Environmental impacts of pumped storage hydropower plants
Norwegian perspectives

Tor Haakon Bakken
SINTEF Energy Research & CEDREN
Structure of talk

1. Typical system design/changes
2. Typical physical and biological impacts
3. Tonstad hydro power system
4. What can we do to reduce the impacts?
5. What we are working on in Norway (CEDREN)
Situation: Extension of existing hydropower plants into pumped storage

- Extension of capacity in head race tunnels and/or build new tunnels
- Installation of reversible turbines or both a turbine and pump in two different water ways
- Extension of grid capacity, if necessary
- Utilisation of existing upstream and downstream reservoirs
- Introduction of new operational regime
  - Changes in seasonal/yearly fluctuations in reservoirs
  - Changes in daily fluctuations in reservoirs
Possible annual fluctuations in reservoir filling

Base case

Scenario
What about daily fluctuations?
Physical impacts in the reservoirs

Lake morphology:
- Limited volume
- Mild slopes along shore
Physical impacts in the reservoirs

- A large portion of volume tapped from reservoir
- Severe reduction in littoral zone
Physical impacts in the reservoirs

Lake morphology:
• Large volume
• Steep walls
• Dominated by rock material?
Physical impacts in the reservoirs

- A limited portion of volume tapped from reservoir
- Reduction in littoral zone
- Limited erodible material/less stranding?
Physical impacts in reservoirs

- More rapid and frequent water level changes (short term basis)
- Changes in reservoir filling over the year (maybe to the better)
- Reduction in permanent wetted littoral zone on short term basis
- Changes in circulation patterns (water velocity/directions)
- Changes in water temperature and ice formation

- Erosion due to wave exposure and pore pressure out of equilibrium
- Landscape changes (tips, flooding of roads/tracks, aesthetic impacts)
Biological impacts

Possible higher risk of spreading of species (also exotic species)

Large part of the biological production is in the littoral zone (close to shore, max 10 m depth). Implications on littoral zone should be detailed analyzed.

Possible changes in feeding pattern due to possible impacts on littoral zone
  • Trout is littoral feeder - invertebrates
  • Char is pelagic feeder – zoo plankton

Possibly lower visibility due to erosion or opposite

Possibly more light (due to less ice), stimulating primary production

Larger volumes of water passing through turbines - fatality of larger species
Example: Tonstad pumping plant (proposed project)

Highlights Tonstad:

- Largest in Norway in production (6.3 TWh)
- Installed capacity: 1760 MW
- Proposed: additionally 960 MW (with pumping)
Example: Tonstad pumping plant (proposed project)
Sirdalsvatn (downstream)

Homstølvatn (upstream)
### Tonstad: Degree of impacts identified in EIA

<table>
<thead>
<tr>
<th></th>
<th>Sirdalsvatn</th>
<th>Homstølsvatn</th>
<th>Ousdalsvatn</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ice, water temp</td>
<td>Insignificant/ small negative</td>
<td>Small negative</td>
<td>Insignificant</td>
</tr>
<tr>
<td>Local climate</td>
<td>Insignificant</td>
<td>Insignificant</td>
<td>Insignificant</td>
</tr>
<tr>
<td>Water quality</td>
<td>Insignificant</td>
<td>Insignificant</td>
<td>Insignificant</td>
</tr>
<tr>
<td>Fish &amp; Invertebrates</td>
<td>Insignificant</td>
<td>Small/medium negative</td>
<td>Medium negative</td>
</tr>
<tr>
<td>Biodiversity</td>
<td>Small negative</td>
<td>Small negative</td>
<td>Small negative</td>
</tr>
<tr>
<td>Landscape</td>
<td>Small negative</td>
<td>Small negative</td>
<td>Medium negative</td>
</tr>
<tr>
<td>Agriculture &amp; forestry</td>
<td>Small/medium negative</td>
<td>Insignificant</td>
<td>Small/medium negative</td>
</tr>
<tr>
<td><strong>SUMMED (*)</strong></td>
<td>Insignificant/ small negative</td>
<td>Insignificant/ small negative</td>
<td>Insignificant</td>
</tr>
</tbody>
</table>

(*) Topics Cultural heritage, society (economical) and local community left out
Follow-up Tonstad case

- More detailed studies on impacts
- Simulation of more extreme scenarios
- Test and develop tools
How to reduce problems?

**Careful selection of sites**
- Large altitude differences (max head)
- Reservoirs containing large volumes of water
- Reservoir with steep sides (reduces loss of littoral zone)
- Reservoirs with low erosion risk
- Avoid spreading of invasive species

**Avoid extreme operational regimes**
- Analyze and find biological threshold values
- Take into consideration seasonality in the biology

**Site specific investigations must be carried out**
- Detailed physical studies needed in order to find biological responses
Centre for environmental design of renewable energy – CEDREN
Renewable energy respecting nature

► 7 large research projects
► 7 Norwegian research partners
► 10 Industry partners and 2 authority partners
► Budget: 263 MNOK (67 MNOK in 2010) (tot. 33 mill Euro)
► 15 PhD and 4 Post-doc positions
PROJECTS

HydroPEAK

EnviPEAK

EnviDORR

BirdWind

OptiPol

SUSGRID

GOVREP

CEDREN Centre for Environmental Design of Renewable Energy
Further info about CEDREN

www.cedren.no (official web site)

tor.haakon.bakken@sintef.no (project leader EnviPEAK)

atre.harby@sintef.no (Director CEDREN)
Summed up

Impacts of pumped HPP depending on:

- Selection of site
- Shape and size of reservoir
- Operational regime
- Mitigating measures
- Can be limited, but must be evaluated case by case

CEDREN is a ‘once in a life-time’ initiative

- Integrates technical, environmental and social/political aspects
- Is open for new participants (especially international)