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Hydropower development in Norway 1945-1990

Financing of investments
Hydropower licensing, the environment and consideration of other user interests

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Norad

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Summary: Norway’s hydropower history is an important reference for our energy-related development assistance as it was essential for the industrialization and inclusive economic development of the country. In the post-war years (1945-1990) Norway constructed and commissioned an unprecedented number of large hydropower schemes despite considerable political, organisational, technological, environmental, and financial challenges. The aim of this report is to inspire experts and decision-makers to see the many opportunities within renewable energy and the green transformation of power systems. Combined with strong national knowledge base, such as technicians, engineers, economists as well as environmental and social experts, there are tremendous growth opportunities in this sector.

Keywords: Hydropower, politics, finance, licensing, environmental development

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1 PREFACE

Norway's hydropower history is an important reference for our energy-related development assistance, as it was essential for the industrialization and inclusive economic development of the country. Many developing countries with significant hydropower potential have now embarked on similar journeys, and hopefully there are more to come.

We hope the report will inspire experts and decision-makers to see the many opportunities within renewable energy and the green transformation of power systems. Combined with strong national knowledge base, such as technicians, engineers, economists as well as environmental and social experts, there are tremendous growth opportunities in this sector.

The report has two target groups. The first group is staff in the Norwegian Ministry of Foreign Affairs (MFA), The Norwegian Agency for Development Cooperation (Norad) and the Norwegian Water Resources and Energy Directorate (NVE) involved in energy related development assistance. The second group is authorities and investors in developing countries with ambitious plans for renewable energy development, particularly hydropower.

The work has been organised as a project undertaken by the International Office in the Norwegian Water Resources and Energy Directorate (NVE) and Norad. Torodd Jensen (NVE), Inge Harald Vognild (Norad), Haakon Thaulow (former NVE employee and former Director General of Norwegian Institute for Water Research, NIVA), have all extensive experience over several decades of different aspects of hydropower development both in Norway and abroad. Inge Harald Vognild (Norad) has experience from transmission planning, system operation and energy-related development assistance. Rune Flatby (former director of NVE's Department for Licensing), Kjell Erik Stensby (NVE), Knut Gakkestad (NORAD) have also given valuable contributions focusing on hydropower and the Norwegian licensing system. Ingvild Vestre Sem, John Brittain (NVE) and Frode Sørskaar (NVE) helped to increase the readability of the report.

The project team has received valuable help and input from NVE employees. For the Orkla and Siso projects, Jon Einar Værnes og Hans Iver Odenrud provided invaluable information regarding financing. Last, but not least, this report could not have been written without the inspiration and information provided in the four-volume series about Statskraftverkene and its successor companies (authors Lars Thue, Dag Ove Skjold, Yngve Nilsen). Additional information regarding Norway's electricity history can also be found in [[v]].

The present (2023) legal and regulatory environment of Norway's power sector is substantially different from the study period 1945-1990. Particularly, this applies to competition in the wholesale and retail market, corporate unbundling requirements for competitive and monopoly-based business areas and licencing conditions for private hydropower developers.

The report is based on the project group's own experience as well as information collected in reviews of annual state budgets, NVE's annual reports, Government white papers and power company jubilee books. Descriptions and opinions expressed in the report are those of the authors.

They do not necessarily reflect Norad's and NVE's positions. Any factual errors are the responsibility of the authors.

Oslo, June 2023

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ACRONYMS AND ABBREVIATIONS

ASCR	Aluminium conductor steel-reinforced
BOOT	Build, Own, Operate and Transfer
CPI	Consumer Price Index
DEM	Deutsche Mark (German currency before the Euro)
ESG	Environmental, Social and Governance
ESIA	Environmental and Social Impact Assessment
FDI	Foreign Direct Investment
GDP	Gross Domestic Product
HPP	Hydropower Plant
HVAC	High Voltage Alternating Current
HVCD	High Voltage Direct Current
IBRD	International Bank for Reconstruction and Development (part of World Bank group)
IPO	Initial Public Offering
JV	Joint Venture
KBN	The Norwegian Agency for Local Government (Kommunalbanken)
kV	Kilovolt
kW	Kilowatt
kWh	Kilowatt hour
LKAB	Luossavaara-Kiirunavaara Aktiebolag
m.a.s.l	Metres above sea level
MFA	Ministry of Foreign Affairs
MW	Megawatt
Norad	Norwegian Agency for Development Cooperation
NVE	Norwegian Water Resources and Energy Directorate
NOK	Norwegian Kroner
OECD	Organisation for Economic Co-operation and Development
O&M	Operation and Maintenance
PPA	Power Purchase Agreement
SDG	Sustainable Development Goal
TBM	Tunnel Drilling Technology
T&D	Transmission and Distribution
USD	US Dollar
VAT	Value Added Tax
VRE	Variable (intermittent) Renewable Energy
WW1	World War 1 (1914-1918)
WW2	World War 2 (1939-1945)

2 SUMMARY

Background

Norwegian experiences in large-scale development of renewable energy resources, particularly hydropower, can provide a useful reference for emerging economies. This applies to both financing and consideration of environmental and social conditions. Norway planned and built more than 400 hydropower plants between 1945-1990. This large-scale hydropower development raised the power capacity from an initial 2,500 MW to 27,000 MW. This translates to an annual increase of 550 MW, almost entirely from hydropower. The total energy generation capacity increased by approximately 100 TWh during this period. By comparison, many developing countries have a significant hydropower potential which is yet to be developed.

This report examines the total investment level, who the investors were, and how the investments were mobilized, among others based on case-studies presented in [1]. Besides, the report also looks into licencing and how environmental and social issues were addressed.

Main findings

Investments. In the study period 1945-1990, total investments in Norway's power sector amounted to about USD 100 billion (adjusted to 2022 price levels by using the Norwegian Consumer Price Index, CPI). In addition, USD 16.5 billion was used on refurbishment and maintenance. For over 30 years, annual investments amounted to about 2% of the Gross Domestic Product (GDP).

The share of investments in hydropower plants and reservoirs amounted to 31 percent and 22 percent, respectively, while investments in transmission and distribution (T&D) amounted to 38%. The remaining 9 percent were used on access roads, control centres, etc.

Investor categories. More than 90% of the investments were undertaken by public entities. The largest investor category was companies owned by municipalities and counties (sub-governmental entities), (63%), followed by the Government through the State Power Utility (Statskraftverkene, 31%) and private companies (6%). Many projects were developed through Joint Ventures.

Financing. Not surprisingly, debt financing was the dominant financing source for hydropower projects, while investments in distribution networks had a much higher equity share. Due to capital constraints, a variety of financing and cooperation models were applied, and many schemes that included hydropower plants in cascades were developed in several phases.

<u>Equity financing</u>. An economically sound power sector meant than many hydropower projects were financed with a low equity share. Accumulated capital from operational surpluses was the main source of equity. In general, power companies were profit-making because tariffs were fixed to ensure cost-recovery of investments, operational costs and maintenance. However, the need to raise equity from operational surpluses had to be balanced against considerations regarding industry competitiveness and social impacts of tariff increases.

The predominantly public ownership of hydropower plants meant that initial public offerings (IPO) were rarely used for raising equity during the study period.

Debt financing. Most of the loan capital in the power sector originated from the central treasury and sub-governmental (municipal) treasuries. The Government and municipalities raised the capital through taxes and loans. Mobilization of public capital for infrastructure investments, including the power sector, was enabled by a high tax to GDP ratio and high domestic savings. An earmarked electricity tax was introduced in 1951, and end-use of electricity was subject to Value Added Tax (VAT) from 1970. Norway needed capital for investments. To free capital, private consumption in many sectors was restricted by restricting access to credits.

Most of the debt capital was raised in the Norwegian capital market. The loans raised by municipal and private power companies came from a variety of financing sources. In addition to loans from municipal owners, state development banks, savings and commercial banks, and insurance companies provided loans. Bond issues were also an important capital source. The predominant financing source for investments undertaken by Statskraftverkene were appropriations (loans) over the state budget. The Treasury raised parts of this financing through loans.

Foreign financing also played a significant role in financing hydropower development and helped advance several hydropower projects. Particularly, in the 1960s and 1970s, the Government encouraged municipal and private power companies to raise financing abroad due to constraints in the domestic capital market. In the 1980s, a favourable interest rate gave incentives for raising foreign loans.

Collateral and guarantees. Both existing assets and assets of projects under development served as collaterals. If this was insufficient, the Government and sub-governmental entities issued guarantees to power companies. Loans from the Norwegian Agency for Local Government (KBN) raised abroad were guaranteed by the central Treasury.

Due to high credit worthiness of power companies as well as collaterals and guarantees, many hydropower projects could be financed with a very small equity share.

Concessional financing. State banks such as KBN provided concessional financing. Besides, projects in rural area were backed by dedicated support schemes, that provided grants and loans. Financing from this scheme was mixed with other financing.

Other issues. As a rule, the hydropower projects were developed to cover domestic electricity demand (industry and general consumption), i. e. not for power export purposes. In a few cases, foreign financing was linked with long-term power export contracts of surplus seasonal power.

The licencing authorities (NVE) had a particular focus on energy security and approved large hydropower projects with large reservoir capacities. This gave a very flexible system not only to meet electricity demand in peak periods like winter, but also to cover demand in drought periods. The plants in the 45-year period 1945-1990 were designed for a situation that allowed power constraints in one of ten years. However, many large-scale projects with large reservoirs during the last decade of the period reduced the risk of loadshedding considerably. This did not last long, however, since the last three decades have included few projects with reservoirs and several TWh of new generation capacity are from small hydro without reservoirs and windpower.

Most construction works were undertaken by national contractors. License requirements favoured use of nationally manufactured equipment.

Lessons from previous projects, systematic capacity building and knowledge enhancement as well as research and development reduced technical risks and improved cost efficiency. From the 1950s onwards, an extensive resource mapping also facilitated a least-cost development of hydropower projects.

After the WW2 many schemes combined development of large hydropower and reservoirs for firm power generation with the erection of large energy intensive industry. The location was determined by the hydropower plant and the development also gave benefit for rural electrification in the vicinity. Picture from Høyanger in western Norway.

In the study period, the financial risks associated with hydropower development were low. Norway had steady economic growth, and there was a steady growth in demand for power until the mid-1980s. As a rule, power companies had a sound financial performance, based on cost recovery-based tariffs. An exclusive right to supply customers within a geographic region also reduced risks.

In addition, the gradual expansion of the transmission network, including cross-border connections, enabled a larger off-take for local surplus power. Moreover, hydrological resource mapping and knowledge-sharing reduced project related risks.

Many larger power schemes supplied industries that produced products in high demand in the world market. These industries provided exports earnings in hard currencies and helped improve the trade balance.

Hydropower licences and third-party interests. The Norwegian hydropower licencing system was developed to secure national control over domestic resources. The system favours publicly owned power companies that were awarded a lifelong licence period but with options for getting a change of licence condition within certain intervals. Private companies received a licence for a certain period of time (for example 50 or 60 Years) and an option for changing the licence conditions. By the end of the licence period the power plant should be given back to the state free of charge and well maintained.

The projects developed in the beginning of the study period did not meet the same environmental and social requirements as today. However, from the 1960s onward, the licencing process paid more attention to environmental issues and in 1973, the Parliament approved permanent protection of 93 watercourses. Following the controversial Alta hydropower project, also social issues, including the rights of the ingenious Sámi people, were given more attention.

In 1986, a national comprehensive Watercourse Master Plan for all major watercourses was approved by the Parliament. Today, hydropower license processing is based on a systematic evaluation and balancing of various considerations.

Relevance for emerging economies

Experiences from hydropower development in Norway can provide a useful reference for renewable energy investments in emerging economies. However, some lessons may not be transferable, or only realistic to draw on in a mid to long-term perspective. Some relevant aspects addressed in this report and an in-depth study of 14 hydropower projects [1]) are:

- A licensing policy that secures national control over water resources.
- The importance of hydropower license processing based on a systematic evaluation and balancing of various considerations.
- The anchoring of baseload and dispatchable electric energy (firm hydropower) development in an industrialization policy.
- The importance of a financially sound power sector.
- The importance of domestic resource mobilization.
- High degree of local acceptance due to inclusive licensing processes and benefit sharing.

Other lessons:

- A pragmatic approach regarding ownership and financing.
- A least-cost approach facilitated by systematic resource mapping, focusing on the entire watercourse rather than individual hydropower projects.
- Knowledge transfer through close cooperation between public sector, industry, universities and research institutions.
- The high focus on reservoir projects for reliable power supply on a seasonal and daily basis.
- Development of a national transmission backbone system and cross-border interconnections to deal with seasonal imbalances between supply and demand.
- Cooperation regarding transboundary river basin hydropower development.
- High focus on refurbishment and maintenance.
- In the period 1945-1990 machinery and supplies from national suppliers had priority to enhance local manufacturing and research projects in the Universities. This strategy was abandoned from 1990.

3 SAMMENDRAG

Bakgrunn

Norske erfaringer er en viktig referanse for land som er i en tidlig fase av utviklingen av sine vannkraftressurser. Faktorer som finansiering, prosjektorganisering, ivaretakelse av miljø og sosiale forhold er viktige i en slik sammenheng. Norge planla og bygde ut over 400 store vannkraftverk i perioden 1945-1990. Dette økte installert effekt fra ca. 2 500 MW til ca. 27 000 MW, noe som tilsvarer en årlig økning på nesten 550 MW i 45 år. Økningen i årlig vannkraftproduksjon var på ca. 100 TWh i denne perioden.

Rapporten beskriver de samlede investeringene, hvem investorene var og hvordan prosjektene ble finansiert. Rapporten beskriver også utviklingen av konsesjonsbehandlingen og hvordan miljø og sosiale forhold gradvis ble mer vektlagt.

Investeringer

Samlede investeringer i perioden 1945-1990 i norsk kraftsektor var på ca. 700 milliarder kroner i dagens pengeverdi, dvs. konsumprisjustert til 2022-kroner. I tillegg ble ca. 100 milliarder kroner i dagens pengeverdi brukt til vedlikehold og oppgradering av permanentutstyr. I mer enn 30 år utgjorde de årlige investeringene i kraftsektoren ca. 2% av norsk brutto nasjonalprodukt. Investeringer i vannkraftverk og tilhørende magasiner, utgjorde 31% og 22 % av totale investeringer. Investeringer i overførings- og distribusjonsnett utgjorde 38%, mens 9% gikk til andre formål som adkomstveger og kontrollanlegg.

Hvem investerte?

Over 90% av investeringene ble utført av offentlig eide selskaper. Kommunale og fylkeskommunale e-verk stod for 63% av investeringene. Det statlige selskapet (NVE-Statskraftverkene) og private selskaper stod for henholdsvis 31 % og 6% av investeringene. Ved større utbygginger gikk ofte flere selskaper sammen på eiersiden.

Finansiering

Lånefinansiering var den dominerende finansieringskilden for vannkraftprosjekter. Prosjekter i distribusjonsnettet var i større grad egenkapitalfinansiert. Finansiering var krevende på grunn av stram kapitaltilgang. Flere vannkraftprosjekter ble derfor bygd ut trinnvis.

Egenkapital

Mange vannkraftverk ble bygd med lav egenkapitalfinansiering. Egenkapitalen kom hovedsakelig fra selskapenes overskudd. Siden man ved fastsettelse av strømtariffene også måtte ta hensyn til industriens konkurranseevne og alminnelige forbrukeres betalingsevne, var kraftselskapenes evne til å generere egenkapital begrenset.

Lån

Offentlig kapital for infrastrukturinvesteringer ble anskaffet gjennom høy skattlegging og høy nasjonal sparing, og gjennom offentlige låneopptak. I 1951 ble en øremerket elektrisitetsavgift innført. Fra 1970 har sluttbrukere, særlig husholdninger, betalt moms på strøm. Stat og kommuner lånte ut midler til offentlig eide kraftselskaper. NVE-Statskraftverkene fikk lån som bevilgninger vedtatt av Stortinget. Andre viktige långivere var statsbanker, særlig Kommunalbanken, samt forretnings- og sparebanker. Også det innenlandske obligasjonsmarkedet var en viktig kapitalkilde. Låneopptak i utlandet spilte en viktig rolle spesielt på 1960- og 1970-tallet. Dette avlastet det innenlandske kapitalmarkedet. På 1980-tallet ga et lavere rentenivå i utlandet kraftselskaper incentiver til å ta opp lån i andre land, selv om dette også medførte en betydelig valutarisiko.

Sikkerhet for lån

Eksisterende kraftverk og kraftverk under bygging ble stilt som sikkerhet for lån. I noen tilfeller utstedte staten, fylkeskommuner og kommuner også garantier.

Statsstønadsordning

NVE administrerte fra 1938 en statsstønadsordning for elektrifisering og nettforsterkninger i utkantområder. Fra 1951 var ordningen delvis finansiert av elektrisitetsavgiften.

Andre forhold ved vannkraft utbygging

Vannkraften ble bygd ut for å dekke innenlandsk forbruk siden det var behov for å bygge moderne industri med langsiktige arbeidsplasser og elektrifisere landet. Salg av kraft til utlandet var diskutert på Stortinget, men hadde ikke stor støtte. Noen få prosjekter ble allikevel bygd med utenlandsk delfinansiering. Nea kraftverk i Tydal i Trøndelag ble bygd med svensk delfinansiering. Lånet ble tilbakebetalt gjennom langsiktig eksport til Sverige. Dette var imidlertid overskuddskraft og ofte flomkraft.

Norges vassdrags- og energidirektorat (NVE) hadde ikke bare i oppgave å forestå konsesjonsbehandlingen av vannkraft- og nettutbygginger, men også sikre at utbyggingene bidro til sikker elektrisitetsforsyning både i form av energi og effekt. Dette ga fokus på planlegging og utbygging av store kraftverk med gode magasineringsmuligheter. Disse kraftverkene sikret elektrisitetstilgang i anstrengte kuldeperioder på vinteren og i tørre perioder. Designkriteriet på 1960- og 1970- tallet var at maksimum ett av 10 år skulle være problematisk. Fullførelsen av de store utbyggingene på 1980- tallet med svært store magasiner resulterte i en sikkerhet som overgikk dette flere ganger. Innføring av kraftmarkedet etter 1990 dro nytte av denne investeringen og sammen med økt nedbør og redusert aktivitet i industrien på 1990-tallet ga det stort kraftoverskudd og lite bygging av nye prosjekter. Hovedtendensen fra 1990 til i dag er et det er kommet mer uregulert kraft inn i kraftsystemet, og større muligheter for eksport og import gjennom flere kabler til utlandet.
I perioden 1945-1990 ble kraftverkene hovedsakelig planlagt av norske konsulentfirmaer og NVE-Statkraftverkene. Kraftverkene ble bygd av norske entreprenører med en høy prosentandel maskin- og elektroleveranse fra norske verksteder. Det siste hadde bakgrunn i et regelverk om å favorisere norske bedrifter selv om de var noe dyrere.

Hensikten var å støtte norske leverandørbedrifter og støtte opp under forskningsmiljøer for kontinuerlig forbedring av teknologien. Det siste bidro til teknologiløsninger i verdensklasse som også ga løsninger med lang levetid.

Årlig oppdatering av ressursmulighetene basert på utviklingen innen teknologi, kart, hydrologi og kostnader, bidro sammen med en forutsigbar vekst i forbruket til at risikoen ved nye prosjekter var små da kraftproduksjon basert på vannkraft med magasiner var ettertraktet. Fram til 1990 hadde også kraftselskapene sine områder, oftest innenfor fylket, som var deres eksklusive hjemmemarked. Lokal overskuddsproduksjon ble etter hvert også lettere å få solgt da utbyggingen av overføringslinjer mellom regioner og også kabler til andre land ga adgang til større markeder.

Konsesjonsbehandlingen for vannkraft

Konsesjonsbehandlingen hadde som ett av målene å sikre nasjonal kontroll over vannkraftressursen. Offentlig eide kraftselskaper fikk en varig eiendomsrett til kraftverkene de bygde, men konsesjonsbetingelsene kunne endres etter vedtak i NVE og Olje- og energidepartementet. Private selskaper kunne få eiendomsrett for 50-60 år med samme forutsetning om endring av konsesjonsbetingelser. Ved konsesjonsperiodens utløp skulle kraftverket leveres tilbake til den norske stat uten statlige omkostninger og det skulle være godt vedlikeholdt (Hjemfall).

I starten av perioden 1945-1990 hadde ikke miljø- og sosiale forhold samme oppmerksomhet som i dag. Fra ca. 1960 kom imidlertid miljøforhold tydeligere fram og en rekke kontroversielle utbygginger ledet til den første verneplanen for vassdrag i 1973 da 93 vassdrag ble vernet. På slutten av 1970 tallet kom konflikten med utbygging av stryk i Alta-Kautokeino vassdraget. Konflikten og debatten om utbyggingen medførte at Stortinget vedtok at det skulle utarbeides en omfattende ressursplan for utbygging av vannkraft der teknologi, kostnader, miljøforhold, sosiale forhold og regionaløkonomi, var noen av flere fagområder som skulle belyses for hvert enkelt prosjekt. Denne ble kalt Samlet Plan for vassdrag og arbeidet startet i 1981. Første fase inkluderte de største vannkraftprosjektene, som fikk sin behandling i 1986. Senere kom en fase med små regulerte vannkraftverk og mellomstore uregulerte kraftverk. Siste fase var en gjennomgang av alle eldre kraftverk for å belyse gevinsten ved å modernisere dem i henhold til gjeldende kunnskap om teknologi, hydrologi og miljø.

Lærdom for andre land

En skal være forsiktig med å kopiere løsninger fra ett land til et annet. Norge er ett av få land i verden med spesielt gode forhold for vannkraftutbygginger med relativt høy nedbør, fjell med store fallhøyder mot sjø, godt fjell og forholdsvis korte avstander mellom inntak og kraftstasjon. Naturgitte forhold for magasiner som kan samle mer enn 30% av årlig nedbør muliggjør en mer fleksibel drift enn for kraftverk som er avhengig av avrenningen i elver (elvekraftverk). Noen punkter er det imidlertid viktig å ha øye for:

- En troverdig konsesjonsbehandling prosess som gir staten langsiktig kontroll over naturressursene
- En konsesjonsbehandling som balanserer alle brukerinteresser i et vassdrag
- Et konsesjonssystem som verdsetter fleksibel kraftproduksjon for å sikre forutsigbar energi og som gir grunnlag for god frekvenskontroll
- Verdien av et økonomisk sunt kraftsystem
- Kunnskap om ressursene som oppdateres med kunnskapsutviklingen innen alle relevante fagfelt
- En utbyggingsprosess må basere seg på lokal aksept og på en slik måte at nytten kommer alle til gode
- Få fram samspillet mellom planleggere, utbyggere, industri og forskningsmiljøer for å bygge kompetanse for optimal bruk av ressursene
- Samarbeid mellom land som deler vannkraftressurser

Part 1

Financing of Investments (1945-1990)

4 INTRODUCTION

Background

The purpose of this report is to share Norwegian experiences in renewable energy development, particularly hydropower. In many emerging economies, hydropower can contribute significantly to the power mix.

Access to reliable electricity (Sustainable Development Goal (SDG)7) is a prerequisite for economic development (SDG8). To achieve these goals, developing countries need to undertake considerable investments in the capital-intensive power sector.

Hydropower, both run-of river and storage, is an enabler for integration of intermittent renewable energy technologies (VRE) such as wind and solar in a power system and thus crucial for a low-carbon development (SDG13). However, a particular challenge with hydropower investments, particularly reservoir projects, is the discrepancy between technical and economic lifetimes on the one hand and the investors’ need to pay off the project over a much shorter period on the other. Hydropower projects typically have technical and economic lifetimes in the order of 60-100 years when properly managed and maintained. On the other hand, equity investors and lenders often require payback times in the order of 10-20 years or even less.

Problem identification

Many developing countries have constrained domestic financial resources. Financing of renewable energy projects competes with other priorities. In Sub-Saharan Africa, the already limited fiscal space for public investments is further constrained by a looming debt crisis. The high debt limits additional concessional loan financing from multilateral banks or increases the financing costs. Substantial grant financing may not be a realistic option.

Foreign direct investments may cover parts of the financing gap. However, this could mean that developing countries will have to give up control of natural resources, at least temporarily. Besides, also this strategy will also necessitate considerable payments in hard currencies. On the other hand, domestic resource mobilization can provide a valuable contribution to bridging the financing gap, possibly with less need for returns in foreign currencies.

Environmental and social issues may sometimes have higher value than generation of renewable energy and therefore constrains development of some energy projects. The report summarizes key factors on the Norwegian licensing procedure and present the development of for the conservation of watercourses in Norway. In this respect special attention has been the Norwegian Master Plan for Watercourses that started with a political decision around 1980 and gave valuable background for decisions on which watercourses could be harnessed for hydropower generation and those which should be left for other user interests, including biodiversity.

Norway’s post World War 2 (WW2) hydropower development may provide a useful reference. A significant part of Norway’s power infrastructure was developed between 1945-1990, with total investments of ca. USD 100 billion (2022 price level). While it took 50 years (between ca. 1895 and 1945) to construct the first 2,500 MW, installed capacity in the next 45 years increased with more than 24,000 MW with a new annual energy generation of almost 100 TWh, almost exclusively hydropower. The report aims to answer how this expansion was made possible, with focus on financing.

Report scope and structure

Scope. The report has a particular focus on **i**) financing and **ii**) hydropower resource mapping to identify good projects and weed out environmentally and socially disadvantageous projects.

It is beyond the scope of this report to address in detail all relevant aspects of hydropower development. The NVE-report [1], which presents into detail 14 hydropower projects from the study period, also provides information on other important tasks like public cooperation with local industry, technological development by using projects as laboratories for research, political goals in strengthening the Norwegian knowhow and technological capacity. To some extent this report also describes environmental, social and governance (ESG) issues as well as how the projects facilitated industrialization.

Structure. Chapter 2 examines power sector investments, also with breakdowns in investor categories and technologies. Chapter 3 examines how investments were financed. The annexes provide background information regarding risk mitigation, capacity building, licensing, resource mapping and environmental considerations. Chapter 4 and 5 highlights information on the licensing procedure, watercourse protection plans and the National Masterplan for watercourses.

Study period

As of 2023, installed generation capacity in Norway is about 40,000 MW with hydropower as the dominant source. In the last two decades, about 5,000 MW wind power has been added. Most of the hydropower capacity was developed and commissioned during the period 1945-1990. During this period, installed capacity accelerate**d**, before stagnating again in the late 1980s. In addition to the observed acceleration of installed capacity and corresponding investments, this period was chosen as the **study period** because financing was a greater challenge then in the following period. Moreover, more detailed investment and financing data is available.

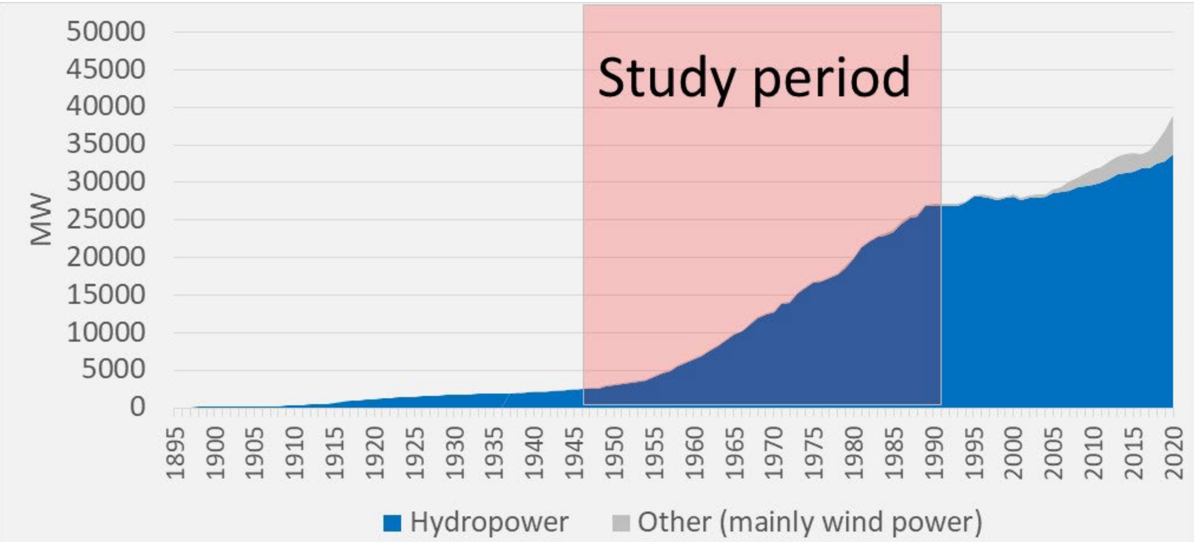

Figure 1. *Development of installed capacity (MW) over time.*

While figure 2.1.a shows the development of installed capacity (MW), corresponding information on annual power generation, consumption as well as cross-border exchange can be found in Annex-2.

5 INVESTMENTS

This chapter examines investments in the power sector during the study period, by looking at:

- Investments as a percentage of GDP.
- Share by technology, i.e., investments in generation (including reservoirs) versus transmission and distribution.
- Share by investor category (the central Government, municipalities and the private sector).
- Share by investor category (the central Government, municipalities (sub-governmental entities) and the private sector).

5.1 A look at the periods prior to and following the study period

The investments in the study period were undertaken to meet increase in general demand and to facilitate **industrialization**. However, before we examine these investments in detail, we provide a in context through an overview of the previous period as well as and the following period.

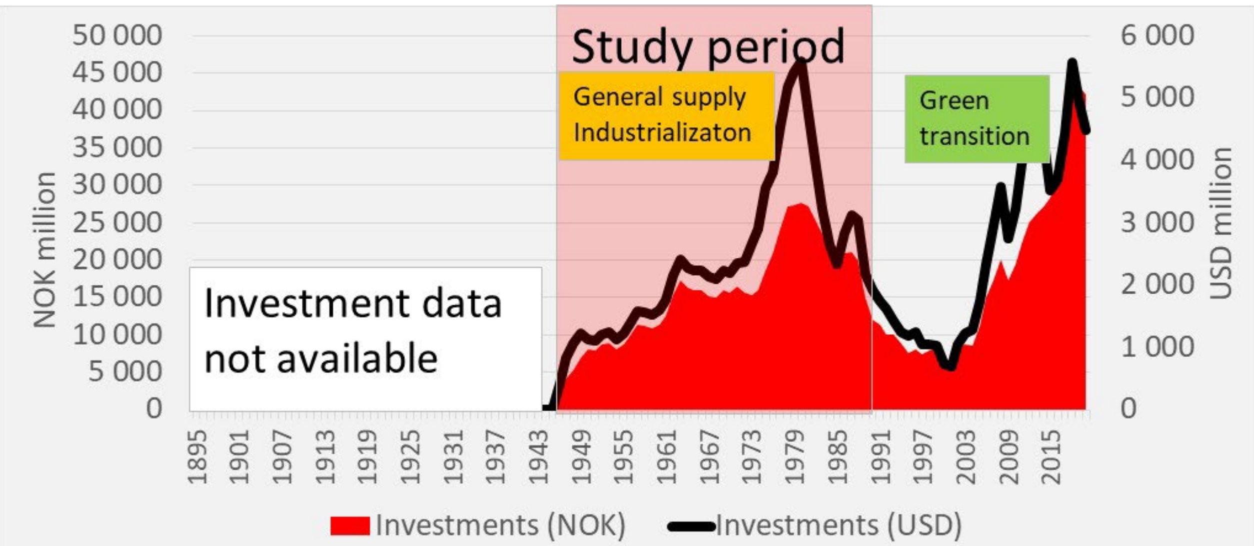

Figure 2.1 *Annual power sector investments.*

Prior to the study period. National investment data for the power sector is not available before the study period. In 1945, installed capacity was about 2,500 MW. A qualified estimate[1] is that aggregated power sector investments, also including transmission and distribution, prior to 1945 was in the order of USD 5 billion (in 2022 currency). The acceleration of hydropower development that happened during the study period cannot be seen in isolation from the capacity building that

[1] Taking into account that many hydropower projects were cheap and located close to demand centres.

took place prior to this period. Appendix-3 provides more details regarding the establishment of education institutions and capacity building obtained through actual projects.

After the study period. The period between 1990 and 2005 was characterized by low power sector investments (Fig. 2.1). Many large hydropower projects were commissioned in the 1980s which led to an energy surplus. The surplus was exacerbated by economic downturns around 1990 and increased domestic hydropower generation due to climate change (increased precipitation).

Svartevatn Dam. Photo: Sira-Kvina kraftselskap

However, from about 2005, power sector investments increased again, peaking in 2018. When stated in Norwegian kroner (2022 level) [2], the annual investments have exceeded the investments during the peaking years of the study period. To a large extent, the present high investment level can be attributed to the ongoing **green transition**. On the generation side, the main investments have been undertaken in small hydro (<10 MW), on-shore wind power and rehabilitation and expansion of existing hydropower plants. Between 1991 and 2022, the share of transmission and distribution investments amounted to 53% of total investments. During the study period the corresponding share was 38%. The increase was due to large cross-border and domestic transmission projects.

Annual investments have decreased again in recent years, particularly due to a stand-still in on-shore wind power and an uncertain market for flexible hydropower. Last, but not least, environmental issues have definitely hampered development of many projects. However, to make

[2] Due to a weaker exchange rate for the Norwegian kroner against the American dollar in recent years.

the green transition happen, many tens of TWh renewable energy will need to be developed in the coming decades.

5.2 Investments compared to Gross Domestic Product (GDP)

Statistics Norway (www.ssb.no) provides data on power sector investments back to 1946. Power sector investments made up 2% or more of the Gross Domestic Product (GDP) for almost 30 years during the study period (Fig. 2.2.). For almost 30 years annual investments were in the order of USD 2 billion or higher. For the whole period 1945-1990, total investments reached about USD 100 billion. Operating cost for refurbishment and maintenance of USD 16.5 billion came in addition.

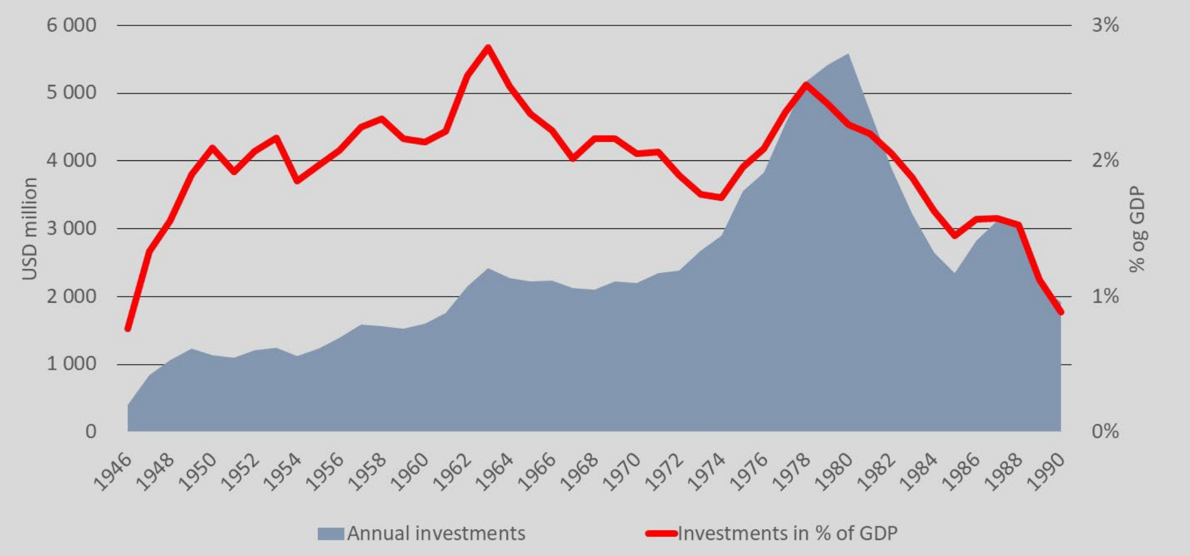

Figure 2.2 *Annual power sector investments (USD million, 2022 price level) and corresponding share of GDP.*

During the study period, investments peaked around 1980. The peak is associated with the construction of the 1,120 MW / 3,254 GWh Sima (Eidfjord) project commissioned in 1980 and the 2,040 MW / 5,300 GWh Ulla-Førre power project commissioned between 1981 and 1985.

Sysen Dam. Photo: Knut Ove Hillestad

5.3 Investment categories

In the study period, estimated[3] investments in generation[4], transmission and distribution (T&D) and other investments[5] were 53% (31% in power plants and 22% in reservoirs), 38% and 9% of the total investments, respectively, as shown in figure 2.3.

[3] From 1957, the electricity statistics present disaggregated data per investment category. For the period 1946-1956, we have assumed the same share per category as for the average of the period 1957-1972. Many large reservoir projects were constructed in this period, among others Tyin, Åbjøra, Aura, Nedre Røssåga, Hol, Øvre Vinstra and Nea power projects.
[4] More than 99% of generation investments were in hydropower.
[5] Control centres, Construction machinery, Roads and bridges, Offices, stores and workshops, Office equipment, Land, etc.

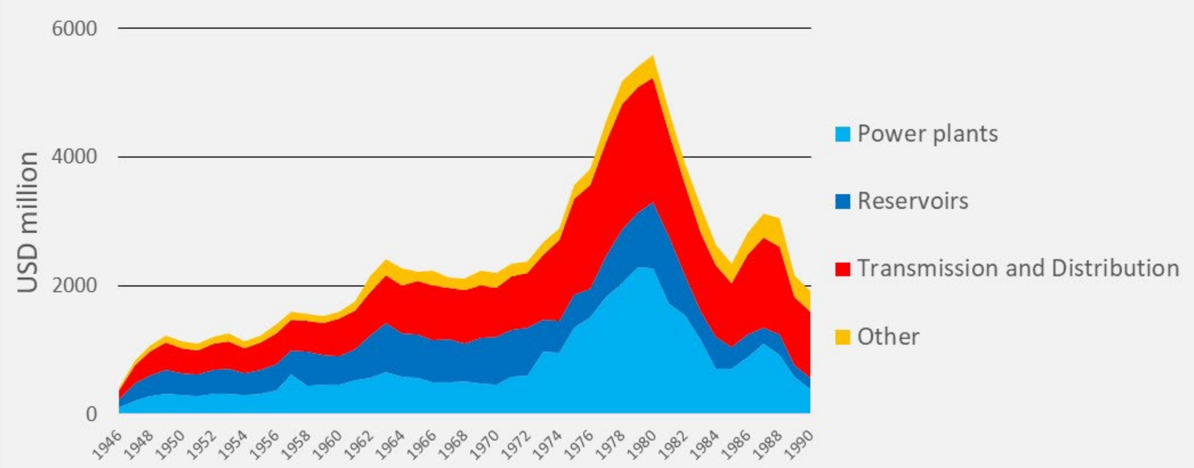

Figure 2.3 *Annual investments by technology (USD million, 2022 price level).*

The most notable observation is the large proportion of investments in reservoirs. In total, reservoir investments amounted to ca. USD 23 billion. These investments were undertaken to even out seasonal differences between inflow and demand, and to deal with dry years. Typically, the inflow in Norway is high during spring and autumn, while the load is high during winter. As shown in figure 2.4, Norway originally consisted of isolated power systems, and each district aimed at being self-sufficient.

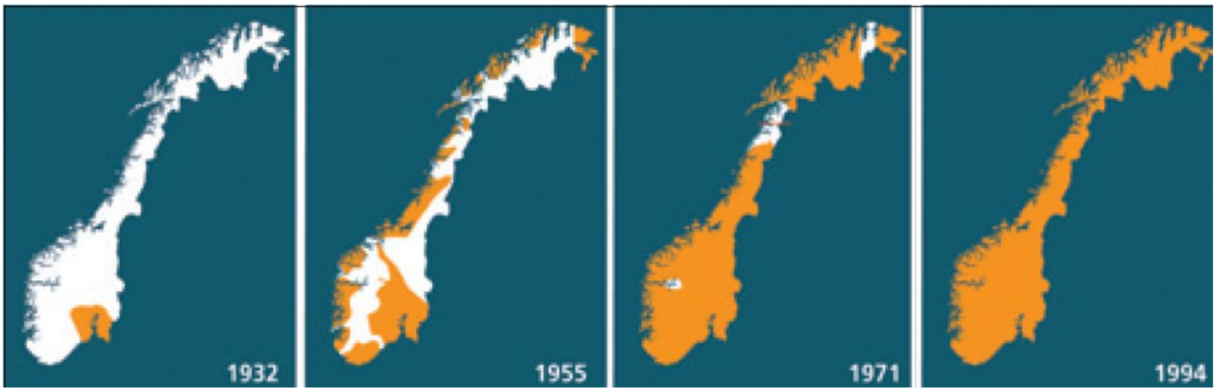

Figure 2.4*. From decentralized systems to a national grid* [2]. *Orange areas show synchronous grids that gradually merged.*

The relative share of annual reservoir investments declined after 1972. The gradual development of a national backbone transmission network and cross-border connections, to some extent reduced the need of reservoir investments, and meant that hydropower projects could be assessed from a national, rather than local, perspective [3].

Technological development with the introduction of cost-efficient rock fill dams helped reduce reservoir construction costs[6]. Reservoirs in Norway are normally storage in natural lakes that by combination of water level tapping by tunnels and water level raising by dams could store flow from flood seasons to season with low flow. However, some projects involved creating artificial

[6] Correspondingly, tunnel drilling technology (TBM) helped reduce power plant costs. Headrace tunnels are defined as hydropower plants in the electricity statistics.

lakes and the inundated land would cause social and environmental constraints. In some cases, plans that included artificial lakes were therefore rejected.

By 2023, the reservoir capacity in Norway amounted to 87 TWh, mostly developed before 1990. This corresponds to more than 60% of the mean annual hydropower generation. From the 1960s onward, Norwegian reservoir capacity was utilised also by neighbouring countries. In the study period, more than 2000 MW HVAC cross-border capacity was developed between Norway and (mainly) Sweden and 500 MW HVDC capacity between Norway and Denmark. This provided import capacity to Norway in dry years and access to dispatchable hydropower for efficient operation of thermal baseload power plants in the other Nordic countries. Later, the cross-border links was an important factor enabling Denmark's development of wind power resources.

Today, Norwegian reservoirs also facilitate integration of intermittent wind and solar power in a northern European context. There has been a steady growth in cross-border capacity. Between 1993 and 2021, High Voltage Direct Current (HVDC) submarine cables between Norway and Denmark (1993 and 2015), the Netherlands (2007), Germany (2021) and United Kingdom (2021), with an exchange capacity of more than 4,500 MW were commissioned. The High Voltage Alternating Currency (HVAC) capacity between Norway and Sweden has also increased since 1990.

5.4 Investor categories

Electricity statistics present investments by investor categories. Between 1945 and 1990, the central Government), municipal- and private companies were responsible for 31 %, 63 % and 6 % of total investments, respectively. Many hydropower projects were developed as Joint Ventures (JV) with two or more power companies as shareholders. In some cases, this also included cooperation between public and private investors.

The Government refers to Statskraftverkene (State Power Utility) and to power companies where at least 50 % of the share capital is held by the state or by a state-owned entity.

Municipal companies refer to companies where municipalities and counties are the majority owners of the company. Many municipal companies have more than one owner. This could also include private (minority) shareholders. In the study period, municipal power companies may refer to vertically integrated companies (which are no longer allowed), distribution companies and/or generation companies.

Private companies refer to companies in which 50% of the capital is in private hands. This includes two different categories: i) a limited number of large industrials with hydropower assets, and ii) local distribution companies, which (in the study period) could also own (normally smaller) hydropower plants.

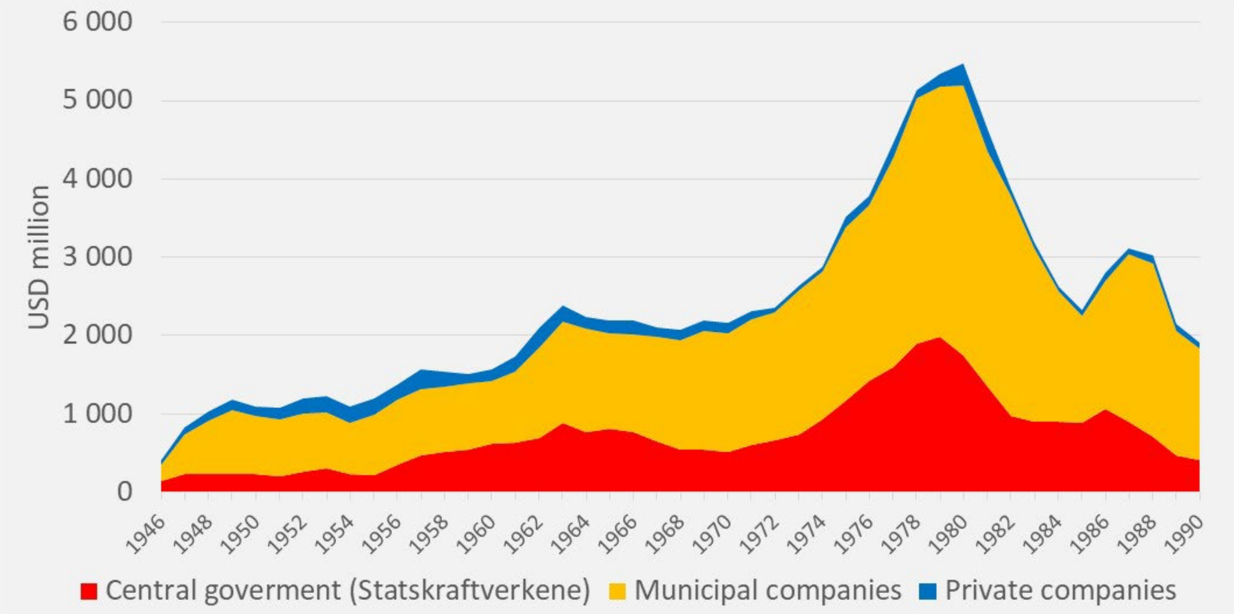

Figure 2.5 *Annual investments (2022 price level) by investor category.*

5.4.1 The Norwegian Government (Statskraftverkene)

The Norwegian Government's investments in the power sector took place through Statskraftverkene[7]. In addition to generation projects, Statskraftverkene also developed most of the transmission network (≥ 132[8] kV). The relative share of Statkraftverkene's investments showed considerable annual variations, associated with development of large hydropower projects and corresponding transmission infrastructure. Examples include the 940 MW Tokke project, commissioned between 1961-1970 [1], and the Sima and Ulla Førre projects.

The Norwegian Water Resources and Energy Directorate - NVE (the power sector authority) and Statskraftverkene (State power utility)

During most of the study period, the power sector authority, NVE, consisted of three Directorates under a common management. Through 1985, also the State Power Utility, Statskraftverkene, was a part of NVE.

To distinguish between NVEs different roles in the study period, the report uses the term "NVE" when referring to NVE's role as power sector authority with responsibility for the management of Norway's water and energy resources. The term "Statskraftverkene" refers to NVE's involvement in generation and transmission (and to a lesser degree in distribution).

5.4.2 Municipal Power Companies

As can be seen from figure 2.6, municipal power companies were the largest investor category[9]. In addition to considerable generation investments, they also undertook most of the investments in the sub-transmission (≤ 132 kV) and distribution network. Electricity distribution was considered a

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[7] Since 1992, Statskraftverkene corresponds to the present state-owned generation company Statkraft (www.statkraft.com) and the state- owned transmission system operator, Statnett (www.statnett.no).

[8] Today, "transmission" means 420 kV, 300 kV and 220 kV. In the study period, also 132 kV lines had a transmission function, while 132 kV lines today mainly serve a sub-transmission purpose.

[9] In the 1990s, the Government owned Statkraft (www.statkraft.com), which is one of the successors of the Statskraftverkene, acquired large equity stakes in municipal power companies.

municipal responsibility. The large municipal involvement in the sector was facilitated by access to both financial and human capital.

In the study period, the most common legal structure for municipal and county power companies were **a**) municipal enterprises (full liability), **b**) so called DAs (companies where each owner is responsible for debt corresponding to his equity share) and **c**) shareholding companies (limited liability). Jointly owned hydropower companies were, and still are, sometimes structured as a DA. Smaller power companies with only one municipal owner tended to be municipal enterprises. Today, municipal involvement in the power sector normally takes place through limited companies.

The legal structure of power companies was, and still is, motivated by tax deduction incentives, among others regarding interest costs.

5.4.3 Private investors

Private investors refer to two different investor groups. Large energy intensive industries that undertook hydropower investments in the study period, had significant foreign ownership, while shareholders of smaller private companies that invested in hydropower, were mainly owned by Norwegian investors[10]. In 1906, foreign investors had developed 77 % of all hydropower plants larger than 2.2 MW [4]. Still, in 1946 [5], 57 % of installed generation capacity was owned by the private sector. During the study period however, the total share of private investments was relatively small.

License requirements that obliged private investors to revert all assets to the Government with no compensation after their production license expired, might have affected private sector incentives to investment in hydropower during the study period. Annex 2 and [1] provides more information. Besides, publicly owned power companies managed to supply cheap and reliable power. Thus, in most cases, major end-users chose to focus on their manufacturing core business.

In 2019, private investors still owned 6.5 % of hydropower assets in Norway, of which the major part is owned by foreign investors [6].

Licence requirements do not prohibit private ownership in small hydropower (< 10 MW) and wind power. By end 2021, foreign investors owned 24 % and 67 % of the mean energy generation capacity of all small hydropower plants and wind farms, respectively.

5.5 Refurbishment and Maintenance

In addition to the about USD 100 billion used on investments, power companies spent USD 16 billion on refurbishment/repair and maintenance for generation, transmission and distribution assets. This corresponds to about 15% of the total investments, showing the considerable focus on maintaining existing assets.

[10] In recent years, the share of foreign investors in small hydro has increased.

As can be seen in figure 2.6, the relative share of maintenance increased throughout the period. This can be explained by an increasing age of the assets.

Most of the refurbishment and maintenance expenditures can be attributed to municipal companies, which own most of the distribution network. Compared to hydropower assets, distribution assets have higher maintenance costs in percentage of invested capital.

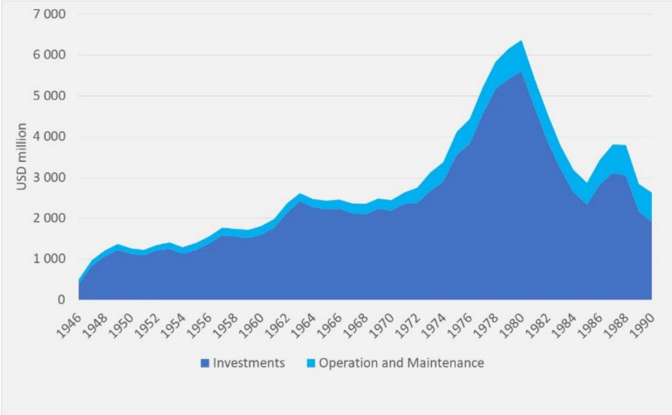


Figure 2.6 *Annual investments and refurbishment and maintenance costs. (USD million, 2022 price level)*

6 FINANCING

In this chapter, we examine how the power sector investments were financed, among others by looking at:

- The share between equity financing and debt financing.
- The sources of equity and debt capital.
- The rural electrification support scheme.
- Use of collaterals and guarantees.

6.1 Debt-equity ratio for different investor categories

Figure 4.1 shows the debt-equity ratio for total assets for Statskraftverkene and aggregated data for municipal and private power companies) in 1961. As corresponding data are not available after 1961, we do not investigate trends in the debt-equity ratio. This snapshot, which we believe is fairly representative for the entire study period, shows that almost 100% of Statskraftverkene's assets were debt financed. In comparison, municipal and private power companies raised about 20% and 35% of the capital, respectively, as equity.

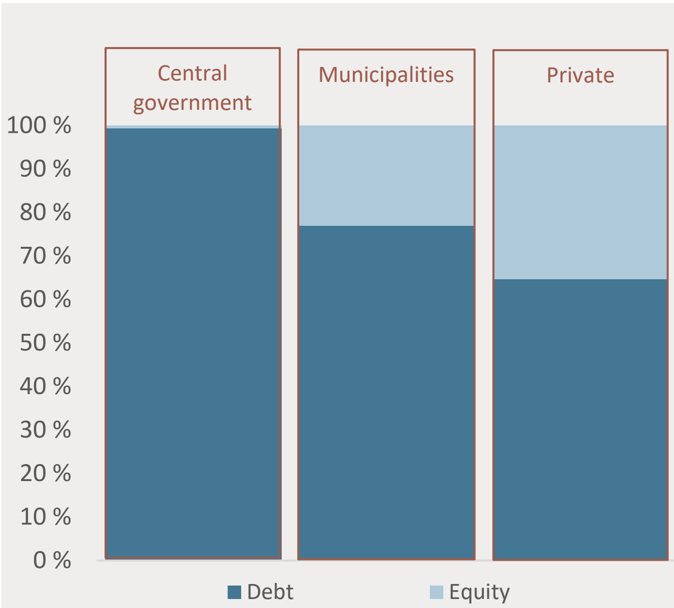


Figure 3.1 *Debt-equity ratio (1961) (source: www.ssb.no).*

6.2 Equity Financing

By and large, equity financing means capital that was raised from operational profits from the investors. Due to the predominantly public ownership of power companies, share emissions (Initial Public Offerings) were not very widely used.

Operational profits depended on the electricity tariff. Until 1990, power companies applied cost reimbursement considerations when fixing electricity tariffs (price). The boards of power companies decided the electricity tariff and had to consider the social impacts of tariff increases. In the 1960s, frequent consumer price freezes imposed by the l Government, made it difficult to increase tariffs substantially.

When fixing the electricity tariff, power companies also had to consider that they could lose deliveries to end-users that had dual-fuel heating systems [10]. In any case, electricity gradually became the dominant source for water and room heating, particularly after the 1973 “oil crisis”.

In the 1960s, NVE encouraged power companies to take future investment plans into account when fixing the electricity tariff [7]. NVE approved the electricity tariff for recipients of rural electrification grants to secure that the tariffs contributed to a sound financial performance.

Unlike generation and transmission investments, distribution network investments were to a large extent equity financed with the capital accumulated from operating surpluses. Typically, distribution network investments could be made in stages [8].

6.2.1 Investor Category Characteristics

The central Government (Statskraftverkene)

Statskraftverkene did not manage to accumulate significant equity for investment purposes. As illustrated in figure 4.2, the financial results of the Utility showed large annual variations.

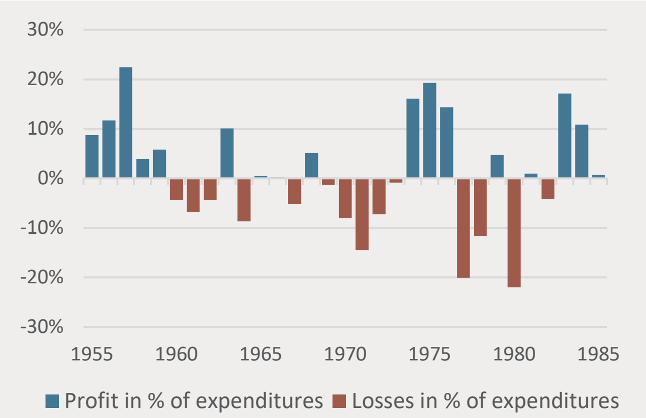


Figure 3.2 *Annual profit/loss of state utility (Statskraftverkene) as a percentage of annual revenues*

Statskraftverkene were not always in a position to charge a cost-reflective tariff (price) to its large industrial and wholesale[11] (municipal)-customers. This tariff was decided by the Parliament as part of the annual approval process of the State Budget. For reasons of employment and foreign exchange earnings, the Parliament also took the competitiveness of the Norwegian energy intensive industries into account. In any case, the financing capacity of Statskraftverkene rested with the Treasury.

The variable financial performance of Statskraftverkene should not be interpreted as lacking focus on cost efficiency. Design of hydropower projects was based on thorough hydrological mapping undertaken by NVE and in-depth analysis of construction costs [9]. Statskraftverkene undertook

[11] With a few exceptions, Statskraftverkene was not involved in electricity distribution.

systematic cost analysis of completed projects, and tested and introduced new technologies, to increase efficiency and reduce costs [7]. Automatization of substations and power plants also helped to improve operational efficiency.

Municipal Power Companies

By and large, public power companies have been operated according to corporate economic principles. On an aggregate level, power companies were profit-making during the study period. With a few exceptions [10], municipal owners could not afford to subsidize power companies over a long period of time. Not surprisingly, companies with a large urban and industrial customer base have been more profitable than companies in rural areas.

Between 1951 and 1961, the average aggregated profits were around 10% of the annual turnover, although with significant annual variations [11]. However, profits were seldom high enough to accumulate substantial equity. Repayment of debt from previous projects also inhibited the self-financing capacity. Besides, public owners sometimes used dividends for other purposes than new investments in electricity infrastructure.

Private Power Companies

The higher equity shares of the balance of private power companies (re. figure 4.1) involved in general supply (excluding industry) may indicate that these companies were more profitable than municipal companies.

In a few some cases, industrials undertook Initial Public Offerings (IPO) to raise equity financing of hydropower projects. One example is the Siso project, described in [1].

Siso hydropower plant has an installed capacity of 180 MW and mean annual generation 916 GWh. The gross head is 650 m and maximum discharge is 34 m^3/s. There are three reservoirs with total capacity 606 mill m^3. The intake reservoir, Siso Lake, has a capacity of 498 mill m^3 and can store slightly more than mean annual inflow. The large reservoirs and glacier in the catchment area makes the scheme extremely flexible to any change in climate.

Source: NVE

6.3 Debt Financing

From 1945 until around 1980, the national demand for debt capital exceeded domestic supply. The c Government’s regulation of the credit market was tight, and each sector received annual quotas for loans that could be raised in the domestic capital market. NVE gave recommendations regarding prioritization between projects [9].

The main domestic lenders to the power sector were state banks, central and municipal treasuries, and commercial and savings Banks. Banks also purchased bonds issued for power sector investments. The issuers were the power companies and/or the municipal owners of these companies.

The loan quotas to the power sector were reduced in the 1960s, among others because it was comparatively easier for the power sector to raise foreign loans.

Annual energy and credit market statistics provide data on power sector debt and where this debt originated. Detailed information is available for the period between 1954 and 1971[12]. Throughout this period, between 65% and 70% of the debt originated from public sources, i.e. state- and municipal treasuries. Other sources of debt capital were raised through both savings and commercial banks, and insurance companies as well as through bond issues and foreign loans.

The capital that the Government and municipalities lent to the power sector was raised through taxes, savings as well as domestic and foreign loans. Since 1945, the taxation level in Norway has been above the OECD average. National savings were also relatively high in the study period.

6.3.1 Investor Category Characteristics

Central Government (Statskraftverkene)

Since Statskraftverkene did not accumulate substantial equity from operating surpluses, the utility depended on annual appropriations from the Treasury. The appropriations were treated as loans. Since profits over time evened out losses, this means that the appropriations were used for investments. The interest rate and loan tenure were associated with the cost of the Treasury's own loans. See also paragraph 4.3.3 regarding foreign loans.

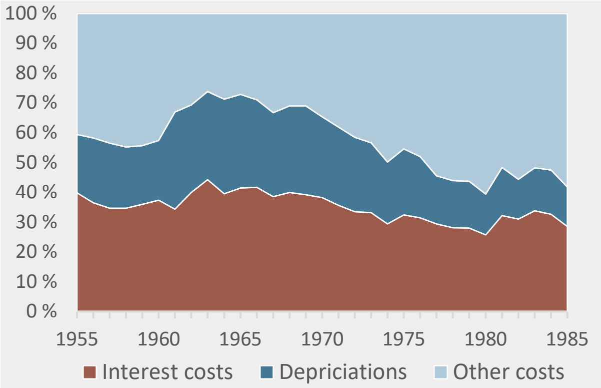


Figure 3.3 *Interest costs and depreications in % of total costs for the Statskraftverkene*

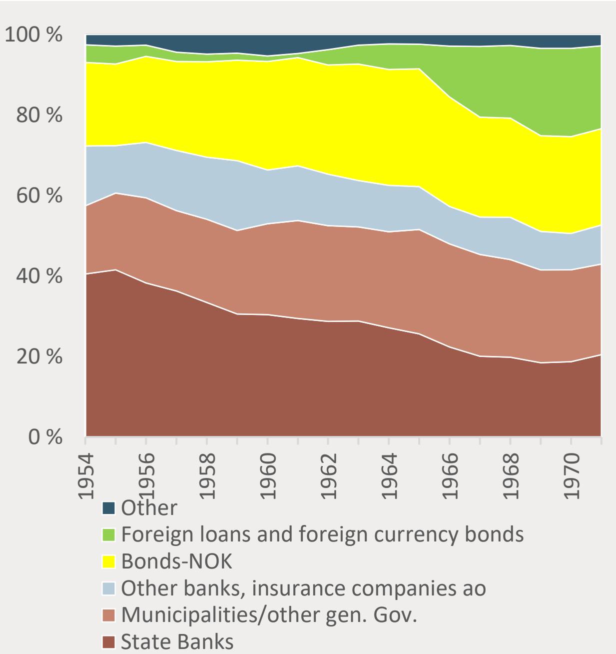
The utility's interest costs amounted to between 30-40 % of total cost during the study period[13], re. figure 4.3. The loans were repaid over 30 years until 1963 [12] and over 25 years from 1964].

[12] Detailed data are not available prior to 1954 and after 1971.

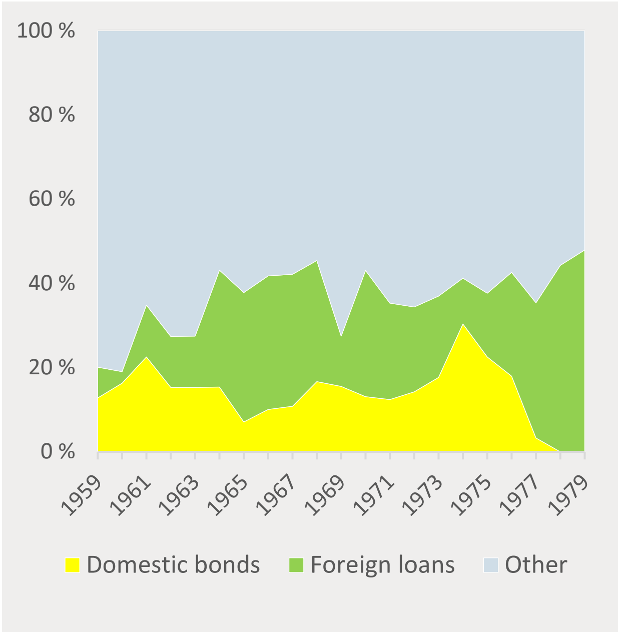
[13] For the period 1966-1985, financial information was found in NVE's annual reports. For the period, 1955-1960, corresponding data was found in the internal corporate magazine "Fossekallen" (no 3/1965).

Municipal Power Companies

Figures 4.4 and 4.5 provide information in electricity sector debt. The figures do not coincide



<u>Figure </u>3.4 *Sources of electricity sector debt between 1954 and 1971 (excluding Statskraftverkene)*



<u>Figure </u>3.5 *Financing of electricity sector investments between 1959 and 1979. (excluding Statskraftverkene).*

entirely in time, and they do not cover the entire period. Moreover, while figure 4.4 provides **aggregated** debt data, figure 4.5 shows the **annual** contribution from two debt sources to the total investments. The main observations are:

- The debt originated from a variety of sources.
- State banks provided the largest source of debt funding in the beginning of the study period, but over time this contribution was reduced.
- The debt share raised from public owners[14], (other) banks and insurance companies and bond issues was significant and remained stable.
- From 1960 onward, the share of foreign debt financing increased significantly.
- The sources of debt financing showed large annual variations. Among others, this was due to the tight regulation of the capital market.

In the following sections, more information is given on financing from state banks, municipal owners and bond issues.

State (development) Banks

<u>KBN</u>

From its start in 1927 until around 1960, the Norwegian Agency for Local Governments (KBN, https://www.kbn.com/en/customer/) was an important debt provider to the power sector. As a State Development Bank, KBN had a dedicated mandate to finance power projects. The loans provided by KBN were concessional, meaning they had a longer loan tenure than foreign loans and lower interest rate than foreign loans and bonds issued in the Norwegian market.

In the 1960s, many municipal power projects were larger than in previous decades and beyond KBN's financial capacity. KBN also prioritized other sectors. On the other hand, KBN took the role as an

[14] Public owners often raised debt capital that was relent to their subsidiary power companies.

intermediary on behalf of power companies in raising foreign financing.
KBN was able to raise capital with better conditions than most power companies, as their loans were guaranteed by the central Treasury. KBN's experience, reputation and the size of the loan transactions also contributed positively. To the extent possible, KBN tried to mitigate the exchange risk through diversifying the loans in different currencies. In the 1980s, KBN also helped power companies to refinance loans.

Other state banks
The Norwegian Industrial Bank (NIB) which was established in 1936, was another concessional financing source. Since the State was a large shareholder, NIB was also often classified as a State Bank. Today, the bank is a part of Innovation Norway. In 1952, a Development Bank for Northern Norway was established, aimed at stimulating socio-economic development in Northern Norway. The Bank provided project loans, guarantees and financed feasibility studies. From 1961, the Development Bank was continued as the Norwegian District Development Fund, with a broader geographical mandate. In 1993, this Fund and NIB were merged and continued through Innovation Norway (https://www.innovasjonnorge.no/en/start-page/).

Municipal Owners

Municipalities and counties provided significant loan financing to power companies in which they had holdings. A large part of this financing was raised through municipalities' own borrowing. An example is the Nea hydropower project [1] where Trondheim municipality took up loans on behalf of its subsidiary power company. Since the 1920s, loans associated with electricity sector investments constituted a large share of the total municipal debt. Between 1950 and 1970 municipal debt associated with the power sector constituted between 50% and 70% of the total municipal debt. This illustrates both the capital intensiveness of the power sector as well as the high priority given to this sector by municipalities and counties. A significant share of this debt was raised as foreign loans.

Bond Issues

During the study period, bonds were issued in the Norwegian capital market by the power companies or by their owners. Bond financing of Norwegian power sector projects can be documented back to the early 1900s. Bonds were purchased by banks and institutional investors. The establishment of the Government Pension Fund (https://www.folketrygdfondet.no/en) increased demand for bonds from 1968 onwards.

While 30% of power municipal and private investments were financed by bond issues in the Norwegian capital market in 1974, this share was zero a few years later. Correspondingly, while foreign loans financed less than 10% of these investments in 1974, the share had increased to over 40% in the late 1970s. In the 1980s, however, the importance of domestic bond issues for power project financing increased significantly again. The capital market became more fluid due to public revenues from the petroleum sector [13].

Bond financing is still an important financing source for Norwegian power companies. Today, many of the companies issue green bonds verified by an accredited institution.

Private Power Companies

Private power companies acquired loan financing from many of the same sources as municipal power companies.

6.3.2 Foreign loans

Foreign loan financing was an important financing source for all investor categories in the power sector. Seven of the 14 hydropower projects presented in [1] were co-financed by project-specific foreign loans. Moreover, most of the remaining projects had indirect foreign financing due to the foreign borrowing by the central Treasury and municipalities. Given the constrained domestic capital market, some power projects might have been postponed, possibly also cancelled, without this additional capital source. As discussed for the Nea project in [1], foreign financing facilitated a future-oriented hydropower development of the watercourse.

The incentives for raising foreign financing changed during the study period. Until around 1970, the main motivation was to raise finance that was not available in the domestic capital market. Since 1960, it was Government policy to finance a considerable part of the power sector expansion through capital imports [14]. In the 1960s, foreign loans tended to be more expensive, but this changed from the mid-1970s. The Norwegian interest rate became increasingly higher than in other OECD countries, peaking in the 1980s. Even though the Norwegian currency lost value compared to European currencies from 1970 onwards, the lower interest rate still made foreign financing attractive. However, when the liquidity in the domestic capital market increased in the 1980s, the Treasury restricted foreign financing in many sectors, among others to stabilize the national currency. Nevertheless, foreign co-financing was approved for a few larger hydropower projects [15].

Central Government (Statskraftverkene)

Based on data on Government debt and earmarked loans to projects developed by Statskraftverkene, a rough estimate is that up to 10 % of the utility's investments originated from foreign financing during the study period. For some of Statskraftverkene's projects, the Treasury raised loans earmarked for hydropower projects, particularly from the World Bank. This capital was re-lent to Statskraftverkene through the ordinary appropriation process. As long as Statskraftverkene was a state directorate, i.e. until 1985, it did not take up its own loans.

World Bank Loans

In the 1950s and 1960s, the World Bank (WB) co-financed four hydropower projects through the International Bank for Reconstruction and Development (IBRD). Three of these, namely the 940 MW Tokke project [1], the 130 MW Trollheim project and the 500 MW Rana project, were developed solely by Statskraftverkene. Also parts of Statskraftverkene's investment in the 231.5 MW[15] KraftverIene i Øvre Namsen project [1] was raised with WB financing. This project was a Joint Venture with a large municipal company.

Loan conditions for the WB loans were favourable compared to the prevailing market rate. The WB provided financing that otherwise might not have been available.

European Recovery Program (ECA[16])

In 1951 the Parliament approved the construction of the aluminums factory at Sunndalsøra. Thus, the capacity of the planned Aura power plant, which was originally designed for general supply, was increased from 120 MW to 288 MW.

[15] Excluding the ownership of the 25 MW turbine in Linnvannselv power station in Sweden.
[16] Often referred to as the Marshall Plan

While the power plant was financed over the state budget, ECA provided favorable loans for the construction of the aluminums smelter. This support helped finance the aluminums smelter without burdening the state budget.

Municipal and Private Power Companies

Municipal power companies have raised foreign financing for hydropower projects at least since 1924 [16].

Between 1959-1979, foreign loans (mainly bonds) amounted to about 25% of total financing of municipal and private power projects, although with significant variations (ref. figure 4.5) over time and between years. The share was lower both before 1959 and after 1979[17]

6.3.3 Upfront Financing from Customers

Some projects were co-financed with upfront financing from customers.

The Tokke power scheme, developed by Statskraftverkene, was co-financed by loans from municipal power companies, which were wholesale suppliers to distribution companies. These companies did not become shareholders in Tokke but provided upfront financing through subscription of prioritized deliveries. Another example is Statkraftverkene's investment in the 91 MW Innset power plant in the Bardu River in Troms County in Northern Norway. This project was co-financed with a loan from the large Swedish industrial company LKAB [17] in return for a long-term power supply contract. Similarly, a few larger municipal hydropower projects were also co-financed by upfront contributions from their customers, i.e. distribution companies and industrial end-users.

In 1956, the municipal (county) company Vestfold Kraftselskap (VK) issued a loan, which was subscribed by municipalities, industrial end-users and private persons. The loan was guaranteed by Vestfold County and most of the city municipalities within the county. The loan raised capital for **a**) subscription for power purchase from Statskraftverkene associated with the Tokke project, **b**) financing of the 110 MW Hjartdøla hydropower project and **c**) financing for 132 kV sub-transmission lines. In addition, a temporary tariff increase of 50 % for a period of 5 years was introduced [18].

As a rule, industrial companies did not take equity positions in the projects where they provided upfront financing. Typically, the co-financing was based on the self-cost principle and provided as loans, among others in the Brokke project [19]. In a few cases, the loans were repaid in free of charge electricity supply. One example is the 14 MW/53 GWh Svartelva hydropower plant in Trøndelag county, commissioned in 1959 [20].

[17] Sufficient data was not available for making an estimate for the entire study period.

6.4 Rural electrification support scheme

In 1938, a Rural Electrification Support Scheme was established after Parliamentary approval [21] for rural electricity access and enhanced electricity supply. The support scheme[18] provided grants and loans[19]. This concessional financing was combined with other financing sources to achieve financial closure of projects while maintaining affordable tariffs. Support scheme applications were assessed by NVE and closely coordinated with KBN's provision of loans to many of the same

Main conditions

- The assets had to be part of the ordinary electricity supply in the district.
- NVE had to approve the tariffs for companies that benefitted from the support scheme.
- The companies that benefitted from the support scheme, had to use the operational profits solely for electricity company purposes.
- NVE had the right to establish the necessary control.

applicants.

The support scheme contributed to increasing the electrification rate from ca. 75 % in the mid-1930s to almost 100% in 1960. Between 1945 and 1955, Government support to rural electrification corresponded to between 5%-9% of annual investments in the power sector. For the whole period 1945-1990, the allocations from the support scheme corresponded to 2 % of total investments.

From 1951, the support scheme was backed by an electricity tax. In the 1970s, the electricity tax became a fiscal tax, providing the Treasury with significantly more revenues than what was appropriated for the support scheme.

From the mid-1950s, the support scheme was also used to finance transmission lines in the outlying districts. One example is the Kraftvelkene i Øvre Namsen project already referred to. Between 1956 and 1970, the support scheme raised more than USD 900 million (2022 price level) to transmission backbone projects, predominantly for investments undertaken by Statskraftverkene.

Over time, the importance of the support scheme was reduced. In the 1980s, the activities shifted to financing of reserve material and network analysis to reduce distribution losses in rural areas, and to finance off-grid energy solutions for the few remaining households that had not been connected to the grid. In the 1990s, it was also used to reduce distribution tariffs in the districts. The support scheme was terminated in 2006.

6.5 Collaterals and Guarantees

Lenders' risks associated with the power project loans were, not surprisingly, mitigated by collateral and guarantees. The legal structuring of the respective project developer (municipal enterprise, liable company, limited liability company etc.) also affected the lenders' security requirements.

Both existing assets as well as the assets of the project under development could serve as collaterals. In the study period, NVE controlled the value of the collaterals for loans offered by KBN, the District Development Bank and the Norwegian Post Savings Bank [12].

[18] In some cases, also municipalities and counties provided similar support.
[19] Some of the loans were project loans, until other financing had been secured.

The steady expansion of the transmission network reduced the lenders' risks, as surplus power in a particular geographic area could be exported to other areas or to neighbouring counties[20]. An integrated transmission network also made it easier for power companies that faced financial difficulties[21], to sell hydropower assets.

Guarantees were required if lenders assessed the value of collaterals as insufficient. In the study period, both the Government and municipalities provide guarantees to power companies. Among others, this was used in joint ventures which did not have other assets than the yet to be constructed power plant. Foreign loans raised by KBN were guaranteed by the government.

Guarantee Fund

From 1949, power companies that received loans from KBN had to pay a fee to a guarantee fund. The fund allowed power companies to take up loans beyond the value of their collaterals, particularly benefitting economically less developed districts.

[20] In the 1920s and 1930s, some hydropower projects were developed solely for industrial purposes in areas not connected to a larger power system. In some cases, the corresponding industry project did not materialize, causing problems for the hydropower developer. One example is the Glomfjord project (see: Thue. Statens Kraft 1890-1947, Kraftutbygging og samfunnsutvikling).

[21] More power companies faced financial difficulties when the power market was deregulated in 1990. The deregulation happened at a time of stagnating demand and high hydropower production.

Part 2

Hydropower licensing, the environment and consideration of other user interests

7 HYDROPOWER LICENCING IN NORWAY – HISTORICAL OVERVIEW

7.1 Background

Traditionally, Norwegian rivers and waterfalls have been utilised to power water mills and for timber floating, to a limited extent also for transportation. Initially, the rivers and waterfalls in Norway belonged to the landowner. However, the rights to utilise waterfalls could be sold separately from the land and utilised for larger scale water powered machinery.

When electricity was introduced in Norway around 1880, a race started to get control over waterfalls suitable for hydropower development. Hydropower pioneers and speculators purchased water rights from landowners and offered them to hydropower and industrial developers, often at a much higher price.

Around the year 1900, the national capacity to finance capital intensive investments in hydropower and industries was limited. On the other hand, foreign companies showed interest in investment in hydropower development combined with larger industrial development in metal smelting, paper pulp and chemical industries.

7.2 Water related Licences

From a Norwegian perspective, it was of concern that foreigners took control of vital resources. Consequently, between 1906 and 1909, the Norwegian Parliament introduced a series of new laws ("Panic laws") to regulate future purchase of waterfalls, leading to the 1917 Waterfall Acquisition Act. According to this law, overruling other legislation, foreign and private companies could only be granted time-limited licences. The licence period was limited–to 50 - 60 years with reversion of all water and land rights and assets to the state with no compensation (compare modern BOOT contracts, Build, Own, Operate and Transfer). By the time of reversion, the plants should be well maintained and in a fully operational state.

Municipalities hosting reverted plants have the right to receive up to 1/3 of the value of the reverted plants. By the time of the reversion, the Government may decide to let the state power generation company (Statkraft) take over ownership and operation of the reverted plants. Statkraft may also choose to lease the plant to the original owner. Other reverted plants have been sold to the previous owner by the state and new licenses have been granted with time limit and reversion after another 50 - 60 years.

Several larger private owned power intensive industrial developments (smelting industries) that received their licenses early, wanted to increase their production during the 1950s, but the remaining license period was too short to achieve enough return on the additional investment. These companies made an agreement with the state based on immediate reversion of assets and rights to the state with no compensation followed by a new license granted for another 50 - 60 years. The reverted assets and rights were leased accordingly.

Municipalities, counties and the state were exempted from this law and could acquire waterfalls without a license until 1969, while the state-owned power company (Statkraft) was exempted until 1991**.** Licences are granted to public owned companies for unlimited time and no reversion.

In addition to the Acquisition Act, hydropower developers also need licenses according to the general Watercourses Act (1917, later Water Resources Act 2000), and Watercourses Regulation Act (1917) if the project included reservoirs or watercourse diversions.

Compliance with European Union (**EU) Directives**
The 1917 Water Acquisition Act was changed in 2008 due to EU directives which Norway was obliged to implement in its legislation to secure equal rights for private and public owners/investors in hydropower. After 2008, private companies are not allowed to acquire waterfalls or existing power plants/companies utilising waterfalls except for shares up to 1/3 or waterfalls below 4000 natural horsepower, corresponding to about 3 MW.

One window policy
NVE has been delegated by the Ministry of Petroleum and Energy the responsibility to process the license applications. The applications including Environmental Social Impact Assessments (ESIAs) are processed by a "One Window" approach by NVE who organise the consultations, public meetings and prepares the license including license conditions and rules of operation. For smaller projects, NVE can grant licenses, but for the larger projects NVE prepares the cases for the responsible ministry[22]. Licenses for larger projects are granted by the King in his Council (Statsråd). Especially controversial projects are approved by the Parliament[23]. A license can only be granted if project benefits outweigh the negative impacts.

Environmental and social issues
Until 1970, the license applications mainly covered technical plans and shorter reviews of impacts on fishing, agriculture and transport. From 1970 onwards, hydropower development plans had to meet increasing environmental concerns and protests that led to revised procedures and requirements to the content of the applications, including ESIA. The controversial 150 MW/ 695 GWh Alta hydropower project also raised the awareness of taking the interests of indigenous people into account. As elaborated in the next chapter, Watercourse Protection plans, and Comprehensive Hydropower Master Plans defined strong limitations on which projects were ready for the licensing process. Today, the general Plan and Building Act (1990) with its ESIA procedures (in accordance with the EU regulations) defines the licensing process with early notification/consultation and a second consultation for the application/ESIA.

Quite a few Norwegian power companies have been certified to issue green bonds. It is expected that most Norwegian hydropower projects will be classified as "renewable" according to the European Commission's taxonomy entered into force on 1 January 2022.

[22] https://www.regjeringen.no/en/dep/oed/id750/.
[23] Before 2005, also projects above 20 000 natural horsepower had to be approved by the Parliament.

Revision of licence provisions

The right to claim a revision of a license's provisions is an important statuary right in Norwegian watercourse legislation. In the coming years, NVE may have to process several tens or even hundreds of cases. The case work will have to balance considerations regarding improvement of environmental conditions, for instance new requirements regarding increased minimum water flows and reservoir operation, on one hand and reduced renewable energy production on the other hand. The EU Water Frame Directive with its targets on good conditions for biological life in rivers will influence on the result of the revisions of licenses.

8 RESOURCE MAPPING, PROTECTION PLANS AND COMPREHENSIVE MASTER PLAN

The Norwegian Water Resources and Energy Directorate (NVE) as well as hydropower companies have invested considerable resources in hydrological mapping. Resource mapping has contributed significantly to least-cost hydropower development. The gradual development of a national transmission backbone system meant that the least-cost approach could be applied to larger geographical areas. From the 1960s, the resource mapping was combined with systematic environmental considerations and assessment of multi-use interests.

8.1 Hydrological Mapping

NVE is Norway's centre of excellence in hydrology. NVE collects data on discharge, snow, ice and glaciers, groundwater, water temperature, erosion, avalanches, sediment transport, etc. Data and analyses are available on www.no. NVE is responsible for the national flood warning service and the preparation of water flow forecasts for the whole country. The service is operational around the clock.

Hydrological mapping in Norway can be traced back to the early 1800s [22]. The river Glomma by Lake Øyeren has the longest hydrological discharge time series, with measurements going back to 1852. Also several other large watercourses have such data going back to the early 1900s. NVE's Hydrological Department was founded in 1895, i.e. 26 years before NVE itself, following Parliamentary appropriations for hydrological surveys of watercourses with the purpose of mapping Norway's hydropower potential.

The accelerated hydropower development after WW2 increased the need for hydrological data and knowledge of the individual watercourse. In the 1950s, NVE expanded the scope from water level and water flow measurements to measuring ice conditions and water temperature. Also monitoring of cryosphere data (snow and glaciers) started in this period. Computerized data processing started in 1961.

8.1.1 Reconnaissance Studies and River Basin Plans

Between 1948 and 1973, the Norwegian Society for Hydropower Studies [23] mapped the hydropower potential, mainly at the reconnaissance level, of more than 180 watercourses and hydropower projects. In many cases, the conceptual solutions of individual hydropower projects and river basin plans were adopted by the respective hydropower developers.

The Society, which had members form the Government and power companies, made recommendations regarding technical design of individual projects and optimal hydropower development within an entire watercourse. Moreover, the Society also looked at interplay between hydropower projects in different parts of the county, taking differences in hydrology into account. A transmission sub-committee was established in 1962.

In 1973, the mission was considered accomplished, and the Hydropower Study Society was dissolved. The resource mapping was continued by NVE. In the 1980s, the undertaken studies formed the starting point for subsequent master plans and watercourse protection plans.

8.2 Watercourse Protection Plans and Master Plans

8.2.1 Development towards Watercourse Protection Plans

In the early days of Norwegian hydropower development, the negative impacts on the environment and third-party interests tended to be overlooked as insignificant relevant to the benefits offered by development. Research and development on landscape, river flow, biodiversity has given results offering the planner both the knowledge and a tool to work 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 is acceptable.

Concerns regarding watercourse protection were raised in the Parliament in 1960, and a committee concerning protection of watercourses was appointed. In 1963, the Committee proposed protection of 94 watercourses. In 1969, the Parliament requested NVE to prepare a plan of watercourses that should be excluded from development, considering outdoor recreation, nature and environmental protection interests.

In 1973, the Parliament approved permanent protection of 93 watercourses, while 57 were temporarily protected. The work on "the 10-year protected watercourses" was especially comprehensive. In addition to documenting values, a suitable methodology was developed for the assessments. The Parliament approved updated watercourse protection plans in 1980, 1986, 1993, 2005 and 2009. Altogether 388 watercourses have been protected against hydropower development. However, in 2005, the Parliament opened up for license applications of smaller hydropower plants (< 1 MW) in protected watercourses.

Norway has more than 1500 hydropower plants with capacity over 1 MW in operation. They generate 136 TWh at a very low cost and with few exemptions have a climate footprint between 2 and 4 g CO2ekv/kWh according to life cycle studies of some reservoir hydropower plants and river power plants.

More than 60% of the country has limitation for hydropower development because of National parks (dark green), Special Wildlife and Fauna protection (light green) and the 6 special hydropower protection plans (blue).

The respective hydropower potential that is protected is about 50 TWh.

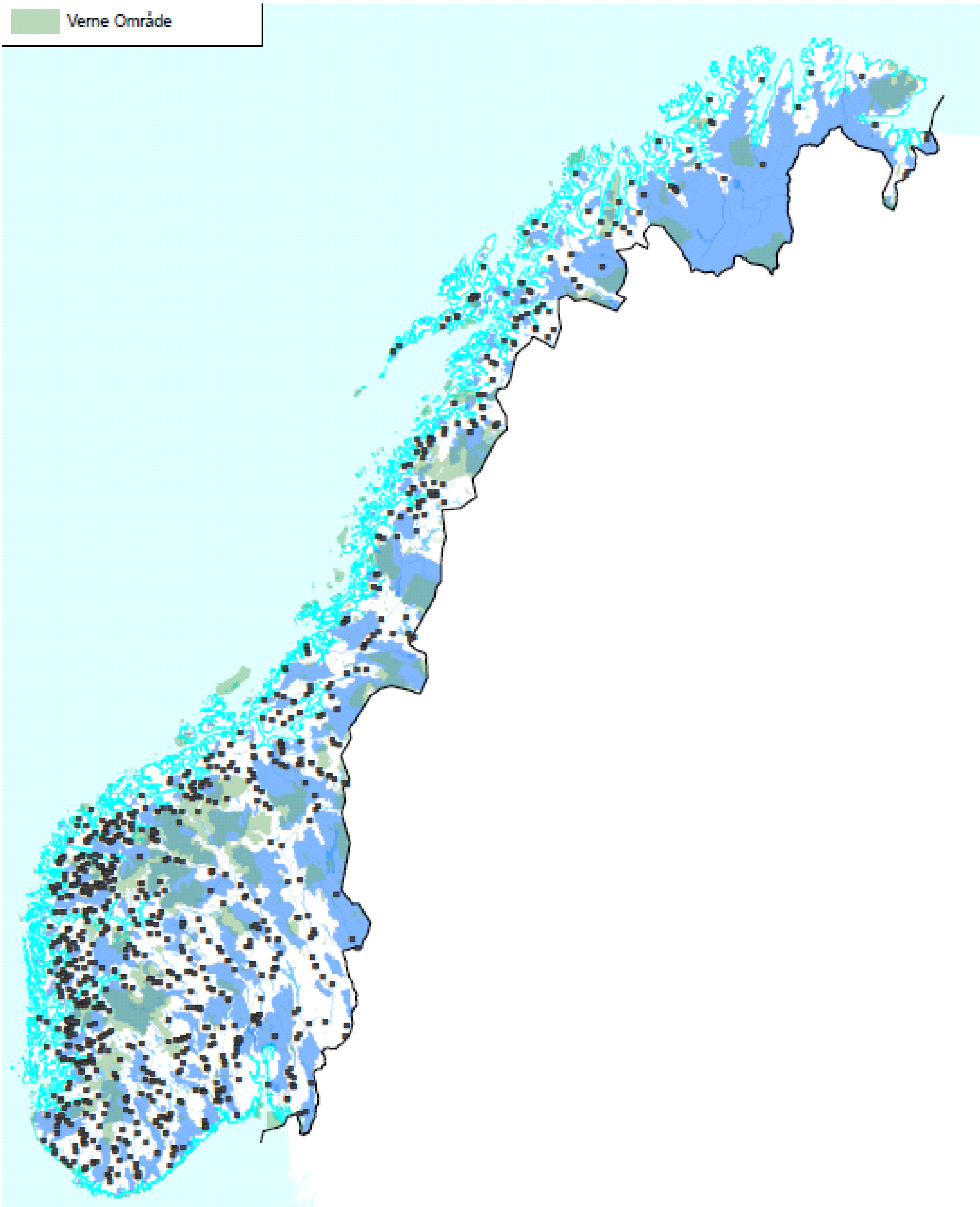


Figure 5. Location of hydropower plants and catchments with restriction for hydropower development. Source: NVE

8.2.2 A national comprehensive Watercourse Master Plan

An overall watercourse plan was approved by the Parliament in 1986, and later updated in 1988 and 1993. The purpose was to establish a comprehensive, national management of the country's watercourses. The plan was based on a method that involves systematically verifiably sorting of hydropower projects, based on the degree of conflict in relation to different user interests and power plant economies. The watercourses were placed in three categories (since reduced to two), where category I includes projects that "can be forwarded for licensing" and category II includes projects that "currently cannot be submitted for licensing".

In 2016, this comprehensive Master Plan was discontinued. Since the plan was established, the general knowledge base on the environmental conditions in the watercourses has been significantly improved. The acquired knowledge base due to the preparation of the Comprehensive Master Plan will nevertheless still be useful in future licensing processes.

The 1960s and 1970s were decades with very high activity in planning and construction of large hydropower projects in Norway. During the same period, environmental awareness increased, especially from the early 1970s. This resulted in increasing and more often conflicts between hydropower development and environmental interests.

Hydropower development had its formal base in a case-to-case handling of applications. There was no national plan neither to develop nor to protect environmentally valuable watercourses. The need for a framework was often discussed, and the first attempt to create a framework for hydropower resulted in the Watercourse Protection Plan. This plan was a defensive type of plan taking watercourses out of hydropower planning.

Nevertheless, conflicts due to environmental impacts and impacts on the activities of the indigenous Sámi people still increased and peaked with the plans and later construction of the hydropower plant in the Alta River in the county of Finnmark in northern Norway. A hunger strike in front of the Parliament and extensive, tough but peaceful demonstrations at the construction site and its following political implications, became a driving force for the decision to develop a framework for further development, a Master Plan. A White Paper to the Parliament in 1980, "Norway's Future Energy – Use and Production", Report to the Storting No. 54 (1979-1980), paved the way for the final decision to develop a Master Plan. The Government needed an extended planning and licensing system that considered a wide scope of stakeholder's interest when developing watercourses.

Alfred Nilsen, leader of one of the organizations against the damming of the Alta-Kautokeino watercourse, talking to the Environment Minister Gro Harlem Brundtland, in Alta. Photo: Odd Mikalsen/Alta museum

In a proposition to the Storting No. 130 (1981-82) “Power Coverage in the 1980s and the Relation to the Master Plan for Water Resources”, the main goal for the Master Plan was defined as follows:

“Propose to the Parliament a priority grouping of hydropower projects for subsequent consideration for licensing. Priority should be given to projects with the least cost and least environmental impacts. The plan should also provide a basis for deciding which watercourses could be reserved for other use”

The Master Plan was organized as a large interdisciplinary project with participation from several ministries, all counties and municipalities with projects in the plan. The task embarked on from the onset was to evaluate 310 projects economically and their environmental impacts. Then all these projects with their alternatives should according to the goal given by the Parliament be grouped according to project economy and environmental impacts.

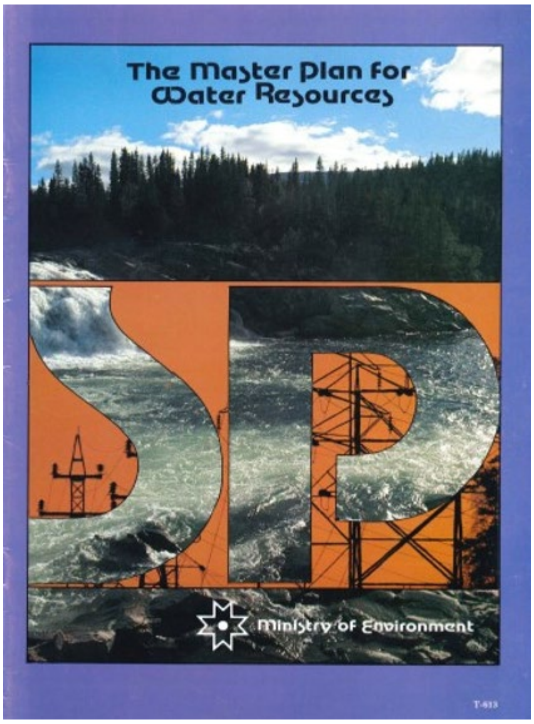


Figure 23. The front page of the main report (NVE).

The purpose of the Master Plan was to reduce conflicts, achieve more effective handling of applications and pave the way for a sequence development where evaluation procedures could be carried out with the least possible practical obstacles.

Ideally the Master Plan should cover all economic exploitable hydropower which was not yet developed, granted a license for development, or become permanently protected in 1982. However, the extent of the Master Plan had to be reduced mainly due to the need to meet the increasing demand for power. A complete freeze of licensing was not possible. A number of larger projects- not too environmentally controversial - thus were exempted from the Master Plan.

To investigate the professional basis for the Master Plan- a total of 16 user interests/topics for study were defined: hydropower, nature conservation, outdoor recreation, wildlife, water supply, water pollution, cultural heritage, agriculture and forestry, reindeer herding, flooding and erosion, transport, ice and water temperature, local climate, mapping and data, and regional economy.

For every project in the Master Plan, these interests/scientific areas were evaluated, and the professional conclusions included in the report on the specific watercourse. User interests were classified according to the extent of the consequences if the water course is developed. A scale ranging from -4 for very serious negative impacts to +4 for very large positive impacts was used for 13 of the impact topics. The impact on regional economy had a special evaluation.

The investigations and studies necessary to chart the different interests were carried out by 9 expert groups that included the 16 above mentioned topics. NVE was responsible for the hydropower expert group, the group for flooding, ice and water temperature, and the working group for mapping and data. The group for mapping and data renewed the use of maps in planning and was the basis for NVE´s strong position today within GIS technology.

Since the 8 other expert groups needed information on hydropower plans it was imperative for their work that NVE could quickly present and describe hydropower projects. This was done by using projects in an early stage of application for license and by using the result of NVEs small hydropower mapping from 1978-1982. The lessons learned from the previous small hydropower mapping based on uniform use of maps, presentation of the project and a cost manual for all components of small hydropower development were fully used in this work.

All projects should have a technical and economic level approaching those required for an application for license. Another important requirement was that the different hydropower projects were directly comparable. This required uniform presentation, cost estimates based on the same data, and the same method for carrying out the calculation of production.

NVE used a mix of own resources and consultants to do the work and had close communication with hydropower companies. Large hydropower projects were often presented in 2 or 3 different alternatives since location of hydropower stations was a matter of concern for the municipalities and their income from taxes, and degree of regulation of lakes and diversion of neighbouring rivers had different environmental negative impacts.

In the first phase (1980-1984/85), 283 project- or watercourse reports covering the 310 projects with its 542 alternatives were produced. The production potential for all projects in the first phase was approximately 40 TWh.

The **hydropower projects** were classified according to the economy connected to the development. The projects were grouped into six economy classes where the five lowest classes were projects where the cost are lower than the limit for economically exploitable hydropower. The six categories included an evaluation of project cost and the ability to meet power demand throughout the year.

The **environmental and social impacts** were grouped in eight classes – consequence- or conflict classes C1-C8. Projects with lowest conflicts C1; highest conflicts C8. 13 of the topics classified according to a scale from -4 to +4 were then weighed and balanced according to formalized procedures and adjusted according to comments.

All projects with project alternatives, a total of 542 in the first phase, now could be found in the 48-square matrix shown below. The numbers 1-16 in each square decide the first level of priority groups: projects in squares with equal number have the same priority economy and conflict balanced. For lower conflict classes, project economy was given more weight. For higher conflict classes, conflicts were given most weight.

Consequence classes

Economy classes

	C1	C2	C3	C4	C5	C6	C7	C8
E1	1	1	2	3	5	7	9	12
E2	1	1	2	3	5	7	9	12
E3	2	2	3	4	6	8	10	13
E4	3	3	4	5	7	9	11	14
E5	4	4	5	6	8	10	12	15
E6	5	5	6	7	9	11	13	16

Category 1 Category 2 Category 3

16 priority groups were to many and to detailed to be presented to the Government and the Parliament. The 16 groups were combined to 3 categories: Category 1 (green): group 1-5,

Category 2 (yellow): group 6-8, Category 3 (red): group 9-16.

Table 4 Matrix for final discussion on prioritizing projects (NVE)

The 16 groups were reduced to 3 Categories and represented the final political result of the Master Plan and constituted the new framework for licensing of hydropower projects. The

Categories were defined as follows:

- **Category 1** Projects cleared for applications for license.
- **Category 2** Projects for both HP development and other use. Decision delayed.
- **Category 3** Projects not suitable for HP development. Many of schemes in this category were included in HP protection plan.

The work on the Master Plan had three main phases each ending with a White Paper to the Parliament. As mentioned, the first phase started in 1980, and a proposal for the Master Plan from the project administration was presented to the Ministry of Environment/the Government in 1984. The Government then issued a parliamentary report to be discussed and endorsed by the Parliament in 1985.

The second phase with its parliamentary report in 1988, included many of the small hydropower schemes with reservoir capacity. This phase included additional projects in 151 watercourses with projects with a total of 236 alternatives.The third phase ended with a parliamentary report in 1993 and included the main bulk of the work on upgrading and enlarging of large old hydropower plants. This phase included projects with 165 alternatives in 82 watercourses.Thus, during all three phases a total of 543 water courses have been studied and 941 alternative hydropower projects have been evaluated, classified, and grouped.

The projects reports were prepared in close cooperation with local planners, the hydropower developers, and the various interest groups. The reports have in turn been sent to counties, municipalities, power companies, and local interest organizations (NGO`s) for comments.

The work with the Master Plan involved full-time and part-time work by many persons, both centrally and in the counties. Large parts of the work on the Master Plan to secure identification of related impacts were done in the counties and coordinated by a Master Plan coordinator in each county. The coordinator was responsible for preparing of the reports on the projects/watercourses and for distribution of the reports for comments.

The Ministry of Climate and Environment was responsible for the Report on the Master Plan. The work was carried out close cooperation with the Ministry of Petroleum and Energy (OED), the Norwegian Water Resources and Energy Directorate (NVE) and other affected parties. A steering committee included representatives from the Ministry of Environment, Ministry of Petroleum and Energy, Ministry of Agriculture, the Ministry of Local Government and Labour and the Ministry of Health and Social Affairs.

The success of the Master Plan was strongly dependent on strong political support by the Government. The importance of this support cannot be underestimated. This support secured sufficient budgets and constructive cooperation between ministries, directorates, and counties.

Other key success factors:

- Unified planning and assessment procedures
- Unified cost estimating system.
- The same expert groups in different topics analyzed all projects.
- Classification system taken into account economy and conflicts.
- Transparency: It was possible trace why a certain project ended up in one of the 3 categories by investigating the layers in the classification av evaluations.

All projects in The Master Plan were presented in separate books/project reports that included the description of the projects with calculations, maps, and the conflicts. Summary reports were presented for each county and national overview could be found in the parliamentary reports with attachments.

The Master Plan worked as a management tool until 2017. From 1993 to 2017 it served as a screening plan before a license application could be accepted. A new or modified project earlier evaluated , according to Master Plan criteria as a category 2 project, could be "lifted" to Category 1. Then licensing procedures could be initiated.

In a parliamentary report on energy in 2017 it was recommended to abandon the Master Plan as a management tool. The main reasons were that some projects had been developed, and the watercourse protection plans included some of the other controversial projects. Thus, the few remaining could be handled by NVE in the normal licensing process.

As mentioned, the political goal with the Master Plan was to reduce conflicts related to the development of a natural resource of paramount importance to Norway and its development as an energy nation. It is no doubt the Master Plan serving as a management tool for more than 35 years has fulfilled its goal.

ANNEX 1. EXAMPLES OF FINANCING OF HYDROPOWER PROJECTS

Project/-scheme	Period[24]	Installed capacity (MW)[25]	Annual generation (GWh)[25]	Investors[26]	Financing	Main customer group(s)
Aura	1946-1962	310	1,964	Government[27]	State budget	Industry General district supply
Åbjøra	1946-1960	95	474	Municipal	Tariff increases Domestic Loans / Bond issue	General supply (in investors' supply areas)
Porsa	1946-1962	14.5	69	Municipal	Rural Support Scheme (grants/loans) District grants Civil Defence and Army	General local supply
Røssåga	1947-1962	525	2,902	Government	State budget	Industry General district supply
Nea	1951-1964	207	837	Municipal	Foreign loans State banks Tariff increases	General city supply and time-limited export
Røldal-Suldal	1952-1967	606	3,293	Industry Government	Equity Foreign Loans Domestic loans	Industry
Skogfoss	1956-1964	70	430	Municipal Industry	Equity KBN Rural Support Scheme	Industry General local supply
Tokke	1957-1965	997	4,832	Government	State budget (partly backed by WB loans) Subscription arrangement	General district supply (Eastern Norway)
Tussa	1957-1965	64	272	Municipal	Equity Loans from local banks	General supply (close to the project area)
Øvre Namsen	1958-1965	305	1,278	JV (Municipal company and Government)	Domestic loans (KBN) State budget (backed by bond issue in Sweden and WB loan and Rural Support Scheme (transmission investment)	General district supply Industry?
Sira-Kvina	1960-1988	1,760	7,115	JV (3 municipal companies and Government	Predominantly loans - domestic (< 40%) - foreign (> 60%)	General supply (Southern and Eastern Norway) Large industry
Lærdal	1960-1988	300	1,227	Municipal	Earmarked tariff increase Domestic bond issue Foreign loans (20%)	General supply (in investor's supply area)
Siso	1962 – 1973	180	916	Industry	Share emissions Loans and bond issue	Large Industry
Orkla	1973-1985	320	1,398	Municipal	Tariff increases Foreign loans Domestic bond issues	General district supply

Source: Norway's hydroelectric development 1945-1990. NVE Rapport 2021:28.

[24] Refers to the original project.
[25] Refers to present data in NVE's database.
[26] When the project was developed. The investors may not be the present owners.
[27] i.e. Statskraftverkene (State Power Utility).

ANNEX 2. ADDRESSING MARKET RISKS AND FOREIGN EXCHANGE RISK

This annex describes how market risks and foreign exchange risks associated with hydropower development were addressed in the study period.

Market risks

The socio-economic costs of a power surplus are much lower than the costs of power rationing. Until the mid- 1970s, the Norwegian power system was designed to have a power surplus in nine out of ten years. As can be seen in figure A2-1, domestic power production has been, and still is, larger than the electricity consumption in most years.

In the 1920s and 1930s, which was a period of unstable economic development and recession, many municipal power companies faced a dire economic situation. This was due to large investments to serve a growing demand that did not materialize.

However, in the study period, the market risk associated with hydropower development was relatively low, due to a steady economic development and fixation of electricity tariffs based on cost reimbursements. The main challenge was to keep pace with a steadily increasing power consumption. Only in the in the late 1980s did oversupply become an issue due to stagnating demand and increased precipitation. This again, led to the 1990 deregulation or liberalization of the power market [24].

Electricity utilities have a long tradition in offering a discounted tariff[28] to flexible consumption, i.e. consumption that could switch between electricity and thermal heating. This reduced spill energy in wet years and did not tie up utilities to supply commitments in dry years. As can be seen in figure A2-1, flexible consumption has been higher in years with a production surplus. From 2020, it is (with some exceptions) prohibited to use mineral oil products for heating purposes. Since then, flexible consumption has not been registered in the energy statistics.

The gradual development of a national transmission backbone system enabled electricity exchange between different parts of the country. From 1960 onward, cross-border interconnections also provided opportunities for exports of surplus electricity in wet years as well as import opportunities in dry years. The actual exchange has increased steadily.

Historically the thermal power system in Europe was fed by nuclear, coal, oil and gas and especially nuclear and coal fired thermal power plants delivered electrical energy to cover base load. The consumption varies during day and night and some coal fired plants were operated with spinning reserve that allowed great flexibility in power generation but were expensive and polluting. Today gas-powered plants are the source for flexibility to meet variation in power demand and variation in power generation from variable renewable electricity generation plants such as solar and wind power. Pump storage hydropower also has this possibility although they are normally designed for meeting the differences between consumption and base load production from thermal plants by a few stop-start operations per day and normally pump during

[28] Some distribution utilities still offer a discounted network tariff for consumption that can disconnect in case of network capacity constraints.

the night. Europe's consumption of energy is many times bigger than Norway's consumption. For example, Germany has approximately a consumption of 2500 TWh, while Norway has around 260 TWh. In Norway approximately 50% is electricity from renewable resources while only 20% is electricity in Germany, and firm power is based on thermal plants (nuclear, coal, gas). Norwegian hydropower could contribute on a limited scale to reduce the need for reserves in the old electricity system dominated by thermal plants. Today Norwegian hydropower can contribute to promote more renewable investments by exporting and importing in low and high peak generation periods. Connection to a large system dominated by thermal plants was seen as a power security for Norway especially in dry years. However, thermal generation also have constraints in dry years due to lack of water for cooling. Gradually, in the years to come variable renewable energy technologies like solar and wind power will dominate the electricity system and the flexible power plants is expected to increase in value.

This means a system with export and import but not necessarily export of large volumes.

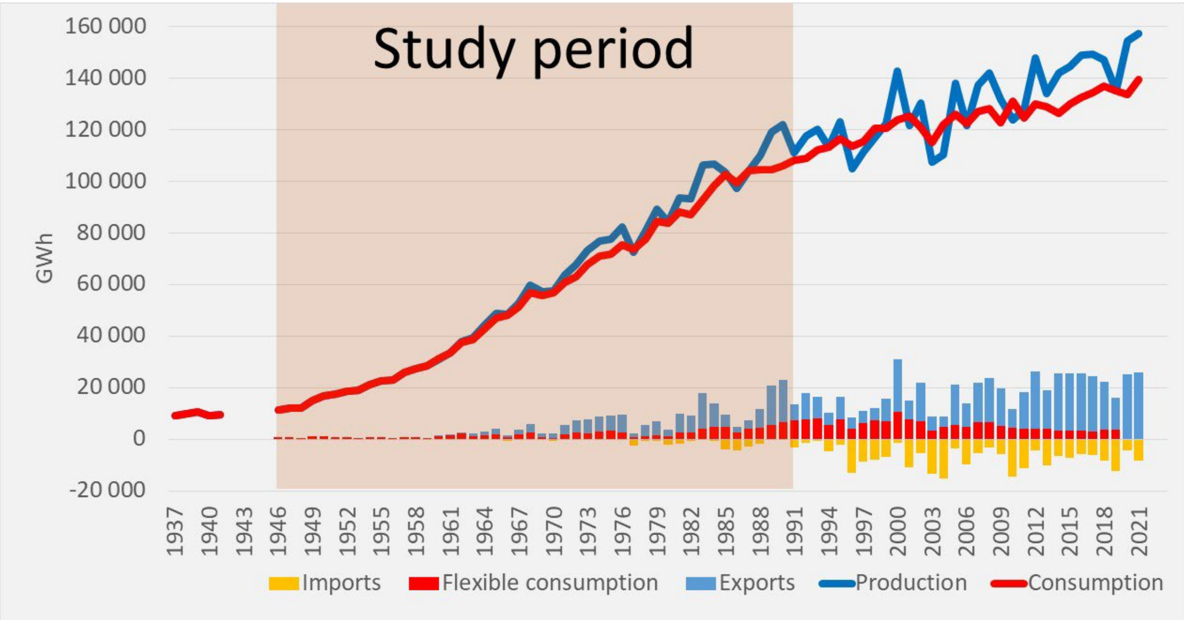


Figure A2-1. *Gross production and consumption of electricity, flexible consumption, power exports and imports.*

Foreign exchange risks

Overall, power sector exposure to foreign exchange risks was limited during the study period. The construction works were undertaken by national contractors, often a significant part of the equipment was manufactured in Norway (which is to a lesser extent the case today) and most of the investment capital was raised in the domestic capital market. However, projects co-financed with foreign loans, faced a significant foreign exchange risk, particularly after 1971.

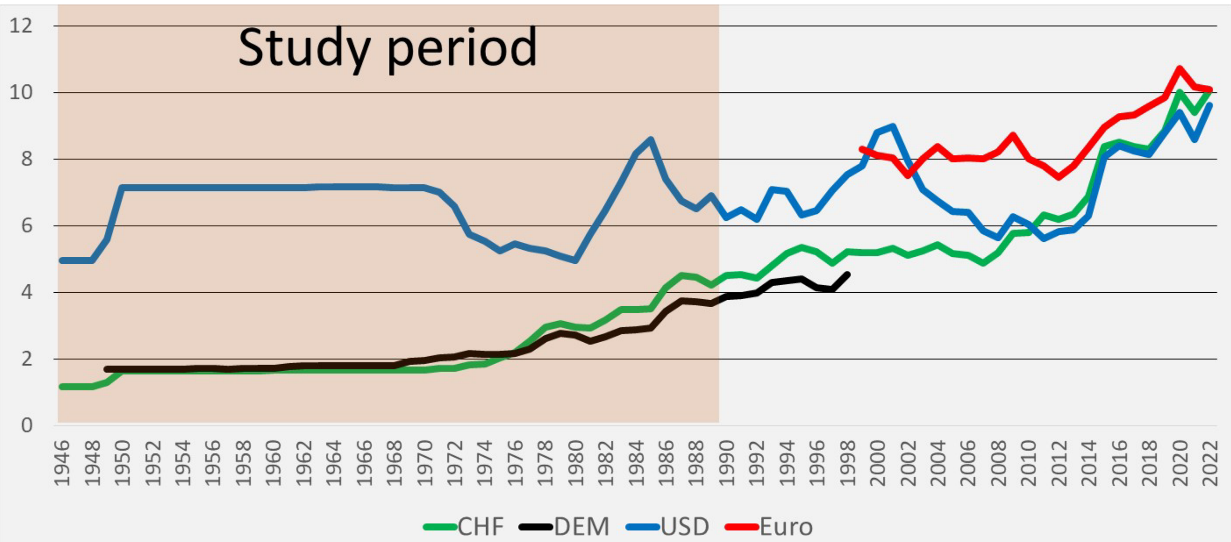


Figure A2-2. *Historic exchange rates of hard currencies compared to the Norwegian krone (NOK).*

In the first part of the study period, i.e. until 1971, the OECC[29]/OECD member countries, including Norway, adopted a monetary policy that maintained its external exchange rates within 1 percent by pegging its currency to gold and the ability of the International Monetary Fund (IMF) to bridge temporary imbalances of payments.

In the 1970s, the Norwegian krone weakened considerably against hard international currencies, such as DEM (West Germany) and CHF (Switzerland). The exchange rate between the Norwegian krone and the US dollar showed considerable fluctuations. The Government increased the discount rate in order stabilize the currency. As a consequence, the interest level in Norway became increasingly higher than in other OECD countries.

The lower foreign interest rate made foreign financing of hydropower projects attractive despite the exchange risk. While the Sira-Kvina project reported foreign exchange losses [25], the Orkla project benefitted from foreign loans [26]. At least one power company established a fund to mitigate foreign exchange losses [27].

[29] The Organisation for European Economic Cooperation (OEEC) was established in 1948 to run the US-financed Marshall Plan for reconstruction of a continent ravaged by war. OECC was succeeded by the Organisation for Economic Co-operation and Development (OECD) in 1961.

ANNEX 3. SECTOR CAPACITY BUILDING

Hydropower development after WW2 was highly dependent on the rise of of competency during the previous 50 years from approximately 1895-1945. During this period, the hydropower sector contributed to developing the skills needed for both financing, construction and use of electricity. A national supply chain of consultants, suppliers and contractors emerged. By the end of 1943, more than 2 000 power plants, mainly hydro, had been developed in Norway, ranging from a few kWs to more than 100 MW [5].

The success behind developing more than 400 large hydropower plants over a period of 45 years can be found in how the licensing was handled and backed by the use of state-of-the-art technology through cooperation between developer, consultant, manufacturer, contractor and research units in the universities.

Formal education

Many of Norway's hydropower pioneers were educated abroad, for instance in Germany, and had also work experience from other countries. However, other industries already had a knowledge base that the electricity industry could tap into.

Also technical institutes (vocational training) and the university already provided relevant technical and academic skills. The first technical institutes were founded in the 1870s and had roots back to an earlier silver mining institute. Norway's first university was founded in 1811.

In 1910, Norway's first technical university which today forms a part of the Norwegian University for Science and Technology (), NTNU, in Norway's third largest city Trondheim, was established, among others with a hydraulics department. A turbine testing laboratory was opened at NTNU in 1917. The accumulated experience from undertaken hydropower and transmission projects was also an important contributor to the national knowledge base.

Energy Research

In 1958, the Norwegian electricity research institute was officially established. The institute, which today constitutes a part of the research organization Sintef (SINTEF - Applied research, technology and innovation), is located adjacent to NTNU. It works in close cooperation with universities and the power industry. The Research Council of Norway (https://www.forskningsradet.no/en/) and the industry provides a substantial part of Sintef Energy's budget. Norwegian hydropower companies have a long history in funding research.

Among others, the Research Council and the energy industry provides funding to Centres for Environmentally Friendly Energy Research (FME). These centres carry out long-term research targeted towards renewable energy, energy efficiency, CCS and social science aspects of energy research. The centres selected for funding must demonstrate the potential for innovation and value creation. Research activities are carried out in close collaboration between research groups, trade and industry, and the public administration and key tasks include international cooperation and researcher training. The centres are established for a maximum period of eight years (5 + 3) and are hosted by universities and research centres.

Other capacity building

Knowledge management in the power sector has also taken place through trade journals, trade unions, trade societies, research and development and international cooperation.

The first trade organization for Norwegian electricity companies, Norske elektrisitetsverkers forening, was founded in 1901. Among others, the organization provided training of staff and knowledge management [28]. Today, its successor, Renewables Norway (English (fornybarnorge.no) provides capacity building through courses and conferences.

Also trade unions for technicians and engineers have also contributed systematically to capacity building of its members, often in cooperation with educational institutions and the trade associations. For instance, the Norwegian Engineer Association established expert committees related to concrete technology, rock drilling and blasting, tunnelling and dam construction and electrical and mechanical engineering].

The Polytechnic Society (https://www.polyteknisk.no) is a Norwegian forum for social and technical debates. It was founded on 23 June 1852 and published a periodical Polytechnic Journal from 1854.

International cooperation

NEK, The Norwegian Electrotechnical Committee (https://www.nek.no/english/), was founded in 1912. NEK became the 21st. member of IEC, The International Electrotechnical Commission. NEK is an independent and neutral organisation promoting electrotechnical standardisation and the use of standards at the national, regional and international levels. NEK has worked closely with the International Electrotechnical Commission (IEC, https://www.iec.ch/) founded in 1906 and with the International Council on Large Electrical Systems (CIGRE, https://www.cigre.org/) founded in 1921.

Norwegian power companies also undertook study tours abroad to study innovative technical solutions. Among others, the State Power Utility benefited from the experiences of the Swedish State Power Utility, among others within tunnel excavation].

At the same time as technical capacity building there has been an increase in the knowledge of the environmental impacts of hydropower production as well as remedial measures aimed at reducing the impact of hydropower on the environment including biodiversity. In the early 1960s Swedish scientist started studying the impact of reservoir management on fish populations. This was followed up in Norway by the then Directorate for Hunting, Game and Freshwater Fisheries and several pioneer studies were made notably in large hydropower reservoirs. In the light of increasing focus on the environmental impact of hydropower development, in 1969 the Watercourse Regulation Association instigated the founding of Freshwater Ecology and Inland Fisheries Laboratories (LFI) at the universities in Oslo, Trondheim and Bergen to conduct studies on the environmental impact of hydropower. The Norwegian Water Resources and Energy Directorate (NVE) also initiated R & D into the effects of regulation and possibilities for remediation in the Weir Project in 1975. This was followed up by successive R & D programmes, such as the Biotope Adjustment Programme and the Environmental Flows Programme. The Licensing Fund financed from licences and founded back in 1917 also provided funding for R & D on regulated rivers and lakes. Several other foundations and consulting companies, such as the Norwegian Institute for Nature Research (founded in 1988) followed up these investigations into the environmental impacts of hydropower and remedial solutions in the ensuing years. In the three decades after 1990 there have been four major R&D programmes on hydropower efficiency and environmental issues. All programmes were partly financed by the Research Council of Norway, Norwegian Hydropower associations, the larger hydropower companies, the industry and the water management authorities like NVE. In the period 1990-2000 two programmes were important, The EFFEN and the EFFEKT programmes focusing on efficiency, technology and the environment. The large R&D programmme CEDREN started around 2005 and developed solutions for more environmentally friendly hydropower development and the ongoing HydroCen research programme started around 2015 to highlight technology development and complete some of the environmental studies from CEDREN. Especially CEDREN and HydroCen has international partners and all outcomes are available from SINTEF, Trondheim (https://www.sintef.no/en/).

ANNEX 4. SOURCES

Data sources

The main sources are provided by Statistics Norway (www.ssb.no), and the Norwegian Water Resources and Energy Directorate (NVE, www.nve.no). For Statistics Norway, this includes statistical yearbooks, and annual electricity and credit market statistics.

Statistics Norway has since 1937 solicited annual returns from electrical utilities on installed capacities, production, electricity sales, employment, payroll costs and so forth, and since 1946 also on annual investments. Data for investor categories go back to 1946, while data for investment categories subsectors are available from 1957. From 1973 onwards, the electricity statistics also shows disaggregated data for transmission, sub-transmission and distribution. Also note that as of 1973, a new definition of gross capital formation was introduced.

Credit market statistics provide detailed information on power sector debt. However, the numbers are not fully consistent with the electricity statistics. The data also include water and gas supply, although it can be assumed that the power sector by far is the most dominant contributor to the aggregated numbers.

Monetary data

Monetary data should be understood as qualitative figures rather than exact numbers. For educational reasons, i.e. to facilitate the dialogue with a contemporary international audience, we have applied the following methodological approach: Firstly, historical nominal monetary data (in NOK) has been indexed to 2022 price level by applying the Norwegian Consumer Price Index (CPI). Secondly, the data has been converted to USD by applying the annual exchange rate as reported by the Central Bank of Norway (www.norges-bank.no/en/).

For these reasons, as well as technology development and site-specific conditions, presented data should not be used to estimate investment needs in other countries or to compare cost efficiency. For example, Norwegian hydropower was comparatively cheap during the study period.

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