

Hydropower resources

Agenda :

1. Data basis
 1. Maps
 2. Hydrology
2. Consept
 1. Dam & intake
 2. Waterway
 3. Power plant
3. El-mech
 1. Turbine & hydraulic steelwork
 2. Generator & transformer
 3. Switchgear and control equipment
 4. Power line
4. Optimalisation
 1. On NPV
5. Risks



The Capacity formula

$$P = Q * g * H * \eta$$

P – Power (kW)

Q – Water flow (m³/s)

g – gravity force (9,81 m/s²)

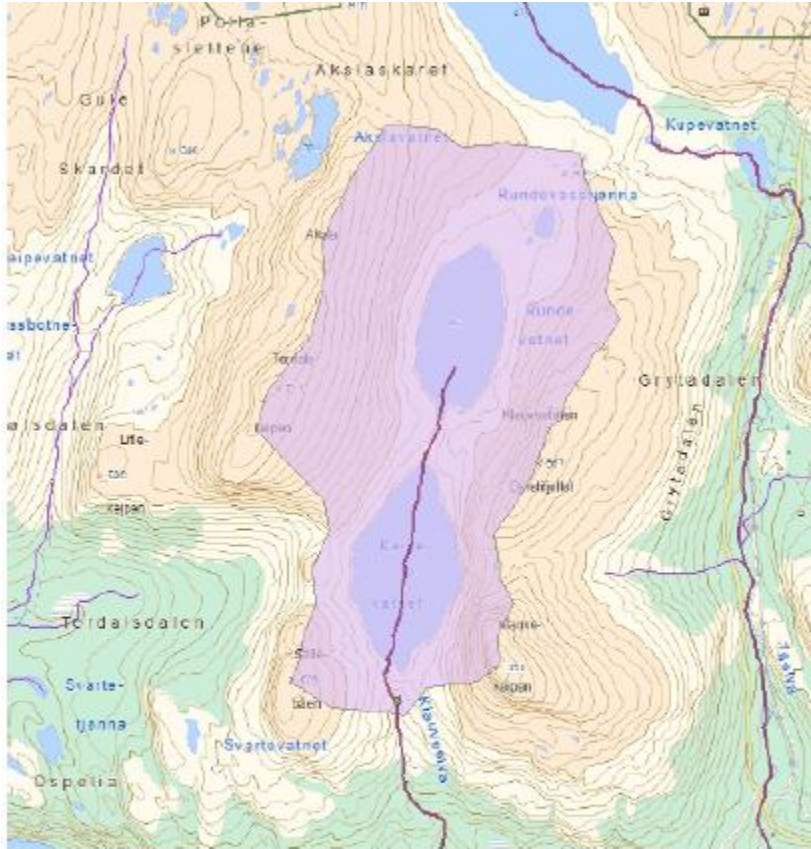
H – head (m)

η – efficiency curve (...)



$$P_{nat.hp.} = Q * H * 13,33 \text{ (whereas } 13,33 = g * 0,736)$$

1 – Data basis



Norges
vassdrags- og
energidirektorat

Kartbakgrunn: Statens Kartverk
Kartdatum: EUREF89 WGS84
Projeksjon: UTM 33N

1. Hydrology
 - NVE Atlas
 - Water marks with daily records
2. Maps
 - NGO map in scale .. 1 : 50 000
 - Detail Map 1 : 5 000
3. NVE Cost basis
 - Cost figures of 2010
 - Own experience figures
 - Budget offers
 - etc



2 – Concepts

1. Dam location

- Principal location acc. water volume
- Location acc foundation circumstances
- Regulation of lakes

2. Waterway trasé

- Main prinsiple
 - Open channel
 - Burried pipes
 - Waterway in rock (tunnel)
- What is possible and reasonable
- What holds the least risk factors

3. Location of power house

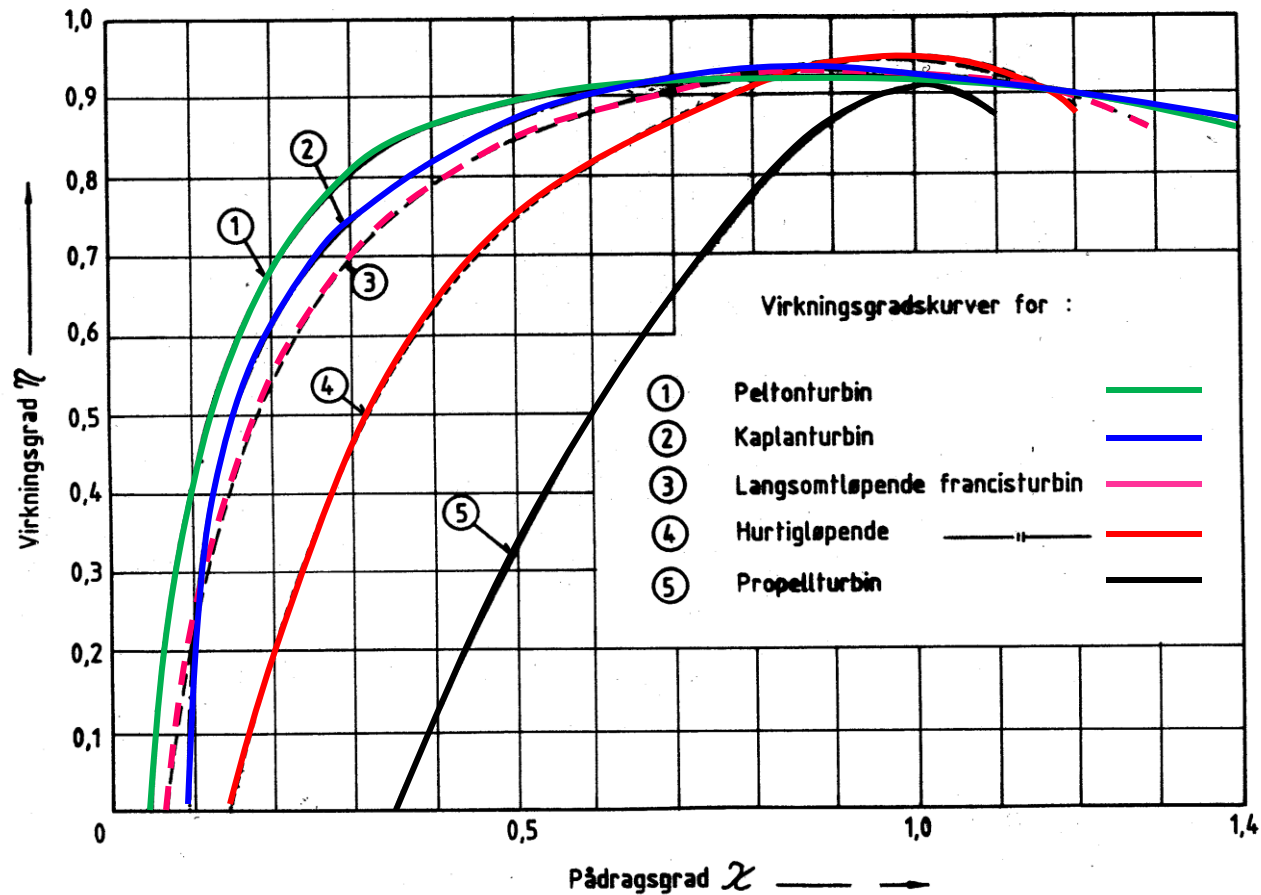
- How far down is possible
 - Property limits
 - Protected areas
 - Anadrom fish areas of the river
 - Ground conditions
 - Benefit

4. Other elements

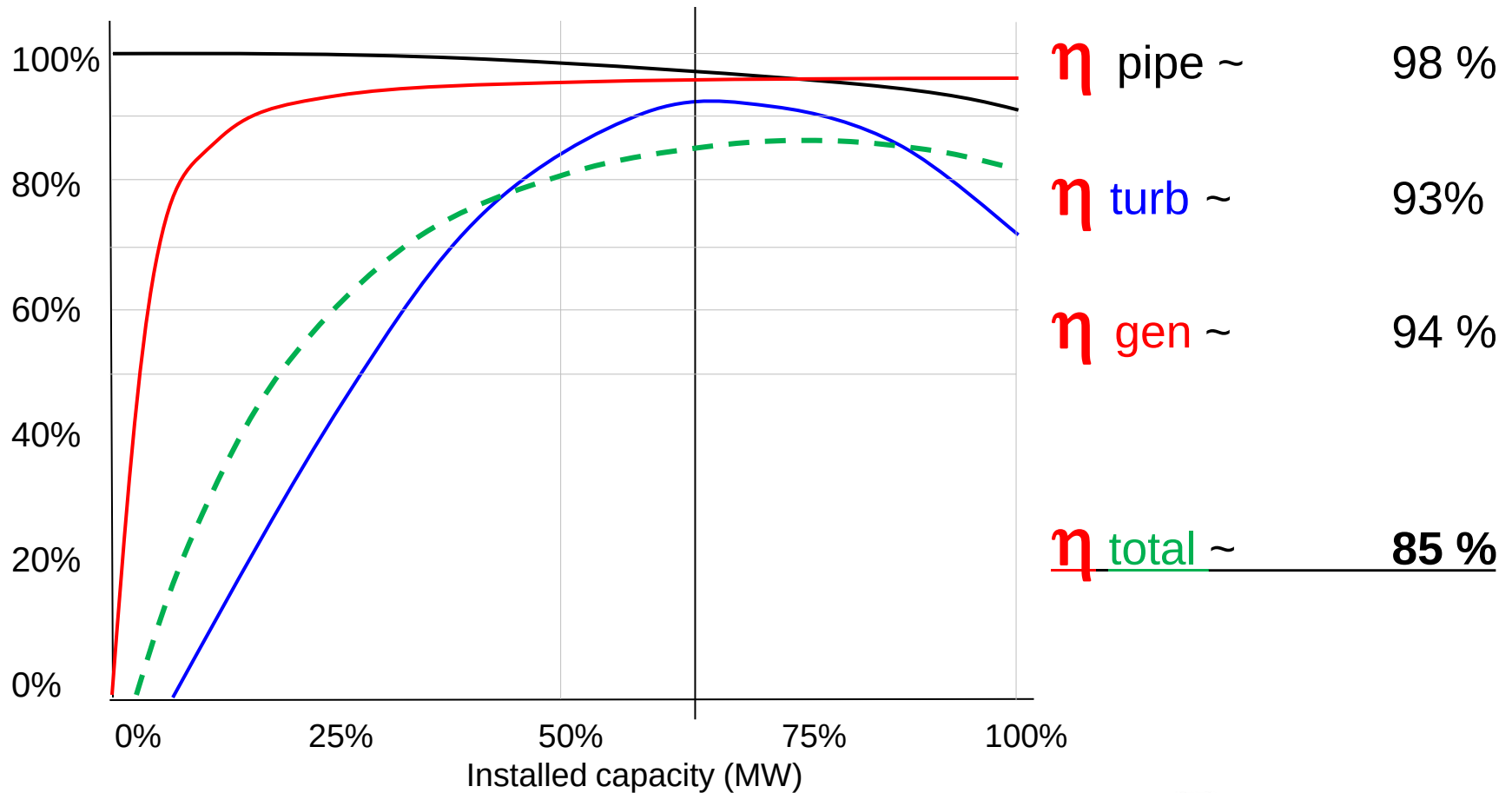
- Access roads
- Power lines



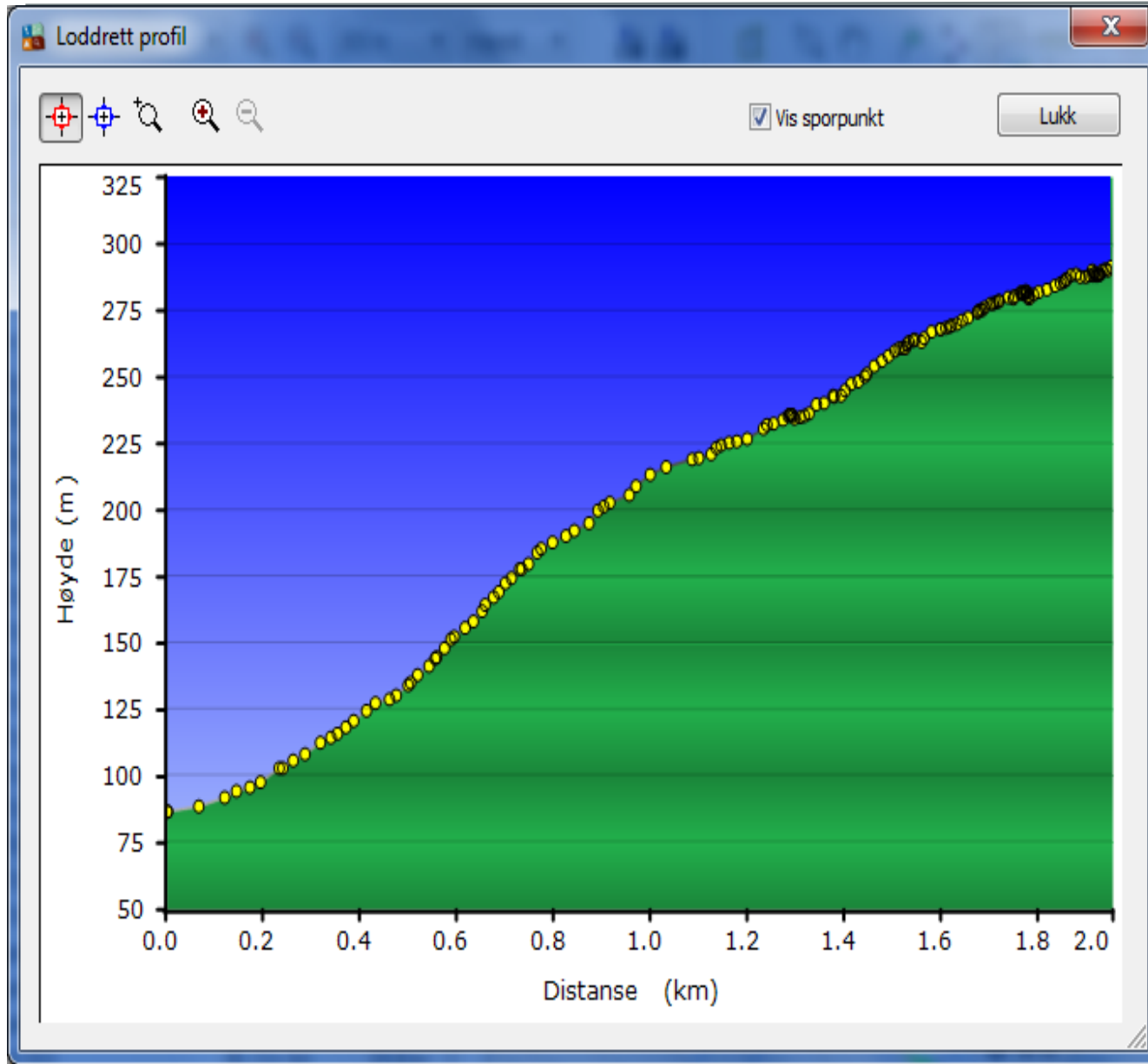
3 – El-mech – efficiency curves for turbines $P = Q * g * H * \eta$



3 – El-mech – Factors of efficiency curves as a product



4 – Optimisation of waterway (net pressure) $P = Q * g * H * \eta$



Hinn = 665 moh

Hpopl = 25 moh

Hgross = 640 m

- **Head loss**
in pipe

- **< 2% = 12,8 m**

Hnet = 627 m

4 – Optimisation of waterways

$$P = Q * g * H * \eta$$

Head loss is depending on :

$$H_f = k(L/D)v^2/2g$$

k – Friction faktor

L – Length of pipe (m)

D – Diameter of pipe (m)

v – Water velocity (m/s)

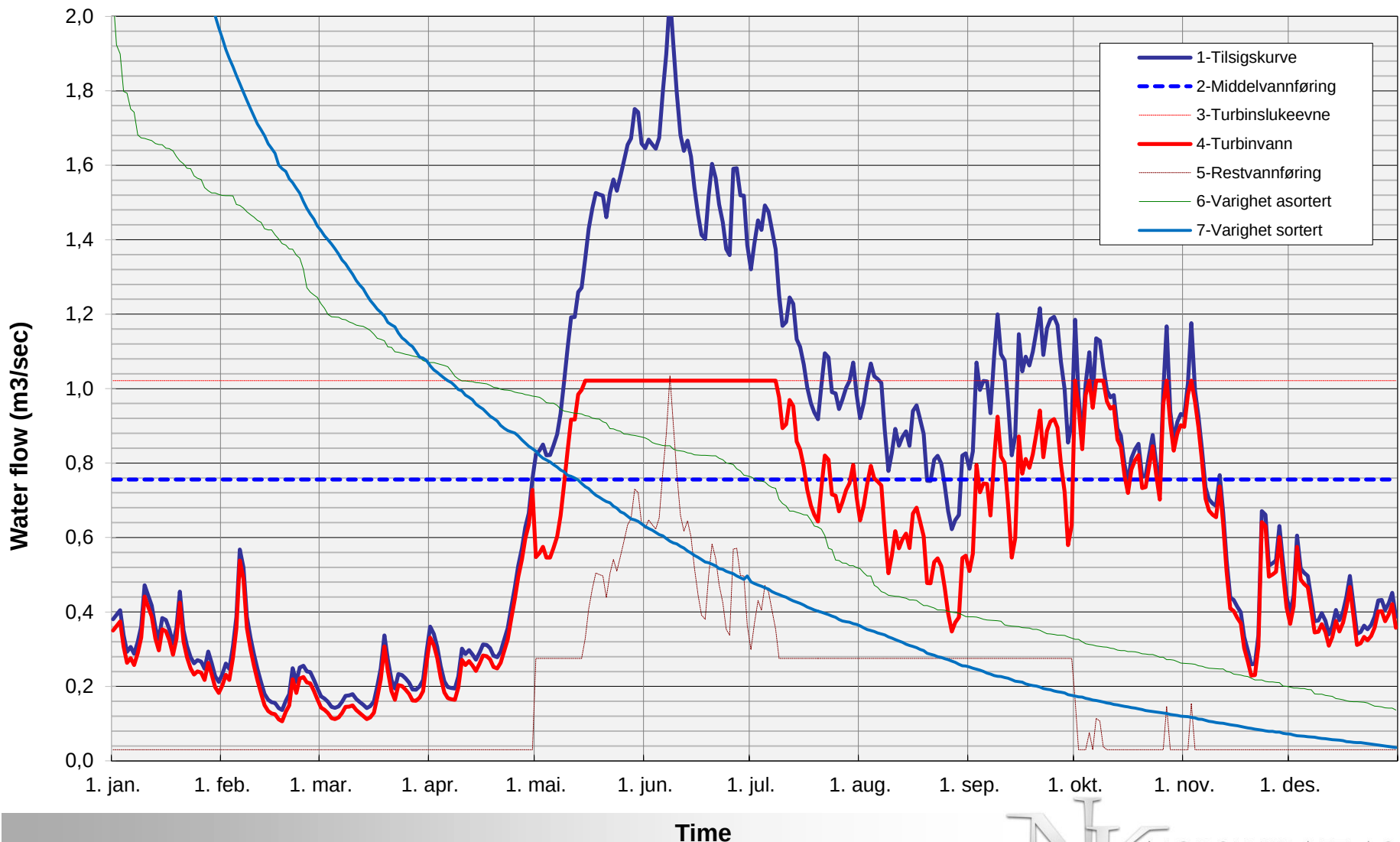
g – gravity factor (m/s²)



4 - Hydrology and turbine capacity

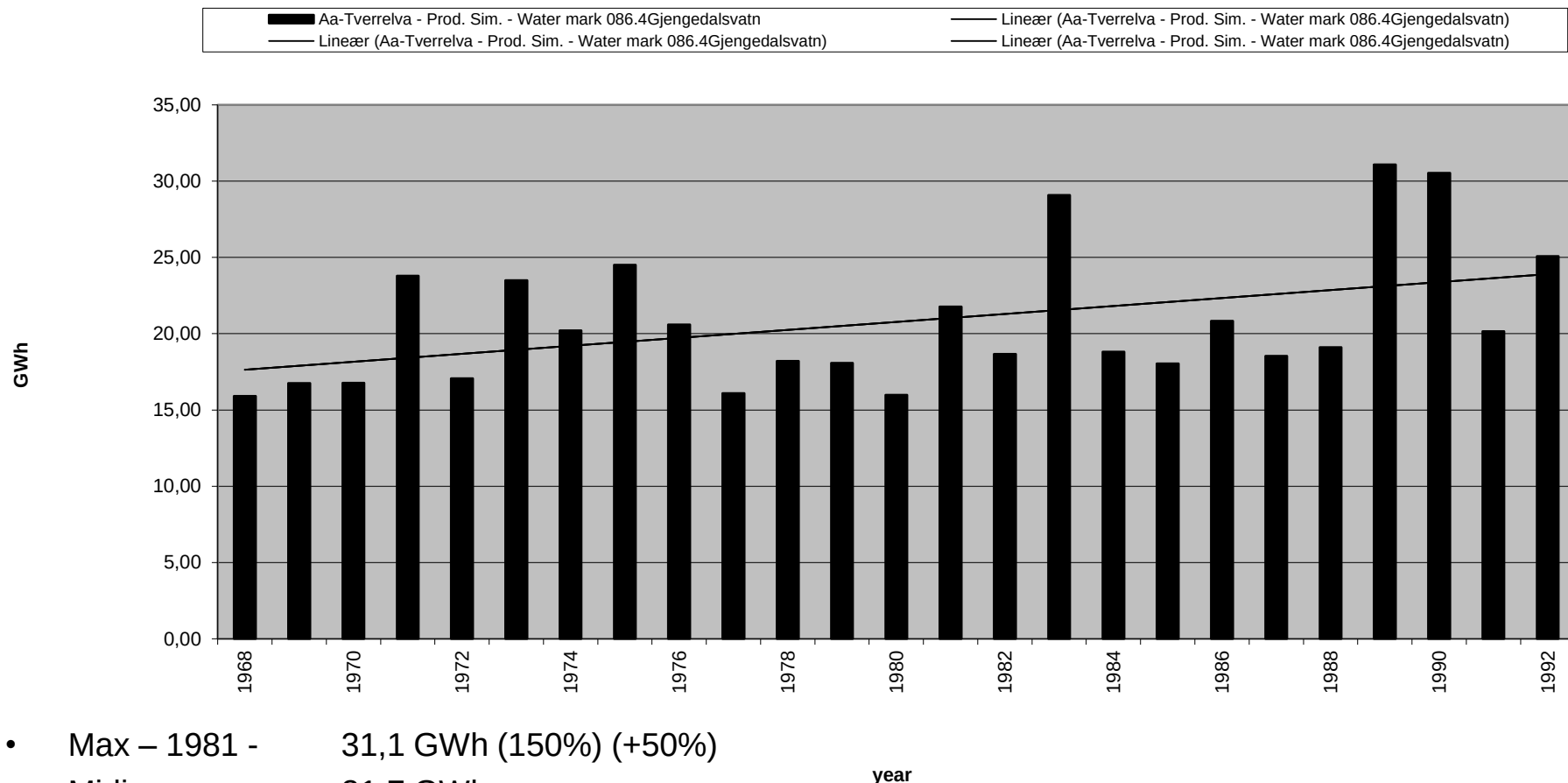
River run-off

Run-off curve



4 – Optimisation acc hydrological annual productions (avg.)

Historiske produksjoner

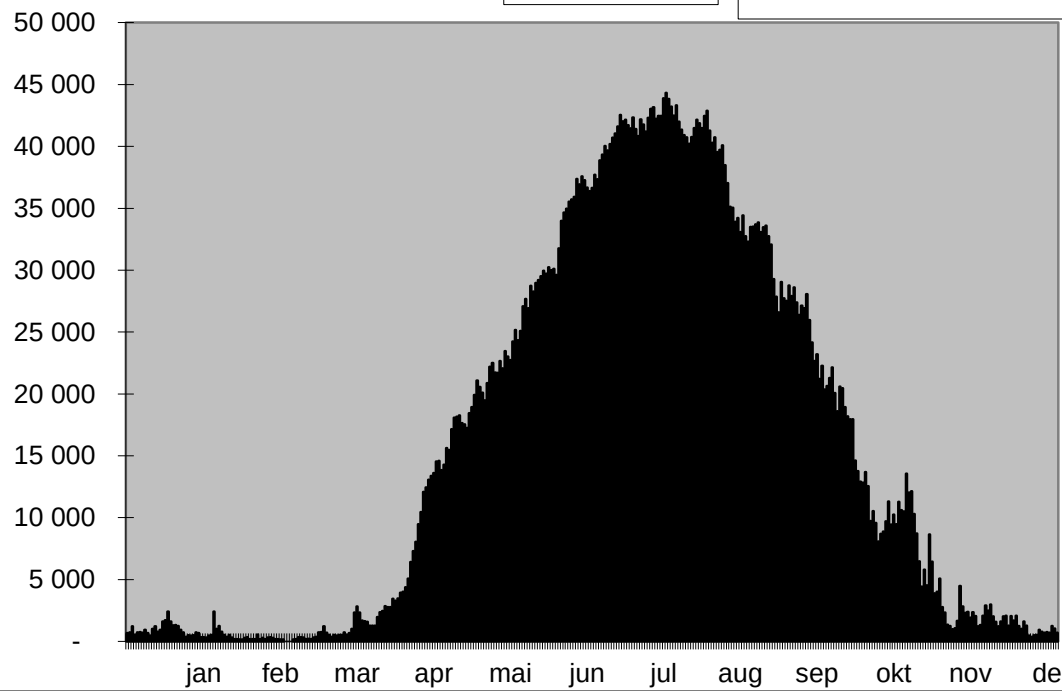


- Max – 1981 - 31,1 GWh (150%) (+50%)
- Midium- 21,7 GWh
- Min – 1988 - 11,5 GWh (50%) (-50%)



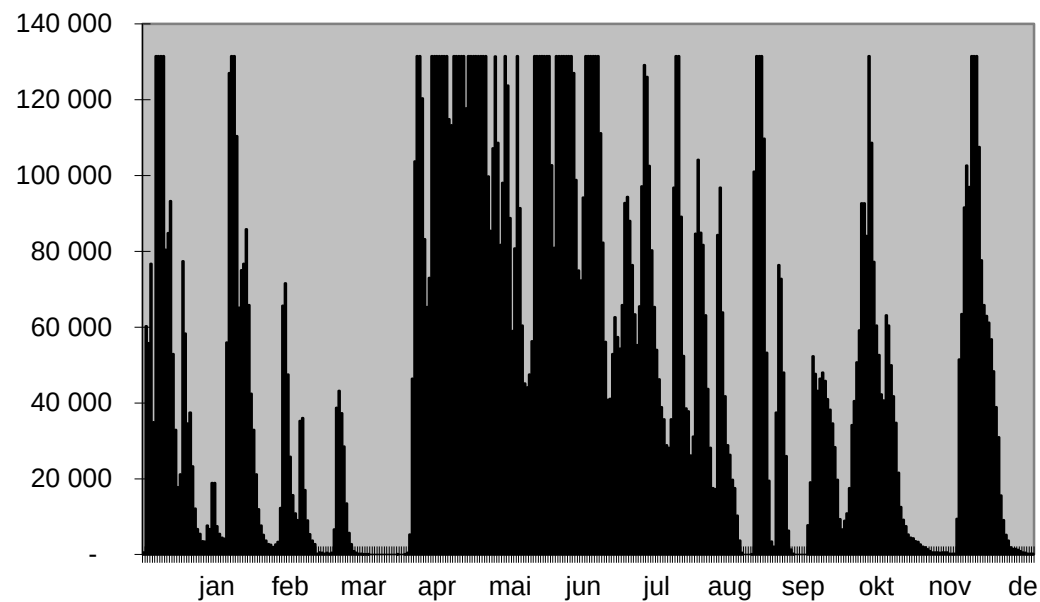
Bøymseiv døgnavrenning

1973-2005



Aa-Tverrelva - Prod. Sim. - Water mark 086.4Gjengedalsvatn

Døgnsproduksjon år



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4 – Optimisation with several scenarios

Klauva - Inntak kote 402 & Avløp kote 2 moh => 400 m Brutto fallhøyde

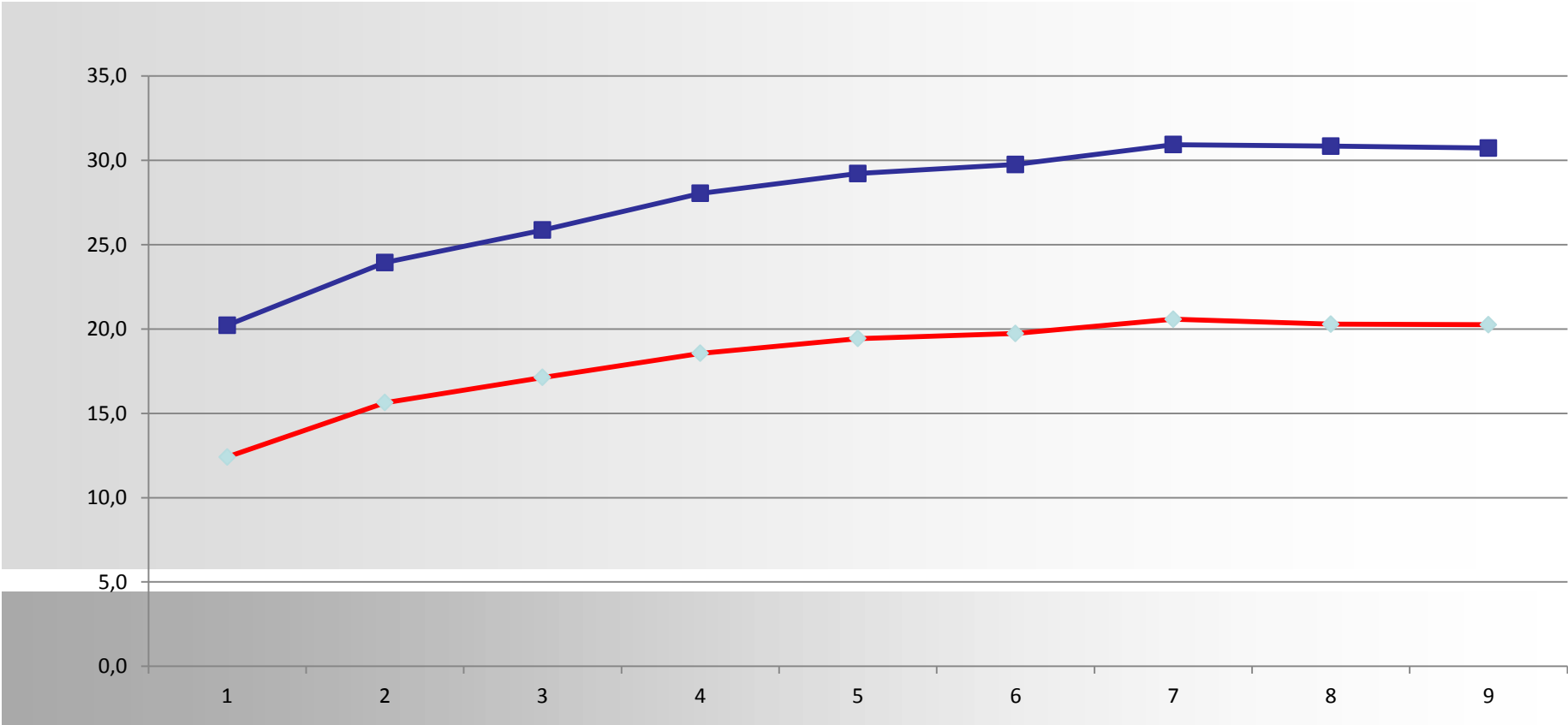
Alternativer			1	2	3	4	5	6	7	8	9
	Turbinslukeevne	%	100 %	125 %	150 %	175 %	200 %	225 %	250 %	275 %	300 %
	Q-maks	m3/s	0,384	0,480	0,576	0,672	0,768	0,864	0,960	1,056	1,152
	Q-min	m3/s	0,004	0,005	0,006	0,007	0,008	0,009	0,010	0,011	0,012
	Rørgate, lengde	m	1 412	1 412	1 412	1 412	1 412	1 412	1 412	1 412	1 412
	Rørgate, diameter	mm	600	600	600	700	700	700	800	800	800
	Fall	m	400,0	400,0	400,0	400,0	400,0	400,0	400,0	400,0	400,0
	Falltap i m	m	3,7	5,7	8,3	5,2	6,8	8,6	5,5	6,6	7,9
	Falltap i %	%	0,9 %	1,4 %	2,1 %	1,3 %	1,7 %	2,2 %	1,4 %	1,7 %	2,0 %
	Netto fall ved maks pådrag	m	396,3	394,3	391,7	394,8	393,2	391,4	394,5	393,4	392,1
	Installasjon	kW	1 300	1 600	2 000	2 300	2 600	2 900	3 300	3 600	3 900
	Middelproduksjon	GWh	6,2	7,0	7,5	8,2	8,6	8,8	9,3	9,4	9,6
	-										30

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Estimated costs			20								
A	Civil works		13,86	13,99	14,12	15,27	15,40	15,52	15,60	15,73	15,85
	Mobilisering og rigging		1,26	1,27	1,28	1,39	1,40	1,41	1,42	1,43	1,44
	Infrastruktur, veier, etc.		0,75	0,75	0,75	0,75	0,75	0,75	0,75	0,75	0,75
	Reg.anl., dam og inntak		4,39	4,39	4,39	4,39	4,39	4,39	4,39	4,39	4,39
	Kraftstasjon		1,59	1,70	1,81	1,92	2,03	2,14	2,25	2,36	2,46
	Rørgate - graving, legging og		3,19	3,19	3,19	3,23	3,23	3,23	3,27	3,27	3,27
	Rørgate i fjell - Ø 800		2,14	2,14	2,14	3,04	3,04	3,04	2,96	2,96	2,96
	Rørgate - rør		-	-	-	-	-	-	-	-	-
	Tunnel 20 m2		-	-	-	-	-	-	-	-	-
	Kanal for Q*= 1,15 m3/sek		0,04	0,05	0,05	0,06	0,06	0,06	0,07	0,07	0,07
	Sandfang		-	-	-	-	-	-	-	-	-
	Hus, lager- og verkstedhall		0,50	0,50	0,50	0,50	0,50	0,50	0,50	0,50	0,50
B	Elektro- maskin		5,77	6,67	7,88	8,71	9,52	10,32	11,42	12,18	12,94
	Komplett aggregat		3,95	4,64	5,59	6,23	6,86	7,47	8,32	8,90	9,48
	Transformator & 22 kV		0,58	0,58	0,58	0,58	0,58	0,58	0,58	0,58	0,58
	22 kV HS anlegg		0,87	1,04	1,28	1,45	1,62	1,79	2,02	2,18	2,35
	Ventilasjon og		0,28	0,30	0,32	0,33	0,35	0,36	0,38	0,39	0,41
	Kran		0,06	0,06	0,06	0,06	0,06	0,06	0,06	0,06	0,06
	Husinstallasjon		0,04	0,04	0,04	0,05	0,05	0,05	0,06	0,06	0,06
C	Kraftlinje (kabel)		2,46	2,76	3,15	3,44	3,74	4,03	4,42	4,72	5,01
=	Sum anleggskostnader		22,10	23,42	25,14	27,43	28,66	29,88	31,45	32,63	33,80
D	Planlegging og administrasjon		1,16	1,23	1,32	1,44	1,50	1,57	1,65	1,71	1,77
	Forsikring	0,25 %	0,06	0,06	0,06	0,07	0,07	0,07	0,08	0,08	0,08
	Erstatninger og utbedringer	0,0 %	-	-	-	-	-	-	-	-	-
	Planlegging og	2,5 %	0,55	0,59	0,63	0,69	0,72	0,75	0,79	0,82	0,85
	Byggeledelse	2,5 %	0,55	0,59	0,63	0,69	0,72	0,75	0,79	0,82	0,85
E	Eiendomskjøp		-	-	-	-	-	-	-	-	-
F	Uforutsett	15,0 %	3,32	3,51	3,77	4,11	4,30	4,48	4,72	4,89	5,07
G	Skatter og avgifter, MVA	0,0 %	-	-	-	-	-	-	-	-	-
H	Prosjektreserver	0,0 %	-	-	-	-	-	-	-	-	-
=	Totalsum for finansiering		26,58	28,16	30,23	32,98	34,46	35,92	37,81	39,24	40,65
	Finanskostnader i 1 år	9,0 %	1,79	1,90	2,04	2,23	2,33	2,42	2,55	2,65	2,74
Total utbyggingskostnad			28,37	30,06	32,27	35,21	36,79	38,35	40,37	41,88	43,39
Spesifikk kostnad Kr/kWh			kr/kWh	3,85	4,56	4,31	4,28	4,30	3,85	4,48	4,52

4 – Optimalisation with several scenarios acc Net pres Value

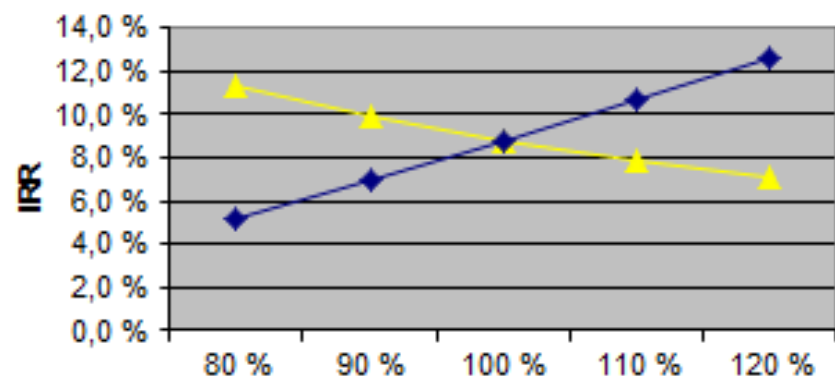
Net Present Value (NPV)



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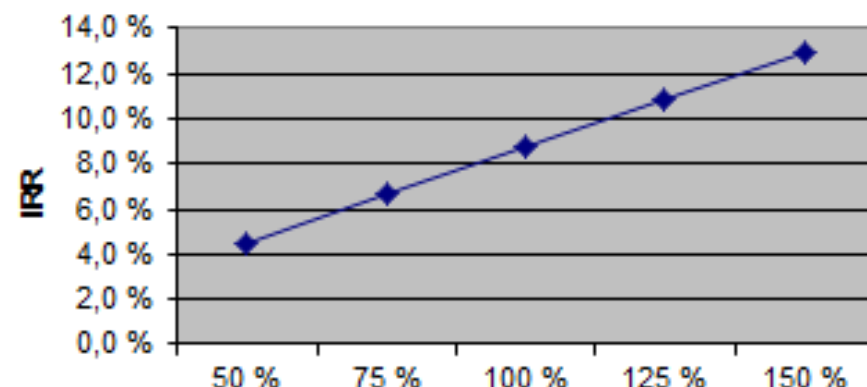
Følsomhetanalyse for

1) Investeringer 2) Produksjon



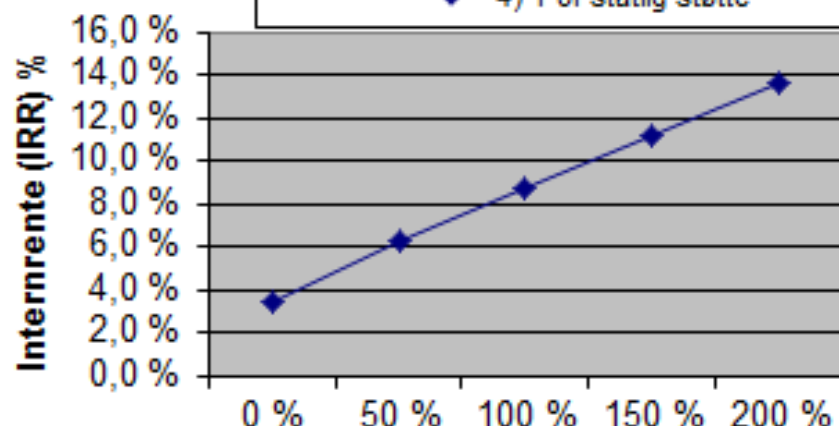
Følsomhetanalyse for

3) Kraftpris



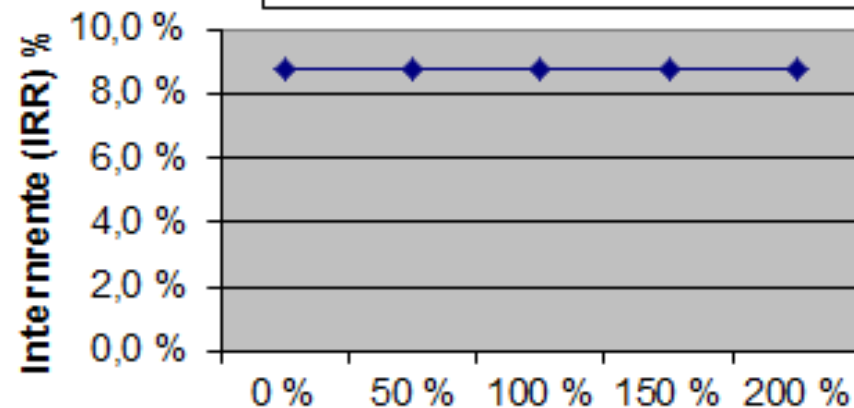
Følsomhetsanalyse for

4) For statlig støtte



Følsomhetsanalyse for

5) Avgifter



5 - Risks

1. Income
 - Electricity tariff and el-certificates
2. Hydrological deviations
 - Annual average volume and river run-off profile
3. Construction costs
 - Earth works and construction costs
4. Taxes and levies
 - Economic interest tax (grunnrenteskatt)
5. Technical issues
 - Deviating- efficiencies, power , quality,
 - occasional events like lightning strokes,
 - Sabotage,
 - etc