Chapter 5
Plant/Layout Design

5.1: Demand Assessment

5.1.1: Prevalent Methodologies

The following are the usual methods for demand assessment that are mainly used for larger plants.

Time trend extrapolation. This consists of extrapolation of past growth trends, assuming that there will be little change in the growth pattern of the determinants of demand such as incomes, prices, consumer tastes, extra appliances, etc. The main advantages of this approach are its simplicity and modest requirements in terms of both data and analytical skills. The major disadvantage is that no attempt is made to explain why certain electricity consumption trends were established in the past.

Econometric forecasting technique. This method correlates past electricity demand with other variables such as prices and incomes; and then future demands are related to the predicted growth of these other variables. This method is more sophisticated and could be more accurate than simple time trend analysis, but there could be problems in acquiring the relevant data.

However, these methods are usually not suitable for MMHP plants, which are almost always isolated systems, and where the distribution network is small. Also MMHP plants usually always supply electricity to areas that did not previously have any electricity.

5.1.2: A Method Suitable for MMHP Plants

Because of the small network, it is possible and convenient to assess the demand by the direct survey methods. Questionnaires should be designed to solicit accurate information from the customers on their present and future patterns of energy use, affordability, willingness to pay, etc.

Since lighting is the first and main use of the power from MMHP plants, demand for lighting is the largest factor in determining plant size. Therefore, demand is assessed by counting the number of bulbs (usually 25W or 40W) required by each customer. Additional power may be required by a household to operate radios, TVs, or cassette players if the number of watts requested for lighting is insufficient to cover this requirement as well. The sum of the power demand of each household gives the maximum power demand, and the plant is sized accordingly.

The advantages of assessing demand by the direct survey method are simplicity and accuracy. However, it does require some skill to design, complete, and interpret the survey questionnaires to get meaningful results.

5.1.3: Suggested Questionnaire Format for a Demand Survey

For domestic demand

- How many bulbs do you wish to install? Family size/land holding/no. of animals?
- Are you willing to pay Rs XX per bulb? What is the maximum you are willing to pay for lighting?
- What kind of lighting do you currently use? What is the consumption? - kerosene lamp/ pressurised kerosene lamp/resinous wood/electricity/candles?
- How much do you currently spend on lighting?- kerosene/resinous wood/candles?
- How much do you spend each month on batteries for radios, torchlights, tape recorders?
- How much do you pay for your fuel requirements(cash and/or kind)? wood, kerosene?
- Do you collect your own firewood? How many hours are spent on this?
- Do you hire someone to collect your firewood? What does it cost you?
- How much alcohol do you produce? How much wood do you use for making alcohol?
- What are the sources of income from outside the village? Remittance from family members working in the city or abroad, pensions, government job in the village(e.g., teacher), portering?

The above questions should give an indication of the energy consumption and the willingness and ability of each household to pay for electricity.

For industrial demand (to existing industries, community leaders, development workers, NGOs, etc).

- How are current energy needs met? e.g., for grain milling, rice hulling, oil expelling?
  - manual, animal, traditional water mill, turbine mill, diesel mill, etc?
- What industries are currently running in the village?
  - How is the energy requirement of the industry met?
  - How much does it cost?
  - How likely is it that they will use electricity to meet their energy needs, and to what extent?
- What industries could be established using the electric power?
  - Are there sufficient raw materials to run the industry?
  - Who are the prospective entrepreneurs who will run these industries?
  - Do their backgrounds/experiences/motivation indicate that there is a good possibility that these industries will in fact be established?

There is no standardised or generally accepted format for assessing load demand for MMHP plants. So far, it has been left to the entrepreneur or his consultant to determine the current and future demands. This has led, in some cases, to plant sizes far in excess of what was needed.

5.2: Determination of Optimum Plant Size

When considering what plant size is required to meet the demand, it is useful to consider the following ratios.

$$\text{Power ratio} = \frac{\text{Power used (peak)}}{\text{Power installed}}$$

$$\text{Plant factor} = \frac{\text{Energy used over a period}}{\text{Energy available}}$$ (The period is usually a year)

An MMHP plant should be designed to have as high a plant factor as possible. A high plant factor means increased energy sales, hence higher income, which increases the possibility of the plant being financially viable. Since there is very little additional cost incurred in generating power from an MMHP plant for additional hours (unlike, e.g., a diesel plant), increasing the plant factor means a reduction in the unit energy cost. This should make the energy more affordable and lead to increased sales, which in turn lead to lower energy costs.

Other factors to be considered in determining the size of the MMHP plant are given below.

1. The natural resources available to generate power; i.e., head and flow. The available parameters might not be sufficient to meet the power requirements of the users.
2. The users' demand for power. The output of the plant should be able to meet the real or expected needs of the users for lighting, running industries, irrigation, etc.
3. The users' ability and willingness to pay for the plant's installation and operation. Regardless of how much power the users may want; it must be within their ability and willingness to pay. If the plant is too large, it may cost beyond what the users are willing and able to pay. This will result in the plant not being built or, if built, lead to closure/ losses due to insufficient income.
4. The users' ability to manage the plant; the size of the plant must be within the capacity of the users to manage it properly.

5.2.1: *Meeting the Current Demand*

Once the power requirement of the customers is known, the process of deciding the plant size can begin. The size of the plant should be the optimum possible that is capable of meeting the needs of the consumers. Building a larger plant than required means that both the capital and operating costs will be higher. However, a larger plant makes it possible to increase revenue by increased sales in future. If there are a number of machines which the plant is expected to operate (e.g., a flour mill, a huller, an expeller), it is essential to ascertain whether it is really necessary to have all the machines operating simultaneously. If all the machines need not be run simultaneously, then the size of the plant can be reduced considerably, thus reducing the capital investment.

In the case of electricity supply, it is usually the requirements for lighting that determine the plant size. In this case, it is worthwhile considering the use of fluorescent lights, instead of ordinary incandescent bulbs, to reduce the power demand but still meet the lighting needs.

5.2.2: *Meeting Future Demand*

It is sometimes advisable to incorporate the near-term future demand also by installing a larger plant. To assess the future demand for power from an MMHP plant, the direct survey method is used. For MMHP plants, demand assessment for five to 10 years is sufficient. The main factors that need to be considered in assessing future demand are:

a. increase in household numbers in the service area;
b. increase in demand for electricity because of additional income due to increase in economic activity, e.g., tourism, industrial activity, etc; and

c. increase in demand for electricity in order to run small industries, processing facilities, etc.

There are a number of options in plant design when building for future growth in demand.

- Build a plant large enough to meet the projected demand. This is advisable only for small plants (up to 15kW) for which the projected demand growth is fairly small; e.g., less than 50 per cent of the current demand.
- Build the intake and head race for the larger flow necessary to generate the extra power. The forebay, penstock, and powerhouse equipment can then be added when required. This assumes that there is extra water available in the river to generate the needed power.
- Build all the structures for the extra power as well, apart from the powerhouse equipment. Add these when the demand reaches its peak.
- Build a new power plant. Assuming that there is extra water or head available from the same or a different river, a new plant can be built to meet the extra demand.

5.2.3: Meeting Demand when Supply is Less than Demand

Usually not many difficulties are faced if the available power is more than the demand. Of course, efforts are made to increase end uses. However, sometimes, because of the constraints on available potential, the plant's power capacity is smaller than required to meet the demand. In such cases, innovative ways must be found to meet the demand of the consumers.

One method is to use compact fluorescent lights (CFLs) for lighting instead of incandescent lights. As the peak demand is for lighting in the evening, using CFLs that consume up to 80 per cent less power for the same amount of light could meet the demand.

Another method is to use batteries to supply lighting. This also has the advantage of saving on transmission costs. Discharged batteries are brought to the powerhouse for recharging. They are then used for lighting. This permits a larger number of customers to be served, since off-peak power is used to charge batteries. However, this is a cumbersome process for the consumers as batteries have to be carried to and from the charging point.

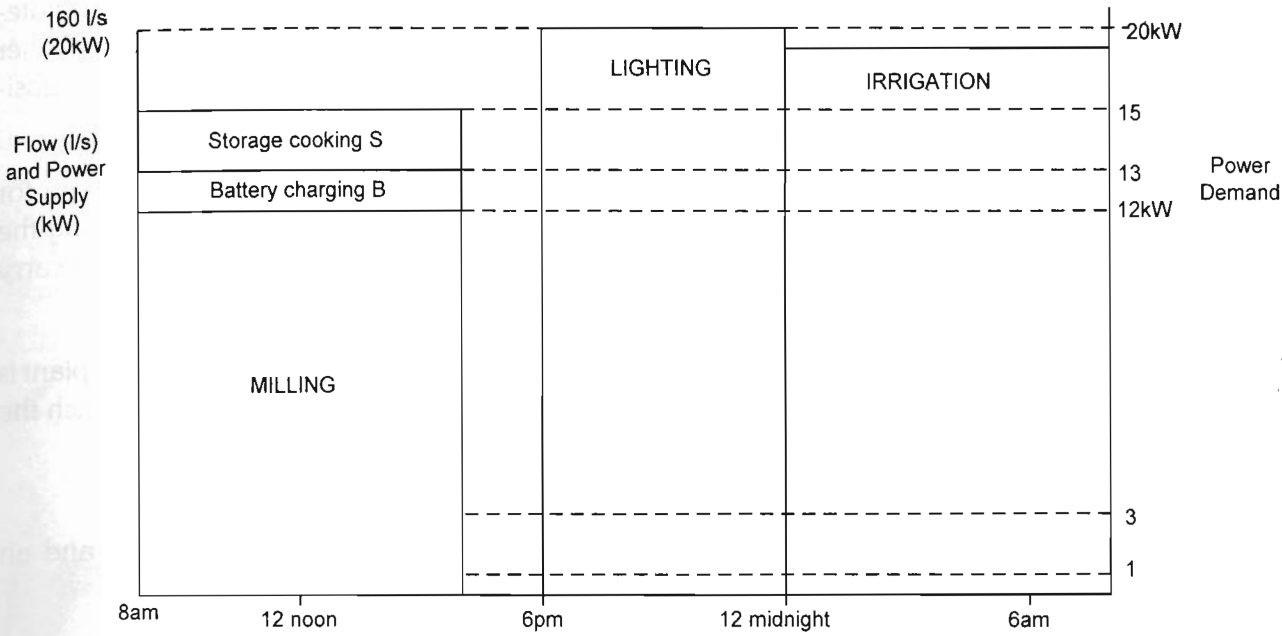
For industrial loads, a system of taking turns to use the power needs to be devised. For example, a bakery, sawmill, and flour mill might use the available power; e.g., bakery, 0400 to 0600 hrs; sawmill, 1000 to 1300 hrs; flour mill, 1300 to 1600 hrs; and so on.

Sometimes less water is available due to seasonal variations, or due to diversion for other purposes. In these cases, demand may be matched by using a daily graph such as the one shown in Figure 5.1.

5.3: User Participation

User participation is essential for the successful implementation and management of an MMHP plant. Insufficient involvement of the users can lead to delays in project implementation due to lack of manpower for construction, delays in house wiring, etc. The operation and management of the plant will also suffer if there is not enough participation from the users. In the absence of the close commitment and involvement of the community, when things go wrong, as they sometimes do, the users are liable to regard the breakdown as someone else's responsibility, and this could lead to the plant being shut down for long periods.

Figure 5.1: A Demand/Supply Graph for a Typical Day in the Dry Season for a 20kW MHP Plant



Notes

- The milling, battery charging and storage cooking demands are 8 a.m. to 6 p.m.
- All the supply is consumed by lighting from 6 p.m. to 12 a.m.
- The plant is shut down between 12:00 a.m. till 8 a.m., and water is used for irrigation.

5.3.1: Discussions with the Users

Planning. The users of an MMHP plant must be fully involved from the very beginning. Participation in planning takes place through discussions with the villagers concerning the results of the demand survey, feasibility study, project size and cost, operation and maintenance costs, and tariffs. Detailed design and construction should begin only when they are fully aware of the costs and responsibilities involved in building and operating an MMHP plant and are willing to bear their share of the costs and responsibilities.

Factors to be considered in the planning discussions are as follow.

- What are the end uses which the MMHP plant is supposed to fulfill?
- Will the MMHP plant fulfill this demand?
- Will everyone in the village receive electricity? If not, why not?
- Is the purpose of the MMHP project clearly understood by all prospective consumers, including the tariff structure?
- What are the other competing development projects and does the MMHP plant have sufficient priority?
- What are the alternatives and how does MMHP compare with them?
- What demand growth rate should the plant be designed for? How many years into the future?
- Is everyone in the village willing and able to put in his contribution to building the MMHP plant?
- Have discussions been held with people who represent all sections of the community in

terms of geography, sex, age, income levels, electricity subscription, education, occupation, caste/ethnic/religious/social group, etc?

Construction. Up to 15 per cent of the project cost can be met by local labour and material contributions. This is a significant portion of the project cost. Possibilities of higher contributions, perhaps in accordance with a policy laid down to reduce/standardise subsidies, must also be discussed.

Involvement of the users in the construction can also partly provide an opportunity for training the operators of the MMHP plant. Involvement of the operators in installing the pipes, the machinery, and transmission will give them confidence and experience to carry out repairs and maintenance.

Operation and management. Involvement in operation and management of the plant is brought about by training the personnel identified for this purpose. The areas in which the concerned persons will need to be assisted/trained are:

- election of a committee to manage the plant;
- setting up tariff rates, other regulations regarding connections, misuse, etc – and an accounting system;
- plant operation and record keeping;
- maintenance, repair, stock of spares; and
- consumer services and public relations.

5.3.2: Agreements among Users

To successfully implement and run the project, it is essential to have consensus among the users about the MMHP plant.

The areas in which agreements are desirable, preferably in writing, are given below.

- The size and cost of the plant, the contributions from the users to build the plant, and the external sources of financing such as loans, grants, etc.
- Agreement on the use of water if it has to be shared between power and other uses such as irrigation
- Agreement on membership of the committee, the operators, and their salaries and terms of employment
- Agreement on the tariff structure and rates
- Fines for possible misuse

5.4 Layout Design

Figure 5.2 shows the various components of a micro-hydro scheme.

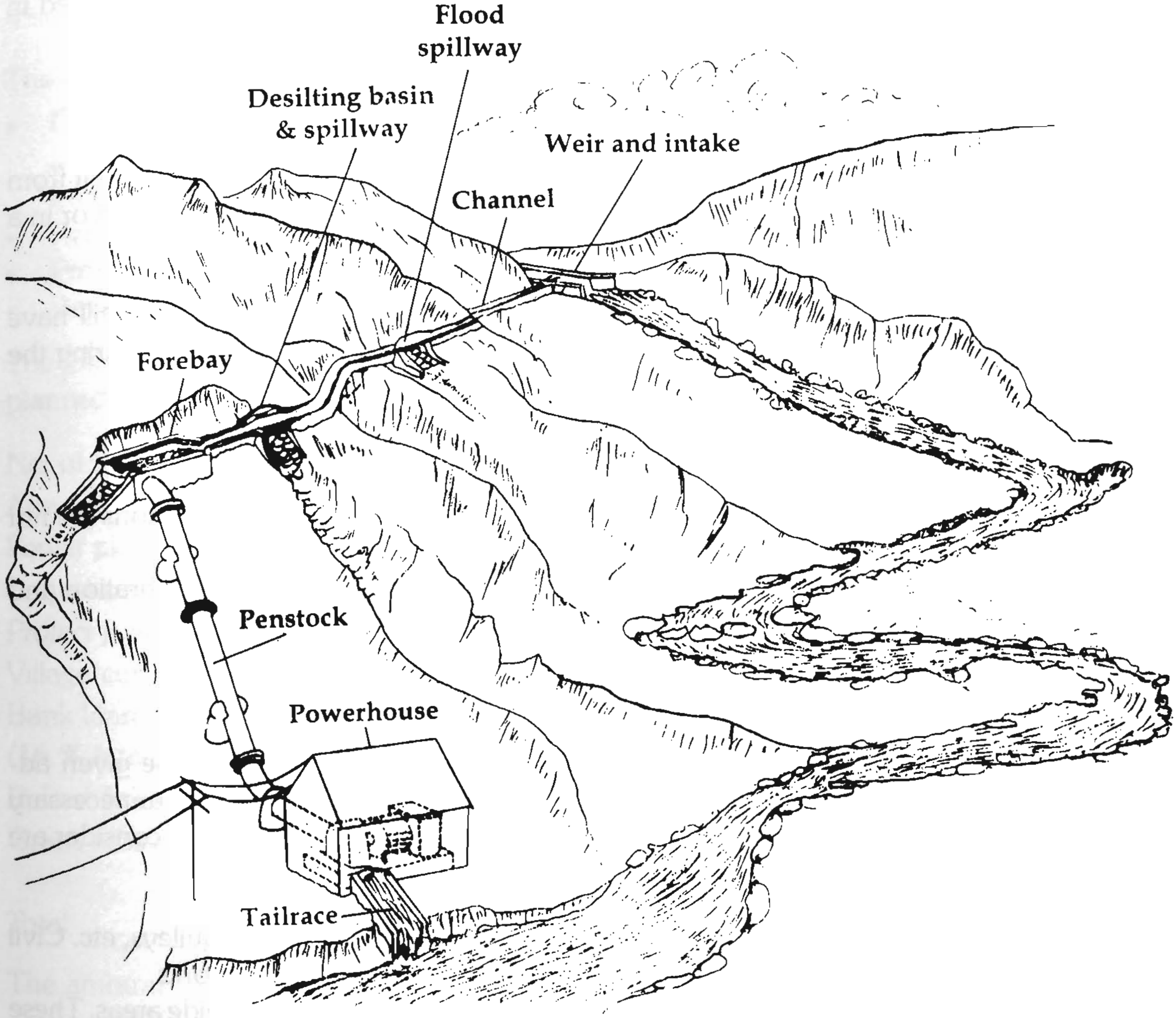
These components, their type, and their functions are described in more detail in the following chapter. However, some suggestions regarding the location of various components are given below.

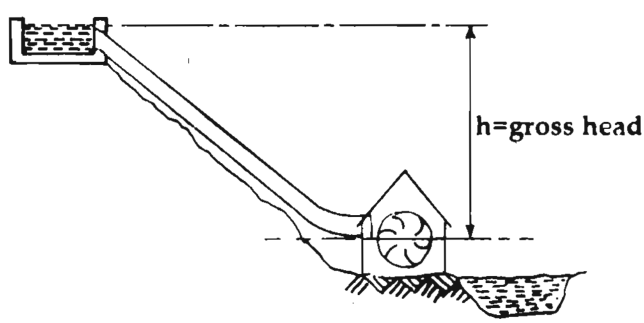
5.4.1: Diversion Weir and Intake

In selecting the location for an intake the following points should receive attention.

- Wherever possible the natural features of the river, such as a pool, a rock bed, or rock bank, should be used so that expenses can be reduced.

Figure 5.2: Components of a Micro-hydropower Scheme





- The intake should be located where there is minimum likelihood of silt deposition or other damage.
- The intake design should be such that excessive flow is prevented through the channel during flood conditions.
- Locations with poor geology should be avoided (see Section 5.1).

5.4.2: *Head race (Power Channel) and Forebay*

Where possible, the path of the channel should be chosen so that it traverses stable ground. Storm gulleys, steep unstable soils, and landslide prone areas should be avoided. The forebay and the desilting basins, which are relatively expensive structures, must also be located in stable places and away from the paths of floods, landslides, etc.

5.4.3: *Powerhouse*

The powerhouse must be located above the 20-year flood level, at least, to prevent it from being damaged by flooding. It should not be located where water is liable to collect or in a place where there is the possibility of flash floods or landslides.

The powerhouse should be large enough for the equipment to be placed and still have sufficient space for the comfortable movement of people while operating or repairing the equipment.

Other important factors to be considered are:

- provision of adequate drainage around the powerhouse so that the foundations are not eroded or saturated with water, and
- the machine foundations must be large and strong enough to withstand vibration and hydraulic forces.

5.4.4: *Geological Considerations*

In designing the above components of the MMHP, geological factors must be given adequate consideration. If this aspect of the MMHP is neglected, there could be unnecessary costs for repair and maintenance, or even loss of the plant. The main areas to consider are as follow.

- Future surface movements: loose rock slopes, areas of mudflow, storm gulleys, etc. Civil works must be protected by slope stabilisation above and below the works.
- Future sub-surface movements: possible landslips, subsidence, and landslide areas. These areas must be avoided, if possible. Aqueducts can be built to traverse a slip zone if costs permit.
- Soil and rock types: different types of soil and rock in the area that could have an effect on the design considerations of the MMHP plant. If the soil and rock type of an area proposed for locating the civil works are unsuitable, there could be additional costs involved in preparing the foundation works.

In extreme cases, the overall geological conditions may be so poor as to make the project site unfeasible.

5.5: Initial Tariff Design and Income Assessment

The tariff structure of an MMHP plant must be designed so that the cost of operating the plant(including loan repayment, reserves for equipment replacement, etc) is covered by the revenues raised. The tariff must also be fair and affordable for various types of customer.

Working out the tariff is part of the process of working out the feasibility of the MMHP plant. An example is given here of a possible approach to financial decision-making suitable for coordination between village bodies, banks, technologists, and expert advisors. This gives a specific illustration of the general point that proliferation of independent MHP schemes will depend ultimately on facilitation of financial decision-making at the local level. The following examples illustrate how tariff rates can be designed and used to find out how much the recipients should pay for the electricity.

The tariff charged must be able to recover the following costs.

- Operation and maintenance. This includes staff salaries, maintenance costs, and costs of keeping spare parts in stock. For an MMHP plant this is taken to be three per cent of the plant cost per year.
- Repayment of any loans taken to build the plant.
- Profits on investments made by the entrepreneur or community.
- Depreciation - money to be set aside for eventual replacement of the plant.

The following **example** illustrates a methodology for designing a tariff for an MMHP being planned and having the following characteristics.

No. of households	200
Average watts per house	100
Power plant size	20kW
Project cost	$32,000 ($ 1,600 per kW)
Project fund breakdown	
Village contribution	$5,000
Bank loan	$9,000
(16 % interest rate, to be repaid over 5 years)	
Raised from entrepreneur/shareholder (dividend 15%)	$10,000
Grant/subsidy	$ 8,000
Total	$32,000

The amount which needs to be raised each year from the tariff is as follows.

- Operation and maintenance costs	$960(3 % of $32,000)
- Loan repayment	$3,000
- Dividend	$1,500
- Depreciation, 5%	$1,600
Total	$7,060

a) Assuming that the electricity is sold on a flat tariff basis and that all the output is sold as planned, the monthly charge per watt will be

$$\frac{\text{Amount to be raised}}{\text{12 x watts available}} = \frac{\$7,060}{12 \times 20,000} = 0.03$$

Therefore, for a household subscribing for 100W, the monthly cost is $ 3.00.

b) However, if only 75% of the electricity is sold, then,

$$\text{Change per watt} = \frac{7.060}{0.75 \times 12 \times 20{,}000} = \$0.04$$

If the power is to be used for lighting only, then the simple method outlined above is adequate. If there are other daytime users as well, then one day (24 hours) is divided into an adequate number of blocks of hours and power allocated accordingly, as has been shown in Table 5.1.

Table 5.1: Tariff Calculation Form

Time	**Customers**									**Total Revenue per Month**	**Total Power Allocated**
	Domestic Households			**Tea Shops**			**Industry**				
	No.	**Watts /hh**	**Tariff**	**No.**	**Watts/ Shop**	**Tariff**	**No.**	**Watts/ In.**	**Tariff**		
Evening hours (6 p.m.- 12 a.m.)	200	100	$0.02	-	-	-	-	-	-	$400	20kW
Morning hours (6 a.m.- 12 p.m.)	-	-	-	5	600	$0.03	1	5000	$0.025	$215	8kW
Afternoon hours (12 p.m.- 6 p.m.)	-	-	-	5	600	$0.03	1	5000	$0.025	$215	8kW
Night hours (12 a.m.- 6 a.m.)											Plant closed
Total Revenue per Month										$ 830	
Total Revenue per Year										$ 9,960	

The tariff is set in such a way that the annual revenue collected is equal to or greater than the amount needed to keep the plant running and to meet all the financial responsibilities. Setting the tariff is a process of iteration between the project cost, how the project is financed, and what tariff rates the customers can bear. Tariff rates for commercial and industrial consumers are usually higher than domestic tariffs. This process can also be used to work out, for example, what the level of subsidy should be or how big a loan can be taken.