1.Background of the Study

1.1 Outline of the Republic of Kiribati

1.1.1 Background

Kiribati consists of 33 islands located in the mid-Pacific, astride both the equator and the international date line in three main groups: the Gilbert, Phoenix and Line Islands. The total land area, which amounts to only 725 square km, is distributed over approximately 3.5 million square km. Most of the islands are low lying coral atolls except for Banaba, which is of lime stone origin. The geographical fragmentation of the islands, their remoteness, and their small size represent fundamental constraints to Kiribati's development.

Kiribati faces difficult challenges in the agricultural sector due to an inhospitable natural environment. Only coconuts, breadfruits, pandanus, swamp taro, papaya, bananas and pumpkins grow well in the infertile soils of Kiribati. There are no forest resources and no known exploitable mineral resources, except for the residual phosphate deposit in Banaba. The nation does, however possess abundant ocean resources, including both fish and a significant amount of manganese nodules within its 200 mile exclusive economic zone(EEZ).

Kiribati gained its independence from Britain in 1979. The I-Kiribati (native people) have a strong cultural tradition and possess an egalitarian ethic which is based on mutual help and cooperation. Kiribati's subsistence economy has been self-sufficient in the past but as urbanization proceeds Kiribati is becoming increasingly dependent on international trade to meet essential requirements.

The population of Kiribati was estimated at 68,200 in 1988 and 72,300 in 1991. Population distribution among the islands is highly skewed; South Tarawa, with only two percent of the land area, accounts for one third of the total population, implying a population density of 1,345 persons per square km. By contrast, the Line Islands (Christmas, Fanning and Washington) account for only four percent of the population and about 60 percent of the land mass. Over-crowding in South Tarawa is considered to be a serious problem and the government has launched a resettlement scheme.

The population of Kiribati expanded at 2.1 percent per annum during the 1979-88 period, close to the average for the region. A high fertility rate averaging five children per woman, was largely offset by the relatively low life expectancy of 53 years compared, for example, with 63 3/4 for Asia.

Despite high levels of literacy, shortages of skilled labor represent a major development constraint in Kiribati. There is only one public secondary school together with five secondary schools that are managed by local church groups; few students complete secondary school education and go on for higher education. A maritime training college and the Tarawa Technical Institute provide limited vocational training. The available evidence suggests that there is also a shortage of fully trained primary teachers, with over 70 percent of positions filled by inadequately qualified incumbents.

Kiribati also faces a number of severe health problems. Health service capacity is inadequate with one doctor per 1,967 persons and only one hospital in the entire country. As noted earlier, life expectancy is low (55.6 years for women and 50.6 years for men) and infant mortality is high at 82 per 1,000 of the population. In addition, there is a general Vitamin A deficiency among the children and evidence of dietary deficiencies (low protein intake) is present in other age groups. Diabetes is also common. Furthermore, there is a shortage of potable water supplies in South Tarawa where the water supply is being depleted, drought is endemic and salinity is on the rise. The water supply on Christmas Island is also in a poor condition.

The bulk of the working population in Kiribati is employed in the subsistence sector. Formal wage employment is largely limited to urban sectors where the civil service and public enterprises account for over two-thirds of total paid employment. Data available from the 1978 and 1985 Census indicate little change in indigenous employment suggesting that much of the increase in the labor force during the intervening years has been absorbed in subsistence activities.

Although no reliable survey data exist, the Ministry of Trade, Industry and Labor believes that there is substantial excess supply of labor. As evidence, it may be noted that applications for entry level positions in the civil service more than doubled during 1988-89.

Table 1.1-1 KIRIBATI: Population & Households in Islands

Name of Islands	Area (km2)	Population 1985	Population 1991	Population +/-	Households 1985	Households 1991	Households +/-
① Banaba	6	46	284	238	10	62	52
② Makin	8	1,777	1,762	- 15	287	295	8
③ Butaritai	13	3,622	3,774	152	581	633	52
④ Marakei	14	2,693	2,863	170	464	443	- 21
⑤ Abaiang	17	4,386	5,233	847	648	743	95
⑥ North Tarawa	15	3,205	3,648	443	456	551	95
⑦ South Tarawa	16	21,393	25,380	3,987	2,907	3,297	990
⑧ Maiana	17	2,141	2,180	39	353	378	25
⑨ Abemama	27	2,966	3,218	252	492	534	42
⑩ Kuria	15	1,052	990	- 62	172	187	15
⑪ Aranuka	12	984	1,002	18	173	169	- 4
⑫ Nonouti	20	2,930	2,814	- 116	534	539	5
⑬ Tabiteua North	26	3,171	3,201	30	591	586	- 5
⑭ Tabiteua South	12	1,322	1,331	9	246	250	4
⑮ Beru	18	2,702	2,909	207	521	539	18
⑯ Nikunau	19	2,061	1,994	- 67	360	369	9
⑰ Onoptoa	16	1,927	2,100	173	377	431	54
⑱ Tamana	5	1,378	1,385	7	267	263	- 4
⑲ Arorae	9	1,470	1,440	- 30	292	276	- 16
⑳ Washington	10	451	936	485	67	163	96
㉑ Fanning	34	445	1,309	864	69	244	175
㉒ Christmas	388	1,731	2,537	806	288	341	53
㉓ Canton	9	24	45	21	5	8	3
Total	726	63,877	72,335	8,458	10,160	11,301	1,141

Table 1.1-2 Social and Demographic Indicators 1988

Indicator	units	Kiribati	Asia
Population	Persons	68,207	
Groeth rate	% p.a.	2.1	1.8
GDP per capita	US $	470	
Daily calorie supply	Per capita	2,935	
Crude birth rate	Per '000	37.5	26.8
Crude death rate	Per '000	14	8.8
Infant mortarity rate	Per '000 births	82	
Life expectancy at birth	years	53	63.7
Population per			
-Doctor	Persons	1,967	1,422
-Hospital bed	Persons	209	--
Acess to safe water			
-Urban	% population	95.0	72.5
-Rural	% population	54.0	--
School enrollment ratio	%	84.0	
Adult illiteracy rate	%	10.0	39.5

1.1.2 Recent Economic Development

Prior to independence, growth of the Kiribati economy was closely linked to exports of phosphates from Banaba Island, whose deposits were exhausted in 1979. However the colonial administration established a Revenue Equalization Reserve Fund (RERF) in 1956 to serve as a trust fund to supplement revenues in the post-phosphate era. Notwithstanding revenues from this source, real GNP fell dramatically when phosphate deposits ran out around the end of the 1970s and had recovered to only US$15.4 million by 1987, compared to US$35.2 million in 1978.

During the 1980s, output followed a highly erratic pattern, reflecting the vagaries of weather and the vulnerability of the country's only export commodities (copra and fish) to price and environmental shocks. Stabilizing influences have been exerted over the years by a steady inflow of aid, budget grants and overseas workers' remittances together with revenues generated by the RERF. In 1988, the per capita GDP of Kiribati stood at US$470, placing it in the category of low income countries.

Available evidence on the fiscal balance of Kiribati indicates a prudent and conservative approach to public expenditure management. Current and development expenditures of the government have been guided by three main principles: (a) to avoid budgetary deficit; (b) to restrain outlays on public services to levels that could be sustained in the medium-term, and (c) to invest in the development of economic and social infrastructure as a foundation for future growth.

To restrain current expenditures, the government introduced several measures such as the introduction of flexible pricing policies; consequently subsidies to these enterprises dropped from 10 percent of GDP in 1980-82 to only 2 percent in 1987. As a result of these measures by 1985 the level of current expenditures was down more than 25 percent from 1982 levels and it remained fairly steady until 1988. The reduction in current expenditure was sufficient to offset the loss of UK budgetary grants in 1986 and to provide a budgetary surplus sufficient to finance about 4-5 percent of capital expenditures. The balance of capital expenditures was financed by external grants.

There is no central monetary authority in Kiribati and the Australian dollar serves as legal tender. This currency constraint accounts in part for the prudent stance of fiscal policy adopted by the Central Government despite the low level of economic activity experienced during the 1980s. Inflation, which ultimately is transmitted to Kiribati through surpluses in the balance of payments, averaged less than 6 percent during the decade. this was the lowest among the PMCs (Pacific Member Countries).

The vulnerability of the Kiribati economy is reflected in the composition of its balance of payments. Imports have equalled GDP in recent years while export earnings (which accrue from the very narrow product base of copra and fish) constitute around 20 percent of GDP. Official transfers (equal to more than one-half of GDP) have more than offset the deficit on merchandise trade yielding a positive current account balance of US$ 6 million (20-25 percent of GDP) on average since 1985. The balance on capital account tends to be slightly negative as RERF reinvestment and financial investments of the National Provident Fund nominally exceed concessional aid from multinational agencies and some private transactions. The overall balance of payments registered surpluses during most of the 1980s, as the surpluses in the current account tended to outweigh capital account deficits.

Kiribati's dependence on two primary exports, copra and fish, which accounted for 71.8 and 27.4 percent of merchandise exports respectively in 1988, has had important implications for the country's economic development. The sharp decline in copra prices in 1982-86 and a drought in 1984-85 significantly reduced export earnings leading to a severe deterioration in the balance of payments. To offset the fall in export earnings, the governments of UK, Canada and New Zealand assisted with projects to support copra and related production as well as other agricultural and farm products.

The fishery sector provides an important source of wage employment and fish is an important food source in the subsistence sector. In an effort to spur development of this sector, in 1981 the government established Te Mautari Ltd. (TML) in South Tarawa as a commercial fishing company to export bulk frozen tuna. However, the initiative has encountered difficulties due to inadequate financing, management practices, technical problems and a low catch in 1987 due to bad weather.

Another government enterprise, the Marine Export Division, was set up in 1987 in Christmas Island to export quality chilled fish (kingfish, milkfish and lobster). Growth has been constrained by limited air service to Hawaii and to other locations, including Japan. Additional problems include the lack of quality control, inadequate managerial and marketing staff, and the absence of banking facilities in Christmas Island for overseas transactions.

Table 1.1-3 Selected Economic Indicators, 1985--1989

Indicators	1985	1986	1987	1988	1989Est
Production and Expenditure					
Real GDP (mil 1978 US$)	17.35	17.84	16.45	19.25	19.44
Growth Rates (% p.a.)					
-Real GDP	-6.4	2.8	-7.8	17.0	1.1
-Agriculture	-25.2	-20.7	-25.6	87.0	--
-Industry	11.8	11.2	-23.6	1.2	--
-Services	2.2	11.7	0	2.9	
Central Government Budget (% of GDP)					
Revenue	52.6	38.6	54.9	44.4	40.9
Tax Revenue	16.1	16.7	21.3	17.3	18.2
Non-tax Revenue	37.6	22.7	33.3	28.3	22.5
Expenditure					
Current	51.2	46.3	47.8	45.4	74.6
Capital	33.5	45.6	41.4	34.3	43.1
Overall ballance	5.9	-9.5	5.1	-1.6	-5.3
Excluding Grants)	-32.2	-53.4	-34.6	-34.3	-39.2
Money and Prices					
Consumer Price Index (1975=100)	160.2	172.7	183.9	189.6	197.0
GDP deflators (1978=100)	168.2	179.3	191.0	196.9	204.6
Balance of Payments (mil US$)					
Exports (fob)	4.3	1.6	2.1	4.5	4.7
Imports (cif)	-15.1	-14.4	-12.6	-19.0	-22.3
Trade Balance	-10.8	-12.8	-15.5	-14.5	-17.6
Services	0.9	6.2	3.1	3.2	4.0
Private transfers (net)	0.9	1.6	2.2	2.4	2.9
Oficial transfers	12.5	14.8	16.4	13.2	16.5
Current Account Balance	3.5	9.8	6.2	4.3	5.8
Overall Balance	2.9	4.6	2.1	-1.2	6.3

1.1.3 Medium-Term Outlook and Prospects

Given its exceptionally narrow resource base, the economic future for Kiribati depends to a large extent on the degree to which policies can be set on a path to exploit the country's few major development assets. These include: fisheries resources, which are vast in terms of ocean area; the lightly populated Line (and possible Phoenix) Islands; and a small but highly capable workforce with overseas experience in mining operations (phosphate in Nauru), shipping and construction.

The primary source of growth in Kiribati is expected to be in the maritime area. Further development of the fisheries resource depends primarily on the introduction of new techniques to extend the range, expand the volume and increase the market value of fish caught by domestic enterprises. For the time being, developments depend what can be achieved by Te Mautari Ltd. (TML), the national fishing company based in Tarawa, and to a lesser extent , by the Marine Export Division (MED) of the Ministry of Natural Resources, operating from Christmas Island. TML generally operates pole and line vessels (and a mothership) with limited range because of the characteristics of bait available from the Kiribati lagoons. The addition of longline vessels (funded by the EEC) could greatly extend operations, improve efficiency and increase returns. Such developments have the potential to double the real value of fish exports within five years.

Kiribati should also seek greatly expanded revenues from licensing income derived from foreign fishing operations in its EEZ. In 1988, it received only A$ 1.8 million (US$1.5 million) for a reported catch of 15,000 tons, with Korea paying 45 percent (for 27 percent of the catch) and Japan 36 percent (for 56 percent of the catch); receipts under the regional US agreement were minimal. A more active policy to increase licensing revenues is warranted.

Increased fishing rents depends in substantial part on Kiribati's ability to police its EEZ more effectively. for this reason, the Australian offer to provide a patrol boat and contribute to its cost of operation should be considered. The offer was first made in 1987, at a time when several other Pacific Island countries accepted this type of aid. It is understood that the provision of the vessel, advisors and spare parts would be at no cost to Kiribati. In addition, support for operating costs during five years of expected usage would be provided under grant aid, as would maintenance and refitting costs for a further five years.

Tourism is the second major development possibility in the Line Islands. There, where people are few, land is relatively abundant and the Government wants to resettle a sizeable part of the total population. At the Kiribati Development Conference held on Kiritimati (Christmas Island) in October 1989, there were numerous indications of support from multinational agencies and bilateral donors for the Government's policy of outer islands development, through settlement of the Line and Phoenix Islands.

Nevertheless, the possibilities are limited for further tourism development on Christmas Island, which already has a small but viable tourism trade based on sports fishing and bird-life. In addition, settlement is constrained by the prevalence of droughts that prohibit most agricultural development on that island. On the other hand, Tabueran (Fanning Island) appears to have significant potential for tourism development mainly for topographic reasons, if airport and related infrastructure can be developed.

The potential benefits from one or more major tourism ventures are substantial. By 1994 as many as 2,000 resettled I-Kiribati could be employed in this type of development, a number equivalent to nearly 30 percent of the employed workforce in 1988 and well above the total currently employed in overseas mining and shipping. Appropriate tourism development would not limit resettlement programs, but would provide development opportunities needed to underpin the resettlement scheme. In addition, tourism would provide an outlet for the excellent local handicrafts industry, thereby widening the benefits of growth.

Several other possibilities exist for major development schemes including the resumption of phosphate mining on Banaba and satellite launching facilities on Kiritimati. The original proposal to re-mine Banaba for its residual phosphate deposits offered the promise of revenues in excess A$3 million a year for three years of operation, plus significant employment benefits. A much expanded Kiritimati scheme to establish satellite launching facilities might be feasible, but the project has not advanced to the stage where is can be considered a firm possibility.

As noted, Kiribati has a sizeable overseas labor force, including 1,070 (as of 1987) seamen serving on South Pacific Marine Service (SPMS) vessels and about 500 working for the Nauru Phosphate Company. Cash remittances from these and other external sources appear to benefit up to one-third of Kiribati households; private transfers amounted in 1988 to A$4.5 million of about A$300 (US$250) per household. The 1,600 workers employed in overseas shipping and mining represent more than 20 percent of total employment in Kiribati. the external labor force is one of Kiribati's main assets. However, it is faced with prospect of exhaustion of the phosphate deposits on Nauru, and by the probable easing of the demand for seamen through advances in marine technology. A national employment strategy should, it appears, include efforts to expand the amount of employment overseas as well as within the national boundaries.

In view of these prospects, the Government should consider discussing with its major partners in development, the possibilities for special provisions regarding employment and settlement of some I-Kiribati outside the country. These partners would include Australia, the United Kingdom, New Zealand and possibly Japan and the United States.

Despite substantial development financed by external aid over the last decade, there are still sizeable infrastructural gaps in Kiribati, especially as regards road and causeway construction in the outer islands, airport upgrading, and the improvement of telecommunications. The continued inflow of grant assistance for the above proposals will provide some growth in employment and income.

Prospects for growth in agriculture (excluding fisheries) are limited. No significant increase in copra production or exports can be expected and possibilities for export diversification are small. One notable exception is seaweed, which appears to be replacing copra production in some of the islands. However, with increased income from other sources, the demand for local fruits vegetables and livestock should increase, stimulating private production and providing needed diversity in diets. Similarly, there will be increased demand for small manufacturers and for general trade and services. While these would not be leading sectors, they could provide considerable scope for private sector development on a scale appropriate to Kiribati.

The manufacturing sector, which is in a rudimentary state, contributes merely 2.5 percent of GDP. This minor contribution underscores the heavy dependence of the economy on imports of manufacturers and the considerable scope that exits for import substitution in basic consumer items. To encourage private manufacturing investment, the government has streamlined licensing procedures, and undertaken the construction of an industrial estate in South Tarawa, to facilitate setting up of plants by private entrepreneurs and by foreign investors. Nevertheless, there seems to be no scope for large-scale industrial expansion as the small domestic market limits the scale of production, while high transport costs offset cost advantages provided by cheap labor. A strategy of small scale, labor intensive manufacturing for the home market is expected to yield industrial growth of 6 percent during 1990-94 and 7 percent in 1995-99.

The potential of the service sector to generate growth and employment remained underutilized in the 1980s. The projected growth rate of 3-4 percent for services during 1990-99 is predicated upon expansion of transport and retail services and rapid growth in tourism.

A fundamental problem of the economy concerns its high level of consumption, relative to income and savings. A key to achieving self-reliance in the long-term would be to restrain private consumption, primarily through taxation, keeping it well below GDP. Such a strategy would increase tax revenues, raise national savings and also limit import growth in the 1990s to 4-4.5 per annum.

High rates of investment (of the order of 30 to 40 percent of GDP) will be necessary to restore growth in the 1990s. External donor support and continued remittance inflows will be required to sustain investment at this level.

Table 1.1-4 Medium Term Balance of Payments, 1988--1993
(in millions of US$)

Items	1988	1989	1990	1991	1992	1993
Exports (fob)	4.5	4.7	4.6	4.7	5.0	5.1
Imports (fob)	19.0	22.3	23.2	24.2	25.5	26.8
Trade Balance	-14.5	-17.6	-18.6	-19.5	-20.5	-21.7
Services, net	3.2	4.0	2.8	3.1	3.5	3.7
Receipts	18.5	20.0	19.6	20.6	21.9	23.1
RERF Interest Receipt	9.1	9.0	8.8	9.1	9.5	9.9
Payments	15.3	16.0	16.8	17.6	18.5	19.3
Transfers, net	15.6	19.4	21.5	22.7	23.8	25.1
Private	2.4	2.9	3.3	3.6	4.0	4.4
Official	13.2	16.5	18.2	19.0	19.9	20.8
Current Balance	4.3	5.8	5.8	6.3	6.8	7.3
Capital Account	-5.5	0.5	-0.6	-0.8	-1.2	-1.4
Overall Balance	-1.2	6.3	5.1	5.4	5.6	6.0

Table 1.1-5 Medium-term Projections, 1990--1999

Items	Estimates 1985--89	Projections 1990--94	1995--99
Growth Rates (% per annum)			
GDP	1.9	3.3	4.5
Agriculture & Fisheries	1.5	3.5	5.0
Industry	4.0	6.0	7.0
Services	1.8	3.0	4.0
Consumption	1.0	2.5	3.0
Gross Investment	7.0	7.5	8.0
Exports	2.4	5.0	8.0
Imports	7.8	4.1	4.5
Prices	5.1	5.0	5.0
Ratio to GDP (%)			
Gross Investment	30.8	35.8	40.0
Gross Savings	53.5	--	--
Debt Service Ratio (%)	1.4	1.5	1.5

1.1.4 Development Issue: Constraints Problems and Prospects

The fundamental challenge of development in Kiribati is to mobilize its limited human and natural resources, to lay the ground work for a supportive economic and social infrastructure and to generate the maximum possible growth of productivity in the medium and longer-term. Although the National Development Plan for 1987-91 makes self-sufficiency a key objective, it is doubtful whether dependence upon aid can be reduced significantly, even over the medium-term. Indeed, such a policy may not be advisable; the outlook for aid in the 1990s appears favorable (a possible increase of 75 percent would be realistic) and aid recipients could go a long way to building the physical infrastructure that Kiribati needs, but is unable to finance out of its own resources. The prudent policy in this respect would be to channel aid into the development of infrastructure and other projects that would contribute to the economy's future growth potential so that self-reliance could become a feasible goal for the subsequent decade.

To protect the investments of previous years, there is the growing need for increased recurrent expenditure to cover the costs of operation and maintenance (O&M) of these investments. Without adequate provision for these costs from local budgetary resources, aid-financed projects and equipment will either be under-utilized or will have an unnecessarily short life-span. There is also a need to make projections of recurrent costs in order to support projected medium and long-term investment levels.

Although the budgetary policy for the 1990s avoided major fiscal imbalance, it must be recognized that for much of the decade, deficits on current operations were also covered by external grants. It is commendable that since 1986, external grants were only applied to development expenditures, leaving current expenditures to be financed entirely from domestic resources. To support long-term growth, it will be necessary to expand the domestic revenue base through reform of tax administration and the introduction of user fees and new forms of taxation, possibly including a value added tax. greater demands on current expenditures are expected as infrastructure and production projects are completed, increasing local O&M financing requirements.

The experience of the 1980s underscores the extreme vulnerability of the Kiribati economy, owing mainly to its narrow resource base. In such circumstances, the development of a self-reliant economy presents enormous challenges, which requires a concerted effort and firm commitment on the part of government. This commitment has been set out in the National Development Plan: 1987-91. Quite appropriately, the development strategy embodied in this plan attaches high priority to resource development, particularly natural resource exploitation. Indeed, forty percent, a doubling of its share in 1980-85 of total public investment is allocated for this purpose, much of which will go to the development of the fisheries sector. Infrastructure investment requirements have been scaled down some what in view of the large earlier outlays in this sector (over 50 percent of development expenditures , 1980-85). Nevertheless, a substantial allocation (19 percent) is made to transportation, underscoring the continuing emphasis accorded this vital aspect of infrastructural development. The projections of 3-4.5 percent GDP growth in the 1990s appear achievable in view of the planned emphasis on the most productive sector (fisheries) and higher productivity expected to accrue from past infrastructural investment.

Other salient features of the plan include (a) promoting private sector participation in investment, (b) a greater emphasis on rural and outer island development through settlement and development of the Line Islands, (c) strengthening family planning activities, and (d) ensuring fiscal discipline, balance of payments stability, and limiting future debt-service liabilities. Although plan objectives and emphasis appear commendable, the challenge is to translate them into effective programs and policies. Serious deficiencies still exist in project preparation, monitoring and implementation of investment programs. The coordinating role of the National Planning Office (NPO) needs to be strengthened and further training of personnel in developing a comprehensive project monitoring system would be in order.

The public sector dominates the Kiribati economy, accounting for 95 percent of gross investment and almost half of total GDP. Although the central government has been prudent in the conduct of fiscal policies, the same cannot be said of some public enterprises whose recurring losses have been a heavy drain of the government's budget. Until 1985, government subsidies to public enterprises ran upwards of 10 percent of GDP before falling to around 5 percent in 1988 due to the cost overhauls at Air Tungaru. Between 1979 and 1985, subsidies grew at a rate of 7.3 percent per annum, a rate faster than the growth of either recurrent expenditures or revenue collections. Other public enterprises requiring heavy subsidies include the public Utilities Board (in charge of water supply, sewerage, and electricity), Telecom Kiribati, and the Housing Corporation.

The appropriate strategy for reducing these costs is to shrink the size of the public sector while encouraging greater private sector participation in investment and enterprise. Evidence of the government's commitment in this respect may be seen in the privatization of major public enterprises (the Ambarka Trading Company and Telecom Kiribati); More companies are slated for privatization. A preliminary assessment of some 40 enterprises for transfer of ownership (or management contact) has been drawn up by a special cabinet committee. Nevertheless, overall progress on privatization has been slow and there is a need for sharply increased pace of privatization; private sector initiatives are being crowded out, removing the stimulus of competition from an already limited range of business opportunities. To achieve greater progress, the government should concentrate its efforts on two goals: (a) divest full or majority ownership of state enterprises (excepting natural monopolies) to private sector interests, domestic and/or foreign; and, (b) refuse to initiate new enterprises in direct competition with the private sector except where the supply of essential goods and services is inadequate. The government's role in creating an efficient and productive economy lies in the provision of the basic physical and human infrastructure and improving the overall policy environment for the private sector.

High on the government's list of priorities will be the need to increase investment in human resource development through manpower planning and training in those skills that are in short supply. At present, there is an oversupply of clerical and administrative staff but a shortage of skilled and professional staff. Current pay scales and promotional prospects do not encourage higher education, causing a number of senior professional posts to be filled by expatriates. Training programs should be initiated or stepped-up in areas of great demand. For example, there is a shortage of secondary school teachers yet there are only three higher education institutions: Tarawa Teacher's College; Marine Training Center; and Tarawa Technical Institute (TTI). The latter and its Rural Training Center are the principal centers for technical and vocational training; for higher education, scholarships are provided by foreign governments

(Australia, New Zealand and UK) and students can be enrolled in the University of The South Pacific Extension Center in Tarawa. Most others seeking higher education attend the University of Papua New Guinea. Higher education, vocational training and skill development are areas where foreign aid and technical assistance are required.

1.2 Energy Situation in Kiribati

1.2.1 Energy Supply and Consumption

Kiribati is currently importing approximately 30 percent of her total energy, relying for the balance on indigeneous biomas resources i.e. locally obtained fuelwood. From 1982 to 1991 about 10 thousand kiliiters of mineral fuel was imported. (see Table 1.2-1)

About 90 percent of the imported fuels are consumed on South Tarawa while the remaining 10 percent is consumed on outer islands refrecting their different levels of development.

Biomass resources will be expected to provide the bulk of the country's energy needs for the forseenable future. Other energy sources including solar, and in specific area wind, offer limited alternative energy sources for exploitation. These alternative may offset future dependence on imports and contribute to the overall aim of achieving the muximum degree of energy independence while providing opportunities for development primarily in the rural sector.

In 1990 a new method of determining the fuel price was introduced and the retail price of fuel is same in South Tarawa and outer islands, the price is:

Landing price(CIF South Tarawa price)
+ Mark up (10 percent of Landing price)
+ Kiribati Oil Company Overhead cost

The Landing price of fuels at South Tarawa is estimated as:

FOB price of fuel 80.6 to 82.7 Percent
Insurance and loss 1.0 to 1.2
Freight for MR tanker 2.4 to 4.2 (MR:Middle range)
Cost of transshippment 0.9 to 2.8
Freight for LCT 4.1 to 11.1 (LCT:Local coastal tanker)

(see Fig. 1.2-1 and 1.2-2)

Table 1.2-1 KIRIBATI: Import of Oil Products (Kilo-liter)

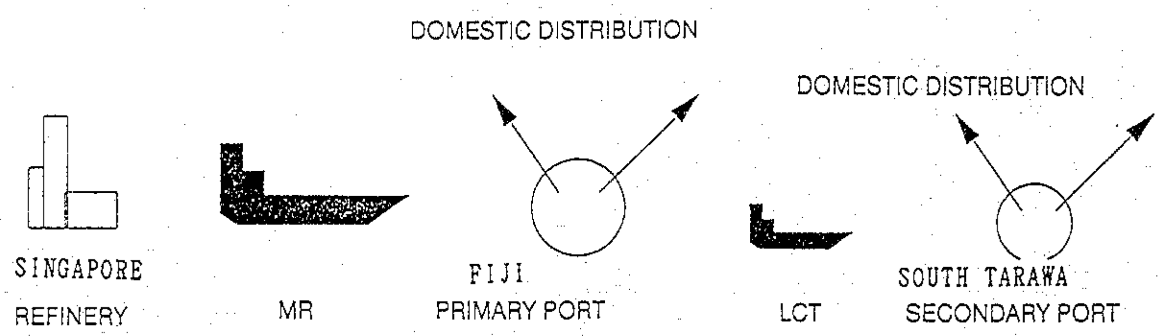
Oil Products	1983	1984	1985	1986	1987	1988	1989	1990	1991
Jet fuel	1001	1017	702	1098	1555				1647
Motor spirit	1716	1954	1797	1511	1738	1883			2698
Aviation gasoline	586	550	443	413	234				402
Kerosene	644	669	660	557	888	773			875
Distillate	4122	5526	5100	5114	5277	6548			5979
Lubricant	18	123	148	147	172				109
Total	8037	9839	8850	8840	9864	9204*	7200*	9100*	11610
Imported value (mil A$)	2.52	3.09	3.24	2.24	2.67	2.96	3.20	3.69	3.63

* Excluding Jet fuel and Aviation gasoline

Fig. 1.2-1 Transportation of Oil Products

SUPPLY LOGISTICS FOR PACIFIC ISLAND COUNTRIES

キリバス共和国のケース



PRIMARY PORT:

FOB + FREIGHT = CIF

SECONDARY PORT:

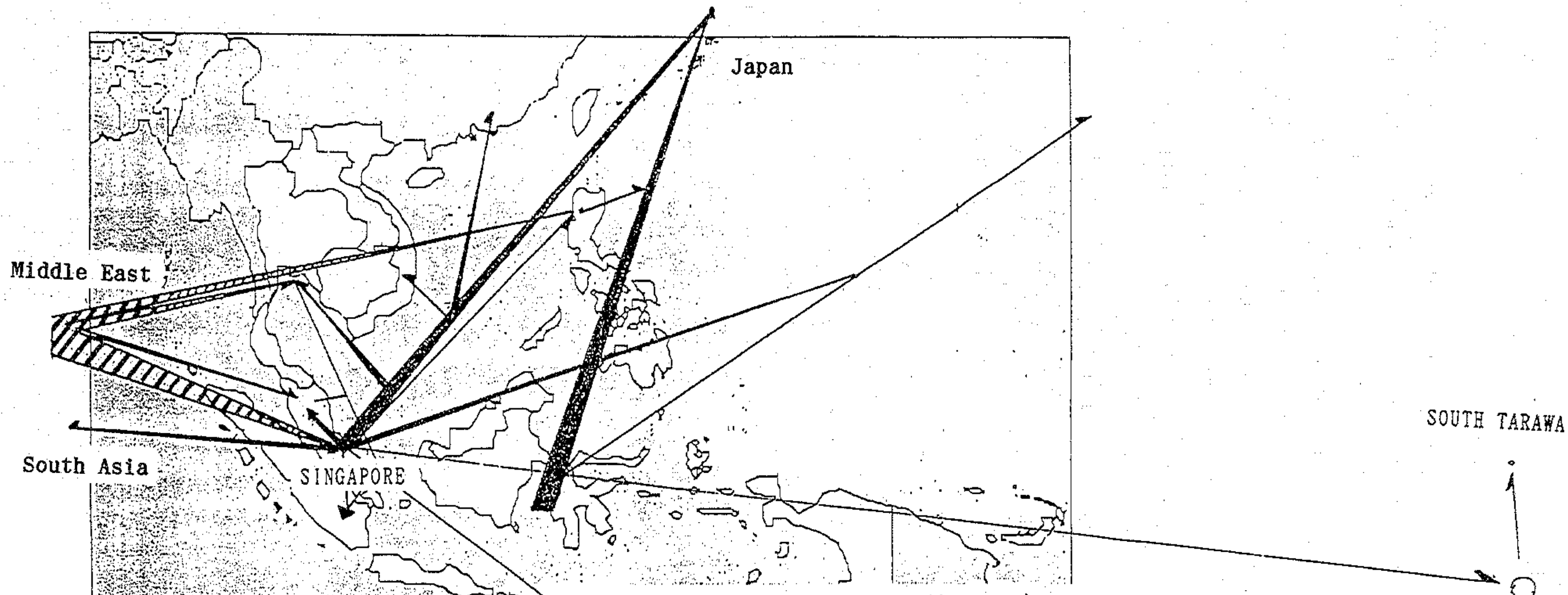
FOB + FREIGHT + S & H LANDING CHARGES + FREIGHT = CIF

MR: Medium Range(25,000-44,999DWT)

LCT:Local Coastal Tanker

Pacific Energy Development Programme
October 30, 1990

Fig. 1.2-2 Flow Scheme of Oil Products in Southeast Asia



Ref. Volume of Oil Products ('000ton)

Products	Singapore		Fiji	Kiribati
	Export	Import	Import	Import
Gasoline	4、300	2、100	75	1
Naphtha	2、700	400	—	—
Kerosene	1、100	90	37	1
Jet fuel	5、900	20	95	1
Light oil	10、900	1、200	172	5
Heavy oil	9、700	13、700	13	—

1.2.2 Electricity supply and demand

At present only the capitol, South Tarawa and Kiritimati, the administrative center of for the Line and Phoenix groups have centralized power distribution systems. All other islands have small scattered populations living largely in a subsistence economy with some monet activity. None of these islands have any centralized power distribution system but small diesel generators are used in some council centers, maneaba and missions or secondary schools. These are only operated for a few hours each evening, and troubles with supply of fuel can mean those generators are unable to operate. The existing Diesel generator sets in South Tarawa are shown in Table 1.2-2.

The peak demand of electricity in South Tarawa increases year by year, it records 1,350kw in 1992 February. The yearly consumption of electricity reaches 6,026Mwh in 1989, the averaged increase rate per year of 1983 to 1989 was 6.6 percent. (see Table 1.2-3)

The conposition of user in 1991 January was: residential 80 percent, commercial 10 percent industrial 9 percent and in consumption, residential 31 percent, commercial 12 percent and industrial 51 percent. (see Table 1.2-4) The main use in residential is for lighting, the daily demand curve is shown as Fig. 1.2-3. The fee of electricity is: for residential 32Ac/kwh, for commercial and industrial 36Ac/kwh.

Table 1.2-2 Facilities for generation in South Tarawa

maker & Model	Rating Nominal	Rating Actual	Year of Install.	Operation H. 1987	Operation H. 1989	Actual state
English Electric (4 SRK)	300kw	260kw	1968	57,119	57,367	Working
ibid	300	260	1968			Broken down
ibid	300	260	1968	45,050	46,250	Working
ibid	300	260	1968	15,912	--	Broken down
ibid (6RK3C)	750	600	1976	45,579	56,006	Working
ibid	750	600	1976	46,265	57,851	Working
Wartsila F38	1,000	1,000	1988	--	9,900	Working

Table 1.2-3 Power Supply of PUB (South Tarawa)

Items	1983	1984	1985	1986	1987	1988	1989
Power generated (Mwh)	5,161	5,521	5,990	6,371	6,536	6,758	7,233
Power sold (Mwh)	4,103	4,333	4,554	5,056	5,342	5,759	6,026
Increse ratio (%)	--	5.6	5.1	11.0	5.7	7.8	4.6
Loss (%)	20.5	21.5	24.0	20.6	18.3	14.6	16.7

Table 1.2-4 Composition of User (Jauary 1991)

Class of Customer	Number of customer Number	%	Consumption of Power Kwh	%
Residentuial	1,937	79.5	166,954	30.9
Commercial	237	9.7	66,873	12.4
Industrial	216	8.9	272,833	50.6
Governmental	49	1.9	32,789	6.1
Total	2,436	100.0	539,449	100.0

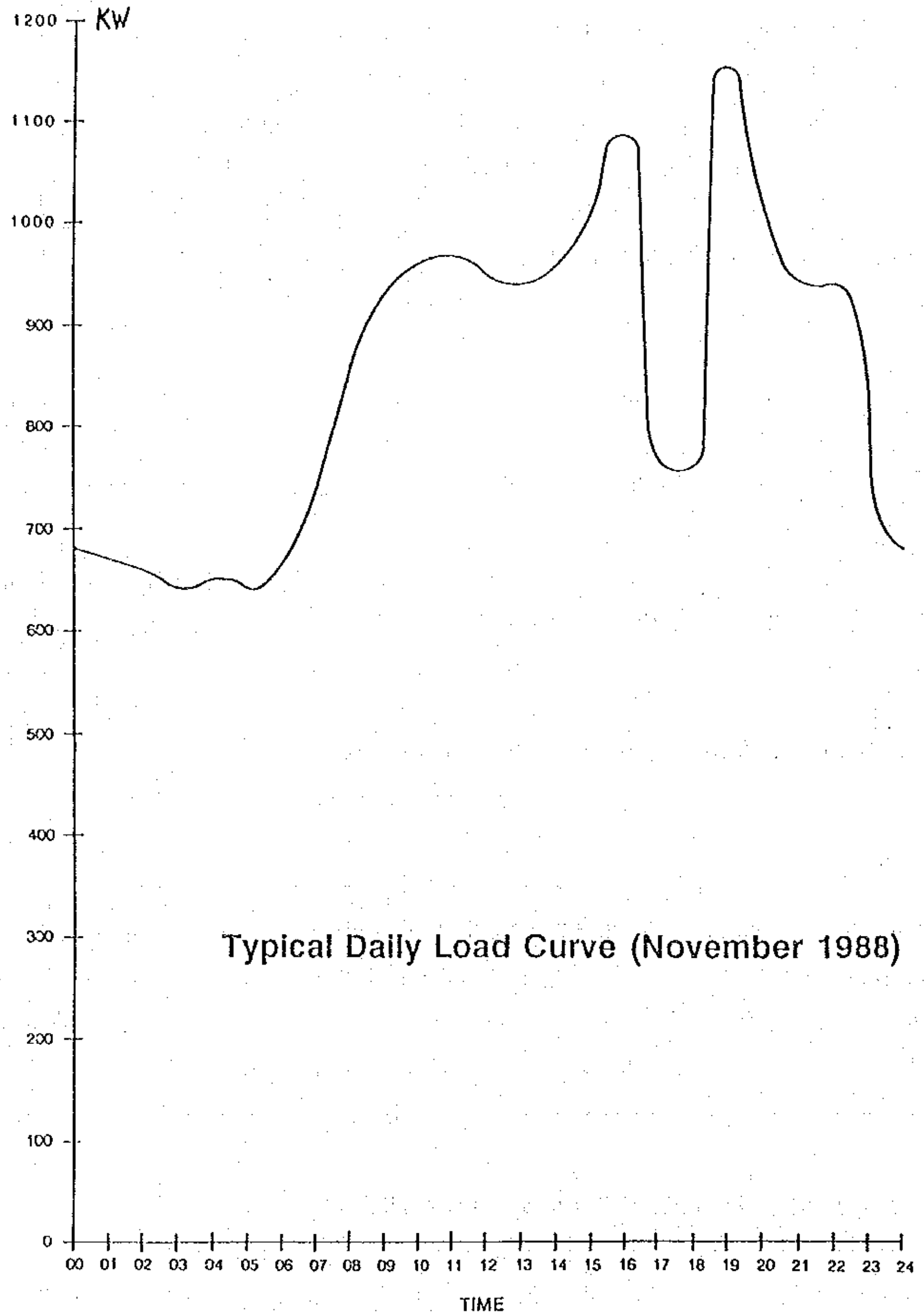


Fig.1.2-3 Daily Demand Curve of South Tarawa

1.2.3 Organizations Concerned to Energy

Ministry of Works and Energy (MWE)

The organizational scheme of MWE is as follows:

- MINISTER (Hon. Baitika Toum)
  - SECRETARY (Mr. Tinian Reiher)
    - SENIOR ASSISTANT SECRETARY
    - ASSISTANT SECRETARY
    - REGISTRY, ACCOUNT
    - ENERGY DIVISION (Mr. Rutete Ioteba)
    - PUBLIC WORKS DEPARTMENT (Mr. Pita Iateba)
    - KIRIBATI OIL COMPANY (Mr. Arintetaake Aran)
    - PUBLIC UTILITY BOARD (Mr. Rameka Takirua)
    - SOLAR ENERGY COMPANY (Mr. Terbentau Akura)

Energy division was once called as Energy Planning Unit and their objectives are:

To reduce Kiribati reliance on imported fuels through the application and use of alternative and renewable energy sources, energy concervation and fuel substitution.

To formulate proporsals concerning energy policies.

To formulate and coordinates all development and other energy programms.

To ensure a reliable supply and acceptable price of imported fuels.

To develop and promote the use of alternative and renewable sources of energy.

To assist and monitor the activities of the PUB, KOIL and SEC to ensure they are promoting the efficient use of energy.

To act as an energy information center.

Public Utility Board is responsible for supplying of electricity water and sewage to urban area that is South Tarawa, a part of North Tarawa and a part of Kiritimati island.

Kiribati oil Company is responsible for the storage and selling of ground fuel for the Gilbert group and ground aviation fuel for the Line and Phoenix group, while B.P South West Pacific provides aviation fuel for the Gilbert group only.

Solar Energy Company was established in 1984 with USA assistance for the selling of solar systems and installation of government solar systems but it was transformed as the utility company that supply electricity through the photovoltaic system to the customer, and their objectives are:

To promote and encourage the use of solar PV system in rural areas.
To design and install Government PV Projects.
Procurement and selling of PV equipment and appliancies in Kiribati.
Responsible for the management of Rural Solar Electrification Program.

The SEC's business situation is shown in another chapter.

1.2.4 Recommendation for Energy Development and Rural Electrification

(1) Energy Development

Developing economically saticefactory indigenious energy resources to reduce imports of petroleum is of interest to Kiribati. Three resources are known to be available: Solar energy, Ocean energy and wind energy. Only solar energy has had any technical or economic success in the Pacific region. In view of this, it is recommended that programs for the gathering of data on the wind and ocean energy resource be continued, but it is not recommended that the GOK undertake any development of these resources until have been proven commercially in the Pacific island environment. The continuing development of solar energy resources for the heating of water and the production of electricity at the domestic or small commercial level is appropriate.

With the establishment of solar electrification programs, GOK should consider environment problems, particularly the proper recycling or disporsal of spent lead acid batteries.

(2) rural Electrification

The extent of rural electrification and technology to be used are issue to be addressed in Kiribati. Rural electrification is unlikely to be a driving force for economic development and should be viewed primarily as an important in comfort and conveniencwe to rural households. Since the application for rural electricity in Kiribati is for home lighting and small appliance operation, the least cost method for electrification for most rural sites will be solar photovoltaics for the foreseenable future.

Kiribati has recognized the appropriateness of photovoltaics for rural electrification, as shown by the establishment of the Kiribati Solar Energy Company (KSEC) in 1984. However, the initial development of rural electrification through the sale of photovoltaic systems to users on outer islands has been a failure. Most of these systems are not working and the users do not have the skills necessary to properly install and maintain them. On the basis of this experience, the transform of KSEC from compornentsales to utility format with systems owned by KSEC and a fee charged customers for electrical service.

2. Selection of Project site

2.1 Selection of village

There are 23 inhabited islands in Kiribati and main items of each island are shown on Table 2.1-1. and only South Tarawa and a part of Christmas island are electrified by commercial electricity. The rest of above, 21 islands, about 150 village, about 8,000 households are unelectrified or only have their own stand alone diesel or PV as their power source or dry cells for radio/cassette.

At the beginning of the JICA project, the Kiribati government suggested three islands as the candidates for installation of PV pilot plant, they were North Tarawa, Nonouti and Marakei, then North Tarawa was decided as the Island for JICA project. The main reason was the convenience of transportation from South Tarawa as the place for pilot project.

In North Tarawa, there are 15 villages and total households is 550, population is 3,650 in 1991. The SEC and the JICA study team selected six villages to install the individual household PV system from 15 North Tarawa villages by considering the efficiency of maintenance that one field technician will be able to take care of the system without car or motorbike. The six villages installed PV systems are shown in Table 2.1-2

Table 2.1-2 Six villages installed PV system

Name of Village	Number of HH	Population	Average income(A$/HH)*
Taratai	41	195	1,938
Notoue	54	324	1,876
Abaokoro	32	218	2,165
Marenanuka	10	60	1,760
Tabonibara	43	300	3,215
Kainaba	21	150	2,033
Total	201	1,247	2,152

* from the survey in 1992

Table 2.1-1 Representative data of each Islands of Republic of Kiribati

Name of Island	Area	Population	Household	Number of	Number of	Fish Sales	Copla Sale	Number of	Wage incom	Remittance	Total inco	Income/per
	k m²			Village	Maneaba	1000A$	1000A$	Employee	1000A$	1000A$	-me 1000A$	-son A$
		1991	1991			1985	1985	1985				
①BANABA	6	284	62	3	0			12	32	2	34	748
②MAKIN	8	1,762	295	2	2	48	143	83	224	268	683	384
③BUTARITARI	13	3,774	633	8	6	188	228	230	621	586	1,623	448
④MARAKEI	14	2,863	443	8	7	144	222	116	313	352	1,031	383
⑤ABAIANG	17	5,233	743	18	15	127	243	241	651	368	1,389	317
⑥NORTH TARAWA	15	3,648	551	14	10	293	128	118	319	192	932	291
⑦SOUTH TARAWA	16	25,380	3,297	17	8	1,738	0	4,076	11,005	1348	14,091	659
⑧MAIANA	17	2,180	378	13	9	34	184	109	294	336	848	396
⑨ABEMAMA	27	3,218	534	8	6	235	296	185	500	378	1,409	475
⑩KURIA	15	990	187	4	3	69	133	50	135	104	441	420
⑪ARANUKA	12	1,002	169	3	2	23	330	76	205	152	710	722
⑫NONOUTI	20	2,814	539	8	6	211	225	184	497	438	1,371	468
⑬TABITEUA NORTH	26	3,201	586	12	10	54	274	157	424	292	1,044	329
⑭TABITEUA SOUTH	12	1,331	250	6	4	26	0	91	246	122	394	298
⑮BERU	18	2,909	539	9	6	147	95	162	437	270	949	351
⑯NIKUNAU	19	1,994	369	6	4	33	175	93	251	274	733	356
⑰ONOTOA	16	2,100	431	7	7	112	144	92	248	266	770	400
⑱TAMANA	5	1,385	263	3	2	20	96	79	213	166	495	359
⑲ARORAE	9	1,440	276	2	2	38	81	64	173	270	562	382
⑳WASHINGTON	10	936	163	5	2	0	68	0	0	0	68	151
㉑FANNING	34	1,309	244	8	4	0	22	107	289	20	331	744
㉒CHRISTMAS	388	2,537	341	4	4	0	23	439	1,185	26	1,234	713
㉓CANTON(KANTON)	9	45	8	1	1	0	0	5	14	4	18	729
							0		0		0	
TOTAL	726	72,335	11,301	169	120	3,542	3110	6,769	18,276	6,234	31,162	488

Average remittance/HH:2,000A$
Average wage:2,700A$/Y

2.2 Selection of Household to install PV systems

The selection of household which to be installed the PV system was done by under the control of the Island president and SEC. The owners of household who expected to install the PV system in their households were informed to come to Maneaba of Abaokoro with 50 A$ as initial installing fee and listed as the candidates.

The number of candidate was less than 55 that JICA provided as the number for studying the utilization of PV system and added some official households in Abaokoro to make up 55 households. The number of household of each villages is shown in Table 2.2-1

Table 2.2-1 Number of household to be installed PV system in North Tarawa

Name of Village	Wanted at July/92	Installed at Jan./93
Taratai	5	2
Notoue	12	15
Abaokoro	20	25
Marenanuka	5	3
Tabonibara	4	6
Kainaba	9	4
	(Maneaba 1)	(Maneaba 1)
Total	55	55
	(Maneaba 1)	(Maneaba 1)

Fig 2.2-1 Location of PV electrified Household in Taratai

ELECTRIFICATION CUSTOMER'S MAP

VILLAGE: TARATAI

No.	CODE No.	CUSTOMER'S NAME
1	R17	TETIKA
2	R	TABOBO

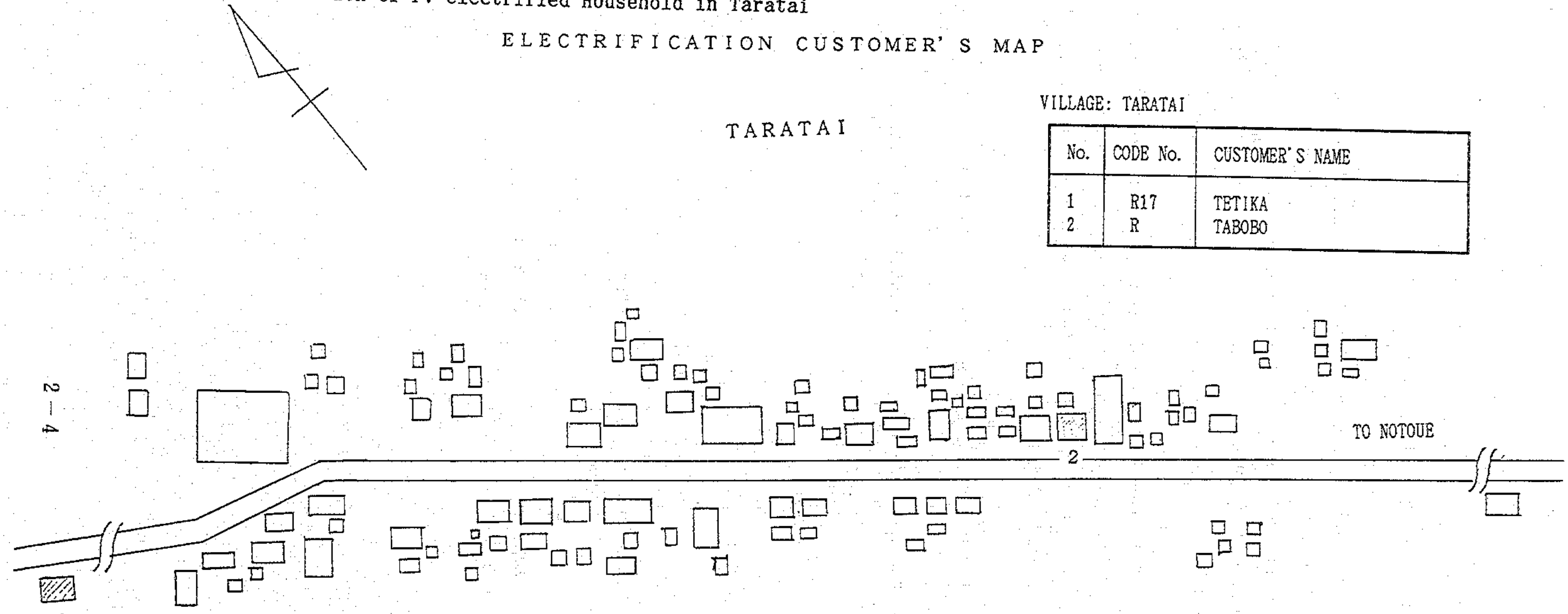


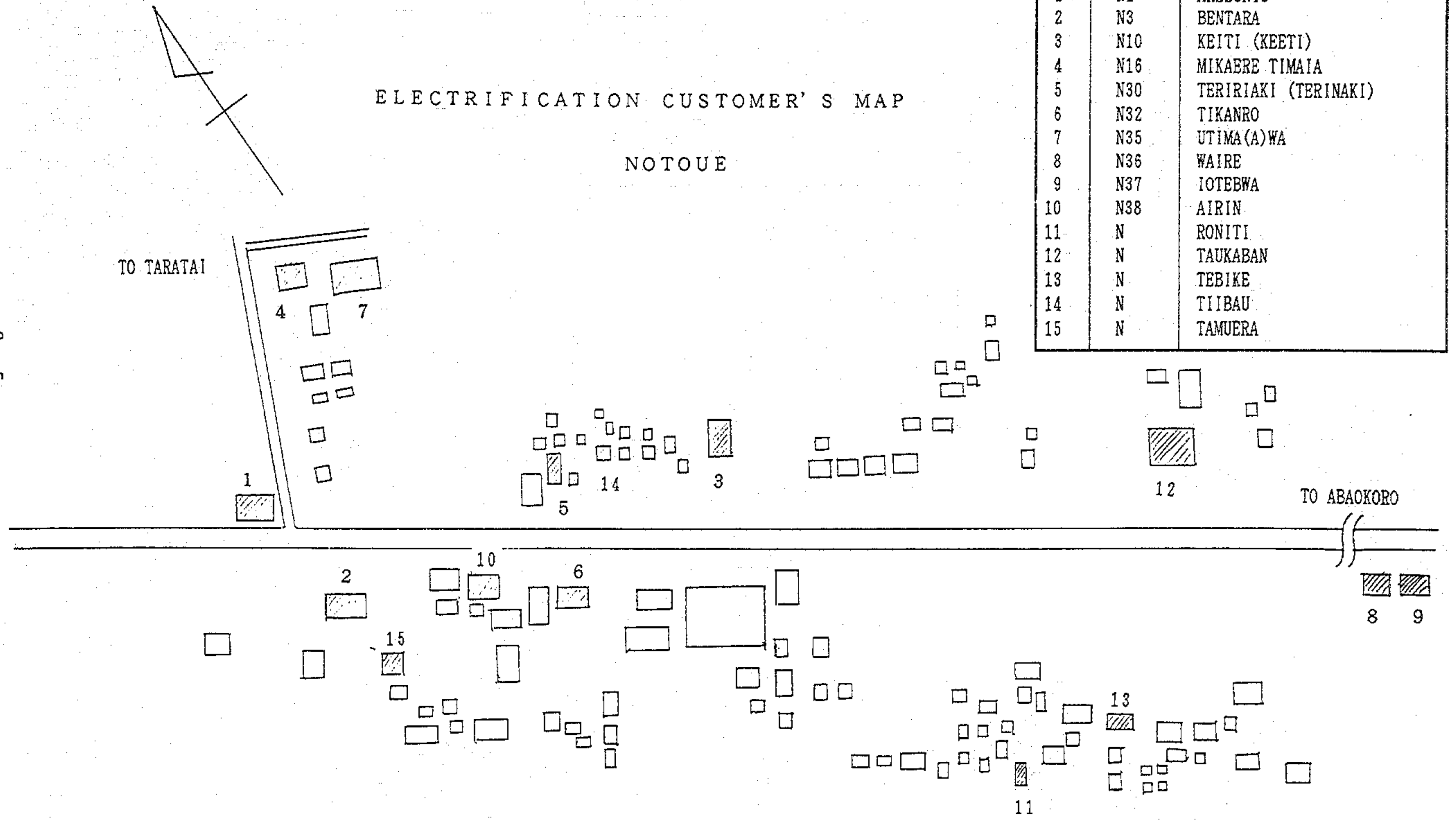
Fig 2.2-2 Location of PV electrified Household in Notoue

ELECTRIFICATION CUSTOMER'S MAP

NOTOUE

VILLAGE: NOTOUE

No.	CODE No.	CUSTOMER'S NAME
1	N1	AREBONTO
2	N3	BENTARA
3	N10	KEITI (KEETI)
4	N16	MIKAERE TIMAIA
5	N30	TERIRIAKI (TERINAKI)
6	N32	TIKANRO
7	N35	UTIMA(A)WA
8	N36	WAIRE
9	N37	IOTEBWA
10	N38	AIRIN
11	N	RONITI
12	N	TAUKABAN
13	N	TEBIKE
14	N	TIIBAU
15	N	TAMUERA



ELECTRIFICATION CUSTOMER'S MAP

Fig 2.2-3 Location of PV electrified Household in Abaokoro

ABAOKORO

No.	CODE No.	CUSTOMER'S NAME
1	A1	ABAKUKA
2	A4	BEIA TOARA
3	A5	EKEIETA ITITAAKE
4	A9	LOUI NAMANE
5	A10	NAITIRIA TAMTON
6	A11	OBETA
7	A16	IERUBAARA
8	A17	TEBUAKA
9	A18	TEKAKIABO
10	A21	TEMARAWA KAWITU (?)
11	A27	MAKIN NGATAU
12	A29	TAUKABAN
13	A32	RIBATI
14	A33	TIOTI
15	A35	ABAUA
16	A36	BWENAWA
17	A37	MATIOTA
18	A	TENAGIMAU
19	A	TEKATAU
20	A	KAUBUNANG
21	A	BAURO
22	A	AMBO
23	A	TEKEAROI
24	A	TETAKE
25	A	BIITA

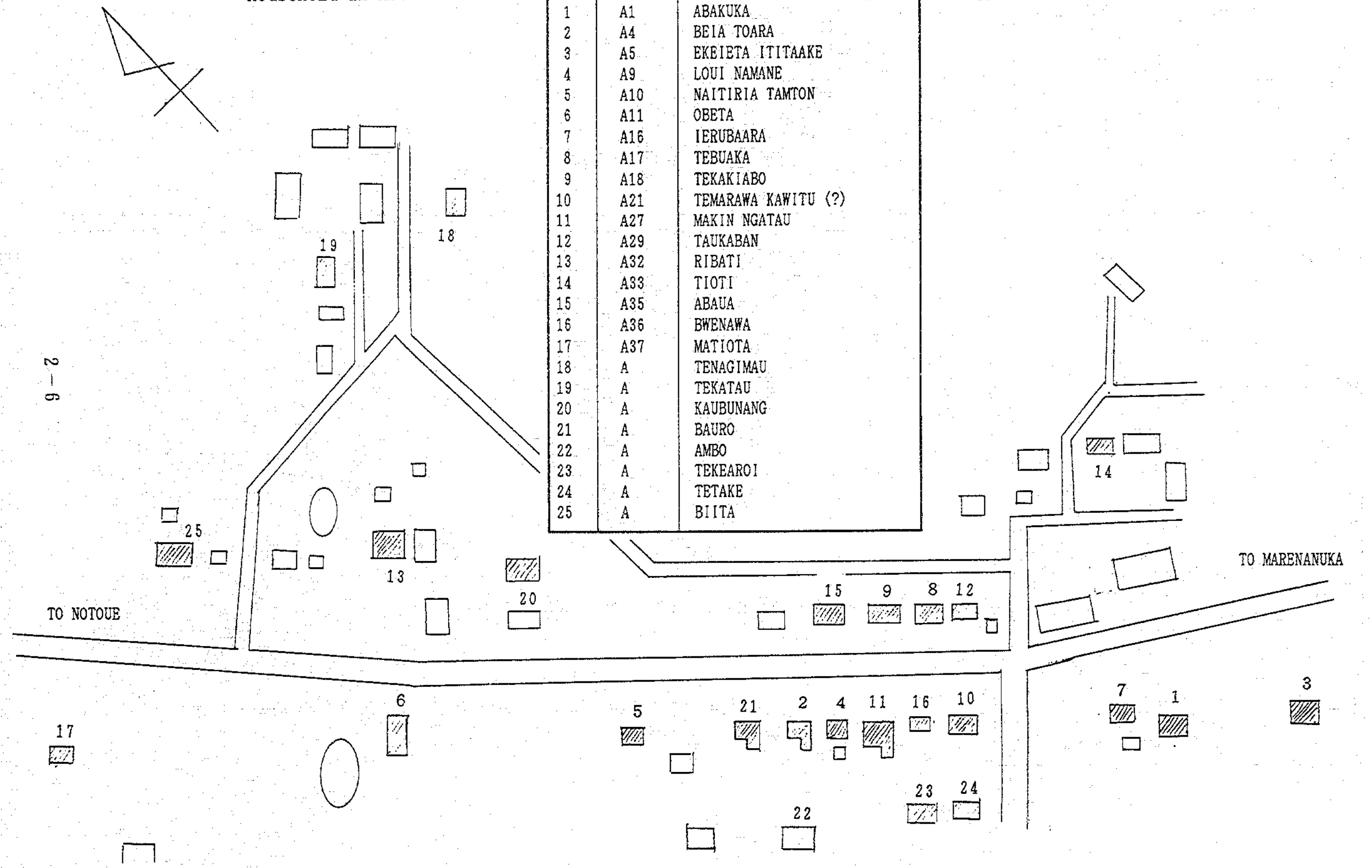
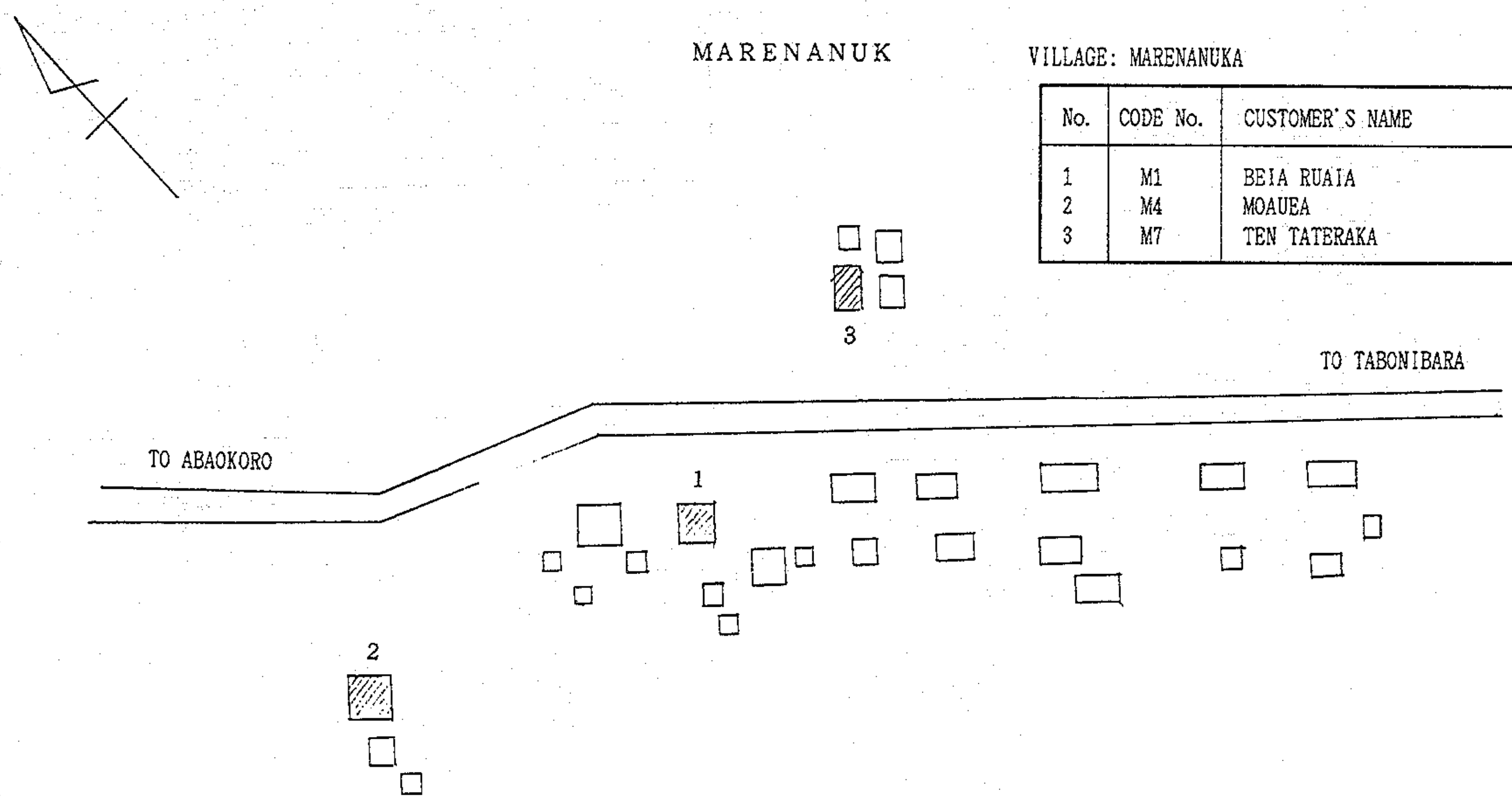


Fig 2.2-4 Location of PV electrified Household in Marenanuka

ELECTRIFICATION CUSTOMER' S MAP



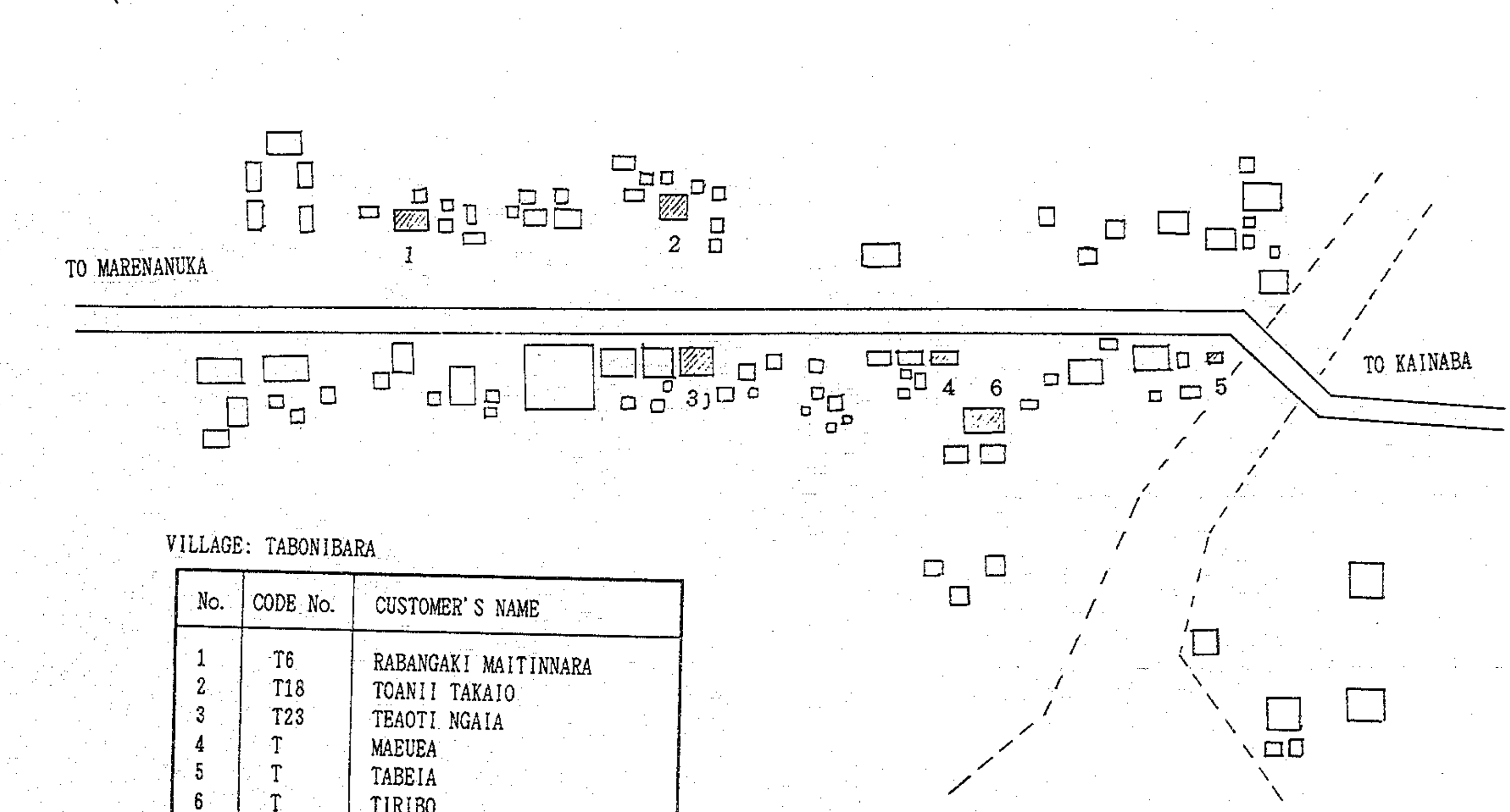
VILLAGE: MARENANUKA

No.	CODE No.	CUSTOMER'S NAME
1	M1	BEIA RUAIA
2	M4	MOAUEA
3	M7	TEN TATERAKA

Fig 2.2-5 Location of PV electrified Household in Tabonibara

ELECTRIFICATION CUSTOMER'S MAP

TABONIBARA



VILLAGE: TABONIBARA

No.	CODE No.	CUSTOMER'S NAME
1	T6	RABANGAKI MAITINNARA
2	T18	TOANII TAKAIO
3	T23	TEAOTI NGAIA
4	T	MAEUEA
5	T	TABEIA
6	T	TIRIBO

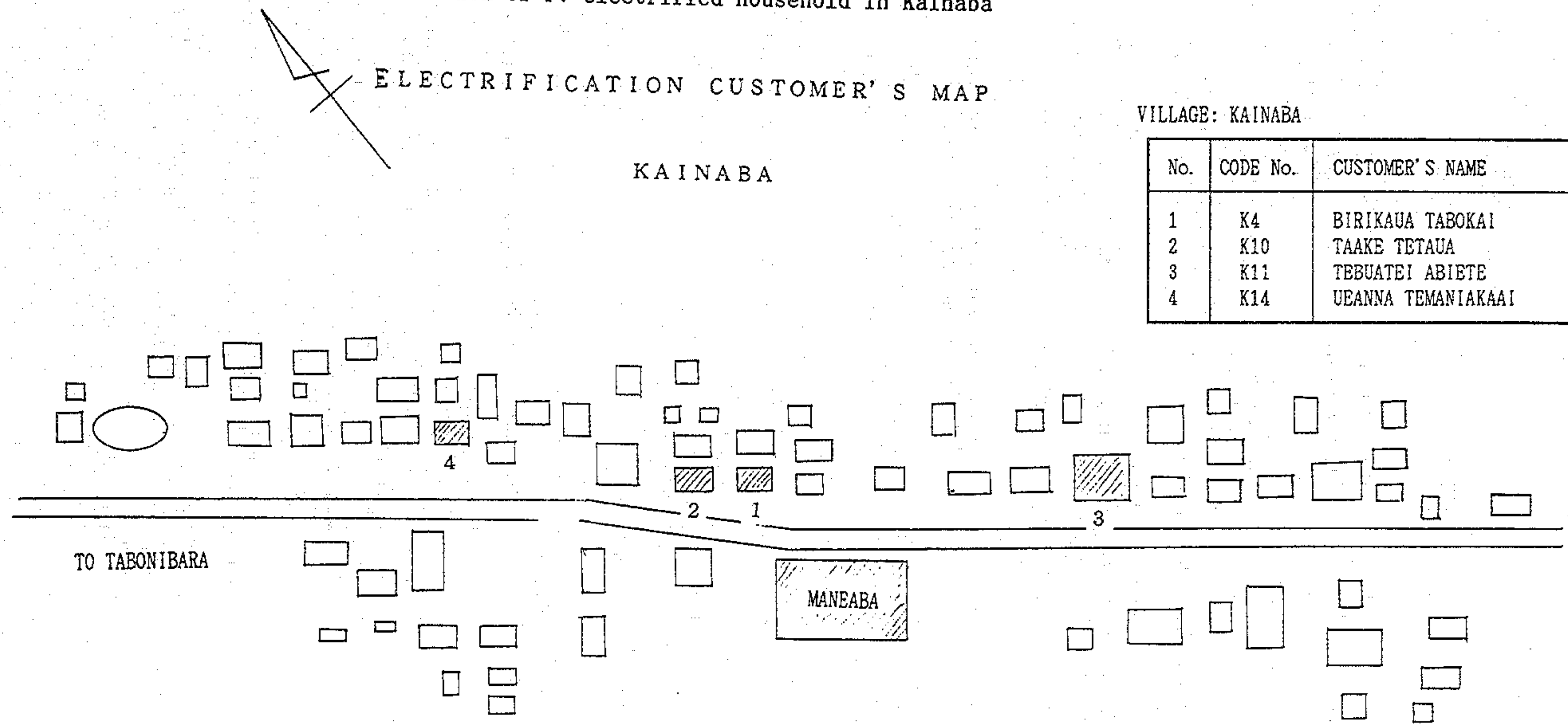
Fig 2.2-6 Location of PV electrified Household in Kainaba

ELECTRIFICATION CUSTOMER'S MAP

KAINABA

VILLAGE: KAINABA

No.	CODE No.	CUSTOMER'S NAME
1	K4	BIRIKAUA TABOKAI
2	K10	TAAKE TETAUA
3	K11	TEBUATEI ABIETE
4	K14	UEANNA TEMANIAKAAI



PV SOLAR SYSTEM UTILITY CONTRACT
(Te BORARAOI IAON KAMANENAAKIN TE TIORA)

This agreement was made on ______________________ 19_____ between the Solar Energy Company Limited (SEC) and _____________for the installation use and maintenance of the solar lighting system installed on ______________ (customer) house.

(Te boraraoi aei e karaoaki n te_________________ 19______ imarenan te Solar Energy Company Limited (SEC) ao_____________ ibukin kanimwan, kaboonganaan ao tararuaan bwain nako te solar ake a kanimwaki n ana auti____________________ (te tia kaboonganaa)).

In return for fees received, the Solar Energy Company agrees to install the following items which remains the property of the SEC:

(Boon te te mwane are e reke iroun te kambana, te SEC e kukurei ni kanim bwaai aika oti inano are ana riki bwa ana bwai te SEC):

2 Solar PV Modules and associated mounting components
(2 te Solar Panel ma bwaina nako)

1 Switch Board and Regulator
(1 tiwiti booti ao te rekureita)

1 Battery with associated box
(1 te baetere ma baokina)

All wiring to connect the above items.
(uaea ni kabane ake a kanimaki nakon bwaai akana oti i eta)

And the SEC agrees to install the following items which become the property of the customer upon the commissioning of the system and after receiving twelve monthly fees:

(E kukurei naba te SEC ni kanim bwaai aika oti inano ake ana riki bwa oin ana bwai te tia kabonganaa te tiora imuiin bwakan roona inanon tebwi ma uoua te namakaina):

1 PL11 fluorescent light and assosiated switch and cable
(1 te taura ae te PL11 ma tiwiitina ao uaeana)

2 PL7 fluorescent light and associated switch and cable
(2 te taura ae te PL7 ma tiwitina ao uaeana)

1 LED night light and associated switch and cable
(1 te taura ae te LED ma tiwiitina ao uaeana)

Upon commissioning and receipt of appropriate fees, the SEC agrees to visit the customer's site once per month in order to maintain the part of the system which is its property to insure the availability of sufficient electrical energy to provide an average of four hours of fluorescent light and eight hours of night light use per day.
(Man te tai are e kauraaki iai te taura ao e karekeaki roon te taura, te SEC e kukurei n tuoa ana taura te tia bwaibwai teuana te tai n te namakaina n te aro are e na teimatoa raoiroin ana bwa te SEC n te aro are e na iai n taai nako te iti ao n tauraoi n reke inanon te maan ae aua te awa uran taura aika taian PL7 ao te PL11 ao waniua te aua ibukin kamanenakin te taura ae LED).

The SEC further agrees to promptly repair faults in the part of the system which is its property to insure that the system is available for use as continuously as possible
(E kukurei naba te SEC karaoa te uruaki n te tai ae riai iaon bwaaiake bonoin ana bwai bwa e na teimatoa nakoraoin te tiora ibukin kaboonganaakina ni katoa bong).

In order for this agreement to remain in force, the customer agrees:
(Ibukin kateimatoaan mwakurin te boraraoi aio, te tia bwaibwai e kukurei ni):

To pay designated fees promptly.
(kabwakaa roon ana auti ni katoa tai)

To allow the SEC access to all all parts of the system at any reasonable time as is neccessary for proper repair and maintenance.
(kariaia rokon te SEC bwa e na roko ni karaoa ana mwakuri iaon te tiora n te tai are e riai n te aro are ana teimatoa tamaroan bwain te tiora).

To inform the SEC of any problems with the systems as soon as they arise.
(kaongoa te SEC taekan uruaki ni bwain te tiora n te tai are e reke naba iai).

To use the system as per the written instruction provided by the SEC.
(kaboonganaa te tiora n arona are e koreaki iaon bokina).
Not to make any changes or to in anyway damage or tamper with any part of the system without written permission from the SEC. This is includes adding or changing electrical appliances.
(N aki bitii ao n urui ke ni kuai bwain nako te tiora ni karokoa ae e karekea te kariaiakaki man te SEC. E na akea bwai riki aika a na kanimaki ke n anaaki irarikin ke man bwaai ake oti n te boraraoi)

Not to allow additional shade to fall upon the solar panel through vegetation growth or building construction.

(N aki kariaia rokon te nuu iaon te tiora panel are e reke man te aroka ke aekan kateitei riki tabeua)

If this agreement is violated, the customer understands that the Solar Energy Company has the right to disconnect or remove its property from the customer's premises.
(Uruan te boraraoi aio, te tia bwaibwai e maataata raoi bwa e inaomata te SEC ni katoka rokon te iti ke n anai ana bwai man ana auti te tiabwaibwai).

This contract remains valid for one year from the day of commissioning which is ______________________
(Te boraraoi aio e na teimatoa inanon teuana te ririki man te tai are e karokoaki iai te iti n ______________________)

Signed by ____________________ ____________________
(Tiaina) Customer Solar Energy Company Ltd.

3. Selection of Technology and System

3.1 Power generation in Kiribati

The domestic energy resources available in Kiribati are only biomass and renewable energies such as solar, wind, wave and ocean. The biomass energy collected in island is consumed as their cooking fuel and not enough to introduce biomass fuel power generator, the wind is also not enough strong except Christmas Island and wave power, ocean thermal power generation technologies are still under experimental state.

Otherwise the photovoltaic power generation technology has developed and proved their availability in many countries of world and South Pacific Countries are blessed with rich sunshine therefore the PV is considered as only one to compare the fossile energy base power generation method.

The most popular electric generation method in rural area that the demand of electricity is small as a few Kw to a few Mw, is a diezel or gasoline engine generator and generated electricity is distributed by transmission and distribution lines.

According to above situation, the comparison in this study is based on the photovoltaic electric generation systems.

3.2 Comparison of PV system and Diesel Generation system

(Based on the works 'Solar Energy: Lessons from the South Pacific Experience' by A. Liebenthal, S.C. Mathur, H. Wade)

3.2.1 Calculation of life-cycle costs

Three different cases, consisting of different representative appliance combinations, are considered in this analysis:

(1)Lights only: In this case, it is assumed that the only appliances that a customer will use are three household lights, with an additional night light included for solar PV systems.
For this case,it is assumed that the diesel system will be operated for only six hours a day, which precludes the use of night light.
This low level of demand for electricity is appropriate for the majority of the rural households in the Pacific islands.

(2)Lights and TV/VCR: In this case, it is assumed that the customer has a TV/VCR set in addition to the lights.
For this case, it is assumed that the diesel system will be operated for only six hours a day.
About one-fifth of the households in a typical rural Pacific island village would fit into this case.

(3)Lights and refrigerator: In this case, it is assumed that the customer has a refrigerator in addition to the household lights.
For this case, it is assumed that the diesel system will be operated 24 hours a day, so that the customer is assumed to use a night light also.
About 5% of the households in a typical rural Pacific island village would fit into this case.

Table 3.2-1 Characteristics of Customers Appliances:
Solar PV systems

Item	No	Usage (hour/day)	Load (wh)	Life (year)	Cost (US$)
Light(11W)	1	6	66	5	40
Light(7W)	2	4	56	5	40
Night LT(0.25W)	1	12	3	5	12
Color TV(80W)	1	2.5	200	7	300
VCR (40W)	1	2.5	100	7	300
220L Refrige.	1	24	720	10	1,200

Table 3.2-2 Initial Generation Equipment Costs per Customer
Solar PV systems: Lights only (125Wh/day)

Item	No	Unit cost (US$)	Total cost (US$)	Life (year)
PV panel(55W)	1	350	350	15
Battery(12v,100Ah)	1	135	135	4
Controller	1	120	120	8
Support	1	100	100	15
Install Hours	12	3	36	
Total			741	

Table 3.2-3 Initial Generation Equipment Costs per Customer
Solar PV systems: Lights and TV/VCR (425Wh/day)

Item	No	Unit cost (US$)	Total cost (US$)	Life (year)
PV panel(47W)	4	325	1,300	15
Battery(6V,160Ah)	4	120	480	6 (24Vsystem)
Controller	1	200	200	8
Support	2	100	200	15
Install Hours	12	3	36	
Total			2,216	

Table 3.2-4 Initial Generation Equipment Costs per Customer
Solar PV systems: Lights and Refrigerator (845Wh/day)

Item	No	Unit cost (US$)	Total cost (US$)	Life (year)	
PV panel(55W)	6	350	2,100	15	
Battery(2V,435Ah)	12	150	1,800	6	(24Vsystem)
Controller	1	200	200	8	
Support	3	100	300	15	
Install Hours	12	3	36		
Total			4,436		

Table 3.2-5 Characteristics of Customers Appliances:
Diesel systems

Item	No	Usage (hour/day)	Load (wh)	Life (year)	Cost (US$)
FL Light(16W)	1	6	96	10	25
FL Light(11W)	1	4	44	10	25
Light(40W)	1	4	160	1	1.1
Night LT(1W)	1	12	3	1	2
Color TV(110W)	1	2.5	200	7	200
VCR (65W)	1	2.5	100	7	300
Refrige.(180W)	1	24	2,600	10	900

Table 3.2-6 Generation Equipment Costs per Customer

Diesel systems:

Item	Lights only	Lights & TV/VCR	Lights & Refrigerator
Per customer (peak) demand (W)	100	250	300
Number of customers	40	40	40
System demand(KW)	4	10	12
Loss/Reserve/Expand(%)	150	150	150
Total system size(KW)	10	25	30
Initial capital cost per KW(US$)	3,000	2,750	2,500
Total capital cost (US$)*	30,000	68,750	75,000
Initial C.C. per customer(US$)	750	1,719	1,875
Future C.C. per customer(US$)**	189	432	472

* Generation, reticulation and connection costs

** Discounted present value of future overhaul costs planned in every five years

Table 3.2-7 Operation & Maintenance Costs per Customer

Diesel systems:

Item	Lights only	Lights & TV/VCR	Lights & Refrigerator
Energy use per month (KWh)	10	25	90
Unit cost of generation (US¢/KWh)	65	60	55
Annual O & M cost (US$)	78	180	594
Total O & M cost (US$)*	593	1,369	4,518

* Discounted present value for 15 years at a discount rate of 10%

3.2.2 Result of calculation

The total costs are culculated as the discounted present value, at a discount rate of 10%, of the cost components, measured in constant dollars, of providing the end use service that consumers want for 15 years.

This time horizen and discount rate are commonly used in planning the supply of electricity.

The focus is on the total costs of providing the end-use service that customers want, rather than the cost of electricity alone. This focus is particularly important in a comparison of the cost of solar PV and diesel systems because of the differing cost structures and energy efficiencies of the appliances that customers use with solar systems (DC power) and diesel systems (AC power). In general, the DC appliances are relatively energy-efficient but cost more than comparable AC appliances.

Table 3.2-8 Comparison of Total Life cycle costs per customer
Solar PV system vs. Diesel system: (US$)

System	Lights only	Lights & TV/VCR	Lights & Refrigerator
SolarPV system	1,386	4,015	7,818
Diesel system	1,604	4,378	8,093

Table 3.2-9 Life cycle costs per customer
Solar PV system:(US$)

Cost element	Lights only		Lights & TV/VCR		Lights & Refrigerator	
Customer Appliance cost		265		1,208		1,784
Initial costs	(132)		(732)		(1,322)	
Future costs	(133)		(476)		(452)	
Generation Equipment cost		984		2,670		5,897
Initial costs	(741)		(2,216)		(4,436)	
Future costs	(243)		(454)		(1,461)	
Operation & Maintenance cost		137		137		137
Based on monthly cost	(1.5)		(1.5)		(1.5)	
Total cost		1,386		4,015		7,818

Table 3.2-10 Life cycle costs per customer

Diesel system: (US$)

Cost element	Lights only		Lights & TV/VCR		Lights & Refrigerator	
Customer Appliance cost		72		858		1,228
Initial costs	(51)		(551)		(953)	
Future costs	(21)		(307)		(275)	
Generation Equipment cost		939		2,151		2,347
Initial costs	(750)		(1,719)		(1,875)	
Future costs	(189)		(432)		(472)	
Operation & Maintenance cost		593		1,369		4,518
Based on generation cost(/KWh)	(0.65)		(0.60)		(0.55)	
Total cost		1,604		4,378		8,093

3.2.3 Conclusion

Solar PV and diesel systems have been compared on the basis of life-cycle costs for providing the final services that the customer desires: household lighting, refrigeration, or video for a number of years. The broad components of life-cycle costs are: (i)initial and future replacement costs of customer end-use appliances;(ii)initial and future replacement costs of generation equipment;and (iii)operations and maintenance(O&M)costs.

One critical design parameter is the reliability of the system because the costs tend to increase sharply when the reliability of the system is increased to higher levels. another key parameter in the design of a power supply system is the number of hours for which electricity will be available. A decision to supply diesel generated electricity on a 24 hour basis will raise unit labor costs significantly for diesel systems but not for PV system as they are inherently capable of 24 hour power delivery. Hence, the power supply system should be designed so that it strikes a balance between the level of reliability that its consumers wish and the level of costs that the consumers can afford.

In general, solar PV has an advantage over diesel based power when: (i)there is no existing power grid;(ii)diesel fuel is costly and/or reliable transportation for fuel is unavailable or costly;(iii)access to land for a power house and distribution system is a problem;(iv)there is high peak load for a short time;(v)the number of customers is likely to increase over time;(vi)noise or air pollution is a concern;and (vii)it is difficult to train and retain in the rural areas technicians for diesel systems.

However, solar PV is at a disadvantage over diesel systems when:(i)village demands for power are high;(ii)there is dense vegetation around homes or the level of cloudiness is high; and(iii)the special appliances or power conversion equipment necessary to operate with the DC electricity provided by PV systems are unavailable or too expensive.

Based on data and assumptions that appear appropriate for the Pacific Islands, the life-cycle costs of solar PV systems are lower than those of diesel systems for households in remote rural areas. The difference in overall costs is about 3-14%,with the higher savings applicable to households with low energy consumption, and lower savings applicable to households with higher energy consumption.

One of the key assumptions underlying this result is that both solar PV and diesel systems will be properly designed and installed and adequately maintained. Another key assumption is that the cost of electricity generated by diesel systems, even with proper maintenance, is high by the standards of the industrialized countries because of the small scale of operations in the rural areas, high fuel costs and high transportation costs.

Table 3.2-11 Qualitative comparison between Solar PV and Diesel system

Items	Diesel central systems	Solar stand alone system
Initial capital costs, Machinery life, Physical characteristics	Low initial capital cost, short useful machinery life without proper maintenance, moderate in bulk and weight	Moderate capital costs, rapid installation possible, long PV panel life but short battery life without proper main tenance, shade free area needed
Operations	Rapid response to load changes,q quick start-up easy shutdown	Immediate response to load change
Fuel cost, Availability and Storage	Imported fuel, high cost, availability good in urban areas but often poor in rural areas, easy to store but storage expensive in rural areas	No fuel requirements good availability sub-ject to weather, storage battery required to ope-rate system at times of low sunshine and at night
Repair and Maintenance	Technicians expensive to train and hard to retain, high maintenance cost, inefficient at light load	Technicians not costly to train, moderate main-tenance costs, operating efficiency changes little with load changes
Parts	Large in number, readily available	Few in number, easily available

(Table 3.2-11 continued)

Items	Diesel central systems	Solar stand alone system
Pollution	Toxic fuel,noise, noxious smoke and smell	Low environmental impact Battery recycling is necessary
Prospects	Factors that make them suitable are: existing power grid, low on-site fuel costs, high load requirements over an extended period per day	Factors that make them suitable are: lack of existing grid, high on-site fuel costs, high peak loads are only for short period of time, concern about air or noise pollution, load growth due to additional customers or increasing individual demand over time. Desire for 24 hour power low load levels

3.3 Comparison of PV system and Grid Extension System

(Based on the works 'A brief comparison of Grid Extensions, Stand-Alone Diesel Generators, and Photovoltaics for Rural Electrification' by Chris Cheatham PEDP)

3.3.1 Case study of Comparative costs: electrification of North Tarawa

A recent study of the costs of electrification of North Tarawa in Kiribati, between the villages of Nabeina and Buariki is provided by the Asian Development Bank. In this study the costs of 'Grid extension' and 'Stand-alone Diesel' were compared. The costs for PVs were derived from a 1990 tender for an EC-funded household PV electrification project.

The cost comparison is based on the overall resource cost of each electrification option, including the initial cost of power generating and distribution equipment, maintenance and fuel costs and household costs including wiring and the purchase of electrical appliances.

The period of the comparison is 15 years(same as for 3.2.1), and it is assumed that all equipment--power equipment, household appliances, etc., is purchased at the start of the period and is replaced as necessary according to the useful life of each item. The major assumptions underlying the comparison are listed in Table 3.3-1.

3.3.2 The result of culcuration

The culculation results of comparing the total present value for 15 years in each electrification method are shown in Table 3.3-2 and Fig. 3.3-1, the grid extension cost is most expensive through the electrification of 500 households (almost all households in North Tarawa).

The diesel generation and PV stand-alone cases are nearly equal at small number of electrification household in finantial culculation and they are mainly varied by the cost of diesel generator and PV panels.

Table 3.3-1 The assumptions underlying the comparison

Items	Glid Extetion	Stand alone Diesel	Photovoltaics
Number of customer			
Households	25 to 500	25 to 500	25 to 500
Maneaba	10	10	10
Main system compornent			
Grid extension	30km		
Diesel generator		Daily demand/3	
PV panel			2 x household 10 x maneaba
Battery			1 x household 4 x maneaba
Controller			1 x household 2 x naneaba
Electric appliances (Number and operating hour)			
Refrigerator(AC 400w)	10	10	
Refrigerator(DC 85w)			10
Radio/Cassettcoder(10w)	same as households		
Iron (1000w)	1/3 households	none	none
Furuorescent light(20w)	2 x households + 5 x Maneaba		
Video cassett (100w)	10	10	10
Unit investment costs(US$)			
Extension of grid	12,000$/km		
Connection cost	875$/system	875$/system	
Diesel generator		2,500$/kw	
Inhouse wiring	90$/system	90$/system	90$/system
PV panels			350$
Battery			150$
Controller			175$
Refrigerator(AC 400w)	950$	950$	
Refrigerator(DC 85w)			1,875$
Radio/Cassettcoder(10w)	50$	50$	50$
Iron (1000w)	60$		
Furuorescent light(20w)	5$	5$	5$
Video cassett (100w)	2,500$	2,500$	2,500$

(Table 3.3-1 Continued)

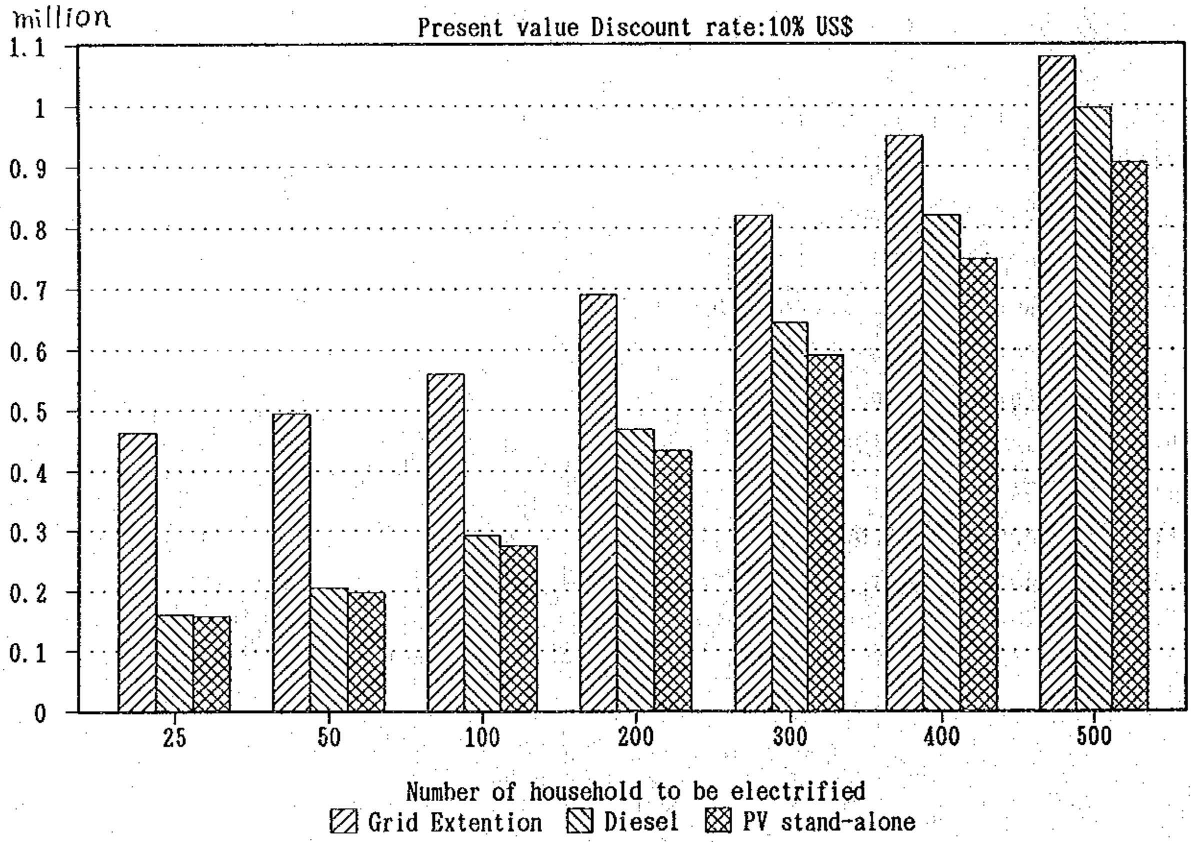
Operation and Maintenance cost			
Fuel requirement	0.291/kwh	0.351/kwh	
Fuel price	0.43$/l	0.43$/l	
Transmission loss	15%		
Distribution loss		10%	
Maintenance cost	1% for initial investment/year	5% for initial investment/year	2% for initial investment/year
Life time of compornents and appliances (years)			
Extension of grid	20		
Connection cost	20	20	
Diesel generator		15	
Inhouse wiring	20	20	20
PV panels			15
Battery			5
Controller			10
Refrigerator(AC 400w)	20	20	
Refrigerator(DC 85w)			20
Radio/Cassettcoder(10w)	10	10	10
Iron (1000w)	15		
Furuorescent light(20w)	3	3	3
Video cassett (100w)	10	10	10
Operating hours of appliances per day			
Refrigerator(AC 400w)	6	6	
Refrigerator(DC 85w)			6
Radio/Cassettcoder(10w)	6	6	6
Iron (1000w)	1		
Furuorescent light(20w)	4	4	4
Video cassett (100w)	3	3	3

Table 3.3-2 Total cost(Present value: discount rate as 10%) US$

Number of Household	Grid extn.	Diesel	PV
25	462,908	160,727	157,248
50	495,340	204,645	196,703
100	560,204	292,480	275,540
200	689,932	468,150	433,215
300	819,660	643,820	590,890
400	949,388	819,490	748,564
500	1,079,116	995,160	906,239

Fig. 3. 3-1 Total cost of 15 years

Present value Discount rate:10% US$



3.4. Comparison of Stand-alone and Centralized PV system

3.4.1 Technical comparison

Item	Stand-alone	Centralized
Power distribution	Negligible	Important item
System size	According to individual needs	According to total Village needs
System components	Simple, easily maintained	High voltage, more complicated
Appliances	High efficiency, low voltage DC	Standard AC appliances may be used but with lowered energy efficiency
System efficiency	Higher than the centralized system	Reduced due to distribution loss and AC/DC conversion and generally lower efficiency appliances
Mobility of system	Easily to move	Difficult to move
Intimacy of system	Intimate, seems like personal property	remote and impersonal
Reliability	Each user not affected by other systems	Many users may be affected by any system problems
System location	Easily located due to small size	Difficult to find good location near the village for the large system
System safety	Safer (low voltage 12 to 24 volts	Hazardous (high voltage 130 to 240 volts)
Field technician requirement	Easily trained	Requires higher level of training
system expandability	Easily expanded	Expensive to increase size due to distribution line and inverter capacity must be increased

3.4.2 Economic comparison

(1) Comparison of systems

Item	Stand-alone	Centralized
Pv array	Small capacity for each household	Large capacity in one location
Charge/discharge controller	A small unit in each household	High capacity in one location
Battery	Small capacity in each household	Large capacity in one location
Inverter	Not necessary	Necessary
Distribution line	Low voltage, short in length	High voltage, long in length
Panel board/meter	Not necessary	Necessary
Appliances	Low voltage DC	High voltage AC
Land for power plant	Not necessary	Necessary
Land for transmission line	Not necessary	Necessary

(2) Example of both types

Stand-alone type
(per household)

Kiribati PV project
(55 households)

PV panels (16V 100W/HH)

Charge/discharge
controller

Battery(12V 100Ah/HH)

Charge/discharge
controller

Distribution line(12V)

Appliances(12V DC)
(lights only)

Centralized type
(total for village)

Thai village electrification
project (60 households)

PV panels (240V 30Kw/village)

Switch board

Charge/discharge
controller(240V 20Kw/village)

Battery(240V 1540Ah/village)

Charge/discharge
controller

Inverter(230V 20Kw 50Hz)

Panel board

Distribution line(230V)

Meter(Household)

Appliances(230V AC)
(lights,TV,fan,refrigerator,etc.)

(3) Cost estimation(per household)

Item	Stand-alone		Centralized	
	unit cost	total cost	unit cost	total cost
PV panel	7 US$/W	700 US$/HH	7 US$/W	3500 US$/HH
C/D controller	2 US$/W	200	1 US$/W	333
Battery	0.2 US$/Ah	240	0.2 US$/Ah	1232
Inverter	---	---	1 US$/W	333
Distri. line	100 US$/HH	100	500 US$/HH	500
Panel board	---	---	50 US$/HH	50
Meter	---	---	50 US$/HH	50
Total		1,240 US$/HH		5,998 US$/HH

(4) Cost by PV capacity

Capacity	Stand-alone	Centralized
100 W/HH	1,240 US$/HH	1,680 US$/HH
200	2,380	2,760
300	3,520	3,840
500	5,800	5,998
700	8,080	8,160
1000	11,500	11,400

3.4.3 Conclusion

The stand-alone PV system is less costly than the centralized PV system through the electricity consumption capacity of each households is almost 1,000watt like in the case of North Tarawa as the number of households is around 50's.

3.5 Conclusion

Considering above comparisons, in the case of rural electrification which the main object is for lighting, the stand-alone PV system is most preferable in economic and technical(maintenance) point of view.

In the case of grid extension from Bouta to Nabeina in North Tarawa, 60% of residential household user's electricity consumption was less than 30kwh/month(<1kwh/day; 100--200w/hour).(see, Table 3.5-1)

This result shows even after electrification by grid extension, main purpose of electricity is for lighting.

Table 3.5-1 Consumption of electricity (Bouta-Nabeina Expansion)
64 Customers connected(48 residential, 15 commercial 1 industrial)

Reading(kwh/M)	Commercial		Residential	
*	Number	%	Number	%
0-- 10	6	12.2	31	21.7
11-- 20	8	16.3	32	22.4
21-- 30	1	2.0	23	16.1
31-- 40	4	8.2	8	5.6
41-- 50	6	12.2	9	6.3
51--100	8	16.3	19	13.3
101--200	12	24.5	15	10.5
201--300	2	4.1	3	2.1
301--500	1	2.0	2	1.4
501--	1	2.0	1	0.7
Average monthly consumption	97.8kwh/M			54.3kwh/M

* Reading of December '92, January '93, March '93, May '93

4.Detail Design and Determination of Specification

4.1Meteorological Data Examination

A survey and analysis of meteorological data has been made for the 7 years from 1980 to 1986 on the island of Tarawa of the Republic of Kiribati.
The availability of meteorological data are shown in Table 4.1-1.

Table 4.1-1 Availability of Meteorological Data

	Unit	1980	1981	1982	1983	1984	1985	1986	Remarks
Global Solar Radiation	langleys	○	○	○	○	○	○	○	
Temperature	°C	○	−	○	○	○	○	−	
Humidity	%	○	−	○	○	○	○	−	

1 Langleys=1 calory/m^2= 0.01163 KWh/m^2

○ : Observation Data exists

Quantity of Solar Radiation:

In the above mentioned 7 years, the average quantity of daily solar radiation was 5.69(KWh/m^2/day), which is about twice as high as Japanese conditions.
About 60% of the days had radiation 6 (KWh/m^2/day).
(Fig. 4.1-1, Fig. 4.1-2)

Atmospheric Temperature:

The daytime range of temperature peaks sharply at 28 to 30℃.
(Fig. 4.1-3)

Humidity:

During the daytime,the range of values of relative humidity also peaked 72 to 82%.
(Fig. 4.1-4)

Seasonal changes in Solar Radiation:

A graph of the changes in daily solar radiation for 1986 as shown in Fig.4.1-5. Also the distribution of daily solar radiation is shown in Table 4.1-2.
The level of radiation is nearly the same throughout the year, and there is no marked seasonal change as there is in Japan.
Daily solar radiating quantity through 1980 to 1986 is shown in Table4.2-3.

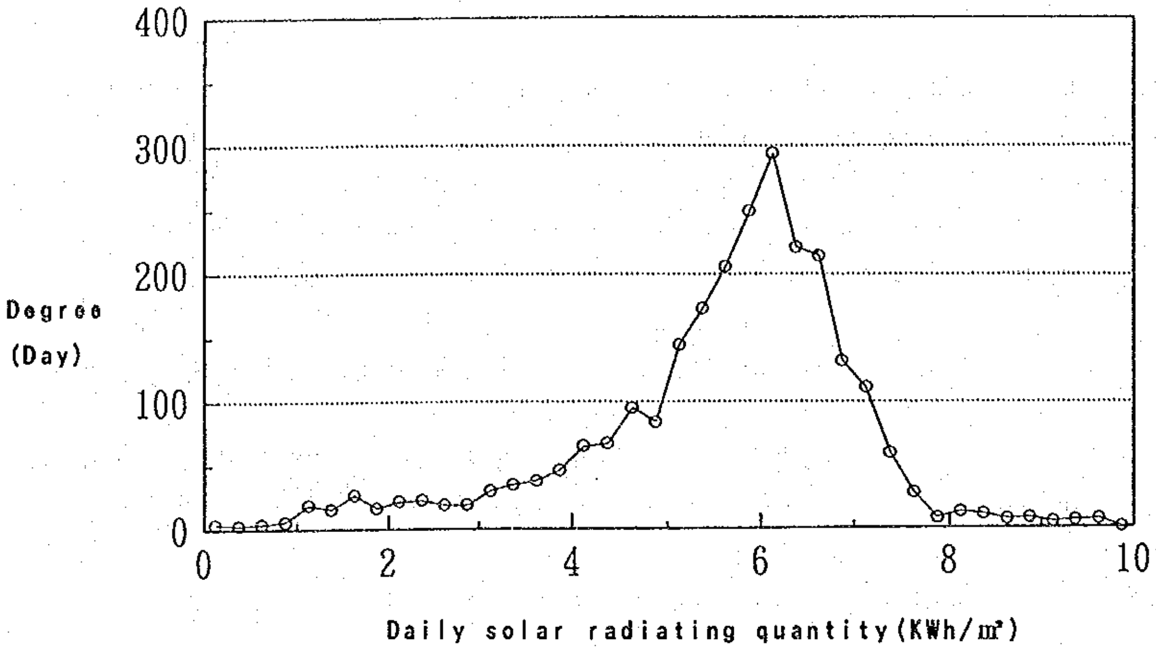


Fig.4.1-1: Daily Solar Radiating Quantity Distribution
(1980 ~ 1986)

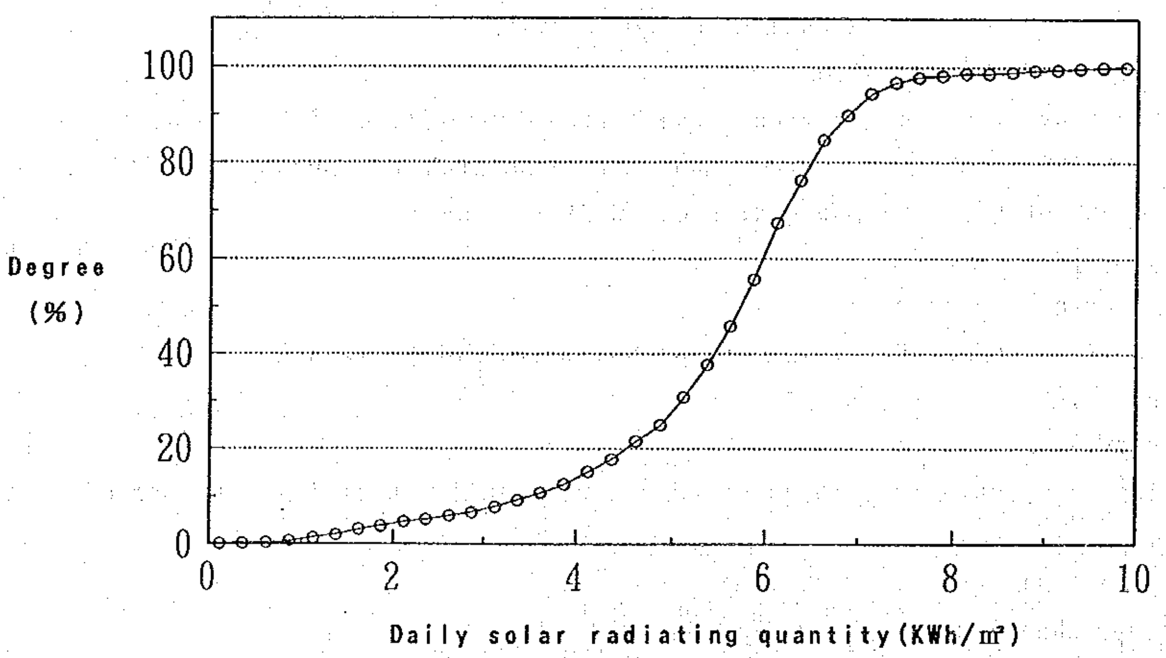


Fig.4.1-2: Daily Solar Radiating Quantity Distribution
(1980 ~ 1986)

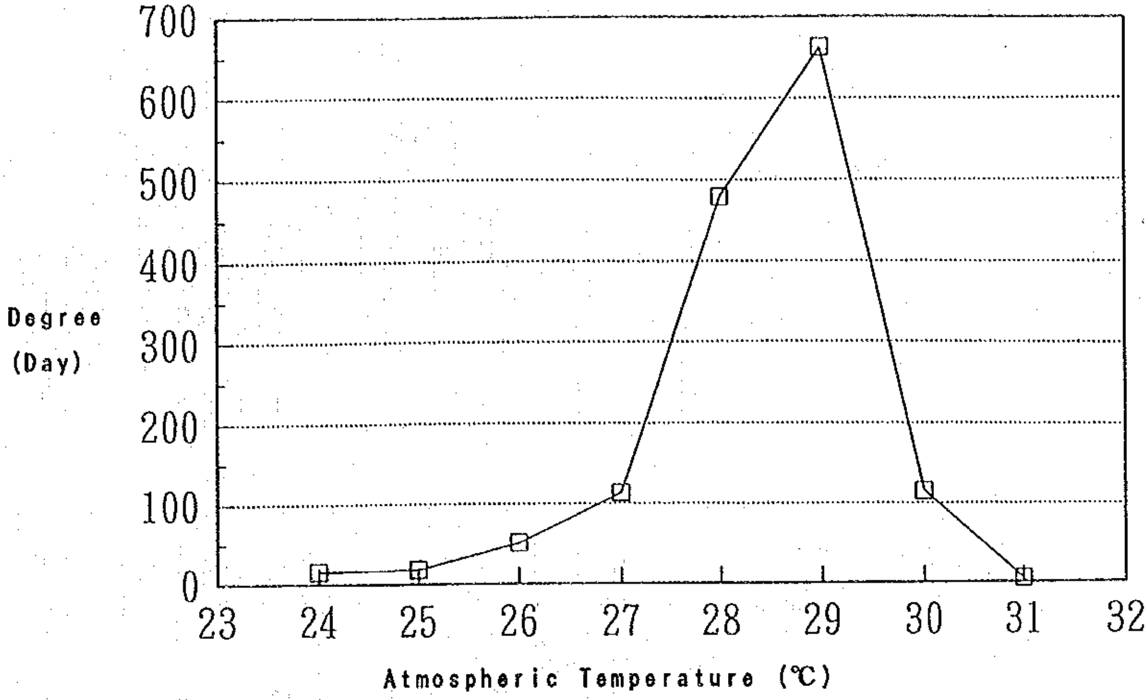


Fig.4.1-3: Distribution of Atmospheric Temperature
(1982 ~ 1986)

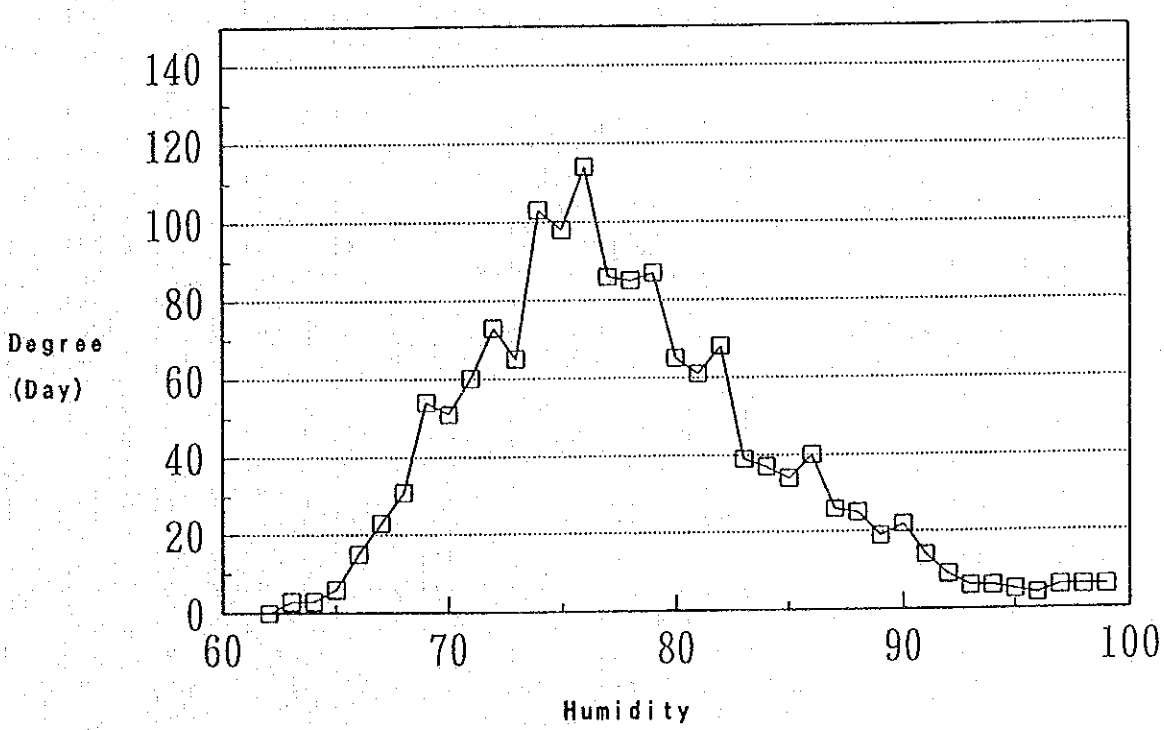


Fig.4.1-4: Distribution of Humidity
(1982 ~ 1986)

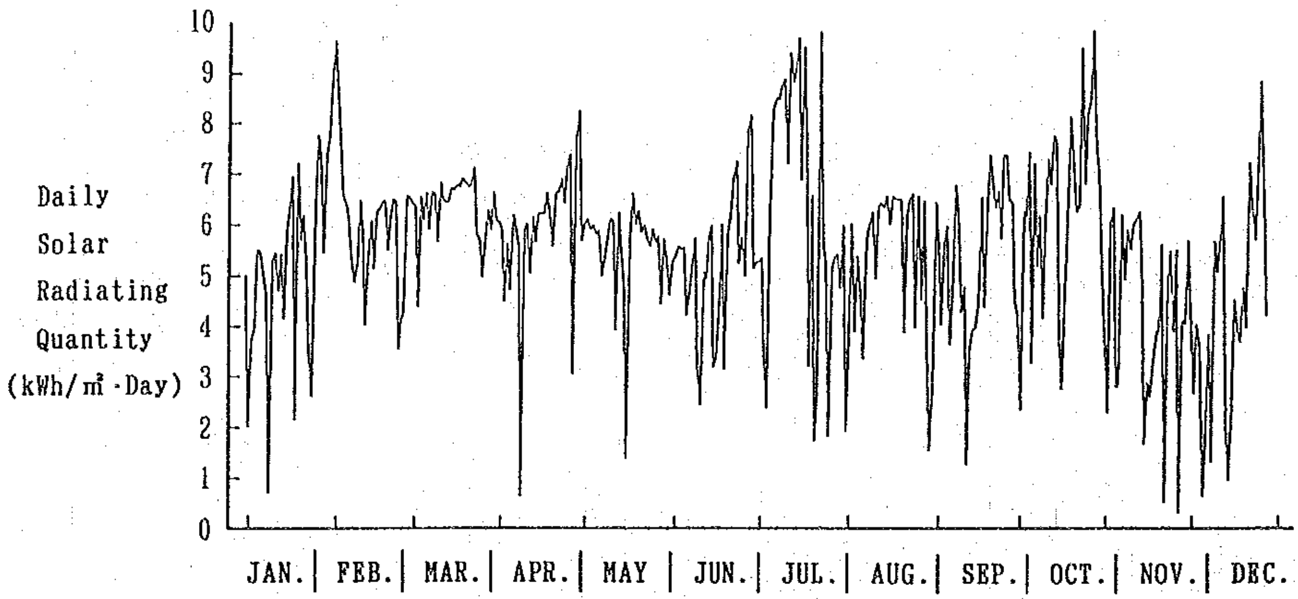


Fig. 4.1-5: Example of Changes in Daily Solar Radiating Quantity In One Year(1986) (kWh/m²·Day)

Table 4.1-2: SOLAR RADIATION VALUES FOR TARAWA 1986 (kWh/m²·Day)

	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.
1	5.01	9.64	6.41	6.06	6.01	5.29	5.28	5.42	6.51	6.54	7.56	0.30
2	2.01	8.68	6.36	5.86	6.12	5.36	5.29	5.43	3.55	6.50	7.19	4.16
3	3.69	7.62	4.38	4.50	5.88	5.59	5.38	4.77	1.55	4.54	5.26	4.09
4	3.95	6.57	6.54	5.64	6.00	5.52	3.50	6.01	2.76	4.24	3.84	5.78
5	5.50	6.42	6.08	4.69	5.80	5.55	2.38	1.93	6.49	2.35	2.29	4.35
6	5.48	6.18	6.62	6.20	5.88	4.22	6.30	3.80	5.65	6.32	6.12	2.69
7	5.04	5.34	5.90	5.95	4.99	4.66	8.28	6.05	4.06	6.22	6.41	4.08
8	4.59	4.80	8.64	5.54	5.38	5.29	8.54	3.92	5.69	7.49	2.79	3.65
9	0.70	5.23	6.58	0.63	5.75	5.76	8.49	5.40	6.02	3.30	2.87	0.63
10	5.31	6.47	5.66	5.97	6.11	3.19	8.76	4.68	3.66	7.27	6.27	1.69
11	5.45	6.87	6.82	6.02	6.09	2.42	8.90	3.36	4.65	5.23	4.98	3.87
12	4.69	4.01	6.47	5.04	9.92	5.08	7.23	5.73	6.82	6.23	5.97	1.30
13	5.42	5.34	6.44	6.16	6.25	4.94	9.42	5.99	6.27	4.18	5.58	5.75
14	4.14	6.07	6.45	5.66	5.48	5.79	8.85	6.28	4.31	5.18	6.06	5.13
15	5.82	5.13	6.73	6.22	4.70	6.00	9.07	4.97	4.80	7.36	6.20	5.80
16	6.26	6.30	6.69	6.22	1.37	3.19	9.72	6.34	1.26	6.85	6.35	6.65
17	6.95	6.30	6.78	6.23	5.77	3.37	6.91	6.48	3.55	7.83	4.87	2.05
18	2.15	6.45	6.75	6.63	6.63	4.51	9.55	6.37	3.97	7.77	1.65	0.94
19	7.21	6.45	6.92	6.16	6.00	6.02	7.62	6.59	3.97	3.74	2.90	2.37
20	5.69	5.49	6.84	5.56	6.30	3.14	3.21	6.04	4.49	2.76	2.61	4.59
21	6.19	6.13	6.75	6.63	5.85	5.82	6.61	6.59	6.58	4.75	3.33	3.95
22	5.13	6.50	6.79	6.64	6.00	6.26	1.72	6.54	4.42	6.57	3.88	3.71
23	3.50	6.43	7.13	6.91	5.72	6.97	—	6.54	6.52	8.19	3.99	4.83
24	2.61	3.52	6.80	6.41	5.58	7.28	—	6.52	7.44	7.45	5.69	4.01
25	6.30	4.11	5.70	7.25	5.92	5.25	—	3.90	6.78	6.32	0.50	7.34
26	7.77	4.26	4.95	7.40	5.64	5.78	2.64	6.21	6.38	6.44	0.19	6.50
27	7.34	6.56	5.73	3.04	5.77	5.01	9.83	6.57	6.73	9.54	4.99	5.79
28	5.45	6.52	6.28	7.68	4.43	7.90	5.63	6.65	5.77	6.87	5.55	7.35
29	7.39	—	5.88	8.26	5.73	8.19	5.25	3.98	7.44	8.25	3.93	8.97
30	7.73	—	5.63	5.68	5.27	5.16	1.81	6.61	7.42	8.54	5.58	6.51
31	8.78	—	6.04	—	4.61	—	5.15	4.55	—	9.89	—	4.26
AVE.	5.27	6.02	6.31	5.89	5.51	5.28	6.48	5.49	5.18	6.31	4.51	4.29

Table 4.1-3 Daily Solar Radiating Quantity in Kiribati (1980～1986)

	'80	'81	'82	'83	'84	'85	'86	Avarage
Jan.	6.57	5.17	6.45	5.57	5.64	5.41	5.27	5.58
Feb.	6.09	5.44	5.86	5.91	5.61	5.87	6.02	5.83
Mar.	5.23	4.97	6.82	6.10	6.10	5.62	6.31	5.88
Apr.	5.13	5.01	5.39	6.03	5.76	5.73	5.89	5.56
May	5.74	5.68	5.82	4.33	5.39	5.45	5.51	5.42
June	5.29	5.58	5.48	5.04	4.92	5.39	5.28	5.28
July	5.69	6.21	4.35	4.96	4.78	5.76	6.50	5.46
Aug.	5.35	6.83	5.02	5.62	5.36	5.80	5.49	6.64
Sep.	6.87	6.98	7.23	6.06	5.85	5.96	5.18	6.30
Oct.	6.56	6.73	5.57	6.02	5.84	5.89	6.31	6.12
Nov.	6.16	8.46	5.88	5.72	5.52	5.65	4.51	5.99
Dec.	5.04	5.56	5.92	5.43	5.53	4.92	4.29	5.24
Avarage	5.73	6.06	5.82	5.57	5.53	5.62	5.55	5.69

4.2 Design of the PV System

4.2.1 Design concepts

(1)Basic System Design

Fundamentally, the design of a PV system must result in a balance between the generation of electricity from the solar modules and the use of electricity at the load. Additionally, for best results the battery should not be discharged more than 50% of its capacity and 50% should be sufficient for about three days of electricity use.

A block diagram showing these relationships is shown in Fig 4.2.1-1.

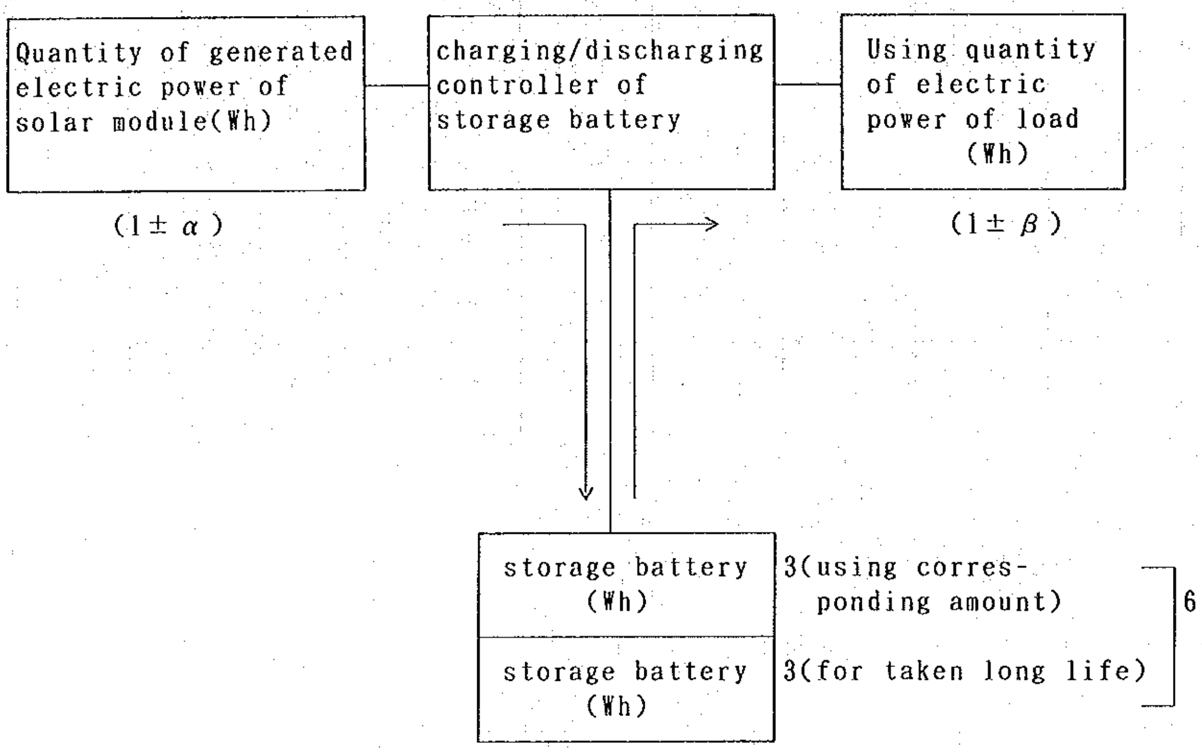


Fig 4.2.1-1 The System Block Diagram

The result is that the quantity electrical energy used per day is nearly equal the yearly average of generated electricity each day. In a practical sense, there are days with higher and days with lower than the average level of solar radiation($\pm\alpha$).

Also the actual use of electric energy is not the same each day as it is determined by the time of turning on and off the lamps($\pm\beta$). The PV system actually operates with an energy balance based on the use conditions and the solar radiation conditions.

During times when the storage battery is not fully charged and has surplus capacity, additional electricity from the modules can be stored. If the battery is fully charged, then additional electrical energy from the module is lost.

A battery with a total capacity twice the average use is chosen because of the longer life for the battery that results. Additionally, the solar radiation as measured in Kiribati was used to simulate the electric energy generation capability of this system and the charge/discharge rate of the battery.

The results showed very stable solar radiation quantity throughout the year and additional battery capacity was not considered necessary.

This state is shown in 「(6)Result of Simulation」.

(2)Requirements for Electric Light

The survey questionnaire shows that there is a demand for electric light in North Tarawa(see 「Social Impact Survey, e:Item on operation control).

However, there is no industry and little cash revenue so there is a concern that paying the necessary fees for the operation and maintenance of the PV system may be a burden.

After examining the issues with management of the SEC and considering the desires of the people of North Tarawa, it was decided to install PV lighting equipment in 55 homes and one Maneaba(Community Building).

To determine the proper level of illumination, an existing installation at the guest house on North Tarawa was checked since it was satisfactorily illuminated according to the local people.

The illumination at the guest house ranged from 20～100lux and a general target for the design was set at 100 lux.
(see the Measurement Result of Irradiance)

(3)Specifications for the Equipment and Materials

Specifications for the solar modules, storage battery, distribution board and wiring materials need to take into consideration the difficult environmental conditions such as ambient temperature and salt in the North Tarawa environment.

Specifically, equipment and wiring needs to be tightly sealed or coated.

Where steel is used, it needs to be hot dip plated with zinc and brass or stainless steel used where practical. Specification for the plating of steel is shown in Table 4.2.1-1.

Table 4.2.1-1 SPECIFICATION FOR PLATING OF STEEL USED FOR THE SOLAR MODULE MOUNTINGRACK

SPECIFCATION FOR PLATING OF STEEL USED FOR THE SOLAR MODULE MOUNTINGRACK
Where corrosion of steel materials is likely due to the presence of salt, a zinc plating type and thickness shown to be adequate in the long term for steel used for electrical distribution equipment placed in salty environme-nts in Japan.

1.Steel Plating Specification

JIS G3302 (steel plate or steel band plated with fused zinc) SGC 4000 or SCH 4000 shall bc used. Plating shall be Z45 and shall not be peeled by hammer-test.

2.Plating test

The test shall be made using the method stipulated in JIS H 0401(fused zinc plating test method)Rank SGC400.
Hammer test (peeling of plating)

---

(4)Operation Control, etc.

The Kiribati PV system shall be operated as shown below. Users will be educated in the proper use of the systems and proper maintenance and performance checks will be made regularly.

Operating control requirements is shown in Table 4.2.1-2.

Table 4.2.1-2 Operating Control Requirements

Item	Requirements
Control by the terminal voltage of the storage battery	While consideration the charge/discharge characteristics of the battery, the upper limit of 90% of change will be the terminal voltage limit. When the daytime charging of the battery reaches the voltage equivalent of 90% of full charge as measured by the terminal voltage. The charging current shall be stopped. For discharge conditions at night, if the terminal voltage falls to a level equivalent to 50% of charge, the load shall be disconnected and discharge stopped.
User education in system use	Users will be instructed to conserve the electricity by turning off lamps when not actually needed.(Generally, local people expect to use the lamps for 4~6 hours a day though longer use may be made on special days such as holidays and festival days. Such special days are expected to number about 20 per year.)
Battery Equalization	A uniform equalizing overcharge shall be made to the battery about once a month. Using a current less than 10(A), the battery shall be charged about 120%(one day in fine weather).

The above requiqments are based on the intent of keeping the PV system in stable operation and maximizing the life of the battery all which depend on the balance between the capacity of the solar modules, the capacity of storage battery and the load.

To keep this balance, users shall not use lights during the day and shall be restricted from adding additional appliances to the PV system.

The users of North Tarawa must understand the above point and cooperation was requested in order to extend the service life of the PV system.

Initially, it was planned to include a load timer to prevent light use during the day. The idea was dropped, however, because no product was available which could reliably work in the humidity and salt environment even though both the watch-type and photo-cell type are used in other places.

Without the timer, electricity can be used even in the daytime. To see the effect, a simulation was made on the use of the system and the influences of time of load was checked. The result indicates that a partial load can be operated about 12 hours but if usage extends beyond 12 hours, the system will have insufficient capacity.

It is therefore important to emphasize to the users that lights must not be left on when not needed.

(5)Control voltage

The basic concept of controller voltages for the charging/discharging of the storage battery is shown in Table 4.2.1-3.

Table 4.2.1-3 Control Voltage of Battery

Over-charge prevention voltages	Over-discharge prevention voltages
Cutout voltage: This is the voltage set to prevent overcharge but must be set high enough to prevent shortened battery life in the due to long periods at less than a fully charge.	Cutout voltage: This is the voltage which is used to prevent the over discharge of the battery. In particular this must take into consideration the slow discharge rate in the PV system and the adverse effect on the battery if a high enough cutout voltage is not used.
Reset voltage: This voltage is the level of voltage for re-establishing the charging current. It must be low enough so that the charging is not turned back on until some discharge has occurred or after a relatively long time in a static condition as indicated by the rate of voltage drop in the battery after charging ceases.	Reset voltage: This voltage is the level of voltage for reconnecting the load to the battery. It should be sufficiently high that the load is not reconnected unless some change has been placed in the battery asindicated by the characteristics of the battery voltage changed with charge.

Using the charge and discharge characteristics of the battery to be used and the characteristics of the solar module, the control voltages were selected as shown in Table 4.2.1-4.

Table 4.2.1-4 Voltage settings of the Charge-discharge Controller

①For houses with vented type batteries (Unit:V)

Charge control		Discharge control	
Charge cutout	15.6 (2.6)	Discharge cutout	11.4 (1.9)
Charge reset	12.6 (2.1)	Discharge reset	12.6 (2.1)

②For test houses with sealed batteries (Unit:V)

Charge control		Discharge control	
Charge cutout	14.4	Discharge cutout	10.5
Charge reset	-	Discharge reset	-

③For MANEABA (Unit:V)

Charge control		Discharge control	
Charge reset	31.2 (2.6)	Discharge reset	22.8 (1.9)
Charge reset	25.2 (2.1)	Discharge reset	25.2 (2.1)

(b)Calculation of the Solar Module Voltage

①Assumed condition

- Solar Capacity: 100(Wp) at a nominal 12(V) DC
- Brocking diode : used
- Cable used : VVF 2.6mm ϕ × 2 conductors
  - oAssumed cable length: 20(m)
  - oWire resistance: 3.35(Ω/km)
- Final battery terminal voltage: 15(V)
- Charging current : 8.33(A)
- Module temperature : 25℃(standard), 60℃(operating)
- Voltage drop for increasing temperature : - 0.4(%/℃)
- Voltage drop in Brocking diode : 6% of system voltage of 12V

Concept diagram is shown in Fig 4.2.1-2.

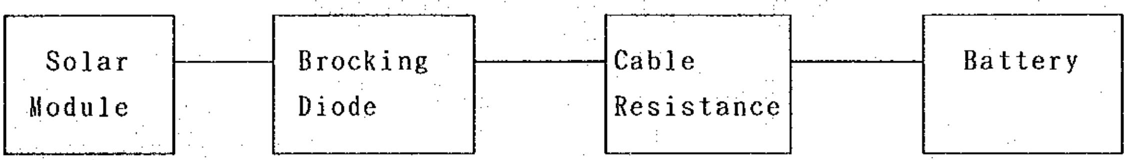


Fig. 4.2.1-2 Concept Diagram of Charging Circuit

②Results of the Calculation

Using the above assumptions the result of the calculation is shown in Table 4.2.1-5.

The voltage at the solar module must therefore be 19.6(V) for the battery voltage to be 15(V).

Table 4.2.1-5 Calculation Result

Battery Voltage	15(V)
Voltage Drop for Resistance	1.2(V)=0.134Ω*8.33(A)
Voltage Drop for Diode	0.72(V)=12(V)*0.06
Voltage Drop for Temperature	(15.0+1.2+0.72)/(1-0.14)
Operating Volt 19.6(V)	

(6)Simulation result

Using the measured solar radiation in Kiribati for the period 1980 - 1986, a system simulation was made for three load cases. The results are shown in Table 4.2.1-6 and 4.2.1-7(See the load-balance simulation).

Case 1 assumes lights used at night for 6 hours for the 11W light and 12 hours for both 7W lights. In case 2, all lights were assumed to be left on for the 12 night hours. In case 1, there is very little likelihood of a loss of power.

In Case2, for about 30 days a year, the available hours are less than 12 hours per day. Case3, assumes the lights are all left on continuously. The system cannot provide enough power for this case. It is therefore important to enforce the rule of not using any light in the daytime.

Table 4.2.1-6 Result of Simulation

Case	Massive Daylight	Average Daylight	Less Daylight
Case 1 Partially, lighting off earlier. 11W- 6h*1 7W-12h*2	◎	◎	○ No lighting in 2~3 day per year, about 3 hours per day. See the table below.
Case 2 Whole night lighting. 11W-12h*1 7W-12h*2	◎	◎	○ No lighting for about 5 hours, yearly several tens days, See the table below.
Case 3 Whole day lighting 11W-24h*1 7W-24h*2	○ No lighting for about 4hrs daily per year	△ No lighting for about 10 hrs, daily, per year.	× It is impossible to light all load,everyday, throughout the year.

Table 4.2.1-7 Days in each simulation year with inadequate power for the full period of lamp illumination.

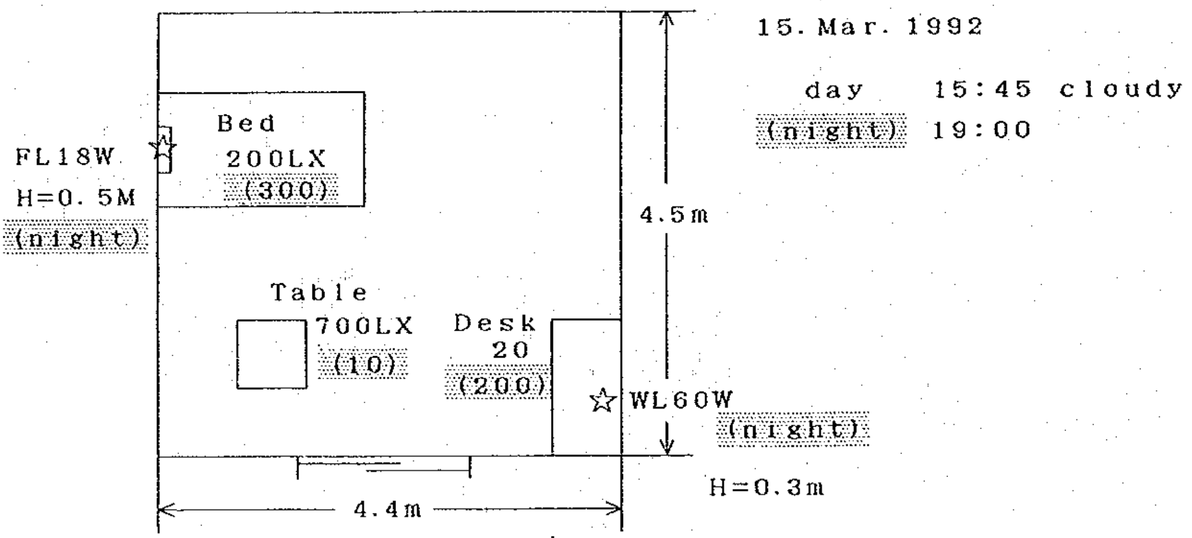
	1980	1981	1982	1983	1984	1985	1986
Case 1	7	1	3	4	0	0	9days
Case 2	41	27	41	35	24	15	64
Case 3	It is impossible to make lighting of all loads for 24hours a day.						

Result of Illumination Measurement

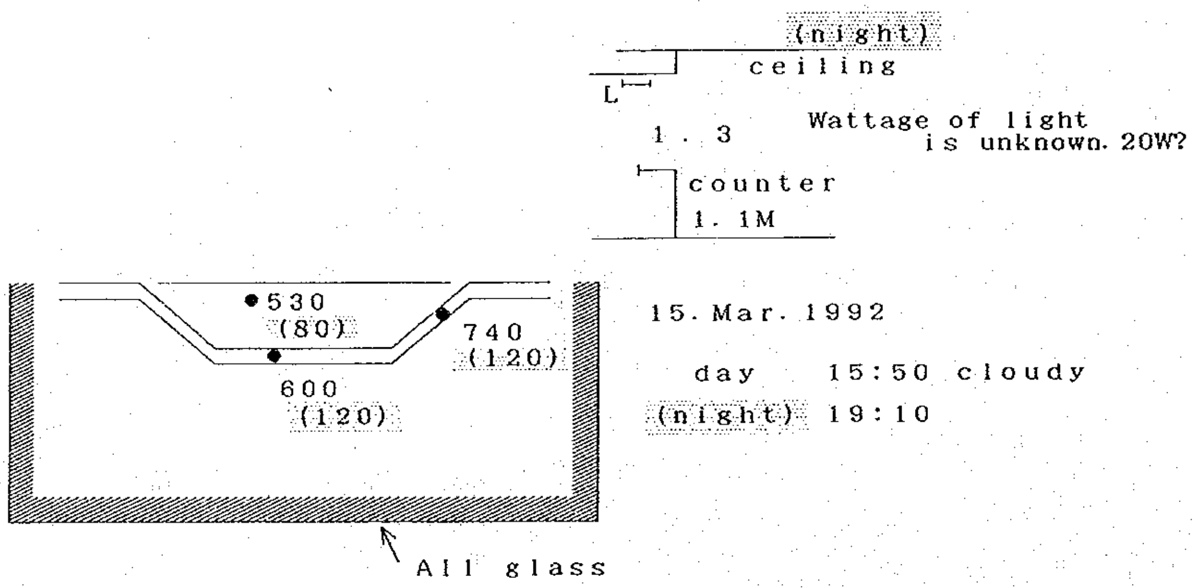
Measurement Date : 15.mar～18.mar.1992

1. Illumination of Hotel

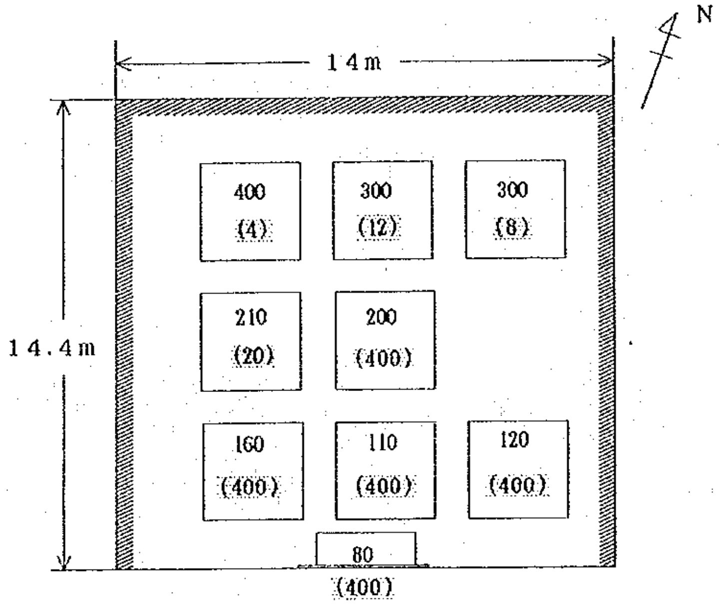
(1) Room



(2) Front



(3) Restaurant

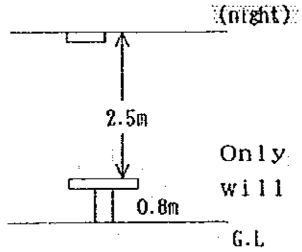


15. Mar. 1992

day 15:15 cloudy

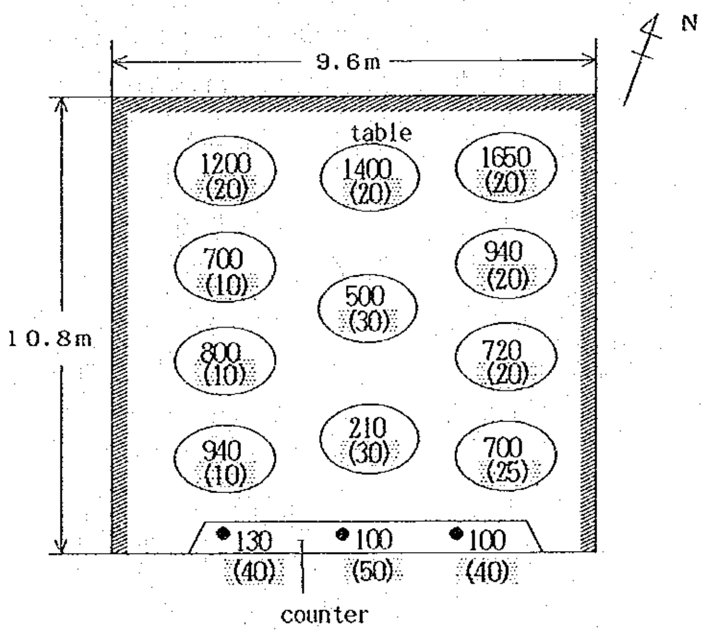
(night) 19:30

Lighting direction is irregular.



Only about 1/4 will light.

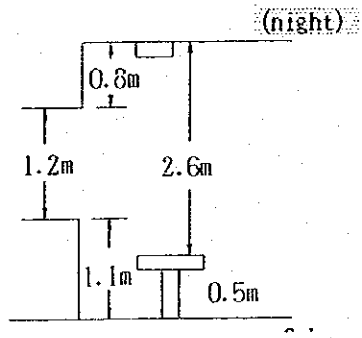
(4) Lounge Bar



15. Mar. 1992

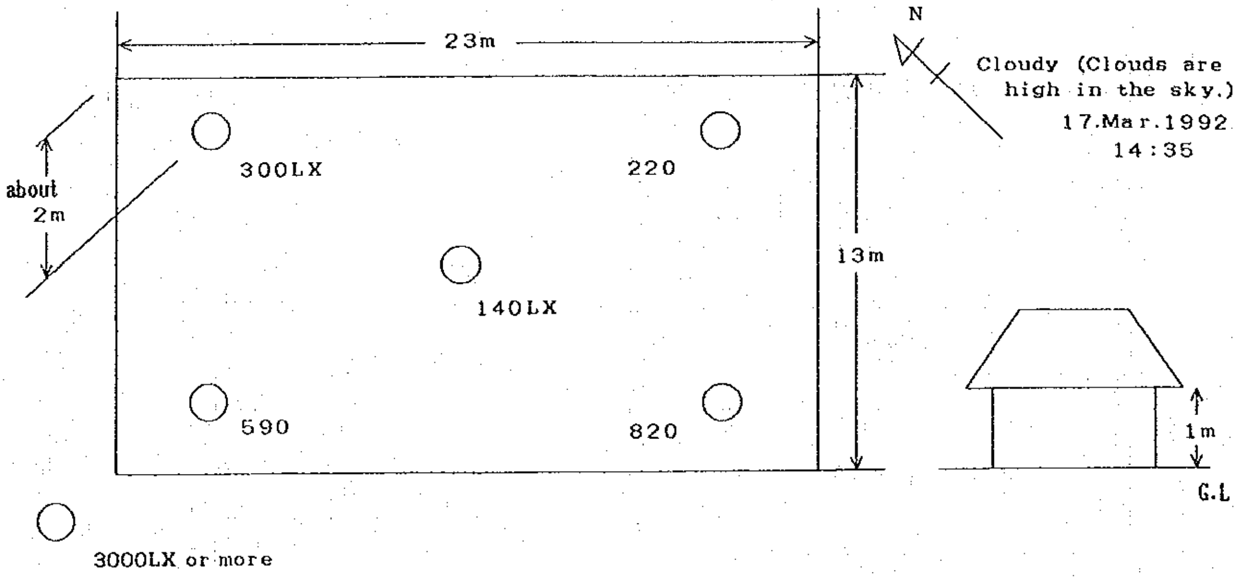
day 15:20 cloudy

(night) 19:30

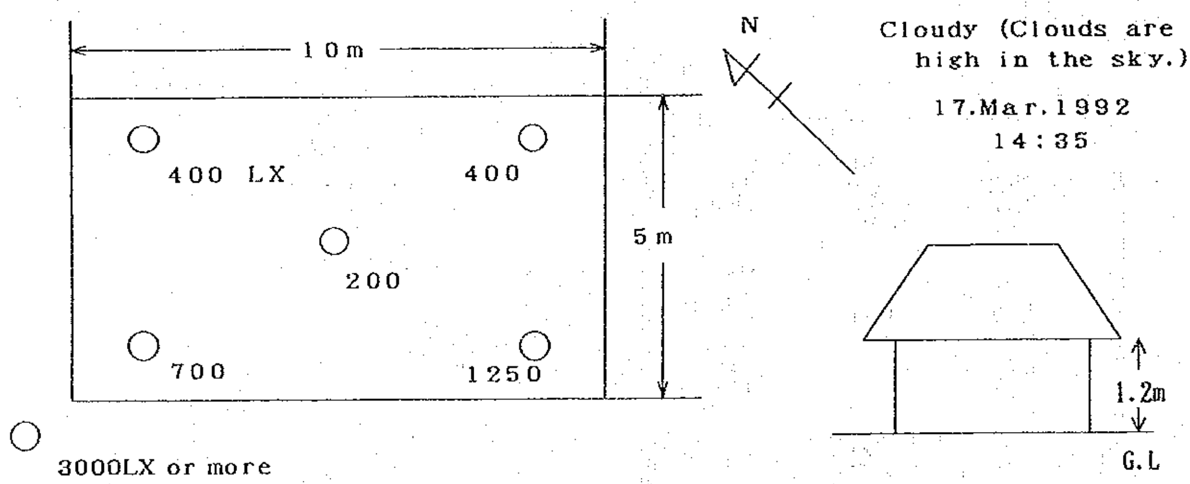


2. Illumination of Maneaba

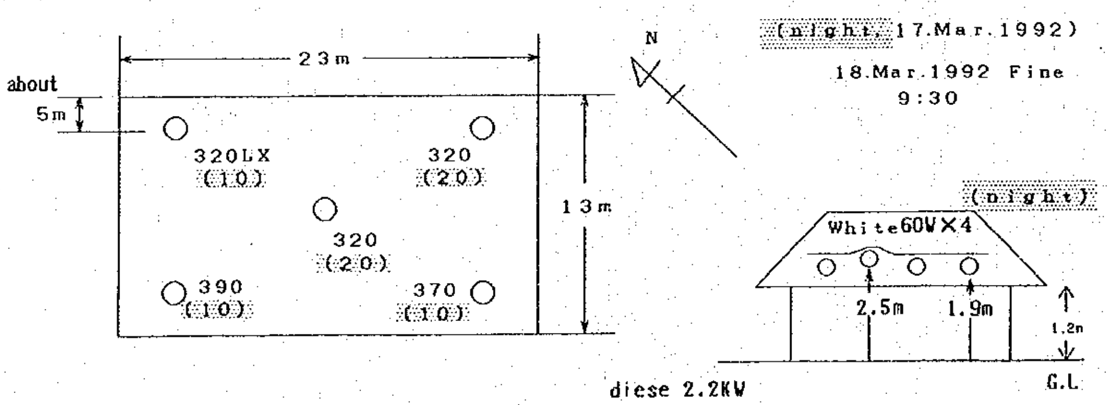
(1) Tabonibara 21peoples



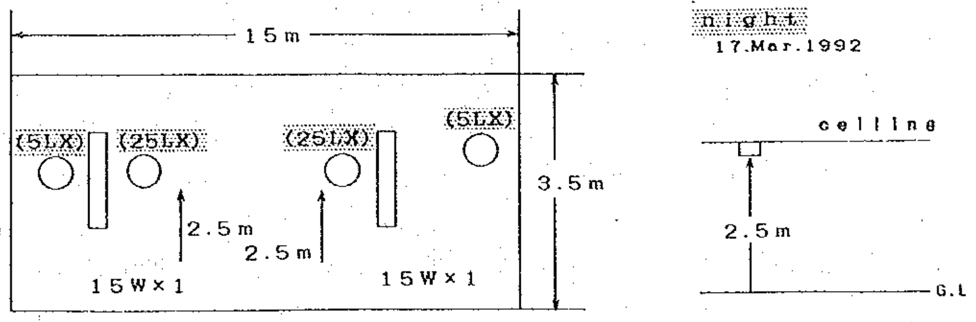
(2) Marenanuka 21peoples



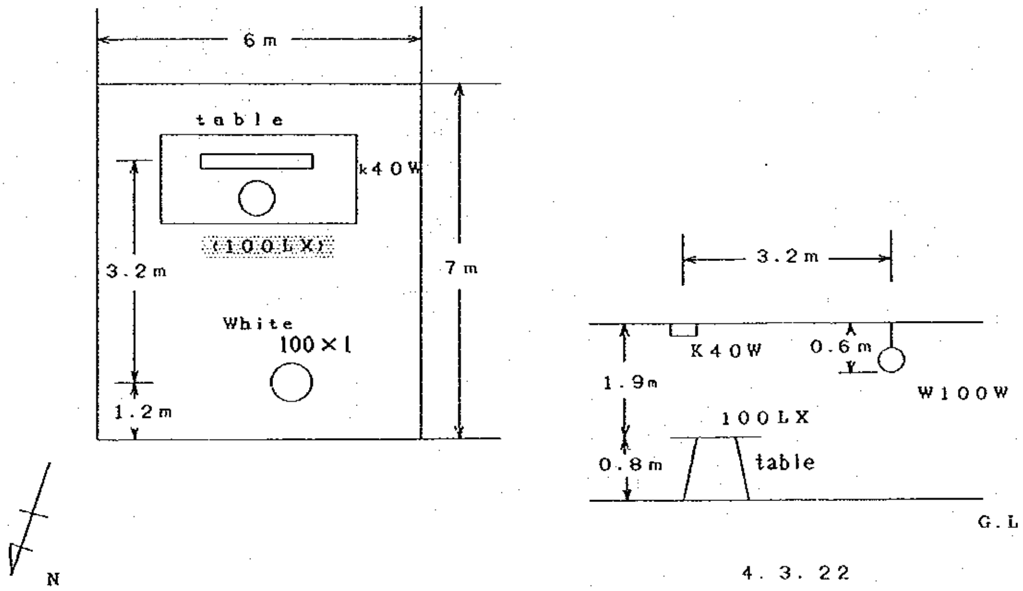
(3) Abaokoro 19peoples



3.Guest House (Abaokoro)



4.House of Mr.Wade (D.R)



<Tool of measurement>

HIOKI Lux Hi Tester 3421

HIOK 1980 NO.10125 JAPAN

4.2.2 Design as Executed

(1)Determination of lamp size and quantity

The result of survey asking about the needs for the electric lighting on North Tarawa was that most people expressed a desire to have electric light.

However, when asked about details of wattage of the lamps or there specific location, most people could not reply definitively. It was then decided to base the size and number of lamps on discussion with the local counterpart.

This situation is not surprising since the people have no prior knowledge of the use of electric lamps and find it hard to imagine. After the installation is complete and some time passes, they will be able to give detailed requests for the selection and placement of the lamps. The lamps selected for the houses and the Maneaba is shown in Table 4.2.2-1 and Table 4.2.2-2.

(a)Lamps to be installed

Table 4.2.2-1 Lamp for Houses (12V system)

Location	Number and size of lamp
Living room	11W×1, 1W×1
Sleeping room	7W×1
Dining room	7W×1

Table 4.2.2-2 Lamps for the Maneaba

Location	Number and size of lamp
Hall of Maneaba	(24V) 20W×4

(b)Room Arrangement of a Typical House

Room Arrangement of a Typical House is shown in Fig 4.2.2-1.

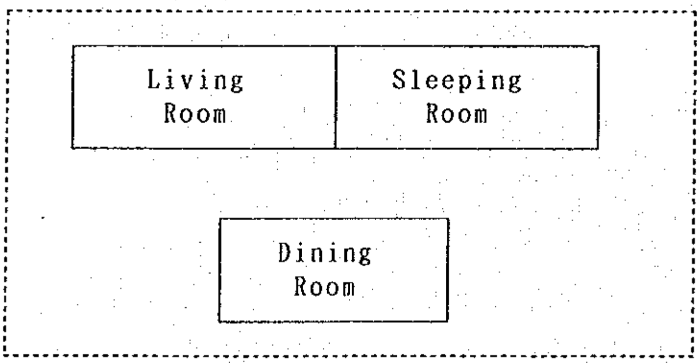
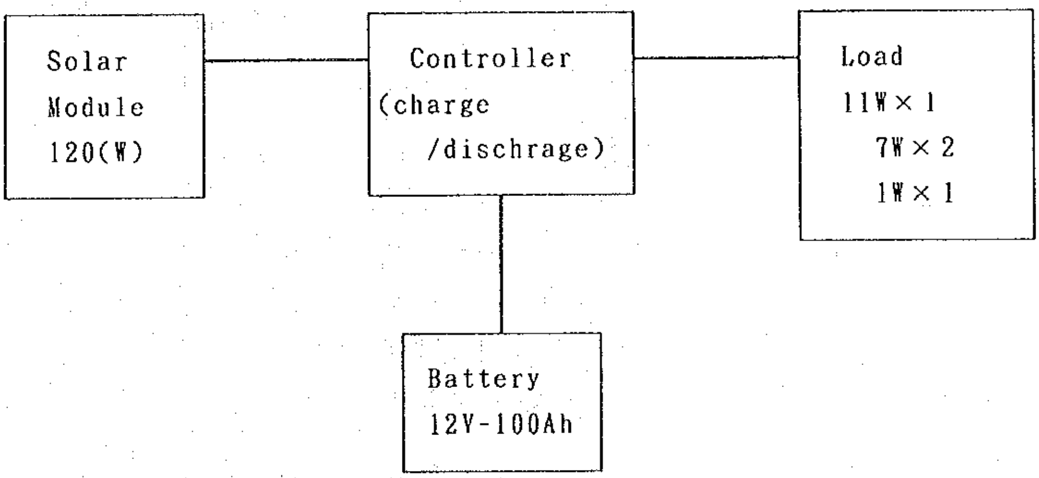


Fig 4.2.2-1 Room Arrangement of a Typical House

(2)Composition of The System

The system composition of general house and maneaba is shown in Fig 4.2.2-2.

(a)General House



(b)Maneaba

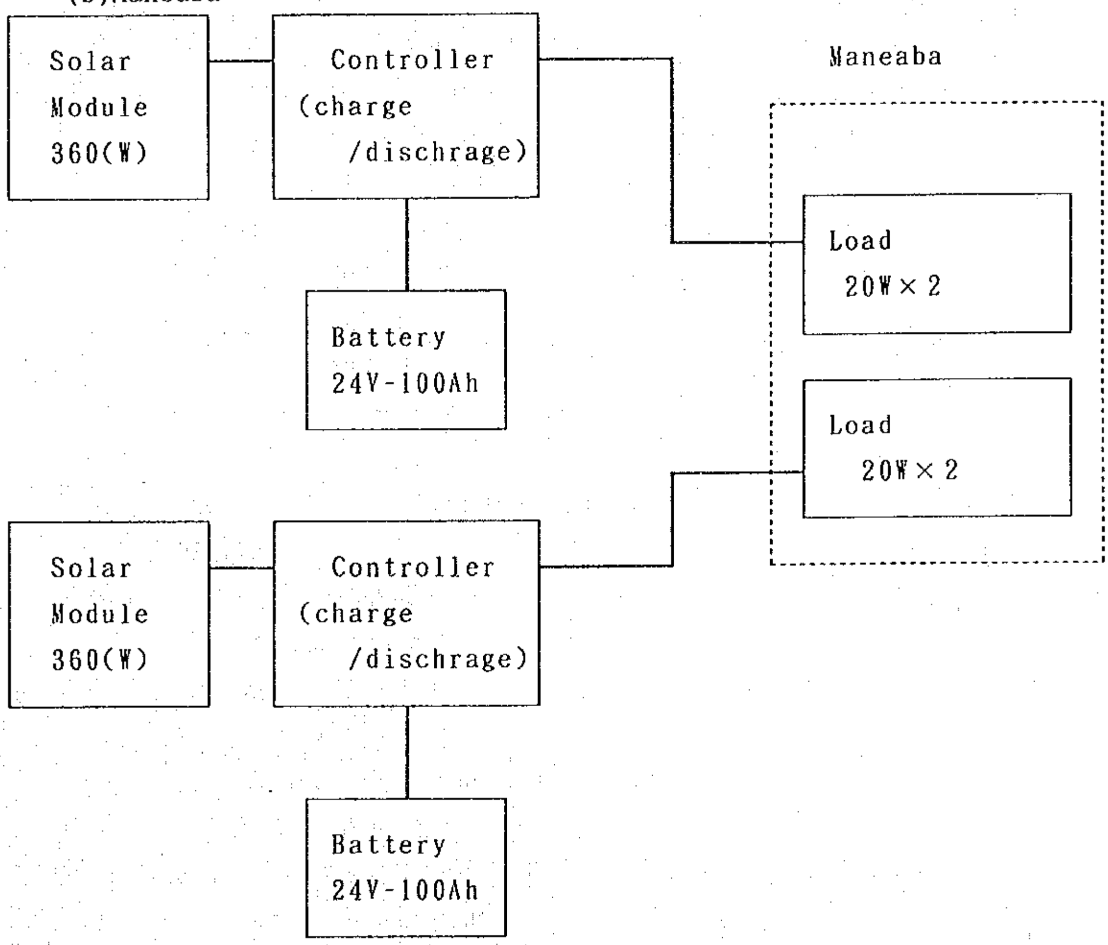


Fig 4.2.2-2 The System Composition of General House and Maneaba

(3)Control Voltage of Controller

Control voltage of controller is shown in Table 4.2.2-3～4.2.2-5.

Table 4.2.2-3 Controller for General House

(Unit:V)

Protection of Over-charge		Protection of Over-discharge	
Charge cutout	15.6	Discharge cutout	11.4
Charge reset	12.6	Discharge reset	12.6

Table 4.2.2-4 Controller for evaluating the General House

(Unit:V)

Protection of Over-charge		Protection of Over-discharge	
Charge cutout	14.1	Discharge cutout	10.75
Charge reset	-	Discharge reset	-

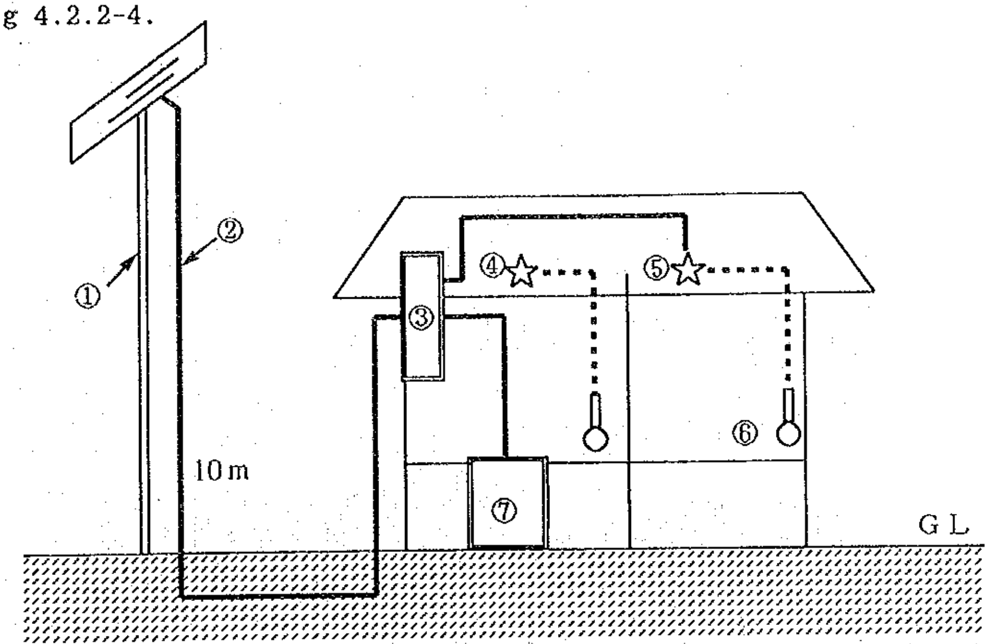
Table 4.2.2-5 Controller for Maneaba

(Unit:V)

Protection of Over-charge		Protection of Over-discharge	
Charge cutout	31.2	Discharge cutout	22.8
Charge reset	25.2	Discharge reset	25.2

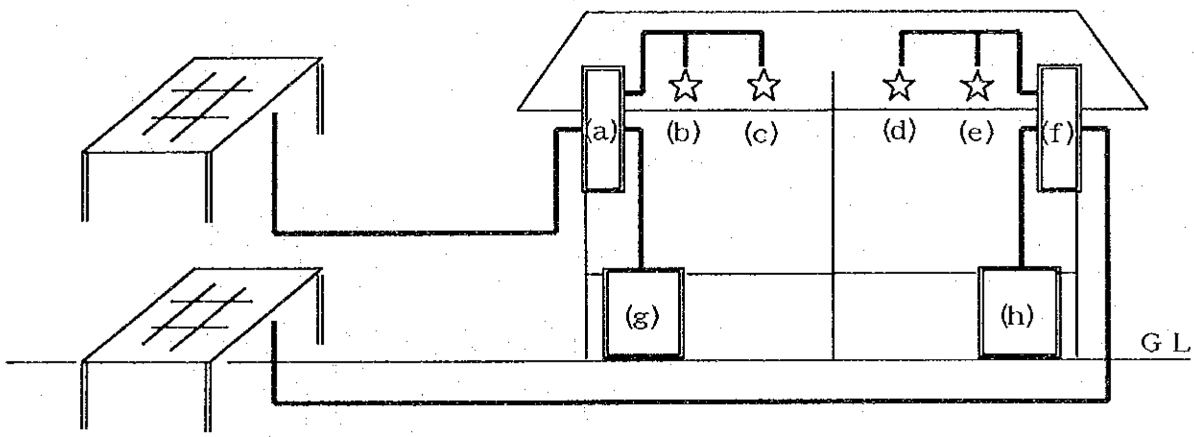
(4)Diagram of Solar system Wiring

The system wiring for general house and maneaba is shown in Fig 4.2.2-3 and Fig 4.2.2-4.



①Pole ②Electric wiring ③Controller/Distribution panel ④Fluorescent lamp ⑤Fluorescent lamp ⑥Switch ⑦Storage battery

Fig 4.2.2-3 The Image for General House



(a)Distribution panel	(b)Fluorescent lamp
(c)Fluorescent lamp	(d)Fluorescent lamp
(e)Fluorescent lamp	(f)Distribution panel
(g)Storage battery	(g)Storage battery

Fig 4.2.2-4 The Image for Maneaba

(5)Comparison of Module Mounting Method

Pole mounting of all modules, as diagrammed below, has been decided for the houses in Kiribati.

Firstly, the diagrams of the pole-mounting type and roof-setting type are shown in Fig 4.2.2-5 and Fig 4.2.2-6.

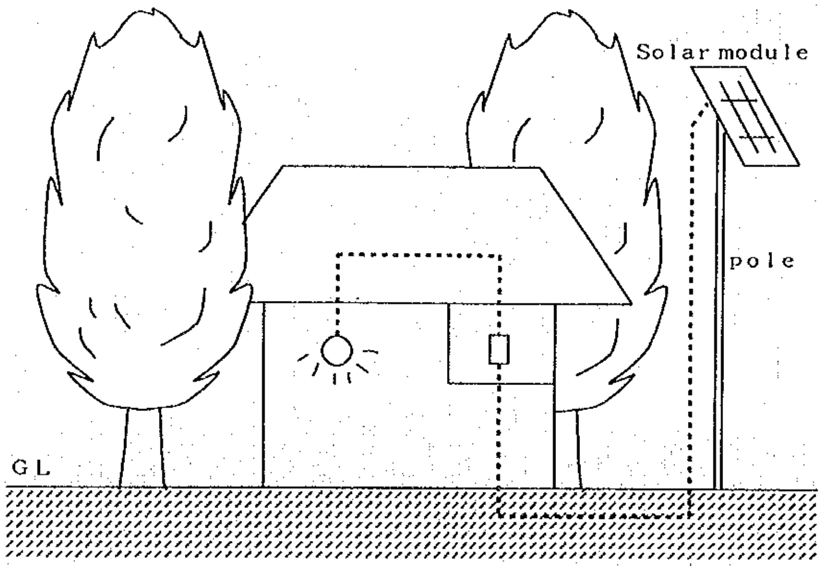


Fig 4.2.2-5 Diagram of Pole-mounting of modules

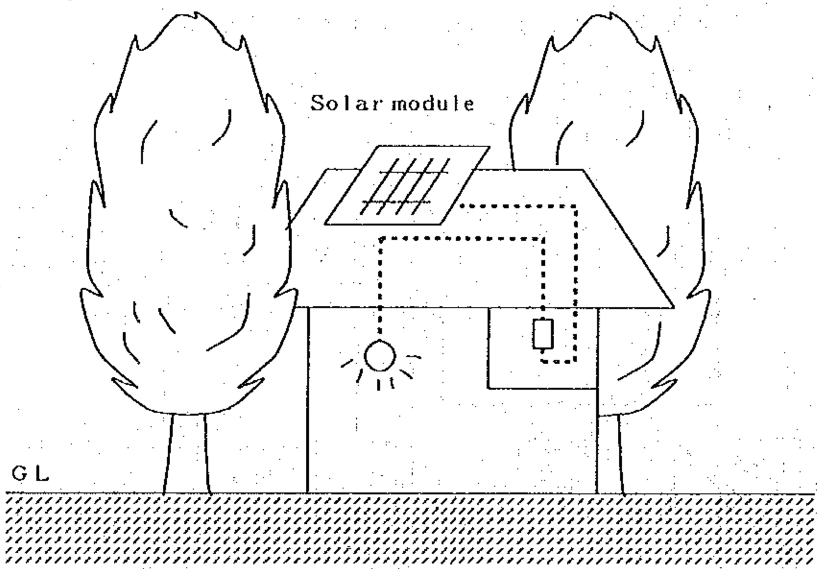


Fig 4.2.2-6 Diagram of Roof-setting of modules

(a)Living Environment in Kiribati and Customs Relating to Housing

Initially, both roof and pole mounted modules were considered for the final design and during the site surveys determined which type of mount was most appropriate for the site.

After talking with residents and other Kiribati people, we found the following:

1)Houses are generally built in the shade of coconut or breadfruit trees. While blue sky can be seen through the trees, there may be no direct sunshine during the day. In particular, the shade from breadfruit trees is very dense.

2)Houses are made simply and often moved. Also, the roof materials are woven leaves which last for up to about 5 years after which houses are often remodeled.
Even at the time of the site survey, persons stated that they intended to replace the roof or to move the house shortly and in fact this proved to be the case as found in later visits.

(b)Comparison of Setting Methods

In view of the above conditions of shade and the need to relatively frequently renew the roof of houses, it was decided not to install any systems on the roof of the houses though the initial investment will be higher for pole mountings.

In particular, if roof mounts are chosen, they may be many problems in determining who will move the modules, who will pay for moving the modules and who will pay for insuring that movement is properly done. With the limited resources available to the country, this cost may be very significant.

The result of comparison is shown in Table 4.2.2-6 and Table 4.2.2-7.

Table 4.2.2-6 Comparison of Setting Methods

Item	Pole Mounting Type	Roof Setting Type
Economic Efficiency of Construction	△ Expensive	○ Inexpensive
Aquision of Energy	○ Placefree·Much	△ Placefix·Few
Difficulty of Construction	△	○
Result of Construction	○	△
Maintenance	○ Simple·Free	△ Difficult
Overall	○	△

Table 4.2.2- Comparison of Construction Cost

(Unit:¥(Yen))

Item	Unit	Unit Price	Pole Mounting Type		Roof Setting Type	
Pole	ea	102,000	1	102,000	--	
PV Module Fitting	set	10,000	--	--	2	20,000
L-Support (Underground)	ea	1,350	1	1,350	--	
Cable	m	110	20	2,200	10	1,100
Protect Tube	ea	200	2	400	--	
Underground Protectsheet	ea	240	10	2,400	--	
Consumable Materials	ea	500	1	500	--	
(tape,saddle etc.)			--		2	1,000
Cost of Construction		2,000	2	4,000	2	4,000
Total				112,850		26,100

(6)Equipment and Materials

Using the results of the site survey carried out in June 1992, the quantity of materials and equipment necessary were calculated after designing the wiring for each house.

The materials and equipment are divided into those locally procured and those procured from Japan.

(a)Provided Materials

Required equipment and materials quantity of a share between internal and local procurement at the execution of the detail design is shown in Table 4.2.2-8 and Table 4.2.2-9.

Table 4.2.2-8 Required Quantity of Equipment and Materials as Internal Procurement

Item	Specification	Unit	Quantity
Solar Module	Monocrystal type 63.0[W]	pcs.	80
Solar Module	Polycrystal type 58.7[W]	pcs.	50
Pole mount (L=5[m]) for General House	Mount for two pieces of module	pcs.	55
Dead-end Pole	L=5.0[m]	pcs.	6
Above-ground mount for Maneaba	Mount for 4 pieces of module	set	3
Controller for Maneaba	DC24[V],300[W]	set	3
Controller for General House	DC12[V],100[W]	set	57

Storage battery	Vent type,DC12[V] 110[Ah](0.01C)	pcs.	63
Above-mentioned box	With a lock	pcs.	59
Measuring equipment for system evaluation	DC12[V],100[W] (Include battery)	set	2
Above-mentioned monitor		set	1
Non fuse breaker (For Maneaba)	DC24[V],20[A]	pcs.	2
Non fuse breaker (For General House)	DC12[V],10[A]	pcs.	58
Main switch (For Maneaba)	DC30[A] Double-cut type	pcs.	4
Main switch (For General House)	DC30[A] Double-cut type	pcs.	174
Cable	VVF 2.6mm X 2C	m	1,500
Cable	VVF 1.6mm X 2C	m	3,400
Cable	VVF 1.6mm X 3C	m	600
Cable	SV 1.6mm X 2C	m	390
Miscellaneous materials and consumable goods		set	1

Table 4.2.2-9 Required Quantity of Equipment and Materials as Local Procurement

Item	Specification	Unit	Quantity
Fluorescent lamp (For Maneaba)	DC24[V],20[W]	pcs.	5
Fluorescent lamp (For General House)	DC12[V],11[W]	pcs.	58
Fluorescent lamp (For General House)	DC12[V], 7[W]	pcs.	114
Lighting Facility (For General House)	DC12[V], 1[W]	pcs.	58
Lighting switch (For Maneaba)	DC24[V] 3way switch	pcs.	5
Lighting switch (For General House)	DC12[V] 3way switch	pcs.	116
Lighting switch (For Maneaba)	DC24[V] Single-cut type	pcs.	3
Lighting switch (For General House)	DC12[V] Single-cut type	pcs.	114

(b)Utilized Materials

Quantity of the principal equipment and materials which had been consumed by the PV system construction from January to February 1993 is shown in Table 4.2.2-10 and Table 4.2.2-11.

Table 4.2.2-10 Utilized Quantity of Equipment and Materials as Internal Procurement

Item	Specification	Unit	Quantity
Solar Module	Monocrystal type 63.0[W]	pcs.	76
Solar Module	Polycrystal type 58.7[W]	pcs.	46
Pole mount (L=5[m]) (For General House)	Mount for two pieces of module	pcs.	55
Above-ground mount (For Maneaba)	Mount for four pieces of module	set	3
Controller (For Maneaba)	DC24[V],300[W]	set	2
Controller for (For General House)	DC12[V],100[W]	set	55
Storage battery	Vent type,DC12[V] 110[Ah](0.01C)	pcs.	57
Above-mentioned box	With a lock	pcs.	59
Measuring equipment for system evaluation	DC12[V],100[W] (Include battery)	set	2
Above-mentioned monitor		set	1
Non fuse breaker (For Maneaba)	DC24[V],20[A]	pcs.	2

Non fuse breaker (For General House)	DC12[V],10[A]	pcs.	56
Main switch (For Maneaba)	DC30[A] Double-cut type	pcs.	4
Main switch (For General House)	DC30[A] Double-cut type	pcs.	166
Cable	VVF 2.6mm X 2C	m	1,100
Cable	VVF 1.6mm X 2C	m	2,400
Cable	VVF 1.6mm X 3C	m	500
Cable	SV 1.6mm X 2C	m	390
Miscellaneous materials and consumable goods		set	1

Table 4.2.2-11 Utilized Quantity of Equipment and Materials as Local Procurement

Item	Specification	Unit	Quantity
Fluorescent lamp (For Maneaba)	DC24[V],20[W]	pcs.	5
Fluorescent lamp (For General House)	DC12[V],11[W]	pcs.	58
Fluorescent lamp (For General House)	DC12[V], 7[W]	pcs.	114

Lighting facility (For General House)	DC12[V], 1[W]	pcs.	58
Lighting switch (For Maneaba)	DC24[V] 3 way switch	pcs.	5
Lighting switch (For General House)	DC12[V] 3 way switch	pcs.	116
Lighting switch (For Maneaba)	DC24[V] single-cut type	pcs.	3
Lighting switch (For General House)	DC12[V] single-cut type	pcs.	114

(c)Spare Parts

The type and quantity of equipment and materials to remain with the SEC as their initial spare parts stock is shown in Table 4.2.2-12.

Table 4.2.2-12. Spare Parts Quantity as Internal Procurement

Item	Specification	Unit	Quantity
Solar Module	Monocrystal type 63.0[W]	pcs.	4
Solar Module	Polycrystal type 58.7[W]	pcs.	4
Dead-end pole	L=5.0[m]	pcs.	6
Controller (For Maneaba)	DC24[V],300[W]	set	1

Controller (For General House)	DC12[V],100[W]	set	2
Storage battery	Vent type,DC12[V] 110[Ah](0.01C)	pcs.	6
Non fuse breaker (For General House)	DC12[V],10[A]	pcs.	2
Main switch (For General House)	DC30[A] Double-cut type	pcs.	8
Cable	VVF 2.6mm X 2C	m	400
Cable	VVF 1.6mm X 2C	m	1,000
Cable	VVF 1.6mm X 3C	m	100
Miscellaneous materials and consumable goods		set	1

(d)Considerations in Equipment and Material Source Selection

The actual materials used in the project were selected taking the following points into consideration:

1)The principal equipment are of Japanese origin which have had field experience and are high in performance. This includes the solar module, battery, and most other principal components.

It is stressed that the equipment selected must have demonstrated through field experience their satisfactory characteristics. However, if the same products are purchased to replace units which fail in the future, there are concerns that the cost will be greater than similar products available locally.

Therefore, it is assumed that replacement components from other sources may be used and it is necessary to assess those presently available.

2)Because of the nearness to the sea, heavy duty corrosion resistant materials had to be used.

The selection of proper materials was considered important. The PV system which was installed by SEC at the guest house two years earlier has considerable rust and a higher quality of corrosion is considered necessary.

On the other hand, excessively heavy materials, particular for the pole mount will cause problems with transportation due to their weight and the lack of heavy machinery for their transport and installation.

Therefore, the materials must be chosen with care to meet both the resistance to corrosion and remain acceptably light in weight.

3)Where possible, general materials should be purchased locally to ease future problems of maintenance and spare parts management.

When locally available materials are used, the local workers are familiar with them and is accustomed to handling these materials. This prevents problem of material shortages and allows the project to progress smoothly.

However, it is noted that many locally available materials have not been produced with adequate quality control, for example many of the new fluorescent light did not work right out of the box, it is important that the components be checked for proper operation before installation.

4.3 Selection of The Components and Materials to be installed

For the longest life of this solar power generation system, it is important to carefully select the components.

The following items have been selected based on past test results and the state of development of the components.

(1)General Items

Selection of the materials and components used based on the above mentioned design concept has been made by considering the following :

1)The design shall be as simple as possible.

2)Locally available materials shall be preferentially used.

3)All materials shall be protected against damage by salt(for instance, mold, plating, etc.).

4)The systems should be easy to assemble and install.

5)Lightning-arresting measures shall not be taken.

The reason is shown in Table 4.3-1.

Table 4.3-1 Reasons for Lightning-arresting Measures not being taken

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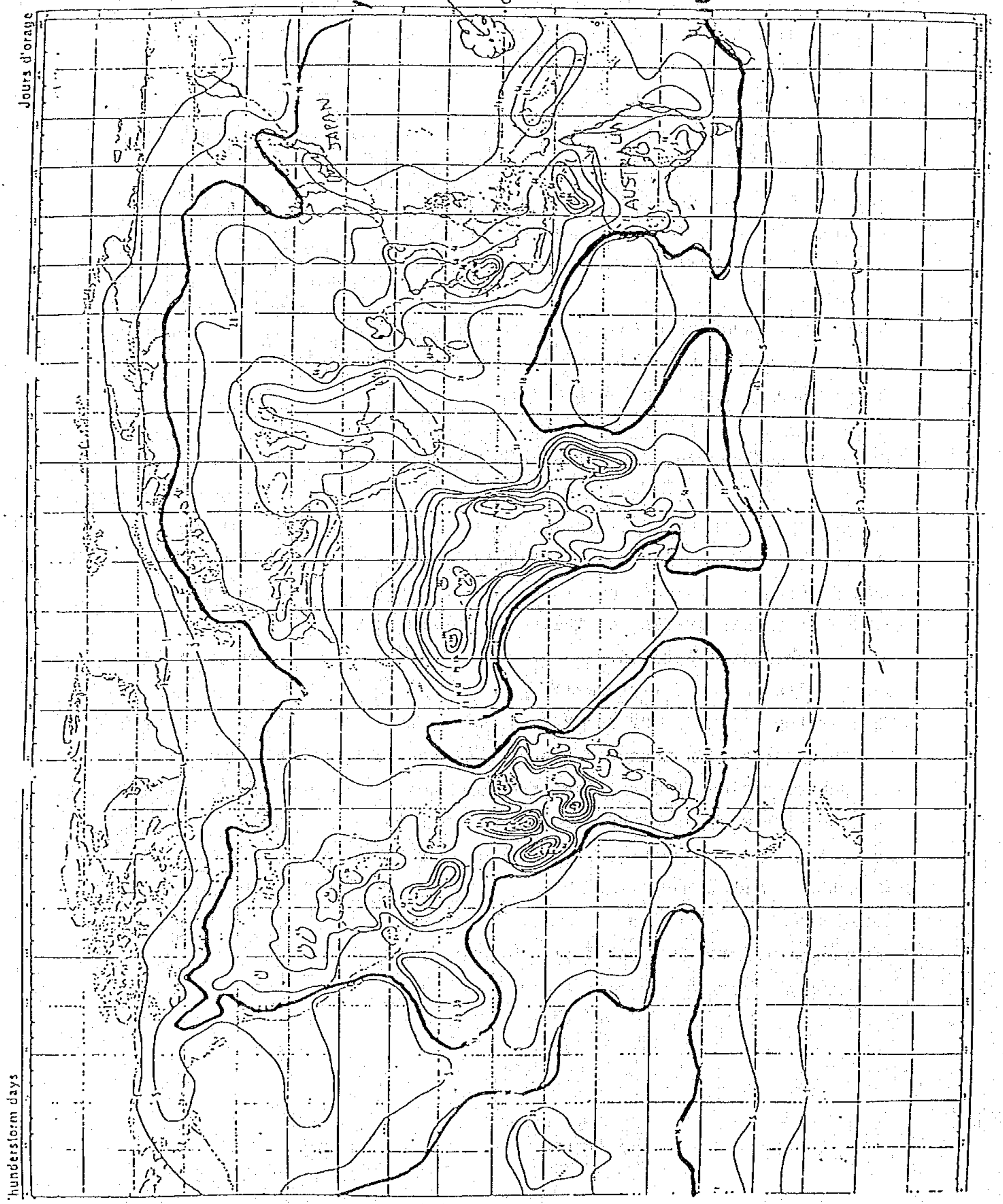
Reasons why lightning-arresting measures are not taken in Kiribati:

As a result of hearing the opinions of Mr.Wade, the staff of SEC and the local government, it was decided not to take any lightning-arresting measures for this system for the following reasons.

- Local lightning occurs only about once in several years, and even if it is occurs, its scale is very small.
- This system includes 12V and 24V circuits, thus, the effect of conventional lightning-arresting measures cannot be expected to be satisfactory.
- The deterioration of lightning arresting components due to high temperature and humidity may cause the occurrence of troubles.
- According to the Thunderstorm Days per Year in the world, Kiribati shows 10~20days, and macroscopically,the number is low compared to that of most other areas of the world.

(The Thunderstorm Days per Year is shown in Fig 4.3-1.)

Fig 4.3-1 INTERNATIONAL MAP OF THUNDERSTORM DAYS PER YEAR



(2)Detailed Selecting Reasons

Detailed selecting reasons of composing devices and materials are as follows.

Composing devices and Materials	Selecting reasons/results
1. Solar module Kyocera Shoseki	It was decided to purchase the solar module from domestic makers. Ten companies delivered their system to Saijo Solar Power Generation Plant. The unit were to be made in Japan having the following specifications. 1)Complaints from users shall be small due to the construction, operation and performance of the unit. 2)At present(1993), quality control is consistent and at least one year of manufacture has been completed without product change. 3)Tests shall be passed for output and dielectric strength. 4)The generating voltage shall be matched to the characteristics of battery voltage changes. See attached sheet 4.3-1 See attached sheet 4.3-2
2.Controller Made in Germany (purchased in Japan) Siemens	The Controller has been selected from 4 makers selling it in and out of Japan by considering the following items. 1)Basic specification on the control voltage shall be observed. 2)Kiribati is a coral reef island and is surrounded by sea. It rises 1~2m above the sea and is affected by abnormally high humidity and salt. In considering the controllers it was decided to adopt the product meeting the following specification.

	·Main contact points are provided with gold plating. ·Wiring on the board is coated. ·Products are already available in the market and are applicable for the above mentioned control voltage settings. See attached sheet 4.3-3 See attached sheet 4.3-4
3.Storage battery Made in Japan Furukawa Battery Inc.	The storage battery was selected from 4 makers in and out of Japan by considering the following items. 1)Adoption shall be made of the vented type cell as has shown favorable results in the NEDO project study. 2)The battery shall be warranted for 5 years of PV system operation. 3)The battery must have been successfully used for PV type application in other projects. 4)Two sets for evaluation shall be of the maintenance free type and not require the addition of water. Matching is made between the voltage of the solar module and changes of the state of terminal voltage with change of temperature and discharge or charge of the storage battery,and also, matching is made for the voltage control of the controller. Storage battery shall have a capability of 100Ah, and is to be operated with a discharging depth about 100~50%. See attached sheet 4.3-5
4.Pole Made in Japan Kyocera	The pole is made of steel coated with a fused zinc plating to prevent salt damage. Other materials made of steel will be coated with fused zinc in the specification Z45.

5.Electric Wiring Related items	Electric wiring was adopted in consideration of the measures needed to prevent salt-damage by specifying the following: 1)Wire core is made of solid wire to prevent salt water intrusion. 2)SV was adopted as the wiring classification to fit the air-tight round hole for the SW board, controller, and VVF was adopted for others. 3)The wire thickness was selected to keep voltage drops at as acceptable level. 4)Wire connection is made by clamping as much as possible, and the connection box is used. 5)For connection between the fluorescent lamp and the electric wire, a bis/screw-connector was adopted.
6.Fluorescent Lamp Made in New Zealand (purchased in Kiribati)	The fluorescent lamp adopted was provided with corrosion-preventing measures against humidity and against rust due to the salt, also using a coating on the board wiring of the ballast. In Japan, there was no lamp available for 12V, 24V DC. Thus, it is considered better to have the lamp available locally for the exchange of defective lamps. 1)11W-fluorescent lamp. 2) 7W-fluorescent lamp. 3) 1W-LED lamp. See attached sheet 4.3-6
7.Electric Instruments,etc. Made in foreign Countries	Electric components such as switches, etc used for the system are not to be manufactured in Japan. Those already available in Kiribati. Thus, it will be easy to purchase new ones locally, and the price is low. There fore, the following device and materials have been adopted for purchase locally.

Tape and saddles are purchased in Japan	In considering the weatherability of tape,plastic materials shall be black, and self-fusing tape and guard tape shall be used. Air tightness shall be provided for the components by using the self-fusing tape. Nails and saddles shall be made of copper or brass.

(3)Main Materials

Main Materials are shown in Table 4.3-2 and Table 4.3-3. Details are attached in Sheet NO 4.3-1~4.3-6.

Table 4.3-2 The Materials for General House

Materials	Unit	Number	Remarks
Solar Module	ea	2	100~200W
Pole Type (for 2 modules)	ea	1	4m
Controller	set	1	
Battery	set	1	100Ah
Fluorescent Lamp			
11W	ea	1	
7W	ea	2	
1W	ea	1	
No Fuse Breaker (circuit breaker)	ea	1	
Distribution Panel	set	1	

Table 4.3-3 The Materials for Maneaba

(40W*2system×2sets)

Materials	Unit	Number	Remarks
Solar Module	ea	12	600～720W
Mounting Type (for 4 modules)	set	3	
Controller	set	2	
Battery	set	4	100Ah/1set
Fluorescent Lamp 20W	ea	4	
No Fuse Breaker (circuit breaker)	ea	2	
Distribution Panel	set	2	

<Attached Sheet 4.3-1>

List of Solar Module Maker

	Name of Maker	Production Equipment	Remarks
1	Mitsubishi Electric	*	No exclusive Production line
2	Kyocera	○	
3	Komatsu Denshi	—	Production stopped
4	Sharp	△	Production stopped (Temporary)
5	Hoxan	△	
6	Toshiba	*	
7	ShowaShell Sekiyu	○	
8	Matsushita	△	
9	Fuji Electric	△	
10	Hitachi	*	

<Attached Sheet 4.3-2>

Characteristics of Solar Module

Item	Unit	KYOCERA	SHOSEKI
Output power	W	58.7	65.0
Working voltage	V	20.3	21.3
Working current	A	2.88	3.05
Open-circuit vol	V	25.4	26.8
Open-circuit cur	A	3.10	3.4
Efficiency	%	10.8	12.75
Max System Voltage 600V、Cell Temp. 25℃、Radiation Condition AM1.5, 1KW/m2			

KYOCERA Vo=20.3V(1-0.377%/℃*35deg)=17.6V

SHOSEKI Vo=21.3V(1-0.377%/℃*35deg)=18.5V

Characteristics of Storage Battery

For house(12CT-110)

at charge	0.1C→100%	2.6V*6=15.6V
at discharge	0.1C→ 50%	13V~11.0V

For test house(12CTE-120)

at charge	0.1C→100%	2.6V*6=15.6
at discharge	0.1C→ 50%	13V~11.0V

<Attached Sheet 4.3-3>

Controller

1.BP Solar (Unit:V)

Protection of Over-charge		Protection of Over-discharge	
Charge cutout	14.4	Discharge cutout	10.35
Charge reset	12.5	Discharge reset	13.1

2.Solar Energy (Unit:V)

Protection of Over-charge		Protection of Over-discharge	
Charge cutout	14.4	Discharge cutout	10.75
Charge reset	-	Discharge reset	-

3.Siemens (Unit:V)

Protection of Over-charge		Protection of Over-discharge	
Charge cutout	14.8	Discharge cutout	10.35
Charge reset	12.5	Discharge reset	12.5

4.Kyocera (Unit:V)

Protection of Over-charge		Protection of Over-discharge	
Charge cutout	15.0	Discharge cutout	11.4
Charge reset	13.5	Discharge reset	12.6

<Attached Sheet 4.3-4>

Voltage Charge-discharge Controller

(a)General House (Unit:V)

Protection of Over-charge		Protection of Over-discharge	
Charge cutout	15.6	Discharge cutout	11.4
Charge reset	12.6	Discharge reset	12.6

(b)For evaluating the General House (Unit:V)

Protection of Over-charge		Protection of Over-discharge	
Charge cutout	14.1	Discharge cutout	10.75
Charge reset	-	Discharge reset	-

(c)For Maneaba (Unit:V)

Protection of Over-charge		Protection of Over-discharge	
Charge cutout	31.2	Discharge cutout	22.8
Charge reset	25.2	Discharge reset	25.2

<Attached Sheet 4.3-5>

Battery Terminal Voltage Comparison Table of Each Maker

Maker & Type		Terminal Voltage at Discharge			Terminal Voltage at Charge		
		100% ↓	50% ↓	0% ↓	0% ↑	50% ↑	100% ↑
FURUKAWA	CSL Vent	2.01	1.975	1.80	1.975	2.16	2.80
	MSE Seal	2.06	2.02	1.80	*	2.17	2.76
	HS Vent	2.02	1.98	1.80	*	2.18	2.85
	Hyb-MF Seal (for Vehicle)	2.08	2.02	1.77	2.05	2.15	2.63
NIHON DENTI	SLB Vent	2.04	1.99	1.875	2.08	2.25	2.89
	MSE Seal	2.05	1.97	1.80	*	*	*
	SFK Vent	2.00	1.95	1.87	1.80	2.15	2.73
	HS Vent	1.92	1.89	1.80	*	*	*
	Vehicle Seal	Didn't have Charge/discharge characteristics.					
YUASA	SCS Vent	2.014	1.950	1.800	2.17	2.30	2.84
	Vehicle Seal	Didn't have Charge/discharge characteristics.					
BP Solar Vent		Didn't have Charge/discharge characteristics.					

<Attached Sheet 4.3-6>

Reasons for Local Purchase of Partial Miscellaneous Materials for Solar Power Generation System

For the purchase of fluorescent lamps and flashing switches, local purchase shall be made by the following reasons.

(1)DC12V-Fluorescent lamp (including the stabilizer) is not available in Japan.

(2)Switch for flashing is cheaper available locally.

(3)For exchange of it, it is easily available locally.

<for Reference>

*Fluorescent Lamp and Switch (as of June, 1992)

	Product Name	Domestic Product	Overseas Product	Remarks
Fluorescent Lamp	DC12V 11W	-	¥3,000	SEC handles it.
	DC12V 7W	-	¥3,000	SEC handles it.
	DC12V 1W	-	¥2,000	SEC handles it.
On/Off switch		¥900	¥750	SEC handles it.

*Cable

	Product	Domestic	Overseas	Remarks
Cable	2.6×3VVF	¥180 /m	¥250 /m	
	2.6×2VVF	¥110 /m	¥170 /m	

Electric wire VVF is purchased domestically.