Snowy 2.0 Pumped Hydro-Electric Storage feasibility

The Snowy 2.0 project is an expansion of the Snowy Mountains Hydroelectric Scheme in Australia.

A pumped-hydro expansion, Snowy 2.0 will increase the production capacity of the existing power generation with improved storage capacity and help to stabilize delivered electricity at the power markets. This has proved important in recent times, as intermittent electricity from wind and solar power stations are constantly increasing.

Assumptions

The scheme in table 1 shows the balanced situation that defines the production cost of electricity. It is characterized by financial performance where earnings from operation and fixed cost weigh each other up, payback period is equal to defined lifetime of 60 years and internal rate of return is equal to defined interest rate of 6%.

Table 1. Snowy 2.0 Base Case Scenario

	Assumptions	Value	Unit
1	Installed production/pumping capacity	2000	MW
2	Energy in full upper storage	350000	MWh
3	Power efficiency of production/pumping	76%	
4	Empty storage, production at full capacity	175	hours/cycle
5	Fill storage, pumping at full capacity	230	hours/cycle
6	One full cycle	405	hours/cycle
7	Utilization of hydroplant	8075	hours/year
8	Number of pumping/production cycles	19,9	cycles/year
9	Utilization hours of production	3487	hours/year
10	Utilization hours of pumping	4588	hours/year
11	Energy from production	6974	GWh/year
12	Energy for pumping	9176	GWh/year
13	**Energy markets**		
14	Peak energy production selling price	88	USD/MWh
15	Off-peak pumping energy price	30	USD/MWh
13	**Earnings from operation**		
17	Revenue from production	616	MUSD/year
18	Cost of pumping	275	MUSD/year
19	Earnings	341	MUSD/year
20	**Fixed Costs**		
21	Cost of pumping storage incl. transmission	4745	MUSD
22	Interest rate	6,00%	yearly
23	Lifetime	60	years
24	Cost of operation and maintenance	1,00%	yearly
25	Yearly cost factor (annuity)	7,19%	yearly
26	Total fixed cost	341	MUSD/year
27	**Financial Performance**		
28	Earnings from operation–Fixed costs	0	MUSD/year
29	Levelized Cost of Storage	49	USD/MWh
	(exclusive cost of off-peak power for pumping)		
30	**Levelized Cost of Production**	**88**	**USD/MWh**
	(inclusive cost of off-peak power for pumping)		
31	Internal Rate of Return	6,0%	
32	Payback Period	60,0	years

It is necessary to have in mind that excluding cost of pumping as shown in line 29 is insufficient and cost of pumping must be included to make the power plant operational as is done in line 30.

Full storage of the upper reservoir of Snowy 2.0 will last for 175 hours, at a full 2000 MW run in the power plant.

Natural inflow to the upper reservoir is not taken into account.

76% efficiency is assumed, meaning that for every 100 MWh for pumping, 76 GWh could be produced later in the power plant.

The year is divided into 19,9 time cycles each of 405 hours, 230 hours for pumping and 175 hours for power production. This leads to 8075 hours/year activity in the production/pumping power plant and 8760-8075=685 hours or 28,5 days for maintenance. At full capacity, 4588 hours/year (9176 GWh/year) will then be needed for pumping and 3487 hours/year (6974 GWh/year) will be available for power production.

Capital Costs of Snowy 2.0 is assumed 4500 MAuD and cost of transmission 2000 MAuD. With currency rate of 0,73 USD/AuD the resulting total cost is then estimated 4745 USD.

Results

Cost of Production will be 88 USD/MWh with financial costs and fixed cost of operation and maintenance included and also variable cost of purchasing power at off-peak prices for pumping. The inclusion of cost of pumping is crucial as mentioned above.

Available at all times when needed will be:

- off-peak market energy for pumping at price of 30 USD/MWh and
- peak energy market to offset produced energy at price of 88 USD/MWh, equal to power production cost.

This will then lead to Internal Rate of Return of 6% and Payback Period of 60 years.

Figure 1 shows how Internal Rate of Return and Payback period varies with market price of sold power production.

Figure 1. Snowy 2.0 Financial Performance

Purchased off-peak power at 30 USD/MWh

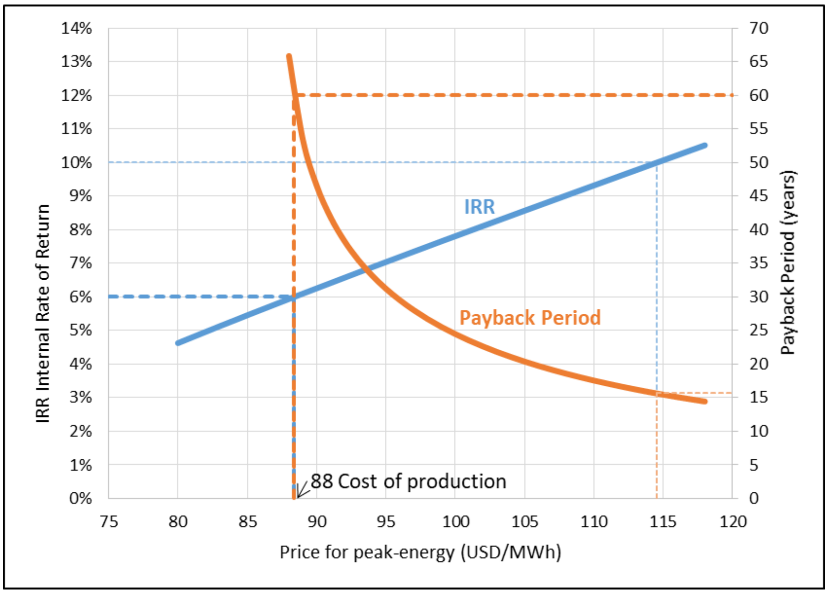


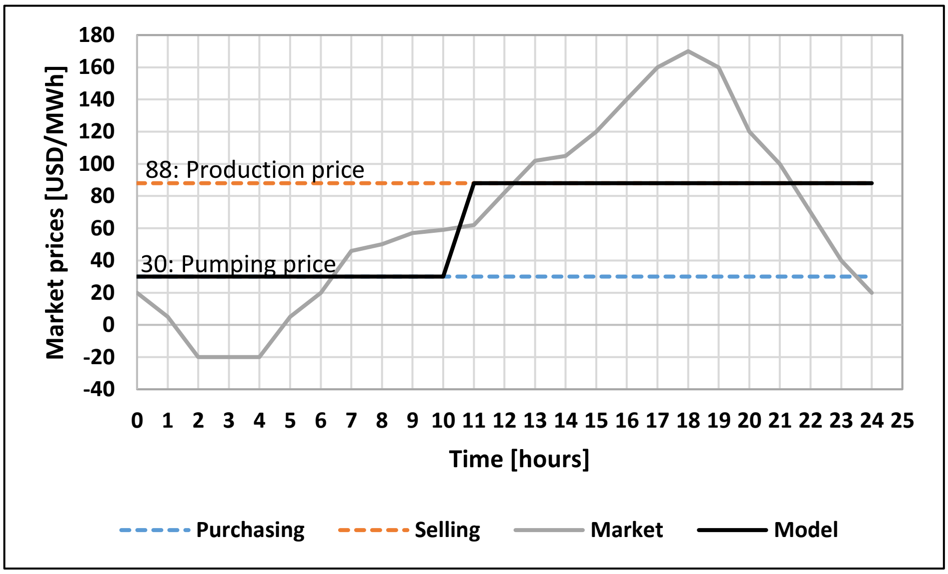
Figure 1 shows that if 10% rate of return is required, the price of sold electricity should be 114,50 USD/MWh and payback period then will be 15,7 years.

Discussion:

Figure 2 explains an example of market price behaviour for one day and purchasing price for pumping and selling price for produced energy. The model behaviour is explained by the black curve, which then sometimes:

- overestimates the purchasing price for pumping
- underestimates the selling price of power production
- overestimates both the period of pumping and the period of power production

Figure 2. Market behaviour



An interesting aspect is what actions will be taken when market price is between the pumping price of 30 USD/MWh and the production price of 88 USD/MWh? What will happen if the market price is in that interval most of the time?

Sensitivity Analysis

If interest rate per year is varied from 0% to 10%, then cost of production, with variable cost of pumping included, would be as shown in table 2.

Table 2. Sensitivity Analysis

Interest Rate	Production Cost [USD/MWh]
0%	58
1%	61
2%	66
3%	71
4%	76
5%	82
6%	**88**
7%	95
8%	101
9%	108
10%	115

Of the production cost, 39 USD/MWh comes from cost of pumping, same result for all values of interest rate, see also table 1.

And finally

A better result would be obtained by computer simulation of the power plant working with the surrounding power system. Thereby one would be able to simulate the power plant pumping and production depending on market prices at all times. It could be complicated to predict the effect Snowy 2.0 itself would have on the market price.

The results presented in this desktop analysis are not exact but should reveal a ballpark value of more extensive research. In many cases it is important to run a simplified version of a project in parallel with wider simulation and optimization studies.

Battery storage comparison

Table 3 shows a comparable desktop analysis of 100 MW battery storage, resulting in production cost of 144 USD/MWh.

Table 3. Battery Storage Scenario

	Assumptions	Value	Unit
1	Installed battery capacity	100	MW
2	Energy in full battery	129	MWh
3	Overall round trip efficiency	80%	
4	Emptying battery. Production at full capacity	1,29	hours/cycle
5	Fill battery. Loading at full capacity	1,61	hours/cycle
6	One full cycle	2,90	hours/cycle
7	Utilization of battery	8075	hours/year
8	Number of battery loading/production cycles	2782	cycles/year
9	Utilization hours of battery production	3589	hours/year
10	Utilization hours of battery loading	4486	hours/year
11	Energy from battery production	359	GWh/year
12	Energy for battery loading	449	GWh/year
13	**Energy markets**		
14	Peak energy production selling price	144	USD/MWh
15	Off-peak battery loading energy price	30	USD/MWh
13	**Earnings from operation**		
17	Revenue from battery production	52	MUSD/year
18	Cost of battery loading	13	MUSD/year
19	Earnings	38	MUSD/year
20	**Fixed Costs**		
21	Cost of battery, excl. cost of transmission	285	MUSD
22	Interest rate	6,00%	yearly
23	Battery lifetime	12	years
24	Cost of operation and maintenance	1,50%	yearly
25	Yearly cost factor (annuity)	13,43%	yearly
26	Total fixed cost	38	MUSD/year
27	**Financial Performance**		
28	Earnings from operation–Fixed costs	0	MUSD/year
29	Levelized Cost of Battery Storage	107	USD/MWh
	(exclusive cost of off-peak power for battery loading)		
30	**Levelized Cost of Production**	**144**	**USD/MWh**
	(inclusive cost of off-peak power for battery loading)		
31	Internal Rate of Return	6,0%	
32	Payback Period	12,0	years

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