Diversification of Energy Power Plants in the North of Chile

Matías Raby

Introduction

- Demand for electricity in the SING is expected to increase considerably during the following years.
- SING depends 99.6% on fossil fuels.
- Government planning to diversify energy generation matrix. Nuclear is an interesting option.

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The System

Evaluation of two investment options of energy power plants for the SING.

- **Fixed Option**: Large nuclear power plant with a capacity of 1,200 MW with no potential to be expanded in the future.
- **Flexible Option**: Medium size nuclear plant with a capacity of 600 MW. This system has the potential to be expanded in the future to either of the following alternatives:
  1. Additional medium size nuclear power plant with a capacity of 600 MW.
  2. Additional medium size gas-fired power plant with a capacity of 600 MW.

Uncertainties

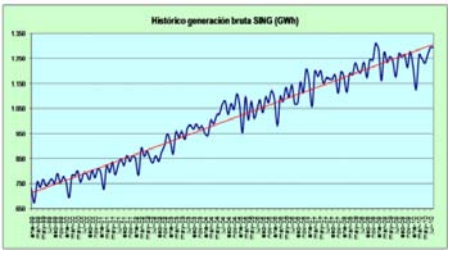
- Future demand of electricity.
- Future price of natural gas.
- Government regulation of carbon emissions.

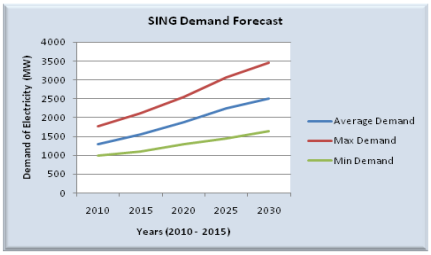
Structure of Analysis

- Evolution of uncertainties.
- Excel Simulation.
- Multidimensional comparison of the results.

Future Demand of Electricity

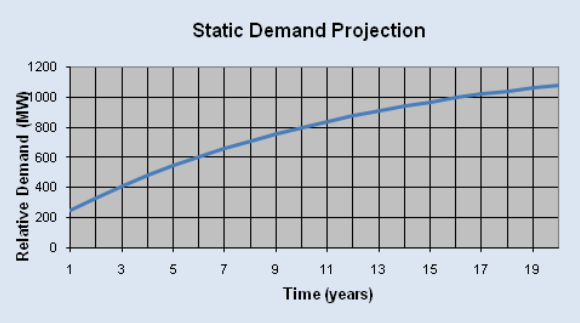
- **Two sources of uncertainties**:
  - **Annual volatility**: 10% based on historical data.
  - **Variability in projection of demand**: 36% based on CNE forecast.





Future Demand of Electricity

1. Exponential model in excel to calculate static projection of demand (based on parking garage example).



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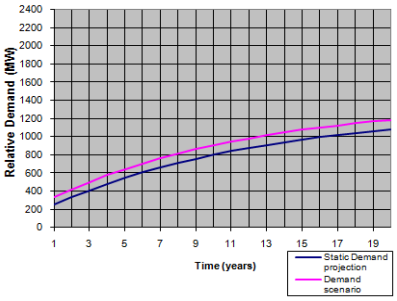
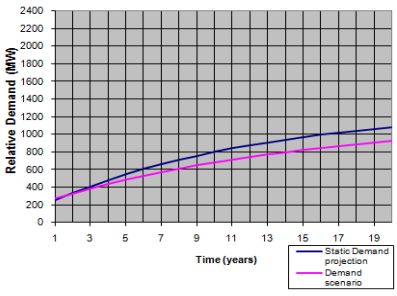
Future Demand of Electricity

2. Exponential model + 36% variability in projection





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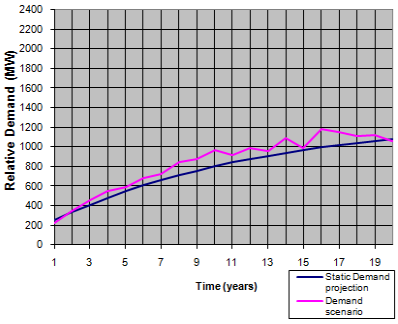
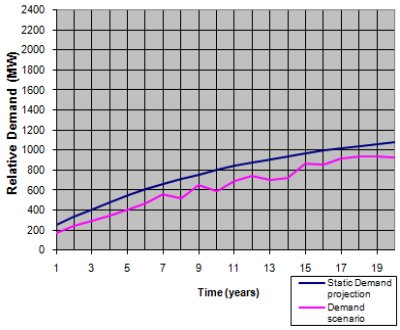
Future Demand of Electricity

3. **Exponential model + 36% variability in projection + 10% annual volatility.**





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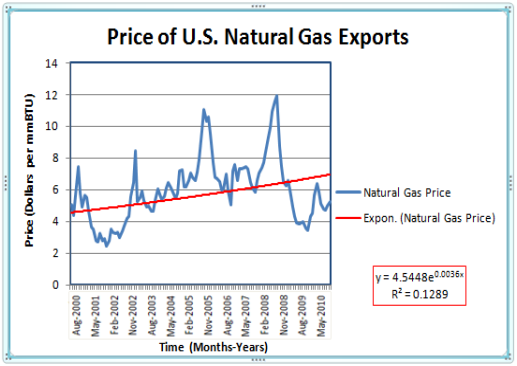
Future Price Natural Gas

- **From historical data:**
  - Grow rate: 4.3%
  - Volatility: 34.11%



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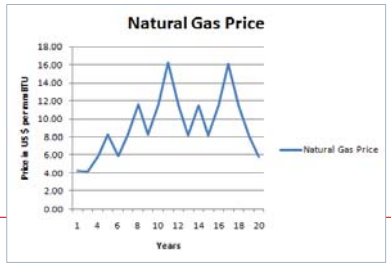
Future Price Natural Gas

- **From historical data, I calculated lattice parameters u, d and p.**
- **Used excel model based on Lattice Analysis, considering p=0.56, u=1.41, d=0.71.**
  - Logic: If random number < 0.56, then *u, otherwise *d.

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Random Entries for Lattice Simulation		0.84	0.14	0.75	0.44	0.29	0.87	0.23	0.40	0.96	0.41	0.52	0.94	0.57	0.36	0.65	0.46	0.36	0.77	0.72	0.95
Realised Price of Natural Gas ($/mmBTU)		4.22	5.92	4.21	5.91	8.29	5.89	8.27	11.61	8.24	11.57	16.24	11.53	8.19	11.50	8.16	11.46	16.09	11.42	8.11	5.76



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Regulation of Carbon Emissions

- **No clear position from Chilean Government.**
- **Assumed 30% chance of being implemented each year and once implemented is never repealed.**
- **Excel model.**
  - Logic: If random number < 0.3, then Approval, otherwise Rejection.

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Random Entries for Tax Simulation		0.58	0.64	0.51	0.71	0.85	0.84	0.17	0.01	0.52	0.67	0.08	0.29	0.72	0.49	0.31	0.39	0.10	0.69	0.46	0.22
RealisedCarbon Emissions Tax ($200 / ton-C)		No	No	No	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

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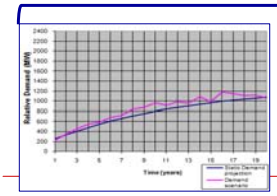
Excel Simulation

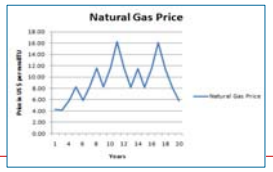
- **Plant Specifications (MIT Center Energy & Env. Policy Research)**

Parameter	Large Nuclear Plant	Medium Nuclear Plant	Medium Gas Plant
Capacity (MW)	1200	600	600
Capital Cost (million $)	4400	2800	510
Fixed O&M Cost ($/KW/year)	56	56	13
Heat Rate (BTU/KWhr)	10400	10400	6800
Fuel Cost ($/ mmBTU)	0.67	0.67	Variable
Carbon Intensity (kg-C/mmBTU)	0	0	14.5
Electricity Price ($/KWhr)	0.16	0.16	0.16
Discount Rate (%)	12	12	12
Time Horizon (2010-2030)	20	20	20

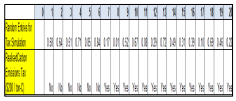
- **Uncertainties**



DEMAND



NAT. GAS PRICE



CARBON TAXES

Excel Simulation

Year	0	1	2	3	4
Demand projection (with 36% variation)		292	359	421	478
Demand growth projection year to year			23%	17%	14%
Demand projection (with 10% volatility)			24%	19%	23%
Projected demand with Uncertainty		292	363	425	518
Capacity (MW)	0	1200	1200	1200	1200
Total Production (TWhr/year)	0	2.56	3.18	3.73	4.54
Revenue ($ millions/year)	$0	$409	$509	$596	$726
Capital Cost ($ millions)	$4,400	$0	$0	$0	$0
Fixed O&M Cost ($ millions/year)	$0	$67	$67	$67	$67
Fuel Cost ($millions/year)	$0	$18	$22	$26	$32
Carbon Emissions Tax ($ millions/year)	$0	$0	$0	$0	$0
Cashflow	-$4,400	$324	$419	$503	$627
DCF	-$4,400	$290	$334	$358	$399
ENPV	$1,037				

18	19	20
947	965	982
2%	2%	2%
9%	-4%	8%
1,011	906	1,041
1200	1200	1200
8.86	7.94	9.12
$1,417	$1,270	$1,460
$0	$0	$0
$67	$67	$67
$62	$55	$64
$0	$0	$0
$1,288	$1,148	$1,329
$168	$133	$138

Sample result for Fixed Option Simulation

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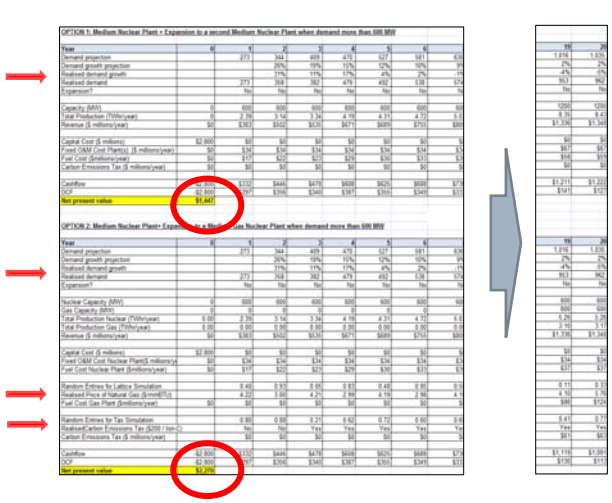
Excel Simulation

Nuclear – Nuclear Option

Nuclear – Gas Option



Sample result for Flexible Option Simulation

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Results

Comparison in terms of ENPV

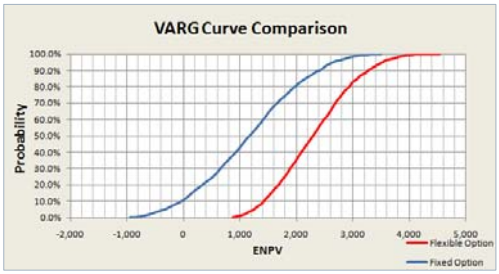
	ENPV (millions)	Standard Deviation (millions)	Average Year of Expansion	Best Alternative to Expand based on ENPV Comparison
Fixed Option	$1,166	$909	---	---
Flex Option (Exp. DR 1)	$2,179	$741	6.71 years	Nuclear Option: 17.55% Gas Option: 82.45%
Flex Option (Exp. DR 2)	$2,267	$709	8.87 years	Nuclear Option: 19.40% Gas Option: 80.60%
Flex Option (Exp. DR 3)	$2,325	$705	12.51 years	Nuclear Option: 20.31% Gas Option: 79.69%

- It is clear that flexible option is more favorable in this case.
- Results affected considerable while changing decision rule that set when to expand. Best results obtained when decision to expand is taken when demand 30% higher than installed capacity (DR 3).

Effect of the Discount Rate

Results

Comparison in terms of Value at Risk and Gain



	ENPV (millions)	P_5 Value (millions)	P_{95} Value (millions)
Fixed Option	$1,166	$ -767	$2,608
Flexible Option	$2,325	$ 943	$3,509

Conclusions

- Since both options presented positive ENPV's, it might be worth to analyze this possibility in Chile.
- Flexible option is more favorable option in terms of profit, risk and return of investment.
- In this case, a certain delay in the decision to expand was beneficial in terms of ENPV because the DR reduced effect of the capital cost of the second plant. This "benefit" outweighed the losses caused by producing less during this time.
- Study provides initial guidance of whether a nuclear (20.3%) or gas power plant (79.7%) is going to be more appropriate if decision to expand turns up. Still, investor have to keep observation in time to take advantage of the flexible design.