An Overview of Using Dynamic Discounted Cash Flow and Real Options to Value and Manage Petroleum Projects

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Presentation agenda

- Valuation in the petroleum industry
- Valuation influences: Uncertainty, structure and value estimation
- A simple demonstration of DCF and RO value mechanics
- Modelling output and input prices
- Case study #1: Long-term cash flows at a SAGD project
- Case study #2: Equity and government cash flows at a coal bed methane project
- Case study #3: Valuing a dual-fuel boiler at a SAGD project
- Final comments

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Economic assessment – Financial market and real asset disconnect

- An economically viable project generates after-tax operating profits sufficient to pay capital and financing costs and provide a return compensating for the project's unique uncertainty profile.
  - Each project has its own uncertainty and risk characteristics that should be recognized in an economic analysis.
- There are many methods of assessing economic viability including net present value, internal rate of return, payback period, present value index, breakeven analysis etc.
- Net present value (NPV) is the most robust method of determining economic viability.
  - NPV is the value added to an organization by investing in the project and represents the value of the project on an open market.

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Evolution of valuation – Financial market and real asset disconnect

- Valuation methods for financial assets have experienced monumental changes since the early 1970's –

  Introduction of derivative valuation methods, and new products and markets (e.g. credit derivatives)

- Valuation of real assets in the natural resource industries has not experienced the same degree of change –

  Important advances have been made on the technical side but valuation has only experienced incremental changes

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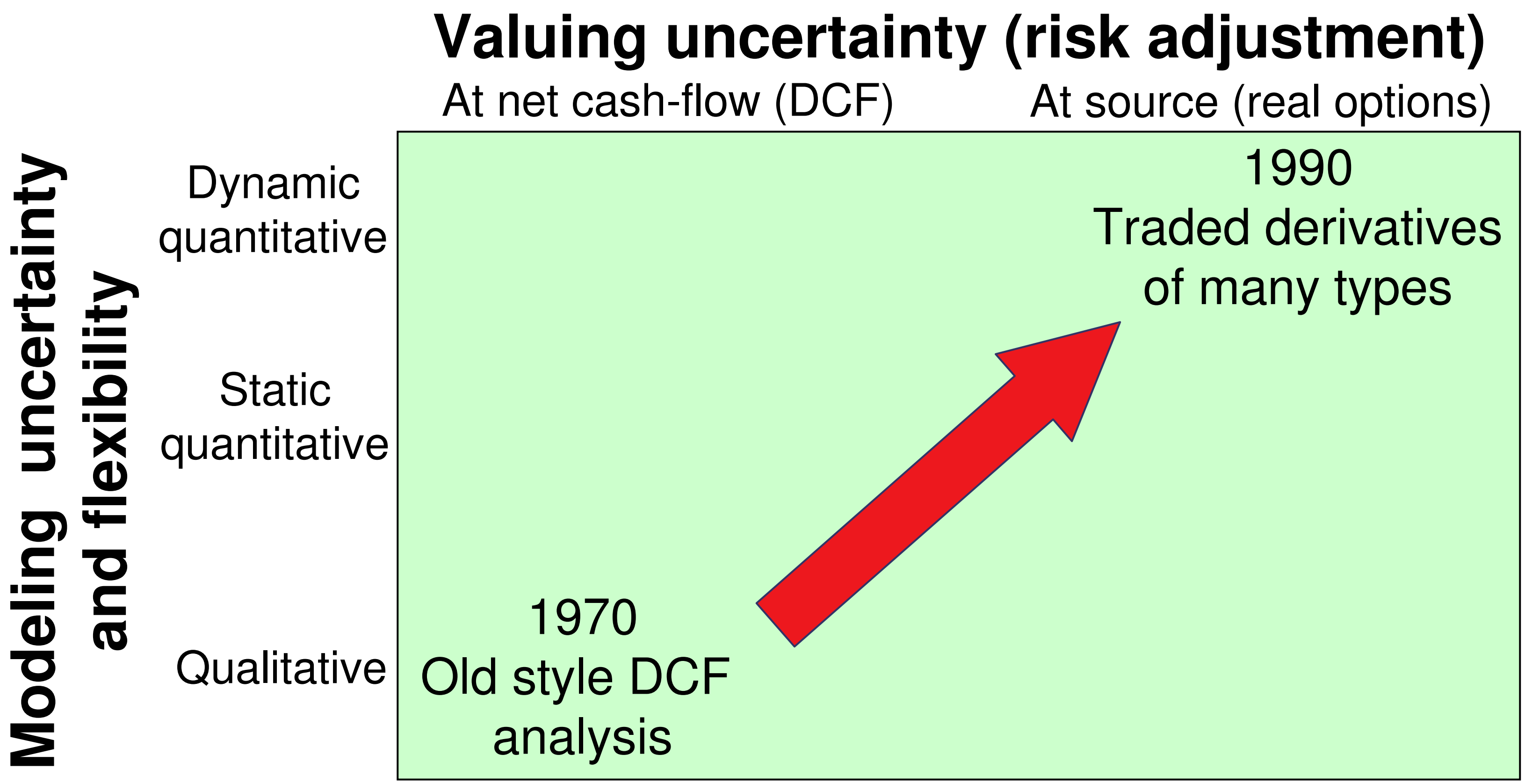
Evolution of valuation –
Financial markets and assets



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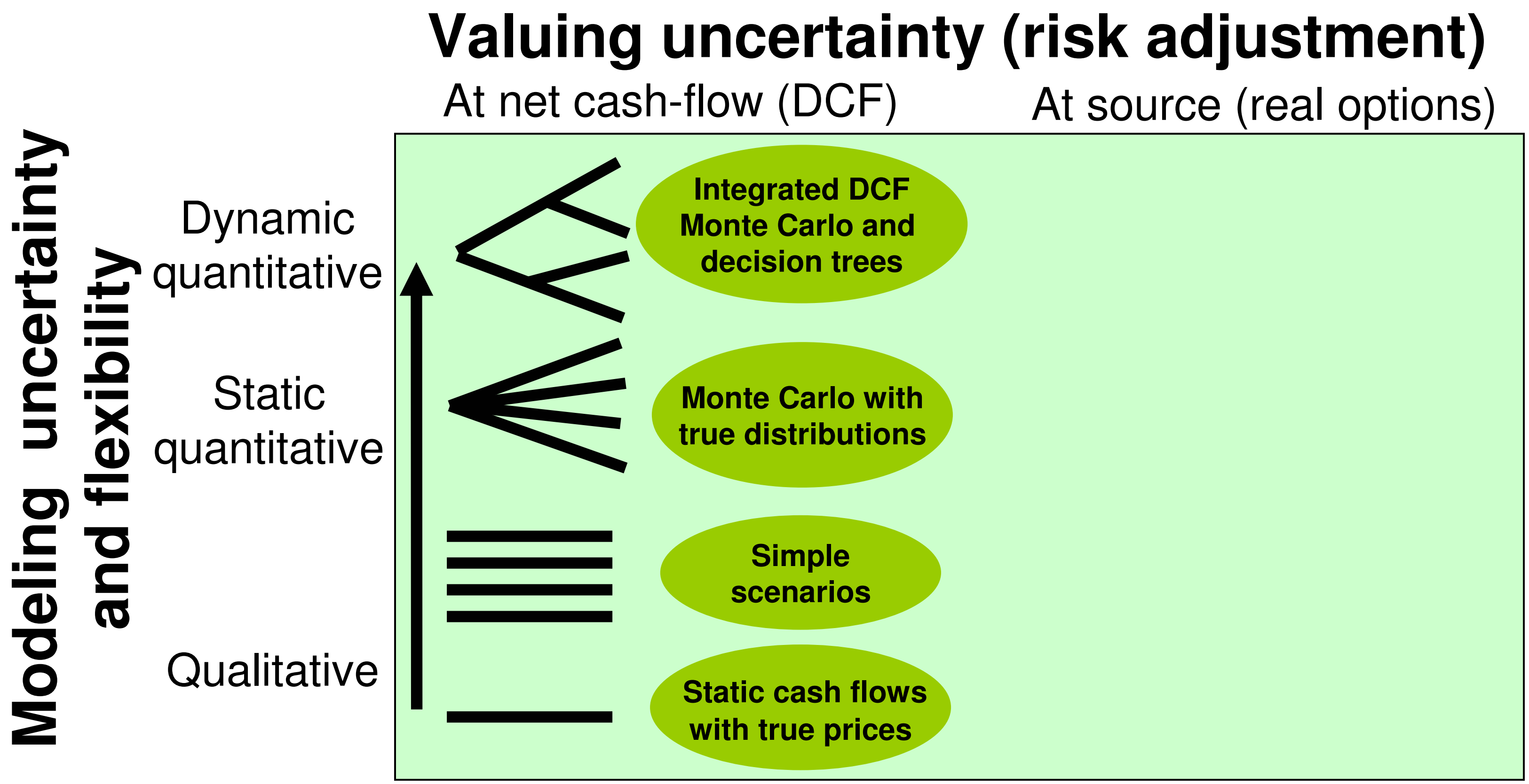
Evolution of valuation – Natural resource industries



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Why question "status quo" valuation?
Six reasons

- The low equity returns in the natural resource industries in the 1990s may in part be linked to poor investment and asset management decisions –
  Return on equity improves when we become more productive allocating and managing capital.
- Current valuation methods often rely on professional intuition (*e.g.* special project discount rates) or inconsistent reasoning to assess risk and calculate value –
  We need a reasoned valuation approach to test intuitive conclusions and highlight inconsistencies.

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Why question “status quo” valuation?
Six reasons

- Conventional DCF valuation methods need to be supplemented with add-ons such as “strategic value” or value multiples or are simply not used in certain valuation problems because they just don’t produce reasonable numbers –
  Earn-in options, exploration, royalties, certain capital expansions, loss-making operations, staged investments, gold mines, world class assets, leases, market capitalizations.
- Renewed emphasis on professionally validated valuation models and project assessments –
  Valuation codes (CIMVal) and financial market regulations (NI43-101) will ultimately require valuation models that explicitly recognize the influences of project uncertainty and structure on project value.

Why question “status quo” valuation? Six reasons

- Two significant biases using current methods:
  - Against long-term production
  - Against investing in future cost reduction
- Current methods do not support as well as possible high quality discussions about:
  - Sources of value
  - The creation and management of future flexibility

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Valuation in the petroleum industry

► Valuation influences: Uncertainty, structure and value estimation

A simple demonstration of DCF and RO value mechanics

Modelling output and input prices

Case study #1: Long-term cash flows at a SAGD project

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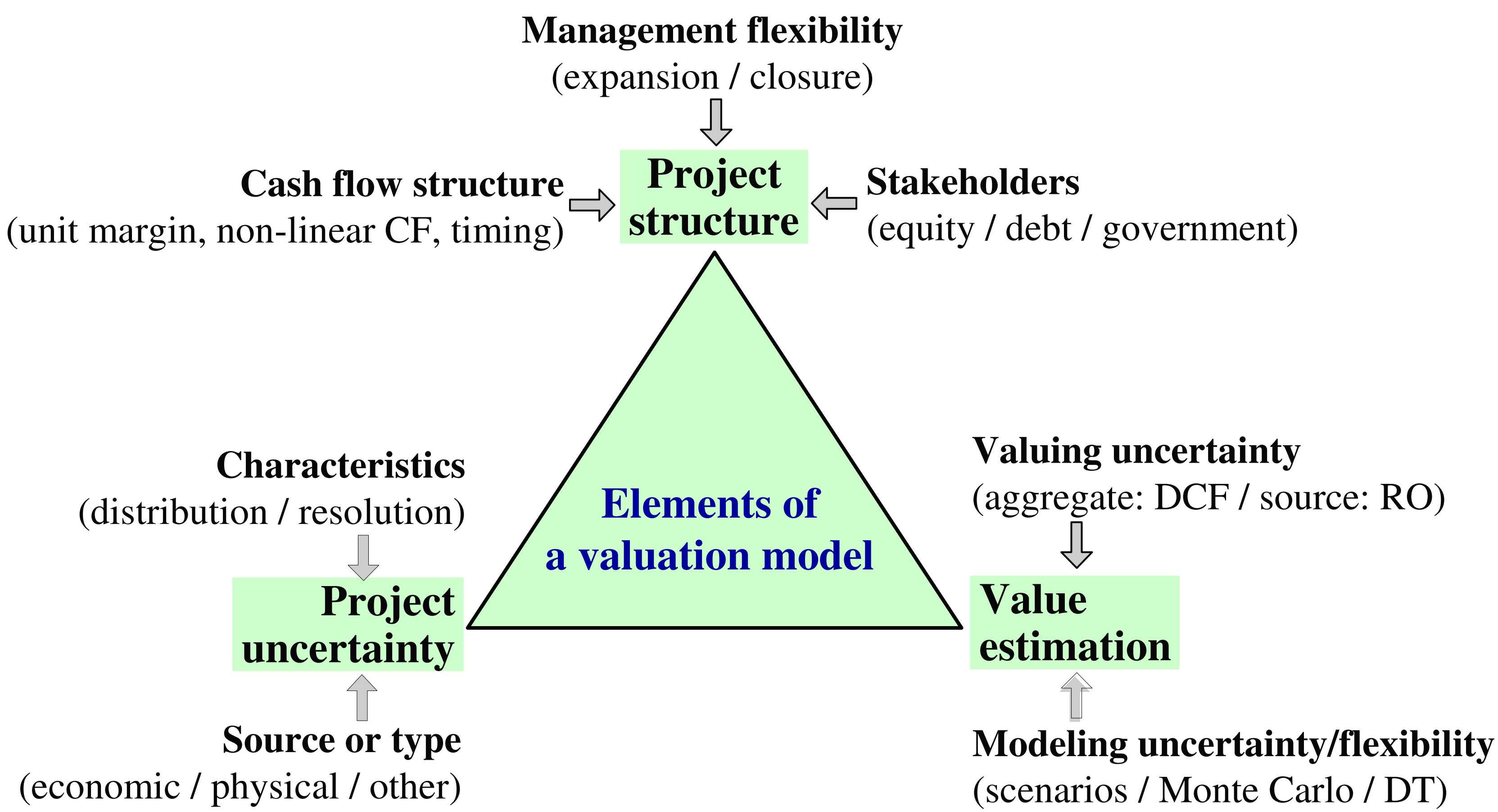
Final comments

Three value influences – Uncertainty, structure, and estimation



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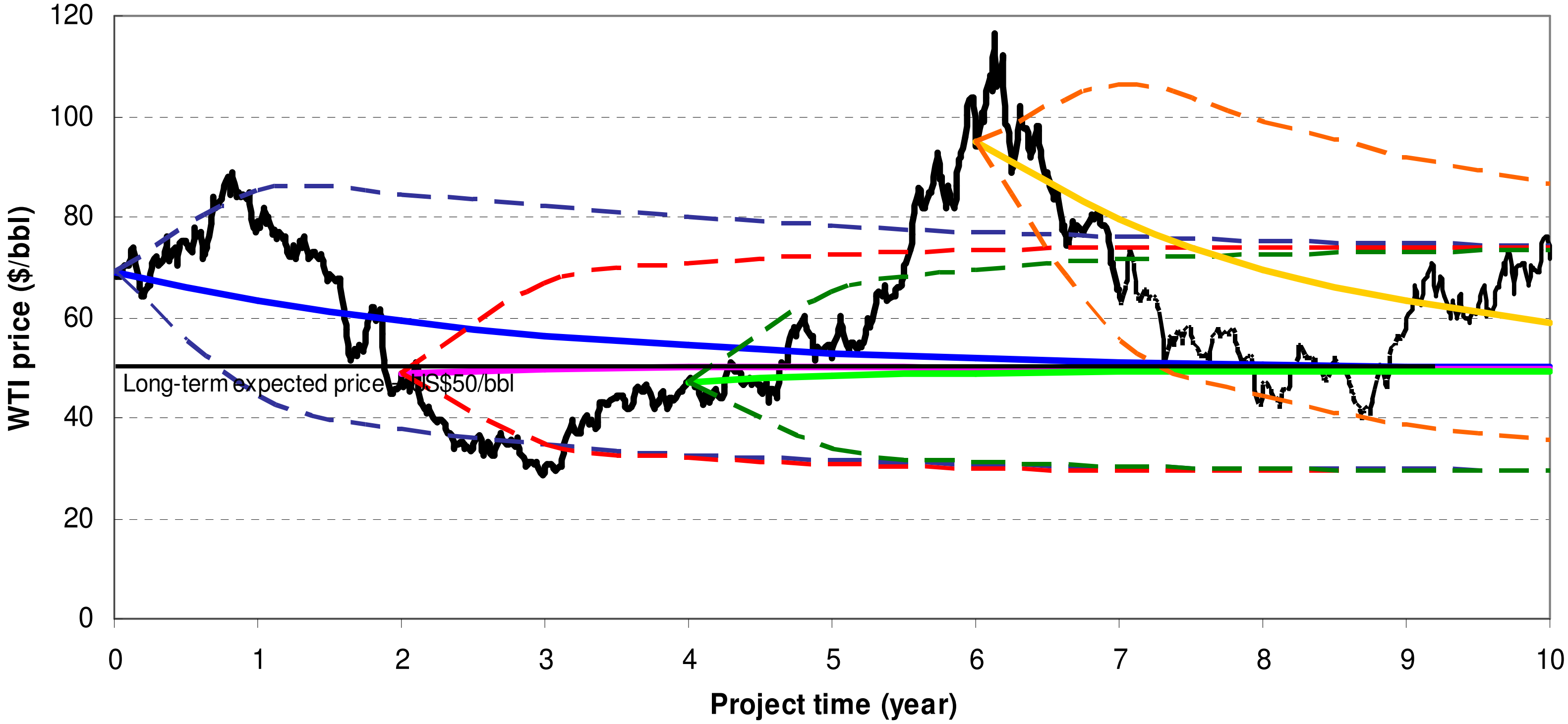
Project uncertainty –
Uncertainty resolution and updating

- Commodity prices exhibit reversion to a long-term equilibrium due to market forces - uncertainty growth slows with term.



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Project uncertainty –
Uncertainty resolution and updating

- Non-reverting processes are used for investment assets like stocks and gold - uncertainty continues growing in the long-term.

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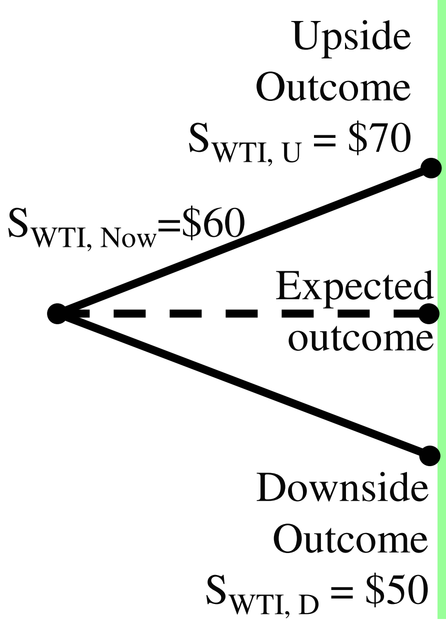
Project structure –
Unit costs and operating leverage

- Unit operating costs vary between petroleum projects which produces different magnitudes of net cash flow uncertainty – Investors are risk averse and care about uncertainty.



Pure WTI Play *Units=2*	**Low-cost Oil Field** *Units=4; UC=\$30/bbl*	**High-cost Oil Field** *Units=8; UC=\$45/bbl*
CF_U = 2*\$70 = \$140	CF_U = 4*(\$70–\$30) = \$160	CF_U = 8*(\$70–\$45) = \$200
E[CF]= 2*\$60 \$120	E[CF] = 4*(\$60–\$30) = \$120	E[CF] = 8*(\$60–\$45) = \$120
CF_D = 2*\$50 = \$100	CF_D = 4*(\$50–\$30) = \$80	CF_D = 8*(\$50–\$45) = \$40
$S_{Cu}(\sigma)$ = ±17%	$CF(\sigma)$ = ±33%	$CF(\sigma)$ = ±66%

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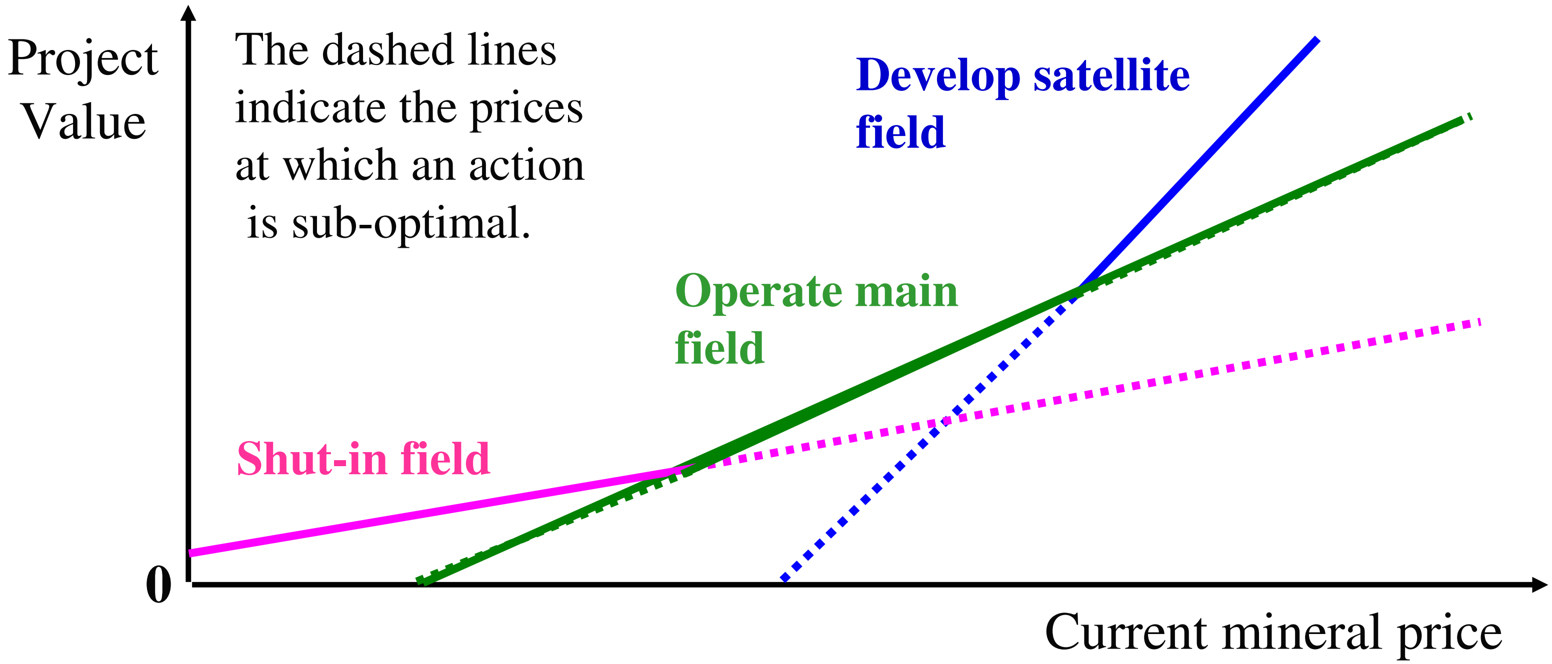
Project structure – Management flexibility

- Flexibility allows management to choose the operating policy that maximizes value as uncertainty is resolved.



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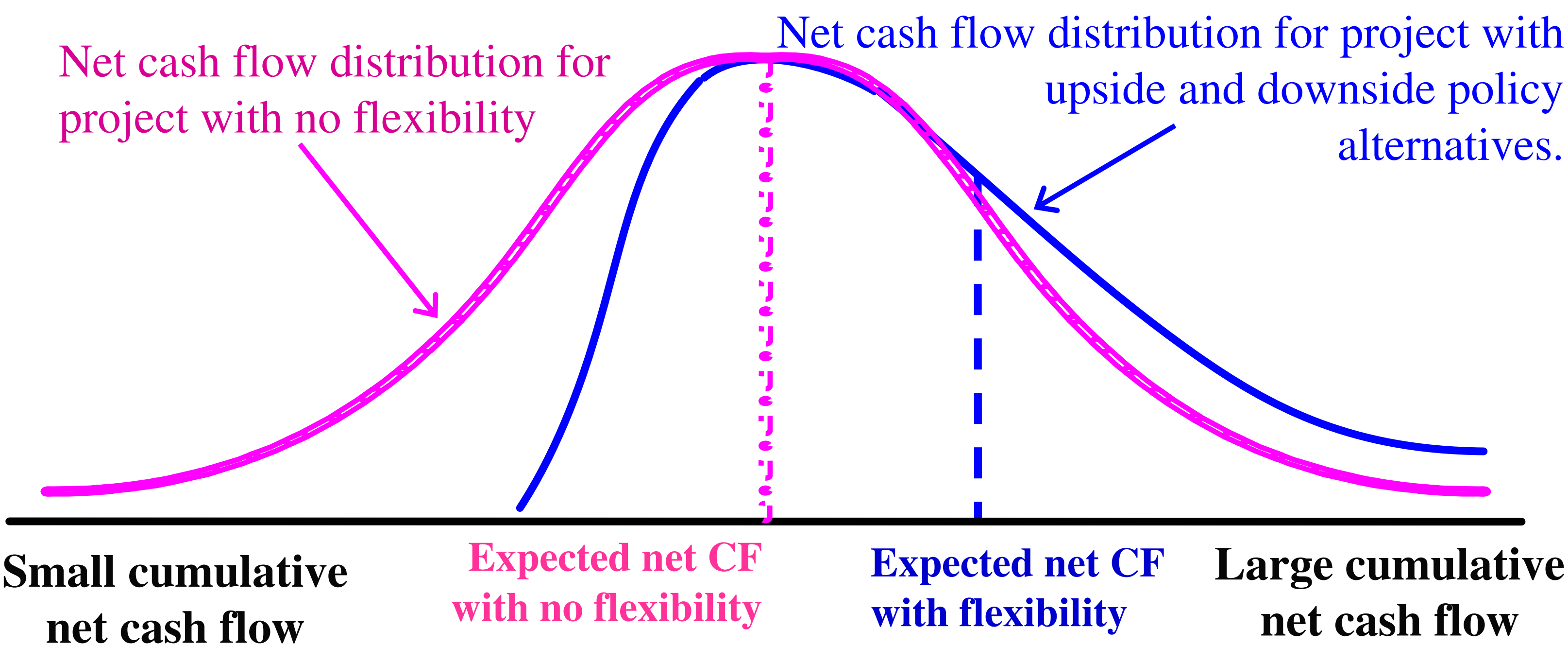
Project structure – Management flexibility

- Flexibility allows management to limit downside losses and magnify upside cash flows over the project's lifetime.



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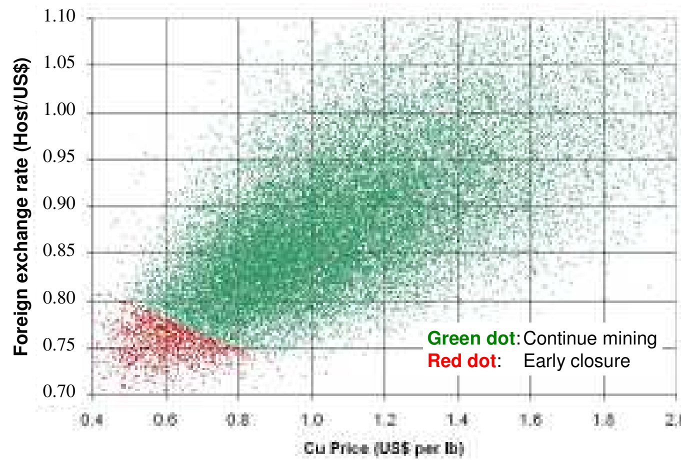
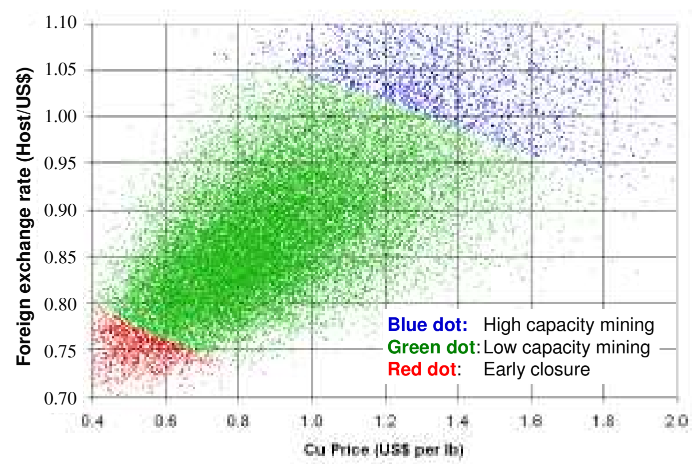
Project structure – Decision phase diagrams

- Monte Carlo simulation can be combined with decision trees to analyze the value and risk-mitigation effects of flexibility.
  - Decision points determined by comparing value resulting from different production alternatives
  - Scatter plots show different optimal choices (e.g. abandon vs. operate) for a copper mine with some local costs given different copper price / exchange rate pairs at a particular time.
  - Use pattern of decision "phases" to determine value and risk effects of flexibility.





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Value estimation –
DCF and RO are methods of calculating NPV

- DCF: traditional discounted cash flow analysis.
- RO: Real options, named in the 1980s when financial option pricing techniques were applied to the valuation of real assets (factories, mines, forests, oil fields).
  - The main emphasis of real options was modeling uncertainty and valuing management flexibility, though here we are interested in its implications for valuation with or without flexibility.
- Both DCF and RO calculate Net Present Value.
  - Valuation analysts often speak of RO project value as being something different to NPV – it is not.

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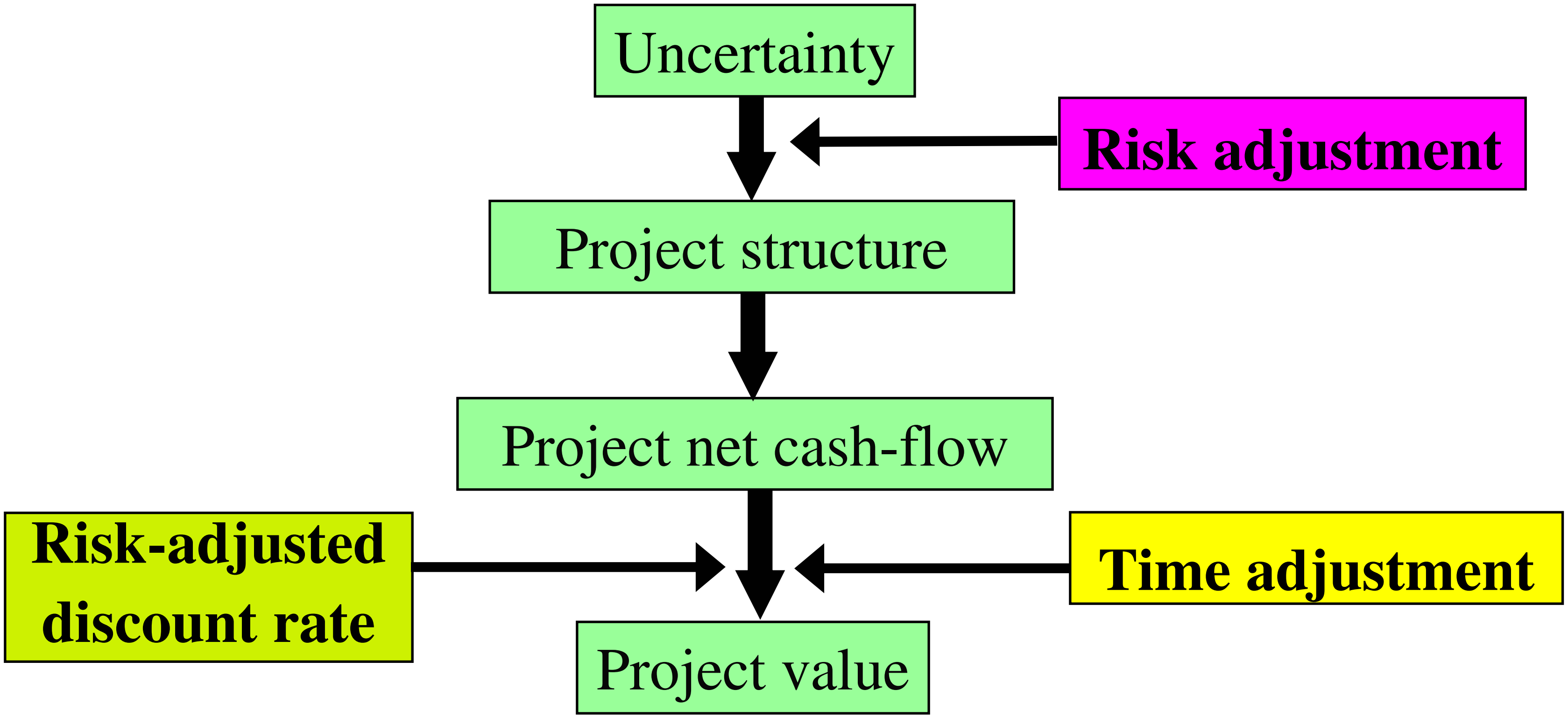
Value estimation –
Differentiating between DCF and RO

DCF
(risk adjust net cash flow)

Real options
(risk adjust at source)



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Value estimation –
DCF uses an aggregate risk/time adjustment

- Conventional static DCF applies an aggregate average risk and time adjustment to net cash flows and ignores flexibility

.

S= oil price (only source of uncertainty in this example)

Aggregate risk and time adjustment applied to the net cash flow stream (*i.e.* discounting with RADR or WACC discount rate).

$E\left[\tilde{S}\right] \cdot$ Oil Amount =Revenue

– OpCost

Operating profit

– CAPEX

Net cash flow

$*$ Time and risk adj.

Present Value net cash flow

Base alternative

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Value estimation – RO separates risk and time adjustments

- Real options applies a risk adjustment to the source of uncertainty and a time adjustment to net cash flow.

Risk adjustment applied to expected oil price (*i.e.* pure oil risk discounting).

$$E\left[\tilde{S}\right] \cdot \text{Risk adj.} = \quad E_{RA}\left[\tilde{S}\right]$$
$$* \text{ Oil Amount}$$
$$\overline{\textit{Risk adjusted revenue}}$$
$$- \text{ OpCost}$$
$$\overline{\textit{Risk adj. operating profit}}$$
$$- \text{ CAPEX}$$
$$\overline{\textit{Risk adjusted net cash flow}}$$
$$* \text{ Time adj.}$$
$$\overline{\textbf{Present Value net cash flow}}$$

Base alternative

Time adjustment applied here (*i.e.* discounting at the risk-free rate).

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Value estimation –
Choosing between single-rate DCF and RO

- The choice between single-rate DCF and RO valuation methods is a matter of selecting the method that is best able to recognize the unique risk characteristics of a particular project.
  - They both recognize uncertainty variation but differ on how to calculate the compensation an investor requires for exposure to project uncertainty (*i.e.* a risk-adjustment).
- RO recognizes the dynamic risk variation within the project environment while single-rate DCF does not.
  - RO applies an adjustment at source based on pure risk characteristics and filters this through to the net cash flow stream.
  - DCF uses an aggregate risk adjustment representing the interaction of all uncertainties and flexibilities. This is difficult to do.

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Consider the following

- You are in an E&P organisation that has been operating primarily in the Canadian western sedimentary basin, and are part of a team looking at prospects off the west coast of Africa.
- As part of the analysis, your colleagues suggest that, without further study, you should approximate the well productivity in any of these prospects to be the average (weighted by production) of all the wells in which your corporation has an interest.
- Would you agree with this course of action?

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A simple 1-period production asset

- Asset cash-flow model

  1 year from now

  net cash-flow = output * output price - cost

	High cost		Low cost
Asset information			
Output		100	
Cost	160		120

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A simple 1-period production asset

Corporate information

Output price forecast	**2.00**
Discount rate	**0.20**
Discount factor	**0.833** = 1/(1+0.20)

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DCF analysis

	High cost	Low cost
Forecast cash-flows		
Revenue	**200** =100*2.00	
Cost	**160**	**120**
Net	**40** =200 -160	**80** =200-120
DCF value	**33.3**=40*0.833	**66.7** =80*0.833

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Now add capital

Asset cash-flow model

now

net cash-flow = - capital cost

	High cost	Low cost
Asset information		
Capital cost	**15**	**50**
DCF value	***18.3*** = 33.3-15	**16.7** = 66.7-50

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Valuing components of a linear cash-flow

- If cash-flow is linear in underlying uncertain variables, e.g.

  Cash-flow = A * **output price** + B

- Value of the claim to the cash-flow can be determined by using value additivity

  Value = A * **value of claim to output price**
  + B * **value of claim to a unit of risk-free cash-flow**

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Forward pricing

Value = A * **value of claim to output price**

+ B * **value of claim to a unit of risk-free cash-flow**

= A * **output forward price** * **time discount factor**

+ B * **time discount factor**

= (A * **output forward price** + B) * **time discount factor**

Recall

Cash-flow = A * **output price** + B

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MBV valuation of the production asset

Market information

Forward output price	**1.80**	
Cash bond price		
(time discount factor)	**0.95**	
Output bond value	**1.71**	=1.80 * 0.95

How can we value a claim to the cash-flow

output * output price - cost ?

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MBV valuation

	High cost	Low cost
Market information		
Output bond value		**1.71** =1.80 * 0.95
Valuation		
Revenue		**171** =100 * 1.71
Cost	**152** =160*0.95	**114** =120*0.95
Net	**19** =171-152	**57** =171-114

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MBV discounting

	High cost	Low cost
Forecast cash-flows		
Revenue	**200**	
Cost	**160**	**120**
Net	**40** =200-160	**80** =200-120
MBV value : Discount factor (value / forecast cash-flow)		
Revenue	**171 : 0.855**	
Cost	**152 : 0.95**	**114 : 0.95**
Net	**19 : 0.475**	**57 : 0.7125**

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MBV discounting (cont'd)

	High cost	Low cost
Risk discount factor (discount factor / time discount factor)		
Revenue	**0.90**	
Cost	**1.00**	**1.00**
Net	**0.50**	**0.75**
Risk discount (1- risk discount factor)		
revenue	**0.10**	
Cost	**0.00**	**0.00**
Net	**0.50**	**0.25**

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Uncertainty and risk discounting

	High cost	Low cost
Corporate information		
Output price realisations	**2.00 ± 0.50**	
Price uncertainty	**0.25** =0.50/2.00	

What is the uncertainty in the net cash-flow?

How does the risk discount relate to the uncertainty?

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Uncertainty and risk discounting

	High cost	Low cost
Corporate information		
Output price realisations	**2.00 ± 0.50**	
Price uncertainty	**0.25** =0.50/2.00	
Uncertainty (absolute : proportional)		
Revenue	**200 ± 50 : 0.25**	
Net cash-flow	**40 ± 50 : 1.25**	**80 ± 50 : 0.625**

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Uncertainty and risk discounting

	High cost	Low cost
Risk discount and proportional uncertainty		
Revenue	0.10 = **0.4***0.25	
Net cash-flow	0.50=**0.4***1.25	0.25=**0.4***0.625

Price of output price risk = **0.4**

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Forward price and price of risk

Forward price

= Expectation *

risk discount factor

= Expectation *

(1 - risk discount)

= Expectation *

(1 - price of risk * amount of uncertainty)

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Prices of risk

- For the same level of uncertainty, the greater the price of risk, the greater the risk discount
- Price of risk measures how averse the marginal investor is to bearing this particular type of uncertainty
- Price of risk = 0 means no risk discounting
  - Typical of local, nonsystematic, diversifiable uncertainty
- Price of risk negative means risk mark-up
  - Marginal investor want to bear this uncertainty
  - Usually hedges other uncertainties

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CAPM and prices of risk

- CAPM is actually a model of prices of risk
- Price of risk
  = economy price of risk * correlation with economy
- Annual economy price of risk is roughly 0.5
- Annual prices of risk typically between -0.5 and 0.5
- Empirical determination of price of risk equivalent to determination of an equity beta risk premium in a WACC calculation

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Back to the example, add capital

Asset cash-flow model

now

net cash-flow = - capital cost

	High cost	Low cost
Asset information		
Capital cost	**15**	**50**
DCF value	***18.3*** = 33.3-15	**16.7** = 66.7-50
MBV value	**4.0** =19-15	***7.0*** = 57-50

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Insights

- Different assets, different uncertainties, different risk discounting
- Greater discountable uncertainty => greater risk discount

- Effect of uncertainty on value governed by "prices of risk"
- Risk discount = price of risk * amount of uncertainty

- We can think systematically about prices of risk
- Equivalent to WACC determination

- Risk discounting still determined centrally
- MBV, if anything, increases consistency and central control

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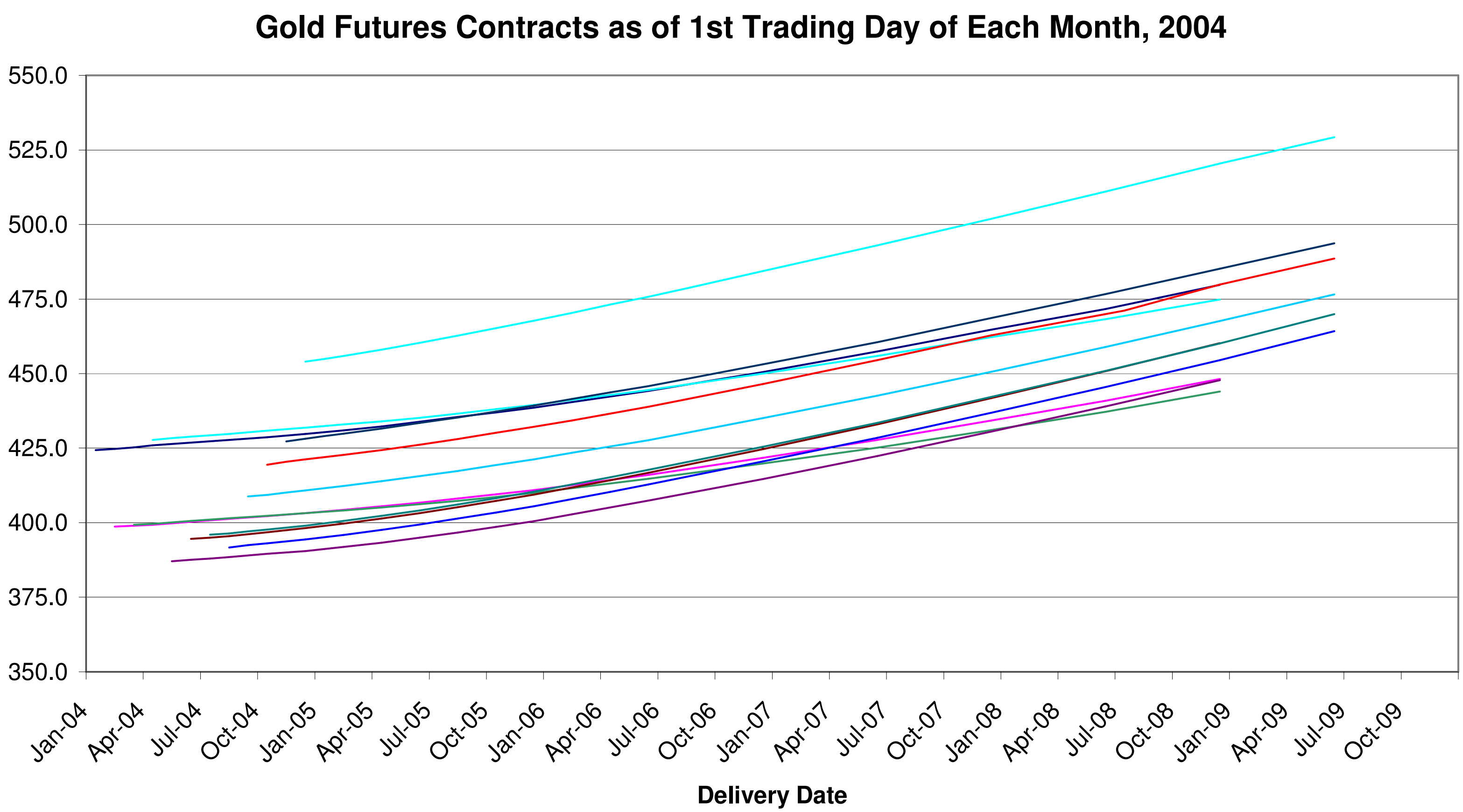
Forward contracts – Gold forward curves



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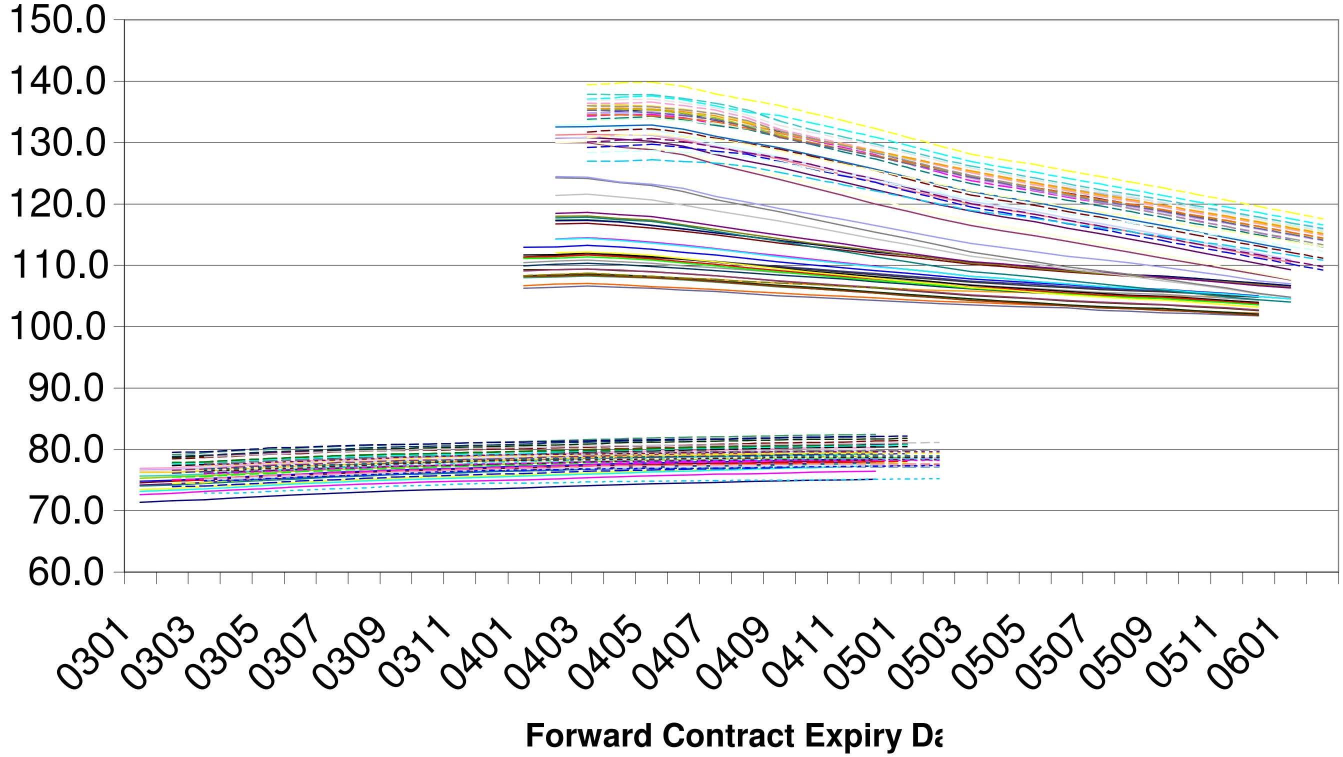
Forward contracts –
Copper forward curves showing reversion



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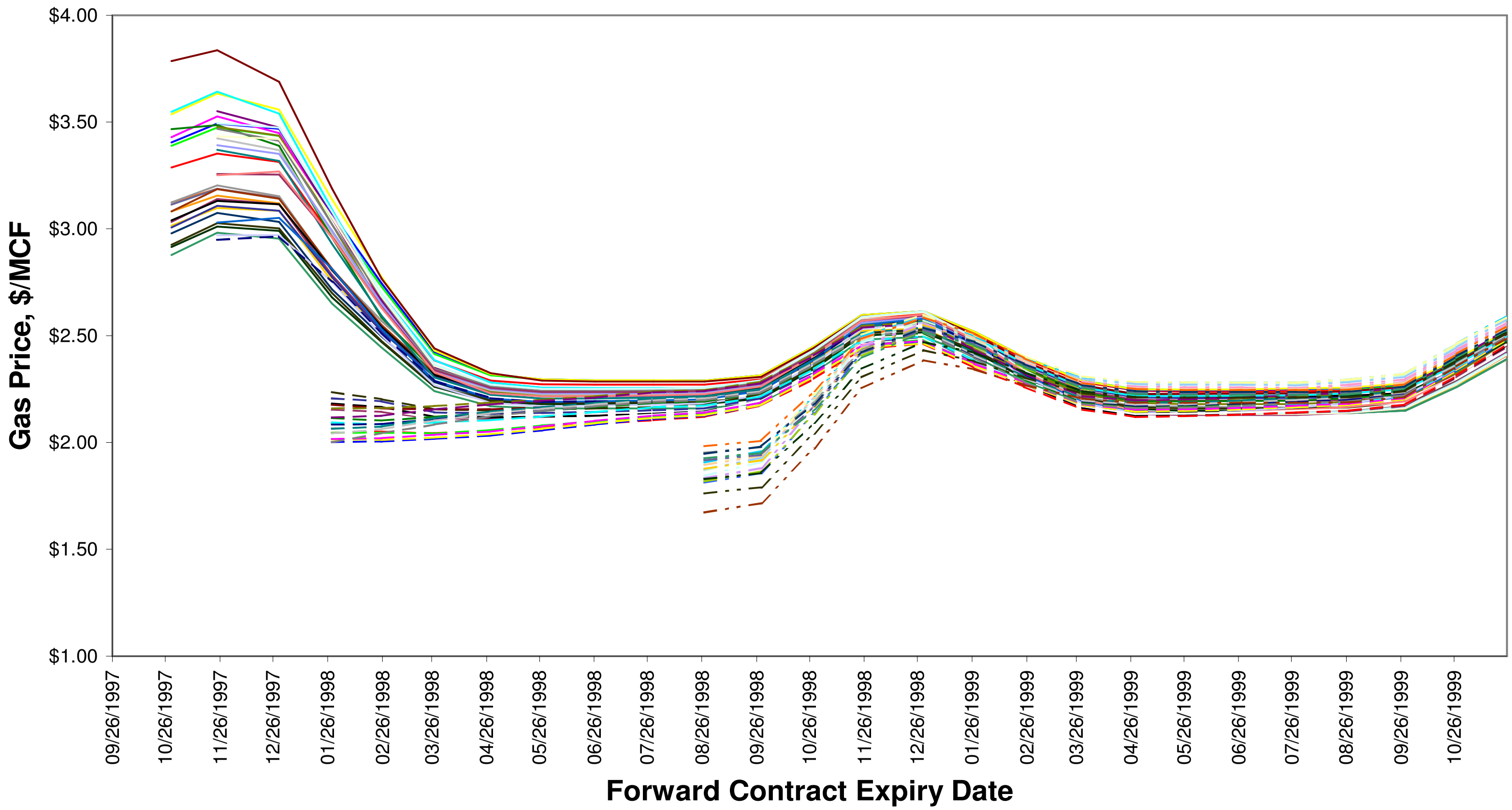
Forward contracts – Natural gas forward curves



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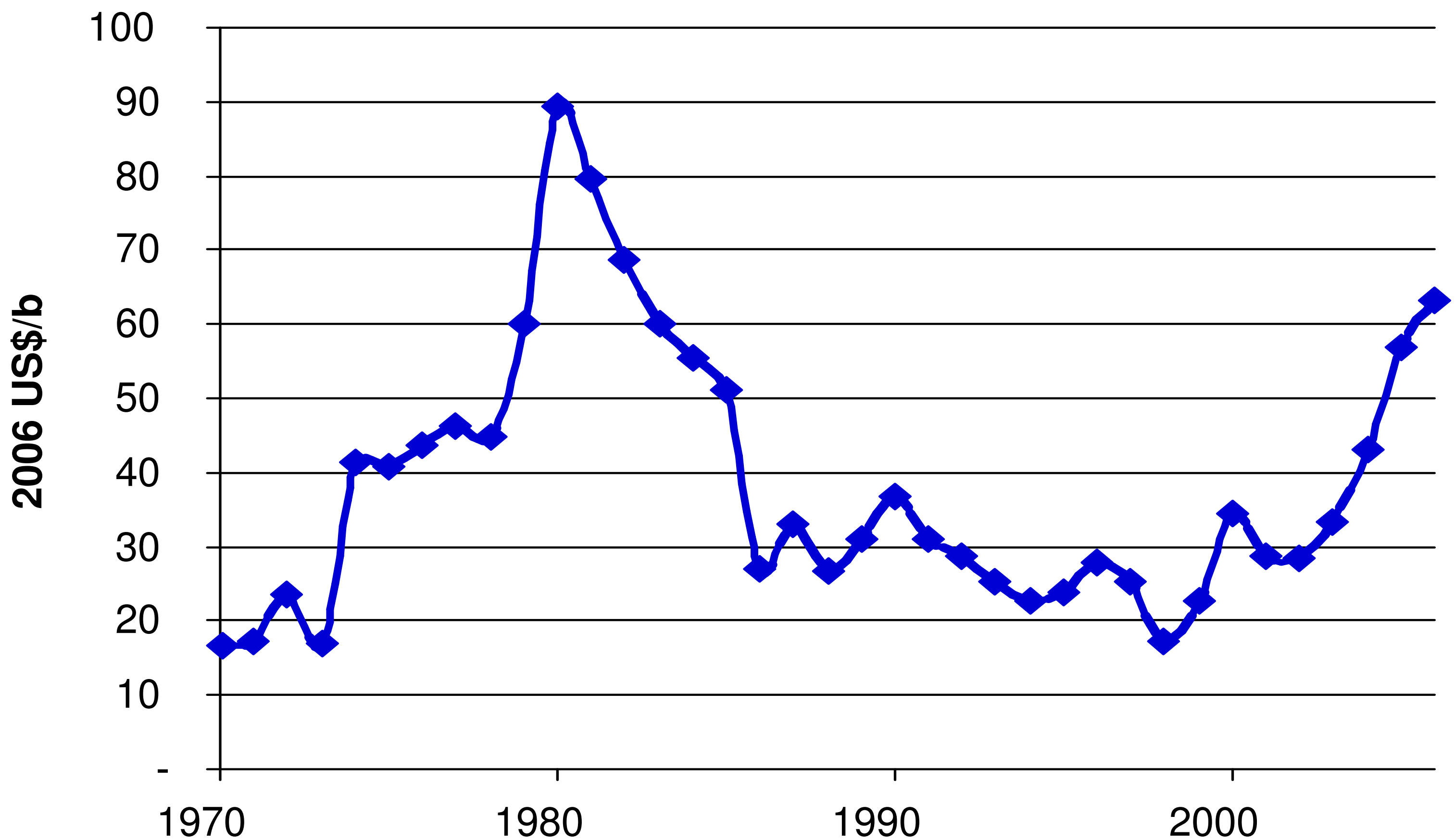
Oil prices –
1970-2005 (real US$/bbl)



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Oil prices –
Four periods of rising oil prices

• 1973-74	Most sustained
• 1979-81	Reversed
• 1991	Short-lived
• 1998-now	???

- Supply-side vs demand-side shocks
- Permanent vs temporary changes
- Long-term vs short-term uncertainty

- Financial market information
- Implications for price models
-

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Oil prices –
Financial market Information

- Before the late 1980s

  Equity prices

  Predicted much lower prices than

  the US$100/bbl by 1990 touted by analysts in 1980

- Since then

  Forward and futures markets

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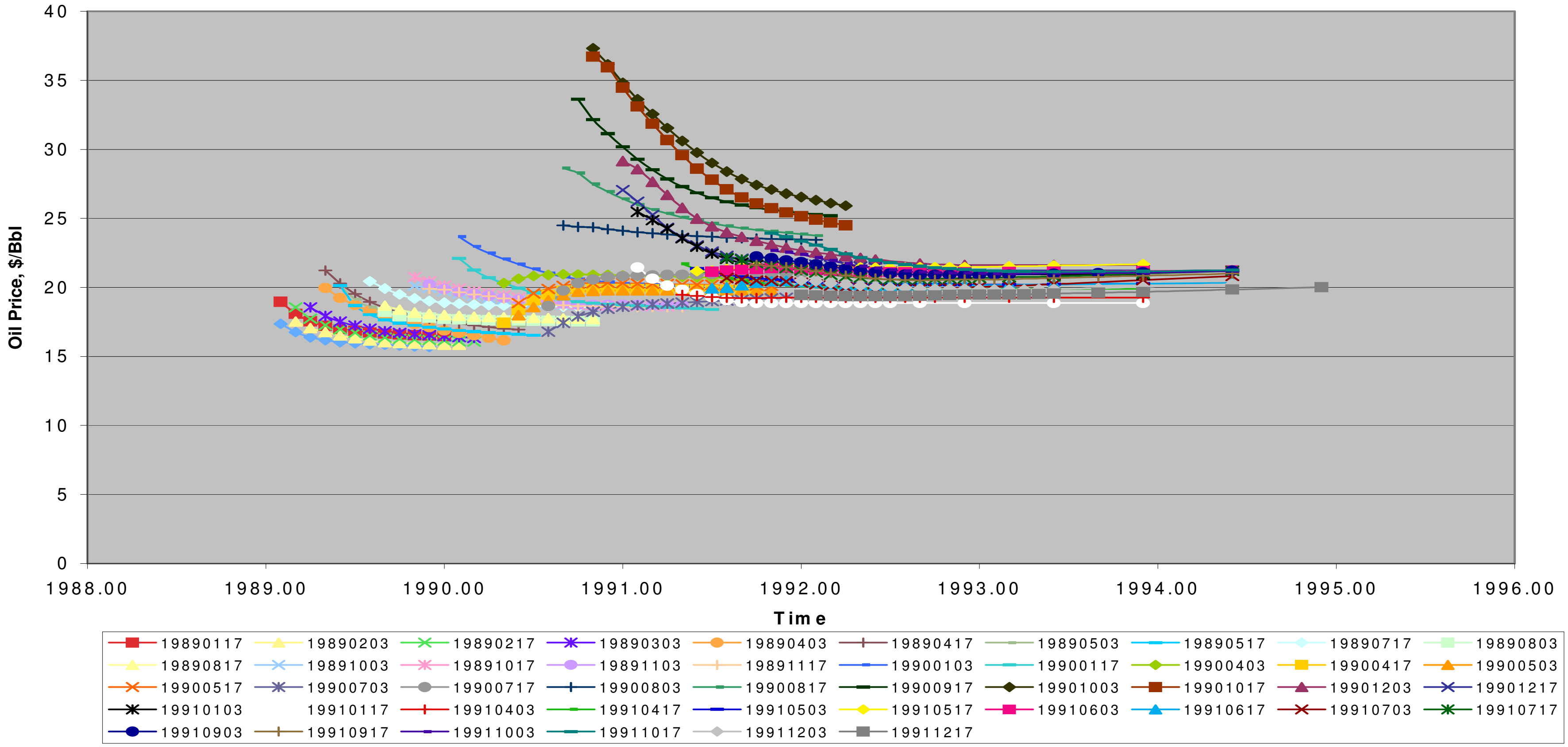
Oil prices –
Oil forward prices 1989-1991



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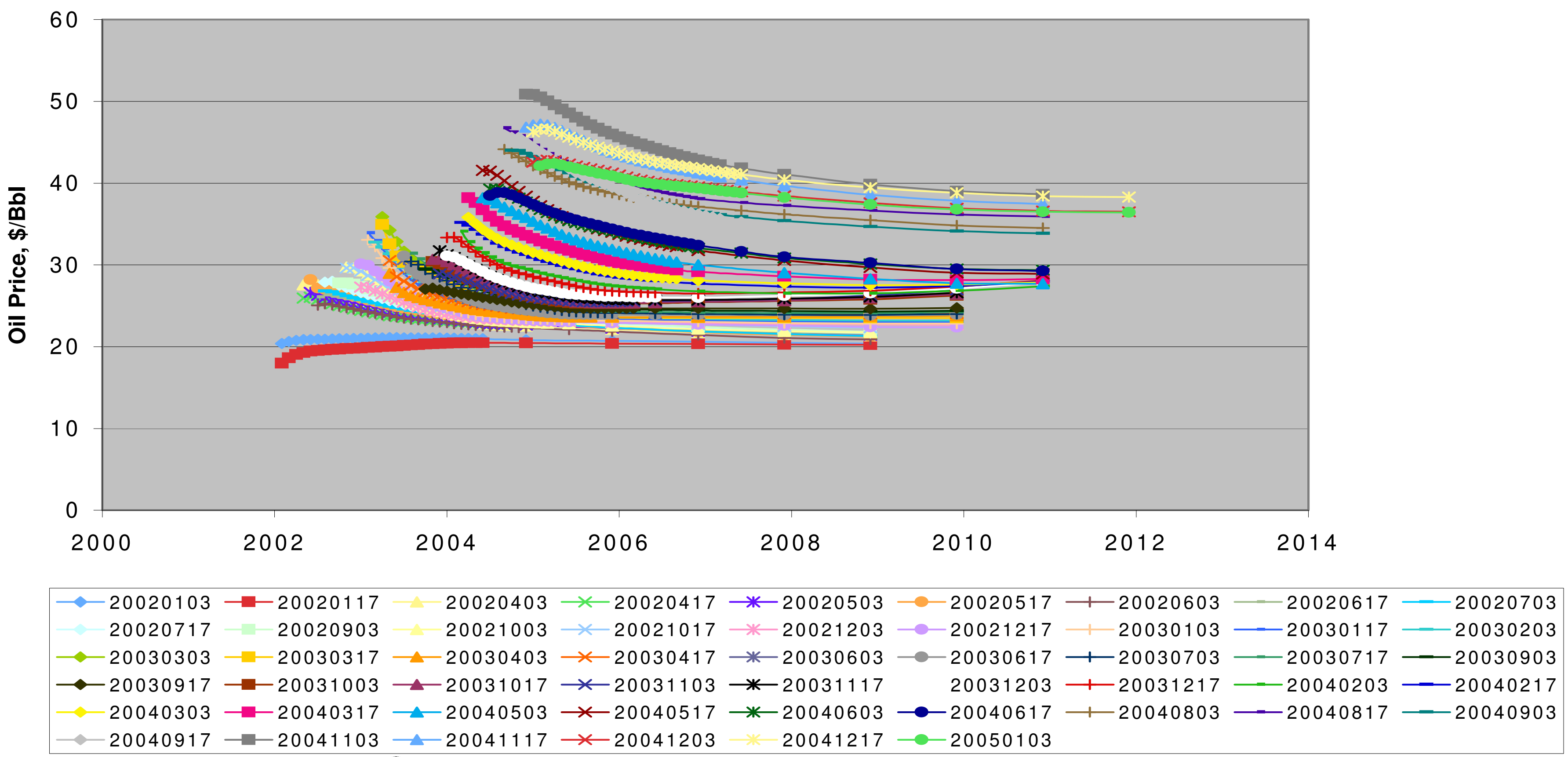
Oil prices –
Oil forward prices 2002-2005



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Oil prices – Models

- Price = long term factor * short term factor

- Long term factor was fairly stable 1983-2002
- Band of US$14-US$26 per bbl

- Now long-term factor increased and more uncertain
  -> Long-term flexibility more valuable

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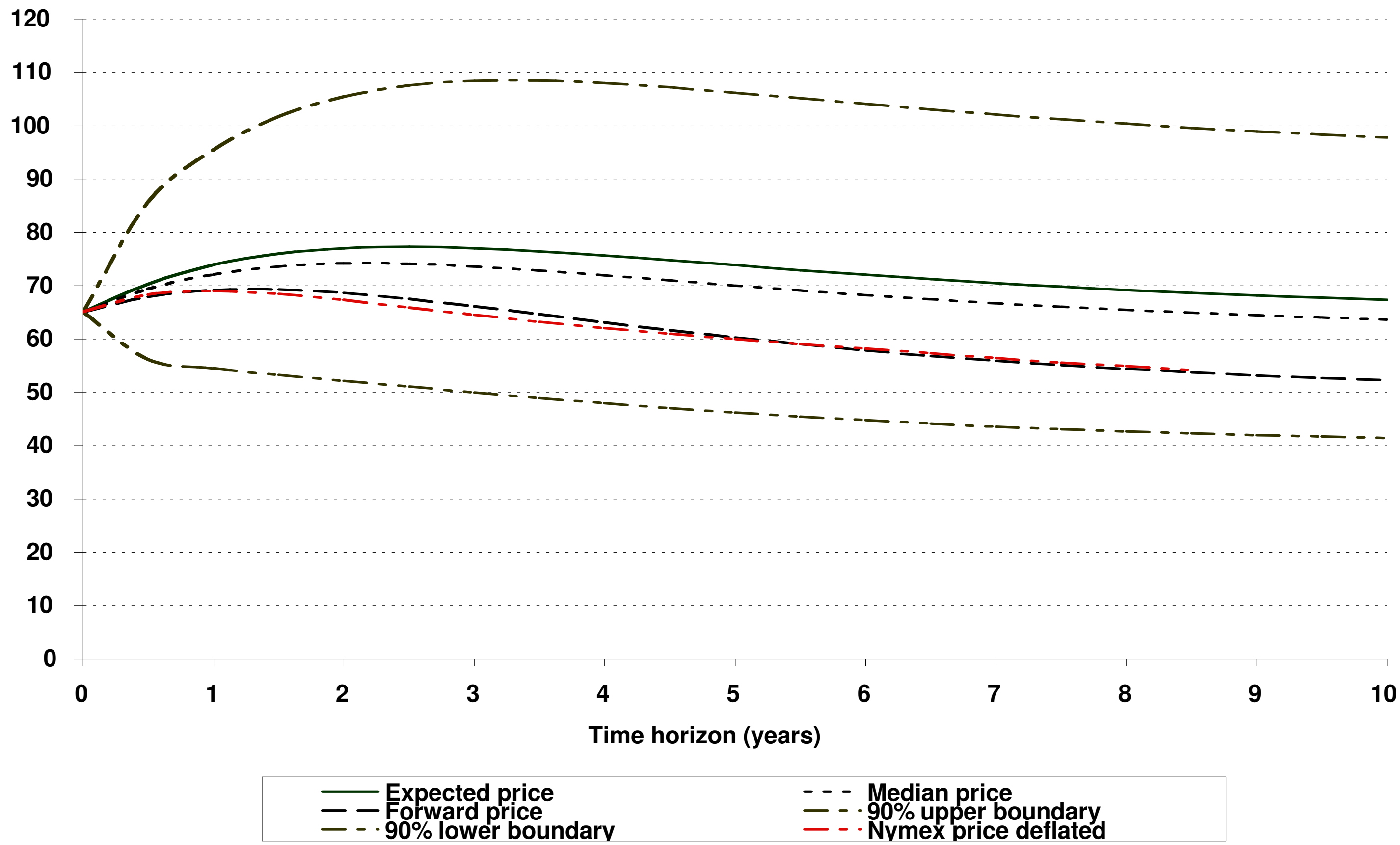
Oil prices –
NYMEX oil forward prices on 27 May 2007



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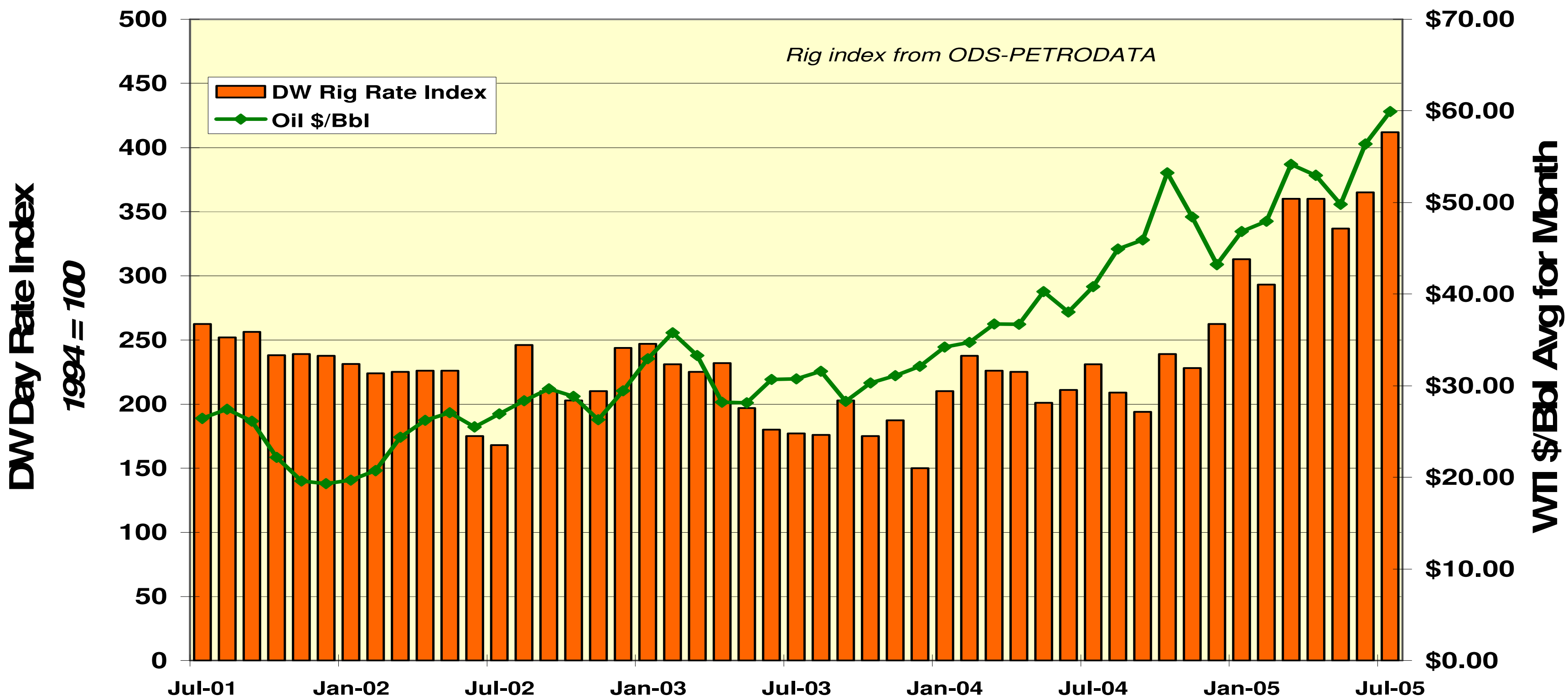
Input prices –
Deepwater rig day rate index vs WTI oil



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Input prices –
Cost index modelling

- Rent effects

  Cost index
  = 1 + a (Price - Current Price) / Current Price

- Quasi-rent effects

  Cost index
  = 1 + b (price change-expected price change)

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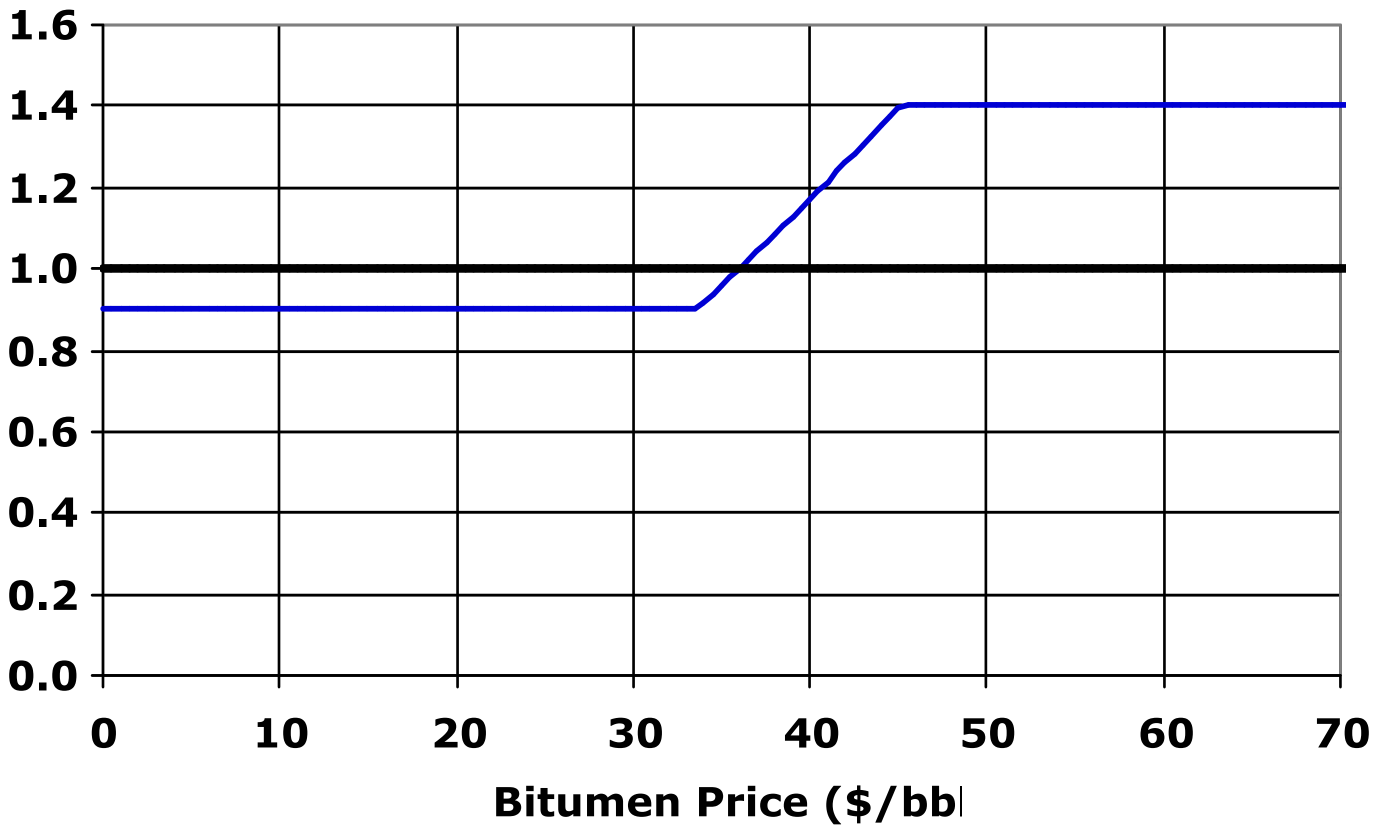
Input prices –
A rough cut at the Alberta SAGD cost index



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Valuation in the petroleum industry

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Modelling output and input prices

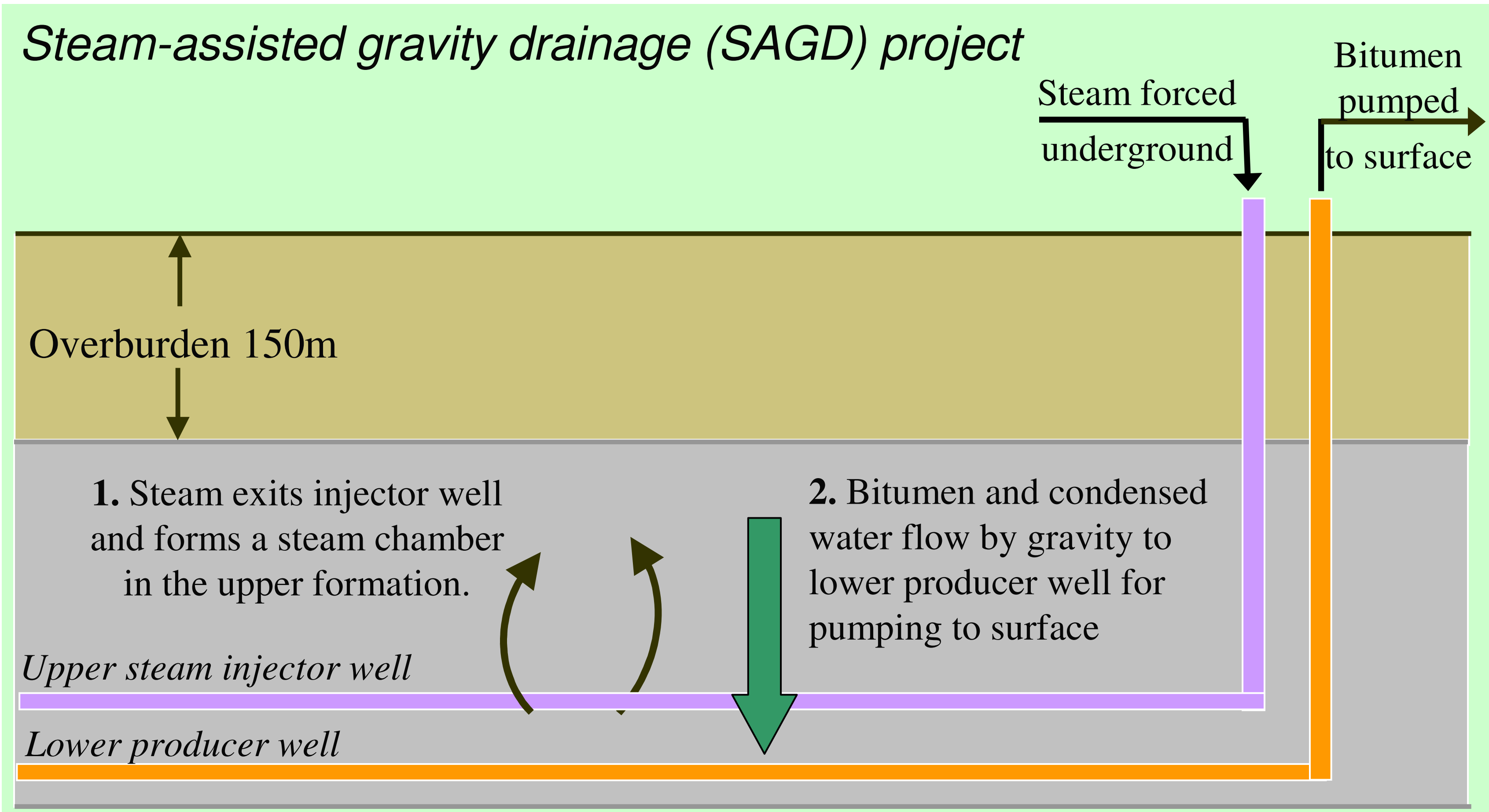
► **Case study #1: Long-term cash flows at a SAGD project**

Case study #2: Equity and government cash flows at a coal bed methane project

Case study #3: Valuing a dual-fuel boiler at a SAGD project

Final comments

Case study #1: Alberta oil sands with no flexibility



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Case study #1:
Project background

- Project background:
  - 2 billion barrels of recoverable reserves at a maximum production rate of 190 thousand b/d (70.6 million b/y).
  - Production increased in phases for a mine life of 35 years.
  - 50% of operating costs are from natural gas.
- Two design options:
  - No on-site upgrader (third party refinery).
    - Development and sustaining CAPEX: CAD$7.6b; US$24/bbl refining penalty; Net CF: CAD$410m/yr.
  - Build on-site upgrader / refinery CAPEX.
    - Development and sustaining CAPEX: CAD$15.6b; No refining penalty; Net CF: CAD$775m/yr.
- A non-linear royalty and CIT tax regime.

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Case study #1:
Sources of uncertainty

- WTI / synthetic crude oil price
  - Moderate levels of uncertainty (25%) with strong reversion to a long-term equilibrium price of US$50.00/bbl.
- Natural gas price
  - High levels of uncertainty (50%) with strong reversion to a long-term equilibrium price of CAD$6.00 mmbtu.
- Light-heavy differential (heavy oil refining penalty)
  - High levels of uncertainty (50%) with strong reversion to a long-term equilibrium price of US$24.00/bbl.
  - Low level of systematic uncertainty.
- Correlations between uncertainties:
  - WTI - NatGas: 0.7; WTI - LHDiff: 0.7; NatGas - LHDiff: 0.5

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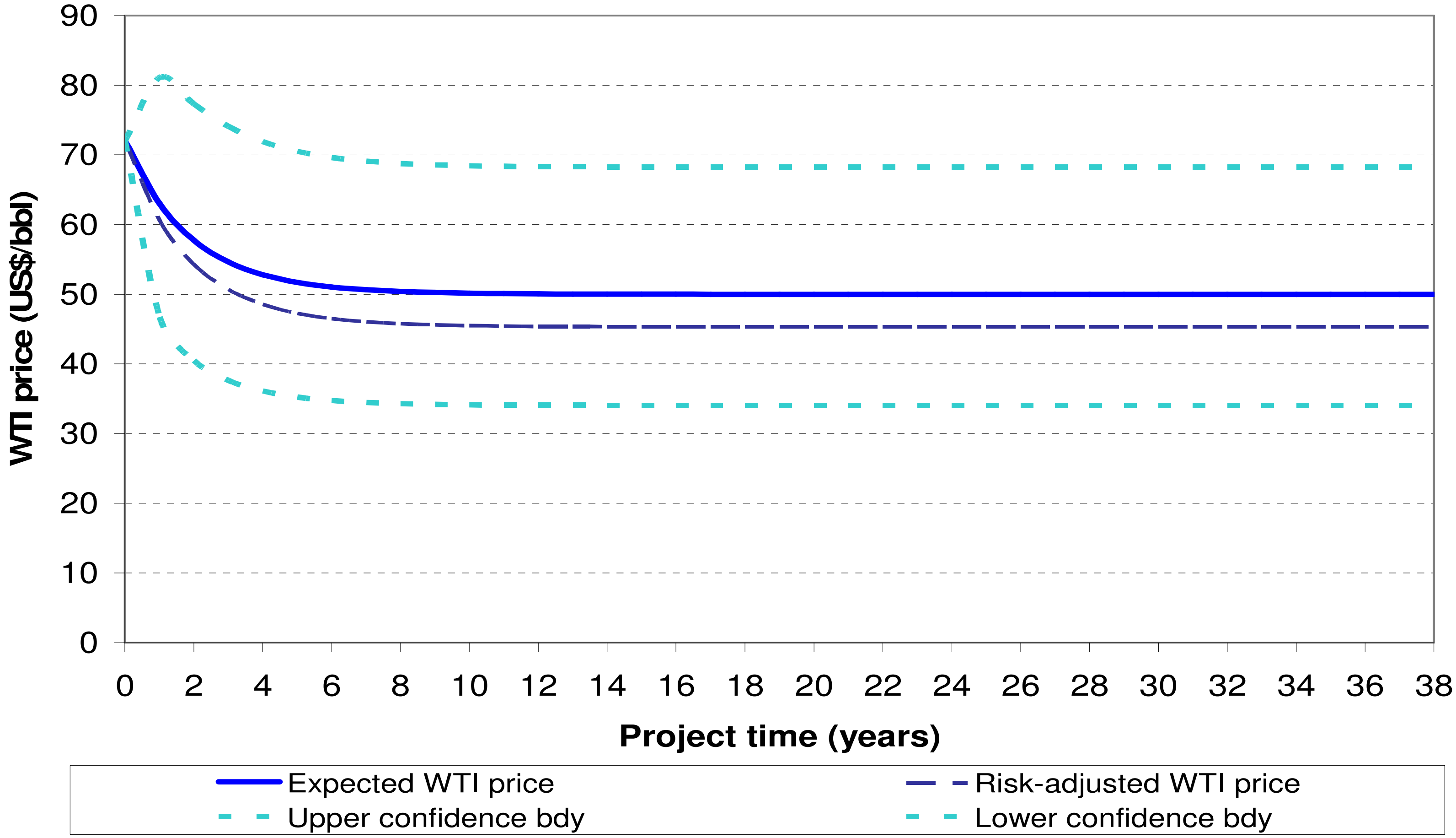
Case study #1:
WTI / synthetic crude oil price



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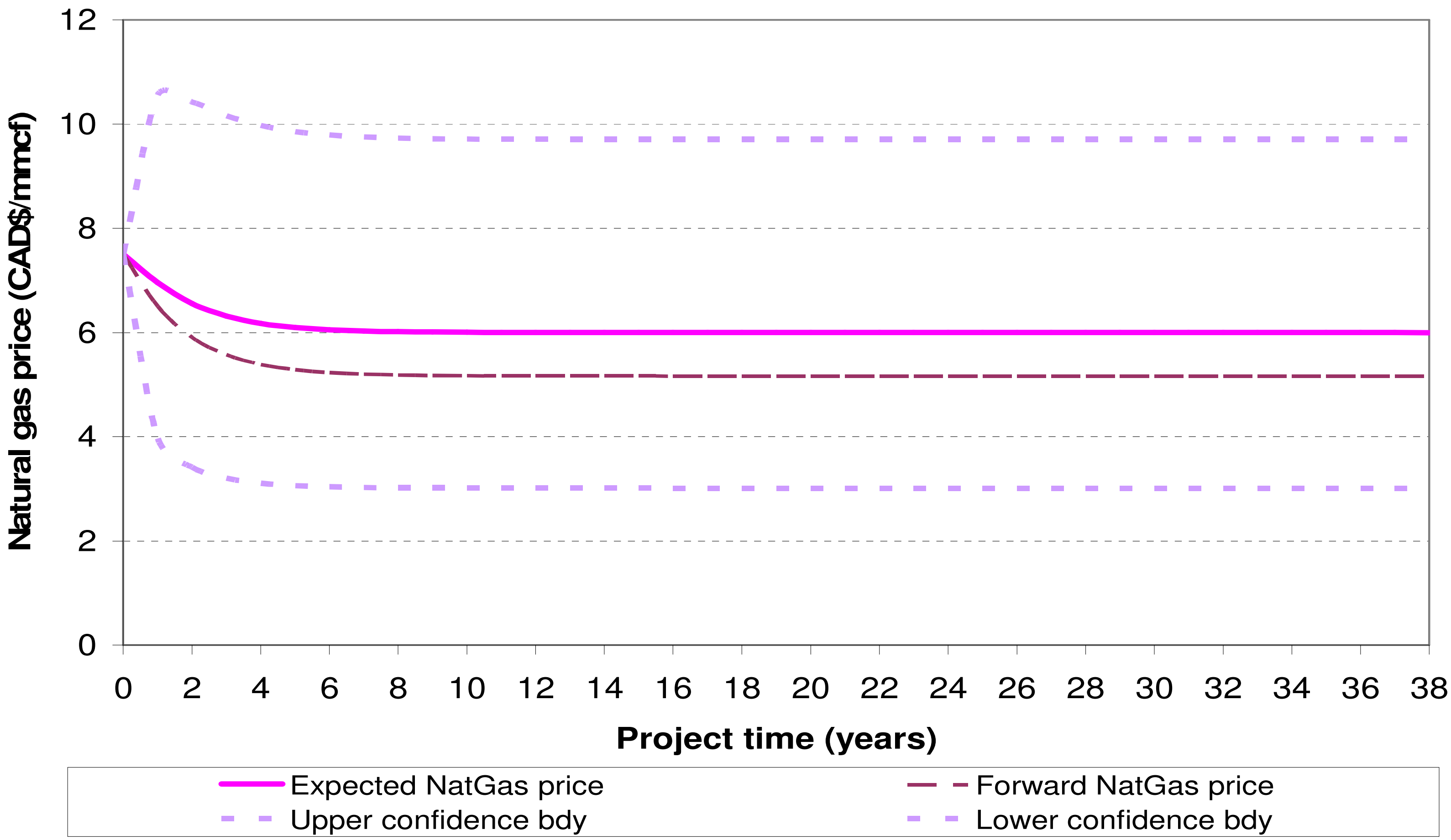
Case study #1: Natural gas price



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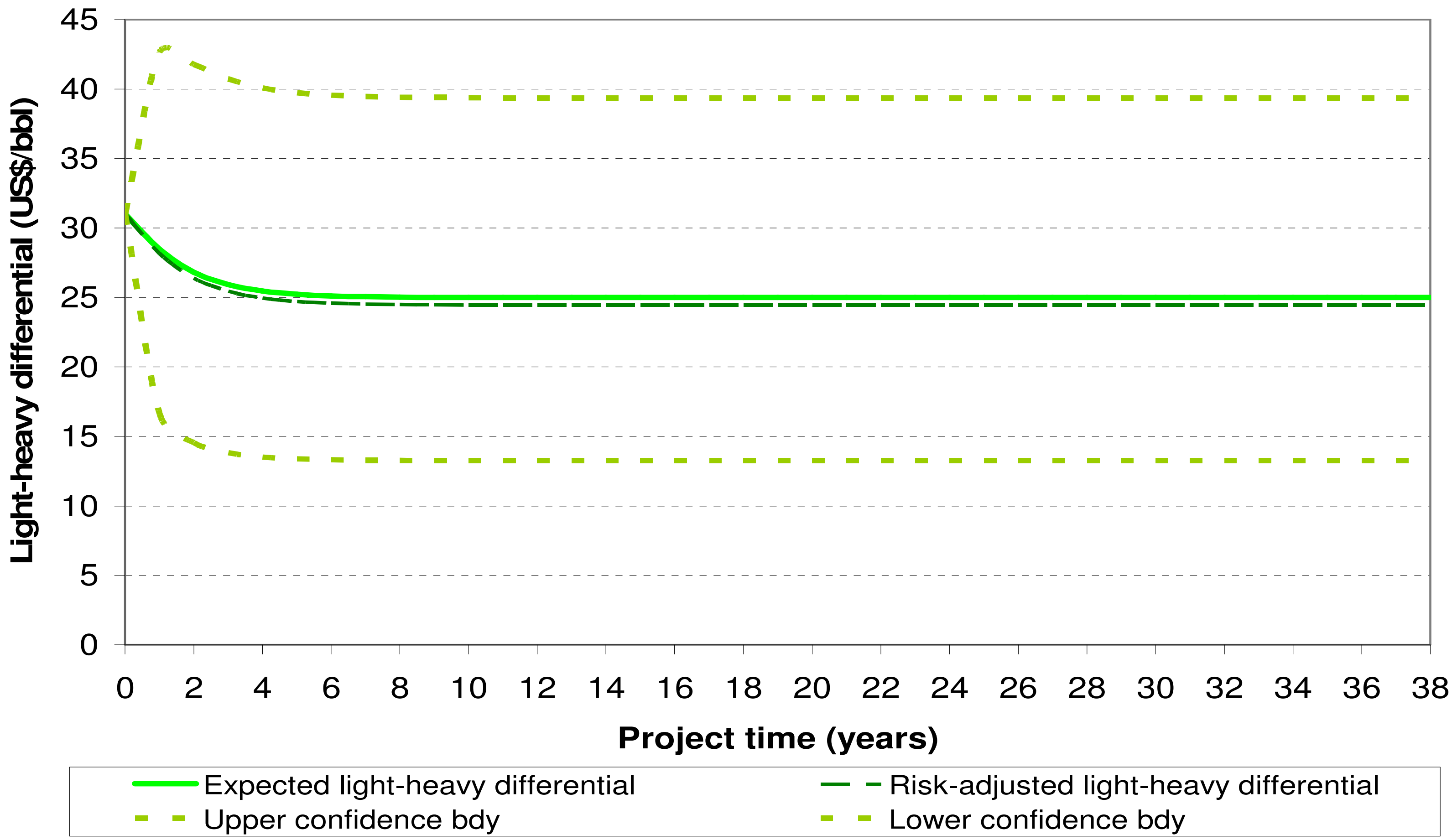
Case study #1:
Light-heavy differential (refining penalty)



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Case study #1: Monte Carlo DCF and RO valuation results

Cumulative net cash flow
SAGD: CAD$ 7201m
SAGD+Upgrader: CAD$ 12309m

Time-adj. cumulative net cash flow
SAGD: CAD$ 3450m
SAGD+Upgrader: CAD$ 5092m

- Discounted cash flow and real options make <u>conflicting design recommendations</u>.

Discounted cash flow		**Real options**	
DCF net present value		*RO net present value*	
SAGD:	CAD$ 277m	SAGD:	CAD$ 1104m
SAGD+Upgrader:	CAD$ -697m	SAGD+Upgrader:	CAD$ 3515m
DCF risk-adj. value reduction		*RO risk-adj. value reduction*	
SAGD:	CAD$3173m	SAGD:	CAD$ 2346m
SAGD+Upgrader:	CAD$5789m	SAGD+Upgrader:	CAD$ 1577m

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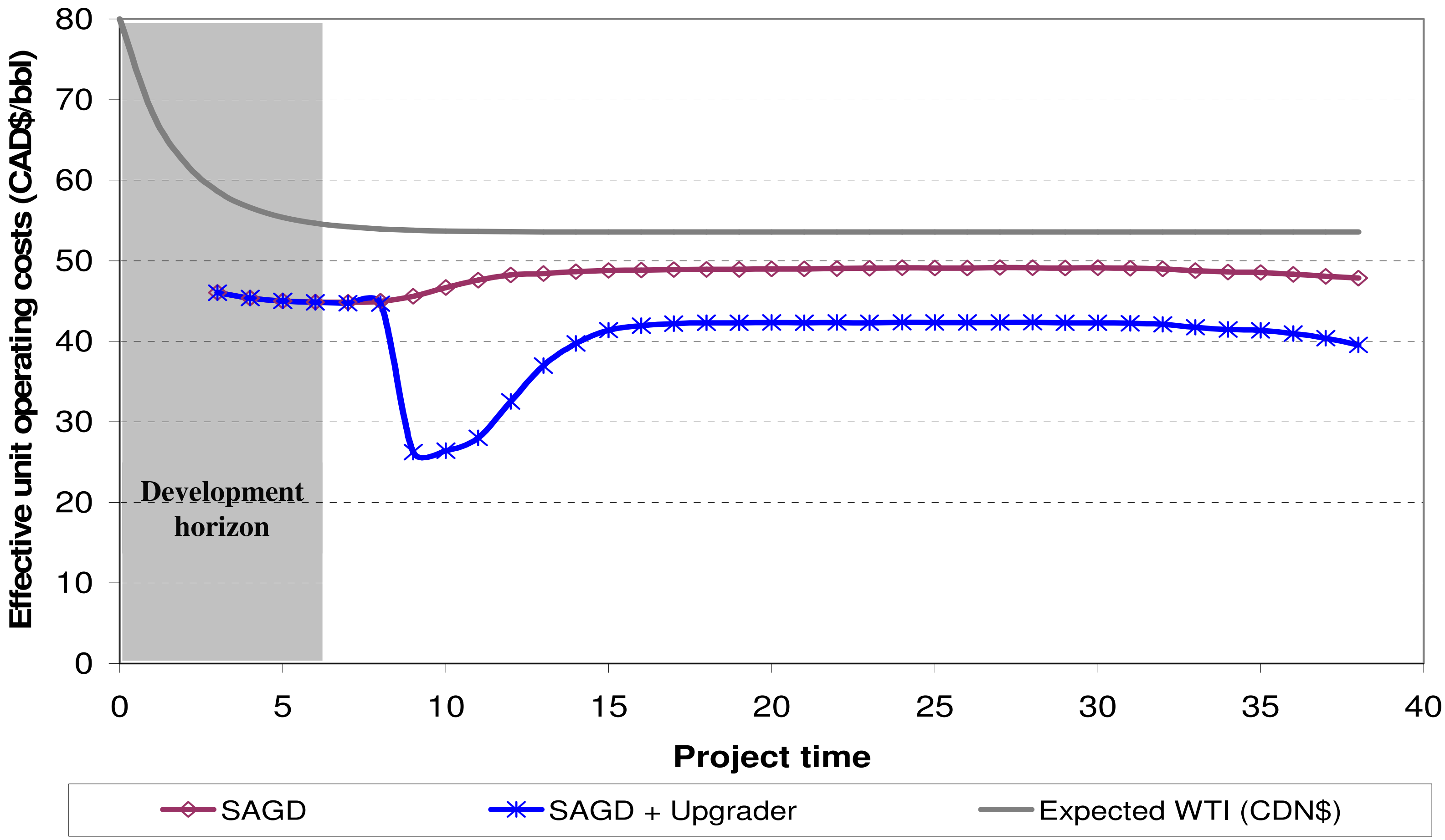
Case study #1:
Project total unit operating costs



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Case Study #1 – CF deviations, NCFDFs, and NCFRDFs

- Cash flow deviations indicate average cash flow variability.

$$\text{CF Deviation}_{t,i} = \frac{\text{Standard deviation (Stakeholder CF}_t)}{\text{Expected CF}_t}$$

- Net cash flow risk discount factors (NCFRDFs) indicate the size of the risk adjustment applied to a cash flow.

$$\text{NCFDF}_t = \frac{\text{Present value of cash flow}_t}{\text{Expected cash flow}_t}$$

$$\text{NCFRDF}_t = \frac{\text{Present value of cash flow}_t}{\text{Expected cash flow}_t \cdot \text{Time discount factor}_t}$$

  - NCFDFs and NCFRDFs profile should change with variations in cash flow uncertainty since both adjustments applied to the project cash flows reflect investor sensitivity to uncertainty.

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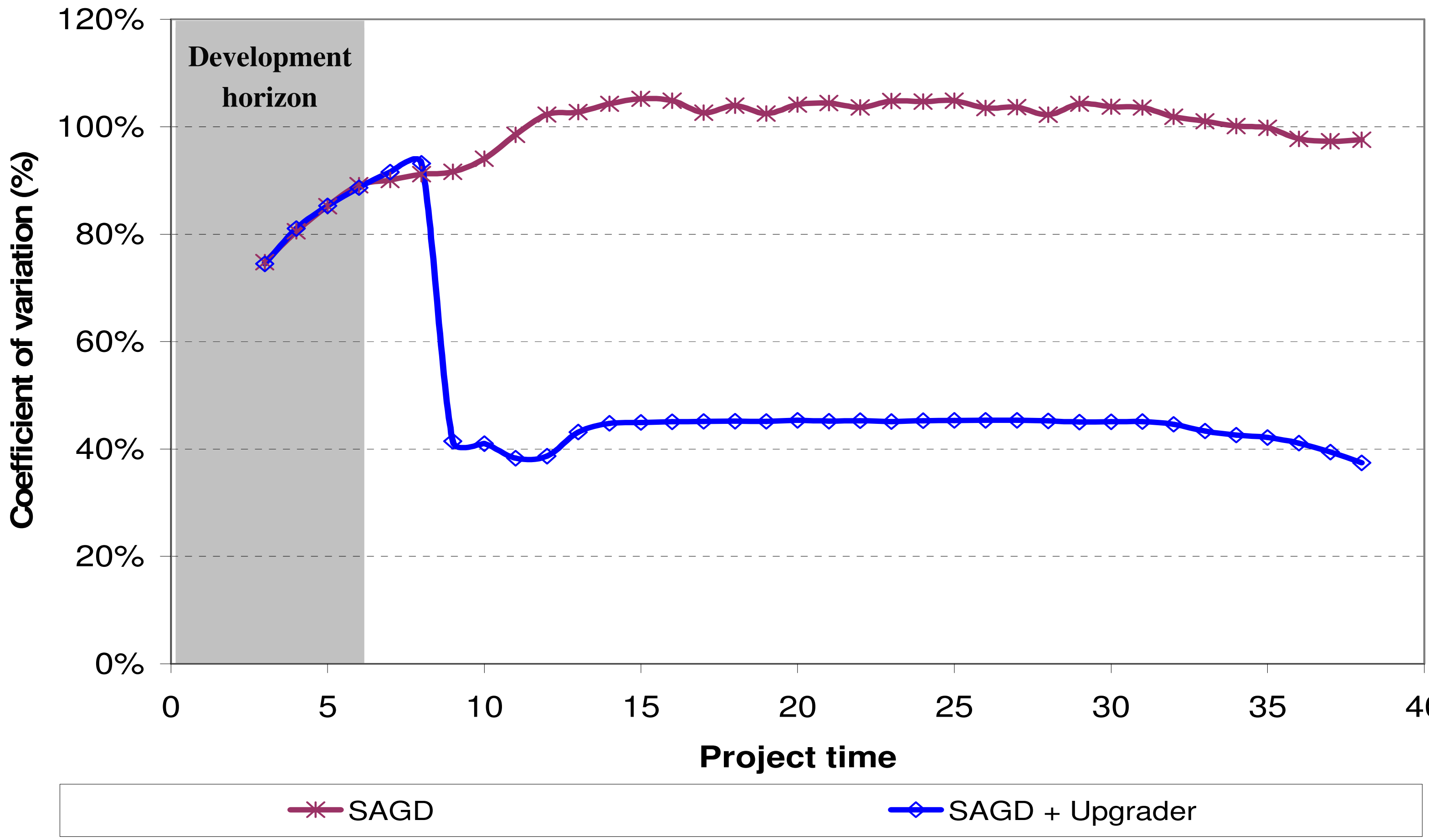
Case study #1: Equity coefficient of variation



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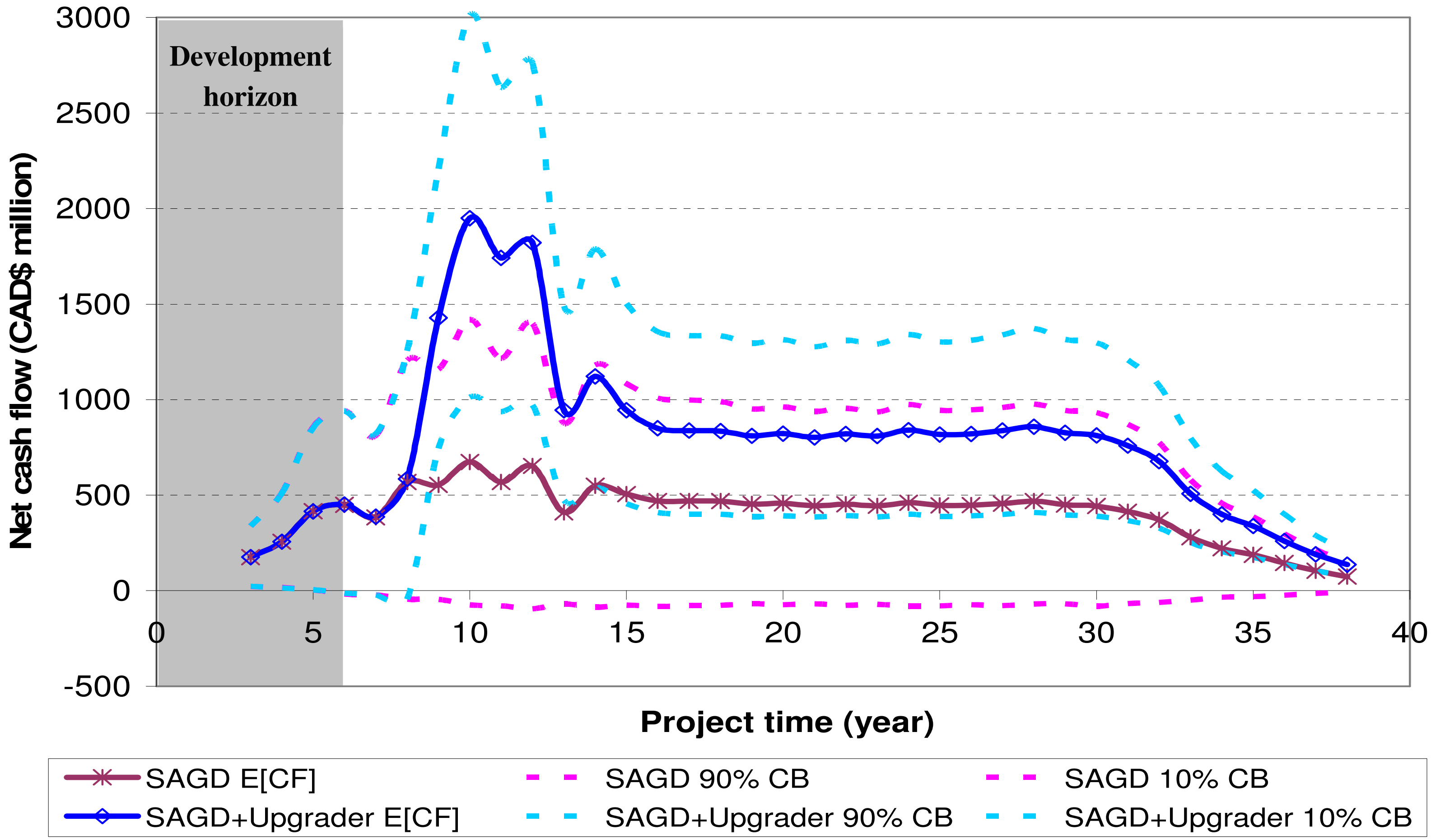
Case study #1: Expected CF and CF boundaries



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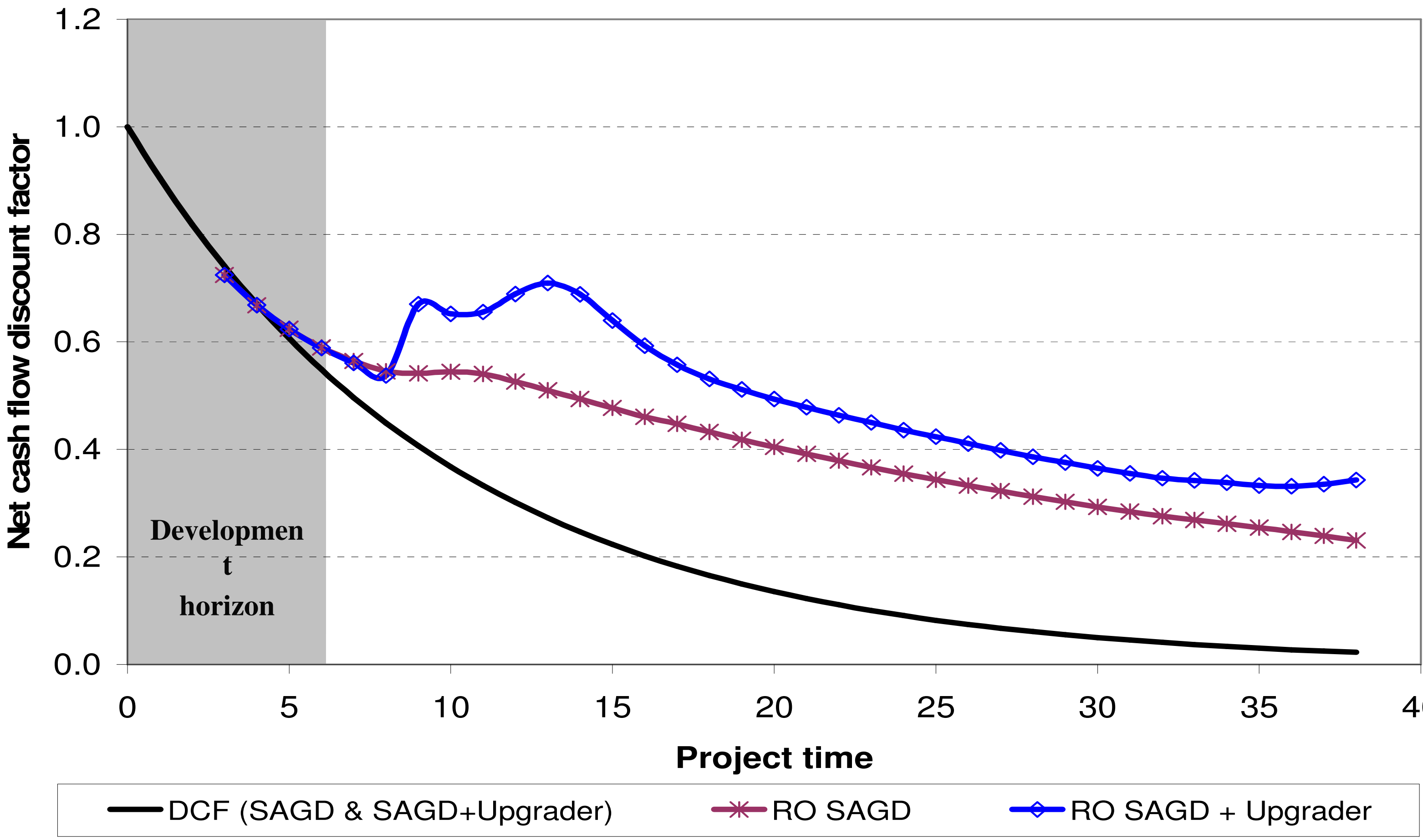
Case study #1:
Net CF time and risk discount factors



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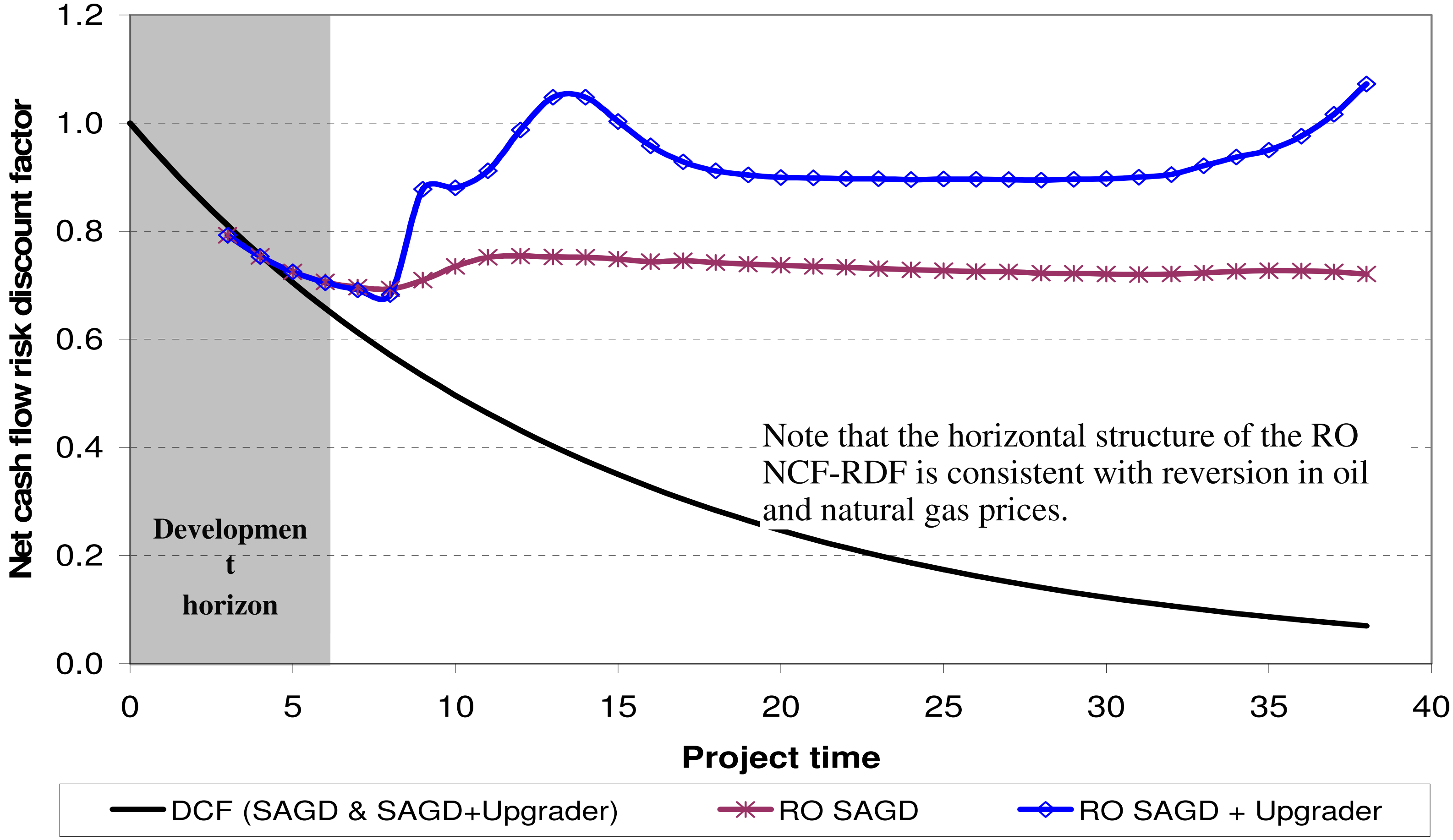
Case study #1:
Net CF risk discount factors



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Case study #1 – SAGD project conclusions

- Interaction of project design and uncertainty has important value effects – especially in the long-term.
  - Conventional DCF assumes project uncertainty grows at a fixed rate; RO recognizes project uncertainty is non-linear.
  - Project cash flow risk is dependent upon design (sometimes in surprising ways). RO respects this while a constant DCF discount rate does not.
- Real option analysis helps focus valuation analysts on explicit recognition of project characteristics.
  - Avoids hiding features in DCF discount rates and circular debates about discount rates (10% or 12%).
  - Facilitates a detailed discussion about the interaction between the economic environment and the project.

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Case study #1 – SAGD project conclusions

- A key parameter in this analysis may be the correlation of the LHDiff with the economy, which determines the amount of risk discounting in its forward prices
- Assumed low here: based on presumption that it is determined by Venezuelan politics
- What if Venezuelan political risk is correlated with the economy or if differential is strongly influenced by supply-demand balance of different types of refining capacity which is in turn driven by the economy?
- MBV highlights the importance of asking these sorts of questions and doing sensitivity analysis around them

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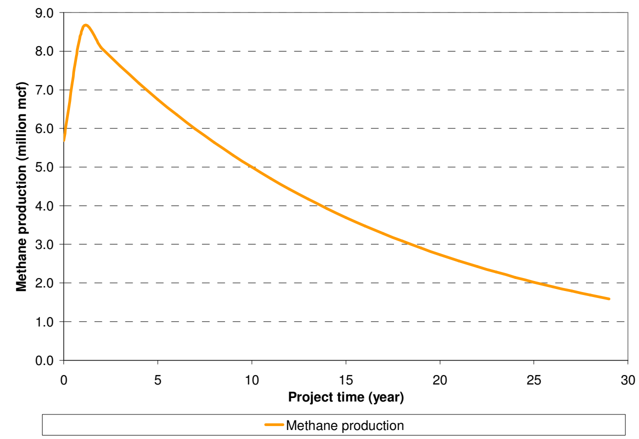
► **Case study #2: Equity and government cash flows at a coal bed methane project**

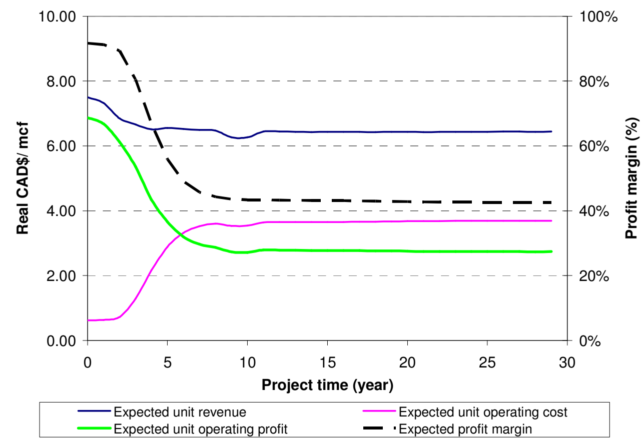
Case study #3: Valuing a dual-fuel boiler at a SAGD project

Final comments

Case Study #2 –
Coalbed methane project

- An undeveloped coalbed methane project containing 104 million mmcf of methane.
- Strong initial production rates declining over the next 30 yrs.
- Development CPX of CAD$190m.
- Stable long-term unit costs and profit margins.
  - Average real unit production cost is CAD$3.64/mmcf (includes tax and royalties).
  - Average profit margin is 43%





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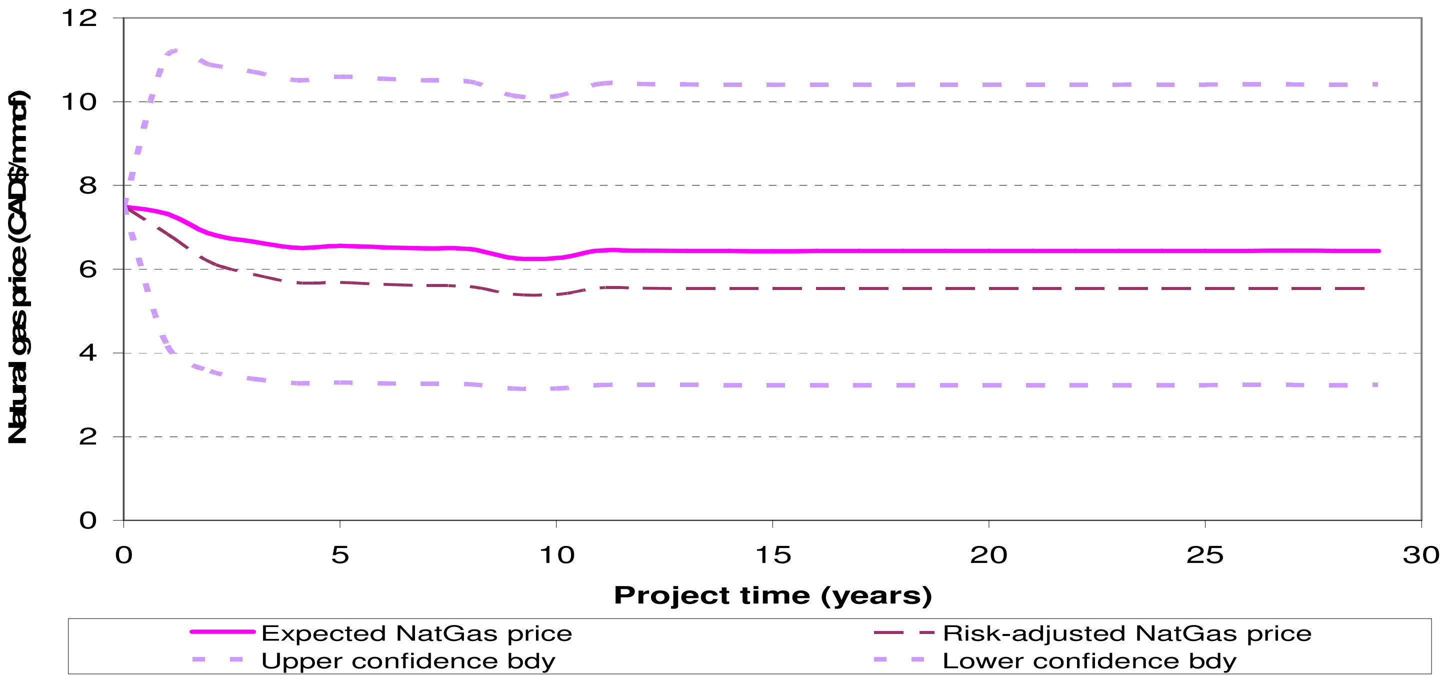
Case study #2 –
Natural gas price model

- Reverting natural gas price model with a real long-term expected price of CAD$6.43/mmcf. High levels of volatility with risk-adjustment because of correlation to financial market activity.



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Case study #2 –
Project tax regime

- A royalty payment dependent on whether pre-production capital has been repaid. Royalty base may be adjusted for field operating costs.
  - 1% royalty rate during capital repayment period.
  - 25% royalty rate after capital repayment period.
- Corporate income tax rate of 35% on taxable income.
  - Tax losses may be carried forward 7 years.
  - Declining balance depreciation with accelerated schedules for pre-production capital (Class 41a).

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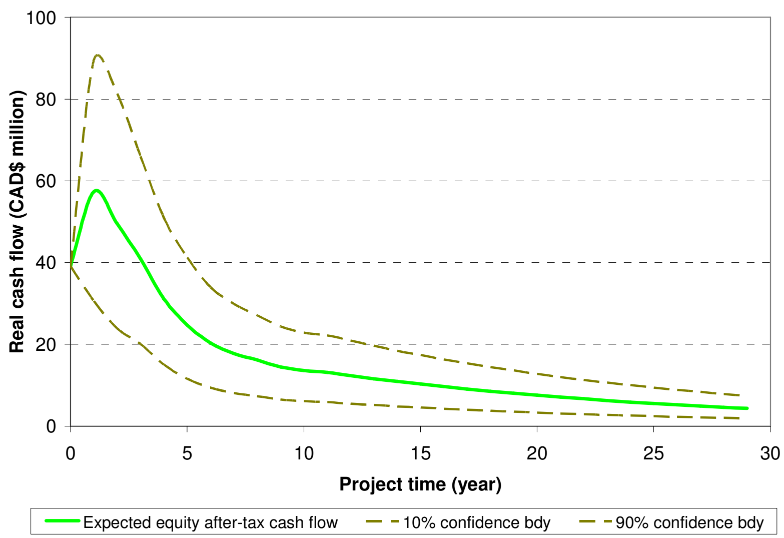
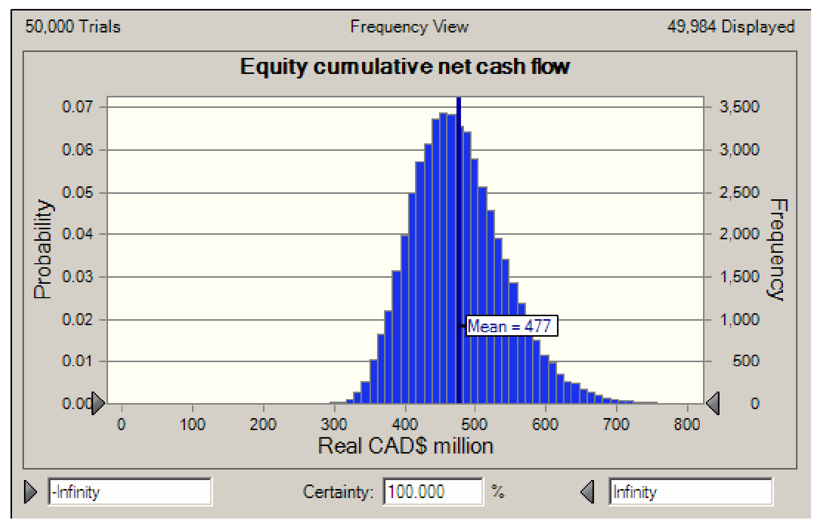
Case study #2 –
Expected after-tax equity cash flows

- Expected equity net cash flow (not adjusted for time and risk) over the life of the project is $477 million.
- Probability of a negative lifetime net cash flow balance is small using the current price model.
- Lower 10% confidence boundary is $398 million.





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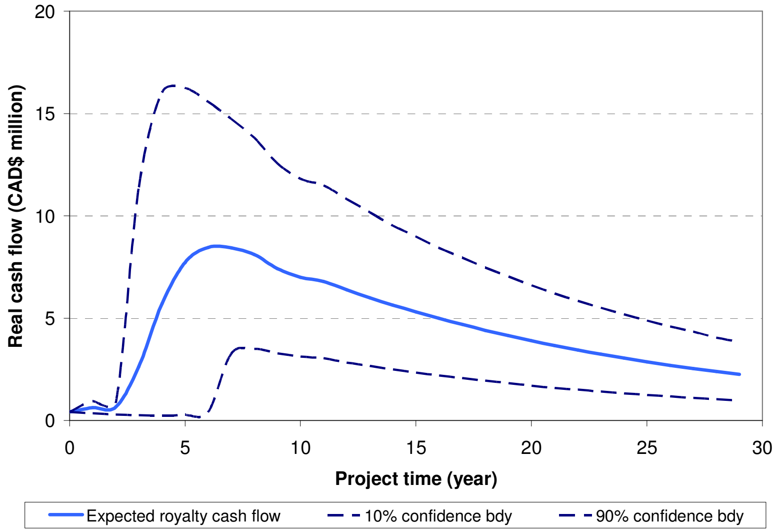
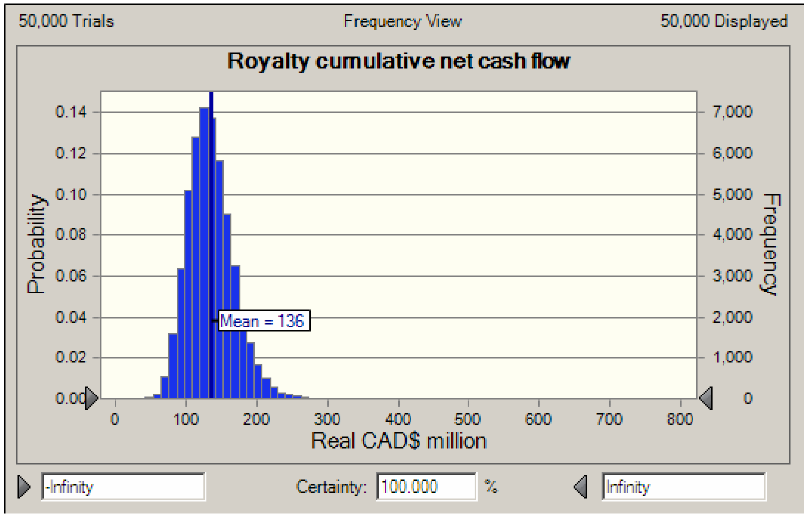
Case study #2 –
Expected royalty cash flows

- Expected royalty cash flows (not adjusted for time and risk) over the life of the project are $136 million.
- There is no possibility of a negative lifetime cash flow balance and the lower 10% confidence boundary is $97 million.
- Narrow histogram when there is no management flexibility.





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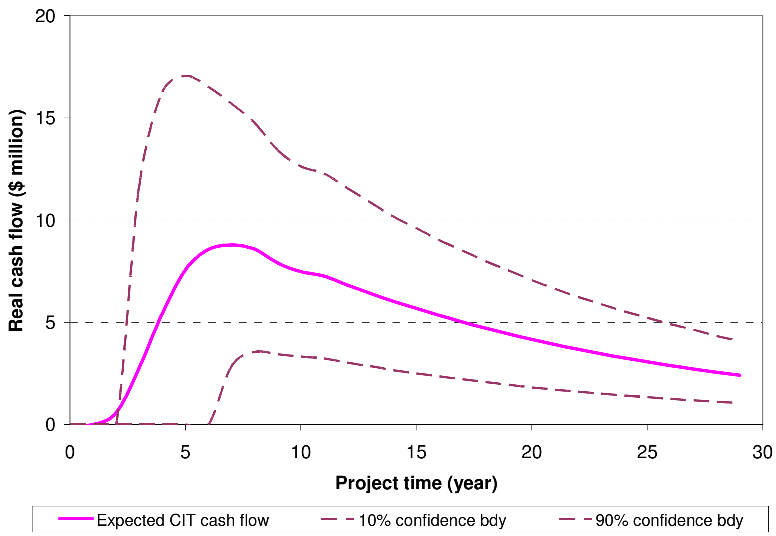
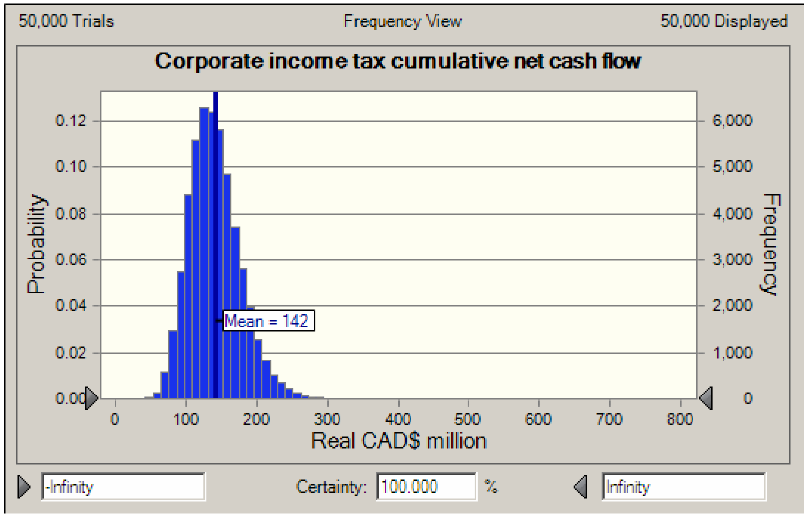
Case study #2 –
Expected corporate income tax cash flows

- Expected corporate income tax cash flows (not adjusted for time and risk) over the life of the project are $142 million.
- There is no possibility of a negative lifetime cash flow balance; the lower 10% CB is $99 million and the upper 90% CB is $189 million.





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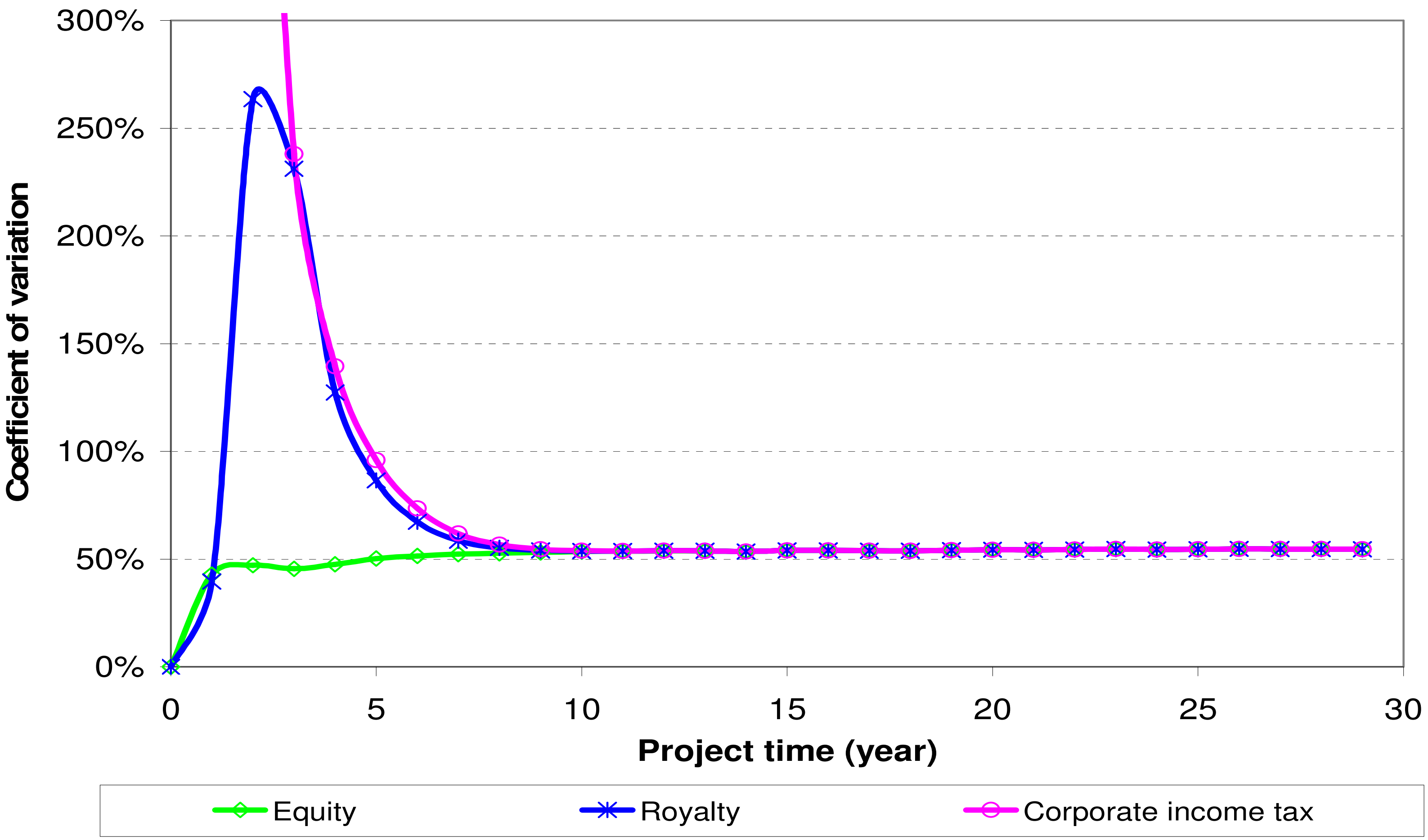
Case study #2 –
Cash flow uncertainty comparison



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Case study #2 –
DCF/RO NOFLEX results

Stakeholder	NPV (CAD$ million)	
	DCF	RO
Equity	73.2	154.0
Royalty	44.5	75.6
Corporate income tax	45.1	76.9

- DCF NPV is calculated with a 12% risk adjusted discount rate. RO NPV is calculated with a 5% risk-free rate and a risk-adjusted price curve.
- Equity IRR is 24.3%. Implied RO cost of capital is 6.6% which is the DCF discount rate that equates DCF NPV to RO NPV. Excess RO return is 17.7%.

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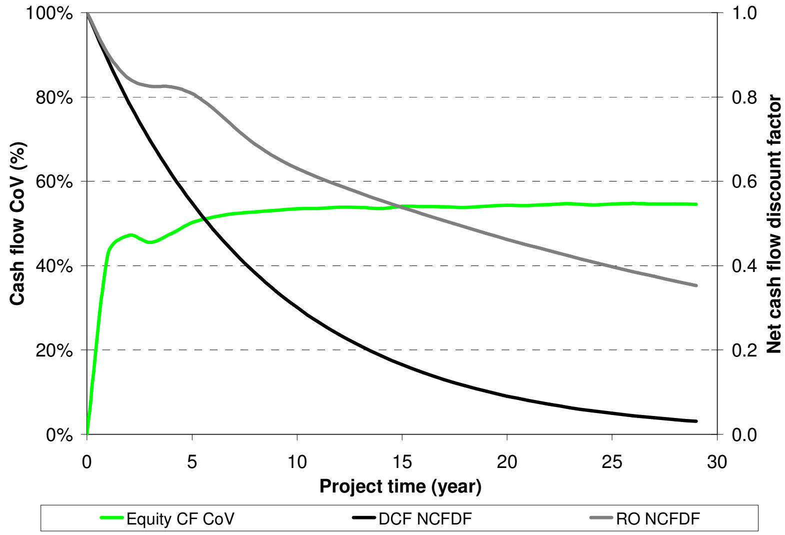
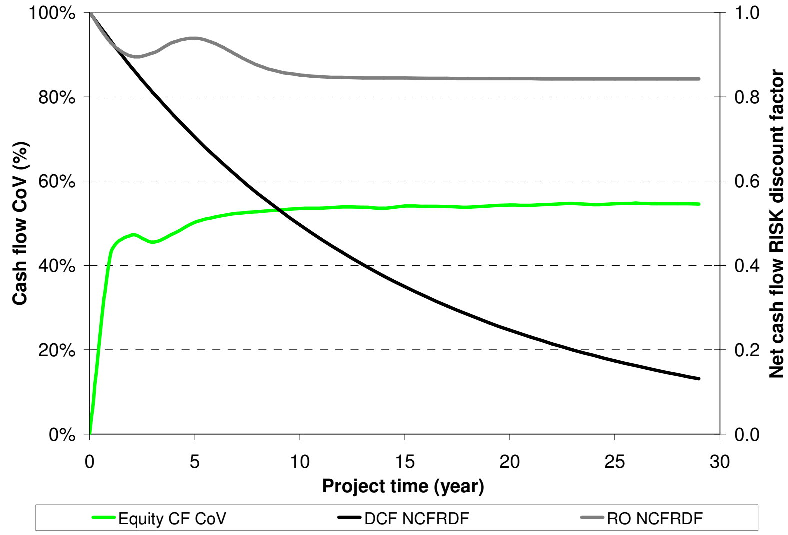
Case Study #2 –
Equity CF deviation, NCFDF and NCFRDF

- Cash flow uncertainty stabilizes in the long term due to price reversion and constant real unit operating costs.
- RO risk adjustments track cash flow variability.
- DCF NPV lower than RO because NCFDFs are on average smaller (i.e. a larger risk adjustment than RO).





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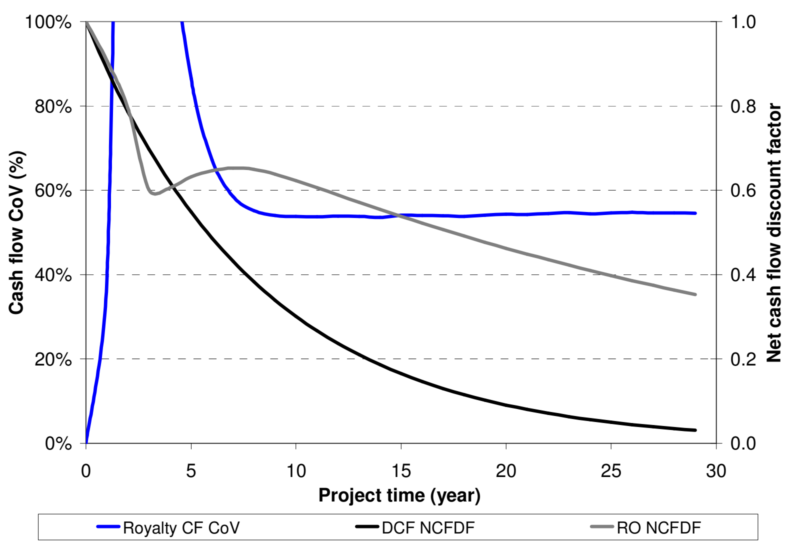
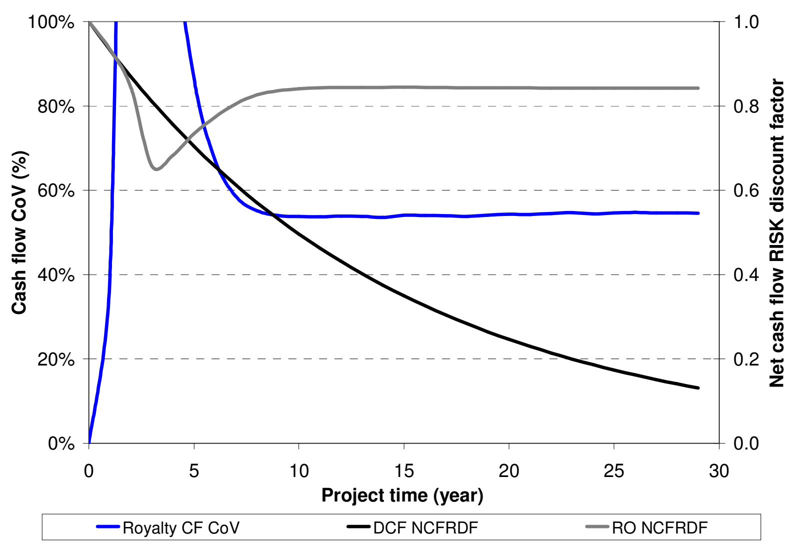
Case Study #2 – Royalty CF deviation, NCFDF and NCFRDF

- Royalty CF uncertainty is initially very high because of uncertainty in capital repayment period and stabilizes once this period is finished.
- Real option risk adjustments are initially high compared to later years because of high initial royalty uncertainty.





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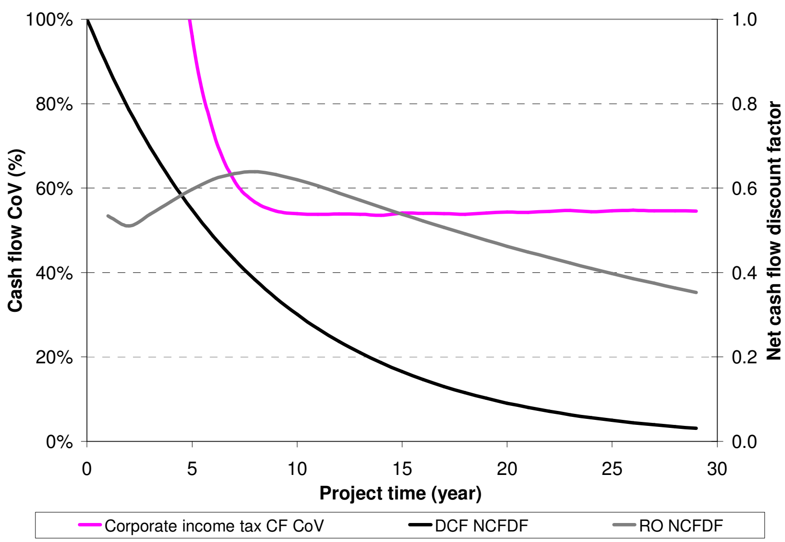
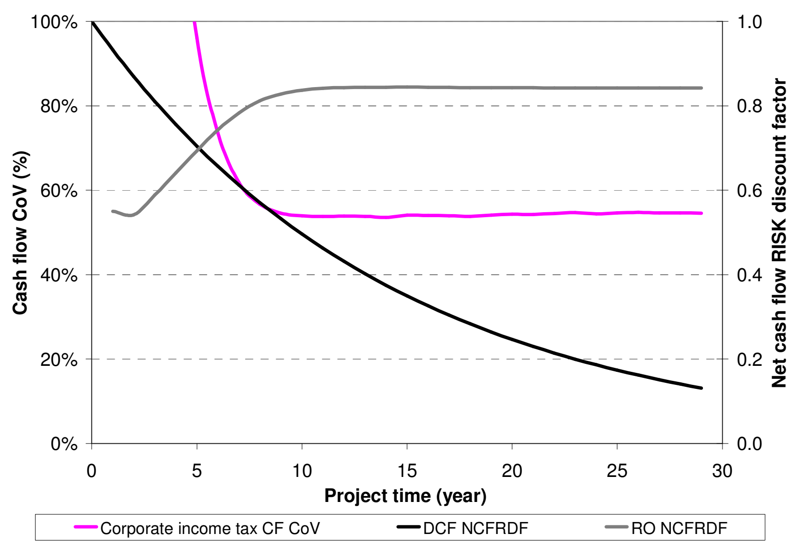
Case Study #2 –
CIT CF deviation, NCFDF and NCFRDF

- High volatility of CIT in early years due to uncertainty in the time necessary to depreciate development capital.
- RO risk adjustments recognize changes in CIT uncertainty.





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Case Study #2 – Final comments

- Highlighted that the level of cash flow uncertainty can vary greatly between project stakeholders and during the project.
  - RO was able to explicitly recognize this variation in its risk adjustment whereas constant discount rate DCF does not.
- This analysis can be extended to analyze the impact of financing terms or tax policy on project development.
  - Flexible models can estimate the increased probability that some areas of a petroleum project are not developed because of onerous terms.

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- Case study #1: Long-term cash flows at a SAGD project
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- ► **Case study #3: Valuing a dual-fuel boiler at a SAGD project**
- Final comments

Case study #3:
Dual-fuel boiler SAGD with fuel switching

- Similar SAGD project to that in Case Study #1:
  - 2 billion barrels of recoverable reserves at a maximum production rate of 190 thousand bbl/d (70.6 million bbl/y).
  - Production increased in phases for a field life of 38 years.
  - Transport cost: $3.00/bbl
- Two design options:

	gas-fired boiler	dual-fuel boiler	
		gas-fired	bitumen-fired
CAPEX ($b)	8.2	9.2	
Nat. gas(mcf/bbl)	1.1	1.1	0.033
Bitumen (bbl/bbl)	-	-	0.179
Other OPEX ($/bbl)	5.50	6.00	8.00

Annual decision with no switch cost

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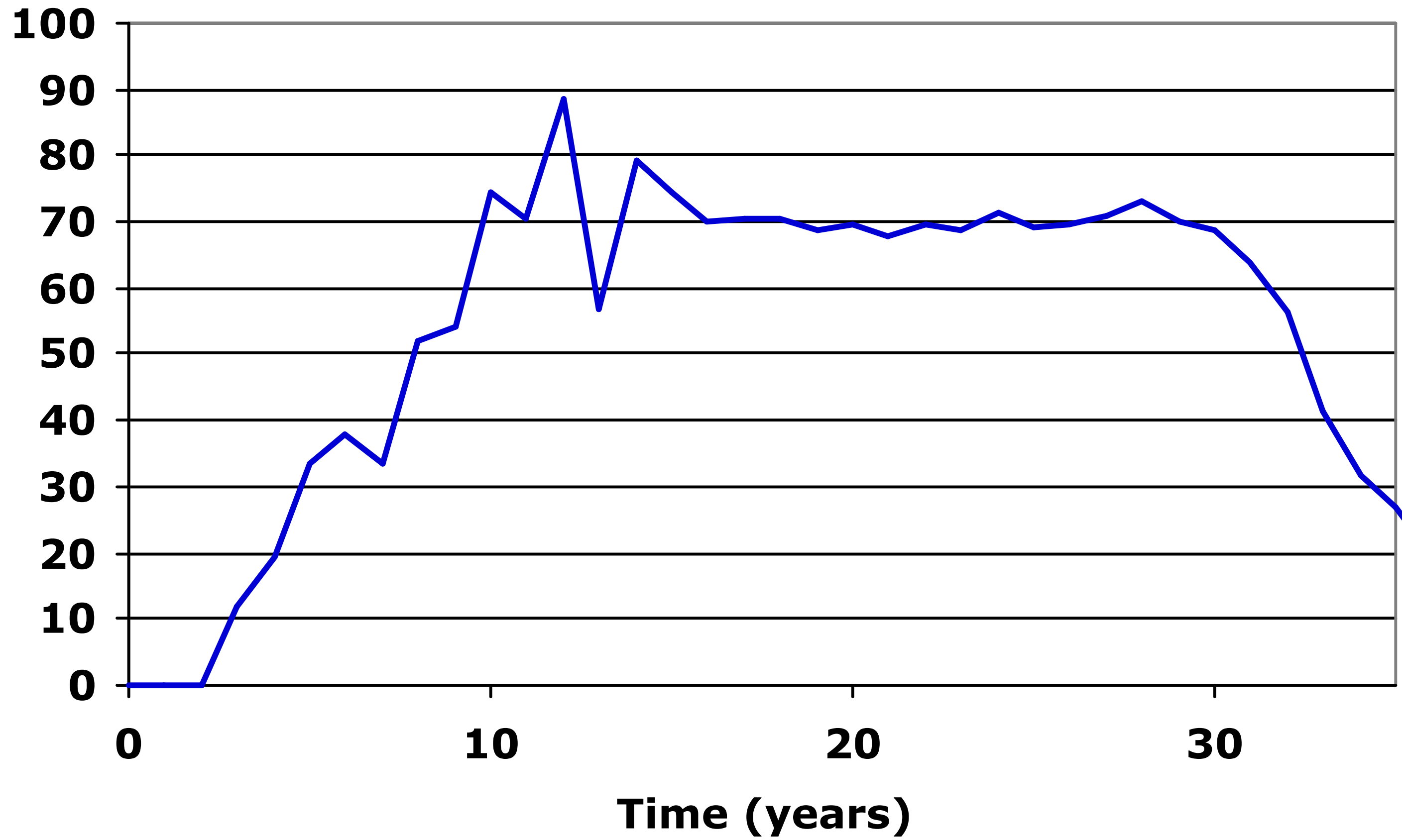
Case study #3: Production profile



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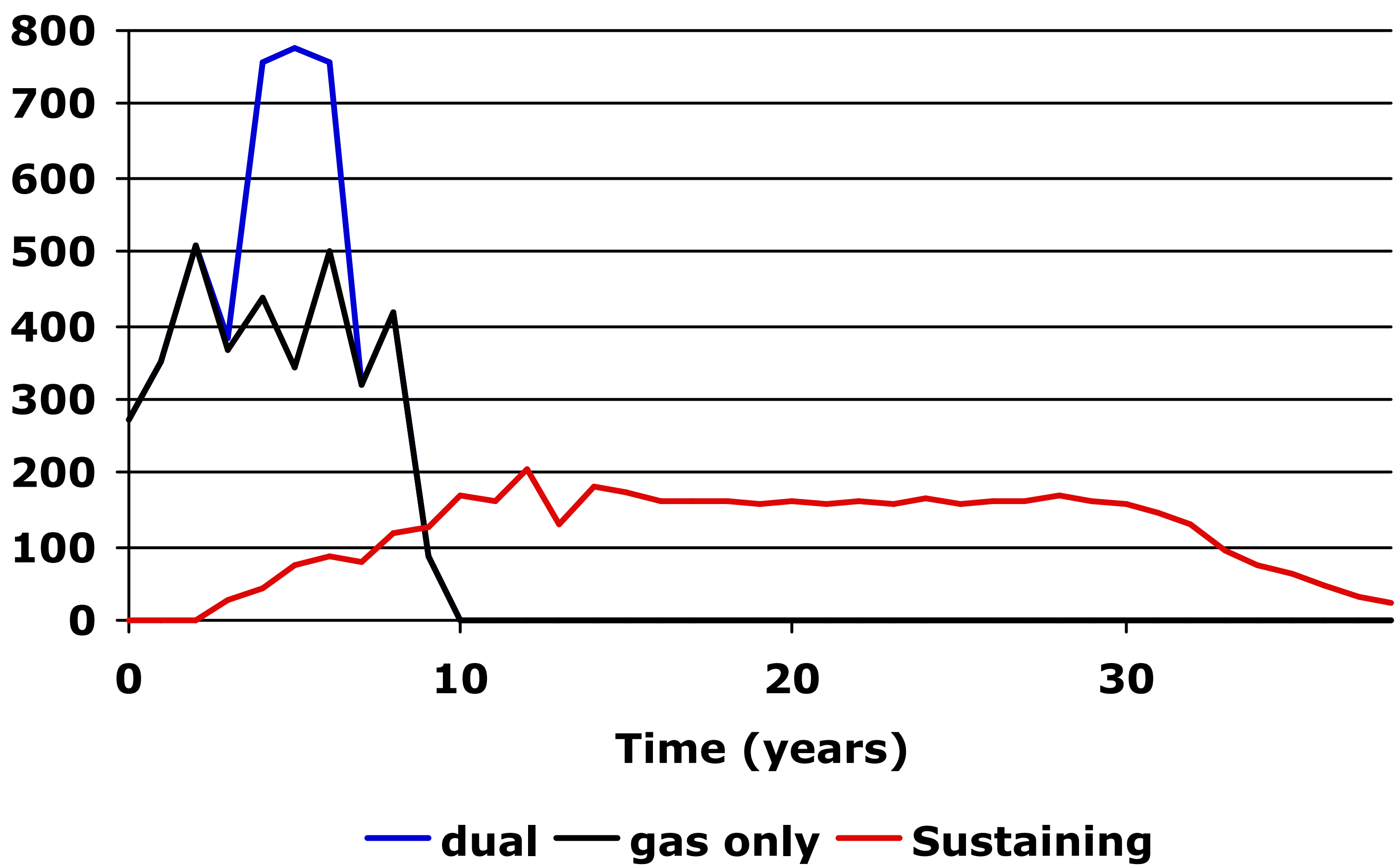
Case study #3: CAPEX profile



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Case study #3:
Sources of uncertainty

- WTI / synthetic crude oil price
  - Moderate levels of uncertainty (25%) with strong reversion to a long-term equilibrium price of $55.54/bbl; current $75.00/bbl
- Natural gas price
  - High levels of uncertainty (50%) with strong reversion to a long-term equilibrium price of $7.00/mcf; current $7.50/mcf
- WTI-bitumen differential
  - High levels of uncertainty (50%) with strong reversion to a long-term equilibrium price of $26.66/bbl; ; current $39.00/bbl
- Correlations between uncertainties:
  - WTI - NatGas: 0.7; WTI - LHDiff: 0.7; NatGas - LHDiff: 0.5

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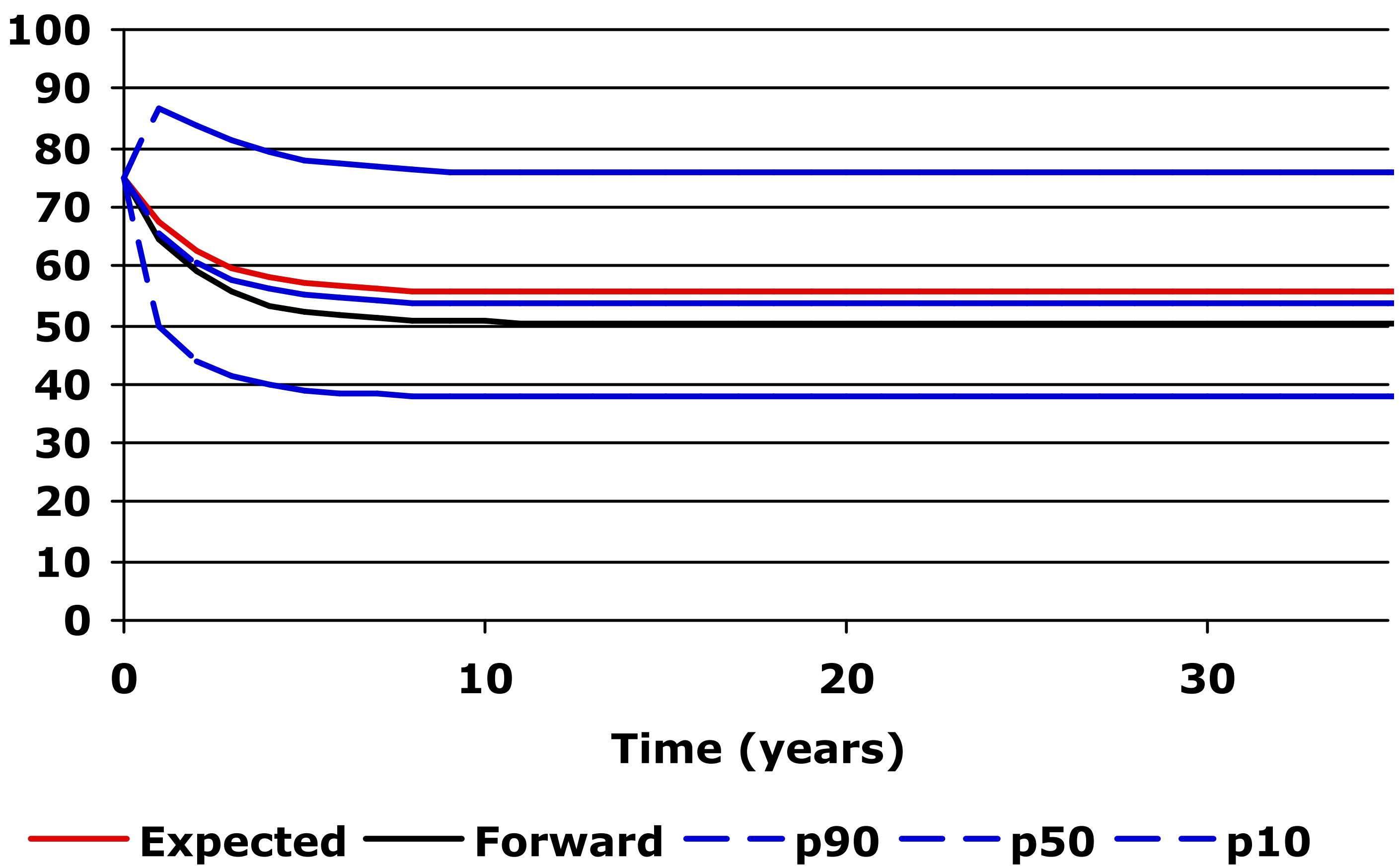
Case study #3:
WTI model



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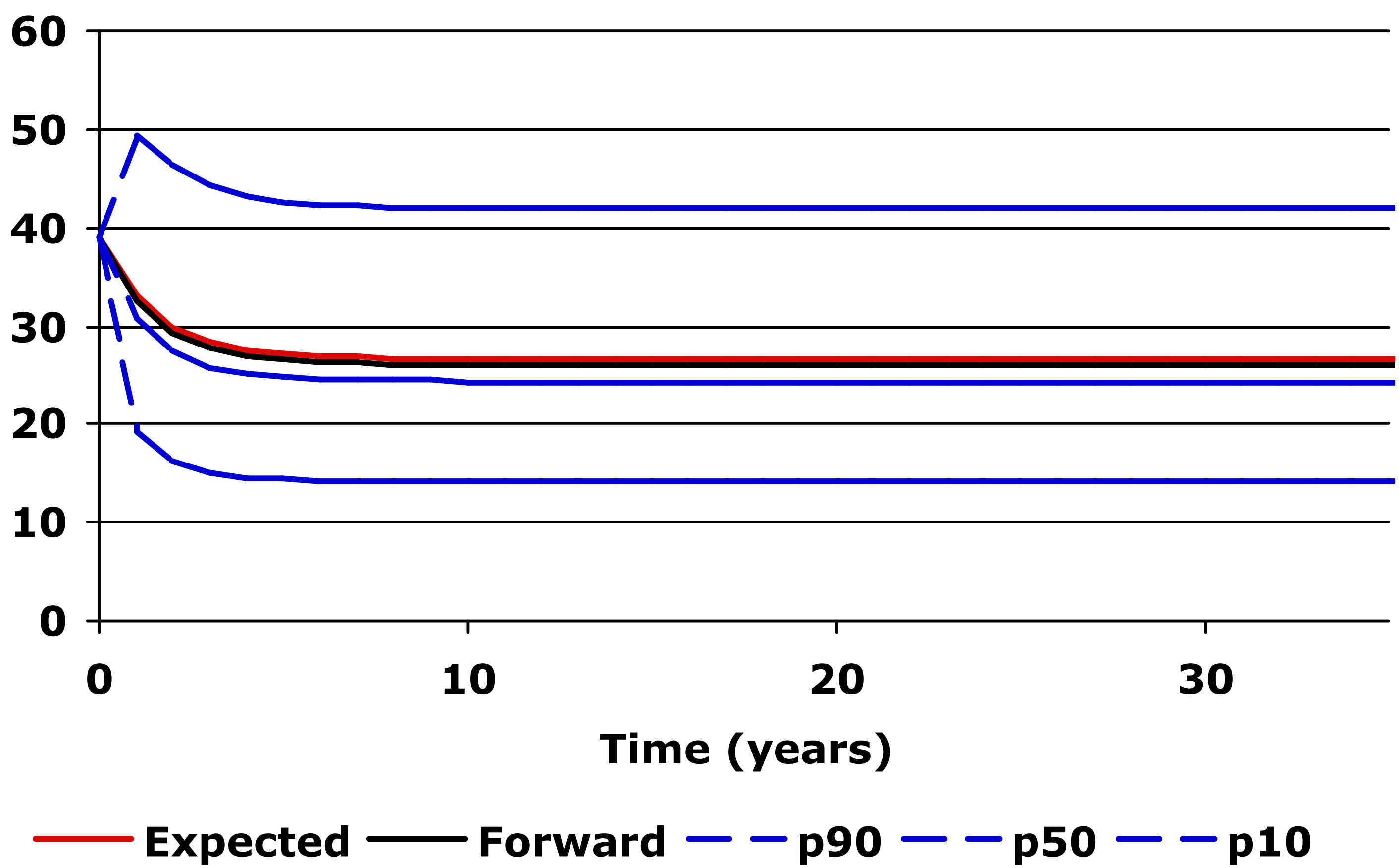
Case study #3:
WTI-bitumen differential model



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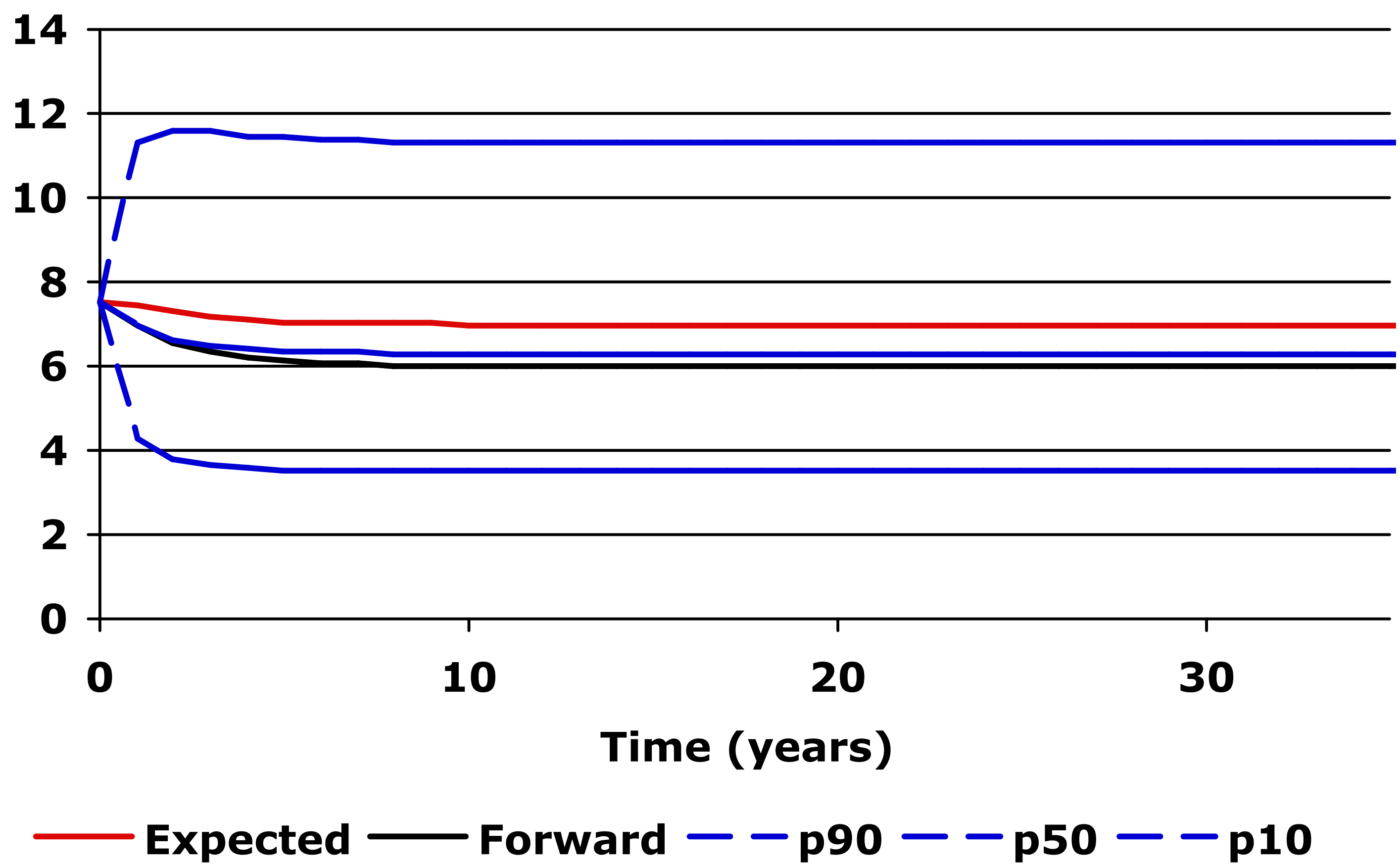
Case study #3:
Natural gas price model



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Case study #3:
Taxes

- Royalty
  - Pre-payout : 1% of plant gate revenue
  - Post-payout: max (pre_payout royalty, 25% of cash-flow)
  - Losses carried forward at long Canada bond rate
- CIT
  - 28.5% rate
  - 30% declining balance on lagged sustaining capital
  - 25% declining balance on half-year lagged development capital
  - 41a: 100% declining balance up to accounting income limit
  - Large other income so losses claimed immediately

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Case study #3: Effects of uncertainty

- Uncertainty relevant only because of "non-linear cash-flows"
  - Taxes
  - Flexibility
- Analysis without uncertainty
- Analysis with varying level of correlation between bitumen and natural gas prices
  - Stong, weak, none
  - Lower correlation, more uncertainty in net
- Value without flexibility down with uncertainty in net
- Value of flexibility up with uncertainty in the effects of the choice

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Case study #3:
Computation: DCF

value of asset

= max over policies p

(sum over realisations r

(probability$_r$

* sum over times t

(asset net cashflow $_t$ (p,r)

* corporate risk discount factor $_t$

* time discount factor $_t$)))

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Case study #3:
Computation: RO

Value of asset

= max over policies p

(sum over realisations r

(probability$_r$

* sum over times t

(asset net cashflow $_t$ (p,r)

* realisation risk adjustment $_{r,t}$

* time discount factor $_t$)))

Same except uniform risk-discounting becomes realisation-dependent risk adjustment

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Case study #3: Policy search

- Depends on state variables:
  - Prices
  - Tax balances
  - Current operating state (if costs to switching)
- Generally done within valuation
- Here an approximation pre-specifies policy that maximises current operating cash-flow
  - Pretax capital costs independent of operating mode
  - Not quite optimal because of operating effects on royalty payout and 41a claim
  - Underestimates value of flexibility

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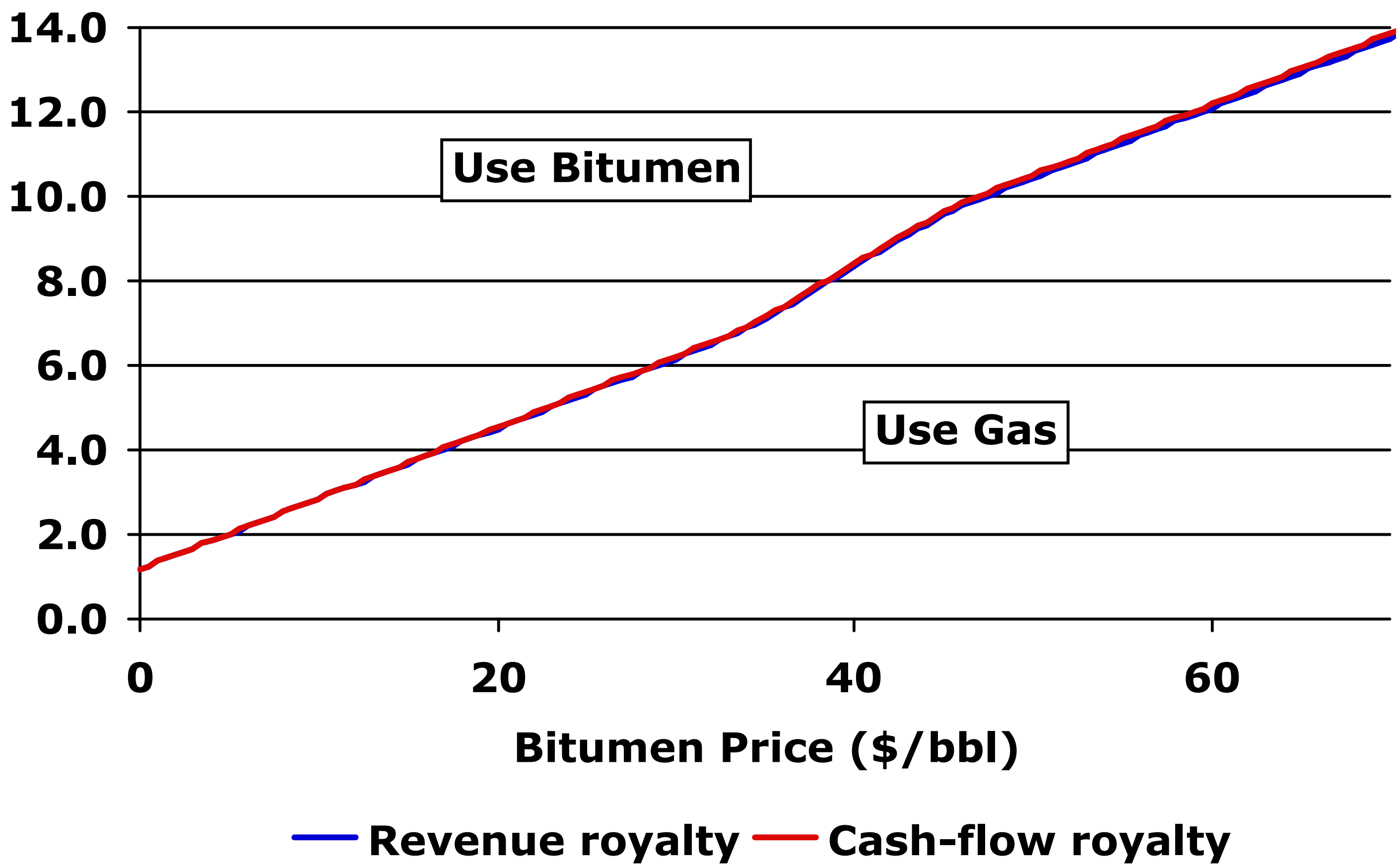
Case study #3: Policy



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Case study #3: Values

	no uncert.	strong corr.	weak corr.	no corr.
DCF				
gas	884	543	536	529
dual gas	409	13	6	-2
dual bit	630	211	211	211
dual choice	630	383	426	462
RO				
gas	3473	2991	2969	2944
dual gas	2693	2135	2112	2086
dual bit	3249	2710	2710	2709
dual choice	3249	3217	3328	3422

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Case study #3:
No 41a

	no unc	strong corr	weak corr	no corr
DCF				
gas	812	471	464	456
dual gas	359	-50	-59	-69
dual bit	571	148	148	148
dual choice	571	314	355	390
RO				
gas	3431	2943	2920	2896
dual gas	2661	2092	2067	2040
dual bit	3214	2667	2667	2667
dual choice	3214	3171	3280	3373

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DAVID LAUGHTON CONSULTING LTD.
Real Asset Risk Analytics (RA)²

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Valuation in the petroleum industry

Valuation influences: Uncertainty, structure and value estimation

A simple demonstration of DCF and RO value mechanics

Modelling output and input prices

Case study #1: Long-term cash flows at a SAGD project

Case study #2: Equity and government cash flows at a coal bed methane project

Case study #3: Valuing a dual-fuel boiler at a SAGD project

► Final comments

Final comments

- Asset valuation methods in the natural resource industries have not incorporated advances in the financial markets –

  There is some agreement on improving the analysis of effects of dynamic uncertainty with Monte Carlo simulation and decision-trees –

  There is not yet an agreement in the industry on whether aggregate risk adjustments (DCF) or source risk adjustments (RO) are better

- Demonstrated that RO recognizes variations in net cash flow uncertainty across assets while the conventional DCF approach does not –

  This has important implications for qualified person reports, and the internal analysis of assets with with atypical uncertainties.

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Final comments

- The ability to manage risk with operating strategies (flexibility) adds value –

  This is true for both DCF and MBV
- Tools are being developed to anlyses complex situations with many incertainties and decisions throughout the asset life cycle
- Work needed on
  - Refining output price models
  - Modelling of input price and technical/geological uncertainty
  - Decision models
  - Methods of presenting multi-dimensional results
  - Creation of commercial-grade software

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