Bidding Strategy for UGS Contract

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1. Optimal Plan Model

A fixed-fee based auction for an underground gas storage (UGS) contract is taking place. The contract duration period is from April 1st, 2026 to March 31st, 2027. The forward curve is given to compute a bidding strategy, in which an optimal plan for injection and withdrawal is devised along with bid recommendations that are both reasonable and competitive in order to secure the contract.

1.1. Optimization Problem Setup

In order to determine an optimal plan for injection and withdrawal and the concomitant intrinsic value, a Mixed Integer Linear Programming (MILP) optimization approach is used. The goal is to maximize the total operating profit (Z) over the contract period (T) given the piecewise constant injection rate (I) and variable injection cost rate (c_{var}), linear withdrawal rate (W), linear constraints of the inventory balance (Inv) and storage volume (WGV), and the forward curve price (P) and corresponding dates ($t = 1, ..., N\ ,\ t \in T$).

The objective function can be defined as

$$maxZ = \sum_{t=1}^{N} [W_t \cdot P_t - I_t \cdot P_t \cdot (1 + c_{var})]$$

which captures the intrinsic value based on the prices given by the forward curve by summing the difference between the daily revenues from gas sales ($W_t \cdot P_t$) and the daily expenditures of gas purchases with the variable injection cost ($I_t \cdot P_t \cdot (1 + c_{var})$).

1.2. Model Constraints

The objective function is subject to the following constraints for all $t \in T$:

Inventory balance: The inventory at the end of day t is defined as the inventory from the prior day plus injections minus withdrawals.

$$Inv_t = Inv_{t-1} + I_t - W_t\ ,\ \forall t = 1, ..., N \text{ (with fixed } Inv_0\text{)}$$

Inventory limits: The inventory must adhere to the physical storage limits.

$$0 \leq Inv_t \leq WGV_{max}\ ,\ \forall t = 1, .., N$$

Final inventory target: The inventory must be zero by the end of the contract period.

$$Inv_N = 0$$

Injection rate limit given by conditional logic using binary variable b_t and "Big M":

Case $b_t = 1$ if $Inv_{t-1} \geq Inv_{thresh}$ (where Inv_{thresh} is the 50% threshold limit of the inventory):

$$Inv_{t-1} - Inv_{thresh} \leq M \cdot b_t - \epsilon$$

Case $b_t = 0$ if $Inv_{t-1} < Inv_{thresh}$:

$$Inv_{t-1} - Inv_{thresh} \geq (-M) \cdot (1 - b_t)$$

Piecewise injection behavior:

$$I_t \leq I_{max} \cdot I_{rate1} \cdot (1 - b_t) + I_{max} \cdot I_{rate2} \cdot b_t$$

Linear Withdrawal rate: The daily withdrawal volume is constrained by the inventory level at the start of the day (Inv_{t-1}).

$$W_t \leq W_{max} \cdot \left(W_{int} + W_{slope} \cdot \frac{Inv_{t-1}}{WGV_{max}} \right)$$

Non-negativity: Injection and withdrawal volumes must be non-negative.

$$I_t \geq 0 \; , \; W_t \geq 0$$

1.3. Results

The optimization results in a total intrinsic value of €807624.67 or a normalized intrinsic value of **€0.81 per MWh WGV**. Figure 1. shows the optimal inventory levels on a given date based on daily injections and withdrawals and the corresponding forward curve. The injections occur at the minima of the forward prices, or when the seasonal gas price is at the lowest points during summer months. Likewise, the withdrawals occur at the maxima of the forward prices, or when the seasonal gas price is at the highest points during the winter prices. Notably, the inventory level increases (gas purchasing) during the summer months and decreases (gas selling) during the winter months. That is, the profit is maximized by optimizing the buying (expenditure) and selling (revenue) of gas.

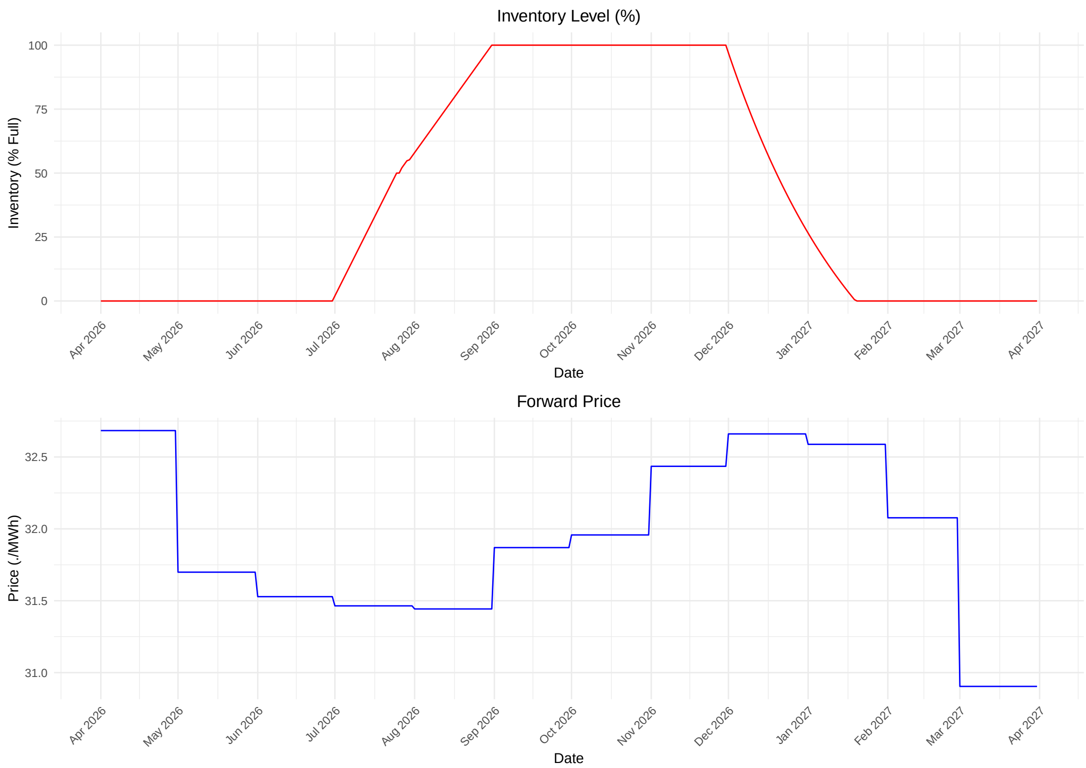

Figure 1. Forward curve prices and corresponding inventory level based on daily injections and withdrawals

The monthly optimal plan of the injection and withdrawal schedule can be seen in Table 1. Corresponding with the graph in Figure 1., the injections occur during the summer months and the withdrawals occur during the winter months, while the storage reaches and maintains maximum capacity in the months between during periods of contango. The daily optimal plan and all the code used to compute the model and create the graphs and tables can be found in the included files.

Table 1. Monthly Optimal Plan (MWh per month)

Month	Inject.	Withdr.	Mean Inv.	EOM Inv.	Notes
2026/04	0	0	0	0	No activity.
2025/05	0	0	0	0	No activity.
2026/06	0	0	0	0	No activity.
2026/07	566000	0	313548	566000	Start of injection phase; Inv_{thresh} reached.
2026/08	434000	0	790000	1000000	Completion of injection; WGV_{max} reached.
2026/09	0	0	1000000	1000000	Storage full.
2026/10	0	0	1000000	1000000	Storage full.
2026/11	0	0	1000000	1000000	Storage full.
2026/12	0	717582	596175	282418	Start of withdrawal phase.
2027/01	0	282419	78880	0	Completion of withdrawal; empty storage.
2027/02	0	0	0	0	Storage empty.
2027/03	0	0	0	0	Storage empty; final target $Inv_N = 0$ met.

Note: The daily optimal plan can be found in the included files.

2. Bid Recommendation

The computed intrinsic value for the UGS capacity was found to be €0.81/MWh, which represents the theoretical profit achievable based solely on optimizing injections and withdrawals given the provided forward price curve and variable injection costs. Notably, this value is markedly low relative to recent European market benchmarks for similar fixed-fee storage contracts, which typically range from €3.00/MWh to €3.60/MWh *[1]*. Such a low intrinsic value suggests that the forward curve used offered minimal arbitrage opportunities or that operational constraints severely limited their capture. Moreover, this baseline calculation excludes the fixed auction fee itself, other operational costs, risk premiums, and the extrinsic value derived from operational flexibility and market volatility. Consequently, **the €0.81/MWh figure alone is insufficient to justify a competitive bid**.

The premium observed in market clearing prices indicates that participants consistently factor in additional value sources. Specifically, this premium reflects the expected extrinsic value generated through the active management of positions in ways a static forward-based optimization cannot capture. Given the persistent volatility in European gas markets, this extrinsic component is often considered a major driver of storage value. Considering these factors among others, a competitive bid must significantly exceed the calculated €0.81/MWh. Targeting the lower end of the observed market benchmark range would balance competitiveness with the risk indicated by the low intrinsic value. Therefore, **a recommended bid range of €2.50 - €3.00 per MWh of WGV is proposed**. This range acknowledges recent market clearing levels while being cognizant of the risk. Bidding below this range significantly reduces the probability of success, whereas bidding higher increases financial exposure considerably.

It must be emphasized that this recommendation carries significant risk. **A successful bid within the €2.50-€3.00/MWh range implies that an additional €1.69 to €2.19 per MWh must be generated from extrinsic value capture, cost efficiencies, or strategic benefits just to cover the fixed auction fee, before any profit is realized**. The primary risk is that the total achievable value (intrinsic + extrinsic) falls short of the fee paid, leading to operational losses. Success is therefore dependent on the ability to effectively manage the storage asset in volatile market conditions and capture value well beyond the €0.81/MWh intrinsic baseline. This bid represents a strategic judgment based on market observations and confidence in factors external to the initial intrinsic calculation.

References

[1] www.ngs.cz, "Auction results," MND Gas storage, *https://www.mndgs.cz/en/auction-results/*