DEVELOPMENT OF A SOLAR TOWN IN IRAN

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Preface

This report is one of a series describing a multidisciplinary multinational IIASA research study on the Management of Energy/ Environment Systems. The primary objective of the research is the development of quantitative tools for regional energy and environment policy design and analysis--or, in a broader sense, the development of a coherent, realistic approach to energy/environment management. Particular attention is being devoted to the design and use of these tools at the regional level. The outputs of this research program include concepts, applied methodologies, and case studies. During 1975 and 1976, case studies were emphasized; they focused on three greatly differing regions, namely, the German Democratic Republic, the Rhone-Alpes region in southern France, and the state of Wisconsin in the U.S.A. The IIASA research was conducted within a network of collaborating institutions composed of the Institut fuer Energetik, Leipzig; the Institut Economique et Juridique de l'Energie, Grenoble; and the University of Wisconsin-Madison.

Late in 1976, IIASA initiated discussions on the extension of this research program to a region in Iran. This memorandum describes one component of our exploratory efforts with Iranian research institutions.

Other publications on the management of energy/environment systems are listed in the Appendix at the end of this report.

W.K. Foell
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by

Mehdi N. Bahadori

ABSTRACT

Iran's rapid industrialization progress has necessitated the development of cities and townships adjacent to the industrial complexes. The source of energy for these townships is similar to the rest of the country, and it is basically oil and natural gas.

Iran is a country rich in oil, natural gas, and solar energy, and the life style of its people--especially the majority of those drawn to these industrial towns--is not highly energy dependent. To save on fossil fuel consumption, the country has already launched the programs to utilize other sources of energy--namely nuclear, geothermal, and solar.

Development of a solar town whose total energy requirements for heating, cooling, cooking, communication, local transportation, etc., are met by solar energy, sky radiation, and other similar sources, is suggested for the first time and is a plan which can have a long-range fuel saving and ecological significance. In this solar community no hydrocarbon fuels, except for those produced through sewage and agricultural waste conversions, are to be used.

To develope such a community one should consider the following factors:

1. The cultural elements and the life style of the people who will constitute the community. This is the most difficult and the most important part of the entire plan in that the success of the project will be entirely based on the social acceptability of the changes--no matter how small--by the people. Therefore, every step of the plan should be carried out very conservatively, and as socially acceptable as possible.

2. Central vs. local generations of electrical and thermal energies, and hydrocarbon fuel production.

3. The energy conversion systems to be employed for heating, cooling, cooking, transportation, etc. Due considerations should be given to the maintenance and the social acceptability of these systems. The models of these systems should be built and placed at the disposal of the families likely to live in the township, well in advance of the execution of the plan.

For a town with a population of 4000, occupying a living space of 100,000 m^2, with a per capita electrical energy need of 1.8 kwh/day, and an average net per capita thermal energy need of 18,000 k cal/day using a seasonal storage and meeting all the energy requirements in a central plant, a collector with 17,000 m^2 area for power production and a collector with 30,000 m^2 area for low and medium temperature thermal applications are needed. A more detailed study on energy consumption patterns of the families and a more systematic approach to solar energy utilization for the town are needed to determine the ultimate requirements and the exact costs and benefits for developing a solar town.

Seasonal or long-range energy storage is an important problem and extensive research and development are needed to make the solar energy utilization economical.

The abundance of solar energy in Iran, the non-polluting nature of this energy and relatively simple technology for its utilization and seven years of experience on solar energy research (at Pahlavi University) makes Iran capable of developing its own natural resource and exporting both technology and energy (rather than importing both) in future.

Introduction

Iran's energy consumption growth in the past few years has been very significant and is expected to be even more rapid in future. Figures 1 - 8 show the general trend for energy sources and uses in Iran [1-11]. It is clear from these figures that the importance of liquid fuels as the energy source is decreasing (very rightly so) and the dependence on nuclear energy will be increasing beyond 1982. Solar energy, while it is being talked about everywhere in the world, has not appeared in the future energy planning because, perhaps, the technology of solar energy utilization available at this time can not compete economically with other energy sources. Indeed, whereas billions of dollars have been spent throughout the world in the past 30 years to bring the status of the nuclear energy utilization to what it is today, practically nothing has been spent on solar energy utilization.

But, the abundance of solar energy in Iran favors the utilization of this energy resource, and the research experience gained in Iran (Pahlavi University) in the past seven years, (which is far greater than many institutions that the writer has visited), puts Iran in a position to utilize its own energy and manpower resources in future, rather than importing both. It is to this end that the concept of a solar town is being promoted.

Development of Industrial Towns in Iran

The rapid industrial development in the past several years in Iran has necessitated the development of new towns adjacent to the industrial complexes, e.g., Ghazvin and Arak, and near existing cities. Occupants of these towns are primarily workers, technicians, engineers and other employees of the factories in that location. The educational level, the standard of living, and the technical background in these towns are higher - and population distribution is more uniform - than the national average. Therefore, it is easier to implement changes in such towns than any other community throughout the country, or even design and develop a new town for a specific energy source - namely solar energy.

General Requirement for the Development of a New Town

In addition to clean air and fresh water any city requires energy to meet its demands. Energy in thermal, electrical and chemical forms are needed. The end uses of energy are in residences, for washing, heating, cooling, cooking, lighting, operating household appliances; in industries, for industrial processes, heating, cooling, lighting, etc.; in commerce; for transportation; and for communication purposes. Figure 9 shows the general energy requirement of a community. Agricultural needs are included to account for cities with both industrial and agricultural status.

Almost every city requires electrical energy for its fresh water distribution. For locations where fresh water has to be produced from the sea, thermal energy should be employed. These energy requirements are not shown in Figure 9 for clarity purposes, however.

The major source of energy in Iran has been fossil fuel, as is shown in Figures 2 & 3. An important side effect of this energy resource is air pollution which has become a public nuisance and unbearable in many places such as in Tehran. In fact, the question of environmental quality is important enough to warrant the study of a non-polluting source such as solar energy. This is indeed a current issue in many industrialized nations like the United States, Western Europe, and others.

Utilization of Solar Energy for a community

There are a number of ways that one could employ solar energy to meet the energy needs of a city. One could, for example, convert solar energy to electricity either directly or by thermo-mechanical systems to meet all the energy needs, or produce liquid and gaseous fuels through photosynthesis or waste conversions. These processes are shown in Fig. 10. A more realistic approach would be, however, to follow the paths indicated in Fig. 11, where thermal energy at different temperature levels is produced to meet thermal and electrical energy needs. Electricity can be used for transportation either directly by operating electric cars, buses etc., or by producing hydrogen through the electrolysis of water and using it in these vehicles. Another method to meet the transportation energy needs is to produce gaseous or liquid fuels by fermentation or pyrolysis of organic materials, including agricultural and city wastes. These artificial fuels may also be employed for cooking or stored for later use.

Figures 12 - 14 show briefly how solar energy may be utilized to meet the thermal energy needs at various temperatures. Many applications such as washing, heating, agricultural and industrial processes, require thermal energy at temperatures below 100°C. Cooling and cooking require heat at higher temperatures. For power production the fluid temperature should be as high as possible. Of course, the higher the temperature of the working fluid the higher will be the conversion efficiency and the difficulty with which solar energy can be utilized. But as compared with the direct conversion of solar energy to electricity where the cells have to be kept at low temperatures for better efficiencies, the rejected heat in the solar-mechanical-electrical systems may be utilized to meet some of the thermal energy needs. Figures 15 - 17 show briefly how organic materials such as agricultural and city wastes or growing of plants may be used to produce gaseous or liquid fuels. The simplest method is the anaerobic (in the absence of air) fermentation of the organic materials mixed with water. The gas generated is about 60% methane, and a high concentration of CO_2. The nitrogen content of the organic materials is retained in the sludge which can be utilized as fertilizer.

In locations with good rainfall plants with high energy yields may be grown for energy production purposes. The growth may be enhanced by using some of the waste heat.

Design of a Solar Town

We consider the development of a purely residential town with 1000 families (about 4000 people) to be located in an area with clean air and available fresh water and with a weather similar to that of Shiraz. It is desired to meet all the energy needs of this town by solar energy.

Energy Needs. The following estimates are made for the energy needs of a family of 4 living in the solar town:

1. Heating and Cooling.

Average living space per family : 100m^2.

The heating requirements in winter is estimated to be 75 K cal/h.m.^{2} maximum, and average of 900 K cal/d.m.^{2}, or 90,000 K cal/d.

The cooling requirement in summer is estimated to be 75 K cal/h.m.^{2} maximum, and average of 750 K cal/d.m.^{2}, or 75,000 K cal/d.

2. Hot Water (at 40°C) for Washing.

Hot water for bathing	1.2 m.^{3}/week
for washing clothes	.6
for washing dishes, etc.	1.0
Total	2.8 m.^{3}/w.or 0.4 m.^{3}/day

The energy required for this hot water in winter is 12000 K cal/d.

and in summer is about 10,000 K cal/d.

3. Cooking.

The average energy required for cooking

at low temperature	5,750 K cal/d.
at high temperature	5,750
Total	11,500

This is equivalent of burning 1Kg of LPG per day.

4. Transportation.

Assume an average of one automobile for each two families with each vehicle being driven an average of 30 km/day and with a fuel consumption of 0.1 liter/km of gasoline equivalent, or the energy expenditure of about

1/2 x 30 x .1 x 8000 or 12,000 K cal/d.

5. Electrical Energy.

The maximum energy use is expected to be in winter with

lighting, 4 hours/day	2 kwh/day
ironing, 1/2 hour/day	1/2
television, 6 hours/day	1 1/2
refrigerator and other appliances	1
Total	5 kwh/d

The electrical energy needs in summer are taken as 80% of that in winter.

6. Street Lighting.

Assume 20% of electricity used in residences for street lighting(1), or average of 1 kwh/d in winter.

7. Commercial Needs.

Assume a total electrical energy need of about 25% of that of the residences and thermal energy needs of about 20% of that of the residences for stores, including restaurants and bakeries, and office buildings.

Table 1 summerizes the energy needs of the town. These figures are of course rough estimates. A more detailed study is needed for more reliable data.

In the above estimates no industrial or agricultural activities but a normal city government have been assumed for this town.

Meeting the Energy Needs by Solar Energy.

Implementing any change in people's way of life has to proceed very cautiously, and after it has been tested and accepted in a smaller scale. To make the changes as little as possible it is proposed that solar energy be used to meet the needs of the solar town in the following fashions:

1. Central generation of electricity and distribution to homes, stores and other buildings - no change from the present method.

There are two alternatives for the central electricity generation - namely, photovoltic or direct conversion, and thermo-mechanical conversion. Technical performance and the economics of each method have to be evaluated carefuly before any final selection is made. At present, however, the thermo-mechanical system is favored for the following reasons:

a. Use of the rejected heat for thermal energy needs.
b. Capability to manufacture the components (except for the steam or gas turbine and some of the collector components) exists in Iran, whereas the solar cells have to be imported completely.
c. More flexibility for storage of energy in the forms of thermal, in fluids; electrical, in batteries; chemical, in production of hydrogen by the electrolysis of water and the subsequent use of this hydrogen in a boiler exists. It is also possible to burn the generated fuel (to be discussed later) in the boiler, and operate the power plant. Figure 18 shows an electrical energy load and a generation pattern, employing both thermal and electrical energy storages.
d. The overall costs of the system is expected to be lower than the direct conversion method.

2. Central or local generation of thermal energy. The thermal energy requirement of the town may be met either by centrally producing hot fluids (water, steam, inorganic liquids, etc.)

and pumping them to each building or meeting the needs locally at each building. The following advantages can be cited for each method:

a. Central plant:

- Easier maintenance
- Social acceptability not a major problem
- Lower total costs of collectors
- Lower cost of storage and auxiliary
- Lower total energy needs
- Less vulnerable to damages
- More flexibility in building design and aesthetic aspects
- Utilization of rejected heat of the power plant

b. Local heat generation:

- Lower total costs of piping
- Private ownership and better care possible
- Less misuse of energy possible

Because of the numerous advantages of the central thermal energy generation, especially the ease of maintenance and its higher chances of social acceptability it is preferred over the local units. In this case hot water for washing, hot water for heating, or cold water for cooling, are produced centrally and delivered to each building in town. Also generated centrally (to be discussed later) and piped to each house are gaseous fuel and water vapor, for cooking at high and low temperatures, respectively. Figure 19 shows the general piping connections to a house. A design worthy of consideration for Iran, because of its potentially low cost, is shown in Figure 20. This design reduces the cost of piping and heat exchangers a great deal, and makes use of the radiation to sky at night for summer cooling. It limits the building designs, however, and its social acceptability has to be proved before it can be employed on a large scale.

3. Central production of gaseous or liquid fuels. The city wastes and sewage (and the agricultural wastes of neighboring farms or city wastes of nearby cities, if available) are brought to the central plant for fuel production. The fuel production can be increased by employing plants grown especially for fuel production, if the location has sufficient rainfall. Part of the gaseous fuel is compressed to a high pressure and delivered to houses, bakeries, restaurants, etc. for high temperature cooking, and the rest is liquified and used for transportation purposes. When the produced fuels can not meet both cooking and transportation demands hydrogen will be produced by electrolysis of water and used for transportation.

The use of gaseous fuels for cooking seems to be quite acceptable as it is very similar to the natural gas presently employed in several cities in Iran. The use of liquified gas or hydrogen in transportation requires some modification in engine design. Because of the low air-polluting nature of these fuels there is a good deal of research in this field in progress in many countries.

4. Central production of vapor for low temperature cooking. Many Iranian dishes require cooking at low temperature and for a long time. Water vapor at atmospheric conditions have been used successfuly for cooking at Pahlavi University in a device such as shown in Figure 21. The vapor may be either produced by flat plate collectors, as shown in Figure 21, or by simple focusing concentrators, and sent to homes or restaurants. Of course, before implementing this cooking method in a large scale its acceptability by the people who are apt to use it has to be proved. If found socially unacceptable, the gaseous fuel available at each house may be used for the entire cooking process. Figure 22 shows a solar energy utilization diagram to meet all of the energy requirements of the solar town at a central plant.

Total Energy Needs for a Town of 1000 Families.

Based on the above discussion on meeting the energy requirements of the town by solar energy the total requirements of a town of 1000 families (population of about 4000) are given in Table 2, and Figure 23. It has been assumed that the thermal efficiency of the power production is 20%, the absorption refrigeration system has a coefficient of performance of 60% and the collector thermal efficiency is about 33%. The thermal energy utilized by a solar concentrator which constantly tracks the sun is not shown in this figure. The total area of this concentrator with a collector efficiency of 50%, thermal efficiency of 20%, electric generator efficiency of 85% and a solar radiation intensity of 5 $kwh/m^2.d.$ is about 17,000 m^2.

Need for Energy Storage

The intermittent nature of solar energy requires the storage of energy. The daily need for energy storage for electrical energy production is exemplified in Fig. 18. In this case it is assumed that a turbine generator with an electrical power capacity of 725 kw operates 10 hrs in winter to meet the electrical demands and charges the storage batteries, while receiving its thermal energy from the high temperature thermal storage.

One can visualize a similar picture of the thermal loads and solar energy availability which have their peaks at different hours of the day for heating and cooling. Daily storages of thermal energy for the thermal applications and for power generation are shown in Fig. 22. No storage is considered for the vapor to be used for the low temperature cooking process, as it is assumed that cooking will be done only during the day and the food is kept warm in the cooking box for supper. Fuel will be used for cooking on cloudy days.

While the daily storage of energy is simple to meet, it is the seasonal storage of energy which can result in a more economical system. A look at Fig. 23 shows that a 30,000m^2 collector without a seasonal storage can not meet the thermal energy needs either in summer or in winter. There is excess energy available during the fall and spring seasons and shortage of energy during winter and summer. A 50,000m^2 collector, on the other hand, can meet the thermal energy needs both in summer and in winter but should collect no energy in other seasons.

Seasonal storages of thermal energy in the following forms are possible. Extensive research and development are needed in many of these areas before they can become economically feasible:

1. Produce excess electrical energy in the fall and spring, electrolyse water to H_2 and O_2 and use the hydrogen during the peak seasons. Or, store the excess electrical energy in suitable and lightweight batteries.

2. Store thermal energy in phase-changing materials.

3. Make use of excess heat to grow special energy-rich plants for fuel production and use the fuel in peak seasons.

4. Produce electrical energy and displace water to a higher elevation for a later use.

Objectives of a Proposed Research Program by Iran

The objectives are to design the system and the equipment for the utilization of solar energy to meet all the energy requirements of a town of 4000 population in Iran.

Research Procedure

The following steps toward fulfillment of the above objectives would be taken by the Iranian research organization:

1. Determine the energy needs of the people who live in similar towns and are likely to live in the solar town. This includes the use patterns for electrical and thermal energies as well as washing and cooking habits.

2. Measure solar radiation in locations likely to be employed for the development of the town. The weather data will be obtained from the meteorlogical office.

3. Develop a computer model for hour-by-hour heating and cooling requirements of different dwellings designed specifically with energy conservation in mind and for the town's residents, accounting for the weather data, storage effect of the building and solar radiation gains and sky radiation losses.

4. Develop a computer model for hour-by-hour, daily average, and monthly average energy needs of the town.

5. Develop a computer model for different alternatives or scenarios of utilizing solar energy, including various systems, equipment, and types and the capacities of storages. This program would give the most economical approach for any location (solar and weather data), for any city planning, and for the various costs of different equipment, materials and labor.

6. Design, build and test the low temperature cooking device, shown in Fig. 21, and the house design of Fig. 20, with the families likely to reside in the town. Evaluate the performances of the cooker and the house and determine carefully if they are socially acceptable or not. The other changes, namely cooking at high temperature with gaseous fuel, centrally providing hot water for washing, hot water for heating or cold water for cooking do not seem to be of major concern. Nevertheless, their social acceptability should be determined before their large scale adaptation is planned.

7. Design, build and test flat plate solar collectors of various design and materials, (see Fig. 12), with a collection surface area of about 10m^2 to determine the most cost-effective unit, and share the experience gained in fabrication with the industries likely to manufacture the final collectors.

8. Design, build and test solar concentrators of various design and materials (see Fig. 14) with a collection area of $10m^2$ or more (to produce at least a power of 1 kw).

9. Carry out research on the improvement of electrolysis of water, storage of hydrogen, and the use of hydrogen in automobiles and other vehicles. Carry out basic research on direct production of hydrogen including microbial, thermo chemical, photosynthesis, photoelectrolysis and other processes.

10. Carry out research on the thermal energy storage in materials with phase change.

11. Carry out research on the bio- conversion, utilizing different wastes and various plants grown specifically for their energy values.

12. Investigate the areas of the country where water may be elevated to higher natural locations for the storage purposes in conjunction with the solar energy utilization scheme.

13. Investigate the use of electric automobile for low-distance driving, employing fuel cells and batteries.

Fig. 24 shows the summary of the timetable for the research project execution.

Conclusions & Benefits

The idea of developing a town whose entire energy needs are met by solar energy is, to the writer's knowledge, a new one; even though the use of solar energy for district heating alone, and for electric generation and district heating, for a community have been investigated before(2).

The technology for solar energy utilization, or at least that suggested in this study, is not very complicated and with the experience already existing in the country Iran is in a position to explore its natural resource on its own without being far behind other nations in this field. It can export technology of solar energy utilization and solar energy derivatives (hydrogen, electricity, gaseous and liquid fuels, etc) to other countries. Of course, when compared with fossil fuel at the present prices the cost of solar energy utilization is high. But the benefits such as no environmental impacts of air and water pollutions justify the use of this energy resource. It is believed that once the technology of solar energy utilization is far advanced it can compete with other sources of energy.

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2. R.P. Stromberg,"A Status Report on the Sandia Laboratories Solar Total Energy Program", J. of Solar Energy, vol. 17, p.p. 359-366,1975.

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Table 1 . Summary of the Average Energy Needs for a Family of 4 in the Solar Town.

	Liq. Fuel Kg/d.	Thermal Energy. K cal/d.			Electrical Energy. kwh/d.		
		Winter	Fall & Spring	Summer	Winter	Fall & Spring	Summer
Size of Residence, $100 m^2$							
Heating or Cooling Load		90,000	------	75,000			
Hot Water for Washing, $.4 m^3/d$.		12,000	11,000	10,000			
Cooking at Low Temperature	.5	5,750	5,750	5,750			
at High Temperature	.5	5,750	5,750	5,750			
Transportation, 1 Vehicle/2 families	1.2	12,000	12,000	12,000			
Electrical Energy					5	4.5	4
Street Lighting					1	.9	.8
Commercial: Electrical Energy					1.25	1.125	1.
Heating/Cooling		18,000	------	15,000			
Cooking at Low Temp.	.1	1,150	1,150	1,150			
Cooking at High Temp.	.1	1,150	1,150	1,150			
Hot Water for Washing		2,400	2,200	2,000			

Table 2 . Summary of the Total Energy Requirements for a Solar Town of 1000 Families.

	Thermal Energy 10^6 K cal/d.			Electrical Energy 10^3 kwh/d.			Low T. Vapor	Gaseous Fuel	Liquid Fuel
	Winter	Fall & Spring	Summer	Winter	Fall & Spring	Summer	Kg/d	Kg/d	Kg/d
Hot Water of Washing	14.4	13.2	12						
House Heating	108	----	----						
House Cooling	----	----	90						
Cooking, at Low Temp.							13,800		
at High Temp.								600	
Transportation									1,200
Electrical Energy				7.25	6.525	5.8			
Rejected Heat which can be utilized (η=20%)	-24.4	-22.2	-20						
Total Thermal Energy Required	98.	-9	142*						

* A coefficient of performance of 60% is assumed for the absorption refrigeration.

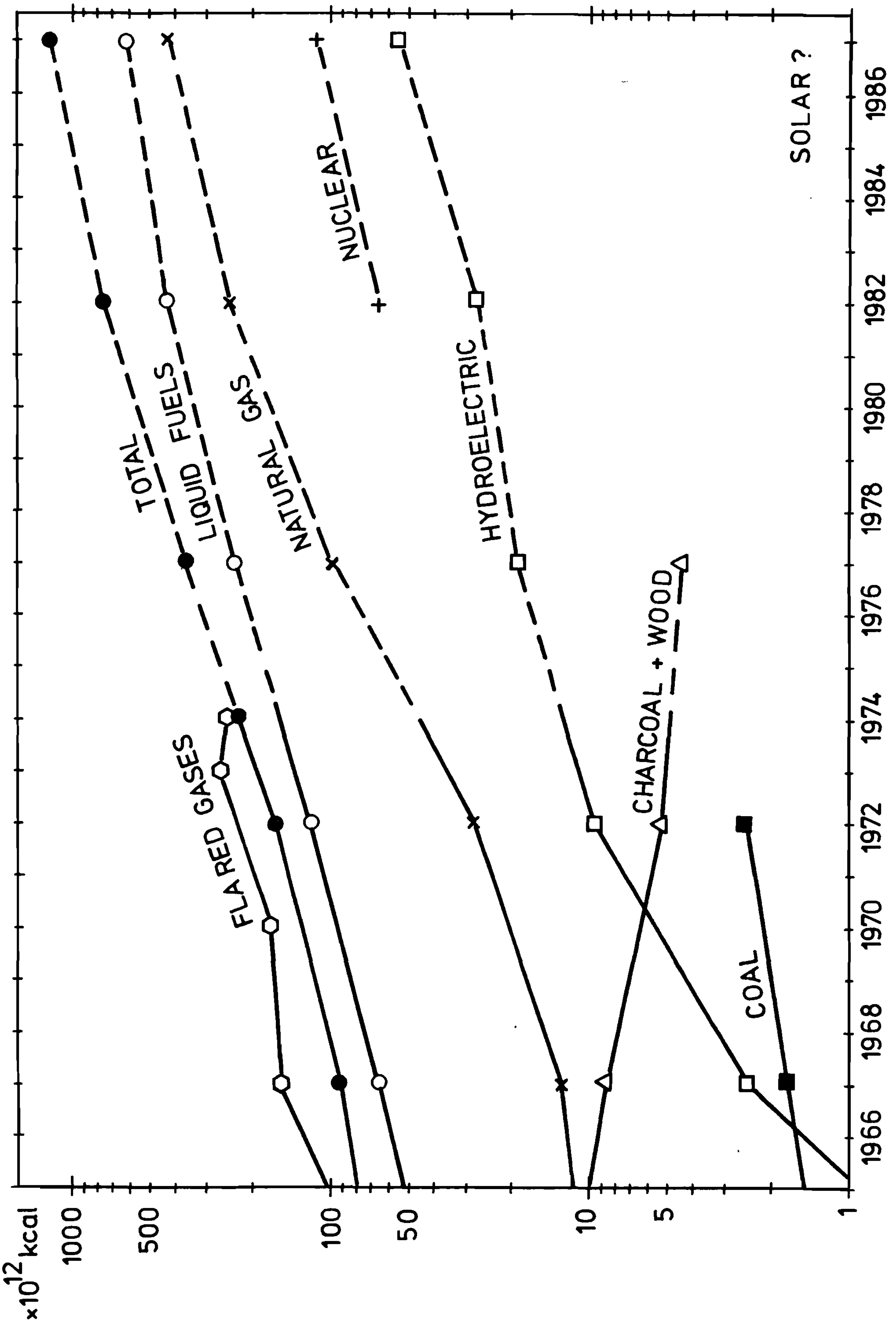

FIGURE 1: ENERGY SOURCES

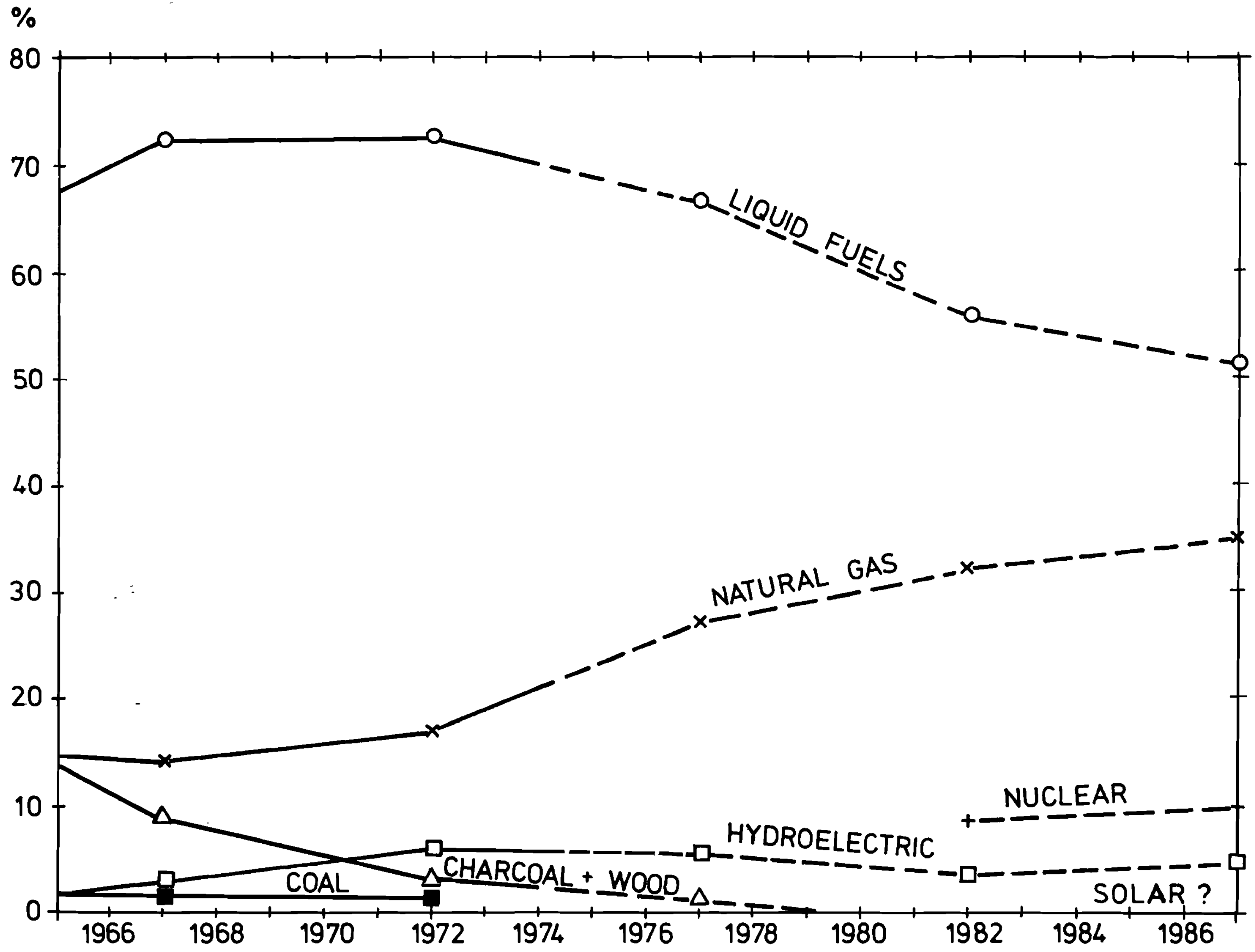

FIGURE 2: ENERGY SOURCES BY % OF ENERGY VALUES

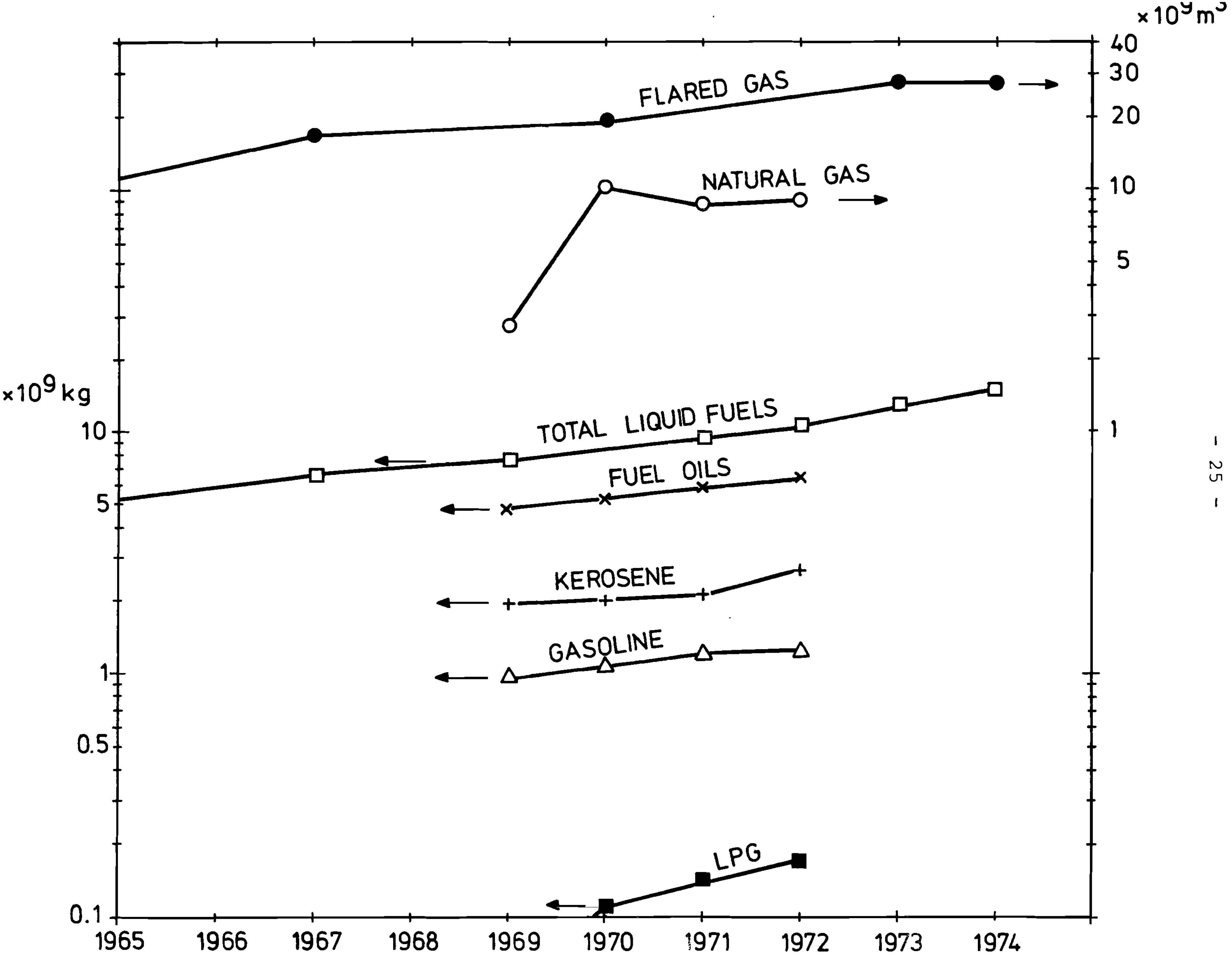

FIGURE 3: PETROLEUM USES BY PRODUCT

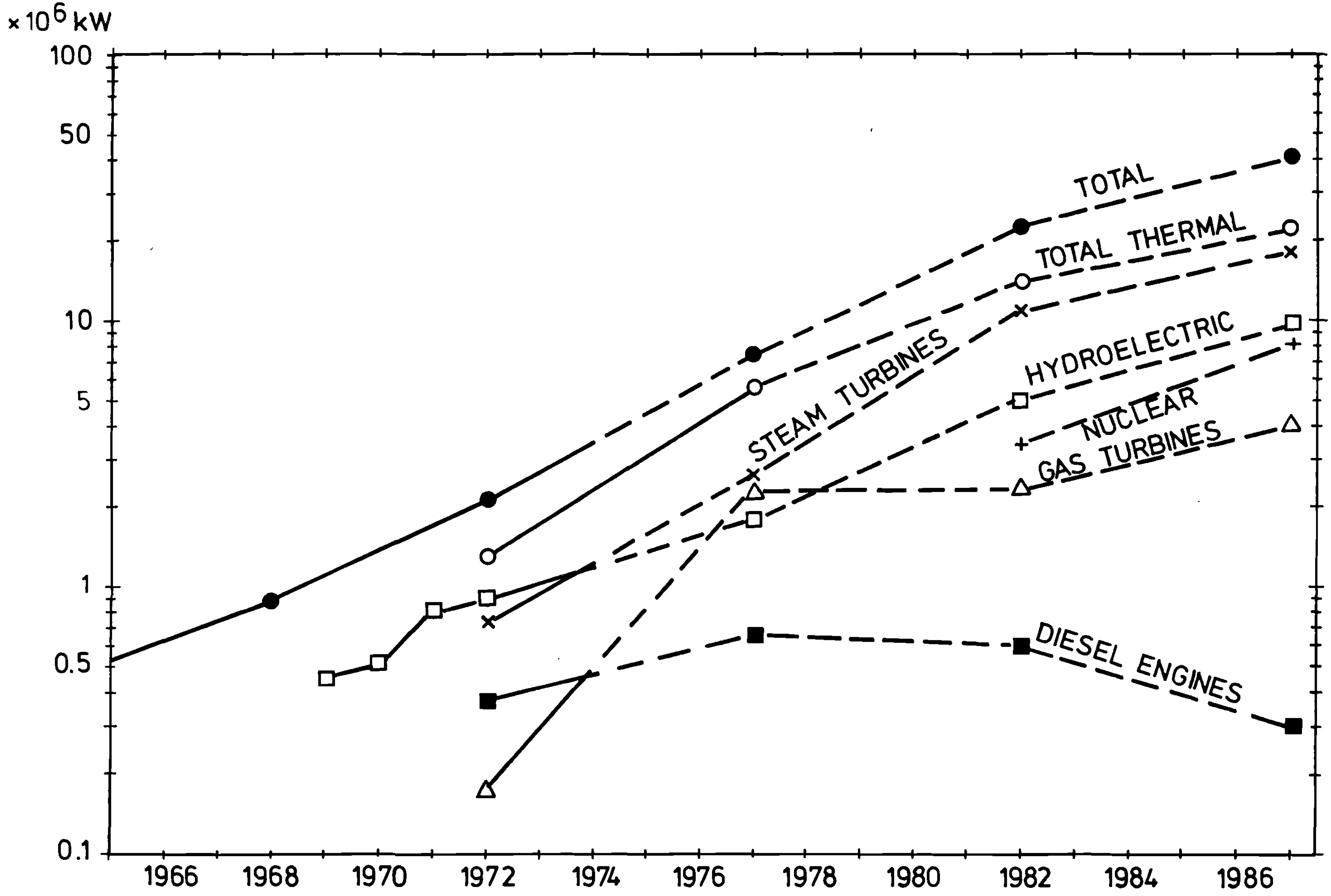

FIGURE 4: INSTALLED POWER FOR ELECTRICAL ENERGY GENERATION

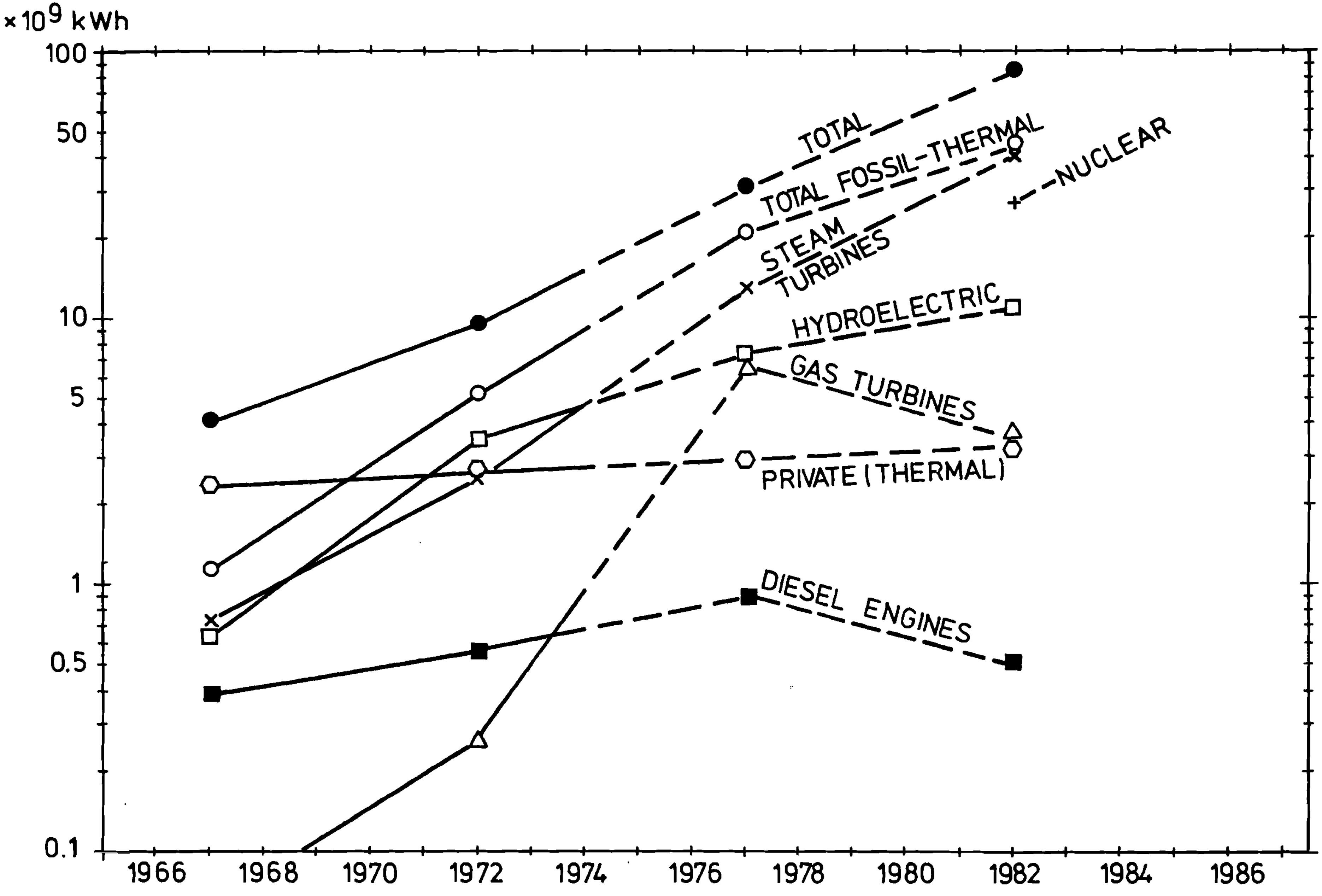

FIGURE 5: ELECTRICAL ENERGY GENERATION

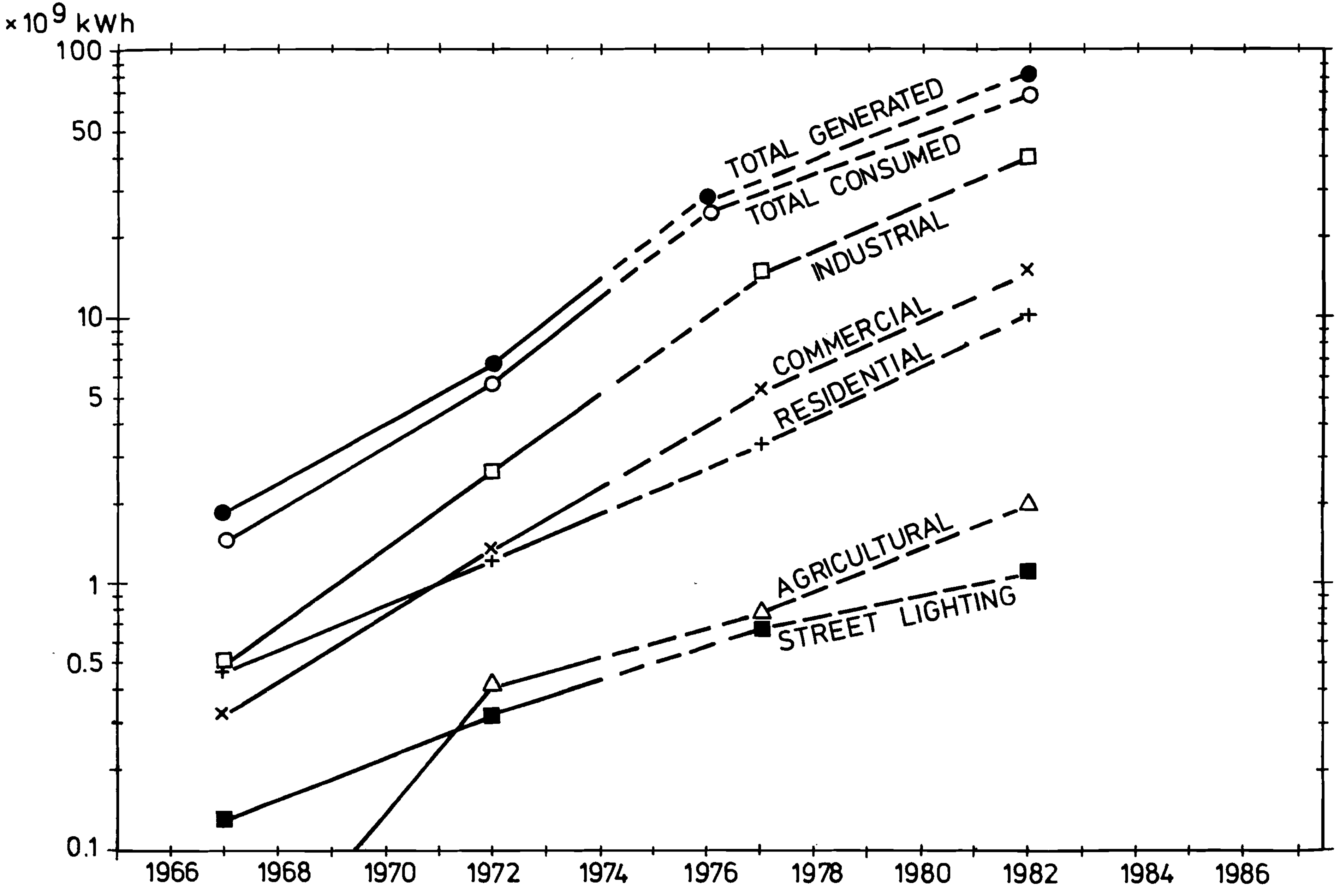

FIGURE 6: THE USES OF ELECTRICAL ENERGY GENERATED BY THE MINISTRY OF POWER BY VARIOUS SECTORS

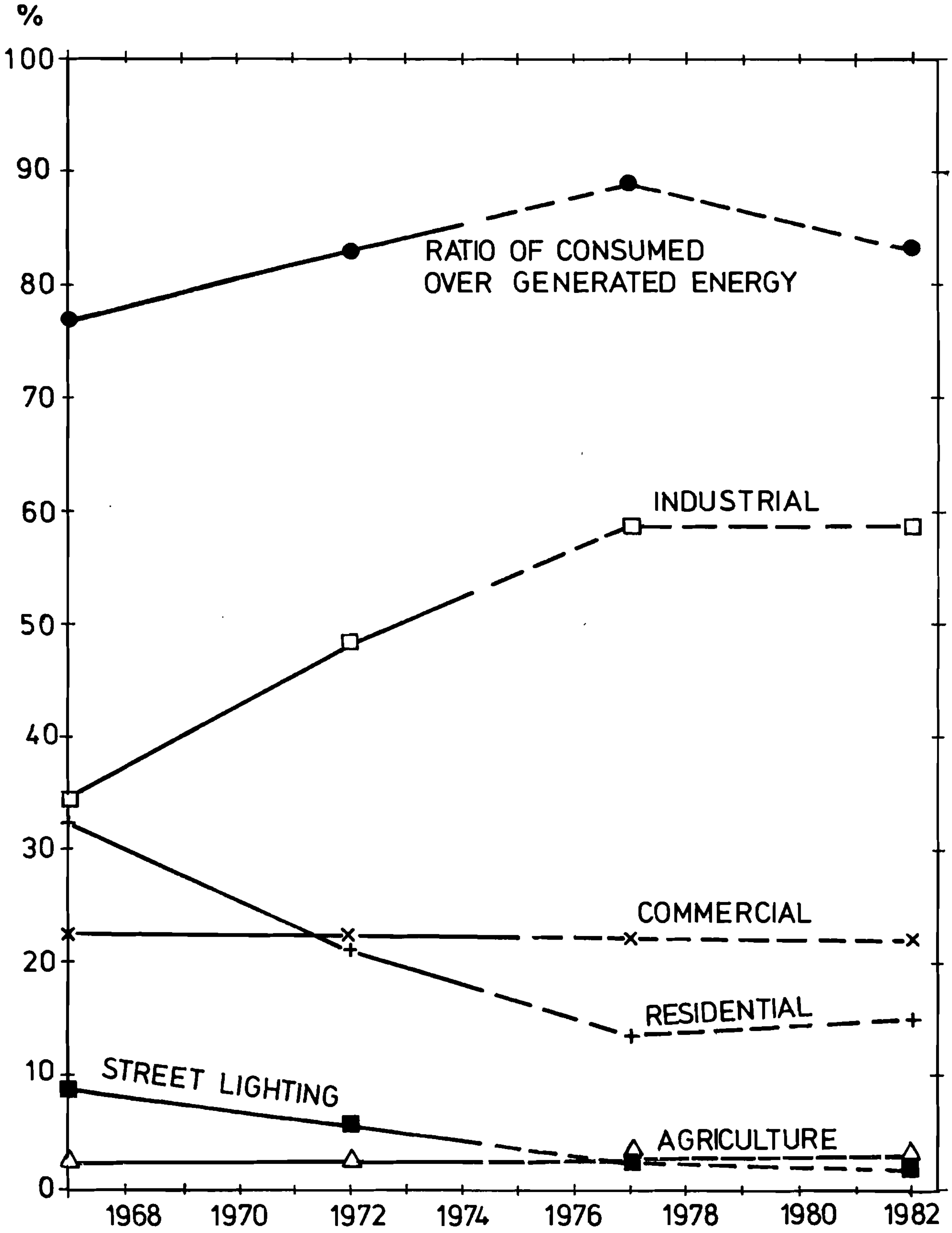

FIGURE 7: DISTRIBUTION OF ELECTRICAL ENERGY GENERATED BY MINISTRY OF POWER AMONG VARIOUS SECTORS

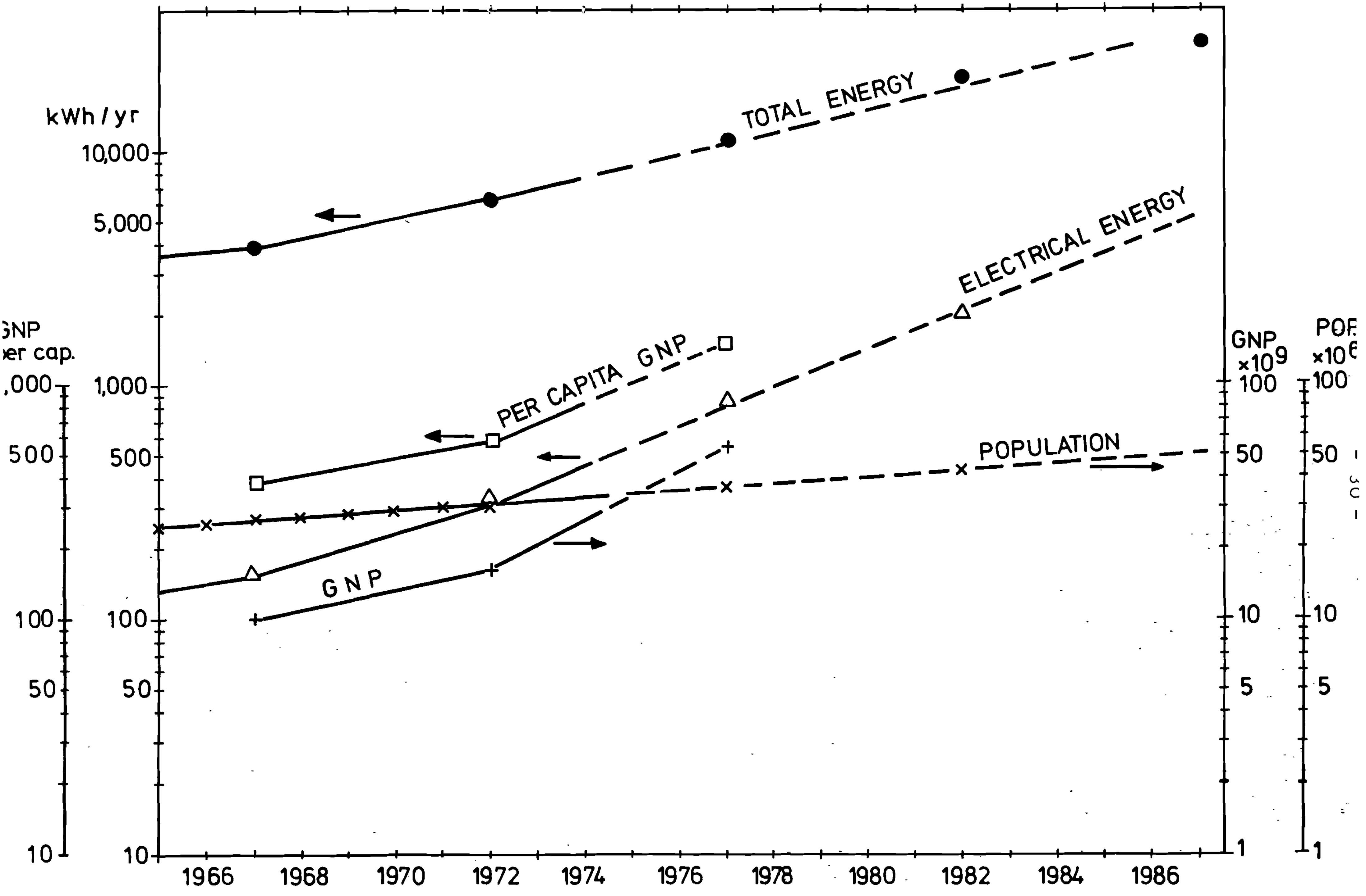

FIGURE 8: PER CAPITA ENERGY CONSUMPTION AND THE GROSS NATIONAL PRODUCT

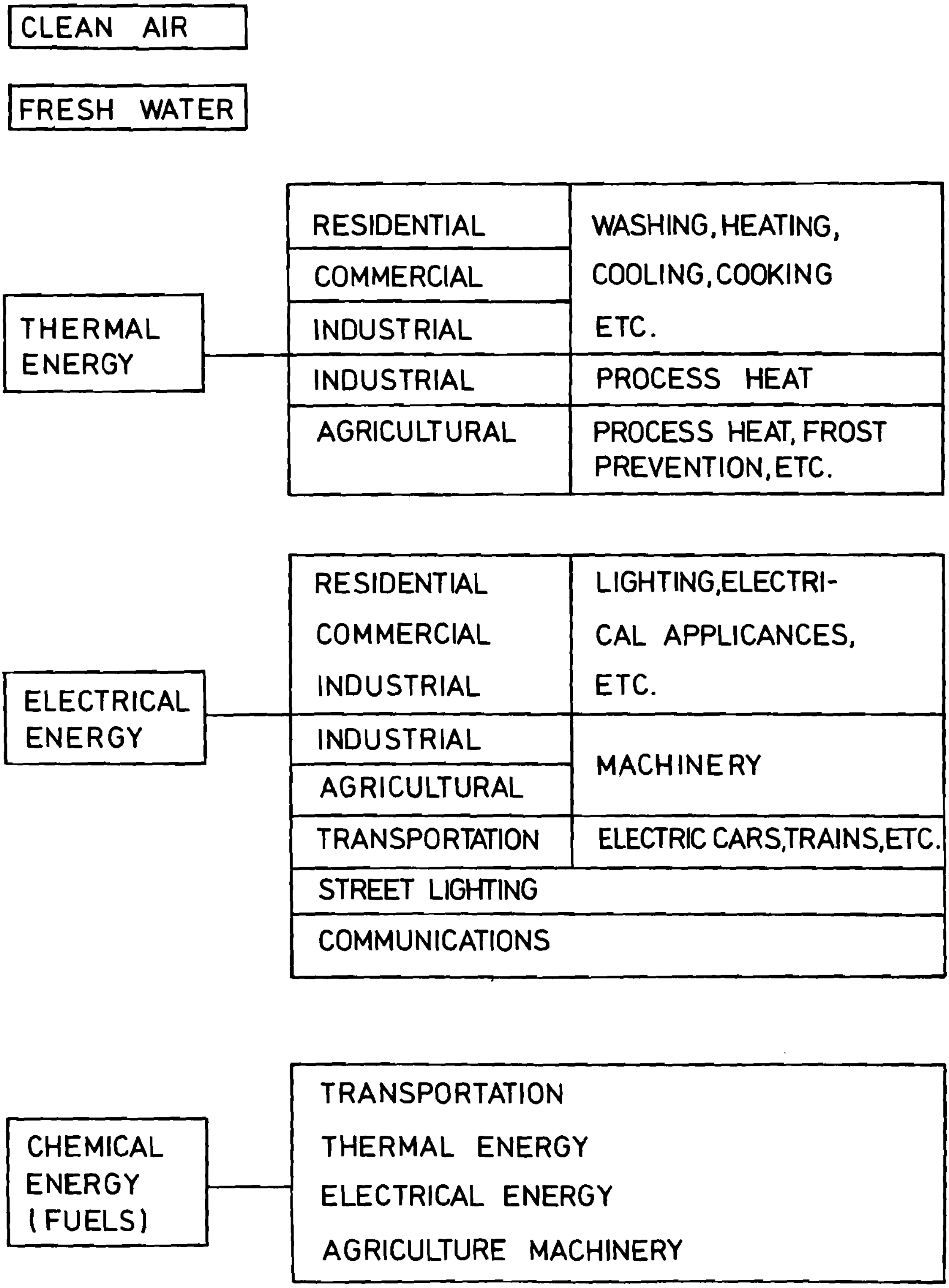

FIGURE 9: THE GENERAL REQUIREMENTS OF A COMMUNITY

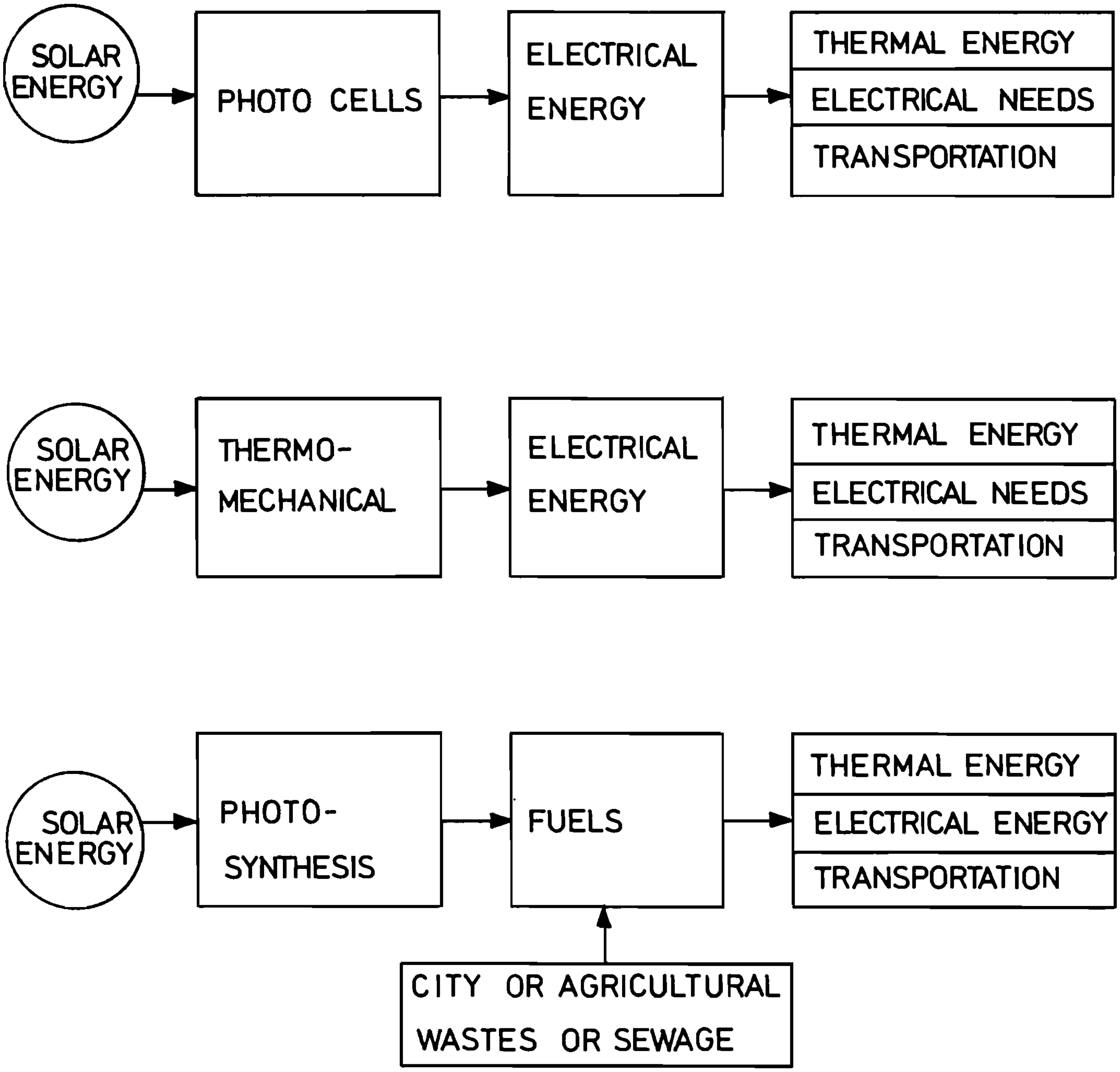

FIGURE 10: VARIOUS METHODS FOR MEETING THE ENERGY NEEDS BY SOLAR ENERGY

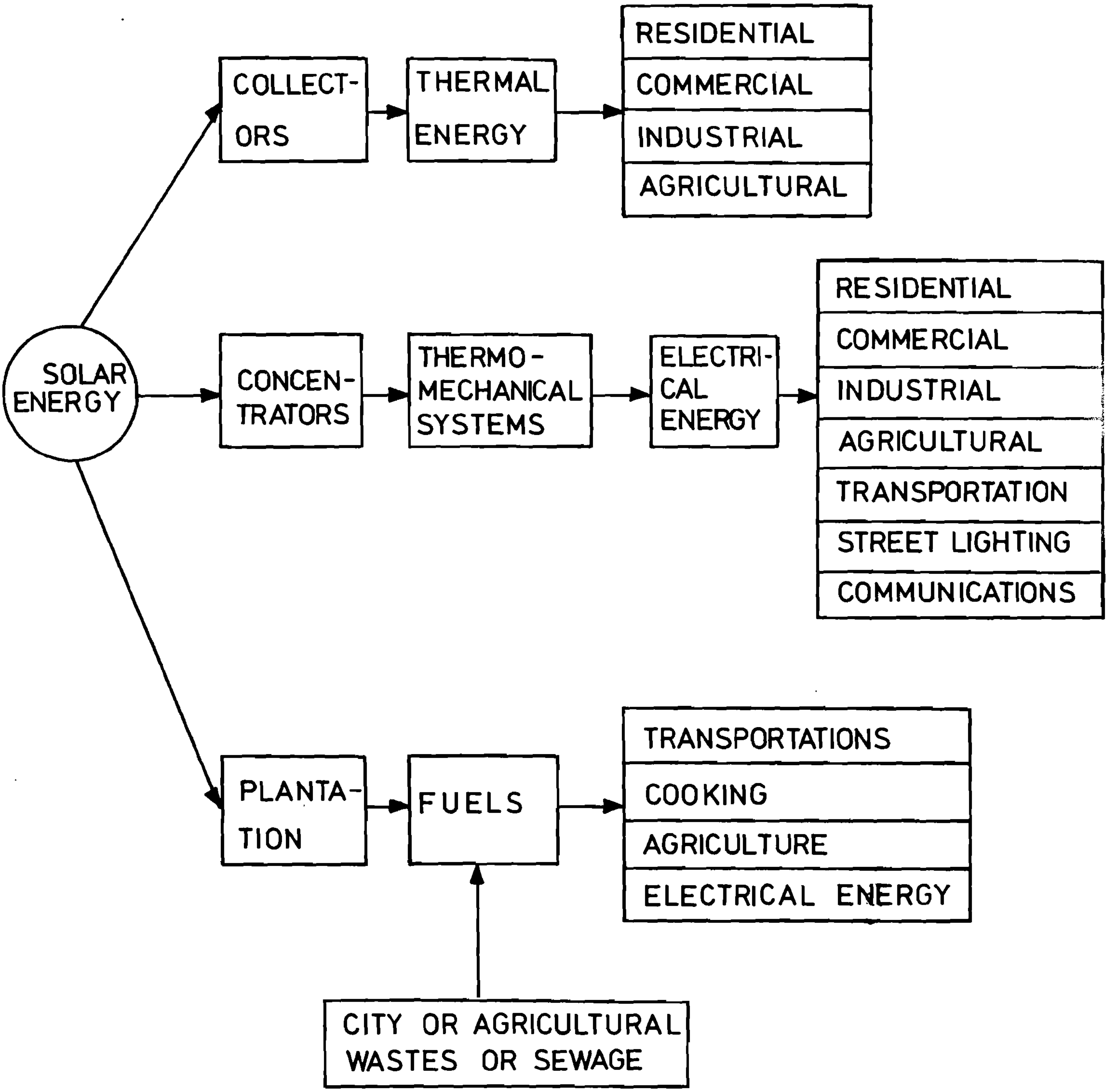

FIGURE 11: A SUITABLE METHOD FOR MEETING THE ENERGY NEEDS OF A TOWN BY SOLAR ENERGY

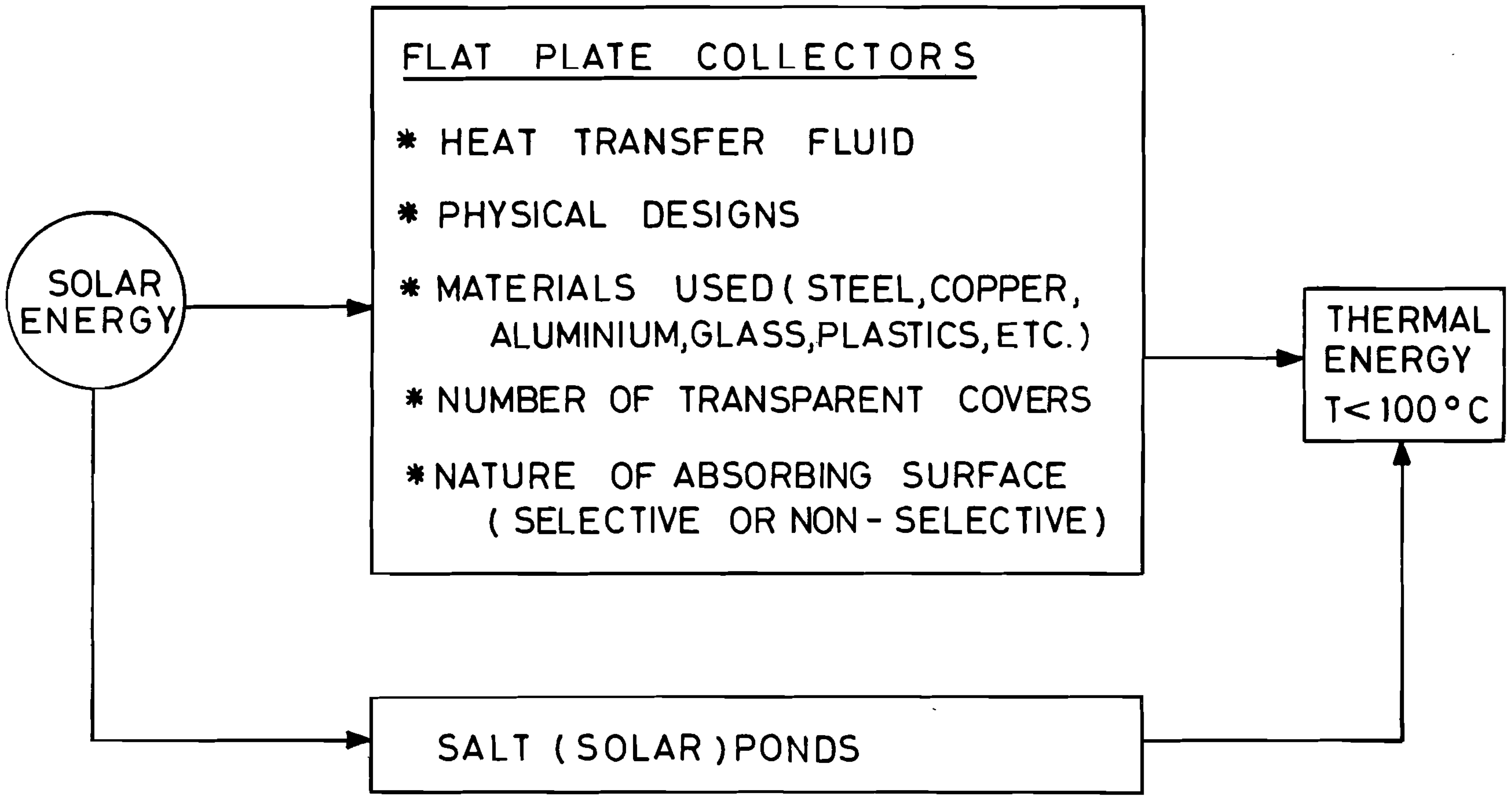

FIGURE 12: METHODS OF CONVERTING SOLAR ENERGY TO THERMAL ENERGY WITH FLUID TEMPERATURES < 100°C.

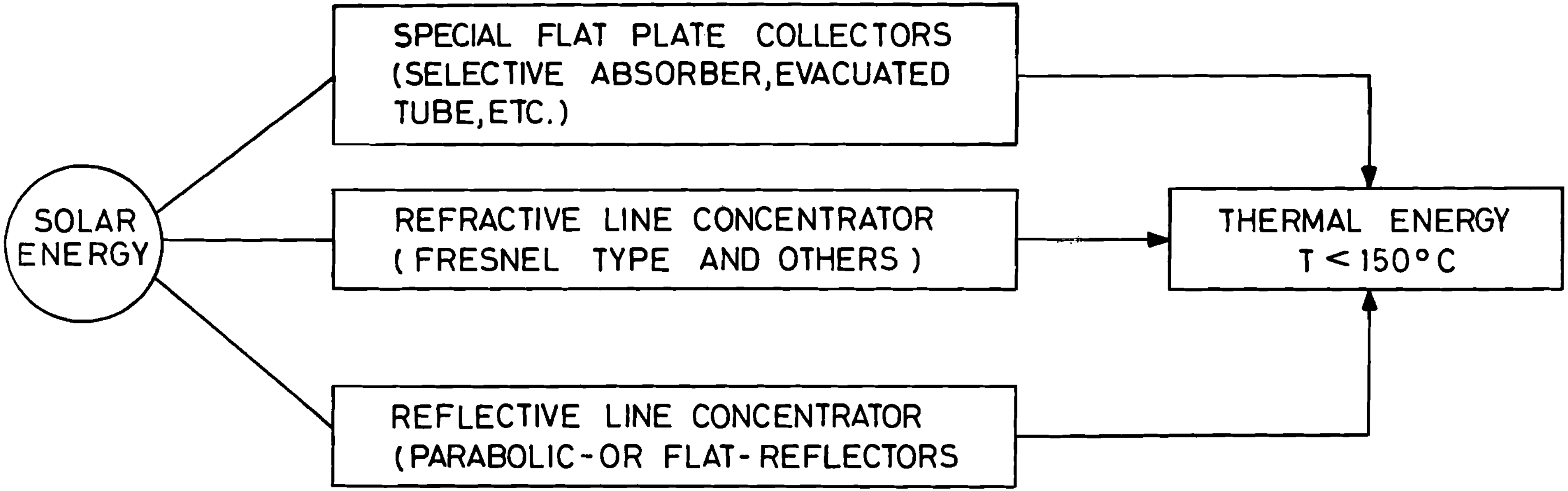

FIGURE 13: METHODS OF CONVERTING SOLAR ENERGY TO THERMAL ENERGY WITH FLUID TEMPERATURES OF < 150°C

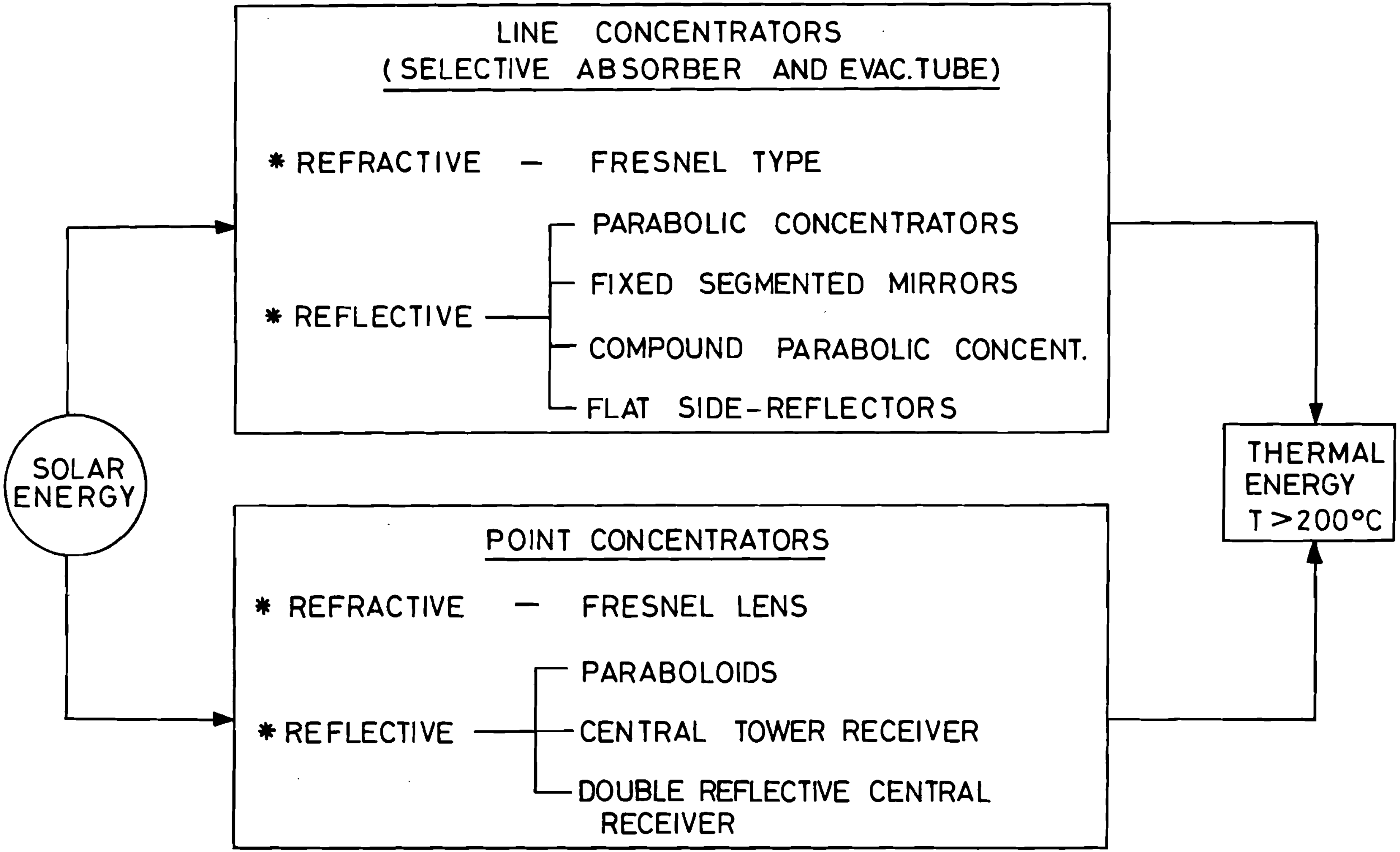

FIGURE 14: METHODS OF CONVERTING SOLAR ENERGY TO THERMAL ENERGY WITH FLUID TEMPERATURES > 200°C

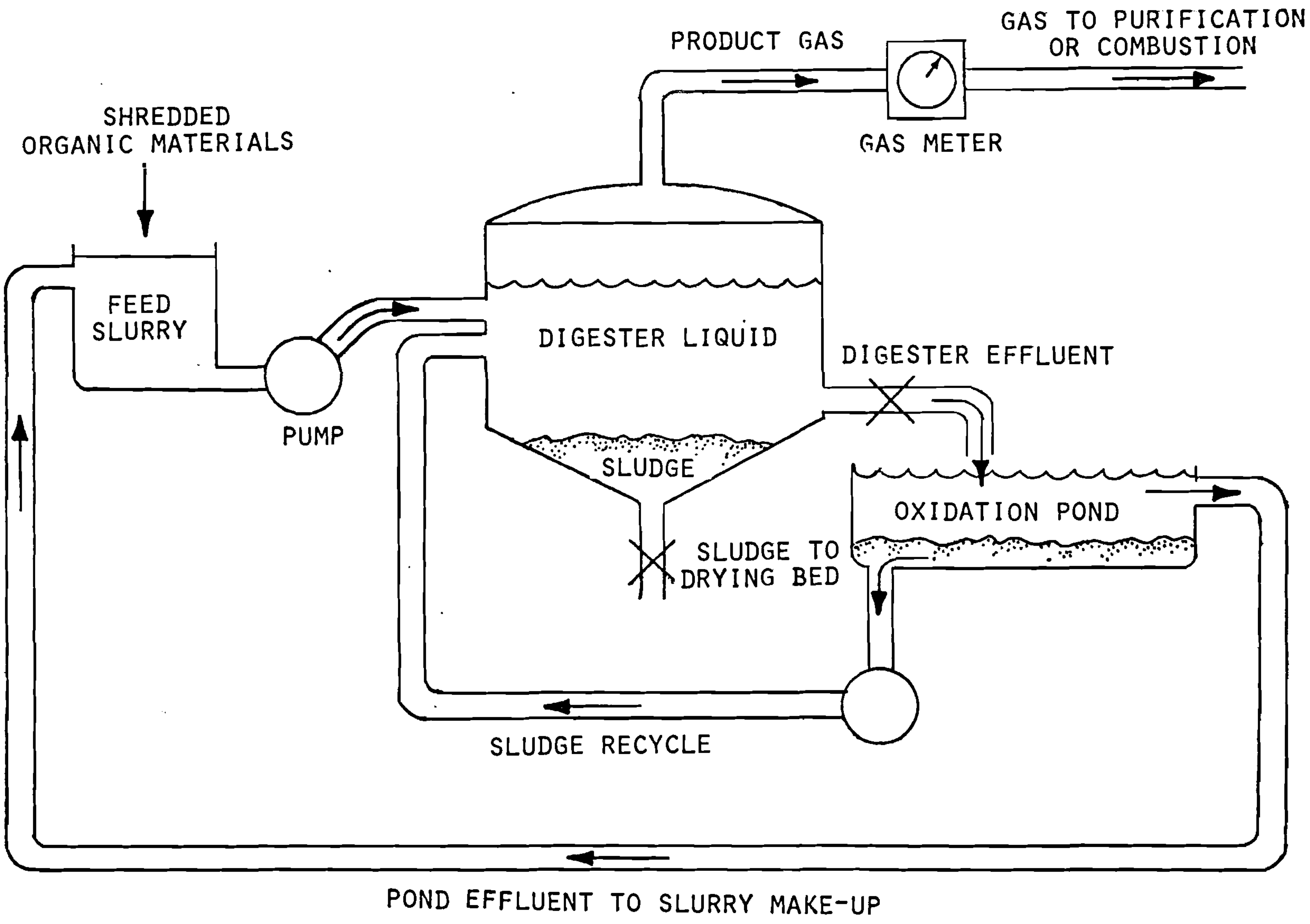

FIGURE 15: CONTINUOUS UNIT FOR CONVERTING ORGANIC MATERIAL TO METHANE BY ANAEROBIC FERMENTATION

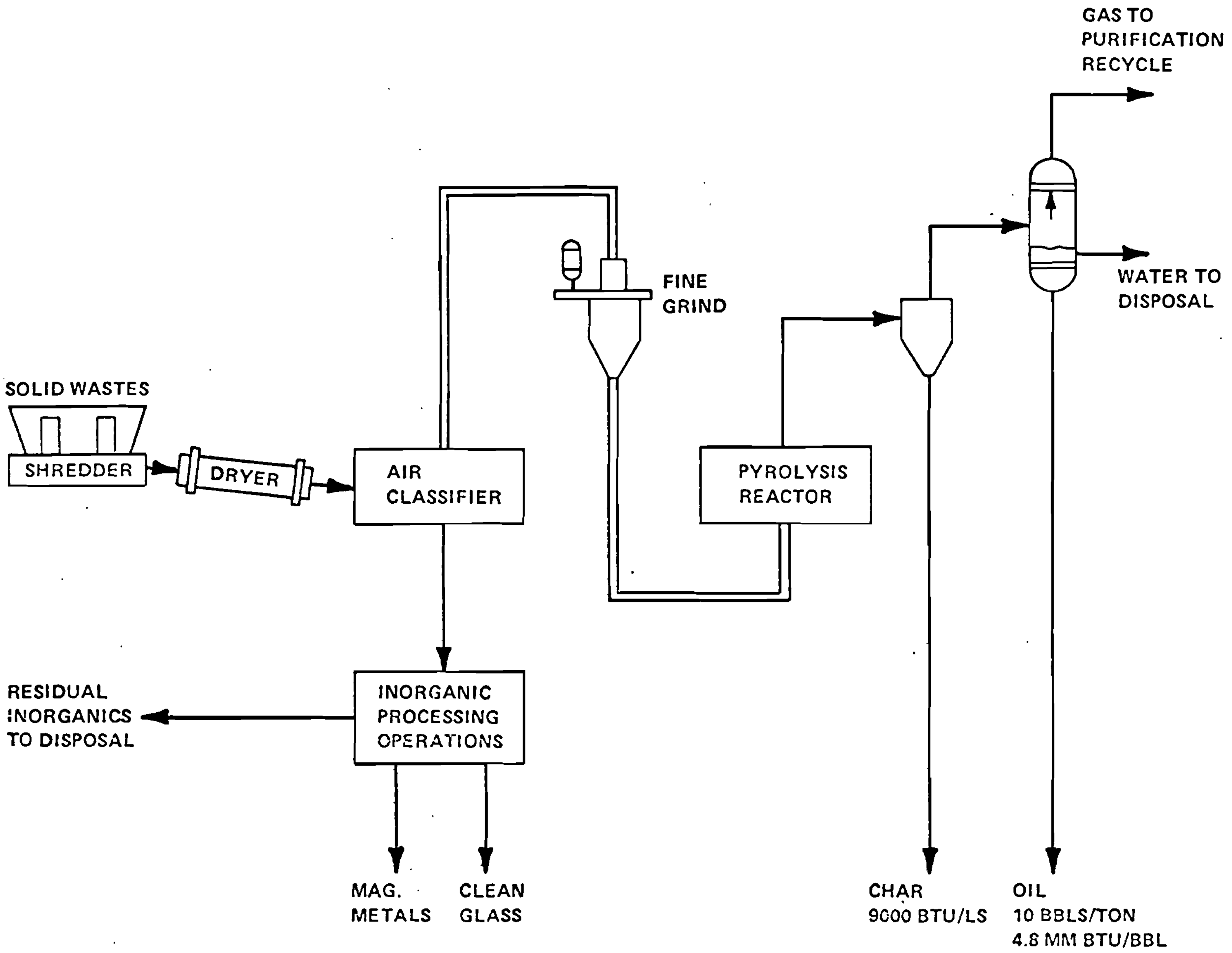

FIGURE 16: SCHEMATIC OF SOLID WASTE PYROLYSIS PROCESS

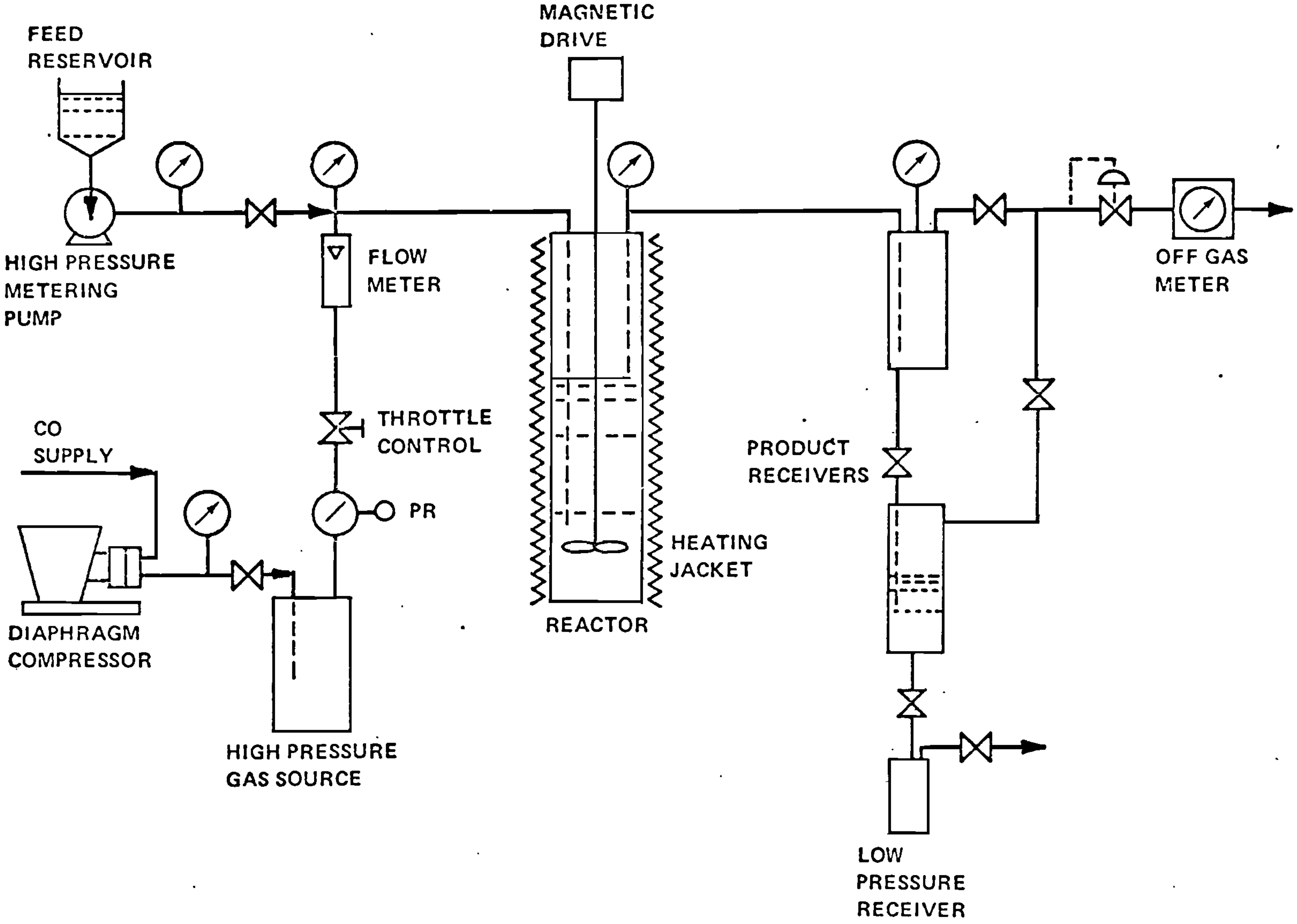

FIGURE 17: CONTINUOUS UNIT FOR THE CHEMICAL REDUCTION OF ORGANIC WASTES TO OIL WITH CO AND H_2O

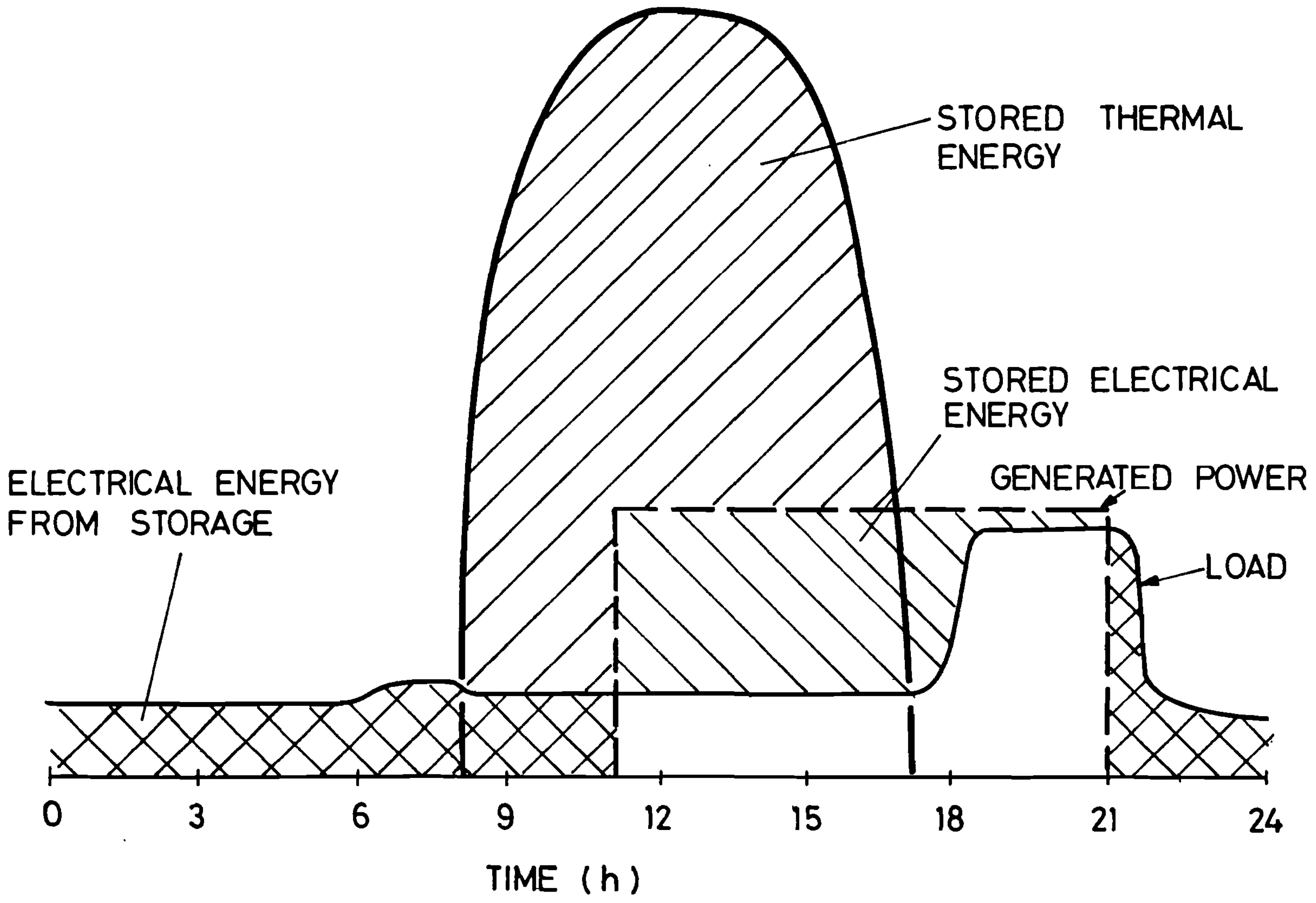

FIGURE 18: ELECTRICAL ENERGY GENERATION AND USE PATTERN EMPLOYING THERMAL AND ELECTRICAL ENERGY STORAGES

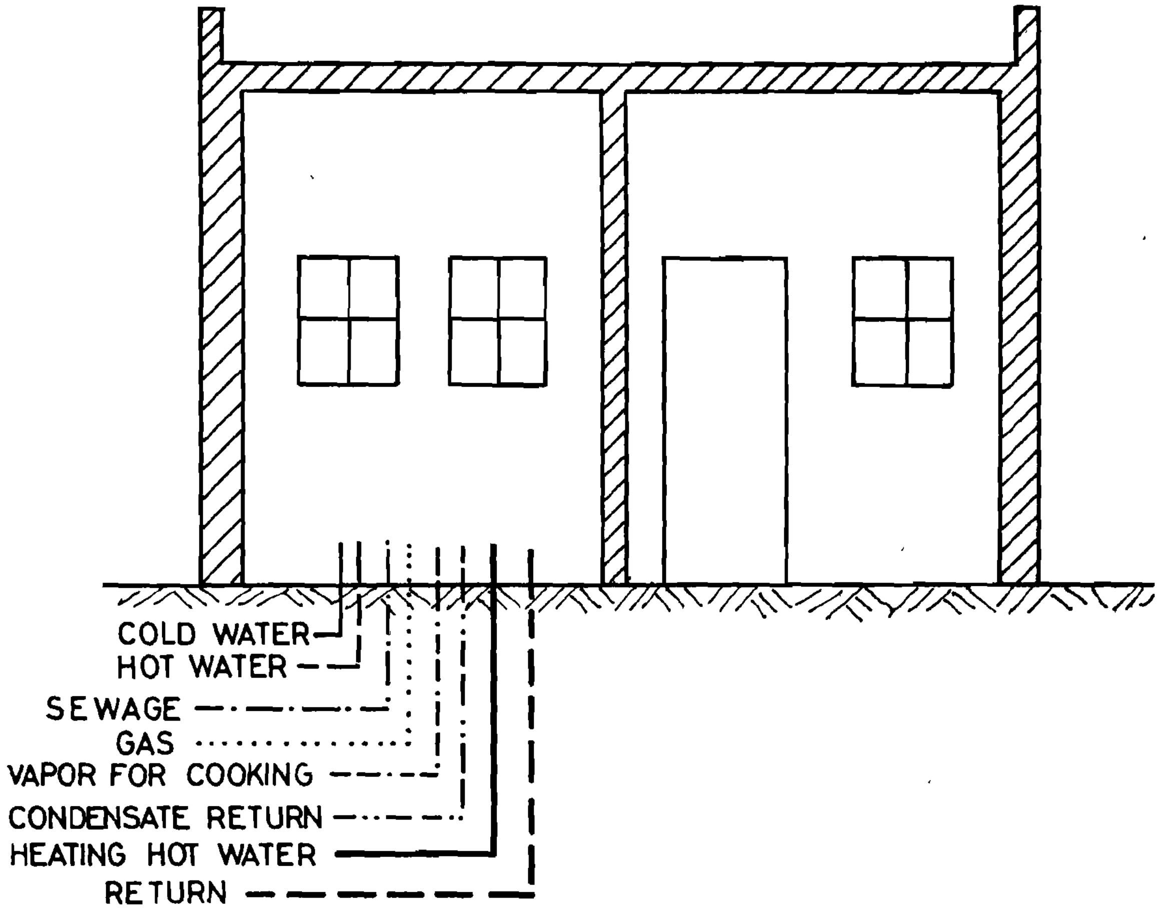

FIGURE 19: THE PIPING CONNECTIONS TO A HOUSE RECEIVING ALL ITS ENERGY NEEDS FROM A CENTRAL SOLAR PLANT

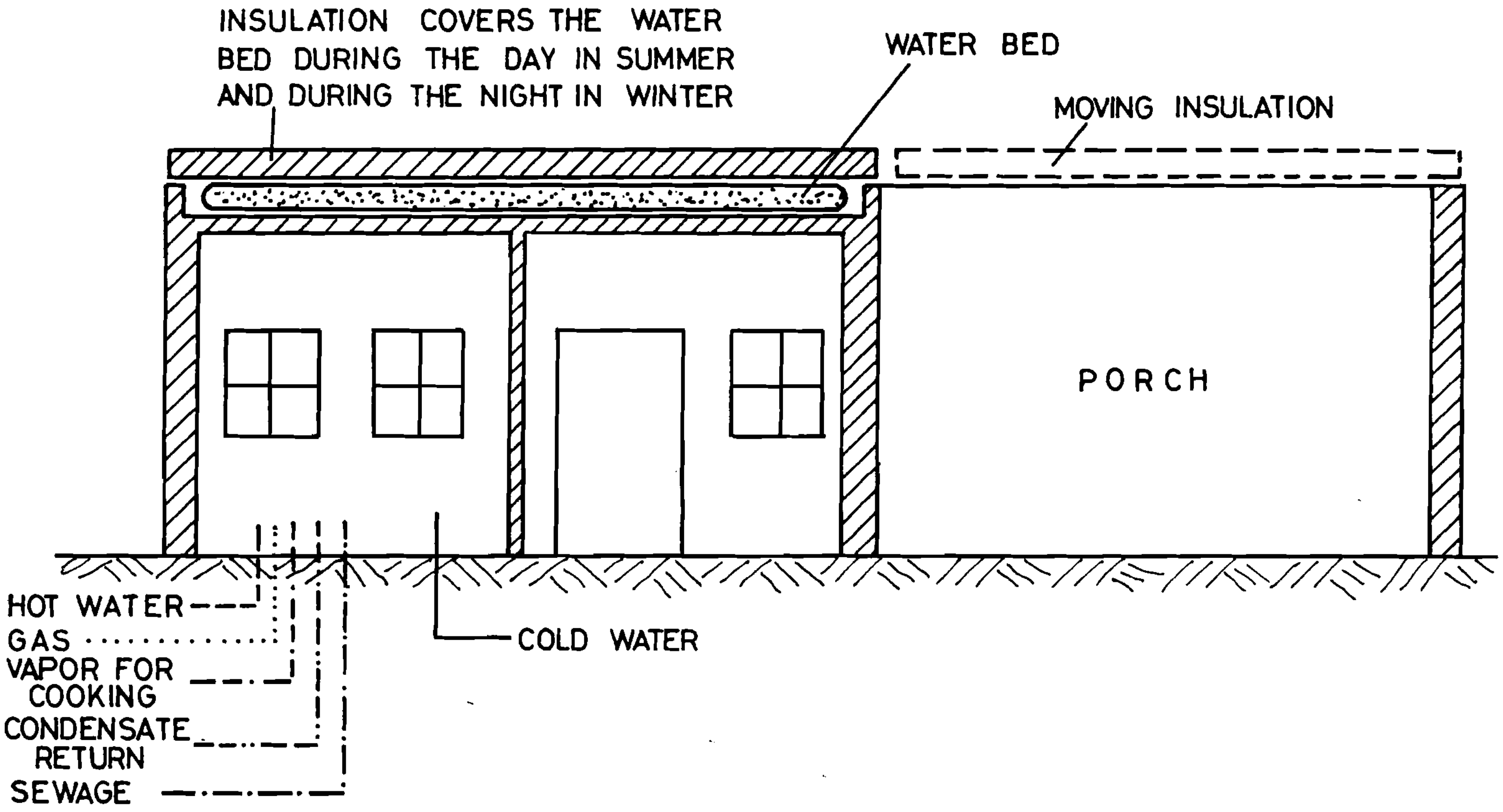

FIGURE 20: A SOLAR HEATED AND NOCTURNALLY COOLED HOUSE WITH ITS PIPING CONNECTIONS

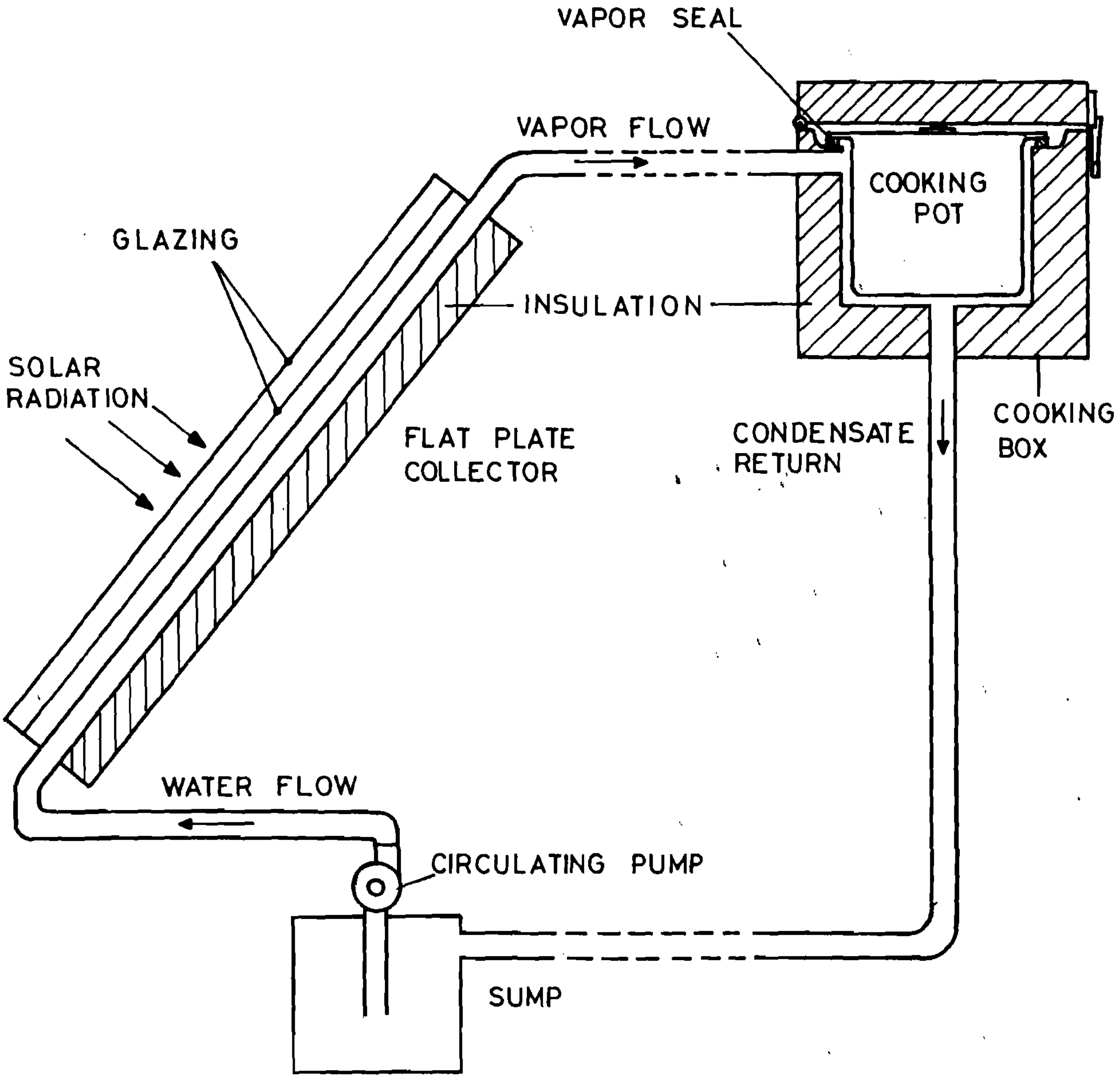

FIGURE 21: LOW TEMPERATURE COOKING BY WATER VAPOR

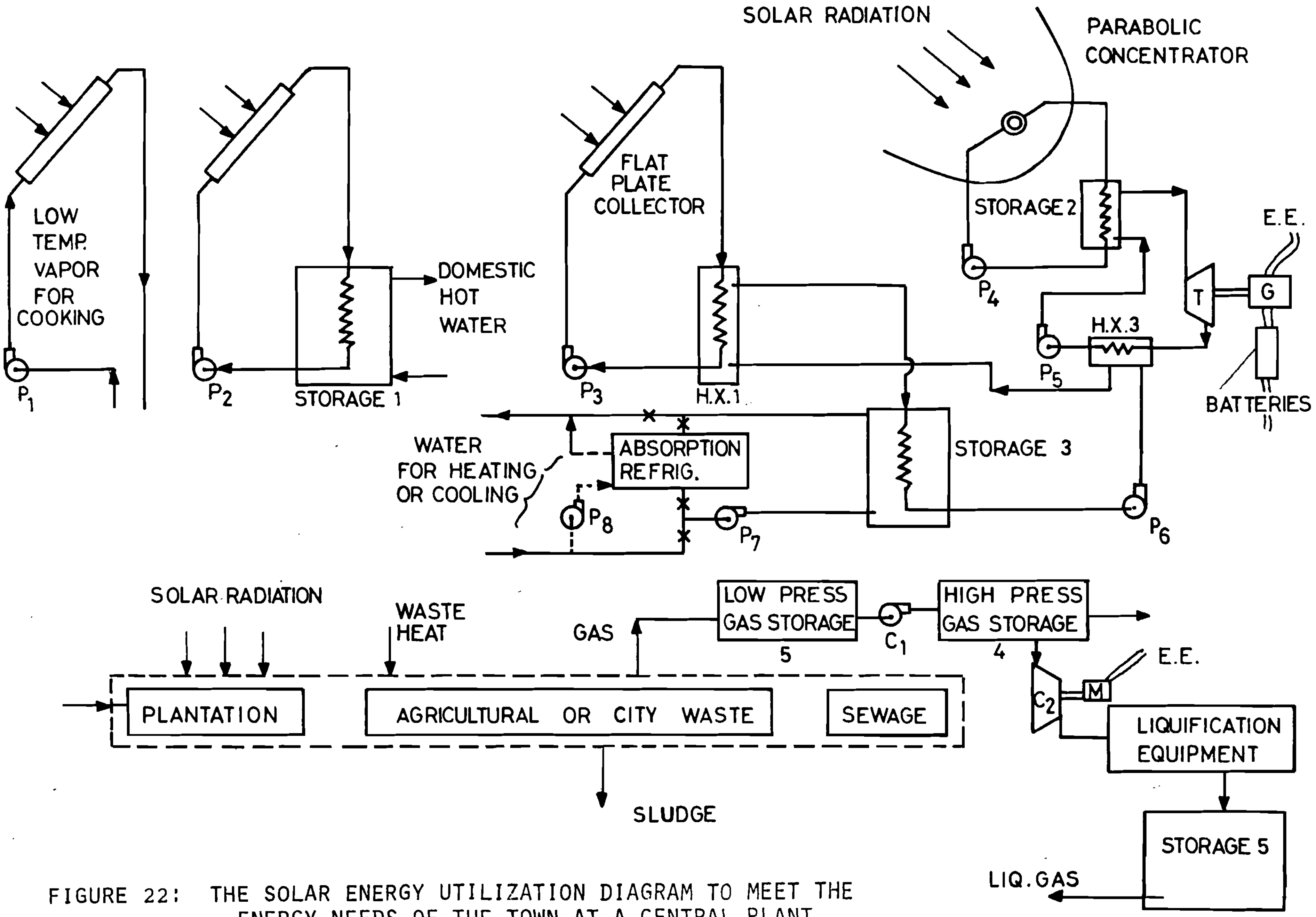

FIGURE 22: THE SOLAR ENERGY UTILIZATION DIAGRAM TO MEET THE ENERGY NEEDS OF THE TOWN AT A CENTRAL PLANT

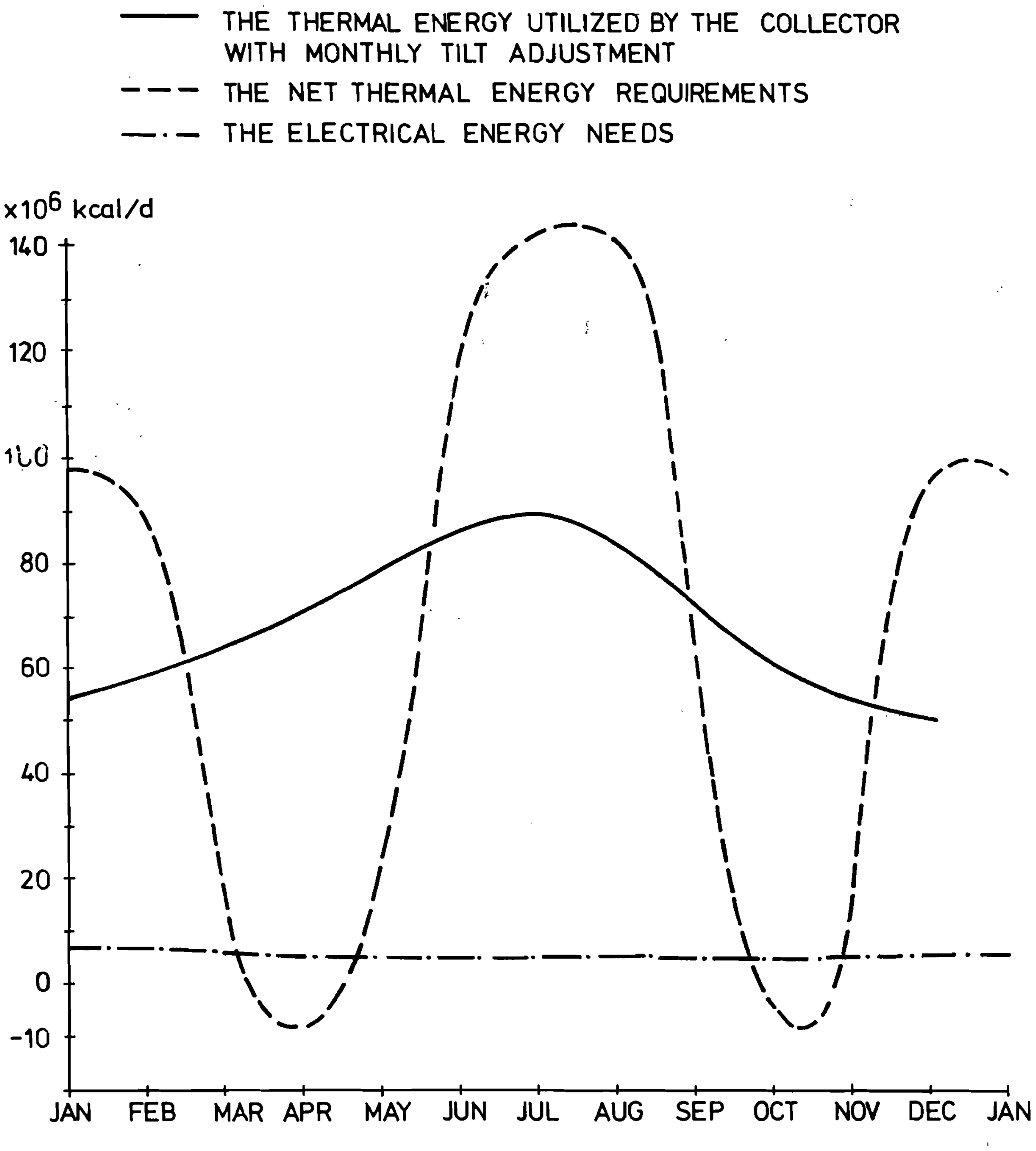

FIGURE 23: TOTAL ELECTRICAL AND NET THERMAL ENERGY NEEDS FOR THE SOLAR TOWN OF 4000 POPULATION AND THE TERMAL ENERGY WHICH MAY BE UTILIZED BY A SOLAR COLLECTOR OF 30,000 M^2

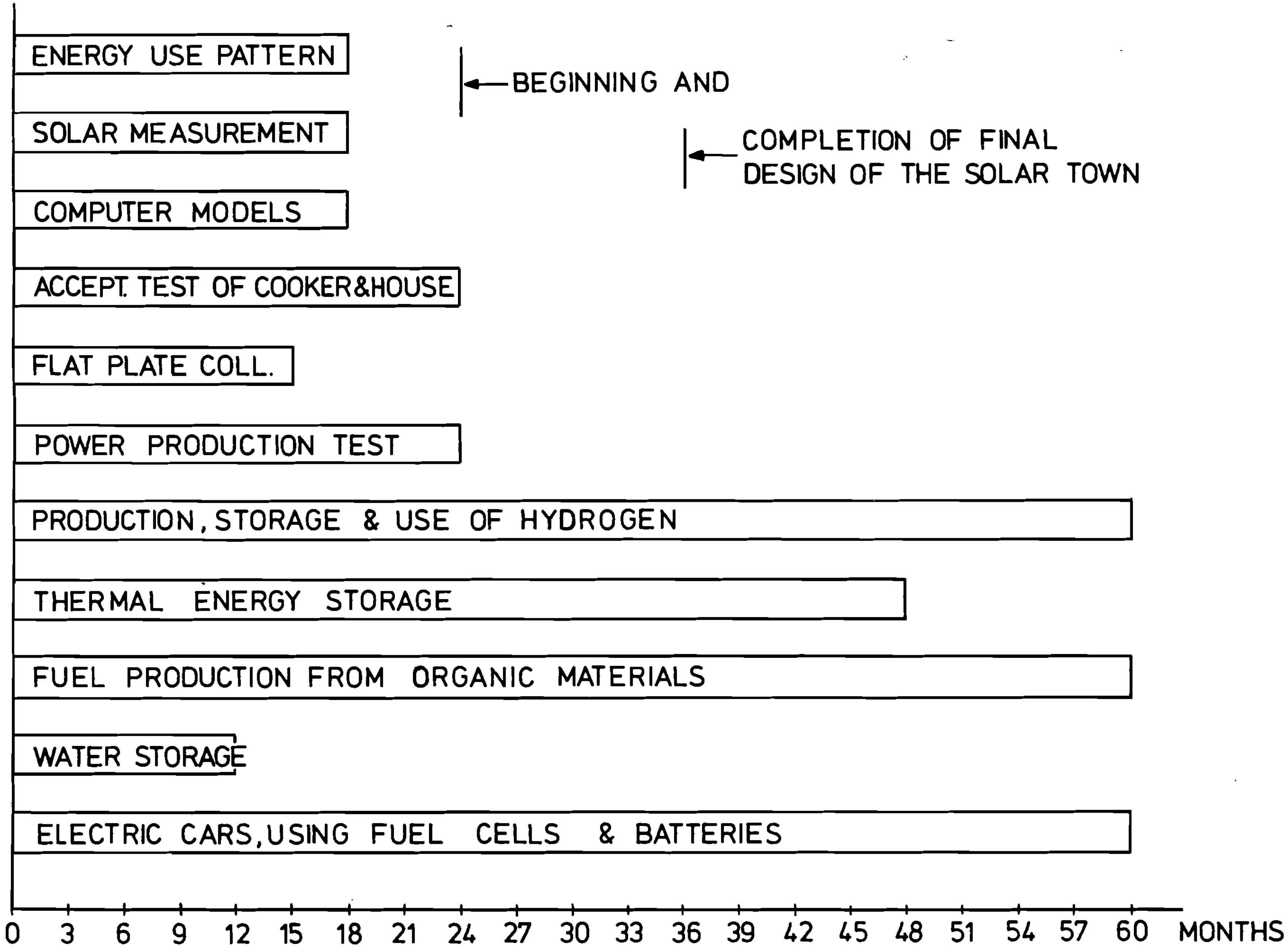

FIGURE 24: THE TIMETABLE FOR THE EXECUTION OF RESEARCH PROJECT