AVANGRID RENEWABLES

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Potential Financial Exposure (PFE)

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Current vs. Future Exposure

Credit risk managers traditionally focus on current exposure (i.e., current mark-to-market (MtM) plus outstanding receivables) and collateral management - Wikipedia.

Even without adding to positions and even without roll off of current positions, MtM evolves over time as market prices evolve. This means potential future credit exposure can be significantly larger than current exposure.

Focusing on current exposure is great, but it doesn't give the foresight needed to approve adequate limits today for what may happen tomorrow.

What does PFE measure?

PFE is a measure of counterparty risk/credit risk. It is calculated by evaluating existing trades done against possible market prices <u>in the future</u> during the lifetime of transactions. It can be called sensitivity of risk with respect to market prices – Wikipedia

Market (price) risk management is also, of course, concerned with market price risk.

<u>What is PFE?</u>

PFE is the maximum expected credit exposure over a specified period of time calculated at some level of confidence - Wikipedia

Example PFE model Output

Year	Max Peak Exposure
2017	$ 98,836,784
2018	$ 104,230,171
2019	$ 102,790,190
2020	$ 97,488,385
2021	$ 90,005,753
2022	$ 81,673,959
2023	$ 73,066,397
2024	$ 64,379,213
2025	$ 55,762,500
2026	$ 47,320,421
2027	$ 39,057,918
2028	$ 30,990,231
2029	$ 23,101,355
2030	$ 15,426,651
2031	$ 7,944,180

These results suggest the maximum potential exposure ($104M) for the position being considered (a 15-year power purchase agreement (PPA)) will occur in 2018. This date is the result of two opposing forces – increased price uncertainty the further out we look and roll off.

The effects of roll off are easy enough to figure out, but how is price uncertainty calculated?

Presentation Overview

1. Introduction – we just went through this and ended with the question "… how is price uncertainty calculated?"

2. Give the question some context

3. Types of VaR (Value at Risk)

4. How to simulate price(s) in Excel

5. Some final thoughts

What Do You (in Credit) and I (in market price risk management) Worry About?

- Market Risk Management:

  How much might our business's mark-to-market (MtM) decrease between, say, today and tomorrow.

- Credit Risk Management: How much might a counterparty owe me if they default and what's the chance they might default in, say, the next few years.

How Much Might They Owe Me?

accounts receivable/payable

+

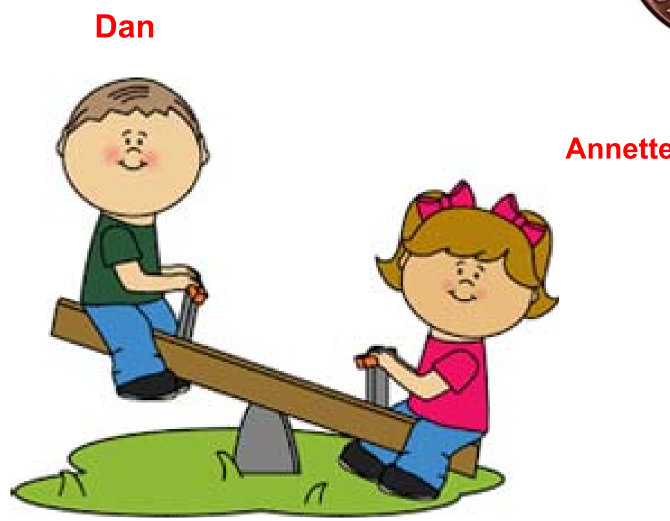
MtM

or

contract replacement cost

Market Risk and Credit Risk

Market Risk worries when we owe them



Credit Risk worries when they owe us

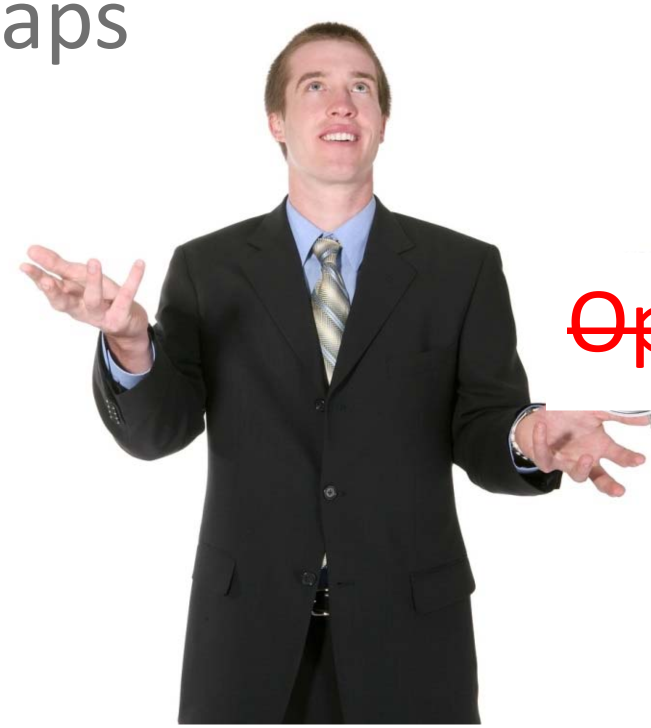
Because our worries are similar (two sides of the same coin), in particular, both of us worry about potential price movements, some market price risk management techniques are useful for credit risk management.

Some Power and Gas Market Instruments

Futures

Forwards

Swaps



~~Options~~

Forward Contract

a non-standardized contract between two parties to buy or to sell an asset at a specified future time at a price agreed upon today – Wikipedia.

Differences Between Futures and Forwards

futures

– trade on exchanges

Margined daily – means little or no credit risk.

forwards

– don’t

Settles at expiry, i.e., at maturity, means there can be significant credit risk.

Forwards vs. Swaps

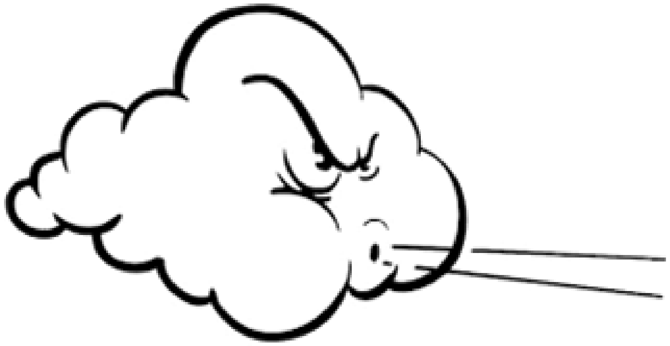
"… a Forward has only a single payment at maturity while a Swap involves a series of payments in the future. In fact, a single-period Swap is equivalent to one Forward contract."

http://digiconomist.net/swaps-forwards-and-futures/

MTM Example

- Product: A long, 25 MW, Mid-C, On Peak, June 2017 delivery forward at $14.50/MWh.
- Quantity (MWhs) = power (MW) x June 2017 On Peak hours = 25 MW x 416 hours = 10,400 MWhs

Time	Market Price ($/MWh)	Mark-to-Market
Execution Time 11:30 a.m., March 29, 2017	14.50	$0
Close of Business March 29, 2017 (16:00 p.m.)	14.75	= 10,400 MWhs x ($14.75/MWh – $14.50/MWh) = $2,478
Close of Business March 30, 2017 (16:00 p.m.)	14.75	= 10,400 MWhs x ($14.75/MWh – $14.50/MWh) = $2,478
…		
Close of Business April 6, 2017 (16:00 p.m.)	16.25	$18,189
…		
Close of Business April 13, 2017 (16:00 p.m.)	15.50	= 10,400 MWhs x ($15.50/MWh – $14.50/MWh) = $10,390
…		



MtM or Exposure can be Sensitive to Volume as well as Price Changes.

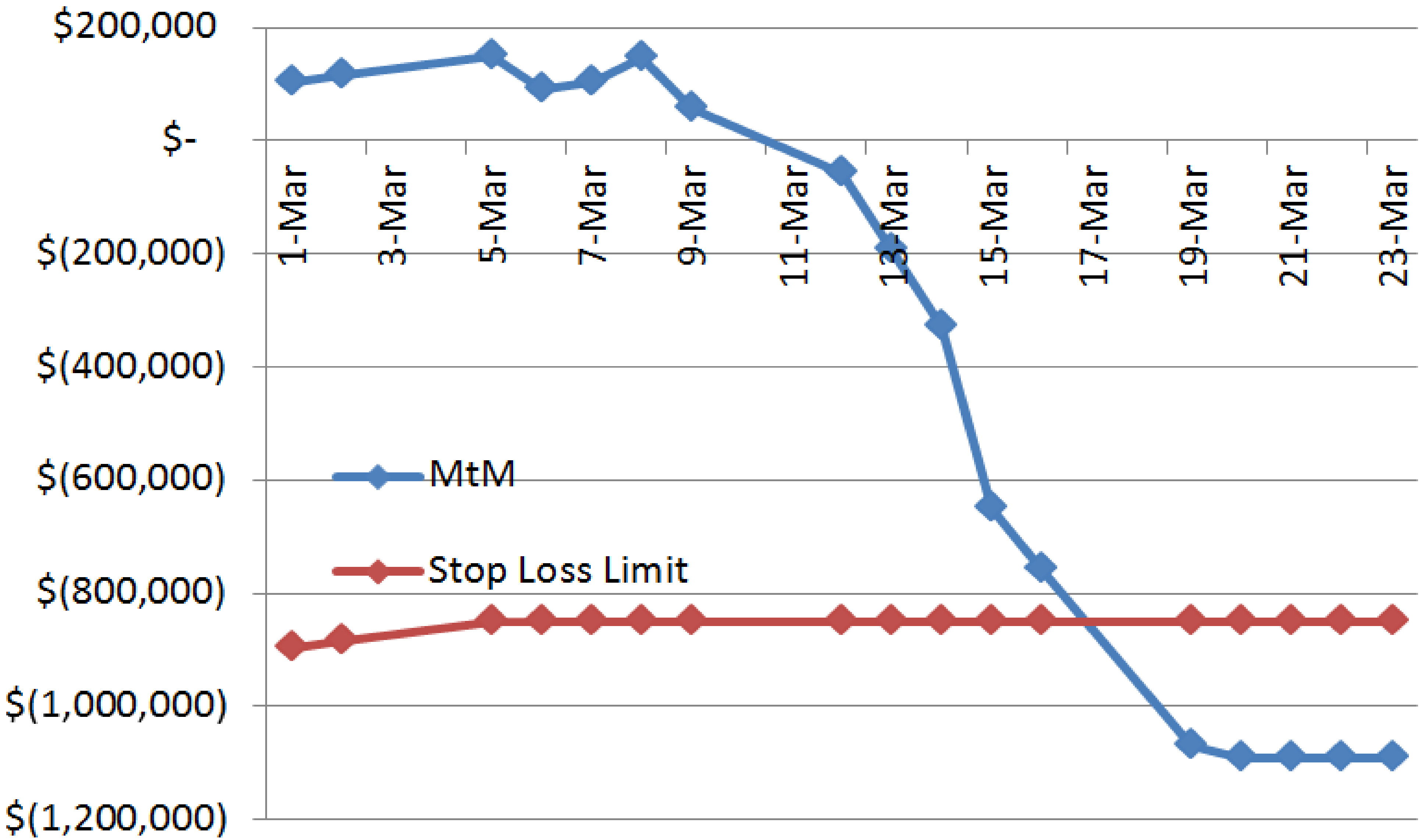
PFE only considers potential commodity market price changes and not potential volume changes due to unexpected weather, force majeure, fat finger errors, etc.

VaR – a Market Risk Management Tool

- VaR or Value at Risk is my best guess at to how much the MtM of my positions might decrease in a short time due to price changes.
- There's always a time horizon and always a confidence level for a VaR.
- For example, right now my one-day, 95% VaR might be, say, $2,000,000. That means I think there's a 5% (= 100% - 95%) or one-in-twenty chance my MtM will decrease by <u>more than</u> $2,000,000 by this time tomorrow.
- VaR limits are to manage future MtM decreases.

Stop Loss limits

are for managing actual MTM losses



PFE

- A Credit Risk Management Tool

PFE is my best guess as to, at some confidence level, how much a counterparty might owe me if they default sometime in the future.

PFE combines stop loss and VaR limits(or, rather the opposites of stop loss and VaR limits). Stop loss limits and VaR limits manage potential MtM losses. PFE estimates potential MtM gains.

Finally, again, from page 4: "…how is price uncertainty calculated?"

- VaR calculations include a calculation of future price uncertainty. Can we use this calculation in the PFE calculation?

- Actually, there are three different methods for calculating potential future price for VaR.

Historical VaR Method

- In the Historical VaR method, past price returns (percentage changes in prices) are used as proxies for future price returns.
- This works great for VaR, which estimates how much MtM might change in, say, a day.
- In, say, four years of historical price data, there are around 1,000 price returns.
- This doesn't work well for calculating the PFE of, say, a 4-year PPA. There is only one 4-year price return in four years of historical data.

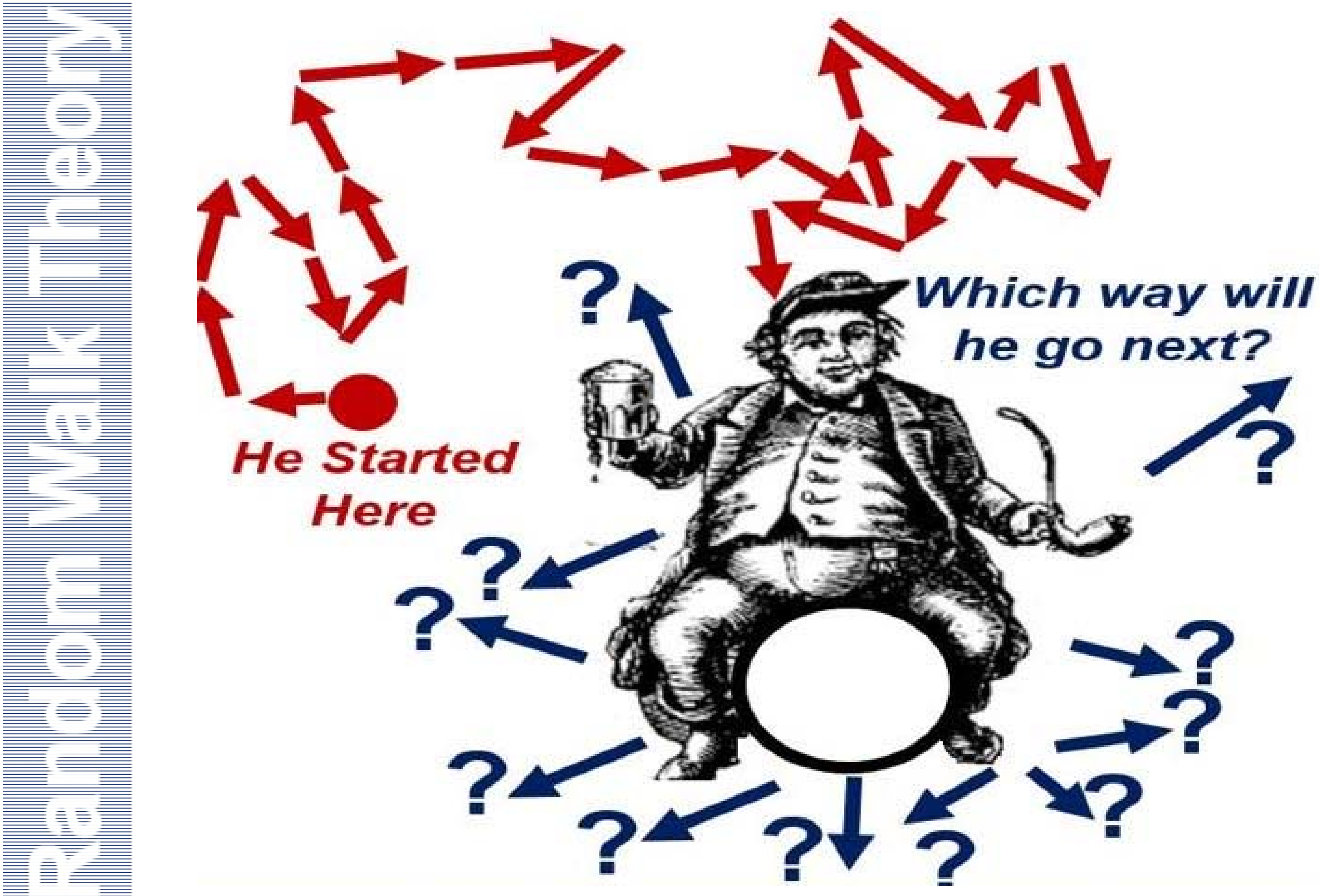
Delta-Normal VaR

- In the delta-normal VaR method, future prices are assumed to be normally distributed.
- While this is (arguably) a good approximation for the distributions of prices one day from now, it is not a good approximation for the distributions of prices months or years from now. In particular, it allows for large, negative prices far in the future.

Monte Carlo VaR

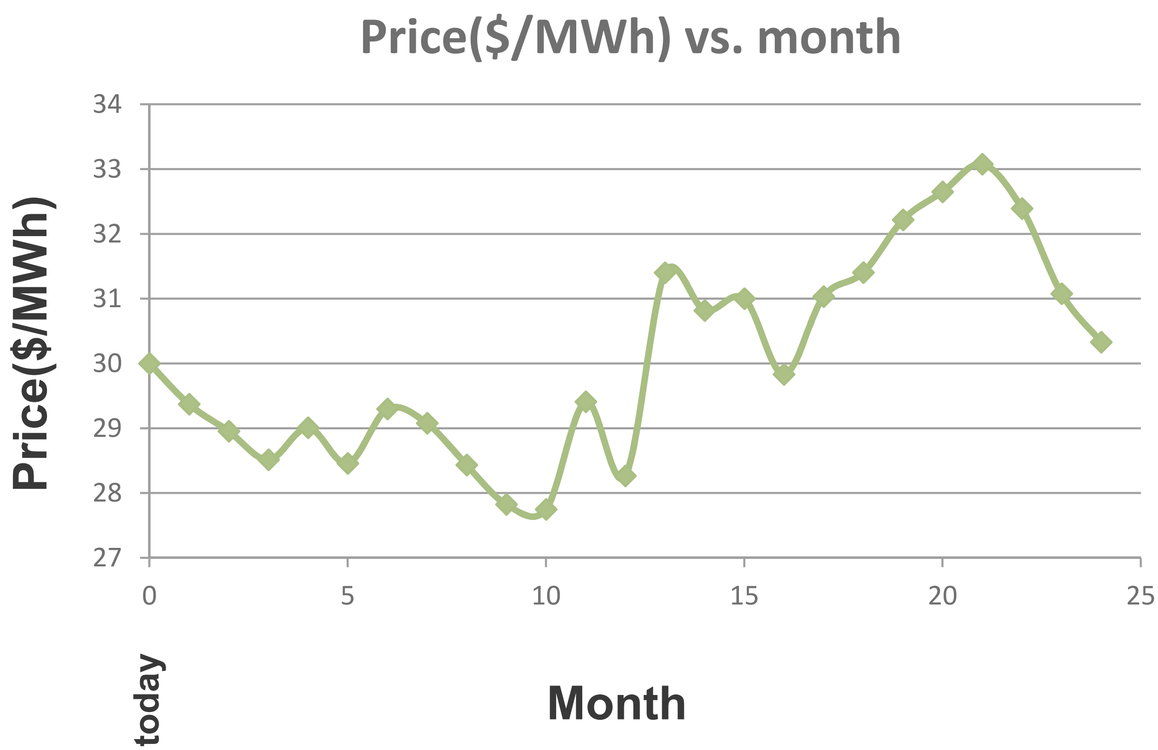
- The Monte Carlo method assumes price returns (rather than future prices) are normally distributed.
- This method is good (or, at least, as good as its inputs) for both short term and long term price forecasts.
- So, PFE uses this method (Monte Carlo price simulations) in its calculations.

Monte Carlo VaR: Prices follow random walks

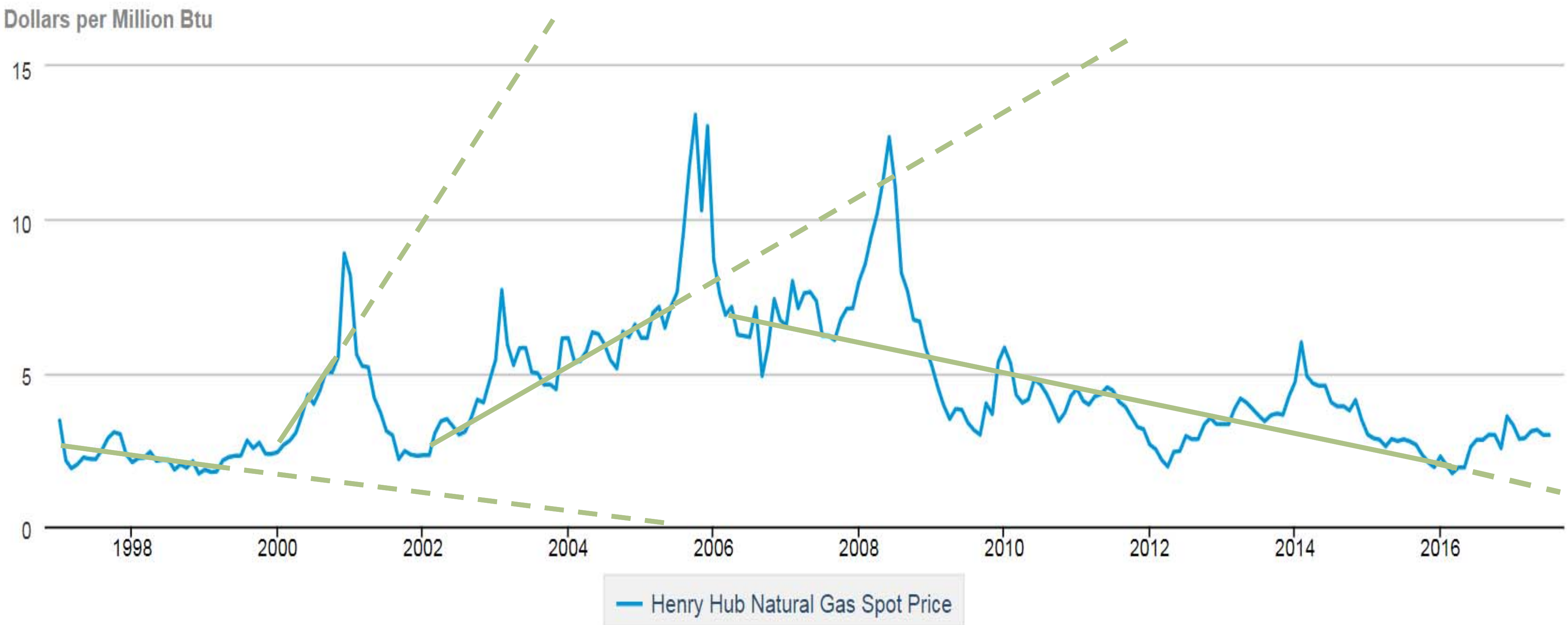


Price Random Walk Example

Below is one possible evolution of a price following "Geometric Brownian Motion", which is a fancy way of saying "a random walk". I simulated this in Excel.

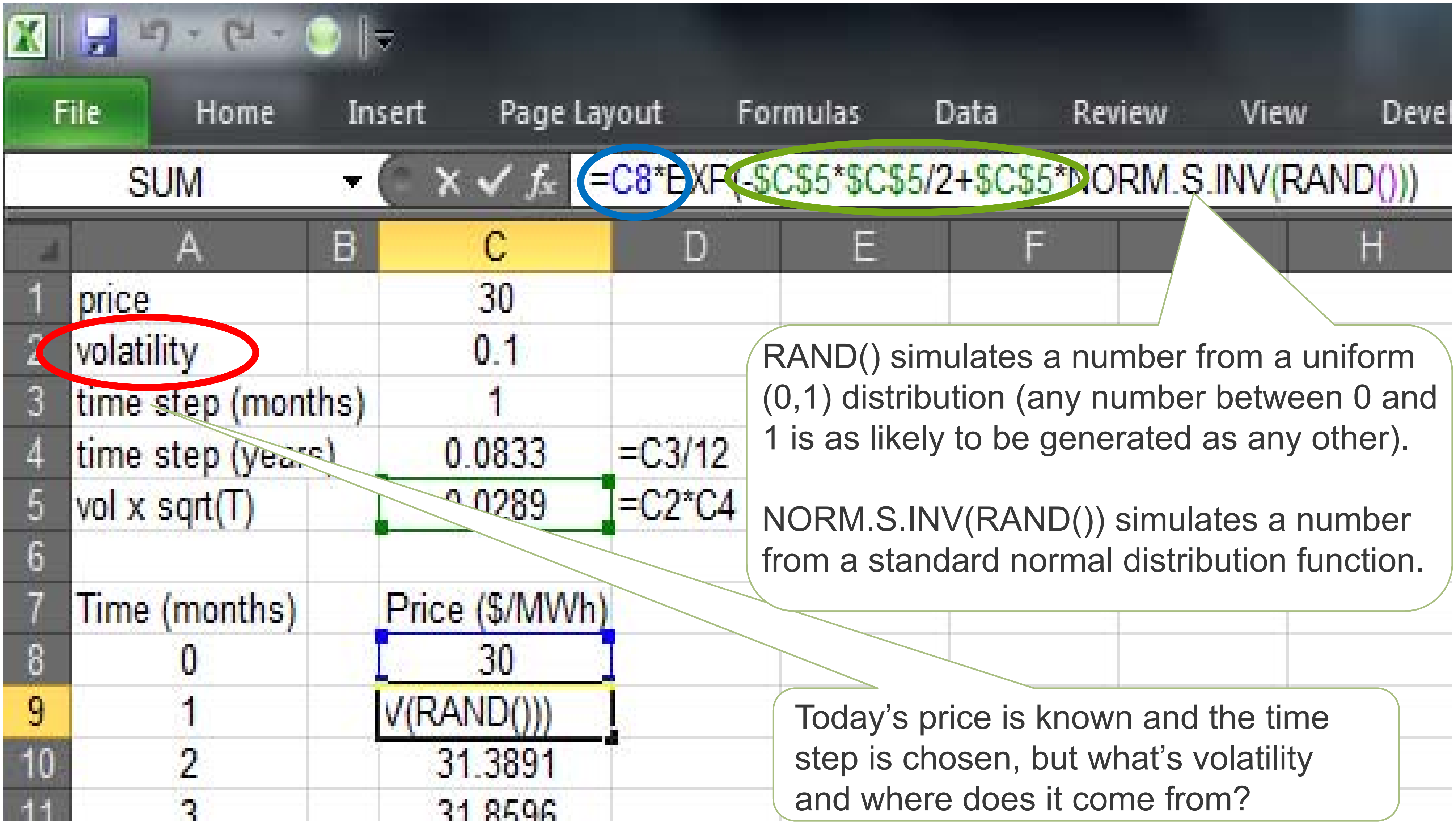


Historical Henry Hub Prices – prices can drift but including drift in forecasts can be dangerous.



IS1

Monte Carlo Simulation in Excel of Geometric Brownian Motion (without drift)



Slide 26

IS1 Iberdrola S.A., 9/14/2017

Volatility

- The standard deviation of price returns, commonly referred to as price volatility or simply volatility, is used in VaR calculations and option value calculations.

There are two types of price returns – arithmetic and geometric.

There's usually little difference between the two.

Geometric is always used for pricing options and is commonly used for VaR calculations.

Each daily volatility shown at the top of the table on the right is the standard deviation of the daily price returns below it.

The annual volatilities are the daily volatilities multiplied by the square root of the number of business days in a year, which is often assumed to be 252.

Daily Volatility		4.353%	4.350%
Annual Volatility		69.100%	69.056%
POD	MIDC_H		
Tenor	1-Jun-17		
Stamp Date	Price	Daily Returns	
2-Mar-17	12.5		
3-Mar-17	13.5	8.00%	7.70%
6-Mar-17	13.5	0.00%	0.00%
[illegible]	[illegible]	-9.26%	-9.72%
[illegible]	[illegible]	0.00%	0.00%
[illegible]	[illegible]	6.12%	5.94%
10-Mar-17	13.4	3.08%	3.03%
13-Mar-17	13.9	3.73%	3.66%
14-Mar-17	13.25	-4.68%	-4.79%
15	[illegible]	-3.77%	-3.85%
16	[illegible]	0.00%	0.00%
17	[illegible]	6.67%	6.45%
20	[illegible]	2.94%	2.90%
21-Mar-17	15	7.14%	6.90%
22-Mar-17	15.3	2.00%	1.98%
23-Mar-17	16.25	6.21%	6.02%
24-Mar-17	16	-1.54%	-1.55%
27-Mar-17	15.25	-4.69%	-4.80%
28-Mar-17	15.75	3.28%	3.23%
29-Mar-17	14.75	-6.35%	-6.56%
30-Mar-17	14.75	0.00%	0.00%
31-Mar-17	15.75	6.78%	6.56%
3-Apr-17	15.5	-1.59%	-1.60%
4-Apr-17	15.75	1.61%	1.60%
5-Apr-17	15.75	0.00%	0.00%
6-Apr-17	16.25	3.17%	3.13%
7-Apr-17	16.25	0.00%	0.00%
10-Apr-17	16.75	3.08%	3.03%
11-Apr-17	16	-4.48%	-4.58%
12-Apr-17	16	0.00%	0.00%
13-Apr-17	15.5	-3.13%	-3.17%

=(13.5-12.5)/12.5

arithmetic rate of return

= ln(13.5/12.5)

geometric rate of return or log return

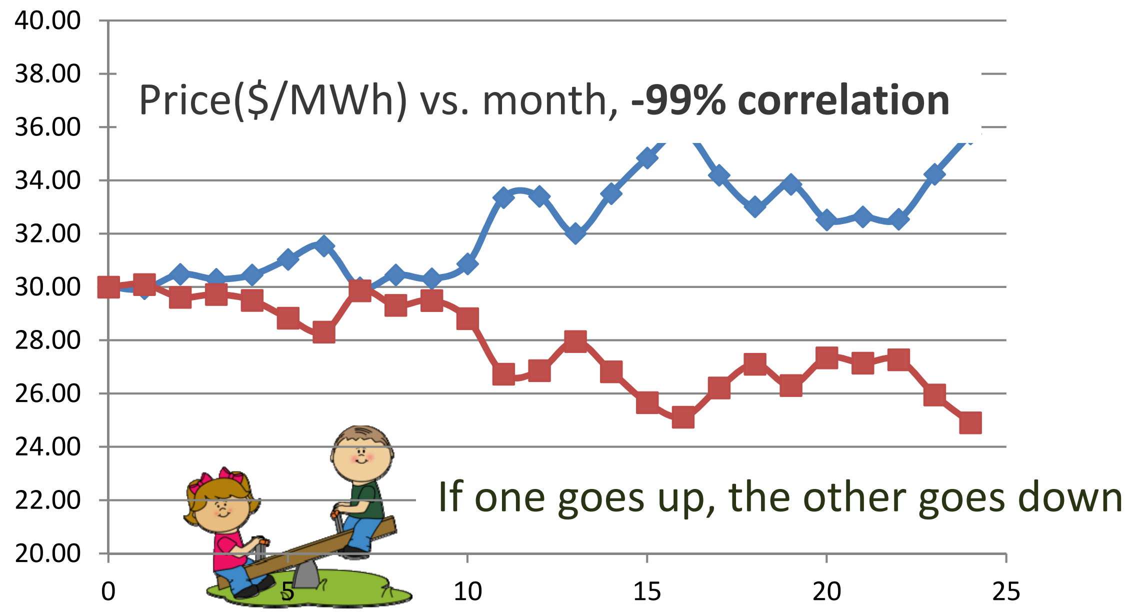
More than one price: Uncorrelated motion

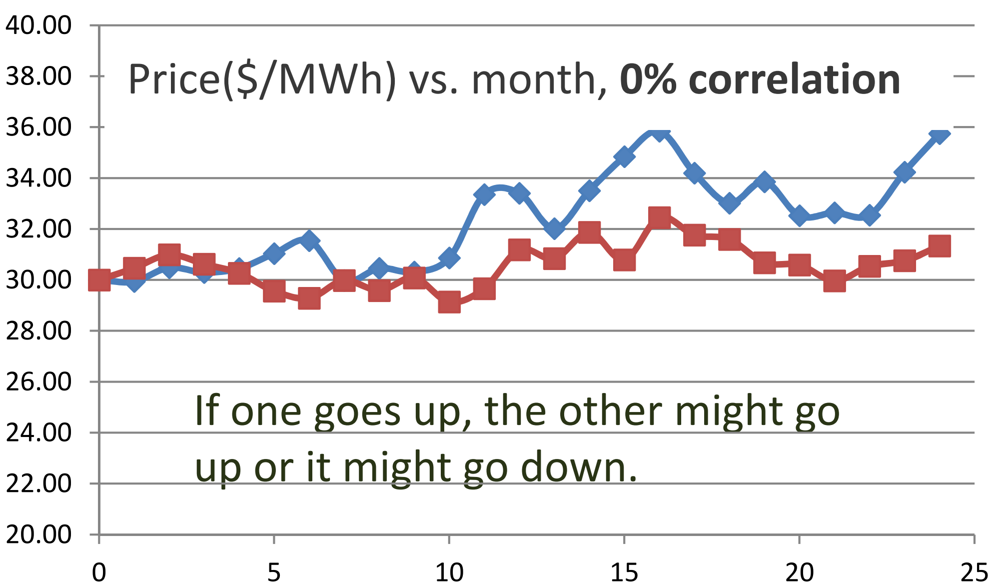
- Although each person (or price, say, the prices for Jan., Feb. March, etc., 2018 delivery) may be moving a lot, the group isn't moving much.

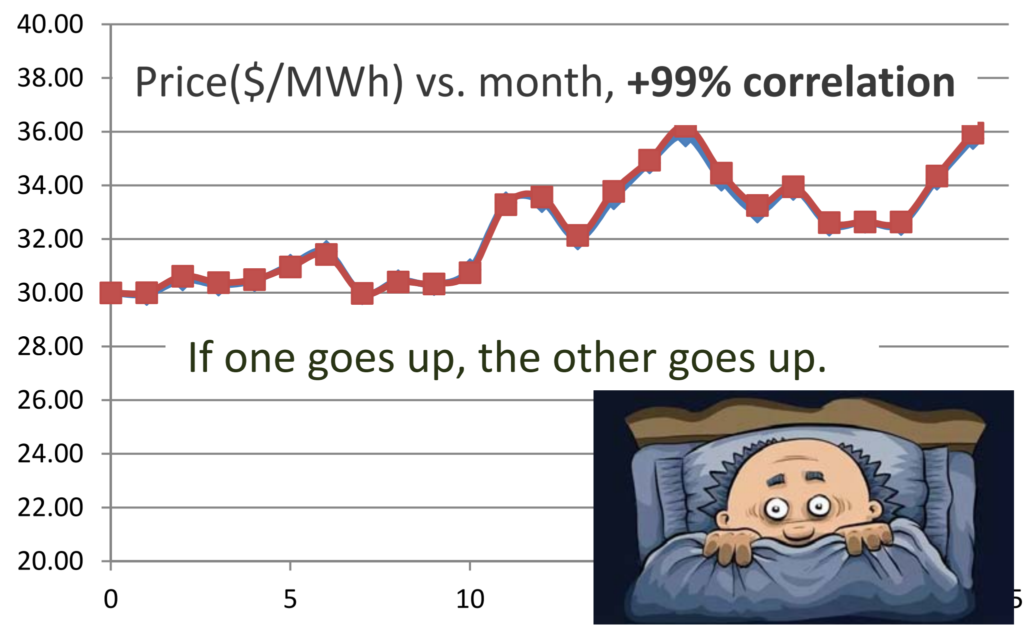
Correlated Motion

- Each person (price) is moving in step with every other person (price), which means as a group they are moving a lot in one direction.
- So, as you might imagine, the greater the correlation between potential price movements, the greater the PFE.

Simulation of Two Prices Following Brownian Motion (without drift)







Simulation of Two Correlated Prices Following Brownian Motion (without drift)

V17

	A	B	C	D	E	H	I
1	price		30	30			
2	volatility		0.1	0.1			
3	time step (months)		1				
4	time step (years)		0.0833	=C3/12			
5	vol x sqrt(T)		0.0289	=C2*C4			
6	correlation between months						-99%
7							
8	Time (months)					Price 1 ($/MWh)	Price 2 ($/MWh)
9	0					30.00	30.00
10	1		2.14	-0.04	-2.13	31.90	28.20
11	2		0.07	0.65	0.03	31.95	28.21
12	3		-1.45	1.15	1.59	30.63	29.53
13	4		-0.21	-0.72	0.10	30.43	29.60
14	[illegible]		[illegible]	0.45	0.22	30.28	29.78
15	6		1.93	-1.31	-2.09	32.00	28.02
16	7		[illegible]	-0.58	-1.34	33.18	26.95
17	8		0.76	2.21	-0.44	33.91	26.59
18	[illegible]		[illegible]	-1.27	0.80	32.94	27.20
19	[illegible]		[illegible]	0.46	-0.64	33.61	26.70
20	11		[illegible]	[illegible]	-0.02	33.59	26.67
21	12		-0.61	0.91	0.73	32.99	27.23
22	13		[illegible]	[illegible]	[illegible]	32.55	27.42
23	14		0.90	0.48	-0.82	33.40	26.76

=NORM.S.INV(RAND())

=NORM.S.INV(RAND())

=I$6*$C10+SQRT(1-I$6*I$6)*$D10

=F9*EXP(-$C$5*$C$5/2+$C$5*C10)

=I9*EXP(-$C$5*$C$5/2+$C$5*E10)

Simulation of Three Correlated Prices Following Brownian Motion (without drift)

	A	B	C	D	E	F	G	H	I	J
1	price		30	30	30					
2	volatility		0.1	0.1						
3	time step (months)		1							
4	time step (years)		0.0833	=C3/12						
5	vol x sqrt(T)		0.0289	=C2*C4						
6	correlation between months		-99%							
7										
8	Time (months)							Price 1 ($/MWh)	Price 2 ($/MWh)	Price 3 ($/MWh)
9	0		Shock 1		Shock 2		Shock 3	30.00	30.00	30.00
10	1		0.29	0.34	-0.24	-0.30	0.20	30.24	29.78	30.16
11	2		-0.06	-0.97	-0.07	-1.01	-0.07	30.17	29.70	30.09
12	3		-0.96	-0.31	0.90	1.53	-0.68	29.34	30.48	29.49
13	4		0.99	1.24	-0.81	-1.38	0.60	30.18	29.76	30.00
14	[illegible]		[illegible]	-0.19	-0.77	0.02	0.76	30.82	29.10	30.65
15	6		-1.16	0.69	1.25	0.60	-1.15	29.80	30.15	29.64
16	7		[illegible]	0.05	0.62	-0.91	-0.74	29.26	30.68	29.00
17	8		-2.00	-1.40	1.79	-0.56	-1.85	27.60	32.29	27.48
18	[illegible]		[illegible]	[illegible]	-0.06	-0.25	0.02	27.83	32.23	27.49
19	[illegible]		[illegible]	[illegible]	1.05	-0.06	-1.05	26.91	33.21	26.65
20	11		-0.80	-0.58	0.71	0.21	-0.68	26.28	33.88	26.13
21	12		[illegible]	[illegible]	-0.87	-0.03	0.86	27.01	33.03	26.77
22	13		0.71	-0.12	-0.72	-1.17	0.55	27.56	32.33	27.19
23	14		[illegible]	[illegible]	[illegible]	0.19	0.54	27.89	31.84	27.60
24	15		[illegible]	[illegible]	[illegible]	0.12	-0.30	27.53	32.12	27.35
25	16		1.27	-1.42	-1.46	0.47	1.51	28.54	30.78	28.56
26	17		1.76	[illegible]	[illegible]	[illegible]	[illegible]	30.02	29.39	29.77
27	18		-0.39	0.48	0.45	0.76	-0.34	29.67	29.77	29.47
28	19		-0.16	-0.18	[illegible]	[illegible]	[illegible]	29.52	29.87	29.37
29	20		-1.35	-0.59	1.25	-0.52	[illegible]	[illegible]	[illegible]	28.26
30	21		0.91	0.03	-0.89	-0.19	[illegible]	[illegible]	[illegible]	28.96
31	22		0.12	-1.10	-0.28	-1.25	0.10	29.21	29.91	29.02

=NORM.S.INV(RAND())

=NORM.S.INV(RAND())

=$C$6*C10+SQRT(1-$C$6*$C$6)*D10

=NORM.S.INV(RAND())

=$C$6*E10+SQRT(1-$C$6*$C$6)*F10

=F9*EXP(-$C$5*$C$5/2+$C$5*C10)

=I9*EXP(-$C$5*$C$5/2+$C$5*E10)

=J9*EXP(-$C$5*$C$5/2+$C$5*G10)

A Few Generalizations and An Opinion

- PFE increases with increasing monthly position size, position lifetime, volatility, and correlation.

- PFE cannot be measured accurately (Can anyone accurately predict a distribution of what prices might be, say, five or ten years from now?), but it can still be useful as a good relative measure of credit risk if calculated in a consistent manner and at regular intervals.