Presentation to Princeton University

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by:
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Presentation Overview

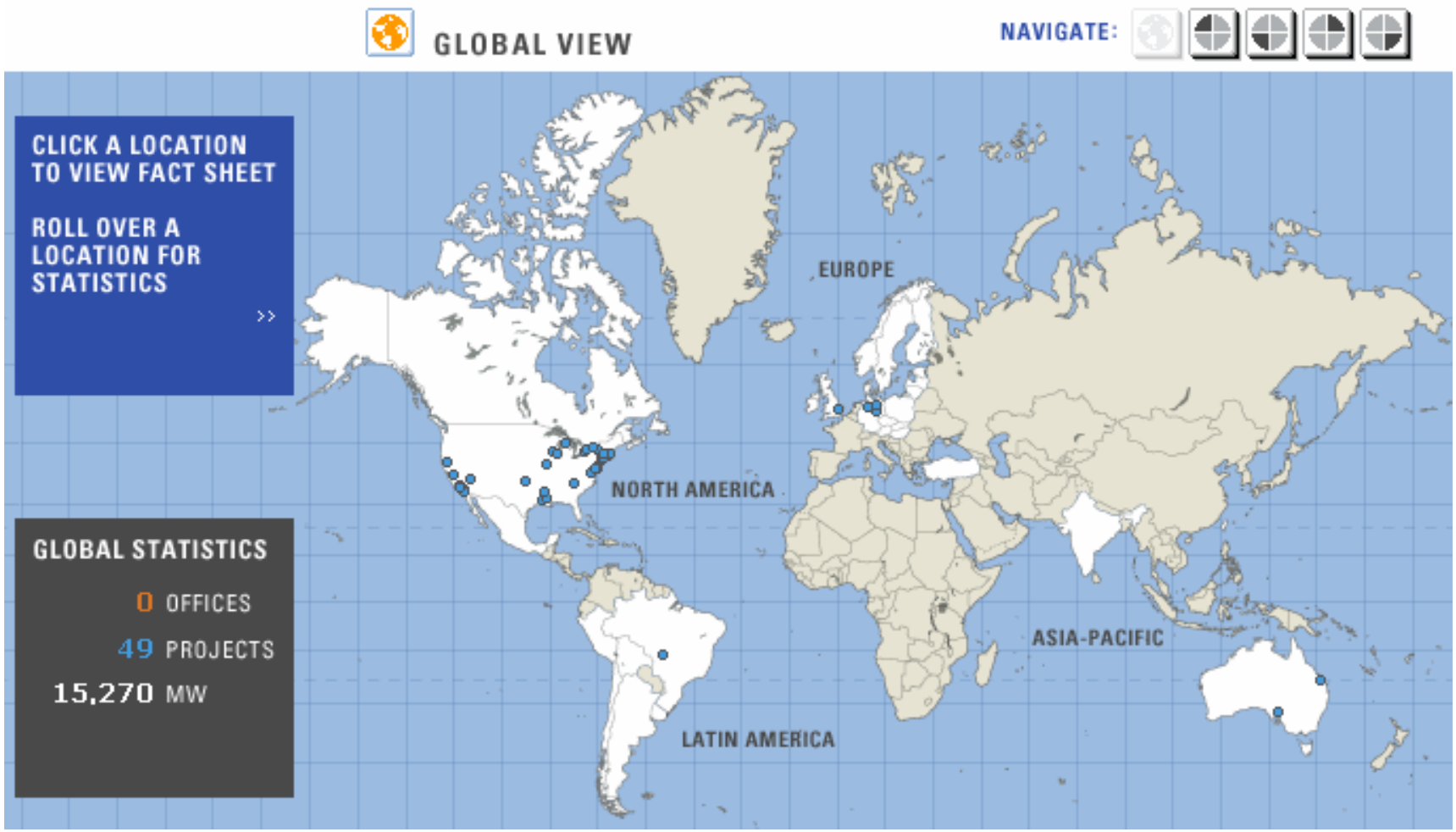
- Introduction
- About structured products in power markets
- Case study: Pricing options in the Alberta electricity market

About NRG Energy

- NRG Energy, a leading competitive energy provider was founded in 1989. NRG owns and operates a variety of energy-related operations worldwide.

  We have one of the industry's most diverse generation portfolios, distinguished by its range in geography, fuel source and dispatch level.

NRG Worldwide



NRG North American Power Marketing

- Real-time dispatch of plants
- Forward power sales
- Short-term and forward fuel purchases
  - Oil
  - Natural gas
  - Coal
- Structured product transactions

What are structured products?

- Financial or physical products that are tailored to the needs of the customer. Such products often have elements that cannot be easily hedged.

Components of structured products in power markets

Will include some of the following:

- Prices of power/gas/coal/oil
- Physical asset parameters
- Load characteristics
- Credit worthiness/margining requirements

Uncertainty!!

Common structured products

- Tolling deals
- Load following deals
- Longer-term contracts with embedded optionality
- Exotic options
- Forced outage insurance

The market for structured products

Structured products are usually transacted between the following market participants:

- Generators/Wholesalers (like NRG)
- Retailers
- Transmission providers
- Speculators (often large financial institutions)

Quantitative Challenges in Power Markets

- Lack of forward curve visibility longer-term
- Market liquidity
- Structural breaks: fluid regulatory environment, technological change, etc.
- Parameter estimation
- Seasonality
- Relationship to underlying supply/demand fundamentals
- Price spikes
- Volatility clustering
- Correlation to underlying fuels used to generate electricity

Case Study: Options In Alberta Electricity Market

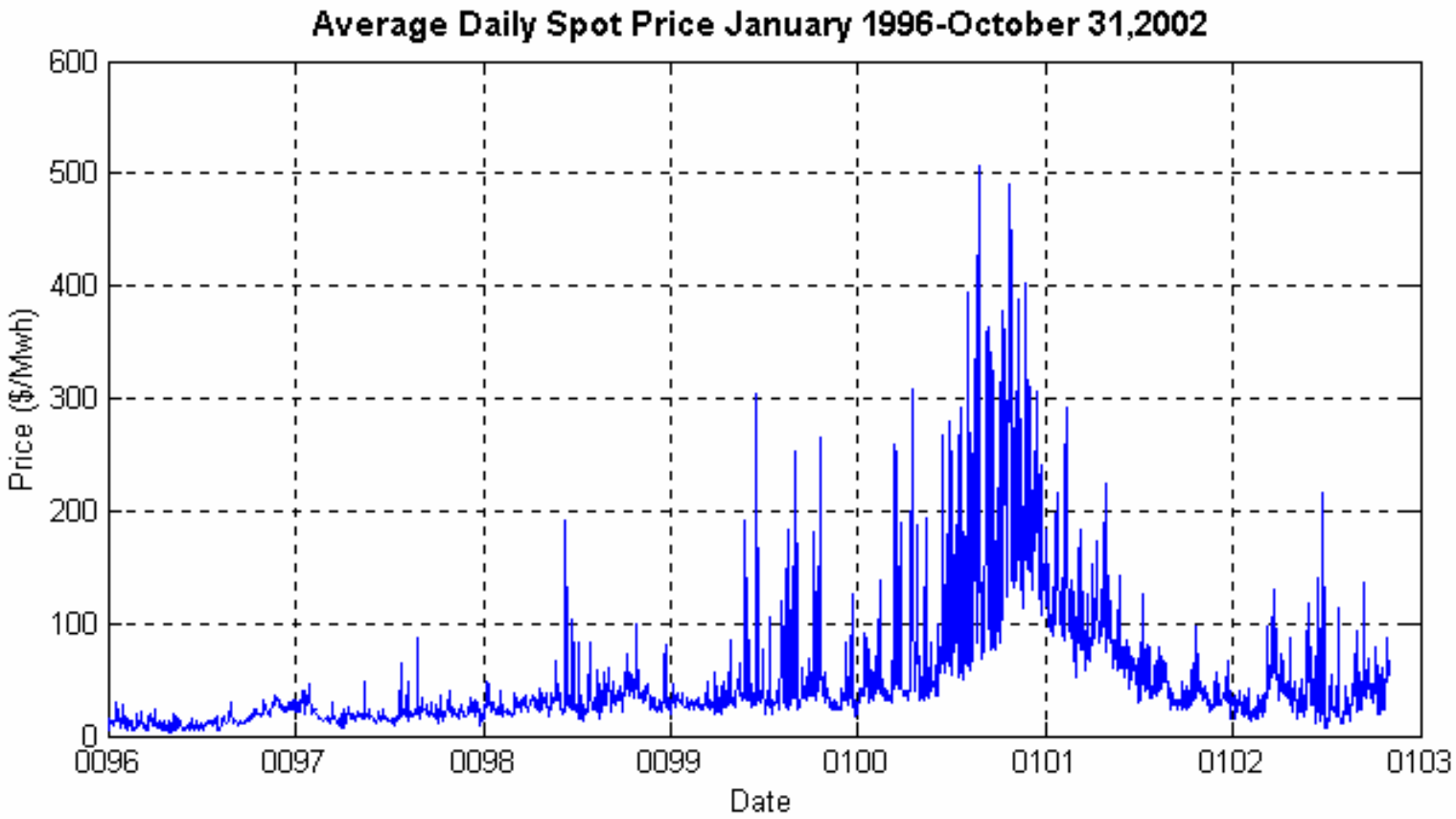
Prepared as part of my Master's thesis, successfully defended September 2003.

Supervisor: Dr. Robert Elliott

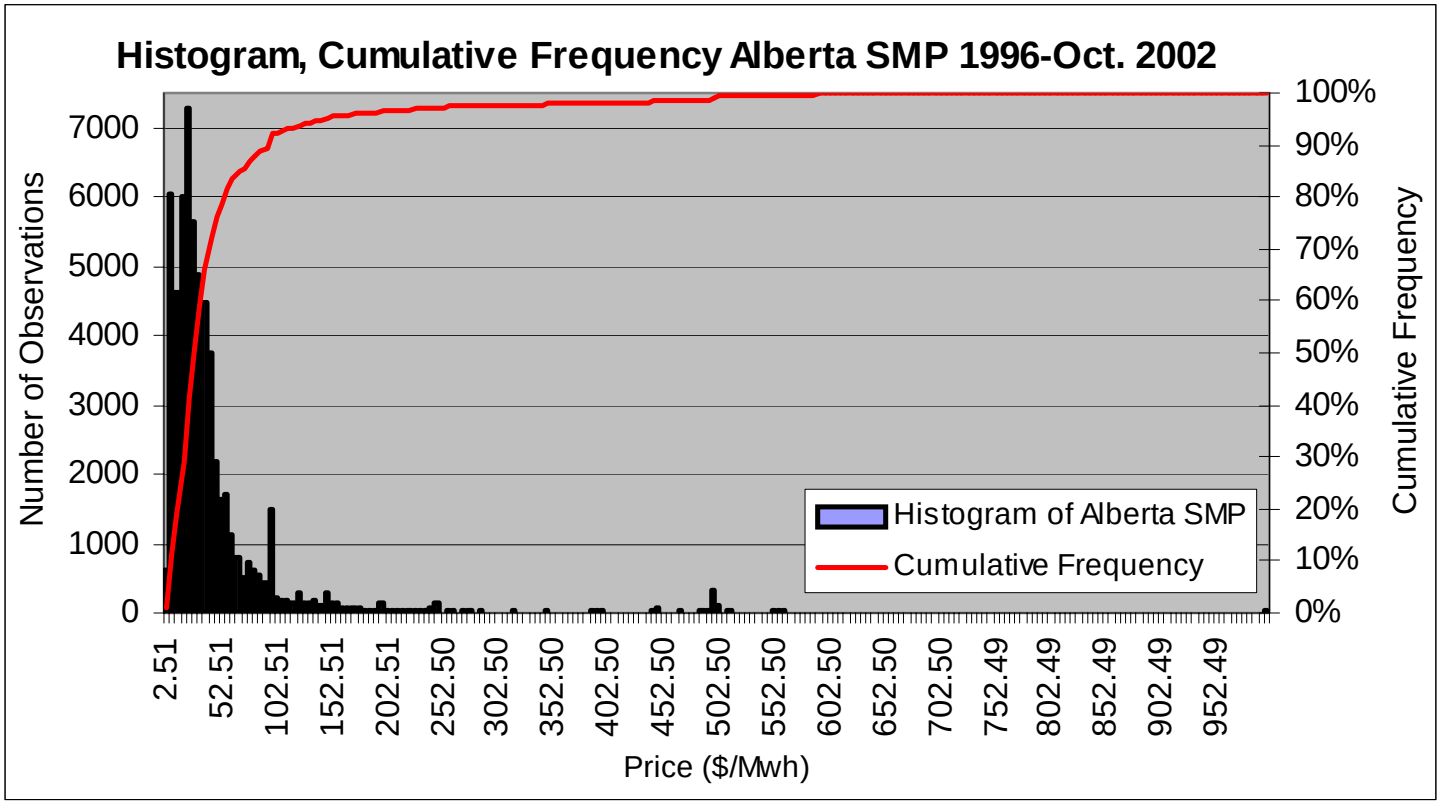
The structured product

- Find the $/Mwh price for a strip of at the money daily call options for a particular month in the Alberta electricity market
- This product is popular in the OTC Alberta electricity market

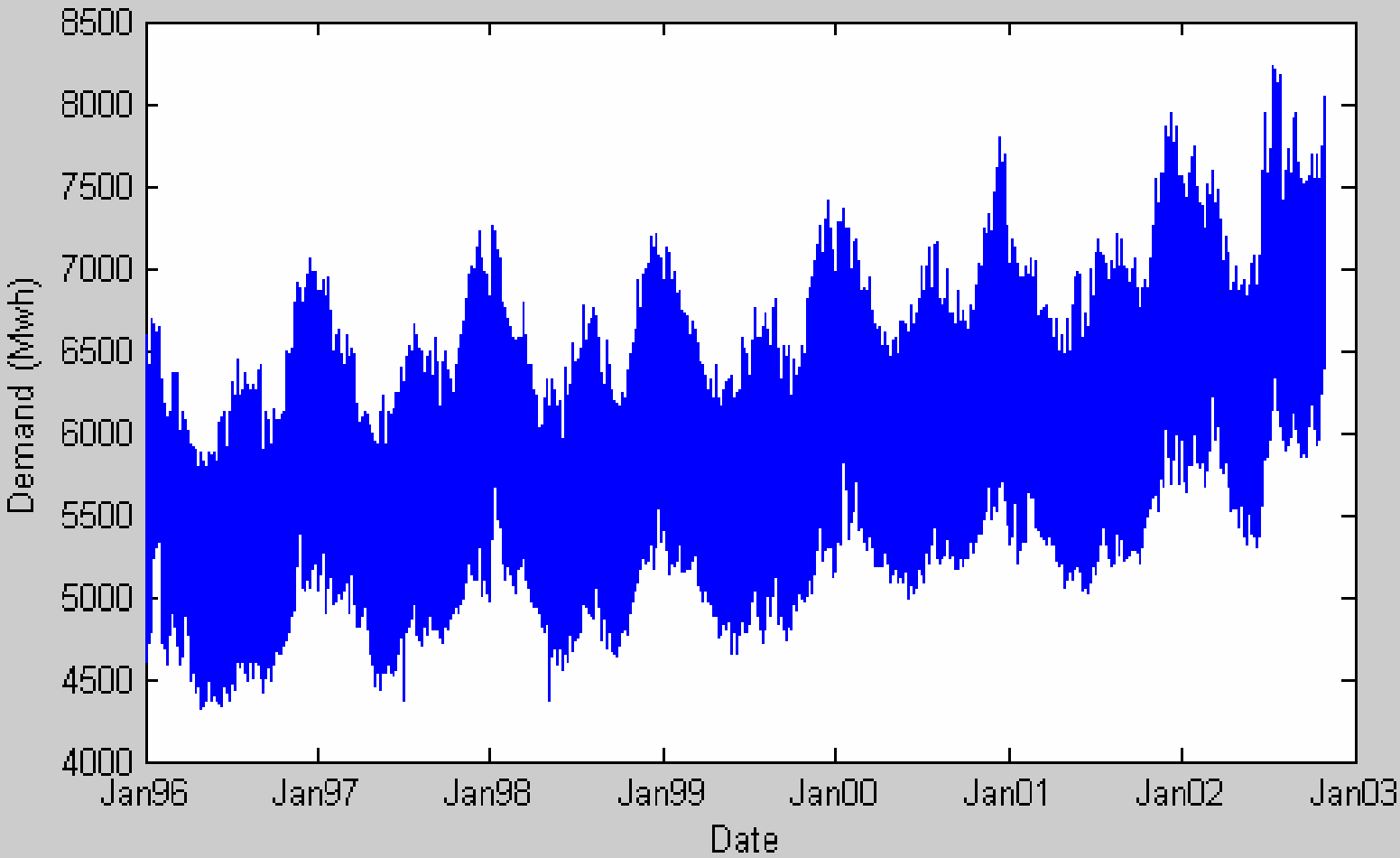
A plot of Alberta daily spot prices



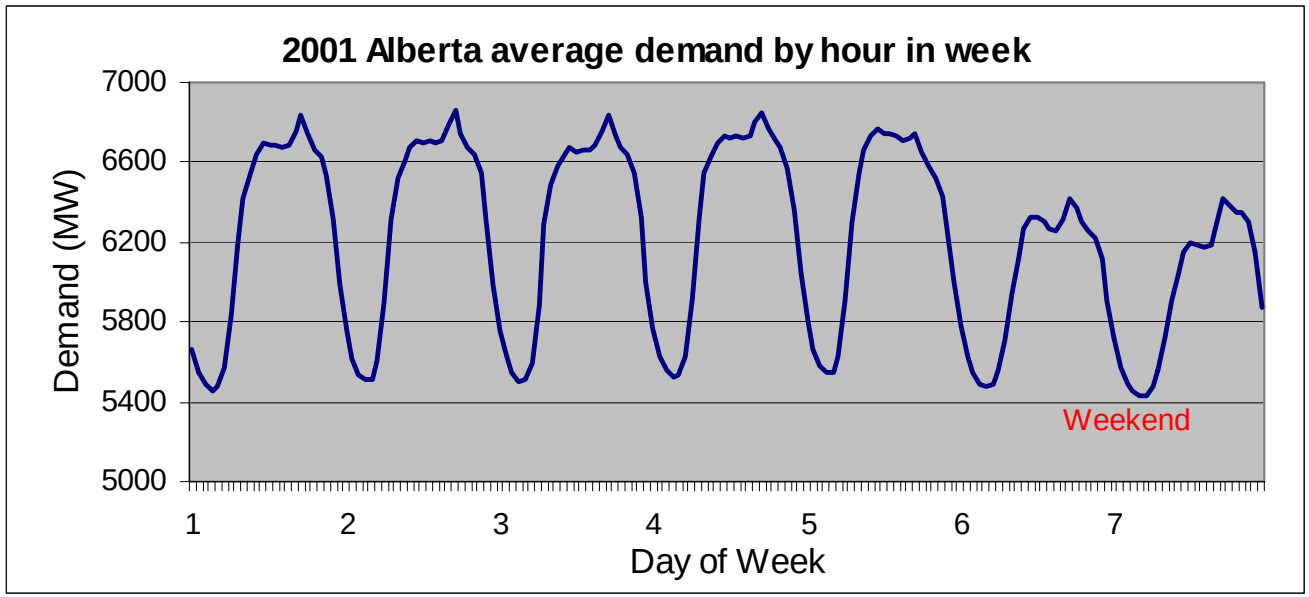
Histogram of spot power prices



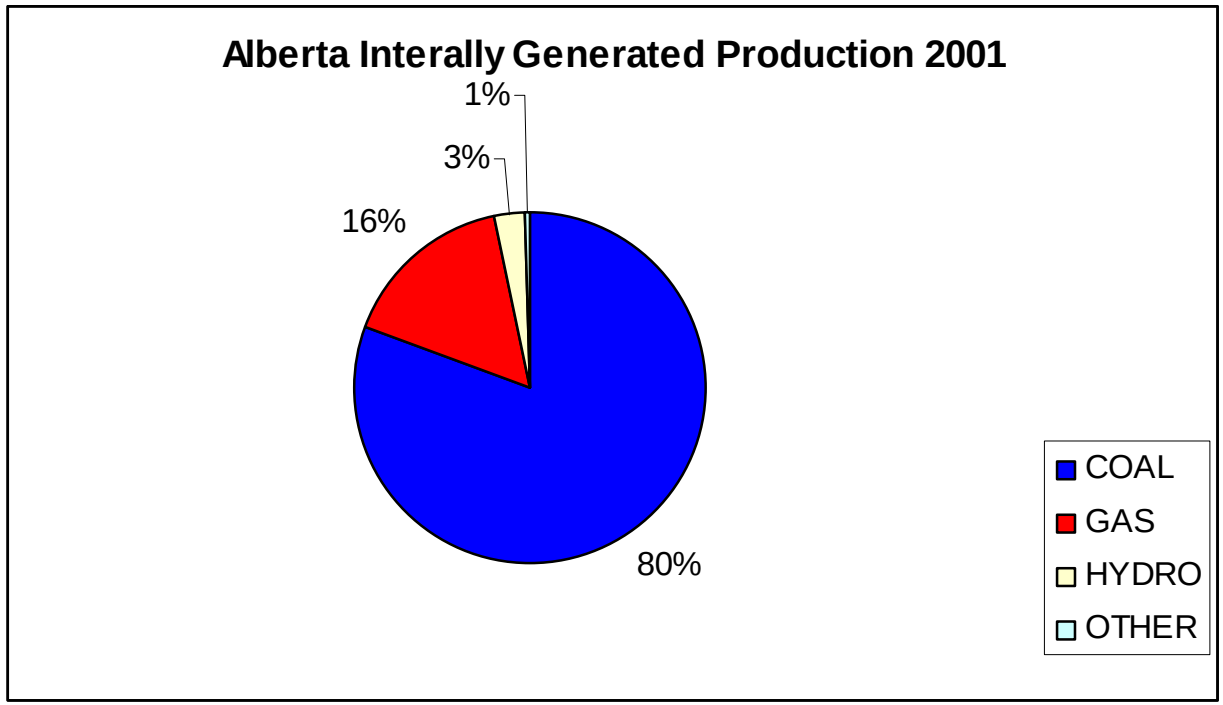
Seasonality of demand (1)



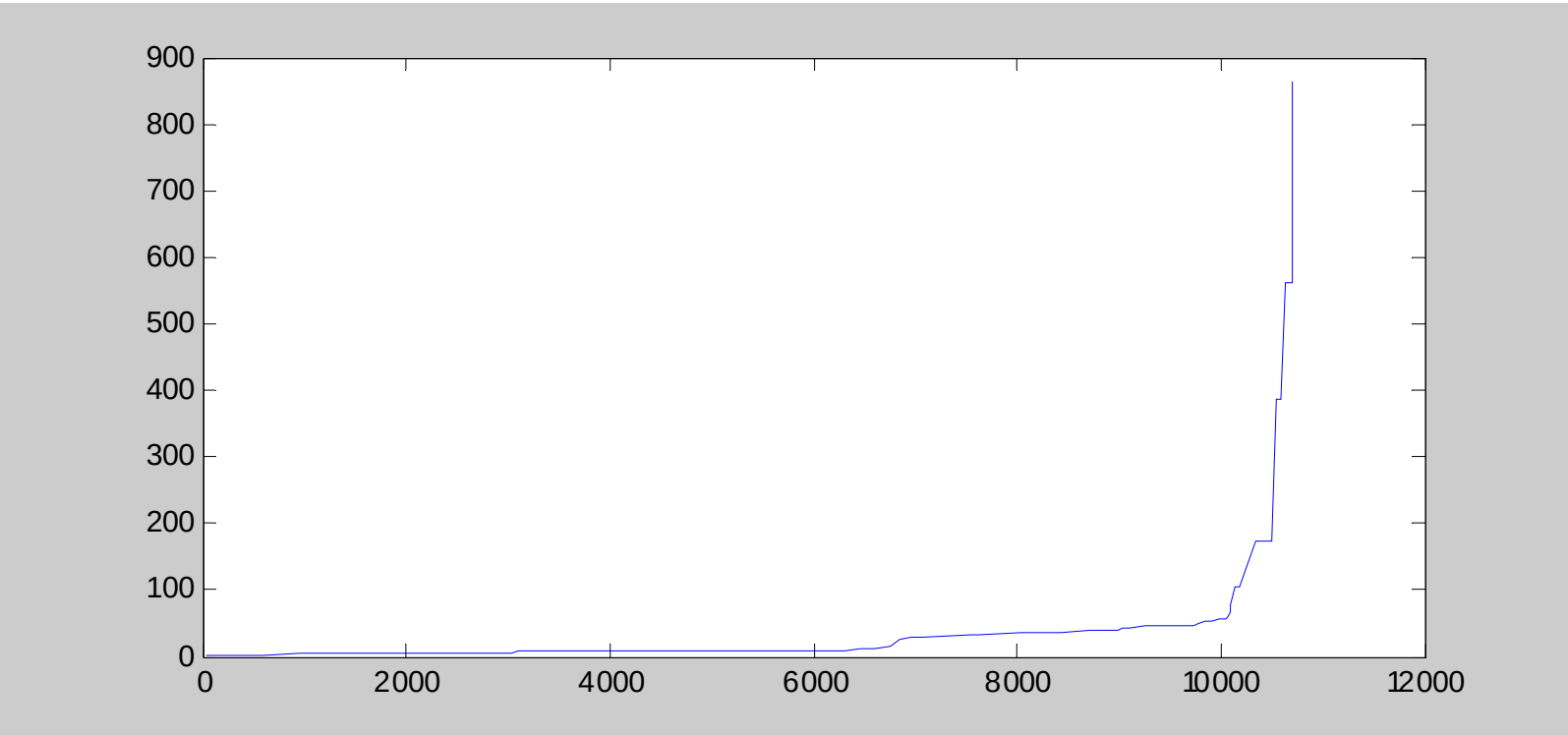
Seasonality of demand (2)



Electricity Production 2001



Illustrative Alberta supply curve



Hourly Transition Probability Matrix

Hourly Transition Probability Matrix: January 1,1996-October 31, 2002							
	from						
	Units On	9	10	11	12	13	14
to	9	0.910345	0.010771	0	0	0	0
	10	0.082759	0.934548	0.010128	0.000169	0	0
	11	0.006897	0.053853	0.955531	0.011866	0.000174	0
	12	0	0.000829	0.033708	0.967945	0.015226	0.000439
	13	0	0	0.000633	0.019908	0.97458	0.020105
	14	0	0	0	0.000112	0.01002	0.979456

Incremental Mean Shock Matrix

Incremental Mean Shock Modified				
State/Quarter	1	2	3	4
9	1	1	1	1
10	1	1.203063	1	1
11	1.110767	1.141521	1.058807	1.048661
12	1.112693	1.216885	1.227774	1.12113
13	1.069425	1.082389	1.119243	1.148778

Correlation of gas and power

Forward Month	2002/11/01	2002/12/01	2003/01/01	2003/02/01	2003/03/01
Correlation Coefficent	0.6895	0.765	0.5963	0.6384	0.6567

Price Dynamics

- Evolution of gas forward curve:

$$\frac{dF(t,T)}{F(t,T)} = \gamma_T dB_t$$

- Evolution of spot price of power (no outages):

$$\frac{dS_E(t,T)}{S_E(t,T)} = \sigma_1 dW_t + \sigma_2 dB_t$$

- Future spot price
- (no outages):

$$S_E(t,T) = S_E(0,T) \cdot exp\left(\sigma_1 W_t + \sigma_2 B_t - \frac{1}{2}\left(\sigma_1^2 + \sigma_2^2\right)t \right)$$

- Evolution of future spot price of power (with outages):

$$\mathrm{E}[\, P_E(T,T) \mid \Im_t \,] = S_E(t,T) < \alpha_\theta, e^{A(T-t)} Z_t >$$

The Formula

$C(t,T,Z_T)=B(t,T)N(d_1)-KN(d_2)$.

Where:

$$d_1 = \frac{1}{\sqrt{T}\sqrt{\sigma_1^2+\sigma_2^2}}\left[ln\left(\frac{B(t,T)}{K}\right)+\frac{T}{2}\left(\sigma_1^2+\sigma_2^2\right)\right]$$

$$d_2 = \frac{1}{\sqrt{T}\sqrt{\sigma_1^2+\sigma_2^2}}\left[ln\left(\frac{B(t,T)}{K}\right)-\frac{T}{2}\left(\sigma_1^2+\sigma_2^2\right)\right]$$

$$B(t,T) =< \alpha_\theta, Z_T > S_E(t,T)$$

$$C(T,K) =< C, e^{A(T-t)} Z_t >$$

$$V(t,T) = \frac{1}{W}\sum_{i=0}^{W-1} C(Z_T, T+i, K)]$$

Initial Results

Average Per Mwh Value of A Strip of Daily Alberta Options By Forward Contract, Marked on October 31, 2002.					
	01-Nov-02	01-Dec-02	01-Jan-03	01-Feb-03	01-Mar-03
Call Option					
Model	2.6200	3.6732	1.9813	2.2058	2.5427
Black Scholes	2.2220	3.8594	3.7080	4.0405	4.5687
	01-Nov-02	01-Dec-02	01-Jan-03	01-Feb-03	01-Mar-03
Put Option					
Model	2.6200	3.6732	4.6225	4.7402	5.0620
Black Scholes	2.2220	3.8594	3.7080	4.0405	4.5687

Modified Results

Estimated Cumulative Shock vector by period							
	Start of the dataset used						
		01-Jan-96	01-Jan-97	01-Jan-98	01-Jan-99	01-Jan-00	01-Jan-01
Units on	9	1.54	1.55	1.64	1.68	1.62	1.56
	10	1.54	1.55	1.64	1.68	1.62	1.56
	11	1.47	1.49	1.57	1.58	1.58	1.56
	12	1.33	1.34	1.41	1.42	1.4	1.5
	13	1.11	1.11	1.13	1.12	1.15	1.19
	14	1	1	1	1	1	1

Associated Option value by maturity Date							
	Start of the dataset used to estimate cumulative shock matrix						
		1-Jan-96	1-Jan-97	1-Jan-98	1-Jan-99	1-Jan-00	1-Jan-01
Maturity date	01-Nov-02	3.23	3.33	3.73	3.89	3.67	3.80
	01-Dec-02	4.10	4.17	4.47	4.59	4.44	4.53
	01-Jan-03	3.79	3.86	4.19	4.31	4.15	4.25
	01-Feb-03	3.92	3.98	4.27	4.38	4.24	4.32
	01-Mar-03	4.23	4.29	4.54	4.64	4.51	4.59

Final thoughts

- In structured product pricing, a merger of economic theory and stochastic analysis is often required.
- Closed form solutions are usually not available. Monte Carlo has proven useful when valuing tolling deals, load following deals, and other exotics.

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