International Cooperation of SHP in China

Hanzhou Regional Centre (Asia-Pacific) for Small Hydro Power (HRC), Hangzhou, China.

1. Historical Progress of Involvement of China's SHP Sector in the International Community

The rapid growth and enormous development of SHP in China tookplace in an historic period of global revitalization of SHP. The boom-bust cycle of SHP development shows that in the early 20th century, after several decades of SHP booming as an embryonic form of hydropower in industrialized countries, a tendency of building large projects to replace SHP emerged. Up to the late 1970s, SHP worldwide was greatly reduced and even almost eliminated. However, in the mid 1970s, drastic inflation of petroleum prices (by 10 times) occurred, and SHP became attractive in many developed countries. Revitalization of SHP was set to surge in countries with rich resources, while some developing countries just started to construct SHP plants to replace diesel generation in rural areas to save foreign currency from importing diesel oil. At this historical stage, the tremendous development of SHP in China from the 1960s to the 1970s astonished SHP peers throughout the world right after China's opening up to the world. Upon request from numerous countries to promote exchange of information, a series of international meetings have been organized by UN organizations and other international institutes since the 1970s. China started to get directly involved in the international SHP community, and from the unfamiliar role it used to have before opening-up, China has gradually grown to become one of the most active member countries. During the past two decades since the early 1980s, the most influential events and meetings that effectively drew China's SHP sector into the world arena should be mentioned as follows:

(1) The UNIDO Seminar-Workshop on the Exchange of Experiences and Technology Transfer of Mini-hydro Electric Generation Units, held in Nepal's capital, Kathmandu in September 1979, was the first international meeting after the oil crisis in the 1970s. It was attended by 68 representatives from 23 developing countries, 10 developed countries and several UN organizations. Knowing that great interest for SHP development was set to develop in the near future in a number of countries, consensus was reached that strengthening of international cooperation would be of increasing importance. An important result of this meeting was the "Kathmandu Declaration", which stated:

-Exchange of information, knowledge and experience is felt to be of basic importance for promotion of this technology, not only between developed countries and developing countries, but also among the developing countries themselves.

-Government and officials and private institutions, as well as UN agencies and other international and bilateral organizations are invited to increase their supporting efforts to accelerate the electrification of rural areas by means of small-scale power production within the framework of rural development plans.

-The participants of the Seminar-Workshop therefore decide to underline the need for strengthening international cooperation in a systematic, efficient and effective manner.

This statement indicated the earliest concept of South-South cooperation in the SHP arena, which has since been extended in a very broad and meaningful way during the past 2 decades.

(2) Another very important meeting, the United Nations Conference on New and Renewable Sources of Energy (UNCNRSE), held in Nairobi, Kenya in 1981, was directly organized by the UN secretariat and attended by 124 countries with 1400 delegates, of whom 98 were leaders at ministerial level or higher. During this meeting, significant messages and decisions were made with respect to SHP development:

-In the report of the Hydropower Technical Panel of the UNCNRSE, it was written, "Perhaps the greatest experience with small-scale hydropower development is in China, where 88,000 hydropower plants have been constructed in the last 2 decades with an average capacity of about 70kW."

This is the earliest recognition of the role of China's SHP development by the international community through an official document from the United Nations.

-According to the officially adopted "Program of Action" of the Conference, it was anticipated that a series of centers of excellence for new and renewable energy sources including SHP be set up to carry out activities in the fields of R+D, demonstration, dissemination, training and information.

(3) Closely following the Kathmandu Meeting, a second Seminar-Workshop/Study Tour on the Development and Application of Technology for Mini-hydro Power Generation was further organized by UNIDO in Hangzhou, China and Manila, the Philippines during October 17-November 8, 1980, showing the great importance and earnest expectation for strengthening international cooperation in the SHP field (which was called Mini-hydro generation then). In this meeting, in-depth studies on the different approaches of SHP development and significant solutions and recommendations were delivered as follows:

-The Seminar-Workshop adopted the Kathmandu Declaration, which emphasized, among other things, the need to intensify action and international cooperation in this important endeavor.

-One of the major objectives of the Seminar-Workshop was the direct comparison of the SHP approaches in China and the Philippines. Both had made successful progress although the methods used seemed to be entirely different. It was stressed that the SHP programs were at different stages of implementation and that the systems were created and adopted under different political, economic, cultural and ecological conditions. In-depth study and comparison were carried out in nine specific aspects of the systems approach: organization and planning, local involvement in the implementation, local involvement in the production of equipment, multi-purpose/socio-economic aspects, technology, involvement of research institutions and universities, national/foreign technical performance, financing and mini-hydro versus other electric energy sources.

The scientific concept of comparison used in the early 1980s has proved to be correct and important, even two decades later in the 21st century. Chief Economist and Senior President of the World Bank, Mr. Nicholas Steven said in the APEC Finance and Program Development 2002 Annual Forum held in Beijing, China on May 26, 2002 that, "One of the most important things we have learned from past experience is that there is no single development model." Up to the present, there are diversified models of SHP development around the world, in which the Chinese approach is only one of the successful models that could be adopted and of valuable reference to other developing countries in some aspects.

-The possibility of establishing a regional/inter-regional development and training center in China proposed by UNIDO was vigorously and seriously discussed during the meeting. The concept of UNIDO in creating Centers of Excellence in selected developing countries, which could function as regional and global focal points of international cooperation on the selected subject such as SHP was explained by UNIDO representatives. It was also felt that the proposed Center in China could be one of a series of similar centers in other regions of the world, which altogether could form the backbone of a global network in the field of SHP. In the summary recommendation, it was stressed that the meeting strongly recommended the establishment of a Center of Excellence in Training, Research and Development related to MHG (SHP) technology. It also pointed out that at the initial stages, the major activities would be mainly for the Asia and Pacific regions.

(4) Under the extensive and intensive influence of the above three meetings and strong support and substantial follow-up work of the United Nations organizations UNIDO, UNDP and UN-ESCAP, the Chinese government authorized the Ministry of Water Resources (MWR) and the Ministry of Foreign Economic Relations and Trade (MOFERT) to take actual steps for establishing the center. Thus, the Hangzhou Regional Center (Asia-Pacific) for Small Hydropower (HRC) was officially established in 1981. The designated objectives of HRC as per relevant documents are to offer and promote international cooperation for SHP development in the field of R+D, training, information and consultancy for the Asia-Pacific member countries. It also acts as a window on China's international cooperation for SHP. Domestically HRC is called the National Research Institute for Rural Electrification (NRIRE) with the objective of providing services of planning and consultancy for construction of electrified counties in rural areas in China.

In the meantime, an Asia-Pacific

Regional Network for SHP (RN-SHP) was set up with its secretariat based successively at HRC and in NEA of the Philippines.

The number of member countries of the RN-SHP was initially 24, and then expanded to 40.

Both HRC and RN-SHP have successfully achieved their objectives as designated in the beginning and mandated by a series of Steering Committees of Renewable Energy Program and Technical Advisory Groups of the RN-SHP

(5) South-South Cooperation

The earliest official program for South-South Cooperation was raised at the UN Conference for Technical Cooperation among Developing Countries (TCDC) held in Buenos Aires, Argentina between August 30-September 12, 1978. The Buenos Aires Action Plan was adopted for promoting and implementing action on technical cooperation among developing countries. The idea of TCDC indicates it is a measure or tool for promoting dissemination of knowledge or experience in the field of human activities among developing countries with the capability of mutual sharing.

Up to 1990, the transition of TCDC to ECDC (Economic Cooperation among Developing Countries) was advocated although the boundary between them is not clear, and mutual support and co-existence should be encouraged.

At the South-South Cooperation Conference held in Santiago, Chile in November 1997, 23 pivotal countries (PC) were determined by the Department of South-South Cooperation, UNDP, including China and other Asia-Pacific countries such as Korea, India, Indonesia, Malaysia, Pakistan and Thailand. The aims of the PCs are to promote developing countries to effectively participate in the growing system of globalization of the world economy and to use trade and investment as the major elements of promoting growth and development.

China has actively participated in TCDC/ECDC activities carried out in the past 20 years or more. In the area of SHP, HRC has also made great efforts in performing TCDC activities organized by UN organizations and the Chinese government, especially in organizing training workshops for SHP. At the turn of the century, HRC was given the award of “Model of South-South Cooperation” by the Chinese Ministry of Foreign Trade and Economic Cooperation (MOFTEC-formerly MOFERT).

(6) The 2nd International Conference on SHP jointly held by the International <Water Power and Dam Construction> of UK and HRC on April 1-4, 1986, in Hangzhou, China.

The conference was attended by 181 delegates from 38 countries (mostly from developed countries) and relevant institutional organizations, together with 96 senior Chinese experts. It was the largest high-level meeting in SHP sector that had been held at that time in China.

The conference provided extensive opportunities for the participants in the following aspects:

-Wide exchange of situation and experience of SHP development around the world, offering a broad opportunity for mutual learning between foreign and Chinese experts;

-Systematic and vivid introduction of achievements and experience of SHP development in China;

-Creation of opportunities for bilateral cooperation between China and foreign countries through concrete mutual understanding of capability, demand and the market situation in China and in western countries;

-Promotion of extensive understanding and friendship between China and western delegates.

The event also indicated that China was continuing its progress towards full integration with the international SHP community and was set to be capable of organizing global conferences and other important events for SHP.

(7) After continuous efforts and numerous activities of international cooperation in the SHP sectors for more than 20 years, China has become more active and capable of joining cooperative activities worldwide. On the basis of the regional center, an International Center for SHP was set up on 1994 in addition to the existing HRC, as anticipated by UNIDO in the early 1980s.

Stepping into the 21st century, China is furthering its contribution in promoting international cooperation in the SHP sector. For example, at the First Regional Workshop on “Renewable Energy Sources in Southeast Asia-Current Stage, Market Conditions and Outlook” organized by the Center for Energy Environment Resources Development and held on 24-25 October, 2002 in Bangkok, Thailand, HRC was authorized to prepare and present a paper entitled “Market Conditions, Barriers and Outlook for Small and Mini-hydro in Southeast Asia”. This shows HRC’s understanding and capability of coordinating SHP activities in the Asian region.

Wrapping up the historical progress of the entry of China's SHP sector into the international community, it is evident that great progress and achievements have been made during the past two decades. Following globalization of the economy and China's accession into WTO, not only will TCDC activities transit to ECDC/TCDC, but market-oriented activities in the SHP sector will boom in the near future. China's recent strategic policies of "go global" will also be implemented in the SHP sector together with importing advanced technology and equipment. It could be anticipated that the prospects for international cooperation in China's SHP business will be very promising for developing in even broader and deeper way.

2. China Contributes to and Learns from the World in the SHP Area

Although China ranks as No. 1 in the world with respect to number of SHP stations in operation with its huge installed capacity, the overall technical level and performance as well as management capability are still far from advanced. With its great achievement and rich experience in SHP construction, China should contribute as much as possible towards promoting SHP development in developing countries. As a window on the SHP sector in China, HRC has made great efforts during the past two decades in fulfilling the commitments both from the Chinese government and the UN organizations. In the meantime, some advanced technology which is necessary for overcoming the prevailing flaws in the SHP sector in China such as technology for automating the SHP stations has been fruitfully imported, absorbed and indigenized under a specific R+D program carried out in HRC. Summarising the major contributions from HRC and learning from the results from our international technical peers, the following items present some concrete ideas to our readers.

(1) Training

Over the past 20 years, HRC has successfully organized 37 international SHP training workshops, with the participation of 615 engineers from about 70 countries in the world. Every workshop was completed as scheduled, and the participants were very satisfied with the training.

-Objectives and contents. For each workshop, definite objectives were defined either for a specific topic such as civil, electro-mechanical, feasibility study, etc., or for comprehensive learning of the whole SHP business. Basic knowledge and theories were avoided as much as possible. Substantial experiences and valuable lessons as well as practical case studies were presented in class and then supplemented by on-site study tours. In addition to a micro-view of technology for SHP development such as design, construction, equipment, procedures of development, etc., macro-view policy study and the overall situation of SHP development in China have been also introduced. These are of fundamental importance for the success of the training.

- Teaching materials. Detailed materials have been carefully prepared and successively up-dated so that participants can study in-depth in addition to listening in class, and to take back for their long-term use. The total amount of various lecturing materials adds up to around 20 million words.

- Lecturers. Selected senior engineers in HRC usually gave lectures as basic courses. For some special topics, well-known professors and acknowledged experts from around the country were invited to give presentations in the workshop with excellent results.

-Study Tour. To instill a deeper understanding of the concept of various types of SHP construction to the participants, several tours were organized during each workshop. Almost all types of SHP engineering exist in China, with respect to powerhouse, penstock, headworks and conduit, dams (earth dam, concrete dam, rockfill dam, masonry dam, RCC dam and rubber dams etc.), turbines (any type) as well as head range (3-1000m). The abundance and versatility of design of SHP development in China could provide opportunity for participants to get a personal feeling for most of the engineering approaches described in textbooks all over the world.

-Facilities and accommodation. HRC's classroom for international training workshops has been equipped with modern facilities including microcomputer based audio video facilities and other necessary electronic devices. To enable participants to keep in touch with the rest of the world and their home countries, a "net bar" equipped with sufficient personal computers has been made available throughout the day time. Participants were very satisfied with these measures, which to a large degree relieve them of their homesickness during a 1 to 2 months' stay in China.

-Country report. Before the conclusion of the workshop, participants were asked to deliver a country report to the class, which was mostly prepared upon HRC's request before they left their home country. Most of the presentations were well-prepared and conscientiously written, and helpful for exchange of information and experience as well as publicizing the requirements of each country. All the papers have then been included in HRC's Internet website, which greatly enhances its information content.

- Feedback discussion. At the end of every workshop, informal discussions were usually conducted for different group of participants. Major topics included the demand for international cooperation in their countries with respect to technical consultancy and equipment import. After understanding the capability and advantages of SHP development in HRC and China, the participants focused on ideas for and needs of cooperation.. "Seeing is believing", so quite a lot of possibilities for cooperative items were thus identified.

- Response from participants and relevant authorities.

Participants of all workshops have expressed their satisfaction with the workshops in various ways, but with the same voice. For example, at the end of the TCDC training workshop held in 2002, the class monitor (representative of the participants), Mr. Wongsavasdi from Thailand stated: "We all learnt a lot from the workshop. The subjects covered were just appropriate for our country. We'll apply what we have learnt here into our work back home."

Positive appraisal for the workshops often came from the authorities both of the Chinese government through MOFERT/MOFTEC and of UN organizations including UNIDO/UNDP. The continuous sponsorship and financial support from MOFTEC and the UN for more than 20 years clearly shows their confidence in the training work.

- Promotion of participants. So far as we know, most participants have been promoted or placed in key positions in the SHP sector after their graduation and with a diploma from China. A lot of them also actively act as the bridge to enhance cooperative relations between our two countries. Most of them keep in contact with HRC, which is conducive to exchange of information.

(2) Information

HRC has continuously edited and published the quarterly 《SHP News》 (English version) under the sponsorship of UNDP/UN-ESCAP-REDP in association with UNIDO for about 20 years. The journal is being disseminated to more than 90 countries around the world. It aims for constant exchange of information and experience in the SHP sector among Asia-Pacific countries and worldwide. The Chinese Ministry of Water Resources also gives financial support to the publication of the journal. During the past two decades, 《SHP News》 has maintained close relations with numerous well-known technical and professional magazines such as 《International Water Power & Dam Construction》, 《HRW》, 《Asian Power》, 《International Electricity》, 《Renewable Energy World》, 《Energy International》 and 《Modern Power Systems》, who are also interested in being involved in and contributing to the SHP industry around the world.

An international SHP website has been set up since the beginning of 2003, and put into initial operation. After its full completion by the end of 2003, it can provide overall SHP information to developing countries bring relief from the problems of "information poverty" and bridge the "digital divide" in the SHP field under a South-South cooperation framework.

(3) Organization of and participation in international meetings

HRC has hosted a lot of international meetings for SHP professionals, among which the 2nd International Conference on SHP jointly organized with UK's 《International Water Power and Dam Construction》 in 1986, Hangzhou attended by 180 international and 100 Chinese specialists was the largest event ever in China's SHP sector at that time(refer to Section 1, Point 6 of this Chapter). At the invitation of the UN and other international organization, HRC has also organized and sent several scores of experts to join meetings in many countries all over the world. Paper presentations including keynote papers were usually offered by

List of the SHP Training Workshops held by HRC
(1983-2003)

No.	Name of Workshop	Countries	Trainees	Time
1	83 TCDC SHP Training Workshop	8	14	May-June
2	84 SHP Hydrology Training Workshop	9	11	Sep
3	85 Training on Electric Engineering	1	1	Jun-Aug
4	86 Training on Water Turbine Pump	7	16	Apr-May
5	86 Training on SHP Feasibility Study	11	19	June
6	86 Training on Low-cost Civil Works	11	18	Aug
7	86 SHP Training for Arabian Countries	6	16	Sep
8	86 Training on SHP Plant Management	8	16	Nov
9	87 SHP Electric & Mechanical Equipment Training Workshop	8	16	Jan
10	87 Training on Water Turbine Pump	1	4	Oct-Nov
11	87 Training on Water Turbine Pump	1	3	Nov-Dec
12	87 Training Workshop on SHP Civil Works	12	20	Oct-Nov
13	87 TCDC SHP Training Workshop for Latin American Countries	3	8	Oct-Nov
14	88 Training Workshop on RE's Social and Economic Impact	10	40	Nov
15	88 Training on SHP Site Selection	12	21	Dec
16	89 Training on SHP Plant Operation	1	2	Aug-Sep
17	90 Training on SHP	1	1	Oct-Nov
18	91 Training Workshop on Civil Works	5	12	Nov
19	93 TCDC SHP Training Workshop	13	24	May-June
20	94 TCDC SHP Training Workshop	17	37	Apr-May
21	95 TCDC SHP Training Workshop	19	35	Apr-May
22	96 SHP Training Course	1	6	Feb-Mar
23	96 Training Workshop on SHP Equipment	8	15	May
24	96 TCDC SHP Training Workshop	18	28	Apr-May
25	97 TCDC SHP Training Workshop	12	19	Apr-May
26	97 SHP Equipment Training Workshop	9	13	June
27	98 TCDC SHP Training Workshop	16	31	Apr-May
28	98 SHP Equipment Training Workshop	4	8	June
29	99 Seminar on SHP in Turkey	1	28	May
30	99 Seminar on SHP in Greece	1	28	June
31	99 SHP Workshop for DPR Korea Participants	1	3	Oct
32	2000 SHP Training Workshop	22	35	Oct-Nov
33	2001 SHP Training Workshop	15	25	May-June
34	2001 SHP Training Workshop for African Countries	5	9	Oct-Nov
35	2002 SHP Training Workshop for African Countries	5	9	May-June
36	2002 TCDC SHP Training Workshop	14	23	Oct-Nov
37	2003 TCDC SHP Training Workshop	21	35^{+}	Oct-Nov

our experts. In some cases, HRC helped some developing countries organize and chair international meetings, such as '90 International Conference on Medium and Small Hydro, jointly organized by the Electricity Administrative Committee of Sao Paulo State, Brazil and HRC, held in Sao Paulo in March 1990. The conference was attended by more than 420 participants from over nine countries including UK, USA, France, Austria and India. HRC and Brazil jointly hosted and presided over the conference with full success.

(4) Research and Development

Since the early 1980s, HRC has undertaken a number of cooperative projects on R+D (including "soft technology"), such as compilation of numerous SHP norms and standards, joint research and application for different types of ELC (electronic load controller) with ITDG, UK and Auckland University of New Zealand.

Continuous efforts have been made on extensive and in-depth study of automating the SHP station and its grid. Starting from the 1980s, with equipment and technology imported from Advanced Computer Solution, USA, a pilot project of automating cascade SHP stations was set up and trial operation and experiment launched by HRC. Although due to various reasons, it only provided experimental and trail operational results to the researchers and was not finally put into commercial operation, it did train and transfer basic know-how to our people. Starting from the 1990s, based on technical cooperation with Canada, a computerized automatic control and protection system was eventually developed by HRC and put into commercial operation with remarkable effect. This unmanned system fits the most important criteria of automation equipment for developing countries, i.e., simple structure, ease of operation and maintenance, reliability and cost-effectiveness. In addition, its practical function and optimized operational features enable it to meet the actual requirements of small hydropower plants, which are different from that of large plants. A typical illustration of commercial operation of this system is the Anti Cascade No.1 Station in Jinhua, Zhejiang province. The station was built in 1965 and renovated in November 2000 for upgrading the capacity to 4×1500kW from the original 1,250kW. During rehabilitation of the plant, the automation system was installed and put into operation in March 2001. The owners and operators of the station are satisfied with the equipment in the following aspects:

-easy maintenance and low cost (with small addition of initial investment of 40,000 Yuan (RMB) versus conventional equipment, it saved 240,000 Yuan per year in operation);

- increased reliability of operation;

-high performance of automation: first reduction of attendants from 24 to 12 and later unmanned operation could be realized;

- quick start and integration with the grid within 2 minutes versus the original 8 minutes;

-versatility of technical requirement;

- sound and safe services;

With the success of the pioneering equipment, extension occurred very often. The prospects for this optimised automation equipment both at home and abroad are therefore very promising. HRC is enthusiastic to offer assistance to the upgrading of technology for the SHP sector in developing countries both in the Asia-Pacific region and worldwide.

(5) Consultancy and transition from TCDC to ECDC/TCDC

Entering into the 1990s, HRC has been making every effort to make the transition from TCDC to ECDC/TCDC. A large amount of hard work has been conducted with fruitful results in the field of international consultation services including planning, feasibility study and design as well as equipment supply for dozens of SHP projects. Friendly and substantial cooperative relations have been set up between HRC and its counterparts in more than 30 countries in the Asia-Pacific region, as well as North and Central America, and Africa. For example, consultation regarding on site selection for turbine-pump projects in Nepal, design for Kota hydropower station (4,000kW) in Malaysia (commissioned in 1997), design for Moco-Moco hydropower station (2×250kW) in Guyana (commissioned in 1997), consultation and equipment supply for 3,000 sets of micro hydropower units in Vietnam, feasibility study for 5 SHP stations in Brazil, and complete package of equipment supply for 2 SHP stations (2×1000kW) to Cuba. These not only brought technical cooperation on to the road of economic cooperation, but also provided us the appropriate approaches on how SHP should be launched during the present situation of globalization of the economy.

In the beginning of the new century, we are facing critical new opportunities and challenges in the following respects:

-globalization of the economy

-the strategy of "go global" recently set by the central government

-de-regulation of the power sector and encouragement of construction of privately invested independent power producers (IPPs) in the SHP sector both at home and abroad.

-China's accession to WTO and its impact on economic cooperation and trade relations in the SHP arena between China and other parts of the world.

HRC is making its best efforts to offer its contribution during this new historical stage. Discussions and negotiations have taken place with owners and developers in more than ten countries for commitment of EPC contracts (Engineering, Procurement and Construction, equivalent to turn-key projects) for SHP projects. Private investment in SHP construction in developing countries has been explored since last year. One example is a pumped-storage project in People's Republic of Mongolia, with feasibility study and engineering design prepared by HRC and capital investment from a Chinese private enterprise. It is estimated that the prospect of Chinese private investors to "go global" into the SHP sector abroad is also promising. This prediction derives from the fact that the interest of Chinese entrepreneurs in investing in the SHP business is now set to boom. For example, in Zhejiang province only, there are 25 privately invested SHP stations each over 10 MW, accounting for 66% of the major stations constructed in the province during 1994-2001. By now, the annual inflow of capital to the SHP construction market in several cities rich in hydro resources in the province has reached 1 billion Yuan (RMB).

Although investors are interested in putting money into the international market of SHP development, they lack information and consultancy. Therefore intermediaries are urgently needed in this respect. HRC is identifying how to fully realize its potential and what contributions it can make in this field. Although this work has only just started, the prospects for the future are bright. ■

Indian Guests visited HRC

On 11th of August, a group of 6 Indian members paid a visit to HRC. After the briefing on HRC and SHP in China, the Indian guests expressed keen interest in SHP training that HRC conducts every year for international participants and micro packaged units that Chinese manufacturers produce. Inquiries were addressed around the supply of micro packaged units and the related expenses on SHP training. The 6 members were at Hangzhou attending 2003 Bamboo Cultivation, Processing and Production Seminar organized by UNIDO.

India is a county badly in need of energy. In 2001-2002 there was a shortage of energy by 7.5%. So, the Indian government has formulated preferential policies to encourage private and foreign investors for SHP projects. The long-term target of the government is to increase the hydropower proportion in the national total installed capacity from the present 24.95% to 40%. ■

(Source: SHP NEWS Editorial office http://www.hrcshp.org)

The 2003 International SHP Training Workshop opened

The 2003 International SHP Training Workshop was opened on 13th October at Hangzhou Regional Center for Small Hydro Power(HRC). Over 30 participants from Micronesia, Sri Lanka, Columbia, Romania, Egypt, etc., of 21 Asian, African, Latin American, East European and Oceanic countries attended the training with the duration of some 40 days.

This training workshop is sponsored by Chinese Ministry of Commerce. All the lodging, boarding, training, pocket money and the domestic transportation fees are borne by the Chinese government. This is part of the Chinese contribution to South-South cooperation.

Participants are required to master the basic theory and principles of SHP development, feasibility study, engineering management, operation, maintenance etc. and increase their ability to solve the concrete problems concerning SHP exploitation. The subjects include procedures of SHP development, feasibility study, hydrological analysis, low-cost civil structure, turbo-generator units and auxiliary, electric equipment design, economic evaluation, operation, maintenance, SHP policy and legal aspects etc.

Lectures are combined with discussions, SHP forum and case study plus study tours, so as to consolidate the theoretical knowledge acquired and get practical experience. Study tour will be arranged to Shaoxing, Shengzhou, Linhai, Yueqing, Ningbo, Xiaoshan, Deqing, where the participants are to visit some SHP stations of various development types, combining the techniques of low-cost civil structures and appropriate automation controlling system as well as some hydro power equipment manufacturers. Study tour will also be conducted to Nanjing and Shanghai so as to see the fast economic development of the China's eastern coastal areas.

HRC was jointly set up by the UN and the Chinese government in 1981. Entrusted by Chinese Ministry of Water Resources, Ministry of Commerce (previously called Ministry of Foreign Trade & Economic Cooperation), Ministry of Science & Technology, UNDP, UNIDO, ILO, FAO etc., HRC has successfully hosted over 50 various training workshops with over 2000 participants, including many international meetings and 36 SHP training workshops with over 600 participants from 70 countries in Asia, Africa, Latin America, East Europe and Oceania.

Due to the outstanding achievement in international SHP exchange and cooperation scored, the Center was awarded as the "Model of South-South Cooperation" by MOFTEC at the turning the century. In the speech delivered at Zhejiang University in mid October 2002, the United Nations Secretary General K. Annan mentioned that "right at Hangzhou China you have made use of the Regional (Asia-Pacific) Center where you have shared your valuable rich experience in the field of renewable energy with those from the numerous developing countries in the world. China is playing a pioneering role in the regional technical cooperation with the developing countries. You developed a lot of cooperative projects not only in foreign countries, but also you have generously implemented." ■

(Source: SHP NEWS Editorial office http://www.hrcshp.org)

Further Cooperation between HRC and Powerbase

In recent days, a Chinese delegation composed of Ms. Cheng Xialei, Deputy Director of HRC, Mr. Xu Jincai, Chief of the New-Tech R&D Center of HRC, and some other experts from the Zhejiang Provincial Department of Water Resources, paid a visit to Canadian partner Powerbase Automation System Inc., for discussing further cooperation on Automatic Control System for SHP.

The kind cooperation between HRC and Powerbase dates back to 1996, when the advanced technology on the Unmanned Control System for SHP was introduced from Powerbase, as the implementation of one of the "948" projects consigned by the Chinese Ministry of Water Resources. The system was mainly developed for the hydropower stations connected to power grids. Being demonstrated, studied and indigenized, the technology has been applied and popularized in dozens of SHP stations nationwide with fruitful results. Moreover, with joint efforts, an upgraded simple automatic control system for the isolated SHP stations is developed successfully, with competitive advantages both in function and price.

In order to further improve the SHP automation in China, in this year, HRC and the Zhejiang Provincial Department of Water Resources apply together for carrying out the "948" project entrusted by the Ministry of Water Resource, which plans to introduce the simple automatic control system from Canada, and demonstrate in Jinhua, Zhejiang province. It is expected that the pilot project will be installed and commissioned in the end of this year and put into operation earlier next year. ■

(Source: SHPNEWS Editorial office http://www.hrcshp.org)

A Chinese Magazine "Small Hydropower" by HRC

The Chinese "Small Hydropower", a magazine that National Research Institute for Rural Electrification (NRIRE) and Hangzhou Regional Centre (Asia-Pacific) for Small Hydro Power has edited and published for 113 issues (bimonthly), was allocated with the International Standard Serial Number ISSN 1007-7642, and China Standard Serial Number CN33-1204/TV. It was published in Chinese attached with title of articles in English. Its special features are technical experience of SHP development in China. Information of international SHP activities and important events in the field of SHP have also been widely included.

This magazine carries news, views and articles on all aspects of small hydro power. It is useful to those who are intersted in technical experience of SHP development in China.

"Small Hydropower" is the only professional publication on small hydropower in China, which is issued domestically and abroad. It is widely circled in allcorners of China concerning SHP, and getting more and more popular in over 600 rural counties which is primarily hydro-electrified, more than 2,300 counties with hydropower resources, more than 50,000 small-sized hydropower stations, thousands of colleges oruniversities, research institutes and other administrative authorities on SHP. Advertising is welcome for any equipment manufacturer to target Chinese market on SHP construction, equipment purchasing or other businesses.

Subscription rates (1 year):USD40.00

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The 3rd-class 2003 Dayu Award goes to "SHP (small hydropower) Unmanned Control System" Project in Water Science Field

Since the beginning of last 1980s, HRC (Hangzhou Regional Center (Asia-Pacific) for Small Hydro Power) started to research and develop SHP (small hydropower) unmanned automatic control system, and also learned some successful experience from those developed countries. With supports from the "Fund Program" and the "948 Program" of Ministry of Water Resources, this automatic control system gradually matured and achieved reliable quality, easy maintenance and high performance/cost rate, and was widely popularized at small hydropower stations. Until now it has already been applied at almost 100 stations in over 10 China's provinces and cities, and meanwhile, exported to some developing countries such as Vietnam etc. This award is really a great encourage given to HRC for continuing its contribution into water resources science. HRC staffs would also further spare no effort to contributing more to the rural hydro electrification in China. ■

(Source: SHP NEWS Editorial office http://www.hrcshp.org)

The main contents of issue No.112 (2003 No 4) read as follow.

Rural Electrification

The planning and practice of SHP exploitation in Maoming city

Technology Exchange

Analysing the selection of installed capacity of water power plant through the case of capacity increase in Human Province

Discussion on SHP cascade exploitation in small river basin

Application of micro hydro power in ecological protecting engineering

Programme design of short circuit electricity calculation

Management

Discussion on management of SHP investment project

Computer Application

Application analysis of computer monitoring system in Wanglong SHP station

The combined and intellectualized system of generation and transformation SHP

Project Construction

Treatment of fault zone in bending section of water conveyance system in Huilong pumped storage power station

Chemical grouting technology applied to hollow dam of Guanyang reservior in Yongding county

Renovation

Technical renovation of drainage system in Dagang SHP station

Renovation of control circuit in air cooling ventilator of generator

Application of elastic metal-plastic bearing in SHP station

Operation and Maintenance

Common Faults and their treatments for hydraulic system of turbine governor

Treatment of vibration caused by looseness of key in magnetic pole

Introduction of trash disposal in Tangyu SHP station of Shitou reservoir

International Exchange

Role of hydropower in sustainable development(2)

Cost-effective and practical technology for automating the small hydropower

Getting its house in order-US deregulation structural concerns under review

Funding private hydropower:Allocating the risk

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SHP-Potential, Technology and Environment

Arun Kumar

Indian Small Hydro-history

The development of small-scale hydropower in India started with the 130 kW installations in Sidrapong (Darijeeling) in the year 1897 and was almost in the pace of world's first hydroelectric installation in 1882 (at Appleton USA).

Few other installations e.g. Shivasamundram in Mysore (2000 kW) and Chamba (40 kW in 1902, Galogi in Mussoorie) (3000 kW)in 1907 and Jubbal (50kW) (1911) and Chhaba (1750 kW) in Shimla in 1913 are the known SHP stations working still in full might.

These plants were used primarily for lighting purposes in the important towns.

After independence several small hydropower stations were installed in different parts of the country but to serve in majority cases as stand alone for isolated remote areas.

Since seventies rural electrification based on grid extensions was launched.

International status

Out of world's total primary energy supply of about 9376 Millions of Tonnes Oil equivalent, about 2.3% only comes out of hydro sources. Out of a total 13652 TWh of electricity production only 18.4% of electricity is generated through hydro sources (see Table 1).

It is expected by 2050 electricity consumption is likely to go up to about 45,000 TWh.

Status for global regional hydro and small hydro (10 MW or less) is given in table 2.

Inventories of Small Hydro Sites have not been updated for many areas throughout the world nor the capacity range of individual sites are assessed in any reliable way. Various definitions of "small" exist and this depicts the problem of determining the present capacities and future prospects.

One of major impediment in establishing an inventory is the nonavailability of hydrological data as most of the small schemes where SHP potential exist are ungauged. AHEC in collaboration with CEH, UK & HimUrja, HP Govt. have developed the software to assess the hydrology

Table 1:hydro Composition VS total Electricity Generation

Source	Share in %		
	1975	1996	India (2000)
Hydro	21.0	18.4	24.8
Nuclear	3.3	17.7	2.1
Gas		12.1	18.4
Oil	24.6	9.3	71.8
Coal		38.3	38.4
Others*	0.7	1.4	1.2
Total Electricity (TWh)	6118	13652	242

* Other includes geothermal, solar, wind, combustable, renewable & waste (source: Key World Energy Statistics IEA, 1998)

Table 2: Capacity and production of global regional hydropower

Region	Large		Small		Percentage of small w.r.t. large hydro	
	Capacity (GW)	Production (TWh)	Capacity (GW)	Production (TWh)	Capacity (GW)	Production (TWh)
North America	133.7	576.8	4.302	19.738	3.20	3.42
Latin America	94.0	390.0	1.113	4.607	1.18	1.18
Western Europe	136.7	405.3	7.231	30.239	5.29	7.46
E Europe and CIS	82.3	260.2	2.296	9.438	2.79	3.63
Mid East and N Africa	13.1	40.2	0.045	0.118	0.34	0.29
Sub-Saharan Africa	16.5	45.1	0.181	0.476	1.10	1.05
Pacific	12.1	38.7	0.102	0.407	0.84	1.05
China	37.9	124.8	3.890	15.334	10.26	12.28
China (2002)	79.35	243	24.58	80	32	30%
Asia	100.7	397.4	0.343	1.353	0.34	0.34
Total	627.0	2,281.2	19.503	81.709	3.10	3.6%
Indian	20.00	70.5	0.250	N.A.	1.31	N.A.
India (2002)	25.5	74.5	1.45	N.A.	5.68	N.A.

(Source: Water Power Dam Construction (1992) and World Energy Council (1994)) of the sites in Himachal Pradesh. This is known as HYDRA-HP. It is proposed to carry out similar exercise for finding out the hydrology for other states also.

There is a general tendency all over the world to define Small Hydro by installed capacity output. Different countries follow different norms, the upper limit ranges between 5 to 50MW.

Potential

Formulation

Basic Equation for Power estimation

Power in kW $= Q \times H \times 9.81\ \eta$

Where,

Q Discharge in cumecs

H Head in metres

η Overall efficiency of turbine, gear-box & generator

The head is relatively constant in run-of-river schemes except for variation in friction losses with the varying discharge. In irrigation canal or dam toe based scheme head also vary depending on water releases and season of release. Head duration curve is then plotted to find out the design head of turbine. The design head is so selected that turbine is operated to the maximum time giving optimum energy generation.

Classification

In India, small hydro schemes are classified by the Central Electricity Authority (CEA) and is as given in table 3.

Potential

In India, out of 150,000 MW hydropowerpotential, a 15,000 MW potential is estimated as small hydro. State wise SHP potential sites identified are given in table 4.

Implementation efforts

- There has been a revival of interest in SHP schemes in recent years in a totally different context and India also has taken this up in earnest. This is in the context of pooling all sources of energy, New and Renewable Energy, to fill in the expected gap. These include solar, wind, ocean and biomass resources.
- India has set up specific ministry departments at the Central and State government levels to give concerted technical and administrative support in developing new and renewable sources of energy.
- The Government of India, through the Ministry of Non-Conventional Energy Sources (MNES) is extending multi dimensional support to the development of small hydro

Table 3: Classification of micro,mini & Small Hydro Schemes in India

Class	Station Capacity in kW
Micro	up to 100
Mini	101 to 2000
Small	2001 to 25000

Table 4: Identified Small Hydro Projects (upto 25 MW Capacity) *

Sl. No.	State	Total No.	Total Capacity (MW)
1	Andhra Pradesh	377	250.50
2	Arunachal Pradesh	452	1243.47
3	Assam	40	119.54
4	Bihar	74	149.35
5	Chhattisgarh	47	57.90
6	Goa	4	4.60
7	Gujarat	287	186.37
8	Haryana	23	36.55
9	Himachal Pradesh	288	1418.68
10	Jammu & Kashmir	208	1294.43
11	Jharkhand	89	170.05
12	Karnataka	221	534.76
13	Kerala	207	455.53
14	Madhya Pradesh	85	336.33
15	Maharashtra	221	484.50
16	Manipur	99	91.75
17	Meghalaya	90	197.32
18	Mizoram	53	135.93
19	Nagaland	84	149.31
20	Orissa	206	217.99
21	Punjab	122	124.22
22	Rajasthan	55	27.82
23	Sikkim	70	214.33
24	Tamil Nadu	155	373.46
25	Tripura	10	30.85
26	UT (A & N Islands)	5	1.15
27	Uttarpradesh	211	267.06
28	Uttaranchal	354	1478.24
29	West Bengal	141	213.52
	Total	**4278.00**	**10265.45**

* State Govt. Departments are requested to provide update/verify the data.

Table 5: Comparative features of low, medium and high head hydro plants

SL. No.	Features	HEAD Low $<$ 30 m	Medium 30-75m	High above 75m
1.	Topography	Flat land	Hilly	Mountainous
2.	hydraulic Characteristics	Run of River	Pondage/Run-of-River	Storage/Run-of-River
3.	Discharge	Large	Medium	Small
4.	Foundation Conditions	Soil	Sand & Gravel	Rock
5.	Diversion Structures	Barrage/weir	Barrage/dam	High dam/weir
6.	Water Conductor System	Combination of Power House/intake	Power Channel and Penstock	Penstock/power tunnel
7.	Arrangement for PH structure	Intake Channel, Machine hall and substructures in one unit	Arrangement as for low and high head	Separate Power house structure
8.	Turbine	Axial Flow, Kaplan, Propeller, Tubular, Bulb	Kaplan, Francis	Pelton, Francis
9.	Size of Equipment	Large	Medium	Small
10.	Machine Layout	Vertical/inclined	Vertical	Vertical/horizontal
11.	Electric Load	Base	Base/Low Peaks	High Peaks
12.	Construction Penstock	Short	Moderate	Long

(Source: Nigam PS, "Handbook of Hydro Electric Engg.")

(up to 25MW) among other renewable energy sources. Small Hydro Power Projects up to 25MW has been transferred to MNES to provide greater thrust for its development.

- With the policy decision of 10% contributions to come from renewable energy in the future 100000 MW by the year 2012, small hydro installation is expected to play a major role.
- Specialised organizations like Alternate Hydro Energy Centre (AHEC) at Indian Institute of Technology Roorkee (formerly University of Roorkee) were set up to devote attention to appropriate technology for this purpose, to render assistance to individuals and to departments in various ways and to carry out research and training activities.
- The Central and State Governments of India have implemented a host of policies and made regulatory and programmatic changes to promote and develop renewable energy resources.

Technology

Layout

A typical layout of small hydropower (SHP) station comprises of

- Diversion weir/barrage
- Power channel
- Desilting devices
- Forebay tank/balancing reservoir
- Penstock
- Bypass arrangements/spillways

Table 6 :List of Manufacturers in India

S.No	Manufacturers	Collaboration	Type
1	BHEL	Fuji, Japan	Technical
2	Boving Fouress, Bangalore	Kvarnaener Boving, now GE UK /Norway	JV
3	HPP, Delhi	HPP France	JV
4	Jyoti, Vadodra	Gilks, UK (now expired) Turbo Institute of Slovenia	Technical
5	Kirloskar, Pune	Ebara Corp, Japan	Technical
6	PPMLG, Chandigarh	Voest Alpine, Austria; Koessler Austria; Bouvier Hydro France	Technical
7	VA Tech Escher Wyss Flovel, Faridabad	VA Tech, Austria	JV
8	Triveni Engg Ltd, Delhi	Esac, France; Litostroj, Slovenia	Technical
9	DLF Industries, Faridabad	Ckd blansko, Czech	Technical
10	Technica Ganz, Delhi	Ganj, Hungary	Technical
11	Steel Industries, Thissur	Koessler, Austria	Technical

(Source: Indian Manufacturers)

- Power House Building
- Equipment
- Power evacuation arrangements

Electro Mechanical equipments

Major equipments are listed below.

Electrical Equipment

- Generator (Synchronous and Induction)
- Control and Protections
- Transformers
- HT Switchgear
- LT switchgear

Mechanical Equipment

- Hydraulic Turbine
- Governor
- Inlet control (valve/gate)
- Speed Increaser (low head aplication)

The advances in governor technology paved the way for completely computerized, automated plant controls, operated by computer keybord rather than switches&data displayed on video display terminals ratherthan meters. The operating and control systems are based on microcomputers and programmable logic controllers for generator load sharing and turbine optimization. This will improve water management as well as reduce overall personnel operating costs.It is recommended that the station should be operated based on today's technology.

Comparative features of different schemes

The same is given in table 5.

Comments on Desilting

Desilting device is necessary where the water contains large quantities of coarse silt to minimise erosion damage to the turbine runner etc. specially in Himalayan areas where most of the SHP potential lie. The extent of desilting requirements would depend on the quantum and type of silt carried by the stream and the runner material. Abrasion effects become more pronounced with increasing head. The desilting chamber may be designed to exclude the particles coarser than the sized mentioned below for various heads of water to achieve a power draft free of abrasion effects.

Head	Size of silt particles to be removed
Low head	0.2 to 0.5mm
Medium/ High head	0.1 to 0.2 mm

India Equipment Manufacturers

In India there is good base for the small hydropower equipment manufacturing. There are several manufactures who have one kind or other collaboration for manufacturing and supply of equipment as shown in Table 6.

Environment

Water courses are responsible for sustenance of life of various forms. Any interference with its natural flow significantly threatens the land and life in its vicinity and imperils the balance in the ecosystem irrespective of the size of the stream. The small hydro power development has some impact though may be little and should not be ignored. It is therefore expedient to analyse the environmental impacts of any proposed scheme and provide suitable measures to mitigate any adverse effects to the extent possible.

The environment concerns pertains to SHP are:

- Effects of construction on the area
- Effects on fisheries and other aquatic life
- Effects of storage of water in barrage on water quality
- Effects on diversion of water through channels downstream of the diversion point in terms of its existing utilization and impact on irrigation and common man
- Effects on recreational facilities
- Effects on excavation and filling of wetlands

Environmental impacts should not be a detracting factor against the SHP development as these can be avoided and mitigated by changes in the project design and operation. Environmental impacts of SHP are site specific and hence need to the investigated for possible adverse impacts to be caused. The run of river SHP schemes which will be the most of the cases will be having the least impact.

For environment clearance, Government of India vide its Notifications dated June 13,2002 in continuation dated Jan 27,1994 mentions that the new SHP projects of up to Rs 100 crore investment do not need any environmental clearance. However the project costing more than Rs. 100 crore need environment clearances in the prescribed manner after carrying out the detail environment impact assessment studies.

Conclusions

India provides very good variety of small hydropower sites for development either as commercial enterprises or as green power generation. Liberisation of procedure is going on and it is expected in near future that SHP potential will be developed in a big way.

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(Source: IREDA NEWS)

HRC expert completed a SHP site investigation in Mongolia

In June 2003, one of the Mongolian Parliament members, Mr.Gundalai paid a visit to HRC, with the hope that HRC could help the construction of SHP stations in Mongolia. After going back, he sent invitation to HRC and HRC dispatched Deputy Chief of International Cooperation, Sr. Engineer Mr.Li Zhiwu for the mission to Mongolia from 10 to 17 July. Site visits were conducted for SHP resources, load demand, mode of SHP exploitation, installed capacity and development arrangement at the two villages in the north-western part of Mongolia. Preliminary suggestions have been presented to the Mongolian side in regard to SHP resources, load demand, mode of SHP exploitation, installed capacity and development arrangement. The Mongolian side expressed that survey work and collection of data concerning topography, geology, discharge, temperature, construction materials etc could be completed within two months, and the related data will be sent to HRC. Based on that, HRC will complete the feasibility study work. Meanwhile, the Mongolian side would seek to settle the funds concerned and try to start the construction in 2004. ■

(Source: SHP NEWS Editorial office http://www.hrcshp.org)

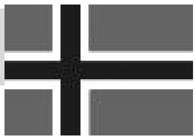
Talk on Cooperation with the World Bank Officials

On 12 September 2003, the talk on SHP cooperation was conducted between HRC and Manager of Energy & Mining Sector Unit, East Asia and Pacific Region of the World Bank, Ms.Wu and Energy expert, official from the World Bank office in Beijing, Mr.Zhao.

Ms. Wu evaluated highly the efforts taken by HRC in promoting the global SHP cooperation and development in the recent years. She took keen interest to learn the latest SHP development in China including the changes in investment modes. Both sides explored the potential of cooperation in jointly conducting international SHP conference, compilation of international SHP norms and standards, SHP automatic technology and etc. ■

(Source: SHP NEWS Editorial office http://www.hrcshp.org)

NORWAY



Report contributed by:
Norwegian Water Resources and Energy Directorate (NVE), and Ministry of Petroleum and Energy

1. INTRODUCTION

1.1 Location and natural conditions

The mainland part of Norway is located between approximately 58º and 71ºN and between 5º and 31ºE. In addition, the Svalbard archipelago and the Arctic island Jan Mayen are parts of Norway. In the national energy context, the Svalbard group of islands is important as a location for coal mining. The area of mainland Norway is 324,000 km^2, and of the Svalbard archipelago, 61,000 km^2.

The geographic location of Norway, on the western side of the European continent, means that there is a high level of precipitation. The long coastline is in the pathway of the polar low-pressure systems, which bring along moist air and abundant precipitation. The rain and snowfall is greatly increased because of the orographic effect of the mountain range running along the coast. Annual maxima of measured precipitation exceed 3500 mm in places, and indirect evidence from runoff data and glacier mass balance shows that some areas receive more than 5000 mm on average. On the eastern, lee side of the mountain range, however, annual precipitation may be 300 mm or less.

The annual runoff from mainland Norway was 369 km^3 in the 1961-1990 standard normal period, corresponding to about 1140 mm. The glacial history of Scandinavia means that the soil cover is very sparse in the Norwegian mountains, but that till and fluvial deposits along rivers often provide local possibilities for groundwater resources.

Norway is well endowed for developing its hydropower resources also from a geological point of view. The steep western side of the mountain range provides high heads over short distances from the mountains to the fjords. Glacial erosion has created both steep valleys and a multitude of lakes, providing many excellent locations for storing water. More than 5% of the area comprises lakes, and about 100,000 lakes are more than 1 ha (0.01 km^2) in size. The total volume of storage reservoirs for hydropower is close to 62 km^3 (62 billion m^3).

1.2 Industrialisation and population

The development of much of Norway's industry has been strongly influenced by the availability of cheap hydropower. The main examples are the pulp and paper industry and the metal smelting sector, in particular the aluminium and ferro-alloy branches. Several industrial towns serving these industries grew up close to hydropower plants. This was typically the case for the paper industry early in the 20th Century, and the metal-based and chemical industries mainly in the period of rapid economic development after the Second World War. Other major sectors of Norwegian industry are less dependent on energy supply and more oriented to consumer markets, such as the food and beverage industry. Not surprisingly, most of Norway's industry is located close to the coast (because of the proximity to import/export facilities, hydropower plants, and population centres).

Since 1970, the production of oil, and later gas from offshore fields has become a major component in the national economy. This industrial sector has its particular problems of ensuring water and electricity supply to the platforms.

The population of Norway is 4.5 million (in 2001), which means an average population density of 15 inhabitants per km^2. However, the population is strongly concentrated along the coast and fjords, as well as major lowland lakes and valleys, where agriculture has been possible. The inner, mountainous parts of Norway are practically uninhabited. 70% of Norwegians live in urban centres, and the proportion is growing.

1.3 Trends

1.3.1 Population and private economy: status and trends

The life expectancy is now above 81 years for women and close to 75 years for men, that is an increase of about 3 years since 1975 for both genders. The growth rate has been steady since the 1920s. Infant mortality estimated for those younger than 1 year old, is very low and stable, about 4 per 1000 live births.

The fertility of the Norwegian population is now 1.78, and quite stable. Since about 1985 there has in general been a marked increase in net immigration, but with strong fluctuations between the years. Immigrants now constitute 6.6% of the population.

The average gross personal income was 237 300 NOK in 2000, equivalent to about US$32 500. The normal standard of housing is a self-owned (78%) house or apartment. Single houses dominate (1.1 million of 2 million housing units). Close to 100% of houses and apartments have separate kitchens, bathrooms and toilets.

1.3.2 Access to public services

The total annual water consumption in Norway, excluding hydropower, is 2400 million m^3. That is less than 600 m^3 per capita and only 0.7% of available water resources, estimated as annual runoff. Most of the consumption is used by industry, and 400 million m^3 is for domestic use.

The whole population has regular access to tap drinking water, either from major water works (89%), or from smaller water works and private sources (11%). About one third of the potable water produced in water works is lost through leakage. Although drinking water quality is generally very good, some water works still have problems with infections from bacteria.

The capacity for purification of sewage before discharge to the recipients is in general sufficient. In 2000, 80% of the population was connected to public purification plants with a capacity above 50 person units, and the remainder to smaller separate installations. Since the 1970s, public investments in the sanitation sector have focused on advanced chemical/ biological treatment, which today accounts for 30% of the purification capacity.

In 1945, 20% of the population still had no electricity, and in the 1950-1980 period there was a highly concentrated effort to develop hydropower resources and transmission lines. The distribution network now extends over more than 320,000 km. Electric energy is available for everybody today.

1.3.3 Per capita water, energy and electricity use

The average daily water consumption, including leakage, is calculated at 498 litres per capita. The figure is based on estimates from water works, and is thus rather uncertain. On the same basis, average daily household consumption is estimated to be 184 litres per capita.

The per capita use of energy in general and electricity in particular, is quite typical of a country rich in natural resources and with a high standard of living. The 2001 consumption of electricity in Norway was 125,000 GWh, including the domestic hydropower production of 121,000 GWh, the difference being covered mainly by imports. The per capita use was therefore close to 27,800 kWh. Only Iceland, other Nordic countries and Canada come close to this per capita figure. However, energy intensive industry, and other small industries and the service sector represent more than 70% of electricity consumption. The remaining 30% is accounted for by households and agriculture. This gives a figure on per capita use of approximately 8000 kWh. Close to 50% of this, however, is used for heating, which saves the use of petroleum products. Since Norway does not have thermal powerplants, there are also few district heating systems, which is normal for countries with thermal plants and a need for heating.

The electricity consumption is 50% of all the national energy use based on energy content, but 65% based on utilised energy.

2. WATER TRENDS

2.1 Trends and issues in relation to the use of water

2.1.1 Principal uses

The national water resources are so abundant that competition over availability between water use sectors seldom arises. The major water user sector is industry, using 1700 million m^3 water for cooling and processing. A substantial portion of the cooling water is provided by seawater. The agricultural sector is a minor water consumer in Norway, as most of the farmland, which covers only 3% of the area, needs only occasional irrigation. Both industry and agriculture contribute to specific water pollution problems, but the situation is in general well under control.

Implementation of the EU framework directive for water in Norway will pose important challenges for integrated water management, but will hardly change the present patterns of water consumption.

2.1.2 Water quality and health

In spite of ample supplies of good quality raw water, there are still water works, mostly small ones, which have difficulties in meeting public hygiene requirements. It is also a common problem that Norwegian raw water has high contents of natural organic matter. New legislation for drinking water quality (2001) requires that two hygienic "barriers" shall protect the quality of the water on its way from the water source to the consumer.

Water quality problems in Norway also exist because of the longrange transport of air pollution. Acidification leading to loss of fish and other aquatic life is, however, showing signs of improvement.

2.1.3 Water supply and sanitation

The current problems in this sector are mainly associated with leaking pipes. The water lost in this way amounts in many instances to 30 or 40%.

Privatisation of the water supply and sanitation sector is not a big issue in Norway, where municipalities, often jointly, generally own and operate water works and purification plants.

2.1.4 Legislation

The Water Resources Act came into force in 2001, replacing similar legislation from 1940. The new act provides better protection of environmental values, and has improved the legal protection and sound management of groundwater. Modern secondary legislation has recently been adopted for drinking water purposes. Implementation of the EU framework directive for water in Norway will pose important challenges including whole-basin management, and improved planning and monitoring procedures.

2.1.5 Public opinion

The public is probably not concerned enough about technical water issues, taking the plentiful supply of water of good quality for granted. Investments in the management and operation of water infrastructure often involve a tough fight for public budgets.

Public opinion is, however, very conscious about the recreational assets of Norwegian natural water and water landscapes. For decades this has been a source of complaints and protests against new hydropower development, even minor additions to existing structures to optimise utilisation of the resources. Political consensus has now in reality barred further development of new large hydropower projects, and sees the national energy future in terms of light of small and medium-sized hydro, the upgrading and extension of existing hydropower plants, new renewables, imports, and possibly gas-powered plants if developed without CO_2 emissions.

2.1.6 Water security

Floods are a menace to life and property in Norway. A major flood in 1995, which was the largest since 1789, gave further impetus to efforts for improving flood awareness and preparedness. The central water authority, the Norwegian Water Resources and Energy Directorate (NVE), operates a nation-wide and continuous forecasting system, and issues flood warnings. Work is well advanced on a national flood zone-mapping programme. Droughts also occur, even in Norway, creating economic stress in districts where private water supply is widespread, mostly in farming districts. Dam safety is the responsibility of the dam owners, and their competence and operational maintenance is supervised by NVE.

2.1.7 Climate change

Hydrological research indicates that with standard climate scenarios coming true, Norway will experience a wetter and milder climate. Winter seasons will be shorter, spring floods lower and autumn and winter rainfall more abundant. For hydropower companies this may well translate into higher production. For many years already, precipitation and runoff data from western Norway have shown increasing trends.

The official statistics for normal hydropower production were adjusted in 2001. The previous normal period of 1931-1990 was replaced by the 1970-1999 period, and average annual production with the existing power system was consequently adjusted from 113.4 TWh to 118 TWh.

2.2 Links between water and energy

Hydropower has a rather unique position in Norwegian water management. Water legislation gives the electricity producer strong tools for managing rivers for economic purposes. Practically every reservoir built in Norway serves hydropower purposes alone, and licences are granted for long periods. Normally, private companies obtain a licence for 60 years, and public companies are given a licence without a time limit.

Other interests in the water resources of a river basin and their use are taken into account during the evaluation of the application and the accompanying Environmental Impact Assessment. In the process of licensing, there is a strong element of local hearings and presentation of other sector user interests. The operating rules developed for a particular regulation scheme usually takes into account both dates for filling and emptying reservoirs, minimum flow requirements, and a host of other regulations to meet environmental and social concerns (see section 4). There is a general requirement that reservoirs should be operated so as not to increase the natural flood magnitude.

The legal position of the licensee is strong and long lasting. Because land use, economic activity,

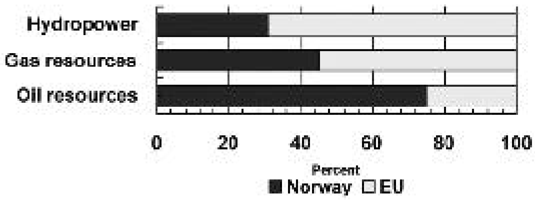


Fig. 1. Norwegian hydro, oil and gas potential.

population, and therefore water use patterns, may change considerably in a river basin during the licence period, conflicting interests may arise, calling for multi-use operation of the installations. Moreover, since the liberalisation of the electricity market in Norway, and gradually also neighbouring countries during the 1990s, the incentive may have become stronger to utilise fully the possibilities for economic optimisation, available within the legal limits.

The future may see more conflicts between water user interests. In the Norwegian context, such conflicts might be expected concerning flood damage reduction, nature protection, and occasionally local water supply during drought periods. Climate change will possibly aggravate the situation. Multipurpose reservoirs are one tool for solving such conflicts, but one which has hardly been fully explored in Norway.

3. ENERGY TRENDS

3.1 Historical energy sources and uses

Bio-energy was the main source for energy consumption before the hydropower development period started. Wood was used forlight, cooking and heating, and still Norway has a high focus on the use of bio-energy for heating. Candles and oil/kerosene lamps replaced wood for light as soon as these technologies were available in the world market. The need for development of the country and the obvious large hydropower resources resulted in constant activities to map these resources.

Hydropower development triggered technology improvements. This, together with the high focus on understanding hydrology and the tools and technology to design plants according to geological knowledge, led to a need to upgrade the resource picture continuously. This resulted in resource studies in every decade after the Second World War. A countrywide study on large hydro was carried out between 1965 and 1975, a similar study on small hydro was carried out between 1978 and 1981, and in 1982 the modern Masterplan on hydropower commenced, which included not only technical and economic issues, but also environmental issues. The work on this Masterplan is ongoing and the plan gives guidelines for schemes, which can be put forward for licence applications. The Masterplan has also provided knowledge on watercourse protection plans against hydropower, and to two large research and development projects. These projects, not only including hydro, focused on security of power supply, market constraints and technology improvements for uprating and refurbishing old powerplants.

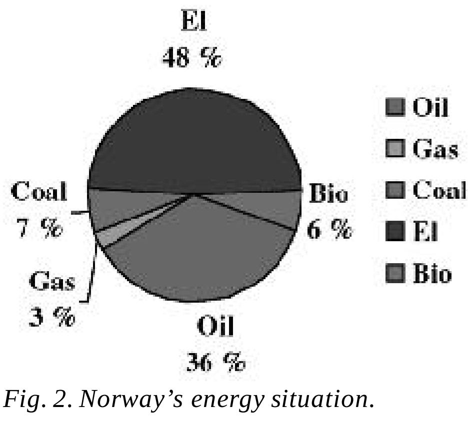


Fig. 2. Norway's energy situation.

In parallel with maintaining the Masterplan, Norway is now also embarking on a countrywide resource study for mapping hydropower resources with a capacity of less than 1 MW. Development of these local resources will enhance economic life in the rural areas of Norway.

NVE carried out a resource study on wind in land along the 25 000 km long Norwegian coast (including fjords) in 2000-2001, and is now busy with a similar study on the potential offshore. The physical windpower potential on land, at sites with wind speeds higher than 6 m/s, is approximately 1100 TWh/year according to the study. The potential offshore is also large. Economic and environmental constraints will significantly reduce the potential, so the possible exploitable resource may only be 10% of the physical resource. In 2003 innovative GIS and cost technology will be used to map the economics of this potential which is among the largest in Europe.

NVE also carries out resource studies on Bio-energy for efficient heating purposes. This potential is approximately 30 TWh with today's cost for energy, and already approximately 50% of this resource is used.

The wave power potential has been assessed, and there is now a focus on potential for other renewable energy. The oil and gas potential is among the largest in Europe (Fig. 1), and the coal reserves in Spitsbergen amount to approximately

60 million ton. The knowledge of the resource base is used for producing a strategy on Norway's future energy generation and use.

3.2 Current energy mix and uses

Norway is very special in its energy use, since 50% of the total energy consumption is based on electricity. The reason for this is the abundant cheap hydropower potential, which for many practical reasons has been considered more applicable than other traditional energy carriers. Oil and coal account for 36% and 7% of the total energy consumption, respectively. Despite very large gas resources in the North Sea, Norway has only a marginal use of gas (less than 3%).

Norway's energy situation is shown in Fig. 2, which shows the great importance of electricity ("El" in Fig. 2). It should be recalled that the source of electricity generation is 99.5% hydro. Norway's total energy consumption is approximately 250 TWh/year.

3.3 Forecast changes and drivers for change

Norway still has a large hydropower potential which could be harnessed. However, even with four conservation plans for watercourses and many small and large National Parks comprising approximately 40% of Norway's area, the resistance against further development is strong, especially in those rivers where no commercial activity is going on.

There is sometimes disagreement between politicians in the parliament and the politicians in the municipalities. The local communities want to have the option of hydropower development to enhance economic life in rural Norway. There will probably be more focus on small hydro and other power generation technologies without undue consequences for Norway's obligations according to the signed Kyoto protocol.

To meet this challenge, Norway has embarked on new development strategies:

- Harnessing of the large wind power potential, with a target of at least 3 TWh/year of wind power by 2010.
- Focus on research and development to enhance gas thermal generation plants with no emissions of CO_2 and NO_X.
- Support for a district heating system, to reduce dependence on oil and electricity for heating.
- Support for the increased use of bioenergy for heating by additional 4 TWh/year by 2010.
- Continued support for energy conservation technologies and schemes.

3.3.1 Role of renewable energy technologies

Hydropower is a renewable energy resource, and additional use of bio-energy in Norway depends heavily on renewable resources for its total energy consumption (more than 50%). For electricity, the renewable part is 99.5%. The harnessing of other renewable resources like wind, wave, solar power and so on, has been modest in Norway.

Up to 1994 there was a focus on wave power technology, but the solutions proved to be expensive and technically complicated with high maintenance costs. Today the main activity in this field is research at the Norwegian University of Science and Technology in Trondheim. However, a group of Norwegian and foreign companies have joined forces to develop technology for harnessing the energy in sea currents, and are now busy with a pilot scheme close to Hammerfest City in Norway.

Because of the very large wind potential, Norwegian and Swedish companies have now formed a company to develop large wind generation plants based on previous technology from the Kvaerner Group. These will be schemes of up to 5 MW each. A pilot scheme is planned to go ahead this year (2003).

Bio-energy has a very long tradition in Norway, and the large forest industry has used waste from wood processing for decades. A lot more bio-energy could be used for heating. The technology is well developed, but still there is room for improvement, which has led to a growing focus on the use of wood for heating. Economic support systems may be developed to use efficiently the wood waste resource from industry, and waste from households and industry. Energy forests are still not an issue in Norway.

Beyond the reach of the countrywide transmission and distribution network, Norway has for decades used solar panels for lighting/radio and TV in the thousands of cottages in mountainous and rural areas. Also, beacon lights are now powered by electricity from solar panels. This market, together with abundant renewable electric energy from hydropower, has also led to the production of the crystalline wafer, which is the important component in solar cells. A considerable proportion of the world's supply of wafers for solar cells is produced in Norway.

3.3.2 Interrelationship with other countries

There are transmission lines to Sweden, Denmark and Finland for the exchange of power to improve the utilisation of the different national power systems. The transmission capacity to Sweden is about 3 GW, to Denmark 1 GW and to Finland only 0.1 GW. Depending on the inflow to the hydropower stations, the exchange with neighbouring countries can vary a lot from year to year.

In accordance with the Energy Act, a concession is required for foreign trade in electric power. The Ministry of Petroleum and Energy is responsible for issuing such concessions. The requirement for a concession provides the authorities with the control they need, for reasons of public interest. Statnett SF and Nord Pool Spot AS hold concessions for the organisation of trade in power with the other Nordic countries. Statnett, as the Transmission System Operator (TSO), is responsible for arranging for the physical flow and Nord Pool Spot administers the capacity on the interconnectors.

4. HYDROPOWER DEVELOPMENT

4.1 Historical review

4.1.1 General

Hydropower is one of Norway's major natural resources, and has come to mean more to Norway than possibly any other country in the world. When the technologies for producing and using electricity on a large scale emerged in the second half of the 19th century, Norway was in a process of rapid industrialisation, and with no coal of its own, it took quickly to harnessing the power of its rivers. Hydropower powered the country both economically and with energy.

When the technologies for the practical use of electricity were introduced in the 1880s, Norway was still a poor country, not only by today's measure, but also relative to her southern neighbours in continental Europe at the time. In Norway, the shipping and forest industries led the growth, followed by the mechanical industry and an expansion in foundries. Technologies for making paper from wood pulp provided new strong markets for the forest industries, and Norway's first wood grinding mill was installed in 1866 at a waterfall in the middle of the capital, Oslo, powered by water turbines. Then came electricity, and the innovations were grasped by Norwegian business and engineering communities. Already in 1885 the outskirts of the town of Skien enjoyed a supply of electricity from hydropower at the nearby Laugstol wood-processing plant on the Skien River.

The most famous start, however is the electrification of Hammerfest City in 1890. Hammerfest is located at 70°N. The idea was launched by a teacher in 1881 who promoted the advantages of electricity for lighting, arousing the town's interest. The construction started in 1890, and the result was one turbine of 15 hp pow-

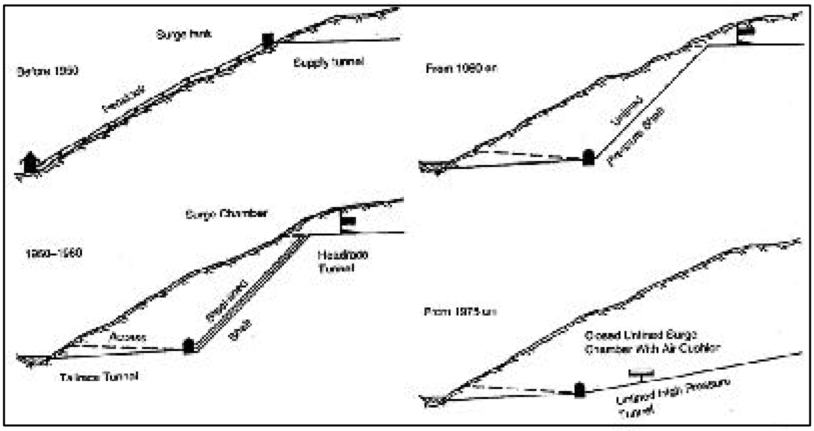


Fig. 5. Different tunnelling technologies.

ering a DC generator of 1.1 kV for street lighting by arc lamps in series. Another turbine of 60 hp was equipped with an AC generator, providing 1.05 kV for general supply in town.

Demand for electric power was to come from the already booming wood processing, pulp and paper industries, but only after practical motors for industrial use had become available in the early 1890s. Foreign investors were keenly aware of the opportunities which lay in Norway's hydropower resources. The Borregaard company, a subsidiary of the British Kellner Partington Group, acquired rights to the western side of the Sarpsfossen waterfall in Norway's largest river, the Glomma, and built a dam and power station for what was to be Norway's largest pulp and paper plant. Two units of 800 kW each were commissioned in 1898, followed by expansions through to 1908 to a total of 9 MW.

In parallel with the introduction of large industry, small industries based on saw mills and flour mills started the development from water wheels to turbines and electricity. The history of various Norwegian hydropower companies and technology developments originated from this, and this includes the development of micro and mini hydroelectric plants to serve local small industry. The use of innovative new technology for electric transmission, reaching new electricity markets, allowed larger power plants to be constructed. The history of Tafjord Power Company and the Sykkylven Municipality Company illustrate this development.

4.1.2 Tafjord Company

Hydropower utilisation to power small flour mills and local saw mills in the Tafjord area took an innovative step in 1883 when the first electric light from hydropower was introduced in a factory producing clothes in a remote valley on the Norwegian west coast. Over the next 20 years similar developments took place in other valleys. The local municipalities joined forces early and created a company to harness the rich hydro resources for the benefit of industrial development and improved living standards for the inhabitants. In 1896 the city of Alesund had electric light in the streets, produced by a hydroelectric powerplant.

The development in Tafjord was based on experiences from the implementation of large hydro such as the powerplants in the Rjukan area, where the 108 MW Saaheim power station was put into operation in 1916, becoming one of the largest powerplants in the world. In these first years, most powerplants were small, having either small reservoirs or none at all. Penstocks were made of wood stave or steel, and turbines and generators were imported from abroad.

The construction of transmission lines and hydro plants are closely linked with the Tafjord development history. The first large hydro station was completed in 1923, producing 15,000 hp. The implementation of a 110 kV and 20 kV line to transmit the power to surrounding small villages, however, was even more impressive than the power station with a reservoir, horizontal tunnel, penstock and turbine-generator units. A representative of the German company responsible for the equipment claimed the transmission line, crossing high mountains and deep valleys, represented a new trend in power transmission.

During the years to the Second World War, the regulation of new lakes and the installation of new turbines increased the output of the power station. After the Second World War, the underground siting of large powerplants was technically and economically more feasible than the old solutions, as a result of improved knowledge on rock construction and new equipment for blasting and excavating of large caverns and tunnels.

The various tunnelling technologies are shown in Fig. 5, where the latest one with an unlined high pressure tunnel and closed unlined surge chamber with an air cushions give a flexible option for harnessing the hydropower resource in a watercourse. Unlined pressure shafts have been operated successfully at pressure heads close to 1000 m (the Nyset-Steggje hydro plant, 965 m, 1987).

In this same period, the Kvaerner Company (today GE Hydro) developed a Francis unit to operate under higher heads, replacing the use of Pelton turbines. This solution increased efficiency and enhanced the use of tailrace tunnels in an economically optimum way. This development is still going on, and today the Francis unit has a higher efficiency than Pelton units and can be used up to a 600 m head, depending on the flow. The latest hydroelectric development is the Svartisen powerplant, having a 120 m high rockfill dam and exploiting 585 m from its high water level to the sea level. One Francis unit of 350 MW is installed in the underground power station.

By 1980, the hydropower resources of the Tafjord mountains were considered fully utilised. However, already in 1985, it was decided to close down the first plant and replace it with a new one. This decision was taken because improved electro-mechanical equipment and new technology for the construction of tunnels (reducing head losses) would make it possible to produce additional power, which could justify the investment.

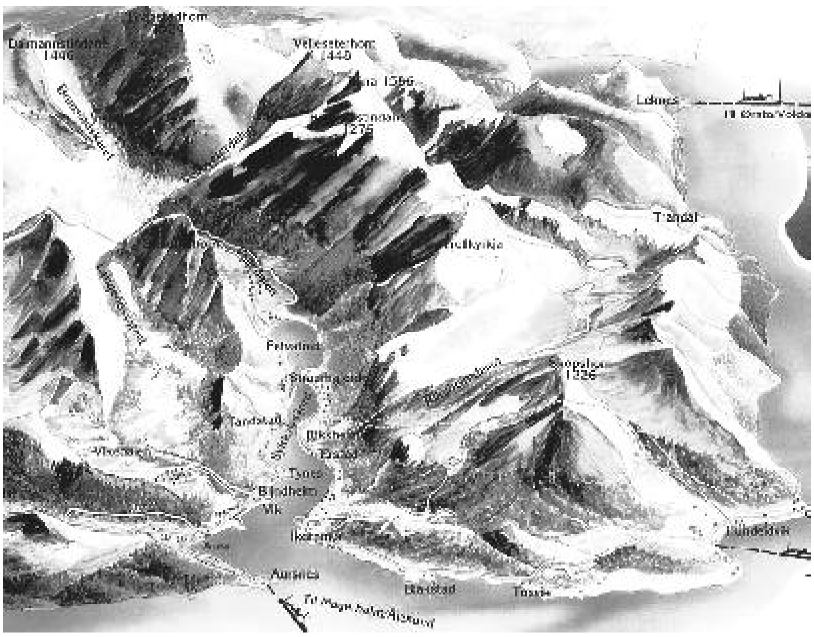
The idea of scrutinising systems like Tafjord to increase power production by enlarging tunnels, redesigning the turbines and introducing innovative technology for system operation has led to the conclusion that there still is energy to be developed in Tafjord.

The hydropower system of Tafjord today includes six power stations with a capacity of 261 MW, and an annual production capacity of approximately 1000 GWh. 15 reservoirs at different altitudes give flexibility to the system to meet peak power demand and variation of consumption throughout the year. The highest reservoir is 1319 m above sea level.

4.1.3 Sykkylven Municipality Company

The Riksheim powerplant is a small hydro station in Sykkylven municipality on the western coast of Norway. This part of the country is characterised by high and steep mountains and deep fjords. On the flatlands between the fjords and the mountains, people started to cultivate the land centuries ago. Their daily income was based on agriculture and fishing.

The community in Sykkylven derived export revenue from the exploitation of the local timber resources. These were rapidly depleted, but the community accumulated both mercantile knowledge as well as experience in the exploitation of hydropower resources during this period. A large number of water powered sawmills were in use. At the beginning of this Century, the increasing population made it necessary to find other sources of income if the people were to continue living and working there. In 1915 there were a total of 2800 inhabitants in Sykkylven and 20 people were employed in the industry.



The experience gained in the timber industry, in the saw-mills and in the various small workshops, led to the idea of utilising the rich hydropower resources for the development of brick production, textile mills and furniture factories. In 1910, a few workshops located near river rapids already had electricity from micro hydro plants. The new technology was brought to the community and high voltage transmission lines became possible. In 1912 local people carried out pre-feasibility studies for seven small rivers in the neighbourhood, including the rivers Aura (150 kW) and Riksheim (2000 kW). The municipal council elected a group to investigate the possibility of purchasing one or more waterfalls, how to construct power stations and how to run them. The group decided to work on more detailed plans for the Aura and Riksheim rivers.

This committee had to find the answer to three major questions:

- the electricity demand (current and in 10 years);
- output and investment costs of the two alternatives; and,
- the income possibilities.

Investigations of public electricity demand and discussions with representatives of the small but growing industry, especially the furniture industry, concluded that the demand 10 years ahead would be 600 kW. The current demand was found to be 120 kW.

The committee found that the Aura River could scarcely cover the present demand and that this solution would not lead to increased industrial development. The output and investment cost was half the size of phase one of the Riksheim River. To find the possible income the committee had a yearly fixed price per Watt on lamps and a fixed price per horsepower (hp) for motors and heating. A slogan urged everybody to join, and they worked hard to persuade people to order electricity. From the local tradesmen they got the yearly consumption of oil and spare parts for oil-lamps and this was compared with the calculated price of electricity.

Most people, however, were satisfied with kerosene lamps. The power companies, having surplus electric power, had to compare prices and explain the benefits of the new light. People could understand that farmers living downstream from the power station could have electricity, but farmers living at an altitude higher than the plant, how could they receive the electricity? Electricity going uphill was unbelievable!

In October 1915, the community municipality decided to utilise the power resources of the 254 m-high Riksheim waterfall by constructing a power station, pipeline, intake pond and a reservoir, sufficient to produce 450 kW.

The construction of the powerhouse, including the 1100 m-long pipeline with a diameter of 400 mm and the intake pond, lasted two years. During the construction local interest was high, and there was never any problem to find willing hands when the heavy equipment arrived. One hundred men pulled the turbine and generator on snow from the harbour to the power station on the hillside, and the pipes were rolled up the steep hill with ropes. It was also necessary to find local solutions for the transmission lines. Since the First World War, the price of copper had increased by 500% and they were forced to use mostly iron wires purchased for agricultural purposes.

Towards the end of 1917 there was excitement in the community. Many people still could not believe that the Riksheim waterfall could bring light to their homes, especially to the farms high on the steep hillside. In January 1918 the first houses got their electricity and the iron wire worked as hoped, because the power production from Riksheim far exceeded the actual demand.

The investment cost had increased by 350%, and although the consumption of electricity increased rapidly, the income could not cover the repayment of the loans. The deficit had to be paid by the community. After three years of operation, increased consumption made it necessary to replace the iron wires by copper ones, to reduce the losses. Three years after that a second turbine of 750 kW had to be ordered. The tariff was increased and many people had problems paying for the power they used. The municipality also wanted to develop industrially, and this new growing industry could not survive without access to enough power at reasonable prices. Finally the problems were solved by cheap loans obtained from the national bank.

During the first 30 years of electricity production, the Riksheim plant was regarded as the heart of the community, providing light for people and creating industrial growth. From 1930 to 1987 the number of employees in the industry increased from 140 to more than 1600, which is a quarter of the total population in Sykkylven. The furniture industry has been the most expansive, and today it exports to several countries in Europe as well as the USA, Australia and the Middle East.

The history of industrial development in Sykkylven, based on exploitation of water resources, may give inspiration to others. Much of the technology applied and experience gained here is highly appropriate for small-scale hydropower development in developing countries.

Fig. 7. Sykkylven municipality, deep in a west coast fjord..

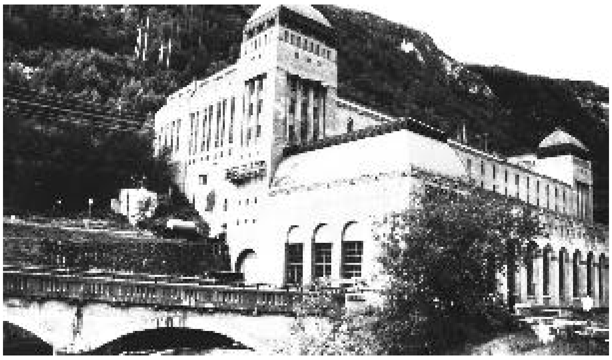


Fig. 8. Saaheim power station (108 MW in 1916, 189 MW in 2002).

The continuously increasing energy demand, new and less expensive technology and possibilities for mixing low quality energy with high quality energy by high voltage transmission systems, have led to the idea of upgrading a lot of the older hydro plants in Norway. A countrywide programme to examine the resources was carried out between 1988 and 1992. The Riksheim watercourse is an example of the small watercourses in this study, which includes schemes from 1 MW to 2000 MW.

The Sykkylven Power Company has now applied to upgrade the old Riksheim powerstation to 3.8 MW.

4.2 Economy and legal framework

The story of Norwegian hydropower development is not only a story of technical innovations. Economy was a matter of deep concern and frustration. The Power Company had a surplus of power, but people could not afford to buy at the prices necessary to pay back loans and interest. The Norwegian State had to give guarantees for loans. To electrify areas with or without an adequate supply, the Government introduced State support. The first allocation was made in the budget for the fiscal year 1938/39. The full effect of the programme was only to come, however, after the wartime occupation of 1940-45.

The prospect of profitable hydroelectric development gave water rights a new value and made them suddenly the object of trade and speculation. The "Panic Law" was introduced in 1906 to make the acquisition of rights dependent on royal licence. Only municipal bodies and the State would be exempt from the need for a licence. The licence could be made conditional on certain obligations from the holder. After the termination of the licence, in 80 years at most, the rights, together with any installation, would revert free of charge to the State.

The Water Course Regulation Act of 1917 came to be the most important Act concerning large scale hydroelectric power development. Without the right to regulate water flow by seasonal storage, development for regular power is not possible. The main core of the legislation was established during the first quarter of the 20th Century. This legislation still regulates the legal context of hydropower development today.

Experiences from this legislation and later improvements form the background for NVE's assistance to other countries in a similar position to Norway's some time ago.

4.3 Hydropower and the environment

Hydropower development has the potential to upset the existing balance between man and his environment, sometimes on quite a dramatic scale. Agriculture and settlements tend to be concentrated along the course of rivers. Outside settled areas, water is still the basis for wildlife, and an important element of the landscape.

In the early days of hydropower development any negative impacts on the environment tended to be overlooked and regarded as less important compared with the benefits offered by development. Research and development on landscape, river flow and biodiversity has produced results offering the designer a tool to work together with the environment, rather than against it. However, large-scale dams, dry riverbeds, roads and transmission lines bring visual changes to the environment which are not always acceptable.

During the period 1970 to 1990, NVE introduced high standards for landscape design in hydropower planning. It was recognised that some of the visible negative environmental impacts caused by hydropower development could be greatly reduced without undue economic consequences for the owner of the powerplant. The photographs below show two examples.

Because of the existence of natural lakes in the mountains, implementations of Norwegian reservoirs have seldom led to resettlement of people. Negative impacts on wildlife, fish and possibilities for recreation have become more important for NGOs (Non Governmental Organisations) and their resistance to hydropower development. This resistance started around 1970 with demonstrations in the high mountain plateau of the Mardoela river. The result was a strong focus, and growing awareness by the population, which has led to many research and development programmes, and to a lengthy licencing procedure for any company wishing to apply for a licence for hydropower development in Norway.

NVE is the executive body concerned with electric power development, and energy resources management. The knowhow of NVE is used by the Norwegian Agency for International Development (NORAD) for its activities on institutional building in other countries. This knowhow was also available for IEA's hydropower and technologies programme, which distributed guidelines on the issue

"Hydropower and the Environment" in May 2000.

4.3.1 Summary history

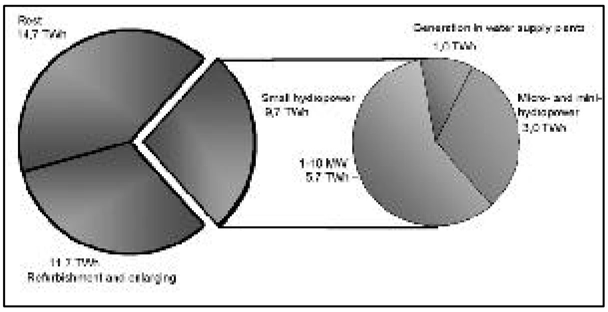
Hydropower development in Norway was triggered by the need for small and large-scale industrial development, and the availability of cheap hydropower and timber for forest industry stimulated the development. However, as learned from the Tafjord and Sykkylven history, the need to electrify towns and villages also promoted hydropower development, and especially transmission development. The Rjukan example, with the Saaheim power station, commissioned in 1916, is an example of the development of an energy intensive industry close to large hydropowerresources. In 1916 the Saaheim power station was among the largest in the world with its nine Pelton turbines of 12 MW each.

The peak of hydro construction was between 1960-1985.From this early development, the technology has continuously been improved. Examples are:

- in construction: tunnelling technology and rockfill dams;
- electro-mechanical equipment: Francis and Pelton units, and, more recently, X-blade runners for Francis units.

The typical large hydropower plant in Norway today is a highhead underground powerplant, and a typial small hydro is tailored to the local environment with a powerhouse and a penstock.

Most powerplants are publicly owned, and the system today has been developed by municipal companies (large, medium and small hydro) ~50%, the State power company (large and medium hydro) ~30%, and private companies (large and medium hydro) ~20%.



4.4 Current situation

4.4.1 Value of the production system

For the purpose of taxation, the re-purchase value (that is, today's construction cost) of all the existing Norwegian powerplants was calculated a few years ago. The total amounted to approximately NOK 200 billion, which is equivalent to US$ 27 billion.

4.4.2 Number of plants

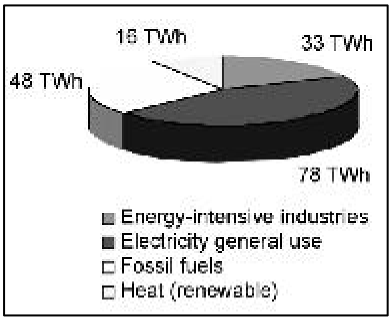
At present 575 powerplants exceeding 1 MW of installed capacity are in operation in Norway. In addition there are some 400 plants smaller than 1 MW.

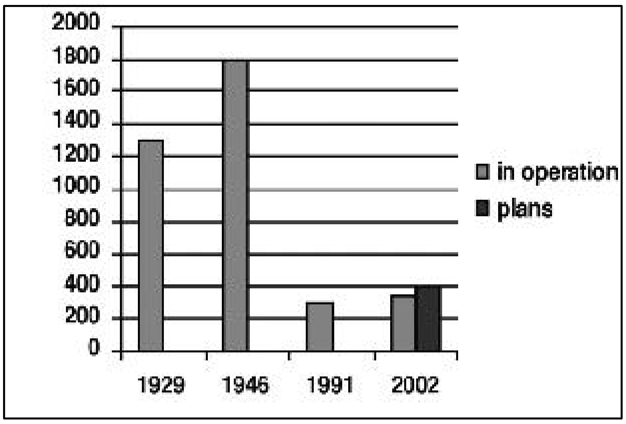
4.4.3 Capacity and production

The total capacity of the 575 powerplants is approximately 28 000 MW, and the mean annual production is estimated at 118.2 TWh.

4.4.4 Other energy sources

About 63% of the energy consumption in Norway (referred to net end consumption by energy carrier), is electricity.Of this, one third is used in energy-intensive industries. Fossil fuels contribute about 27% and renewable heat 10%. Hydroelectric powerconstitutes about 99.5% of the electrical production, and the rest is





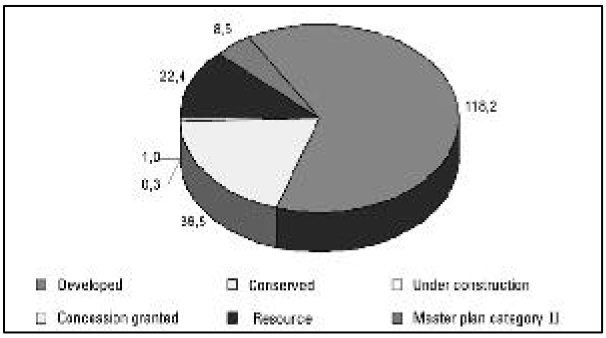


Fig. 9. Hydropower potential in Norway.

thermal and wind energy.

4.4.5 Types of plants

A large number of the Norwegian powerplants, especially the largest ones, are high-head storage plants. Conditions for the development of this type of plant are very favourable in the western part of the country, with steep mountains and natural lakes created by glaciers thousands of years ago. By damming or lowering (for example, by the tailrace tunnel) such lakes, one can create very cheap reservoirs. In addition to these topographical conditions, high precipitation provides for abundant water to the plants.

In the largest rivers, located in the eastern and central part of the country, low-head run-of-river plants designed for the discharge of more than 1000 m^3/s have been developed.

Over the last few years there has been an increasing interest among private property owners to develop mini and micro powerplants. These are usually run-of-river schemes located in the tributaries of larger rivers, typically with a modest discharge in relation to the available head.

4.4.6 Electricity market

Norway was the first of the Nordic countries to deregulate its power market. The new Energy Act of 1990 formed the basis for deregulation in Norway, and was also a model for other Nordic countries. The main objective of the Energy Act is economic efficiency, security of supply and national equalisation/levelling of electricity prices. The Norwegian electricity market is today the most open electricity market in the world:

- All customers have access to a competitive market and retail wheeling has been implemented to cover all customers groups, including small households.
- An entry-exit transmission tariff system based on nodal pricing has been set up. Transmission tariffs are completely independent of trading systems.
- The Nordic electricity exchange, Nord Pool, organises a spotmarket and a financial settled futures market where it is possible to trade weekly contracts up to three years ahead.
- Dispatching of the system is based on commercial bids from sellers and buyers of electricity in the market. Also for short-term operation of the network, the system-operators are obliged to use market operations as far as possible.
- Everyone is free to negotiate bilateral physical contracts. But trade in the future market is increasing rapidly. An increasing portion of long-term contracts are now financial, with physical electricity being traded in the spot market.
- Prices in all markets, including bilateral contracts and the retail market, relate to the spot-market, and are to a great extent reflecting changes in supply and demand.

4.4.7 Role in rural electrification

From the very beginning hydropower in the form of mini hydro plants powered small mills and farms in Norway's rural areas. Most of them were closed down in the decade after the Second World War. The interconnection of most of the rural areas to the main grid was the main reason for this, together with time-consuming operation and expensive maintenance of the small units. Modern technology, which includes remote controlled operation by cell phones, has resulted in an upsurge of interest in mini hydro development in Norway. Most of the sites are linked to farms, allowing the farmer to have a necessary extra income from his local resources. Fig. 12 shows the number of plants with output less than 1MW in different years.

4.4.8 Grid system

To supply the consumers with electric power from the plants, a transmission grid was needed. The national transmission grid in Norway was gradually developed during the last century in line with the increased demand of electricity. Transmission lines have also been built to Sweden, Denmark and Finland to exchange power and thus to improve the utilisation of the various national power systems.

There are different voltage levels on the transmission grid depending on the quantity of power and distances the power is transmitted. The larger the quantity and the longer the distance the power is to be transmitted, the higher the voltage level used. This is to avoid the electricity losses which could otherwise occur. The total annual losses in the transmission grid are about 8% of the total gross consumption.

In the last 15 years, investments in the transmission grid have decreased significantly. In spite of this, the total line length has increased from 282,000 km in 1987 to 321,000 km in 2000. The local grid (<22 kV) is about 91%, the regional grid (22-132 kV) is about 6%, and the central grid (>132 kV) is about 3% of the total line length. In the local grid the share of cables are about 37%, while in the regional and central grid it is about 3%.

4.4.9 Pumped-storage

There are a few pumped-storage plants in Norway. They are designed for seasonal pumping, and typically operate in the pumping mode during the snow-melting season in the springtime. Water is then pumped to large reservoirs for use in the powerplants in winter.

The largest pumped-storage plants are:

- Saurdal: (640/320 MW)
- Aurland III (270/270 MW)
- Duge (200/200 MW)

(Figures show plant capacity in the turbine and pumping modes).

4.4.10 Main power companies

There are approximately 160 hydropowerproducers in Norway, most of them very small with only a few GWh/year of production. The main companies are, as per January 2002:

- Statkraft SF: 36.2 TWh, 30.7%
- Norsk Hydro: 8.6 TWh, 7.3%
- E-CO Vannkraft AS: 6.9 TWh, 5.9%
- Agder Energi AS: 6.5 TWh, 5.5%
- BKK AS: 5.9 TWh, 5.0%

(The figures show annual production and % of national total).

There are also several hundred distribution companies. There is a historical reason for this. Before the country had a national grid, almost every municipality had to provide for its own electricity supply, and small local, municipality-owned companies were established.

Today Statnett SF has a special role as operator of the main national grid. There are also a number of relatively large regional distribution companies.

4.4.11 Private/public ownership

Approximately 87% of the electricity is produced by public companies, and the rest (13%) by private companies. The State-owned company Statkraft SF produces around 35%, and the rest of the public production is divided between companies owned either by municipalities or counties. The privately owned powerplants are mainly for industrial purposes (metal smelting industries, wood processing industries, and so on). Concerning distribution, in reality all companies are public.

4.4.12 Sources of finance

Finance sources forhydropower development are mainly bank loans and the issuing of bonds. Financing of hydropower projects has traditionally not been difficult in Norway, since they have been considered low risk projects.

4.4.13 Current changes in the sector

A clear sector tendency, since the deregulation of the power market took place in 1991, has been a concentration of ownership, especially in power distribution. Small local distribution companies,without their own power production, are being sold to larger and more professional companies. This development will most likely continue in the coming years.

4.4.14 Refurbishment projects

About one-third of the remaining potential for hydropower development is in the form of refurbishment and enlargement projects, which amounts to about 11 TWh/year. Of this potential, refurbishment- only projects constitute 5 – 10%, but in most of the projects refurbishment is combined at the same time with an enlargement of the scheme. The uprating of the project contributes mostly to the increased production and thus makes the project economically viable.

At present,the Bjoelvo and Tyin hydropower plants are being modernised and uprated. Bjoelvo hydropower plant was commissioned in 1918 and expanded later with more turbines by 1971. The penstock has forge-welded pipes and the Government has decided that this type of pipe will be dismantled in the near future. The owner decided to build a new underground hydro station and at the same time to transfer more water into the hydropower system. The installed capacity will increase by 15 MW to 95 MW and the mean annual production will increase by 65 GWh to 387 GWh.

The Tyin hydropower plant was commissioned in the mid-1940s, and was the basis for location of the aluminium industry in the area. To keep in line with safety and technical standards, it was necessary to modernise the plant as well as the headrace tunnel and shaft to maintain the production at the present level and to secure the supply to the aluminium industry. The new plant will utilise a larger head following the construction of a headrace pressure tunnel and shaft between the inlet at about el. 1050 and the fjord. The installed capacity will increase by 168 MW to 360 MW and the mean annual production will increase by 218 GWh to 1398 GWh. Fig. 13 shows the age of electro-mechanical equipment in Norwegian hydropower plants today. Many plants have been modernised, and this development will continue.

4.4.15 Environmental management

Hydropower development in Norway is subject to strong regulations, mainly for environmental reasons.

The most serious impacts are

usually related to establishment of water reservoirs and removal of water from the rivers for use in the powerplants.

All planned hydropower projects in Norway have to be considered within the National Masterplan for remaining hydropower resources. The most favourable projects, taking into account project economy and environmental impacts, can be submitted for a licence.

The licensing process may seem elaborate and time consuming. The intention is that all stakeholders should have the possibility to express their views, and this ensures a very transparent process.

Ranges of different acts and regulations have to be dealt with. The most important ones, and relevant for hydropower projects, are:

- The Industrial Concession Act;
- The Water Resources Act;
- The Watercourse Regulation Act; and,
- The Energy Act.

The outcome of a licensing process will be that either:

- 1) a licence is obtained according to the application;
- 2) a licence is obtained with project modifications compared with the application; or,
- 3) the application is refused.

An important part of a licence is the set of conditions. The most important ones might be the rules of operation, which regulate the water levels in the reservoirs and when and where to release water in the affected river sections.

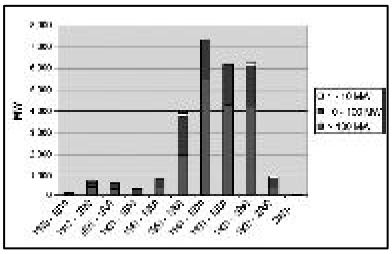
4.4.16 Degree of public acceptance

The development of hydropower, especially large projects, can be sensitive and subject to conflicts. However, after a development has been carried out, the project is usually accepted. Probable reasons for public acceptance are that hydropower is considered environmentally favourable to other electricity generation plants, and also that hydropower development today is more carefully carried out than ever before.

The attitude towards the development is normally positive in the affected areas. The reason for this is often increased activity and economic benefits for the local area.

4.4.17 Main challenges and issues affecting future development

There is still a considerable hydropower potential in Norway. However, there seems to be a political view that most of the remaining untouched rivers should remain untouched. A future challenge will be to find a balance between hydropower production and other utilisation of the rivers. Careful hydropower development does not mean devastation of the river, and planned in co-operation with other stakeholders it could bring solutions which are positive, for example flood control and low flow control.



Another aspect is the ageing of the hydropower production system. With a deregulated and open power market, there might be a tendency to postpone the necessary maintenance and modernisation of the powerplants beyond what is technically advised.

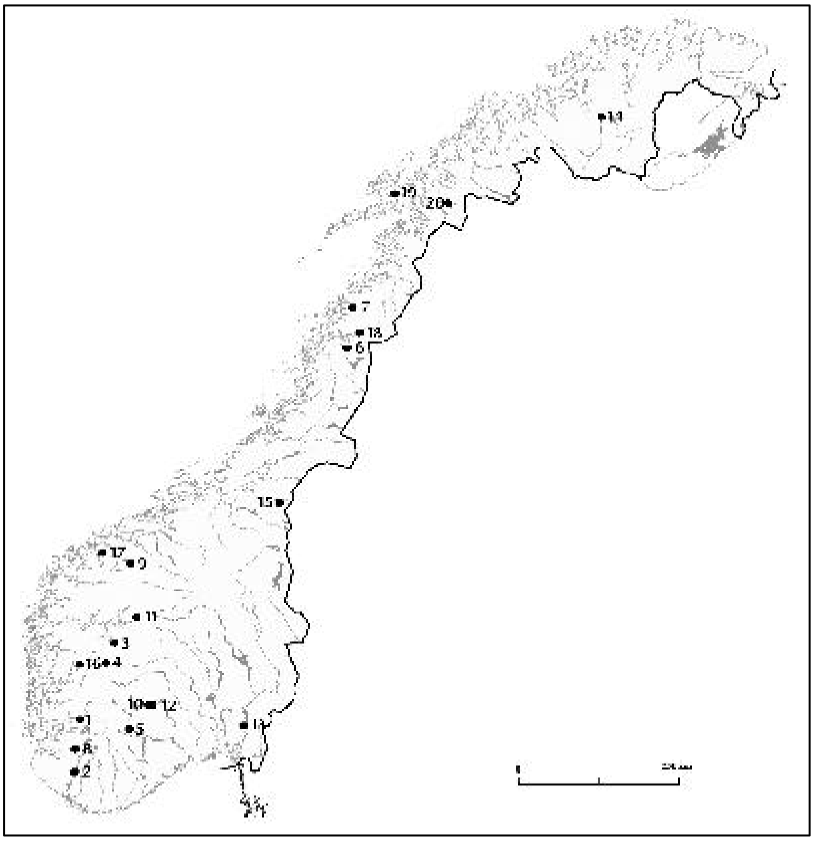


Table 1 – 20 Major hydro schemes in Norway (see map on previous page).

Number on map	Name of scheme	Powerplants	Name of river	Capacity of power scheme (MW)	Mean annual production (GWh) [1970-1999]	Other services (flood control, water supply, irrigation etc.)	Year of commiss-ioning	Owner	Relationship to subject in text of this article
1	Ulla-Førre	Hylen, Kvilldal, Saurdal and Stølsdal	Suldalslågen	2057	5762		1980-1986	Statkraft	
2	Sira-Kvina	Duge, Roskrepp, Solhom, Tjørhom, Tonstad, Åna-Sira and Kvinen	Sira and Kvina	1760	6829		1973-1981	Sira-Kvina Kraftselskap	
3	Aurland	Aurland I-III, Vangen and Reppa	Aurlandselva	1119	3241		1973-1983	E-Co Vannkraft	
4	Sima	Lang-Sima and Sy-Sima	Austdøla and Sima	1120	3404		1980/1981	Statkraft	
5	Tokke	Tokke	Skien	430	2221		1961	Statkraft	
6	Røssåga	Upper and lower Røssåga	Røssåga	410	2533		1955-1961	Statkraft	
7	Svartisen	Svartisen	Fykanåga	350	1996		1992	Statkraft	Planning modification
8	Tjodan	Tjodan	Stølselva	329	110		1985	Lyse Produksjon	Unlined high pressure tunnel
9	Tafjord	Tafjord I-VI	Tafjord	261	967		1923-1995	Tafjord Kraftproduksjon	Development of hydro-power
10	Vemork	Vemork	Skien	204	841		1911-1971	Norsk Hydro	One of the old " large" plants in Norway
11	Tyin	Tyin	Ardal	192	1137		1945	Norsk Hydro	Finishing upgrading in 2004
12	Såheim	Såheim	Skien	189	909	Partly combined with water for industrial purposes	1916/upgraded	Norsk Hydro	One of the old " large" plants in Norway
13	Solbergfoss		Glomma	185	902		1924/1985	E-Co Vannkraft	
14	Alta		Alta	150	709		1987	Statkraft	
15	Meråker	Meråker and Tevla	Stjørdalselva	128	572	Planned with environmental base flow	1994	Nord-Trønderlag Elektrisitetsverk	
16	Bjølvo	Bjølvo	Bjølvo	54	367	Will be combined with water for industrial purposes and potable water	1918	Statkraft	Finishing upgrading in 2003
17	Riksheim	Riksheim	Riksheim	3,3	16,8		1928/upgraded	Sykkylven Energy	
18	Svabo	Svabo	Andfiskåga	3,2	21,6	Combined with cooling water for industrial purposes	1996	Mo Industripark	
19	Strielva	Strielva	Djupfjordelva	1,7	7,3		1984	Vesterålskraft AS	Small under ground hydro -power plant. First with drilled shaft (North Sea Technology)
20	Taraldsvik	Taraldsvik	Taraldvikelva	1,5	10,5	Combined with potable water supply	1986	Narvik municipality	

The reason is that the plant owner does not find it economically viable to make such investments with the current electricity prices and the current cost level. A consequence is increased risk of plant failure or even breakdown. Actions should be taken to find possible measures within the free market system to secure a reliable and well functioning production system.

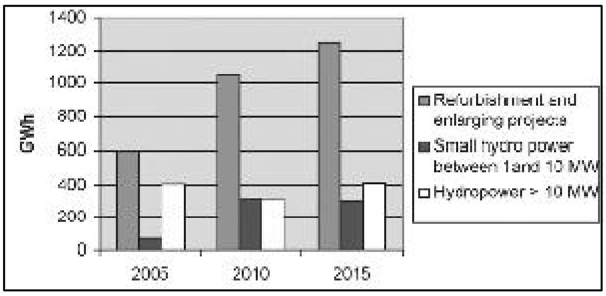
4.4.18 Examples of some existing plants

The Table lists 20 hydropower schemes in Norway including some basic data. Among these are the largest plants in operation, and some with special technology, like the "North Sea drilled" shaft for small hydro (Strielva), water supply and energy generation (Taraldsvik), environmental, indigenous people and salmon constraints (Alta), water management and local economy issues (Stjørdalselva).

4.5 Future Aspects

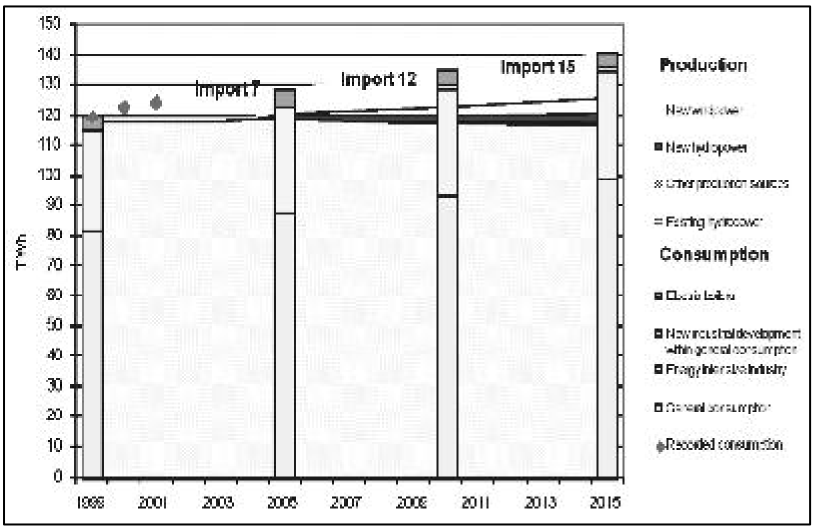
4.5.1 Demand forecasts

The electricity demand has been growing by approximately 1.5% each year for the last 10 years, and in the forecast for the next 10 years, we expect a growth of approximately 1.2%. The growth depends on the climate, and activity in industry, especially the energy intensive industry. The growth in household electricity consumption over the last two years has been close to zero. Fig. 15 gives the scenario for consumption to 2015, based on normal weather conditions.



4.5.2 Potential for demand-side management and cost-efficiency improvements

Norway uses a lot of electricity for heating, and there is a political goal to reduce the dependence on electricity and substitute this energy carrier with other carriers which utilise renewable energy resources, or by energy conservation. Electricity consumption in Norway is quite efficient. However, there is still a large potential for energy efficiency, especially in the buildings sector. Most of this is linked to better energy management and better use of energy management technology and systems.



The Norwegian Government has established a new agency to promote more efficient use of energy as well as production of energy from new and renewable sources. Hydropower is the task of NVE. This Agency (ENOVA) has an annual budget of about NOK 500 million (about US$ 68 million). ENOVA is responsible for obtaining 11 TWh by 2010. Of this, 4 TWh should come from district heating based on renewable energy, 3 TWh from wind power, and 4 TWh from energy efficiency. There is also focus on the use of heat pumps. The potential for energy efficiency has been estimated at 14.2 TWh in buildings (households and non-residential buildings).

Approximately 10.8 of those are electricity savings. A potential of 5.3 TWh energy (3.5 TWh electricity) savings within industry has been identified. 2.5 TWh (1.4 TWh electricity) of this is estimated to be profitable for the business.

4.5.3 Future energy mix and changes in the electricity sector

The present picture of energy use as presented will not change dramatically in the foreseeable future. Electricity generation, however, will probably include windpower to a larger scale than today. The prospect of solutions for CO_2 from gas thermal plants will result in the use of gas for electricity production in Norway, but the development of this technology may take more than ten years. The use of wood will increase for direct heating or to power water heating systems. In the rural areas we will probably see use of innovative new solutions for mixing gas, solar and wood resources.Some of themwilluse fuel cell technology. Norway already has examples of these schemes in areas where a farm is too far from the main grid system, and where the new technology is the least cost alternative compared with maintaining and operating a distribution line.

Fig. 15 shows that Norway will have to rely on electricity imports from the other Nordic countries in years with normal precipitation if we continue with low hydropower activity, no gas generation plants, and a modest activity in developing the wind energy resources. This may not be a sustainable future, because the imported electricity is generated in coal-fired thermal plants, which is not in line with Norway's obligations according to the Kyoto agreement.

4.5.4 Potential for further hydropower development

Fig. 16 gives the type of hydropower schemes that we expect will be developed in the next ten years. Although the remaining hydropower potential in Norway is large, and the focus on renewable energy is growing, we expect only modest activity. This might change, however, as a result of higher prices for renewable energy in the European electricity market. This could result in the implementation of many upgrading and refurbishment projects, which are considered to be too expensive with the present prices in the market.

Norway has a focus on small hydro, and is giving this technology special attention through research and development, and by giving priority in the licensing procedure. The new trend of using fixed prices for special renewable generation plants will also be discussed in Norway.

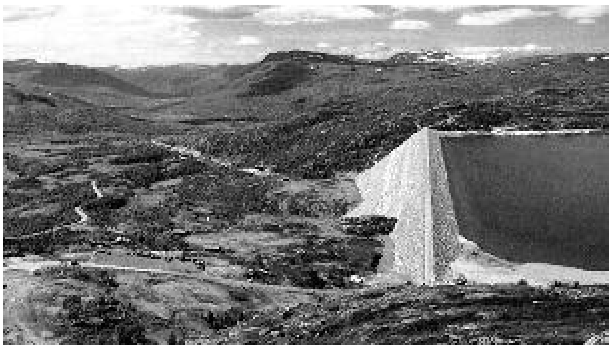
4.5.5 Overall trends in hydro development

Modern hydropower development is very different from the development 20-40 years ago. By using the experiences from more than 100 years of hydropower development, hydro can today be the heart of a power system, the control plant for flooding and low flow constraints in riverbeds, the source for municipality income and the means of fulfilment of the Kyoto agreement.

The case of Stjørdal river is a Norwegian example of successful co-operation between a hydropower developer, the municipality and the public control sector like NVE and the Directorate for Nature Conservation. The Stjørdal river is a salmon river. A statement from the local fish organisation this summer was: "This year with drought we saw the positive impacts of hydropower development. Thanks to the release of compensation water, and good co-operation by the owner Nord Trøndelag Energy Utility, which resulted in a river flow of 10 m^3/s instead of less than 2 m^3/s, the river still carried large salmon." Other unregulated rivers in the vicinity had low flows, which seriously hampered salmon migration. The upper part of the catchment area has been used for hydropower generation in three different power stations with a total output of approximately 135 MW, and generation capacity approximately 650 GWh/year. The reservoir capacity is approximately 320 million m^3 and the annual inflow is approximately 795 million m^3. Downstream tributaries of the main river are protected against hydropower development, and the tributaries that are heavily modified have a release of compensation water, and are subject to biological adjustment programmes.

The large reservoir capacity enhances the control of the river, for example in periods with the need for extensive river training works, where a flood could cause unacceptable damage to agricultural activities and destabilise the riverbeds, which in turn could cause unsafe living conditions for people. For example this summer there was a need for emergency actions to prevent landslides along the riverbed, which could cause serious disasters for infrastructure and houses. By using the Water Resources Act, NVE in co-operation with the hydropower owner, was able to reduce flow in the river for long enough to carry out the most critical river training work in a safe and controlled matter.

The Meråker Municipality accepted the development because it found the positive impacts greater than the negative ones. For example, the added value created by the development is also shared with the municipality. This improves its capacity to attract small industry, maintain and develop a high standard in schools, and support adult programmes. The statement from the municipality is that the river powers the transmission system in Norway, and at the same time powers the local economy. This enables people to continue living in this remote village.



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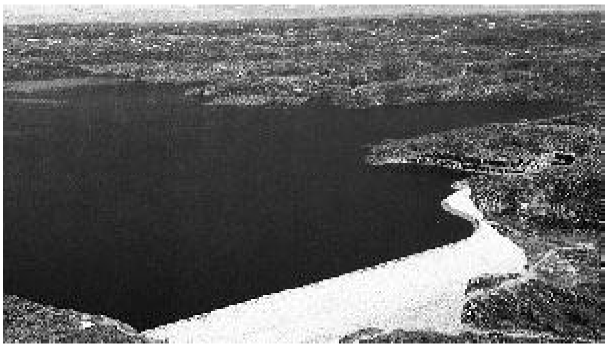

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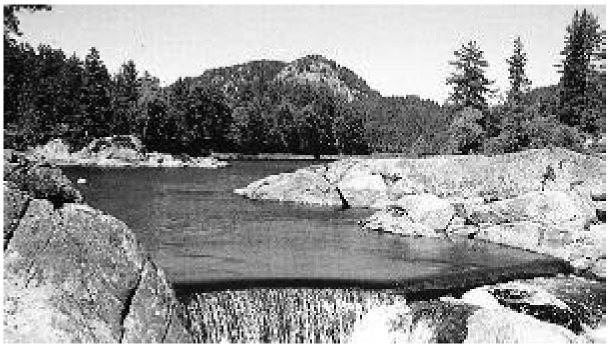

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