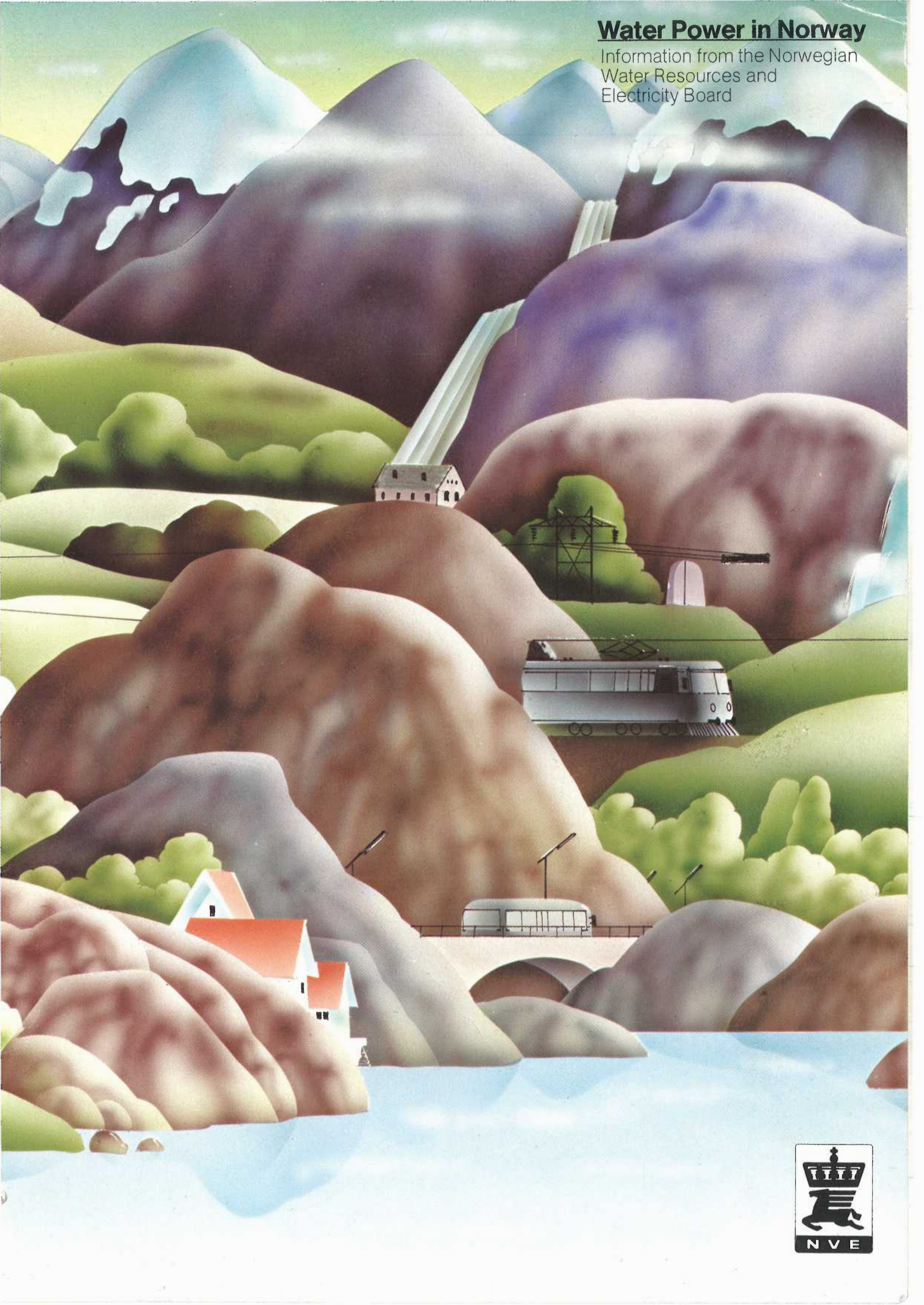
# Water Power in Norway

Information from the Norwegian Water Resources and Electricity Board



NVE

**Content**

## WATER AND WATER POWER RESOURCES

The average annual precipitation in Norway is 1.415 millimetres. This is almost twice as much as the European average, and represents about ca. 300.000 litres per inhabitant per day. Roughly 15% of all precipitation evaporates, whereas the remaining flows through brooks and rivers to the sea.

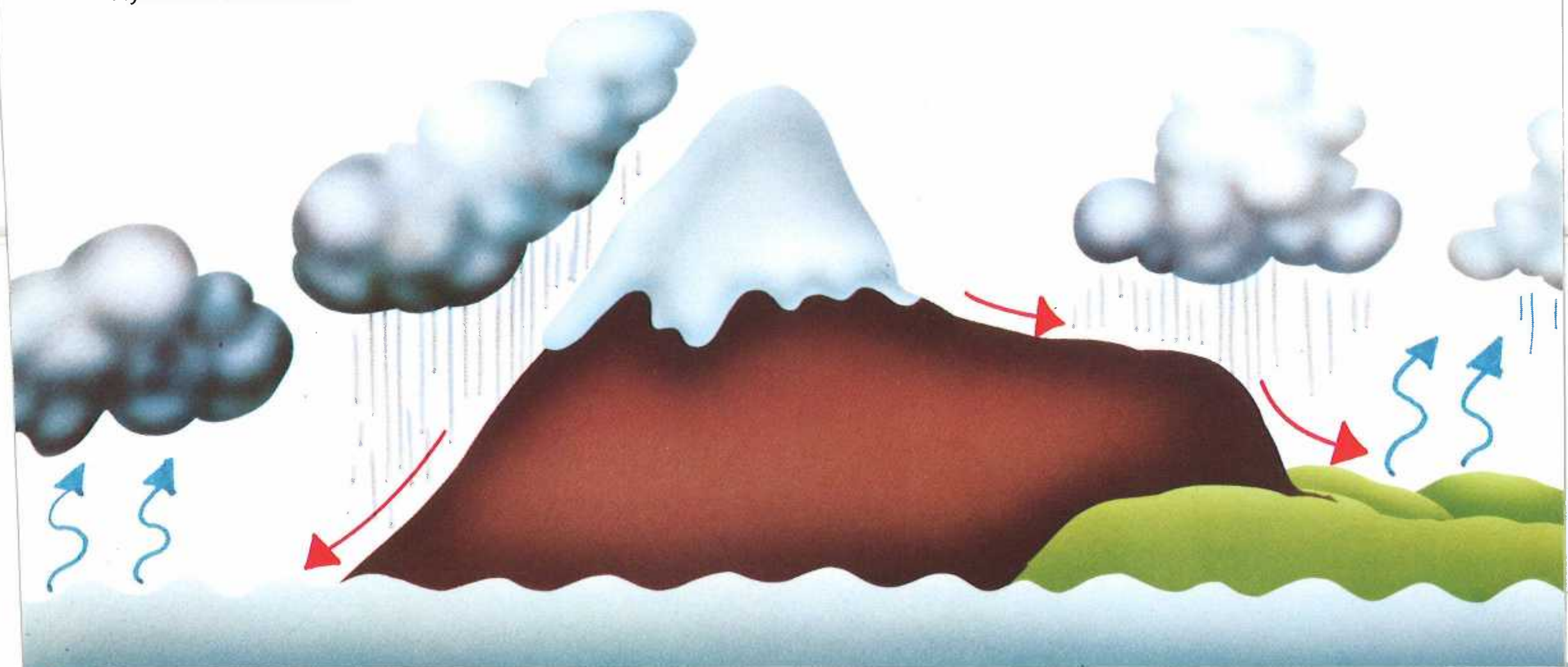
### Precipitation and Discharge

Precipitation is very unequally distributed over the country. Some inland districts in southeastern Norway and in Finnmark far to the north have only 300 mm. per annum – less than in some desert areas. Some places in western Norway have more than 15 times as much – corresponding to a water column of 4,5 metres above ground level.

The distribution of precipitation is also unequal throughout the year, and there is an unequal proportion of rain and snow. The flow of the rivers depends on the precipitation distribution as well as on other weather conditions.

The Norwegian Metrological Institute and NVE execute measurements of precipitation at 750 stations and measurements of water flow at 880 stations, all over the country.

*Hydraulic Circulation.*



## What is Water Power?

Water power is a form of solar energy: The sun "raises" water up from the ground and the sea surface through evaporation. The water falls down again as precipitation.

All precipitation which falls over land represents a form of energy, increasingly so the higher above sea level it falls. Precipitation gradually gathers in brooks and rivers. To convert water power to electrical energy, we need sufficient amounts of water in falls which can be exploited. The lower the fall, the more water is needed. In order to adapt the water flow to the power stations throughout a year, or from years of rich precipitation to poorer ones, water is stored in reservoirs. Potential energy from the water in a reservoir depends on the head from the reservoir to the power station. For example, 1 $m^3$ of water in lake Ustevatn will give 10 times as much energy as 1 $m^3$ in lake Øyern, because the utilized heads downstream Ustevatn are 10 times as high as those downstream Øyern.

1 $m^3$ of water has to fall approximately 400 m to generate 1 kWh.

Thanks to rich precipitation, high heads and many lakes which can be regulated by raising or lowering the natural water levels, Norway is one of the leading water power countries in Europe.

**Norways Highest Waterfalls According to Approximate Vertical Falls**

| Name | County | Head m | Average natural water flow, $m^3/s$ | State |
|---|---|---|---|---|
| Tyssestrengene | Hordaland | 300 | 4,5 | Developed |
| Ringedalsfossen | Hordaland | 300 | 10 | Developed |
| Skykkjefossen | Hordaland | 300 | 1,7 | Developed |
| Vettisfossen | Sogn og Fjordane | 275 | 1,2 | Permanently conserved |
| Austerkrokfossen | Nordland | 256 | 4,5 | Developed |
| Søre Mardalsfossen | Møre og Romsdal | 250 | 2,2 | Developed |
| Storfossen in Ulla | Rogaland | 210 | 6 | Under construction |
| Vedalsfossen | Hordaland | 200 | 1,5 | Permanently conserved |
| Feigumfossen | Sogn og Fjordane | 200 | 2,5 | Temporarily conserved |
| Glutrefossen | Møre og Romsdal | 171 | 1,7 | Partly developed |

**There Are More Than 200.000 Lakes in Norway. These Are The Biggest Ones.**

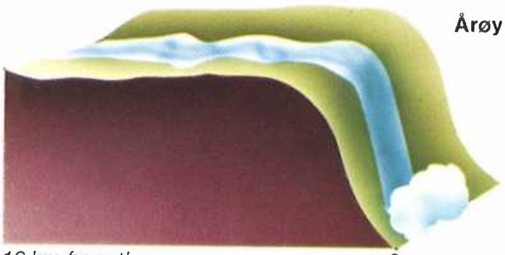
| Name | Area $km^2$ | Volume $km^3$ | Maximum depth m | Height above sea level m |
|---|---|---|---|---|
| Mjøsa | 368 | 56 | 449 | 123 |
| Røssvatn after regulation | 210 | 15 | 240 | 383 |
| Femund | 210 | 6 | 132 | 662 |
| Randsfjorden | 135 | 6 | 120 | 135 |
| Tyrifjorden | 134 | 14 | 295 | 63 |
| Snåsavatn | 117 | 5,5 | 121 | 22 |

**Largest Watercourses in Norway**

| Name | Length km | Catchment area $km^2$ | Average water flow $m^3/s$ | Maximum flood observed $m^3/s$ |
|---|---|---|---|---|
| Glomma | 598 | 41.767 | 720 | 3.600 |
| Tana with Anarjokka | 360 | 15.690 | 190 | 3.700 |
| Numedalslågen | 337 | 5.670 | 120 | 1.400 |
| Drammen Watercourse | 309 | 17.096 | 330 | 2.100 |
| Skien Watercourse | 244 | 10.777 | 310 | 1.800 |
| Otra | 242 | 3.700 | 155 | 1.400 |
| Namsen | 210 | 6.265 | 280 | 3.500 |
| Arendal Watercourse | 209 | 3.990 | 125 | 1.000 |
| Alta | 200 | 17.410 | 100 | 1.100 |

**Three Typical Watercourse Profiles**

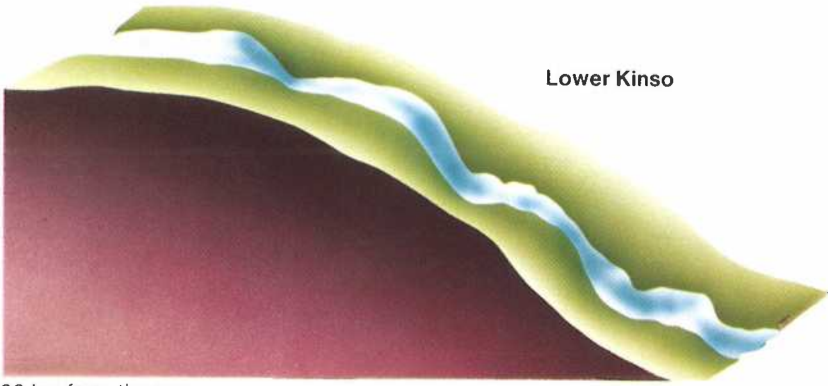
170 m above sea level



**Årøy River**

16 km from the sea 0

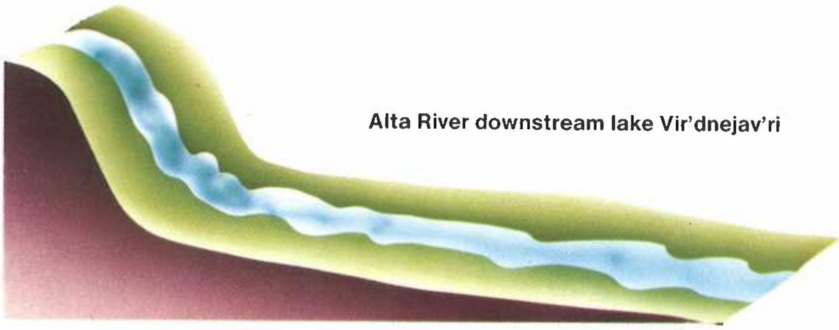
1200 m above sea level



**Lower Kinso**

28 km from the sea 0

250 m above sea level



**Alta River downstream lake Vir'dnejav'ri**

50 km from the sea 0

## How Much Water Power Do We Have in Norway

World-wide water power plays a minor role. However, for a few countries, such as Norway, water power is an important and valuable source of energy.

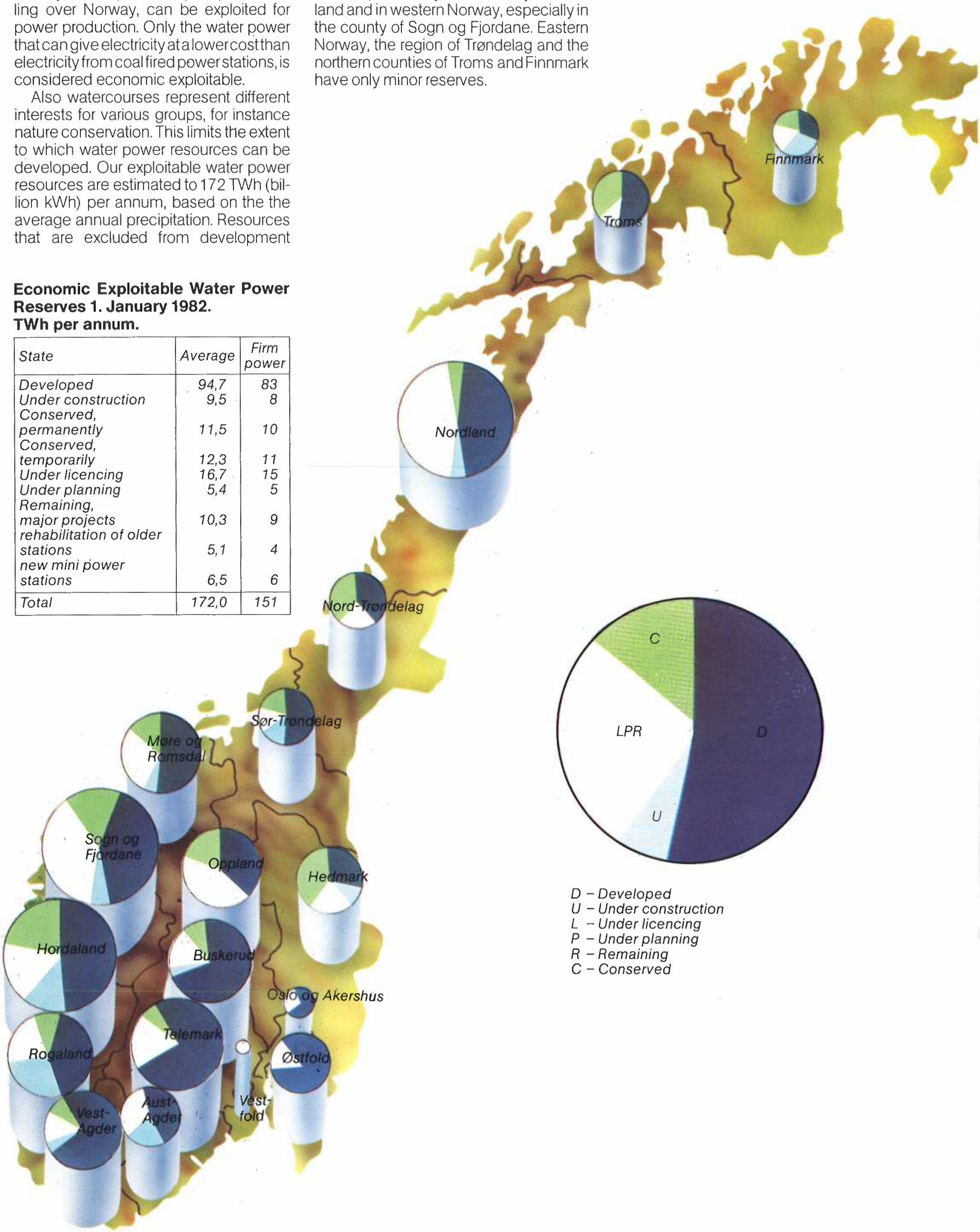
Only a small part of the precipitation falling over Norway, can be exploited for power production. Only the water power that can give electricity at a lower cost than electricity from coal fired power stations, is considered economic exploitable.

Also watercourses represent different interests for various groups, for instance nature conservation. This limits the extent to which water power resources can be developed. Our exploitable water power resources are estimated to 172 TWh (billion kWh) per annum, based on the the average annual precipitation. Resources that are excluded from development under the planning or licencing procedure are deducted from this estimate. Another 23,8 TWh must be subtracted as conserved, half of them permanently and half of them until 1985.

Remaining water power reserves are located particularly in the county of Nordland and in western Norway, especially in the county of Sogn og Fjordane. Eastern Norway, the region of Trøndelag and the northern counties of Troms and Finnmark have only minor reserves.

**Economic Exploitable Water Power Reserves 1. January 1982. TWh per annum.**

| *State* | *Average* | *Firm power* |
|---|---|---|
| *Developed* | *94,7* | *83* |
| *Under construction* | *9,5* | *8* |
| *Conserved, permanently* | *11,5* | *10* |
| *Conserved, temporarily* | *12,3* | *11* |
| *Under licencing* | *16,7* | *15* |
| *Under planning* | *5,4* | *5* |
| *Remaining, major projects* | *10,3* | *9* |
| *rehabilitation of older stations* | *5,1* | *4* |
| *new mini power stations* | *6,5* | *6* |
| *Total* | *172,0* | *151* |



## Future Power Development

Parliament has decided that the power supply until year 2000 should be provided by a continuing moderate water power development.

Additional contributions may come from utilization of industrial waste heat, power import, or construction of smaller thermal power stations. Alternative power resources, as wave or wind power may offer a modest supplement by the year 2000.

The licencing procedure for a number of water power projects will be concluded during the next few years. Most of the bigger ones are located in the counties of Nordland and Sogn og Fjordane. Some smaller projects are scattered all over the country. There are also plans for the modernizing of older power stations in order to improve their efficiency.

Power supplies that are most cost efficient, both in terms of money and environmental factors, are obtained by developing the cheapest and least controversial projects before the more expensive and demanding ones.

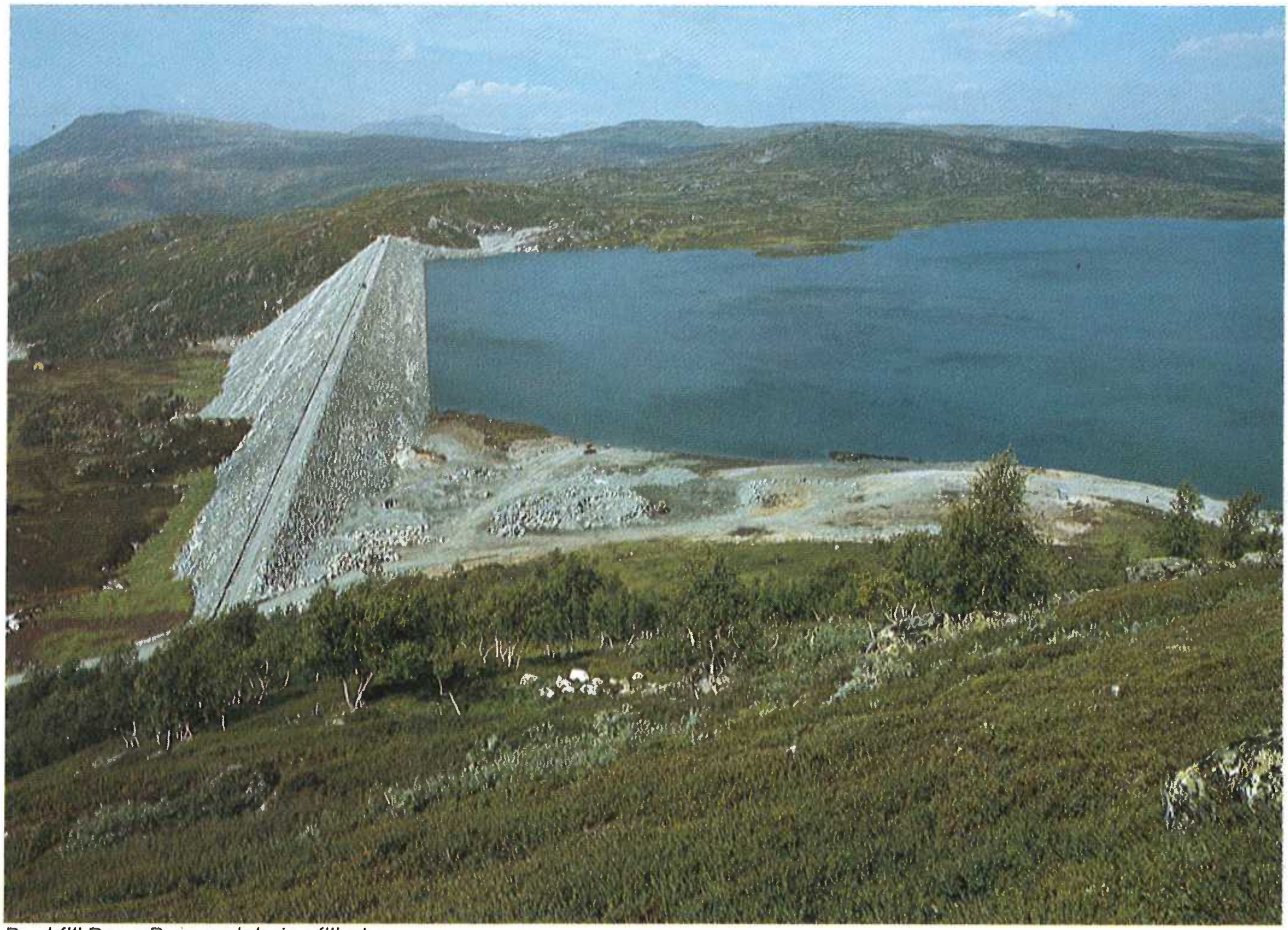
In any case, the projects have to pass the statutory licencing procedure.

The equal distribution of power supply in all regions must also be taken into account when deciding the sequence of projects to be developed.

In a few years a comprehensive plan for the remaining, exploitable watercourses will be completed. This plan may be a guideline for the order in which future licence applications are treated.

*Entrance to a power station.*

*Generator hall in a power station.*



*Rockfill Dam. Reservoir being filled up.*

## WATER POWER GENERATION

### How Do We Harness Water Power

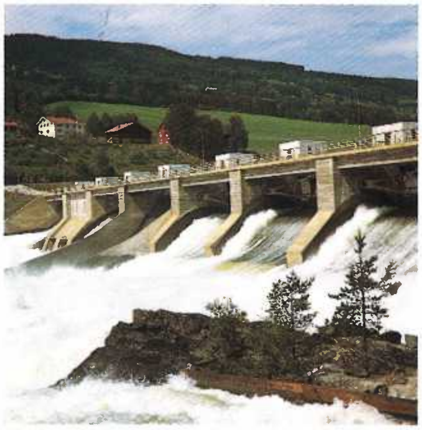
Water power has been utilized in this country since the Middle Ages. It's first use was for the running of mills and saws. Principally, the mode of utilization has allways been the same: The water is conducted through the shovels of a water wheel (for power stations a turbine). The water causes the turbine to rotate. The turbine is connected to a generator, which rotates with the turbine. In the generator the mechanical energy is converted to electrical energy. From the generator the electricity is transmitted to a transformer, where the voltage is raised before transmitting the electricity to the grid.

### Water Power Station

A distinction is usually made between low pressure stations and high pressure stations. Low pressure stations are often run-of-river power stations with only minor water storing capabilities. They are most often open air located along the major watercourses. High pressure power stations are almost exclusively placed in rock caves where the water is supplied through a tunnel from a reservoir. From the power station the water may flow back to a river, into another reservoir or directly into the sea.

Bingsfoss power station in the Glomma River is a typical low pressure, run-of-river plant with a head of 5 m and a water flow of 750 $m^3$ per second. Sima power station in Hardanger, with a head of 1158 m and a water flow of 52 $m^3$ per second is a typical high pressure power station.

Approximately 3000 water power stations have been built in Norway. In 1982 a little more than 600 were still in operation. The first Norwegian water power station was built in 1885 at Laugstol Brug in Skien with a capacity of 10 kW. In 1982 our biggest power station is Sima, with a capacity of 1120 MW.



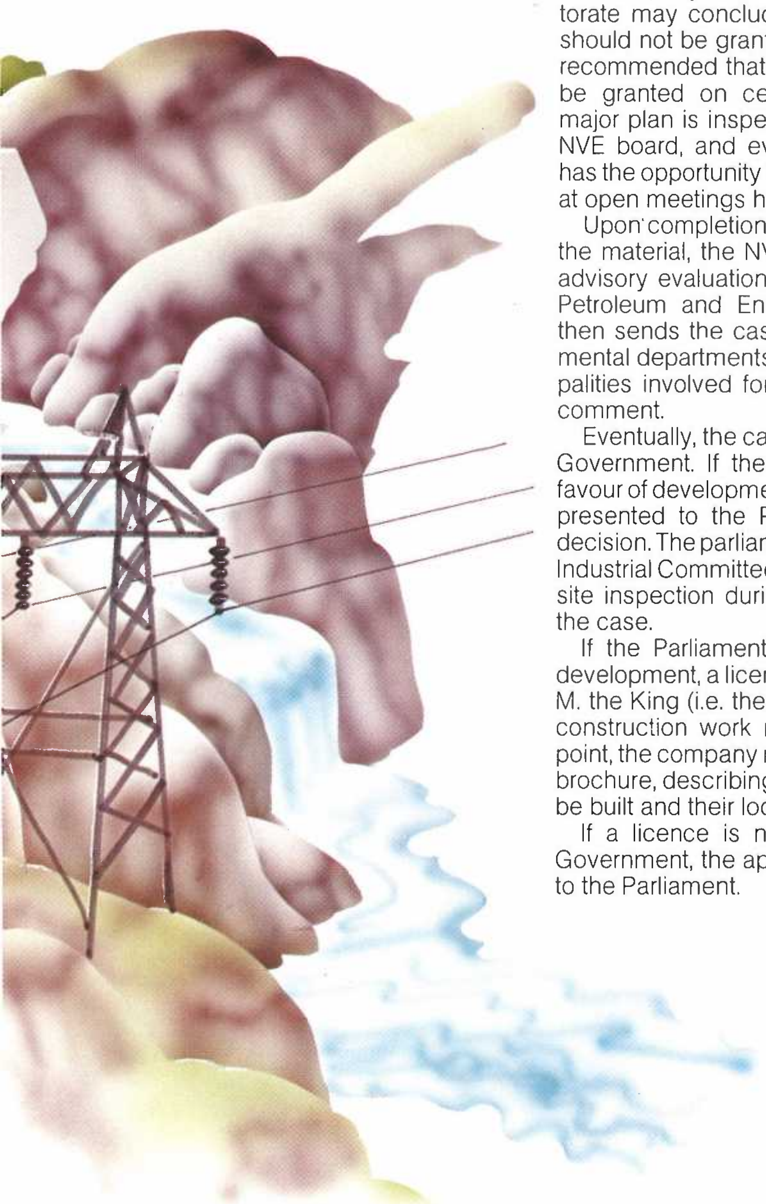
**The Biggest Power Stations in Norway 1.1. 1982.**

| Name | County | Max. power MW | Average annual production capacity GWh |
|---|---|---|---|
| Sima | Hordaland | 1.120 | 2.725 |
| Tonstad | Vest-Agder | 640 | 3.816 |
| Rana | Nordland | 500 | 1.830 |
| Aurland I | Sogn og Fjordane | 450 | 1.500 |
| Tokke | Telemark | 430 | 2.118 |
| Evanger | Hordaland | 330 | 1.237 |
| Brokke | Aust-Agder | 324 | 1.575 |
| Suldal | Rogaland | 310 | 1.527 |
| Kvilldal (1. unit) | Rogaland | 300 | 1.680 |
| Skjomen | Nordland | 300 | 1.115 |
| Vinje | Telemark | 300 | 1.023 |
| Aura | Møre og Romsdal | 290 | 1.706 |
| Aurland III (pumped storage) | Sogn og Fjordane | 270 | 81 |
| Lower Røssåga | Nordland | 250 | 1.605 |

## From Drawing Board to Finished Power Station.

From the beginning of the planning stage until a hydroelectric plant is operational many years of work are involved. 8–10 years is normal, and for very large projects even more time may be needed for completion. The reasons for this are the conflicting interests of various groups involved.

A power company with development plans is initially required to announce to the Directorate of Water Resources in NVE.



The announcement is published by the Directorate and submitted to central and local authorities, organizations, etc. The power company must also distribute a comprehensive brochure describing the plans to all households in the district. In that way, everybody interested can make their points of view known to the planners. Open meetings are also often held in the district concerned.

When the company has finished the plan, application for licence is sent to the Directorate of Water Resources. Again the material is published, it is displayed for public examination and submitted directly to a great number of parties for hearing. At this stage, once again a brochure is distributed to all households in the district describing the plan applied for.

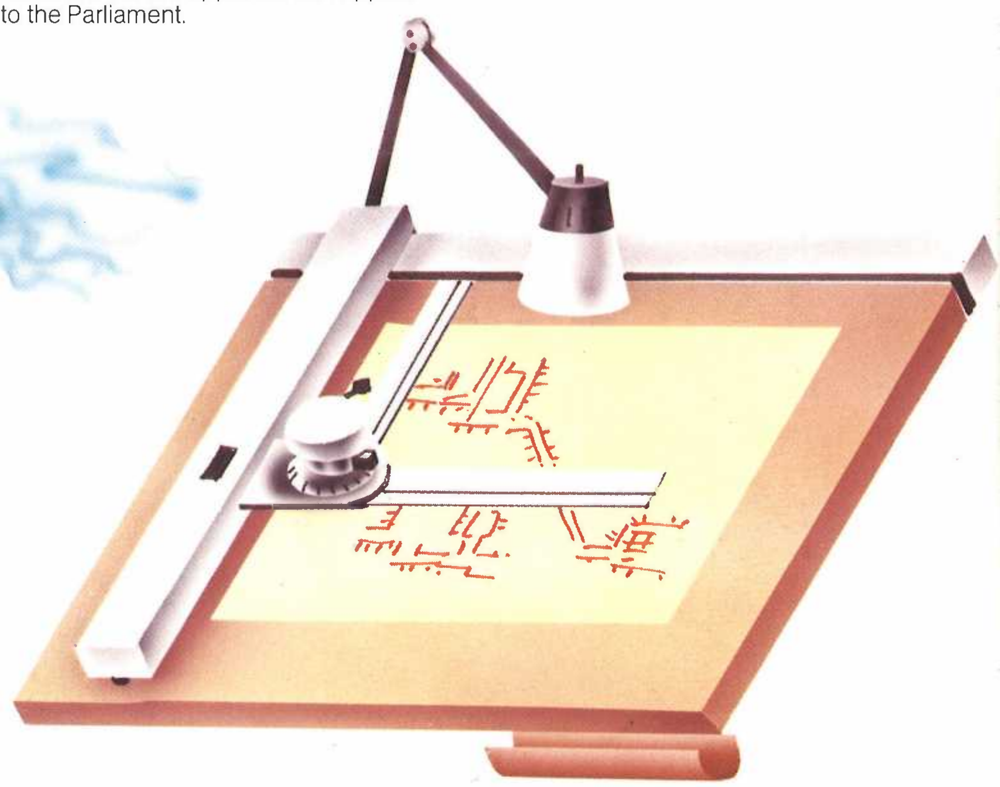
Before the Directorate of Water Resources makes an overall assessment of the plan and sends its recommendation to the NVE board, opinions of all interested parts are submitted to the company for comment. The Directorate may conclude that the licence should not be granted. More often it is recommended that the licence should be granted on certain terms. Every major plan is inspected on site by the NVE board, and every party involved has the opportunity to express opinions at open meetings held by the board.

Upon completion of its discussion of the material, the NVE board sends its advisory evaluation to the Ministry of Petroleum and Energy. The Ministry then sends the case to other governmental departments and to the municipalities involved for further study and comment.

Eventually, the case is put before the Government. If the Government is in favour of development, major cases are presented to the Parliament for final decision. The parliamentary Energy and Industrial Committee often makes an on site inspection during its treatment of the case.

If the Parliament votes in favor of development, a licence is granted by H. M. the King (i.e. the Government), and construction work may begin. At this point, the company must publish a third brochure, describing the plants that will be built and their local impacts.

If a licence is not granted by the Government, the applicant can appeal to the Parliament.



The Directorate of Water Resources in NVE executes technical and environmental inspections of the construction works.

Private companies' licences have a time limit, usually 50 years. At this point reservoirs and power stations are transferred to the State free of charge.

Counties and municipalities are granted licences with no time limits, but the terms may be revised after a certain period, usually 50 years.

The "licences" for the State's own water power developments, are called "permission for regulation". These can, of course, be revised by the authorities at any time.

Companies having power stations and reservoirs in the same watercourse cooperate through regulation assosiations. These assosiations form the national "Water System Management Association".

The licencing procedure for watercourse regulation is subject to many laws, some of which are given below:

- *Aquiring Act of 14. Desember 1917.*
- *Regulation Act of 14. Desember 1917.*
- *Watercourse Act of 15. March 1940.*
- *Electricity Act of 19. June 1969.*
- *Water Protection Act of 16. June 1970.*

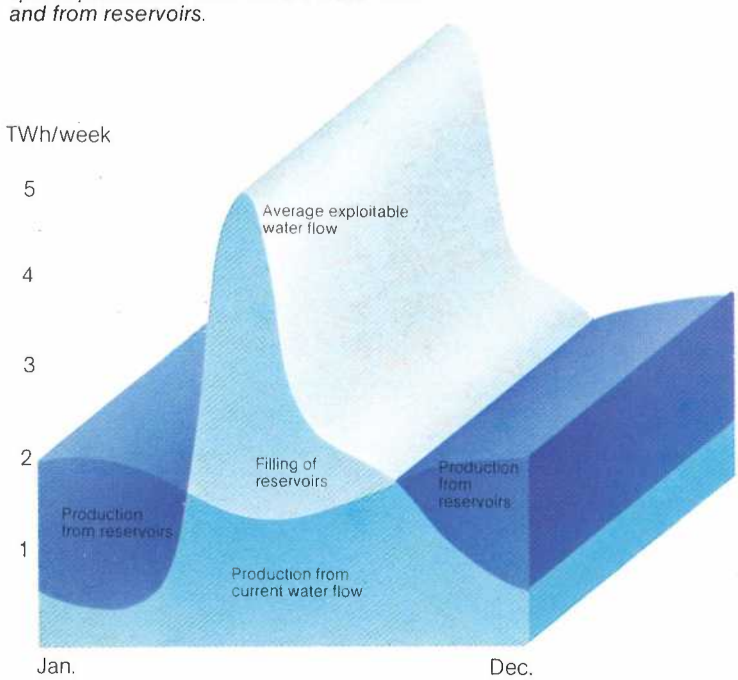
## The Electricity Must Be Generated Just When It Is Needed.

Storing of energy, for instance in batteries, is expensive. Therefore, the electricity must be generated at the same moment it is needed. The consumption is higher in the daytime than at night and less in summer than in winter. This puts heavy requirements on regulation of water flow to the power stations.

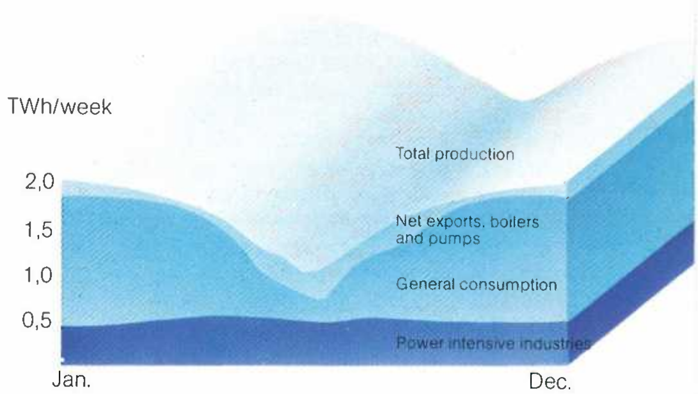
Electricity is delivered as alternating current at a frequency of 50 cycles pr. second. All turbines and generators run at a rotating speed corresponding to this frequency. When the load increases as a result of increasing electrical consumption, the turbines can no longer maintain the same speed at the actual water flow. When the speed and thereby the frequency consequently drops, an automatic signal is given to increase the water flow until the proper speed is restored. By decreasing load, the opposite procedure occurs. Water power machinery is easily regulated in this manner.

In the winter the water flow in our rivers is low, whereas the electricity consumption is high. In the reservoirs water is stored from summer till winter, and to some extent from years of rich precipitation to years of poor precipitation. By interconnection and coordination of the power stations a reservoir can be utilized in regions apart from its own location, and in power exchange with neighbouring countries. Therefore our water reservoirs are of great value.

*Electricity production throughout a year, split in production from current water flow and from reservoirs.*




*Electricity production throughout a year split in consumption sectors.*



**Dry and "Wet" Years.**

The water inflow to the reservoirs varies not only with the seasons, but also from one year to the next. Consumption on the other hand, is independent of these variations. Therefore, we cannot meet the demand by relying only on the water flow obtained in "wet" years. We have to develop a production capacity so that the demand will also be met in years with little precipitation. As well we may have to provide a supplementary power supply in "dry" years.

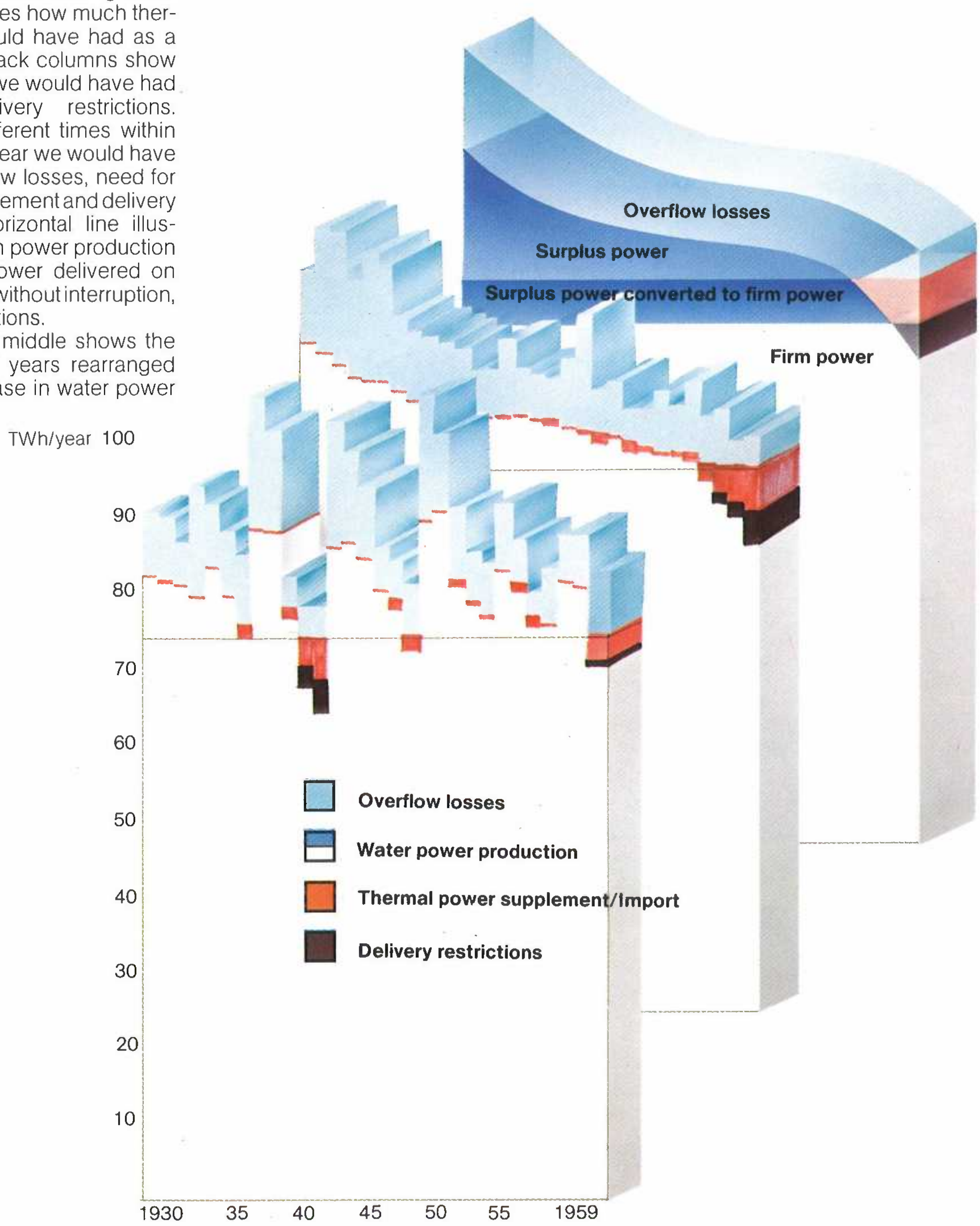
The white columns of the forward figure indicate how power production from the power stations of Norway in the late seventies would have varied according to the water flow, as this has varied throughout a number of years. The light blue colour on the diagram shows how much power would have been lost by water overflow, mainly in the run-of-river stations during flood periods. Red indicates how much thermal power we should have had as a supplement. The black columns show that in some years we would have had periods with delivery restrictions. Observe that at different times within one and the same year we would have experienced overflow losses, need for thermal power supplement and delivery restrictions. The horizontal line illustrates the limit of firm power production capacity. That is power delivered on long term contracts without interruption, with certain reservations.

The figure in the middle shows the same sequence of years rearranged according to decrease in water power production.

**Firm Power and Surplus Power.**

The figure in the back shows schematically the production distribution throughout the years. The firm power production is increased by means of our import options from Sweden and Denmark. Most of the firm power increase is surplus power, supplemented with import in short periods only. Some of the surplus power is sold to the power intensive industries. Surplus power is also used for pumping water into the reservoirs for later use during peak load periods. Surplus power is also used in electric boilers for steam production which is usually produced by oil during dry years. In addition, a great deal of surplus power is exported.

The figure in the back also shows how import possibilities increase our firm power production, while it is only the surplus power that is exported. Thanks to exportation, losses due to spillovers are now very small. Remaining losses could be avoided by enlarging the run-of-river power stations.



**From Power Station to Consumer.**

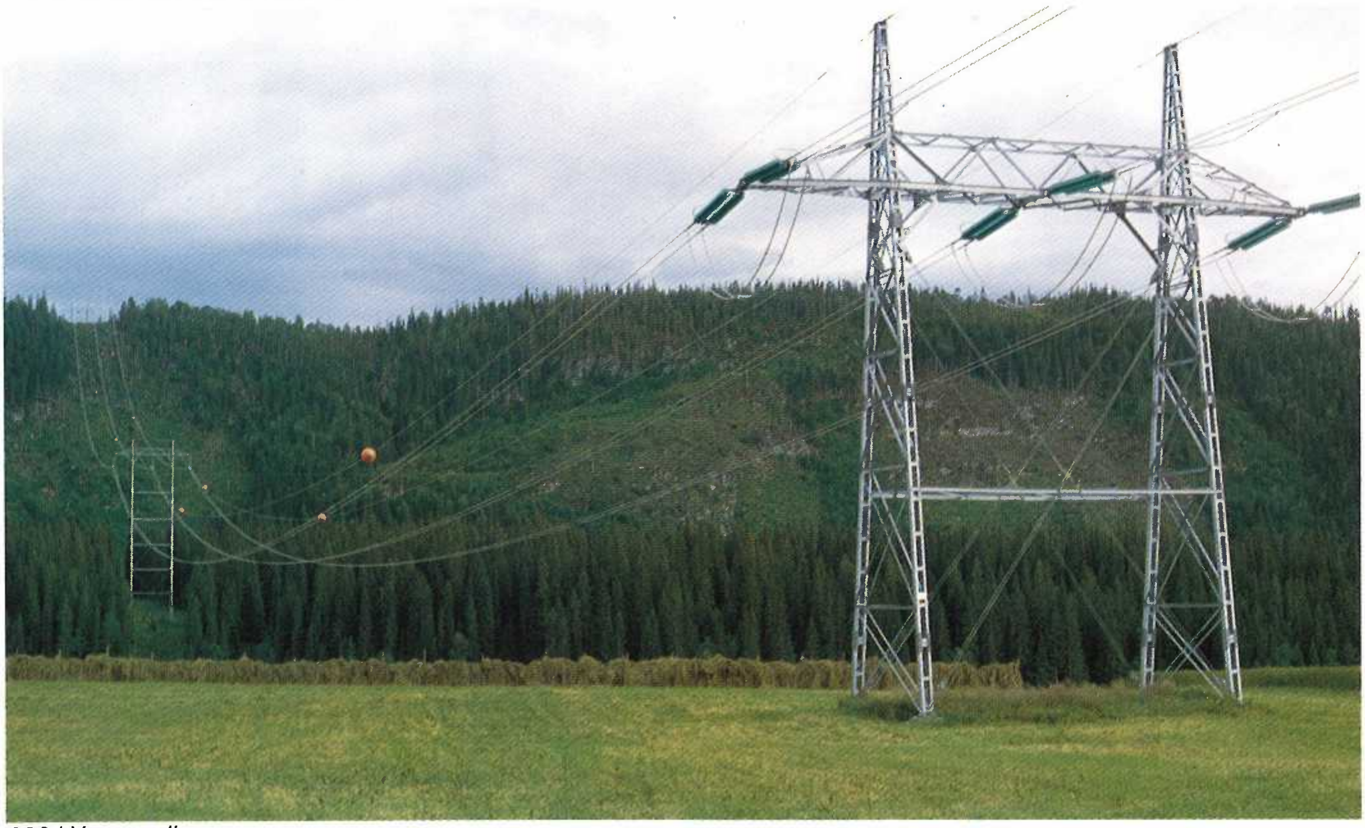
Electrical power is transmitted from the power station over high tension lines to great transformer stations that are centrally located in main consumption areas. High tension lines also interconnect power stations, different regions of the country, and Norway to neighbouring countries. This provides for better utilization of the power through coordinated operations. From the transformer station the electrical power is distributed on lines at a lower voltage to consumers.

The electrical network reaches almost every house and every work place in Norway. At the end of 1981 only 260 Norwegian households were not supplied with electricity from water power. In the power stations the electricity is generated at a voltage of 5–24 kV. To minimize energy losses in transmission, the electricity is transformed up to 132, 300 or 400 kV before it is transmitted to the transformer stations in the consumption areas. There it is transformed down and distributed at voltages of 66, 22 or 11 kV before it is transformed further down to 230 volt and supplied to consumers.

Approximately 31% of Norway's total power production is in the hands of the State Power System. Municipal and county utilities produce approximately 51%, and private utilities, mostly industrial companies, produce approximately 18% of the power. We have approximately 70 production utilities or companies besides the industrial power companies.

The distribution of electricity to the consumers is mainly a municipal task, which is carried out by approximately 280 utilities. "The Norwegian Power Pool" arranges exchange of surplus power among the power companies, and performs tasks related to power supply.

*Transformer kiosk or substation.*



*300 kV power line.*

## DEVELOPMENT POWER AND OTHER INTERESTS.

"Until the first half of the sixties there was practically complete political agreement on water power development. Since that time, there has been a great deal of public controversy concerning the environmental effects of continuing development of hydroelectric power. This point of view has become increasingly more important compared to the public good further development of water power may have". (Parliamentary report No. 54 (1979–80) – The Energy White Paper.)

### Multi-purpose Planning.

Many conflicting interests are involving the watercourses. Exploitation may represent benefits to some but inconveniences to others. The present watercourse administration will guarantee that every interest be evaluated and weighed against each other. This task is very demanding, as there are many interests and values that cannot be easily measured.

General quantitative interests are power production, log driving, navigation, fishing, water supply, irrigation and outlet of sewage wastes.

It is much more difficult to set up a value scale for experiences and recreational possibilities in nature. As well, it is also very difficult to predict a power station's effect on local climate and the effect of many subtile changes over a period of time.

The harmful effects of the watercourses on cultivated land, industry, settlements and roads by flood, drifting ice and erosion must also be taken into account.

The requirement for an overall evaluation of the various interests is steadily becoming more stringent. Gradually, total water utilization plans – or multipurpose plans – for the most important watercourses will be prepared. Sector plans for power development or conservation will be a part of the water utilization plans.

### Nature and Environmental Considerations.

Preparatory work for the protection of watercourses from power development began at an early stage. The first conservation plan was adopted by the Parliament in April 1973, and the second plan in October 1980. Conservation plan no. 3 is now under preparation and is due to pass in Parliament in 1985. Conservation of watercourses or parts of watercourses can also take place under the general licencing procedure by rejecting applications, or by excluding parts of the watercourse for conservation.

Conservation of watercourses is done to secure interests such as recreation, scientific research and education.

## Recreation, Hunting and Fishing.

Experiencing nature is important in outdoor life, with rivers and lakes playing a central part in our environment. To many people fishing and hunting are important for their well-being and as a meaningful leisure.

Road construction for water power development projects in previously impassable terrain is considered by many people as an advantage. Others think that something essential becomes lost when roads are built in untouched areas. Therefore some roads are closed after the construction period, and in some places landscape is restored to its original state.

By a lot of water regulations the fisheries are damaged. The power companies are therefore directed to implement various actions to reduce the harmful effects, such as:

- *Stocking watercourses*
- *Regulations concerning minimum waterflow*
- *Construction of weirs to keep the water level*
- *Establishing fishery funds*
- *Clearing up of fishing sites*
- *Construction of fish ladders*

*Production of fish for stocking.*

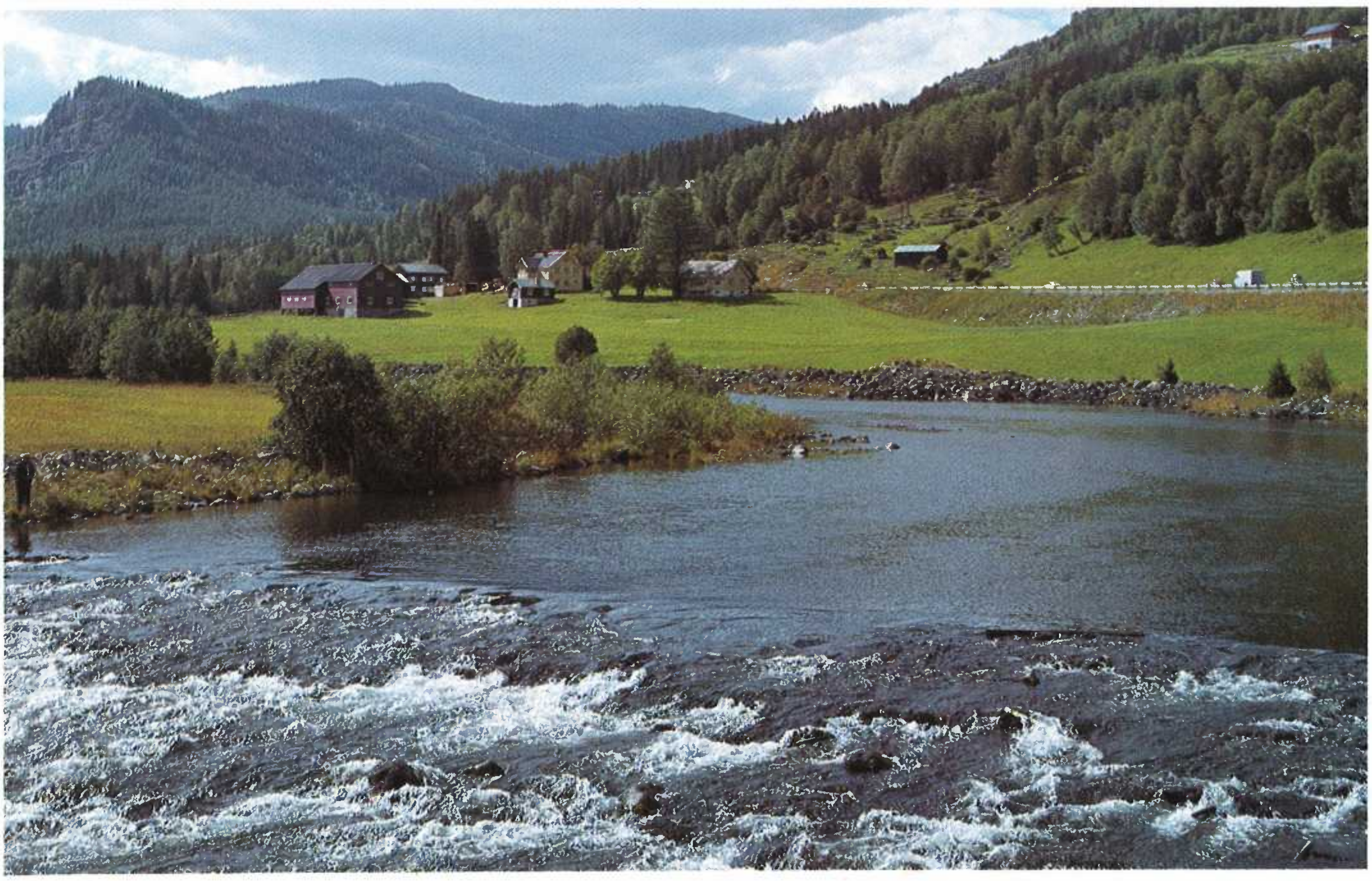
## Agriculture and Forestry.

Agriculture and forestry have always been dependent on watercourses. Farmers must have sufficient water for crops and cattle. For the timberman rivers for a long time provided the only possibility for transporting the timber out of the woods to the customers.

On the other hand the watercourses have also been harmful when floods or drifting ice have devastated cultivated fields, forests, settlements and roads. To avoid such damage, every year the Directorate of Water Resources in NVE carries out erosion prevention and flood control for 30–40 million Norwegian crowns. This is done in cooperation with agricultural authorities, road authorities and "The National Fund for Natural Disaster Assistance". Every year during the last 20 years 8000–9000 decares of land have been saved through such efforts.

Timber floating is now closed down in most watercourses, and instead forest roads are built for transportation. Old floating facilities are being removed to improve the appearance of the rivers, to reduce potential dangers and to reduce other disadvantages connected with them.

*Timber slide and fish ladder.*



*Weir in a regulated river.*

## Water Supply and Sewage Discharge.

Sufficient drinking water and water for the industry can no longer be taken for granted, not even in Norway.

The water supply works are becoming bigger – even medium sized water works can be just as extensive as minor power plants. The problems and inconveniences also often are of the same kind as those connected to power plants. In addition, restrictions are placed on agriculture, settlement and traffic in the catchment area of the water works.

Irrigation has increased considerably during the last few years. At the end of 1981 we had 5.060 single irrigation plants and 770 joint plants in operation in Norway. These plants irrigated 780.000 decares, and would have used about 160 million litres of water an hour if they all had been in operation simultaneously.

*Polluting discharge.*

During dry periods the water works can create such a heavy demand on the water flow of the rivers, that user and consumption conflicts arise. The Directorate of Water Resources therefore implements restrictions on the quantities of water that can be removed.

Cleaned and uncleaned sewage water is discharged into many watercourses. As population concentrations increase along the watercourses, rivers and lakes are fed by great quantities of polluting substances, which can result in severe ecological disturbances. Therefore, hundreds of millions of crowns are allocated to laying sewage pipes and to building purification plants each year.

The power companies have great demands placed upon them as they utilize water for power production. Securing water supply and water purification are the most important of these demands.

## Effects on Fiords and Adjacent Sea Areas.

Watercourse regulations usually mean an altered fresh water discharge to fiords and coastal waters during the year. In the fiords this can lead to alterations in salinity and temperature in the surface layers, and thereby increase the risk of ice formation in winter.

Altered fresh water discharge may also lead to alterations of water exchange in deeper layers of the fiords. In connection with this, tides, weather conditions and the shape and depth of the fiord also play important roles.

Altered fresh water discharge may have multilateral effects on the animal and plant life in the fiords.

In the waters outside the fiords, few unusual changes will be noticed. Regulation of many watercourses will result in a great total fresh water discharge, which may alter the natural conditions in some coastal waters. More often, however, the natural variations of fresh water discharge will prevail over the variations from the watercourse regulations. Only about one third of the fresh water disharged into the sea off the Norwegian coast comes from Norway. Fiords and coastal waters have been subject to comprehensive investigations during the last few years in order to shed more light on some of these problems.

## THE IMPORTANCE OF WATER POWER FOR OUR SOCIETY

### Local Society.

The numerous power developments have, for good and evil, in some cases lead to comprehensive alterations in the water resource districts. Most of the municipalities have placed more weight on the positive sides of the use of water for power production and thus have welcomed the power plant constructors.

A power plant development and the resulting power production give the districts great revenues from taxes, fees, fundings and the like. Particularly tax revenues from the power plants can be of great importance. The municipalities also receive taxes from the construction workers moving in and settling down, and from the relatively few, but permanent operation staff positions at the power stations. Municipalities having hydroelectric plants are among those having the highest tax and fee revenue per inhabitant.

The water power municipalities are entitled to get "royalty" power from the local power plants.

The power companies are often directed by the licencing authorities to construct or to contribute fundings for the construction of roads. Workshop and administration buildings, houses etc. are often handed over to the municipalities when the construction period is finished.

In 1978 municipalities with power stations or water reservoirs within their borders founded "The National Association of Water Power Municipalities". This association raises questions and give statements about the relationship between the member municipalities and power development.

*Administration building and workshop at a power construction site.*

*Housing area at a power construction site.*

## Water Power and Energy Use.

Norway's annual energy consumption has increased by a factor of seven since the year 1900. Solid fuel – coal, coke, wood and peat – accounted for more than 98% of the energy consumption at that time. Today the consumption of solid fuel has dropped to close to 9%. Now oil and electricity are most important. Water power which provides almost all electricity, covers about 40% of our energy consumption – from renewable sources. No other industrialized country covers as much of her energy consumption from water power.

These figures are based on primary energy consumption, i.e. conversion and transmission losses are included. In addition comes 7 million tons of oil a year that is consumed by ships in foreign trade.

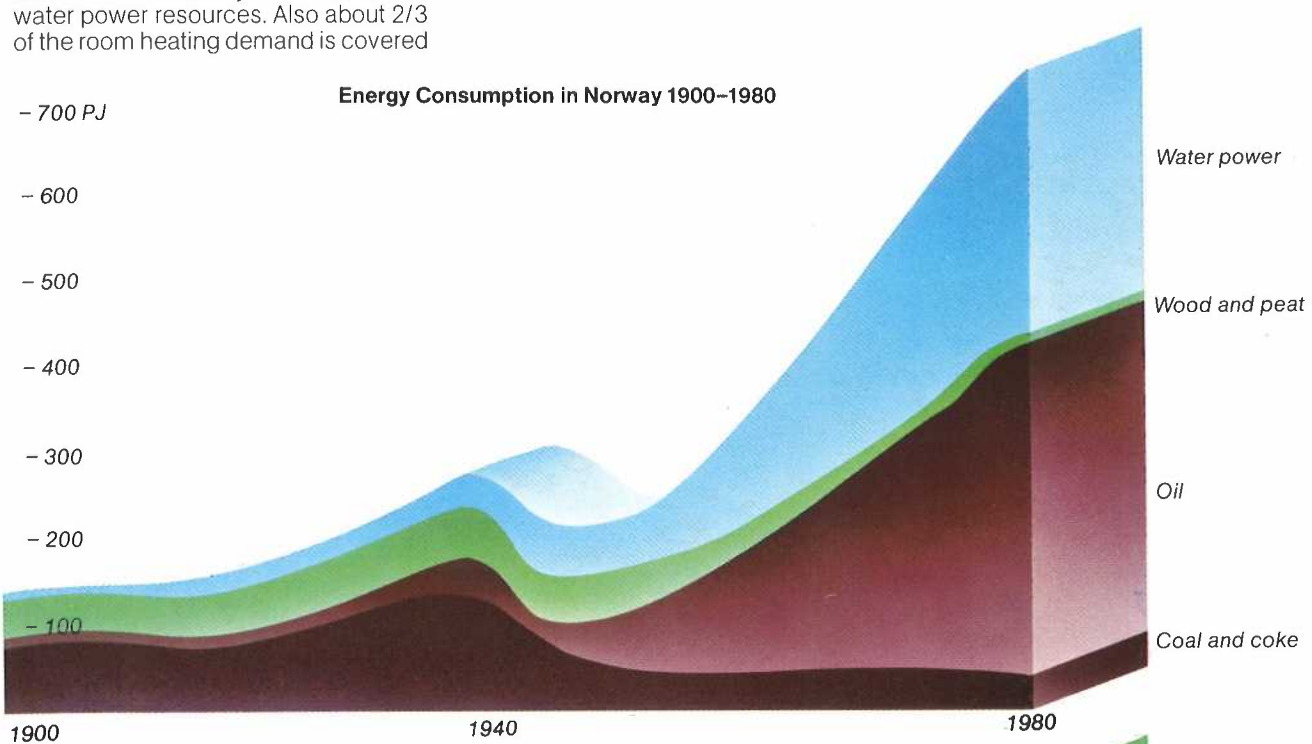
Norway has the highest per capita electricity consumption of the world. The reason is that we have developed a considerable industry to utilize our rich water power resources. Also about 2/3 of the room heating demand is covered by electricity. On the other hand our oil consumption is low. Still our total pr. capita energy consumption places us on the top among European industrialized countries.

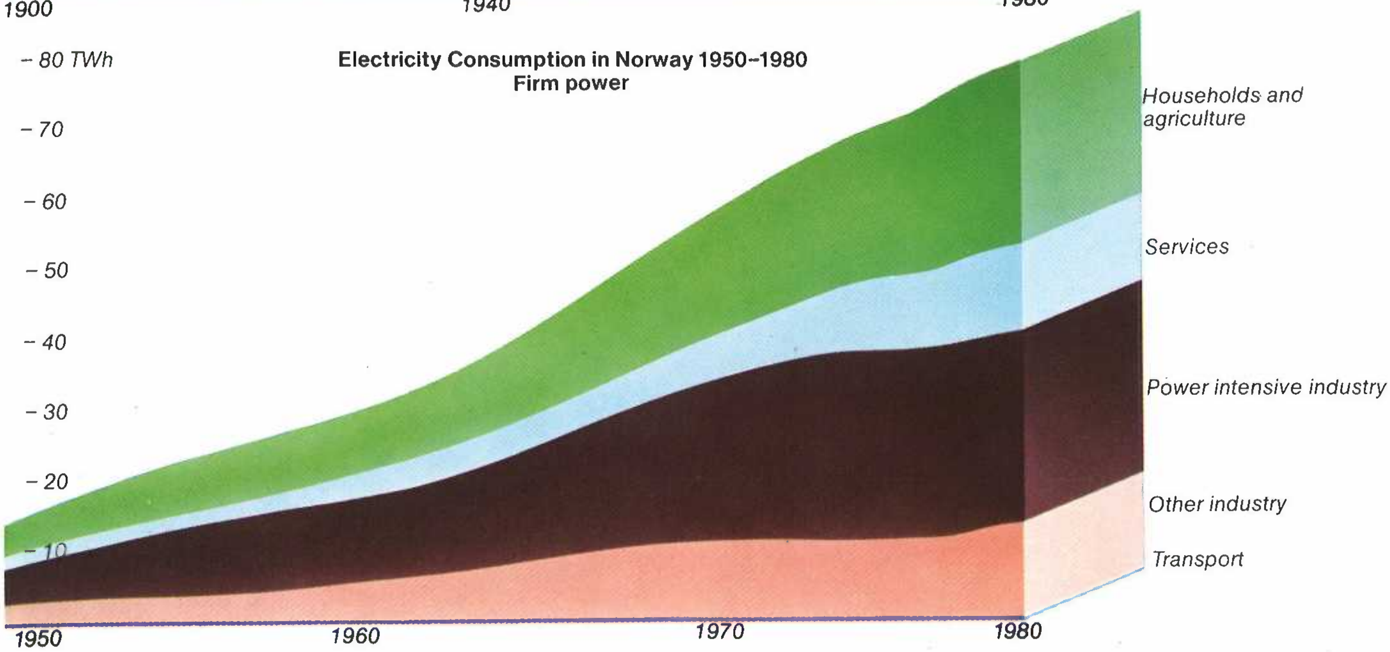
## Who Uses Electricity in Norway.

In 1981 power intensive industry used 36% of our firm power supply. Total industrial consumption was about 51%. Another major consumption sector is households, which uses about 33% of the electric power. The remaining, 16% is used by business, institutions, services etc. Transportation uses less than 1%.

**Energy Consumption per Capita in Some Countries in 1979**

| Country | Energy Consumption Gigajoule, GJ | Of this Electricity Consumption kilowatthours, kWh |
|---|---|---|
| USA | 333 | 10 669 |
| Canada | 316 | 13 623 |
| Netherlands | 191 | 4 519 |
| **NORWAY** | **191** | **20 228** |
| Australia | 183 | 6 381 |
| West-Germany | 176 | 6 103 |
| Sweden | 167 | 11 424 |
| Denmark | 163 | 4 998 |
| USSR | 163 | 4 653 |
| Finland | 154 | 7 495 |
| Great Britain | 151 | 5 368 |
| Iceland | 136 | 12 746 |
| France | 126 | 4 617 |
| Hungary | 111 | 2 864 |
| Japan | 109 | 5 018 |
| New Zealand | 101 | 7 106 |
| Italy | 89 | 3 267 |
| Cuba | 39 | 953 |
| Brazil | 22 | 1 036 |
| China | 21 | 229 |
| Egypt | 14 | 361 |
| Zambia | 13 | 1 487 |
| India | 5 | 174 |
| Nigeria | 2 | 69 |
| Bangladesh | 1 | 27 |
| The World | 59 | 1 849 |



**Water Power and Economy.**

Norway is the only industrialized country where all electricity is produced from water power. This gives us considerable advantages concerning economy and resources. In most other countries electricity is produced by coal, oil, gas or nuclear fired power stations with only minor water contributions. The water which keeps our power stations running is renewable in unending circulation.

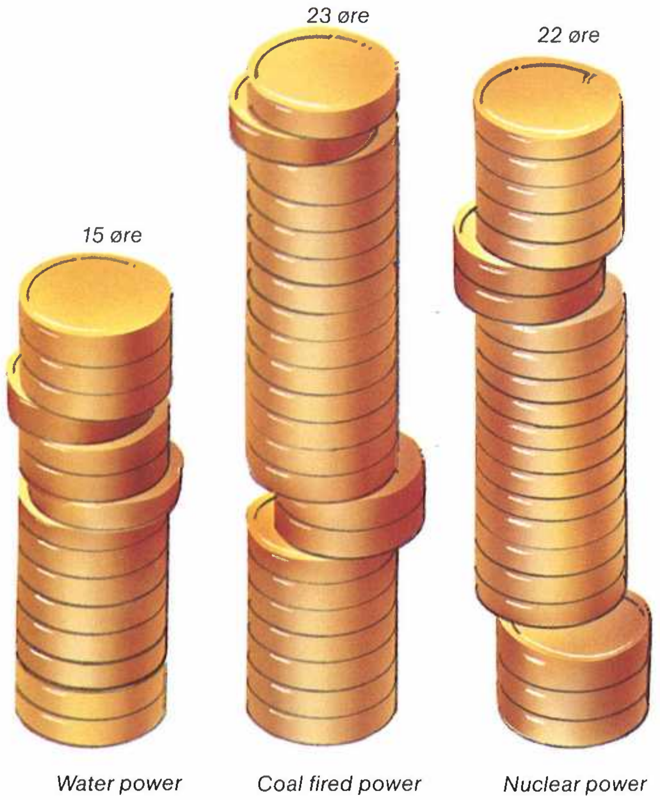
If our electricity demand in 1981 of about 87 TWh had been met by thermal generation, we would have needed 29 million tons of coal.

At the beginning of 1982 the production cost for 1 kWh from a new water power station was about 15 øre. A coal fired power station could have produced 1 kWh at a cost of 23 øre. Oil fired power stations are now considered uneconomic because of high oil prices. Nuclear power costs is supposed to be somewhat lower than coal power costs.

A water power station has a very long life span. The more expensive parts, such as tunnels, dams etc., have the longst life span compared to machinery and instrumentation. When the power plant is fully paid for after for example 25 years of operation, it produces power at a cost of 1–2 øre pr. kWh, which covers operation and maintenance. The energy source – the water – may then be counted as free. All kinds of thermal power stations have considerable fuel costs.

As a water power nation Norway saves billions of crowns every year compared to nations which have to produce their electricity in thermal power stations. If our electricity consumption of 87 TWh i 1981 was supplied by coal fired stations, it would have cost us an extra expense of about 13 billion crowns. The economic advantage of water power compared to thermal power is supposed to increase in the long range.

**Costs in Øre per kWh by Various Power Generation Forms.**



## Water Power and Industry.

From the time around the change of the century an extensive industry has been developed in Norway, based on the utilization of electricity from water power. Industry accounts for a little more than one half of our power consumption of which 2/3 is to power intensive industry and about 1/3 to other industries. About one half of the industrial electricity consumption is used for export products.

Particularly after World War II great efforts were made for a fast expansion of the metallurgical industry in Norway based on water power. Great quantities of cheap water power gave us an internationally competitive advantage. Today Norway is a leading producer of aluminium, magnesium, ferro alloys and other energy intensive products. About 30.000 people are directly employed in power intensive industries and many of the factories are located in outlying districts. In 1980 export of these products amounted to 13,5 billion crowns.

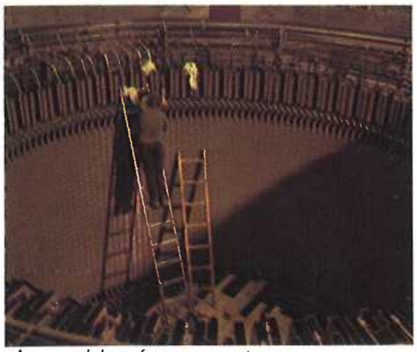
The power intensive industries have created an industrial basis which no industrialized nations are able to do without. In Norway these industries represent knowledge and experience, and they have been a growing point for development of expertise within electrochemistry, electrometallurgy and electrotechnics. They have also created spin-off effects through further processing activities and through orders to Norwegian engineering industries.

Early industrial development took place in this country for production of machinery and other equipment for the building of hydroelectric plants. Some examples of this equipment are penstocks, turbines, generators, transformers, switchgear, cables etc.

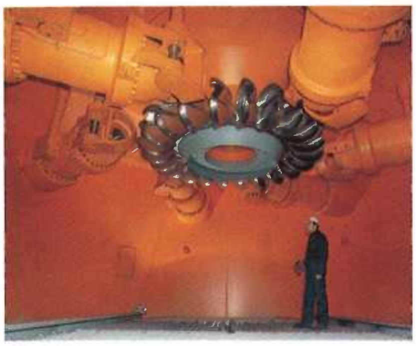
Norwegian industry is capable of delivering all kinds of machinery and equipment to power stations and the transmission system. A Norwegian speciality is production and laying of big submarine cables.

The construction of hydroelectric power plants in Norway has lead to the development of entrepreneur expertise in the fields of tunnel blasting, dam building, concrete structure engineering and power line construction. Further we have engineering companies with more than 80 years of experience within hydrology, civil engineering, electrotechnics and mechanical engineering. The expertise of planning and constructing water power plants was also developed within the major power companies. First and foremost, it was developed within the State Power System in NVE.

During the last few years these industries, contractors and engineering companies have also undertaken jobs abroad, mostly on commercial basis, but also as developmental aid. Through many years NVE has provided developing countries with experts, both through UN's activities, and in cooperation with NORAD – "The Norwegian Agency for International Development".



*Assembly of a generator.*



*Turbine.*

*Electrolyses hall in an aluminium smelter.*

## WORDS AND PHRASES IN RELATION TO WATER POWER

*alternating current* – electric current with periodically alternating direction. (As opposed to direct current, which has uniform direction.)

*dam* – a construction damming up the water in a reservoir and regulating the flow in the watercourse.

*discharge* – quantity of water flowing into a watercourse and further into the sea.

*electric voltage* – a measure for the force pushing the electricity through a conductor. Voltage is measured in V (volt) or kV (kilovolt) = 1000 V.

*energy* – capability to execute a certain amount of work. Energy is measured in Joule.
1 J = 1 Ws (wattsecond)
MJ (megajoule) = 1 million J
GJ (gigajoule) = 1 billion J
PJ (petajoule) = 1 million GJ

Electric energy is measured in:
kWh (kilowatthour) = 3.600.000 Ws
MWh (megawatthour) = 1.000 kWh
GWh (gigawatthour) = 1 million kWh
TWh (terawatthour) = 1 billion kWh

*firm power* – electrical energy delivered on long term contracts which is practically whithout interruption.

*flood and erosion control* – protection of riversides and shores etc. from the washing away of soil.

*frequency* – number of oscillations by the alternating current pr. second. Frequency is measured in Hz (hertz).
1 Hz = 1 oscillation or period pr. second.

*generator* – machine that converts mechanical energy to electrical energy.

*gross power consumption* – power consumption metered at the power station. It includes net power consumption and transmission losses.

*head* – the vertical distance between the water inlet and the water outlet of a power station.

*joint operation* – a number of power stations interconnected to a common grid and operating together.

*licence* – permission or concession from public authority to develop a watercourse for power production.

*mean annual production of electricity* – calculated average annual production of electricity over a number of years.

*net power consumption* power use metered at the place of consumption.

*power* – energy or amount of work executed pr. second. Power is measured in J/s (Joules pr. second).
1 J/s = 1 W (watt)

Electric power is measured in:
kW (kilowatt) = 1000 W
MW (megawatt) = 1000 kW = 1 million W

*power intensive industry* – industry for production of fertilizer, plastic raw materials, iron, steel, ferro alloys, aluminium, magnesium and some other commodities.

*reservoir* – natural or artificial lake where water is stored during periods of high precipitation and low power demand. In periods of high demand and low precipitation water is tapped from the reservoir.

*surplus power* – power produced in water power stations in water rich periods in addition to firm power. Arrangements for delivery of surplus power may be entered and cancelled on short notice.

*thermal power station* – power station operated by heat from combustion of fossil fuels (oil, coal, gas), other fuels or heat from fission of uranium atoms.

*transformer* – apparatus which converts alternating current from one voltage to another.

*turbine* – a machine in a water power station that is rotated by water power and is able to convert this into mechanical energy.

*waste heat* – heat which is lost for instance in industrial processes, in thermal power stations etc.

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