MASTER PLAN

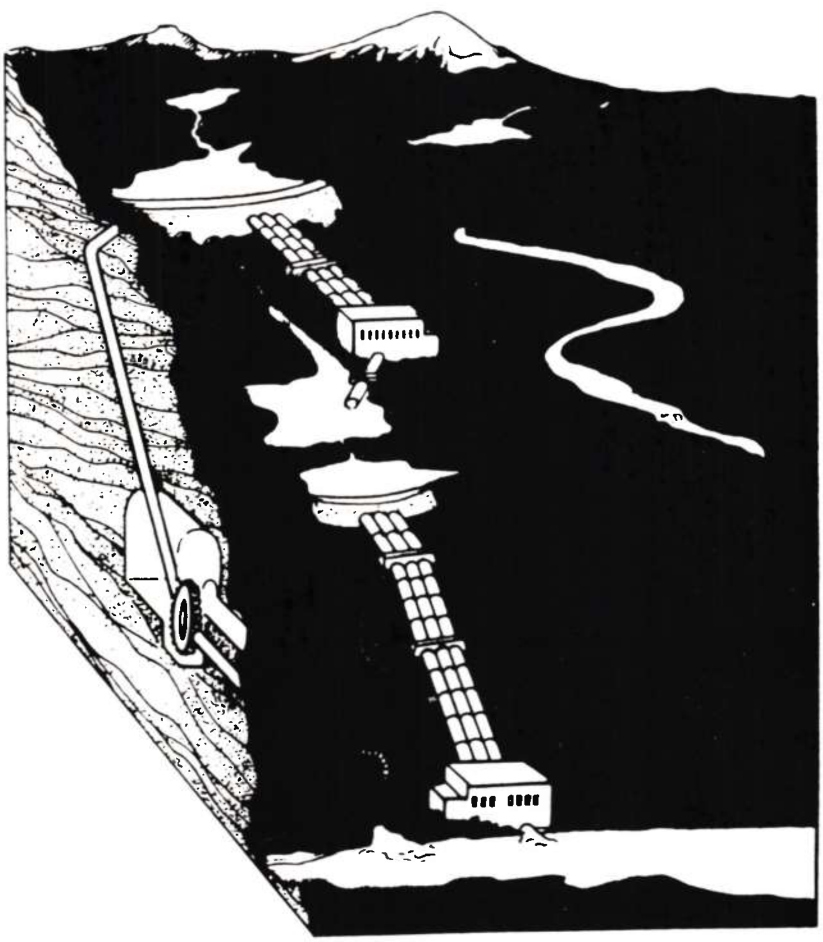
FOR

UPRATING AND REFURBISHING

HYDROELECTRIC POWER PLANTS

IN

NORWAY



NVE
NORWEGIAN
WATER RESOURCES AND
ENERGY ADMINISTRATION

FOREWORD

This paper is prepared for presentation at The Second Conference on Uprating and Refurbishing Hydro Power Plants to be held in Zurich, Switzerland, from October 16th to 18th 1989.

It describes A Master Plan, which is undertaken by The Norwegian Water Resources and Energy Administration, to uprate and refurbish old power plants in Norway. This Master Plan has put particular emphasis on plants which can be commissioned before the year 2005. One of these plants is described in detail in order to illustrate some of the problems which can arise when uprating old power plants in Norway.

MASTER PLAN FOR UPRATING AND REFURBISHING POWERPLANTS IN NORWAY

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MASTER PLAN FOR UPRATING AND REFURBISHING HYDROPOWER PLANTS IN NORWAY

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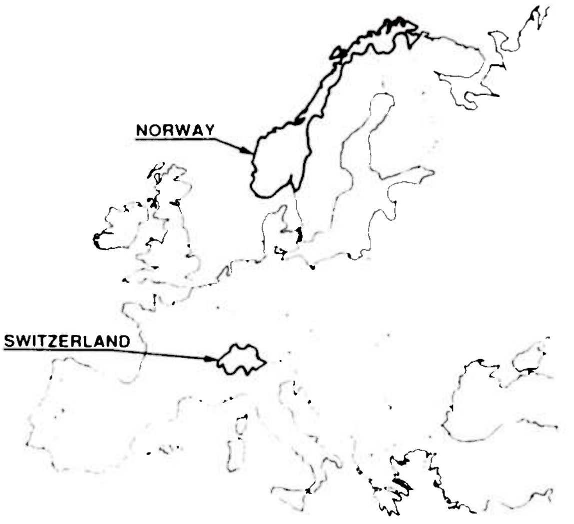
ABSTRACT

This paper describes a Master Plan for uprating/refurbishing hydropower plants in Norway. The plan is undertaken by NVE in collaboration with energy organizations and power utilities in Norway. The main purpose is to identify old schemes which can be uprated before the year 2005. The plan also identifies problems related to uprating/refurbishing old plants such as technical, environmental, financial matters and problems where a power plant has more than one owner.



The work with the plan started in 1986 with a resource study. The energy potential was found to be 8 500 GWH mean annual production. As a preliminary step NVE has advised the Norwegian Government to develop 3 000 GWH before the year 2000.

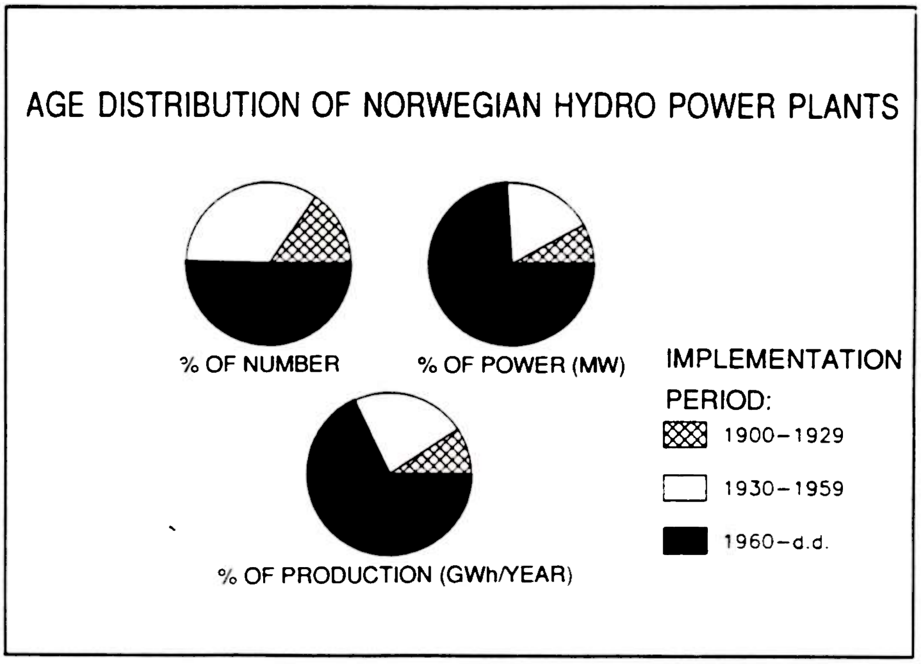
1 HYDROPOWER RESOURCES IN NORWAY

1.1 Developed and remaining resources

The four million inhabitants of Norway have access to enormous hydropower resources. The gross potential is estimated to be 550 000 GWH. Compared to the cheapest coal-fired thermal power plant, the economic energy potential is estimated to be approximately 200 000 GWH. Of this economic potential 105 600 GWH is developed, 3 600 GWH is under construction, 55 000 GWH is conserved and 12 000 GWH of the remaining 36 000 GWH can be developed causing only minor environmental damage.

The utilization of water courses for hydroelectric power production started 103 years ago. Today 99% of the electricity produced in Norway is based on hydropower. With the exception of grids in a few remote parts of the country, local transmission networks are now connected to the main grid. Even power plants with no reservoirs can therefore be built to utilize most of the water in a waterfall, since energy from these run-of-river plants is combined with the energy from hydropower plants with large reservoirs.

Appendix 1 shows the age of power plants in operation in Norway with output of more than 1 MW. During the last four decades, one hundred schemes have been commissioned in each decade. Fig 1 shows the situation in percentage terms, which indicates that half of the power plants have been running for 30 years or more.



This fact, together with the possibilities of having increased peak power and production during wintertime from these old plants if they were uprated, gave rise to the idea within The Ministry of Petroleum and Energy of starting a project to evaluate the viabelities of uprating/-refurbishing old hydropower plants in Norway. The need for peak power and production during wintertime is essential because another Master Plan which dealt with hydropower development and environmental problems has concluded that reservoirs and peak power from new plants cause unacceptable environmental problems.

1.2 Construction of new hydropower plants and uprating/-refurbishing hydropower plants before 2000.

The demand for electricity is expected to grow even if the total energy consumption in Norway is stabilized. In the year 2000, demand is expected to be 112 000 GWh firm power, which requires 115 000 GWh mean annual production from a hydropower system to give 99% security.This demand for electrical energy can be met by the construction of new hydro-electric power plants, uprating of old power plants or by the construction of gas-fired thermal power plants. There is today an ongoing political discussion involving the Brundtland commission's report on whether Norway should go in for a combination of constructing new and uprating old hydroelectric power plants or for the construction of gas-fired thermal power plants. Being a renewable and clean resource, hydropower development has made new friends even among environmental groups.

Fig 2 shows average hydropower resources which can be developed in this century. The different plants in this resource have the following characteristics:

* They are found to be environmentally acceptable
* Feasibility studies or tender documents exist
* Construction costs per KWh are acceptable (less than NOK 3.40)
* There are peak power possibilities and more than 60% is produced during wintertime.

In its programme to meet the demand for electricity NVE will work towards obtaining 3000 GWh from upgrading/-refurbishing old plants before 2000.

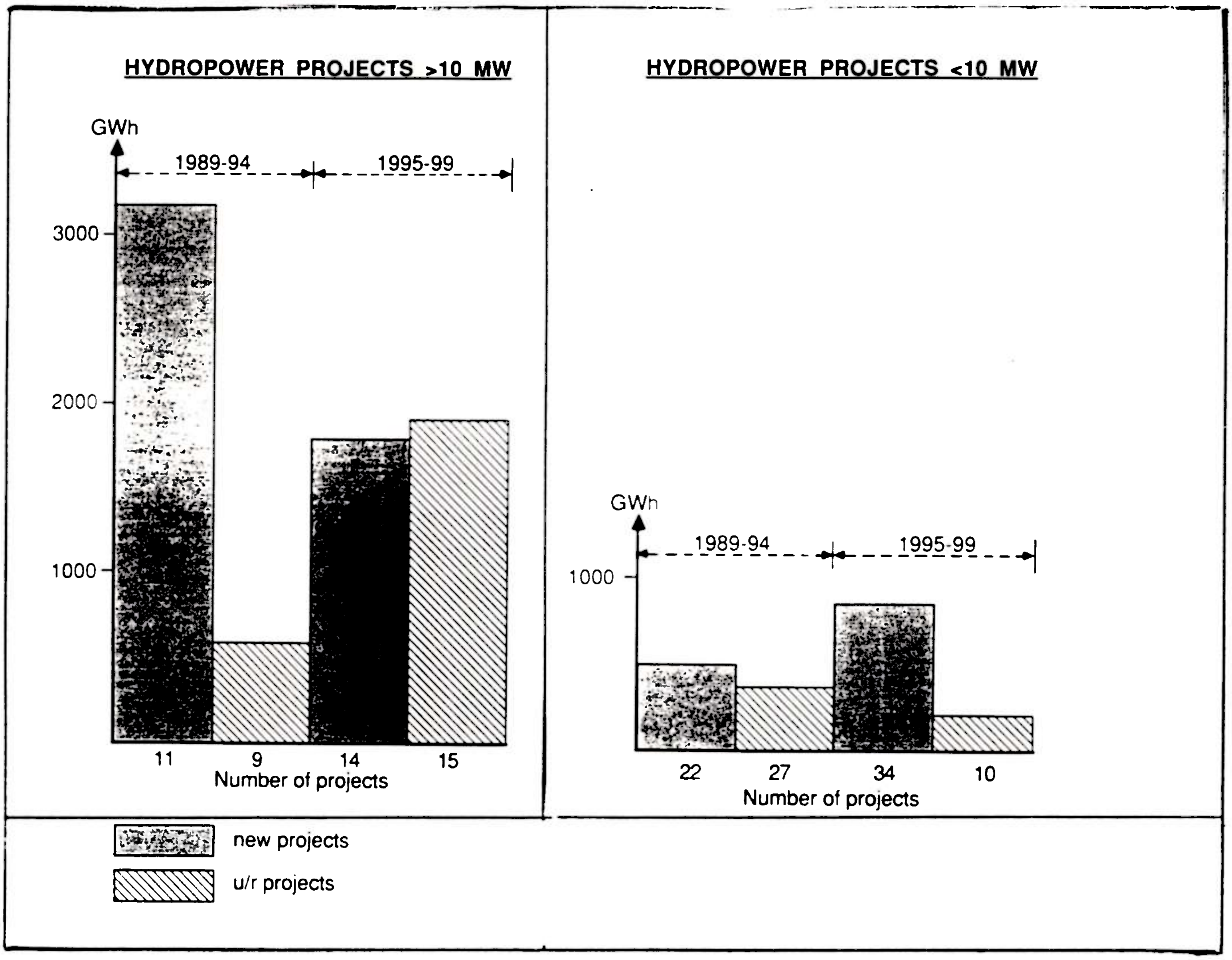


Fig 2: Mean annual production from hydroelectric power plants which can be commissioned before 1995 and between 1995 and 2000 if the construction of gas-fired thermal electric power plants is restricted due to air pollution. In addition Hydroelectric power plants producing approximately 5 000 GWh annually can be commissioned between 2000 and 2005.

2 THE UPRATING/REFURBISHING PROJECT

2.1 Organisation - objectives

The uprating/refurbishing project was established in 1986 by the Ministry of Petroleum and Energy in order to identify energy resources for electric production causing only minor environmental damage.

In this project uprating is defined as:

> Transferring water from undeveloped neighbouring catchment areas to the existing power plant.
>
> Construction of new reservoirs or increasing the existing ones.
>
> Increasing the head by constructing a new power plant and/or a new intake.

Increasing the capacity of the power plant in order to produce peak power and/or utilize more water during flood periods.

Refurbisment is defined as:

Reducing headloss i.e by enlarging the cross-section of the waterways.

Increasing efficiency by the installation of remote controll systems and of more reliable electro/mechanical equipment.

Uprating of a power plant is subject to concession according to the Water Resources Act which requires detailed environmental investigations to be carried out. Refurbishment requires concession according to the Electricity Act and is normally granted within 6 months.

The work is organised with NVE as the agency with executive responsibility. A steering committee has been appointed to direct the work. This committee has members from :

The Ministry of Petroleum and Energy
NVE
Representatives of private and county power companies.

To carry out the work NVE is using :

Own resources
Resources within the power companies
Research laboratories and official institutions
Private consultants

The main tasks are:

To define the total potential of uprating/-refurbishing hydro power plants.

To carry out feasibility studies on a few projects, identify the problems preventing implementation and indicate solutions to these problems.

To promote the implementation of the projects

To stimulate interest in uprating and refurbishing old plants by means of seminars and workshops and by provideing information through appropriate media. In this context it is worth mentioning that information on approximately 50 schemes which have been uprated/refurbished in the last 8 years is being collected.

2.2 Uprating/refurbishing resources

The extent of the resource is estimated on a basis of NOK 2.70 per KWh during summertime and NOK 4.70 per KWh during wintertime. This means that by using a rate of return of 7 % and a lifetime of 40 years one cannot invest more in construction than these limits permit. There is no extra value for peak power unless the power capacity in the power station gives an operation time of less than 4500 hrs. This means that all available water during a year can go through the turbines by using less than 4500 hrs. For output (in KW) which gives an operation time of less than 4500 hrs the value is set at NOK 2000 per KW.

By using results from pre-feasibility and other more recent studies the resource is estimated at 8 500 GWh annually with the following characteristics:

Only concession under the Electric Act needed. 700 GWh

Concession under the Water Resources Act needed and involving severe environmental problems....4000 GWh

Concession under the Water Resources Act needed and involving minor environmental problems.....3800 GWh

2.3 Hydroelectric power schemes studied in the project

BACKGROUND
As mentioned above this project would involve various private and official companies carrying out the plans for the different schemes. In order to compare the different schemes, it was necessary to specify the layout of the reports, indicating what we wanted to be included and omitted. The cost figures for different items in a hydropower development, like civil works (dam construction, tunneling, roadwork etc), mechanical/electrical works were prepared and were supposed to be used by everyone carrying out plans for this project. The cost curves were based on extensive data of hydropower development in Norway. The accuracy of the curves has been tested and found acceptable within +/- 20 %. Appendix 2 gives an example of the curves showing costs for unlined tunneling with moderate rock conditions and tunnel length of 3 000 m.

When uprating /refurbishing hydroelectric power plants it is normally necessary to estimate the capital value of the existing power station including el/mech equipment. We very soon found that this part was the most difficult, because there were as many opinions as there were owners and consultants.

In a resource study it is not possible to evaluate every hydropower station thoroughly, we therefore decided to produce a graph showing the average remaining lifetime as a function of time. Appendix 2 shows this graph which should be used carefully and be corrected on the basis-knowledge of the existing plant. There is for example a difference if the plant is a low head river plant or a high head plant with tunnels and rockfill dams. The graph was also corrected by simple el/mech investigations. A rate of return of 7 %, and expected selling price of the production during the remaining lifetime, operation and maintenance costs etc. were used to calculate the value of the old power plant at the expected commissioning time for the new plant.

THE DIFFERENT SCHEMES

The resource study was based on a Master Plan for the remaining hydroelectric power resources in Norway. The plan which was completed in 1987 placed a special emphasis on environmental problems. This study has been updated in this project and it was decided that a number of interesting schemes should be investigated more thoroughly. The selection of these schemes was based on the need to evaluate realistic problems and try to find solutions. In addition it was emphasised that some of the plants should provide peak power if this should be needed within the next ten to fifteen years.

The project will continue at least for another two years, and so far it is possible to draw the following conclusions:

> Two or more hydropower stations in a waterfall with different owners will give a reduced utilization of the potential because of different economic circumstances and interests.
>
> In Norway there is not enough value in peak power to justify uprating an old power plant if this plant still has ten or more years to live.
>
> If it is possible to transfer more water to the developed watershed, then there is a probability that uprating the plant will be viable.
>
> Reducing headloss by enlarging the waterway is usually not economically viable due to the loss of income from reduced production during the construction period. A parallel tunnel will normally be the best solution enabling the plant to operate while most of the work is carried out.
>
> Peak power from a power station with an outlet in a river is not environmentally acceptable due to the variation of flow. During wintertime this variation causes icing problems, and during summertime flora, fauna and fish will be affected. The river's capability to receive polluted water will also be reduced.

Up to now eighteen schemes have been investigated. Among these power plants we have low-head river plants, high-head plants, large and small plants. Appendix 3 gives further information on each plant. Among these plants we have Rjukan power plant which we have briefly presented in this paper to provide an idea of the problems and possibilities related to uprating/refurbishing old hydropower plants in Norway.

When uprating big power plants with penstocks and power station on the surface, one will try to find an underground solution as indicated in fig 3. The old plants will be closed down or operated during peak demand and high flow periods.

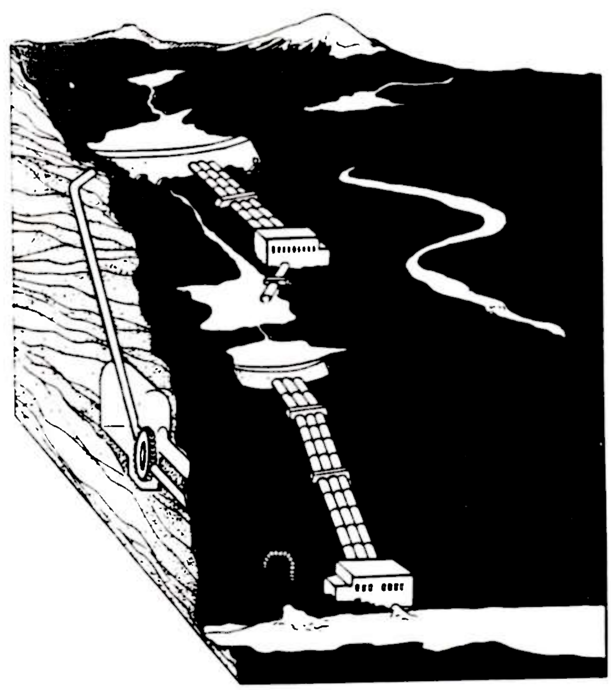


Fig. 3
One of the most common solutions is to replace old surface power plants by an underground plant

2.4 Peak energy resources from existing reservoirs

During the last few decades electricity production has been planned with a calculated buffer of 2-3 000 GWh. The reason for this is that Norway is 99% electrified by hydropower. The hydrological variation from year to year will sooner or later give some dry years which will cause expensive energy problems. The buffer has been based on statistical and economic data. Due to increased reservoir capacity, improved network and new high voltage transmission lines, the buffer will be reduced to zero by the year 2000. There are still uncertainties, however, and it has been decided that the Uprating/Refurbishing Project should investigate the potential and possibilities for increasing the regulation in reservoirs by using existing lake tap tunnels to reduce energy shortages in dry years.

In collaboration with the power companies the potential from 164 existing reservoirs was calculated to be 3 044 GWh. This potential is a storage potential, and cannot be utilized annually. It can only be utilized every ten years. It is, however, an alternative to the above mentioned buffer capacity, and since the tunnels etc already exist the cost of using it is low. The value can be compared to the cost for load shedding and energy rationing which will vary from NOK 0.50 to NOK 5.00 per kWh.

By using the lake tap tunnels the reservoir will be lowered below the level accepted in the regulation concession. Such extra tapping can also cause underwater slides in areas with large sediments, destroy fish and cause other environmental problems.

The 20 largest reservoirs, representing approximately 2 000 GWh, are expected to be acceptable in terms of environmental criterias and concession under the Water Resources Act. A programme to prepare water course law to be used during dry periods and to calculate necessary investments to prevent slides, etc., in these reservoirs is under way.

The potential in the 20 largest reservoirs will eliminate the need for a buffer within the hydro-electric production system. The cost for preparing the use of this potential is much less than its value, estimated to be not less than NOK 500 mill.

2.5 Energy from compensation water releases

Compensation water releases are necessary in connection with hydropower development to keep a minimum flow in rivers affected by the development. In Norway this is often combined with the construction of weirs which give a better landscape picture than a small stream in a large riverbed. The compensation water is also necessary to keep the fish, flora and fauna alive for the benefit of the general public. Within this project we will study the following:

The viability of utilizing the compensation water for energy production where it is released from dams.

The practicability of constructing reservoirs in the lowlands to provide compensation water and thereby reduce the flow from mountain reservoirs.

The amount of water needed.

Work on this project has recently started with the registration of all compensation water releases. The potential is not expected to be high (less than 500 GWh annually), but it is firm power and valuable.

In Norway the possibilities of utilizing compensation water released from dams are limited. Nevertheless a study comprising 5 schemes will be completed this year together with the description of experience from similar power plants like the Strandfossen power plant shown in fig 4.

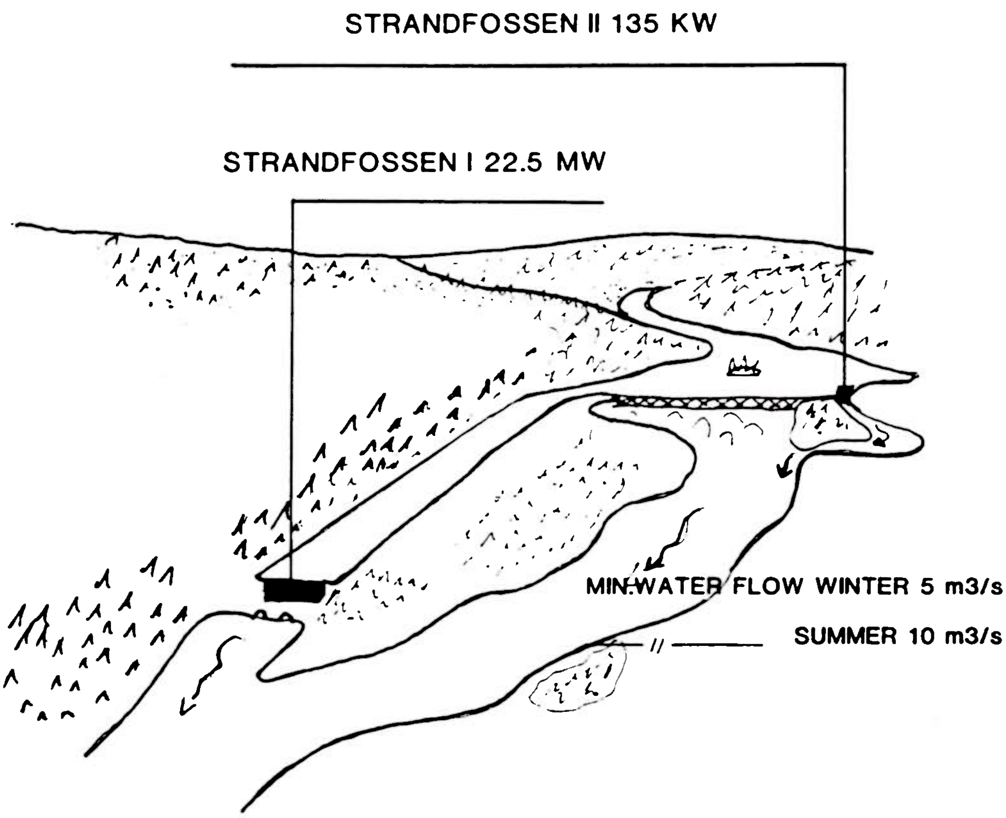


Fig 4
The Strandfossen power plant affects 1.5 km of the river Glomma. The compensation water released from the dam will secure acceptable life conditions for fish. The compensation water is utilized by a 135 KW Francis turbin working on 3.1 m head.

2.6 Experience acquired from schemes commissioned since 1980.

This is a programme to acquire know-how on uprating/-refurbishing hydroelectric power plants. 50 schemes will be described, ranging from 1 MW to 350 MW. The reports especially emphasize problems such as terms of concession, economic evaluation of alternatives, financing, construction while the old plant is in operation, etc. It is expected that this information will be valuable for electricity boards when planning similar projects for implementation in the near future.

3. THE RJUKAN SCHEME

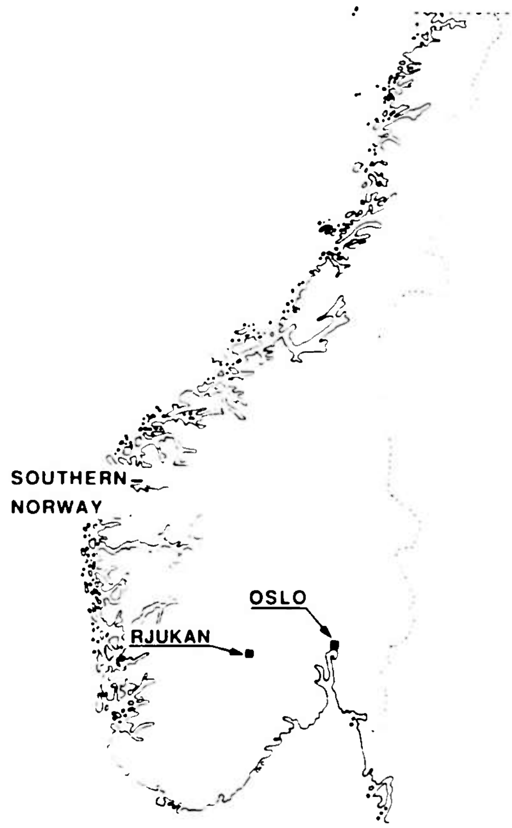


Fig 5

RJUKAN SCHEME, LOCATION IN NORWAY

3.1 General

In order to illustrate the issues involved in uprating hydro-electric power plants in Norway, it is perhaps appropriate to present the plans for uprating hydro-electric power plants in the Rjukan area.

The rivers in the Rjukan area were among the first to be developed for hydro-electric production in Norway. The development started at the beginning of this century, when industrialization of the country began.

The old plants constructed by the use of technology 30-50 years ago are not utilizing the full head or the water potential. There are reservoirs, however, with sufficient capacity to store water from the spring melting season and the rainy autumn season to the dry and cold winter season.

3.2 Current situation

See Appendix 4 for location map of the different power plants.

MÅNA RIVER				
PLANT	INSTALLED CAPACITY	ENERGY PRODUCTION	YEAR OF COMMISSION	OWNER
Frøystul	22.5 MW	196 GWh	1926	P/S
Vemork	180.0 MW	1105 GWh	1971	P
Såheim	158.0 MW	975 GWh	1958-71	P
Moflåt	25.0 MW	161 GWh	1955	P
Mæl	36.0 MW	233 GWh	1957	P

MÅR RIVER				
PLANT	INSTALLED CAPACITY	ENERGY PRODUCTION	YEAR OF COMMISSION	OWNER
Mår	180.0 MW	1030 GWh	1948	S

TINNE RIVER				
PLANT	INSTALLED CAPACITY	ENERGY PRODUCTION	YEAR OF COMMISSION	OWNER
Årlifoss	23.0 MW	129 GWh	1989	C
Grønvollfoss	26.0 MW	155 GWh	1933	C
Svelgfoss	92.0 MW	513 GWh	1958	P
Tinnfoss	49.0 MW	230 GWh	1926	P

P = Private, S = State, C = Municipal Electricity Board.

3.3 Peak power and winter energy from Rjukan

The existing power plants were built in order to deliver energy for industrial production. The plants were designed for a production period of about 6-7000 hours per year.

The Måna/Mår/Tinne watersheds are well suited for production of peak power and winter energy. The main reason for this is: Both intake and outlet can be placed in large reservoirs which permit sudden changes in waterflow due to start and stop operation of the power plants. One can, in other words, operate the power stations flexibly.

Contributory factors of importance are:

a) There is still some head in the watercourse that has not yet been developed for energy production.

b) Rjukan has a favourable geographical location in relation to the most heavily populated areas in Norway and also in relation to existing high voltage transmission lines.

c) Environmentally it is advantageous to uprate hydro power schemes in watersheds that are already developed to some degree, rather than to build new projects in untouched areas.

3.4 Plans for uprating and refurbishing the plants

(Appendix 5 shows the water system after uprating).

In 1987 pre-feasibility studies for uprating/refurbishing of the existing plants were carried out. The plans were worked out with the aim of providing for peak power supply and also transforming energy production from summer to winter.

In short, the plans are as follows:

Måna River

Uprating Frøystul power plant. Rated output 64 MW.
New Rjukan power plant. Rated output 350 MW.

Mår River

New Kalhovd power plant. Utilizing a head of 35 m between lake Mårvatn and lake Kalhovdvatn. Rated output 13 MW.
New Rjukan power plant. Rated output 270 MW.

The Rjukan power plant will be operated using two different water-heads:

1. From the tailrace water of Frøystul (lake Skardfoss) the water will be conveyed through a headrace tunnel and a pressure shaft to the Rjukan power plants. The gross head will be about 670 m. Installed capacity will be 350 MW from a Francis turbine.

2. From the Mår/Kalhovd reservoir a gross head of 892 m is available down to the Rjukan power plant. A Pelton turbine of 270 MW is planned to be installed.

The new Rjukan power plant will replace the existing plants that utilize the same head. These will, however, as long as the technical conditions allow it, serve as reserves. They will be put into operation during flood periods and when there is a need for peak power.

4. A considerable increase in the installed capacity upstream of lake Tinnsjø will create a demand for increased capacity also in the power plants downstream of Tinnsjø. Therefore, a new plant, Heddal power plant, is planned parallel to the old ones. Installed capacity will be 170 MW.

3.5 Economy of the project

As a basis for calculating the economic feasibility of the project, the complete power system in the watercourse is concidered. Usual project benefits due to energy production are calculated and so are the project costs. However, one has to take into consideration some matters of great importance for this special project. Explanations of the calculations are given below.

Production value is calculated on the basis of fixed energy prices. In addition, installed capacity that will enable production of peak power is given a value. An additional value has also to be given because of the transformation from summer to winter production.

Energy production (mean annual)	new system	5445 GWh
	old system	4727 GWh
Increased energy production		718 GWh
Increased output		845 MW
Energy transformed from summer to winter		124 GWh

Revenue (price level at 01.01.86) *)

Production value 1)	5445 GWh*NOK 0.22/kWh*14.04	NOK 16819 mill
Value of peak capacity 2)	406 MW * NOK 1700/KW	NOK 690 mill
Transforming summer production to winter production 3)		NOK 217 mill
Total revenue after uprating		NOK 17726 mill

Value of existing system

Value of stored water 4)	NOK 3491 mill
Calculated value of existing plants 5)	NOK 8256 mill
Total value of existing system	NOK 11747 mill

Available for the new project, also including replacement of the existing plants	NOK 5979 mill

*) NOK 1.00 = US$ 0.15.

1. Energy price: NOK 0.22/kWh. Related to the existing hydro power system.
   Interest rate: 7% p.a.
   Discount factor: 14.04, based upon an economic life of 60 years and a interest rate of 7% p.a.

2. Capacity exceeding production for 4500 hrs/year is given a value of NOK 1700/kWh.

3. The power system after uprating has a net increase in energy production of 718 kWh/year. The increase in winter production is 842 GWh/year while summer production decreases by 124 GWh/year. The value of the energy transformation from summer to winter is calculated at NOK 217 mill.

4. Stored water in the reservoirs already exists in the system. Its value is estimated at NOK 1.00/kWh.

5. The value of the existing plants is calculatd based on their production capacity, their remaining lifetime based on general technical condition and the interest rate of 7% p.a. Remaining lifetime is a matter of discussion. In this project we have therefore used the general age graph especially developed for the uprating/refurbishing project.

Costs

Project costs include usual development costs such as construction, electric/mechanical equipment, environmental and local compensation. The total cost of the Rjukan scheme including modernizing of the existing plants to new standard, is calculated at approx. NOK 5250 mill.

3.6 Implementation problems

Based on the above criteria the project is found to be feasible. It does not seem likely, however, that the project which is described above will be realised in the near future. There are many reasons for this:

1. The general economic situation in Norway

   Norway has had, and has still to some degree, a high interest rate. Hydro power investments are therefore very expensive.

2. The condition of the existing plants.

   Although many of them are old, the existing plants seem to be in good condition and it is expected that they will last at least 20 years with proper maintenance.

3. The present power situation

   Today there is a surplus of power in the Norwegian market. Future demand is uncertain. Discussions about future thermal power plants fueled by natural gas make the utilities not very willing to go ahead with comprehensive and expensive hydro power projects for the time being.

4. Ownership

   There are three utilities involved, each of them producing electricity for different purposes and with very different objectives.

A private company demands quick returns from its investments. For its own use, a company needs a steady and continuous electricity supply throughout the year.

The State Power System has a national responsibility for electric power supply. Financial viability is usually considered over a period of 40 years. Power production during the year has to accomodate the power requirements of all consumers. This calls for enough installed capacity to cover the need for power during winter time.

A municipal utility can be compared to The State Power Board. The main difference is that it has the responsibility for power supply in a limited area.

3.7 Conclusion

The pre-feasibility study has shown that the potential in the Rjukan area is considerable and that the development of these resources is feasible both from an economic and environmental point of view.

It has been decided that the studies shall continue in order to find a solution to the problems that occur when three owners with different economic interests are involved.

A likely way forward is a separate uprating of the Mår scheme and the Måna scheme. Dependent on the plans for uprating of the schemes upstream of lake Tinnsjø, new plans for uprating will then be carried out also for the plants in Tinne River.

4 FINAL REMARKS

It is expected that the Uprating/Refurbishing Project will provide knowledge of the possibilities for peak power plants and winter energy plants which will enable more run-of-river plants to be constructed. It is also possible that the Nordic countries through NORDEL (organization representing state power systems in Finland, Sweden, Norway, Denmark and Iceland) will utilize the different possibilities in each country better. For Norway this could mean that the demand for peak power in Finland and Denmark could be covered by better utilization of hydroelectric storage power plants in Norway. In return, Norway could use basic energy from these countries.

Being a country closely associated with the Brundtland Commission report, it is expected that the vast undeveloped clean hydropower resources will limit the possibilities of constructing gas-fired thermal power plants in the near future. The construction of new power plants and the maintenance requirement of the existing power plants producing 105.6 TWh means that there will be a hydro-power market for consultancy services and producers in this country in the foreseeable future. As a conclusion one can say that the hydro power period in Norway has not ended.

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"Vannkrafttilgang fram til år 2005", 1989

3. Ing. Chr. F. Grøner A/S, Nybro-Bjerck A/S, Ing. A. B. Berdal A/S, "Kraftanlegg - grunnlag for omkostningskalkulasjon (entreprenør- og leverandøromkostninger)", 1987.

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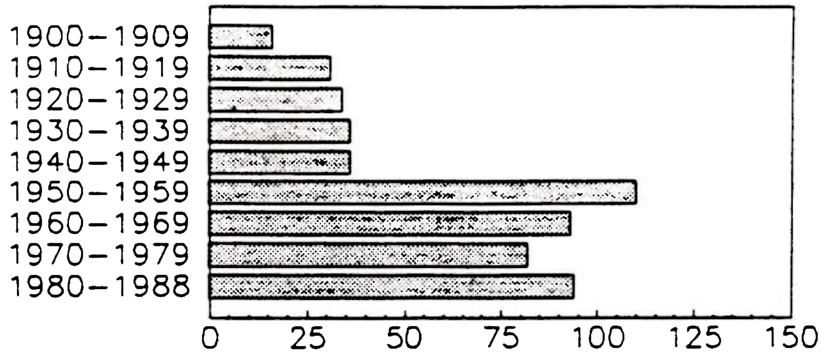
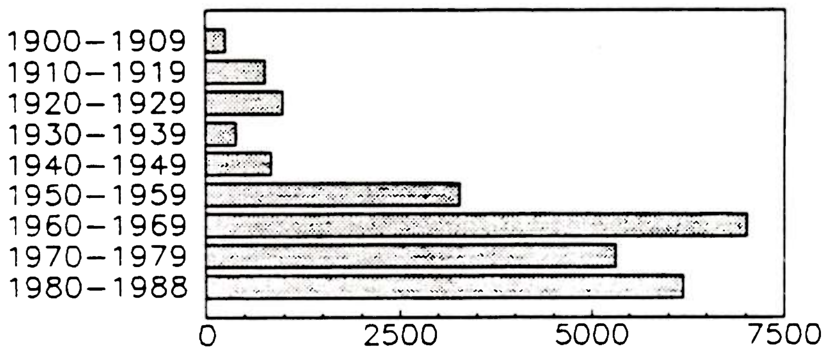
AGE DISTRIBUTION OF EXISTING NORWEGIAN HYDRO ELECTRIC POWER PLANTS > 1MW

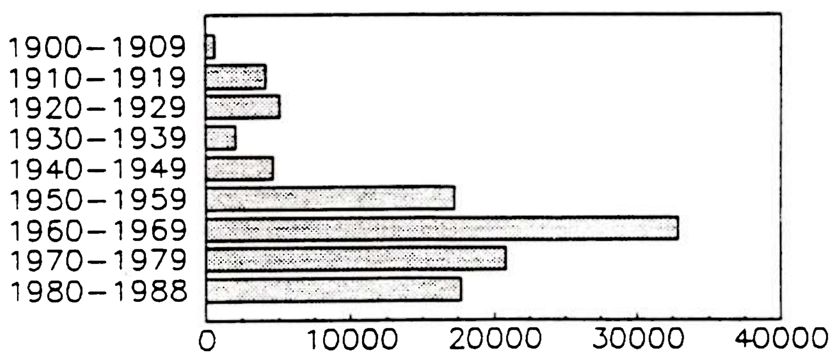
NUMBER OF POWERPLANTS BUILT IN EACH DECADE

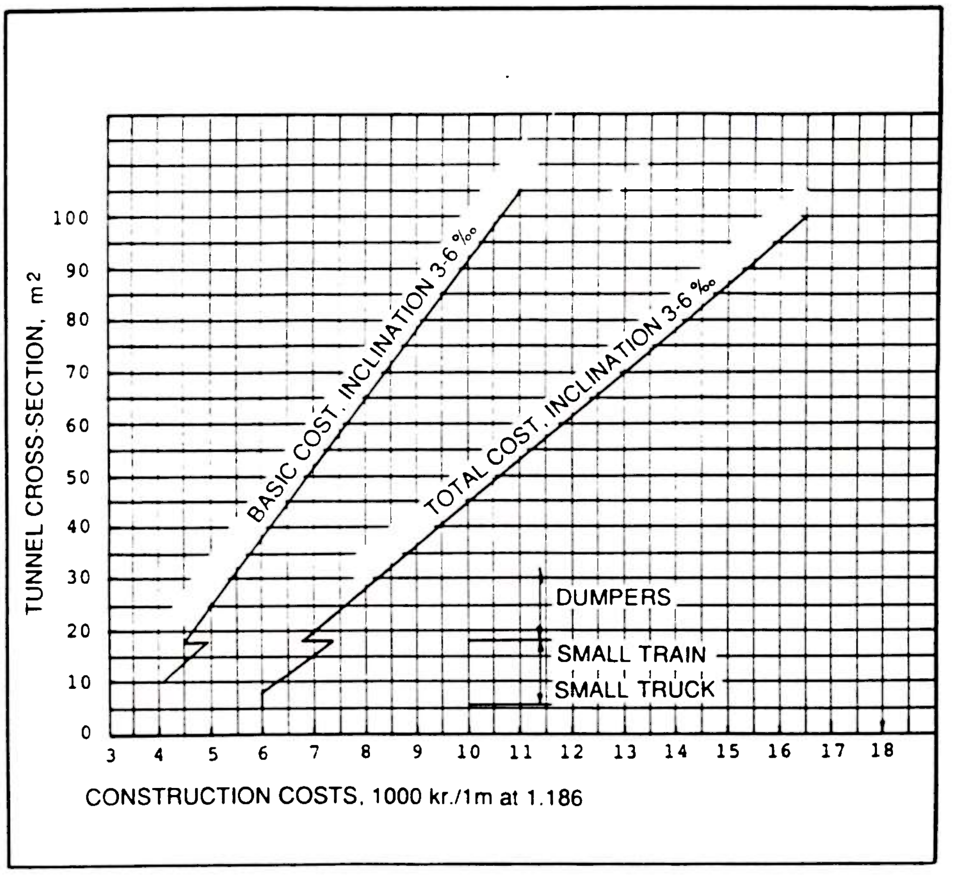


OUTPUT IN POWER MW IN EACH DECADE

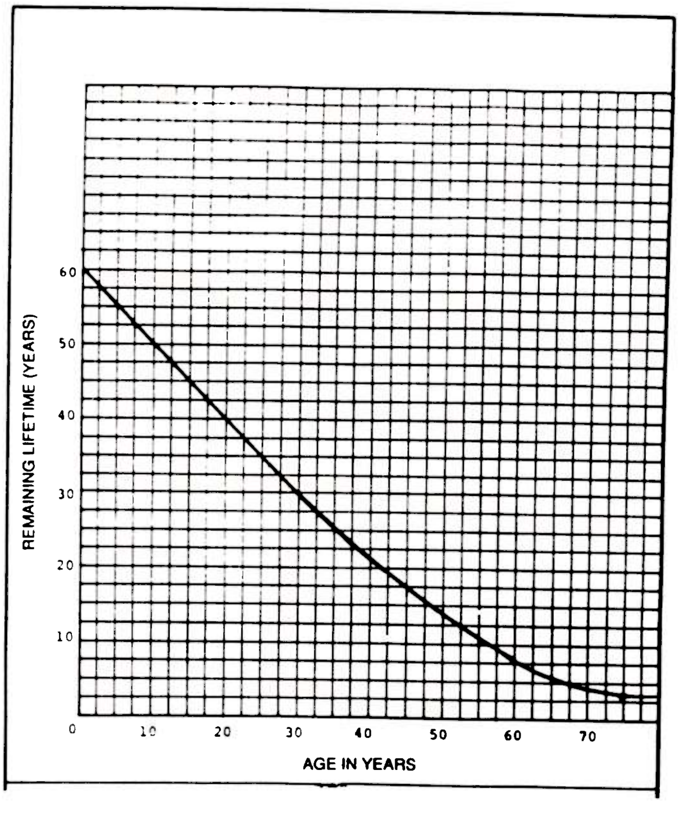


DEVELOPED PRODUCTION CAPACITY (GWh/YEAR) IN EACH DECADE





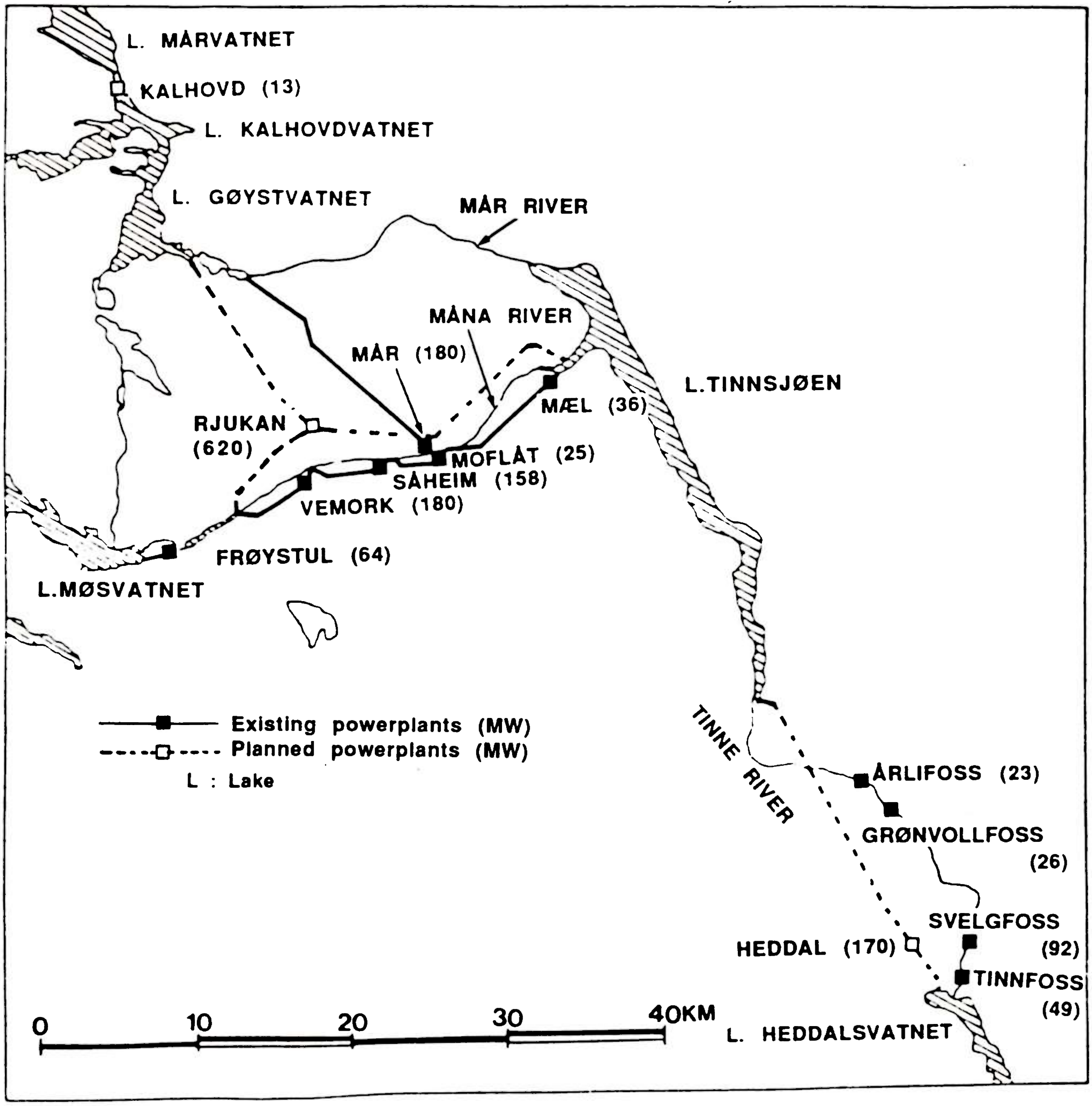
CONSTRUCTION COSTS FOR UNLINED TUNNEL;3 000 m, GOOD ROCK.



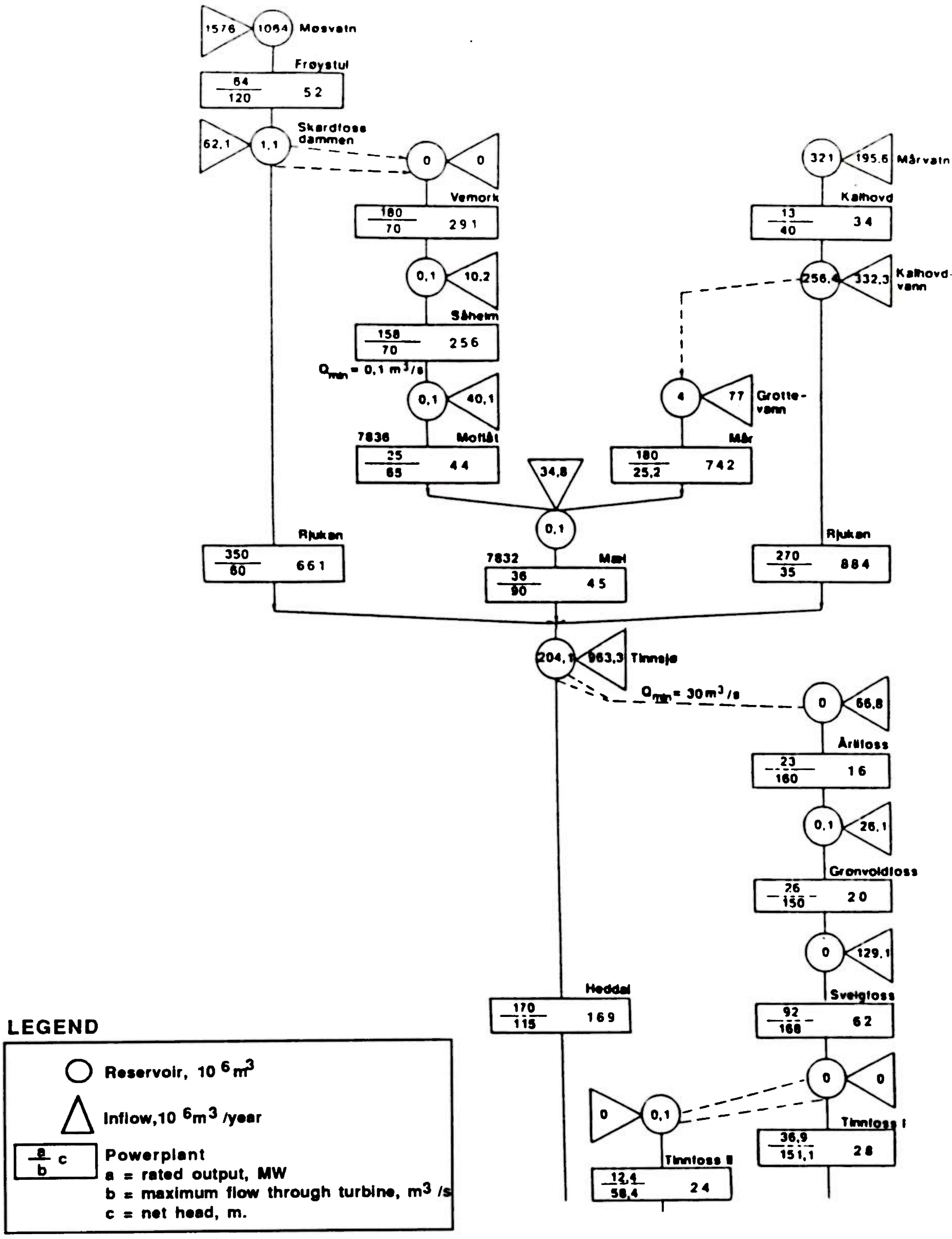
REMAINING LIFETIME
OF HYDRO POWER PLANTS
(maintained) AS A FUNCTION
OF AGE.

INFORMATION ON PLANTS STUDIED IN THE PROJECT

SCHEME	NUMBER OF POWER STATIONS, TOTAL OUTPUT		PRODUCTION GWh	ESTIMATED COST, NOK MILL (COST LEVEL PER 01.01.89)
	OLD NO/MW	NEW NO/MW	OLD/NEW	
Rjukan	10/791	14/1636	4727/5445	3900
Nore	2/256	3/642	1304/1525	1670
Røssåga	2/410	3/1110	2450/2500	2450
Rekvatn	1/20.5	3/40.3	207/282	410
Aura	2/310	2/810	1692/2220	1560
Langfjord	1/6.3	1/19.0	31/73	193
Hylla	1/0.6	1/2.65	4.6/11.1	25
Dale	1/84	2/138	504/592	290
Rognsfossen	1/0.45	1/6.2	3.5/25	69
Leinafoss	1/1.05	1/7.8	5/31	65
Skjerka	1/80	4/151	503/738	1280
Sauda	4/160	10/353	1070/1603	2060
Lindland	2/2.4	1/45	4.6/134	364
Begna	2/22.6	2/37	160/200	180
Modum	4/132	6/239	943/1316	1070
Vigelandsfoss	1/26	1/39	179/197	96
Hunsfoss	2/12.2	1/30.6	79/155	194
Nesåa/Tunnsjødal	4/194.5	5/207.3	1053/1194	333



Location map



Rjukan scheme, water system