Middle term management of a generation portfolio

Master Energy – Master 2

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Introduction to portfolio management

Portfolio management

Risk management

Use value

Trader

Porfolio management (1/2)

The general objective of portfolio management for a producer is to maximize its economic margin (minimize the total cost of generation) under physical and financial risk constraints

This objective translates into decisions from long term to real time.

	Horizon					
	Long term	Middle term	Weekly	Daily	Infraday	Real time
Decisions	> 3 years	1 w – 3 y	1 w – 2 w	1–2 d	< 1 day	
Investments						
Heavy maintenance						
Storage use strategy						
Fuel sourcing						
Buy and sell on future markets						
Scheduling, buy and sell on spot						
Schedule update						
Balancing						
Generation						

Modelling of the generation assets — Simplified → Detailed

Modelling of aleas — Stochastic ← Determinist

Portfolio management (2/2)

- At each of the previous steps, the planner faces various important uncertainties, bother internal and external (exchanges with other systems, gas, heat, other areas...)
- BUT "Generation = Consumption" must be guaranteed at all time
  - Uncertainty of demand
    - Temperature, nebulosity
    - Economic cycle
    - Customer portfolio
    - Use evolution
  - Uncertainty on supply
    - Water runoff
    - Unplanned outages
    - Longer than expected maintenance periods
    - Intermittency of wind and PV
    - Depth of buy and sell market order books (including interconnections)
  - Financial uncertainty
    - Fuel costs (gas, coal, oil…)
    - CO_2 emission price
    - Spot and future market price
    - Bankruptcy
  - Regulatory uncertainties
    - Political choices (nuclear phase out…)
    - Subsidies to some energy sources.

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Risk management (1/13)

- For each company, risk management depends on choices linked to its structure, its position in the system, its internal perception of risk, the share of its activities in its turnover
- Different risks at various horizons
  - The price risk deals with an unfavourable event now
    - The variation of market prices during the 10 next days may decrease the value of the portfolio, i.e. the expected gains on the portfolio on a future period of up to several years.
    - This event may happen years before the delivery date (for example, the gas to be consumed in 2 years has not yet been purchased and the future price of gas for delivery in 2019 increases → immediately the producer loses money compared to the situation in which nothing happened.)
  - The volume risk deals with an unfavourable event at maturity
    - The generation capacity available at the delivery date is lower than expected or the demand to supply is higher (For example because of a cold wave).
    - In both cases, this risk appears essentially close to the physical delivery date.
  - The credit risk (difficulty to raise liquidities) covers all the duration of hedges. It is the risk that a borrower does not reimburse its credit.

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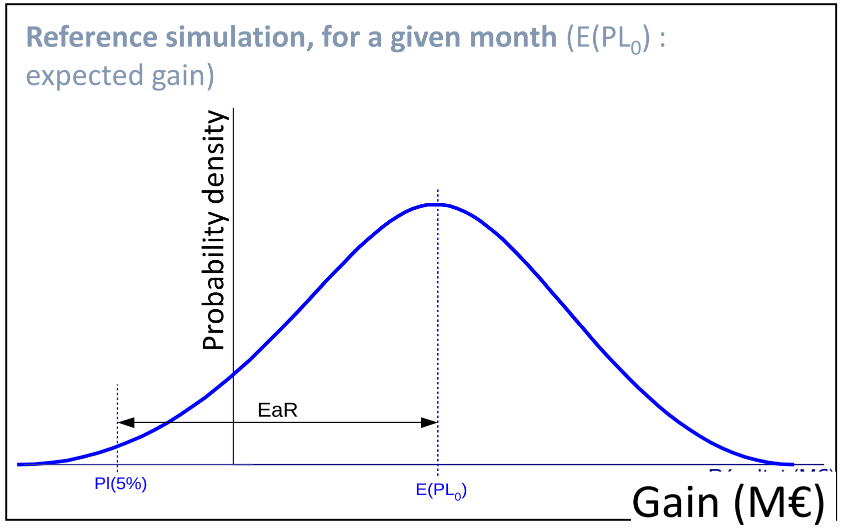
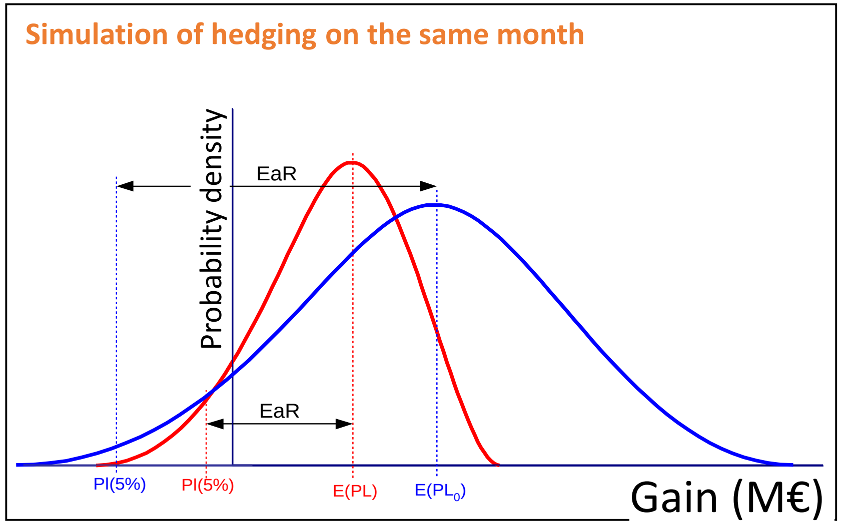
Risk management (2/13)

• The price risk

- For a Balancing Responsible Party, the risk is financial (the system operator will balance remaining imbalances)
- Risk policy based on indicators:
  - Profit & Lost (P&L)
  - EaR (Earning at Risk): spread between the mean and the 5% quantile of the P&L
  - eEaR (extreme Earning at Risk): spread between the mean and the mean of the worst 5% of the P&L
- Risk management: keep indicators with bounds thanks to hedging, which correspond to a trade-off between expected gain and expected risk





Risk management (3/13)

- Hedging of the price risk:
  - Exposition to a financial risk as soon as derivatives are bought or sold.
  - These products create an uncertain financial flow because market prices are uncertain.
  - Buying an option is a mean to hedge against an unfavourable evolution of the electricity price (called the underlying security)
  - Selling an option exposes the seller to the associated risk.
  - An option therefore transfers the market risk from the buyer to the seller.
- The principle of financial hedging is to reduce the sensitivity of the portfolio to the various underlying securities by taking positions on them (purchase or sale).
- These positions are chosen to offset the sensitivity of the portfolio.
- Hedging positions must be dynamically updated when the underlying securities evolve.

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Risk management (4/13)

- The main sensitivity indicator is the delta: the delta of an option is the sensitivity of its market value with respect to the price of the underlying security (forward electricity price F)

$$\Delta = \frac{\partial}{\partial \mathrm{F}} (\text{ value })$$

- The delta is measured as a power in MWh. It corresponds physically to the amount of the underlying security to hold in order to cancel the sensitivity to it "to the first order".
- The total open situation is the sum of the sensitivities of the portfolio of an actor.
  - An actor has a **long** position if it make a gain from an increase of price. Delta is positive (for example, it owns a power plant or a call)
  - Inversely, an actor has a **short** position when it looses money from an increase of price. Delta is negative (for example, the actor sells at fixed price and must buy for its customers)

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- The “risk neutral” behaviour consists in preferring a higher expected gain, whatever the risk. The product A is preferred:
  - Product A: 1 chance out of 2 to gain 100€
  - Product B: 49€ in all cases

- Lottery players are not “risk neutral” but the organizer behaves in a “risk neutral” way because it distribute only a fraction of the revenues.
  - Certain gain for the organizer
  - Expected loss for all players.

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Risk management (6/13)

- The value of an asset is the expected future gain it will make. An actor can secure part of the gains
- Example: value of a power plan with a generation of 120 €/MWh with 4 evolution hypothesis (identical to a call option)

T1 | T2 | T3

Final price = 140 | Gain = 140-120 = 20

Intermediate price = 120
Value = 10

Final price = 100 | No exercise. Gain = 0

Initial price = 100
Value= 5

Final price = 100 | No exercise. Gain = 0

Intermediate price = 80
Value = 0

Final price = 60 | No exercise. Gain = 0

- Expected gain: 20 / 4 = 5
- In 3 out of 4 situations, the unit gain is 0. Is it possible to decrease the risk?

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Risk management (7/13)

- Early sale of part of the asset to reduce the sensitivity to price (Δ)
- How much should be sold at T1? (Which fraction α?)

T1

Initial price =100
Value = 5

T2

Intermediate price =120
Value = (140 - 120) / 2 + 0 = 10
P&L= 10 + α * (100 – 120)

Intermediate price =80
Value = 0 + 0
P&L = 0 + α * (100 – 80)

T3

Final price =140

Final price =100

Final price =100

Final price =60

Same P&L in lower and upper scenario of T2 $\Rightarrow$

$10 + \alpha * (100 - 120)$

$= 0 + \alpha * (100 - 80)$

yields:

$\alpha = 0.25$ and P&L = 5

- 25% should be sold at T1 to secure the gain

Risk management (8/13)

- How much to sell at T2 in the upper scenario? (Which fraction β?)

T1

Initial price =100
Value= 5
P&L = 5

T2

Intermediate price =120
Value = 10
P&L = 10 + 0.25 * (100 – 120)
= 5

Intermediate price = 80
Value = 0
P&L= 0 + 0.25 * (100 – 80)
= 5

T3

Final price = 140
Value = 20
P&L = 20 + 0.25 * (100 – 140)
+ β * (120 – 140)

Final price = 100
Value = 0
P&L= 0 + 0.25 *(100 –
100) + β * (120 – 100)

Final price = 100

Final price = 60

Same P&L in lower and upper scenario of T3 $\Rightarrow$

$$
\begin{aligned}
& 20 + 0.25 * (100 - 140) \\
& \quad + \beta*(120-140) \\
= \; & 0 + 0.25 * (100 - 100) \\
& \quad + \beta*(120-100)
\end{aligned}
$$

yields:
β = 0.25 and P&L = 5

- One should sell, again, 25% to secure the final gain.

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Risk management (9/13)

- How much to sell at T2 in the lower scenario? (Which fraction β?)

T1 T2 T3

Final price =140

Intermediate price =120
Value = 10
P&L = 10 + 0.25 * (100 – 120)
= 5

Final price =100

Initial price =100
Value = 5
P&L = 5

Final price =100
Value = 0
P&L= 0 + 0.25 * (100 – 100)
+ β * (80 – 100)

Intermediate price =80
Value = 0
P&L= 0 + 0.25 * (100 – 80)
= 5

Final price =60
Value = 0
P&L = 0 + 0.25 * (100 – 60)
+ β * (80 – 60)

Same P&L in lower and upper scenario of T3 ⇒

$$0 + 0.25 * (100 - 100) + \beta*(80-100) = 0 + 0.25 * (100 - 60) + \beta*(80-60)$$

yields:
β = -0.25 and P&L = 5

- One should **buy back** 25% in T2 to secure the final gain.

Risk management (10/13)

- The value of an asset is the expected gain it will make
- Example of a call with a strike of 120 €/MWh with for unwinding hypothesis.

T1

Initial price =100

Sale
25%

T2

Intermediate price =120

Sale
25%

Intermediate price =80

Buy
25%

T3

Final price =140

Gain = 140-120
+ 0.25 * (100-140)
+0.25*(120-140)
= 5

Final price =100

No exercise. Gain = 0
+0.25*(100-100)
+0.25(120-100)
= 5

Final price =100

No exercise. Gain = 0
+0.25*(100-100)
-0.25*(80-100)
= 5

Final price =60

No exercise. Gain = 0
+0.25*(100-60)
-0.25*(80-60)
=5

- Expected gain: 20 / 4 = 5
- Thanks to the purchase and sales, in all cases, the gain is 5.

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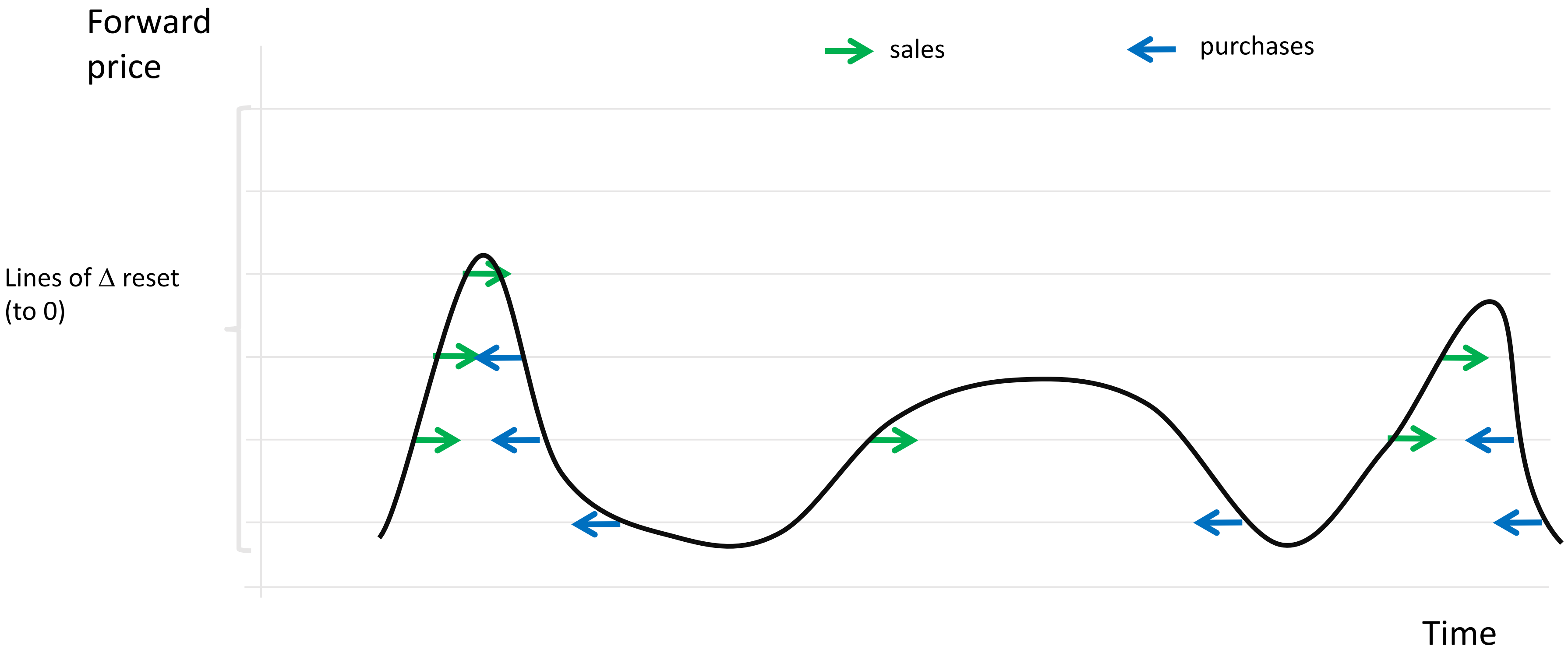
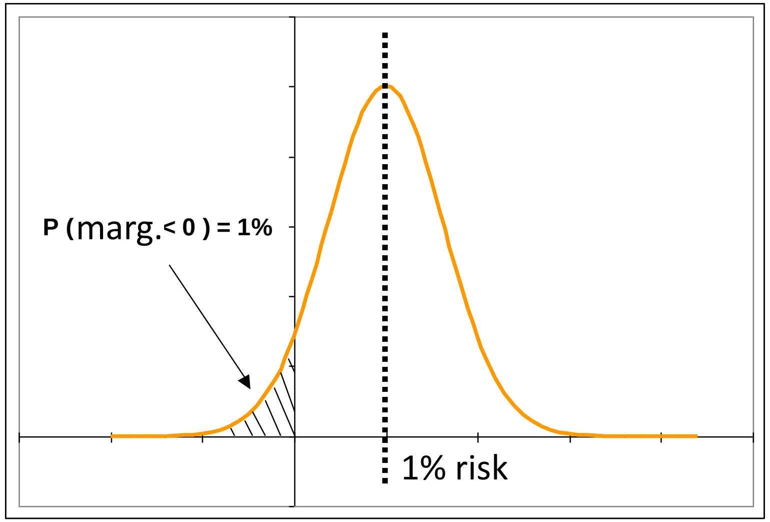
Risk management (11/13)

- To hedge a call (or a thermal generation asset)
  - One sells when price increases
  - One buys when price decreases



Volume risk (12/13)

- The power volume risk called “1% risk” is the margin to take in order that the risk to resort to exceptional means for balancing the perimeter is 1%.



- The weekly margin should be above the 1% risk for every week of the horizon.
- If not, hedging is done:
  - Modification of the schedules of stops and trials on thermal or hydraulic power plants.
  - Outright purchases are made

Volume risk (13/13)

- The <u>energy</u> volume risk:
- For a BRP, when a storage is empty and it is not able to satisfy the demand because of this lack of energy, one speak of **energy default**.

- To avoid this situation, the producer needs to determine a strategy to manage its storage and put « **milestones** »: levels under which it does not want to be at a given time.

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Use value (1/13)

Saint-Pierre-Cognet power plant (1954)

- Water value = expected gain from the later use of 1 m3 of stored water.
- The use of stored water now costs what it would have gained later by avoiding the use of another generation technology.
- The value of water allows to give a cost to the decision to use the stored water now. It is possible to compare this cost to other generation cost in order to decide whether to use it now or later.
- The value of water is a particular case of use value that allows to manage any kind of storage (demand response, fuel, pollutant emission,…)

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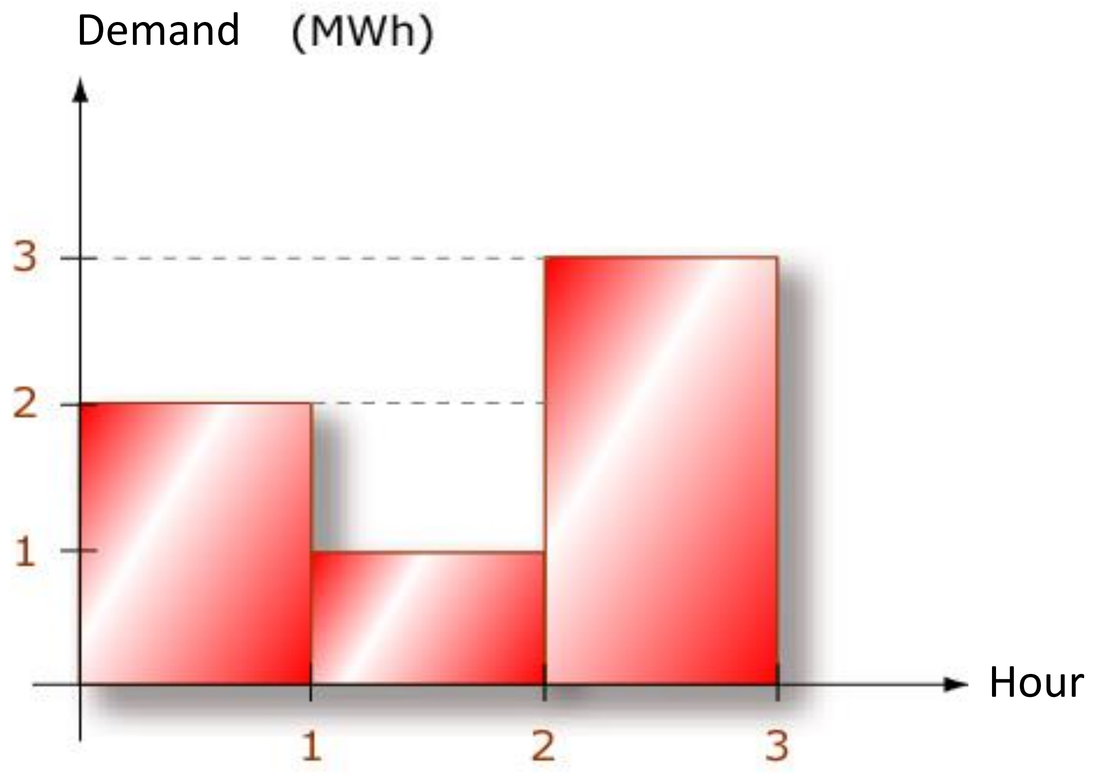
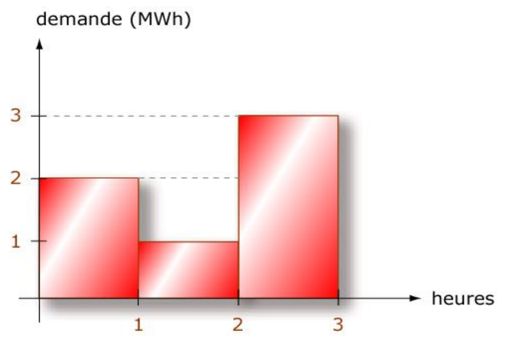
Use value (2/13)

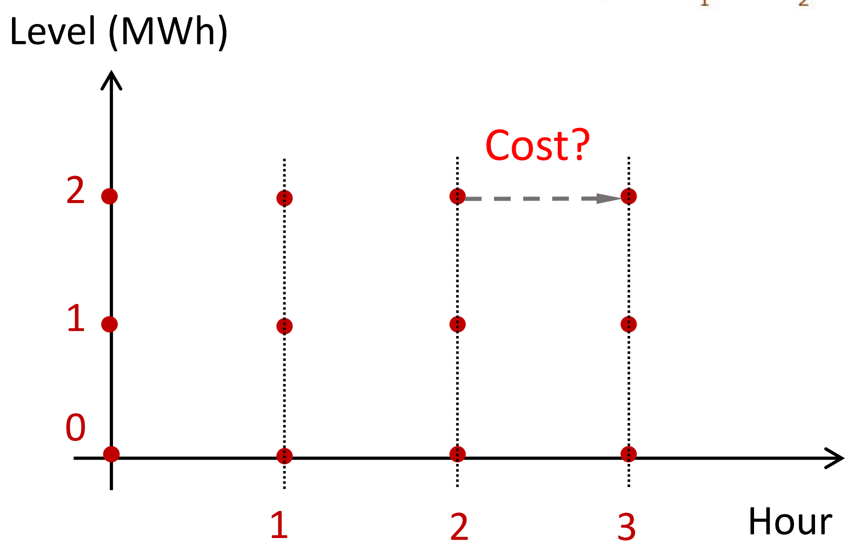
- A practical example of dynamic programming:
  - A thermal portfolio with 3 power plants:
    - Unit A ; cost=10€/MWh and Pmax=1MW
    - Unit B ; cost=20€/MWh and Pmax=1MW
    - Unit C ; cost=30€/MWh and Pmax=1MW
  - A lake with three levels of storage (0 MWh, 1 MWh, 2 MWh)
  - A 3h study period.
  - With a time step of 1 hour
  - Without inflows in the reservoir
  - And varying demand (see graphic)



Use value (3/13)



- Cost computation of the transition in red on the graph:
  - Hydro gen. = 0 MWh
  - Demand = 3 MWh
  - Thermal gen = 3 MWh



Applying the merit order rule:

- *Unit A :* Gen. = 1 MWh
  Cost = 1*10=10€
- *Unit B :* Gen. = 1 MWh
  Cost = 1*20=20€
- *Unit C :* Cost = 1 MWh
  Cost = 1*30=30€

Total cost = 10 + 20 + 30 = 60€

Expected gain of the use of water
= 0 € (no use of water)

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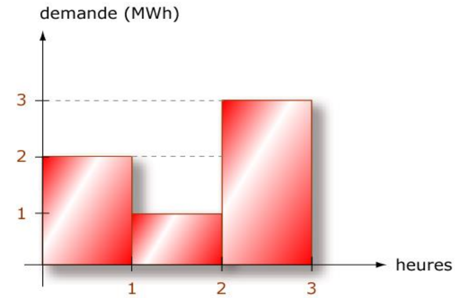
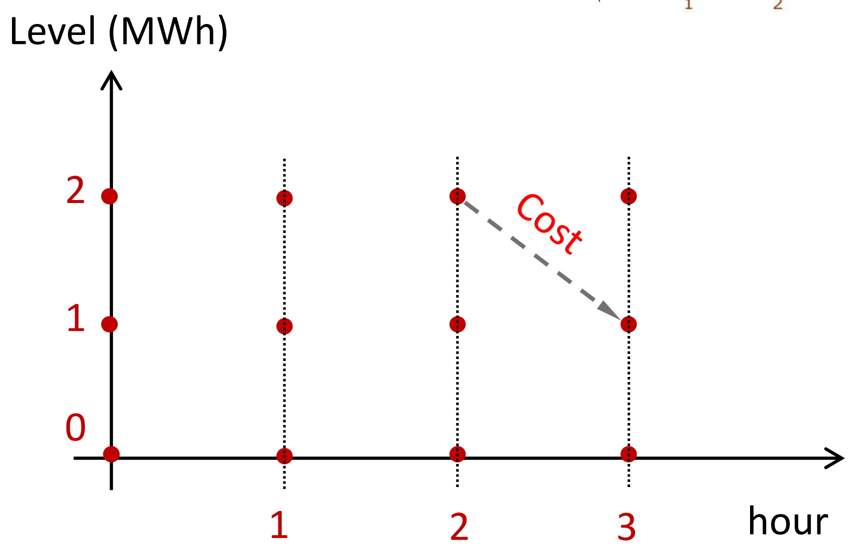
Use value (4/13)



- Cost computation of the transition in red on the graph:
  - Hydro gen. = 1 MWh
  - Demand = 3 MWh
  - Thermal gen. = 2 MWh



Applying the merit order rule:

- *Unit A :* Gen. = 1 MWh
  Cost. = 1*10 = 10€
- *Unit B :* Gen. = 1 MWh
  Cost = 1*20 = 20€

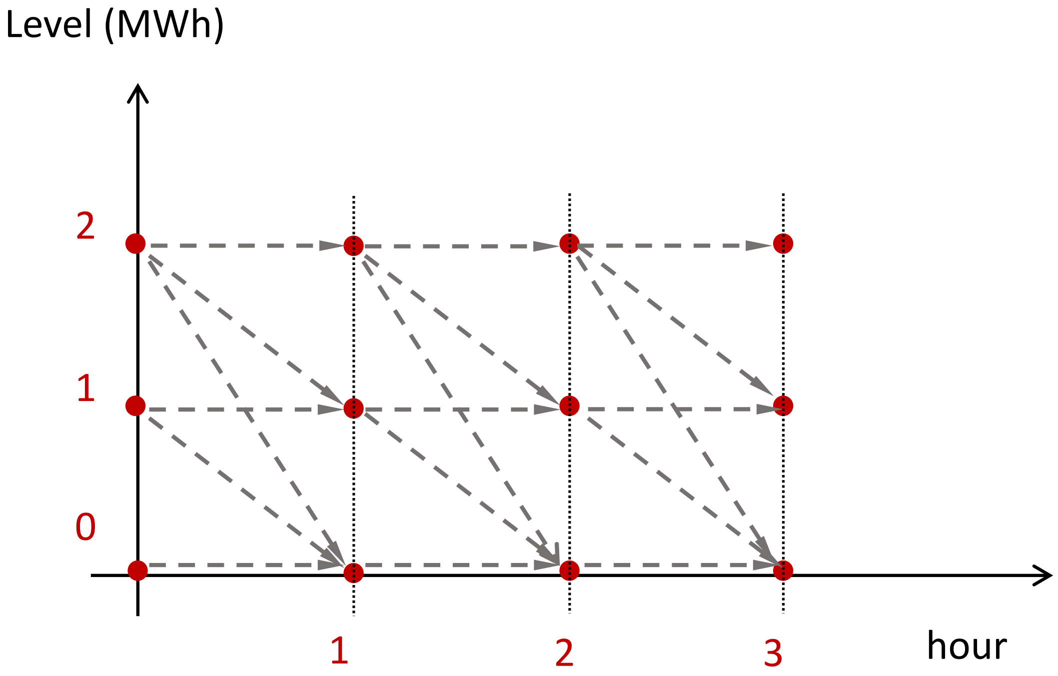
Total cost = 10 + 20 = 30€

Expected gain compared to the situation without water use = 60€ - 30€ = 30€

(Avoided cost because the most expensive unit was not started)

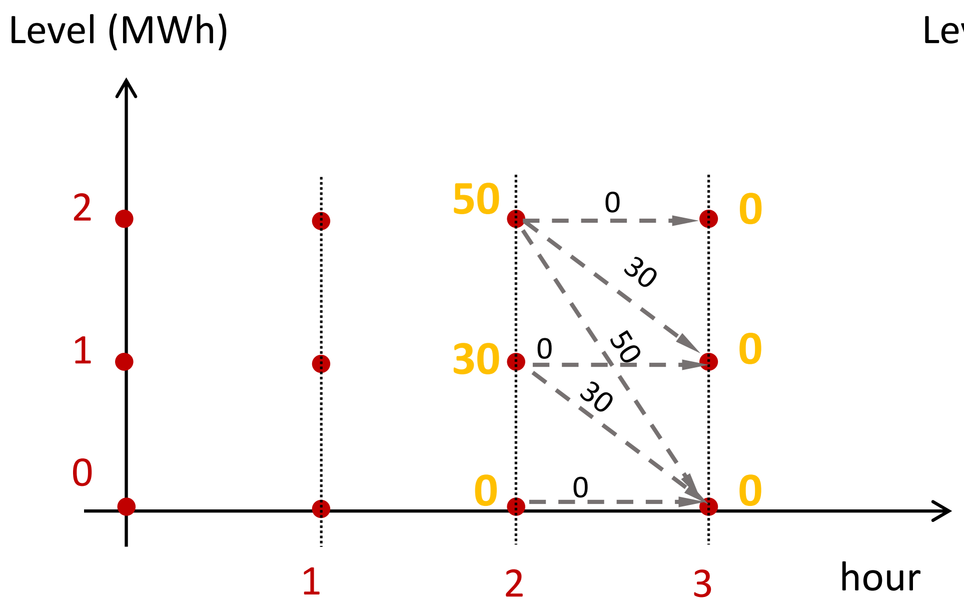
Use value (5/13)

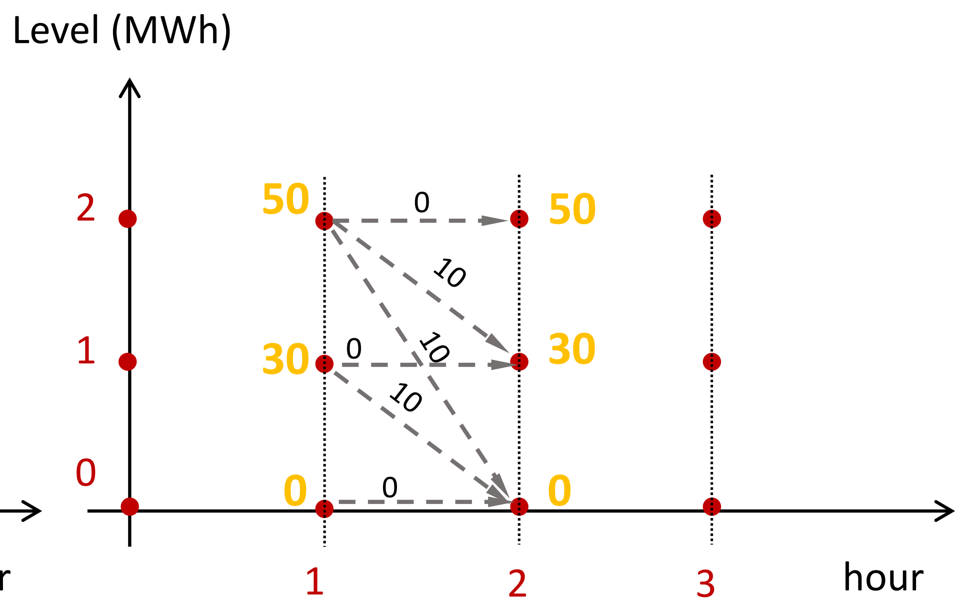
- Computation of all transition costs and all the associated gains for all storage level and all time steps.
- Practically, solvers or heuristics are used.



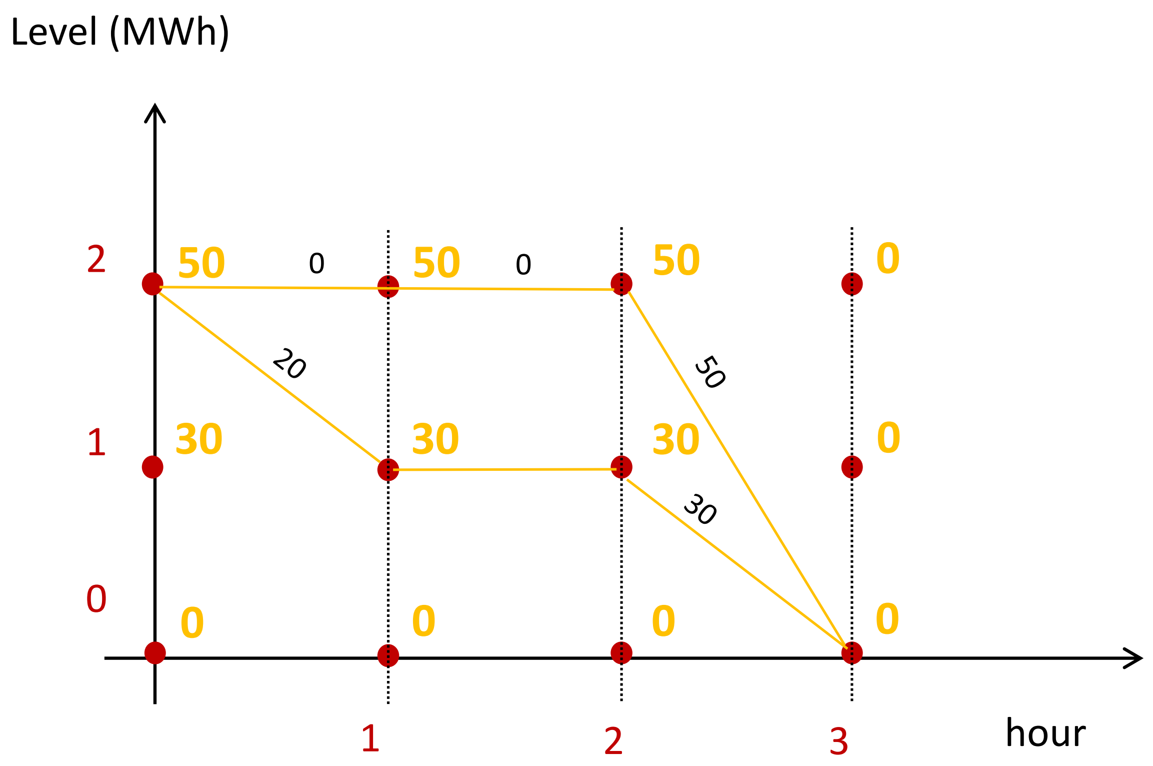
Use value (6/13)

- Bellman value = maximum over all possible transitions (transition gain + end game value) at each point
- The end game value is the Bellman value of the transition target
- Minimizing costs or maximizing gains is equivalent



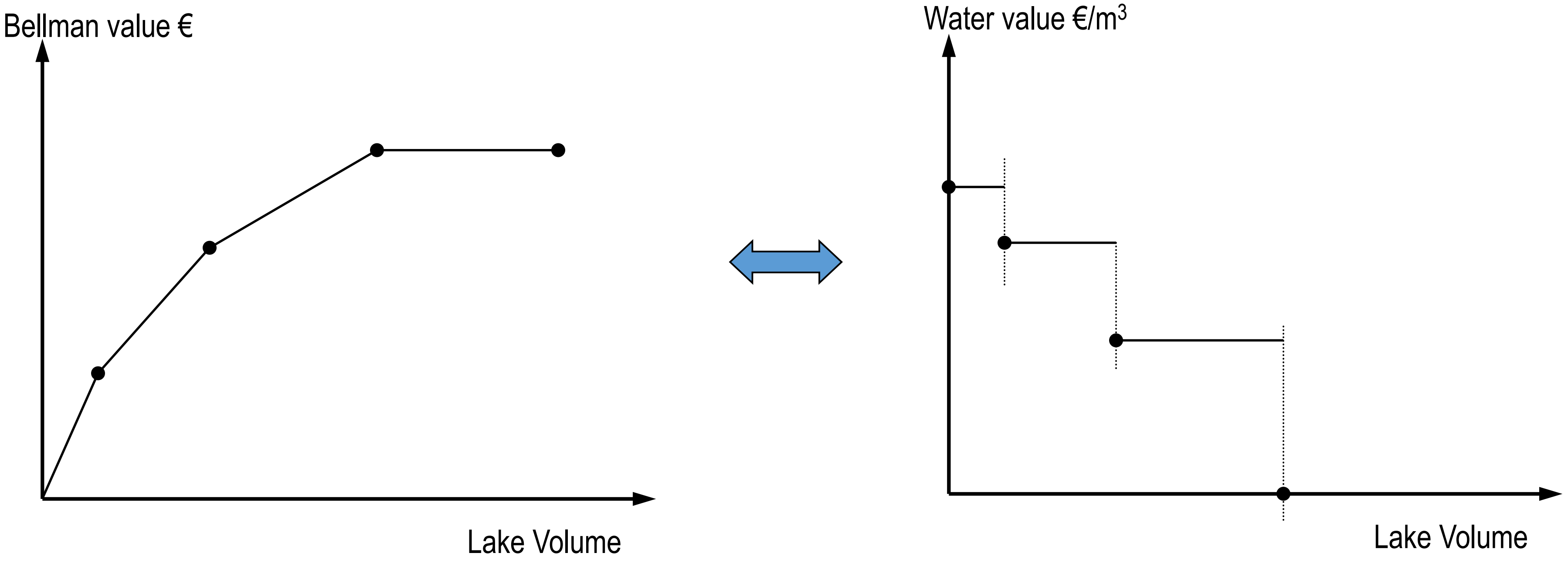


- When all the Bellman values are computed, it is possible to define an optimal strategy



Use value (8/13)

- Use values (or water values) at time t are the derivative of Bellman value with respect to the storage level.



Bellman value = expected future gain for a given lake storage level at a given time.

Water value = expected future gain of one unit of storage level.

One different value for each time step

Interpolation between time step

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Use value (9/13)

- Simulation: Storage optimal strategy determination

- I use water if:

What I expect gain later without the water + What I will gain from using the water now ≥ What I expect to gain later with the water

- i.e.:

$$\mathrm{VBell}(t, niv - 1) + \mathrm{Generated\ energy}(t) * \mathrm{price}(t) \geq \mathrm{VBell}(t, niv)$$

- In other word:

$$\mathrm{price}(t) \geq \left(\frac{\mathrm{VBell}(t, niv) - \mathrm{VBell}(t, niv - 1)}{\mathrm{Generated\ energy}(t)}\right) = \mathrm{Use\ value}(t)$$

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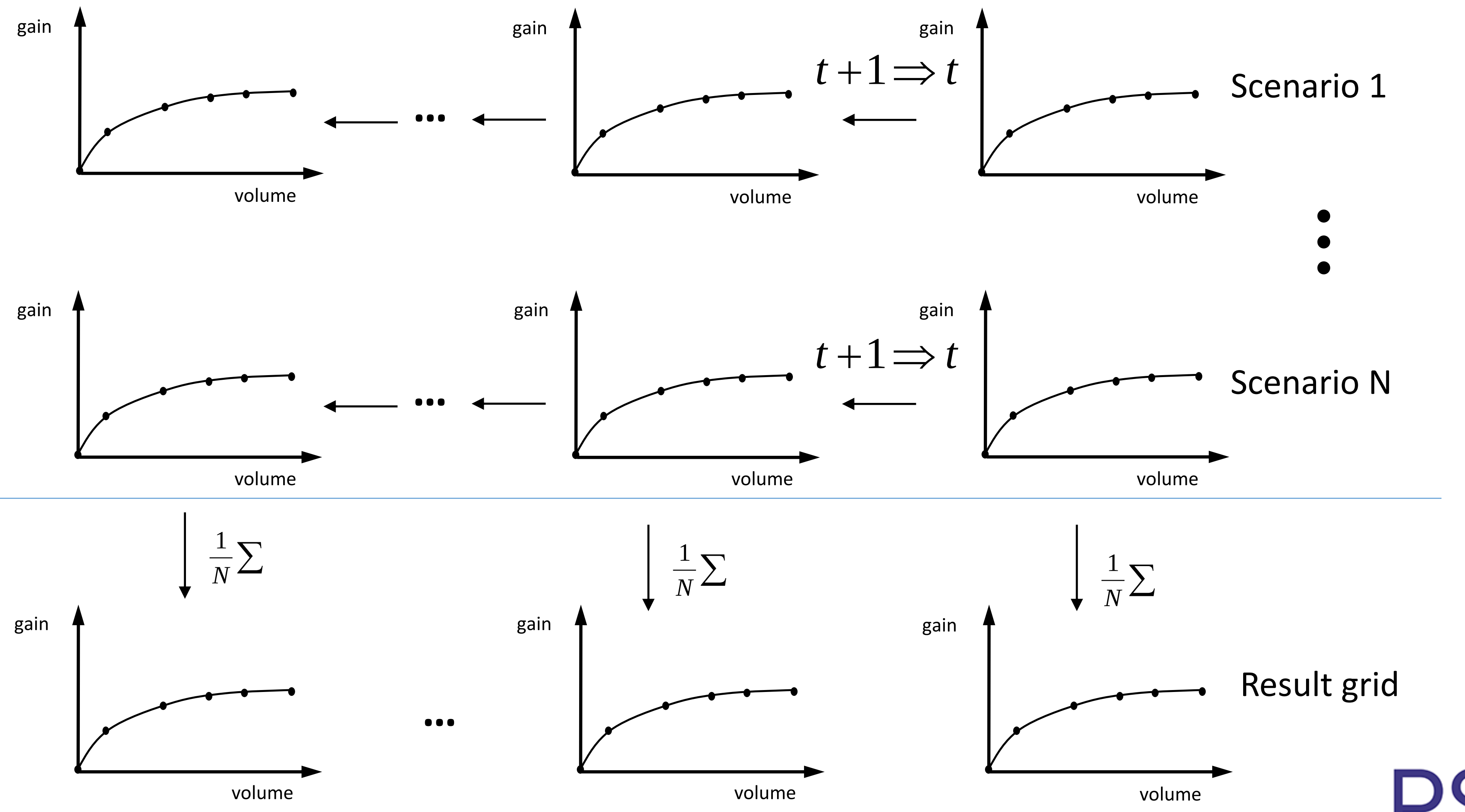
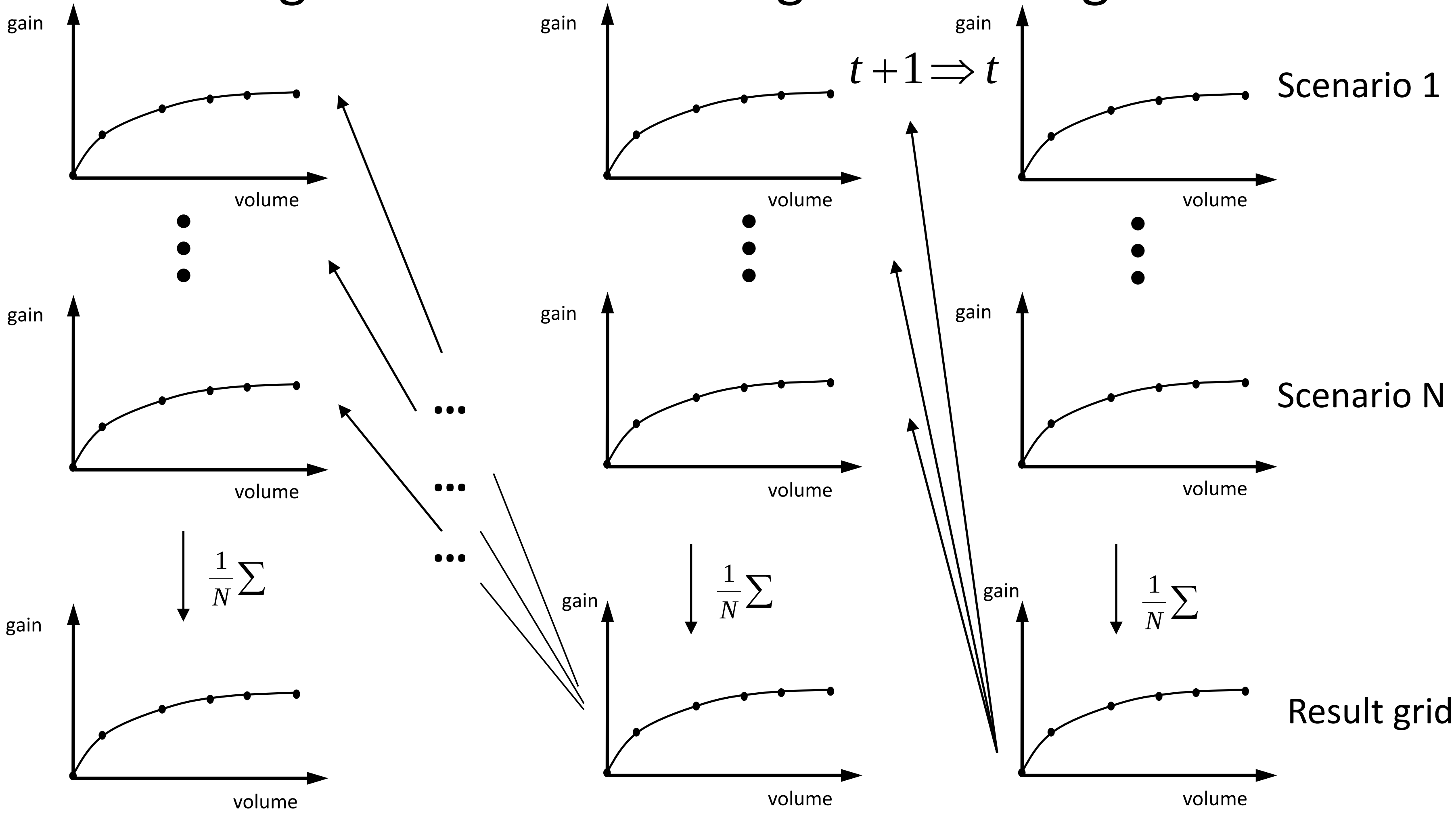
Use value (10/13)

- Handling uncertainties: The average of grids



Use value (11/13)

- Handling uncertainties: The grid of average



➔ This method allows to make decision based on richer visions of the future (all the scenarios).

➔ The decision is therefore more realistic with this method.

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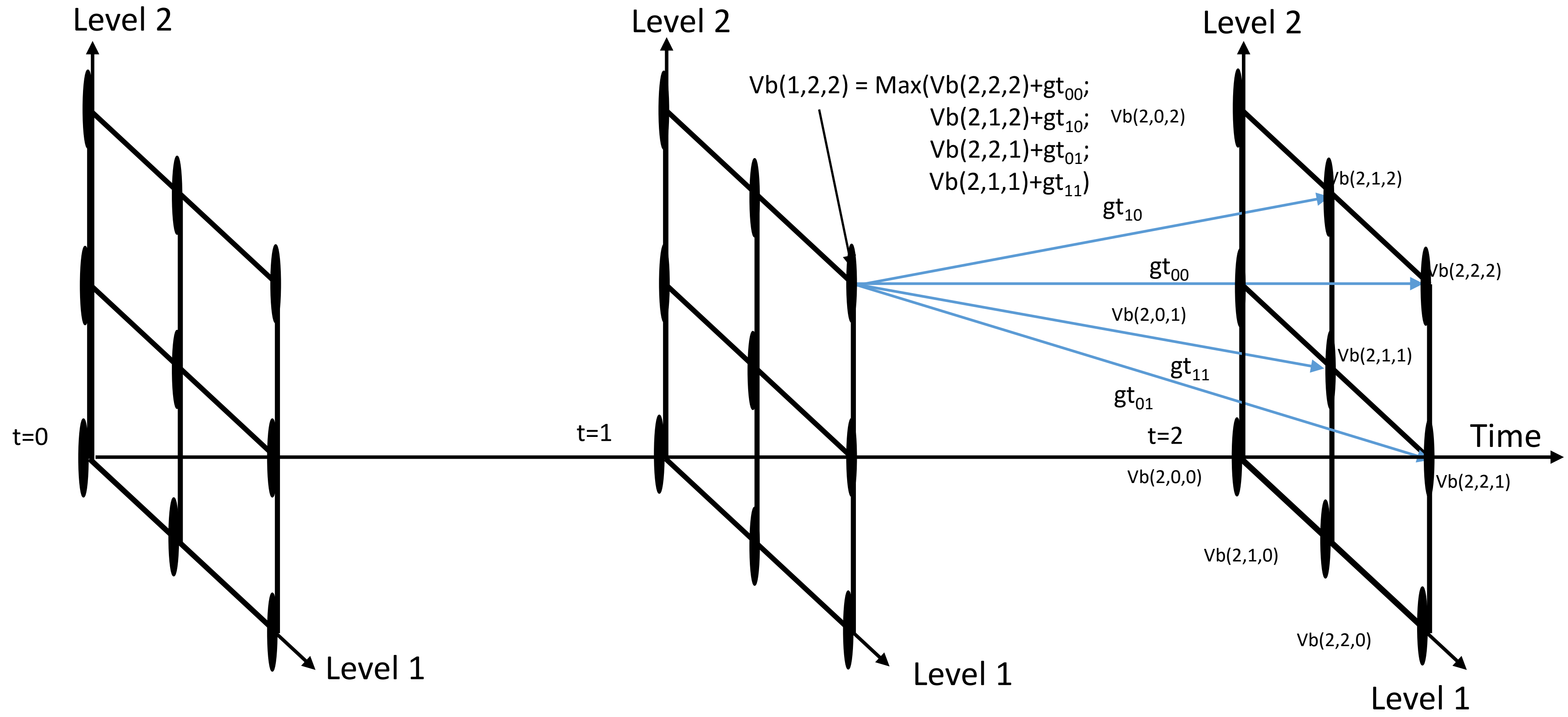
Use value (12/13)

- Multiple storages: example of a Bellman “cube”
- Bellman values defined on (time, storage level 1, storage level 2)
- The curse of dimensionality strikes fast !

  Complexity = # scenarios * # time steps * (# storage levels)^(# storages)



The SDDP (13/13)

- SDP (Stochastic Dual Programming) :
  - A “backward” phase: for each time step, starting from the study period end, computation of the use values for all scenarios and all storage levels on a predefined grid.
- SDDP (Stochastic Dual Dynamic Programming) :
  - Iteration of “forward” and “backward” phases:
    - “Forward”: for all given use values, simulation of the storage trajectory for all scenarios on all the study period, starting from the beginning.
    - “Backward”: computation of use values on some scenarios given the storage levels encountered during the “forward” phase, starting from the end.
  - At each iteration:
    - In the “forward” phase, storage levels used as reference levels in the “backward” phase.
    - In the “backward” phase, the use values for some storage levels. They are added to the one previously computed.
- The SDDP allows to give storage values for each storage independently. It is used by producers with many different storages (Brasil, NordPool, New Zealand)

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Trader

- The trader is responsible of the optimization of the portfolio on the markets.
- Its activities are:
  - Arbitrage: making a gain without taking risk by taking simultaneously to antagonist positions
    - Example: buying in country A and selling in country B while one own transfer capacity from B to A.
  - Hedging: Achieve a transaction that reduces a risk exposition or secures a gain.
    - Example: hedge of a call option.
  - Speculation: holding position in anticipation of a given evolution of future prices.
    - Example: buying electricity for a maturity that the trader anticipate to be undervalued.
    - Speculation requires important analysis technics.
    - It implies risk taking and a specific tracking by a risk control entity.

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Middle term generation management

Objectives and stakes

Building a global vision

Market representation

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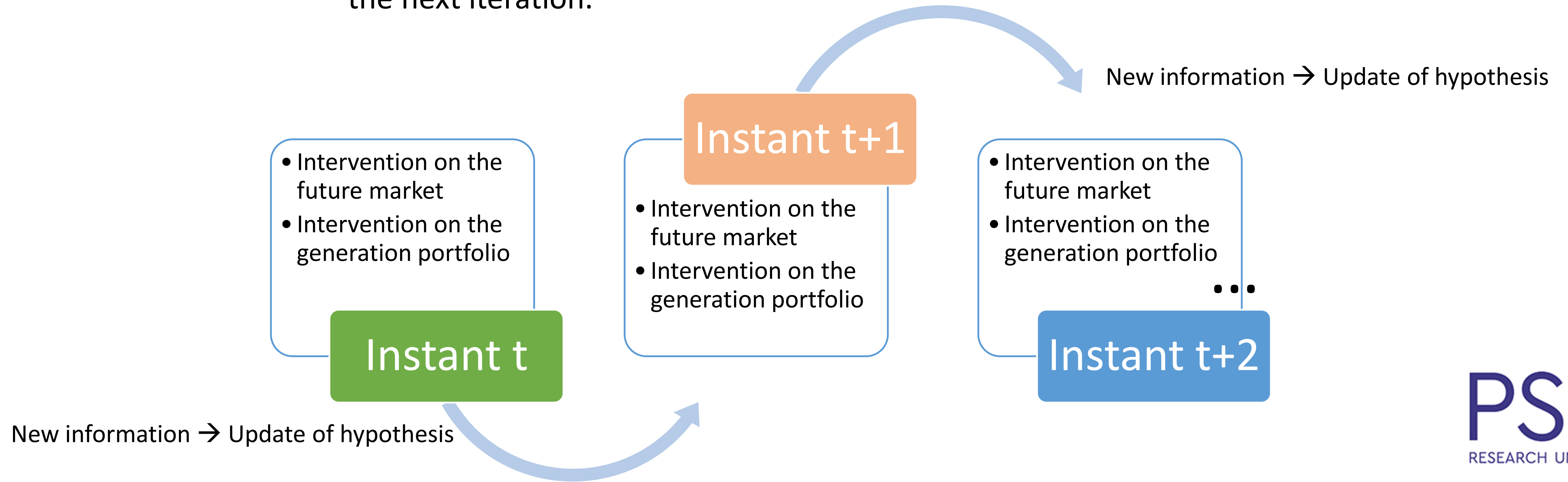
Objectives and stakes

- The objective of a generation portfolio operator is to maximize its economic margin under physical and financial risks.
- Practically, on the middle term (from a few weeks up to 5 years), it translate into the following decisions:
  - On the generation portfolio: optimizing outages of thermal and nuclear generation, determining the storage use strategy (water, demand response, fuel, nuclear fuel)
  - Action on the future market of electricity and fuels.
- The middle-term management process provides the short term management process with the storages uses strategies.
- It also allows to make draft budgets.

- The big differences with long-term management are:
  - No investment in new generation capacities is possible.
  - The future prices of electricity and fuel prices are known.

Building a global vision (1/3)

- Building a global vision with simplifications and then using the global equilibrium to make fine-grained marginal visions.
- An iterative process in order to adapt decisions to events and to correct them if needed:
  - Important sale on the future market with a 1 month maturity while an unplanned outage occurred → purchase at the next iteration in order to satisfy the risk doctrine.
  - Important use of water? → the storage level is low and less water will be used at the next iteration.



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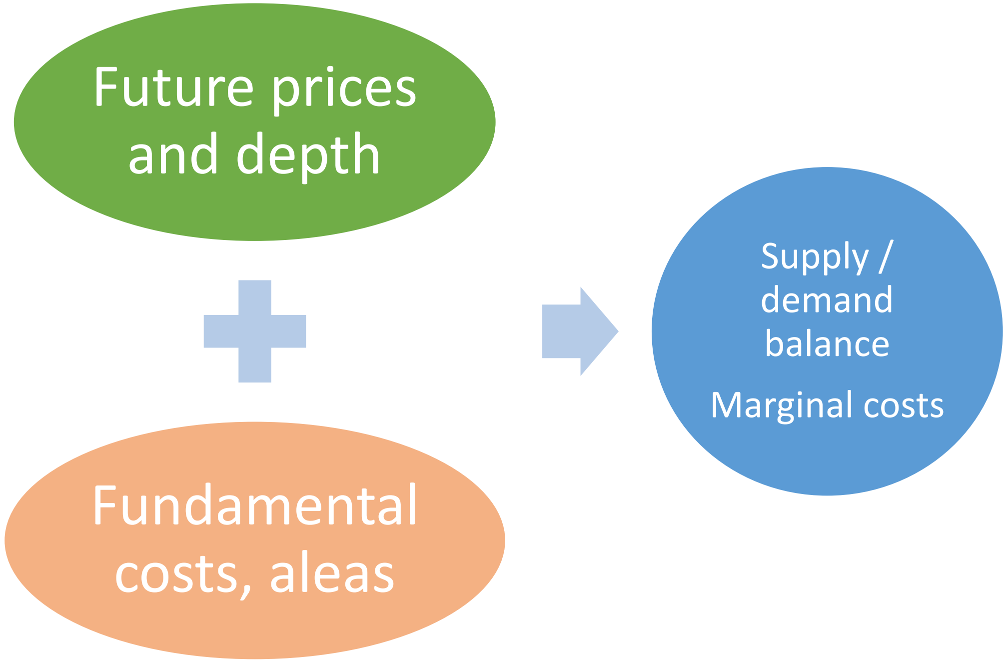
Building a global vision (2/3)

- The future market is an important indicator for hedging decisions because transactions are expected to be made at this price.
- For a producer, knowing the depth of the markets is important.
- The marginal cost can be build taking into account:
  - Fundamental costs
  - Future market prices of commodities
  - Depth of markets



Building a global vision (3/3)

- Once the middle term vision of the supply and offer equilibrium is available, the producer has:
  - Production balance sheets in order:
    - To build draft budget
    - To buy fuel for thermal power plants
  - Indicators for volume hedging (margins, 1% risk) and risk hedging (P&L, EaR, eEaR) in order to take decisions on future markets (buy/sell, options) or on the portfolio (outage schedule)
  - Multi-year marginal costs in order to determine a fine-grained storage management strategy, transmitted to the short term management processes through use values:
    - Water
    - Demand response
    - Pollutants (CO_2, SO_X, NO_X)
    - Nuclear fuel
  - Schedule of use of thermal power plants to schedule outages.

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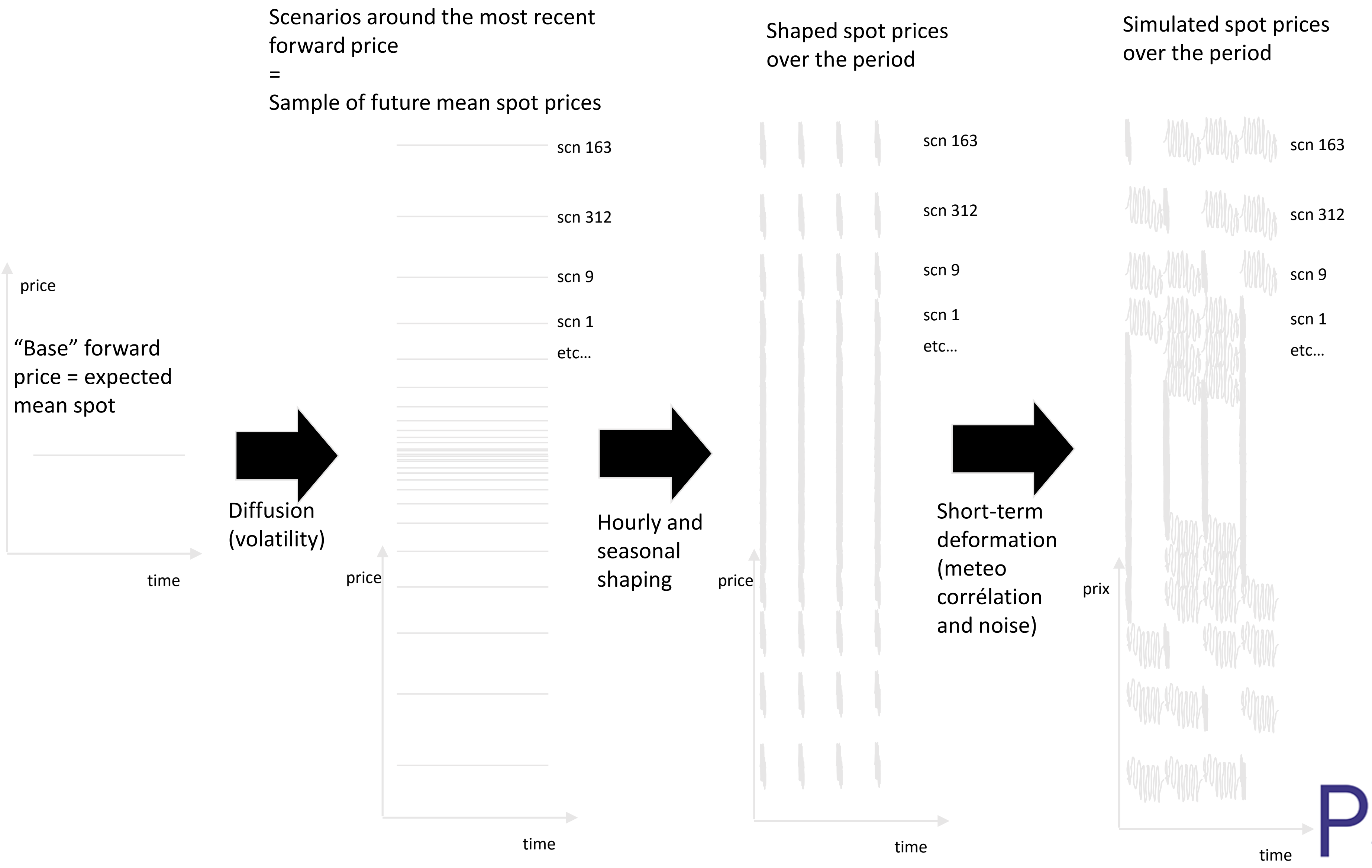
Market representation (1/5)



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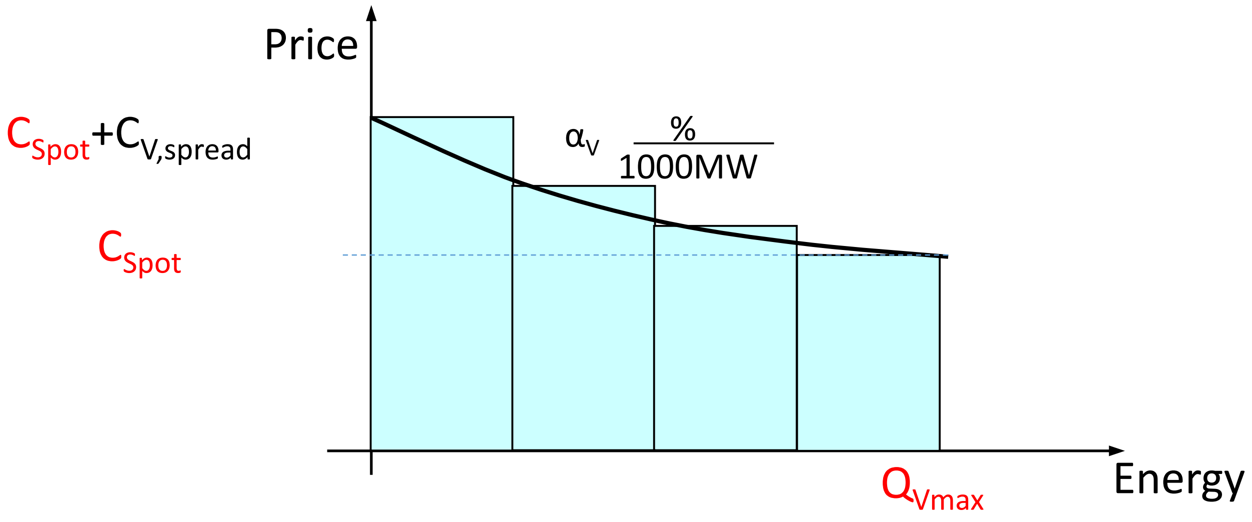
Market representation (2/5)

- The trader has to know what to buy and sell if the price varies around its expectation (its price sensitivity).
- Sale and purchase depth are defined.
- Prices and depth are correlated to the weather. For example, in case of cold temperatures, purchase depth is reduced and sale depth is increased.
- Buy and sale blocks are defined and inserted into a stack according to their marginal cost.



Market representation (3/5)

- Buy blocks (call options) are easy to represent:
  - They are inserted as if they corresponded to a power plant.
- Sell block (put options) representation is more difficult:
  - The maximum sale volume is computed: firm demand (futures) and potential demand (options).
  - Virtual “sale offset power plants” are added in the stack at the potential sale price.
- The solution is satisfactory because:
  - All sales below their marginal cost are not made because they would result in losses.
  - All sales over their marginal cost are made because they would result in gains.

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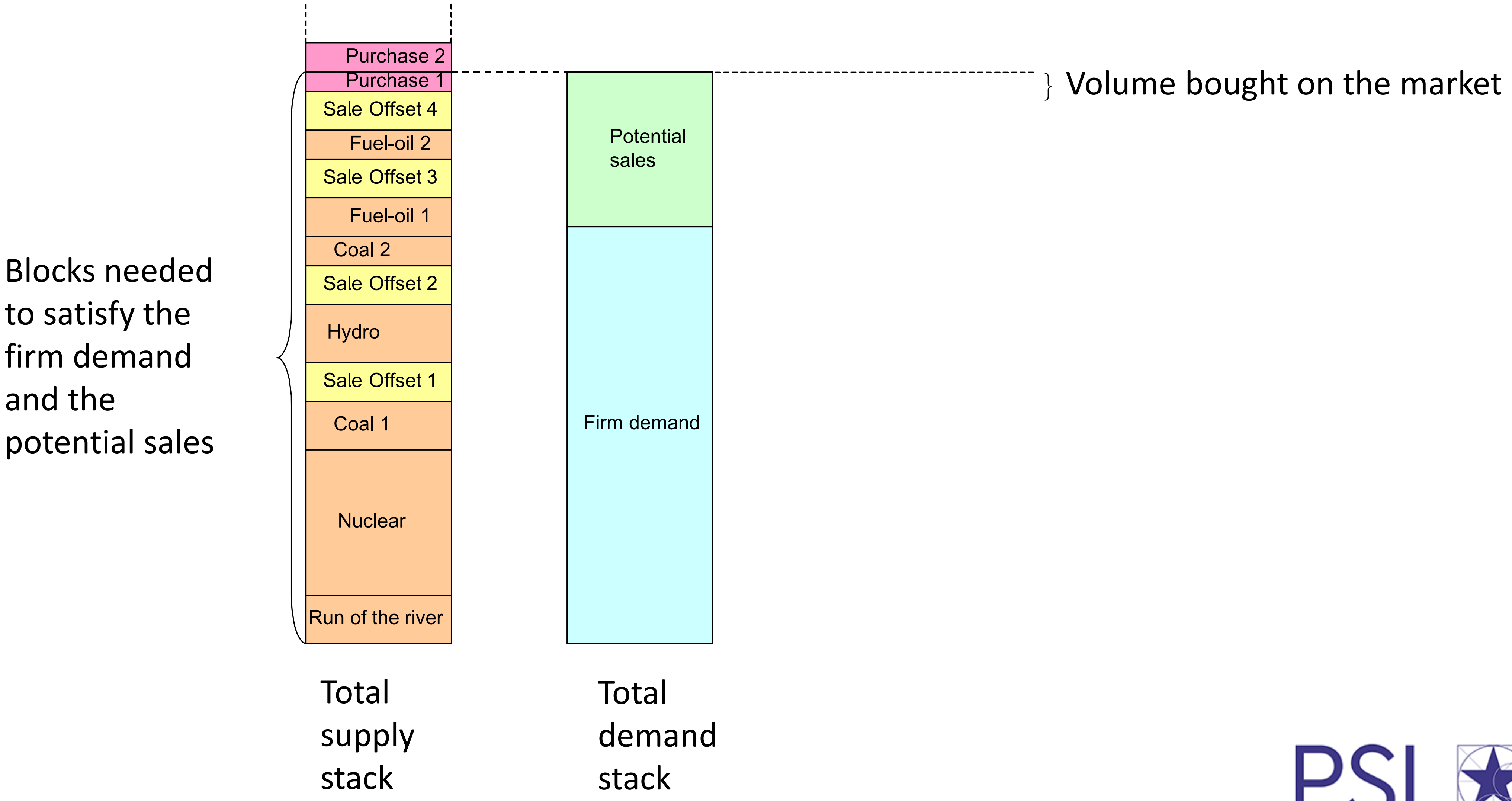
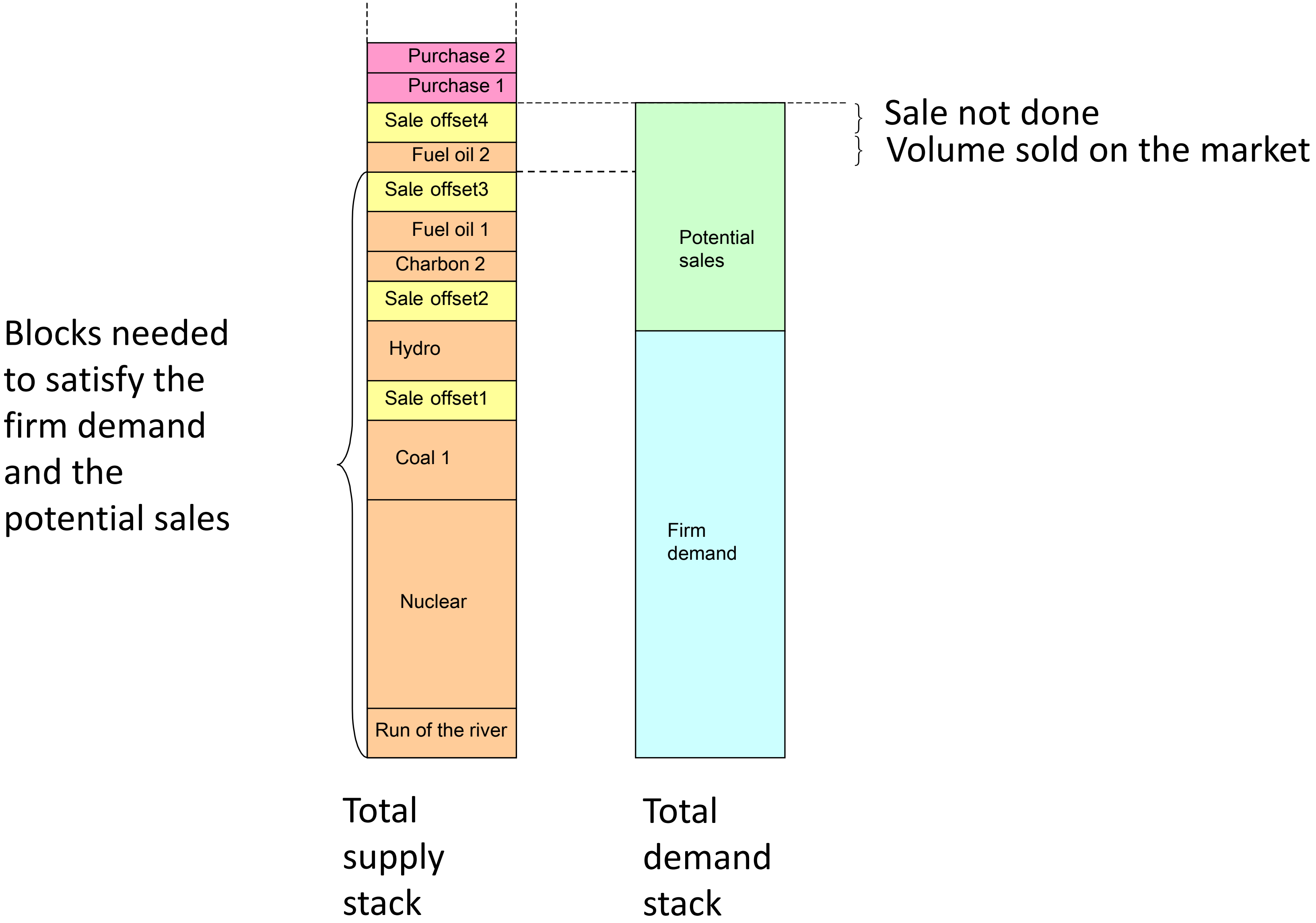
Market representation (4/5)

Example resulting in buying



Market representation (5/5)

Example resulting in selling



Outage scheduling

- With the multi-year global vision, decisions with marginal impact are possible to make
- Long outages (more than a week) are scheduled to minimize their costs. They are determined several months ahead because of the needed notice (specialized teams, hardware…)

- Short outages (a few days) are decided more opportunistically during week-ends or low consumption days.

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Annex 1 – SDDP

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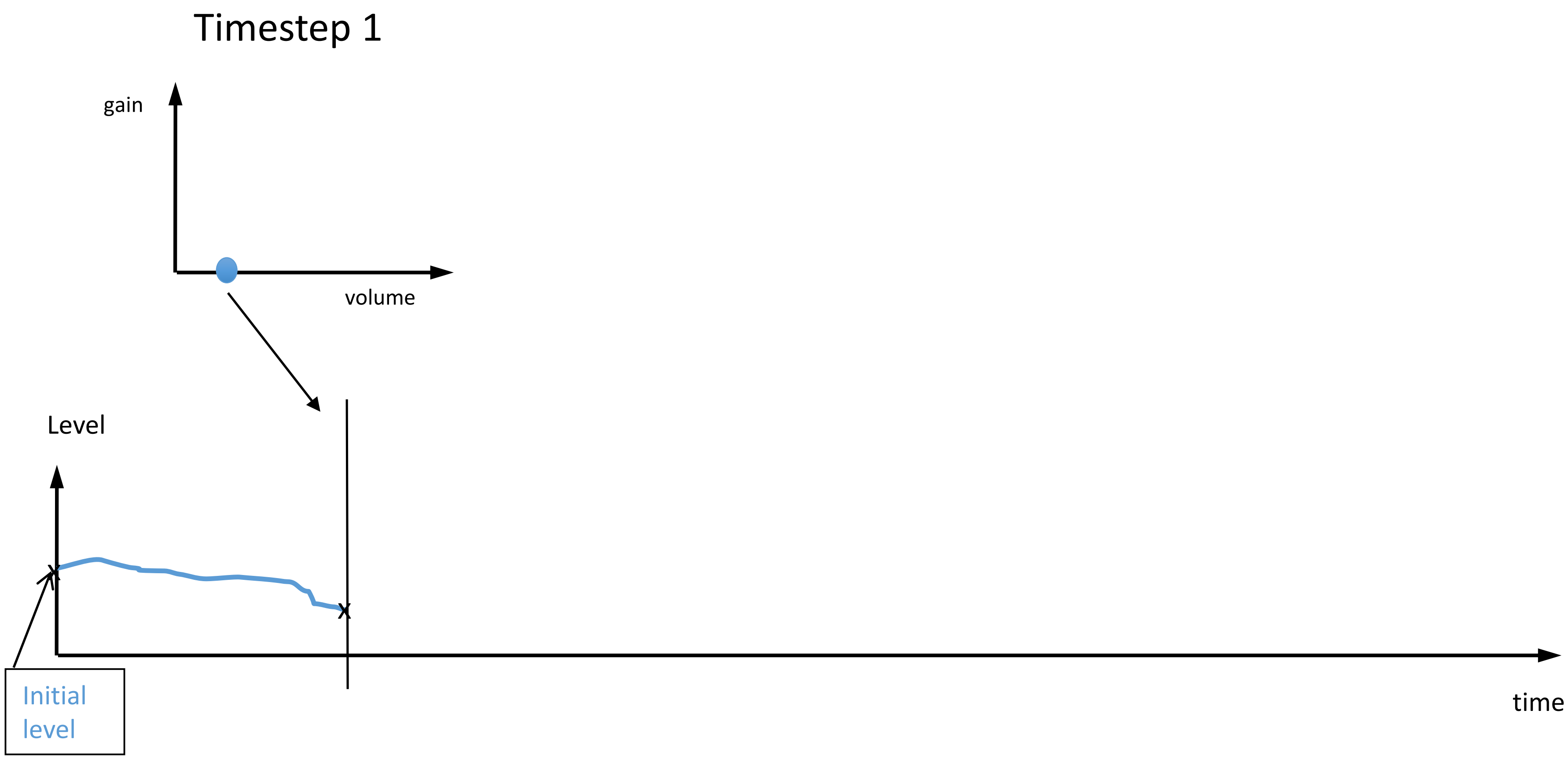
SDDP use value computation → Forward

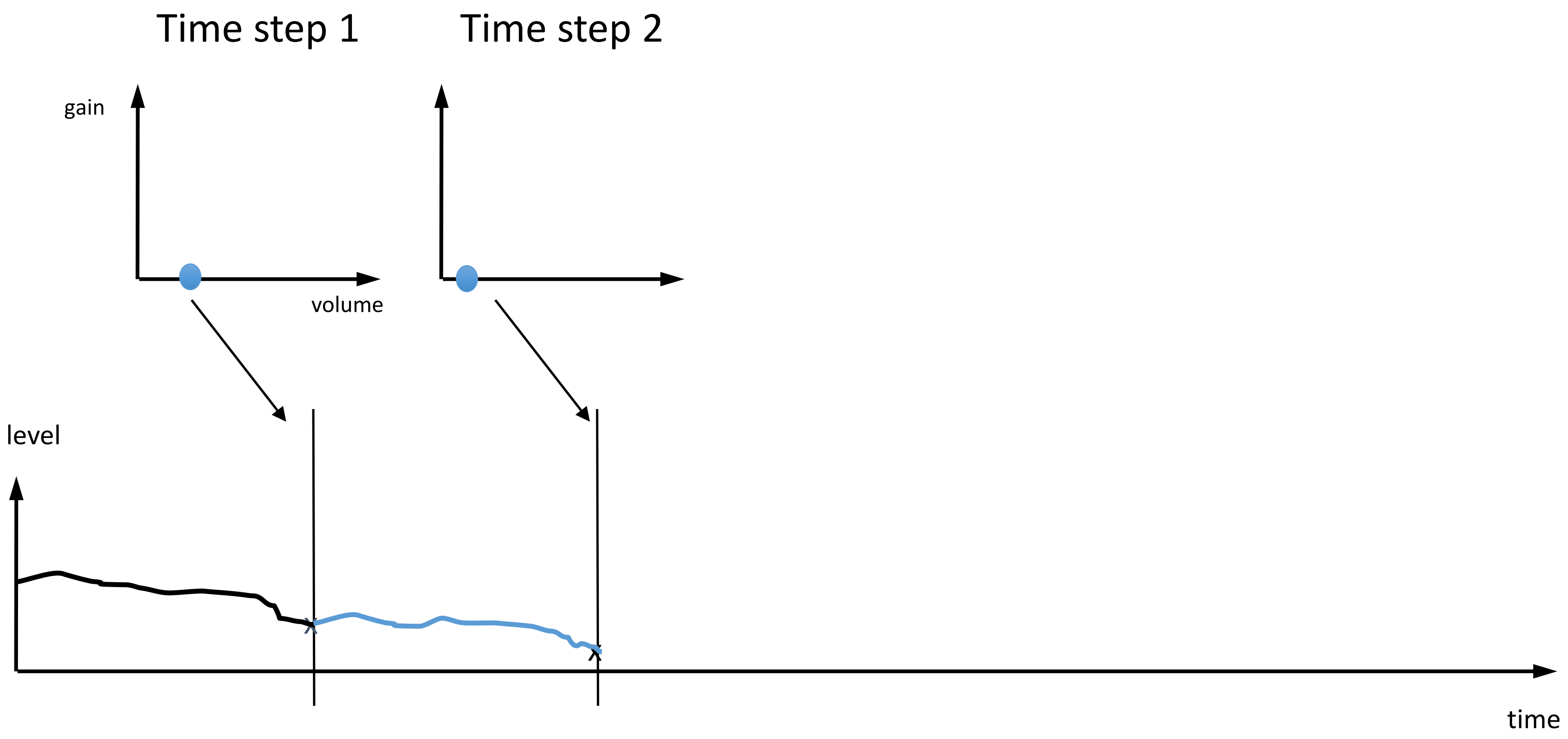
For a given set of initial Bellman values (for example, 0) and an initial stock → 1st timestep:

- Storage value is stored



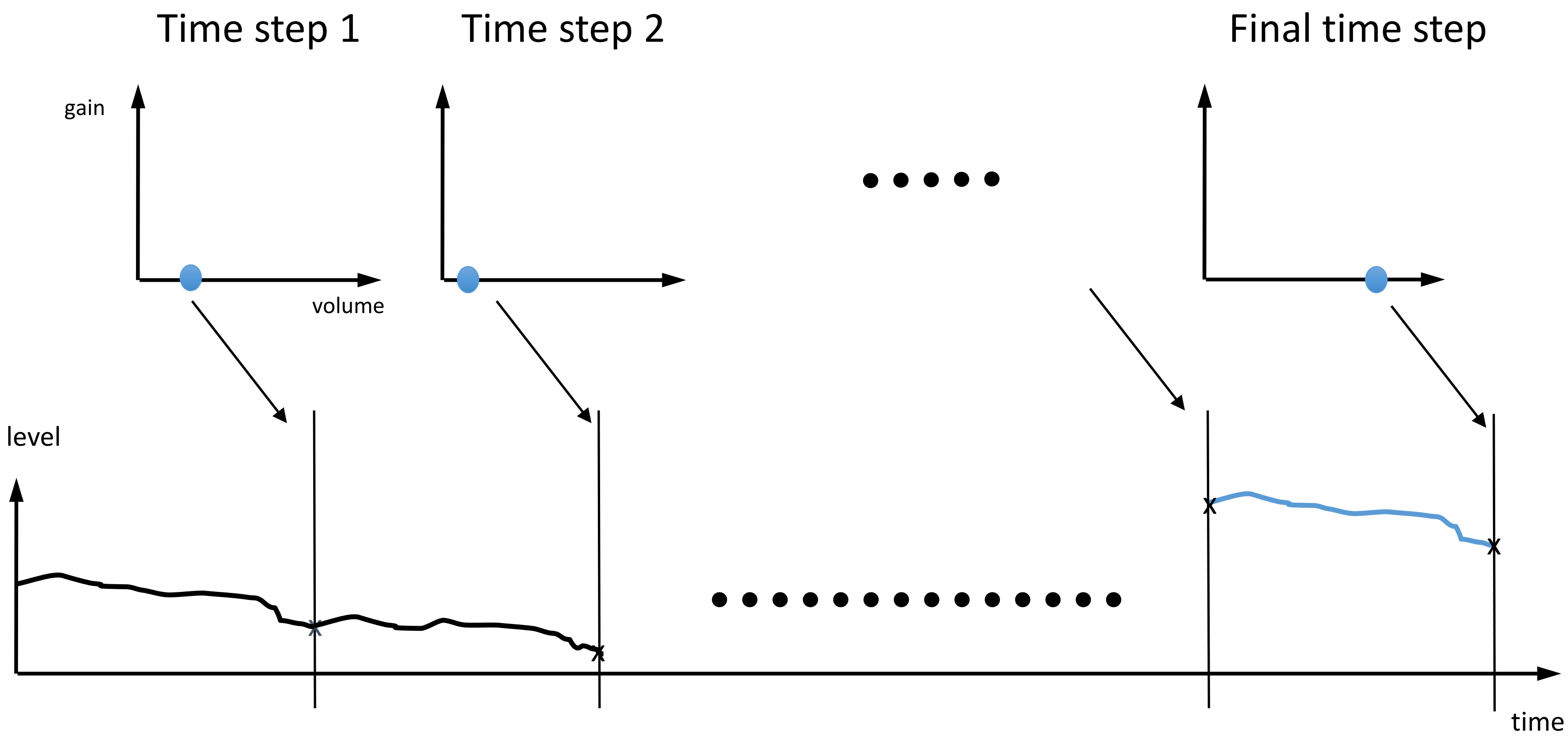
SDDP use value computation → Forward

Trajectory simulation on a scenario → 2nd time step



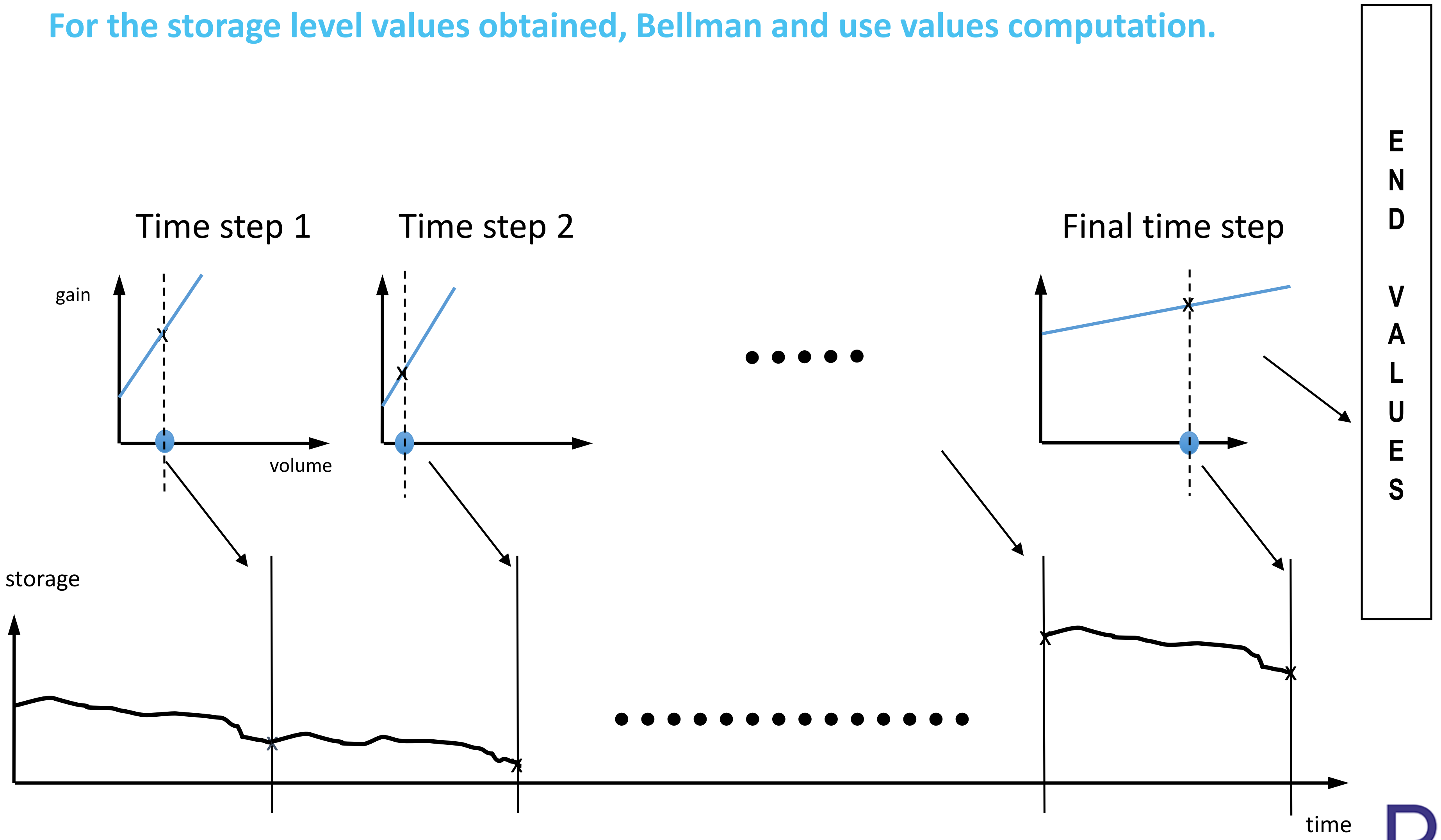
SDDP use value computation → Forward

Trajectory simulation on a scenario → Next time steps



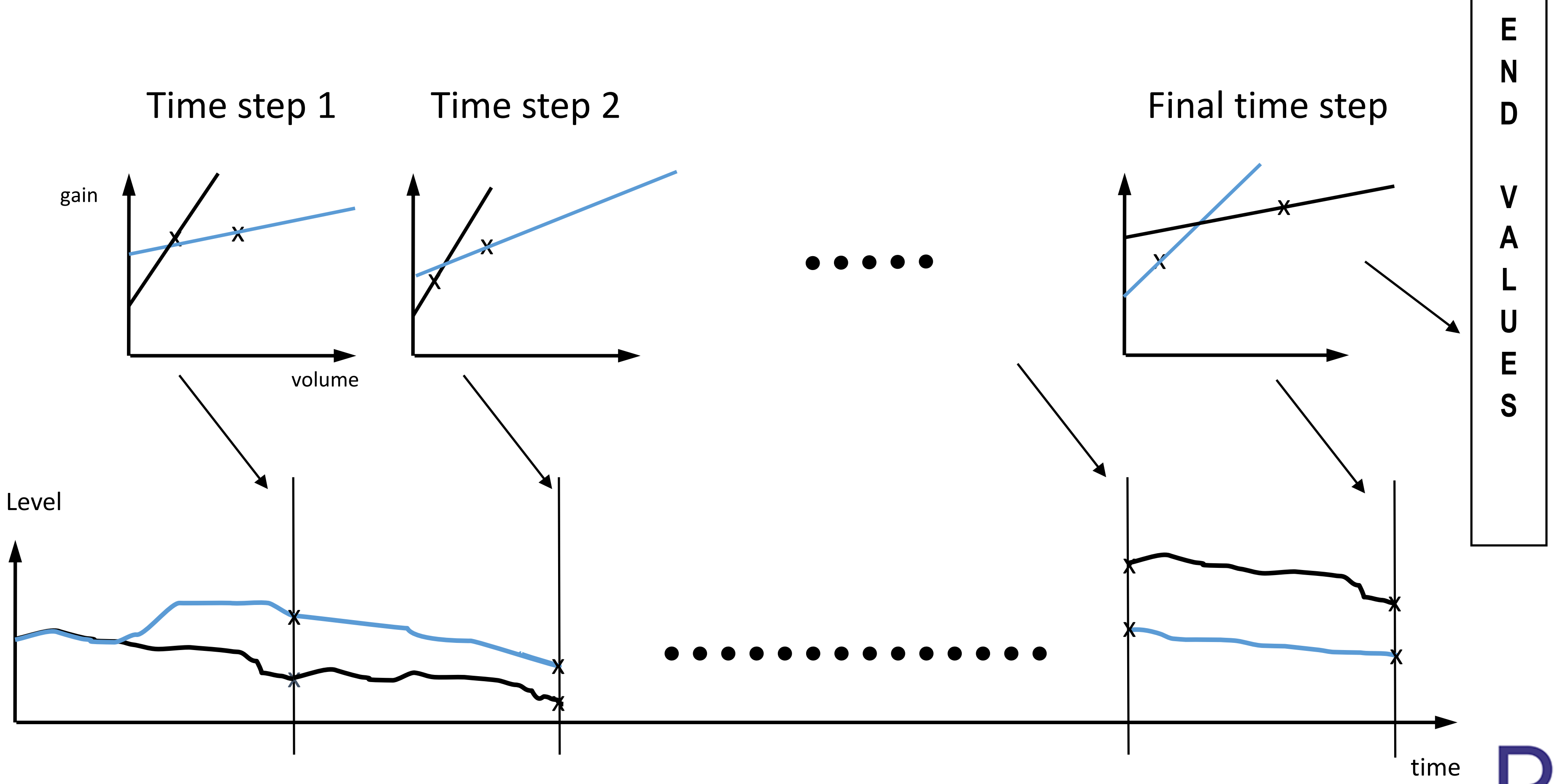
SDDP use value computation → Backward

For the storage level values obtained, Bellman and use values computation.



SDDP use value computation → Iteration

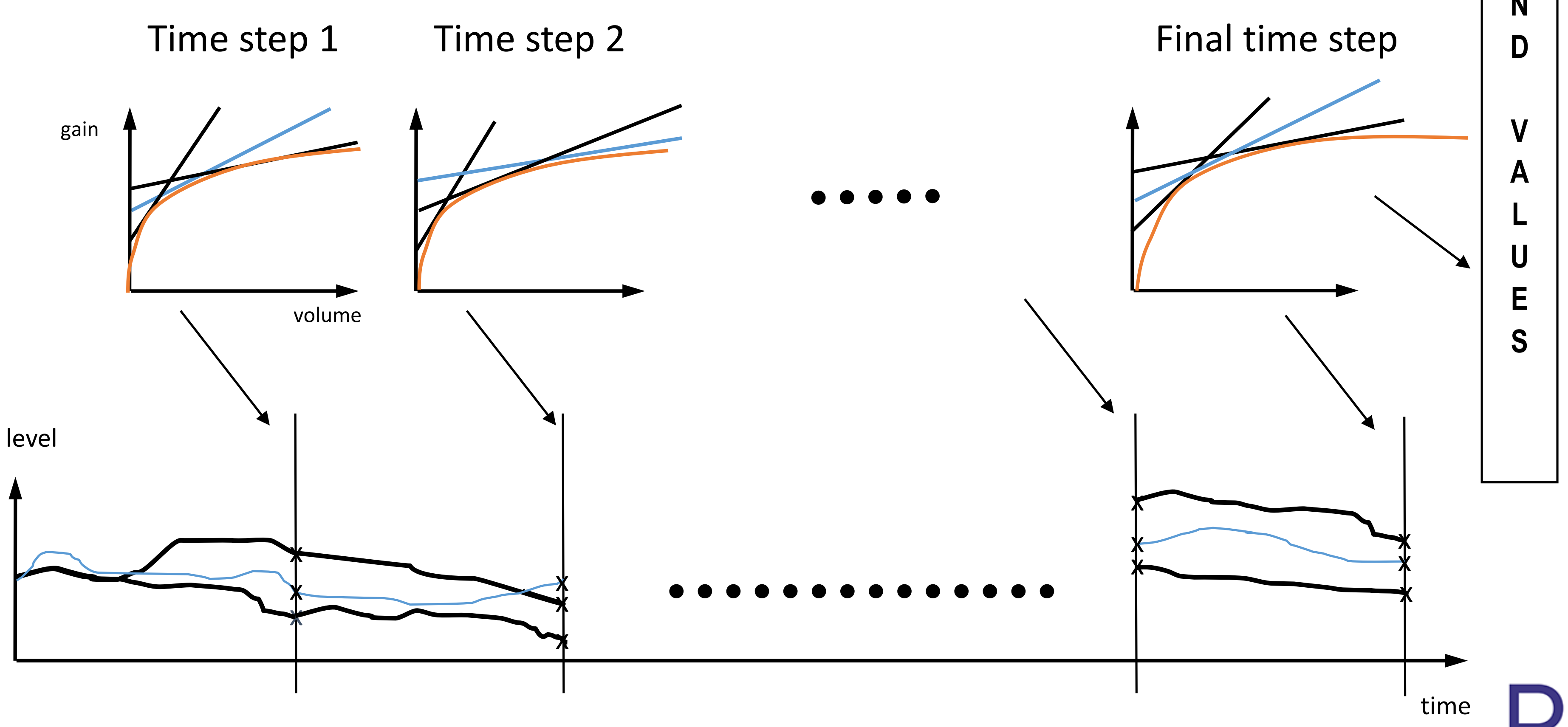
New use values are used for the next iteration: Forward ⟷ Backward



SDDP use value computation → Iteration

Convex Bellman functions are approximated by affine functions.

Close to convergence, use values are kept.

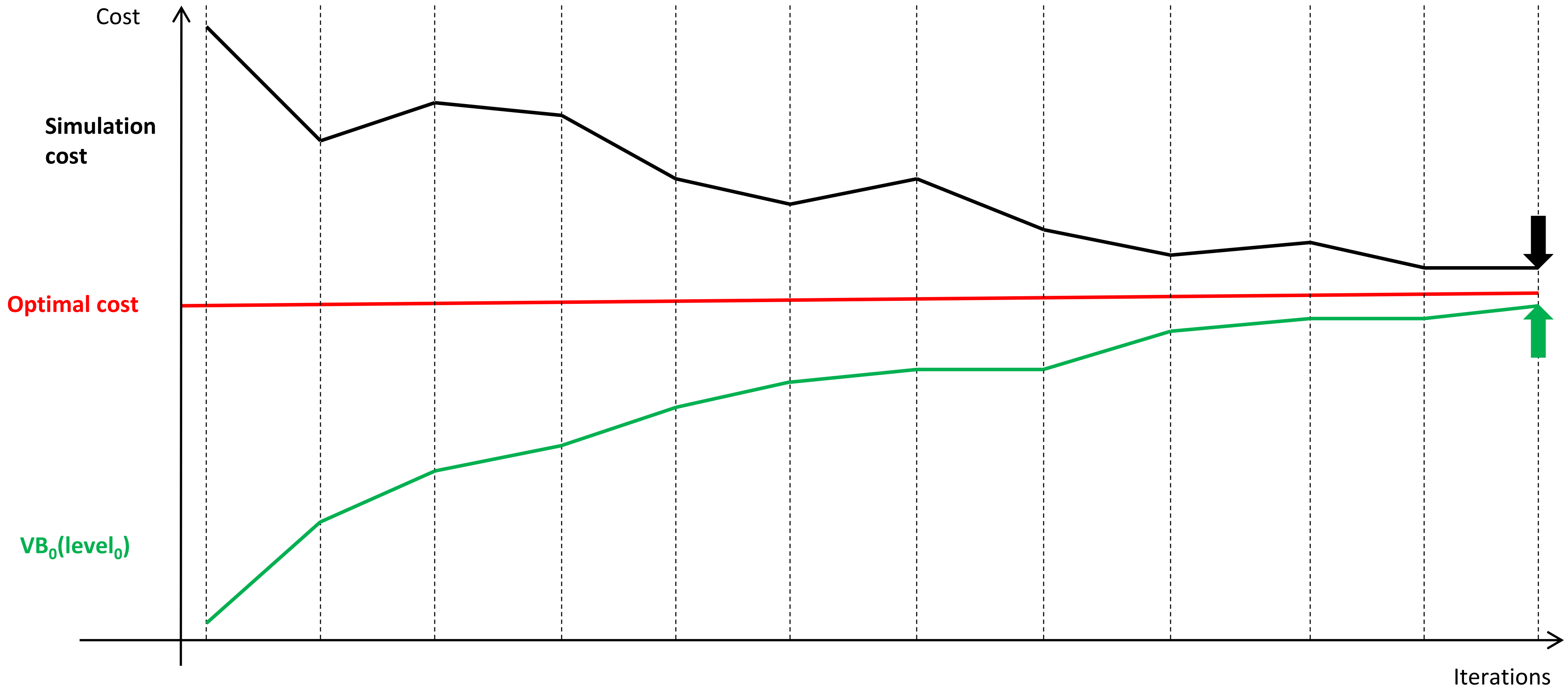


Convergence

The optimization cost (in the backward step) increases. The approximation converges towards the Bellman curve as lower boundary.

The simulation cost (in the forward step) decreases towards the optimal cost. The approximation improves at each iteration

The algorithm is stopped when the gap is « narrow enough ».



Advantages and drawback

ADVANTAGES:

- Useless storage points are ignored
- Useful storage points are refined
- The method can handle several stocks

DRAWBACKS:

- The problem must be convex (no dynamic constraints), else the SDDP is an heuristics
- Deciding of convergence is not easy
- More complex to set up than classical Stochastic Dynamic Programming.

SOME COMMERCIAL TOOLS PROPOSE THIS METHOD:

- SDDP from PSR (Brasil)
- DOASA from Stochastic Optimisation Limited (SOL) (New Zealand)
- EMPS from SINTEF

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