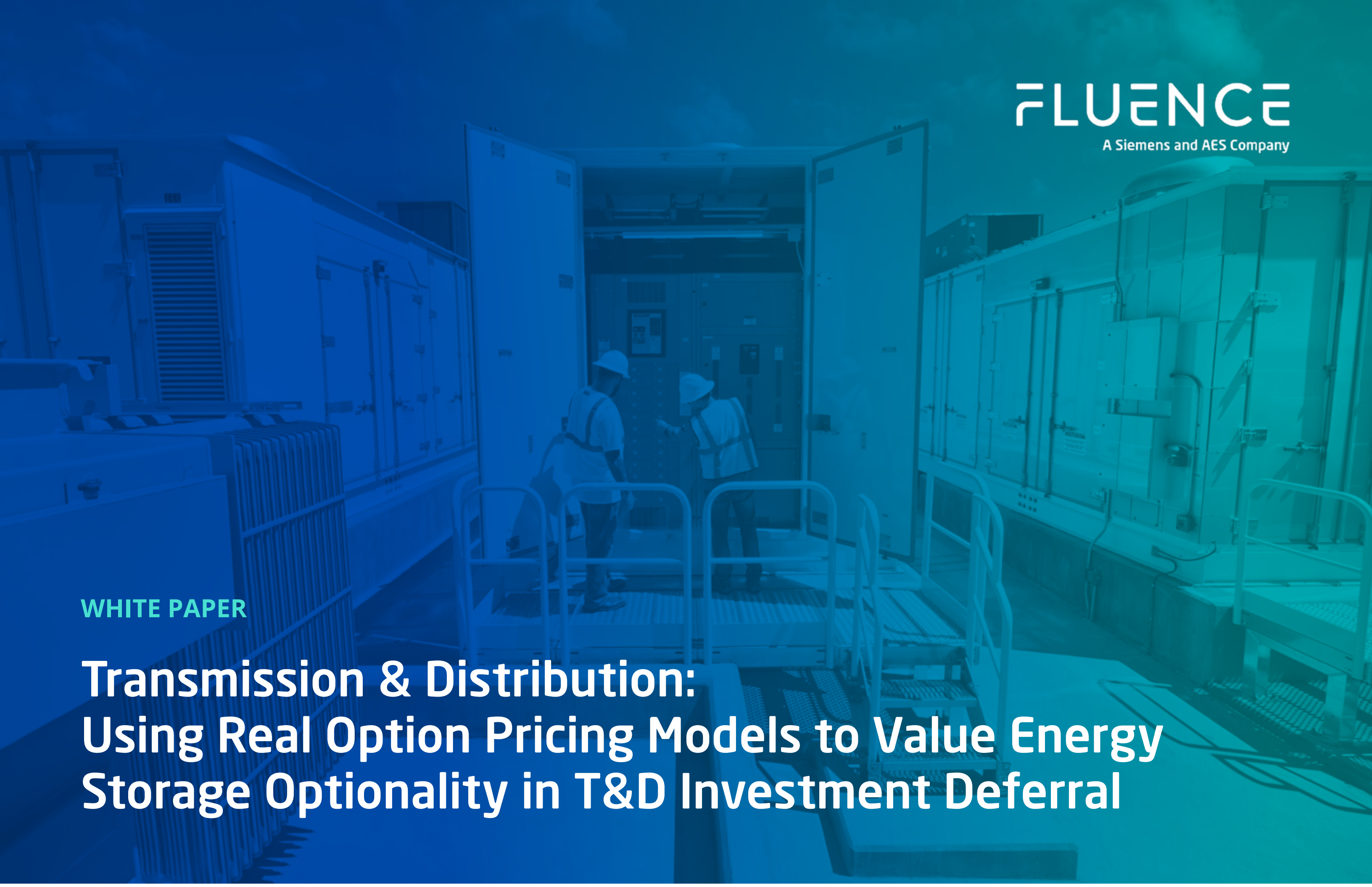

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Transmission & Distribution: Using Real Option Pricing Models to Value Energy Storage Optionality in T&D Investment Deferral

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Background

In 2017 Arizona Public Service (APS) built a 2 MW, 4-hour duration battery energy storage system for less cost than its next best alternative – a 20 mile transmission upgrade – making them one of the first electricity companies in the nation to use battery-based energy storage in place of traditional infrastructure for basic grid operation.

For APS, this new system will provide much-needed T&D capacity, saving them the time and cost of rebuilding lines and poles over difficult terrain. In addition, this battery energy storage system will provide additional benefits like voltage regulation and delivery of excess solar power, as well as the capability to add additional storage as needed, all at a similar cost.

The project is a prime example of how energy storage can address local needs in areas experiencing population growth – and associated load growth. Punkin Center is a growing rural community of 600 residents, roughly 90 minutes northeast of the urban core of downtown Phoenix. To increase power reliability for those customers, APS chose battery-based energy storage because of its faster speed of deployment, lower implementation costs, and the additional services it could offer.

Utilities are realizing that there are certain cases where energy storage can defer investments in a variety of fundamental, single-function grid assets like wires, poles, and substations, and in the process help utilities get the most value from the transmission and distribution lines they already own and use. However, valuing these opportunities can be difficult because unlike traditional utility T&D investments, battery energy storage is quick to build, modular, and re-deployable, which gives these assets option value.

Simple Example of Real Option Pricing

Utility ABC is considering a $100M T&D upgrade today based on forecasted load growth in 3 years and foresees two scenarios each with a 50% probability (see Figure 1A).

If the T&D upgrade is made today, ABC will spend $100M for sure. However, if ABC is able to spend $10M on an energy storage solution that can address the near-term reliability need, then there is an option value of delaying the capital expenditure decision until year three. Note that with a “right-sized” energy storage solution in place, the traditional distribution capital expenditure will only be made in the High Load Growth Scenario (A) and not in the Low Load Growth Scenario (B). Because (A) has a 50% probability of occurring, the expected capital expenditure today decreases from $100M to $50M because of the optionality provided by deferring the investment decision. After accounting for the $10M cost of energy storage, the net savings of energy storage is $40M (see Figure 1B).

FIGURE 1A

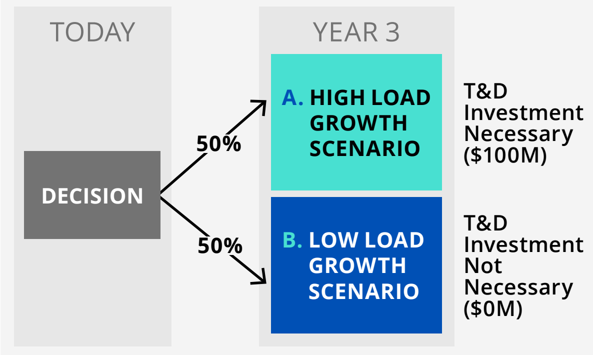
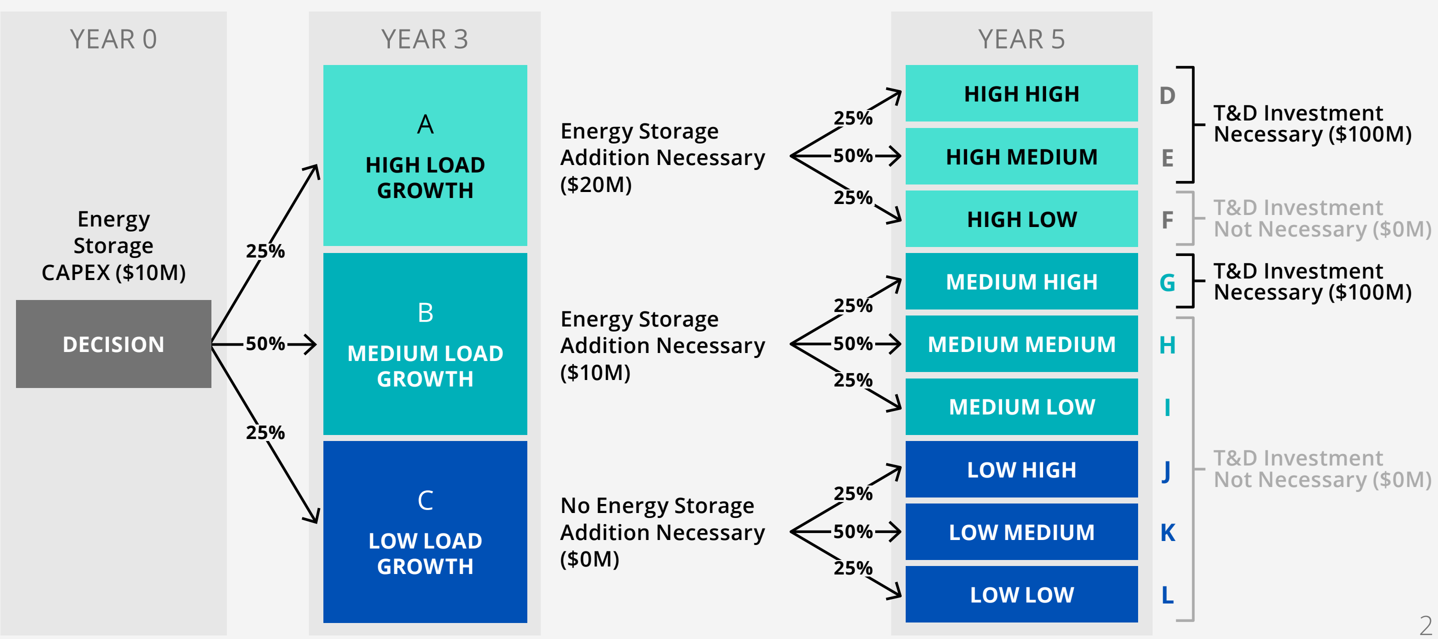


FIGURE 1B

SCENARIO	FORMULA	EXPECTED CAPEX
Base case: Without energy storage	$100M x 100%	$100M
With energy storage optionality	$0M x 50% + $100M x 50%	$50M
Savings with energy storage		$50M
Cost of energy storage		($10M)
Net savings with energy storage		$40M

Complex Example of Real Option Pricing

Energy storage is modular and can be installed in standardized blocks and relocated if needed. As such, this model can become more sophisticated to cover multiple decision points in order to reflect multiple period optionality. In the chart below, Utility ABC is expecting high, medium, and low load growth with 25%, 50%, and 25% probabilities across two-time intervals. In Year 3, if load growth is high or medium, additional energy storage modular units will need to be added to ensure reliability. In year 5, Utility ABC will have greater certainty over future load growth and will only construct an additional transmission line in scenarios D, E, and G at a cost of $100M. For all other scenarios, the additional transmission line is not necessary to ensure reliability.



The cumulative probabilities of ending up at nodes D-L is found by multiplying the two probabilities for a given path. For example, Node G has a probability of 50% x 25% = 12.5%. See complete probabilities for each path in Figures 2A and 2B.

As such, the T&D investment will be necessary for nodes D, E, and G, which have a combined probability of 6.25%+12.5%+12.5% = 31%, and T&D investment will not be necessary for nodes F, H, I, J, K, L, which have a combined probability of (1-31%) = 69%. Using the same technique as shown in the simple example (see Figure 2C), the expected value of energy storage is calculated as follows:

FIGURE 2A

SCENARIO	PROBABILITY
D	6.25%
E	12.5%
F	6.25%
G	12.5%
H	25.0%
I	12.5%
J	6.25%
K	12.5%
L	6.25%

FIGURE 2B

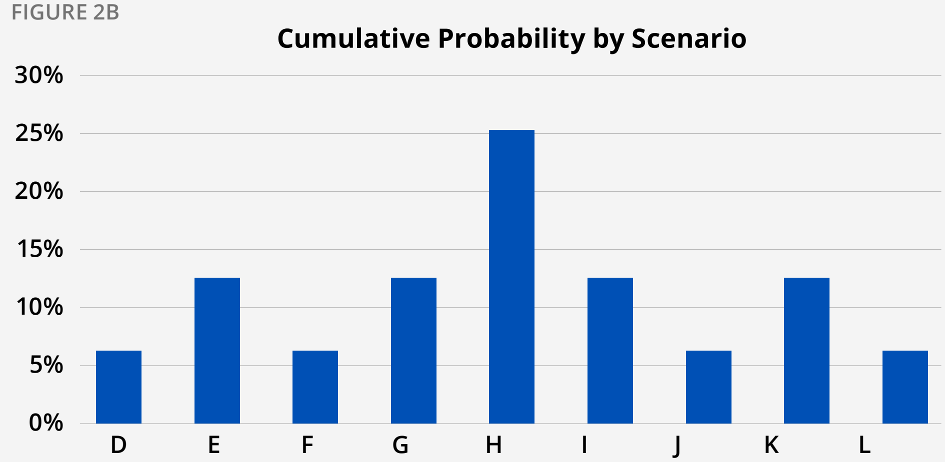


FIGURE 2C

SCENARIO	FORMULA	EXPECTED CAPEX
Base case: Without energy storage	$100M x 100%	$100M
With energy storage optionality	$0 x 69% + $100M x 31%	$31M
SAVINGS WITH ENERGY STORAGE		**$69M**

However, we must adjust the $69M to account for the initial $10M cost of energy storage required in all scenarios plus the expected energy storage additions necessary for nodes A and B. The expected energy storage additions for node A and B can be seen in Figure 2D.

Therefore, the total expected CAPEX for energy storage is $19M, which we can use to calculate the net savings with energy storage can be seen in Figure 2E.

FIGURE 2D

NODE	FORMULA	EXPECTED CAPEX
Year 0	$100M x 100%	$10M
A	$20M x 25%	$4M
B	$10M x 50%	$5M
TOTAL		**$19M**

FIGURE 2E

SCENARIO	FORMULA	EXPECTED CAPEX
Base case: Without energy storage	$100M x 100%	$100M
With energy storage optionality	$0M x 69% + $100M x 31%	$31M
SAVINGS WITH ENERGY STORAGE		$69M
COST OF ENERGY STORAGE		($19M)
Net savings with energy storage		**$50M**

Based on the above scenario, the net savings with energy storage, or option value of energy storage, is $50M because it is eliminating the risk of making a T&D investment that is ultimately unnecessary. In fact, the savings is actually even higher because in the event that in year 5 the T&D investment is made, the deployed battery energy storage assets can be redeployed to another location. This is additional upside not included in the $50M option value above.

Time Value of Money

So far these models have not considered the time value of money, which further improves the economics of using energy storage. Assuming the same example as above with a 7% discount rate, we can calculate the time value of money benefit of deferring the T&D investment from year 0 to year 5.

Recall from Figure 2E that the net savings of energy storage was $50M. Therefore, the time value of money benefit is $60.6M - $50M = $10.6 M and the total savings to rate payers is $60.6M.

Sensitivity Analysis

The two key inputs that drive the option value are the input probabilities and the difference between the T&D investment cost and the energy storage cost. To see the impact of these sensitivities, we held energy storage cost constant as above and flexed T&D investment cost (y-axis) and probability of high load growth each period (x-axis). As can be seen in Figure 3A, when the T&D investment cost is 10x or more than the initial energy storage cost, it always makes sense to defer the investment because of the time value of money impact of making an investment in year 0 versus year 5. When the T&D investment cost is 7.5x energy storage, it makes sense to use energy storage to defer the investment when there is less than a 95% probability of high load growth. When the T&D investment cost is 5x energy storage, it makes sense to use energy storage to defer the investment when there is less than an 80% probability of high load growth.

FIGURE 2F

	YEAR 0	YEAR 3	YEAR 5	TOTAL
EXPECTED CASH FLOW WITH STORAGE	($10M)	($9M)	($31M)	
EXPECTED CASH FLOW WITHOUT STORAGE	($100M)	$0	$0	
Difference	$90M	($9M)	($31M)	
PV of difference @ 7% discount rate	$90M	($7.3M)	($22.1M)	**$60.6M**

FIGURE 3A

Sensitivity of NPV of energy storage optional value for T&D deferral to changes in T&D Capex and load growth uncertainty

T&D INVESTMENT COST	10%	20%	30%	40%	50%	60%	70%	80%	90%	95%	100%
2.5	8	5	2	(1)	(4)	(7)	(10)	(13)	(16)	(18)	(19)
5.0	31	26	22	17	12	7	2	(2)	(7)	(10)	(12)
7.5	54	48	41	35	28	21	15	8	2	(2)	(5)
10.0	78	69	61	53	44	36	27	19	11	7	2
12.5	101	91	81	70	60	50	40	30	20	15	10
15.0	124	112	100	88	76	64	52	41	29	23	17
17.5	147	134	120	106	92	79	65	51	38	31	24
20.0	170	155	139	124	108	93	78	62	47	39	31

Conclusions

In the first examples above, over three-quarters of the value of T&D deferral came from the optionality of energy storage rather than time value of money. Therefore, it is critical that utilities accurately value non-wires alternatives like battery energy storage when making T&D investment decisions in order to protect ratepayers.

Real-world applications of this real option pricing model will undoubtedly be more complex than the examples above and there will be uncertainty quantifying the input probabilities. Nevertheless, this framework accurately captures both the option value as well as the time value of money value of using modular energy storage units to defer T&D investment decisions when facing uncertain future load growth.

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