

A GIS tool for mapping of pump storage potential in Norway

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Background



- Large interest in Norway's potential for pumped storage hydropower (PSH) to develop renewable energy sources
- Pre-study from 2011 for southern Norway: selection of potential PSH connections based on expert knowledge
- GIS-tool: mapping for entire Norway based on documented selection criteria (first stage; no costs or reservoir interactions included)





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GIS mapping of PSH potential in Europe



 Linking two existing reservoirs, or
 Transformation of one existing lake or reservoir to PHS by detecting a suitable site for a second reservoir



Schmidt et al. (2011); Mapping of potential in Thüringen (Germany)

Norway:

Only linking of existing reservoirs, no construction of new ones

JRC SCIENTIFIC AND POLICY REPORTS

Assessment of the European potential for pumped hydropower energy storage

A GIS-based assessment of pumped hydropower storage potential 3

Marcos Gimeno-Guti Roberto Lacal-Aránte

2013





n of new ones



Scheme of a pumped hydropower storage reservoir pair



GIS mapping of PSH potential in Europe

Recommendations from a PSH GIS mapping workshop (Arántegui and Tzimas, May 2012)

Criteria	Scope			
	National	Region	County	Grid
Max distance between reservoirs (km)	20	20	20	20
Minimum head (m)	50 - 200	25 – 200	15 - 200	50 – 200
Topologies 1 & 2: minimum usable volume of existing	1 Hm ³ /	0.1 Hm ³ /	0.05 Hm ³ /	1 Hm³/
reservoir (Hm ³), or hydropower installed capacity (MW)	10 MW	5 MW	1 MW	10 MW
Topology 2, assumed new reservoir size (m ²)	1 000	700	700	1 000
Topology 2, assumed new reservoir average depth (m)	10	7	7	10
Minimum distance to inhabited sites (m)	2 000	1 000	200	2 000
Minimum distance to existing transportation infrastructure	100	100	0	100
(m)				
Distance to national parks	2 000	1 000	500	2 000
Distance to Natura 2000 sites	200	100	50	200
Distance to special protection areas	200	100	50	200
Minimum distance to a UNESCO site (m)	2 000	1 000	500	2 000
Maximum distance to suitable grid connection (km)	20	20	10	20

Table 1: Proposed values for some of the criteria described, depending on the scope of the assessment. Minimum distances are between the new reservoir under assessment and the given feature⁶.



GIS Mapping Norway

Input data (maps) from the Norwegian Mapping Authority, NVE, and Environmental Agency

Norway has 905 existing reservoirs, 886 of them with a reservoir volume of >100 000 m³

Grey: User-defined input parameters or data sets Green: Result files

Flow chart



Python script tools, included into ArcGIS 10 geoprocessing toolbox







Tool 1: Topographical analysis









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Tool 2 & 3: Production- and environmental related selection criteria

- □ There must be transmission capacities for the produced electricity.
- The water level changes (m/hour) in the upper reservoir and lower reservoir are limited because of environmental considerations (fish stranding etc.) and erosion issues.
- □ Protected areas (e.g. INON) should not be affected.





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Calculates the position	III of environmental influence points (EIP). Computes the distances between EIP and nearest powerline, road and environmentally restricted areas. Adds and calculates new field p	arameter	ter	×



200 Kilometers

100

50

0

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User-defined parameters (can be varied in sensitivity tests)

Table 3: User-defined criteria and default values used in the present study

Criteria	Unit	Default	Note	
Maximum distance between reservoirs	km	50		
Minimum head	m	50		
Minimum hydropower installed capacity	MW	100		
Maximum distance to roads	km	10		
Maximum distance to suitable grid connection	km	20		
Maximum rate of water level change in reservoirs	m/hour	0.13	Based on river data	
Minimum distance to INON areas (not affected by heavy technical installations or constructions)	m	500		
Minimum distance to cultural landscape areas of high priority with biological and historical values	m	500	Distances with response Update and expert	ect to EIP.
Minimum distance to wild reindeer areas	m	2000	assessment necess	ary!
Minimum distance to existing and suggested natural protection areas	m	500	Тоо	I 3:
	•		Scre	eening



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Some screening results

P-Screening-Mode

PSH potential for power production of 400, 700 and 1400 MW, minimum storage duration one day, maximum water level change rate in reservoir 0.13 m/hour





PSH connections for three and 30 days storage





Performance test example: Tinnsjø (C1)



Figure 6: The Møsvatn-Tinnsjø-Kallhovd/Mår area with the PSH cases suggested by Solvang et al. (2012, left) and the GIS-screening results obtained using the P-Mode for 400, 700 and 1400 MW. Dashed lines: PSH lines which are in conflict with the environmental restriction zones.

Table 8: Net inflow from the reservoirs for Case C1

Different net inflow rates, depending on assumptions

		Upper Reservoir: Møsvatn			Lower Reserve	oir: Tinnsjø	
		Solvang et al. (2012)	Arnesen (2013)	So	lvang et al. (2012)	Arnesen (2013)	
Other inflow	m ³ /s			-	99.7		
Other discharge	m ³ /s	87.1			150.2		
Net inflow	m ³ /s	-87.1	-90.5		-50.5	-130.6	



Testing and suggestions for improvements/development



PumpStorageNorway - Southern test area

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Master thesis C. Cortinez (2013):
Suggestions for improvements of some algorithms (e. g. terrain criterion)
Inclusion of a simplified cost estimation as additional selection criterion for a test region in Telemark







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20 Kilometers

Cost estimation



NVE Guidelines for cost estimates; with some simplifications



Testing and suggestions for improvements/development





$$E = \rho g \eta \cdot GPH \cdot V$$

E = total potential energy storage (GWh) GPH = gross pressure height V = volume





Establish a minimum E to clip out lines with very low energy storage potential.



Choose the best GWh/NOK for each reservoir

C. Cortinez (2013)



Conclusions

- The GIS tool showed high PSH potential in the mountains in the southern part of Norway, some relevant sites in Central Norway, few in North-Norway.
- Results are highly depending on net inflow due to existing power plants and reservoir interactions.
- Many of the PSH connections are in conflict with environmental restrictions. Further investigations of environmental restrictions are needed (expert assessment)!
- Suggested improvements and new routines for cost calculation and selection in case of multiple reservoir connections need to be implemented into the GIS tool.







Thank you!

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