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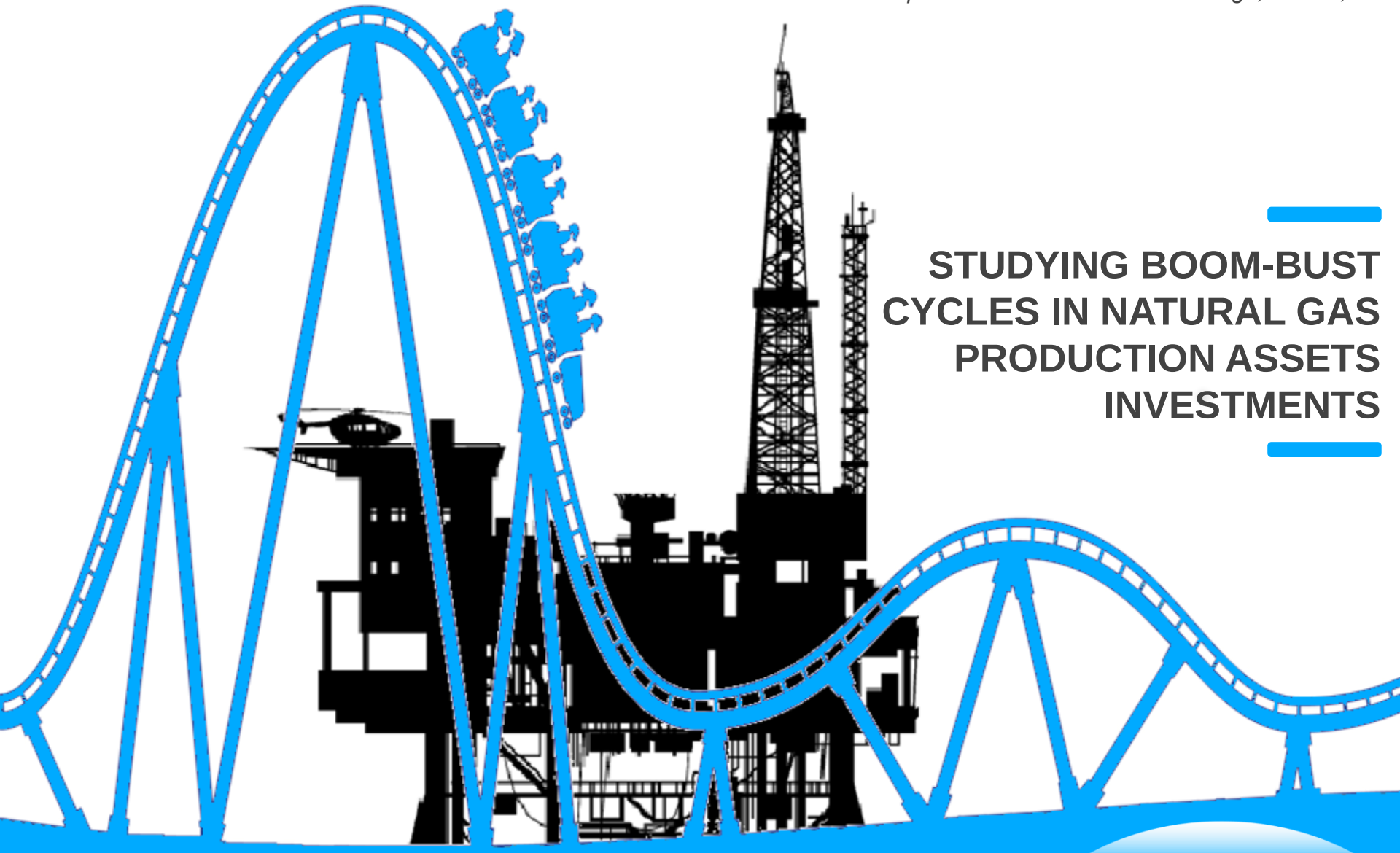

STUDYING BOOM-BUST CYCLES IN NATURAL GAS PRODUCTION ASSETS INVESTMENTS

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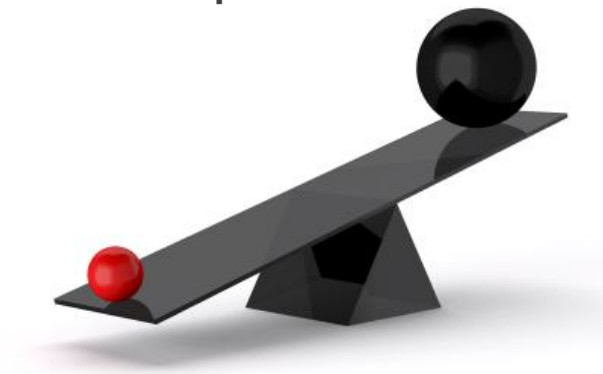
Global Natural Markets are facing significant upheavals…

- LNG global oversized investments

- Shale gas revolution in the US

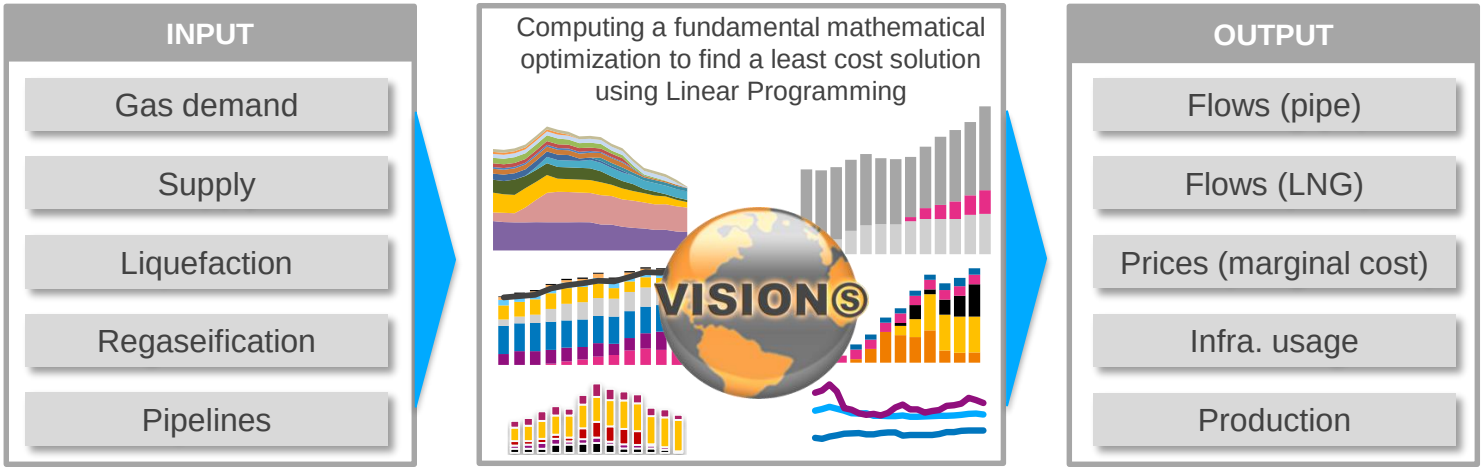
- Doubts on the Chinese natural gas demand

Global natural markets are arguably out of a medium and long-term equilibrium



… nevertheless, most of forecast models assume a static market equilibrium

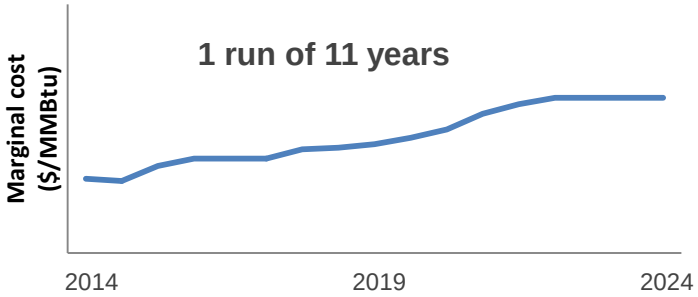
The starting point: VISIONs, an ENGIE in-house global gas model similar to the US Energy Information Administration's (EIA) International Natural Gas Model (INGM).



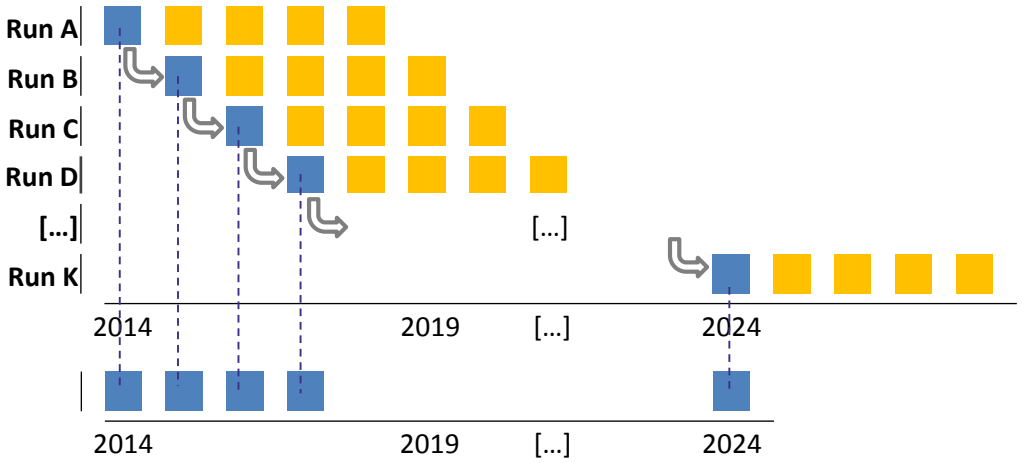
- **Static analysis:** the role of time is not considered.
- **Perfect foresight:** every agent foresees the future correctly.
- **Market equilibrium:** the market price is established through competition such that the amount of goods or services sought by buyers is equal to the amount of goods produced by sellers.

Moving from market optimization to market simulation

VISIONs, the classical static market equilibrium paradigm



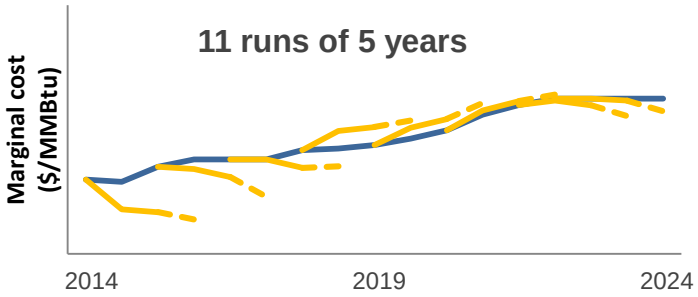
Integrating VISIONs into a dynamic simulation architecture



Achieved price: temporal dimension [1]

Forecasted price: temporal dimension [2]

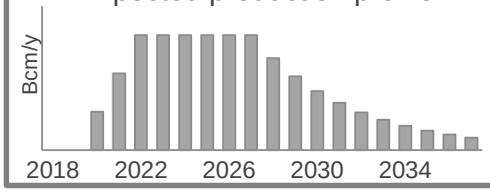
Dataset update with endogenous consequential information



An endogenous development plan emerges from the irreversible decisions in production assets investments

Asset X key economic and technical characteristics

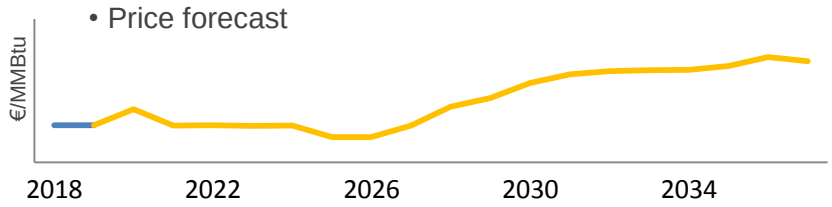
- Expected production profile



- Capital expenditure (CAPEX)
- Cost of capital (Wacc)
- Full production cost regime

Price forecast as perceived from year 2018

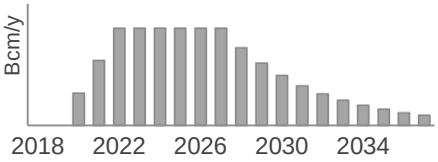
- Price forecast



Assessing a complete business plan using the price forecast to estimate natural gas expected revenues

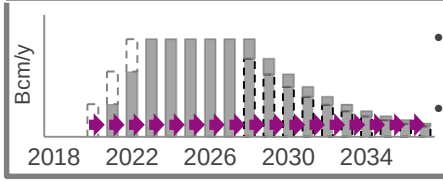
- Net Present Value (NPV)
- Internal Rate of Return (IRR)
- Profitability Index (PI)
- Pay Back (PB)

All criteria are validated



- The Final Investment Decision (FID) is irreversibly sanctioned
- The asset X is priced at its variable cost regime

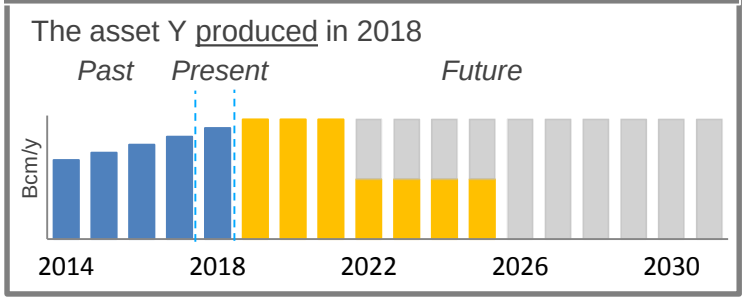
At least one criteria is not validated



- The project is postponed by 1 year.
- The business plan will be studied again within the following runs

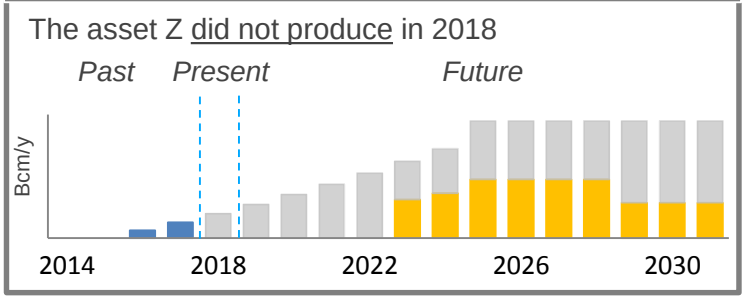
The simulation architecture allows a dynamic representation of the depletion of existing production capacities

Output run E: situation of the asset Y

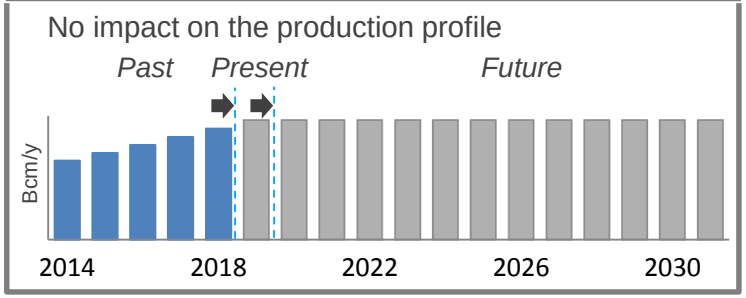


- Production in the temporal dimension [1]
- Production in the temporal dimension [2]
- Non-used production capacity

Output run E: situation of the asset Z

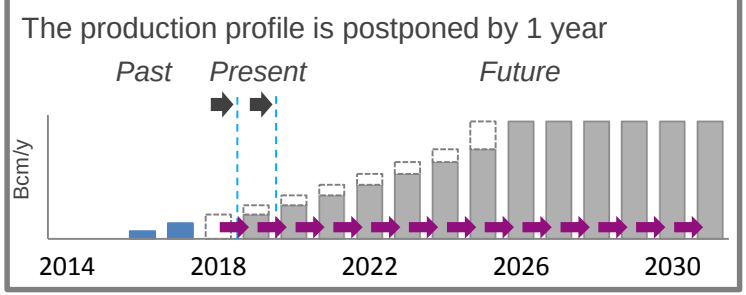


Input run F: impact on the asset Y



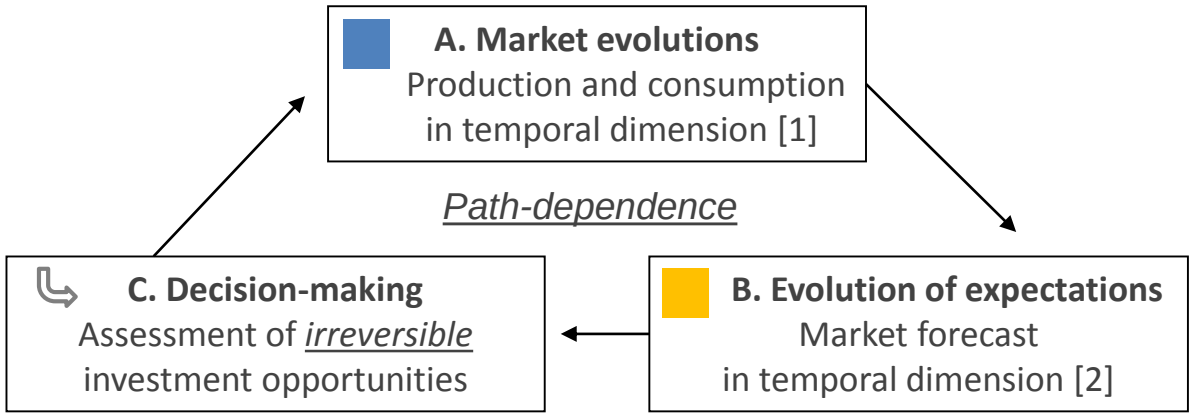
- Production in the temporal dimension [1]
- Available production capacity in temporal dimensions [1] and [2]

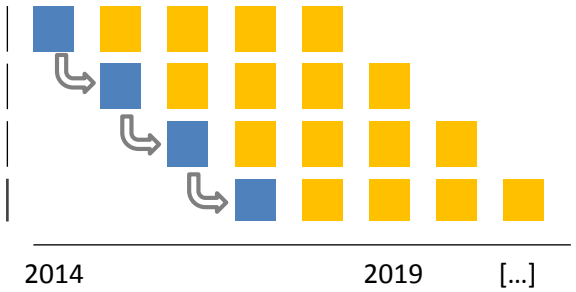
Input run F: impact on the asset Z



3 structural consequences on natural gas markets modeling

- **A causality loop emerges from the simulation architecture**



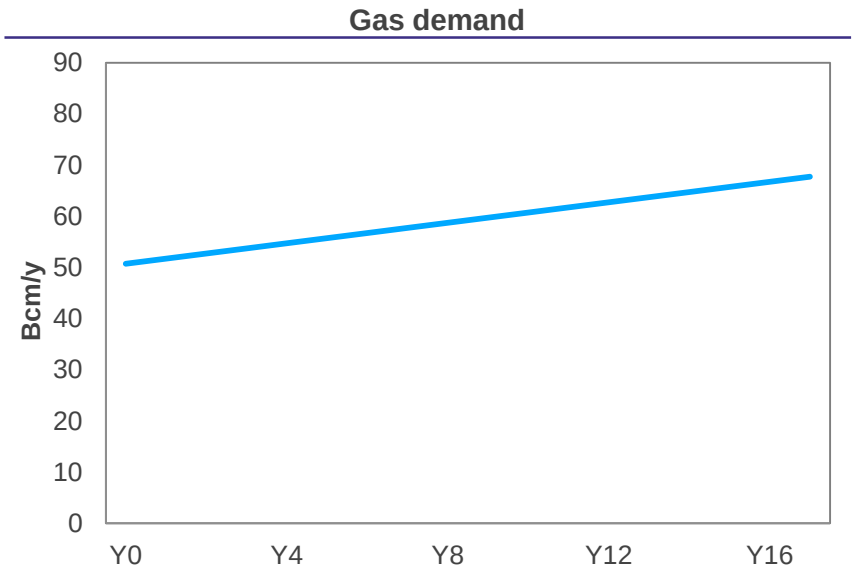


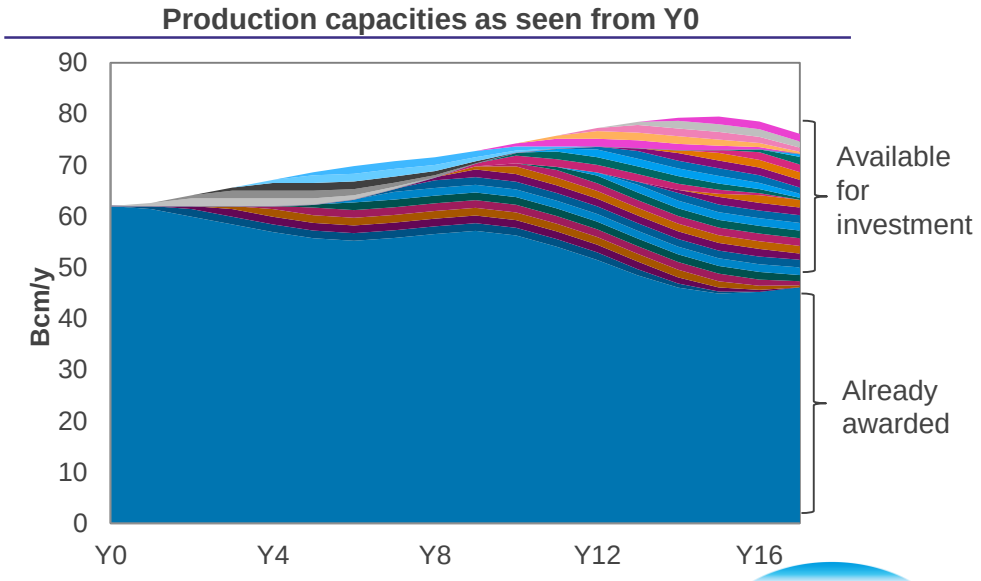
- **Dual mechanisms associated with differentiated economic regimes**
  - Allocation market: variable cost regime
  - Investment committee: full cost regime
- **Heterogeneous and independent agents**
  - Physical traders assure an optimal flow allocation in the short term
  - Business developers study production projects independently one from another ➧ *Agent-Based Modeling*

An easy dataset to meet complex objectives

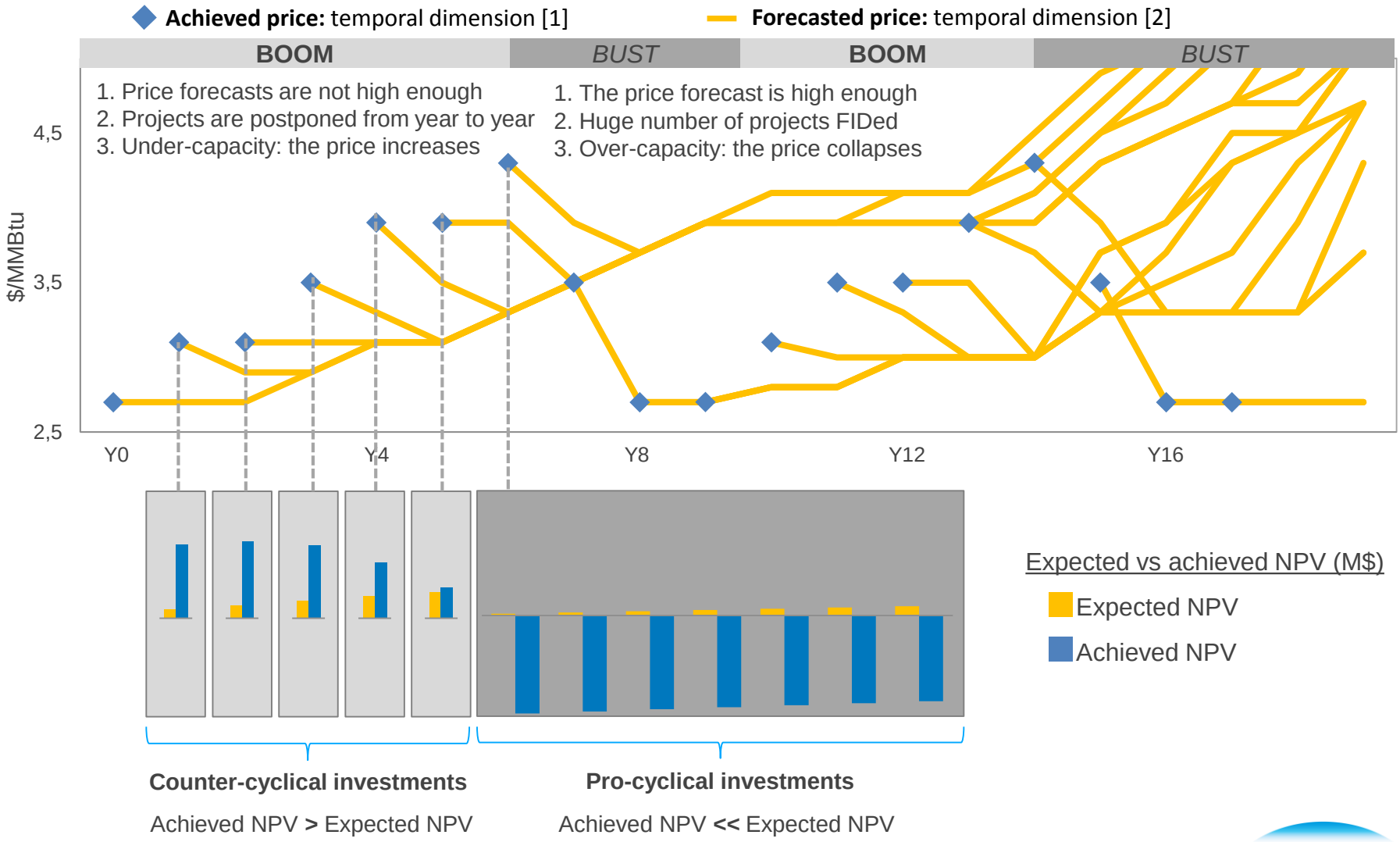
- **Objectives:**
  - Modeling a series of Boom-Bust cycles in natural gas production assets investment.
  - Identifying the best/worst times to invest in natural gas production assets within these cycles.

- **Assumptions:**
  - One single node
  - Gas demand: static, steady increasing
  - Gas supply: declining awarded production + a series of projects available for investment



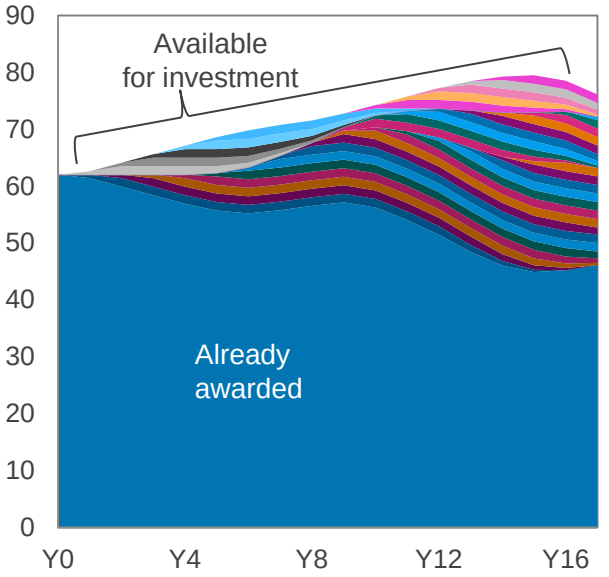


The model generates endogenous Boom-Bust cycles

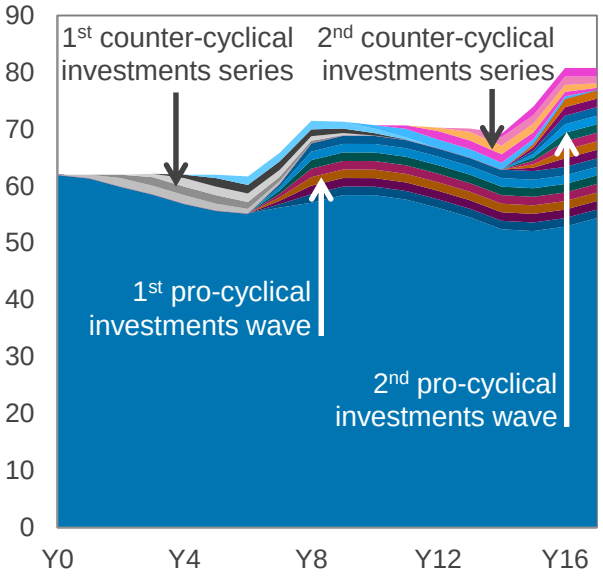


Production profiles are fully consistent with the price evolution

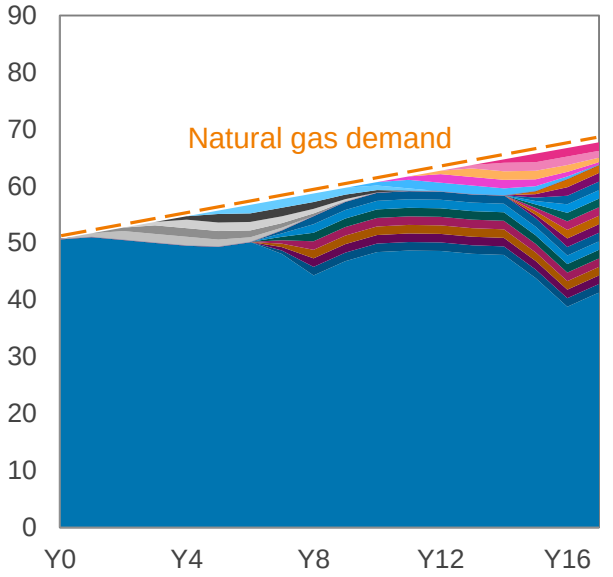
Production capacities as seen from Y0 Forecast in the temporal dimension [2]



Production capacities available in the temporal dimension [1]



Physical throughput in the temporal dimension [1]



Conclusion

- **Moving from optimization to simulation**
  - A causality loop emerges from the simulation architecture. ➧ *Path-dependence*
  - Dual mechanisms associated with differentiated economic regimes.
  - Heterogeneous and independent agents. ➧ *Agent-based modeling*

- **Demonstration on a limited dataset**
  - Modeling a series of Boom-Bust cycles in natural gas production assets investment.
  - The model shows that in those conditions, counter-cyclical investments are highly profitable whereas pro-cyclical investments are fatal.

- **Next steps**
  - Test on an extended dataset.
  - Additional dynamic functions: elasticity of demand, market power,…

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