Carnegie Mellon Electricity Industry Center

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Enhancing IGCC economics with a diurnal syngas storage scheme

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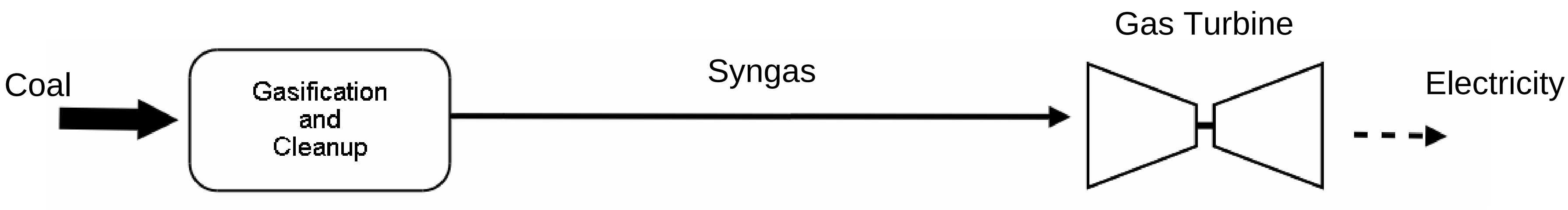
Research Question

What is the value of adding gas storage capabilities to a coal gasification facility?

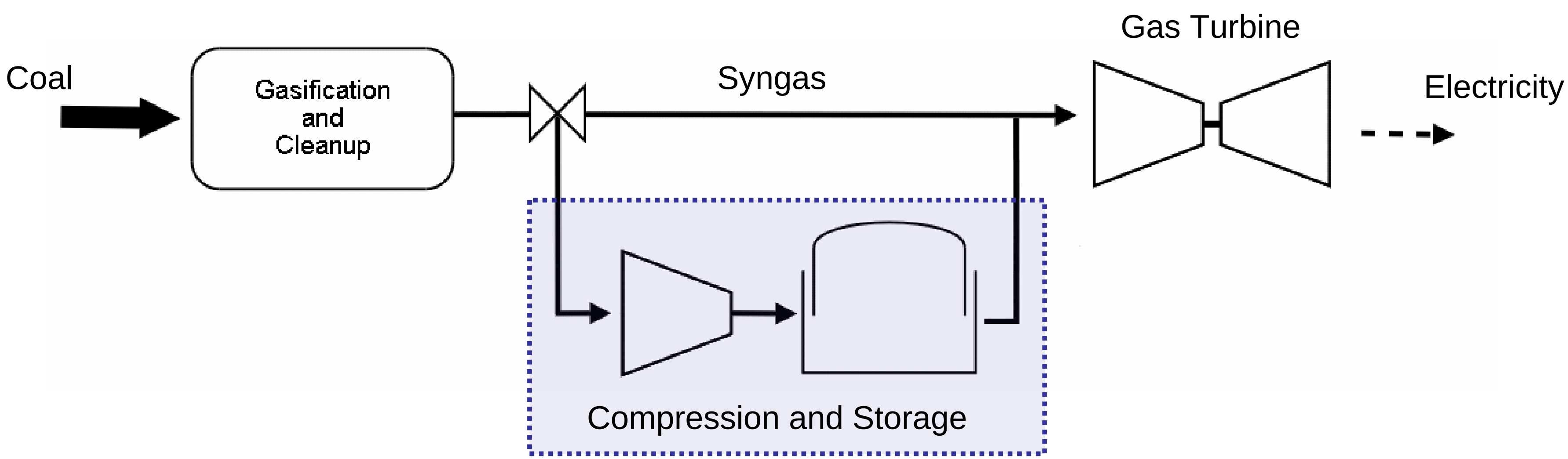
or, put another way

Can syngas storage lower the carbon price at which IGCC enters the generation mix?

Project overview and methodology



Current gasification operations: End use (turbine) coupled with gasifier



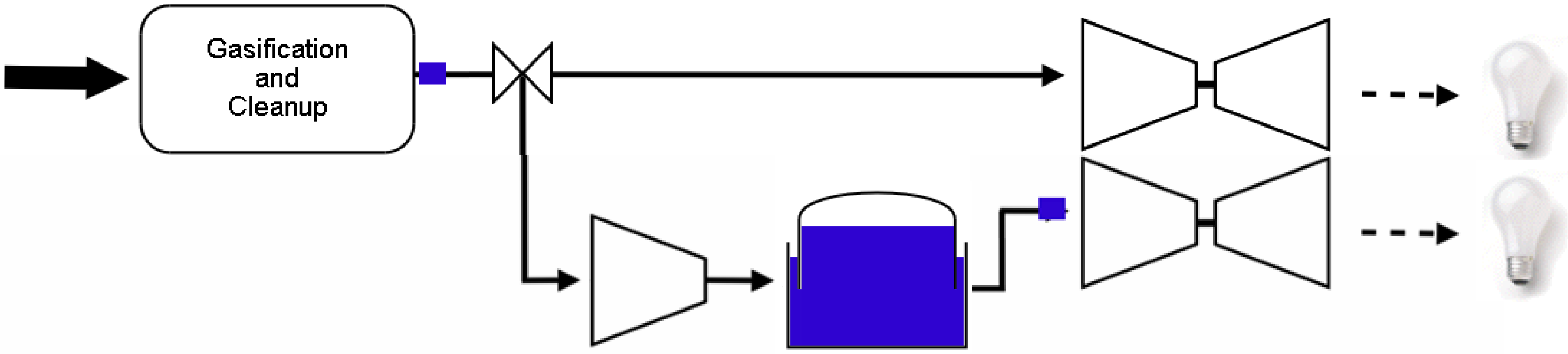
Storage scenario: Turbine can operate independently of gasifier

Storage allows for additional flexibility in facility configuration and operation

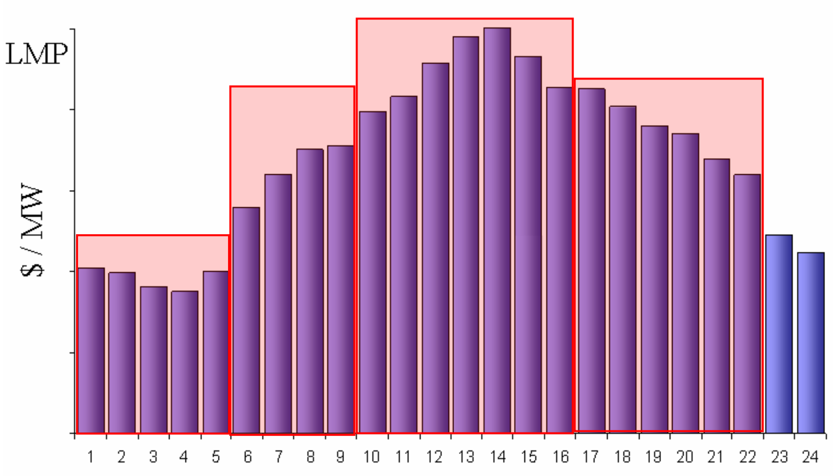
Example: Producing Peak Electricity with Stored Syngas

Valve setting: to gasifier

Electricity Generated: 2x



LMP $/MW: high



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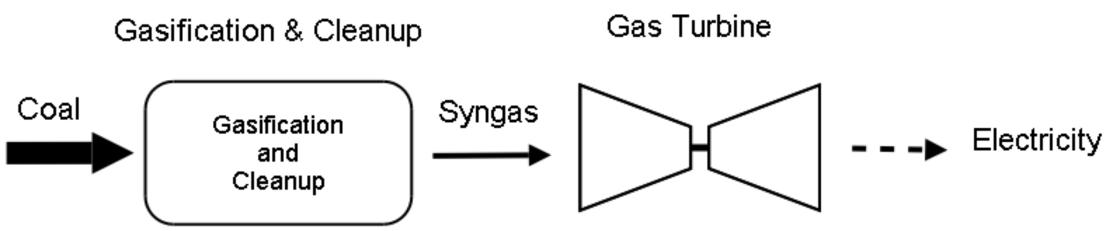
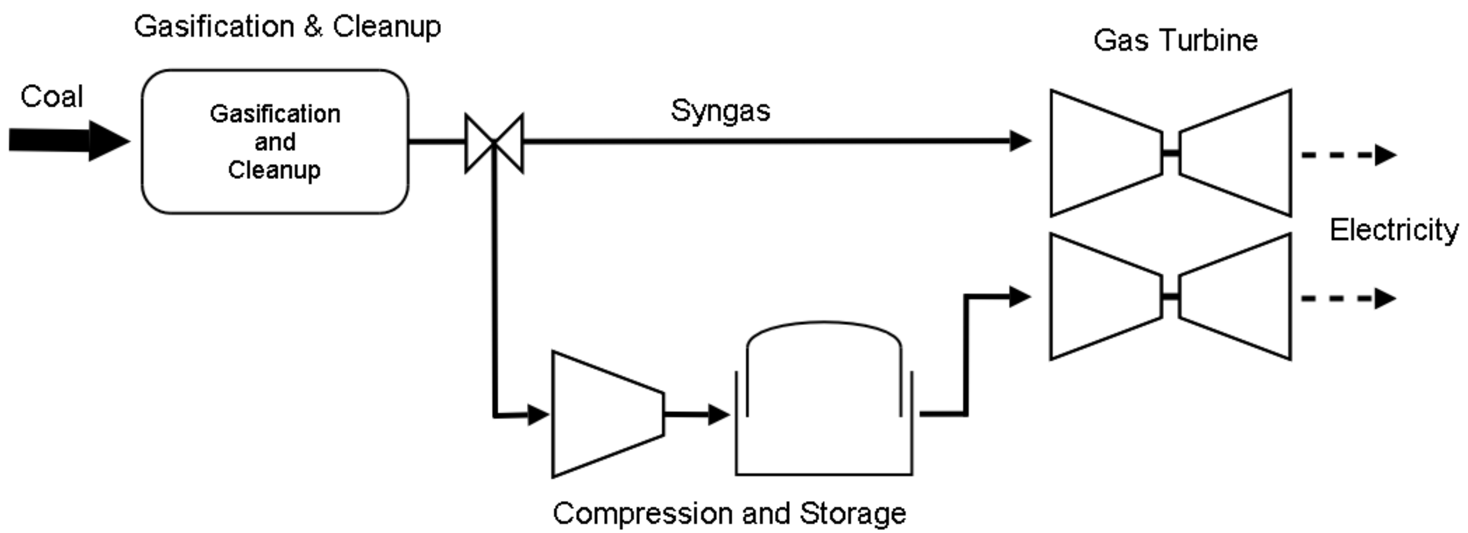
Scenarios

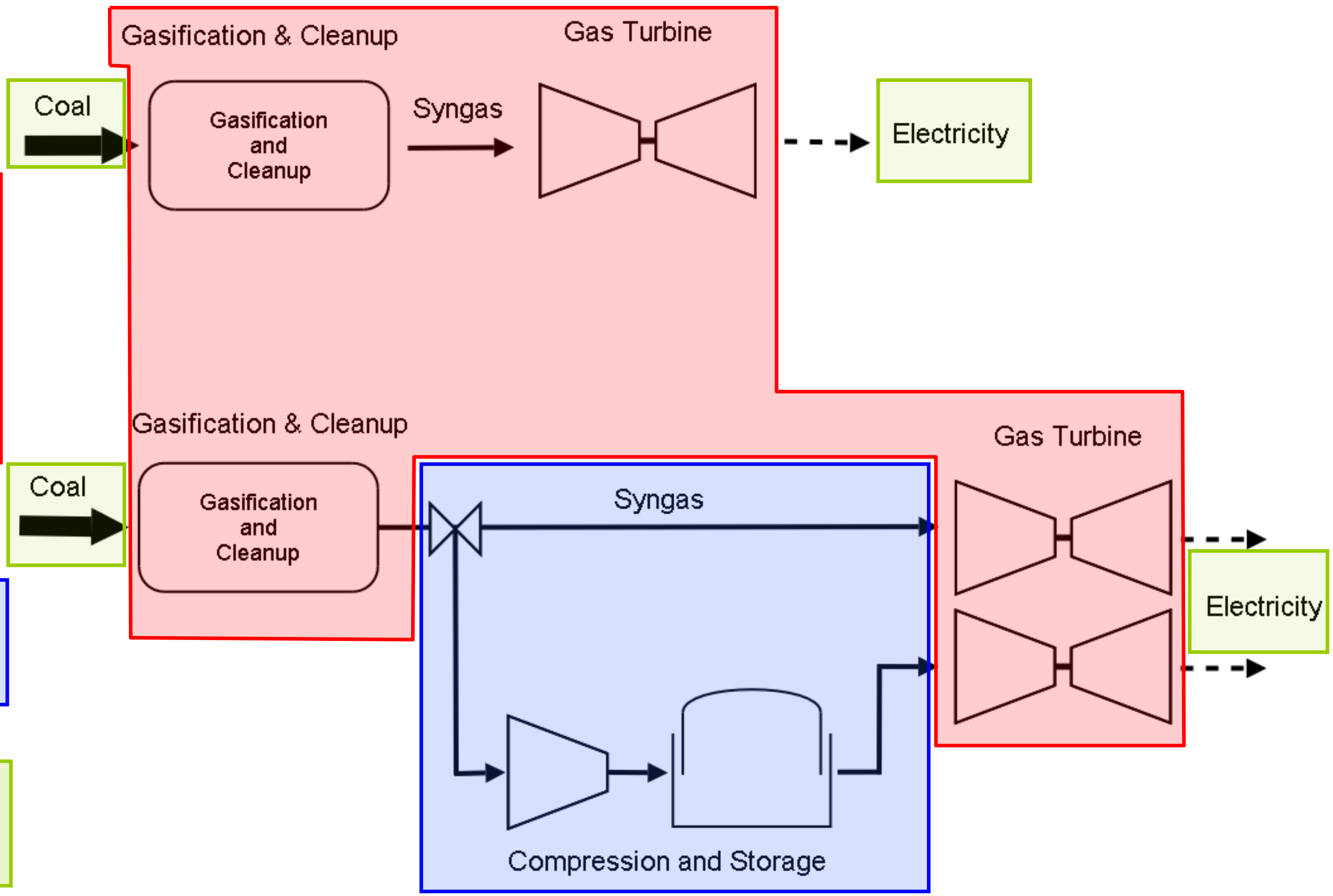
Baseline: No Storage



Diurnal Syngas Storage



Scenario Data Sources



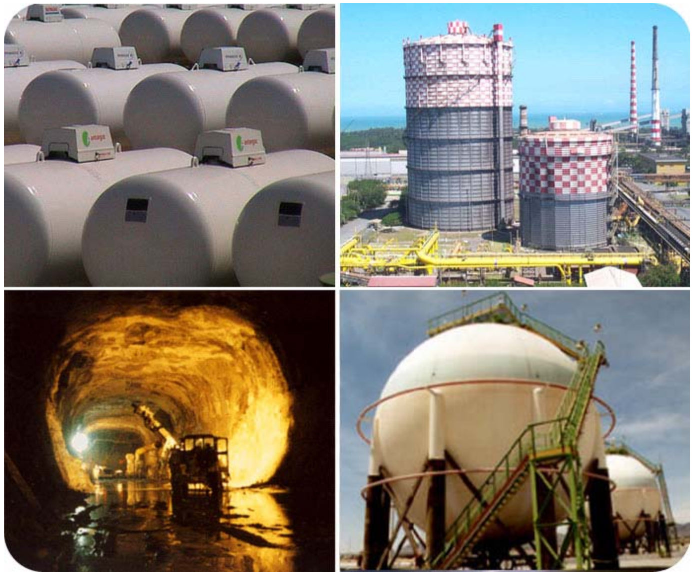
Integrated Environmental Control Model (IECM)
www.iecm-online.com

Engineering Economic Model

Historical and Future Prices

Storage Options

- Examined only compressed gas storage options
- Diurnal storage
- Storage technologies considered
  - Above ground
    - Low pressure (gasometers)
    - High Pressure
    - (cylindrical bullets, gas spheres)
  - Underground
    - Rock caverns
    - Salt caverns
- Explored the costs and tradeoffs between
  - storage pressures and storage volumes
  - storing low energy density syngas versus storing methanated syngas (synthetic natural gas or SNG)



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Economic Data Sources

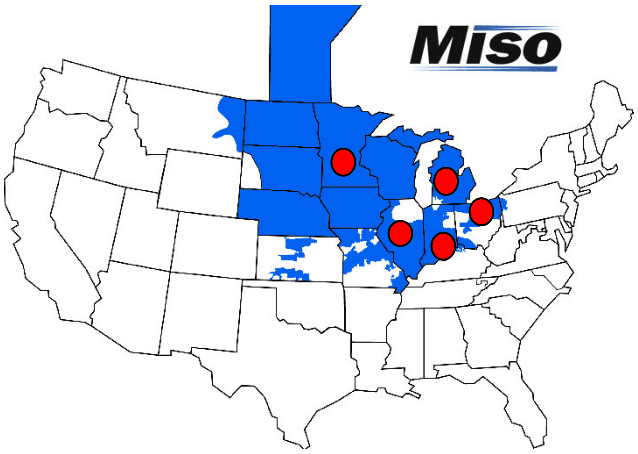
- Input

  Coal Historical (Aug 05-06) : Monthly average FOB prices for Illinois Basin coal

  Future (2007): EIA AEO forecast, EIA AEO forecast with accuracy factor, NYMEX futures

- Output

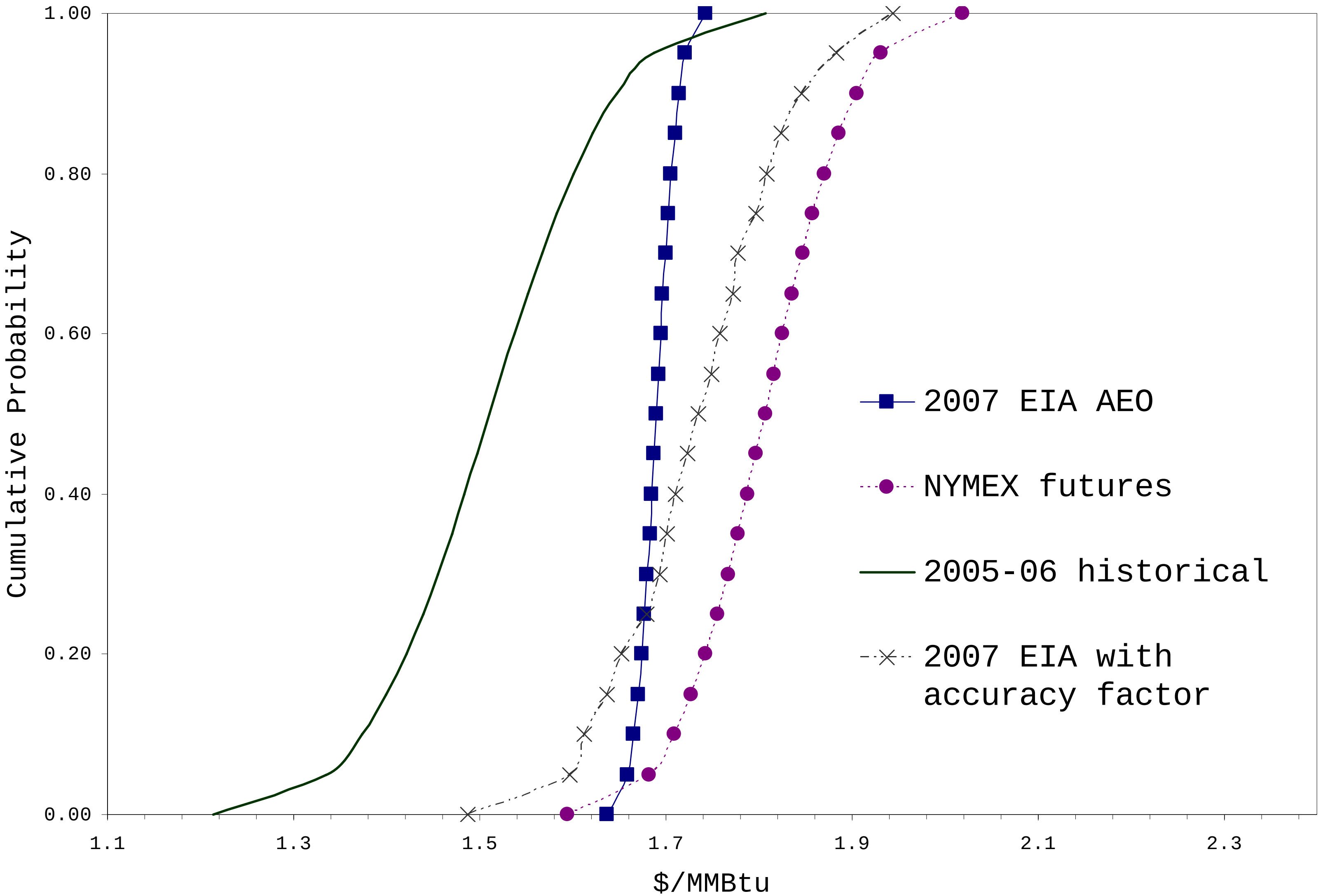
  Electricity Historical (Aug 05-06) Locational marginal price (LMP) data from Midwest ISO (MISO)



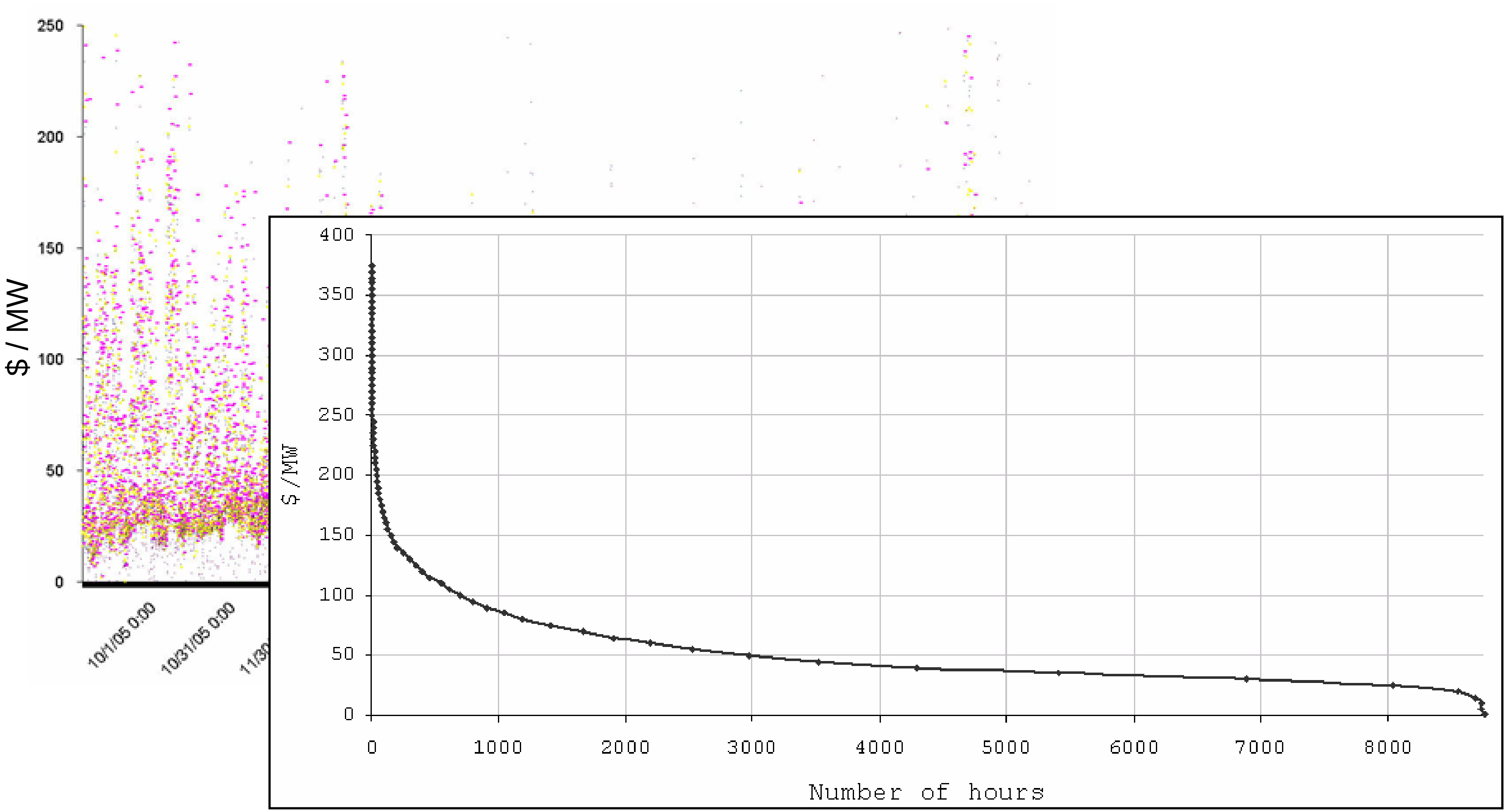
Source: Adapted from Midwest ISO

- CDFs of all price data were created for input into the engineering economic model

Coal Price Data



Electricity Price Data



Price duration curve. Cinergy node, Aug 05 - Aug 06

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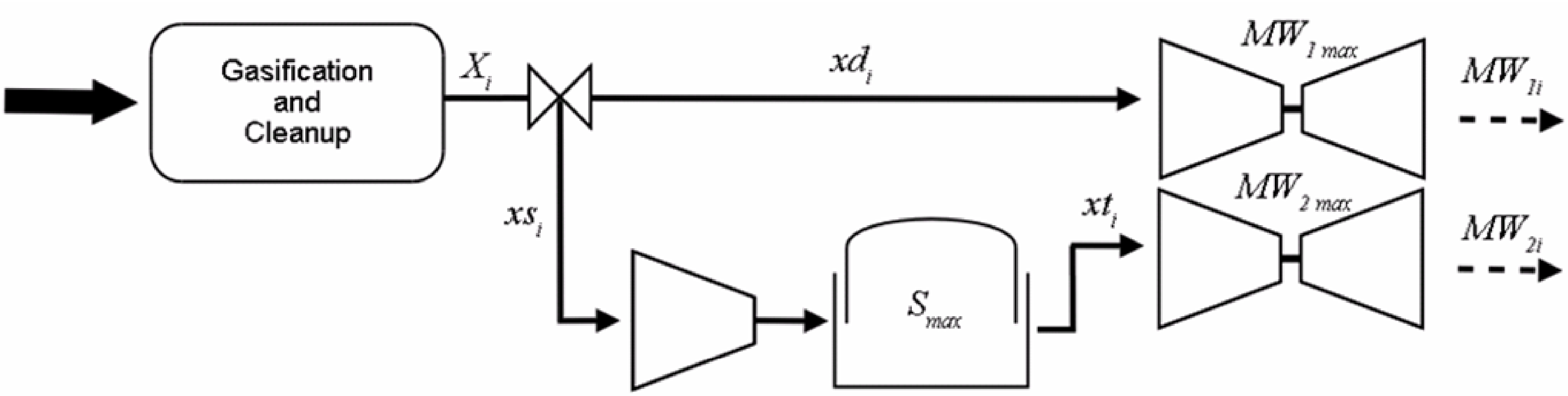
Scenario Analysis Details



Parameter	Description	Value(s)
i	hourly index	1 to 24
X_i	syngas output from gasifier	260 tons (IECM)
xd_i	syngas from gasifier direct to turbine	0-260 tons
xs_i	syngas from gasifier to storage	0-260 tons
xt_i	syngas from storage to turbine	0-260 tons
S_{max}	maximum storage size	4, 8, 12 hours
MW_{1i}	electricity produced from turbine 1	0-270 MW (IECM)
MW_{2i}	electricity produced from turbine 2	0-270 MW (IECM)

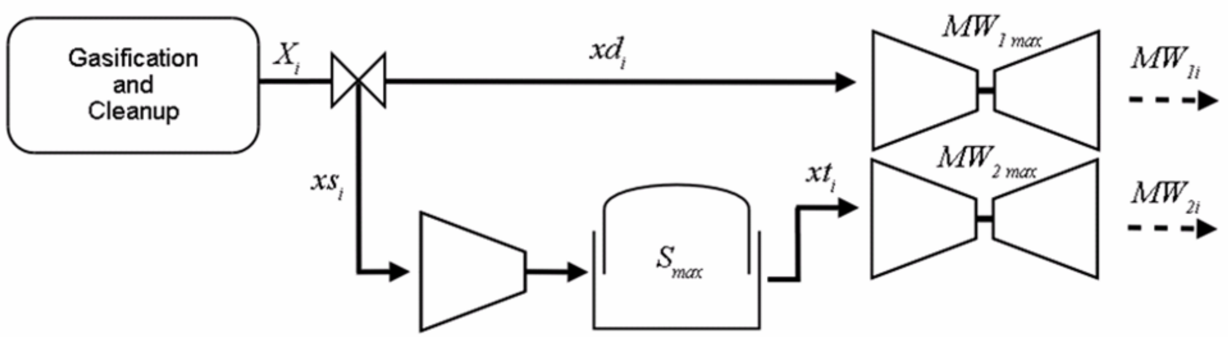
Scenario Analysis Details

$$\text{ROI} = \frac{\text{annual revenue}}{\text{total levelized annual expenses}}$$

where

$$\text{annual revenue} = \text{availability} \cdot \sum_{i=1}^{8760} (\text{MW}_{1i} + \text{MW}_{2i}) \cdot \text{LMP}_i$$

total levelized annual expenses =
levelized capital costs + fixed O&M costs + (availability • variable O&M costs)



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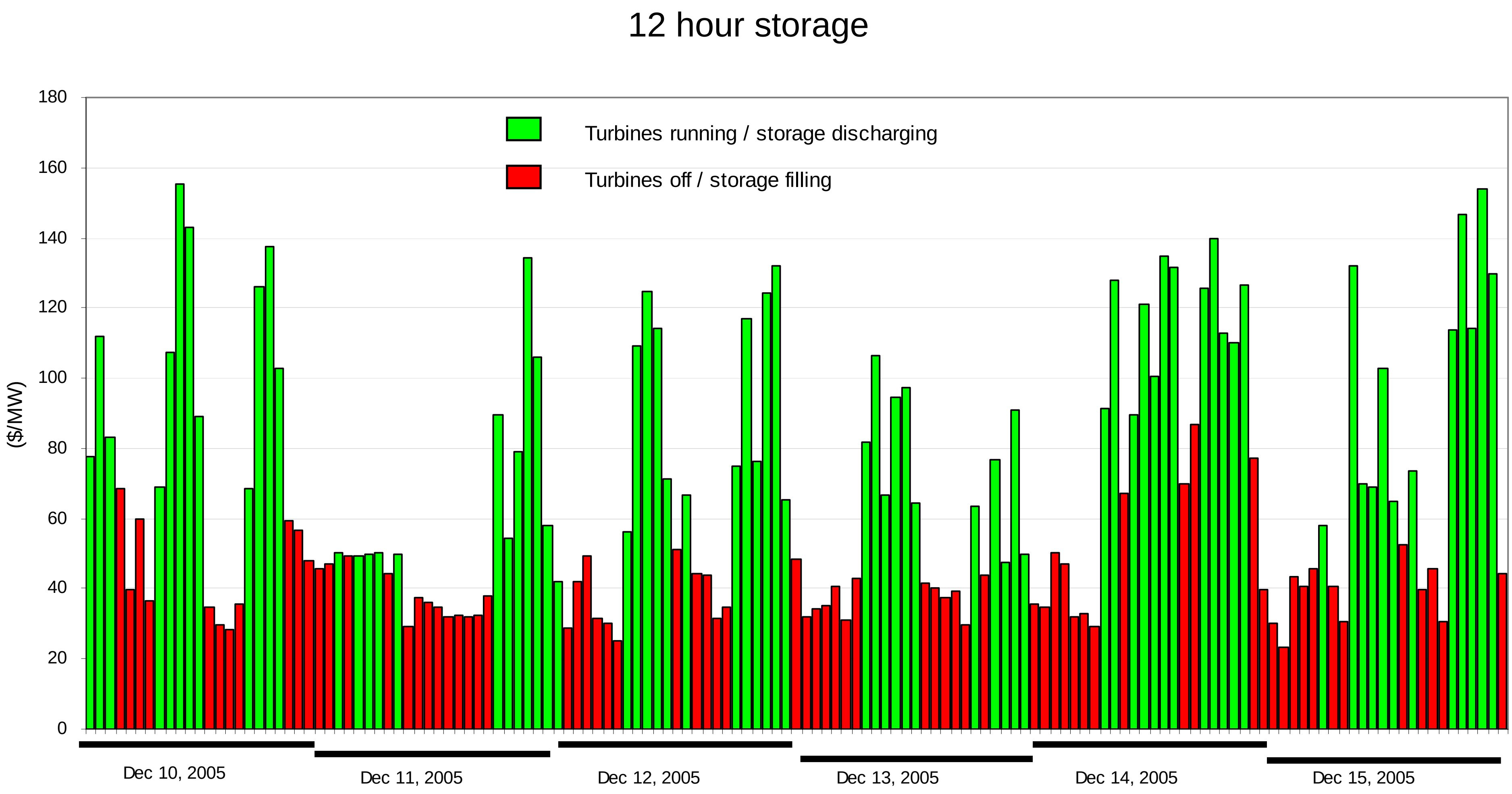
Scenario Analysis Details



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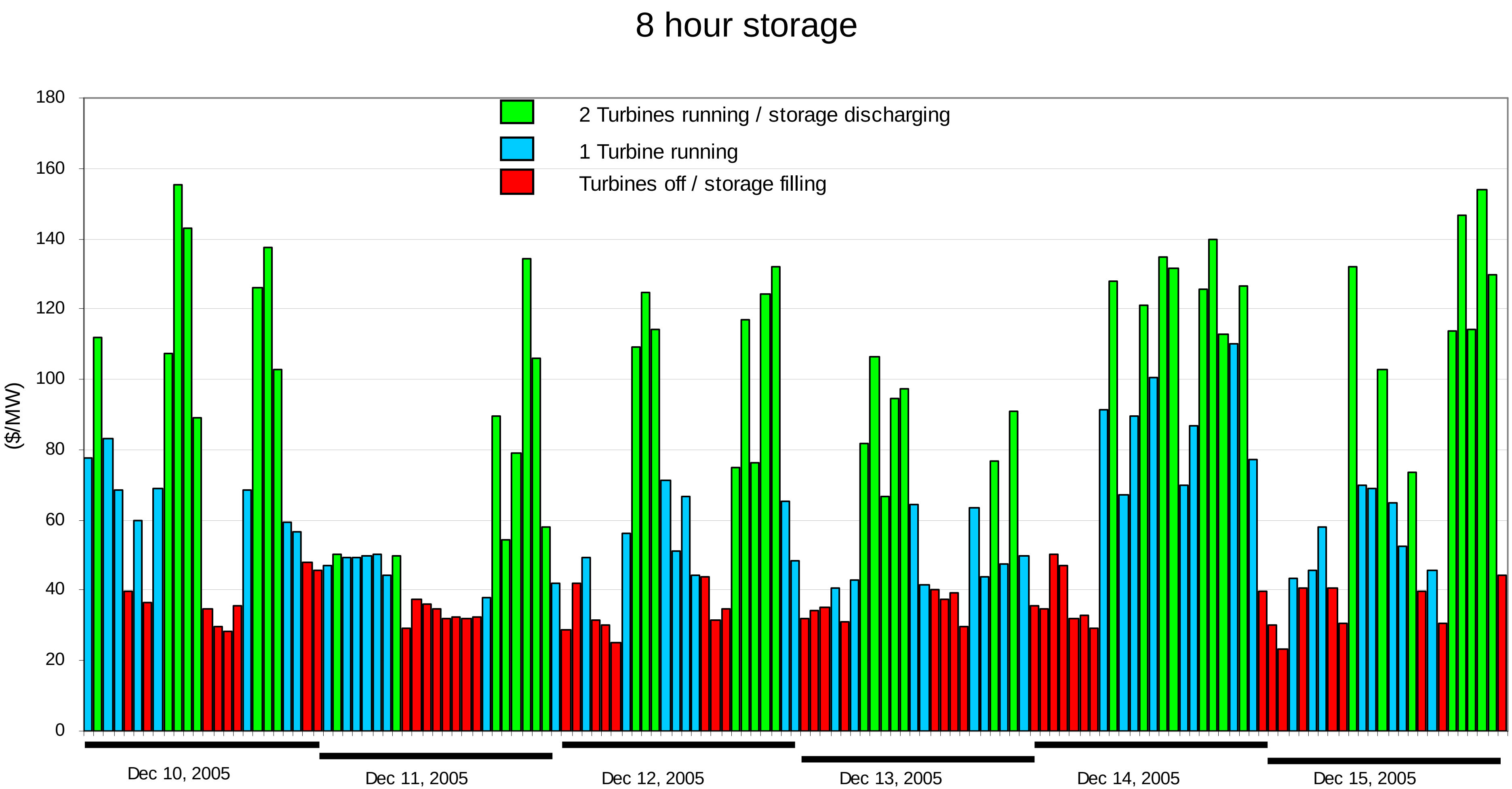
Scenario Analysis Details



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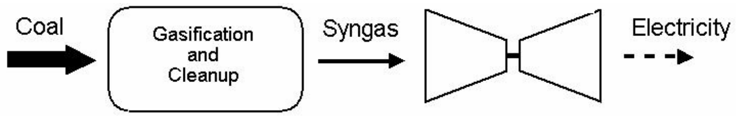
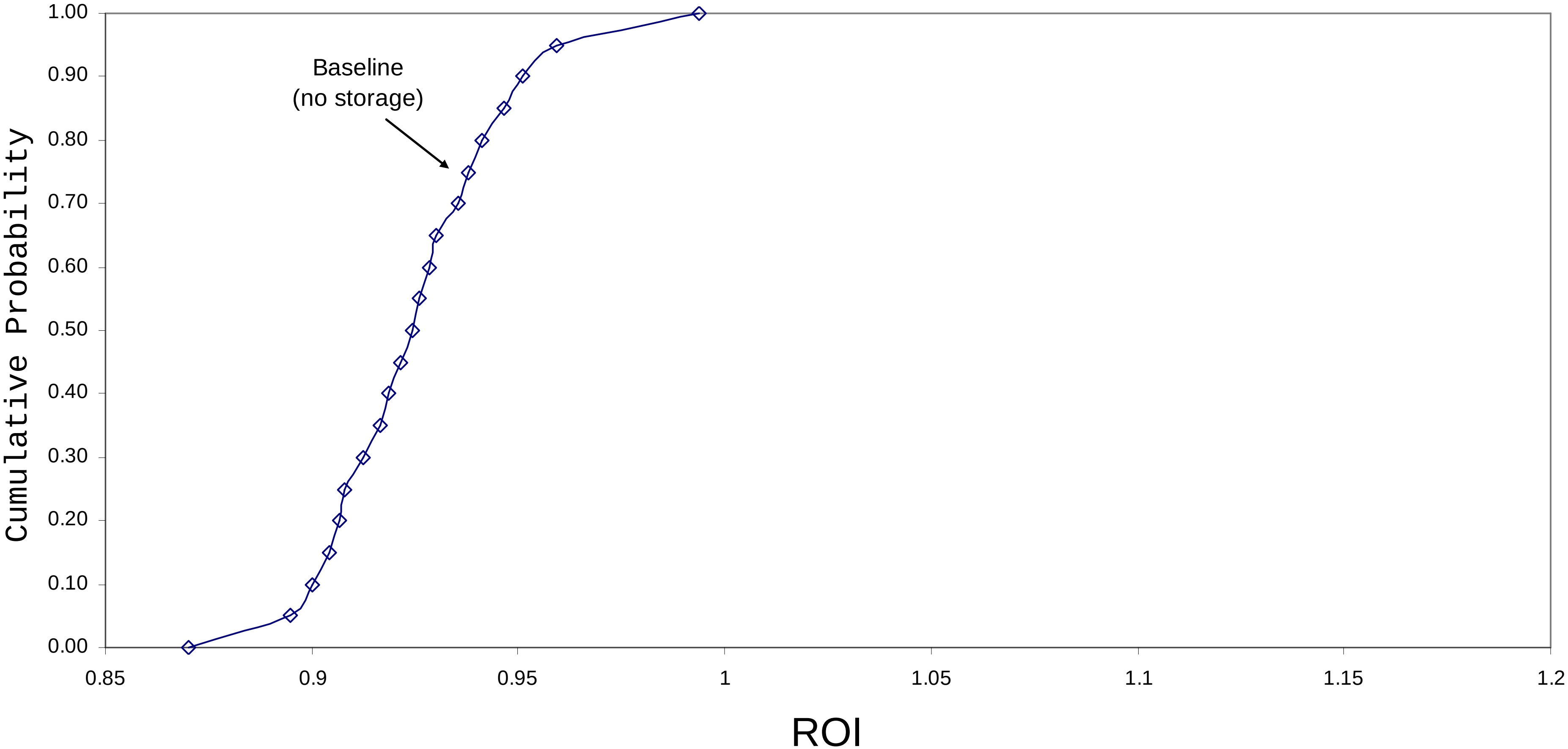
Preliminary Results: Gasifier + Turbine (baseline)





Key financial parameters: 30 year economic/loan life, 100% financing, 8% interest rate, Cinergy node, historical coal prices

Key operating parameters: 80 percent availability, 1 operating gasifier and 1 spare gasifier (1+1)

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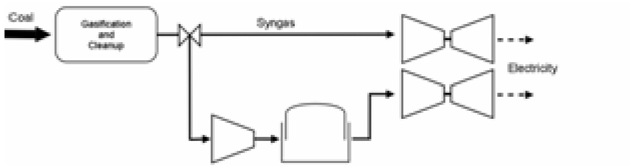
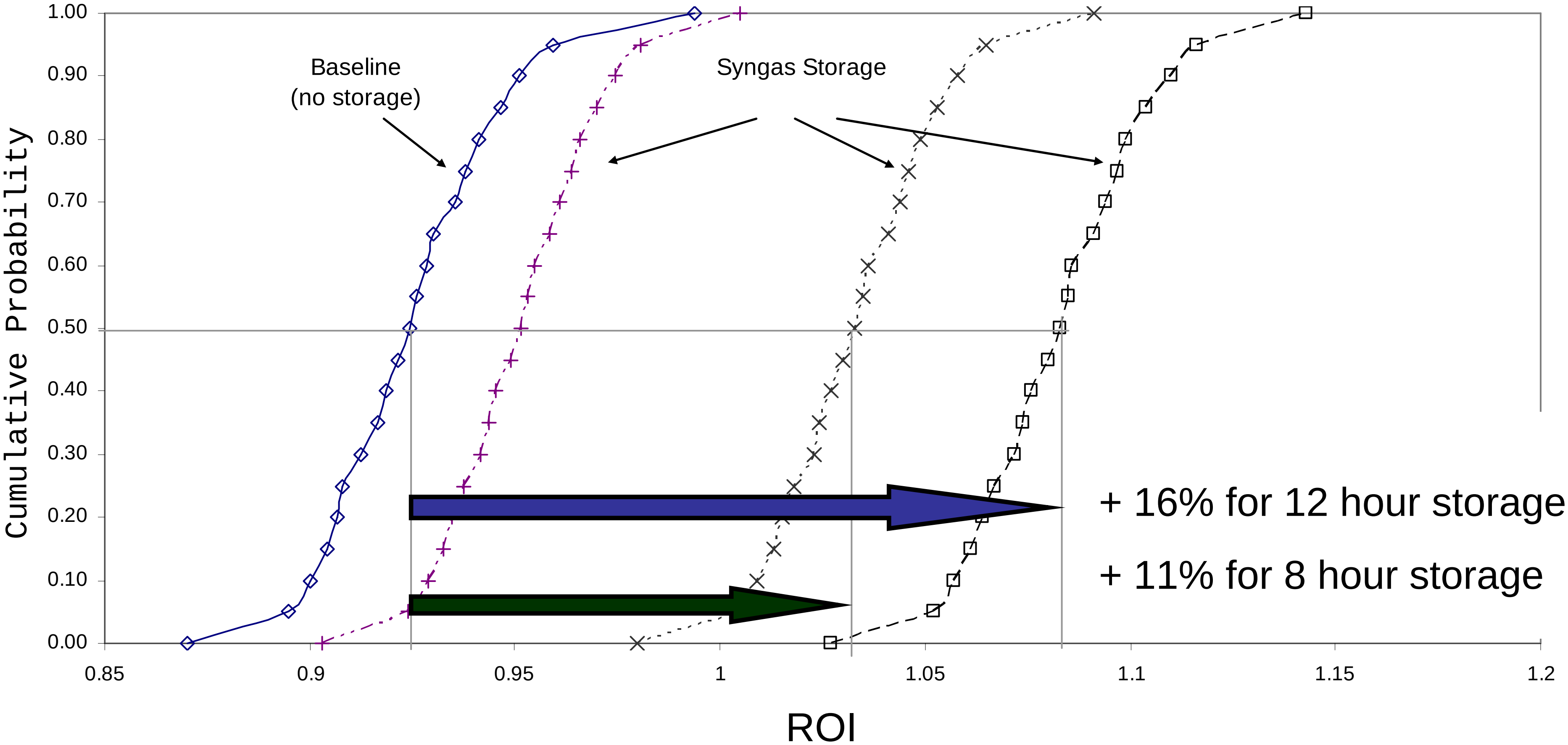
Preliminary Results: Syngas Storage

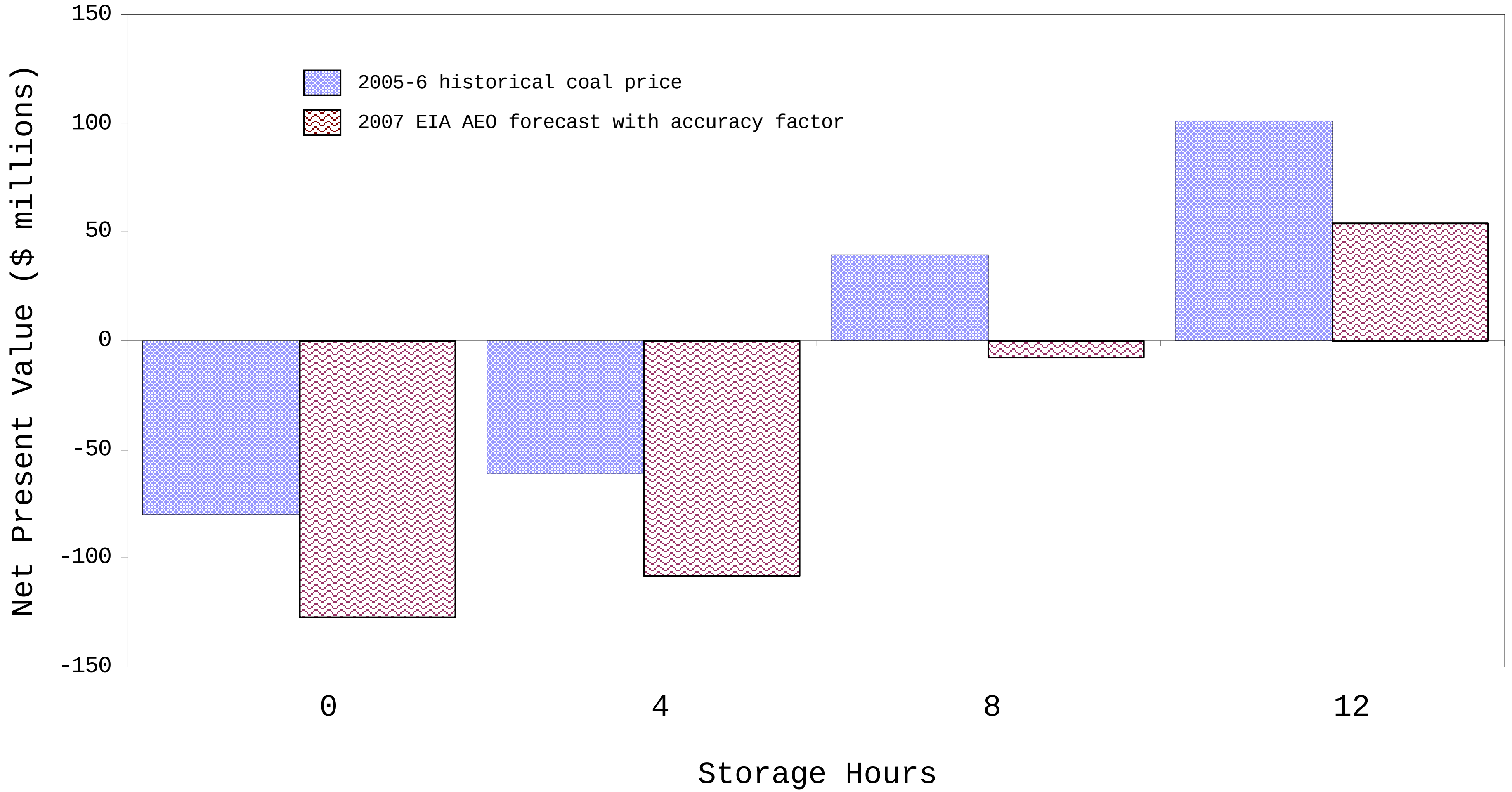




Key financial parameters: 30 year economic/loan life, 100% financing, 8% interest rate, Cinergy node, historical coal prices

Key operating parameters: 80 percent availability, 1 operating gasifier and 1 spare gasifier (1+1)

Preliminary Syngas Storage NPV



Key financial parameters: 30 year economic/loan life, 100% financing, 8% interest rate, Cinergy node

Key operating parameters: 80% availability, 35 bar pressure, above ground storage, 2000 hp compressor, 1 operating gasifier and 1 spare gasifier (1+1)

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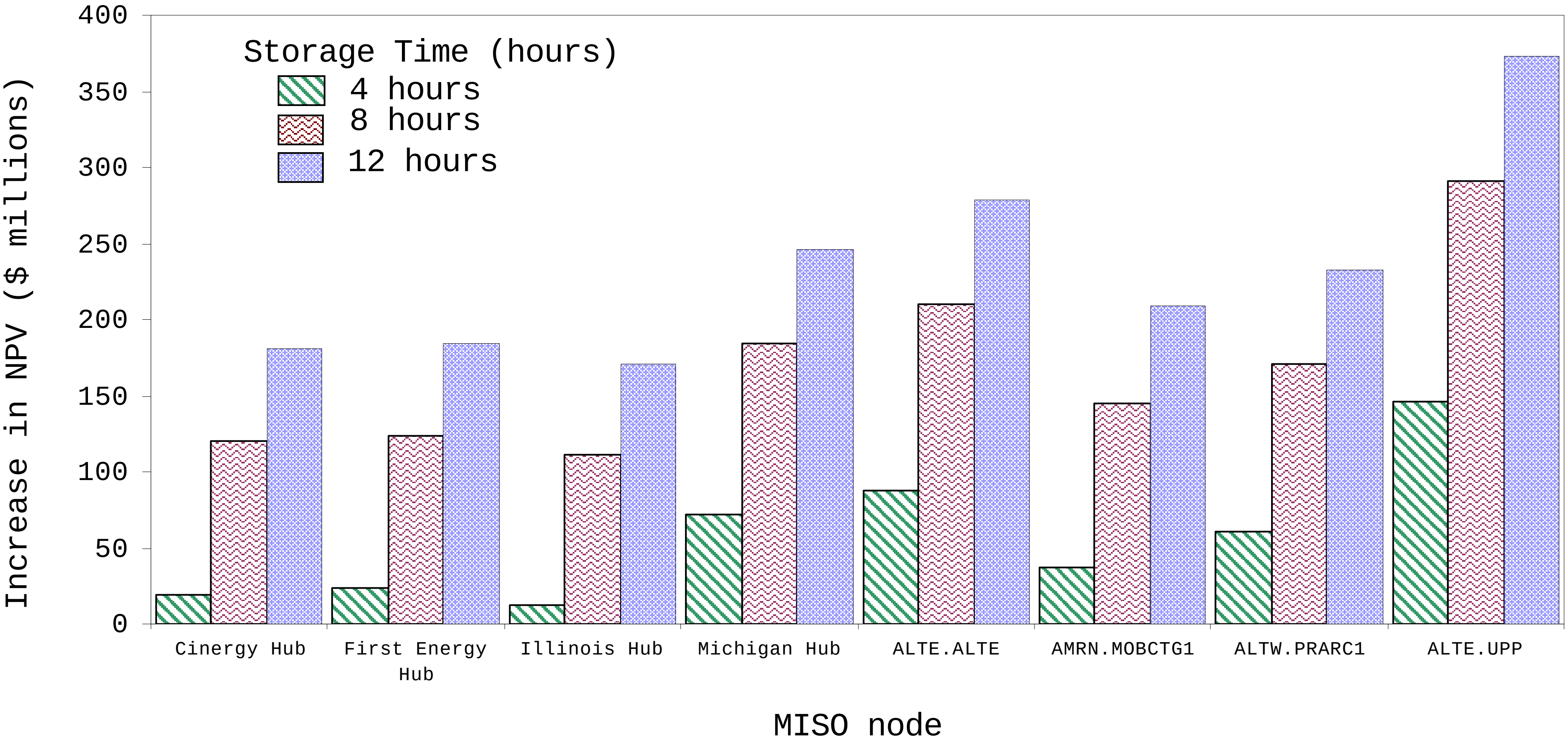
Preliminary Syngas Storage NPV

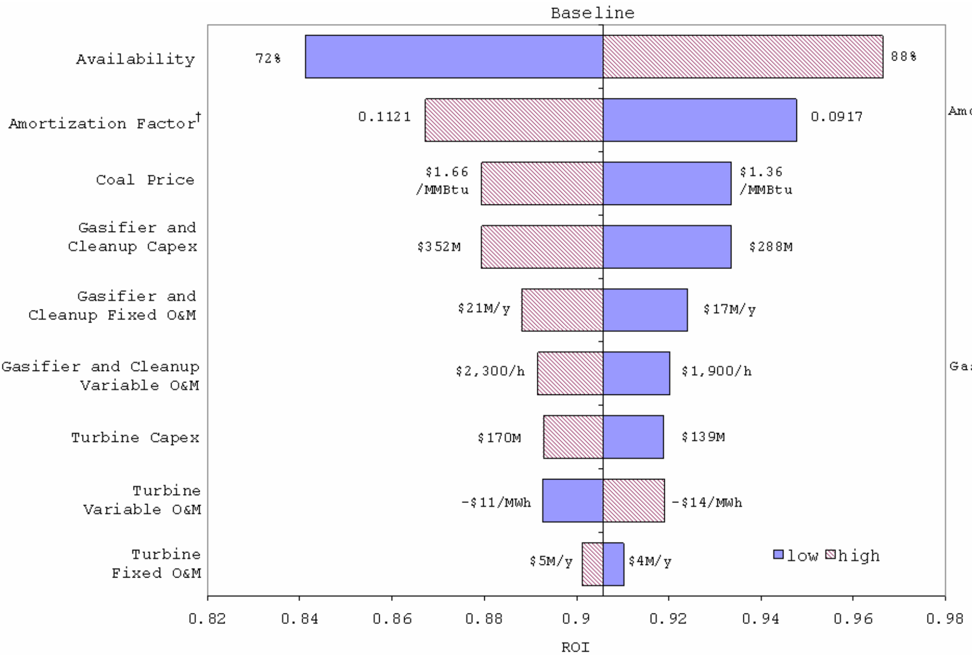


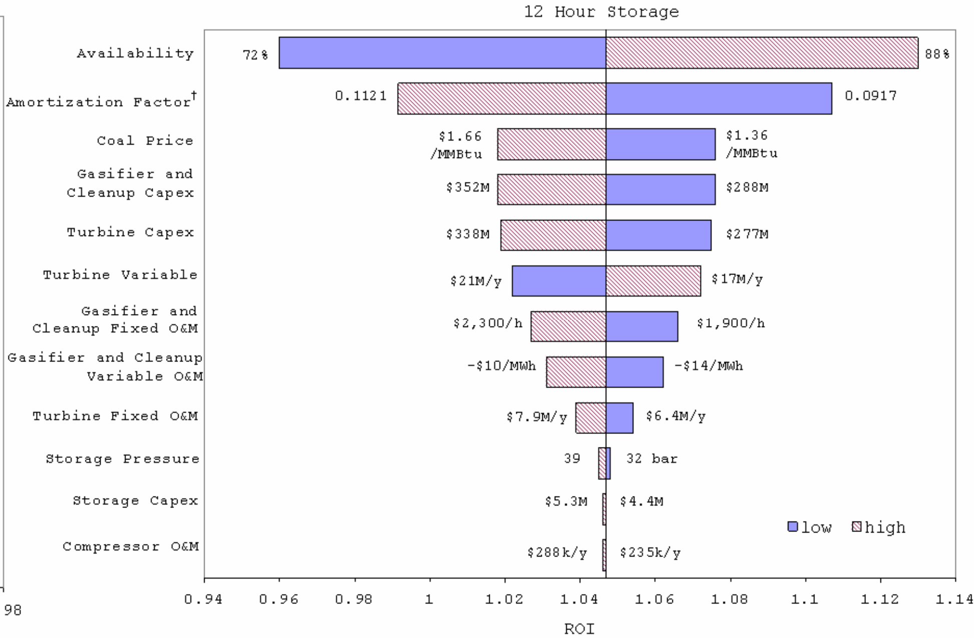
Key financial parameters: 30 year economic/loan life, 100% financing, 8% interest rate

Key operating parameters: 80% availability, 35 bar pressure, above ground storage, 2000 hp compressor, 1 operating gasifier and 1 spare gasifier (1+1)

Sensitivity Analysis

Syngas storage scenario, ± 10% variation in parameters





ROI is most sensitive to : Availability, Financing and Coal Price

Note: ROI is also sensitive to facility size and gasifier configuration

12 hours of syngas storage at a larger 800 MW facility (with 3 operating gasification trains and 1 spare) increases ROI by 14 percentage points (from 1.06 to 1.14)

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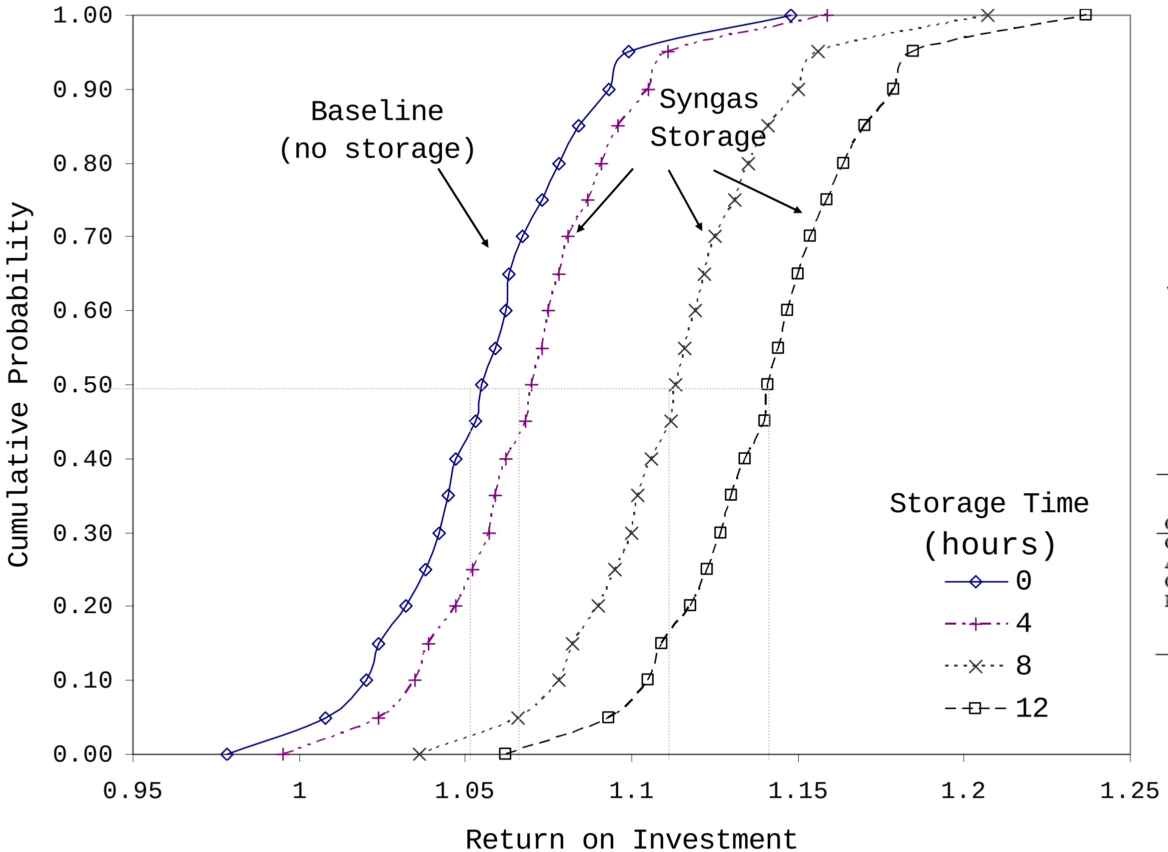
3+1 analysis



Increased ROI due to:

- Economy of scale
- Less idle capital (with the 3+1, only 25% of the gasifier capital is idle versus 50% for the 1+1)

	Capital costs (mean) $2005 million		O&M costs Fixed ($M/y)		O&M costs Variable	
Component	(1+1)	(3+1)	(1+1)	(3+1)	(1+1)	(3+1)
Gasifier	196.6	448.3	10.8	20.8	609 ($/hr)	1,671 ($/hr)
Air Separation Unit	90.5	255.6	4.7	8.1	1,530 ($/hr)	3,684 ($/hr)
Cold-gas Cleanup	32.4	72.9	3.3	4.3	-22 ($/hr)	-367 ($/hr)
Power block	154.6	459.3	4.7	9.7	-6.2 ($/MWh)	-5.5 ($/MWh)
Total ($ million)	474	1,236	23.5	42.9		
($/kW)	1,760	1,520				

Key financial parameters: 30 year economic/loan life, 100% financing, 8% interest rate, Cinergy node, historical coal prices

Key operating parameters: 80% availability, 35 bar pressure, above ground storage, 2000 hp compressor, 3 operating gasifiers and 1 spare gasifier (3+1), 4 GE 7FA turbines total with 2 turbines in baseload operation and 2 turbines operating with the diurnal storage scheme

Preliminary Results

Scenario	ROI, 90% CI min	mid	max	NPV (million)	Sensitivity Analysis (parameters most affecting ROI)
Baseline					Availability
no storage†	0.89	0.92	0.96	-$80	Financing structure
no storage#	0.86	0.88	0.91	-$127	Coal price
					Gasifier + cleanup capital costs
Syngas Storage					
4 hours†	0.92	0.96	0.98	-$61	Availability
4 hours#	0.89	0.91	0.94	-$107	Financing structure
					Coal price
8 hours†	1.00	1.03	1.07	$40	Gasifier + cleanup capital costs
8 hours#	0.97	0.99	1.03	-$7	Turbine capital costs
12 hours†	1.05	1.08	1.12	$101	
12 hours#	1.02	1.04	1.07	$54	

† 2005-06 historical coal price
# modified 2007 EIA coal price forecast

Key financial parameters: 30 year economic/loan life, 100% financing, 8% interest rate

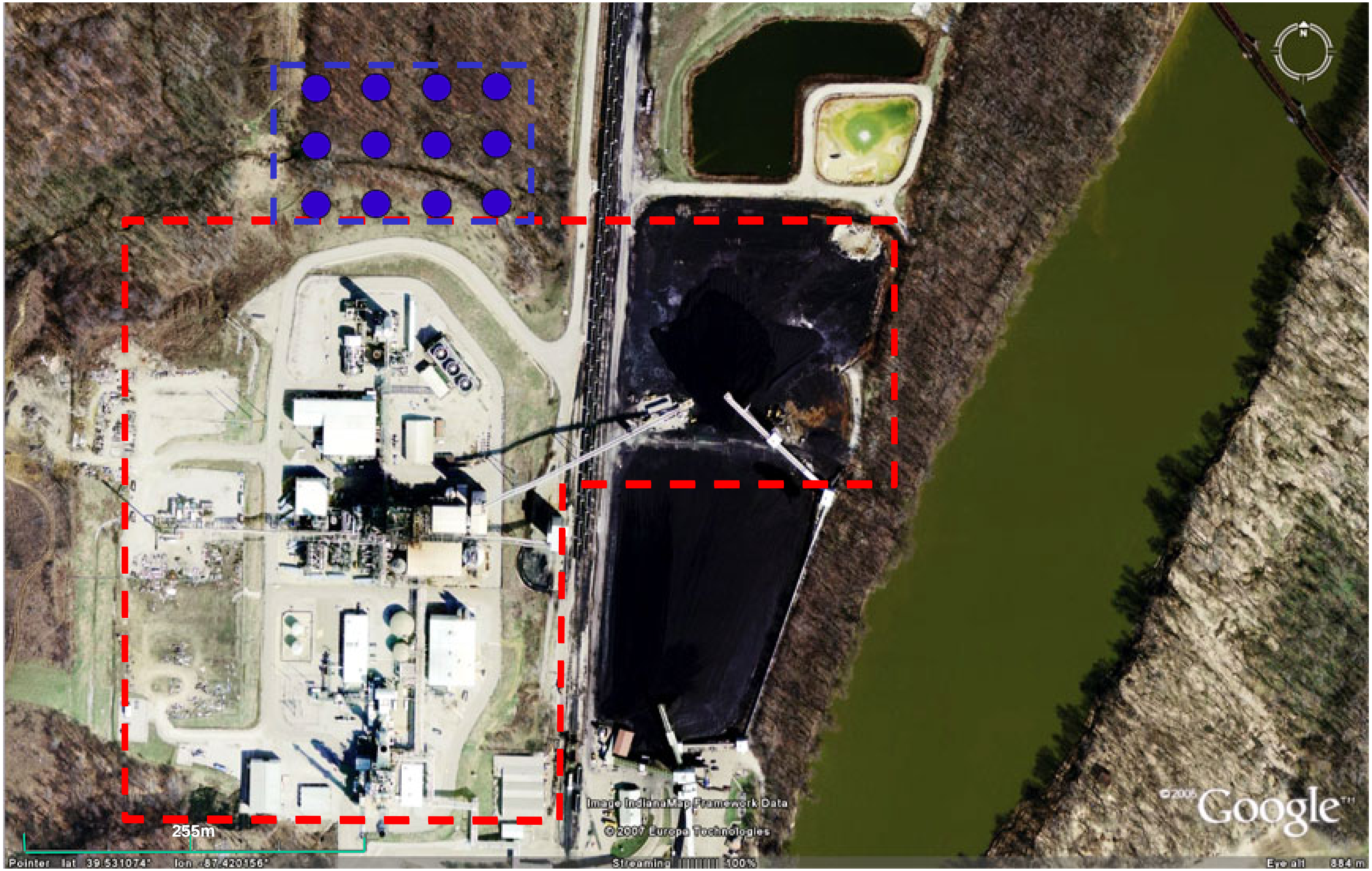
Key operating parameters: 80% availability, 35 bar pressure, above ground storage, 2000 hp compressor, 1 operating gasifier and 1 spare gasifier (1+1)

High pressure storage in industry

Wabash River

~250 net MW IGCC facility, ~40 acres

12 hours of storage adds <10 acres, or 25%



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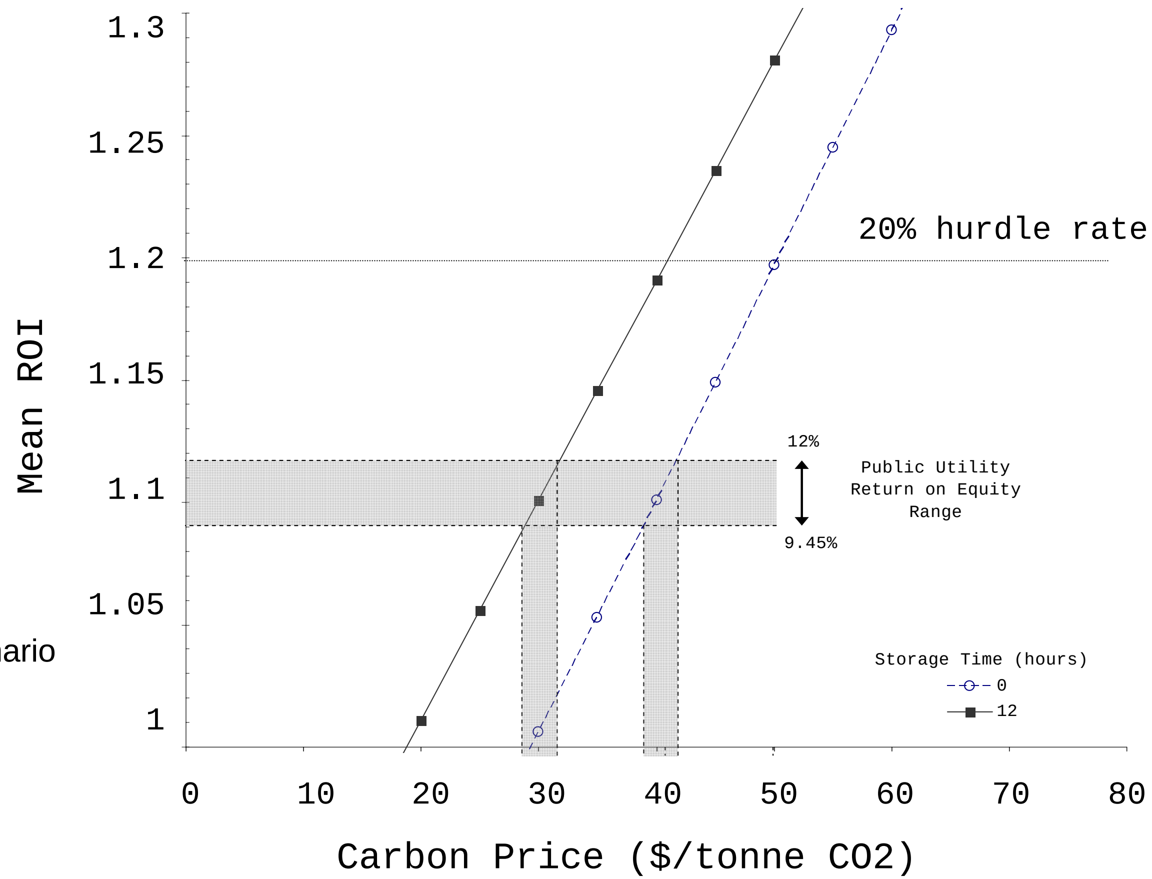
Carbon Price Implications

Steps

- Use IGCC facility with carbon capture, transport and storage (IECM)
- Increase the LMP prices by adding a carbon price using an appropriate CO_2/kWh factor for the MISO region
- Plot the mean facility ROI versus the carbon price and examine the hurdle rate crossover

Syngas storage scenario

1.34 lbs CO2/kWh



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Preliminary Conclusions and Implications

- The ability to store syngas adds value to gasification facilities
- Syngas storage in above ground vessels appears to be the most cost effective storage method
- Availability and structure of the financing are the most important parameters over which the designer/operator has control
- Syngas storage can lower the carbon price at which IGCC enters the generation mix
- This engineering economic tool can be used to quantify this value under different facility configurations, and under any cost and price distributions
- Increases in profitability may make gasification facilities more attractive to investors and developers – thereby providing a valuable physical resource to the electricity industry

Questions

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