Statistik / Statistics

Nordelstatistiken för 1983 är delvis preliminär. Vanligtvis är de justeringar som måste göras små. De införs i nästa års statistik

The Statistical data for 1983 are preliminary. The necessary adjustments, which are usually small, will be made in the next annual report.

Definitioner

I Nordels definitioner har de använda uttrycken följande betydelse:

Installerad maskineffekt i en kraftstation angives i MW och är summan av de enskilda aggregatens nominella effekt, inklusive stations- och reservenheter.

Överföringsförmåga för en kraftledning är den effekt i MW, som ledningen med hänsyn till en eventuell begränsning härrörande från de anslutna anläggningsdelarna kan överföra under normala förhållanden.

Elproduktion angives i GWh och är den produktion, som vederbörande land uppger i sin officiella statistik.

Mottrycksproduktion är elektrisk energi, som produceras i en turbogenerator med ånga, som efter turbinen används till ett annat ändamål än elproduktion, till exempel fjärrvärme, industriånga etc.

Kondenskraftproduktion är elektrisk energi, som produceras i en turbogenerator med ånga, som efter turbinen kondenseras så att ångans energi uteslutande utnyttjas till elproduktion.

Import och export av elektrisk energi angives i GWh och är de energimängder, som avräknas som köp och försäljning mellan de respektive länderna. Nettoimport är skillnaden mellan import och export.

Bruttoförbrukning av elektrisk energi angives i GWh och är summan av elproduktion och nettoimport.

Nettoförbrukning av elektrisk energi angives i GWh och är summan av de energimängder, som är levererade till och uppmätta hos förbrukarna samt de energimängder, som produceras i industrin för eget bruk.

Förluster är skillnaden mellan bruttoförbrukning och nettoförbrukning.

Tillfällig kraft till elpannor är elektrisk energi, som används för framställning av ånga eller hetvatten i stället för olja eller annat bränsle, och som levereras på speciella villkor.

Magasinskapacitet för ett vattenmagasin angives i GWh som den energimängd, som kan produceras i de nedanför liggande kraftverken vid en engångstömning av fullt magasin.

Definitions

Used expressions have the following meanings according to Nordel definitions.

Installed capacity is the installed generating capacity of a power station given in MW and constitutes the arithmetic sum of the rated capacity of the units installed, including station service and stand-by units.

Transmission capacity is the rated capacity in MW of a line with due regard taken to the limits imposed by the transformers connected to it.

Electricity production is given in GWh and represents that output the individual countries officially report.

Back pressure production is the production of electric energy by a generator set driven by steam which, when discharged from the turbine, is applied for a purpose irrelevant to power production (such as district heating, process steam etc)

Condence power production is defined as the output from a turbogenerator set operated by steam that is expanded in a cooling water condenser to enable the steam to be utilized exclusively for electric power generation.

Imports and exports is the exchange of power given in GWh for the commercial blocks of power delivered or received by the individual countries. Net import is the difference between import and export.

Gross consumption of electric energy is given in GWh and is the sum of domestic production and net import.

Net consumption of electric energy is given in GWh and is the sum of the power delivered to and metered at the consumers plus the power produced by industry for its own consumption.

Losses are defined as the difference between gross consumption and net consumption.

Excess power to electric boilers is defined as intermittent deliveries of temporary surplus power for raising steam or district heating in electric boilers on terms agreed on by the parties concerned.

Storage capacity of a reservoir is given in GWh and is equivalent to the power that is expected to be generated by all downstream power stations by full discharge of the impounded water.

Magasinsinnehåll vid en given tidpunkt angives i GWh som den energimängd, som kan produceras i de nedanför liggande kraftverken av magasinets vatteninnehåll över lägsta reglerade vattentillstånd.

Magasinsfyllnadsgrad vid en given tidpunkt angives i procent som förhållandet mellan magasinsinnehåll och magasinskapacitet.

Storage contents of a reservoir at certain times is indicated in GWh as being the quantity of energy which can be extracted from the water contents above the lowest regulated water level at all power stations below the reservoir.

Rate of storage contents at given time is given as a percentage of the total reservoir capacity in terms of GWh.

Enheter

Effekt	=	energi per tidsenhet
kW	=	kilowatt
MW	=	megawatt = 1000 kW
kVA	=	kilovoltampere
MVA	=	megavoltampere = 1000 kVA
Energi	=	produkten av effekt och tid
J	=	Joule
kJ	=	kilojoule = 0,24 kcal
TJ	=	terajoule = 10^{12}J = 23,9 toe
PJ	=	petajoule = 10^{15}J
kWh	=	kilowattimme = 3600 kJ
MWh	=	megawattimme = 1000 kWh
GWh	=	gigawattimme = 1 million kWh
TWh	=	terawattimme = 1000 GWh
	=	1 miljard kWh
Mtoe	=	1 miljon-ton-olje ekvivalent motsvarar 11,63 TWh

Symboler

—	Värdet noll
○	Mindre än hälften av den använda enheten
● ●	Uppgift inte tillgänglig eller alltför osäker för att anges
●	Uppgift kan inte förekomma

Units

Power	=	energy per time
kW	=	kilowatt
MW	=	megawatt = 1000 kW
kVA	=	kilovoltampere
MVA	=	megavoltampere = 1000 kVA
Energy	=	the product of power and time
J	=	Joule
kJ	=	kilojoule = 0.24 kcal
TJ	=	terajoule = 10^{12} = 23.9 toe
PJ	=	petajoule = 10^{15} J
kWh	=	kilowatt-hour = 3600 kJ
MWh	=	megawatt-hour = 1000 kWh
GWh	=	gigawatt-hour = 1 million kWh
TWh	=	terawatt-hour = 1000 GWh = 10^9 kWh
Mtoe	=	1 million tons of oil equivalent corresponds to 11.63 TWh

Symbols

—	Magnitude zero
○	Magnitude less than half of unit employed
● ●	Data not available
●	Category not applicable

Installerad effekt

Den sammanlagda installerade effekten i Nordelländerna steg under 1983 med 1 388 MW till 72 867 MW, dvs med 1,9 %. Den installerade effekten i vattenkraftstationer utgjorde ca 56 %. I Sverige och Finland fanns vid årets utgång totalt 9 565 MW kärnkraft.

Fördelningen mellan vatten- och värmekraft är mycket olika Nordelländerna emellan. I Danmark användes enbart värmekraft och i Norge enbart vattenkraft. På Island dominerar vattenkraften medan Sverige har ungefär lika stor effekt installerad i vatten- och värmekraft. I Finland utgör värmekraften drygt tre fjärdedelar av den installerade effekten.

Installed capacity

In 1983 the total net capacity in the Nordel countries increased by 1 388 MW to 72 867 MW. Of the total capacity 56 % consisted of hydro power. The nuclear capacity was 9 565 MW.

In Nordel the distribution of hydro and thermal power differs considerably. In Denmark the generating plants are entirely thermal, where as in Norway they are hydro. In Iceland hydro power predominates while Sweden has an equal amount of thermal and hydro installations. In Finland thermal amounts to more than 3/4 of the installed capacity.

Fig 9. Installerad effekt 1983-12-31 och korresponderande medelårsproduktion för installerad vattenkraft
Installed capacity Dec. 31.1983 and corresponding average-year production by hydro power

	Danmark	Finland	Island	Norge	Sverige	Nordel
Vattenkraft MW Hydro power MW	8	2 490	752	22 302	15 292	40 844
Medelårsproduktion, GWh Average-year production, GWh	20	11 880	4 000	100 212	61 798[4]	177 910
Värmekraft MW Thermal power	7 336	8 840	156[2]	278	15 413	32 023
Därav of which						
mottryck, fjärrvärme konv. back pressure, district heating conv.	277	1 590	—	—	2 469	4 336
mottryck, industriell back pressure, industry	—	1 540	—	165	882	2 587
kondens, process condence, process	—	110	19	54	—	183
kondens, kärn condence, nuclear	—	2 210	—	—	7 355	9 565
kondens, konventionell condence, conventional	6 771[1]	2 480	—	24	2 932	12 207
gasturbin, diesel gasturbine, diesel	288	910	137[2]	35	1 775	3 145
Totalt installerad effekt Total installed capacity 1983 MW	7 344	11 330	908[2]	22 580	30 705	72 867
1982 MW	7 423	11 270	904[3]	22 173	29 709	71 479
Nytillskott under 1983 MW Additions in 1983 MW	43	60	4	407	1 137	1 651
Bortfall under 1983 Retirements in 1983 MW	122	—	—	—	141	263

1) Inkl. kondensturbiner med uttag för fjärrvärme Incl. condensing turbines with some steam drawn for district heating
2) Härav geotermisk kraft 29 MW Of which 29 MW is geothermal power
3) Härav geotermisk kraft 26 MW Of which 26 MW is geothermal power
4) Nytt preliminärt utgångsvärde eftersom medelårsproduktionen baserats på ny årsserie (1950—80) för tillrinningsvärdena. New preliminary value based on the new inflow series for the years 1950—80.

Fig 10. Nya aggregat tagna i drift under 1983
New power plant capacity 1983

Kraftslag/ kraftstation Power category/plant	Nyinstallation under 1983 New units taken into operation			Totalt 83-12-31 Total	
	Antal aggr. Number of units	Ny effekt New capacity MW	Ökning av medelårsprod. Increase in average-year production GWh[1]	Inst. netto effekt Total installed net capacity MW	Medelårs-produktion Total average-year production GWh[1]
Danmark					
Vattenkraft Hydro power	—	—	—	8	20
Konv. värmekraft Conventional thermal power	1	1	g	7 336	•
Finland					
Vattenkraft Hydro power	2	22	111	2 490	11 880
Anjalankoski	1	19	90	19	90
Klåsarö	1	3	21	5	32
Konv. värmekraft Conventional thermal power				6 630	•
Inkeroinen	1	37	a	56	•
Kärnkraft Nuclear power	—	—	—	2 210	•
Island					
Vattenkraft Hydro power	—	—	—	752	4 000
Konv. värmekraft Conventional thermal power	••	4	—	156	•
Norge					
Vattenkraft Hydro power	••	407	1 979	22 302	100 212
Aurland	3	95	423	872	2 285
Årøy	1	91	306	91	306
Orkla/Grana	1	53	260	283	1 092
Rånåsfoss	1	45	112	45	131
Konv. värmekraft Conventional thermal power	—	—	—	278	•
Sverige					
Vattenkraft Hydro power	••	77	325	15 292	61 798[2]
Stenkullafors	1	56	235	56	235
Malgomaj	1	10	40	10	40
Konv. värmekraft Conventional thermal power	2	130	•	8 058	•
Helsingborg	1	55	k/o	55	•
Norrköping, Händelö	1	75	k	75	•
Kärnkraft Nuclear power	••	930	•	7 355	•
Ringhals B4	1	915	•	915	•

[1] Endast för vattenkraften. För nytillskott i konv. värmekraft anges bränsleslag (o = olja, k = kol, g = gas, t = torv, a = avfall)
Only for hydro power. For new conv. thermal power type of fuel is stated: (o = oil, k = coal, g = gas, t = peat, a = garbage, waste)

[2] Nytt preliminärt utgångsvärde p g a att medelårsproduktionen nu skall baseras på tillrinningsvärden för årsserien 1950—80.
New preliminary value based on the new inflow series for the years 1950—80.

Fig 11. Beslutade större kraftstationer.
Decided large power plants

Kraftslag/ kraftstation Power category/plant	Inst. netto-effekt 83-12-31 Installed net capacity MW	Medelårs-prod. 83-12-31 Average-year production GWh	**Beslutad nyinstallation** Decided new plants: Antal aggr. Number of new units	Ny effekt New capacity MW	Ökn. av medelårsprod. Increase in average-year production GWh[1]	Beräkn. idrifttagn. Estimated to be brought into service in
Danmark						
Konv. värmekraft Conventional thermal power						
Strudstrupværket	415	•	2	700	k/o	1984/85
H. C. Ørstedværket	181	•	1	88	k/o	1985
Amagerværket	256	•	1	235	k/o	1989
Avedøreværket	—	—	1	235	k/o	1991
Finland						
Vattenkraft Hydro power						
Vajukoski	—	—	1	21	68	1984
Raasakka 3	37	200	1	22	25	1985
Kollaja	—	—	1	40	180	1989
Konv. värmekraft Conventional thermal power						
Salmisaari	92	•	1	140	k	1984
Äänekoski	20	•	1	42	a	1985
Vaskiluoto	160	•	1	160	k/o	1985
Jyväskylä	35	•	1	80	t	1986
Joensuu	—	—	1	60	t	1986
Oulu	70	•	1	70	t	1987
Tampere	128	•	1	60	t/k	1988
Pori	—	—	1	60	k	1989
Island						
Vattenkraft Hydro power						
Blanda	—	—	3	150	750	1988
Norge						
Vattenkraft Hydro power						
Sjønstå	—	—	2	76	283	1984
Lomen	—	—	1	45	155	1984
Kvitingen	—	—	1	40	125	1984
Tjodan	—	—	1	90	310	1985
Ulla-Førre	780	2 828	6	1 280	1 519	1985/87
Naddvik	—	—	1	100	345	1986
Skarje	—	—	1	160	325	1987
Alta	—	—	2	150	687	1987/89
Kobbelv	—	—	2	300	691	1987/90
Sverige						
Vattenkraft Hydro power						
Messaure G3	300	1 834	1	150	0	1984
Stornorrfors G4	410	2 019	1	170	125	1985
Laxede G3	130	815	1	70	20	1987
Porsi G3	175	1 146	1	95	20	1988
Kärnkraft Nuclear power						
Forsmark B3	1 800	•	1	1 050	•	1985
Oskarshamn B3	1 020	•	1	1 060	•	1985

[1] Endast för vattenkraften. För nytillskott i konv. värmekraft anges bränsleslag (o = olja, k = kol, g = gas, t = torv, a = avfall)
Only for hydro power. For new conv. thermal power type of fuel is stated: (o = oil, k = coal, g = gas, t = peat, a = garbage, waste)

Det nordiska högspänningsnätet

Sverige har förbindelser med Danmark, Finland och Norge. Mellan Finland och Norge finns enbart ledningar för lokala leveranser från Norge till förbrukare i Finland. Vid årets utgång var den totala överföringsförmågan från Sverige ca 4 100 MW och till Sverige ca 3 400 MW. Mellan Danmark (Jylland) och Norge finns en likströmsförbindelse med överföringsförmågan 510 MW i vardera riktningen. Södra Jylland har 400, 220 och 60 kV-förbindelser med Västtyskland. Mellan Finland och Sovjetunionen finns en 600 MW likströmsförbindelse. Detta är den första stamnätsförbindelse av denna storleksordning mellan Sovjet och Västeuropa. Sedan tidigare finns en mindre samkörningsförbindelse mellan Norge och Sovjet, och lokala förbindelser mellan Finland och Sovjet. Island är ej elektriskt förbundet med övriga Nordelländer.

The grid system in the Nordel countries

Sweden is connected to Denmark, Finland och Norway. The latter two countries are not interconnected except for a few lines from Norway to Finland for local consumption there. The total capacity from Sweden was about 4 100 MW and to Sweden about 3 400 MW. The DC cable connection between Denmark (Jutland) and Norway has the capacity of 510 MW in both directions. From southern Jutland there are 400, 220 and 60 kV interconnection links to western Germany. Between Finland and the Soviet Union there is a 600 MW DC link. This is the first main grid connection of this size between the Soviet Union and western Europe. Between Finland and the Soviet Union and between Norway and the Soviet Union there have for many years been a number of local interconnections. Iceland is not electrically connected to the rest of the Nordel countries.

Fig 12. Överföringsledningar (km)
Transmission lines

	400 kV		220, 300 kV		110, 132, 150 kV	
	Tagna i drift under 1983 Brought into service in 1983	I drift 83-12-31 In service 83-12-31	Tagna i drift under 1983 Brought into service in 1983	I drift 83-12-31 In service 83-12-31	Tagna i drift under 1983 Brought into service in 1983	I drift 83-12-31 In service 83-12-31
Danmark	0	803[1) 2)]	0	223[2)]	10	3 307
Finland	0	3 029	0	2 152	400	11 900
Island	—	—	—	468	237	1 200
Norge	111	1 155[4)]	48	4 834[3)]	160	8 600
Sverige	26	8 789[1)]	75	5 740[3)]	• •	13 600[5)]

1) Inkluderar halva kabelförbindelsen (4 km) Sjælland—Sverige
Including half of the cable line (4 km) Zeeland—Sweden

2) Härav 293 km i drift med 150 kV, och 48 km med 132 kV
Of which 293 km in service with 150 kV, and 48 km with 132 kV

3) Härav 80 km i Danmark och 96 km i Sverige (Kontiskan) samt 89 km i Danmark och 151 km i Norge (Skagerak) i drift med 250 kV likström
Of which 80 km in Denmark and 96 km in Sweden (Kontiskan) and 89 km in Denmark and 151 km in Norway (Skagerak) with 250 kV DC

4) Härav 32 km i drift med 132 kV
Of which 32 km with 132 kV

5) Värde för 1982
1982 value

Fig 13. Nordels högspänningsnät
The Nordel main grid

Nordel Statistik/Statistics 1983

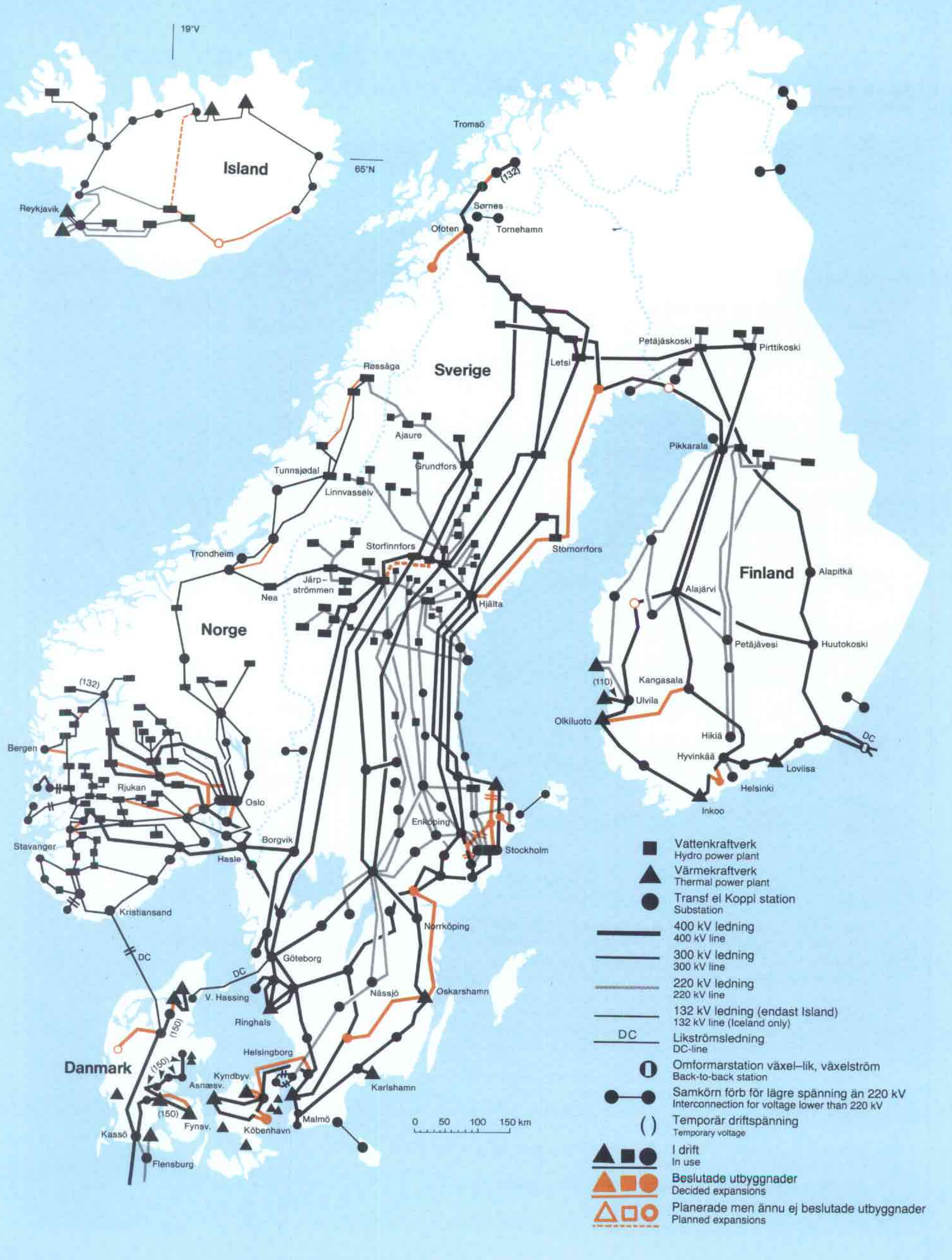


Fig 14. Samkörningsförbindelser mellan Nordelländerna
Interconnections between the Nordel-countries

Länder Countries	**Stationer** Terminal stations	**Nominell spänning** Rated voltage kV	**Överföringsförmåga** Transmission capacity MW		**Längd** Length km	**Kabel** Cable km
			Från Danmark From Denmark	Till Danmark To Denmark		
Danmark—Norge	Tjele—Kristiansand	±250 =	510	510	240/pol	127/pol
			Från Sverige From Sweden	Till Sverige To Sweden		
Danmark—Sverige	Teglstrupgård—Sofiero	132 ~	350[1]	350[1]	23	10[2]
	Hovegård—Helsingborg	400 ~	700[1]	700[1]	91	8
	Vester Hassing—Göteborg	250 =	260	260	176	87,5
	Hasle (Bornholm)—Borrby	60 ~	60	60	47,6	43,3
Finland—Sverige	Ossauskoski—Kalix	220 ~			93	
	Petäjäskoski—Letsi	400 ~	900 (for the preceding 3 stations)	400	230	
	Pikkarala—Messaure	400 ~			423	
	Hellesby (Åland)—Skattbol	70 ~	35	35	76,5	56
Norge—Sverige	Sørnes—Tornehamn	132 ~	200 (for the preceding 2 stations)	200	39	
	Ritsem—Ofoten	400 ~			58	
	Røssåga—Ajaure	220 ~	260[3]	100[3] [4]	117	
	Linnvasselv[5]	220/66 ~	50	50	—	
	Nea—Järpströmmen	275 ~	500[3]	500[3]	100	
	Lutufallet—Höljes	132 ~	40	20	17,5	
	Hasle—Borgvik	400 ~	1 100[3] [6] (for the preceding 2 stations)	1 100[3] [6]	106	
	Halden—Skogssäter	400 ~			110	
Totalt			4 615	3 935		
Beslutad: Decided:			Från Sverige From Sweden	Till Sverige To Sweden		
Danmark—Sverige	Hovegård—Helsingborg (1985)	400	[7]	[7]	91	8

[1] Även vid parallelldrift är totala överföringsförmågan 700 MW i vardera riktningen
At parallel operation of the interconnections the total transmission capacity amounts to maximum 700 MW in both directions

[2] Kabelsträckan består av fyra trefaskablar som är parallellkopplade två och två
The cable line consists of four three-phase cables which are parallel connected two by two

[3] Med hänsyn till slingdriften över flera samkörningsförbindelser Norge—Sverige och vissa andra driftsituationer kan dimensionerade felfall ge en lägre överföringsförmåga
Transmission capacity is in some cases reduced by dimensioning fault case

[4] 100 MW gäller vid maximal produktion i Gejmån—Ajaure—Gardikfors. Vid minimiproduktion i dessa stationer och maximalt 250 MW produktionsöverskott i Helgeland är överföringsförmågan 200 MW
100 MW maximum production in Gejmån—Ajaure—Gardikfors. With minimum production in these stations and 250 MW surplus production in Helgeland the transmission capacity is 200 MW

[5] Samkörningslänken är en 220/66 kV transformator i den norsk—svenska kraftstationen Linnvasselv
The interconnection consist of a 220/66 kV transformer in the Norwegian—Swedish power station Linnvasselv

[6] Efter nätutbyggnader i Norge (Oslo-området)ökar kapaciteten ca 100 MW
After extensions in Norway this will increase by 100 MW

[7] Överföringsförmågan efter utbyggnaden ännu ej fastställd
Transmission capacity is at present unknown

Fig 15. Maximal belastning 3:e onsdagen i december 1983
Maximum load on the 3rd Wednesday in December 1983

	Max kraftstations-belastning Max power station output Lokaltid Local time	MW	Installerad nettoeffekt Installed net capacity MW	Max systembelastning Max system load 1982 Lokaltid Local time	MW	1983 Lokaltid Local time	MW
Danmark							
Väster om Stora Bält (ELSAM) West of the Great Belt	8—9	1 800	3 685	17—18	2 575	8—9	2 600
Öster om Stora Bält exkl Bornholm (ELKRAFT) East of the Great Belt excl Bornholm	8—9	2 048	3 659	10—11	2 042	17—18	2 012
Finland	16—17	6 119	11 330	8—9	6 565	17—18	6 890
Island	18—19	570	908				
Norge							
Söder om (south of) 67,5° N	10—11	15 793	21 243	9—10	12 385	9—10	14 069
Norr om (north of) 67,5° N	16—17	933	1 337	14—15	819	15—16	936
Sverige	15—16	18 610	30 705	8—9	18 336	15—16	19 652
Nordel exkl Island (excl Iceland) Mellaneeuropeisk tid Central-European time	8—9	44 802	72 867	8—9	42 905	8—9	45 080

Elenergiomsättning
Electric energy turnover

Fig 16. Översikt över omsättningen av elektrisk energi i Nordel 1983
Review of the electric energy turnover in Nordel 1983

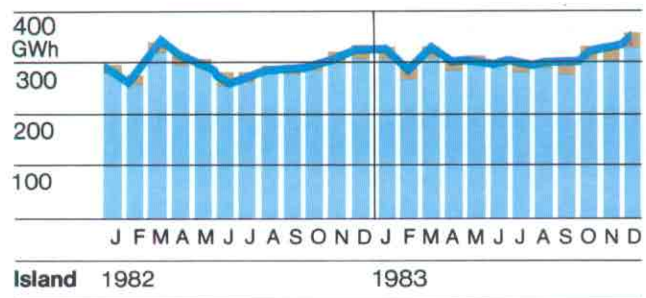
Fig 17. Elenergiomsättningen 1983 (GWh)
Electric energy turnover in 1983

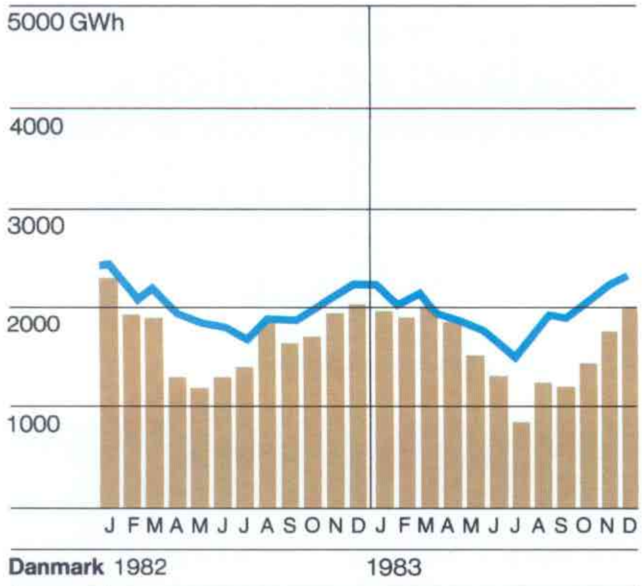
	Danmark	Finland	Island	Norge	Sverige	Nordel
Produktion Production	19 194	40 236	3 766	106 199	105 878	275 273
Därav vattenkraft Of this hydro power	20	13 376	3 588	105 870	62 771	185 625
Import	8 135	5 477	—	483	10 397	4 251
Total produktion och import Total production and import	27 329	45 713	3 766	106 682	116 274	279 524[2]
Export	2 390	679	—	13 885	5 449	2 162
Bruttoförbrukning Gross consumption	24 939	45 034	3 766	92 797	110 826	277 362
Tillfällig kraft till elpannor etc. Excess hydro power for electric boilers etc.	•	876	•	3 840[1]	4 715	9 431
Bruttoförbrukning exkl tillfällig kraft till elpannor etc Gross consumption excl. excess hydro power for electric boilers etc.	24 939	44 158	3 766	88 957	106 111	267 931
Förändring från 1982 % Change as against 1982 %	2,0	6,4	5,3	5,2	7,6	6,1

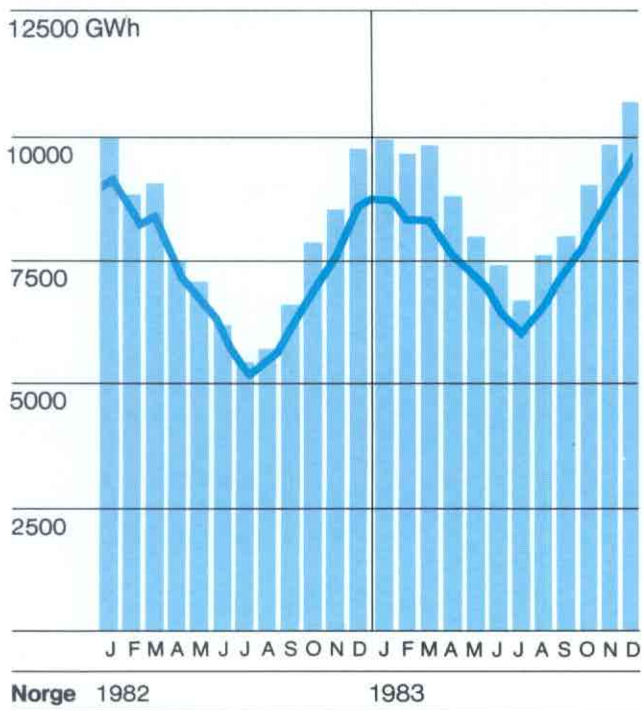
[1] Därav pumpkraft 480 GWh
Of this pumped storage power 480 GWh

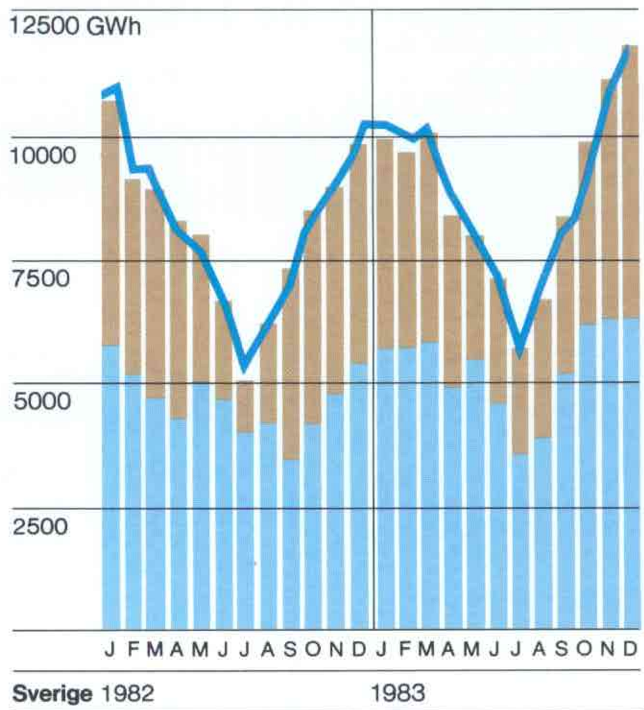
[2] Summan inkluderar utbyte med länder utanför Nordel
Total includes exchanges with countries outside Nordel

Fig 18. Produktion och bruttoförbrukning exkl avkopplingsbara elpannor
Production and gross consumption excl excess hydro power to electric boilers









Elproduktionen

Den totala produktionen inom Nordel var 1983 275,3 TWh, en ökning med 8,7 % jämfört med 1982. Vattenkraften svarade för 67,4 % och kärnkraften för 20,3 %. Motsvarande siffror för 1982 var 64,5 resp 21 %.

Electricity production

The total production in Nordel was 275.3 TWh in 1983. This is an increase of 8.7 % compared to 1982. Hydro power amounted to 67.4 % (64.5) and nuclear power to 20.3 % (21) of the total production.

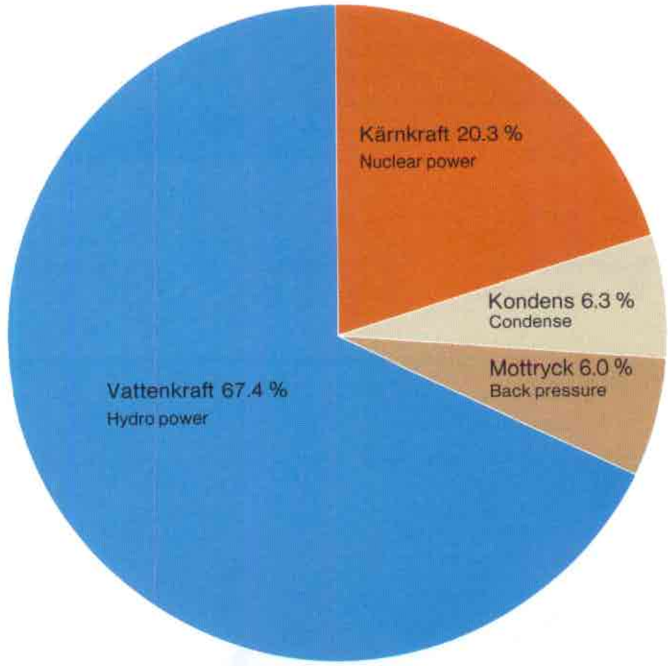


Fig 19. Totala elproduktionen i Nordel
Total electricity production within Nordel

Fig 20. Elproduktion (GWh)
Electricity production

	Danmark	Finland	Island	Norge	Sverige	Nordel
Vattenkraft 1983 Hydro power	20	13 376	3 588	105 870	62 771	185 625
Vattenkraft 1982 Hydro power	20	12 958	3 407	92 943	54 191	163 519
Värmekraft 1983 Thermal power						
Mottryck, fjärrvärme Back pressure, district heating	3 400	4 198	•	—	1 270	8 868
Mottryck, industri Back pressure, industry	257	4 646	•	158	2 458	7 519
Kondens, process Condense, process	—	374	—	—	—	374
Kondens, kärn Condense, nuclear	—	16 711	—	•	39 077	55 788
Kondens, konventionell Condense, conventional	15 407	802	•	79	174	16 462
Gasturbin, diesel m.m. Gas turbine, diesel etc.	110	129[1]	178[2]	92	128	637
Värmekraft 1983 Thermal power	19 174	26 860	178	329	43 107	89 648
Värmekraft 1982 Thermal power	20 706	26 397	168[3]	268	42 379	89 918
Total produktion 1983 Total production 1983	19 194	40 236	3 766	106 199	105 878	275 273
Total produktion 1982 Total production 1982	20 726	39 355	3 575	93 120	96 570	253 346
Förändring i procent Change, per cent	– 7,4	2,2	5,3	14,0	9,6	8,7

[1] Därav 125 GWh med naturgas Of this 125 GWh from natural gas
[2] Därav 172 GWh geotermisk kraft Of this geothermal 172 GWh
[3] Därav 159 GWh geotermisk kraft Of this geothermal 159 GWh

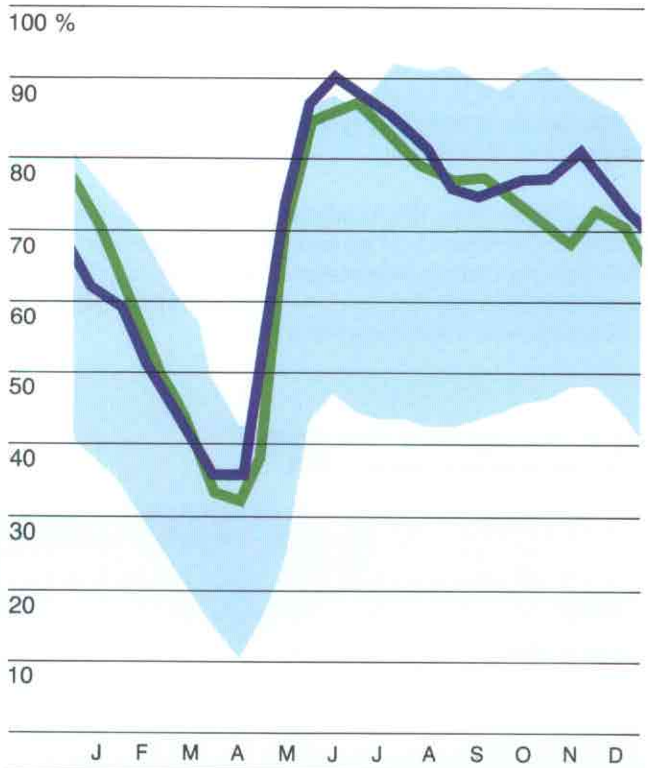
Fig 21. Magasinsfyllnad

Kurvorna visar magasinsfyllnaden i % av helt fyllda magasin under åren 1982 och 1983. De övre och under begränsningskurvorna för de senaste årens magasinsvariatoner är markerade. Begränsningskurvorna är högsta respektive lägsta veckovärden under perioden 1973—1982.

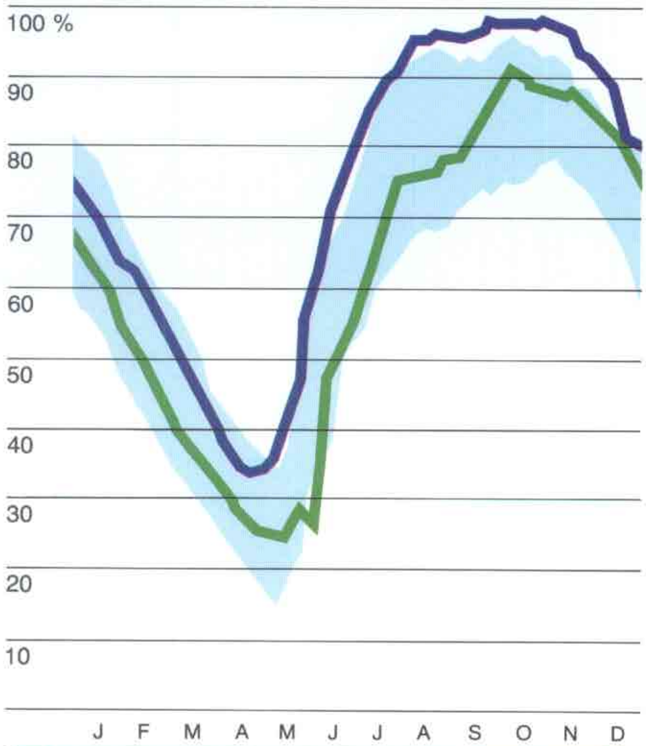
Water reservoir

The curves show the impounded water in per cent of total storage capacity for 1982 and 1983. The field gives upper and lower extremes which are composed of the weekly maxima and minima recorded for the period 1973—1982.

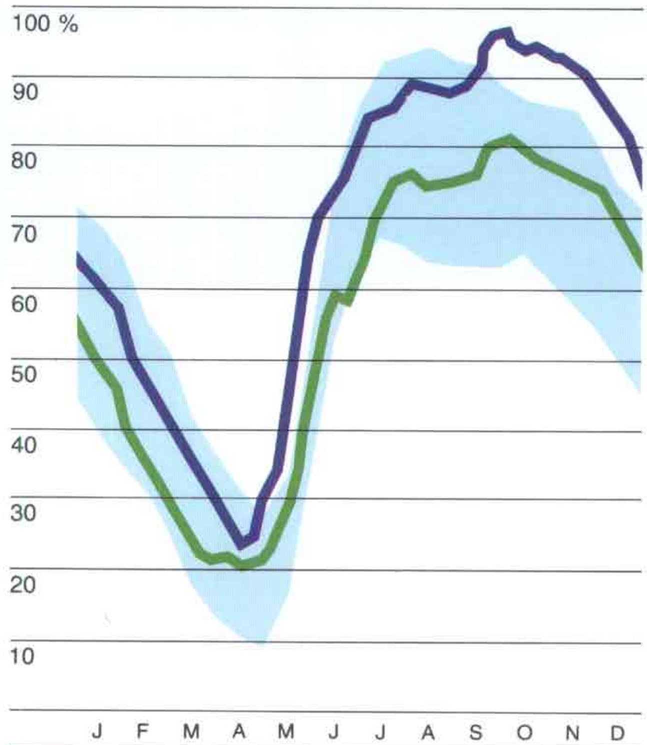
1982
1983
Extrema värden (1973-01-01 - 1982-12-31)
Extreme values



Finland	Magasinskapacitet Reservoir capacity	82-12-31 83-12-31	4546 GWh 4546 GWh



Norge	Magasinskapacitet Reservoir capacity	82-12-31 83-12-31	63352 GWh 64769 GWh



Sverige	Magasinskapacitet Reservoir capacity	82-12-31 83-12-31	32410 GWh 32670 GWh

Elenergiutbytet

Kraftexporten från Norge ökade kraftigt jämfört med föregående år. Danmark, Finland och Sverige var nettoimportörer under året.

Tabellvärdena avser det avräknade kraftutbytet. Om ett land exporterar el på en samkörningslinje, och samtidigt importerar motsvarande kvantitet el på en annan linje från samma land, medräknas båda utbytena i export- och importangivelserna.

Power exchange

The electrical energy export from Norway increased very much compared to 1982. Denmark, Finland and Sweden had a net import during the year.

Fig 22. Elenergiutbyte 1983 (GWh)
Exchange of electric energy in 1983

Export	Import till / Import to	Danmark	Finland	Norge	Sverige	Nordel-länder / Nordel countries	Andra länder / Other countries	Total export 1983	Total export 1982
Export från: / Export from:									
Danmark		•	•	8	220	228	2 162	2 390	694
Finland		•	•	•	679	679	—	679	1 738
Norge		4 387	—	•	9 498	13 885	—	13 885	6 825
Sverige		3 621	1 355	473	•	5 449	—	5 449	2 577
Nordel-länder / Nordel countries		8 008	1 355	481	10 397	20 241	2 162		
Andra länder / Other countries		127	4 122	2	—	4 251			
Total import	1983	8 135	5 477	483	10 397				
	1982	4 418	4 052	771	5 940				
Nettoimport	1983	5 745	4 798	− 13 402	4 948				
	1982	3 724	2 314	− 6 054	3 363				
Nettoimport/ bruttoförbrukning i % / Net import/gross consumption in per cent	1983	23,0	10,7	− 14,4	4,5				
	1982	15,2	5,5	− 6,9	− 3,4				

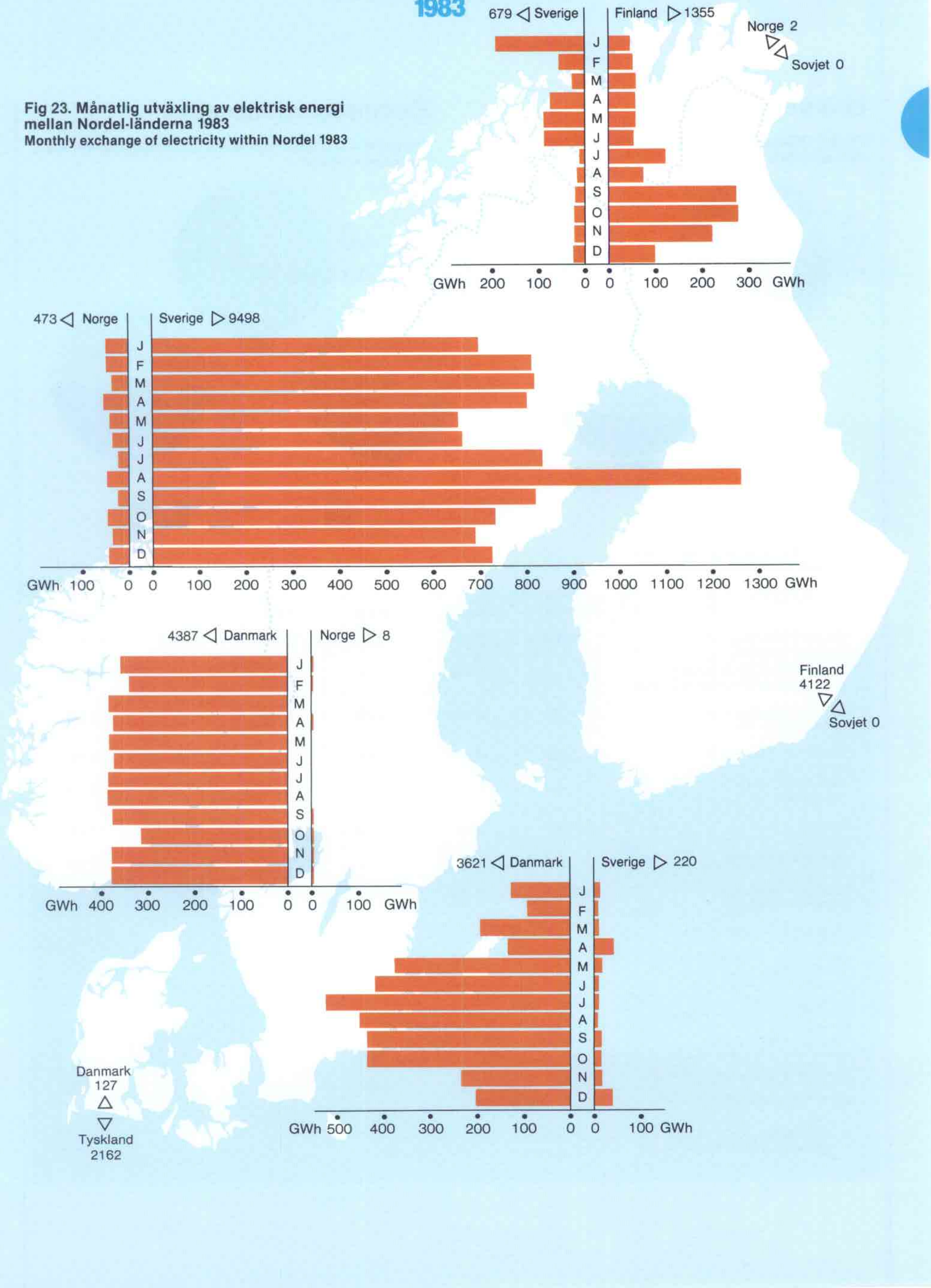


Fig 23. Månatlig utväxling av elektrisk energi mellan Nordel-länderna 1983
Monthly exchange of electricity within Nordel 1983

Elförbrukningen

Electricity consumption

Fig 24. Elförbrukningen fördelad på konsumentgrupper exkl elpannor

Electricity consumption distributed on consumption groups Excl electric boilers

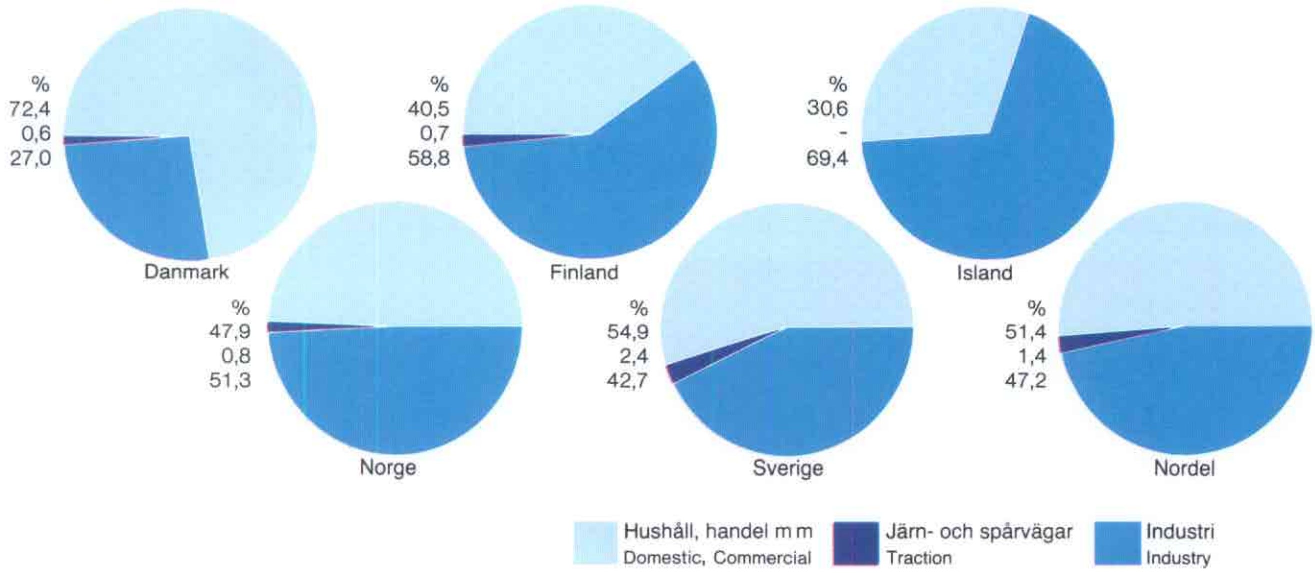
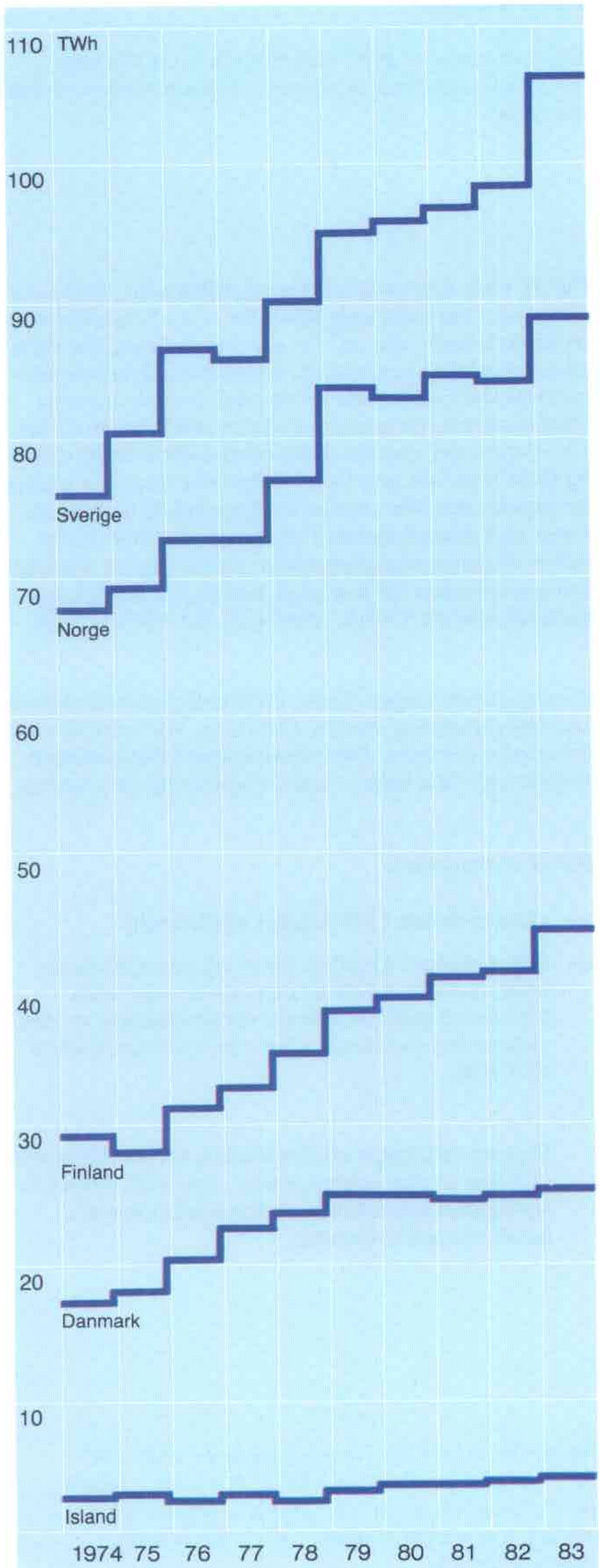


Fig 25. Elförbrukning 1983, GWh
Electricity consumption 1983

	Danmark	Finland	Island	Norge	Sverige	Nordel
Bruttoförbrukning Gross consumption	24 939	45 034	3 766	92 797	110 826	277 341
Tillfällig kraft till elpannor Excess hydro power to electric boilers	—	876	—	3 840[2]	4 715	9 431
Bruttoförbrukning[1] Gross consumption	24 939	44 158	3 766	88 957	106 111	267 910
Förluster Losses	2 539	2 484	400	10 036	9 735	25 194
Nettoförbrukning Net consumption	22 400	41 674	3 366	78 921	96 376	242 716
Industri Industry	6 050	24 500	2 336	40 490	41 154	114 530
Järn- och spårvägar Traction	140	304		650	2 330	3 424
Hushåll, handel m.m Domestic, commercial	16 210	16 870	1 030	37 781	52 892	124 783
Förändring av bruttoförbrukningen jämfört med föregående år i %[1] Change in gross consumption as against previous year, %	2,0	6,4	5,3	5,2	7,6	6,1
Genomsnittlig förändring av bruttoförbrukningen under de sista 10 åren i %[1] Average change in gross consumption in the last 10 years, %	4,0	4,1	5,1	3,1	4,3	3,4
Bruttoförbrukning per invånare i kWh[1] Gross consumption per inhabitant	4 880	9 092	15 800	21 508	12 740	11 891

[1] Exkl tillfällig kraft till elpannor — Excl. excess hydro power to electric boilers.
[2] Därav pumpkraftverk 480 GWh — Of which pumped storage power 480 GWh.



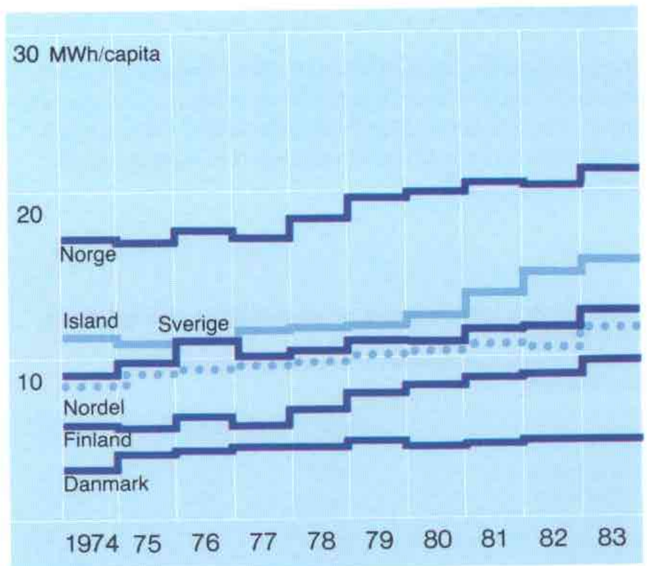


Fig 27. Bruttoförbrukning[1] av elenergi per invånare
Per capita consumption[1]

[1] Exkl tillfällig kraft till elpannor
Excl. excess hydro power to electric boilers

Fig 26. Bruttoförbrukningen[1] av elenergi 1974—1983
Gross consumption of electricity

[1] Exkl tillfällig kraft till elpannor
Excl. excess hydro power to electric boilers

Prognoser

Prognoserna för åren 1985 och 1990 bygger på kraftföretagens egna värderingar om den sannolika utvecklingen. Prognoserna ligger till grund för utbyggnadsplaneringen av kraftöverföringssystem och produktionsanläggningar.

Fig 28. Faktisk och prognoserad elenergiförbrukning TWh/år exkl elpannor
Electrical energy consumption, and forecast TWh/year excl. electric boilers

	1983	1985	1990
Danmark	24,9	26	30
Finland	44,2	48	56
Island	3,8	4	5
Norge	89,0	96	104
Sverige	106,2	114	130
Nordel totalt	268,1	288	325

Fig 29. Faktiska och prognoserade eleffekter MW
Power and power forecast MW

	1983	1985	1990
Danmark	4 955	5 250	6 100
Finland	7 600	8 200	9 400
Island	570	630	820
Norge	15 300	17 400	19 100
Sverige	20 862	22 100	25 000
Nordel totalt	49 287	53 580	60 420

Fig 30. Faktiska och prognoserade installerade effekter i MW inom respektive land (värden per 31.12 respektive år)
Installed and forecasts for installed capacity in MW in each country (valid per Dec. 31.)

	1983	1985	1990
Danmark	7 344	8 000	7 800
Finland	11 330	11 700	12 250
Island	908	900	1 050
Norge	22 580	23 700	26 550
Sverige	30 705	33 100	33 550
Nordel totalt	72 867	77 400	81 200

Forecasts

The forecasts for 1985 and 1990 in the following tables are made by the power companies in the Nordel countries.

Fig 31 visar den faktiska elenergitillförseln 1980 samt prognoser för 1985 och 1990. De olika Nordelländerna utom Island visas var för sig. Uppdelning har skett på kategorierna vattenkraft, kärnkraft och annan värmekraft med angivande av de olika bränsletyperna. Vattenkraften i prognosen avser medelårsproduktion. För Norges del innebär detta betydande mängd tillfällig kraft som kan utnyttjas i inhemska elpannor och/eller exporteras. Den norska kraftproduktionen förutsättes vara dimensionerad med extra fastkraftreserv utöver förbrukningsprognosen, jämför fig 28. Produktionspotentialen för fast kraft inkl importrättigheter förmodas bli 99 TWh/år 1985 och 112 TWh/år 1990.

Elenergifördelningen visas i jämförelse med ländernas energiförbrukning utanför elsektorn. För varje år visas två staplar per land. Den vänstra anger fördelningen av elenergi. Den högra visar övrig energiförbrukning.

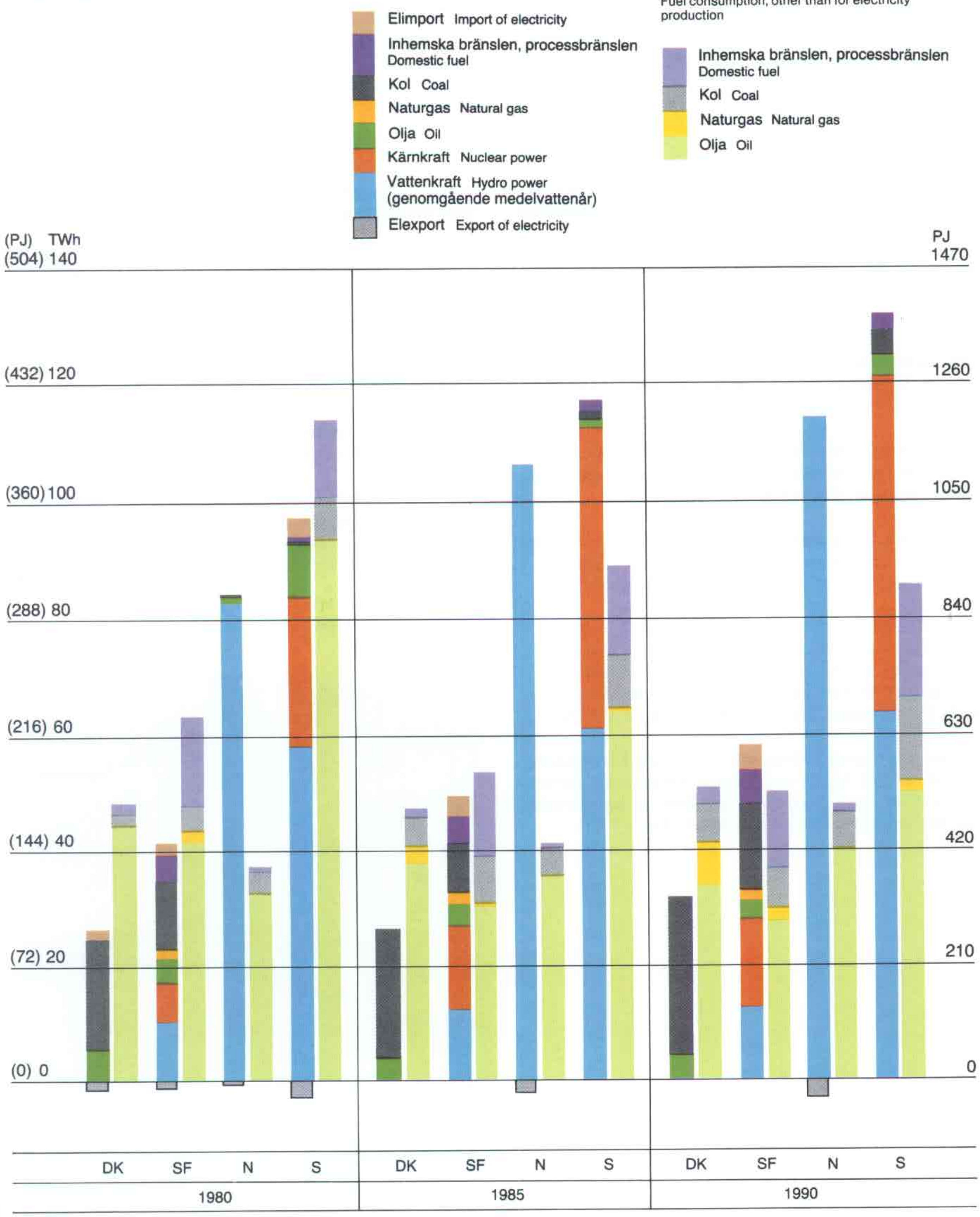
För skalorna gäller:

- vänstra skalan i TWh gäller eltillförseln
- högra skalan i PJ gäller för övrig energiförbrukning, och är vald så att den också visar vilka bränslemängder som åtgår till produktion av den elektricitet som ingår i den vänstra stapeln (10,5 PJ/TWh).

Figuren möjliggör en jämförselse mellan elsektorn och den övriga energisektorn. Speciellt tydligt visar figuren vattenkraftens dominerande roll i norsk energiförsörjning.

Figure 31 shows the energy supply in 1980 and the forecasts for 1985 and 1990. For each country the distribution of electric energy supply (left) and the total energy supply except electricity (right) is shown.

Fig 31. Energitillgång i Norden
Energy supply within the Nordic countries



Total energitillförsel

I äldre tider var de nordiska länderna i stort sett självförsörjande på energi. Ved var den främsta energiråvaran fram till en god bit in på 1800-talet. Från omkring år 1900 började kol och koks att svara för en större del av energiförsörjningen än ved. Omkring 1950 övertog oljan kolets roll som den viktigaste energiråvaran.

Under 1800-talets senare del började vattenkraften användas för elproduktion, och sedan dess har elandelen i energiförsörjningen ökat ganska jämnt.

I början av 1970-talet introducerades kärnkraft i Finland och Sverige och den svarar nu för en betydande del av elförsörjningen i Norden.

Efter oljekrisen 1973 har målet varit att minska oljeberoendet. Detta har bl a resulterat i att kol har kommit tillbaka och har börjat ersätta olja.

Idag är alltså Norden långt ifrån självförsörjande på energi och en övervägande del av bränslet importeras främst i form av olja och kol.

De inhemska energiråvaror, som är av någon större betydelse, är förutom vattenkraften ved, torv (Finland), kol (Svalbard, Norge) och geotermisk energi (Island).

Olje- och gasfyndigheter finns i de nordiska delarna av Nordsjön och från 1974 har de norska fyndigheterna utvecklats till en årsproduktion av 30,6 miljoner ton olja och 25,6 miljarder kubikmeter gas under 1983. Tillsammans motsvarar detta cirka 2 350 PJ.

Figuren visar energitillförselns utveckling i Danmark, Finland, Island, Norge och Sverige under tioårsperioden 1974-83. Vattenkraft och kärnkraft är omräknade efter det teoretiska energiinnehållet, dvs 1 TWh = 3,6 PJ.

Total energy supply

Long ago the Nordel countries were self-supporting for their energy supply. The main energy source was wood. Later a change occured and coal became the prime source. From about 1950 oil was the most common source of energy.

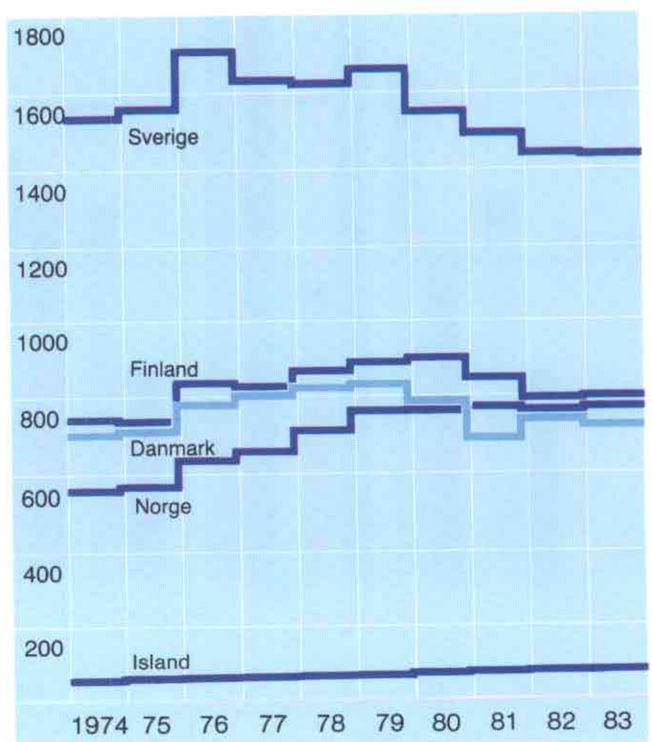
About a century ago hydo power was introduced and it now accounts for an important share. Nuclear power came about 1970 and is very significant in Finland and Sweden.

Today the Nordel countries for their energy supply are highly dependent on imported oil and coal. However, since the oil crises in 1973 the goal has been to became less dependent on imported energy.

The domestic sources of energy in the Nordel countries are hydro power, wood, peat, coal on Svalbard, Norway and geothermical energy on Iceland. The oil and gas from the north-sea in 1983 amounted to 30.6 miljon tons of oil and 25.6 billion m^3 of gas.

The figure shows the energy supply in the Nordel countries during the period 1974-83. Hydro and nuclear power are valued according to their theoretical energy content, i.e. 1 TWh = 3.6 PJ.

Fig 32. Total energitillförsel PJ
Total energy supply



English Summary

Nordel 1983

The electricity consumption in the Nordel countries increased by 6,1 % compared to 1982. Denmark had the lowest and Sweden the greatest increase.

The hydro production, which is the base of the Nordic power production, amounted in 1983 to 67.4 % of the total production. This is almost 3 % more than the previous year. Nuclear power was 20.3 % of the total production.

The oil based power production in the Nordic system is small. Oil is used only in combination with district heating och industrial back-pressure. In Denmark coal is used for most of the production. Nuclear power was produced in Finland and Sweden.

In 1983 the power exchanges between the Nordel countries set a new record. Thanks to the very high hydro production Norway had a net export while Denmark, Finland and Sweden had net import.

Nordel's Activities in 1983

The ordinary annual meeting of Nordel was held in Bergen, Norway on August 24. At the meeting the actual power situation within the five Nordic countries and future prospects were reviewed. There were also reports from a number of committees and ad hoc working groups beeing responsible for and coordinating the work within Nordel, and the Nordelś contact group within various international organizations.

The Nordel meeting gave its approval of the recommendations by the Operating Committee about maintaining frequency in the synchronous Nordel system. An article about this is included in this report.

The report » Coordinated expansion of production within the Nordel system» was presented by the Planning Committee. A very short summery which can be regarded as a complement to the report NORDENERGI 2020 is also included in this annual report.

The Nordic norm for sulphur emission was discussed and the Thermal Power Committee was asked to study the matter.

At the meeting Mr. Eirikur Briem resigned and Mr. Halldor Jonatansson was elected as the new Icelandic member.

During the year Nordel has worked unusually much with external infomation. The governments and departments of the Nordic countries, the Nordic Council and Council of Ministers have been informed with a series of newletters. A new version of the Nordel brochure has been produced. There have been special meetings with the Nordic Council and on two occations representatives of Nordel have meet the Nordic ministers of Energy. At the 32nd session of the Nordic Council in Stockholm Nordel had an exhibition which was opened by the Swedish minister of Energy Birgitta Dahl.

Operations Committee

As in previous years, the Committe dealt continuously with questions regarding joint operations, such as power balances in the Nordic countries, power exchanges between the Nordic countries, operational reliability, technical aspects of operations and interruptions within the Nordic power system.

.Output and energy balances have been prepared for the next three years in order to evaluate the power situation during this period. A very satisfactory energy balance is anticipated.

There was a definite increase in electricity consumption in the Nordel area. The increase was particularly noticeable in Finland, Norway and Sweden. The economic upswing in industry was a major factor contributing to the increase. Another contributing factor in Sweden was the current process of conversion oil-fired to electrical heating.

The hydro power situation in the Nordel system was very favourable in 1983. The spring floods were earlier and larger than normal. The autumn floods were also very large. In Sweden and Norway, the hydro reserves available after the autumn floods were therefore the largest for the past ten years. In 1983, about 7 TWh of hydro power was spilled past on-stream units in Norway and Sweden.

Nuclear power plants functioned very well in 1983. In order to maintain power balances, nuclear production was reduced by about 2 TWh, primarily in

Sweden. The cause of the reduction was the very favourable hydro power situation.

Very large quantities of power were exchanged between the Nordic countries during the year. The high level of hydro production generated very large exports from Norway to Denmark and Sweden as well as from Sweden to Denmark. Sweden also exported relatively large quantities of power to Finland.

With reference to the current power situation, in 1983 the Committee decided that:

- Residual hydro reserves should be distributed within the Nordel system so as to obtain optimal division of the risk of overflow.

- Production based on fossil fuels should be minimised.

- Exports to Denmark should be maximised, including re-exports to West Germany.

- Deliveries to electric boilers should be utilised as much as possible.

- Installation of new electric boilers should be accelerated and tax regulations should be modified accordingly.

On December 27, 1983 a comprehensive power outage in Sweden had serious consequences for Nordic power supplies. A busbar fault in a 400 kV transformer station near Stockholm resulted in a breakdown of the main grid in southern and central Sweden. All the nuclear plants in Sweden were put out of action, as were most of the tie-lines between the Nordic countries. The total power capacity of 17,000 MW was reduced by 11,400 MW. The outage lasted between one and six hours in the areas affected. Electricity consumption was cut by 24 GWh during the outage, which corresponds to 120 system minutes as defined by Nordel. Some parts of Denmark were also affected. Production on the island of Zealand was reduced when the link to Sweden was cut off, so that consumption was reduced by about 30 %. Resumption of power supplies following the outage included imports of 1,200 MW from Norway and 1,000 MW from Denmark, which enabled normal consumption to be restored much faster.

The Operations Committee will follow up the investigation of the breakdown which will be made in Sweden. This investigation is intended to determine whether changes should be made in existing recommendations for emergency reserves, grid protection and composite regulating characteristics.

In 1983 the Committee initiated a study of all power exchanges between the Nordic countries. The goal is to determine whether exchanges are optimal from the standpoint of over-all economy. The results of this study will provide a basis for a coming review of the 1971 regulations for coordination of Nordic electricity supplies.

The Nordel Annual General Meeting of 1983 approved the Committee's proposal entitled »Recommendations for frequency controlled grid protection in the synchronous Nordel area». These recommendations include rules for automatic disconnection in frequency stages in case of overloads, as well as for automatic adjustment of power transmission over DC links.

The Committee dealt with the question of the magnitude of the composite regulating characteristic at low load periods. A pilot operation with a reduced composite regulating characteristic was implemented in the summer of 1983. As a result of the high levels in reservoirs, it was not possible to run the system with a reduced criteria for composite regulating characteristic to any significant extent. A similar pilot operation will therefore be implemented in 1984.

Tests have been initiated for new settings of damping equipment in power stations. The new settings contribute to improved damping of fluctuations in the power system and will be introduced gradually.

The Committee has authorised a study of power balances in dry years through 1990.

Early in May, 1983 the Committee attended a meeting in France with its continental counterpart, UCPTE, at which a valuable exchange of experience took place. The next such meeting is scheduled for October, 1984 in Sweden.

Mr. Rolf Wicdswang resigned during the year and Mr. Arne Ring-Nielsen replaced him as chairman.

Planning Committee

In the 1982 NORDENERGI 2020 report, the Planning Committee indicated the possibility of obtaining additional economic benefits from Nordel cooperation by treating the jointly operated Nordic power electrical system as a single unit without national boundaries. In the interest of analysing this possibility more closely, working group has prepared a survey entitled ADVANTAGES OF EXPANDED NORDIC ELECTRICAL COOPERATION (an optimisation study), which covers the period through the year 2000. Coordination of high-voltage grids has already gone so far that the joint system can in principle be treated as one unit. The new study has therefore concentrated on the benefits of increased coordination of production. Three alternatives for expansion of production have been studied. These alternatives indicate the various conditions for expansion of hydro, nuclear and coal-condense power. Each of the alternatives is analysed on the basis of interest rates of 4 %, 7 % and 9 %. The conclusion drawn is that by the year 2000 conditions should permit a reduction of the expansion of production in the joint Nordel system. This applies to all three of the alternatives studied. The reduction is small for the alternative which assumes continued expansion of hydro and nuclear power. A brief presentation of the conclusions presented in the study can be found on page 31.

The study could not deal with all the important factors which can be assumed to have an effect on the result of calculations. The Planning Committee is preparing more detailed analyses of the relevant uncertain factors.

A working group for production questions was appointed in the autumn. The group, which is currently functioning ad hoc, replaces the previous contact man for production questions. Its initial activities will consist of collection and systematisation of data for production units in the Nordel system. It will also identify various computational models for production studies, which will be evaluated for various types of studies. An important task for the group will be to provide the necessary production data for the grid-analysis group's studies of transmission capacity on tie-lines between the Nordel countries. The production group will also participate in the analysis of uncertain factors in the optimisation study.

The work of the grid-analysis group was concentrated mainly on studies of appropriate transmission capacity for grid links in 1990. A report containing a proposal in this regard is scheduled for presentation at the Nordel Annual Meeting of 1984. The group will also analyse the uncertainty factors in the optimisation study with reference to the expansion of grids which may be necessary for increased power exchanges between countries.

The Planning Committee issued a report entitled HVDC Transmission in the Nordel Countries in 1983. This report was prepared primarily as a basis for current work by the Electricity Committee of the ECE (Economic Commission for Europe) regarding increased electrical cooperation between Eastern and Western Europe, for which DC current is an attractive alternative.

Nordel has instructed the Planning Committee to monitor developments in the field of renewable energy. The Committee has therefore issued a report on Identification of projects in the field of wind power and geothermal power, in which power companies are participating or on which they are well informed. The report was approved at the Nordel Annual Meeting in 1983.

An ad hoc-group for heat pump questions was appointed to monitor activities related to heat pumps in the Nordic countries.

In response to an inquiry from the Nordic Ministerial Council's Official Committee on Energy Policy, a report on The cost of various types of power production is being prepared in cooperation with the Thermal Power Committee.

The Planning Committee is also working on reports dealing with interest rates and calculation methods and on criteria for reliability of deliveries of electricity used by power companies in the Nordic countries. These reports are scheduled for presentation to Nordel during 1984.

In cooperation with the Thermal Power Committee and the NKA (Nordic Contact Agency for Nuclear Energy), preparations are being made for a seminar on the economy of nuclear power. The seminar is scheduled for the winter of 1984—1985.

The Planning Committee is also preparing studies on the general subject the role of electrical energy in relation to energy. Statistical material on the development of electrical energy and total energy in the Nordic countries was collected and processed in the course of the year.

The chairman of the grid study group is participating as Nordel's representative in a working group within Unipede, that is studying the actual transmission of power on tie-lines in Western Europe in relation to transmission capacity. The Planning Committee has submitted a data base on the Nordic tie-lines to this group. The Unipede report is scheduled for completion in the autumn of 1984.

Thermal power Committee

The committee and its working groups have through meetings and seminars during the year promoted the exchange of experience within the thermal power field. Urgent matters have been given special attention.

The annual report from the committee's group for nuclear fuel states that there is a continued ample access to raw uranium and capacity for enrichment and fuel production. The report expands on the treatment of spent fuel and the related costs. The total operating cost related to the nuclear fuel is estimated to SEK 0.06-0.07/kWh for a power plant that is taken into operation in 1995.

The committee's operation and maintenance group has dealt with different matters as e g condition control and efficiency control of thermal power plants. The group has published the yearly report on »Availability Statistics for Thermal Power Plants» where availability and outage data are given for Nordic gasturbines and fossile and nuclear power plants. At a seminar for maintenance managers experiences were shared or matters as maintenance strategies, computer-based maintenance information system and maintenance procedures for boilers and turbines.

Two other seminars has been arranged during the year by the committee. The first presented the foundings of the Swedish »Coal-Health- Environment» project, where ways to deal with the health and environmental problems connected with increased use of coal power in Sweden are given. At the second seminar, concerning material problems associated with thermal power plants, issues as the longevity of components, different kinds of corrosion and choice of material were discussed.

The thermal power committee has been asked by Nordel to follow the Nordic work on a common standard for sulphuric discharge in order to allow a proper impact from the power companies on the future work by the Nordic Council.

At the request of the Nordic Council of Ministers, the committee is together with the Planning Committe performing a survey on the expected production cost of future power production in the Nordic countries.

The research and development activities within the thermal power field have been followed by the committee. Special attention has been given to the work by NKA (the Nordic Contact Organization for Nuclear Energy) and its project on »Human Reliability» (LIT) has been presented to the committee. Certain projects concerning nuclear power, as well as the problems of desulphurization and the handling of fly ash will be followed specially.

Other matters treated by the committee are e g

— the use of Life Cycle Cost (LCC) analyses

— the information to the public concerning the safety and the waste disposal connected with nuclear power

B Møller Jensen from Sønderjyllands Højspændingsværk has joined as a new member during the year.

Denmark

Economic development

There was a perceptible easing in 1983 of the balance of payments problems that have marked the economy of Denmark in recent years. The balance of payments deficit was reduced to 10.5 milliard DKK as against 18.5 in 1982. Growth in prices and incomes was halved. At the same time there was a pronounced fall in the level of Danish interest rates. Finally, several years increase in the number of unemployed came to a standstill. The rate of unemployment, adjusted for seasonal variations, has thus remained largely unchanged since the spring of 1983. This implies that employment in the private sector was increasing for the first time in a number of years.

This favourable state of affairs is the result of widespread economic and political intervention: outside factors have played a part too. Energy prices and the level of international interest rates have been decreasing. Moreover, industry had the benefit of improved conditions of export markets following upon slight but obvious signs of an upswing in the outlook for international trade.

Improved marketing conditions led in 1983 to an increase in production in the private urban trades of 3 % compared to 2 % in 1982. The growth in the gross national product remained, however, at 2.5 % because growth in the public sector was weaker.

This encouraging picture of the economy in 1983 is also expected to hold good in 1984. Employment, incomes, prices and the deficit in public finances are thus expected to continue to develop positively, but a deterioration is expected in the balance of payments.

Energy policy

The Danish government confirmed in 1983 the main lines of its energy policy, which has hitherto enjoyed widespread support. This multi facetted policy will thus continue to have as its objective to ensure that society has access to energy at lowest possible prices, to reduce vulnerability to failures of supply, and to increase the efficiency of energy utilization.

Attempts are made to further as fas as possible the prospecting for and extraction of Danish sources of energy. For example, steps were taken to include a number of new oil and natural gas concessionaries in such activities. Dansk Undergrunds Consortium — hitherto the sole concessionary — recovered in 1983 some 2.5 million tons of oil, corresponding to about 15 % of Denmarks's gross energy consumption. The production of natural gas will be initiated in 1984, and oil production will be further increased at the same time.

The purposeful efforts of the power companies to convert stations from oil- to coal-firing (which led in 1983 to coal constituting 96 % of all fuel consumed by Danish power stations) are in complete agreement with the objectives of Denmark's energy policy. This policy also implies that expansions of power stations are made by constructing combined heat and power units in location where the heat can be used to the advantage of society.

Denmark's power sector plays a significant part in several fields when heat supplies are planned for the country: heat is supplied directly from the power stations in the most densely populated areas, while electrical heating, together with a number of alternative sources of energy, will in time replace much of the oil used for heating in areas that cannot advantageously be supplied with power-station heat or natural gas.

The transition to coal-firing of power stations is not without problems, however. It is difficult to get acceptance for the disposal of ash that cannot be utilized, and of future desulphurization products. Moreover, imports from politically sensitive areas of the world can lead to problems. As a case in point the government and Folketing (parliament) appealed in 1983 to Danish power companies to terminate their large imports of coal from the Republic of South Africa before 1990. Because South Africa dominates the coal market, a committee of representatives of the Ministry of Energy, the Ministry of Foreign Affairs and the power companies was set up to evaluate the possibilities and consequence of terminating coal imports from this country.

In the nuclear sector Danish power companies assisted the Ministry of Energy with information on nuclear fuel prices, as well as on the construction cost of coal-fired and nuclear power plants. This information will be incorporated into the Ministry's comparison between coal and nuclear power. During 1983 the authorities continued to work on their report on the safety of nuclear power and on their evaluation of the utilities' investigation of the disposal of highly active nuclear waste. The authorities plan to complete their work in the spring of 1984, whereafter the reports may be included in the basic information material on which a decision could be taken regarding the use of nuclear power in Denmark.

Power production and consumption

In 1983 Danish power stations imported approximately 8.1 TWh from Sweden and Norway and exported a total of 2.4 TWh, mainly to West Germany. The net import of 5.7 TWh covered about 23 % of the power consumed in Denmark, as against some 15 % in 1982 and about 30 % in 1981.

The remaining 77 % of the power consumed in 1983 was produced by coal- and oil-fired power stations, in part in conjunction with the production of heat by combined heat and power plants. The production of 19.2 TWh was about 8 % less than in 1982.

The combined costs of and import of power in 1983 were lower than budgetted. Reasons for this lie partly in coal prices that were lower than expected and partly in the increased imports of power at prices lower than production costs in Denmark. These circumstances led to a reduction of power prices over the whole of Denmark.

Power consumption in Denmark was 24.9 TWh — an increase of 2.0 % compared to 1982. The increase is thus a little greater than that for 1981—82, in spite of the fact that the first months of 1982 were marked by an unusually hard winter, whereas the same period of time in 1983 enjoyed the mildest weather for that season during the last 50 years.

Fuel

Supplies of power-station fuel, which consisted almost entirely of coal in 1983, amounted to about eight million tons. Of this, some 15 % was transported by ships owned by power companies, whose tonnage increased to 312,900 tdw during 1983. Now ELSAM, the owners, are Denmark's third largest shipping line judging by tonnage.

The main part of the extensive programme for converting power stations to coal-firing is now complete, and it will presumably come to an end in 1987. The result is that coal continues to comprise an increasing share of the fuel consumed by Danish power stations, which in 1983 corresponded to a total of a good 8.3 million tons of coal. The share of coal in the year under review was 96 %, and it is expected to be about 95 % or more so long as there are large differences between the prices of coal and oil.

The international coal market was marked by excess production. Conditions for coal purchasers were better than expected with low-prices spot offers and generally falling prices. The price level has now, however, dropped so far that production will doubtless be adapted to demand in order to stabilize developments. Prices are therefore expected to increase again after a period of time.

Coal purchases by the power companies are distributed over eight supplier countries a system that, for example reduces the effects of possible failure of any single supplier country. The most market difference in the distribution pattern in 1983 was a reduction in the share of coal supplied by the USA. The reason for this was that their prices were not competitive as a result, among other things, of high rail-freight charges. Coal from Poland in particular was able to assert itself; this tendency is expected to continue.

Expansion

On Zealand, the expansion of the 143 MW unit 1 of the Stigsnaes power station was completed in 1983. According to plants this is the last conversion from oil- to coal-firing east of the Great Belt.

Two Danish power stations were being extended in 1983, both being provided with combined heat and power units. Studstrup, north of Århus, is having two 350 MW units, which will be in operation in 1984 and 1985, while the R.C. Ørsted plant, Copenhagen, is being provided with a back-pressure unit of 88 MW to be operational in 1985. The maximum electrical output of the Ørsted unit will be the 88 MW + 182 MJ/sec. water, while the maximum heat output will be 224 MJ/sec. steam + 49 MWe. The electrical capacity of the Studsrup units will be limited to 2 x 245 MW when the heat output is at its maximum of 2 x 480 MJ/sec.

In northern Jutland a start was made on converting the 269 MW unit 1 of Nordkraft to coal-firing. It is expected to be in operation again in mid 1986.

Work started on strengthening the 400 kV connection between Zealand and Sweden. It is expected to be finished during 1985.

In 1983 the final decision was taken regarding the next expansion to take place on Zealand. This will be two combined heat and power units in Copenhagen. These units, each of 235 MW, are unit 3 of the Amager power station, to be put into operation during October 1989, and the first unit of the Avedøre power station, to be operational in February 1991. The handling of applications by the authorities and the project engineering are on schedule. The first official approvals are expected in 1984, when the first orders will be placed too.

The power companies east of the Great Belt decided in 1983 to set up a wind-power farm on southern Zealand. The wind farm is expected to be complete in 1986 and will then consist of five identical wind-power plants with a total output of about 3.8 MW. In addition it is expected that a number of small wind-power farms, each of about 1 MW, will be established, mostly under private management.

A basis has been achieved for an agreement concerning a link-up between the eastern and western power supply systems in Denmark. This will take the form of a 350 MW submarine cable connection for high-voltage direct current. The matter has not yet been dealt with by the board of the respective power companies.

Expansion plants further comprise a conversion to coal-/ oil-firing of NEFO's 305 MW unit 2 in northern Jutland. Work is expected to be carried out between 1985 and mid 1987. Finally, work continues on small CHP plants. Denmark's first natural-gas-fired CHP plant, 2 MWe, was put into operation in 1983. In addition a decision was taken to set up an experimental CHP plant of 5 MWe at the Technical University of Denmark.

Finland

Economic devolpment

The international recession, which had continued since the second oil crisis turned into growth at the beginning of 1983. The total production of the OECD-countries increased by 2 % during the year. As a result of increased exports to the West the economic activity in Finland grew in 1983. The gross national product increased by 3.5 % (2.6) to FIM 265,000 million. The industrial production increased by 3.5 %. Imports increased by 5 % to a value of FIM 83,000 million. The value of energy imports increased to FIM 18,900 million, which is 23 % of the total value of imports in 1983. Exports increased by 4 % and the deficit in the terms of trade increased to FIM 5,300 million. Consumer prices rose by on an average 8.4 % during the year.

The number of unemployed continued to grow during the year. The number of unemployed averaged 156,000, which is 6.2 % of the total work force.

English Summary

Energy policy

Energy programme. The Council of State approved a new energy programme in February 1983. In the programme the changes in energy situation during the last years have been observed.

General plan for electric power supply. In October the Council of State approved the general plan for electric power supply for the years 1983— 1992. In the plan the Council of State did not state its position to further construction of hydro power nor to the proposed 1,000 MW nuclear power plant.

Nuclear energy legislation. In September the Council of State appointed a group of ministers to prepare the Governments bill to a new Nuclear Energy Act. For the bill the Ministry of Trade and Industry has prepared a proposition, which to its main part is based on a report from the Draft Commission for Legislation of Nuclear Energy.

Energy consumption

As a result of the better economic development there was a small increase in the consumption of primary energy during the second half of the year, and it totalled 221 TWh for the whole year. (The different energies have been converted to primary energy according to heating content. Hydro power, nuclear power and net imports have differing from official practice been converted according to energy content, i.e. with a conversion coefficient 1.) The share of electricity of the total energy consumption continued to grow. Domestic input in energy production increased from 28 % during the previous year to 29 % in 1983. Consumption of fuel oil declined significantly. As a result, the share of oil decrease to 46 % of the total energy consumption. Production of condensing power was low during the year. Therefore also coal consumption remained low.

Electricity consumption increased during the year by 6,4 % to 45 TWh. The increase was a result of higher industrial production and increased electricity use especially by industry and district heat production. The number of homes heated with electricity rose during the year by 27,000 to a total of 270,000. Most of the new one-family homes are heated with electricity.

Electricity production

Nuclear power production rose to 16.7 TWh, which is more than 40 % of the total electricity production. The load factor was high, 87 %. As a result of the favourable water situation, hydro power totalled 13.4 TWh, which is about 10 % higher than normal. As a result of high production levels of hydro and nuclear power, back-pressure production was at the same level as in the previous year, 8.8 TWh. The above production and net imports of 4.8 TWh covered 97 % of the total demand.

Fixed imports from the Soviet Union amounted to 4.1 TWh and will continue in accordance with the present agreement with 4 TWh/year until the end of 1989.

Teollisuuden Voima Oy carried out power escalation tests on both nuclear power units at Olkiluoto of 660 MW each. The capacity was raised by 3 % to 680 MW.

Deliveries to electric boilers amounted to 0.9 TWh. The electric boilers replaced the use of fossile fuel in heat production at district heating and industrial back-pressure plants during low load periods.

Conversions. Due to changes in the fuel price situation six oil-fired power plants were converted to coal or peat firing. The last one, Kristiinankaupunki (220 MW), which to its capacity is the biggest, was converted during the year.

Construction. Two hydro power plants were commissioned: a new one, Anjalankoski (19 MW) and Klåsarö (5 MW), which was renovated in the river Kymi. Inkeroinen (37 MW) was added to the number of industry's back- pressure power plants.

The conversion of Kotkan Höyryvoima Oy's Mussalo I from condensing power to district heat production was completed.

In Helsinki a district heating plant of 140/270 MW (electricity/heating capacity) is under construction. Of the hydro power plants Vajukoski (21 MW) in the river Kitinen in Lappland is estimated to be completed in 1984. Imatran Voima Oy (IVO) has started the construction of a peat-fired district heating plant of 60/120 MW at Joensuu and one of 80/180 MW at Jyväskylä. Deliveries of district heat to the two towns is estimated to begin in 1986.

Investigations. IVO completed its investigation of a new basic power plant and submitted a report to the Ministry of Trade and Industry. Condensing power plants were compared with respect to economy, adjustment to the electricity system, operational reliability, fuel availability, and their impact on the economy and environment. Nuclear power proved to be the best alternative. See figure 4 on page 10.

IVO also investigated the prospects for development of local energy supply in conjunction with communities and industry.

Investigation of energy supply alternatives in the Helsinki metropolitan area was continued. Among others the prospects for using natural gas for heat production and for using heat from the coal condensing power plant at Inkoo by building a heating line to Helsinki were investigated. The investigation of a Swedish district heating reactor was completed.

National grid

Use of a second transformer of 400/110 kV, 400 MVA at Lieto began during the year. About 400 km new 110 kV power lines were completed.

Construction work on a 400 kV power line between Olkiluoto-Kangasala, 162 km, and on Kangasala 400/110 kV transformer was continued and will be completed in 1984.

Electricity prices

The structure and price level of the bulk price of electricity was modified twice during 1983, which resulted in a decrease of 4 %. The average prices of IVO's bulk tariff sales decreased by 12 %. The average prices of the distribution tariffs of the utilities declined by on an average 0.4 p/kWh to 32.3 p/kWh from December 1982 to December 1983.

Research and development

Electric heating. IVO's nation-wide heating project for one-familiy homes was completed in the autumn. In addition to investigating heating methods and energy consumption in 1,000 one-family homes, electric heating techniques were also developed. The result of the projekt was an objective confirmation of electric heating being an economic heating method for one-family homes. The project continues, and is now directed at renovating one-family homes.

Heat pumps. At Uusikaarlepyy and Forssa it is decided to build demonstration plants for district heat production by heat pumps using municipal waste water and ground water. Exhaust-air heat pumps were tested and installed in a few multi-story houses.

Parallel use of electricity and fuels. Prospects for producing heating energy for houses and industry by parallel use of electricity and fuels were studied and test plants were built. The potential is estimated to 7- 8 TWh/a, of which the share of electricity variates between 5-95 % depending on water and capacity situation.

Environment and nuclear waste. Environmental effects of different energy production methods were compared and the results were used in the work of studies of basic power plants. The work was expanded to comprise studies, development and optimization of suitable technical solutions for treatment and final disposal of nuclear waste.

New applications. Investigation of domestic fuels was contninued by concentrating on peatland research and development of methods for peat production. IVO started a large willow setting for studying different kinds of willows. From the research programme for nuclear fuel in co- operation with organizations from the Soviet Union the first concrete results were received during the year under rewiev.

Demonstrations of different methods for storing heat for instance in the bedrock, and salt in combination with heat pumps were started. Concrete results were received from the investigations of prospects for a more rational energy utilization in small and medium-sized industry.

Iceland

Electricity production

Total electricity production in Iceland in 1983 amounted to 3,766 GWh (3,575), of which 95.3 % (95.3) was generated by hydro, 4.5 % (4.4) by geothermal and 0.2 % (0.3) by diesel power.

Gross consumption amounted to 3,766 GWh (3,575), of which 3,499 GWh was primary and 267 GWh non-contracted. Gross consumption grew by 5.3 % (9.7). Energy-intensive industry accounted for 56.5 % (56.4) of gross consumption and grew by 5.5 % (12.2). After adjustment for limited rationing to energy-intensive industry during the first few months of 1982, the figures for 1983 show an increase of 4.8 % (instead of 5.3) in total consumption and an increase of 4.5 % (instead of 5.5) in consumption by energy-intensive industry (actual consumption in 1983 compared with consumption in 1982).

General consumption increased by 5.1 % (6.7).

Installed capacity of Icelandic power plants at year-end 1983 totalled 908 MW (904), of which 752 MW (752) referred to hydro, 127 MW (126) to conventional thermal energy plants (diesel, condense, gas turbines) and 29 MW (26) to geothermal power.

The figures for geothermal plants refer to available rather than installed capacity. Available capacity was limited as in previous years by the accessible quantities of geothermal steam. At year-end, the Krafla plant was generating 20 MW, and steam for another 10 MW had been brought to the surface but had not yet been supplied to the plant.

National grid

The expansion of the 132 kV national grid continued in 1983 with the construction of the final 250-km link in a circular power line around Iceland, from Høfn in the southeast in a westerly direction along the south coast to the Sigalda hydro plant in Sydlandet. This power line was scheduled for completion in late 1983, but the cutbacks in public investment resulting from the new government's economic programme to combat inflation required postponement of construction activities, so that the line will be completed by 1984 at the earliest.

Energy policy

Elections for the Icelandic Alting (parliament) were held in April and a new government took office in May. The new government's energy policy is not very different from its predecessor's, except on one point: energy- intensive industry and foreign investment in this industry. The energy policies of both governments placed great emphasis on the significance for the country's future economy of utilisation of energy resources for energy-intensive industry, in the light of the fact that the most important fisheries and the country's vegetation resources are over- exploited. But while the previous government's policy emphasized the concept of »effective Icelandic control» of energy-intensive industrial operations, which often took the form of requiring an Icelandic majority shareholding in the companies involved, the new government has adopted a more flexible position regarding foreign investment. It has stated that an Icelandic majority shareholding is not always desirable, e. g. when there is a high level of risk. Each case is to be handled individually in this respect.

In the summer of 1983 the government appointed a so-called Big Industry Committee, whose task is to promote the development of energy-intensive industry in Iceland and in particular to establish contact with possible foreign interests and partners. The Committee has had preliminary discussions with companies in a number of countries, but it is still unclear whether these will lead to concrete results.

Negotiations with Alusuisse

As mentioned in the Annual Report for 1982, negotiations are in progress between the Icelandic government and Alusuisse regarding adjustment of the price of power paid by the latter's Icelandic subsidiary ISAL, which on January 1, 1983 was paying SEK 0.047/kWh (about mUSD 6.475/kWh at current exchange rates).

These negotiations had not yet been completed when the new government took office in May, 1983. This government resumed negotiations and on September 23, 1983 an interim agreement was signed under which the contracted price of SEK 0.0509/kWh (mUSD 6.475/kWh) will be increased by SEK 0.0081 (mUSD 1.025/kWh) retroactively from July 1, 1983 and by an additional surcharge of SEK 0.0157/kWh (mUSD 2.0/kWh) from September 23, 1983. The price of power to ISAL inclusive of these surcharges will thus be SEK 0.0747/kWh (mUSD 9.5/kWh) as per September 23, 1983. An additional charge of SEK 0.0039/kWh (mUSD 0.5/kWh) will be levied if the price of aluminium on the London Metal Exchange (LME) exceeds USD 0.78/lb for 20 consecutive days, which has not yet occurred as of this writing (March 1, 1984). (The agreement, like the original contract, stipulates prices in mUSD. These have been converted to SEK in this report at the rate prevailing on September 23, 1983.) The interim agreement applies until the parties agree to a permanent adjustment of the main contract, or — if such an agreement is not reached by June 23, 1984 — indefinitely, subject to termination on three months' notice.

Norway

Economic development

Norwegian GNP increased by 3.3 % in 1983, a relatively strong increase in comparison with the two previous years. Growth continues to be somewhat below the uniform growth level of the 1970's, when the annual increase was about 5 %.

Operations in the oil sector comprised the main factor contributing to the strong growth in GNP in 1983. Production of oil and gas in 1983 exceeded 55 million tons. GNP generated by oil exploitation (including drilling and pipelaying) increased by 15 % from about 17 % to about 18.5 % and referred primarily to the expansion of capacity in the Statfjord field.

The pattern of growth in other industrial sectors was more varied. The GNP declined in sectors which are protected from competition and in those which compete on the domestic market, while GNP rose in industries competing on the international market. Among other things, this resulted in a considerable increase in energy-intensive industries. The electricity-supply industry was also one of the high-growth sectors, but this must be seen in the light of the good flow conditions in 1983.

The foreign trade surplus (oil included) accounted for 8 % of GNP, about the same level as in the two previous years, but in comparison with the average for the 1970's a foreign trade deficit of about 3 % is in the nature of a considerable surplus because of the oil activity.

Private consumption rose by 1.5 % in constant prices, which was somewhat above the level for the two previous years.

Real capital expenditure by businesses exclusive of the oil sector declined by 6.6 %. The greatest declines were in shipping and industry. There was also a considerable drop in investment in the housing sector. Housing construction in 1983 was substantially below the goal set by the government.

Total employment did not increase in comparsion with 1982, but there were great structural changes in employment in different industries. Employment declined in primary sectors and industry, while there was a corresponding growth in the service sectors. The number of man-hours worked in the Norwegian economy has been more or less constant since 1980.

The growth of total employment was lower in 1983 than for several years, while there was a considerable increase in the work force. A total of 72,000 people were unemployed at year-end. The average unemployment figure for the year was 63,500.

Energy policy

No new important White Papers on general energy policy were presented to the Norwegian parliament (Storting) in 1983, but a number of papers presented in 1982 were dealt with.

The Paper on new and renewable energy sources received the general support of parliament, but the desirability was indicated of a stronger link between industrial interests and research activities these energy sources.

The Storting also gave its support to Government Bill no. 130 (1981—1982) on meeting power needs in the 1980's and the conditions for the total hydro plan, but emphasis was given to the importance of assigning priority to energy savings as part of the effort to meet national power needs.

The Storting dealt with Government Bill no. 157 (1982—1983) regarding joint ownership rights of the countries of Rogaland, Hordaland and Nordland in expansion of state hydro power, and restricted the rights of one of the countries somewhat in comparison with the government's proposal.

Government Bill no. 6 (1982—1983) contained a proposal for easing of specific price and delivery conditions regarding energy supplies from state power stations to energy-intensive industry and the wood-conversion industry. A number of points in this proposal were changed so as to be more favourable to industry.

Electricity production

Electricity production in 1983 amounted to a full 106 TWh, which corresponds to an increase of about 14 %. Flow conditions were particularly good in 1983, and the strong increase in relation to 1982 should be considered in the light of the fact that flow was somewhat less than normal in 1982.

Together with a substantial increase in domestic consumption, the favourable power situation provided a basis for record net exports of a full 13.4 TWh.

Reservoir supplies increased by about 6 TWh during the year and at year- end were about 115 % of normal. Reservoir capacity increased by 1.4 TWh to 64.9 TWh.

Electricity consumption

Primary power consumption increased by about 5.7 % in relation to 1982. The average annual increase over the past 10 years was 4.3 %.

General consumption of primary power increased by 2.1 % as compared with an annual average of 4.4 % over the past 10 years. The increase was about 3.3 % after adjustment for temperature conditions in 1983. The rate of growth of adjusted general consumption was in 1983 somewhat lower than assumed in the government's basic forecast, but the adjusted general consumption is still about 3.7 TWh above the level assumed in the government forecast. The main cause is presumed to be the fact that electric heating in recent years has been considerably cheaper than oil- fired heating, so that conversion to the former has been more intensive than previously anticipated.

Consumption of primary power by energy-intensive industry increased by 11.7 % in 1983. This strong increase reflects the improved international market situation for such industry and is connected with the general improvement in international business conditions. The improvement in business conditions appears to have had less effection on industry in general.

The maximum system load in 1983 amounted to 15,300 MW. Electricity accounted for 48.2 % of the theoretical energy content delivered to users (net end-user consumption). Oil consumption accounted for 40 %, while solid fuel and gas accounted for the remaining 11.8 %. Electricity consumption continued to increase its share of total energy consumption at the expense of oil. After several consecutive years of decline, there was a limited increase in comparison with 1982.

Energy prices

The price of energy delivered by the State Power Board for general consumption increased from 11.13 øre/kWh to 13.36 øre/kWh on July 1, 1983. A decision has been made regarding an additional increase to 14.70 øre/kWh on July 1, 1984. The price is the calculated average for 6,000 hours of consumption and refers to central areas served by step-down transformers.

The average price of electricity delivered to households and agriculture was 27.8 øre/kWh in 1983, including all charges. It is assumed that this price will be 31 øre/kWh.

The industrial and service sectors pay in some areas slightly more for general electricity supplies than do households and farms. This problem was the object of a good deal of discussion in 1983, and industry wants several power stations to change their pricing policies.

The general electricity tax levied on users in 1983 amounted to 2.5 øre/kWh and applied to deliveries to energy-intensive industry and the general public. The iron, steel, aluminium and ferro-alloy industries were exempted from this tax for the whole of 1982 and the first half of 1983. This exemption was subsequently extended to the second half of 1983 for all these industries except aluminium.

The cost of expansion of hydro power has risen sharply in recent years. This is traceable to the introduction of new working-environment regulations and to the competition for specific types of manpower in the oil industry. The long-term maximum cost for hydro is being reviewed. The current figures for delivery of primary power for general consumption by a subscriber are 27 øre/kWh plus an annual total charge which varies locally. (NOK 1.500-3.500 year) per subscriber. The corresponding cost for oil-heating as projected in 1983 was about 38 øre/kWh (70 % efficiency).

Expansion of capacity

At year-end 1983 production capacity for primary power in the Norwegian system amounted to about 92 TWh, including import potential. New installation during the year increased capacity by about 1.8 TWh, or about 2.0 %. The annual increase in capacity over the past five years has been 2.7 %.

There was a slight increase in installation of new units in 1983. Plant capacity (maximum capacity in plants with an output of at least 1 MW) in the Norwegian system increased by 407 MW or about 1.8 %, to 22,580 MW (including 278 MW referring to district heating).

State power stations own about 30.9 % of plant capacity, municipalities and counties 52.6 % and private and industrial corporations 16.5 %.

The oil industry

Operations continued at a high level on the Norwegian continental shelf in 1983. Drilling operations were at about the same level as in 1982. Promising finds were made in Block 34/4 and in the Haltenbanken. Construction of the statpipe line was started in 1983. The projected cost of this pipeline is about NOK 20 billion. It will connect the Gullfaks, Heimdal and Statfjord fields and will transport gas to the continent via Kårstø in Rogaland.

The government and the Phillips Group decided in 1983 to implement a water-injection project in the Ecofisk field at a cost of about NOK 9 billion. The project is expected to increase the oil output of this field by about 27 million tons.

Sweden

General Economic Development

The improvement of the international and above all the North American business climate beginning in early 1983 led to a certain recovery of the Swedish economy as well. Sweden's gross national product rose by 1.9 % according to preliminary calculations, owing mainly to a substantial rise in exports of goods and services. Market share development benefitted both from a decline in relative prices after the devaluations in 1981 and 1982 and by a favorable composition of goods in Swedish exports.

Overall, exports are estimated to have increased by more than 11 % in volume as compared to 1982. Total domestic demand, on the other hand, declined by an estimated 1.5 %. Private consumption was down by 2 % and investments by more than 3 %.

The strong growth of export demand as well as a certain increase in the market shares of Swedish industry on the home market led to an estimated increase in industrial production of slightly more than 4.2 % between 1982 and 1983. Increases in output were reported for all industrial sectors except for ironore and shipbuilding. There were especially significant increases in nonferrous ores, the pulp industry, petroleum refineries and non-ferrous metallurgy.

Foreign trade in 1983 yielded a surplus of approximately SEK 10 billion, which represents an improvement of 17 billion as compared to 1982. The improvement is in its entirety attributable to a strong increase in the real foreign balance. While, as mentioned, exports rose by more than 11 % in volume terms, imports were up by only a little more than 1 %. The deterioration of terms of trade after the devaluation of the autumn of 1982 was less than expected. Export companies used the devaluation in part to raise their formerly depressed profit margins, while import companies reduced their margins to some extent in order to avoid loosing market shares. The balance of services was also strenghtened by increased net shipping revenues and a reduced deficit on tourism. The positive trend in the balance of goods and services was counteracted by a continued increase in net interest paid to other countries. Overall, however, the deficit in the balance of current payments was down by slightly more than SEK 16 billion. This is to be compared to a deterioration of 8.5 billion in 1982.

Crude oil and petroleum products accounted for 22 % of the total value of imports in 1983, which is one percentage point less than in 1982. Imports of crude increased significantly, but at the same time, there was a sharp increase in exports of refined products, which now constitute one of Sweden's biggest export sectors. Net imports were around 9 % below 1982 in volume terms, and were at about 60 % of what they were in the mid- 1970s. The shift in oil imports from the Mideast to suppliers in Europe is continuing.

Deliveries of fuel oil in Sweden, especially industrial fuel oils, were down sharply, while gasoline consumption continued to increase somewhat.

Investments continued to drop for the third year in a row. The decline was preliminarily 2.5-3.0 % both for buildings and machinery (not including the merchant marine). Business and industrial investments (including public utilities) were down by slightly more than 4 %, while public authorities showed a rise of nearly 3 %. Investments in new housing were down by 11 %. Investments in renovation increased by an estimated 5 %, which represents a substantially slower rate than in 1982. The number of housing units completed in 1983 was around 43,000, as compared to 45,100 the previous year. The net increase in single-family homes was around 3,600 less than the year before, while the output of flats in multi-family dwellings increased somewhat.

Unemployment continued to rise. At year-end, 3.3 % of the labor force was out of work, and 4.4 % were employed as a result of labor market policy measures. In addition, there was considerable partial unemployment. The number of newly registered job openings did, however, increase slightly during the year, and especially in the engineering industry there was a lack of skilled workers and technical personnel.

The consumer price index rose by 9.3 % from December 1982 to December 1983, which is a slightly smaller increase than in the preeceding 12- month period. The net price index, which is equal to the portion of the consumer prices not made up of taxes (but augmented by subsidies), was up by 5.5 % in the same period.

Energy Policy

The National Swedish Energy Board began its operations on July 1. At the end of the year, the Government established a council on energy technology which, under the direction of the Minister of Energy, is intended to serve as a forum for regular consultations in questions of energy technology between the Government, manufacturers, energy-users, and employees.

The commission on hydroelectric power appointed by the Government in 1982 submitted its report in September. The report proposes that the next ten years' expansion of hydroelectric power should comprise additions or renovations of existing power plants as well as new installations to be built on rivers or sections of rivers which are deemed not to be among those given highest priority for conservation. Power plants are not to be built on the four main rivers not yet harnessed in Sweden, according to the proposal. The National Energy Board was later commissioned to carry out certain supplementary studies on questions including which profitable developments can be started first, the consequences of the proposal for manufacturing industry and the possibilities of retaining competence in the area of hydraulic engineering. A Government bill is expected in the spring of 1984.

During the autumn, the Government presented a bill on nuclear engineering activities which essentially follows the proposal made by the Nuclear Legislation Committee earlier in the year. The law, which was adopted by the Swedish Riksdag (parliament) in early 1984, supercedes the Atomic Energy Act, the Act on Conditions for Nuclear Plant Operation, and the Act on Public Insight in Safety Work at Nuclear Power Plants. The phrase of »entirely safe», which is used in the Conditions Act in reference to methods of disposing of spent nuclear fuel, is not included in the new law. Nuclear companies are instead obliged to show that there is a method which is acceptable from the standpoint of safety and radiation protection requirements, as well as to have a research program aimed at fulfilling these conditions. The programs are to run for six years at a time and are to be reviewed and evaluated every third year.

Applications for permission to charge the last two units in the Swedish nuclear program, Forsmark 3 and Oskarshamn 3, were submitted to the Government in May. At the same time, the KBS-3 study was presented, which according to the applicants shows that spent nuclear fuel can be definitively stored in a safe manner.

Svensk Kärnbränsleförsörjning AB received Government permission during the year to construct and operate a final depository for low and middle active waste in Forsmark. The facility is being built in rock far below the seabed.

The Government set the charge for handling of spent nuclear fuel and for the phasing out and dismantling of Sweden's nuclear power plants at SEK 0.017 per kWh in 1983 and at SEK 0.019 per kWh in 1984.

During the spring, the final report for the Coal-Health-Environment Project was submitted to the Government after three years of study. The committee concludes that the Swedish environment can tolerate increased use of coal, provided that advanced technology is used. The report and the extensive documentation on which it is based will, along with official comments - of which many have been critical - serve as the basis for a Government bill on coal questions in the spring of 1984.

On July 1 a coal environment fund was set up in order to facilitate investments in modern purification and combustion technology. The fund is financed by a surcharge on oil of SEK 10 per cubic meter.

Several plants for firing with domestic fuels were built or started during the year with financial support from the oil replacement fund and the National Energy Board. Among the projects receiving support were some 50 new peat plants. Special measures were taken to increase the use of domestic fuels in the province of Norrbotten. The Swedish Riksdag decided further to grant continued support in various forms for oil replacement measures during the period of 1984—1987.

Deliveries of natural gas from Denmark to southwestern Scania province in Sweden (The Sydgas project) are planned for the autumn of 1985. The state now owns 50 percent of Sydgas AB.

During the spring, Vattenfall presented proposals for a pipeline for transport of northern Norwegian natural gas to the Continent. Vattenfall was subsequently charged with continuing the design and planning to some extent.

Energy taxes

The Riksdag decided in December on guidelines for future energy taxation. Energy taxation is to be one of the means of carrying out the transition to an energy system based on lasting preferably renewable, domestic energy sources with minimal environmental impact. The tax on oil is to be altered whenever required so as to produce an appreciable real price increase; domestic fuels are to be favored by tax-emption; the tax on coal is to be raised in stages until it reaches half the tax on oil and the tax on natural gas is to be equal to 3/4 of the oil tax in both cases as computed on the basis of energy content; industrial use of electric power should be given tax benefits as compared to the use of electricity for heating; and electricity taxes should to some extent conform to the oil tax.

The energy tax on electricity was raised in July 1983 by SEK 0.012 per kWh, with the exception of consumption in excess of 40,000 kWh in industrial activity. The energy tax on oil was raised on November 1, 1983 by SEK 120 per cubic meter. In December, the Riksdag decided to raise the tax on coal from SEK 6 to SEK 97 per ton as of January 1, 1984. Moreover, the tax on natural gas was set at SEK 308 per 1,000 cubic meters. Convertible electric boilers of at least 1 MW were exempted from electricity tax during periods when electricity is not being produced in oil-fired power plants.

A special surcharge on oil products of SEK 108 per cubic meter had previously been levied for the financing of the oil replacement fund, the energy research fund, and the coal environment fund. The Riksdag decided in December to raise the oil surcharge by SEK 10 per cubic meter and simultaneosly introduced a surcharge of SEK 0.06 per liter on gasoline, SEK 10 per ton on coal, and SEK 0.002 per kWh on electricity produced in nuclear power plants. The surcharges apply as of January 1, 1984.

Electricity Consumption

Total consumption of electricity in Sweden, including transmission losses, amounted to 110.8 TWh in 1983. This represents an increase of 10.9 TWh, or 10.9 %, in comparison with 1982. This is the largest annual increase ever in absolute terms.

Of the total electricity consumption, 4.7 TWh consisted of deliveries of excess power to electric boilers (1.3 TWh in 1982). The consumption of firm power in Sweden was thus 106.1 TWh, which is 7.6 % higher than in 1982.

Industrial consumption of electrical power, which had previously declined for three years in a row, recorded increasing monthly figures from January 1983. The rise was very strong in the second half of the year. Annual consumption in 1983 was 42.3 TWh, which is 3.2 TWh, or 8.0 %, higher than in 1982. Of the total industrial consumption, 1.1 TWh consisted of excess power to electric boilers. If this consumption is excluded, the annual increase amounts to slightly more than 6 %.

Industrial sectors which showed especially large increases in electricity consumption were the paper and pulp industry, the chemical industry, the wood products industry, and mining. The textiles industry was the only one to report a slight decline in consumption. Consumption of electric boiler power by the paper and pulp industry was 0.8 TWh, which is 5 % of the total consumption of electricity by that sector. Otherwise, excess power was used in the iron and steel industry and the food industry.

Electricity consumption by railroads and tramcar lines was 2.3 TWh, or barely 3 % more than in 1982.

Electricity consumption in other sectors (households, farming, services, etc.) was up by almost 6.5 TWh, or 12.9 % to 56.5 TWh, of which 3.5 TWh was excess power to electric boilers in heating plants. This kind of power accounted for more than 2.5 TWh of the increase. Available statistics do not permit a more detailed analysis of the increase. However, it is known that the use of electric boilers for firm power to multi-family dwellings and offices as well as of heat pumps has also increased sharply. Further, the full impact of the shift to electric heating in single-family homes, which culminated in 1982, was felt in 1983.

The highest recorded figure for hourly electricity consumption during the year was 20.862 MWh/h, and occured on December 12, between 8 and 9 a.m. The average temperature at 7 a.m. that day, weighted with regard to the distribution of the electricity load, was around 11 degrees Centigrade below the normal figure.

Electricity Production

Total electric power production in Sweden, excluding power plants' own consumption, was 105.9 TWh in 1983, 9.3 TWh (9.6 %) more than in 1982. Hydro-power production reached its hitherto highest annual value, at 62.8 TWh. The increase over 1982 was 8.6 TWh. Owing to the rainy autumn and increased nuclear power capacity, reservoirs could at the same time be built up by nearly 4 TWh. The storage level for all Swedish regulation reservoirs was 65 % at the beginning of the year and nearly 77 % at year- end, which is around 14 % above the median value for the past ten years. The annual runoff was 19 % above the averge for the period of 1950—1980. The spring floods were 16 % above normal.

Installed hydro power capacity increased by about 75 MW in 1983. The largest addition of new capacity was Stenkullafors on the Ångerman River, with 56 MW.

Nuclear power production increased from 37,3 TWh in 1982 to 39.1 TWh, an increase of 1.8 TWh. Nuclear power thus accounted for 36.9 % of Sweden's total electricity production in 1983. Owing to a good supply of water in both Sweden and Norway, production capacity was not fully utilized. The underutilization was equal to around 2 TWh.

After the steam generators in Ringhals 3 and 4 had been rebuilt during the year, and Ringhals 4 brought on line in November, Sweden now has ten nuclear power units in full operation. The total net capacity in all ten units is 7,355 MW.

The overall energy utilization factor for the nine units in commercial operation for the whole year was 65 %, which has to be regarded as satisfactory in view of the underproduction mentioned above. Not counting Ringhals units 1 and 3, which were out of operation for extended periods on account of rebuilding, the utilization factor was 73 %.

Work at the future nuclear power units Forsmark 3 and Oskarshamn 3 is proceeding according to schedule, with a planned commissioning date of 1985.

Backpressure production totalled 3.7 TWh, which is 21 % less than 1982. The decline is due in its entirety to combined power and heating plants, whose electricity production was nearly halved in comparison with 1982. Production in condensing units, gas turbines and diesels showed a continuing declining trend. The totality of electricity production based on conventional fuels constituted only 3.8 % of total electricity production in Sweden in 1983.

Two major combined power and heating plants were commissioned during the year, in Helsingborg and Norrköping, both of them coal-fired. In addition, some combined power and heating plants have been converted from oil to coal.

Imports of electric power amounted to 10.4 TWh in 1983, which is the highest figure ever. The year before, 5.9 TWh were imported. In relative terms, exports showed an even bigger increase from 2.5 TWh in 1982 to 5.4 TWh. Thus, net imports were 5.0 TWh (3.4 TWh in 1982).

Electricity Prices

In 1983 the electric power companies generally applied the tariffs which were introduced as of 1981, although with the slight reduction of summer energy charges which was introduced as of 1982. The clauses included in the tariffs which are based on the consumer price index, oil price and uranium costs did, however, lead to a certain rise in the price level: by around 5 % from 1981 to 1982 and by around 8 % from 1982 to 1983.

On October 9, 1982, a general price freeze was introduced in Sweden, which also affected electricity prices. The price freeze was lifted as of March 1, 1983 and as a rule it resulted in only a slight reduction in the price level which otherwise applied for electricity in 1983.

During 1983 some companies decided on new high-voltage tariffs, in several cases for the five year period of 1984—1988. The price level for 1984 will on the average rise by 4 % as compared to the 1983 level, but it is around 4 % below the price level which would have resulted from an extension of the tariffs applied in 1983.

During the first half of 1983, new low-voltage tariffs were introduced, which represent an increase of 7-8 % of the tariffs, applied since the beginning of 1982. Studies are under way on the new low-voltage tariffs which will be introduced in 1984. A certain increase is dictated by the forementioned increases of the high-voltage tariffs, but also by increased costs for the low-voltage distribution itself. In order to even the consumption pattern some power companies have introduced low-voltage tariffs with different prices during high and low load periods.

The electricity companies also decided in 1983 to introduce special tariffs for convertible electricity deliveries to electric boilers. The purpose was to take advantage of the existing electric power surplus during low-load periods and make it possible to reduce consumption of oil for heating purposes. Since the deliveries are made primarily during low- load periods, it was possible to reduce the capacity charges in the normal tariffs.

National Grid

Measures to increase short-circuit reliability and load capacity have been implemented or are in progress on a number of lines and substations.

The construction of a double 400 kV line from Forsmark to the northern

Stockholm area is under way, and the line is scheduled for commissioning in 1984. Permission has been granted for a southward continuation of the line, including a crossing of Lake Mälaren. The southern section, including the Mälaren crossing, is scheduled to be brought into operation in late 1985. In addition to the link-up to Forsmark unit 3, these new lines are designed to reinforce the feed to the Greater Stockholm area. Extensive planning is currently being done so as to ensure that the interruptions required in connection with the rest of the work are done in an optimal manner. It is inevitable that the interruptions will affect the transmission capacity and reliability of the grid during the period in which the work is being done, especially in connection with the crossing of Lake Mälaren during 1985.

A 400 kV line from Boden to Hjälta is under construction and planned for commissioning in the autumn of 1984. The poles for this line were erected with the help of a helicopter, which provided for a significant savings of time as compared to conventional methods. The new line will increase transmission capacity from the Lule River and southward.

It is planned that the link-up of unit 3 in the Oskarshamn nuclear power station will be made with two 400 kV lines, one north to Norrköping and the other south to Alvesta. Permission has been obtained for the northern section, but not for the southern one. The northern section is scheduled to be commissioned in the spring of 1985, and the southern section in the late autumn of 1985.

Work is proceeding on the construction of a second 400 kV joint line between Sweden and Zealand. Cable has already been purchased. The link is scheduled to be brought into operation in 1985.

A second direct-current link between the mainland and the island of Gotland went into operation in 1983. The link is a 150 kV line, with a maximum transmission capacity of 165 MW. With this link in operation, Gotland can be supplied entirely with electric power from the mainland and there will be no need to operate thermal power plants on Gotland.

Extensive studies are under way on the future of those sections of the 220 kV grid. It is likely that the 220 kV power lanes will be utilized for the construction of one or two new 400 kV transmission lines. In connection with these studies, new and more compact 400 kV pole designs have been developed.

Frequency control in the synchronous Nordel system

By Sture Lindahl, Sydkraft AB

For power production Iceland and Norway depend almost totally on hydro power. Denmark has mainly thermal power and Finland and Sweden mixed systems. This fact makes cooperation and power exchanges between the countries very profitable. Today there are seventeen tie-lines between the Nordic countries. Because of the distance Iceland is not interconnected to the rest of Scandinavia.

To organize and systemize the cooperation Nordel was founded in 1963. It is an organization for people who are active in the field of power supply in Denmark, Finland, Iceland, Norway and Sweden. It is an advisory and recommendatory organization aimed at promoting international, mainly Nordic, cooperation in the field of production, distribution and consumption of electrical energy.

A common task is to maintain the frequency in the synchronous Nordel system. How this is done is described here. The Nordel recommendations for maintaining frequency are also presented.

The synchronous Nordel system

The synchronous Nordel system comprises power systems in Denmark east of the great Belt as well as in Finland, Norway and Sweden. In a synchronous area, all the connected synchronous generators must rotate at the same speed, i.e. the average frequency must be the same for all generators. AC-links are used for power exchanges within the synchronous area. Some power stations outside the synchronous Nordel system are connected to the system through AC-links. For other power systems outside the Nordel system, power is exchanged through DC-links.

Background

Normal electricity deliveries are unique in that there is no inventory of stock, as it is technically impossible to store electrical energy in the form of alternate current. The inventory of half-finished goods represented by the mechanical energy stored in the rotating components of the turbine generators is very limited, corresponding to about

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5-10 seconds of production. This means that there must be a continuous balance between the input of mechanical energy and the output of electrical energy in an AC system. If consumption is greater than production, the grid frequency drops. If production is greater than consumption, the grid frequency rises. In this respect the power system can be compared to a set of scales, with production in one scale and consumption in the other. The speed at which the pointer swings back and forth represents the grid frequency. The balance beam can be compared with the transmission grid.

The number of weights in the scale for consumption is determined by a continuously decentralised decisionmaking process. When an individual consumer turns on the tap to obtain water for his morning coffee, a small weight is placed in the scale. When another consumer turns off a light, a small weight is removed from the scale. Each power company in the joint Nordel power system has a production scale and a consumption scale. The beams are united by a common axle: the tie-lines for joint operation.

The power companies in the synchronous Nordel system have joint responsibility for putting the weights on the scales and taking them off, so as to obtain a continuous balance between production and consumption. If the balance beams were not interconnected, each subsystem would have to continuously move the weights on and off the scale in order to maintain the pointer at the midpoint. Thanks to joint operation — the axle on which the beams are mounted — the only requirement is that the total of the weights in the production scales must equal the total of the weights in the consumption scales.

Joint tie-lines create an opportunity for power exchanges that are economically beneficial for the various countries in the Nordel system. The investment in tie-lines for joint Nordic operation is one of the more profitable investments in the power industry. One prerequisite is the difference in structure of the production systems in the different countries, which varies from Denmark's thermal power system to the mixed of hydro and thermal in Finland and Sweden and the hydro system in Norway. In a year with heavy precipitation, a hydropower country such as Norway naturally exports electricity to Denmark, a thermal-power country. This means that the number of weights in the Norwegian production scale exceeds the number in the Norwegian consumption scale. On the other hand, there are fewer weights in the Danish production scale than in the Danish consumption scale. The surplus in the Norwegian set of scales must be equivalent to the deficit in the Danish set of scales. In years with below-average precipitation, conditions are appropriate for power exchanges in the opposite direction.

Sweden serves as a middle-man in the synchronous Nordel system, as Sweden is the only country that has tie-lines with all the other Nordic countries (excepting Iceland). Nordel studies the conditions obtaining for power exchanges and provides recommendations as to the transmission capacity required for tie-lines. Within Nordel, information is also distributed regarding the current power situation, and guidelines are determined for daily power exchanges.

Requirements for maintaining frequency

Grid frequency is normally maintained within a narrow band around 50.0 Hz. Frequency deviations can be regarded as a measure of the quality of the electrical energy delivered. In normal operation, frequency is maintained within ±0.1 Hz, with a standard deviations of about 0.03 Hz. This degree of accuracy appears to be quite sufficient for most consumers.

One obvious effect of frequency deviations is that synchronous electric clocks driven by grid frequency indicate the wrong time. If grid frequency has been precisely 49.9 Hz for one hour, i.e. if there has been a frequency deviations of 0.1 Hz, a synchronous electric clock will have lost 7.2 seconds. If the grid frequency over the next two hours is exactly 50.05 Hz, the clock will indicate the right time. The inaccuracy of a synchronous clock in this context is called the time deviation and is a measure of the integrated frequency deviation. At present, the goal is to maintain frequency deviations within ±0.1 Hz and time deviations within ±10 seconds.

In connection with production losses of faults in the transmission grid that result in disconnection of parts of the grid with production surplusses, grid frequency can drop below 49.9 Hz for a very short period. If grid frequency falls below 47.5 Hz, there is a risk that the large thermal power plants must be disconnected in order to avoid damaging vibrations in the steam turbines. Hydro power plants are more robust and normally tolerate a drop in grid frequency down to 45 Hz without sustaining damage.

Within Nordel the design-base production loss has been defined as the largest production loss that can be expected to occur more than once every three years. The goal is to prevent grid frequency from dropping below 49.0 Hz following a design-base production loss and to ensure that grid frequency will be maintained above 49.5 Hz 30 seconds after such a loss. See fig. 5.

If the production loss is so great that there is a risk of grid frequency dropping below 47,5 Hz, load shedding is activated, so that 20-50 % of consumption is disconnected. The idea is to remove weights from the consumption scale fast enough to avoid having the large production weigts fall out of the production scale as the beam tilts sharply. In connection with many large production losses, the balance between production and remaining production capacity can be restored without excessively extreme effects.

Variations in consumption

Experience shows that electricity consumption is subject to regular changes. The consumption has increased from year to year as a result of electrification, increased industrial production and the introduction of electric spaceheating. Consumption normally drops during the summer holidays. Consumption increases during the winter as a result of increased heating needs. The need for lighting during the dark hours of the winter day when people are awake is expressed as increased consumption of electrical energy. The hours when meals are prepared and TV-sets are on are also reflected in electricity consumption. These variations in electricity consumption can be forecast to a large extent. Consumption forecasts usually take the form of average hourly values.

Switching on and off of electric motors, lighting and electric heating elements causes temporary variations in consumption which can amount to 1-2 % of the average value of consumption in a given 60-minute period.

If there is a voltage drop at the consumer's end, a switched-on heating element will use somewhat less current. The concept of load voltage dependency on a scale of 0 to 2, indicates that if consumer voltage increases by 1 % consumption will increase by 0-2 %. It should be noted that continuous voltage drops are not a means of saving energy. Indoor temperature is maintained by switching on a heating element for a longer period of time. The quantity of energy used is determined by the insulation of the building and the difference between the indoor and outdoor temperature.

Changes in grid frequency normally cause pumps, fans and other electric-driven units to change speed and thus power consumption. The concept of load frequency dependency on a scale of 0 to 2, indicates that if grid frequency increases by 0.1 Hz consumption will increase by 0-0.4 %.

Generation control

Generation control is defined as all purposeful efforts to control production of electrical energy in a power system. The basic goal of generation control is to maintain — within the framework of the limitations, production costs, exchange potential and safety requirements of the system — a balance between production and continuously varying consumption and to maintain grid frequency in the joint power system within a narrow band around nominal frequency. Predictive generation control can be manual or automatic and can be divided into three stages:

1 Predictive generation control
2 Local automatic frequency control
3 Correction of production set-points or changes in predetermined power exchanges

The first type of control utilises a production plan based on a consumption forecast which can be more or less accurate. Plans are converted to production orders, which are implemented by running the units in a power station at the required rate of output.

Even if production follows the plan strictly, there will still be an imbalance because the average hourly value of consumption will not correspond to the forecast, and because of temporary variations in consumption which have not been forecast. This imbalance is handled by local automatic frequency control, which modifies the output of the power plants by regulating the turbines. Deviations in actual production from production set-point are normally proportional to frequency deviations. The constant of proportionality is called the composite regulating characteristic of the unit, or R (MW/Hz) and indicates the magnitude of the production change which has arisen as a result of a continued frequency deviation. Monitoring the composite regulating characteristic and the frequency deviations enables us to get an idea of the difference between the production set-point and actual consumption. This can be expressed as

$$I = R \cdot \triangle f$$

where I is the control error, i.e. the difference between total production and production set-point (MW), R is the total composite regulating characteristic (MW/Hz) and $\triangle f$ is the difference between actual frequency (Hz) and nominal (50.0 Hz).

Production set-points are adjusted as needed in order to compensate for inappropriate distribution of production, to adjust power exchanges or to correct deviations in frequency or time.

The imbalance between production and consumption can arise from incorrect forecasts of production and/or consumption, start-up and shutdown of individual turbines, faults in the grid or temporary variations in consumption.

Area control error

As long as one company alone is responsible for maintaining frequency in a power system, frequency deviations and time deviations are the measurement values required for control of production, on condition that the variations in output can be utilised without regard to limitations connected with transmission. If two systems of different sizes are operated jointly over one or more tie-lines, acceptable results can be achieved by having the smaller system cover variations in consumption by regulating production so that the total exchange on the tie-lines is held close to the agreed value. If both systems have units which participate in automatic frequency control, there is a risk that use of the regulating technique mentioned above will lead to a situation where deviations are regulated simultaneously in opposite directions in the two systems. This conflicting regulation can be avoided if both systems take account of frequency deviations and inadvertent exchanges on power deviations in the tie-lines.

In connection with frequency control in a joint system composed of a number of equal partners who make decisions on the basis of magnitudes which are measured in their own systems, the concept of a area control error I (MW) is of great value. For the ith subsystem, I is defined as follows:

$$I_i = \triangle P_i + R_i \cdot \triangle f$$

where $\triangle P_i$ is the cumulative inadvertent excange on tie-lines from the subsystem to other subsystems. R_i is the cumulative composite regulating characteristic (MW/Hz) within subsystem (i) and $\triangle f$ is the frequency deviations (Hz), i.e. the difference between actual and nominal frequency (50.0 Hz).

The area control error (MW) thus indicates how much the set production value exceeds the production value that should have been set. When the frequency deviation is zero, the cumulative inadvertent exchange indicates the difference between the set production value and the value that should have been set. When the first term is zero, the difference is obtained by multiplying the composite load-regulating characteristic by the frequency deviation.

Guidelines

From 1974 to 1979, the Nordel Operations Committee's Working Group for System Operation dealt with the question of common guidelines for frequency control. A number of full-scale tests were implemented during this period. The results of the tests were analysed and reported on a continuous basis to the Operations Committee. Since 1979 these common guidelines for frequency control are followed by the Nordel countries.

The guidelines are aimed at maintaining satisfactory operational reliability while at the same time:

- Ensuring satisfactory quality with regard to grid frequency and synchronous time
- Enabling an improvement of the total economy of the Nordic electric power system and an appropriate distribution of resulting profits
- Enabling optimal utilisation of the national production systems and transmission lines
- Enabling a high degree of utilisation of tie-lines between the Nordic countries

The guidelines are devoted exclusively to frequency control and generation control during normal operation. The guidelines are based on the assumption that each of the national power systems always has enough installed capacity available during normal operations so that within 15 minutes it can cover its own consumption + contracted deliveries — contracted purchases + contracted operating reserves.

Predictive generation control

It is assumed that consumption forecasts can be developed in various ways, but the goal is a time step of about one hour. It is also assumed that a developed production plan to cover demand will be available by the start of the next hour at the latest. The plan should indicate an integrated area control error of zero for each individual hour. The national subsystems are free to select means that will enable them to maintain a continuous capability for adjusting production to meet national demand.

Automatic frequency control

The total composite regulating characteristic should be in the range 6,000-8,000 MW/Hz. This commitment is divided among the national systems on the basis of annual energy consumption. Distribution according to consumption in 1981 was as follows:

Denmark (Zealand) 4.5 % 270 MW/Hz
Finland 17.4 % 1 050 MW/Hz
Norway 37.0 % 2 220 MW/Hz
Sweden 41.1 % 2 460 MW/Hz

The total frequeny control reserve should be at least 600 MW at 50.0 Hz. Distribution of this reserve on the basis of electricity consumption in 1981 was as follows:

Denmark (Zealand) 4.5 % 27 MW/Hz
Finland 17.4 % 105 MW/Hz
Norway 37.0 % 222 MW/Hz
Sweden 41.1 % 246 MW/Hz

The frequency control reserve should be activated at 49.9 Hz. The composite frequency regulating characteristic and the frequency control reserve within the national systems should be positioned so as to provide maximum internal transmission capacity. It should also be possible to exchange the composite frequency regulating characteristic and the frequency control reserve between countries as needed in order to maximise transmission capacity on tie-lines and/or to achieve better utilisation of the power system.

Adjustment of production

Decisions to adjust production set-points or contracted power exchanges are based on the following measurements of estimates of the following values:

- Own immediate area control error
- Own integrated area control error
- Frequency deviation
- Time deviation
- Power exchange deviation on individual tie-lines to own subsystems

Adjustment of production set-points or contracted power exchanges may be implemented in stages. The magnitude of each stage can be selected with reference to optimal economy in each of the subsystems. Adjustments should be made in the following cases:

- If the immediate area control error is about to exceed the permissible limit and the adjustment will simultaneously reduce the value of $\triangle$ f
- If the immediate set-point fault on a tie-line is about to exceed the permissible limit. However, in Sweden it is not necessary to adjust for conditions on tie-lines with Finland/northern Norway of Denmark/Zealand.
- If the integrated area control errors as measured over a period of one hour is about to exceed the permissible limit.
- If the time deviation is about to exceed 10 seconds (i.e. about 8 seconds). This is a task for Sweden and Norway, as these countries jointly account for about 75 % of Nordic electricity consumption.
- If the frequency deviation is about to exceed 0.1 Hz. Sweden and Norway have the prime responsibility for maintaining frequency in this case.
- On request from a neighbouring system. Economic compensation in this connection is determined bilaterally by the two subsystems involved.

Adjustment of contracted power exchanges can serve as an alternative to adjustment of production, provided that the frequency deviation in the total system remains within permissible limits. Offsetting of energy deviations is subject to bilateral agreements.

Bilateral agreements can also cover offsetting/compensatory deliveries for energy deviations over periods exceeding one hour.

Permissible power and energy deviations under normal operation

In the summer of 1982 the Operations Committee approved the following guidelines:

- Permissible immediate power deviations for individual tie-lines are to be limited for reasons of operational reliability to a value which is determined bilaterally.
- Permissible integrated area control

errors lasting more than one hour are to be integrated, unless otherwise stipulated in bilateral agreements, to a MWh-value equal to 10 % of the numeric value of the composite regulating characteristic. Currently permissible integrated area control errors by country are as follows:

Country	MWh/h
Denmark (Zealand)	30 (integrated by △ P)
Finland	60
Norway	202 (of which 25 MWh/h refers to northern Norway)
Sweden	246

■ The permissible immediate control error is also limited to a value equal to 1.5 times the permissible integrated control error, but not less than 200 MW.

Frequency control during disturbances

The members of Nordel have also agreed on the magnitude and distribution of the immediate production loss reserve. The required production loss reserve in the Nordel system is determined every week on the basis of the design-base productions loss. The magnitude of the reserve is generally determined by the capacity of the largest thermal power plant currently in operation, which is usually the joint design-base production loss for Norway and Sweden. At present, the required immeditate production loss reserve is defined as the designbase reserve less 200 MW, which is determined by the frequency and voltage dependency of the consumption. Reserves are distributed among member countries in proportion to the design-base production loss in each country.

A reactive power reserve is needed to ensure that production losses and grid faults do not generate disturbances in stability. Each subsystem is responsible for maintaining a reactive power reserve in its own area. In general, the immediate reserve should deliver a reactive production back-up within 5 seconds.

A rapid production loss reserve should be available to restore the immediate reserve within 15 seconds after it has been used. In general, the magnitude of the rapid and gradual prodution loss reserves are determined at the national level.

The following rules for production loss reserves were determined by the Operations Committee in the summer of 1982:

■ Within the Nordel system an immediate reserve should be maintained of a magnitude and a composition so that faults which occur with a greater probability than once every three years will not generate disturbances of stability or lasting frequencies of less than 49.5 Hz.
■ An rapid reserve should be available to the extent required to avoid the unacceptable distribution of loads which can be anticipated in a subsystem after a disturbance. This reserve should also be available for rapid restoration of immediate reserves after the latter have been used to compensate for a disturbance.
■ The activation of the joint immediate reserve should not be restricted by limitiations in grids.
■ Within each subsystem, a weekly identification should be made of the most severe fault that would require application of the production loss reserve. This application should not involve temporary power exchanges through tie-lines. Fault identification should be reported to the Swedish State Power Board by telex on the Thursday before the week in question, together with other reports on operational conditions.
■ A joint immediate production loss reserve is to be determined each week by the Swedish State Power Board. This reserve is to be distributed among the member countries. The Board informs the various sub systems as to their share of the reserve for a given week, no later than 5 PM on the Thursday of the preceding week.
■ Determination of the magnitude of the joint immediate reserve should take account of the self-regulating characteristics of the grids. The Operations Committee has for this and other reasons decided that the joint reserve will be limited to 200 MW below the design-base loss.
■ Each individual subsystem then determines how great a share of the reserve it will maintain or purchase. Purchase and sale of immediate production loss reserves can occur between countries on the basis of bilateral agreements. The parties to power exchanges are responsible for the increases in the reserves which can be required as a result of temporary power exchanges.
■ In addition to immediate and rapid reserves, graudal reserves corresponding to at least the magnitude of the most severe fault should be maintained within the Nordel system.
■ The immediate production loss reserve should be available for use until the rapid reserve is adjusted. If the rapid reserve is insufficient in relation to the fault that has occurred, the gradual reserve should be transferred to the rapid reserve in the most appropriate manner.
■ Load shedding caused by voltage or frequency drops is not normally included in the production loss reserve, with the exception of contracted load sheddings such as shutting off of pulp-mill load or other disconnectable consumption such as electric boilers.
■ In adjusting for faults and/or shutting down of tie-lines that determine the Nordel production loss reserve, the production loss reserve should be redistributed as a means of re-evaluating its magnitude.
■ A reactive power reserve should be available within the subsystems with regard to the design-base faults in the subsystems.
■ In general, high-quality (faster) reserves may be used to replace low-quality (slower) ones.

Grid protection

Grid protection is defined as automatic protective equipment that is not primarily used to protect specific parts of a plant, but is designed to prevent larger or smaller parts of the joint power system from being exposed to uncontrollable operational conditions after a disturbance, as such conditions can involve involuntary cut-off of deliveries or a total breakdown.

Frequency-controlled grid protection comprises automatic protective equipment which is activated by frequency deviations that are greater than those for which the frequency control reserve and the immediate production loss reserve are designed.

Grid protection operations, whose magnitude is adapted to the extent of the frequency deviation, affect the power balance in a power system and are designed to limit frequency drops and restore an acceptable frequency level. For large thermal power plants, this involves a frequency level of over 47.5 Hz. Following the implementation of grid protection, the power system may be in a condition that involves scheduled shut-down of deliveries.

Experience shows that implementation of grid protection is scarcely relevant as long as the Nordel network is operated jointly (synchronously). Load shedding is thus a means to attempt to restore power balances in various subsystems following comprehensive disturbances. Such a subsystem can comprise southern Sweden, Zealand, northern Norway or southern Finland. In order to avoid overloading tie- lines, load shedding is localised primarily to areas with production deficits.

The following recommendations were approved at the Nordel Annual General Meeting on August 25, 1983:

- The high-voltage DC (HVDC) links in the Nordel system are to be used for emergency supplies in the frequency range 49.5-49.0 HZ.
- Utilisation of capacity (MW/s and MW) contracted for individual HVDC links should be based on the restrictions that apply to neighbouring grids both in and outside the Nordel system.
- Load shedding in national power systems should be activated when frequency drops to 48.7 Hz. This can be done in stages at frequency intervals of 0.2 Hz which should cumulativiely account for 20-50 % of the total load, depending on the magnitude of the anticipated production loss.
- The magnitude, positioning and distribution of individual load shutdowns within a frequency stage should be determined with regard to the requirements of joint Nordel operations. This means that the first load- shedding stage should be implemented at or near the central load points of the Nordel system, i.e. in central Sweden, southern Sweden and Zealand. This also means that load shedding in more peripheral areas such as southern Finland, northern Norway and Vestlandet should not be implemented until there has been a further drop in frequency. This implementation should occur in such a way and to such an extent as to minimise the risk of overload tripping of vital transmission links resulting from changes in load conditions.
- Load shedding can be distributed over grids, so that grids in subsystems with production deficits can be disconnected from the rest of the Nordel network. In general, grid separation based solely on frequency criteria should be implemented only at frequencies below 47.5 Hz.
- Local problems in secondary grids that are not important to the operation of the Nordel system should be solved at the national level.

Concluding remarks

Electrical energy in the form of alternating current must be produced and consumed and the same time. If there is a lack of production, frequency drops and vice versa. Frequency is the balance indicator in a cooperating power system. Without the tie-lines between the countries each country would have to maintain its own frequency. Because of the tie-lines frequency regulation is a common task for the Nordel power companies. Nordel has approved guidelines for frequency regulation, operating reserve and load shedding. In the Nordel system frequency is maintained in a mainly manual way. In many companies (esp. US) frequency regulation is performed by computers. The operating experiencies show however that the frequency variation in the Nordel system is of the same size as in other systems. Thus is it possible to maintain the frequency and power exchanges by simple methods by exploiting the inherent properties of the Nordel-system.

Coordinated expansion of production

Summerized by Anders Löf, Statens Vattenfallsverk

Background

The results reported in the 1982 study NORDENERGI 2020 indicated that additional benefits could be achieved for Nordel activities through increased coordination with regard to planning, expansion and operation of the joint Nordel system. This requires treating the system as a single unit without national boundaries to an even greater extent than at present.

Nordel consequently assigned the Planning Committee the task of implementing more penetrating studies that would nevertheless have the nature of a survey.

With respect to the high-voltage grid, the system is already treated as one unit in all essentials. Additional benefits can be obtained primarily through greater coordination of production.

The framework of production and loads

Denmark

Electricity production is wholly based on conventional thermal power, 96 % of which is generated by coal-firing. Planned expansion will also involve thermal power, in either conventional or nuclear plants. A decision has not yet been made on the introduction of nuclear power.

Total electricity consumption in 1982 amounted to 24.5 TWh and maximum output to about 4,950 MW. Projected figures for 2000 are 38 TWh and 7,700 MW.

Finland

Electricity production is based on hydro, conventional thermal and nuclear power. Conventional thermal power is mostly coal-fired, but some plants are peat-fired. Back-pressure is widely used. Finland also contracts for annual imports of 4 TWh, 600 MW from the Soviet Union. The required expansion is expected to take the form of both back-pressure and nuclear or coal-fired power plants.

Total electricity consumption in 1982 was 41.8 TWh, with a maximum output of about 7,100 MW. The projected figures for 2000 are 70 TWh and 12,100 MW.

Norway

Hydro power acconts for almost 100 % of Norway's electricity production. There are large untapped reserves of hydro power. It is anticipated that required expansion through the year 2000 can be based entirely on hydro power.

Primary electricity consumption in 1982 amounted to 84.3 TWh, with a maximum output of about 16,000 MW. Primary consumption of 122 TWh and a maximum output of 24,100 MW are anticipated for the year 2000.

Sweden

Electricity production is based on hydro, conventional thermal and nuclear power. The Riksdag has authorised the phasing out of nuclear power by the year 2010. The Nordel study assumes that nuclear plants will still be in operation in 2000. Required expansion until 2000 is expected to involve some increase in hydro power as well as additional increases in conventional thermal power.

Primary electricity consumption in 1982 amounted to 98.6 TWh, with a maximum output of about 19,250 MW. The projected figures for 2000 are 145 TWh and 26,900 MW.

The differing production structures in the Nordel countries comprise a vital precondition for obtaining economic benefits through joint Nordel operations. Intensified cooperation is expected to increase these benefits. However, this requires abandoning the current basic principle that each land should maintain a production capacity that can cover its own needs. Capacity will instead be expanded where it will be of maximum value for the over-all system. The study has been based on these assumptions in terms of both expansion and operation.

Expansion alternatives considered in the study

National grids

In all expansion alternatives, it has been assumed that there is no limit to the degree of joint operation, either internally or across national boundaries. This results in somewhat excessively large benefits when the system is considered as a whole.

It is assumed that the two Danish grids are linked across the Stora Bält, so that Denmark can be treated as a single unit.

Production system

Comparisons are based on the national plans for expansion of production.

In calculating the potential profits that can be obtained by treating the system as one unit, it is assumed that district heating (back-pressure) production will first be expanded to the maximum in Denmark, Finland and Sweden. It is assumed however that maximum utlilisation of district heating will already have been attained before 2000. Three alternatives have been studied for additional required expansion:

A. Continued expansion of hydro and nuclear power

According to this alternative, Denmark and Finland would each build two 1 000 MW nuclear power plants. In Norway and Sweden, hydro power would be expanded to an average annual production of 136 and 72 TWh, respectively.

B. Limited expansion of hydro and nuclear power. Expansion of coal-fired plants

For Denmark, this would involve replacing one of the nuclear plants in alternative A with a 1 000 MW coal-condense plant. Alternative A would apply as above for Finland. In Norway, hydro power would be limited to an average annual production of 124 TWh and a 1 000 MW coal-condense plant would be built. In Sweden, 7 TWh per year of hydro would be replaced by 1 000 MW of coal-condense.

C. Strictly limited expansion of hydro. Additional expansion exclusively of coal-fired plants

According to this alternative, no nuclear plants would be built in Denmark or Finland. Each country would install 2 000 MW of coal-condense instead. In Norway, hydro would be limited to an annual average of 116 TWh, with an additional 2 000 MW of coal-condense. Alternative B would apply as above for Sweden.

Calculation techniques and preconditions

In each of the above alternatives, the fixed and variable costs for the power system have been calculated for new plants and optimised (minimum cost level). The resulting figures for costs have been compared with the corresponding costs of national expansion. The cost differential is the profit obtained by treating the system as one unit.

In terms of consumption, both primary and variable electricity deliveries have been considered. The magnitude of primary deliveries is reported above. In addition, there is a rather large market for variable deliveries which could be supplied in the form of electricity, the power situation permitting, to the extent that consumers have equipment (electric boilers, etc) which would enable electricity to be used. The total potential for variable deliveries by 2000 is estimated at 30—35 TWh annually (or 8—9 % of the total system load).

Calculations have been based on a simulation program for studies of power balances. Calculations for hydro power are based on conditions over a statistically established 25-year period. Those for conventional thermal power and nuclear power are based on probable availability of these types of energy. Electricity loads correspond to the average weekly value through the year. Fuel costs for conventional thermal plants and for nuclear plants are assumed to be equal in all countries. Norweigian and Swedish figures have been used to estimate the cost of expanding hydro power. For other types of energy, the costs are assumed to be independent of locality. In all countries, the same criteria have been used for power system design with regard to reliability of supplies.

The costs of the power system are illustrated schematically in figure 7. »Required oil« represents the cost of oil for that part of the variable market which cannot be supplied with electricity.

The interest rates used for calculating costs in the Nordel countries vary widely. As interest is a parameter which has considerable effect on the results of calculations, three alternative rates have been applied : 4 %, 7 % and 9 %.

Assumptions as to the development of fuel prices also have a considerable effect on results. Studies have therefore been made for two alternatives: a) constant real prices and b) a 2 % annual increase in real prices.

Conclusions

The study has centred on the situation in the year 2000. Calculations indicate that in all three of the alternatives examined it will then be possible to reduce the expansion of production.

The calculation techniques available have not allowed for consideration of all the important factors which can affect the results of calculations. The Nordel Planning Committee will analyse the uncertain factors in greater detail in a follow-up to the present study.

The following factors should be studied in greater detail:

- Variations in daily and hourly loads and power exchanges have not been taken into consideration, although they are of great importance.

- Only years with average precipitation have been considered with regard to hydro power. Extremes of climate, i. e. wet and dry years, are of great interest for studies.

- No assumptions have been made as to the limits imposed by transmission capacity on links and international grids or by the effect of losses in transmission systems. These must be studied more closely.

- The study is directed to a specific point in time, i. e. the year 2000. This means that expansion has not been avaluated over time.

An optimisation of the total Nordel system would involve a reduced need for expansion of production and thus lower annual capital costs and fixed operating costs. On the other hand, fuel costs would increase, particularly if the reduction applies to hydro and nuclear power. The cost of oil for variable deliveries will increase with the magnitude of the reduction in production capacity, as the capacity for variabel deliveries declines in direct proportion to the cutback of expansion.

Figure 8 illustrates how various costs affect optimisation.

At constant real prices and low interest rates the optimal expansion according to alternative A would be the same for total optimisation and for continued national expansion. At higher interest rates, savings are achieved with total optimisation. In alternatives B and C, savings are also achieved at the minimal interest rate and savings increase with rising interest rates.

If savings are considered in relation to total annual costs for the joint system as well as to the costs of the required expansion of joint capacity, the savings are relatively small. This indicates that the system is already close to optimal size. However, the savings are of such a magnitude that they can well justify more detailed studies within Nordel of the possibility of obtaining these additional benefits.

The conclusions generated on the assumption of a 2 % annual increase in real fuel prices through the year 2000 indicate that for any interest rate the optimal expansion in alternative A is the same for total optimisation as for individual national expansion. In contrast, alternatives B and C generate savings at all interest levels. These savings are however considerably lower than at unchanged real fuel prices.

The conclusions described above assume that there are no general requirements for scrubbing of sulphur emissions. If these requirements are applied, the cost of coal-fired plants increases. This generates a higher value for joint expansion, particularly in alternative C.

Nordel in brief

Nordel, founded in 1963, is an association for people who are active in the field of power supply in Denmark, Finland, Iceland, Norway and Sweden. It is an advisory and recommendatory organization aimed at promoting international, mainly Nordic, co-operation in the field of production, distribution and consumption of electrical energy.

Nordel has the following permanent tasks:

- to continually follow developments in production and consumption of electrical energy in the Nordic countries by, for example, publishing suitable statistics
- to collocate consumption forecasts and extension plans drawn up in the resepective countries
- to publish an annual report which, in addition to information about work completed during the year in Nordel, and statistical information about power supply in the Nordic countries, can also contain special articles of interest in the field of Nordic power co-operation.

A considerable amount of Nordel's work takes place in standing and special committees. Standing committees have been appointed to deal with recurrent questions while special committees deal with questions of a more transient nature. In some cases contact groups have also been appointed.

The chairman of Nordel is elected for a period of three years. The chairmanship circulates among the countries. The chairman appoints a secretary who is responsible for the administrative functions during the three year period.

Nordel

Nordels ordförande Göran Ekberg, omgiven av fyra nordiska energiministrar. Från vänster ses Kåre Kristiansen, Norge, Knud Enggaard, Danmark, Birgitta Dahl, Sverige och Sverrir Hermansson, Island
The chairman of Nordel and the Nordic ministers of Energy

Nordel, som grundades 1963, är en sammanslutning för nordiskt elkraftsamarbete. Nordel består av ledande personer inom kraftförsörjningen i Danmark, Finland, Island, Norge och Sverige. Det är ett rådgivande och rekommenderande organ med syfte att befrämja internationellt, främst nordiskt samarbete, beträffande produktion, distribution och konsumtion av elenergi.

Nordel har följande fasta arbetsuppgifter:

— att kontinuerligt följa utvecklingen av produktionen och konsumtionen av elenergi i de nordiska länderna, bl a genom publicering av lämplig statistik.

— att sammanställa inom respektive länder uppgjorda konsumtionsprognoser och utbyggnadsplaner

— att publicera en årsberättelse, som förutom uppgifter om under året utfört arbete inom Nordel samt statistiska uppgifter angående elkraftförsörjningen i de nordiska länderna även kan innehålla speciella artiklar av intresse för nordiskt kraftsamarbete.

En stor del av Nordels arbete utförs av utskott och grupper. Genom dessa har man tillgång till specialister inom alla områden av elförsörjningen. För insamling av statistik och annan periodisk rapportering finns speciella kontakmän i de olika landen. Inom Nordel finns också kontaktmän i många internationella organisationer på energiområdet.

Nordels ordförande väljs för en period om tre år. Ordförandeskapet cirkulerar mellan länderna. Ordförande utser sekreterare och svarar för sekretariatet som alltså även det växlar vart tredje år.

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