Optimal Valuation of Project Options in Electric Power Generation and Transmission Planning

Cameron MacKenzie
Gazi Nazia Nur
Jay Sandeep Ghodke
Kyung Jo Min

Industrial and Manufacturing Systems Engineering
Iowa State University

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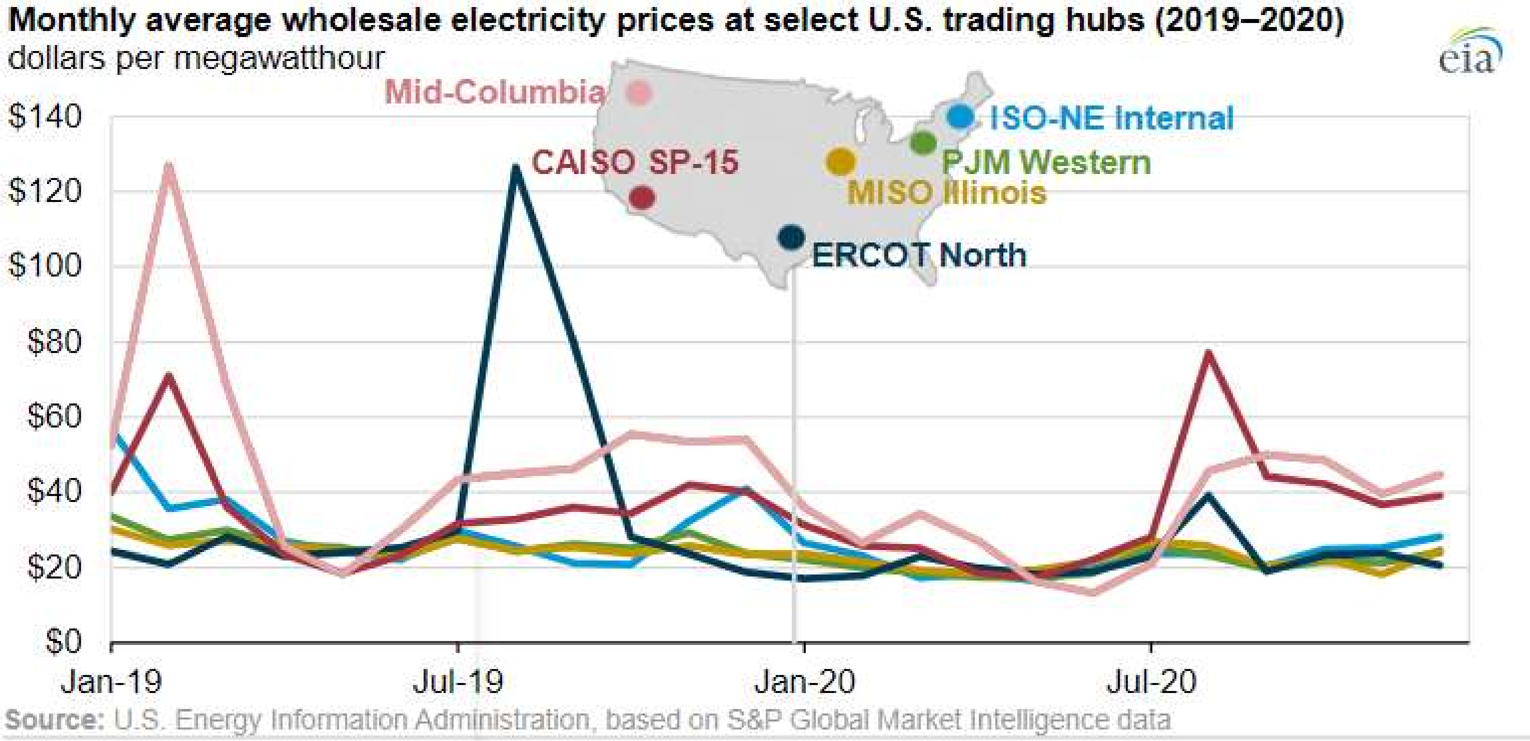
How should we value new renewable energy resources?

Electricity prices can be very volatile and uncertain



Solar and Wind Energy Using Engineering Economics Theory (SWEEET)

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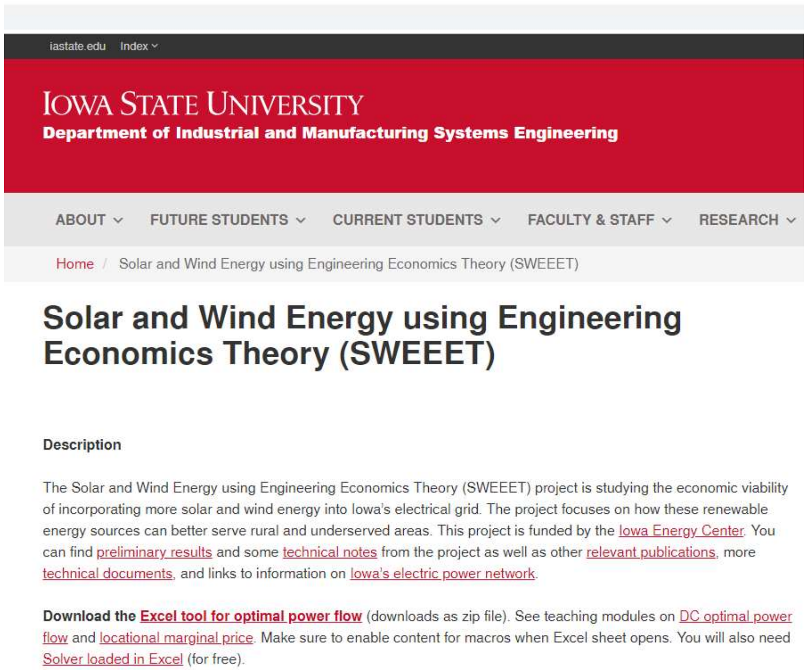

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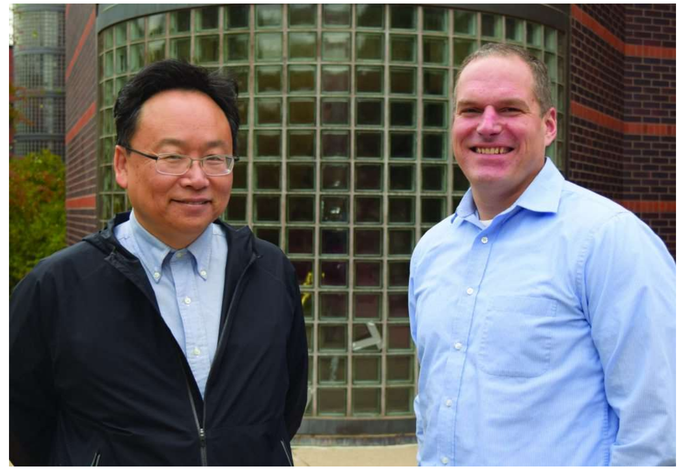
Solar and Wind Energy using Engineering Economics Theory (SWEEET)

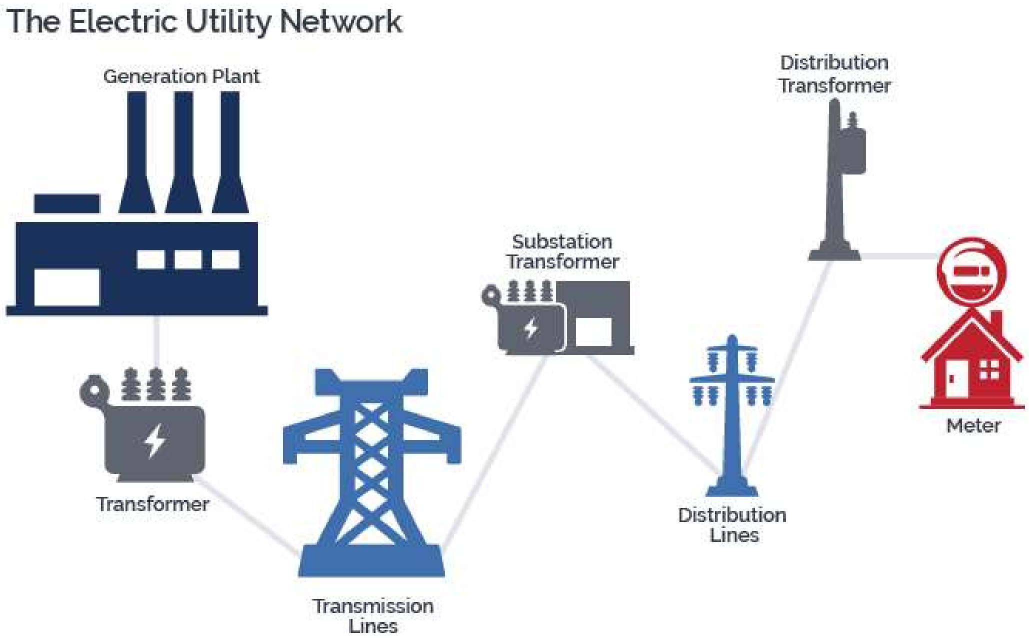
Description

The Solar and Wind Energy using Engineering Economics Theory (SWEEET) project is studying the economic viability of incorporating more solar and wind energy into Iowa's electrical grid. The project focuses on how these renewable energy sources can better serve rural and underserved areas. This project is funded by the Iowa Energy Center. You can find preliminary results and some technical notes from the project as well as other relevant publications, more technical documents, and links to information on Iowa's electric power network.

Download the Excel tool for optimal power flow (downloads as zip file). See teaching modules on DC optimal power flow and locational marginal price. Make sure to enable content for macros when Excel sheet opens. You will also need Solver loaded in Excel (for free).



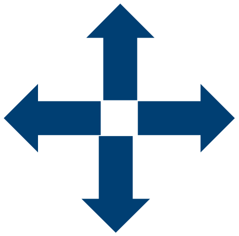
Optimal power flow model determines best operating levels for electric power generation



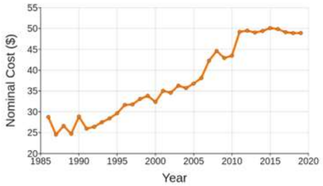
Objective: Minimize cost while meeting demand

Real options give firms the right but not the obligation to undertake business opportunities

Timing / waiting option

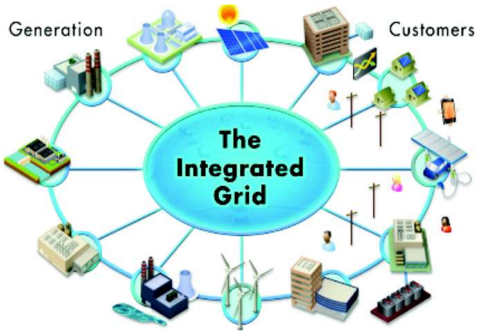


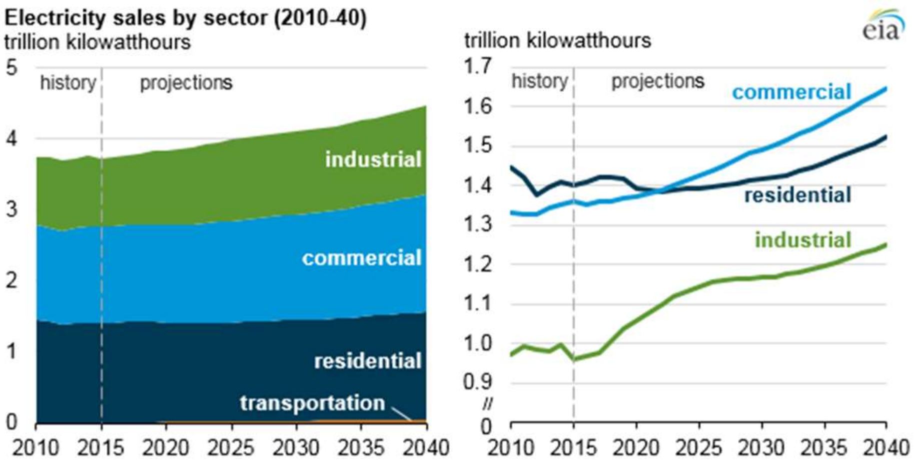
Growth option



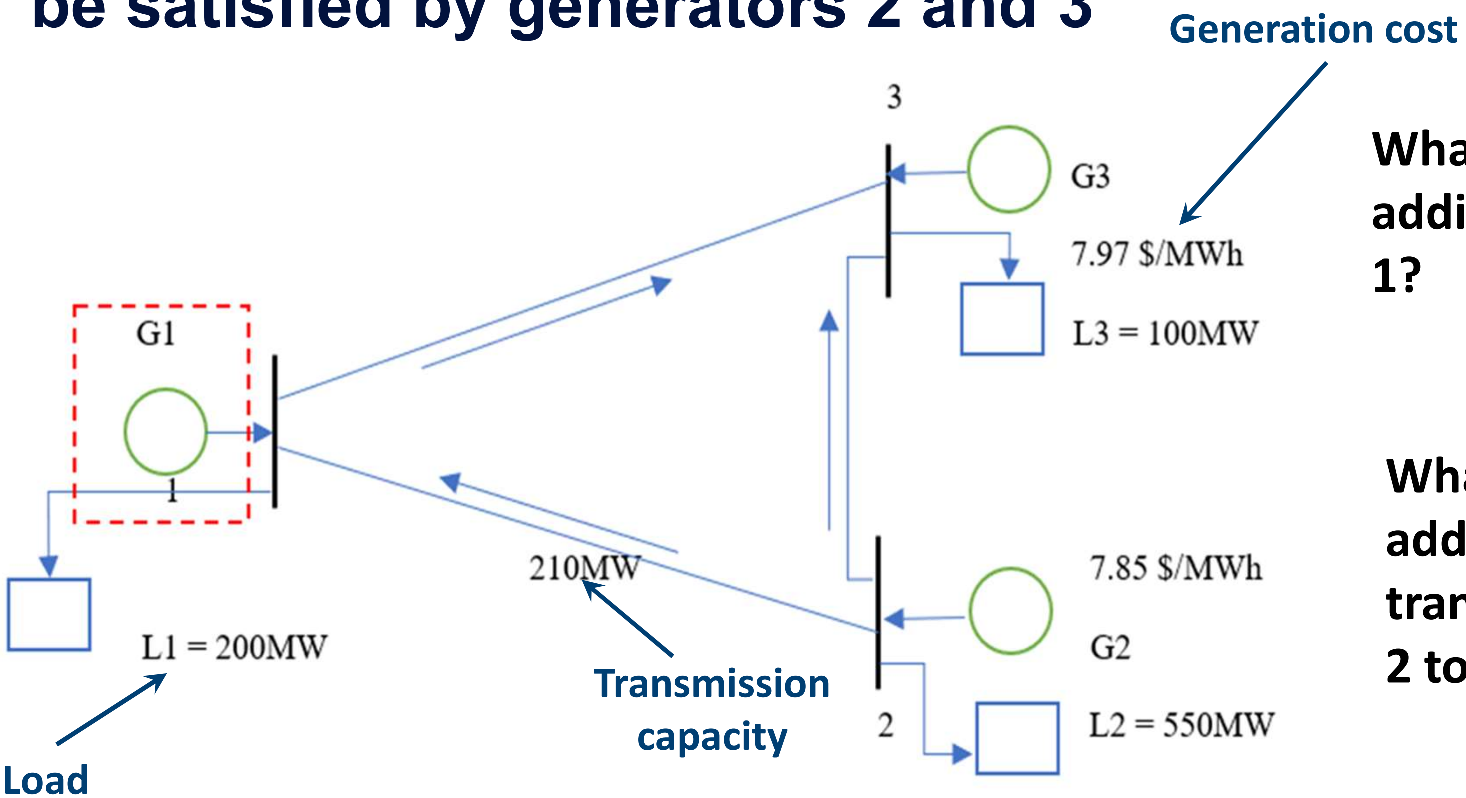
Abandon / switch / install option

Adding new generation sources or transmission capacity is a critical part of power planning





3-bus network: Bus 1 has no generator and the demand will be satisfied by generators 2 and 3



What is the value of adding a generator at bus 1?

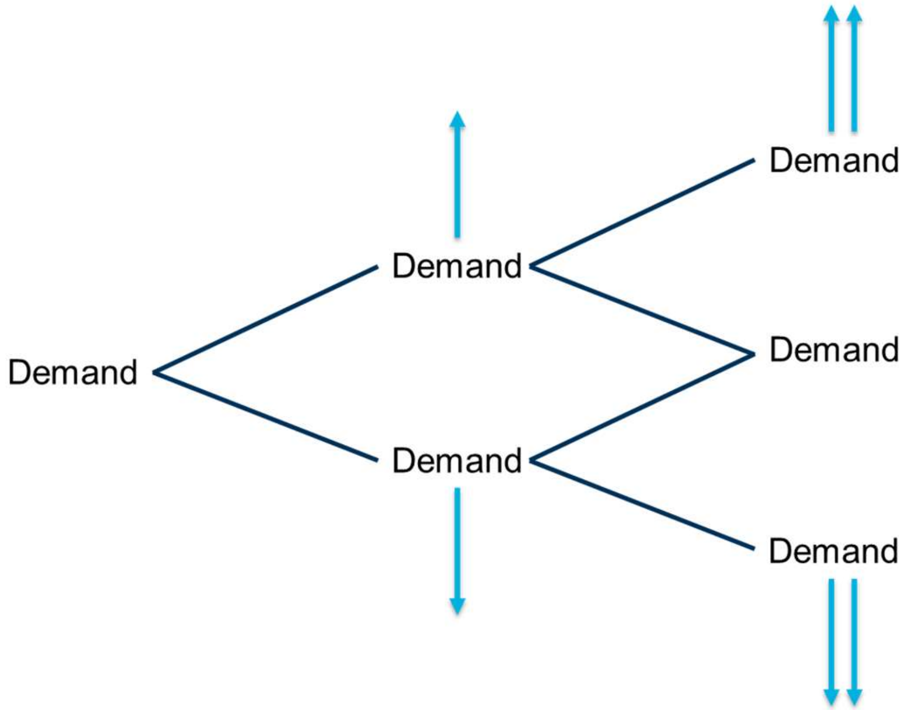
What is the value of adding another transmission line from bus 2 to bus 1?

Demand at bus 1 follows geometric Brownian motion and can increase or decrease in each period (lattice)

Initial demand = 200 MW
Volatility = 30% per year
Risk-free discount rate = 5% annual
Time horizon = 5 periods

Up value = 1.35
Down value = 0.741

Risk-neutral probabilities
Probability of up = 0.51
Probability of down = 0.49



If a new generation unit at bus 1 costs $100,000 with a generation cost of $7.92 per MWh, the real option value is $620,000

Millions of $

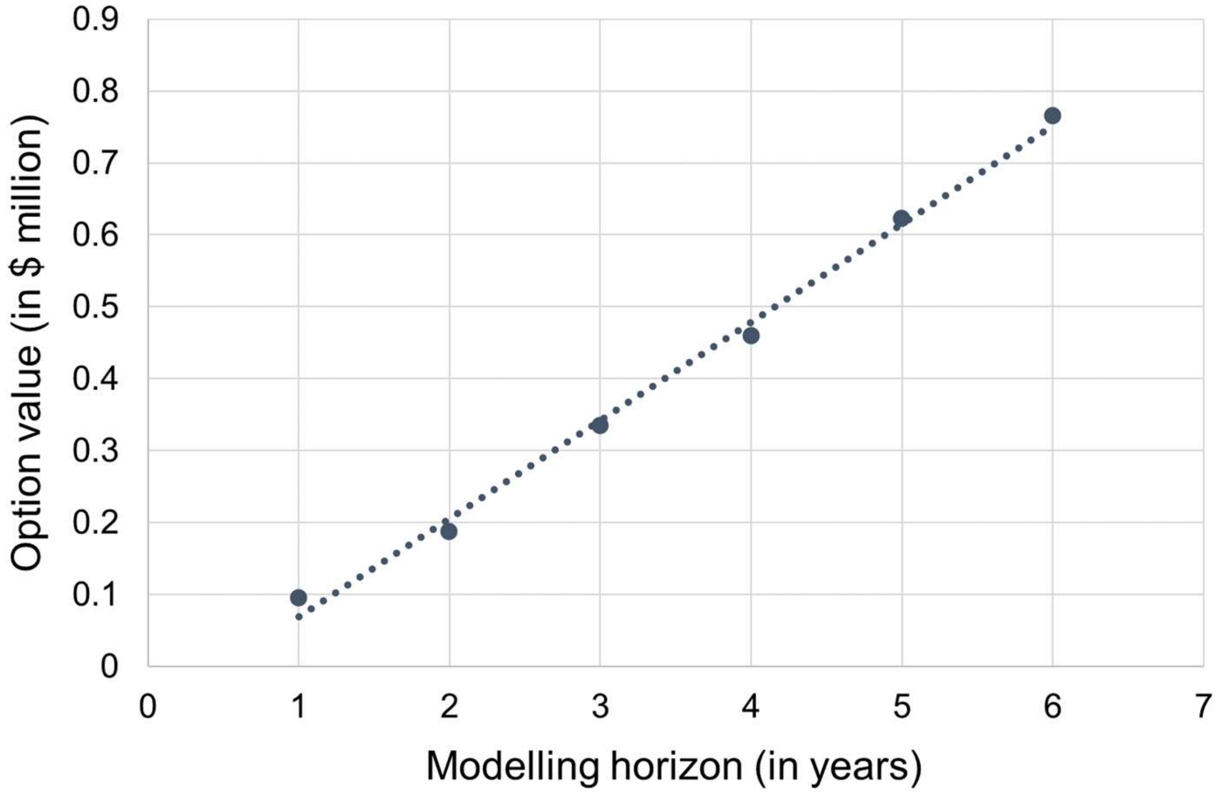
time	0	1	2	3	4	5
						0.98
						0.88
					1.45	0.00
					1.35	0.88
				1.62	0.63	0.54
				1.52	1.35	0.44
			1.53	0.98	0.80	0.00
			1.43	1.52	0.70	0.44
		1.22	1.04	0.75	0.30	0.30
		1.12	1.43	0.65	0.70	0.20
	[illegible]	0.85	0.39	0.38	0.14	0.00
	[illegible]	1.12	0.29	0.65	0.04	0.20
	0.62	0.21	0.33	0.07	0.09	0.00
	0.62	0.11	0.33	-0.03	0.09	-0.10
		0.17	0.03	0.05	0.00	0.00
		0.17	-0.07	0.05	-0.10	0.00
			0.02	0.00	0.00	0.00
			0.02	-0.10	0.00	-0.10
				0.00	0.00	0.00
				0.00	-0.10	0.00
					0.00	0.00
					0.00	-0.10
						0.00
						0.00

Hold

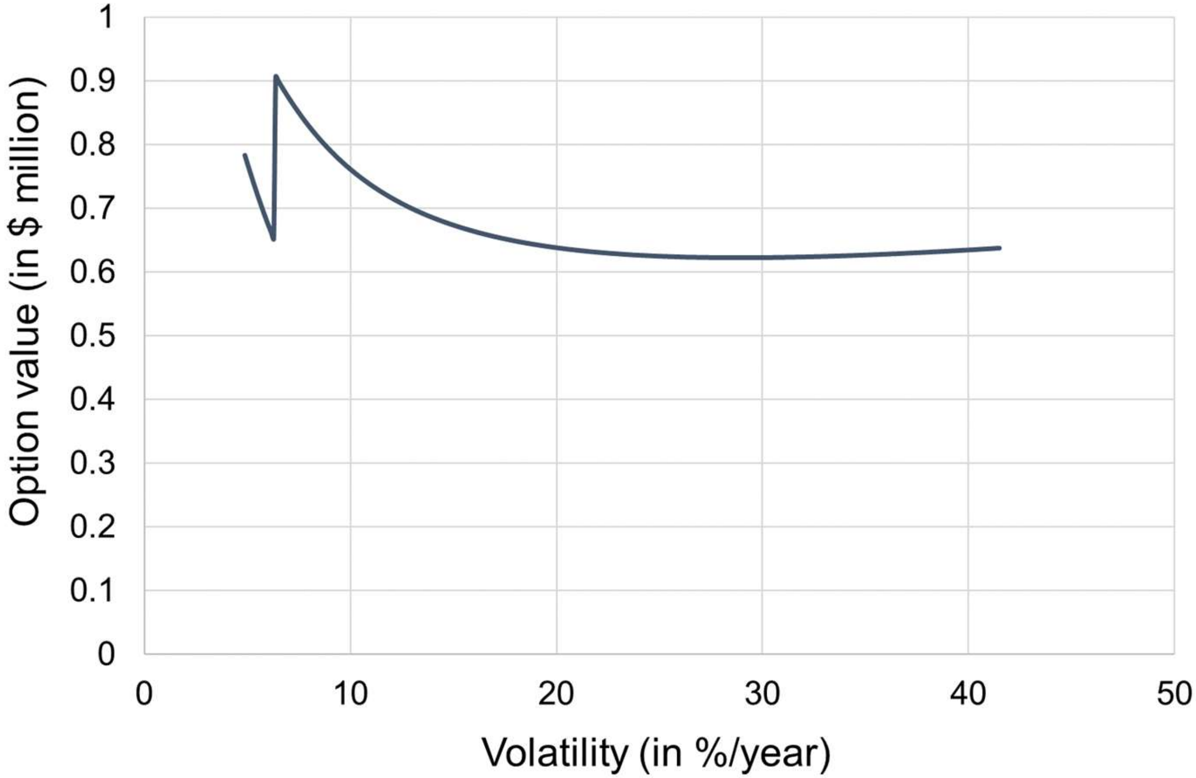
Add

Hold

Option value increases with modelling horizon



Option value is non-monotonic with respect to volatility



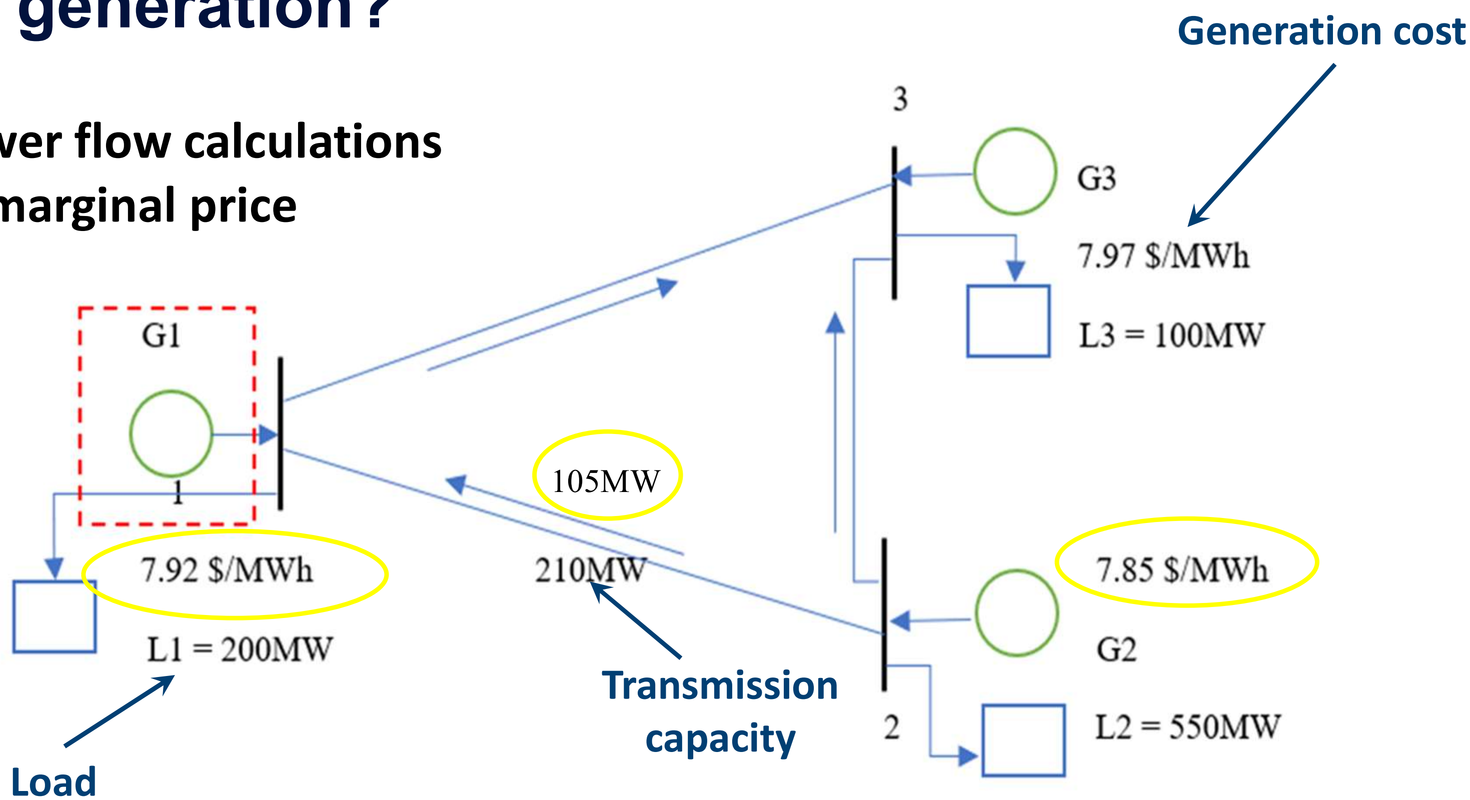
If a new transmission line with capacity of 105 MW from bus 2 to bus 1 costs $100,000, the real option value is $1.01 M

Millions of $

time	0	1	2	3	4	5
						1.53
						1.43
					2.27	0.00
					2.17	1.43
				2.52	1.04	0.84
				2.42	2.17	0.74
		Add	2.39	1.59	1.25	0.00
			2.29	2.42	1.15	0.74
	Hold	1.90	1.67	1.17	0.53	0.46
		1.80	2.29	1.07	1.15	0.36
	[illegible]	1.37	0.62	0.64	0.22	0.00
	[illegible]	1.80	0.52	1.07	0.12	0.36
	1.01	0.32	0.56	0.11	0.17	0.00
	1.01	0.22	0.56	0.01	0.17	-0.10
		0.29	0.05	0.08	0.00	0.00
		0.29	-0.05	0.08	-0.10	0.00
		Hold	0.04	0.00	0.00	0.00
			0.04	-0.10	0.00	-0.10
				0.00	0.00	0.00
				0.00	-0.10	0.00
					0.00	0.00
					0.00	-0.10
						0.00
						0.00

Why is the option value for transmission more than the value for generation?

Optimal power flow calculations
→ location marginal price



Real option value model assumes cost uncertainty can be hedged

Loss to initial position

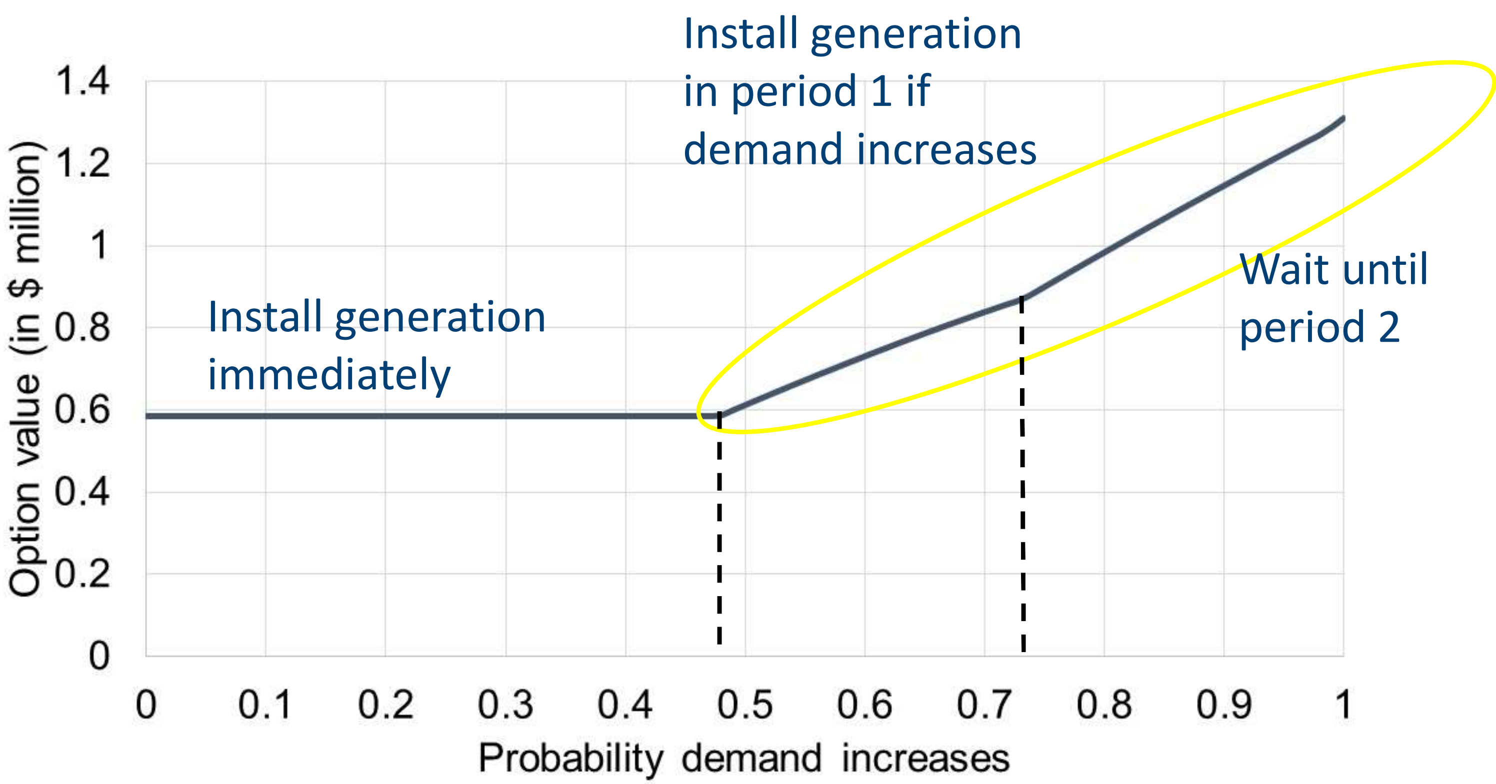
\+

Gain to hedge

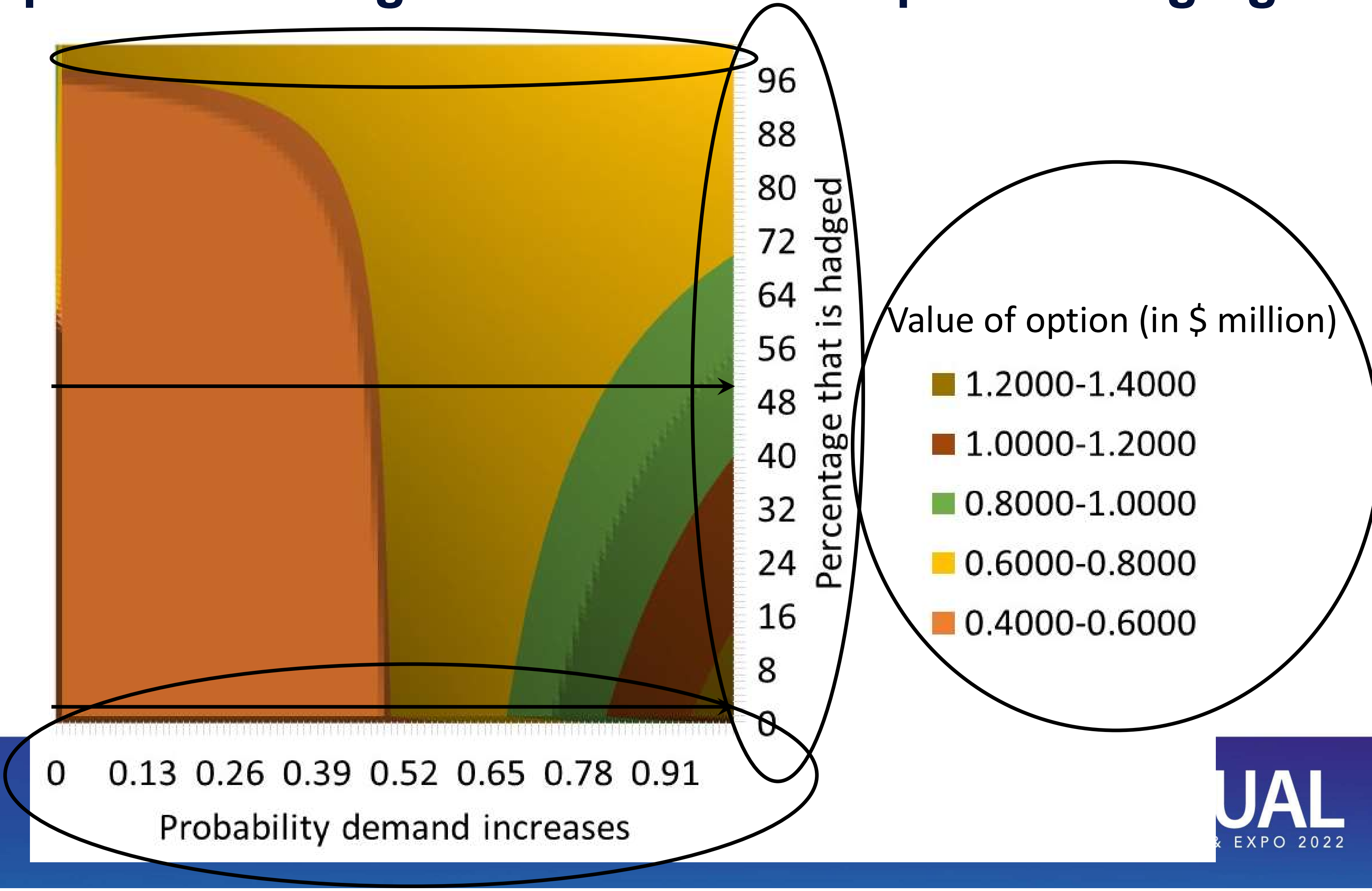
= **Neutral exposure or reduced risk**

What if cost uncertainty cannot be hedged or only partially hedged?

Value of option for new generation unit with no hedging



Value of option for new generation unit with partial hedging



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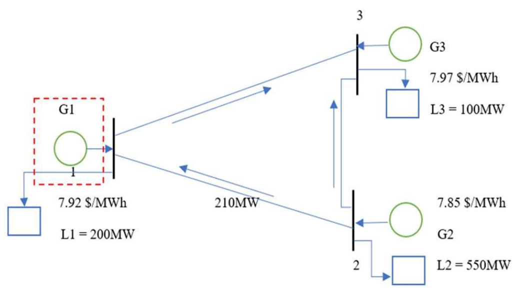
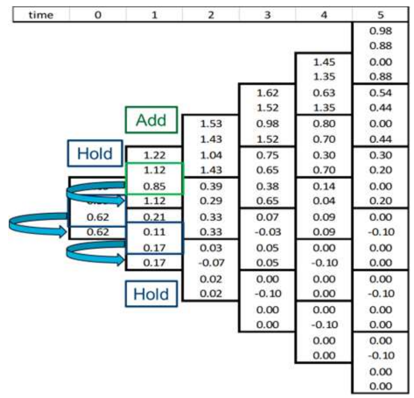
Real option theory with optimal power flow model can value new generation and transmission capability





	Load	Generation units available	Max generation capacity	Generation cost ($/MWh)
Bus 1	270	1		$7.92
Bus 2	550	1		$7.85
Bus 3	100	1		$7.97

Transmission Capacity	(leave blank if no transmission capacity)		
From \ To	Bus 1	Bus 2	Bus 3
Bus 1		210	
Bus 2	210		
Bus 3			

Line Reactance	(leave blank if no transmision from one bus to another bus)		
From \ To	Bus 1	Bus 2	Bus 3
Bus 1		0.1	0.125
Bus 2	0.1		0.2
Bus 3			

$620,000 for new generation unit

$1.01M for new transmission line

Excel spreadsheets to enter your own calculations

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Q&A

Cameron MacKenzie, camacken@iastate.edu,

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