 ^b	2.9 ^a	4.2 ^b	3.8 ^a
Argentina ^a	1977	8.1	18.0	4.8	10.8	4.8	4.8	4.2
Chile ^a	1977	11.0	20.0	2.4	8.1	.8		2.2

^a Source: IMF Directions of Trade 1971-1977

^b Source: Commerce Department Overseas Business Reports.

Figure 2-5 Percentage of Exports to Select Latin American Countries by Major Exporting Countries

has the largest share of imports. Furthermore, in Asia, the leading nation, Japan, encounters stiff competition from other industrialized countries in the markets for communications and electric power equipment. The same is true for Latin America. Although the United States consistently has the largest share of imports, Japan, West Germany, Sweden, and other European nations supply a significant amount of Latin America's imports of communications and electric power equipment.

Telecommunications: In addition to the United States, Japan, Sweden, and West Germany are the major exporters of telecommunications equipment to Latin America. The Mexican market for telephone and telegraph equipment receives 58.7% of its imports from Sweden. Domestic production of telephone and telegraph equipment is controlled by a Mexican subsidiary of the Swedish firm, Ericcson. Also the Mexican subsidiary of Seimens provides a significant share of local production of telex and telegraph equipment.

In 1974 approximately one-half of Japan's exports of communications equipment to Mexico were telephone and telegraph equipment. Japan and the United States supplied most of Mexico's imports of radio and TV equipment. Japan provides 28.6% of the imports of non-broadcast radio and TV and 57% of the imports of broadcast radio and TV equipment. The United States share of non-broadcast radio and TV imports exceeds Japan's share and the U.S. share of 41% of imports of broadcast radio and TV equipment was second to Japan's share.

Most of the information on the communications market in Brazil and Colombia is five years old, and because Japan is capable of doubling its share in a matter of years, the conclusions about the markets may not reflect the current state of the markets. In Brazil and Colombia, as in Mexico,

Japan is the successful exporter of radio and TV equipment but not telephone and telegraph equipment. In 1974, Japan supplied 20.2% of Colombia's non-broadcast radio and TV imports and only 10.4% of Colombia's imports of telephone and telegraph equipment. Also in 1974 Brazil received 25% of its imports for new equipment and 9.9% of its imports for telephone and telegraph equipment from Japan. Japan was not the major supplier in any country or category. The leading source of telephone and telegraph imports in Brazil was Germany with 31% of the market, and then Colombia and Sweden led with 35% of the market. In radio categories the United States accounted for 63% of the Colombian imports, and 26% of the Brazilian imports. Of the imports of all types of communications equipment in Colombia, the major suppliers were the United States, Sweden, Germany and Japan, with 28%, 12.7%, and 11% shares respectively. In Brazil, Germany led in 1974 with 24% of the total communications imports and was followed by the United States with 24.8% and Japan with 15%. In telecommunications, Japan is strong in radio and television, and weak in telephone and telegraph equipment. It is not clear if a similar pattern occurs in the electric power generation market.

Electric power equipment: A brief history of Japan's import of electric power equipment to Mexico shows Japan's lead in the import market and its ability to move from a small to a large market very quickly. In 1974 the United States supplied 65.9% of all imports of electric power equipment and also dominated imports of generation and transmission and distribution equipment. The next largest supplier was Sweden with 4.3% of the market. By 1976, the Japanese had increased their share to 42% and the United States share had fallen to 24%. Sweden accounted for 12.4% of the imports in 1976. Japan reportedly increased its share by selling equipment at prices that were as much as 30% less than American prices.

In 1974, Japan's share of Brazilian imports of electric power equipment was much larger than its 1974 share in Mexico, but it was still only 9.6% of the market. The United States and Germany supplied 34.6% and 16.1% respectively. Japan's strength was in the sale of generation equipment. In generation, it still had the third largest share at 18.7%, but the share of the United States, the leading supplier, dropped to 25.7%.

Germany is also the most active European exporter in the market for electric power equipment. The United Kingdom provided 10.9% of Columbia's imports of electric power equipment in 1974 but is not mentioned as a supplier in Mexico or Brazil nor is France mentioned as a major supplier. Germany is a major supplier to several countries but does not have the largest share of electric power equipment imports in any Latin American country. In 1974, 16.1% of Brazil's imports of this product area came from Germany, which was second to the United States share of 34.6%. Yet Siemens and its Brazilian subsidiaries are reported to sell 25% of electric power equipment sold in Brazil. Germany supplied 17.3% of Columbia's imports in 1974, but the United States clearly dominated the market, accounting for 52% while Japan's share was 20.9%. In 1976, Germany provided 8% of Mexico's imports of electric power equipment, but this share was much less than the 42% Japanese share, and the American share of 24%.

Agricultural equipment: Although Japan sells communications and electric power equipment to Latin America, it is practically absent from markets for agricultural equipment. Japan is not noted as a major supplier of agricultural equipment to the countries addressed. Of the three product categories, the United States is strongest in the area of agricultural equipment. The United States accounts for a large share of imports to Mexico and Venezuela. In 1977, it supplied 63% of Venezuela's imports of agricultural equipment, and in 1976 approximately 70% of Mexico's imports in this area. The closest competitors are the United Kingdom, Italy, and Canada.

3.0 EUROPEAN COMPETITION

3.1 Characterization of the PV Industry

3.1.1 European Firms Active in Photovoltaics

A few prominent European firms stand out as active participants in the photovoltaics industry. These tend to include major silicon producers, solar cell manufacturers, companies supporting applied R&D, and those anticipating manufacturing in the near future. Figure 3-1 provides an overview of the current corporate participation in the European photovoltaics industry. No attempt is made to identify the broad range of firms doing relevant R&D or firms with the potential to become PV manufacturers. Rather the following listing reflects the known firms with an expressed interest in terrestrial photovoltaics and those active in the PV industry. A few representative firms conducting relevant R&D are also noted only to illustrate the type of major corporations capable of entering this area in strength. They are not included in Figure 3-1.

The descriptions¹ are intentionally brief, the intent of this section being limited to identifying the corporations involved in the PV industry. They are grouped by country as follows:

Germany

AEG Telefunken is the major German manufacturer of terrestrial solar cells. It was the first company in the world to develop and manufacture large modules from polycrystalline

¹ Descriptive sources include: telephone interviews, Jane's Major Companies of Europe, Dunn and Bradstreet, Who Owns Whom: Continental Europe, and Corporate literature. Most sales data reflects 1976 figures.

Company	Production & Marketing	Production Process Development	Advanced Materials R&D	Raw Materials Production & Supply	Systems Applications
<u>Germany:</u>					
AEG Telefunken	xxxxxxxxxx	xxxxxxxxxx	xxxxxxxxxx		xxxxxxxxxx
Wacker-Chemie Gmbh			xxxxxxxxxx	xxxxxxxxxx	
<u>Netherlands:</u>					
Philips*	xxxxxxxxxx	xxxxxxxxxx	xxxxxxxxxx	xxxxxxxxxx	xxxxxxxxxx
<u>France:</u>					
RTC	xxxxxxxxxx	xxxxxxxxxx	xxxxxxxxxx	xxxxxxxxxx	xxxxxxxxxx
LEP			xxxxxxxxxx		
France-Photon	xxxxxxxxxx				xxxxxxxxxx
SAHEL	(marketing only)				
Photowatt International S.A.	(to begin)	(to begin)	(CGE labs)		
<u>United Kingdom:</u>					
Ferranti	xxxxxxxxxx	xxxxxxxxxx	xxxxxxxxxx	xxxxxxxxxx	xxxxxxxxxx
<u>Italy:</u>					
Montedison	(marketing only)		xxxxxxxxxx	xxxxxxxxxx	xxxxxxxxxx

*Philips is parent company for RTC and LEP thus capabilities are duplicated.

Figure 3-1 Overview of Current Corporate Participation in European Photovoltaics Industry.

silicon. Telefunken is also the leading European manufacturer of solar cells for space applications.

AEG Telefunken is Germany's second and one of the world's largest electrical engineering groups. It is the 26th largest industrial firm in Europe and the 12th largest exporter. Total annual sales are about \$6 billion of which \$2.5 billion are export sales. The firm's activities include: power plant, industrial plant, telecommunications, and data processing, transportation equipment, electronic components, industrial products, domestic appliances, audio-video equipment, office machines and others. Subsidiaries are spread throughout the world including: 49 in Europe, 3 in Africa, 14 in America, and 7 in Asia and Australia.

Wacker-Chemie GmbH is the major manufacturer of silicon and silicon cells in Germany, working in conjunction with AEG-Telefunken. Together they are developing a polysilicon process and have established two new companies, "Chemetronics" to be involved in module production and "Heleotronics" to support material development.

Founded in 1914, Wacker is a manufacturer of plastics plasticisers, fibrous adhesives, hydrocarbon chloride, solvents, silicones, industrial chemicals and intermediates, pesticides and insecticides. Major factories and plants are in Europe, the United States and Mexico. Exports account for about 35 percent of the company's sales volume. The parent company and consolidated subsidiaries employ about 16,000 persons and worldwide subsidiaries employ about 9,000.

Siemens AG is not at present a manufacturer of PV systems. The company has manufactured solar cells for space applications, maintains a relevant R&D program, and is a

potential participant in terrestrial photovoltaics. Siemens is also active in a number of other solar technologies.

Siemens AG is in the top twenty of the largest industrial companies in Europe with an estimated 390,000 employees worldwide and annual sales of over \$8.7 billion. The company ranks sixth among European firms in exports.

The firm's activities include electrical and electronic equipment and appliances, components, data processing, power plant, installation of systems, medical equipment and telecommunications. Major non-European foreign factories and plants are located in Turkey, Brazil, Argentina, Mexico, U.S., South Africa, India, Pakistan, Malaysia, Singapore, and Australia.

Philips is a major manufacturer of PV energy systems. Today, R.T.C. (La Radiotechnique - Compelec), the French component division of Philips Elcoma, is the manufacturer of their solar panels. Another division in France, L.E.P. (La Laboratoires d'Electronique et de Physique Applique) does applied R&D in photovoltaics.

Philips is one of the five largest industrial firms in Europe with annual sales over \$12 billion. It is a highly integrated multinational firm with fourteen major product divisions which include: lighting, major domestic appliances, small domestic appliances, audio, video, electrical components and materials (Elcoma), electro-acoustics, telecommunications and defense systems, data systems, industrial equipment, medical systems, pharmaceutical-chemical products, allied industries and glass.

In 1974, North American Philips Corporation acquired a majority interest in the Magnavox Company. Philips in 1975 concluded an agreement to take over the Signetics Corporation,

Sunnyvale, California, a manufacturer of integrated circuits. Philips has organizations in about 65 countries and manufacturers in about 50 of these countries.

France

La Radiotechnique, a Philips subsidiary, is the parent company for RTC (La Radiotechnique - Compelec) and LEP (La Laboratoires d'Electronique et de Physical Applique). RTC, a major manufacturer of photovoltaics, pioneered terrestrial applications as early as 1961. LEP focuses on applied R&D in photovoltaics. RTC is currently the manufacturer for the Philips BPx47 range solar panel.

La Radiotechnique is one of the oldest French electronics companies. Today the firm is a major manufacturer of electronics equipment, radio receivers, and television sets. "Radiola" and "Philips" are brand names of their products. The Radio-technique group resides in France and has about 15,000 employees.

France-Photon, a producer of photovoltaic panels, was established in 1978 as a joint venture between Solarex Corporation of the United States and Moteurs Leroy-Somer of France. Solarex currently supplies the solar cells and the panels are manufactured by France-Photon. Leroy-Somer is the largest manufacturer in Europe of small electric motors with annual sales of about \$1 billion.

Societe des Applications de L'Helivenergie (SAHEL) is a recently established joint venture of Thomson-CSF of France and Exxon Corporation. The new company will specialize in photovoltaic applications and benefit from the technical and marketing positions of the parent companies. Solar Power Corporation, a subsidiary of Exxon Corporation, will have the primary role with their expertise in solar cell technology.

Thomson-CSF is a major electronics firm with annual sales of \$2.2 billion, ranking in the top 130 industrials in Europe. The firm is represented in all branches of the electronics industry with expanding interests in telecommunications. The four main divisions of the company are electronics equipment, electronic components, scientific instrumentation, and electronic data processing. Thomson-CSF maintains offices in over 80 countries with commercial and manufacturing subsidiaries in 18 countries. In 1977, 44% of the firm's sales were outside France.

Photowatt International S.A. is a new French company established by a joint venture between Sensor Technology Incorporated, a Dyneer Corporation subsidiary in the United States and Compagnie Generale d'Electricite (CGE) a major French electrical and electronics company. The new company will develop, produce and market PV modules in the U.S. and France. The U.S. counterpart is Photowatt International Incorporated located in California. Sensor Technology and CGE will cooperate in technology development through a cross licensing agreement.

The French parent company CGE is a holding company with over 200 subsidiaries engaged in electrical engineering, building and public works, telecommunications, cables, batteries, electrical equipment, services, radio, nuclear power stations, railway equipment, and consumer products. The group operates about 160 major factories in France and abroad. CGE is one of the thirty largest industrials in Europe. Annual sales are over \$5.5 billion of which about \$2 billion are exports, CGE being one of the 16 largest exporters in Europe.

The primary CGE subsidiaries in the venture are Compagnie Industrielle des Piles Electrique (CIPEL) and Ste' des Accumulateurs Fixes et de Traction (SAFT) major battery

manufacturers operating on a worldwide scale. Also the CGE research component, Laboratoire de Marcouris is active in photovoltaics R&D.

Groupement d' Interet Economique (GEW) is a joint French venture with the objective of applying PV technology in developing countries. The group is made up of the firms Pompes Guinard, a major French pump manufacturer (and subsidiary of Leroy-Somer); the Societe Nationale Elf Aquitaine, a major oil company with over \$7 billion annual sales; and Les Piles Wonder, the second largest electric battery producer in the European Common Market with about \$80 million in annual sales. GEW is not a PV manufacturer at this time but rather a systems integrator having completed a number of PV projects many of which are water pumping applications in Africa.

United Kingdom

Ferranti Limited processes silicon and manufactures solar cells and modules. The firm has produced solar cells for space applications beginning in the 1960's and since 1974 has turned to terrestrial photovoltaics. Ferranti with about \$400 million annual sales is 50% owned by the British Government. The firm manufactures a wide range of electrical and electronic equipment, a variety of metering and industrial instrumentation, military and civil computing systems, information displays and communications systems, microwave links, integrated circuits, inertial navigation systems, and aircraft instruments. The major company factories are located in Britain and Canada. Exports accounted for about 12% of annual sales.

The Plessey Company Limited, a major semiconductor manufacturer in Britain, is conducting R&D in photovoltaics

including the areas of gallium arsenide and concentrators. Plessey is not a PV manufacturer at this time. With annual sales of about \$850 million, Plessey is one of the 300 largest industrials in Europe. Export sales are about \$315 million. The firm is a holding company with nine major product groups and regional organizations in Australia, North America, South Africa, Europe and the Middle East. Plessey is a multinational corporation in the fields of telecommunications, electronics, dynamics and components, employing over 69,000 people in 16 countries.

Italy

Montedison SPA is a major industrial corporation involved in solar cell R&D and in building an experimental photovoltaics plant for the EEC. Montedison recently entered into a joint venture with Solarex Corporation of the U.S. to develop the technology to manufacture silicon. The new company is called Solaris.

Montedison, one of the 30 largest industrial corporations in Europe, has annual sales of about \$5.5 billion of which \$1.9 billion represents exports. The Edison group has a wide range of interests with major emphasis on chemicals, pharmaceuticals, man-made fibers and retailing. Recent expansion has been in the area of textiles and textile machinery. Two more recent companies set up were Vitrofil for fiber glass production and Smiel in high-purity silicon. In the last few years new directions taken by this group included new facilities to produce materials used in the electronics industry, such as silicon crystals and slices. Most corporate holdings are in Europe.

3.1.2 Recent U.S. Photovoltaic Industry Links with Europe

Over the past year and a half, U.S. photovoltaic manufacturers have established several joint ventures in Europe, primarily in France. Figure 3-2 illustrates these corporate links between U.S. photovoltaic manufacturers and European firms. The circled companies are primary participants in the photovoltaics industry today or in a few instances are new ventures committed to an active role in the industry. A number of more subtle and complex corporate relationships exist across the Atlantic which are potentially important to the future PV industry. These relationships deal with multinational linkages and major corporate capabilities which are not currently active in the PV industry. The scope of this study necessitates avoiding such a broad analysis and instead focuses on developments in today's PV industry. European distributors or representatives of U.S. PV manufacturers although important in marketing U.S. products, are not addressed.

The corporate links with European companies illustrated in Figure 3-2 are all recent developments with two exceptions. There are Solar Energy Systems, Inc. (SES) and Photon Power, both cadmium sulfide technology ventures in the U.S., the first a Shell sponsored undertaking, the other partially sponsored by CIE Francaise des Petroles. The more recent activity and subject of this section is characterized by four of the leading U.S. photovoltaic manufacturers entering into joint ventures with major European firms.

The first of these was the establishment of France-Photon by a joint venture between Solarex and Moteurs Leroy-Somer of France. The company now manufactures PV panels in

Figure 3-2 European and U.S. Corporate Links in the Photovoltaic Industry

France with Solarex supplied cells. Advantages to this arrangement include an improved market position for Solarex and a source of investment capital. By manufacturing locally their market position is improved for French government funded PV purchases. Much of the West African market today is supported by French development funds. Also the link with Leroy-Somer includes the subsidiary Pompes Guinard, a French pump company which specializes in small scale PV powered water pumping applications. The company is particularly active in Africa. Pompes Guinard is also a partner in GEW a French company concentrating in marketing and installing PV applications in developing countries. Neither GEW nor Pompes Guinard are committed exclusively to Solarex or France-Photon products.

Solarex has established another joint venture with Montedison, a major Italian conglomerate. Solaris, the new company being formed, will focus on developing the technology to manufacture silicon. A factory is to be built in Italy. Montedison is particularly active in silicon processing R&D. An anticipated benefit of this venture will be an excellent market position for selling PV systems in Italy.

Another recent joint venture is the formation of the Society des Applications de L'Helioenergie (SAHEL) by Exxon Corporation and Thomson CSF. The Exxon subsidiary Solar Power Corporation is a major PV manufacturer in the U.S., while Thomson is a major electronics firm in France. The objective of the venture is initially limited to evaluating the potential PV market in Europe. A consideration is the French government market for photovoltaics which until recently was limited to one supplier, RTC. Another consideration in the venture is that Thomson is a major firm in the telecommunications industry with a worldwide presence. Thomson's strong telecommunications equipment sales compliment Solar Power Corporation's marketing

position because PV telecommunications applications will continue as a major area for photovoltaic power systems. After two years the joint venture will be reevaluated. Possible scenarios range from withdrawal from the venture to establishing a PV manufacturing capability in France.

A more definitive alliance has recently been established between the U.S. PV manufacturer, Sensor Technology Incorporated, and Compagnie Generale d'Electricite (CGE) a major French electrical and electronics firm. This joint venture includes two new companies named Photowatt International Incorporated, one in the U.S. and another in Paris. The relationship includes a licensing agreement on R&D results and PV manufacturing is expected to begin this year in France.

In the past year, Sensor Technology Incorporated was bought by Dyneer Corporation (a \$150 million business) and a relatively small company in terms of the size of most of the PV manufacturers. Sensor Technology benefits from this venture in several ways. CGE is a \$8.1 billion company, the largest primary battery manufacturer outside the U.S. and the largest in the developing countries. This significantly increases the presence of Sensor Technology products on world markets.

Moreover, West Africa, a major area for near term PV sales, is a French preserve. The CGE link places Sensor Technology in a favorable marketing position in the area. CGE also has a strong research capability which includes R&D in amorphous, polycrystalline and ribbon silicon technologies. CGE is interested in total systems, module manufacturing being but one aspect. Sensor Technology will continue to have its own sales network with technology being shared through a

joint licensing agreement. Both partners are optimistic: Sensor Technology is expanding its worldwide marketing positions, with access to increased investment capital, and with acquiring a broader R&D base. The French company immediately acquires the capability of being a PV manufacturer with a very competitive PV product.

These recent joint ventures with European firms help to characterize the posture of the U.S. PV industry today. Of the five largest PV manufacturers in the U.S. only Arco Solar and Motorola have not as yet entered into joint ventures in Europe. Motorola is already a major international electronics firm whose product line and worldwide manufacturing distribution and sales facilities complement their PV products. Motorola has a French manufacturing facility which will probably be utilized for PV production in the near future.

Arco Solar Incorporated, a subsidiary of Atlantic Richfield Company, while lacking the complementary product line and associated overseas manufacturing facilities of Motorola, nevertheless has strong parent company support and is a relative newcomer in the French and African market. At this time Arco is not ready to establish a European joint venture although it is recognized that foreign manufacture will be a necessity in a number of areas as the market grows.

In contrast, Sensor Technology and Solarex both require external investment to continue in leading roles in this rapidly expanding field. Investment requirements have grown considerably over the past few years for applied R&D, manufacturing processes and facilities, and vertical integrations, from raw materials to total systems.

The primary incentive for the joint ventures with French companies is to improve the marketing position of U.S.

manufacturers in the French and African markets. One of the better markets today for PV products is Francophone Africa. This market is characterized by: French government development funding which often dictates a preference for French manufactured products; local currencies tied to the French franc; and close language/cultural ties with France. Most of the U.S. PV industry agrees that by manufacturing in France their market position in Francophone Africa is greatly enhanced.

The following conditions account for the recent joint-venture activity in Europe:

- Most PV manufactures today are U.S. companies
- Considerable investment capital is essential to maintain a lead position in the PV industry
- There are apparent market advantages to manufacturing in Europe
- Major European corporations are alert to and receptive to importing highly competitive U.S. PV manufacturing expertise.

3.2 Current and Potential Markets

3.2.1 Market Overview

Photovoltaic module sales for 1978 totalled worldwide about .9 MWp, although independent estimates range from a low of .5 MWp to a high of 1.3 MWp. For the current year it is anticipated that module sales will be about 1.6 MWp or almost double last year's production. Industry estimates on 1979 sales range from about 1.2 to 2.2 MWp with much of the differences resulting from whether or not major U.S. Government purchases are included (i.e., FPUP, PRDA's, Saudi/U.S. project). Figure 3-3 below provides a rough estimate of worldwide sales

to illustrate the relative size of the European manufacturers market share rather than a definitive world sales volume.

PV Cell and Module Sales (MWp)		
	<u>1978</u>	<u>1979</u>
• United States		
Domestic	.380	.650
Export	.300	.580
• European	.175	.300
• Japanese	<u>.045</u>	<u>.070</u>
TOTAL	.9	1.6

Figure 3-3 Overview of World PV Sales

Currently, European manufactured cells and modules are not a factor in the U.S. domestic market, primarily because of price and the fact that the domestic market consists largely of government sales. Most European manufactured PV products are exported. The market in Europe is limited to a few commercial, small-scale stand-alone applications similar to the U.S. domestic non-government market. Also in Europe there is a market for limited government buys and consumer products (such as watches, toys, etc.).

From discussions with various European manufacturers, there is considerable optimism for a growing market demand in developing countries and in the less developed areas of Southern Europe (e.g., parts of Italy, Greece and Spain). Also there is a corresponding effort to increase PV production capacity in Europe to meet this growing market.

Near term markets are naturally the primary concern when discussing PV markets with the industry. This is even more pronounced when talking with European PV manufacturers. The point is that the near term market emphasis is tempered to some degree in the United States because of the large government program to make photovoltaics a major domestic energy source by the turn of the century. This long view is less apparent in Europe where most manufacturers look to new markets in areas not yet electrified by central utility grids.

Another difference is the European attitude about PV module costs. The cost goals of the United States Department of Energy Program and the competitive nature of the Government procurements have of course resulted in module costs per peak watt being emphasized. In Europe cost is also important but government markets have been captive markets. Philips and Telefunken representatives, for example, have consistently stressed the importance of product reliability and cell efficiency over cost considerations. The fact that European module prices are generally higher than U.S. prices helps explain this European emphasis on quality rather than price. Also, Telefunken does not have a competitive product on the market at this time, and Philips is experiencing growing competition from less expensive U.S. manufactured modules.

In today's market U.S. manufacturers are providing a quality product at very competitive prices overseas. There is common agreement that module prices based on existing technology will continue to drop well below \$10/Wp in the immediate future and that the market will continue to expand rapidly. There is confidence in a developing country market which justifies corporate investment in the PV industry with

prospects of turning a profit within the next five years. Domestic United States Government goals are long-term and inviting, but the belief is a large stand-alone power generation market is the key to increased European activity in photovoltaics.

3.2.2 Module Prices and Production Plans

Today PV modules are manufactured in Europe by RTC (a Philips subsidiary), Telefunken, Ferranti, and France-Photon. In late 1979 Photowatt International S.A. is expected to begin manufacturing in France. Total sales for 1979 for these European firms is estimated to be about 300 KWp. The range of sales by company is as follows:

<u>Company</u>	<u>(KWp)</u>
Philips (RTC)	200 - 260
France Photon	10 - 30
Telefunken	10 - 30
Ferranti	<u>20 - 30</u>
<u>TOTAL</u>	240 - 350

The above estimates are provided to illustrate the relative importance of the various European manufacturers in today's market. European production represents about 18 percent of the world total for 1979. If we exclude United States domestic sales, this represents about 33 percent of the available international sales volume. Considering that many of these international sales are linked to German or French government programs where local manufactured products are preferred, it is apparent that United States manufactured PV products are very competitive overseas.

A major reason for the United States having a large share of the market is that European and Japanese modules are higher priced for a comparable quality. Today, United States manufactured PV modules on the world market are priced at an average of about \$13/Wp or about 10-15 percent above the domestic United States price. Prices will vary considerably with the size of the order. Philips (RTC), the major European manufacturer, sells its' product for 10-15 percent higher than United States module prices overseas, or at about \$14-15/Wp. Ferranti prices are fairly close to Philips, again slightly higher than the United States product. France-Photon is of course producing a Solarex product, with United States manufactured cells. Their pricing reflects the above quoted United States average product prices. Telefunken panels reportedly sell for about \$22-24/Wp, but the product has not been observed in open market competition.

The current price differences (excluding Telefunken) in themselves are not sufficient to have a major effect on today's sales. As low United States module prices became more apparent in the foreign market this past year, Philips module prices have continued to be competitive. Prices today are viewed as transitional. Most manufacturers believe that module prices of under \$10/Wp are essential to remain competitive next year. Cost reductions are expected to continue as the result of improved manufacturing methods for single-crystal cells made possible by increased sales volume and the use of new silicon materials, notably polycrystalline technology.

Telefunken, in a joint venture with Wacker Chemitronic GmbH, is being funded by the German Government at \$75 million through 1985. The two companies are supplying an additional \$20 million. The intent is to utilize polycrystalline silicon

using a ingot casting method to produce 10 by 10 centimeter cells at better than 10 percent efficiency. The program includes a highly automated production facility with a goal of under \$2.40/Wp module by 1985. It has been reported that polycrystalline production is expected to grow from 30 KWp this year, to 70 KWp next year and 500 KWp by 1985.

Ferranti Limited currently focuses on the same single crystal technology as most of its competitors. They utilize similar techniques in module manufacture, achieve similar cell efficiencies and perhaps have the same or slightly lower labor costs. Although British Government funding is limited, Ferranti is studying high volume automated module production sponsored by the EEC. Also, they anticipate manufacturing a polycrystalline square cell in the near future. One view of the reason for this higher module price today is that the company must directly fund R&D, which in other countries is funded largely through government programs.

Philips and its subsidiary RTC also have active R&D programs aimed at drastically reducing module prices by the early 1980's. These and more detailed description of R&D efforts are addressed in Section 3.4.

In summation, it is worth noting that today U.S. manufactured PV modules are less expensive than the European product. However, the price difference, usually 10 to 15 percent, is insufficient in itself to make a major difference in sales volume given the products are of comparable quality. It might be added that today typical single crystal silicon cell encapsulated on glass is a fairly competitive product which does not differ appreciably from manufacturer to manufacturer. None of today's products stand out as unquestionably superior or inferior to the rest. What does reflect a difference in sales volume is how the product is marketed.

3.2.3 Marketing Activity

One view of today's marketplace for photovoltaic systems is that it covers so vast an area and is so fragmented that companies rarely meet in open competition. An exception to this are the large sales for which most of the larger companies bid competitively. Other exceptions are government programs. The largest world market, the U.S. Government, is dominated by U.S. manufacturers. Foreign manufactured PV systems are not cost-competitive at this time in the U.S. market, moreover there is a preference to buying domestic products. The other primary markets in the world are the German and French governments, the latter of which can be viewed in conjunction with the West African market developed largely through French development assistance programs. German government funding can also be viewed in terms of development assistance and demonstration projects largely in developing countries. Again German products are preferred for these activities. Another fairly active market has been Australia, where there is substantial interest in PV applications.

Currently, emphasis is being placed on West Africa as a market today and as a large potential future market. Water pumping applications are being demonstrated in a number of these countries including Upper Volta, Senegal, Nigeria, Mali, Cameroon, Rwanda, and others. A variety of PV telecommunications applications are also in place including educational television power source applications. Much of the above activity involves the French Government and French firms. United States AID and most United States PV manufacturers are active in West Africa but clearly the area has been predominantly a French testing ground for developing country

PV applications. For example, PV powered educational television has long been a French supported concept, and it has been applied on a relatively broad scale in the area. Also, small high-efficiency water pumps to be utilized with PV power systems were an early interest of the French Government and the French private sector.

The current high interest in the African market stems from early French government funding which has resulted in a relatively high concentration of PV applications and local and international interest. Given a few years for PV systems to receive similar exposure elsewhere in the world other areas will enjoy similar or increased attention as important markets. What is important today about West Africa is that it contains the only fairly concentrated PV applications activities in the developing countries.

A considerable amount of activity is developing elsewhere in the world and much of this involves European based firms. Ferranti Limited, the British PV manufacturer, is attempting to increase its share of this market and is concentrating on products that will earn sales now. The firm is installing a 2 KWp system (funded by the EEC) on the roof of their building near Manchester which powers a satellite receiver station (Ferranti manufactures this receiver product). It is intended to demonstrate PV industrial applications in northern latitudes.

Lacking a domestic market in the United Kingdom, Ferranti's efforts focus on the developing countries. The firm is responsible for PV applications in upper Egypt and the Sudan. Ferranti is also exploring potential markets in the People's Republic of China. Although a major firm in the electronics and telecommunications equipment, Ferranti does

not have as strong a marketing organization as its' major competitors in photovoltaics. Ferranti is aware of the importance of linking with other companies having product lines and distributions systems which compliment the PV market. Ties with British pump manufacturers and other firms which compliment Ferranti's PV product and total system approach to the market may be forthcoming.

In contrast, Philips has the most impressive worldwide organization which complements today's PV marketing activities. As a highly integrated multinational firm with products in lighting, appliances, telecommunications and other relevant products, Philips manufactures in about 50 countries. This combination of size, relevant product lines, and integrated corporate structure have made Philips the leading PV manufacturer in Europe and the major foreign competition for U.S. firms. Philips excellent distribution system for electronic components is a major asset in the PV market. In today's fragmented and dispersed world market for photovoltaics, Philips competes very well. For example, by the time a U.S. firm finds out about a potential sale for a solar village exhibition in Egypt, Philips is already making the sale. Their extensive distribution system is very effective in today's market. Most competitors have been attempting to establish overseas distributors or have recently entered into joint ventures to acquire this local presence. U.S. competitors comment that Philips is especially strong in Latin America, Australia, and the Middle East.

In today's market--which can be characterized as a product demonstration market for many of the applications and audiences involved--Philips is stressing the importance of product reliability and efficiency. Over the past year Philips has had production problems which has partially

contributed to not achieving their market share expectations. Although their prices are still 10 to 15 percent higher than U.S. competitors, Philips is supported by extensive R&D activity and will continue to be a major competitor with an excellent product. Philips does not see price as the critical element in this early market. One view is that good products must be demonstrated if there is ever to be a chance for major market development.

Until recently the Philip's subsidiary RTC was the only French PV manufacturer and therefore retained the lead role for French government funded applications especially in West Africa. France-Photon, the Solarex and Leroy-Somer joint venture, is now manufacturing in France and Photowatt International S.A., the CGE and Sensor Technology joint venture, will be manufacturing in France later this year. Consequently, the special market position available through domestic production in France is being more broadly shared.

Photowatt International S.A. will be manufacturing panels beginning later this year from a CIPEL plant in the Paris suburbs. The firm anticipates an immediate market demand stimulated by the CGE broad distribution network especially for primary batteries in developing countries. They view the market as being telecommunications, water pumping and similar applications abroad. The European market is anticipated to include applications for: vacation homes, televisions, lighting, recreation vehicles and other consumer products. European enthusiasts of the venture see their sales volume increasing from 5 to 10 times the current Sensor Technology sales volume in the near future. Competitors are more skeptical and have noted that the battery market and the PV market are not necessarily as similar as one might be led to believe. Nevertheless, the entry of CGE as a PV manufacturer will provide additional international competition. It is too early to appreciate the intensity of this competition.

Telefunken, another major multinational firm, has been actively marketing PV systems for the past year. Being the only German producer of PV systems and being heavily funded by the government, most of Telefunken's sales are in conjunction with government overseas activities. Telefunken has provided PV applications for the limited domestic German market, and has systematically approached the potential developing country market. At present Telefunken products are being actively marketed in Southeast Asian countries in conjunction with German government development aid programs. Similar activity is apparent in the Middle East and Telefunken PV products will be utilized on the German "Vontlan" project in Mexico. Other cooperation projects in Mexico and South America range from the sale of cells to funded local R&D efforts to demonstrations. Water pumping applications for developing countries are viewed as a long-term market in which Telefunken has been demonstrating total PV powered water pumping systems.

Telefunken's market activity can be summed up as a government supported effort to establish a market position in preparation for a forthcoming highly competitive polycrystalline product. Today's market activities are but part of a total government funded program.

In reviewing the European companies active in the marketplace, only Philips is a major competitor with U.S. manufacturers today. Telefunken and Ferranti are relative late comers, but both have the potential to increase their market share, especially Telefunken with aggressive government support and focused R&D effort.

France-Photon, Photowatt International S.A., Solaris and other joint ventures between European firms and United

States PV manufacturers will probably continue to increase in number as the market expands. Moreover, Montedison, CGE and a few other major firms independently or initially through joint ventures and licensing agreements will emerge as major forces on the world markets in their own right.

3.2.4 European Export Posture

The following comments identify specific characteristics of European business activity which assists in providing an appreciation of European competition in photovoltaics today. Most are perceptions by informed observers which do not require considerable elaboration.

3.2.4.1 European Firms are Traditionally More Oriented to Export Sales than U.S. Firms

It is not uncommon for European firms to have 60-70% of their sales in exports. In contrast, U.S. firms traditionally develop products for a domestic market and then eventually export these products where a demand exists. There are of course a considerable number of exceptions but this view has been popular in pointing out U.S. export shortcomings. This reluctance to develop and market new products for an export market is evident today in the area of total photovoltaic systems. The PV industry for the most part has been aggressive in developing an export market for its products (PV cells and modules). Often firms have found it necessary to stimulate specific applications, i.e., water pumping, cathodic protection, and refrigerators only because there was little interest or support from relevant domestic product manufacturers to develop the application and the market.

This general observation which is more meaningful when contrasted with activities in Europe. The largest small

electric motor manufacturer in Europe, Moteurs Leroy-Somers, has actively sought and claims a major role in the application of the PV systems. Their subsidiary Pompes Guinard is a major contender for PV water pumping applications and perhaps the most experienced company today in this area. U.S. PV manufacturers have found it beneficial to associate themselves with European pump companies and other firms which are developing the market. Few of these are U.S. companies for several interrelated reasons: most of this overseas activity is in regions where U.S. firms are not well represented (partly due to the tendency to minimize export opportunities). There is broad interest in France for solar power applications and few U.S. firms have relevant domestic products which compliment this early market or the product is manufactured abroad. For example, most small size diesel engines and engine generators relevant to developing country markets are manufactured in Japan and Europe. Few water pumps under 50 HP are exported by the U.S. manufacturing facilities overseas. We have yet to see a U.S. equivalent to the French pump company, Pompes Guinard, take an active part in PV market development.

There are U.S. firms involved in developing the PV market in a number of areas particularly telecommunications, where U.S. business is well represented. However, in most other areas particularly in the potentially large developing country markets there is a noticeable shortage of U.S. firms active in total systems applications. The French are especially active in the applications area. Also German sales approaches to developing countries are well represented by German firms (i.e., pump companies) capable of providing "turnkey" systems. The role of U.S. firms in the international market today can be characterized as that of the leading supplier of PV power cells and modules. The Europeans appear more active in the application of this power system especially

in the developing country market. This view is supported by: (1) the limited interest shown by relevant U.S. manufacturers compared to the European response to applications development, and (2) the expansion of some U.S. PV manufacturers into the total systems area to fill this void.

3.2.4.2 European Industry/Government Cooperation

European industry/government cooperation is more conducive to competitiveness in the marketplace than the corresponding U.S. industry/government cooperation.

This generalization must be qualified because of the variance in government/industry relations in Europe. For example, Germany is an excellent example of industry/government cooperation while it would be more difficult to support this position with regard to Britain. Because of the potential of Germany as a major competitor in PV exports, most observations in this section focus on the German industry/government relationship.

In Germany and elsewhere in Europe, private firms retain the patent rights resulting from government sponsored research. There is little fear that government funding might undermine corporate objectives in this area. Moreover, government provides industrial grants and support with few public information stipulations. Published R&D results tend to be distilled information, in contrast to the U.S. freely making available the result of all funded R&D activity. For example, in collecting data for Section 3.3 of this report, an effort was made to identify all PV program descriptions and R&D results in the major European countries. In most instances little was available beyond general program description literature and the usual published papers from international conferences. Nor did the U.S. Department of Energy or the

Solar Energy Research Institute possess any more substantial literature on the subject. In contrast, the Europeans contacted were much better informed of U.S. program activities and results than their U.S. counterparts were of European events.

In Europe, both government and industry take a hard line on marketing activities, especially in Germany. Grants, loans and integrated financing are strongly supported between government and industry. An excellent example is the German government support of Telefunken and Wacker on a multi-year program to develop a polycrystalline product. Also the German energy investment program for developing countries is sensitive to the government sponsored PV initiatives. Germany is systematically marketing PV systems through its assistance programs. The point is that German efforts appear to be focused and coordinated in terms of government support and industries participation. There are few industrial participants and the program is smaller than the U.S. PV program which accounts to some degree for the more solidified approach.

Underlying the above observations is a basic difference between the industry/government relationship in the U.S. and Germany (and to some degree in France). One informed observer in Germany notes that "government and industry go hand in glove". Rarely can we observe differences of opinion between the two in public. Most government officials have strong private industry ties. The relationship is based on a whole different philosophy from that experienced in the U.S.

3.2.5 Energy Investment in Developing Countries is a Major Factor in Today's Market

To date most PV sales to developing countries have been financed by the host government dependent on the availability of development funds. In 1977 roughly \$7.4 billion

was committed to the energy sector of developing countries by: official development assistance programs (15% of the total); non-concessional official including multinational development lending and bilateral official export credits (29% of total); and private, officially guaranteed export credits (56% of total).

The total U.S. commitment for energy investment in developing countries in 1977 was \$1.4 billion of which \$9 million was for the exploitation of energy resources (which includes renewable energies). The United Kingdom investment was a total of \$190 million with no specified amount for exploitation of energy resources. Britain is doing little in the alternative energy area compared with other major developed countries. In contrast, the French investment totaled \$697 million of which \$25 million was for the exploitation of energy resources. German's investment was \$1.3 billion and \$9 million respectively. The international development institutions (World Bank Group) totaled \$1.0 billion with \$10 million committed to the exploitation of energy resources.

The above figures provide some understanding of the relative contribution of various countries and the minimal attention paid to a renewable alternative energy resource in 1977. More recent figures are not available, although the development of renewable energy sources for developing countries is receiving considerably more attention today and in the next few years. It should be noted that the French were more sensitive to this area in 1977 in terms of development funds available. Also French aid is more regionally focused in Francophone Africa. This, coupled with the French early emphasis in solar, help explain the current PV market activity in Francophone Africa.

3.3 Status of PV and Related Technology

3.3.1 Overview of European Activities

Throughout Europe a large number of universities, research institutes and industrial research centers are performing research and development work related to photovoltaic systems. The total government funds available for this R&D is in excess of \$35 million annually; France and Germany providing more than 85 percent of the total. The work in each country is generally concentrated on only several of the technologies defined by the U.S. program. The R&D centers in Europe were identified by obtaining literature from each government when available and by examining the published literature on photovoltaics from conferences and other resources. This was supplemented by telephone interviews with a number of government and private industry representatives in the U.S. and Europe. From this information a large number of centers were identified, although it is certain that not all the centers have been identified, especially in industry. The discussion in the following sections is based on those R&D centers identified, which represent the most R&D activity in Europe, and on information available in the research in progress at these centers.

European R&D activities identified are compared with the U.S. Photovoltaic Program in Figure 3-4. The extent and focal points of each European national program can be identified in this Figure. France has the largest program and it is oriented toward silicon technology development and emerging materials. The German program is the next largest and is focused on cast ingot polycrystalline silicon technology development and on the advanced technologies of Cadmium Sulfide, CdS, and amorphous silicon cell research. The recently completed four year plan of the Commission of the

U.S. Photovoltaic Subprograms (\$100 M/a)

I. Photovoltaics Research	CEC Contracts Support Activities in Each Country Dollars are for the 4 Year Plan					
	France \$21 M/year	Germany \$10 M/year	Italy \$1 M/year	United Kingdom	Others	
(1) CdS/Cu ₂ S and Cu Ternary	U of Langeudoc - CNRS* U of Paris CNRS* Saint Gobain	W.C. Heraeus U of Dortmund U. of Stuttgart Leybold - Heraeus Battelle Inst.	U of Parma	G.V. Planer New Castle Polytechnic IRD U of Durham EMI, Ltd. Preston Polytechnic Portsmouth International Cranfield Inst. of Technology	Inst. of Nuclear Research, Poland U Autonoma de Madrid	(5 contracts \$0.4 million)
(2) Polycrystalline Silicon	LEP* CNRS* CRN* CGE*	Wacker-Chemtronic AEG-Telefunken	U of Modena U of Naples U of Pavia	Royal Military College of Science Plessey Co, Ltd.	U of Nijmegen Rijksuniv. of Utrecht	(4 contracts \$0.4 million)
(3) Amorphous Silicon	CNRS* LETT* CGE*	Inst. f. Ang. Physik, Karlsruhe Siemens U of Marburg M.P. Inst. f. Kerophysik M.P. Inst. f. Fest- korperforschung, Stuttgart U of Stuttgart Battelle Inst. AEG-Telefunken KFA*, Juelich	U. of Rome	Heriot-Watt U Cambridge U U of Sheffield U of Dundee	Rijksuniv. of Gronath	(6 contracts \$0.3 million)
(4) Polycrystalline GaAs	LEP* Ecole Nationale Supérieure de Chimie		CISE, SpA U of Naples SICI-ATES	Plennay Co, Ltd.		(3 contracts \$0.02 million)

Figure 3-4 European R&D Activity Categorized by U.S. Program Elements

I. Photovoltaics Research						CEC Contracts Support Activities in Each Country Dollars are for the 4 Year Plan
	France \$21 M/year	Germany \$10 M/year	Italy \$1 M/year	United Kingdom	Others	
(5) Emerging Materials	CRN* CRNS* LETI* U of Paris U of Strassbourg U of Montpellier U of Lyon ENS*	Battelle Inst. KFA* U of Konstanz	IAMM	Royal Military College of Science	U of Gent Zaklad Fiziki Ciala, Poland	(6 contracts \$0.4 million)
(6) Amorphous Materials (non Si)						
(7) Advanced Concentrators and Concentrator Cells	CRN* IEP*	Battelle Inst. Fraunhofer Inst.	CISE, SpA SGS-ATES U of Bologna	Oxford Univ. Std Telecom Lab Plessey Co., Ltd.	U of Polytechnica, Madrid U Leuven, Belgium	(9 contracts \$0.9 million)
(8) Electrochemical PV Cells	CNRS*	Philips GmbH Fritz Haber Inst.	U of Rome U of Milan			
(9) Basic Mechanisms	U Languedoc IEP* CESR* U of Louvain LAAS-CNRS*			U of South- ampton		
(10) Test and Measurement	CNES*	U of Stuttgart		RAE Farnborough Ferranti Electronics	U Leuven, Belgium	
(11) Technical Issues						

Figure 3-4 Continued

		France \$21 M/year	Germany \$10 M/year	Italy \$1 M/year	United Kingdom	Others	CEC Contracts Support Activities in Each Country Dollars are for the 4 Year Plan
II. Technology Development							
(1) Low Cost Silicon Array	MTC* LEP* CRN* CGE*		AEG-Telefunken	Montedison IAMEL-CNR SECIES	Metals Research, Ltd. Ferranti Electronics	U Leuven, Belgium	(7 contracts \$0.5 million).
(2) Concentrator Systems	CNES* LAAS-CNRS*		MAN Neue Technologie Kleinwachter	Montedison Ansaldo Galileo SGS-ATES		U Polytechnica, Madrid B. Kidric Inst., Yugoslavia U Leuven, Belgium	
(3) Total Energy Systems							
(4) BOS	CNES*		AEG-Telefunken		AERE, Harwell	U Odense, Denmark Lab v. Elect. Mat., Belgium	
III. Systems Engineering and Standards							
(1) Systems Definition and Development	CNES* Tech. h. Berlin		SERI Renault	ENEL*		Energies Nouvelles et Environnement Belgium	(5 contracts \$0.5 million)
(2) Standards Development							
IV. Test and Applications							
(1) Application Experiments	CNES* CNET*					N.V. Philips, The Netherlands	(7 contracts \$0.6 million)
(2) Field Demonstrations							
(3) Field Tests		AEG-Telefunken			Ferranti Electronics		

Figure 3-4 Continued

V. Planning Assessment and Integration	France \$21 M/year	Germany \$10 M/year	Italy \$1 M/year	United Kingdom	Others	CNC Contracts Support Activities in Each Country Dollars are for the 4 Year Plan
(1) Mission Analysis						
(2) Economic and Policy Studies				U of Southampton		
CESR - Centre d'Etudes Spatiales des Rayonnements CGE - Compagnie Generale d'Electricite CHES - Centre National d'Etudes Spatiales Toulouse CNET - C.N.E.T. Paris CNR - Center of National Research, Italy CNRS - Centre National de la Recherche Scientifique CRN - Centre des Recherches Nucleaires ENEL - National Electric Utility, Italy ENS - E.N.S. d'Electronique et de Radioelectricite IRD - International Research and Development Company KFA - Kernforschungsanlage, Julich LAAS-CNRS - Laboratoire d'Automatique et d'Analyse des Systems du CNRS LEP - Lab. d'Electronique et de Physique Appliquee LETI - Lab. d'Electronique et de Technologie de l'Informatique RTC - Radiotechnique Compelec						

European Communities (CEC) concentrated on cell research but the forthcoming four year plan will focus more on technology development and system issues. The British program is focused on amorphous silicon with some work in CdS. The Italian program is oriented toward concentrating systems development with considerable activity in silicon technology development. Other countries are doing a very limited amount of photovoltaic R&D and much of this is through the sponsorship of the CEC program.

Collectively, the European R&D programs support activities in each subprogram area of the U.S. program. However, the primary emphasis has been in the areas of photovoltaic research and technology development. System engineering and test and applications efforts in Europe have been more limited.

In all the European countries examined, industrial or commercial companies performing research and development work under government contract are required to share the project costs. In France, the United Kingdom and Italy contributions equal to the government funding are normally required. In Germany, government support ranges from 20 to 100 percent of the project cost. In these arrangements the private firm retains all the rights to the results of the research, and project reports are considered confidential information by the government. On the other hand, some information from university and national laboratory research is usually available.

In summary we find that the focused R&D efforts of the European countries span the spectrum of R&D efforts underway within the U.S. Often the results of European R&D are not available to researchers within the U.S. because the work is

carried out at industry centers. The following statements can be made in comparing the U.S. and European government sponsored photovoltaics R&D programs:

- The U.S. maintains a lead position in most photovoltaic R&D areas.
- The focused programs of the European countries permit each to maintain state of art R&D activities in a limited number of photovoltaic technologies.
- Both U.S. and European photovoltaic research results (cell R&D) are available after the usual publication delays.
- The results of European technology development activities are not usually available because these are the exclusive property of the firms performing the development work.

In conclusion, the focused R&D efforts in Europe provide each country with a relatively strong research capability in specific aspects of photovoltaic technology. The early U.S. lead in semi-conductor and photovoltaic R&D and the large funding level of the U.S. program has resulted in focused European R&D efforts that follow the U.S. lead. The exchange of benefits for R&D in cell development is characterized by significant contributions from both the U.S. and Europe. The U.S. program provides a broad base of R&D for a significant portion of the possible photovoltaic technologies while the European activities add depth and new approaches to solving problems.

In the next section the activities in each country are described. The activities in France, Germany, Italy, United Kingdom and the CEC program are addressed.

3.3.2 Major European Photovoltaic R&D Activities

3.3.2.1 France

The French program in photovoltaics is the most developed in Europe. The French have been building terrestrial photovoltaic systems for over eighteen years and are performing extensive research in most areas of photovoltaic technology.

R&D Activities. The French R&D activity is comprehensive covering a broad range of topics. Solar research in France is supported primarily by COMES (Commissariat A L'Energie Solaire) and is performed by universities, government laboratories, and industry. Included is research in the areas of: CdS related films, polycrystalline and amorphous silicon, emerging materials, concentrator cells, basic mechanisms, single crystal silicon, systems analysis and system test and demonstration.

Cadmium sulfide research in France is limited. The University of Sciences and Technology at Languedoc and CNRS (Centre National de la Recherche Scientifique) in Mulhouse are investigating sprayed CdS/Cu₂S cells and the University of Paris is investigating electrolytic deposition of CdS. CNRS also has a joint program with St. Gobain for CdS research. No other research on CdS was identified in France.

Polycrystalline and amorphous silicon based photovoltaic devices have generated more interest than CdS. Research is currently underway at LEP (Laboratoire d'Electronique et de Physique Appliquee), CNRS, and CRN (Centre des Recherches Nucleaire). These efforts all are focused on developing thin film cells using silicon and include a number of techniques including ion implantation, laser annealing and ribbon on drop film growth.

A wide variety of emerging materials is also being investigated by French researchers. The centers performing this work are listed in Figure 3-4. The materials under investigation include:

- Amorphous SiGe - CNRS
- AlGaAs, GaAs - LAAS-CNRS
- III - V thin films - ENS
- AlSb - CNRS Meudon
- CdTe - CNRS Meudon
- Si-In₂O₃, GaAlSb - University of Montpellier
- GaAs - LEP
- CdTe - LETI
- Cu₂O - University of Strasbourg
- InSe - University of Paris
- CdTe, InAlSb - CNRS Bellevue
- CdTe - CNRS Toulouse
- GaInP - CNRS Meudon.

The diversity of these materials and the number of centers involved indicate that the French consider advanced concepts an important facet of the photovoltaic program.

As shown in Figure 3-4, the French also have research teams at the major research centers (CRN, CNRS, and LEP) involved in some work on advanced concentrator cells, basic mechanisms and electrochemical cells. There are also extensive French technology development programs at RTC (Radiotechnique-Compeles) LEP, and CRN. These activities are aimed at developing silicon cell technology and reducing costs to \$1 - \$5/Wp. Activities in systems analysis have been underway in the design of a 1 MWp demonstration for CEC by SERI Renault.

Government Sponsored Programs. The French Government support for photovoltaic activities has risen to over \$21 million in 1979 from \$14 million in 1978. Photovoltaics are an important element in the French Solar Program, accounting for 33% of the program funding in 1979 and 27% in 1978. The French perceive the major market for photovoltaics to be in exports and over 90% of the current production is for export. To develop this market the French program is supporting activities in:

- fundamental research on new materials
- applied research for inexpensive silicon cells
- industrial development of production facilities
- concentrating system development
- power conditioning system studies.

The French Government is also supporting water pumping system demonstrations in developing countries. These demonstrations include: one in Corsica, two in Senegal, three in Upper-Volta, two in Mali, and one in Cameroon. Other demonstrations include a photovoltaic/wind hybrid system at LaTurbie for a remote microwave repeater.

Considering the scope of the current French research program, it would be expected that research results and program information would be readily available. The lack of available information is partly attributed to the policy that the results of the work contracted to industry are considered the property of the contractor.

Technical Achievements. The French Program has had marked success in obtaining technical and economic results from the R&D efforts. Thin film CdTe cells have been produced

with 6% efficiencies and RAD (ribbon on drop) pulled polycrystalline silicon films have produced cells with efficiencies of 9 percent. The work on manufacturing process done at RTC is expected to reduce the cost of manufacturing single crystal silicon cells by a factor of two to three for 11 to 13 percent efficient cells.

3.3.2.2 Germany

The Germans have the other extensive photovoltaic research and development program in Europe. Government sponsored activity includes virtually every photovoltaic cell technology as well as systems and balance of systems (BOS) development. The major German photovoltaic development program is the Wacker-Chemtronic/AEG-Telefunken Polysilicon project, funded with \$78 million in government funds and \$20 million in corporate funds (over 8 years). Although this project dominates the German R&D effort, cell efficiencies obtained by German researchers for advanced materials are essentially the same as those in the U.S., but most of this research is centered on CdS/Cu₂S and amorphous silicon.

R&D Activities. The major centers of advanced photovoltaic and cell R&D work in Germany are comprised of several universities and research institutes. The University programs include programs in CdS, amorphous silicon, other emerging materials and electrochemical cells. The University of Stuttgart has an extensive program to develop CdS/Cu₂S cells and manufacturing processes. Cells with efficiencies of 6.7% are being made at the CdS/Cu₂S pilot plant in Stuttgart. The processes identified are being examined by the firm, Leybold-Heraeus, for possible automated assembly applications.

Amorphous silicon cells are being investigated by numerous research groups throughout the country (see Figure 3-4). These researchers are examining various junction structures, but have only been able to obtain efficiencies in the 2-3% range. The Battelle Institute, Frankfurt, and the University of Konstanz are the primary centers for work on other emerging materials. Work has been limited to CdSe-MIS, and CdTe heterojunction at Battelle and several exotic compounds (Zn_3P_2 , InSe, GeS, WSe_2 , etc.) at the University of Konstanz. Difficulties have been experienced in cell fabrication although some 2 percent efficient cells have been made at Battelle and up to 5.3 percent at Konstanz. Other cell research includes activity in electrochemical photovoltaics at the Fritz-Haber Institute in Berlin and at Philips GmbH in Hamburg.

The major cell development effort is at Wacker-Chemtronic and AEG-Telefunken where the intent is to develop photovoltaic systems based on polycrystalline silicon cells. This program will:

- develop high efficiency polycrystalline silicon cells cut from cast ingots (10 percent cells measuring 10 cm x 10 cm have been produced)
- develop manufacturing processes to produce modules from these cells at \$2.40/Wp by 1985
- develop balance of system elements as needed
- perform field tests of promising systems.

The German Government is providing \$78 million for this program over the eight year period from 1977 through 1985 and Wacker and Telefunken are providing \$20 million. A pilot production

line is in place and is reportedly producing approximately 30 kWp of polycrystalline cells this year. Production is expected to reach nearly 400 kWp/year by 1983.

Government Programs. The photovoltaic program activities in the Federal Republic of Germany are carried out as a part of the Efficient Use of Energy in Application and Secondary Energy Subprogram, of the Energy Research and Energy Technologies program. The program is administered by the Ministry for Research and Technology in Bonn, while project management is the responsibility of the Julich Nuclear Research Establishment (KFA). The program goal is to achieve an array price of \$2.40/Wp by 1985. To meet this goal the German Photovoltaic Program is highly oriented toward production of low cost polycrystalline silicon modules by 1985. The government investment in photovoltaic project is:

- 1977 - 1980 Wacker/AEG - \$32 million
- 1981 - 1985 Wacker/AEG - \$46 million
- Other Projects (1978) - \$0.8 million/year.

Funding for the polycrystalline silicon cell project is nearly ten times that of other photovoltaic R&D activities. Many of these other R&D activities include funding from other sources, primarily from the Commission of the European Communities (CEC).

In addition to these efforts on cell R&D and polycrystalline manufacturing development, the German Government is sponsoring several demonstrations of photovoltaic systems. By 1978 demonstrations of communication applications were installed in Germany (350 Wp), Iran (2.6 kWp), and Indonesia (300 Wp). More recent demonstrations of village power and water systems are being installed in Mexico and Indonesia. Germany also has

an active joint solar test program with several countries including Brazil, India and Iran.

Technical Achievements. The accomplishments of the research done under the support of the German Government rivals that in the U.S. program in advanced material cells. In polycrystalline silicon cell and module production the German program is possibly as much as a year ahead of U.S. manufacturers.

The German program in non-silicon materials includes pilot plant producing CdS/Cu₂S cells with greater than 5% efficiency. This plant produces less than 1 kWp per year, but scale up for automated production is under study. Research on other advanced materials has helped researchers understand the various problems and techniques related to amorphous silicon and various compound semiconductor cell technologies. The German program for concentrating cells is virtually nonexistent; a small effort is underway on CdTe cells for concentrators at Battelle, Frankfurt, but no others were identified. The Germans have, however, developed concentrators for solar thermal collectors that could be used for photovoltaics. These include the parabolic dish collectors developed by M.A.N. (Maschinen fabrik Augsburg Nurnburg AG) and Prof. Kleinwachter Research Laboratory. The emphasis in the German program is on flat panel systems, especially polycrystalline silicon based systems. In this technology the Germans obtained 10 percent efficient 10 cm x 10 cm cells early in 1978; this was not repeated in the U.S. until early 1979. The German concentration on polycrystalline silicon technology is based on producing cells from ingots of polycrystalline silicon. In the U.S. the major R&D effort in polycrystalline silicon is oriented toward thin film technology with the major support to ingot technology resulting from recent system test contracts (PRDA's).

The German concentration on polycrystalline silicon technology development complements the activity in the U.S. This program orientation toward polycrystalline has allowed the German researchers to take the lead in this area while their efforts in other cell technologies, have enabled them to maintain their expertise in "a state of the art" position.

3.3.2.3 Commission of the European Communities (CEC)

CEC provides significant support for photovoltaic research and development throughout Europe with funding being provided by its member countries. Photovoltaic research is supported in Great Britain, France, Germany, Belgium, The Netherlands, and Italy. Figure 3-5 lists the topics, contracts and level of funding provided by the CEC for photovoltaic research for the 1975 through 1979 period. As a rule the CEC provides 50 percent of the project funds and the contractor or host country supplies the remainder. In July of 1979 a new four year plan was to be initiated; however, final approval of that plan has been delayed. It is anticipated that this second four year plan will be more heavily oriented toward prototype system demonstrations than the previous plan. Work will also continue on the current cell research activities.

Program Element	Number of Contracts	CEC Contribution (Millions of \$)
1. Silicon Films	4	0.4
2. Silicon Cells and Production	7	0.5
3. Amorphous Silicon	6	0.3
4. CdS Cells	5	0.4
5. CdTe Cells	4	0.25
6. CdSe Cells	2	0.15
7. GaAs Cells	3	0.2
8. Concentrations and Concentrator Cells (Silicon)	9	0.9
9. Application Tests	7	0.6
10. Conceptual Design and Analysis of 1 MWp Plant	5	0.5

Figure 3-5 CEC Photovoltaic R&D Programs

In addition to this program, which is administered by Director General XII, several systems are being fielded as demonstrations. These are sponsored by Director General VIII and include two water pumps in Togo (900 Wp), three water pumps in Mali (1kWp) and a 25 kWp hospital in Mali.

3.3.2.4 Italy

A spectrum of photovoltaic research activities are underway in Italy including silicon material and cell development for flat panels and concentrators, and research on advanced materials, such as CdS/Cu₂S and GaAs. The Italian program funding is divided approximately equally between industry and universities with industry activities oriented toward silicon and systems technologies and university activities oriented toward advanced materials.

R&D Activities. The largest share of the silicon research and development activities is performed by an industry joint venture that includes Ansaldo, ENI, Galileo, Montedison and SGS-ATES. This joint venture is a three year, \$15 million program to develop silicon photovoltaic cells in Italy. About \$2.8 million was spent in 1978 of which \$2 million was private funds, the remainder government. The program includes:

- solar grade silicon metallurgy
- silicon cells development (for flat panels)
- silicon cells for concentrators (ion implanted cells)
- concentrators (up to 100X)

The advanced cell research efforts include experimental studies of CdS/Cu₂S cells at University of Parma; polycrystalline and amorphous silicon cells at the University of Naples, CISE and SGS-ATES; and electrochemical cells at the

Universities of Rome and Milan. In addition to these R&D activities, ENEL, the national electric utility has performed several analyses of utility integrated systems.

Government Program. The Italian program on photovoltaic conversion is administered by the National Center of Research (CNR) and is part of the Solar Energy Subprogram of the Program on Energetics. This program is divided into two areas: silicon technology and compound semiconductor and measurements. Each area supports approximately 10 projects with a total program funding of \$930,000/year of which \$550,000 is for silicon and \$380,000 is for others. This funding provided by CNR is used for operating expenses only and does not include salaries for the university projects. Industrial contractors are expected to provide 50 percent of the program costs in all instances. Technologies supported under government contract include:

- low purity "solar grade" silicon
- ion implanted silicon cells
- laser annealing of silicon cells
- concentrator development
- amorphous silicon film cells
- GaAs concentrator cells
- CdS cells
- Electrochemical cells

Technical Accomplishments. Although the Italian program is modest in funding, concentrator cells are produced with high efficiencies. Gallium arsenide cells have been produced with an efficiency of 21 percent under 1 sun illumination and 15 percent under 1000 suns. Silicon concentrator cells have been produced with 17 percent efficiency at 50X. The Italians are fielding Fresnel lens and parabolic trough

concentrating modules for tests. The tracking mechanisms of these concentrators have angle pointing errors of only 10 minutes or arc. Concentrating systems are an important element of the Italian Program and as such the major accomplishments have been related to concentrators.

The Italian photovoltaic activities have just recently become an element of the CNR program. The interest in photovoltaics is based on the need for alternative power systems within Italy. The objective of the Italian program is to provide a R&D base to develop systems for use in Italy. Little or no work has been done on demonstration projects designed to promote exports. Tests and demonstrations are underway (several kW concentrators) to evaluate the value of photovoltaics to Italy.

3.3.2.5 United Kingdom

Britain does not view photovoltaics as an important potential domestic energy source and therefore their photovoltaic R&D program is limited in scope. The photovoltaic R&D being done is under the auspices of the Department of Industry. Much of the cell research is supported by CEC and complemented by the Science Research Council.

R&D Activities. Research and development activity on photovoltaic cells in Britain is limited to work on CdS structures and amorphous silicon. Other test and technology development activities are related to private industry initiatives.

The CdS research in Britain is being performed by several universities and companies. Included is a joint effort on electrophoresis deposition by EMI, ICI and Preston

Polytenic which has achieved cell efficiencies of 1 to 5 percent. Another noteworthy effort includes studies on energy band structures at the University of Durham.

The major photovoltaic research effort in Britain is on amorphous silicon. The first a-Si pn junction was made at the Carnegie Laboratory of Physics, University of Dundee (Scotland) and this laboratory is still a leader in the preparation and characterization of glow discharge a-Si:H. current programs investigating a-Si cells also exist at the Universities of Cambridge, Scheffield and Herrot-Watt where investigations of MIS cells are underway.

Government Program. The Department of Industry's photovoltaic program is small. The Government perception of future photovoltaic applications is that they will be used for small remote applications in high insolation climates. All Department of Industry contracts with manufacturers are held in strict confidence. The funding for these R&D programs is divided equally between the government and the contractor and all results remain the property of the contractor.

Research on photovoltaics is also sponsored by the United Kingdom Science Research Council, but most of this support is for those programs supported in part by CEC contracts. The research efforts on photovoltaics in Great Britain are dwarfed by the three major program efforts in Europe; France, Germany, and the CEC. The program is small primarily because Britain does not perceive photovoltaics as a significant energy source in Great Britain.

3.3.2.6 Other Countries

Research activities are underway in other European countries. These activities addressed in Figure 3-4 include

R&D in Belgium, the Netherlands, Spain, Poland and Sweden. The most significant of these programs are in the Low Countries and Spain.

In Belgium photovoltaic R&D is very limited and centers around MIS and CdS cell development. In The Netherlands photovoltaic activity is directed toward producing thin film polycrystalline and amorphous silicon cells. These countries support this R&D in conjunction with CEC contracts.

In Spain some work is underway at the University of Autonoma de Madrid and at the University as Politecnica de Madrid. These efforts include work on silicon concentrator cells and on CdS/Cu₂S cells.

In general, the above activities in the European nations with small programs are limited and are centered around research programs in universities on advanced photovoltaic materials.

3.4 Preliminary Conclusions

In this Section the most important findings of the study are summarized. The study focused on the assessment of the current and potential competition in world markets between European and U.S. firms producing terrestrial PV power systems. At present the U.S. has a dominant position in the world market and is the leader in PV technology. However, the technology is in a rapid state of change and today's markets are hardly representative of the marketplace two to three years from now. The following findings are an attempt to view current activities within the dynamics of the PV industry.

- The European PV industry is comprised of a few large multinational corporations most of which are active

in electrical and electronic equipment and telecommunications equipment. A few are major firms with impressive capabilities in silicon materials. All support internal R&D programs.

- Joint ventures with U.S. PV manufacturers provide European firms with advanced PV manufacturing capabilities, a proven PV product, and access to U.S. R&D results. In turn, U.S. manufacturers benefit from capitalization, improved market position and access to European R&D.
- The PV industry is largely comprised of multinational corporations which do not readily fit into the mold of being supportive of national export initiatives. Joint ventures with foreign firms, manufacturing overseas and shared R&D results are realistic business strategies which will become increasingly common as the foreign market develops.
- Today U.S. manufacturers dominate the world market. Only Philips is currently a major competitor although Telefunken and Japanese firms could be major competitors in the next few years.
- The current focus of European firms and U.S. exporters on the Francophone African markets reflects early French attention in this area. Europeans view the major PV markets to be in developing countries and other regions where central station grid-power is not available.
- European firms (especially French firms) exhibit a greater sensitivity to total system applications in developing countries than U.S. firms. Systems integration activity overseas is largely being done by European firms.
- The European presence in the world market today in photovoltaics is closely linked with national government development funding. French development assistance is largely responsible for the attention West Africa is receiving today as a major potential market. German exposure overseas is almost exclusively related to government development activities in support of PV demonstrations.
- U.S. R&D today is in a lead position in most areas of European R&D activity. The notable exception is the cast ingot polycrystalline effort in Germany.

- If a cell technology "breakthrough" occurs at a European research center, the U.S. is in a position to develop that technology rapidly. If the reverse happens, at least one European country will be able to develop the technology quickly. This reflects the focused programs of European countries in comparison to the broader U.S. programs.
- The results of technology development activities in Europe are not readily available because these are the exclusive property of the firms performing the development work. In contrast, U.S. results are more readily available to Europe.

The above findings support the conclusion that Europe trails behind the U.S. in both technology development and PV product sales. However, European firms are more active in the development of total systems for developing country markets. U.S. manufacturers may be supplying the bulk of the PV cells and modules but European firms are instrumental in developing the markets.

This largely reflects the current African market activity. Development funding is the primer for this market area and it will also be instrumental in other developing country areas. The continued European role in total systems activity will depend on their ability to transfer this early experience in the Francophone African market to less familiar ground in Asia and Latin America. Development funding will be an important factor in this transition.

It is likely that given the continuation of the same relative level and scope of R&D in the U.S. and Europe, the U.S. will retain its present lead position and successfully compete overseas and dominate the domestic U.S. market.

4.0 JAPANESE COMPETITION

4.1 Characterization of the Industry

Photovoltaic cells produce d.c. electricity directly from sunlight, with no moving parts. Cells are made from semiconductor material, which is also used to make transistors and integrated circuits. The technology required to make PV cells is not sophisticated and is well understood in Japan, due to the similarity with transistor and integrated circuit production.

4.1.1 Historical Background

Japan is an island nation with little raw material and a keen interest, since the Meiji Period of the mid-19th century, in assimilating western ideas, particularly industrialization. By exporting finished goods, imports are balanced and trade has historically flourished, especially with lesser developed southeast Asian countries. Japanese firms for many centuries have been formed in Oligopolistic groups called Zaibatsu. The Zaibatsu were dissolved following World War II but the succeeding Keiretsu, conglomerate groupings of major corporations, often follow traditional patterns established by the Zaibatsu. The main Keiretsu presently operating in Japan are: the Daiichi Kangyo (DKG) Group, the Fuyo Group, the Sanwa Group, the Mitsubishi Group, the Mitsui Group, and the Sumitomo Group. The latter three are Zaibatsu-descendent groups and thus have stronger mutual ties than the first three newer, city-bank groups. In exporting, these groupings allow efficiency in marketing, manufacturing, and trading.

4.1.2 Japanese Firms Active in Semiconductor and Photovoltaic Production

Since World War II, Japan's industry has developed several groups of strong manufacturing firms--each with activities in the electrical, electronics, and semiconductor areas. Soon after the photovoltaic cell was invented at AT&T's Bell Labs in the mid-1950's, Japanese firms began to manufacture cells on a pilot basis. While devoting major resources to transistor and later integrated circuit production, each major group member has maintained activity in photovoltaic cell research, development and manufacture. A brief sketch of the firms with major interests in PV manufacturing firms follows:

- Fujitsu, with annual sales of \$1.2 billion including semiconductor sales of \$80 million is at present inactive in photovoltaic production.
- JSEC (Japan Solar Energy Company) is a joint venture (Kyoto Ceramic, Sharp, Matsushita, with Mobil Oil and Tyco Labs of the U.S.) created to exploit the Mobil-Tyco single crystal ribbon growth process. JSEC participates in Project Sunshine Research and Development and has limited PV product sales worldwide.
- Hitachi, probably the largest of the major firms, has annual sales of \$10 billion including \$260 million in semiconductor products. Hitachi does market solar collectors but is presently not manufacturing cells. It does have limited funding under Japan's Project Sunshine for work in polysilicon cells. Up to 7 percent cell efficiency has been reported.
- Matsushita (U.S. trade name is Panasonic), one of the two largest of the major firms, has annual sales in excess of \$8 billion, including over \$299 million in semiconductor production. While limited in the marketing of photovoltaic devices, Matsushita is active in thin film II-VI compound cells such as CdS/Cu₂S and CdS/CdTe.
- Mitsubishi Electric Industrial Company, primarily a trading firm, has annual sales of \$4.5 billion. It is active in telecommunications, transistor, and power device marketing though is currently inactive in photovoltaics.

- NEC (Nippon Electric Company) is the Japanese equivalent of AT&T with total electronic sales of \$2.3 billion. Its sales of \$340 million in semiconductor products make NEC Japan's leading firm in that area. The company is active in transistor and integrated circuit marketing in the U.S. NEC has a \$400,000 Project Sunshine effort in polycrystalline silicon, manufactured by plasma deposition. The firm is in a good position to market remote microwave repeater stations powered by PV modules. NEC is active in marketing this concept in Australia.
- Sharp, at \$1.4 billion in sales is a relatively small member of the group. Sharp was one of the first firms in photovoltaic power and currently sells about \$1.6 million, making it one of the major PV manufacturers today. It is reputed to have captured 80% of the Japanese photovoltaic market. Sharp also has the largest share of Japan's Project Sunshine R&D funding, amounting to about \$1.6 million annually. Sharp is working with both flat plate and concentrating systems.
- Sony, established primarily as an exporting company, had sales of \$1.4 billion last year. The firm is currently inactive in photovoltaics.
- Toshiba is the third largest of the major firms with \$6.2 billion in sales including \$240 million in semiconductor products. Toshiba manufactures PV cells, and is active in Project Sunshine work with ribbon growth techniques.
- Toyo Silicon is a major refiner of single crystal silicon, and is active in R&D in the ribbon growth area.

The total worldwide market for photovoltaic terrestrial modules was about \$20 million in 1978, of which Japan supplied about 5 percent and the U.S. about 75 percent. Japan's Project Sunshine is currently funded at about \$2 million annually, while the DOE is currently funding about \$74 million in research and technology development. Other government programs to support basic semiconductor R&D amount to over \$200 million in Japan and perhaps twice that amount in the U.S.

4.2 Current and Potential Markets

4.2.1 Domestic Consumption and Exports

Little is known about Japanese solar cell production levels or sales volumes. The 1978 Japanese domestic market is quoted at \$2 million by Electronics, a McGraw-Hill Trade Publication. Japanese firm representatives in the United States quote a \$30/Wp for domestic Japanese sales. Other sources suggest that \$30-40/Wp is a better estimate of the 1978 price. The above domestic market size quote appears high if it solely represents module sales or just domestic sales. We estimate that the total Japanese sales for 1978 range between 30 and 50 KWp and that maximum Japanese production today is between 40 and 80 KWp.

The lack of specific PV market information on Japan suggests it is better to avoid trying to make a quantitative distinction between domestic and export sales. Two general observations can be made: domestic sales are small and depend mainly on government purchases. Secondly, foreign sales are limited and the module prices high. The Japanese domestic market is not impressive. It is expected to develop slowly and perhaps reach 200-400 KWp annual sales in 1985. A small potential market exists because the country has a highly developed central utility grid and few undeveloped regions.

The largest single domestic installation is claimed to be about 500Wp. Most PV applications range from well under 200 Wp to the smaller chip size applications, i.e. watches and toys. The Japanese Solar Energy Company (JSEC) was selling domestically about 2 KWp last year. The domestic sales volume of Sharp, the largest PV manufacturer is uncertain but probably not more than 15 KWp. It is reported that the Japanese government buys about 2 KWp/year. A large portion of

the government funded applications are power systems for navigational aids. The Maritime Safety Agency of Japan is the world's largest present user of PV powered navigational aids, with over 300 fixed-light and over 20 lighted buoys. Should the government support an effort to develop a large domestic market, annual sales would increase substantially. At present, photovoltaics are not a national priority - they are not viewed as a serious major potential energy source for Japan. It is unlikely that a government program will be instituted to support domestic purchases over the next few years.

In the area of foreign sales, Japanese export activities can be summed up as exploratory. Japan exports PV systems to a wide range of countries in Africa, South America and Asia. Australia is considered a leading market area. Most U.S. PV companies state that they rarely compete with Japanese products. A partial reason for this is that the world PV market is extremely fragmented today. This is characterized by small volume sales over broad geographical regions. It is not uncommon to meet few competitors except where the potential sales are of significant size and frequency.

Australia is a recent example of such activity and the Japanese presence was apparent. Sharp modules were selling for \$12-25/Wp in Australia in 1978 and JSEC modules for \$17-19/Wp. Some observers of the marketplace note that Sharp sells the same modules for \$30/Wp in Japan. Unquestionably, the Japanese product costs are high and not competitive on the world markets today. Most concede that their module costs must be priced below \$10/Wp now if they are to compete anywhere. Today's activity by Japanese PV manufacturers amounts to testing the market and gaining experience with this new product. Their current sales volume and high module prices only reinforce the point that we have not really seen Japan in the marketplace. These initial probes suggest the view

that an analysis of today's PV market activities tells us little about Japan as a potential competitor. Japanese experience in semi-conductors may place this current PV market activity in a more meaningful context.

4.2.2 Japanese Semiconductor Industry

An overview of the semiconductor industry is necessary to illustrate the similarities that exist between semiconductor products (transistor and integrated circuit) production and photovoltaic production, and in the types of materials used by each. Most Japanese firms pursue photovoltaic development as part of a larger semiconductor activity. The involvement in photovoltaics and strong similarities between PV and the semiconductor industry could permit an easy and rapid entry by Japanese firms into the photovoltaic power manufacture and export market.

Japanese semiconductor firms now are second only to those in the United States in product line innovation and often first in quality and delivery schedule. A few leading trends in the Japanese semiconductor industry that are relevant to photovoltaic power manufacture and export are; a trend beyond rapid assimilation and adaptation of U.S. R&D toward state-of-the-art products, an emphasis toward high reliability components priced at a differential to reflect the quality, and the acquisition of U.S. manufacturing capability via joint agreements to produce in Japan. Recent trends by Japanese firms to establish electronics assembly plants in the U.S. allows them to take advantage of the slightly more cost effective labor, the better skilled labor pool, and to avoid import restrictions.

4.2.3 Size and Strength of Production, Sales and Distribution Base

There are about ten companies in Japan which are actively involved in photovoltaic production, or which have the potential, based upon similar product lines, to enter the field quickly. With the exception of Toyo Silicon, and Japan Solar Electric Company, these firms are very large, having annual total sales in the range of 1 to 10 billion dollars. A typical example is Matsushita Electric Industrial Company, whose American subsidiary is Panasonic. In 1977 Matsushita Electric has total sales of \$8.5 billion, the percentage breakdowns of total sales is outlined below;

●	Consumer Equipment	45.6%
●	Home Appliances	28.9%
●	Communications and Measuring . .	5.2%
●	Industrial	4.7%
●	Lighting Equipment, Tubes, and Semiconductors	3.8%
●	Batteries	3.8%
●	Miscellaneous.	8.0%

Semiconductor sales and in particular, photovoltaic sales comprised a small fraction of the total sales. This situation appears to be typical of most Japanese PV manufacturers.

Extensive exporting of numerous products has allowed the seven major companies combined to establish affiliate companies in 22 countries, subsidiary companies in 9 countries, and branch offices in 51 countries. The sales and distribution networks of these companies are prepared for increased marketing and export of photovoltaic devices.

4.2.4 PV Module Costs

The Japanese are experiencing serious problems in reducing costs to make their PV devices competitive on the foreign market. The reasons for their high costs in solar cell manufacture include high power cost, high labor cost, and the requirement to import much of the raw material. Use of silicon ribbon is considered perhaps the key to holding these production costs down.

Solar cells can be sold for \$30-35/Wp in Japan, but competition in the United States requires that this figure approach \$10/Wp before significant sales can be realized here. For this reason, JSEC has ceased exporting PV devices to the U.S., with the exception of a seven-watt panel currently selling at \$15/Wp. Total sales by JSEC in the U.S. last year consisted of seven of these panels to the Jet Propulsion Laboratory (JPL) for testing purposes. Sharp modules are also being tested at JPL but are not on the U.S. market. Exports to other countries are more promising for the Japanese because competition is not nearly as keen as in the U.S. Sharp and JSEC are both exporting PV devices to Australia, for example, to be sold at \$15-20/Wp. JSEC had initial sales of about 370 Wp in 1977, but are anticipating rapid growth in this area. Their stated goals are 5kWp/month production by June 1979, and 25 kWp/month production by the end of 1979. The other three known producers, Matsushita, NEC and Toshiba, had minimal sales in 1977. Their anticipated growth rates in the PV area are not known.

4.2.5 PV Cell Performance

The somewhat limited data available on the performance of Japanese-produced solar cells comes directly from the manufacturers. Independent evaluations of some cells (e.g., of JSEC and Sharp cells by JPL) is currently being conducted, but results are not yet available. It is anticipated that their performance and durability are comparable to U.S. and European products.

Japanese cells are of two types: single crystal silicon, similar to that used by most American commercial producers, and silicon ribbon, a technology which has been pushed strongly by the Japanese. Research on cast polysilicon substrate production in Japan parallels U.S. and European interest in their potentially cost-effective cell manufacturing technique.

It appears that Japanese produced cells have slightly lower efficiencies than their American counterparts, but the differences are not large. The power density of American made panels (power per unit panel area) is higher, due to emphasis on high density packing. With emphasis in this area, Japanese producers could probably provide similar results. The expected lifetimes of panels (or modules) are not well known for either American or Japanese devices, and more testing is needed before a comparison can be made.

4.2.6 General Marketing Posture

Because Japan is an island nation with few natural resources relative to its labor supply, its economy is heavily based on importing raw materials and exporting finished products. The need for expanding export volume to provide the currency to support continued growth and pay for necessary raw materials, especially fuel, is a recognized fact of life, supported by the attitudes and policies of both the industrial sector and the Japanese government.

Trading companies have worldwide networks of marketing facilities well staffed with employees trained in local languages and experienced in local business conditions. They offer managerial and marketing skills and financial back-up, attractive to small and medium enterprises interested in overseas operations. In developing countries, many Japanese

ventures have the following pattern of capital ownership: about 50 percent is locally owned, 20-30 percent is owned by the Japanese manufacturer involved, and the rest is financed by a trading company.¹

Japan is also more tolerant in the area of monopolies and mergers in support of export. The Japanese Anti-Monopoly Law of 1947, enacted during the postwar occupation to break up the concentrated economic power of the Zaibatsu (oligopolistic) groups, has been amended to permit the so-called "recession and rationalization cartels." These cartels were originally intended to assist industries affected by the economic slowdown in the 1950's and 1960's. Later they came to be used to strengthen domestic industries against the liberalization of direct foreign investments in Japan. The Fair Trade Commission, the administrative body for the Anti-Monopoly Law, has grown highly tolerant of merger movements of Japanese firms, placing more emphasis on surveillance of foreign companies or foreign Japanese joint ventures. The stringency of Japanese antitrust law is seen in its application to foreign firms in Japan.²

In contrast, the United States antitrust laws are more strongly oriented to consumer protection than are Japan's and the institutions responsible for enforcing the laws have the objective of preventing unfair competition, monopolization, and restraint of trade. While monopolization is prohibited, growth attributable to efficiency and superior management is not restrained by the antitrust laws. Agreements by existing firms to share market strategies or pricing plans are illegal,

¹ Terutome Izawa, Transfer of Technology from Japan to Developing Countries, UNITAR Research Report No. 7 (New York: UNITAR, 1970) pp. 31-35.

² Herbert Glazer, The International Businessman in Japan, (Rutland, Vermont: C.E. Tuttle and Company, 1968), p. 38.

however, and are viewed as conspiracy in restraint of trade. The law applies to international agreements if U.S. markets are affected. The Webb-Pomerence Act in the U.S. allows firms to coordinate in order to compete more effectively against foreign cartels in export markets. Problems of unfair competition involving foreign firms in U.S. markets are dealt with by a separate body, the U.S. International Trade Commission, which investigates charges of illegal subsidization of U.S. imports.

Another example of Japan's attention to trade is the preferential tariff program for imports from developing countries, initiated August 1, 1971. This is a gesture to respond to the desire of developing countries to earn foreign exchange through "trade, not aid." Thus, Japan's manufacturing investments in developing countries may be increasingly designed to partake of the benefits of its own preferential tariffs for developing countries. This is strengthened by the labor shortage in Japan and labor availability in developing countries although the shortage of technically trained labor supply conditions may limit this effect.

In the area of taxation, the nominal corporate profit tax rates are at approximately the same level in Japan as other industrial countries. However, nominal tax rates do not represent the relative burdens on corporate incomes because countries vary widely in depreciation deductibles, investment tax credits, taxfree reserves, or other systems of promoting investment or other objectives. The effective tax rate paid by corporations on gross profits is one measure of the effect of these provisions. It is computed as tax liability as a percent of profits before deduction of depreciation allowances. The effective corporate income tax rates of Japan are much lower than the U.S. In 1972, for example, while

Japan's top nominal fee (including local taxes) was 48 percent, the effective rate was 20.1 percent; in the U.S. the top nominal rate (federal and average state) was 50 percent, while the effective rate was 27.1%.¹ (An alternative estimate of the total (effective rates) on corporate income are as follows: for income up to 3.5 million, 35 percent; from 3.5 to 7 million, 36 percent; and for income over 7 million, 49 percent²). Tax incentives are thought to be highly effective in promoting Japanese economic growth. Significant measures include accelerated depreciation for industrial equipment, a special deduction for income from exports, and an increase in the initial depreciation for machinery and equipment used for the prevention of environmental pollution. Japan's tax incentives for investment and export are far more comprehensive than U.S. tax provisions.

4.3 Status of PV and Related Technology

This section compares Japanese R&D programs in photovoltaic and semiconductor processing with those of the United States.

4.3.1 Photovoltaic R&D Activities

In 1974 Japan launched a broad R&D program in solar energy called "Project Sunshine." The project is administered by the Agency of Industrial Science and Technology, (AIST) which is part of the Ministry of International Trade and Industry (MITI). The avowed goal is to produce new sources of clean energy by the year 2000. Areas covered include solar energy, geothermal, synthetic natural gas and hydrogen fuels.

¹ J. Pechman and K. Kauzuka, "Taxation" H. Patrick and H. Rosovsky (editors), Asia's New Giant: How the Japanese Economy Works (Washington, D.C.: The Brookings Institution, 1975).

² Taizo Hayashi, Guide to Japanese Taxes 1976-1977 (Tokyo, Zaisei Shoho Sha).

The solar energy program is headquartered in a Solar Energy Center which was sited to provide for abundant solar insolation and for personal amenities such as schools and transportation. The budget is approximately \$200 million capital and operating funds over three years for the staff of 250 to 300. Major equipment (existing or planned) includes a 30,000 m² building (300,000 sq. ft.), a one Mwth research solar furnace and 13 demonstration sites for various solar heating and cooling projects.

"Project Sunshine" includes work on photovoltaics; the program emphasis is on cell fabrication techniques, especially those related to mass production. Participants in photovoltaic R&D in Japan are shown in Figure 4-1. All major cell technologies are represented, including several on edge defined film feed, plasma and chemical vapor thin film deposition, ion beam and conventional epitaxial thin film growth, and polysilicon production.

The exploration of various junction types and cell technologies is impressive. Work on heterojunction thin film, and II-VI compound cells is evidenced. Both flat plate and concentrator systems are under development, as well as work in performance, lifetime and reliability issues. A total of \$2 million was spent in 1978 on photovoltaic R&D, with six firms and one government lab participating in the program.

Photovoltaic R&D outside of "Project Sunshine" is underway at several universities and private companies. This includes work on emerging materials and amorphous silicon. Those universities and corporate programs identified in this study are shown in Figure 4-1 and may represent a portion of the work at this type of institution. One other university (Tokyo Institute of Technology) has an interest in photovoltaics but with no identified research activities.

PROJECT SUNSHINE

<u>Laboratory</u>	<u>Project</u>	<u>Cell Efficiency Or Other Result</u>
ETL, Tokyo (Electro- Technology Laboratory, a government lab)	<ul style="list-style-type: none"> ● Integrated concentrating cell arrays ● Thin film Si ● Chemical vapor deposition SnO_2/Si ● Ion beam epitaxial growth Si ● Compound semiconductor studies (Inp) ● Heterojunction concentrator cells $\text{Ga}_{0.5}\text{As}_{0.5}\text{P}$ 	13% (AM2)
Toshiba, Kawasaki-shi	<ul style="list-style-type: none"> ● Vertical ribbon growth techniques 	7-11%
Toyo Silicon, Tokyo	<ul style="list-style-type: none"> ● Horizontal ribbon growth techniques 	8%
Hitachi	<ul style="list-style-type: none"> ● Thin film processing Polycrystalline Silicon 	3-7%
NEC (Nippon Electric Company)	<ul style="list-style-type: none"> ● Plasma Deposition ● Polycrystalline Silicon 	7.9% 2.8-6.8%
Sharp, Nara	<ul style="list-style-type: none"> ● Improved diffusion ● Electrode formation ● Concentrating Systems ● Low cost automated process 	\$7/kWp 12% 20 to 100 X Fresnel Lens
Matsushita, Osaka	<ul style="list-style-type: none"> ● Degradation mechanisms $\text{CdS}/\text{Cu}_2\text{S}$ ● Heterojunction cells CdS/CdTe 	5.8%

Figure 4-1 Principal Japan Project Sunshine Photovoltaic Projects
as of February 1978

<u>Laboratory</u>	<u>Project</u>	<u>Cell Efficiency Or Other Results</u>
Central Research Institute of Electric Power Industry	● Photovoltaic power system	
<u>UNIVERSITY RESEARCH</u>		
Kyoto University	● Thin film $\text{IN}_2\text{O}_3/\text{p-Si}$	7.6%
Osuka University	● $\text{SNO}_2/\text{N}^+\text{-pSi}$	12.9%
	● a-Si ITO/p-i-n/stainless steel	4.5%
University of Tokyo	● Electrochemical cells	
Kanagawa University	● Electrochemical cells	
The University of Electro-Communi- cations	● Electrochemical cells	
<u>CORPORATE RESEARCH</u>		
Sanyo Electric Co.	● Amorphous Si	2.5%
Fuji Electric Co.	● Amorphous Si (7cm X 7cm)	2%

Figure 4-1 Principal Japan Project Sunshine Photovoltaic Projects
as of February 1978 (Continued)

Although the Japanese photovoltaic program covers a broad range of research topics, the U.S. Department of Energy's program is larger in absolute terms (~\$100 million in FY79) and broader in scope. U.S. DOE advanced photovoltaic R&D and technology development is funded at about \$30 to \$40 million. The more extensive DOE program places emphasis on advanced R&D as well as technology, systems and subsystems development. The significant difference in the programs is related to the DOE emphasis on systems experiments and operational tests to develop useable systems and to develop the photovoltaic industry through incentive purchases.

The U.S. photovoltaic program elements outlined in Figure 4-2 are matched with the Japanese activities in each area. It is evident that the Japanese are maintaining a capability in photovoltaic technology by supporting broad research and technology development programs at the expense of tests and experimental systems programs. There is little detailed published information available on most of the research efforts, but that which is available indicates that the Japanese are no more than a year or two behind the United States' effort in the areas they actively pursue. The Japanese R&D program allows researchers in Japan to keep abreast of the developments throughout the world, but the limited funding and broad program scope restricts the researchers' role from leading technological developments.

The lack of systems test experiments and demonstration reflects the traditional Japanese approach to market stimulation and development. This approach is to provide incentives to export rather than to use incentive purchases for domestic market stimulation. Though the Japanese government has purchased a few photovoltaic systems, there is no indication that the government will become a major purchaser.

U.S. Photovoltaic Program Element

Japanese Program (\$2M)

I Photovoltaic Research and Development

- (1) CdS/Cu₂S and CuTernamy
- (2) Polycrystalline Silicon
- (3) Amorphous Silicon
- (4) Polycrystalline GaAs
- (5) Emergency Materials
- (6) Amorphous Materials (non-Si)
- (7) Advanced Concentrates & Concentrator Cells
- (8) Electrochemical PV Cells
- (9) Basic Mechanisms
- (10) Test and Measurement
- (11) Technical Issues

Matsushita
Sharp, Hitachi, ETL
(Sanyo) (Fuji)

Kyoto University, Osaka University,
ETL

ETL, Sharp

University of Tokyo, Kanagawa
University, University of
Electro-Communications

II Technology Development

- (1) Low Cost Silicon Array
- (2) Concentrator Systems
- (3) Total Energy Systems
- (4) BOS

Toshiba (Ribbon), Toyo Silicon
(Ribbon), Sharp (Automation)
ETL, Sharp

III System Support

- (1) Systems Definition
- (2) Standards Development

Central Research Institute

IV Test and Evaluation

- (1) Application Experiments
- (2) Field Demonstrations
- (3) Field Tests

V Analysis Support

- (1) Mission Analysis
- (2) Economic & Policy Studies

Figure 4-2 The U.S. Photovoltaic Program Outline Compared with Activities in Japan

In conclusion, the Japanese R&D effort in photovoltaics reflects an interest to keep up with worldwide technological developments, but little emphasis is placed on market stimulation or systems development specifically for photovoltaics. This posture will allow Japanese industry to exploit breakthroughs or technological developments made in photovoltaics, but minimizes the risk involved.

4.3.2 Related R&D Programs

Other Japanese and U.S. R&D programs may assist photovoltaic development through the synergism that naturally occurs between projects funded for other reasons.

Japan is committed to a vigorous increase in semiconductor technology through active government involvement. The VLSI (Very Large Scale Integrated Circuit) program, also administered by the MITI, is the present keystone of organized Japanese R&D in semiconductors. Built on approximately \$90 million in prior efforts, the four-year VLSI program projects contract and government in-house research at the \$230 million level. It is the outgrowth of programs, begun in the late 1950's, to initiate a coordinated advance in Japanese technology.

Parallel efforts in semiconductor technology in the U.S. are difficult to gauge precisely. Vast expenditures in Department of Defense (DOD) R&D, NASA and private investment (e.g., venture capitalization) have no counterpart in Japan. The DOD has begun a special \$200 million R&D initiative in high-speed integrated circuitry, partially in response to the Japanese VLSI program. There is probably more relevant semiconductor R&D performed in the U.S. but the Japanese may be better organized to utilize appropriate information. Nearly all of the U.S. program is unclassified and thus

published results are available to Japanese researchers almost immediately. The different focus of the VLSI and PV programs, both here and in Japan, eliminates most areas of overlap. Those areas that do overlap include growth of large diameter silicon boules, investigation of advanced electro-optical sensors, automated wafer handling machinery, and improved junction diffusion technology.

Other DOE programs are actively pursuing low cost concentrating collector designs which, if achieved, would be applicable for photovoltaic systems.

4.3.3 R&D Projections

It appears that the Japanese R&D program is focused on processes with a high potential for high volume production (e.g., Edge-defined-Film-fed-Growth (EFG), Chemical Vapor Disposition (CVD), epitaxial growth, etc.) with relatively little emphasis on followup work, such as module integration or quality control. The remaining research work is primarily in areas of new cell types. Basic work in Gallium Arsenide (GaAs) and Indium Phosphide semiconductor (InP), and in Schottky barrier devices (Metal/semiconductor) could easily provide benefits to the solid state microwave portion of the semiconductor industry. This program approach is conservative and limits risk if the basic production or cell economies fail to materialize. If these processes or similar processes succeed in Japan or elsewhere, Japan has the necessary experience to exploit the technology for photovoltaic systems and for other semiconductor products such as low speed memories, electro-optical sensors, and microwave circuits.

Through Project Sunshine, Japan appears to be researching only those ideas with the highest potential payoffs to solar applications and generally in industry.

The program currently contains no major innovative features but instead remains with technically accepted ideas. This coincides with Japan's past performance in a number of technologies and should not be used to disparage the effectiveness of Japan's PV program.

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