Power generation assets valuation adopting a real options approach applied to the Colombian electricity market

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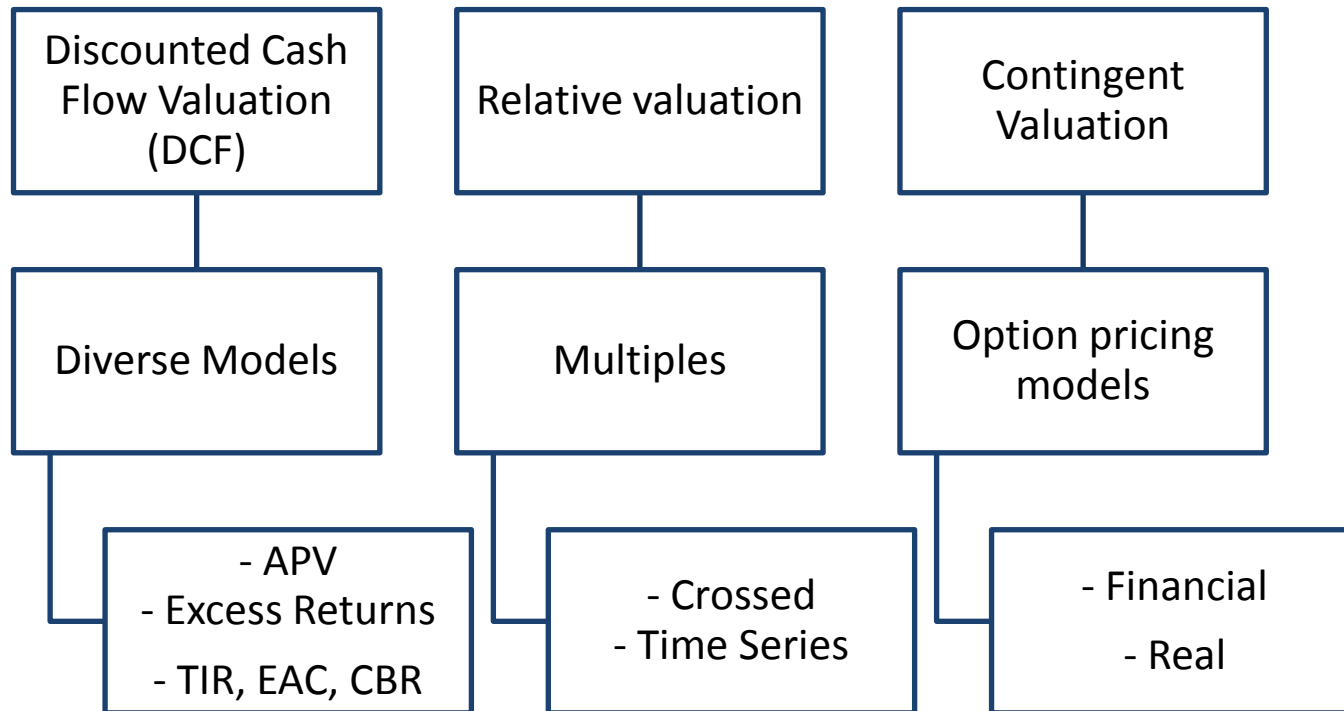
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"Valuation is not an objective exercise, and any preconceptions and biases that an analyst brings to the process will find their way into the value. And even the very best valuation will yield an estimate of the value, with a substantial likelihood of you being wrong in your assessment."

   - Domodaran

Problem definition

- Power generation sector develops in a highly uncertain and competitive environment where private investment is the main driver of expansion.

- Discounted cash flow valuation is the conventional technique used for power generation assets valuation.

- The Classic DFC method is inappropriate to value this kind of assets due to high uncertainty of the sector and its lack of capability to assign value to possible particular competitive advantages beach asset.

- This project pretends to pose an alternative methodology to valuate power generation assets in the Colombian market

Asset valuation

Discounted Cash Flow Valuation (DCF)	Relative valuation	Contingent Valuation
Diverse Models	Multiples	Option pricing models
- APV - Excess Returns - TIR, EAC, CBR	- Crossed - Time Series	- Financial - Real

Advantages

DCF Valuation

- Simple and replicable application method.
- Intrinsic valuation.
- Ease of understanding
- Widely used, considered the fundamental base of the other methodologies.

Relative Valuation

- Intuitive method, used in a daily, unconscious manner.
- Useful and simple method applied easily to different cases.
- The development of multiples offer relevant information that can be useful.

Contingent Valuation

- Flexible method
- Takes into account the uncertainty associated to the asset properties.
- Accurate reality modeling
- Valuates the optionality present in the assets or in possible strategic decisions

Disadvantages

DCF Valuation

- Rigid method
- Requires a priori knowledge of the future expected cash flows
- Difficulty to incorporate risk and uncertainty to the valuation
- High sensitive parameters

Relative Valuation

- Ignores available information
- Time static valuation.
- Requires an assets with similar characteristics
- Supposes the correct market valuation of similar assets

Contingent Valuation

- Complex method
- Difficulty to define the necessary parameters for real assets valuation
- Non-replicable (easily) method
- Due to an incorrect problem definition it may cause possible systematic errors in the valuation

# Power generation assets flexibilities

- Operational flexibilities
  - Frequency control
  - Quick operating ramp (Peaking capacity)
- Commercial flexibilities
  - Contract level
- Investment flexibilities
  - "Wait to invest"
  - Installed capacity decision
  - Possible expansion opportunity

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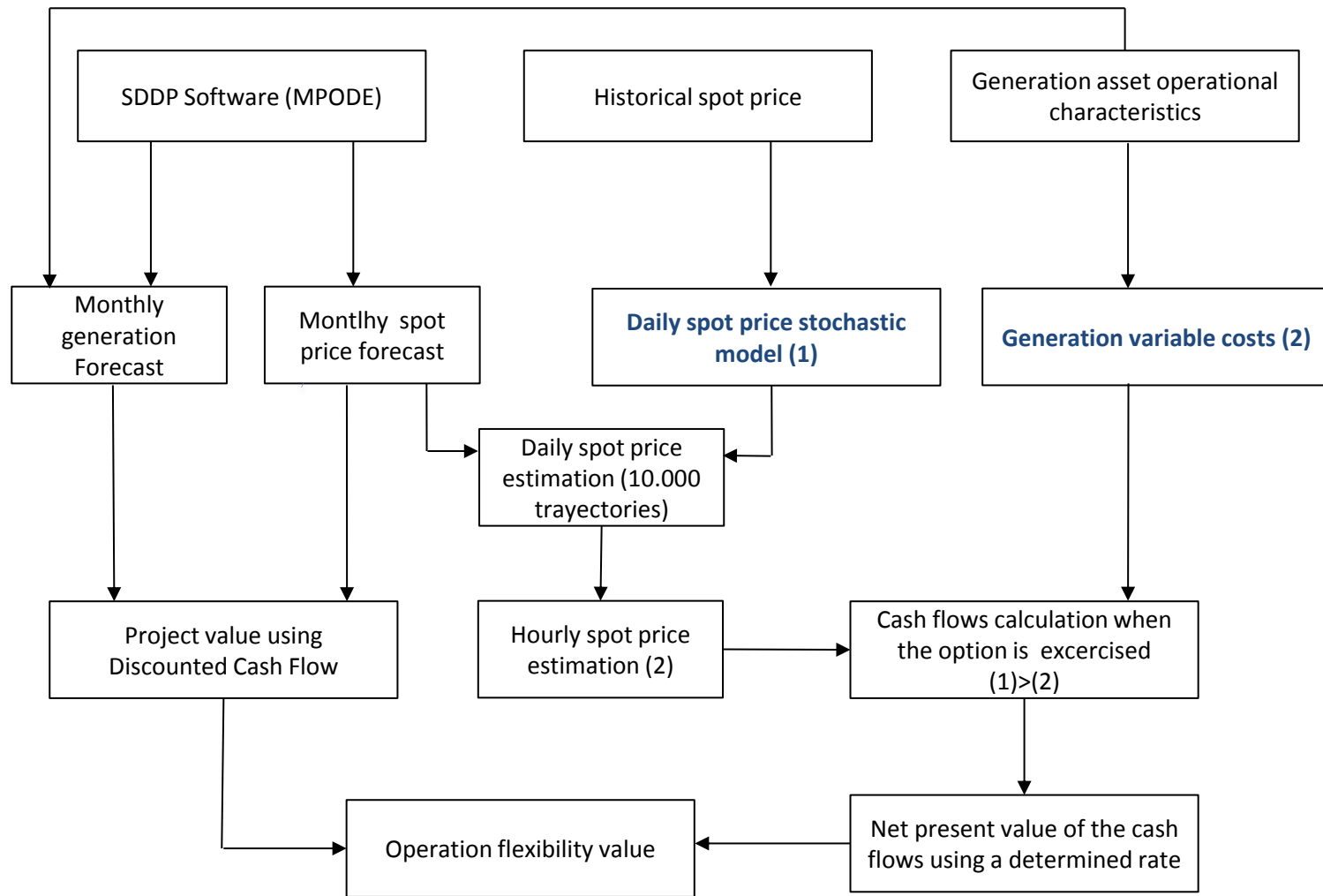 - Possible expansion opportunity

Operational flexibility
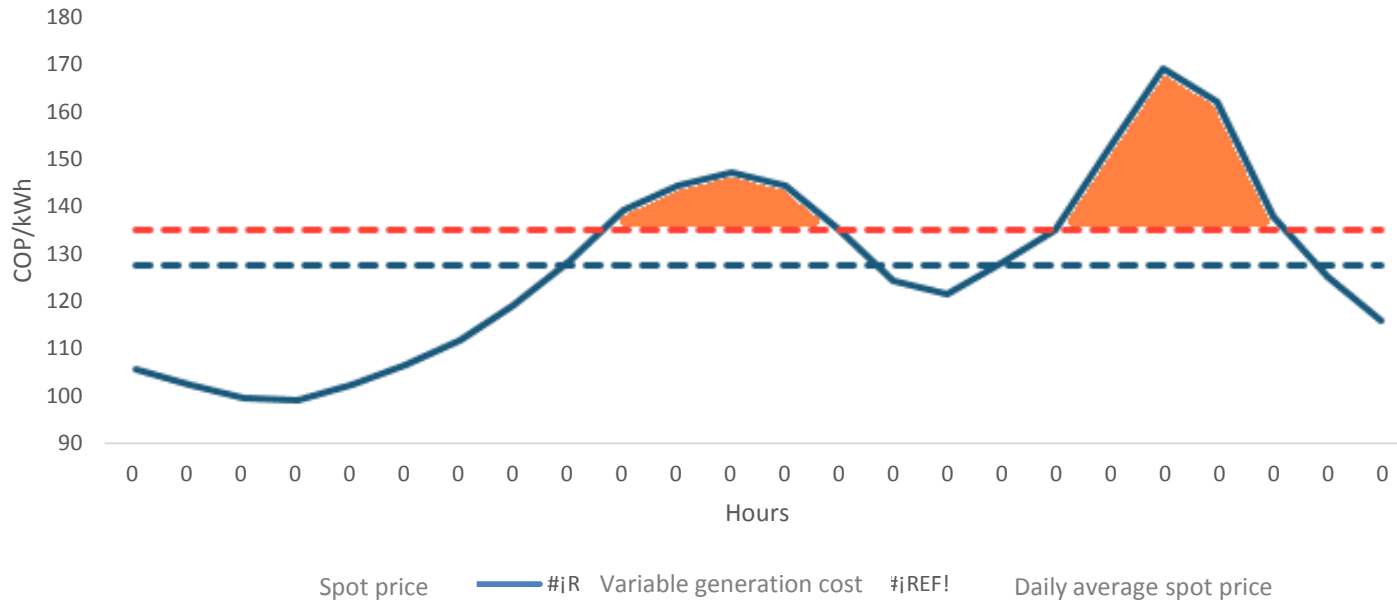
The technology used in a power generation project can offer significant operational advantages over other plants. On this depends on the ability to optimally capture intraday peaks of energy prices.

Methodology diagram flow

Real options approach

The contingent cash flow takes place when the spot price exceeds the power generation variable cost in which case is a economically rational decision to operate
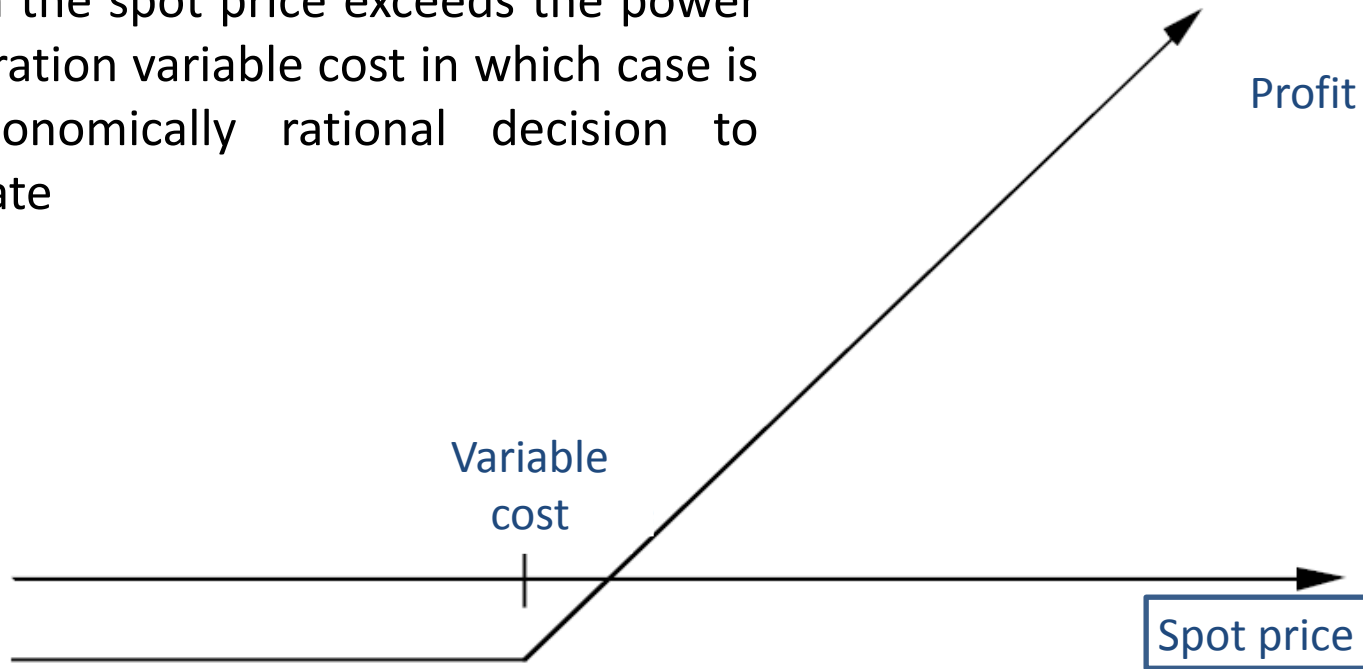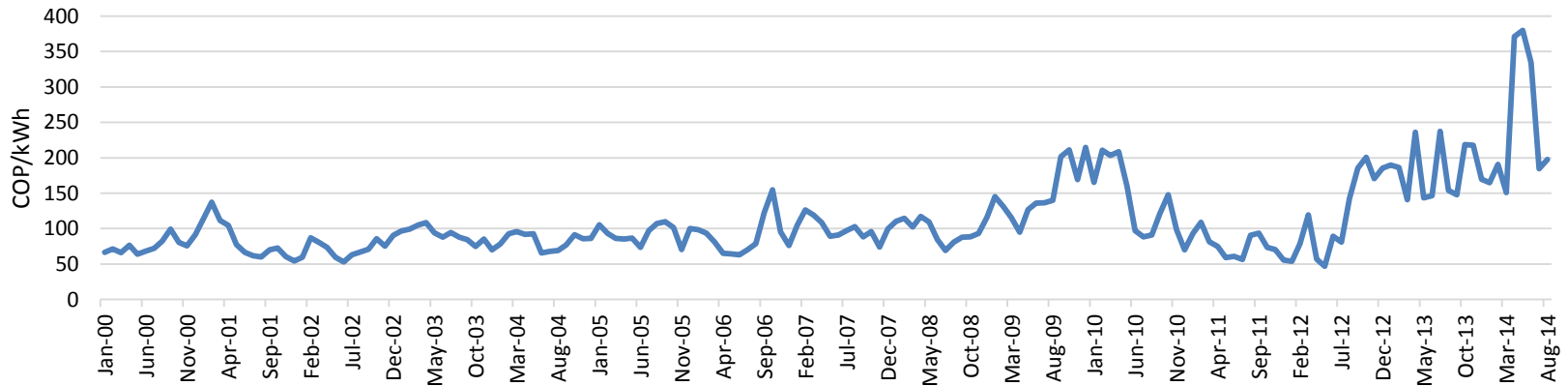
Profit

Variable cost

Spot price

Real options approach

The contingent cash flow takes place when the spot price exceeds the power generation variable cost in which case is a economically rational decision to operate
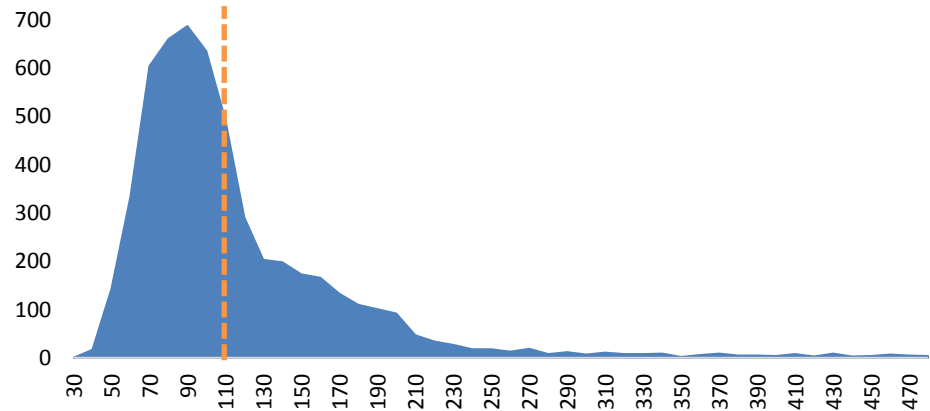
Profit
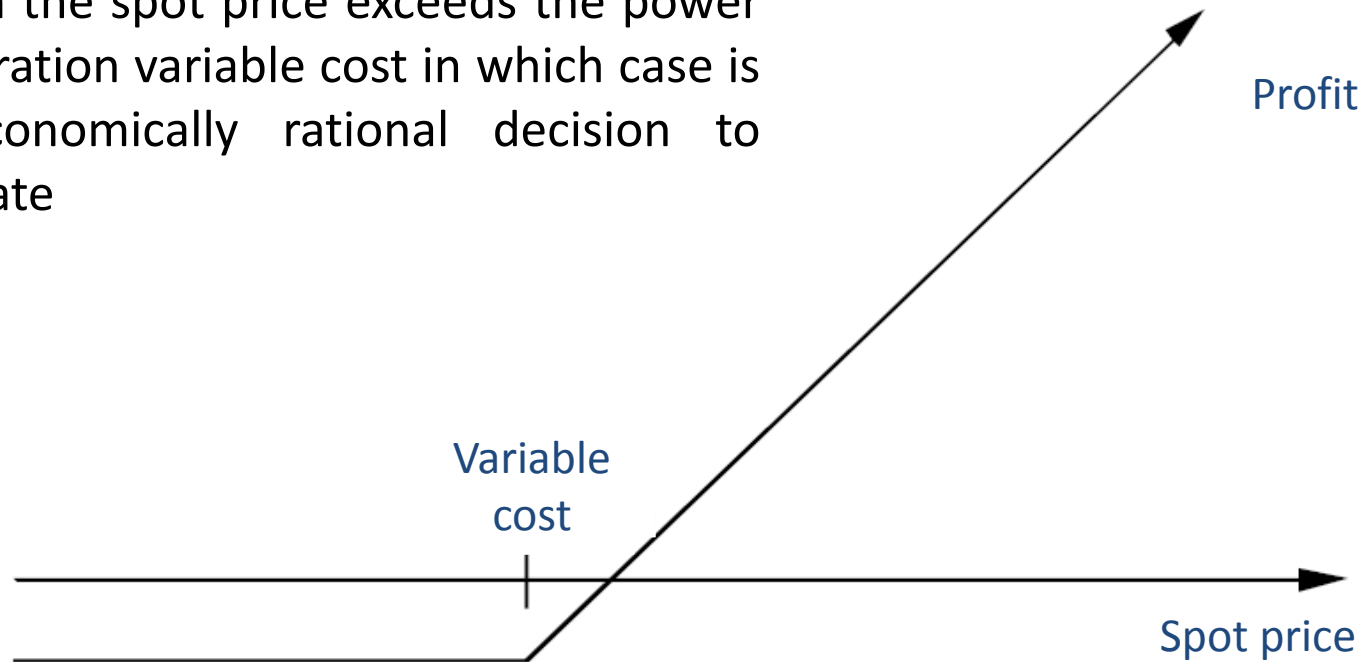
Variable cost

Spot price

Spot price

Monthly electricity spot price (Constant 2014 - COP/kWh)

The spot price fluctuates in a wide range of values. It can be inferred that the spot price is a highly volatile signal.

Histogram

Variance analysis

	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
January	1,00	0,00	0,05	0,00	0,03	0,00	0,00	0,05	0,05	0,00	0,00	0,00
February	0,00	1,00	0,03	0,00	0,05	0,00	0,90	0,04	0,04	0,01	0,12	0,36
March	0,05	0,03	1,00	0,00	0,84	0,00	0,02	0,98	0,98	0,00	0,00	0,00
April	0,00	0,00	0,00	1,00	0,00	0,60	0,00	0,00	0,00	0,19	0,02	0,00
May	0,03	0,05	0,84	0,00	1,00	0,00	0,03	0,87	0,86	0,00	0,00	0,00
June	0,00	0,00	0,00	0,60	0,00	1,00	0,00	0,00	0,00	0,42	0,08	0,01
July	0,00	0,90	0,02	0,00	0,03	0,00	1,00	0,02	0,03	0,01	0,14	0,42
August	0,05	0,04	0,98	0,00	0,87	0,00	0,02	1,00	0,99	0,00	0,00	0,00
September	0,05	0,04	0,98	0,00	0,86	0,00	0,03	0,99	1,00	0,00	0,00	0,00
October	0,00	0,01	0,00	0,19	0,00	0,42	0,01	0,00	0,00	1,00	0,34	0,10
November	0,00	0,12	0,00	0,02	0,00	0,08	0,14	0,00	0,00	0,34	1,00	0,50
December	0,00	0,36	0,00	0,00	0,00	0,01	0,42	0,00	0,00	0,10	0,50	1,00

A two sample F-test is done to determine if the volatility between months is statistically equal

Variance analysis

	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
January	0	0	1	0	0	0	0	0	1	0	0	0
February	0	0	0	0	1	0	1	0	0	0	1	1
March	1	0	0	0	1	0	0	1	1	0	0	0
April	0	0	0	0	0	1	0	0	0	1	0	0
May	0	1	1	0	0	0	0	1	1	0	0	0
June	0	0	0	1	0	0	0	0	0	1	1	0
July	0	1	0	0	0	0	0	0	0	0	1	1
August	0	0	1	0	1	0	0	0	1	0	0	0
September	1	0	1	0	1	0	0	1	0	0	0	0
October	0	0	0	1	0	1	0	0	0	0	1	1
November	0	1	0	0	0	1	1	0	0	1	0	1
December	0	1	0	0	0	0	1	0	0	1	1	0

There is not a clear definition of clusters or groups of months with the same behavior in terms of volatility.

Model specification

A monthly mean reversion stochastic process with a conditional heteroskedasticity variance model is proposed to model the zero-mean logarithm spot price
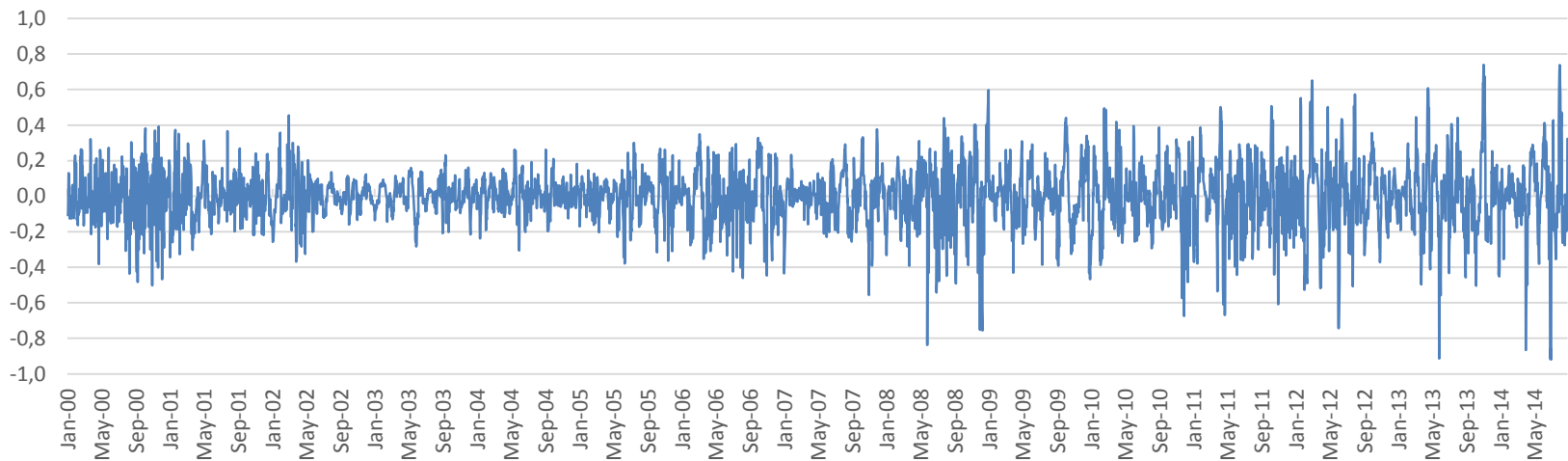
$$Y_t = \ln(P_t) - \ln(\bar{P}_t)$$
$$dY_t = \alpha(\mu - Y_t) + dZ$$

P_t: $Daily\ spot\ price$
$\bar{P}_t$: $Monthly\ spot\ price\ mean$
dZ : Variance model $process\ differential$

Spot price transformation

Model parameter estimation

$$Y_t = Y_{t-1} + \alpha(\mu - Y_{t-1})\Delta t + \varepsilon_t$$
$$\varepsilon_t = h_t z_t \therefore z_t \sim tstudent(\delta)$$
$$h_t^2 = \beta_0 + \beta_1 h_{t-1}^2 + \beta_2 \varepsilon_{t-1}^2$$

|	μ	α	β_0	β_1	β_2	δ
January	0	86.73	0	0.46	0.54	3.05
Febraury	0	63.30	0	0.56	0.44	2.91
March	0	85.04	0	0.67	0.33	3.17
April	0	47.15	0	0.74	0.26	3.24
May	0	96.20	0	0.60	0.30	3.36
June	0	88.75	0	0.75	0.25	3.90
July	0	86.81	0	0.72	0.28	4.02
August	0	111.53	0	0.81	0.19	4.36
September	0	95.33	0	0.79	0.18	6.36
October	0	44.63	0	0.61	0.39	2.77
November	0	77.06	0	0.61	0.39	4.66
December	0	76.87	0	0.83	0.17	3.78

Intraday spot price

- From a statistical analysis using the historical spot price from 2012 to 2015, the intraday spot price behavior is estimated with three demand blocks, defined as follows:

	Hours	Total hours
Low price	0, 1, 2, 3, 4, 5, 6, 23	8
Medium price	7, 8, 9, 10, 13, 14, 15, 16, 17, 21, 22	11
High price	11, 12, 18, 19, 20	5

|	% over the average daily price		
	Low	Medium	High
January	-12%	2%	14%
February	-9%	2%	11%
March	-13%	2%	16%
April	-13%	3%	14%
May	-15%	3%	18%
June	-18%	5%	18%
July	-20%	5%	21%
August	-16%	4%	16%
September	-11%	3%	11%
October	-11%	4%	10%
November	-13%	4%	11%
December	-10%	3%	10%
	-13%	3%	14%

Intraday deviations
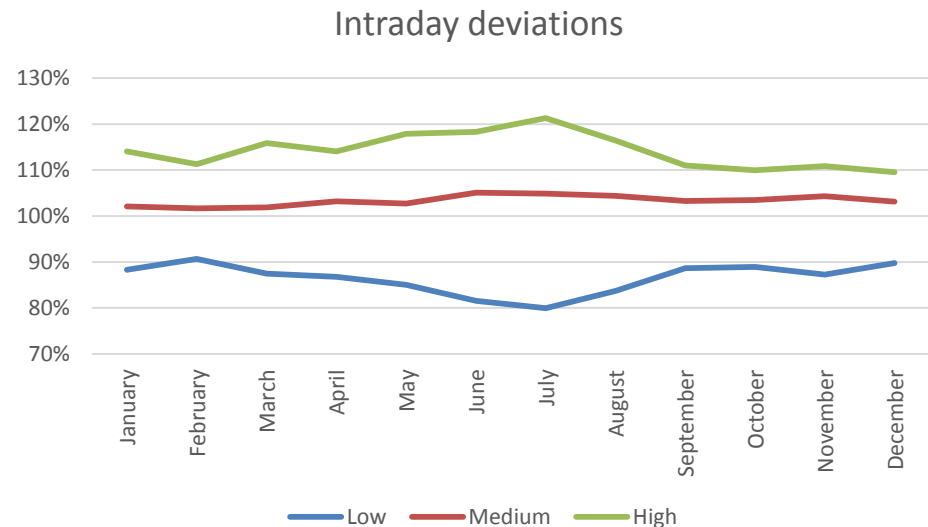
Real options approach
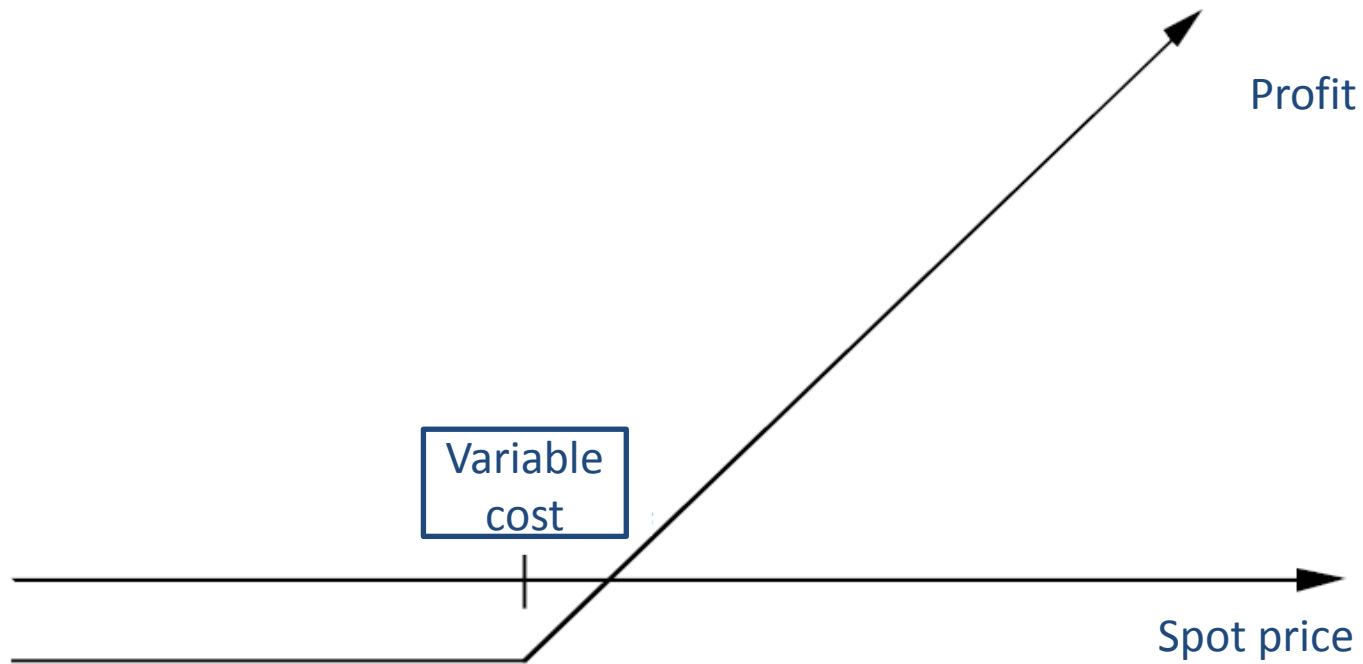
Variable cost calculation

The variable cost depends on the following factors:

- Fuel supply cost

- Cost of operation and maintenance

- Other variable costs

- Plant status (Daily)

- Start ramp (Heat rate and load)

Warm   Cold
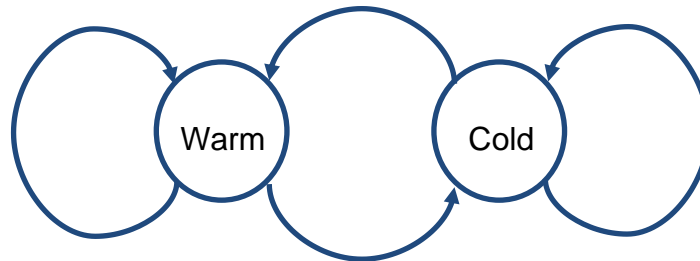
Variable cost calculation example

TRM	2.049	COP/USD
Fuel Cost	6,2	USD/MBTU
Maintenance	9,5	COP/kWh
Other costs	48	COP/kWh

Hour	Heat Rate (MBTU/MWh)	Load (MW)
1	23,5	20
2	19,8	30
3	19,8	30
4	16,0	50
5	8,9	119
6	8,6	138
7	8,4	150
8	**8,3**	160
	10,40	

State	Variable Cost [COP/kWh]
Hot	162,8
Cold	189,4

In the calculation of the variable cost in cold state, the startup/shutdown cost are taken into account. While the variable cost in hot state assumes the maximum efficiency of the power plant.
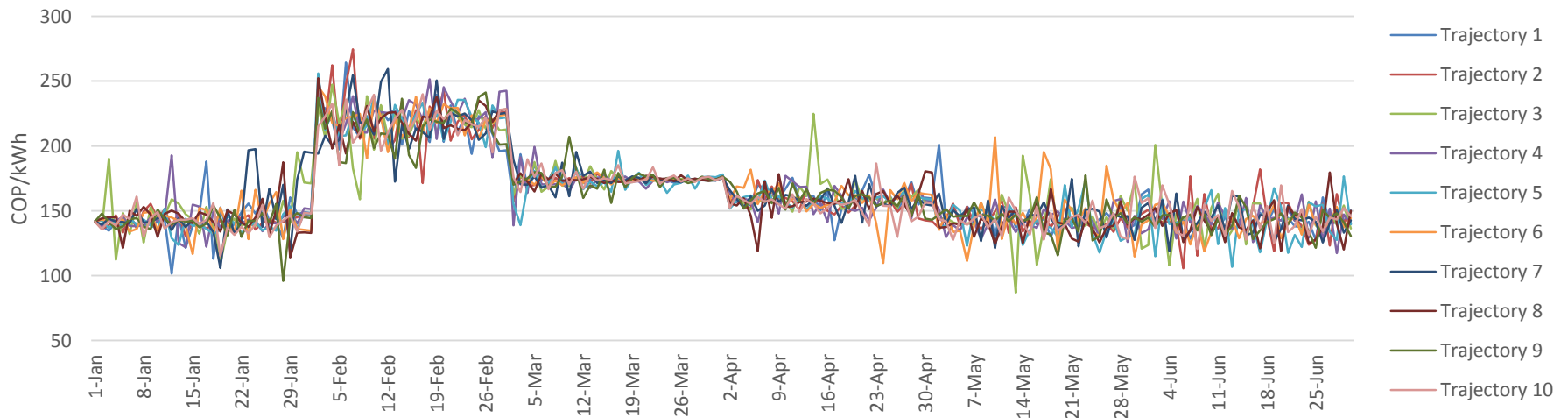
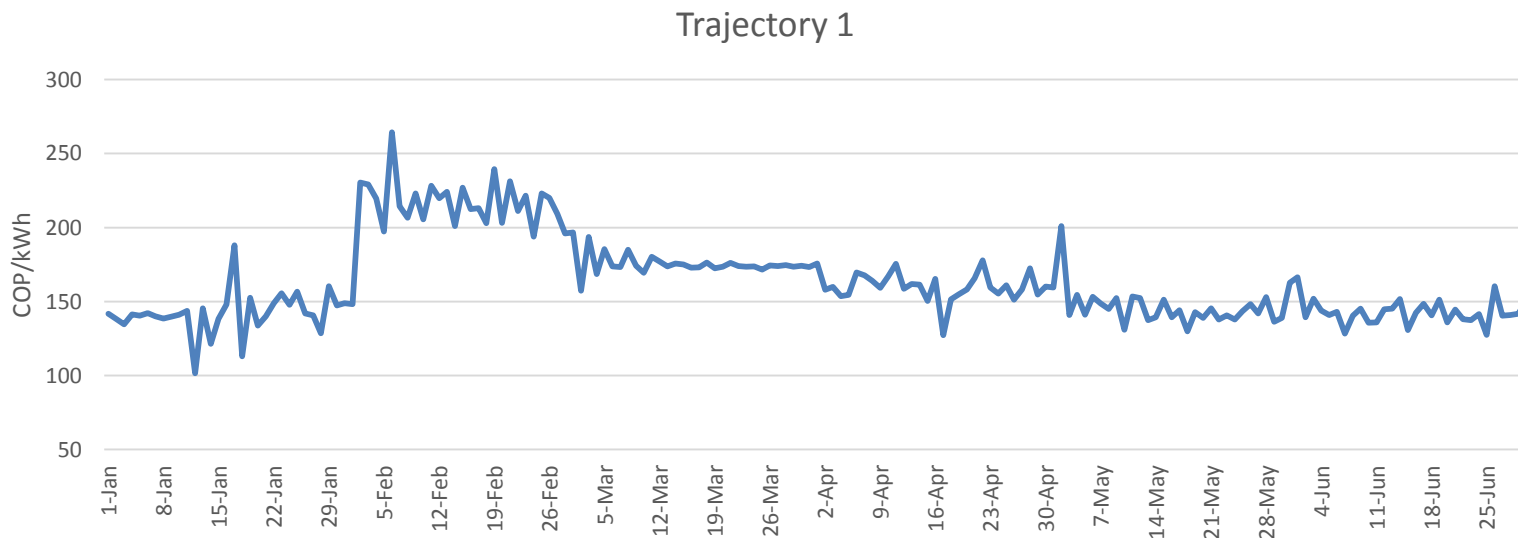# Methodology example

Monthly price SDDP (2015)
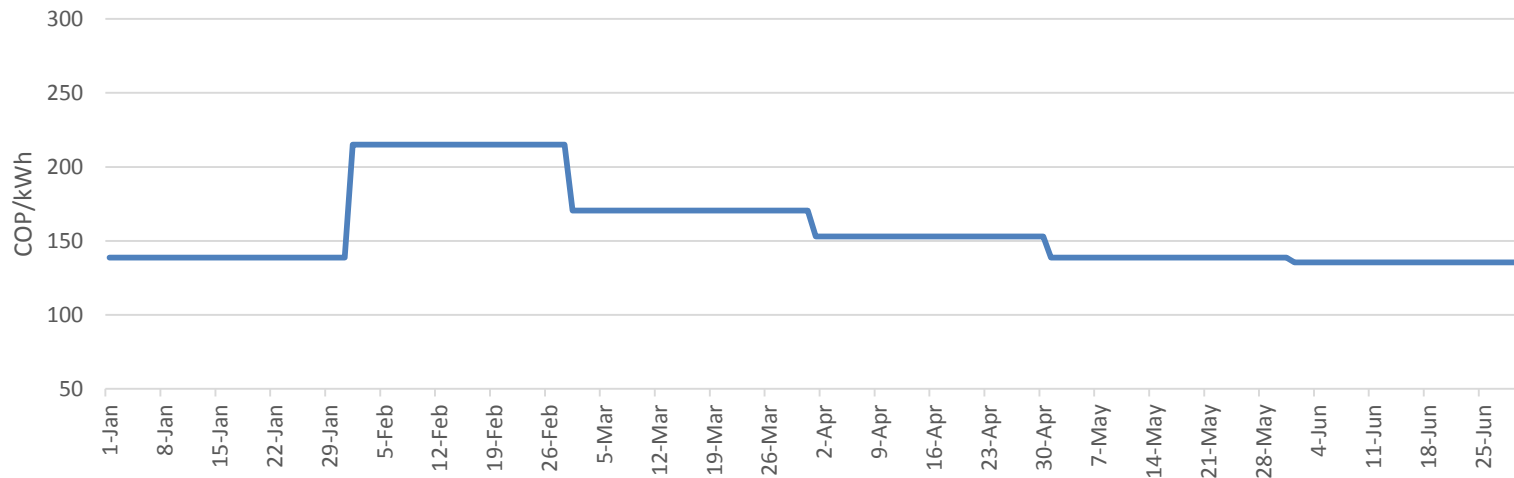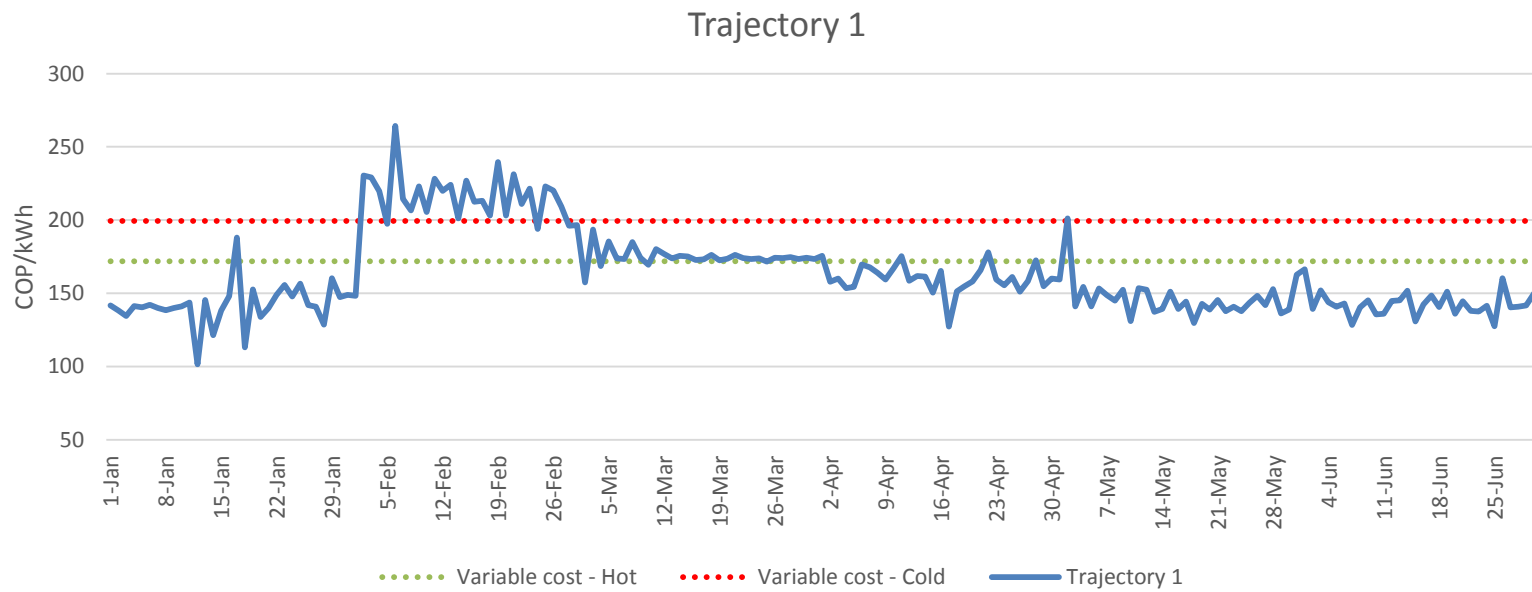
Methodology example

Simulated daily spot price (2015

Methodology example

Trajectory 1

Methodology example

Experiments

A valuation is done to four hypothetical projects using the proposed real option methodology and traditional discounted cash flow valuation.

	A	B	C	D
Technology	Internal combustion engines	Steam turbine	Combined cycle	Steam turbine
Fuel	Natural Gas	Coal	Natural Gas	Coal
Alternative Fuel	Fuel Oil 6	-	Fuel Oil 2	-
Project installation year	2015	2021	Active	Active
Installed capacity [MW]	204	300	450	154
Investment [USD/kW]	1100	2076	-	-
Fuel transportation cost [USD/MBTU]	0.96	0	0.57	0
Unavailability rate	10%	10%	14%	15%

Under the following assumptions

Discount rate	12.56%
Inflation rate	3.50%
Other variable costs [COP/kWh]	35.14
TRM [COP/USD]	1.900

Project characteristics

The starup ramp of each plant are the following:

Hora	Heat Rate [MBTU/MWh]				Load [MW]			
	A	B	C	D	A	B	C	D
1	7.9	27.2	20.0	25.2	204	6	40	3
2	-	25.3	20.0	23.4	-	31	40	16
3	-	20.1	20.0	18.6	-	41	40	21
4	-	13.1	13.9	12.2	-	134	100	69
5	-	10.4	8.9	9.6	-	210	220	108
6	-	10.1	8.1	9.3	-	273	280	140
7	-	10.0	7.7	9.3	-	300	340	154
8	-	-	7.7	-	-	-	380	-
9	-	-	7.7	-	-	-	410	-
10	-	-	7.7	-	-	-	450	-

An operational flexibility is clearly present in project A

Results: Project A

	Real options	Discounted cash flow
Use factor	**14.4%**	6.7%
NPV – Generation	**$123,047**	$17,421
NPV – *Cargo por confiaiblidad*	$ 378,268	$ 378,268
Total NPV	$ 501,315	$ 395,689
Investment	($ 426,360)	($ 426,360)
Project NPV	**$ 74,955**	($ 30,671)

The value of the operational flexibility is $105.626 millions.
Reflected in increase in the project's generation.
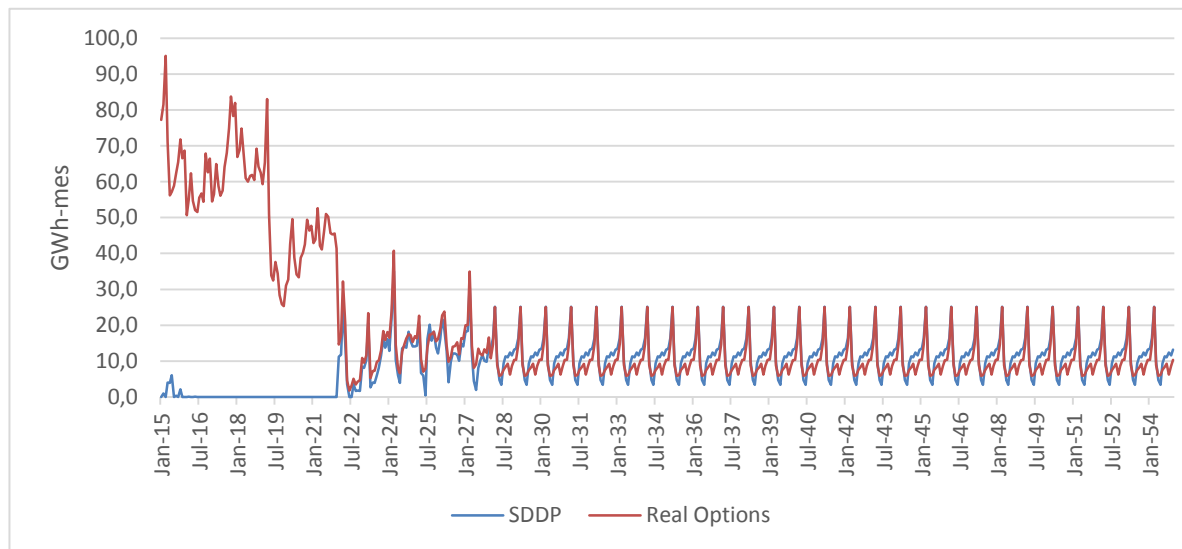
Results: Project B

	Real options	Discounted cash flow
Use factor	80.70%	75.47%
NPV – Generation	$ 1,043,072	$ 951,271
NPV – *Cargo por confiaiblidad*	$ 556,276	$ 556,276
Total NPV	$ 1,599,348	$ 1,507,547
Investment	($ 1,183,320)	($ 1,183,320)
Project NPV	$ 416,028	$ 324,227

A non significant increment is present in the generation and the value. In this project there is not an operational flexibility
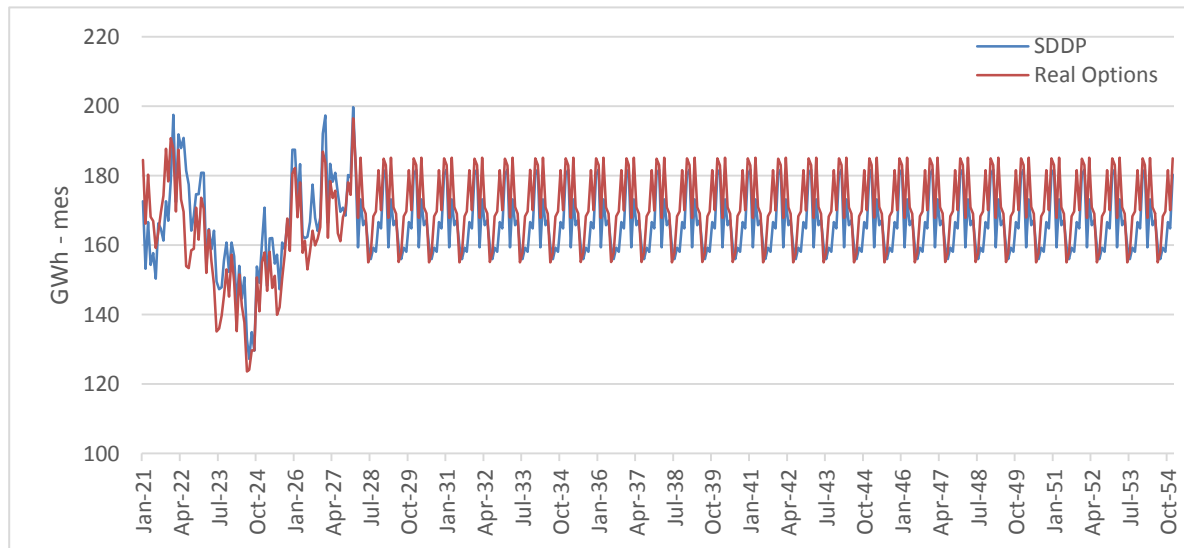
Results: Project C and D

The plant use factor decreases due to lack of flexibility. Opposite situation to that presented in the project A. Even when both projects share the same fuel type the start ramp favors project A.

C	Real options	Discounted cash flow
Use factor	39,36%	48,82%
Value	$ 188.908	$ 114.213

Similar to what took place in project B with a slight increase in use factor. Both plants have similar characteristics, so the robustness of the methodology is proven.

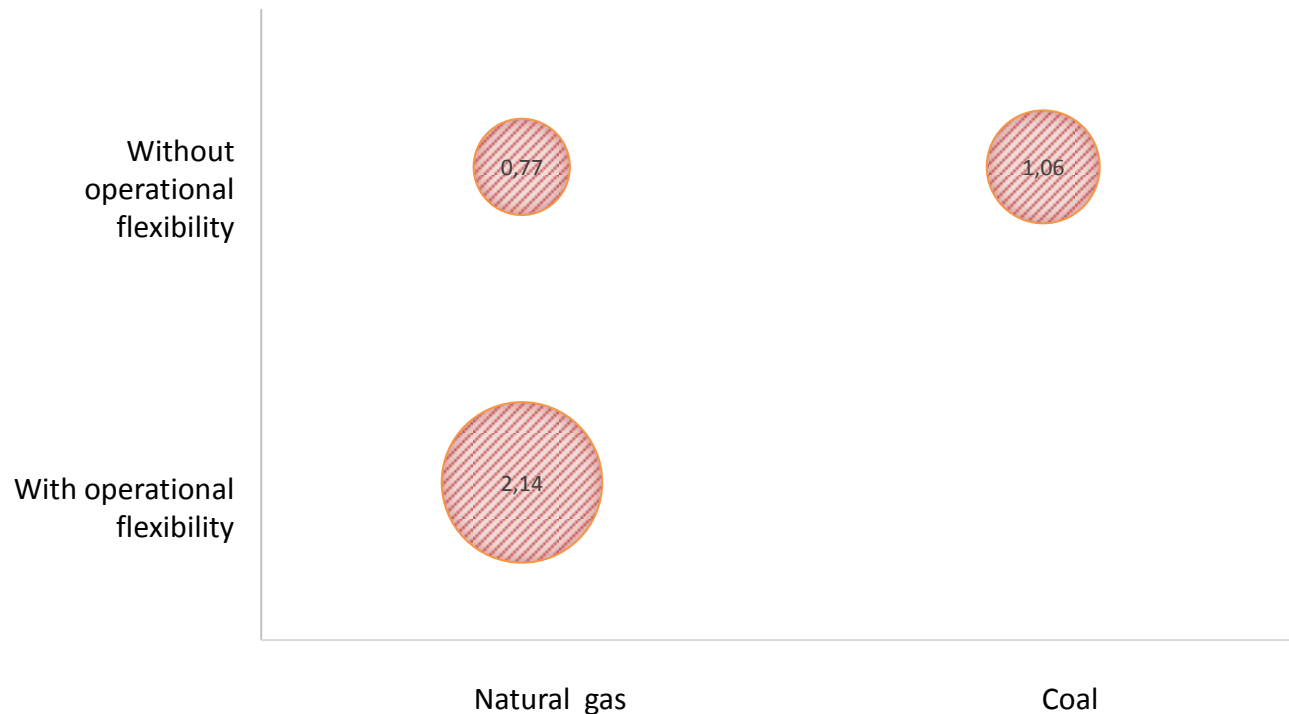| D	Real options	Discounted cash flow
Use factor	72,22%	66,93%
Value	$ 376.500	$ 337.758

Results analysis: Value

INCREASE IN VALUE VIA REAL OPTIONS COMPARING
TO THE VALUE USING DCF
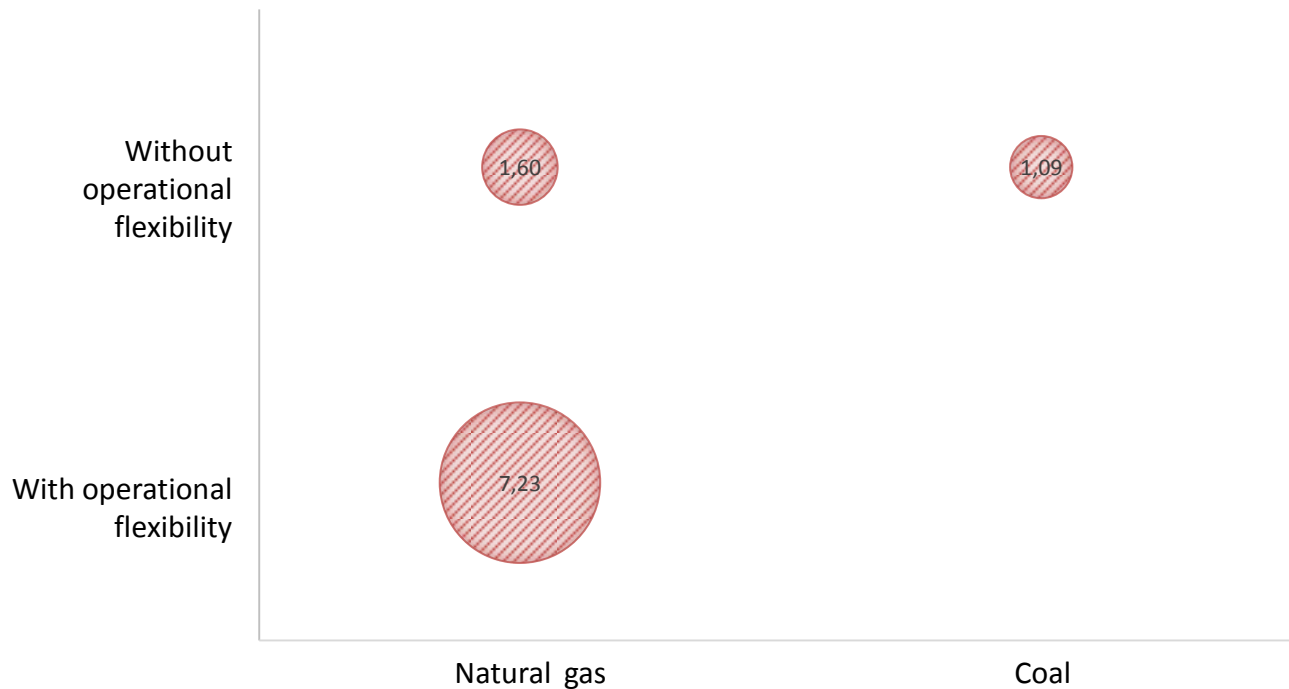
In all cases an increase in the value is presented, with a significant increase in the case of operational flexibility with 7.23 times its value compared to DCF.

Result analysis: Generation

The generation was being overestimated in the case of natural gas without operational flexibility by FCD and underestimated case with operational flexibility

Thanks for your attention!

Any questions?