

# Application Portfolio: Fort Carson Solar Project



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- 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**

- 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, 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

\* Images from Google Maps, Accessed 25 November 2008.

- **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

- **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 Insolation: Amount of sun impacting Fort Carson in kWh/m<sup>2</sup> is used to calculate amount of electricity created by the solar fields

- 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

- 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%

- Annual Insulation (kWh/m<sup>2</sup>)
  - 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

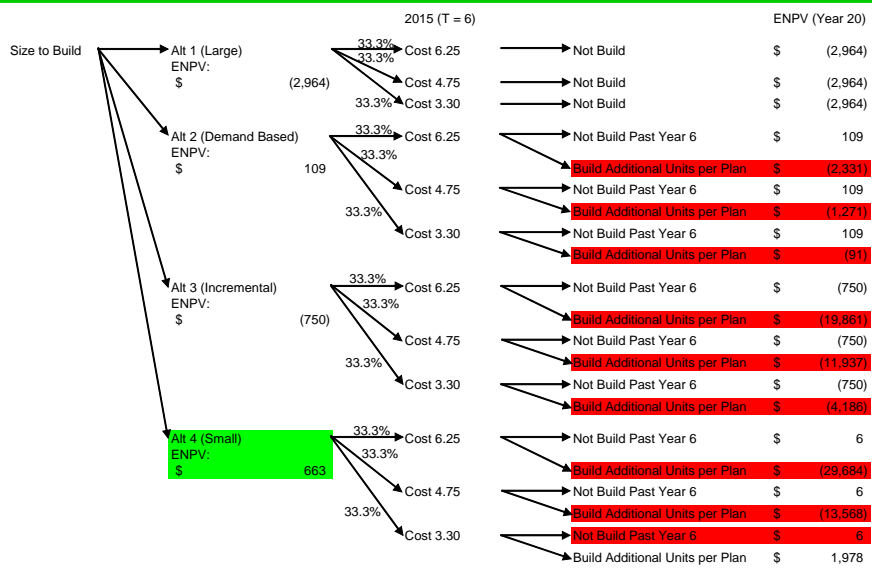
**Additional Model Parameters**

- Solar Field Size: 10 MWe
- Solar Field Area: 92,900 m<sup>2</sup>
- 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%

- **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

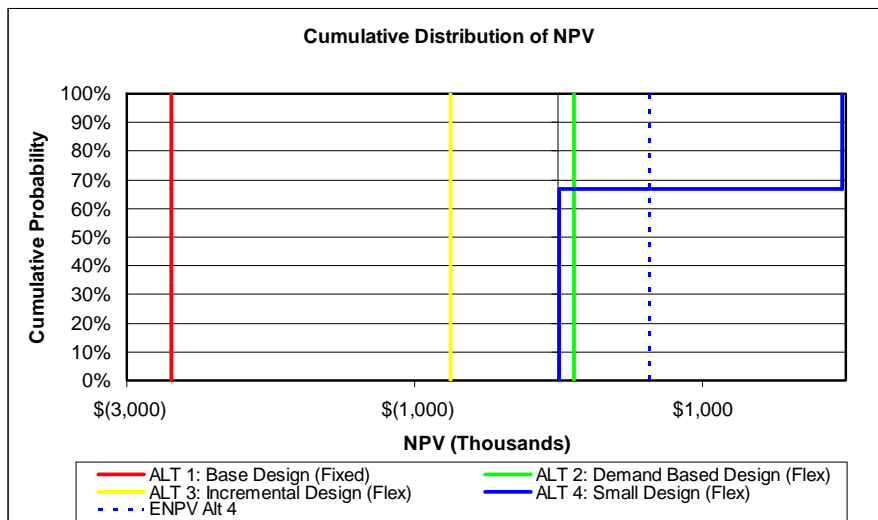
- **Design Alternative 3 (Incremental Growth)**
  - Number of Solar Fields built will meet demand goal of 5%, 10%, 15%, and 20% every 5 years
  - 7 Solar Fields are built in Year 0
  - 7 additional Solar Fields are built every 5 years
- **Design Alternative 4 (Small Design)**
  - Initially build small 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

- 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



- 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









- Example of Expand Decision Point

PV 10 (Expand Design)			PV 10 (Option Design)	
10	11		10	11
133,159	188,616	>	\$ 126,127	\$ 169,828
	93,002			\$ 79,253

- Example of Not Expand Decision Point

PV 10 (Expand Design)			PV 10 (Option Design)	
10	11		10	11
(2,877)	5,869	<	\$ 2,091	\$ 1,956
	5,811			\$ 1,937

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

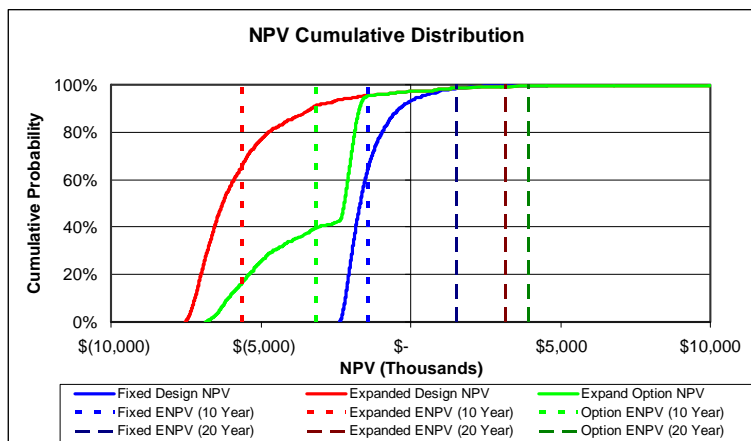
Exercise Expand Option																			
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
N/A						YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
	N/A					YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
		N/A				YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
			N/A			NO	NO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

- 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

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



- 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

- 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?