A Technical and Economic Outlook of Ammonia-Based Post-Combustion CO_2 Capture

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Objectives

- Provide cost and performance numbers that informs energy policy
- Specifically how much carbon capture and sequestration is likely to cost at a full sized power plant.

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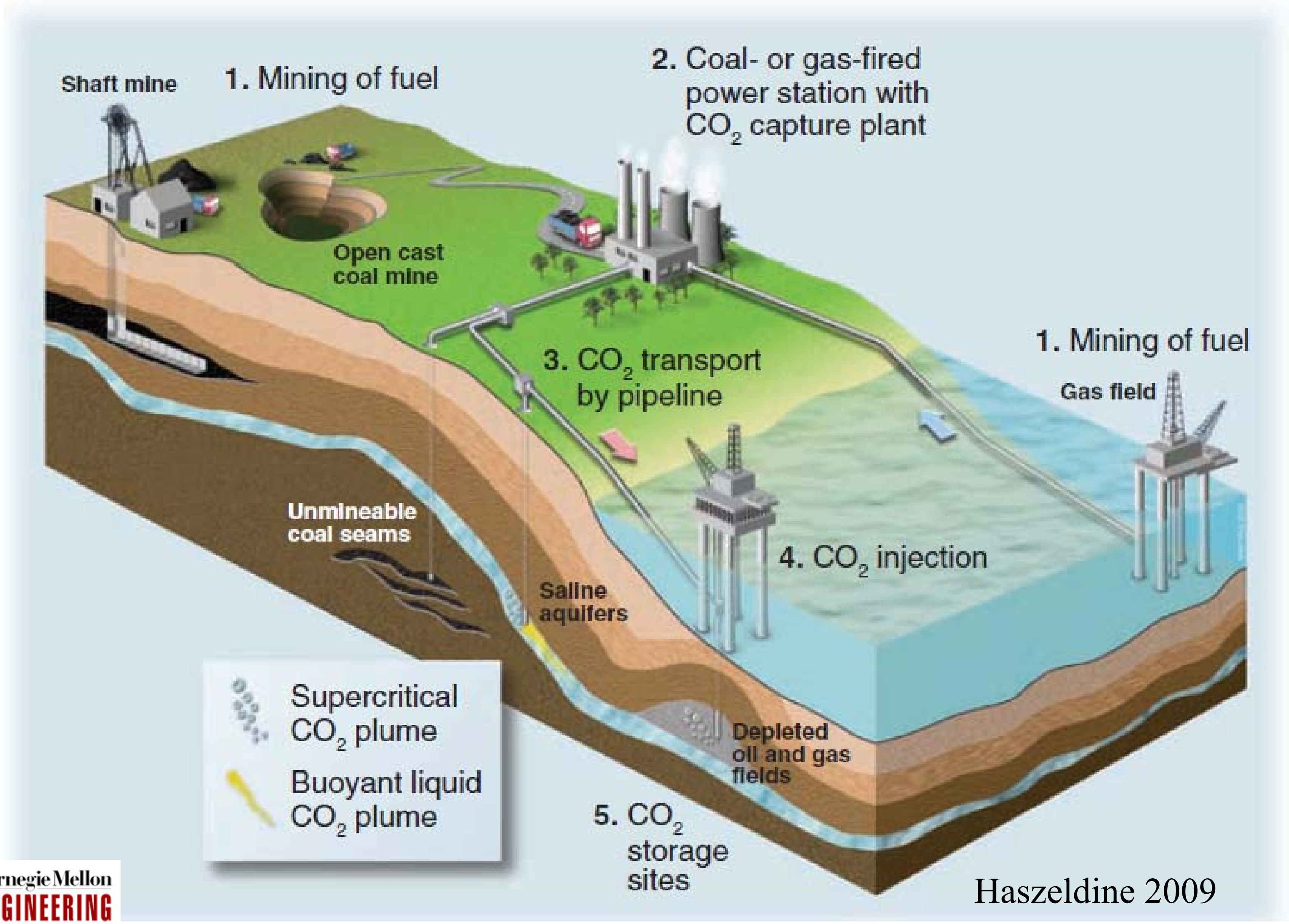
Ammonia-Based Post-Combustion CO_2 Capture



Haszeldine 2009

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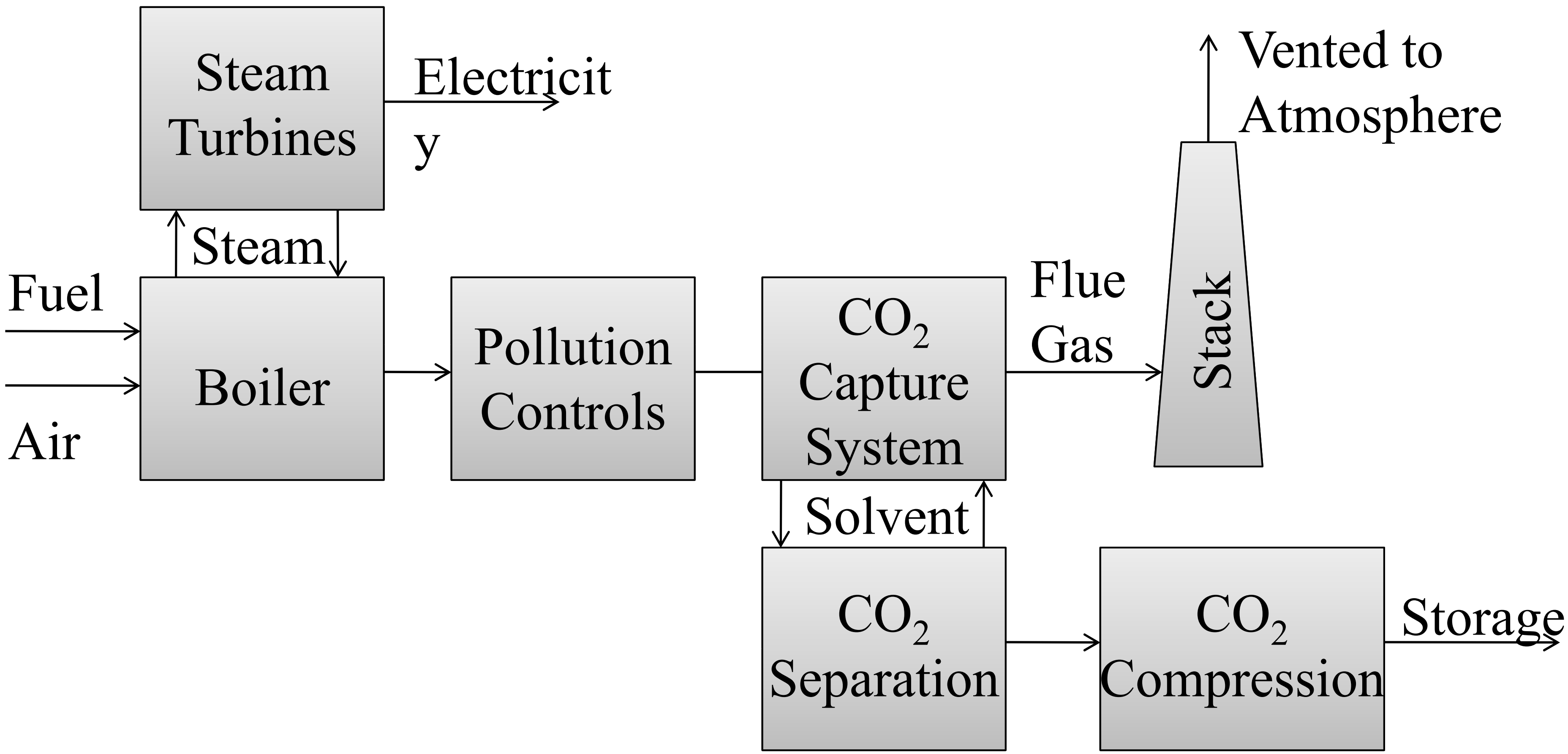
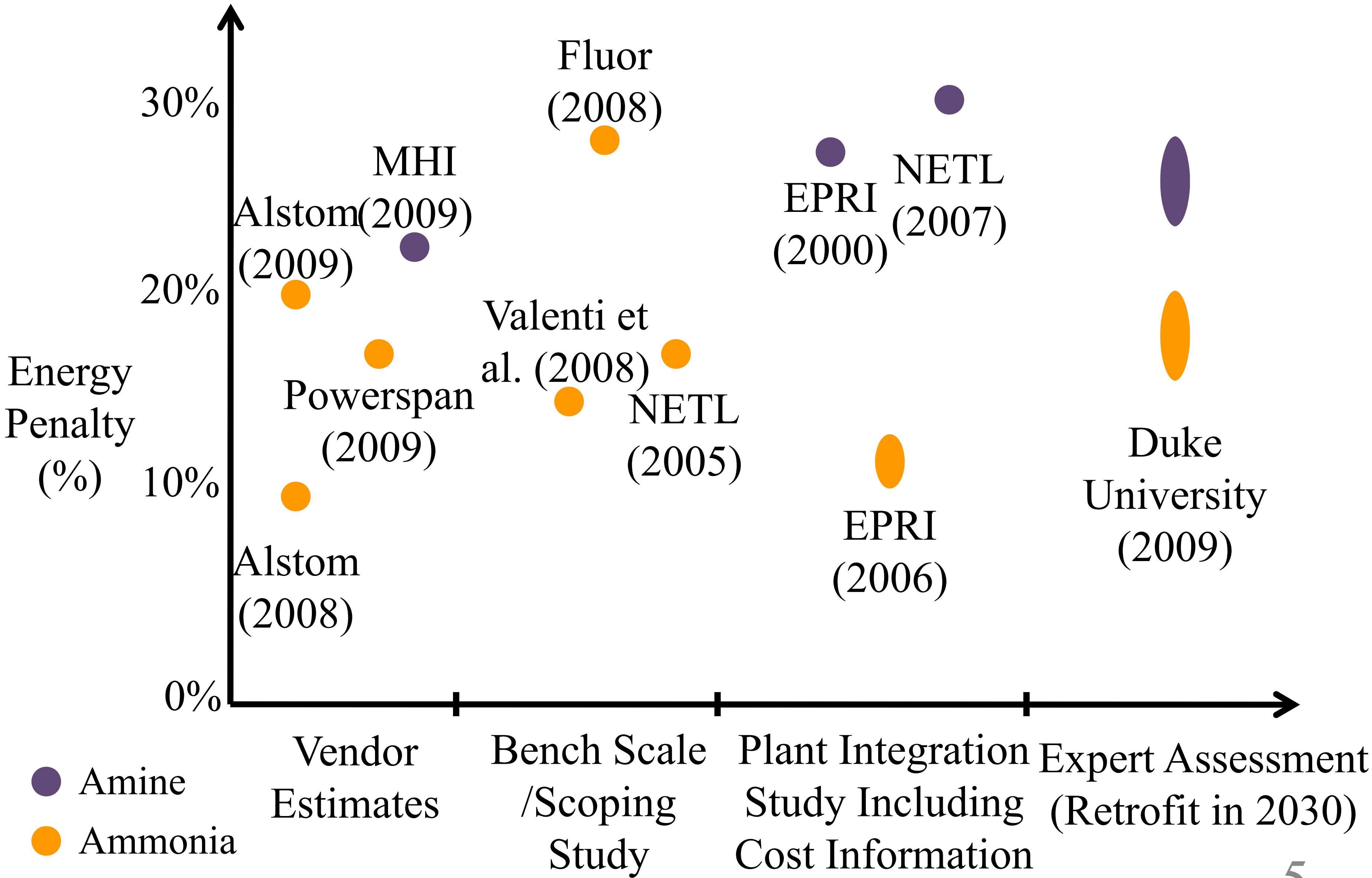
Ammonia-Based Post-Combustion CO_2 Capture



Adapted From Rubin et al. 2007

CO_2 Capture Studies Using Ammonia and Amines

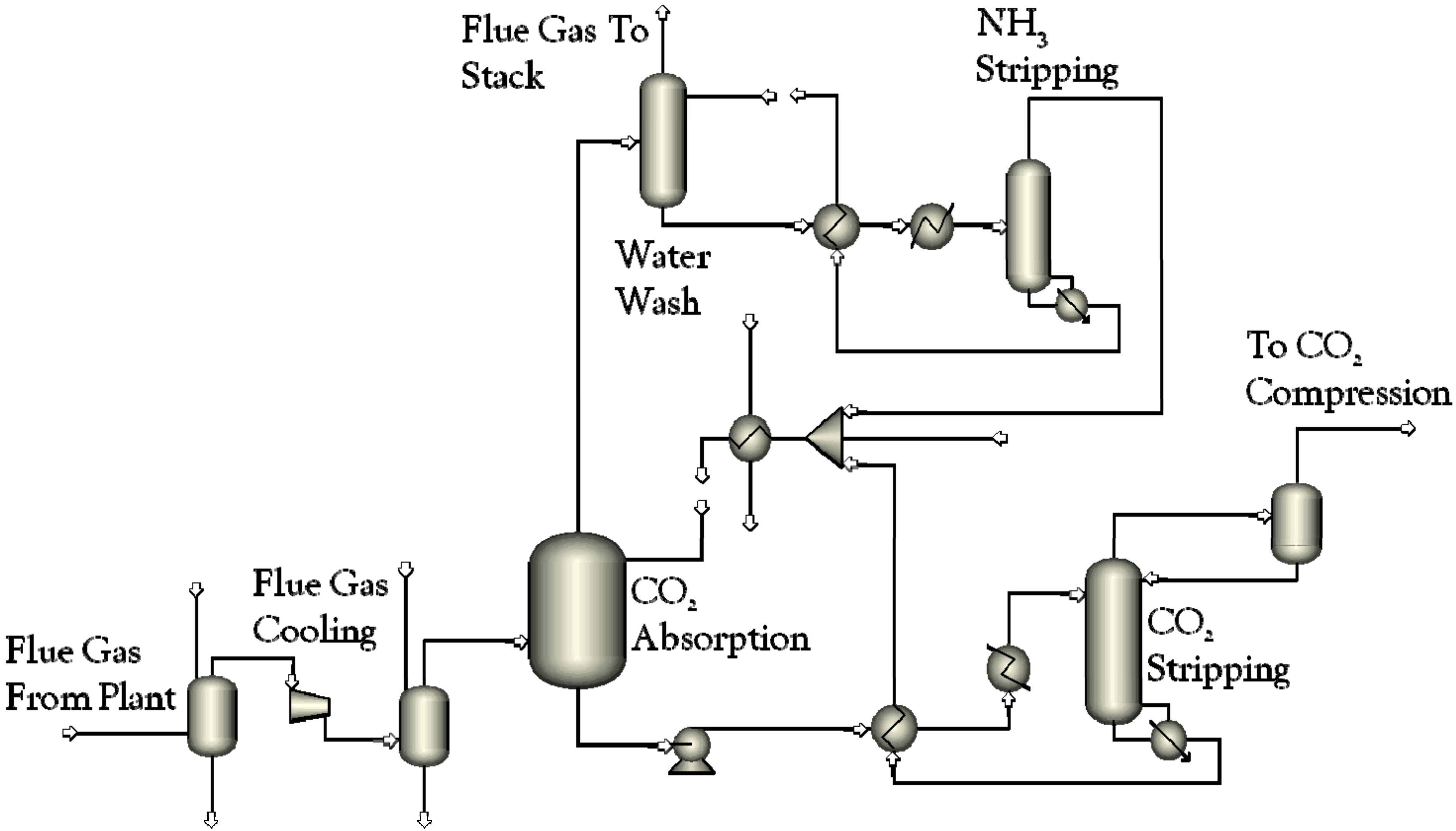


The Baseline Power Plant

- Derived from the 2007 NETL Baseline Report
- Includes amine post-combustion CO_2 capture

Parameter	Value
Plant Location	Midwestern USA
Steam Cycle Type	Supercritical
Coal Type	Illinois No. 6
Coal Flow Rate	74 kg/sec
Gross Power	663 MW
Flue Gas Flow Rate	860 kg/sec
CO_2 Mole Fraction	13.3 %
CO_2 Flow Rate	175 kg/sec
Overall CO_2 Capture	90%
Net Power	546 MW

Ammonia Based CO_2 Capture Model



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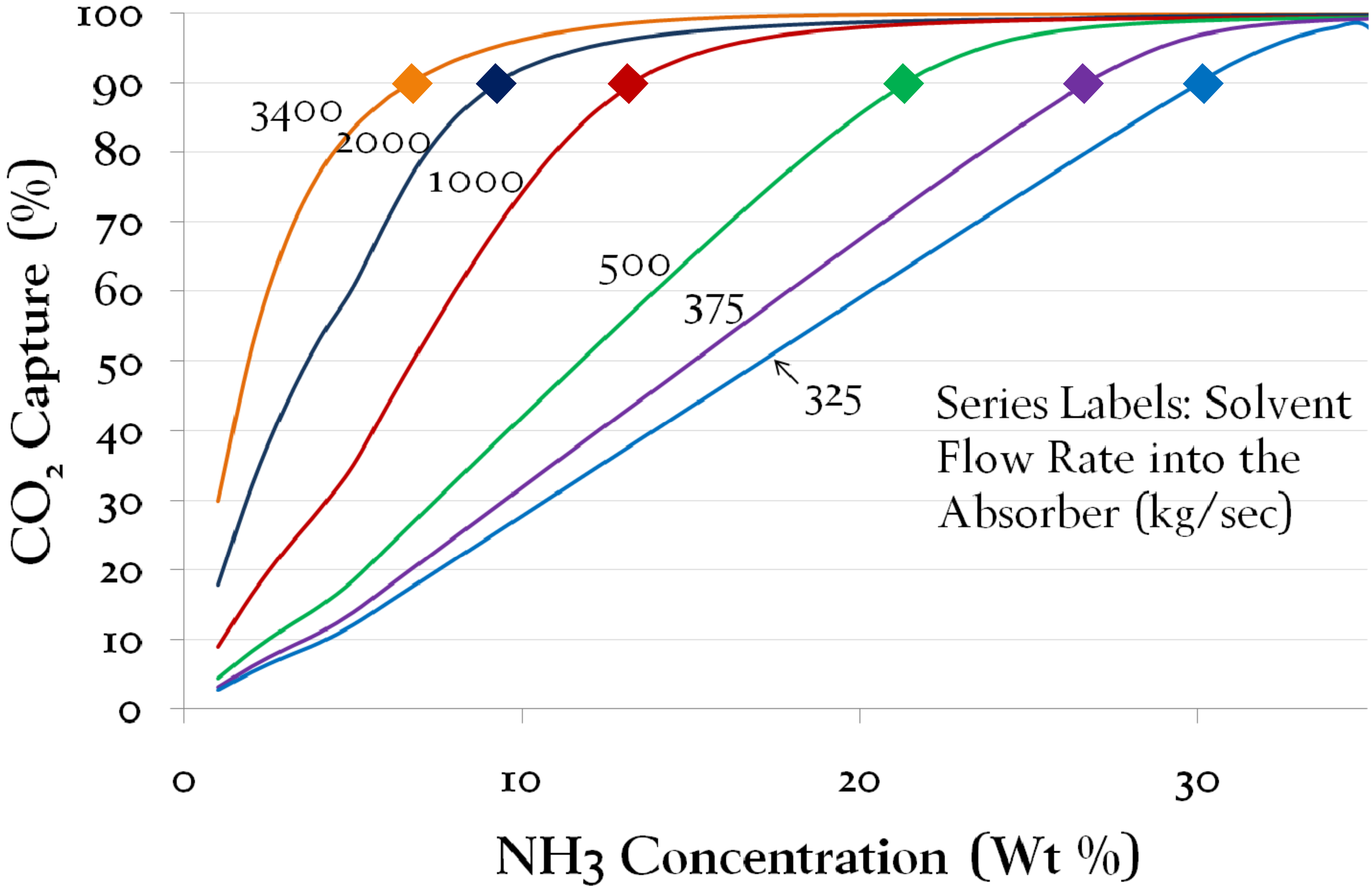
CO_2 Capture vs. NH_3 Concentration



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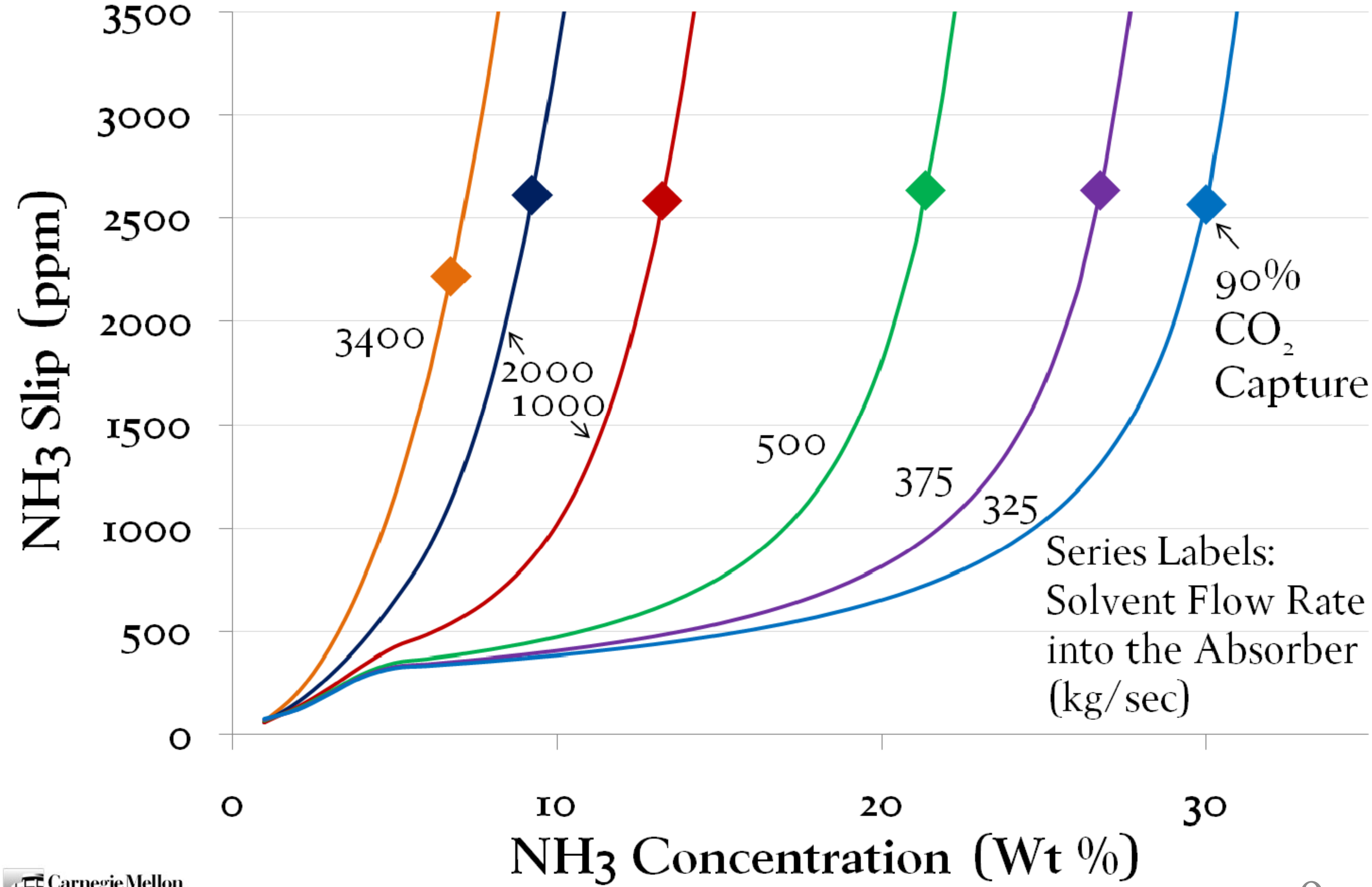
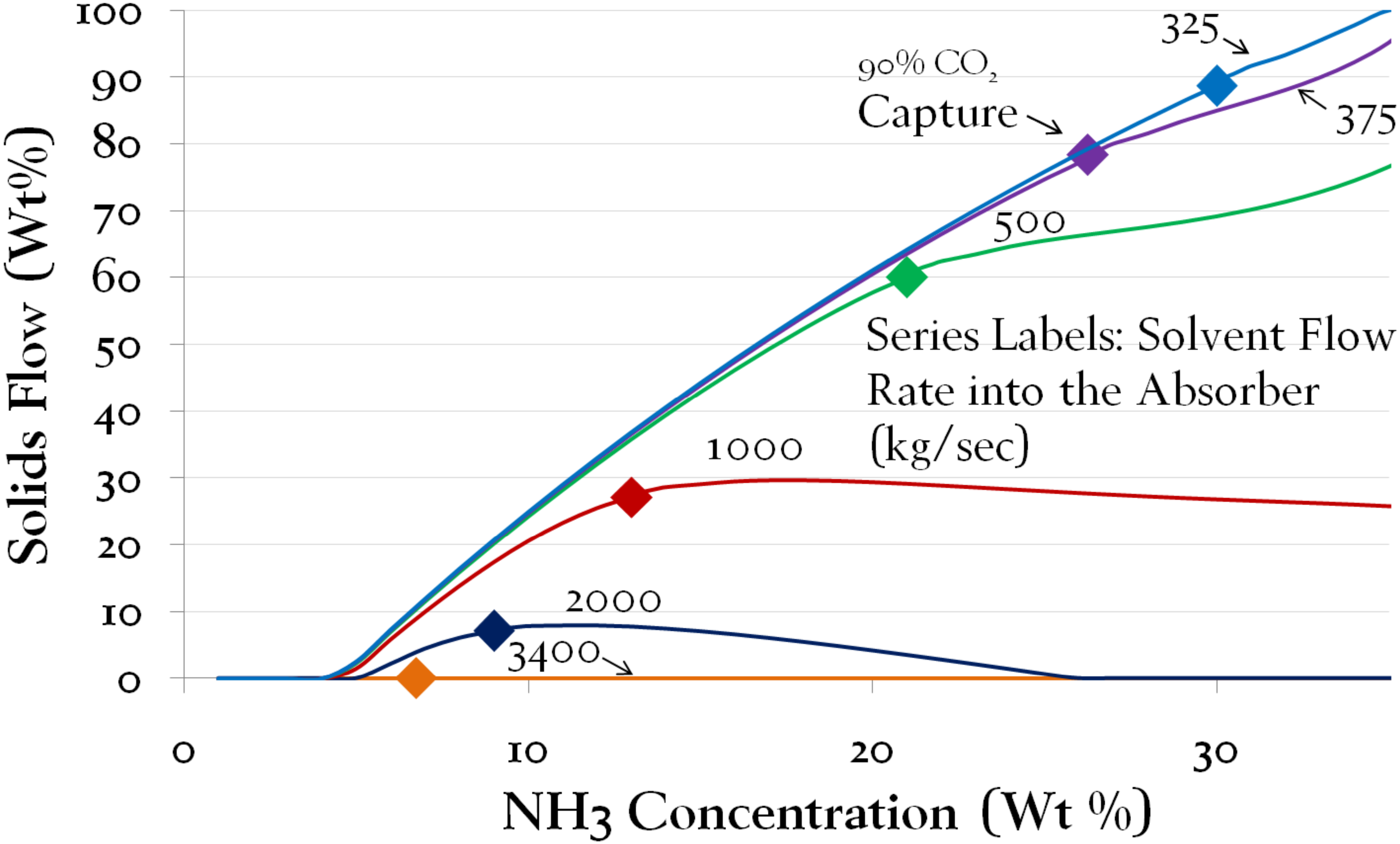
NH_3 Slip vs. NH_3 Concentration



Solids Flow vs. NH3 Concentration



CO_2 Capture System Designs

Key Variable	Low Conc. Design	High Conc. Design
NH_3 Concentration	6.5%	21.0%
Flow Rate (kg/sec)	3400	500
Overall CO_2 Capture	90%	90%
NH_3 Slip	1930 ppm	2240 ppm
Solids	Do Not Occur	60 wt %

Overall Model Performance Summary

	Low Conc.	High Conc.	Amine*
Potential Power Available (MW)	827.6	827.6	827.6
Auxiliary Steam Load (MW)	174.5	109.1	164.3
Steam Turbine Power (MW)	653.0	718.5	663.3
Auxiliary Electrical Load (MW)			
Base Plant (MW)	49.0	49.0	49.0
CO2 Capture System (MW)	116.8	90.6	21.3
CO_2 Compression (MW)	16.4	16.4	46.9
Plant Net Power (MW)	470.9	562.6	546.0
Plant Efficiency (% HHV)	23.5%	28.1%	27.2%
Energy Penalty (%)	**40.0%**	**28.3%**	**30.6%**

* NETL 2007 Baseline Report

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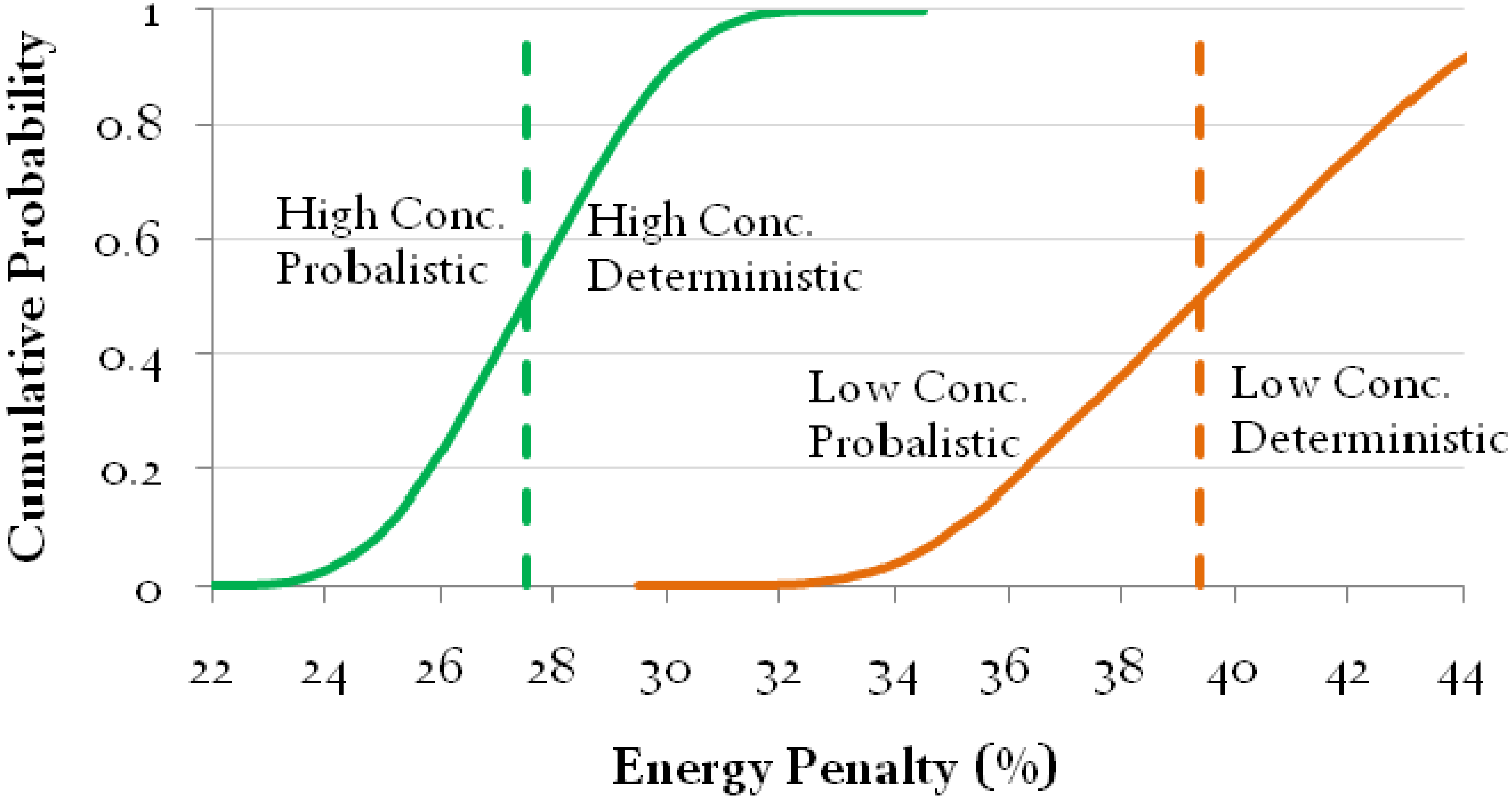
Key Performance Variables with Uncertainty

Parameter	Units	Nominal	Distribution Function
Solvent Chilling Loads			Uniform(-25%,+25%)
Auxiliary Steam Loads			Uniform(-25%,+25%)
ΔP Across the DCC2 and CO_2 Absorber	Psi	4	Uniform(2, 6)
Chiller Electrical Use, 45°F Water Product	kW/ton	0.47	Triangular(0.47, 0.47, 0.50)
Chiller Electrical Use, 37°F Water Product	kW/ton	0.55	Triangular(0.50, 0.55, 0.60)
CO_2 Compression, 30 bar to 152 bar	kWh/kg CO_2	0.029	Triangular(0.026, 0.03, 0.032)
DCC2 Chilling Loads	1000 tons/hr	32.2	Triangular(29.0, 32.2, 35.4)

Ammonia System Energy Penalty



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Overall Model Cost Summary

	Low Conc.	High Conc.	Amine*
Base Plant	1150.3	1169.0	1166.2
CO2 System	607.6	408.30	394.0
Plant Total Capital Requirement	1757.9	1575.9	1560.0
CO_2 TS&M O&M/Year	13.7	13.7	13.7
Balance of Plant O&M/Year	116.7	116.7	116.7
Total O&M Costs/Year	130.4	130.4	130.4
Capital Required ($/kW-net)	3733.3	2790.7	2857.0
Revenue Required ($/MWh)	**141.6**	**109.5**	118.7

* IECM, CF = 75%

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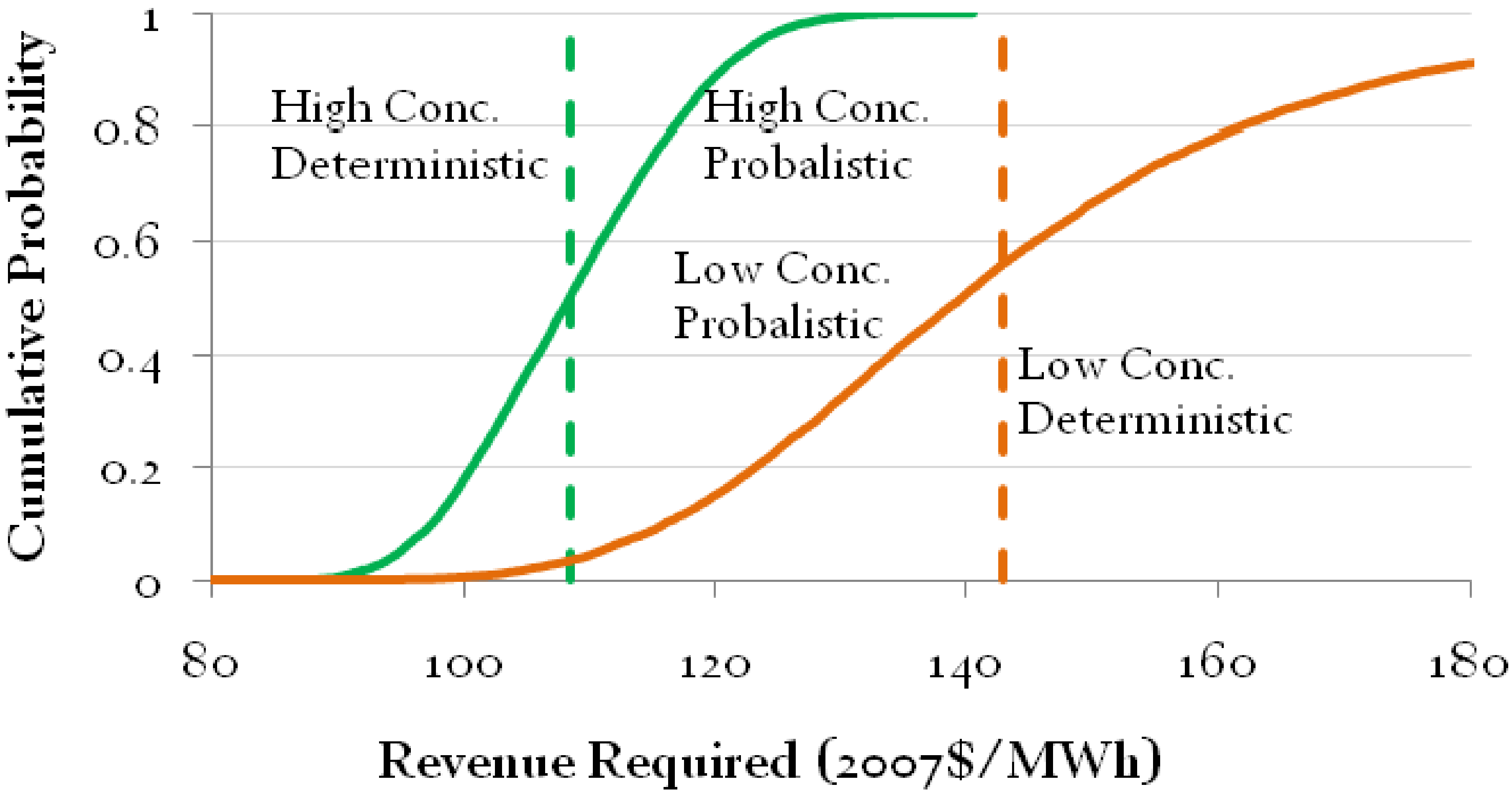
Overall Cost Results with Uncertainty

Parameter	Unit	Nominal	Distribution Function
General Facilities Capital	%PFC	1.6	Triangular(1, 1.6, 2)
Engineering & Home Office Fees	%PFC	9.4	Triangular(7, 9.4, 12)
Project Contingencies	%PFC	16.4	Triangular(10, 16.4, 20)
Process Contingencies	%PFC	4.7	Triangular(2, 4.7, 10)
Ammonia Cost (28 wt% delivered)	$/ton	129.4	Uniform(116, 142)
Cooling Equipment Costs	$/ton cooling	441.2	Uniform(309, 573)
IECM Based Equipment Costs	$		Uniform(-30%, +30%)
Aspen Icarus® Equipment Costs	$		Uniform(-40%, +40%)
Power Plant Fixed Charge Factor	--	0.175	Uniform(0.16,0.19)
Power Plant Levelized Capacity Factor	--	0.75	Weibull(8.5, 0.81)

Ammonia System Revenue Required



Summary

- The plant with high concentration ammonia-based CO_2 capture was found to have an energy penalty 2-3 percentage points lower and a levelized cost 9 $/MWh lower than the plant with amine-based CO_2 capture.
- The stochastic results suggested better performance and lower costs

Plant Configuration	**Energy Penalty**	**Plant Efficiency**	**Capital Required** ($2007/kW-net)	Revenue Required ($2007/MWh)
Without CCS	--	39%	1460	61
Amine	31%	27%	2860	119
Low Conc. NH_3	40%	24%	3670	140
High Conc. NH_3	28%	28%	2790	110

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Conclusion/Limitations

- High concentration ammonia-based CO_2 capture performs well against amine-based CO_2 capture and could lower the costs of CO_2 mitigation in the electric power sector
- This analysis could be refined and extended with improved thermodynamic models, more detailed simulations of process components, heat integration, and more detailed/current vendor cost estimates

Acknowledgements

NETL

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