資料4－1－1

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Cover design by
Jim Jarabi

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General enquiries should be addressed to:

The Registrar
The Papua New Guinea University of Technology
Private Mail Bag
LAE
Papua New Guinea

Enquiries concerning courses and student matters should be addressed to:

The Admissions Officer
The Papua New Guinea University of Technology
Private Mail Bag
Lae
Papua New Guinea

Telephone: (675) 434999
Fax: (675) 447667
Telex: NE42428

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CONTENTS SECTIONS

RENEWABLE ENERGY RESEARCH ACTIVITIES AND PLANS

Mechanical Engineering Department

by

Associate Professor A.H. Uppal

Acting Head of Department

November 1993

Department of Mechanical Engineering
PNG University of Technology
LAE
Papua New Guinea

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表5－1－1

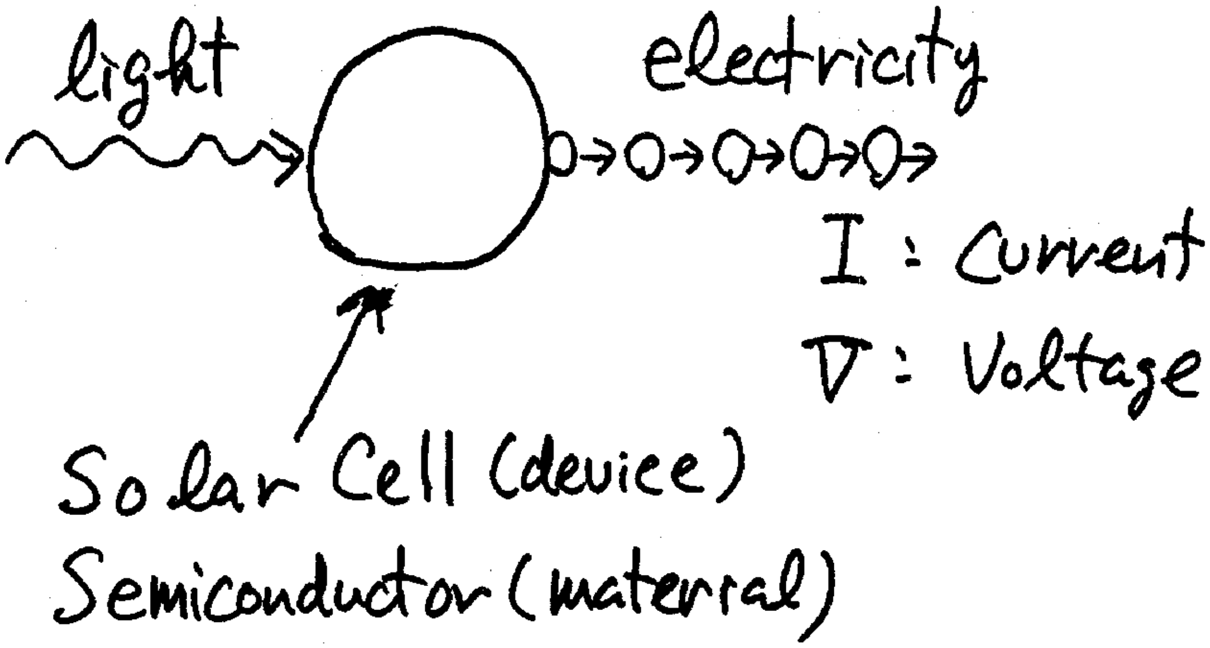
電力事情の比較

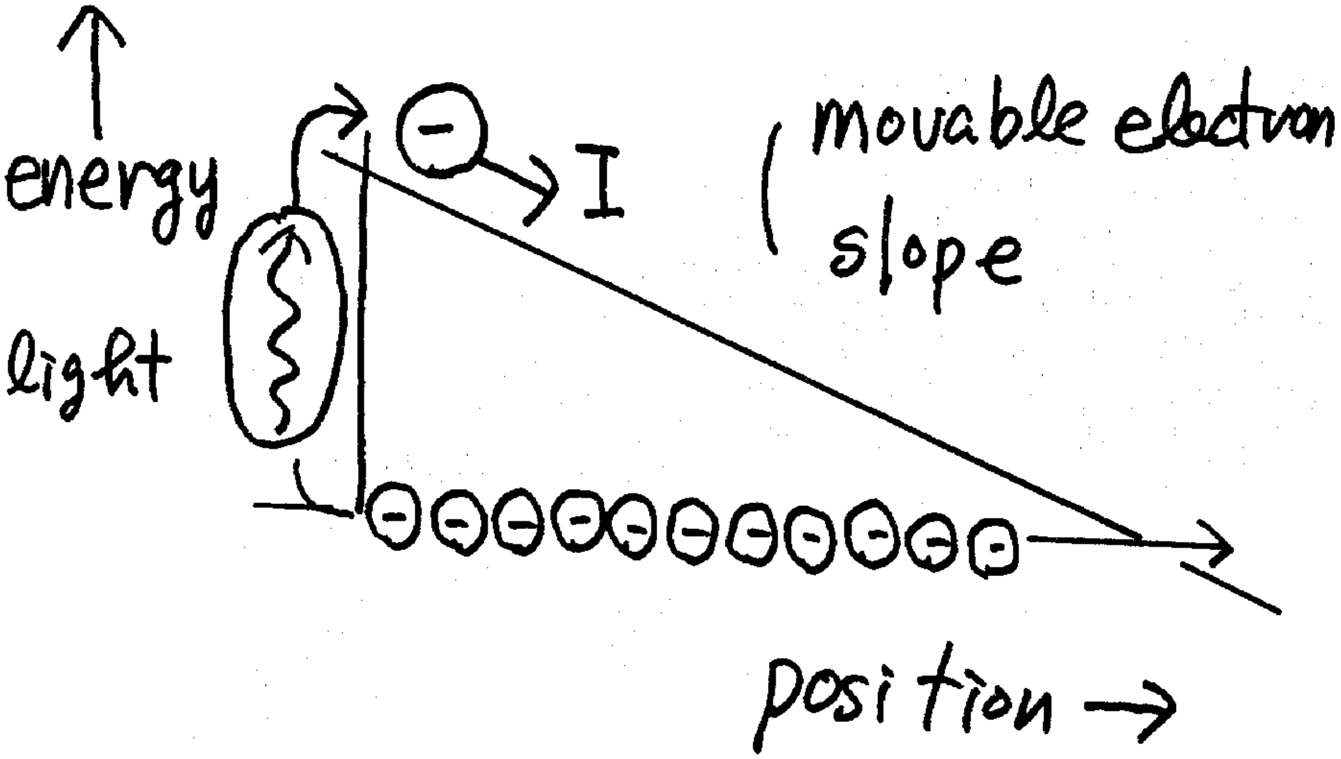
	電力量 (10^8kWh/年)	普及率 (%)	Renewable energy (10^8kWh/年)	使用例
PNG	18	–	–	Telikom 学校、 地域センター
WS	0.46	98	–	Telecom
JPN	8500	100	8 (0.1%)	個人住宅

	人口		電力	
JPN	120	) 30倍	8500	480
PNG	4		18	

資料5－4－1

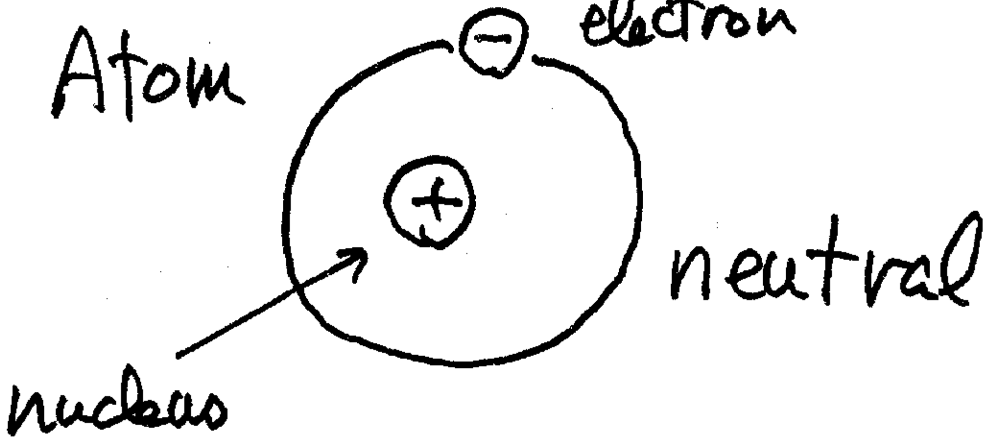
Energy Conversion



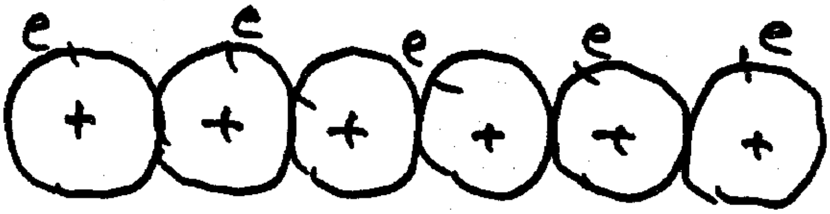


Semiconductors

- Atom



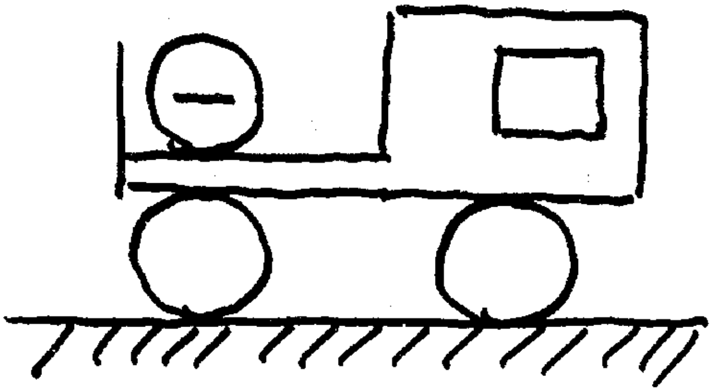
- Solid



	# of movable electron	condition
insulator	—	
semiconductor	small	depend*
metal	large	always

* temperature T
impurity N_d
light

Movable Electron



"metal"

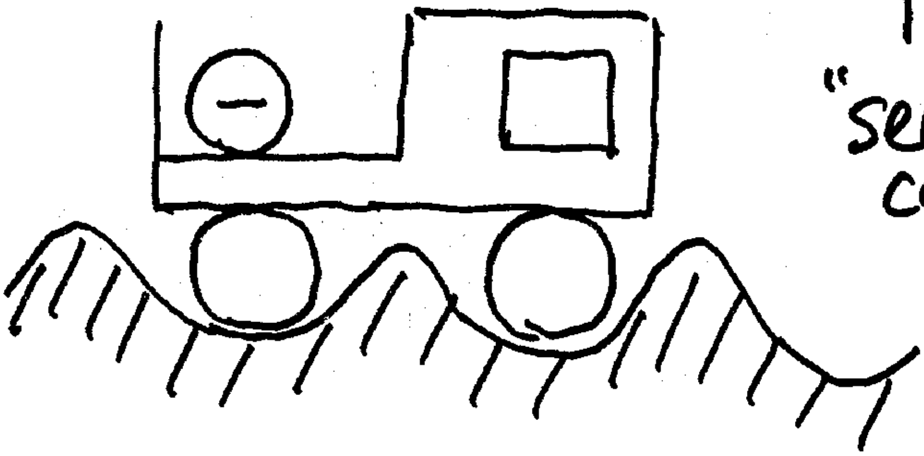
↑

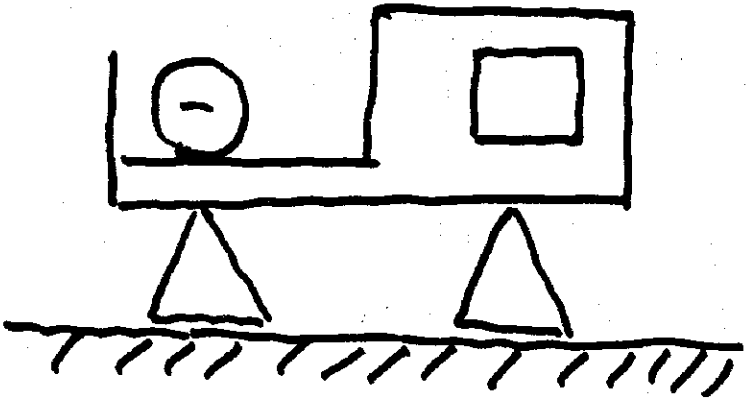
light . T

Nd

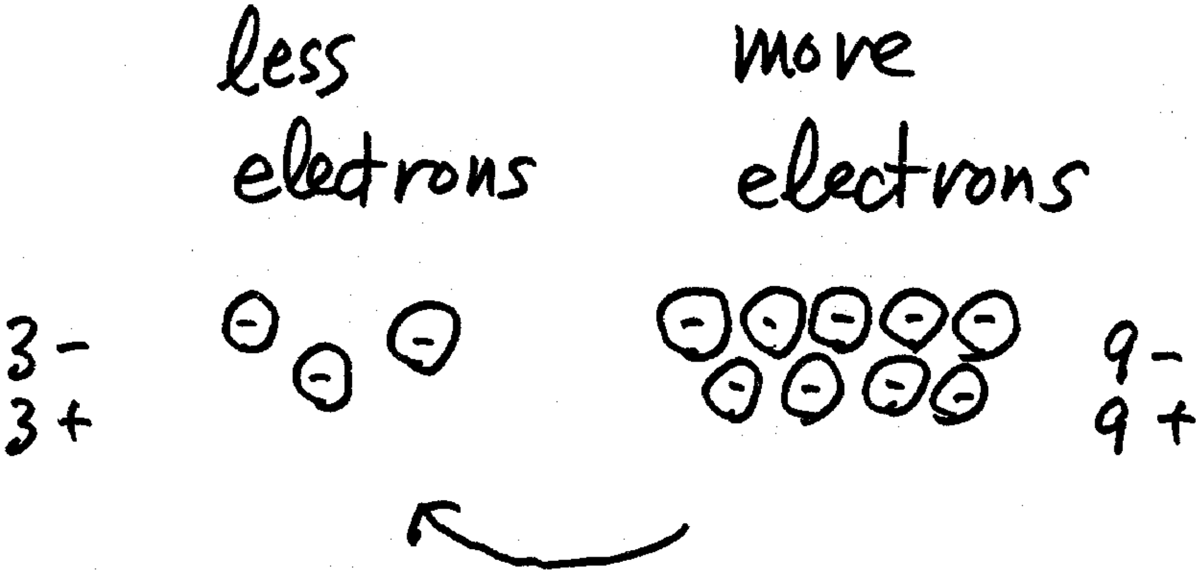
|

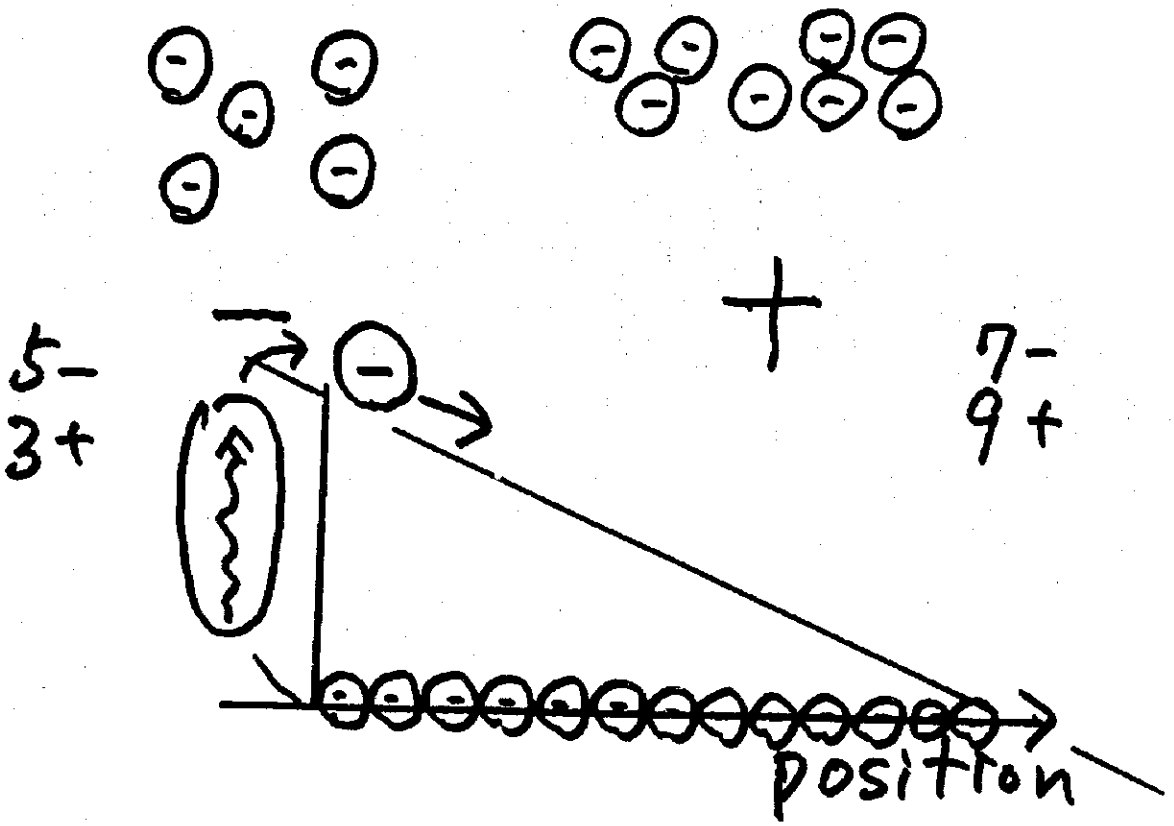
"semi-conductor"





Slope





資料５－４－２

シナリオ／SCENARIO　Monda

CO_2削減目標、妥協点は

地球温暖化防止条約の第三回締約国会議（COP3）が、十二月に京都で開催される。ここで採択する京都議定書で、先進国は具体的な目標数値をあげて二〇一〇年までの二酸化炭素（CO2）の排出削減計画を示さなければならない。一九九〇年比で一五％減という高い数値を掲げる欧州連合（EU）と日米など他の先進国との対立は深刻で、いまだに妥協点は見つかっていない。途上国にも削減義務を課す提案や、排出権取引など温暖化対策を「市場化」する新しい仕組みの模索など、課題が山積し、議長国日本の肩に重くのしかかっている。

五年前、リオデジャネイロで開かれた地球サミット（国連環境開発会議）で温暖化防止条約が結ばれた時、条約をめぐって各国の利害・思惑の対立がこれほど鮮明に表面化すると誰が予想しただろうか。砂漠化、低地の水没、熱帯などの病気を携えて訪れる恐れのある温暖化を未然に防ぐため、今から温室効果ガスの排出を抑制する、というのが条約の理念だ。あくまで予測、推定していない百年後の危機。それを回避するために、現実の経済活動や生活に[illegible]を求める。未来への責任に目覚めた人類が、自己犠牲の精神に基づいて文明の舵（かじ）をきるという、歴史上例のない実験・挑戦といえる。

先進各国とも輸送分野はCO2削減のネックの一つになっている

その後の五年間、[illegible]の答えが非常に厳しいことを、各国は痛感し始めた。先進国のうちCO2排出量を二〇〇〇年までに九〇年と同じ水準に抑えるという当初の約束を達成できるのは、ドイツなどほんの二、三カ国にすぎない。日米は早くから達成不可能を宣言しているし、大抵の国は逆に九〇年比で一〇―二〇％増えてしまう見通しだ。

二年前にベルリンで開いた第一回締約国会議（COP1）では、今回の京都会議で、先進国が二〇一〇年までの削減目標の数値を定めることを決めた。産業革命以来大量に化石燃料を燃やし続け、CO2など温室効果ガスを大気に排出してきた先進国がまず責任を果たせというわけだ。

ベルリン会議では、途上国は新しい義務を負わないことも確認している。米議会はこれに反発し、途上国にも義務を課さないなら、議定書を批准しないという決議が、上院に提案されている。二〇〇〇年以降は、途上国の排出量が先進国を上回ると予想されているからだ。

先進国の削減目標の数値も、EUがいち早く閣僚会合などで、九〇年比一五％減というきわめて高い数字を掲げたため、日米などが猛烈に反発している。

欧州が強気に出ている背景には「削り代」の多い旧東独や英国と、ほとんど削減余地のないフランスなどをひとまとめにして、EU全体で一五％減というカラクリがある。日本の通産省や米国政府は削減ゼロ、二〇一〇年に九〇年水準に保つという主張だが、先進国に削減義務の実行を求める途上国の圧力は強い。

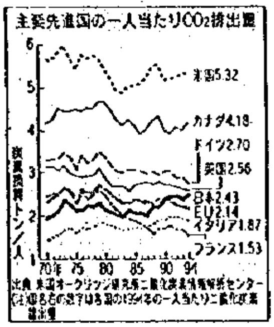
また、排出削減で化石燃料の輸出が減る産油国が、「経済的な損失の補償」を求めるなど、京都でのCOP3は波乱要因がいっぱいだ。議定書に盛り込む数値目標の落ち着きどころも見[illegible]た[illegible]中、議長国日本の主導権を発揮するため、政府は九つの関係省庁の合同会議を設け、[illegible]も対策チームをつくった。

○…①米欧の間とり5％前後

×…②10％前後、途上国にも義務付け

△…③実質的な削減は先送り

米欧の対立深刻化
手腕問われる日本



主要先進国の一人当たりCO_2排出量

出典 米国オークリッジ研究所二酸化炭素情報解析センター
（注）国名右の数字は各国の1994年の一人当たり二酸化炭素排出量

シナリオ①

〈欧米の間をとり五％前後で決着、排出権取引や共同実施などの新制度で、米国の主張を反映〉

日本国内でも、ゼロを唱える通産省とそれなりの削減枠の設定を主張する[illegible]の対立があり、首相・官邸主導で、日米欧、途上国の間でそれぞれ立つ五％あたりに落ち着く。

そのかわり、排出権の売買や、技術援助で途上国の排出量を減らした分を、自国の削減枠に取り入れる代替方式、削減枠の両国間の融通や、排出権の取引を認める取引方式など、目標を実質的に緩和する仕組みを採用する。

シナリオ②

〈一〇％前後の削減目標が明記され、代わりに途上国も今後は削減義務を負うことが決まる〉

経済成長より環境優先のムードが一気に高まり、欧州の目標に近い二ケタ削減で合意する可能性もある。

ただ、世界最大のCO2排出国で全体の四分の一を出している米国が抜けては、条約の意味を失う。このことから、途上国にも今後は排出削減の義務を課す新たな枠組みをみせることで、米議会での批准可能性をはかる。

シナリオ③

〈二〇一〇年に九〇年水準とし、実質的な排出削減は先送りする〉

米国の産業界や日本の通産省の主張が通り、経済社会に過剰なダメージを与えない範囲、すなわち二〇一〇年のCO2排出量を九〇年水準に保つという線で落ち着く。実質的には排出削減の先送りだが、石油の消費が減ることを懸念する産油国も巻き込んで、途上国の反発を封じれる。

×××

一番やっかいな時期に議長国を引き受けたところが、外交下手で定評のある日本らしいところ。しかし、橋本首相がこの問題に力を入れており、省庁の思惑を超えた首脳レベルの決断が期待される。京都での日本のパフォーマンスは、次期常任理事国問題にも影響する。シナリオ①なら七〇％、②が二〇％、③が一〇％か。

（編集委員 [illegible]）

「行革で孝行してくれよ、君」

第2次橋本改造内閣が発足、総務庁長官にロッキード事件で有罪が確定した佐藤孝行氏が就任。6大改革も大変だが来年夏の参院選はもっと大変

絵 R・ルリー

今週のデータ

8月の米鉱工業生産

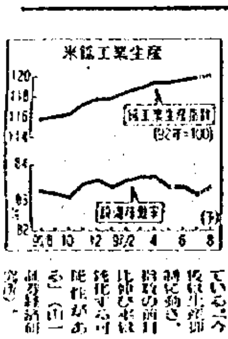
（16日）

米連邦準備理事会（FRB）が発表する八月の鉱工業生産指数（九二年＝一〇〇、季節調整済み）は一二〇程度と前月比で〇・四％前後上昇する見通し。[illegible]比で〇・二％程度伸びそうだ。

八月も生産の勢いは衰えていないとみる向きが多い。「NAPM（全米購買部協会）生産指数や雇用統計を見ても、企業の生産意欲は高い」（[illegible]研究所）。また、七月はGMなど自動車のストがあり、八月は反動増が見込まれるとする強気要因を挙げる声もあった。

ただし四―六月期に在庫が大きく積み増している。今後生産調整の動き、[illegible]の可能性がある」（[illegible]経済研究所）。

企業の意欲高く
小幅上昇見通し



米鉱工業生産

Forecast 私の予測　外銀などの対日進出

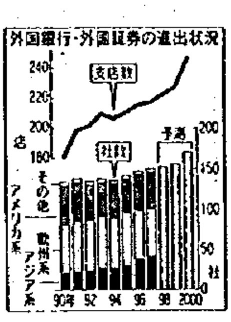
ビッグバン向け再び増加

かし、国の[illegible]外国銀行、証券の合計社数、支店数ともバブル後も減らず、九四年から目増しに増えている。リストラによって欧米系が縮小する半面、アジア系がやってきた。

しかし、ここに来て様相が変わりつつある。二〇〇一年までに完成する金融システム改革（日本版ビッグバン）を好機と捉（とら）え、欧米の金融機関が拠点を整備しようとしている。九六年以降も、九七年六月の有力投資信託会社フィデリティなど米系証[illegible]

めたこともあり、進出にはやや慎重になりはじめている。一方、欧米系の進出は本格派との提携も含め、さらに加速するだろう。

結局、これまでとは対照的に、アジア系の減少を欧米系が埋め、この二年ほどは百八十前後で推移しよう。その後は、機関整備が加速し、進出社数は百七十―百八十になるだろう。こうした動きは、都心部のオフィス市場にも波及するはずである。（日興総合研究所経済調査部 主任研究員）



外国銀行・外国証券の進出状況

資料５－４－３

From the EDITOR

創刊30周年

本誌編集長
荒木光弥

ＯＤＡを本音で論じた　経済協力政策報告書

「国益」がキーワード

財政構造改革の大合唱が始まると同時に、わが国ＯＤＡは予算面での聖域が取り払われ、97年度予算の伸び率は防衛予算より低い2.1%にとどまった。ＯＤＡはまさに逆風のなかに立っている。

今後ＯＤＡをどういう考えで持続させていこうというのか。現在、ＯＤＡの本質を問う、いわゆる「ＯＤＡ見直し」論議も活発で、ＯＤＡの第５次中期目標が終了する本年末に向けて、政府内では産業構造審議会（通産相諮問機関）、経済協力政策研究会（経済企画庁調整局長の私的研究会）、21世紀に向けてのＯＤＡ改革懇談会（外相の私的諮問機関）などの報告や、外部では経団連の「財政構造改革のなかのＯＤＡのあり方」をめぐる提言などが目白押しの状態だ。

先陣を切ったのが経企庁の経済協力政策研究会（中間報告）である。全体の構成は、第１に冷戦後の経済協力を総括しながら、第２にわが国経済協力の基本的なあり方を求め、第３に効率的・効果的な経済協力のあり方を具体的に探求し、最後は国民の協力と支持による経済協力を訴えている。

本報告書の特色は、「市場経済が従来にも増して重視される今後の世界にあって、わが国の財政・経済上の負担の問題とも関連して、経済合理的で持続可能なあり方を模索することが、わが国経済協力が当面する課題であり、それへの回答が本報告書の目的である」に代弁されている。つまり、経済協力を経済政策的な観点から見るとの立場に立ち、わが国の受ける経済的利益を国益としてとらえていることである。したがって、経済協力を行う意義のところでは、「国益」がキーワードになっている。それについては、たとえば「実際に経済協力を行う局面では、その意義として人道援助、国際社会への国際貢献とともに国益が混在しており、国際的にはむしろ人道援助などが強調されているが、それと同じくらいに国益という面が大きいと言っても過言でない。国益がなければその国の経済協力が持続される保証はなくなる」と述べ、「国益というと、政治外交的な利益や経済面での短期的な利益と考えられがちであるが、経済協力という観点から国益を考えると、途上国の経済発展が長期的にわが国にもたらされる利益と考えるべきである。このような国益に資する経済協力は、わが国に長期的に利益を生み出す一種の投資であるとの考えの下に行われるべきである」としている。

経済発展に寄与する経済協力

こうして、ＯＤＡは途上国の経済発展のなかで位置付けされるべきだと強調する。いわく「経済協力は、最低限の生活水準の確保のためのものと、経済発展のためのものにわかれる。しかし、国民の最低限の生活水準の確保という課題も、その国の自助能力の構築を通じ経済発展が促進されることによってのみ最終的な解決が図られ得る。それゆえ経済協力の基本は経済発展のためのものであるべきで、最低限の生活水準の確保のための人道的な援助が途上国の経済発展に伴いその役割を減じていくのが理想である」とする。そこで、限られたＯＤＡを効率的に利用するためにも、彼らの経済発展、社会生活水準の向上を経済協力の条件にすべきだとしている

以上が報告書の核心に触れるものだと思う。特に、今後の新しいＯＤＡ政策を考える上で非常に大切な１つの基本コンセプトを提示したものだ。最近の議論を見ていると、財政困難だからといって、いきなり効率的な援助機関の再編へと走りがちである。小手先の効率化論が幅をきかせて、本質を衝くような基本政策の検討が隅に追いやられている感じだ。その意味で、本音をさらけ出したようなＯＤＡ必要論が今求められている。

昨今の財政改革議論は、国民におぶさってくる500兆円もの財政赤字を将来どう軽減していくかに端を発している。だから、ＯＤＡどころではない。場合によっては人道主義どころではないと言うかもしれない。とにかく時代の流れはＯＤＡを国内予算と同じように一律カットにするという荒っぽい議論へ傾斜している。

こうした動向に対して、一律カットの気持ちはわかるが、ＯＤＡを経済的視点から長期的に見ると、わが国の財政赤字の軽減に寄与できる国益的な局面が十分備わっているので、ＯＤＡを持続させても決して国民的、国家的に損失にはならないということを唱えているのが本報告書ではなかろうか。そして、その行間には国益に即しない経済協力があるならば、この際大いに改める必要があるという示唆がこめられている。

美化された無国籍的援助論

とにかく国益を全面に出した経済協力論を展開することには賛成である。しかし、経済協力を必要とする日本の背景はもっと広いはずである。国益を論ずるならば、経済協力のもっと奥深い所にある日本独自の島国的サバイバル条件を提示しながら論じてほしかった。

もっと言えば、日本の経済的生存の将来像を描きつつ、その経済的生存の条件を満たし得る戦略的手段として経済協力があることを強調すべきではなかったかと思う。資源もなく国内市場にも限界のある日本と米国を比較すれば、国のサバイバルへの対応が鮮明に浮かび上がるはずである。

これら議論は、日本が高度成長から経済大国へのし上がってくるにつれて影をひそめ、同時に経済協力論もうわつき始めていった。日本の経済利益になるような経済協力は“邪道”であるといったような論調が、国益という言葉さえも邪道として封じ込めていった。戦前に国益という名の下で総動員がかけられ、国民が多大の犠牲を強いられたという苦い過去の経験のみが化け物のように横行して、新生日本の国益を口にするといかにも右翼のように言われるのを恐れて、多くの賢人さえも口を閉じてきた観がある。

こうした風潮のなかで、経済協力と国益を結び付けた議論がタブー視され、参議院外交委員会での公聴会でＯＤＡを国益（広く国民益と言ったにもかかわらず）と結び付けたら、野党系の議員に「今頃、国益とは古い」とばかりに抗議を受けた経験をあるジャーナリストから聞いたことがある。

人びとは、「ＯＤＡとか経済協力には決して自国の利益を求めてはならない」という美化された援助論が正論かのように思ってきた観がある。日本人的なバランス感覚の欠如がそこにある。一方から一方へ振幅の大きい感覚が、援助を一方的に献身する宗教的援助論へ追いやり、時に“無国籍的援助論”を賛歌するようなＯＤＡ議論へと発展させた。

今大切なことは、改めて日本人そして日本国が得意とする国際貢献分野を綿密に検討し、それを日本の生きる道（国益）と符合させながら、日本国としてのＯＤＡ政策に練り上げることであろう。それが相手の経済発展に寄与する経済協力であれば、それを日本の得意なＯＤＡ分野として国際的にアピールすべきである。ただ、日本の国益論は国際益のなかでしか存在できないことを忘れるべきでない。

国際開発ジャーナル　1997. 5

FOREWORD

Electricity gives us a strong support to maintain the quality of our life. Many technologies have been developed on the basis of the presence of electric power. Therefore, the supply of the electricity is one of key issues to develop a society taking advantage of the application of the recent technology. Being consistent with environmental preservation has become an absolute condition for such development in recent years, and solar power generation has become an effective means of satisfying this condition. Solar power generation is ideal for satisfying small demand spread out over remote area and island nations, and is a means of promoting local economies consistent with environmental protection. There is consequently an urgent need to train qualified personnel in related fields in order to promote sustainable development that takes the environment into consideration.

The lectures of this course offer participants a basic knowledge of solar power generation and its application system. They have been prepared for participants like yourselves who are involved in projects in the area of solar power generation and its application system and also for those of you who may give instruction on this subject in your communities. Solar power generation is, simply stated, the conversion of the sunlight energy to electricity using semiconductor devices. Some of the lectures are to help you to understand the energy conversion process itself together with processes to handle the obtained electricity. Since the solar power generation has specific characters distinguishing it from other methods of electric power generation, each of you may find a specific application which fits your own community. This is one of the reasons why we prepared lectures covering rather wide engineering fields including environmental engineering. On the basis of the knowledge you obtain through these lectures, you may want to begin discussing possible applications of solar power generation among yourselves and with us. We intend to enhance communication and collaboration among engineers in different fields and in different communities. Thus , we expect to develop new applications of solar power generation taking advantage of the collaboration between your communities and us.

This text is composed of ten chapters. The first five chapters are for rather fundamental knowledge of physics and chemistry related to the subject. The next two chapters are related to electric circuits and instruments. The chapters 8 and 9 are for the design of a system from the point of view of planning of architecture and environment. The last chapter is to show the subjects of the individual training in this course.

We would like to express our sincere thank to Osaka City University Foundation for his efforts to start and maintain the course. For the same reason, we also acknowledge to Osaka City Government and the Osaka International Center of Japan International Cooperation Agency (JICA). This project would not run without the collaboration of Sanyo Electric Co. Ltd. We are highly grateful to his collaboration. The final thanks are to Prof. Kenichiro

Yamamoto, President of Osaka City University and Mr. Tsuneo Kawamura, Secretary General of Osaka City University and members of the teaching staffs, administration office and students of Osaka City University. Their understanding of this course and warm heart were essential to have successful results and continuation of this course since the start of the first year in 1995.

Yuzo Mori
Susumu Tago

付属資料

公開セミナープログラム

Seminar on Solar Power Generation and its Application System

13:00 - 13:05	Opening Remark
13:05 - 13:15	Introduction to JICA's Training Mr. Norio NAITO Dy. Director, Training Div., Osaka International Centre, JICA
13:15 - 14:25	Seminar 1 " An Approach to Solar Power Generation and its Application System " Dr. Yuzo MORI Professor, Dept. of Applied Physics, Osaka City University
14:25 - 14:45	Coffee Break
14:45 - 15:55	Seminar 2 " Photovoltaic Power Generation and its Application System " Mr. Toshimasa HIRANO Chief Researcher, System Design Lab., Electronic Device Dept., New Materials Research Center, Sanyo Electric Co., Ltd.
15:55 - 16:25	Discussion
16:25 - 16:30	Closing Remark
18:00 - 20:00	Reception

公開セミナー資料（森団員）

An Approach to Solar Power Generation and its Application System

Yuzo Mori
Faculty of Engineering
Osaka City University

Abstract

In this talk, I would like to give you a rough sketch of the JICA (Japan International Cooperation Agency) training course "Solar Power Generation and its Application System" together with a sketch of Osaka City University, a training institution, and Osaka. In the talk, I will mention the research projects and their recent results selecting a few topics from the research programs which are now under way in the university. I hope this talk can contribute to enhance your understanding of the course as well as a present status of solar energy engineering.

1. Introduction

The solar power generation and its application is still developing technique even in Japan as well as other developed countries. This is very characteristic feature of this course among many group training courses offered by JICA.

2. The aim of the course

The aim of this course is to provide engineers from developing countries and countries attempting environment-friendly development with a general understanding of the theory and practice of solar power generation through lectures, practices and field study, so that solar energy can be utilized in their countries.

2. Our role

3. Contents of the course

The course includes lectures on basic engineering and applied technology. The latter part includes practice and provided by Sanyo Electric Co., Ltd., one of top companies of the related engineering. The course also includes Individual training for specialized subjects.

4. Osaka City University

Osaka City University (OCU) is the largest municipal university in Japan, and it comprised of the eight Faculties and the eight Graduate Schools of Business, Economics, Law, Literature, Science, Engineering, Medicine and Human life Science, and the three Institutes for Economic Research, Health Science and Physical Education, and Dowa Mondai.

The Origin of the university dates from the foundation, in 1880, of Osaka Commercial Training Institute, a major center of commercial and industrial studies in Osaka. The institute developed from Osaka City Commercial School and Osaka City Commercial College into Osaka University of Commerce in 1928.

At the founding this first municipal university in Japan, Dr. Hajime Seki, the Mayor of Osaka City at that time, proclaimed a clear vision of its organization and task: the new university should not simply be an institute for professional training, but a place for in-depth research. Further, he believed that the results of such research should be closely integrated with the lives and unique heritage of the citizenry of Osaka. In this way the university would be clearly distinguished from other national universities. Dr. Seki also declared that the purpose and sprit of founding the university would be fulfilled when the university accomplishes the highest level of creative studies and, ultimately, guides the cultural, economic and social lives of Osaka City.

Under the post-war Education Reform, OCU was founded in 1949 when Osaka City Technical College, Osaka City Women's College, and the Institute for Economic Research of Osaka City joined with Osaka University of Commerce. Since then the University has been growing with the incorporation of the Osaka City Medical School, and the foundation of the graduate schools.

Osaka is the oldest city in Japan, an international city which developed through trade and exchange with foreign countries. Since Edo era (1603 - 1867), Osaka has been the hub of Japan and has played a central role in its economic activities. Even today, Osaka is the greatest distribution center in Japan, a base where people, goods, and information congregate from all over the world.

The University has made distinguished contributions of academic excellence and will continue to do so by undergoing development according to the Mater Plan of OCU drawn up in conjunction with the Comprehensive Plan of Osaka City for the 21st Century. (taken from Osaka City University 1995-1996)

5. A few examples of research projects in our faculty

a. Carotenoid solids -the reason to study the solids and the present results. Carotenoids are important pigments in biological systems. A typical example is carotenoids in photosynthetic system, namely solar cell in nature. In photosynthetic systems, carotenoids act as light-harvesting molecules and provide photprotection of the plant.

6. Osaka City

7. Summary

ANNUAL BUDGET

Expenditures (1994 Fiscal Year)

University

Expenditures	Amount (million yen)
Personnel	14,895
Non-personnel	24,821
Total	39,716

Revenue	Amount (million yen)
Tuition and fees	3,347
National Government Subsidies	385
Donations	140
Miscellaneous	209
City Bonds	4,864
Total	8,945

University Hospital

Expenditures	Amount (million yen)
Personnel	9,257
Non-personnel	28,256
Total	37,513

Revenue	Amount (million yen)
Hospital Charges	4,745
Medical fees	917
Medicine	5,434
Treatment after operation	7,089
National Government Subsidies	197
Transfer from current account	18,643
Miscellaneous	488
Total	37,513

Tuition Fees

(April 1. 1994)

		Application Fee (Yen)	Admission Fee (Yen)	Annual Tuition (Yen)
Under-graduate	Degree Student (Day)	15,000	320,000	411,600
	Degree Student (Night)	8,800	160,000	205,800
	Non-Degree Student (1)	8,600	32,000	11,500
	Non-Degree Student (2)	8,600	96,000	22,900
Graduate	Degree Student	26,000	320,000	411,600
	Non-Degree Student (1)	8,600	32,000	11,500(for credit)
	Non-Degree Student (2)	8,600	96,000	22,900(for month)

Land and Buildings

(June 1. 1994)

Campuses		Land (m^2)	Building (m^2)
Sugimoto Campus		249,404	122,542
Abeno Campus		33,500	108,683
Other	Academic Extention Center	34	420
	Botanical Garden	255,500	3,607
	Cosmic Ray Institute	2,405	123
	Hakuba Seminar House	6,074	268
	Others	12,498	1,725
Total		559,415	237,368

I. COURSE OUTLINE

1. Duration: From September 15, 1997 to December 14, 1997

2. Number of Participants: 5

3. Training Needs

Development of a sound social infrastructure, and particularly electric power development, is indispensable for economic development in developing countries. Being consistent with environmental preservation has become an absolute condition for such development in recent years, and solar power generation has become an effective means of satisfying this condition. Solar power generation is ideal for satisfying small demand spread out over remote areas and island nations, and is a means of promoting local economies consistent with environmental protection. There is consequently an urgent need to train qualified personnel in related fields in order to promote sustainable development that takes the environment into consideration.

Solar power generation has less of an effect on the environment than thermoelectric or nuclear power generation, and is a clean, renewable energy resource that produces no harmful waste or emissions such as carbon dioxide. Although it may be affected by weather and time, it requires no maintenance for routine operation and does not require shipment of fuel, so can be produced on site and is effective for remote locations. These advantages indicate that solar power generation would be a source of electric power well suited to developing countries and countries attempting to develop without disturbing the natural environment.

Practical application of solar power generation in these countries requires technicians who have not merely knowledge of solar power generation technology, but also adequate understanding of various points affecting application technology, such as the purpose that power is used for (including related motors, inverters, etc.), local natural conditions, and environmental considerations. Although solar power generation does not need maintenance for routine operation, it does require technical support to maintain proper working order for an extended period of time. It will consequently be necessary to educate and train engineers in order to make solar power generation practical in developing countries. This course is designed as a starting point for educating and training such engineers.

4. Purpose

The aim of this course is to provide engineers from developing countries and countries attempting environment-friendly development with a general understanding of the theory and practice of solar power generation through lectures, practices and field study, so that solar energy can be utilized in their countries. Participants will receive instruction in the technology necessary to store generated power and convert it to energy, and the application technologies needed to utilize it in line with residential and industrial demand while preserving the natural environment. The course will also teach the skills needed to carry out feasibility and suitability studies in connection with the introduction of solar energy generation in these countries, as well as those required to import, set up and operate solar power generation and application systems. It is thus hoped to contribute to improved living standards and the stimulation of local industry in participants' countries through the introduction of solar power generation.

5. Objective

By the end of the course, participants will have acquired:

(1) understanding of solar power generation systems (semiconductors, solar batteries, etc.),
(2) understanding of structure and manufacturing method of solar batteries,
(3) ability to evaluate operating characteristics of solar batteries and maintenance technology,
(4) fundamental knowledge of related equipment including storage batteries, inverters and other electronic equipment,
(5) knowledge of natural conditions affecting sunlight intensity and methods of quantitative analysis,
(6) skills for evaluating energy consumption of users such as villages, medical facilities, airconditioning systems, communications facilities and storage pumps, and
(7) environmental assessment skills.

6. Curriculum

Part I: Basic Engineering
(1) Semiconductors: (i) semiconductors, impurities, electric conduction
  (ii) p-n junction, photoelectromotive force, solar batteries
(2) Photomaterials: light absorption, spectrum and efficacy
(3) Batteries: theory and types of storage batteries, their charging and discharging characteristics
(4) Electronic equipment: electric motors, data communication equipment, lighting equipment, inverters
(5) Fundamental environmental technology
  (i) solar movement and solar bearings, amount of sunlight and energy from light and heat, local climate
  (ii) temperature and humidity levels, draughts and ventilation, indoor thermal environment
(6) Environmental planning and environmental systems
  (i) practical application of solar power generation
  (ii) technology for systems employing heat-driven devices
  (iii) planning practical application to living and working environments, solar houses, etc.

Part II: Applied Technology
(1) Effectiveness, cost efficiency and future potential of solar batteries
(2) Manufacturing process of solar batteries
(3) Design, manufacture, testing and inspection of solar battery power sources
(4) Servicing and inspection of solar battery power source systems
(5) Systems incorporating electric motors, data communication equipment, sensors and measuring instruments
(6) Solar house systems and auxiliary systems

Part III: Study Tours
(1) Lighthouse
(2) Power Station
(3) Solar house or office

Part IV: Individual Training for Specialized Subjects
(1) Superheated steam drying system using solar-assisted absorption heat pump and laser measuring system.

(2) Characterization techniques in solar power generation.
(3) Solar cell-converter-motor-load system.
(4) Conceptual design of battery system for solar power generation.
(5) Practice on regional environment and architectural plan.
(6) Practices on electronics including solar cells and their characterization.
(7) Photovoltaic effects in semiconductors.
(8) The relation between light and materials in view of energy conversion.

Tentative Schedule

Date		Subject
Sep. 15	Mon.	Arrival in Japan (Osaka)
16	Tue.	Briefing (OSIC)
17	Wed.	Orientation (OSIC)
｜		
19	Fri.	
22	Mon.	Intensive Japanese Language Course (OSIC)
｜		
Oct. 3	Fri.	
6	Mon.	Opening Ceremony at Osaka City University (OCU)
7	Tue.	Technical Training (Basic Engineering, OCU)
｜		
20	Mon.	
21	Tue.	Study Trip 1
｜		
25	Sat.	
27	Mon.	Technical Training (Applied Technology, SANYO Electric. Corp)
｜		
Nov. 14	Fri.	
17	Mon.	Study Trip 2
｜		
20	Thu.	
21	Fri.	Individual Training for Specialized Subjects (OCU)
｜		
Dec. 5	Fri.	
8	Mon.	Report Writing
｜		
10	Wed.	
11	Thu.	Evaluation Meeting at OCU
12	Fri.	General Evaluation Meeting and Closing Ceremony (OSIC)
13	Sat.	Departure from Japan
14	Sun.	

OSIC: Osaka International Centre
OCU: Osaka City University

7. Methodology

(1) Instruction Method

The training will be conducted in the form of lectures, practices and observations.

(2) Language

The course is generally conducted in English, or through interpretation of Japanese into English if necessary.

(3) Training Equipment

An overhead projector, a video tape-recorder for VHS and other systems, a slide projector and 16 mm film projector are available during lectures.

8. Training Institution

The course is organized by the Osaka International Centre (OSIC), which is one of the thirteen training centres of JICA. OSIC entrusts the implementation of the technical training to the Osaka City University Foundation.

(1) Osaka International Centre (OSIC), JICA
25-1 Nishi-Toyokawa-cho, Ibaraki-shi, Osaka 567, Japan
Tel.: 81(*)-726(**)-41-6900
Fax.: 81(*)-726(**)-41-6910
(*): country code for Japan
(**): area code for Ibaraki

(2) The Osaka City University Foundation
3-3-138 Sugimoto, Sumiyoshi-ku, Osaka 558, JAPAN
Tel.: (06) 605-2080

Founded in 1965 with the aim of enhancing the cultural level of the Japanese nation, the Osaka City University Foundation provides material and financial support for scientific endeavours and for the expansion of educational and research facilities which are required for the further development of the university. Since its inception in 1993, the foundation's research department has been involved in surveys and research commissioned by outside institutions for the purpose of social progress.

(3) The Faculty of Engineering, Osaka City University
3-3-138 Sugimoto, Sumiyoshi-ku, Osaka 558, JAPAN
Tel.: (06) 605-2650

Osaka City University is the largest municipal university in Japan. Rooted in the civilian traditions of Osaka, the university boasts a rich history of over one hundred years, and has supported education and research in the Osaka cultural and economic sphere as a general studies municipal college. Cherishing independence and liberty in the pursuit of both the fundamentals and the advanced technology which rests on them, the Faculty of Engineering has always strived to fulfill a role of technical leadership in local society.

9. Certificate

Participants who have successfully completed the course will be awarded a certificate by JICA.

II. ORIENTATION PROGRAMME

Orientations addressing specific concerns of participants are generally scheduled before training begins. Several kinds of orientations, focusing on different issues, are given at different times.

1. Pre-Departure Orientation

A pre-departure orientation is held at JICA overseas offices (or Japanese diplomatic missions) to provide the selected candidates with details of travel to Japan, conditions of training and other matters. "INFORMATION" (this booklet), "TRAINING IN JAPAN" and "GUIDE TO TRAINING IN JAPAN" are to be provided.

(Refer to IX. PRE-DEPARTURE INSTRUCTIONS for related information.)

2. Arrival Orientation

A briefing session is organized the day after arrival in Japan at OSIC to cover the following:

(i) Registration
(ii) Allowances & Expenses
(iii) Accommodation
(iv) Medical Services
(v) Return Flight Arrangements
(vi) "A Guide to JICA"

3. General Orientation for Introduction to Japan

Participants are scheduled to participate in a 3-day orientation programme offered by Osaka International Centre# in Osaka.

The main purpose of the introduction programme "Japan Past and Present" conducted by the Centre is to provide participants with general information on key points regarding Japan and with the tools needed for adapting to life and training in Japan. Basic information is provided about Japanese values, behaviour and customs, as well as economic and social institutions.

The contents of the programme are:

(i) Japanese Society and People
(ii) Japanese History and Culture
(iii) Education in Japan
(iv) Japanese Economy
(v) Japanese Politics and Government
(vi) Japanese Conversation
(vii) Bus Tour of the Kansai Area

\# Osaka International Centre (OSIC), JICA
25-1 Nishi-Toyokawa-cho, Ibaraki-shi, Osaka 567, Japan
Tel.: 81(*)-726(**)-41-6900
Fax.:81(*)-726(**)-41-6910
(*): country code for Japan
(**): area code for Ibaraki

4. Course Orientation

The course orientation is intended as a guide to assist participants in achieving the target of the programme by providing course details and reaffirming course objectives.

III. JAPANESE LANGUAGE COURSE

An intensive Japanese language course will be conducted prior to the technical training for 2 weeks (45 hours).

A general Japanese language course is organized in the evening along with the training programme for those participants who are interested in learning the language.

IV. CONDITION OF APPLICATION

1. Qualification of Applicant

Applicants should:

(1) be nominated by their government in accordance with the procedures mentioned in 2 below,
(2) have a bachelor's degree of science and/or engineering in a field related to this course, or the equivalent,
(3) be between twenty-five (25) and forty-five (45) years of age,
(4) have two (2) years or more experience related to electricity,
(5) have a sufficient command of spoken and written English,
(6) be in good health, both physically and mentally, to undergo the training; pregnancy is regarded as a disqualifying condition for participation in the course, and
(7) not be serving in the military.

2. Procedure for Application

(1) A government desiring to nominate applicants for the course should fill in and forward five (5) copies of the Nomination Form (Form A2A3) for each applicant to the JICA office (or the Embassy of Japan) by <u>July 15, 1997</u>.
(2) The JICA office (or the Embassy of Japan) will inform the applying government whether or not the nominee's application has been accepted by <u>August 15, 1997</u>.

3. Questionnaire

Each applicant should fill in the questionnaire which is used for screening of applicants (format attached - see Annex I). After filling out the form, cut it off and submit it together with the Nomination Form. <u>Application not accompanied by a completed questionnaire cannot be duly considered</u>.

4. Country Report

Applicants should prepare a report of about 8 to 10 pages on the present situation of their own field of study and concern in their own country. This country report should be typewritten in accordance with the format indicated in Annex II and submitted to JICA on arrival in Osaka. Applicants' country reports are used as training materials in the course (especially useful in comparative studies).

LIGHTING KITS

EnerTec
Energy Technologies International
P.O. Box 1285 Boroko, N.C.D.
Papua New Guinea
Phone: 321 4700 Fax: 321 4632

LIGHTING THE NATI

THE SOLUTION

EnerTec's Solar Lighting Kit provides up to 300 watts of pure sine wave, 240 volt AC power and sufficient DC power to run ten 20 watt, 12 volt fluorescent lights.

Long warranty, quality components and skilled support makes it the premier solar lighting solution available in Papua New Guinea.

The solar lighting kit contains batteries, solar panels, inverter/regulator and all the necessary cabling, switches fittings, etc. Specifications are detailed below:

1 BATTERIES

- Century Yuasa SSR 620-636AH 12 Volt Tubular Plate batteries.
- 3 years warranty.
- 12 month watering intervals.
- Tubular positive plates.
- High cyclic life.
- High efficiency.
- High reliability.
- Ability to withstand high temperature.
- Low corrosion of the positive plate.
- Fast recharging.
- Withstands plate expansion as battery ages.

Note: Battery performance deteriorates though either shedding of active material from the positive plate (by either cycling or vibration), or by corrosion of the positive plate. Century Yuasa tubular plate batteries are designed and built to minimise these problems because:-

- *The active material is held in place by a sealed woven tube and shedding is minimised during service life. This means that the battery will be able to withstand cycling better than conventional flat plate batteries. As the active material is contained, it is less affected by vibration.*
- *The spines of the tubular positive plates are surrounded by a concentric layer of active material which is considerably deeper than that on conventional flat pasted positive plates. The rate of corrosion of the spine or grid is directly related to the depth of cover of active material. In comparable deep cycling conditions, tubular plate battery cycle life is substantially greater that that of an*

2 SOLAR PANELS

- 80 watt high efficiency solar panels.
- Light energy to electrical energy conversion efficiency of over 14%.
- Guaranteed for 12 years.
- Maximum protection from the severest environmental conditions.
- Supported in anodized aluminium frames to provide structural strength and ease of installation.

3 INVERTER/ REGULATOR

- Butler Solar MicroSine Inverter with built in Regulator.
- Microprocessor controlled pure sine wave inverter converts 12 volt battery power to 240 volt AC power (ELCOM power) for TV's, VCR's, HF radios etc.
- Continuous power rating of 300 Watts at 40° C.
- Peak power rating of 450 Watts at 40° C.
- Monitors and controls solar input power and battery output power to maximise the life of the battery.
- Stores information on the performance of batteries, solar arrays and the loads placed on the system for later analysis and site management.
- Built in protection against over discharge and overloading.
- Shuts down if overloading occurs and will stay shut down until the overload is removed and the inverter is restarted.
- Detects when the battery has been disconnected and reconnected and when significant loads have been connected directly to the battery.
- Detects the regular use of large appliances which should not be used on the system.
- Uses pulse width modulation (PWM) technology for maximum battery charge efficiency.
- Suitable for indoor use to maximum 60°C.
- Relative humidity, 95% non condensing

Osaka Way

- A Challenge to 2008 Marin Olympic Games -

The 21st century, the third dawn of a millennium, is coming very soon. In the last 2,000 years, many cities have been born, flourished and declined. And now more world cities are enjoying a civilized society. Few of them, however, have a history dating before 1,000 AD, the first millennium. The history of Rome began in 753 BC and that of London and Paris in the first century BC, but there are many cities that cannot be called a world city any more in spite of their old place names. In Japan, Osaka and Kyoto can be regarded as "millennium cities". Osaka prospered 1,500 years ago as a gateway of intercultural communication and in 645 Naniwa-no-miya was established there, and Kyoto has a history from the establishment of Heian-kyo as an imperial capital.

Osaka, however, has not always flourished throughout its history of over 1,500 years. The first Naniwa-no-miya was burnt to ashes and the second one, which was established as a sub-capital of Heijyo-kyo, had already been abolished when the capital was transferred to Heian-kyo. Ishiyama-Honganji Temple built in the Muromachi period and Osaka Castle built by Toyotomi Hideyoshi, both of which symbolized Osaka, were lost in a fire. In the modern age, due to devastating damage from war, storms and floods, and due to heavy chemical industry attached too much importance as an industrial basis, air and water pollution has increasingly worsened and brought an outflow of population in Osaka, a so-called city of smog and a city of water. In its long history, although Osaka has been confronted with so many trials, it has overcome hardship and has revived like a phoenix, supported by predecessors' efforts.

Now Osaka is changing into an international visitors' city, having the Kansai International Airport as a gateway to the world.

Today Osaka accept 200 thousand visitors a year consisting mainly of business people. So that those visitors also enjoy Osaka for sightseeing, amusement and shopping and more visitors are allured by various events including sports events, we are projecting and constructing various facilities, and pushing forward a city renewal scheme in order to vitalize the city.

Around Osaka, the land of which is composed of earth and sand carried by the Yodo and Yamato Rivers, dredging operations have to be continued, but they leave much earth and sand behind. A subway has also been constructed to facilitate a traffic network as the basis of urban life, but consequently earth has been left. In the daytime Osaka has 2.6 million permanent residents and 1.5 million people who commute to the city. The Osaka city government is capable of incinerating the rubbish brought by activities of such many people, but ashes always remain. Utilizing such earth and ashes, three artificial islands, Saki-shima, Mai-shima and Yume-shima, were made in the Osaka Bay as an ideal urban space, by which harbor facilities supporting citizens' life are expanded without destroying the marine environment.

Part of these islands have already been used as the foothold of international trade and a residential area called Port Town. Especially in Mai-shima, sports facilities and accommodations are being built for many sports fans including the disabled and people of middle and advanced age. The Osaka city government has a project to make Mai-shima a sports island by constructing facilities in which first-class international sports events can be held. Together with sports facilities that have already been completed in the city area, there will be "Sports Paradise Osaka" centering around Mai-shima. When this project is accomplished, Osaka is ready to host the Olympic Games, and thus, the concept of city renewal will be effective. It was 5 years ago, in 1992, that the city government and the city assembly had a concrete idea of holding the Olympic Games in Osaka. In the same year, the Society for the Research of the Olympic Games Holding Problems was formed, and the examination resulted in the agreement that in 2008, when the subway is extended to Saki-shima, Yume-shima, Mai-shima and Konohana Ward as planned, it will be possible to hold the Olympic Games by using houses planned to be built in Mai-shima as the competitors' accommodations.

Let's make a model city of the 21st century in the artificial island to create a new environment. Let's realize the eco-friendly Olympic Games on the sea by means of local environment control such as the subway, electric cars and energy circulating systems. The access to main facilities will be secured not only by car but by train or ship. And for VIPs, helicopters will also be available. In the city, you can find many first-class hotels. We hope many competitors, officers and spectators from within and without can enjoy local food, amusement quarters and urban facilities unique to Osaka such as Kaiyukan, Asia Trading Center (ATC), World Trading Center (WTC) and Universal Studio Japan which will be open in 2001. Furthermore, they can fully enjoy the historic road (Rekishi Kaido) in Mie, Wakayama, Shiga, Nara, Kyoto, Hyogo and Osaka where the Japanese culture of 1,500 years can be experienced. Thus, Osaka is the best place, which can fully offer us an opportunity of intercultural exchange, another characteristic of the Olympic Games.

Both citizens and financial circles are desirous to hold the Olympic Games in the Osaka way, making the most of history and culture that citizens are proud of, and hospitality that is much superior to any other cities. Fortunately, voluntary supporting parties have been formed by citizens one after another. And heads and assemblies of local governments in the Kinki district also support the plan. So that we can hold the Olympic Games to make young people in the 21st century recognize world peace, friendship and wholesome national sense, we hope that people in the world understand the Osaka way.

PHOTOVOLTAIC POWER GENERATION AND ITS APPLICATION SYSTEM

Toshimasa HIRANO

Chief Researcher
New Materials Research Center, R & D Headquarters
SANYO Electric Co., Ltd.
1-1, Dainichi Higashimachi, Moriguchi-City, Osaka 570, Japan.

Abstract

Solar energy is more appropriate than fossil fuels for developing countries to meet the increasing energy demand, in particular for the areas with inadequate infrastructure. This paper will review recent technology of solar cell and its applications.

1. Introduction

Our lives have become vastly richer thanks to the advance of civilization. But humankind today is facing a great crisis that could take away not only the luxuries of today's living, it could also deprive us of our lives themselves. The danger is global environmental problems. Problems such as the greenhouse effect and acid rain are caused primarily by massive consumption of fossil fuels such as coal and oil. The key to resolving these problems lies in the development of clean energies. Solar cells, which convert sunlight directly into electricity through the photovoltaic effect of semiconductors, are a key technology toward the conquest of global environmental problems. In this paper, the author will review the steps and status of solar cell development before going into application technologies. Then the author will cover future prospects by talking about a global energy supply system comprised of solar cells.

2. Energy problems

2-1. Global environmental problems

The earth that nurtures us is surrounded by an atmosphere that maintains the temperature and creates clouds and rain. If the diameter of the earth, around 12,700km, is reduced to 1 m for purposes of comparison, the atmosphere that covers its surface (12km) would amount to only 1 mm. Into this ultra-thin atmosphere man has released the gases from burning fossil fuels. This is like running your car in an enclosed space, choking the air with exhaust fumes. It is clearly suicidal behavior.

The fossil fuels were created in ancient times by carbon dioxide assimilation by plants of the energy of the sun (The conversion efficiency of the sun's energy by plants is thought to be approximately 0.02%.), in a process lasting around 200 million years. The resulting fossil fuels will be exhausted by man in a mere 100 to 150 years. If the period of 200 million years is thought of as 1 year for purposes of comparison (approximately 30 million seconds), man will use up these fossil fuels in a mere 15 to 23 seconds. As a result of man's disgraceful behavior, the amount of carbon dioxide and sulfur oxides have increased rapidly, and it is only natural that we should be faced by the resulting environmental problems (see Fig. 1).

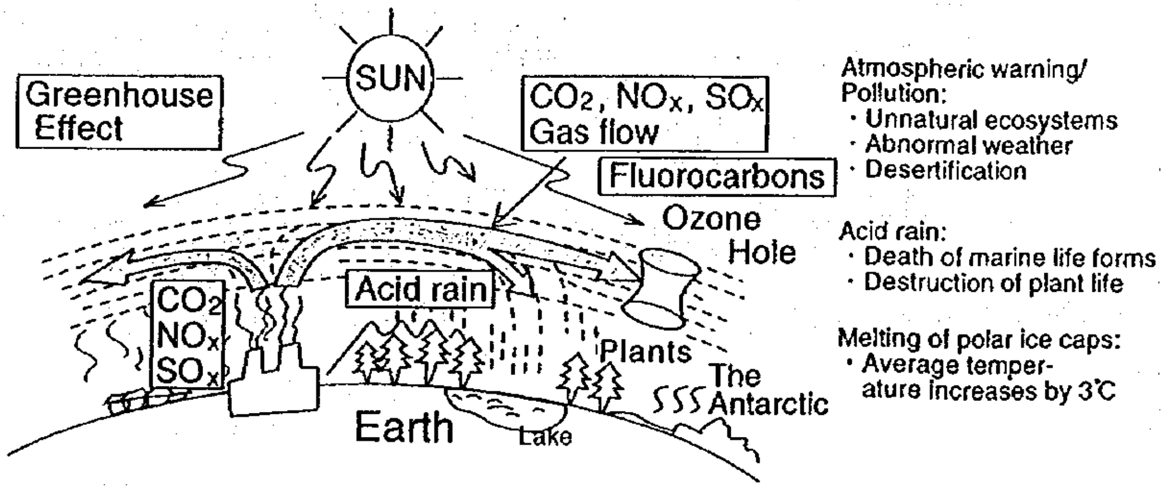


Fig. 1 Degradation of the global environment

2-2. Dwindling energy resources

The consumption of fossil fuels such as coal and oil has reached a turning point from the standpoint of confirmed global energy reserves, as you can see in Fig. 2. If we continue to consume energy at current levels, we will expend all fossil fuel resources on the Earth within 200 years. On the other hand, some hold the view that there is no need for concern because the amount of confirmed reserves will gradually increase, but those that believe this are wrong. Not only is there a limit to the ultimate amount of reserves, but predictions hold that future population increases as shown in Fig. 3. Therefore, we can expect an explosive increase in the amount of energy consumed in the future, as shown in Fig. 4, as the population of the world and energy consumption per capita increase. In the year 2020-2030, a gulf between energy required for humankind and production volume of fossil fuels (called "energy gap") will be grown. We need new energy for solution of that problem.

2-3. Solar energy as a new source of clean energy

In view of global environmental problems and dwindling energy resources, we must develop new energy sources that are both abundant and safe as a substitute for fossil fuels. In this respect, solar energy is the ideal form of energy because it is clean, inexhaustible, and available everywhere in the world. The amount of solar energy that showers the Earth is 170 billion MW. This quantity is so massive that one hour's worth could supply the energy needs of the entire world for one year. And because the life span of the sun is extremely long compared to the history of humankind, it may well be considered a semipermanent energy source.

Among the methods available for utilizing the sun's energy, the most prominent method is solar cells, which use the photovoltaic effect of semiconductors to convert solar light energy to electrical energy, as shown in Fig. 5. When light enters a semiconductor which has a p-n junction, a hole (electron hole) with a positive charge and an electron with a negative charge are produced. These are separated along the p-n junction, and the positive and negative charges collect at both electrodes. When these two electrodes are connected, electric current flows and work is performed. Since sunlight is used as the energy source, the result is a power generating element which does not require fossil fuels, does not produce exhaust gas, and does not have moving parts.

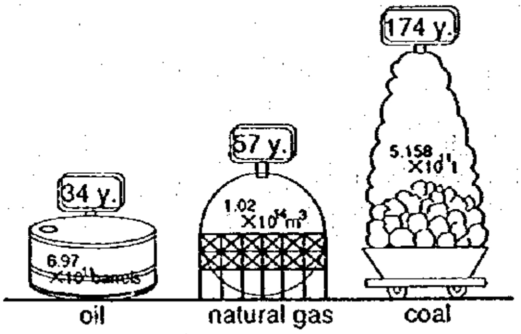


Fig. 2 Reserves of various energy sources.⁽¹⁾

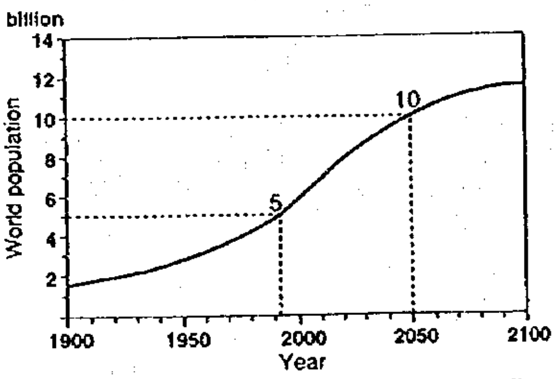


Fig. 3 Prospect of population in the world. ⁽²⁾

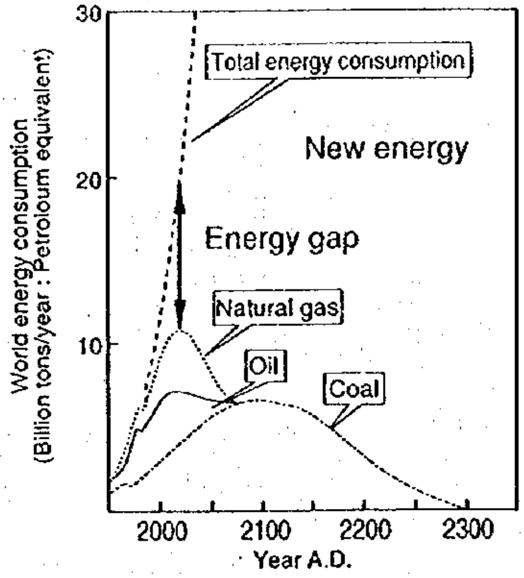


Fig. 4 Progress and forecasts for consumption of various energies. ⁽³⁾

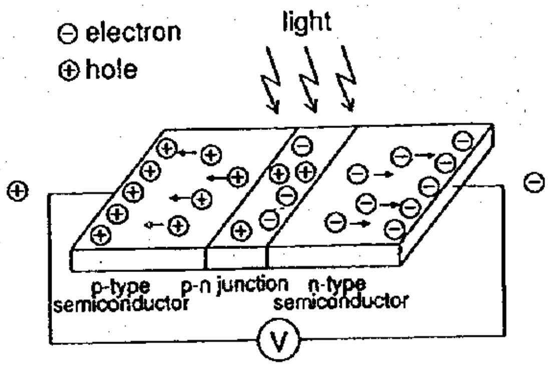


Fig. 5 Theory of photovoltaics

In addition to providing the many features of solar energy, solar cells also offer the following.

(i) They provide electrical energy directly.
(ii) The conversion efficiency is the same irrelevant of the scale of power generation, that is, whether it is 1 W or 1 MW.
(iii) Power is generated even with diffused light such as on cloudy days.
(iv) The service life is basically semipermanent because there are no movable parts.

And finally, silicon -- the main material comprising solar cells -- is the second most plentiful element on the Earth, so there is absolutely no problem from the standpoint of resource availability.

3. Progress in solar cells

3-1. The history of solar cells

The history of solar cells began with Pearson and others in the United States in 1954. In 1958, solar cells were sent up into orbit on the the U. S. Vanguard 1 satellite and used to provide power for telecommunications. Since then, they have been used in radio relay stations, lighthouses and other locations, but their high price prohibit them from achieving widespread use. Following the so-called "oil shocks" of 1973, however, the superior characteristics of solar cells caused attention to be focused on them as a substitute source of energy. Technical development was pursued in the United States under the auspices of the Department of Energy and in Japan under the New Sunshine Program (Formally, the Sunshine Project) of the Ministry of International Trade and Industry (MITI). The history of solar cells is shown in Table 1.

3-2. The status of solar cells

(A) Types of solar cells

There are many different types of solar cells, depending on the material used (silicon, compound semiconductors, organic semiconductors, etc.) and the shape of the crystals of the material (single crystal, poly-crystal, amorphous etc., or a combination). Silicon is a main material for solar cells. Some representative methods for manufacturing Si solar cells are shown in Fig. 6.

Single crystalline silicon (c-Si) solar cells were the first to be developed. They enable a high energy conversion (defined as the percentage of incident energy that can be converted to electrical energy) of 20% or greater for a small area. There are two major problems with this type of solar cell : complex manufacturing process and high costs.

In order to solve these problems, a method was developed in which molten silicon is hardened in a mold and then sliced into wafers to form poly-crystalline silicon (poly-Si) solar cells. These cells have a conversion efficiency of around 16%, lower than single crystal cells, but costs are also lower.

Table 1 The history of solar cells

1954	Single crystalline silicon solar cell (Pearson)
1958	Satellite equipped with solar cells (Vangard 1)
1973	Oil crisis
1974	National projects started in U.S., E.C and Japan etc. (ex. Sunshine project)
1976	Amorphous silicon (a-Si) solar cell
1980	Massproduction of a-Si solar cells Consumer electronics powered by a-Si solar cells
1984	7MW solar power generation plant (U.S.)
1987	PVUSA project (U.S.)
1991	Industrialization of solar air-conditioner Roof. 1000 project (Germany)
1992	Practical reverse-flow solar power generation system (Japan) Solar 2000 project (U.S.)
1993	New Sunshine Program

The production method for amorphous Si (a-Si) solar cells differs greatly from that of the two solar cells described above. Because a gas such as SiH_4 is decomposed using glow discharge and then deposited on a substrate such as glass, (i) the production processes for a-Si solar cells are simple, (ii) the energy required for production is low with processes demanding less than 300℃, (iii) the quantity of materials used is low with thicknesses less than 1 μm, whereas with crystal-based silicon the thickness is about 300 μm, (iv) the use of gas reaction facilitates larger sizes, (v) a high output voltage can be drawn from a single substrate using the integrated-type structure unique to a-Si solar cells. These and other characteristics make a-Si solar cells ideal low-cost solar cells.

(B) Energy payback time (EPT)

One of the most important concepts when evaluating solar cells as a new energy source is energy payback time, or EPT. EPT is the number of years that are required for solar cell modules to generate the same amount of electric power as was consumed in their fabrication and depends on conversion efficiency and production volume of solar cells. EPT calculations for a-Si and poly-Si solar cells are shown in Fig. 7. EPT decreases as the production volume increases. At a production volume of 10 million W/year in case of 8% conversion efficiency solar cells, the

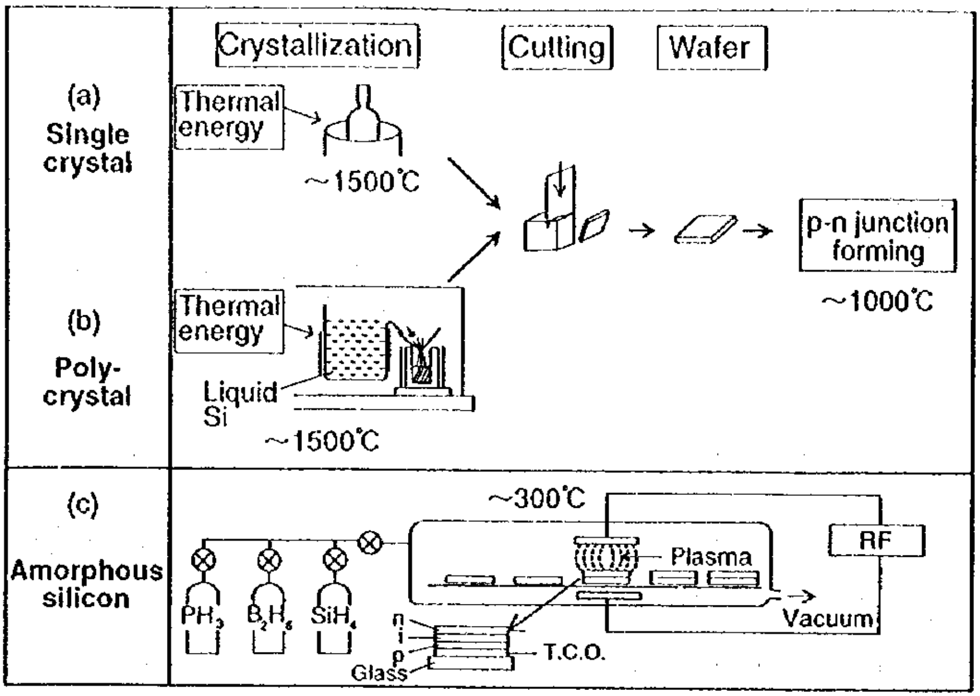


Fig. 6 Comparison of fabrication methods for various solar cells

EPT is estimated to be 1.2 years for a-Si solar cells, and 4.2 years for poly-Si solar cells. The EPT of a-Si solar cells is much shorter than that of poly-Si solar cells. This is because of the low fabrication temperature, simple manufacturing process, and other a-Si solar cell features. In any case, the EPTs of these solar cells are very much shorter than their lifetime, which is estimated at longer than 20 years. Namely, solar cells are possible to multiply themselves, as shown in Fig. 8. This means that solar cells are quite suitable as a new energy source.

(C) Improvements in conversion efficiency

Figure 9 shows the progress and forecasts for the conversion efficiency of silicon-based solar cells. In the past 10 years we have seen the conversion efficiency for small-area cells improve from 18 to 23% for c-Si based cells, from 12 to 18% for poly-Si based cells, and from 5 to 13% for a-Si based cells. Much improvement continues in the conversion efficiency of modules for practical use as follows :

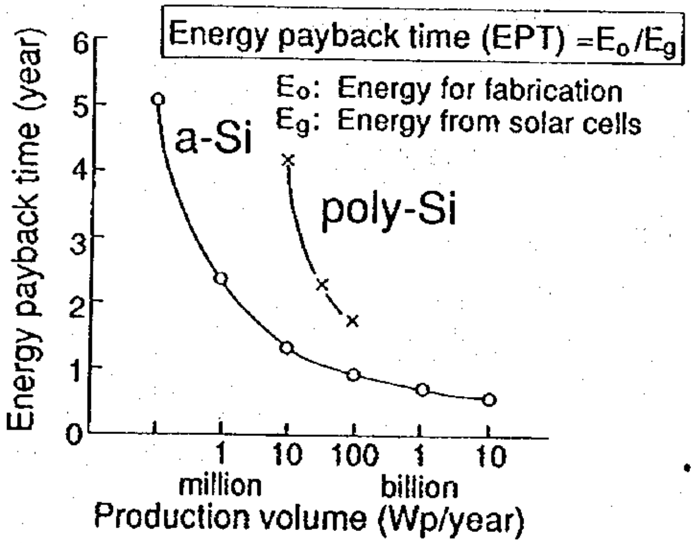


Fig. 7 Estimation of the EPT for a-Si and poly-Si solar cells (4)

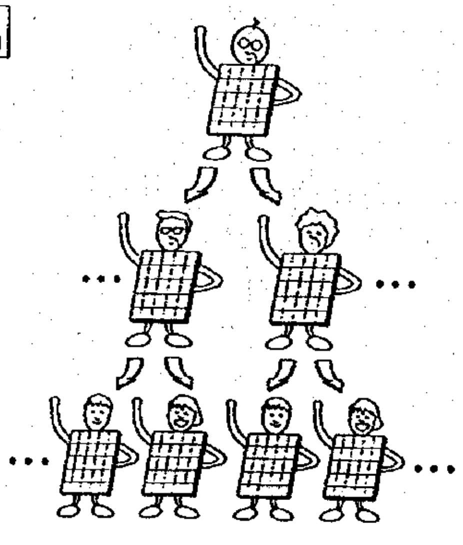


Fig. 8 Self-multiplication of solar cells with solar energy

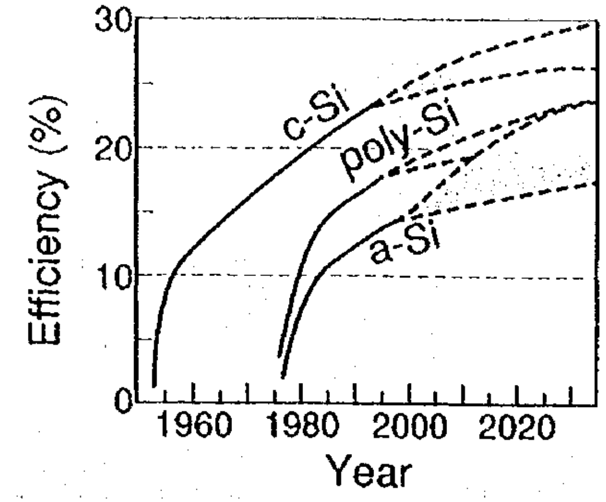


Fig. 9 Progress and forecasts in conversion efficiency for silicon-based solar cells

c-Si : 7 - 8 % → 12 - 14 %
poly-Si : 6 - 7 % → 11 - 13 %
a-Si : 2 - 3 % → 6 - 9 %

We expect that research and development in this area will accelerate to the point where we should see the conversion efficiency improve to 27% for c-Si cells, and 24% for both poly-Si and a-Si cells.

National projects such as the New Sunshine Program, U.S. DOE Project and EC project etc. have contributed greatly to these achievements. The targets of several national programs are shown in Table 2. Further improvements in conversion efficiency and reduction of costs are anticipated from these national projects in the future.

4. Applications and systems using solar cells

4-1. Production volume and cost

The production volume of solar cells has increased rapidly in recent years (Fig. 10). The total production volume in the world was about 70 MW in the year 1994. Japan, the United States and the EC countries share about one third of the total production volume.

Figure 11 also shows trends in the actual and projected cost of solar cells. The sharp fall in cost is a consequence of the increased production volume and the development of manufacturing technologies.

4-2. Use of solar cells in consumer electronics

The application of solar cells in electronic goods, i.e., consumer electronics, has progressed rapidly since 1980. This has been achieved as a consequence of vastly lower power consumption in the electronic goods themselves through advances in ICs and LSIs, and as a result of integrate-type amorphous silicon solar cells coming into practical use. Applications in calculators, radios, watches, and chargers have been growing. Most of those presently found in card-type calculators are amorphous

Table. 2 The targets of several national programs

	Target by 2000
USA	12~20 ¢/kWh(5)
E.C.	1 ECU/Wp(6)
Japan	¥170~210/Wp(7)

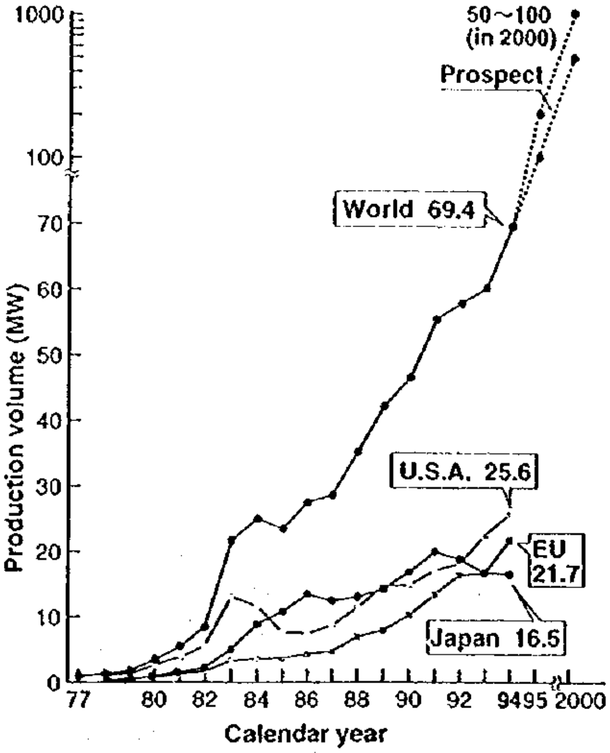


Fig. 10 Progress in production volume of solar cell(8) and future prospect

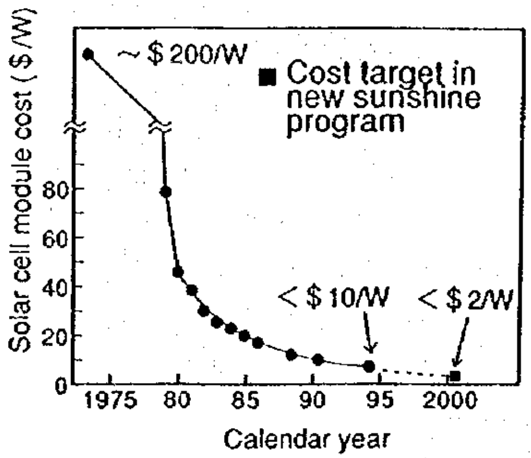


Fig. 11 Actual and projected cost for solar cells(7)

silicon solar cells (Fig. 12).

4-3. Applications to stand-alone power systems

Photovoltaic power generation systems of several tens of watts to several kilowatts have already achieved practical use. In the past, solar cells have served as power supplies for various kinds of electrical equipment located in places to which people could not get power (electricity) easily, such as radio relay stations on mountain tops and remote lighthouses. Recently, solar streetlights, solar guideposts, and solar refrigerators for storing vaccines (Fig. 13(a),(b),(c)) have come into practical use.

Furthermore, rural area systems are also practical use, for example, house lighting systems, lights or medical instruments for villages (Fig.14), electrodialysis desalination systems (Fig. 15) and so on.

Another development is a new type of ultra-lightweight, flexible a-Si solar cells fabricated on a plastic film substrate . Such cells can be fabricated due to their low deposition temperature. Modules consisting of these cells have a very high ratio of electric power to weight (~ 0.34W/g), a mere 0.12 mm thickness, and flexibility that allows them to be bent to a radius of 5 mm. These cells were applied to a parasol and a tent, for use as a power source for electric appliances while camping. A plane equipped with

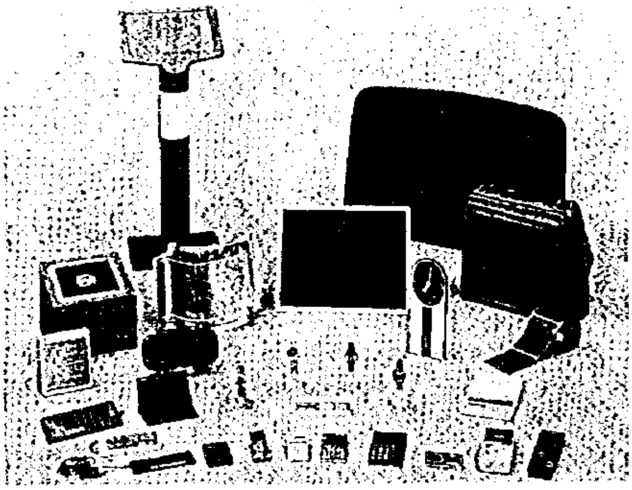
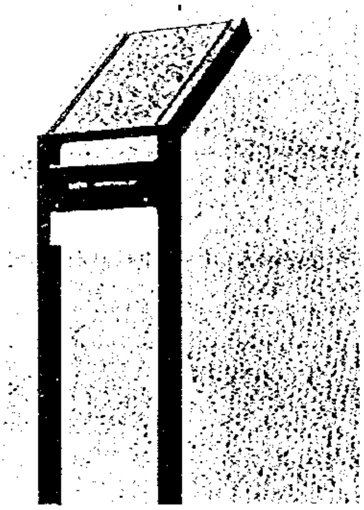
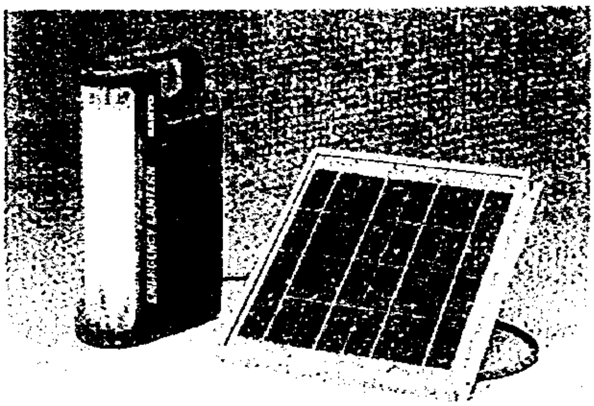


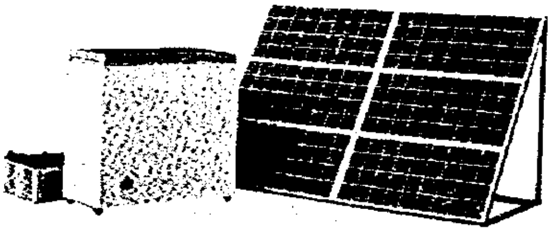
Fig. 12 Applications to consumer products



(a) Street light



(b) Solar lantern



(c) Solar refrigerators for storing vaccines

Fig. 13 Stand-alone systems

flexible a-Si solar cells, as shown in Figure 16, completed its maiden transcontinental flight across the United States in 1990, setting new records for solar-powered aviation .

To further expand the solar cell market, the "see-through" solar cell has recently been developed. This is a translucent solar cell with many uniformly-spaced microscopic holes on an integrated-type a-Si solar cell submodule. Incident light can pass naturally through this submodule, making it suitable for use in home windows and sunroofs, as shown in Fig. 17 and for the windows of buildings, as shown in Fig 18.

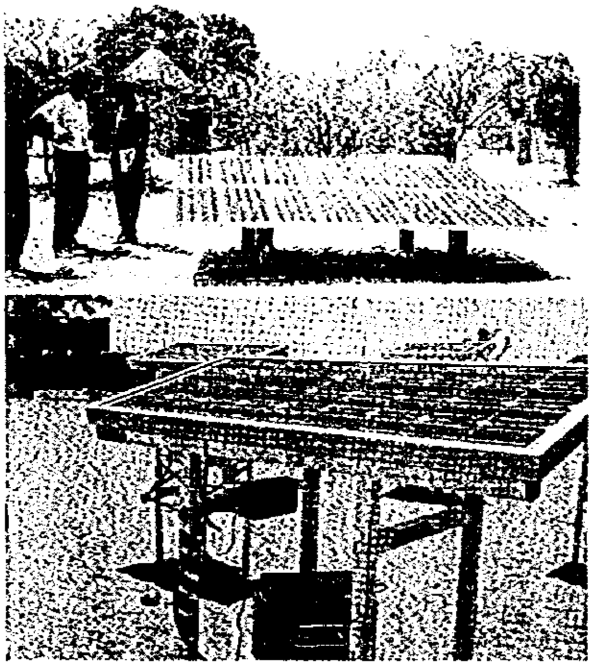


Fig. 14 Rural area system (Senegal in Africa)

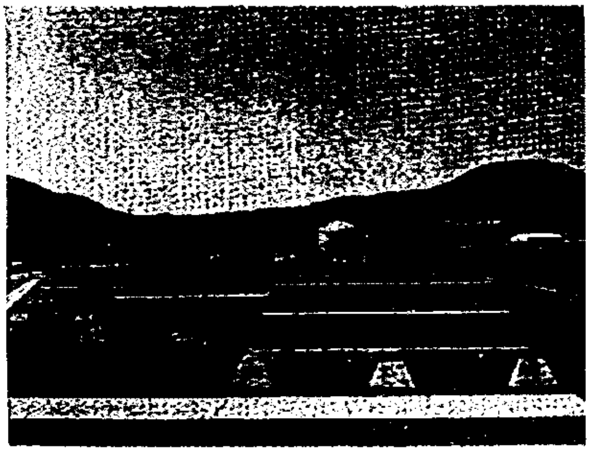


Fig. 15 Solar Desalinator system

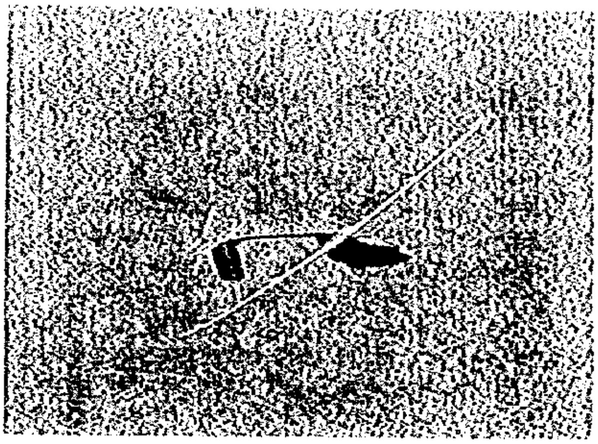


Fig. 16 Solar plane with ultra-light flexible a-Si solar cells

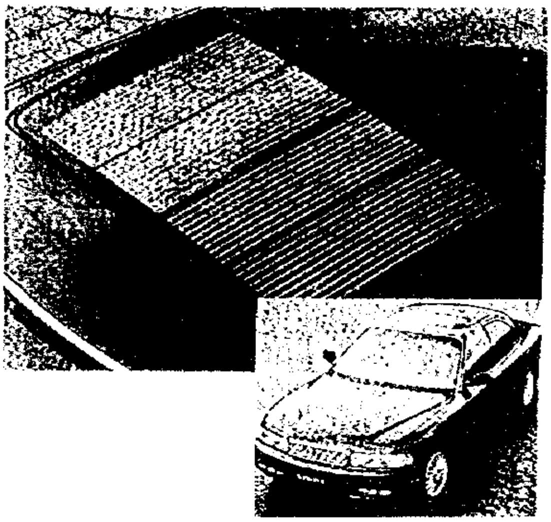


Fig. 17 Car sunroof using a see-through solar cell (Photo provided by Mazda)

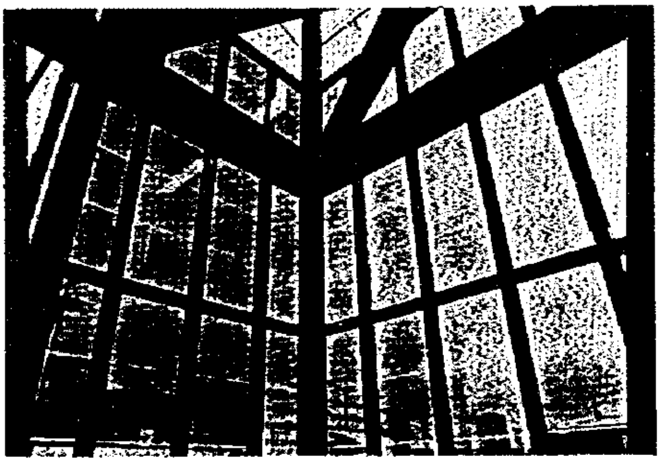


Fig. 18 Window with see-though solar cells
(Hokuriku Electric Power Co.,)

4-4. Systems

Systems for use in ordinary homes are critical to expand the market for solar power generation. Recently in Japan, it has opened the way toward interconnection of solar power generating systems. Fig. 19 shows the first practical application in Japan of a reverse flow 1.8kW solar power generating system in an actual home.

Reverse flow means that surplus power is fed back to the power system. This solar power generating system has no storage batteries.

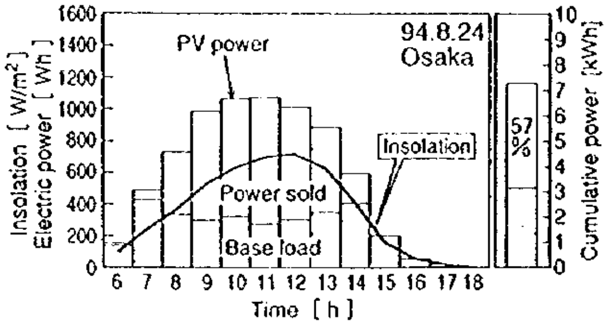
Fig. 20 shows the actual results of generated power. The peak demand while noon time is a problem in Japan. As you can see Fig. 20, this system generates electricity especially among the noon time. So, this system is very effective to cut the peak demand. The total amount of electricity generated by this system on August 24, 1994, was approximately 7.2kWh. Of this total, approximately 4.1kWh or 57% of the electricity generated was sold to an electric company (Fig. 20(a)). In the month of August 1994, the system's solar cells generated approximately 200kWh of power, and about 42% of this power was sold (Fig. 20(b)). It was found that the electricity consumption in this house was 30% less than that in the same month of the before the system was installed year. Therefore, a photovoltaic system is effective for saving electricity - that is, for saving energy.

Fig. 21 shows the solar cells, the inverter with built-in protective circuit, the transformer, and the wattmeter that are marketed specifically for this application. A reverse-flow solar power generating system for buildings (3.7 kWp ordinary a-Si solar cells + 1.4 kWp see-through a-Si solar cells) has also been installed (Fig. 22). Since the walls and windows are used for installing the solar cells, the system requires no extra installation space, making it a promising solar power generation system for buildings in the future.

Environmental problems have prompted the world's governments to expand their plans to promote solar cell applications. In Germany, private home use is growing through the Roof-1000 Plan. This plan is using federal and state funds (70% support) to place about 1000 (currently 2250) small-scale (1 to 5 kW) solar power generators that are connected to the commercial power system on the rooftops of homes.

Data provided from such facilities will lead to both hardware and software improvements that should increase

(a) 1 day



(b) 1 month

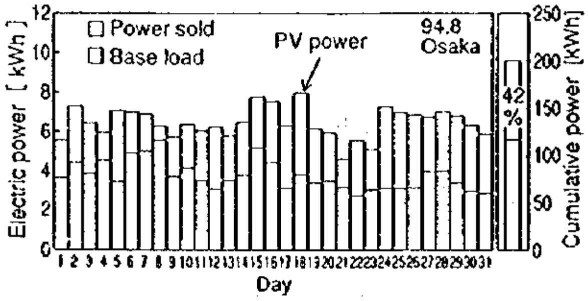


Fig. 20 Operating data of PV system (This data was obtained through the cooperation of The Kansai Electric Power Co. Inc.)

Fig. 19 The first practical use of a reverse-flow 1.8 kW solar power generating system in a Japanese home

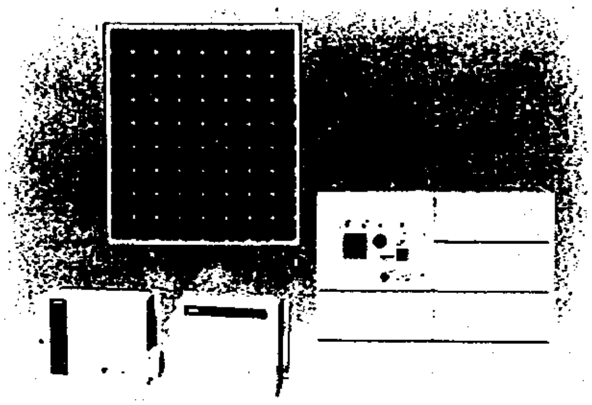


Fig. 21 A reverse-flow solar power generating system for houses (on sale from April 1994)

the use of solar power generation in the future.

In Japan, starting this year, the Ministry of International Trade and Industry (MITI) is offering financial assistance for the installation of solar power generation systems in private houses. According to the plan, MITI will cover half of the installation cost (up to ¥900,000 per kW, from a total budget of ¥2,000 million in the first fiscal year, 1994 and that of ¥3,300 million in 1995) for 1023 houses this year. This financial assistance program prompted several private companies to announce the marketing of solar power generation systems in newspapers (Fig. 21). Therefore, this year may be called the first year for the full-scale distribution of solar power generation systems.

Subsidies have been enacted in which the national government pays for 2/3 of the installation cost when regional public organizations install photovoltaic power generation systems. Using this subsidy in 1992, a 25 kW system supported by NEDO as a part of the Sunshine Project in Hyogo Prefecture (Fig. 23) as well as 11 systems additional sites have completed installation, and more are expected in the future.

In addition to these, a 200 kW system was installed by The Kansai Electric Power Co. Inc. in Hyogo Prefecture (Fig. 24) as a dispersible photovoltaic power generation system. It is also supported by NEDO.

In the United States, the world's largest PV plant, having 7 MW output power, started operation in Carrisa Plain, California in 1984. A PV power station is also being evaluated as a practical power source under what is called the PVUSA Plan (Fig. 25).

Here, a variety of technological studies required for the industrialization of centralized solar power generating systems are now being conducted.

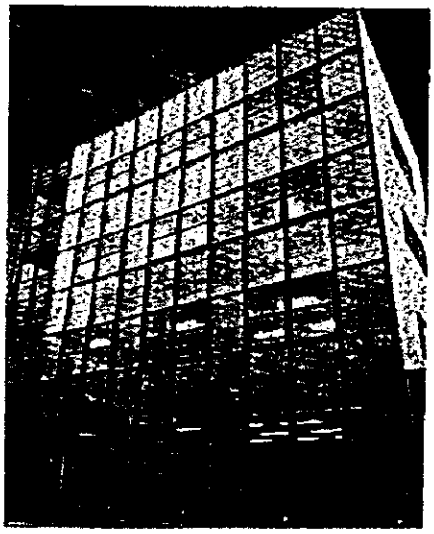


Fig. 22 The first practical use of reverse-flow solar power generation systems for buildings in Japan (TSUKASA Electric Industry Co.,Ltd.)

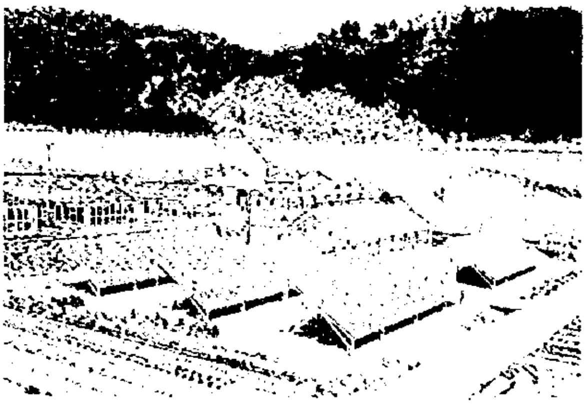


Fig. 23 Air conditioning system for green house (Grid-connected system with reverse-folw:25kW)

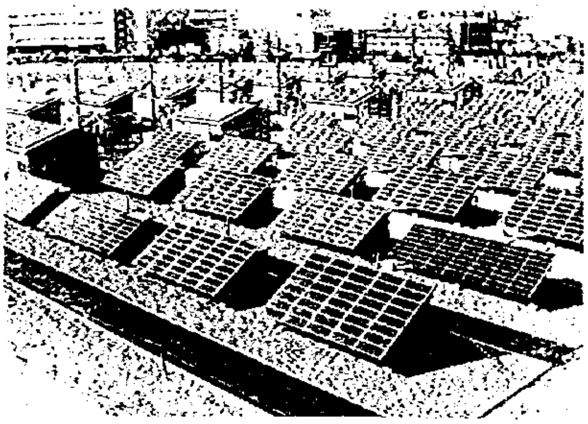


Fig. 24 200kW power generation system (Rokko-island, Kobe, Japan ; NEDO Project)

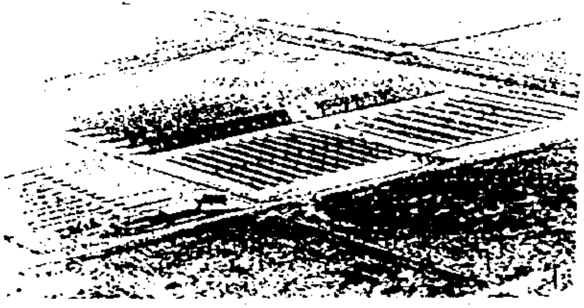


Fig. 25 800KW Photovoltaic Plant of PVUSA plan. with 400kW a-Si solar cell power generating system. (Davis, CA. USA)

4-5. Topics and responses toward the widespread acceptance of solar cells for electric power

In order to bring solar power-generation systems for electric power into practical use, it is necessary to reduce costs.

As shown in Fig. 26, it is necessary to cause a "chain reaction" (positive feedback) with the following three items. It is critical actively assist in starting the growth in demand.

a) Performance increases of solar cells, the development of peripheral technologies, the development of low-cost mass-production technologies
b) Creation of new demand
c) Increase of production volumes

With regard to technology development in a), increased efficiency and cost reduction efforts have already begun, particularly within the New Sunshine Program in Japan. The cost of power at the beginning of the 21st century has been calculated as the same as today's electricity rate at nearly $ 0.2 / kWh. According to the New Sunshine Program, innovative technology development is necessary to enable large-scale power generation possible by the year 2010 with further reduced costs. The importance of ultra-high efficiency for solar cells is also noted.

In the U. S. and EC, technology development of solar cells has been proceeding as well as Japan.

5. Future prospects
- GENESIS Project -

Described next is the GENESIS Project which Sanyo proposes as a future energy generation system based on solar power generation.

The main disadvantages of solar cells are their inability to generate power at night, and that their output fluctuates dramatically depending on the sunlight conditions. These problems give some concern to those who feel that solar energy is unstable as a prime energy source.

As outlined in Fig. 27, a Global Energy Network Equipped with Solar cells and International Superconductor grids (GENESIS), is the Sanyo's proposal for resolving these problems. A look at the Earth from outer space shows that rainy and cloudy areas cover less than 30% of the total land mass, and that it is always daylight on the opposite side of the globe to those areas under the shade of night. A worldwide photovoltaic power generating system connected by superconducting cables with no transmission losses would enable daylight areas to provide clean solar energy around the clock to those areas where it is nighttime, rainy or cloudy. This would ensure that no area on the Earth is without power.

It is forecast that in the year 2000, energy demands will be the equivalent of 14 billion kl of crude oil per year. To meet this requirement, 800 km square of solar cells would be needed, assuming a conversion efficiency of 10%. Calculated data by the author's group was shown in Table 4. This plan is quite feasible because barely 4% of the world's desert area would suffice. In the midst of the worsening energy crisis and environmental concerns, this plan must be put into effect for the sake of a prosperous 21st century.

Making this plan is not so unrealistic. The three steps shown in Fig. 28 are our view to realize this project.

Step 1 : When a large number of people install photovoltaic power generation systems in their homes and in factories, and these are connected to the electric power grid, all of

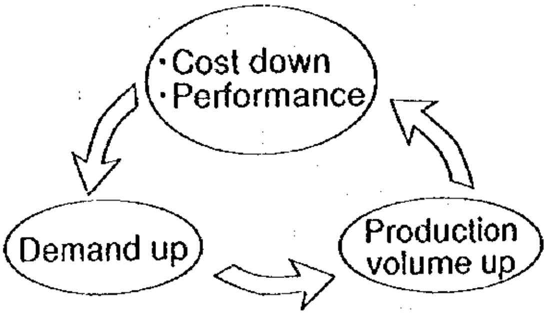


Fig. 26 Positive feedback for the low-cost of solar power generation

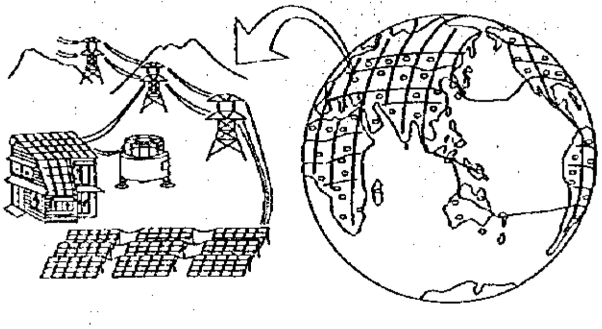
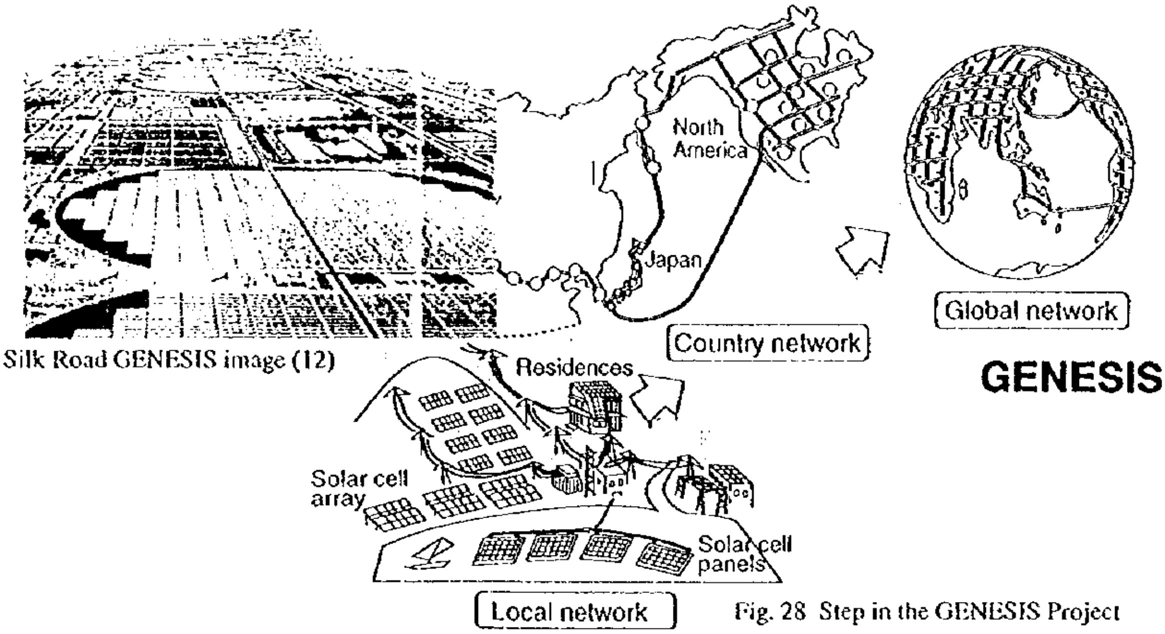


Fig. 27 Conceptual view of GENESIS (Global Energy Network Equipped with Solar cells and International Superconductor grids) (11)

Table. 4 World's consumption and required solar cell system area

Year	Primary enrgy consumption (billion kl/year oil equivalent)	Conversion efficiency of solar cell system (%)	Required solar cell system area (100%solar cell) (km square)
1990	10	10	710
2000	14	10	807 4% of desert area
2050	62	15	1367
2100	270	15	2880



Silk Road GENESIS image (12)

Fig. 28 Step in the GENESIS Project

Japan will be made into a network through photovoltaic power generation power lines. If the same pattern is repeated in several countries, photovoltaic power generation networks will be created in each of these countries.

Step 2 : Each country's transmission lines are subsequently connected. For example, South Korea and Japan (Kyushu) are separated by only 200 km. If the countries' transmission lines are connected, a country network will be created. In European and continental, Electric power supply grids have been connected each other countries. As a next step, a plan called "Silk Road GENESIS"(12) was proposed to construct photovoltaic power generating systems along the ancient trade road which will become new energy trade road.

Step 3 : If the country network is widely expanded, a global network will be created. During the interim period until superconductive cables become available, it may be possible to use high-voltage direct-current transmission technology.

6. Conclusions

Solar cells, since they convert solar light directly into electrical energy, are the most prominent candidates for a new, clean energy source. In order for us to resolve the energy problems facing us today and live comfortable lives in the 21st century, we must build a global solar power generating system with solar cells. Whether we choose to concentrate our efforts in this direction right now or not will determine the future of humankind.

Acknowledgement

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