Managing a Hydro-energy reservoir: A Policy approach

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Reservoir based Hydro

Decision: Produce how much and when
(i) Any water used today cannot be used tomorrow
(ii) Producing today creates capacity in the reservoir to accommodate future inflows

===> Decision to produce or not at a given instant depends on "value" assigned to water in reservoir
Value of water in reservoir depends on many interrelated elements

- Current reservoir level
- Expected inflow
- Current electricity price
- Anticipated demand
- Total generation capacity
- Expected future electricity price
- Expected future reservoir level
- Turbine capacity

=> Assigning "a number" to the value of water is an unrealistic expectation
Research question

How do simple reservoir management policies achieve different objectives:
- Profit maximisation
- Minimisation of electricity cost

Policy
A simple, easily applicable, decision rule which enables a decision maker to decide whether or not to produce at a certain point in time, and how much, based on currently available information
(current reservoir level, forecasted inflow, availability of other generators, price expectation for the period covered by the decision period, …)

Methodology: Deterministic simulation
The model

Stylised model calibrated for Switzerland

25% reservoir based hydro, 25% run of river, long term import contracts
Most of inflow to hydro plants in spring

Reservoir based hydro is the only strategic player

Policies: Hourly production as a function of forecasted reservoir level

Key technical input: Offercurve excluding Hydro

Simulated inputs: (i) hourly demand (1 year = 8640 hours)
(ii) hourly inflow to reservoir and run of river plants

Outputs: (i) Total electricity cost for consumer
(ii) Total contribution of reservoir based hydro
(iii) Overflow
Fixed price
(17 policies)

Production policies

Piecewise linear
(81 policies)
Logic of "Offercurve excluding hydro"

Policy of Hydro producer
1. Decide desired price $P$
2. Use curve to determine production $Q$ of non-hydro producers at price $P$
3. Evaluate residual demand at this price: Demand - $Q$ - RR production
   $$\Rightarrow$$ Maximum quantity HS can offer
Factors affecting the choice of decision policy

(ii) Reservoir size compared to total demand

(ii) Turbine capacity of the hydro plant relative to reservoir size

(iii) Correlation between inflow and demand
    (i.e. do inflows peak during peak demand periods or low demand periods)

(iv) Share of hydro capacity compared to the total generating capacity

(v) Availability and relative cost of alternative generation sources

(vi) Potential for overnight pumping
Results

Two objectives

Minimise total electricity cost in a non-liberalised market: "Consumer choice"
Maximise profit in a liberalised market: "Producer choice"

General conclusions

- Optimal strategies surprisingly robust to changes in reservoir size and turbine capacity
- Consumer mostly prefers fixed price policies, producer piece-wise linear policies
Fixed price policies

Large turbine capacity and reservoir: Producer price > Consumer price

Small reservoir: Producer "always" produces

Low turbine capacity: Both produce mostly
Piece-wise linear policies

Producer: Concave policies (keep price high for most water levels)
   Exception: large reservoir with very small turbines
Consumer: Less convex policies, Concave policies for small turbine capacity
Conflict of interest

When implementing the preferred producer policy

Reservoir size and turbine capacity limited impact on contribution and cost

When consumers decide, much larger impact

Cost difference between consumer and producer choice

==> Increase in turbine capacity and in reservoir size

Contribution: Largest difference for intermediate reservoir and large turbines
### Social optimum

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<th>Turbine capacity</th>
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Net loss when switching from preferred consumer policy to preferred producer policy

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Net loss increases in:
- turbine capacity
- reservoir size except for very small turbine capacity
Hydro-storage production

Higher total production under producer policy

==> Implies less overflow

Consumer choice: Non-monotonicity of production in turbine capacity

Caused by switch in policy type
Price obtained for Hydro storage electricity

Mostly higher for Producer policy

Two exceptions: When consumer favours type 2 policy
**Intra-year results**

Illustration of the danger of accepting a low price

P1-1500-1-C –
- Consumer policy (type 1)
- Reservoir = 1500
- Turbine capacity = 1
Intra-day variations
Price behaviour on a typical autumn day

Consider extreme combinations of reservoir size and turbine capacity

Similar price behaviour when small turbine capacity

Intra-day price variations more significant for producer choices when large turbines, especially when small reservoir
Intra-day variations

Hydro-storage production on a typical autumn day

Large reservoir, small turbines: Producer produces constantly at maximum capacity

Producer does not use large capacity

Otherwise: - No production at night
- Producer produces less than Consumer
Air-conditioning: A typical summer day

Scenario: Small reservoir and low turbine capacity

Hypothesis: Increased demand in summer (afternoon / evening) due to air-conditioning

Result: Peak-price nearly doubles
Next steps

Impact on results of
- Correlation between inflow and demand
- Share of hydro capacity compared to the total generating capacity
- Availability and relative cost of alternative generation sources

Robustness of policies w.r.t. uncertainty regarding future inflows and demand
(which implies uncertainty regarding future prices)

Overnight pumping
- Different time-frame: Shorter time-horizon
  Focus on intra-day behaviour