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Application Portfolio: Fort Carson Solar Project

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Purpose

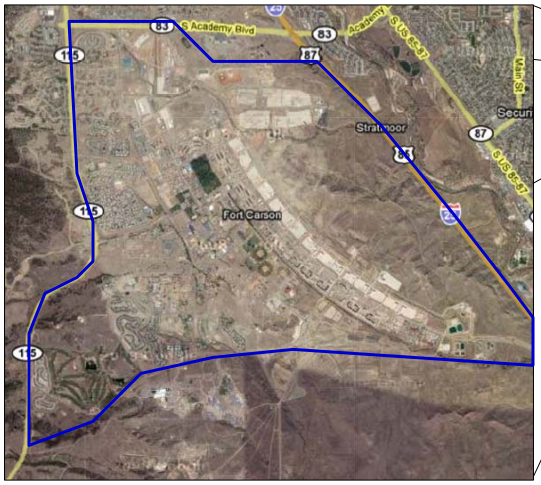
- The purpose of this Application Portfolio is to apply methods learned throughout the semester to a real world project. Specifically, decision analysis and lattice analysis will be used to evaluate flexibility in design alternatives to address uncertainty.

Agenda

Agenda

- Background Information
- Project Description
- Uncertainty Factors
- Design Alternatives
- Decision Analysis
  - Decision Tree
  - Multi-Variable Decision Analysis
- Lattice Analysis
  - Lattice Development/Valuation
  - Lattice VARG

Fort Carson Background



* Images from Google Maps, Accessed 25 November 2008.

• Fort Carson, Colorado is located in Colorado Springs, about an hour south of Denver
• On average there are over 300 days of sun a year
• Ideal location for solar power because of high levels of insulation and number of days of sun

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Project Description

- Fort Carson Solar Project:
  - This application portfolio will evaluate the economic feasibility of building Solar Fields to provide a portion of Fort Carson's electricity
  - The goal for the project is to generate 20% of Fort Carson's electricity from Solar Energy within the next 20 years
  - This project will evaluate the economic feasibility of design alternatives using the Net Present Value (NPV) of the project

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Uncertainty Factors

- Uncertainty Factors
  - Price of Electricity: Cost of electricity in $/kWh if Ft. Carson had to purchase the electricity created by the project from Colorado Springs Utilities
  - Demand for Electricity: Fort Carson's demand for electricity which will drive the number of solar fields required to meet the 20% goal
  - Annual Insulation: Amount of sun impacting Fort Carson in kWh/m^2 is used to calculate amount of electricity created by the solar fields

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Price of Electricity

- Price of Electricity ($/kWh)
  - Prices gathered from historic data from Colorado Springs Utilities
  - Several factors drive the uncertainty in the price of electricity: cost of coal or oil, technological factors, regulations, carbon tax, etc.

Regression Data

- Price (Year 0): $0.0692
- Growth Rate: 3.51%
- Standard Error: 37%

Year	Supply Charge	Access Charge	Cost Adj.	Total Price
2000	$ 0.0274	$ 0.0236	$ 0.002368	$ 0.0534
2001	$ 0.0274	$ 0.0236	$ 0.003461	$ 0.0545
2002	$ 0.0274	$ 0.0236	$ 0.004003	$ 0.0550
2003	$ 0.0274	$ 0.0236	$ 0.005007	$ 0.0560
2004	$ 0.0280	$ 0.0243	$ 0.007765	$ 0.0601
2005	$ 0.0346	$ 0.0310	$ (0.0029)	$ 0.0627
2006	$ 0.0346	$ 0.0310	$ 0.0019	$ 0.0675
2007	$ 0.0346	$ 0.0310	$ 0.0082	$ 0.0738
2008	$ 0.0346	$ 0.0310	$ 0.0036	$ 0.0692

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Demand for Electricity

- Demand for Electricity (kWh/year)
  - Demand gathered from Energy Information Association
  - Several factors drive the uncertainty in the demand for electricity: technological factors, number of Army units assigned to Fort Carson, number of people living on Fort Carson, etc.
  - Fort Carson's demand for electricity is about 138,000,000 kWh annually
  - The EIA estimates that demand is growing by 0.7% annually
  - Without historical data, I imposed a volatility on this growth rate of 50%

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Electricity Generated

- Annual Insulation (kWh/m^2)
  - 30 Year averages were used to generate the chart below for annual insulation at Boulder, CO
  - Insulation is the total amount of solar energy available for collection
  - These values are used to determine the electricity generated by the solar fields
  - Without historical data to develop a regression, I used a volatility of 10%

Annual Insulation Boulder, CO (Langleys)											
JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
203	279	377	474	531	585	575	512	428	325	225	182

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Model Parameters

Additional Model Parameters

- Solar Field Size: 10 MWe
- Solar Field Area: 92,900 m^2
- Solar Field Cost: $6,250,000 / field
- Solar Panel Efficiency: 24%
- Solar Refund: $37,500 / field
- Solar Tax Credit: $1,875,000 / field
- Renewable Energy Credit: $0.20 / kWh
- Discount Rate: 5.1%

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Design Alternatives (1 of 2)

- Design Alternative 1 (Base Case)
  - Build enough 10 MWe Solar Fields to meet 20% of predicted demand throughout project live
  - 28 Solar Fields are built in Year 0
  - No flexibility in design alternative
- Design Alternative 2 (Demand Based)
  - Build enough 10 MWe Solar Fields to meet 20% of predicted demand for the first few years of project
  - 23 Solar Fields are built in Year 0
  - Flexibility to build 2 additional 10 MWe Solar Fields if demand goals are not met for 2 consecutive years

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Design Alternatives (2 of 2)

- Design Alternative 3 (Incremental Growth)
  - Number of Solar Fields built will meet demand goal of 5%, 10%, 15%, and 20% every 5 years
  - 7 Solar Fields are built in Year 0
  - 7 additional Solar Fields are built every 5 years
- Design Alternative 4 (Small Design)
  - Initially build small and take advantage of possible reduction in construction costs at Year 6
  - 1 Solar Field is built in Year 0
  - Flexibility to build 2 additional 10 MWe Solar Fields beginning in Year 6 throughout the live of the project

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Decision Analysis

- Decision Analysis
  - Method used to compare design alternatives when a decision is introduced into the design
  - At Year 6, the cost for construction could range from current price of $6.25 / Watt, $4.75 / Watt, and $3.30 / Watt
  - Decision results in two options:
    - Option 1: Continue to build Solar Fields as planned
    - Option 2: Discontinue additional construction, but continue to operate project

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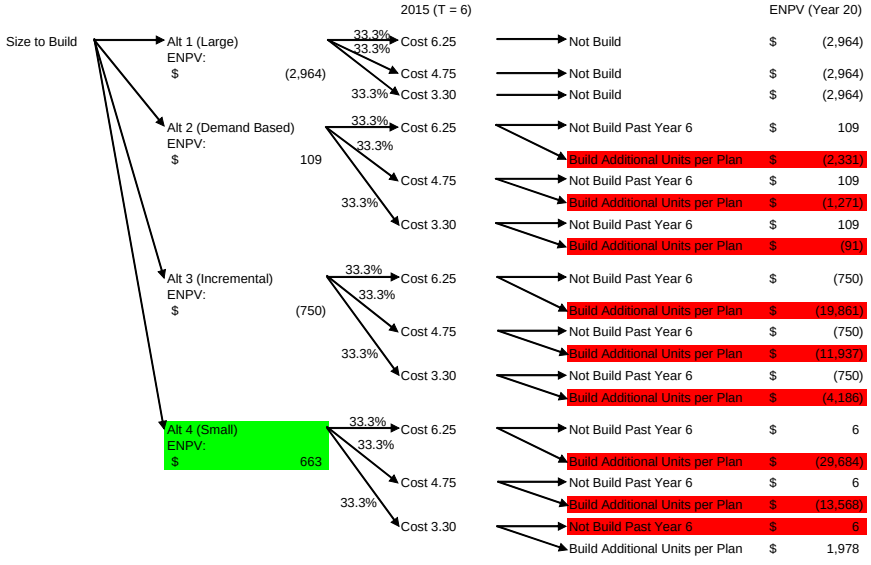
Decision Tree

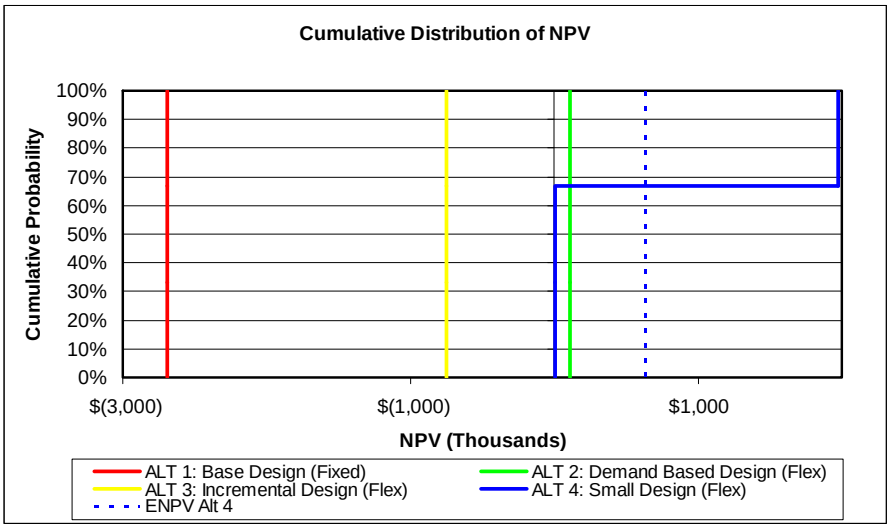


Decision Analysis

- Decision Analysis Data
  - Design Alternative 4 becomes the best design after utilizing decision analysis
  - This design alternative has the largest ENPV of $633 (thousand) as well as the largest Max NPV of $1,978 (thousand)
  - The subsequent slide shows the VARG graph for the decision analysis

	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Best Choice
ENPV	$ (2,694)	$ 109	$ (750)	$ 633	Alternative 4
Max NPV	$ (2,694)	$ 109	$ (750)	$ 1,978	Alternative 4
Min NPV	$ (2,694)	$ 109	$ (750)	$ 6	Alternative 2
Initial CAPEX	$ (121,450)	$ (99,763)	$ (30,363)	$ (4,338)	Alternative 4

Decision Analysis VARG Graph



Lattice Analysis

- Lattice Analysis
  - Method used to evaluate the possible outcomes for a project based on an uncertain variable
  - For the Fort Carson Solar Project this method can be used to evaluate the effect of the cost of electricity on the NPV of the project
  - Regression Data based on historical values:
    - Initial Value: $0.0692
    - Growth Rate: 3.51%
    - Standard Deviation: 37%
    - Upside Factor: 1.448
    - Downside Factor: 0.691
    - Upside Probability: 54.74%

Price Lattice

Price Lattice ($ / kWh)	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
	0.07	0.10	0.15	0.21	0.30	0.44	0.64	0.92	1.34	1.93	2.80	4.05	5.87	8.49	12.30	17.80	25.77	37.31	54.01	78.20	113.21
		0.05	0.07	0.10	0.15	0.21	0.30	0.44	0.64	0.92	1.34	1.93	2.80	4.05	5.87	8.49	12.30	17.80	25.77	37.31	54.01
			0.03	0.05	0.07	0.10	0.15	0.21	0.30	0.44	0.64	0.92	1.34	1.93	2.80	4.05	5.87	8.49	12.30	17.80	25.77
				0.02	0.03	0.05	0.07	0.10	0.15	0.21	0.30	0.44	0.64	0.92	1.34	1.93	2.80	4.05	5.87	8.49	12.30
					0.02	0.02	0.03	0.05	0.07	0.10	0.15	0.21	0.30	0.44	0.64	0.92	1.34	1.93	2.80	4.05	5.87
						0.01	0.02	0.02	0.03	0.05	0.07	0.10	0.15	0.21	0.30	0.44	0.64	0.92	1.34	1.93	2.80
							0.01	0.01	0.02	0.02	0.03	0.05	0.07	0.10	0.15	0.21	0.30	0.44	0.64	0.92	1.34
								0.01	0.01	0.01	0.02	0.02	0.03	0.05	0.07	0.10	0.15	0.21	0.30	0.44	0.64
									0.00	0.01	0.01	0.02	0.02	0.02	0.03	0.05	0.07	0.10	0.15	0.21	0.30
										0.00	0.00	0.01	0.01	0.01	0.02	0.02	0.03	0.05	0.07	0.10	0.15
											0.00	0.00	0.00	0.01	0.01	0.01	0.02	0.02	0.03	0.05	0.07
												0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.02	0.02	0.03
													0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.02
														0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01
															0.00	0.00	0.00	0.00	0.00	0.00	0.00
																0.00	0.00	0.00	0.00	0.00	0.00
																	0.00	0.00	0.00	0.00	0.00
																		0.00	0.00	0.00	0.00
																			0.00	0.00	0.00
																				0.00	0.00
																					0.00

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Probability Lattice

Probability Lattice

1.000	0.547	0.300	0.164	0.090	0.049	0.027	0.015	0.008	0.004	0.002	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	0.453	0.496	0.407	0.297	0.203	0.134	0.085	0.053	0.033	0.020	0.012	0.007	0.004	0.003	0.001	0.001	0.001	0.000	0.000	0.000
		0.205	0.336	0.368	0.336	0.276	0.211	0.154	0.109	0.074	0.050	0.033	0.021	0.014	0.009	0.005	0.003	0.002	0.001	0.001
			0.093	0.203	0.278	0.304	0.291	0.255	0.210	0.164	0.123	0.090	0.064	0.045	0.031	0.021	0.014	0.009	0.006	0.004
				0.042	0.115	0.189	0.241	0.264	0.260	0.237	0.204	0.167	0.132	0.102	0.076	0.055	0.040	0.028	0.019	0.013
					0.019	0.062	0.119	0.174	0.215	0.235	0.236	0.222	0.197	0.168	0.138	0.110	0.085	0.065	0.048	0.035
						0.009	0.033	0.072	0.118	0.162	0.195	0.214	0.217	0.208	0.190	0.166	0.141	0.116	0.092	0.072
							0.004	0.017	0.042	0.077	0.115	0.151	0.180	0.197	0.202	0.196	0.183	0.164	0.142	0.120
								0.002	0.009	0.024	0.048	0.078	0.111	0.142	0.167	0.183	0.189	0.186	0.176	0.161
									0.001	0.004	0.013	0.029	0.051	0.078	0.107	0.134	0.156	0.171	0.178	0.177
										0.000	0.002	0.007	0.017	0.032	0.053	0.078	0.103	0.127	0.147	0.161
											0.000	0.001	0.004	0.010	0.020	0.035	0.054	0.076	0.099	0.121
												0.000	0.001	0.002	0.006	0.012	0.022	0.037	0.055	0.075
													0.000	0.000	0.001	0.003	0.007	0.014	0.024	0.038
														0.000	0.000	0.001	0.002	0.004	0.009	0.016
															0.000	0.000	0.000	0.001	0.002	0.005
																0.000	0.000	0.000	0.000	0.001
																	0.000	0.000	0.000	0.000
																		0.000	0.000	0.000
																			0.000	0.000
																				0.000

Cumulative Probability

1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

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Lattice Valuation

- Lattice Valuation
  - Based on the price lattice, the ENPV for the project could be calculated
  - This valuation evaluated a “call” option beginning in year 6 to build an additional 2 solar fields
  - The strike price for the option is the construction cost less tax and refund credits: $8,675 (thousand)
  - Using dynamic programming the model evaluated when to exercise the call option
    - If: PV (Expanded Design) – K > PV (Option Design)
    - Then: Expand

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Lattice Decision Points

- Example of Expand Decision Point

PV 10 (Expand Design)	
10	11
133,159	188,616
	93,002

>

PV 10 (Option Design)	
10	11
$ 126,127	$ 169,828
	$ 79,253

- Example of Not Expand Decision Point

PV 10 (Expand Design)	
10	11
(2,877)	5,869
	5,811

<

PV 10 (Option Design)	
10	11
$ 2,091	$ 1,956
	$ 1,937

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Decision Lattice

- Decision to exercise “call” option to expand project by 2 Solar Fields

Exercise Expand Option

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
N/A	N/A	N/A	N/A	N/A	N/A	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
	N/A	N/A	N/A	N/A	N/A	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
		N/A	N/A	N/A	N/A	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
			N/A	N/A	N/A	NO	NO	NO	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
				N/A	N/A	NO	NO	NO	NO	NO	NO	YES	YES	YES	YES	YES	YES	YES	YES
					N/A	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
						NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
							NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
								NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
									NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
										NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
											NO	NO	NO	NO	NO	NO	NO	NO	NO
												NO	NO	NO	NO	NO	NO	NO	NO
													NO	NO	NO	NO	NO	NO	NO
														NO	NO	NO	NO	NO	NO
															NO	NO	NO	NO	NO
																NO	NO	NO	NO
																	NO	NO	NO
																		NO	NO
																			NO

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Present Value of Cash Flows

- Present Values of Cash Flows with the option to expand beginning in Year 6

PV (Cash Flows) Expand Option (thousands)

5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
$ 34,264	$ 46,575	$ 61,080	$ 79,708	$103,403	$133,159	$169,828	$213,966	$265,674	$323,788	$384,550	$441,071	$478,726	$471,832	$377,245	$134,217
$ 15,759	$ 21,473	$ 28,208	$ 36,900	$ 48,001	$ 61,984	$ 79,253	$100,072	$124,490	$151,954	$180,667	$207,345	$225,007	$221,397	$175,931	$ 64,161
$ 7,385	$ 9,496	$ 12,524	$ 16,476	$ 21,568	$ 28,025	$ 36,039	$ 45,731	$ 57,130	$ 69,970	$ 83,391	$ 95,831	$103,954	$101,911	$ 79,881	$ 30,736
$ 4,304	$ 4,837	$ 5,662	$ 6,946	$ 8,956	$ 11,823	$ 15,420	$ 19,805	$ 24,991	$ 30,854	$ 36,980	$ 42,626	$ 46,198	$ 44,903	$ 34,054	$ 14,788
$ 3,350	$ 3,461	$ 3,642	$ 3,922	$ 4,343	$ 4,979	$ 5,944	$ 7,435	$ 9,657	$ 12,191	$ 14,837	$ 17,241	$ 18,642	$ 17,703	$ 12,189	$ 7,179
$ 2,994	$ 2,981	$ 2,990	$ 3,031	$ 3,110	$ 3,239	$ 3,426	$ 3,678	$ 3,998	$ 4,386	$ 4,824	$ 5,258	$ 5,610	$ 5,682	$ 5,170	$ 3,549
	$ 2,768	$ 2,710	$ 2,665	$ 2,633	$ 2,624	$ 2,638	$ 2,679	$ 2,747	$ 2,844	$ 2,961	$ 3,071	$ 3,138	$ 3,066	$ 2,709	$ 1,817
		$ 2,576	$ 2,490	$ 2,406	$ 2,330	$ 2,262	$ 2,202	$ 2,150	$ 2,109	$ 2,072	$ 2,027	$ 1,959	$ 1,817	$ 1,535	$ 991
			$ 2,406	$ 2,298	$ 2,190	$ 2,083	$ 1,975	$ 1,865	$ 1,758	$ 1,648	$ 1,529	$ 1,396	$ 1,222	$ 974	$ 596
				$ 2,246	$ 2,123	$ 1,997	$ 1,866	$ 1,730	$ 1,590	$ 1,446	$ 1,292	$ 1,127	$ 937	$ 707	$ 408
					$ 2,091	$ 1,956	$ 1,814	$ 1,665	$ 1,510	$ 1,349	$ 1,178	$ 999	$ 802	$ 580	$ 319
						$ 1,937	$ 1,790	$ 1,634	$ 1,472	$ 1,303	$ 1,124	$ 938	$ 737	$ 519	$ 276
							$ 1,778	$ 1,619	$ 1,454	$ 1,281	$ 1,098	$ 909	$ 706	$ 490	$ 255
								$ 1,612	$ 1,445	$ 1,271	$ 1,086	$ 895	$ 692	$ 476	$ 246
									$ 1,441	$ 1,266	$ 1,080	$ 888	$ 685	$ 469	$ 241
										$ 1,263	$ 1,077	$ 885	$ 681	$ 466	$ 239
											$ 1,076	$ 884	$ 680	$ 465	$ 238
												$ 883	$ 679	$ 464	$ 237
													$ 678	$ 464	$ 237
														$ 463	$ 237
															$ 237

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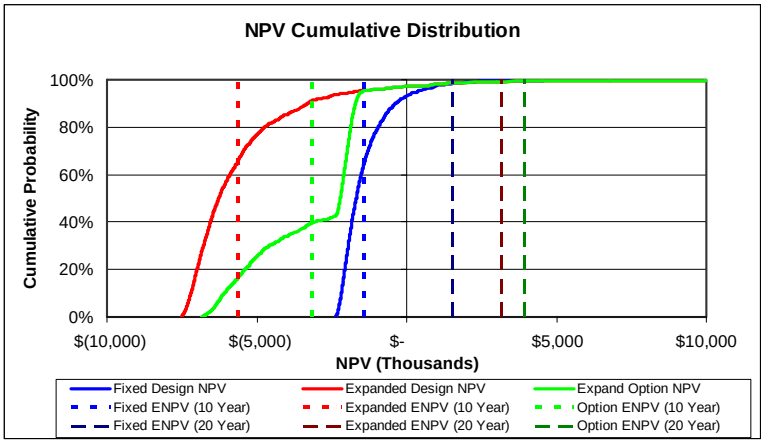
Lattice VARG Analysis

- Initial Lattice Valuation provides a ENPV for the project
- Examining the possible paths during the first 10 years provides additional information on possible NPVs



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Lattice Multi-Variable Analysis

- From the possible lattice paths additional information can be determined to evaluate the option
- Like the VARG analysis, this evaluated 3 designs:
  - Fixed (1 Solar Field)
  - Expanded (1 Solar Field, then 2 additional in Year 6)
  - Option (1 Solar Field, with option to build 2 additional beginning in Year 6)
- The design with the "call" option provided the highest 20 Year ENPV and the highest Max NPV
- The 10 Year ENPV of the fixed design is better; however, this is because additional costs are incurred by the option design in Year 6

	Fixed	Expanded	Option	Best Design
ENPV (10 Year)	$ (1,423)	$ (5,610)	$ (3,154)	Fixed
ENPV (20 Year)	$ 1,506	$ 3,183	$ 3,922	Option
Max NPV	$ 4,543	$ 9,980	$ 9,980	Expand/Option
Min NPV	$ (2,360)	$ (7,533)	$ (6,847)	Fixed

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Conclusion

- In general, the Fort Carson Solar Project will benefit greatly from incorporating flexibility into design alternatives to account for uncertainty
- Using Decision Analysis, Design Alternative 4, which initial built 1 Solar Field was the best alternative with an ENPV of $633 (thousand)
- Using Lattice Analysis, a "call" option to expand Design Alternative 4 from 1 to 3 Solar Fields depending on the price of electricity proved to be worthwhile
- Overall, the Fort Carson Solar Project is economically feasible using Design Alternative 4

Questions?