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UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org

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STRENGTHENING THE TECHNOLOGICAL BASE OF MONGOLIAN PEOPLE'S REPUBLIC (MPR) STATE COMMITTEE FOR SCIENCE AND TECHNOLOGY FOR DESIGNING, PRODUCTION AND TESTING OF PROTOTYPES BASED ON SCIENTIFIC RESEARCH

ST/MON/82/T01

MONGOLIA

Technical report: Alternative energy sources*

Prepared for the Government of Mongolia

by the United Nations Industrial Development Organization,

acting as executing agency for the United Nations Development Programme

Based on the work of M. V. Vedernikov, expert in thermoelectricity

Backstopping officer: Yuri Gladilov
Engineering Industries Branch

United Nations Industrial Development Organization

Vienna

712

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ABBREVIATIONS

MPR	-	Mongolian People's Republic
(1)	-	Reference Number
SCST	-	State Committee for Science and Technology of the MPR
IPT	-	Institute for Physics and Technology of the Academy of Sciences of the MPR
SB	-	Solar Battery
TEG	-	Thermoelectric Generator
SEB	-	Special Engineering Bureau of the SCST

ABSTRACT

The project "Strengthening the Technological base of MPR State Committee for Science and Technology for Designing, Production and Testing of Prototypes based on Scientific research" ST/MON/82/001 has general aim to favour the development of a system for realization of scientific achievements for Mongolian agriculture and animal husbandry. Electric power supply for autonomous rural consumers by means of alternative energy sources is the most important direction of the project activity.

The duration of the mission is 2 months including stay in Ulan Bator (MPR) since 21/10 - 11/12/1985. Mission objectives are: Training of national personnel in thermoelectric energy conversion, situation analysis and consultations on development, manufacture and further progress of thermoelectric and photoelectric energy sources.

Main conclusions and recommendations:

1. Different alternative autonomous energy sources for small isolated rural consumers in MPR have to be used jointly, as a complex. It is necessary to include thermoelectric generators in the complex.

2. Special Engineering Bureau with design and manufacture divisions should be organized at MPR SCST for the quickest and wide introduction of new energy sources in Mongolian agriculture and animal husbandry. Special experimental center for practical assimilating of these sources should be organized too.

TABLE OF CONTENTS

INTRODUCTION

According to Job Description "ST/MON/82/T01/11-02/31.9.B one should understand under the term "prototype" photoelectric devices for direct conversion of solar energy in electrical one. These devices should be used in agriculture and animal hushandry as autonomous energy sources. After arrival to the duty station, the present expert has studied previous results of project ST/MON/82/T01 as well as UNDP project DP/MON/75/006 "Demonstration of New Sources of Energy in rural Development" and natural conditions of Mongolia. The expert and National Project Manager specified mission objectives and formulated a plan of expert activity in Mongolia, which is based on comprehensive analysis of the problem of autonomous energy sources and above-mentioned results. The most considerable aspect of the plan is that expert's activity is directed mainly at thermoelectric method of conversion of thermal energy in electrical one. This method has very good prospects with natural conditions of Mongolia. Nevertheless, it was not considered by previous experts.

Training of the national personnel in thermoelectric energy conversion method was an important part of the mission. There were formal training arrangements (lectures and seminars) as well as informal consultations in laboratories.

I. CONCLUSIONS AND RECOMMENDATIONS

1. The important work was performed in MPR earlier on analysis of natural factors that can be utilized for energy production by non-traditional methods. The main attention was paid to high intensity of solar radiation and possibility of the conversion of solar energy to electrical one by means of photoelectric solar batteries. It was not taken into consideration however that a long cold period is typical for climate of Mongolia. Heating of each yurt is absolutely necessary during this period (Ch. II, B).

2. Thermal energy of a domestic stove can be converted to electrical energy directly by means of thermoelectric generator. One should use TEG for electric power supply of isolated rural consumers at natural conditions of Mongolia together with other alternative energy sources (Ch. III; Ch. IV, A).

3. Since thermoelectric method of energy conversion lags behind in Mongolia, one should pay an additional attention to it now (Ch. IV, B).

4. R & D stage of prototypes of alternative energy sources for application in agriculture and animal husbandry of MPR is almost completed. Realization of commercial production of solar batteries, wind and solar heat storage arrangements, thermoelectric generators is becoming a primary problem now. So it is expedient to create Special Engineering Bureau at SCST MPR including designing and production divisions (Ch. V, B).

5. Still before a commercial production of alternative energy sources it would be rational to organize Special Experimental Center for their practical application. If the center will acquaint future consumers with new sources and train them in application of these arrangements, it will help to introduce new energy sources in agriculture of Mongolia as soon as possible (Ch. V, C).

6. A participation in the creation of Special Engineering Bureau can be recommended as subject of a new UNIDO project for MPR. Taking into consideration peculiarities of the activity the duration of this project should be not less than 3 years (Ch, V, D).

II. ADDITIONAL ANALYSIS OF POSSIBILITIES OF INDEPENDENT ELECTRIC POWER SUPPLY AT NATURAL CONDITIONS OF MONGOLIA.

A. General Considerations

In the course of the project DP/MON/75/006 a lot of work was performed for data collection and analysis of natural conditions of Mongolia which could be used for creation of autonomous energy sources (2,3,4). The main conclusion was at solar radiation intensity and duration are very large and there are hence very good conditions for the utilization of photoelectric solar batteries as autonomous sources of electric power. It was also indicated that rather dry and cold climate of Mongolia increases the effectiveness of SB in comparison with hot and humid tropical and sub-tropical areas where one supposes to use SB usually. Experts of DP/MON/75/006 recommend to use wind energy and directly solar heat too. The first phase of ST/MON/82/T01 has its main objective to perform a preparation work for organization of Special Engineering Bureau at SCST MPR in order to introduce new prototypes in manufacturing process as soon as possible. Taking into consideration above recommendations, designing and manufacturing of SB should be among main tasks of the SEB. It would be helpful however to amplify it with some considerations about natural conditions analysis as well as about SEB's work direction. These considerations are given in this chapter.

B. Thermoelectric Energy conversion in Mongolia conditions

The analysis of natural conditions performed earlier does not include one important aspect. If high solar radiation is typical for Mongolia so long cold period of the year with short days is typical too. Absolute condition of the vital activity during this period is heating of a dwelling and it is heating by means of individual stove everywhere in remote areas. Thermoelectric generator is a device for direct conversion of thermal energy (heat of domestic stove) in electric one. Therefore TEG is the most natural source of electric power during long cold period for such isolated consumer as the yurt of a Mongolian cattle breeder. It is a pretty stable source of energy during winter time, when the people in the remote areas permanently use their domestic stove to heat their yurts.

According to the report of the Chief Technical Adviser of DP/MON/75/006 V.P. Murugov (2, p.p.15, 17 and 19) one of the main objectives of the project was: "To determine rational technical means for energy supply of small agricultural elements based on new and renewable energy sources". It was proposed to "investigate the possibility of using TEG (by burning of firewood) in forest-steppe region with the help of an international expert". Then however this programme was differed due to organization reason. The present mission solves this problem partly. The conclusion is that there is no need to limit the use of TEG only in the forest steppe region of this country.

C. Complex use of alternative energy sources

Continuous electric power supply of high reliability can be ensured at present by traditional energy sources only. All alternative sources have principal limitations: Solar radiation depends on time, season and on weather; wind energy is often affected by the changing of intensity. For practical use we have to combine these variations. One can chose a method of using an accumulator, but it is not always convenient. That is why one recommends to use jointly two or more alternative energy sources. Some experts of project DP/MON/75/006 and ST/MON/82/T01 suggest, for example, to use solar and wind energy in one complex (2, 5). This is a conclusion of high importance. It is clear however from preceeding text that the reliability of such complex would be significantly higher if it would be added by a thermoelectric generator with heating stove too.

III. THERMOELECTRIC GENERATORS: TECHNICAL POSSIBILITIES

The last 30 years semiconductor TEG has had significant development and now various applications as autonomous sources of electric power are carried out for space instruments and meteorological stations in the arctic, for transcontinental gas pipelines and microwave radio links, for starting car engines at low temperatures, for tourist and mountaineer groups. Many books deal with this problem and there is no necessity to repeat general material here. Technical possibilities of TEG are discussed in this chapter in connection with demands of application in agriculture animal husbandry in Mongolia.

Thermoelement is the main part of TEG. It is made of two different semi-conductor legs which are mechanically and electrically connected by commutation metallic stripe. Free ends of legs are switched in the load circuit. If the junction (i.e. the commutation stripe) of the thermoelement gets warm and its temperature is higher than temperature of free ends, then electromotive force (thermo - e.m.f.) will arise in the thermoelement and electrical current will flow in the load circuit. The thermoelement converts thermal energy, which has flowed from its hot junction to cold one, in electrical energy without any intermediate process or arrangement. For high efficiency of conversion we should maintain the largest permissible temperature difference between hot and cold junctions as well as use semi-conductor materials of high thermoelectric figure of merit for thermo-element legs. Modern thermoelectric materials develop thermo e.m.f. about 200.10^{-6}V per 1^{o} of temperature difference. At difference 300^{o} on the thermo-element it will develop e.m.f. 6.10^{-2}V. In order to obtain necessary values of voltage and current, thermoelements are connected in thermoelectric batteries. TEG is assembled from such batteries.

TEG is a solid state device without any moving parts. This is the reason why it has high reliability and does not need any maintenance. Service life reaches 10-20 years.

At present TEG's are produced with power output ranging from a fraction of watt up to few hundred watts. There are power stations containing few TEG's of total power up to few kilowatts.

TEG can work together with heat source of any type if it can provide nominal thermal regime for TEG. At present there are thermoelectric materials (semi-conductor materials for legs of the thermoelement) with the higher figure of merit for different temperature grades. They are divided on low temperature (0-300^{o} C), middle - temperature (300-700^{o} C) and high - temperature (above 700^{o} C) materials. Low - temperature materials have the highest efficiency at the same temperature difference. They are ternary alloys of bismuth, tellurium and antimony (Pseudobinary solid solution $Bi_2\ Te_3 - Sb_2\ Te_3$).

IV. THERMOELECTRIC GENERATORS: APPLICATION IN MONGOLIA

A. Expediency of inclusion of TEG in an alternative energy sources complex for agriculture of Mongolia

The contents of Chapter II shows that objective conditions of Mongolia allow wide application of TEG's. It is also indicated that the presence of TEG would increase significantly the reliability of an autonomous complex of alternative energy sources. Different factors, determing the expedient way of application of TEG's in Mongolia, are analysed in detail in this chapter, based on the technical possibilities of TEG (Chapter III).

Local conditions of Mongolia enable a practical link between TEG and solid fuel-stoves (firewood and other types of fuel used in different regions). As we know, there is no solid fuel - TEG link in the whold world at present. This does not mean however that there are any principal difficulties for development of a new variant of TEG. It is necessary to optimize mutually the generator and the stove. A possibility of development of solid fuel - TEG link was discussed in the USSR and the conclusion of the experts was positive about generator of 25-30 W power.

Domestic stoves have such thermal parameters that TEG could be operated at temperatures ranging from room temperature up to few hundred degrees. It is the most favourable temperature for thermoelectric conversion because low-temperature thermoelectric materials must be utilized. This group is the most effective among other thermoelectric materials.

A development of autonomous source of small power (10-20W) for one yurt is at present the main interest of the electrical supply programme. There is however a problem of supply of a larger rural elements. Therefore, TEG's have good prospects for such case since TEG's on organic fuel of few hundred watts power are produced now.

When one will come to a decision on application of TEG's in Mongolia, it will be interesting to know about a possibility of independent manufacturing in the country. Process of TEG's manufacturing does not require any very complicated or specific stages, so it can be performed in Mongolia. There are additional favourable circumstances. First, there are a few physicists available here, who have sufficient knowledge in scientific and technological aspects of thermoelectricity. Second, Mongolia is rich in polymetallic ores but they are not sufficiently explored. One may hope to find in the future ores containing such components of thermoelectric compounds as bismuth, tellurium, lead, selenium, antimony.

One should not be in hyperbolical hopes of TEG merits. Naturally, there are factors limiting their application. The main limitation is rather low efficiency of energy conversion, i.eg. TEG can be highly convenient in technical sense but not applicable from economic point of view. In situation under consideration however this objection is not valid because heating of yurt is necessary by itself.

If all factors are analysed, one can decide with confidence that thermoelectric generators should be introduced in the complex of alternative energy sources for supply of autonomous rural consumers in Mongolia without any doubt of the leading position of solar batteries.

B. Immediate arrangements for development of thermoelectric energy conversion in Mongolia

1. It is necessary to have a group of specialists in the country who have sufficient knowledge in thermoelectric conversion technology. They can perform some developments, prepare technical specifications and other documentation, select special equipment, advise state organizations of MPR. One should supply the group by modern equipment for synthesis of thermoelectric materials as well as for thermoelectric measurements. The list of the equipmentis enclosed as Annex 1. All these are comparatively simple equipment. It is rational to have such group in IPT.

2. In order to obtain modern level of knowledge and technology the thermoelectric group has to be in contact with appropriate foreign organizations. There are thermoelectric Researches and Developments in the USSR, Romania, France. Physical-Technical Institute A.F. Ioffe, of the Academy of Sciences of the USSR in Leningrad could receive Mongolian specialists for training and fellowship as well as send Soviet Scientists to Mongolia to render consultancy services.

3. To accelerate thermoelectric activity it would be expedient to order abroad a design of a first solid fuel - TEG and manufacturing of a few experimental prototypes. It is known that such an order can be placed to the USSR Via V/O "Vneshtechnica".

V. THE LEVEL OF ALTERNATIVE ENERGY SOURCES FOR AGRICULTURE ACHIEVED IN MONGOLIA AND PRESSING PROBLEMS OF THEIR PRODUCTION

A. The Level Achieved

Up to date a lot of work has been performed in MPR on investigation of alternative methods of energy production of solar batteries, wind aggregates and solar heat storage devices. There are now groups of competent specialists in each of these fields which have developed prototypes of corresponding arrangements. This fact is of very great importance.

Few prototypes were tested successfully. Progress in development of SB seems as the most successful. During the course of this mission a calculation analysis was made of a pay-back of investment in small scale commercial productionof SB in Mongolia. UNIDO developed programme COMFAR 1.1 was used for these calculations by IPT people together with UNIDO experts on computer. The calculation is performed for an annual production of SB of total power 15 KW and 150 KW. The result is presented in Annex 2.

Rational value for the power of single SB is 6W. At accounting retail price about 700 tughriks the investment will pay for itself within 5-7 years (for both versions). Such retail price is acceptable for Mongolia. Such a result justifies a transition to commercial production of SB. Taking into account the technical level of SB design as well as the necessity of purchase of foreign accumulator batteries and other components for SB, one should recommend to prepare the production of 15 KW per year.

There are of course some unsolved problems on the stage of experimental developments, two of that are the following: First preliminary work on thermoelectric generators is very inadequate. Second special efforts should be made in order to get the equipment for manufacturing of silicon elements of SB in IPT. The forthcoming mission of 2 Scientists of IPT in India should be exploited with maximum effectiveness for achieving this objective. It is important to start a small-scale production of new energy sources in Mongolia.

B. Creation of Special Engineering Bureau at SCST

There is no organization or plant in Mongolia which could carry out designing and production activities of new and comparatively complicated components or devices developed in research institutes of the country. Workshops of these institutes can only construct prototypes. That's why it is expedient to establish a Special Engineering Bureau at State Committee for Science and Technology including design and production devisions. It will develop a full technical documentation for prototypes and produce under this documentation limited quantity of solar batteries, wind and solar heat storage devices as well as thermoelectric generators in the future. In the first place the capacity should be created for performance of the most labour consuming works: metal working, electric wiring and so on. It would be more expedient to continue to perform some special operations in research institutes, for example, development of semiconductor crystals for SB or synthesis of semiconductor compounds for TEG.

If future activity of SEB is planned, it would be helpful to discuss a possibility of works on automation and electronics. Another important point is a production in Mongolia of chemical accumulator batteries which are necessary to complete some alternative energy sources. An international expert can be invited to discuss a possibility of such production.

C. Strategy of Practical Assimilating of New Sources of energy supply. Creation of Special Experimental Center.

The ultimate end of all these activities in the field of alternative energy sources in Mongolia is not only development and demonstration of prototypes but wide and effective application in agriculture and animal husbandry. It is not sufficient to organize the production only; it is necessary to develop an optimal strategy of the whole process of development - design - production - training of consumers - and effective utilization of the product. One obligatory aspect of the integrated strategy is as follows: that is a complex use of several alternative sources of energy (with leading position of SB). Another very important aspect is that special experimental center for real work with this complex of new sources of energy should be organized before the beginning of commercial production. This center will allow:

1. To test and compare prototypes of new Mongolian and Foreign made energy sources equipment. These prototypes should be tested at real conditions of application, during a long period of time, underload, with continuous measuring and recording of parameters.

2. To develop and test an integrated prototype of alternative energy sources of different type under different external conditions for different consumers.

3. To train future consumers to handle with new sources of energy.

D. Possible Participation of UNIDO

It is clear that participation of UNIDO in the creation of SEB at SCST is most desirable for the Mongolian Government. Its participation would be rather typical activity for the Agency: Establishment of design and production divisions, providing with production equipment, technical assistance through international experts, assistance in training of national personnel. Such a project would include some stages of long time duration: A construction or reconstruction of buildings or rooms; procurement of significant number of production equipment, application of new manufacturing methods. The duration of the project is recommended not less than 3 years. It is necessary to pay attention to careful selection of international experts, especially the team leader.

ANNEX 3

The List of main materials, equipment, and Devices required as the minimum for Normal Activity of TE group

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Materials for Synthesis of Semiconductor compounds (purity 99.99%)

1. Bismuth, Metallic ....10 Kg.
2. Antimony, Metallic .... 7 Kg.
3. Tellurium ....10 Kg.
4. Selenium .... 3 Kg.

Equipment for Compounds Technology

1. Crucible Furnace (for melting), Max. Temperature 1000 - 1200° C, Volume (inside) 8 x 8 x 25 Cm^3 .... 2 pieces
2. Muffle Furnace (for thermal treatment), Max.Temperature 1
   1000°C, Vol. 20 x 30 x 15 Cm^3
3. Press for materials testing of 10-20 ton force 1
4. Mould for cold and hot compacting of samples of thermoelectric materials (sample size about 6x6x20 mm^3).... 5
5. Variable Voltage Transformer of 5-10 KW power 4
6. Rotating Vacuum Pump 4
7. Oil Vacuum Pump 4
8. Quartz Tubes for ampules diam. 15-30 mm ....100 M.

Devices for Electrical Measurements

1. Direct current potentiometer of low resistance,sensitivity 1 μV, limit of measuring 20 mV .... 2 pieces

/...

2. Digital direct current voltmeter, input resistance not less than 1 MΩ, sensitivity 1 µV, limit of measuring 20 mV 2

3. Direct current Ammeter, accuracy class 0.1-0.2, limit of measuring 5A 2

4. Special multi-pole slide switch for thermocouples and resistance thermometer circuits, 6 and 12 positions 2

5. Thermocouple wire, standard, diam. 0.2 mm: Platinum/platinum + 10% Rhodium and Chromel/Alumel.

CALCULATION OF PAY-BACK INVESTMENT IN PRODUCTION OF SB (150 KW TOTAL POWER PER YEAR)

Cashflow tables, construction in 000 [illegible]

Year	1986	1987
Total cash inflow ..	3020.00	5970.00
Financial resources .	3020.00	5970.00
Sales, net of tax ..	0.00	0.00
Total cash outflow ..	3020.00	5970.00
Total assets	3020.00	5970.00
Operating costs ...	0.00	0.00
Cost of finance ...	0.00	0.00
Repayment	0.00	0.00
Corporate tax ...	0.00	0.00
Dividends paid ...	0.00	0.00
Surplus (deficit) .	0.00	0.00
Cumulated cash balance	0.00	0.00
Inflow, local	3020.00	0.00
Outflow, local	3020.00	0.00
Surplus (deficit) .	0.00	0.00
Inflow, foreign ...	0.00	5970.00
Outflow, foreign ...	0.00	5970.00
Surplus (deficit) .	0.00	0.00
Net cashflow	-3020.00	-5970.00
Cumulated net cashflow	-3020.00	-8990.00

[illegible] --- 26 october

Cashflow tables, production in 000 [illegible]

Year	1988	1989	1990	1991	1992	1993
Total cash inflow . .	22098.96	20000.00	20000.00	20000.00	20000.00	20000.00
Financial resources .	2098.96	0.00	0.00	0.00	0.00	0.00
Sales, net of tax . .	20000.00	20000.00	20000.00	20000.00	20000.00	20000.00
Total cash outflow . .	23082.86	18219.38	16397.00	16397.00	16397.00	16417.00
Total assets	6685.86	186.00	0.00	0.00	0.00	20.00
Operating costs . . .	16397.00	16397.00	16397.00	16397.00	16397.00	16397.00
Cost of finance . . .	0.00	0.00	0.00	0.00	0.00	0.00
Repayment	0.00	1636.38	0.00	0.00	0.00	0.00
Corporate tax . . .	0.00	0.00	0.00	0.00	0.00	0.00
Dividends paid . . .	0.00	0.00	0.00	0.00	0.00	0.00
Surplus (deficit) .	-983.90	1780.63	3603.00	3603.00	3603.00	3583.00
Cumulated cash balance	-983.90	796.72	4399.72	8002.72	11605.72	15188.72
Inflow, local	22098.96	20000.00	20000.00	20000.00	20000.00	20000.00
Outflow, local	6794.77	7287.38	5651.00	5651.00	5651.00	5671.00
Surplus (deficit) .	15304.18	12712.63	14349.00	14349.00	14349.00	14329.00
Inflow, foreign . . .	0.00	0.00	0.00	0.00	0.00	0.00
Outflow, foreign . . .	16288.08	10932.00	10746.00	10746.00	10746.00	10746.00
Surplus (deficit) .	-16288.08	-10932.00	-10746.00	-10746.00	-10746.00	-10746.00
Net cashflow	-3082.86	3417.00	3603.00	3603.00	3603.00	3583.00
Cumulated net cashflow	-12072.86	-8655.86	-5052.86	-1449.86	2153.14	5736.14

[illegible] --- 26 october

Cashflow tables, production in 000 kgh

Year	1994	1995	1996	1997	1998	1999
Total cash inflow . .	20000.00	20000.00	20000.00	20000.00	20000.00	20000.00
Financial resources .	0.00	0.00	0.00	0.00	6.00	0.00
Sales, net of tax . .	20000.00	20000.00	20000.00	20000.00	20000.00	20000.00
Total cash outflow . .	16397.00	16397.00	16397.00	16397.00	16417.00	16397.00
Total assets	0.00	0.00	0.00	0.00	20.00	0.00
Operating costs . . .	16397.00	16397.00	16397.00	16397.00	16397.00	16397.00
Cost of finance . . .	0.00	0.00	0.00	0.00	0.00	0.00
Repayment	0.00	0.00	0.00	0.00	0.00	0.00
Corporate tax . . .	0.00	0.00	0.00	0.00	0.00	0.00
Dividends paid . . .	0.00	0.00	0.00	0.00	0.00	0.00
Surplus (deficit) .	3603.00	3603.00	3603.00	3603.00	3583.00	3603.00
Cumulated cash balance	18791.72	22394.72	25997.72	29600.72	33183.73	36786.73
Inflow, local	20000.00	20000.00	20000.00	20000.00	20000.00	20000.00
Outflow, local	5651.00	5651.00	5651.00	5651.00	5671.00	56[illegible]00
Surplus (deficit) .	14349.00	14349.00	14349.00	14349.00	14329.00	14349.00
Inflow, foreign . . .	0.00	0.00	0.00	0.00	0.00	0.00
Outflow, foreign . . .	10746.0C	10746.00	10746.00	10746.00	10746.00	10746.00
Surplus (deficit) .	-10746.00	-10746.00	-10746.00	-10746.00	-10746.00	-10746.00
Net cashflow	3603.00	3603.00	3603.00	3603.00	3583.00	3603.00
Cumulated net cashflow	9339.14	12942.14	16545.14	20148.14	23731.14	27334.14

Cashflow tables, production in 000 [illegible]

Year	2000	2001	2002
Total cash inflow . .	20000.00	20000.00	20000.00
Financial resources .	0.00	0.00	0.00
Sales, net of tax . .	20000.00	20000.00	20000.00
Total cash outflow . .	16397.00	16397.00	16397.00
Total assets	0.00	0.00	0.00
Operating costs . . .	16397.00	16397.00	16397.00
Cost of finance . . .	0.00	0.00	0.00
Repayment	0.00	0.00	0.00
Corporate tax . . .	0.00	0.00	0.00
Dividends paid . . .	0.00	0.00	0.00
Surplus (deficit) .	3603.00	3603.00	3603.00
Cumulated cash balance	40389.73	43992.73	47595.73
Inflow, local	20000.00	20000.00	20000.00
Outflow, local	5651.00	5651.00	5651.00
Surplus (deficit) .	14349.00	14349.00	14349.00
Inflow, foreign . . .	0.00	0.00	0.00
Outflow, foreign . . .	10746.00	10746.00	10746.00
Surplus (deficit) .	-10746.00	-10746.00	-10746.00
Net cashflow	3603.00	3603.00	3603.00
Cumulated net cashflow	30937.14	34540.14	38143.14

Cashflow Discounting:

a) Return on Equity:

Net present value 16466.07 at 10.00 %

Internal Rate of Return (IRRE) .. 35.44 %

b) Internal Rate of Return without outside financing:

Net present value 12127.82 at 10.00 %

Internal Rate of Return (IRR) .. 22.93 %

c) Future Value of cash outflow during construction:

Total cash outflow .. 8990.00

Future Value 9292.00 at 10.00 %