Cost comparisons for New Coal and Gas-Fired Power Plants

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Case Study
Power plant planned for Rayong (eastern seaboard) Thailand

- EGAT, Thailand's state-owned power utility, has launched yet another IPP Bid Solicitation for 3000 MW of new power capacity.
- Bids allowed for both coal and gas-fired plants.
- Acceptable plant sizes:1000-1800 MW (net)
- Maximum unit size = 950 MW (net).
- Given today's EPC costs and expected efficiencies of new gas and coal-fired power plants, what plant type offers the least cost solution for a site in Rayong, Thailand?
- Main assessment challenge - deciding between power plant options in the midst of uncertain fuel prices and an even more uncertain regulatory environment.
- For this analysis, I am assuming that the IPP has set an 18% Equity IRR as his threshold return

Analysis done with discounted cash flow (DCF) model

- **A DCF model for power plant projects is essentially a revenue & cost accounting model, with project periods separated into:**
  - a Construction Period
  - an Operating Period.

- **For the Construction Period, the DCF model performs the following intermediate calculations from inputs to the model:**
  - debt and equity draws over the construction period as payments to the EPC contractor and lenders (IDC, front-end and commitment fees)
  - A roll-up of the amount of debt and equity invested in the project by the end of the construction period (SANDU Statement)

- **For the Operating Period, the DCF model provides estimates of:**
  - Annual fuel and O&M costs based on plant performance inputs (Capacity, Heat Rate and Capacity Factor) to the model
  - the biannual debt repayments over debt term based on financing inputs

DCF Model's Methodology (cont.)

- With these inputs and intermediate calculations, the DCF model generates equivalent "all-in" tariffs (expressed in US$ per MWh) for different power plant options
- Equivalency is achieved by using (a) the same target equity return (Internal Rate of Return [IRR]), (b) the same PV time slot and (c) the same cost accounting and IRR calculation methodology for all options.

Estimating the "all-in" tariff

- IPPs typically appoint a financial model manager to compile the data from which the electricity tariff from a new power plant is calculated with data acquired from:
  - The Owner's Engineer
  - Project Financial advisor
  - The Project Fuel advisor
  - Tax and insurance advisors

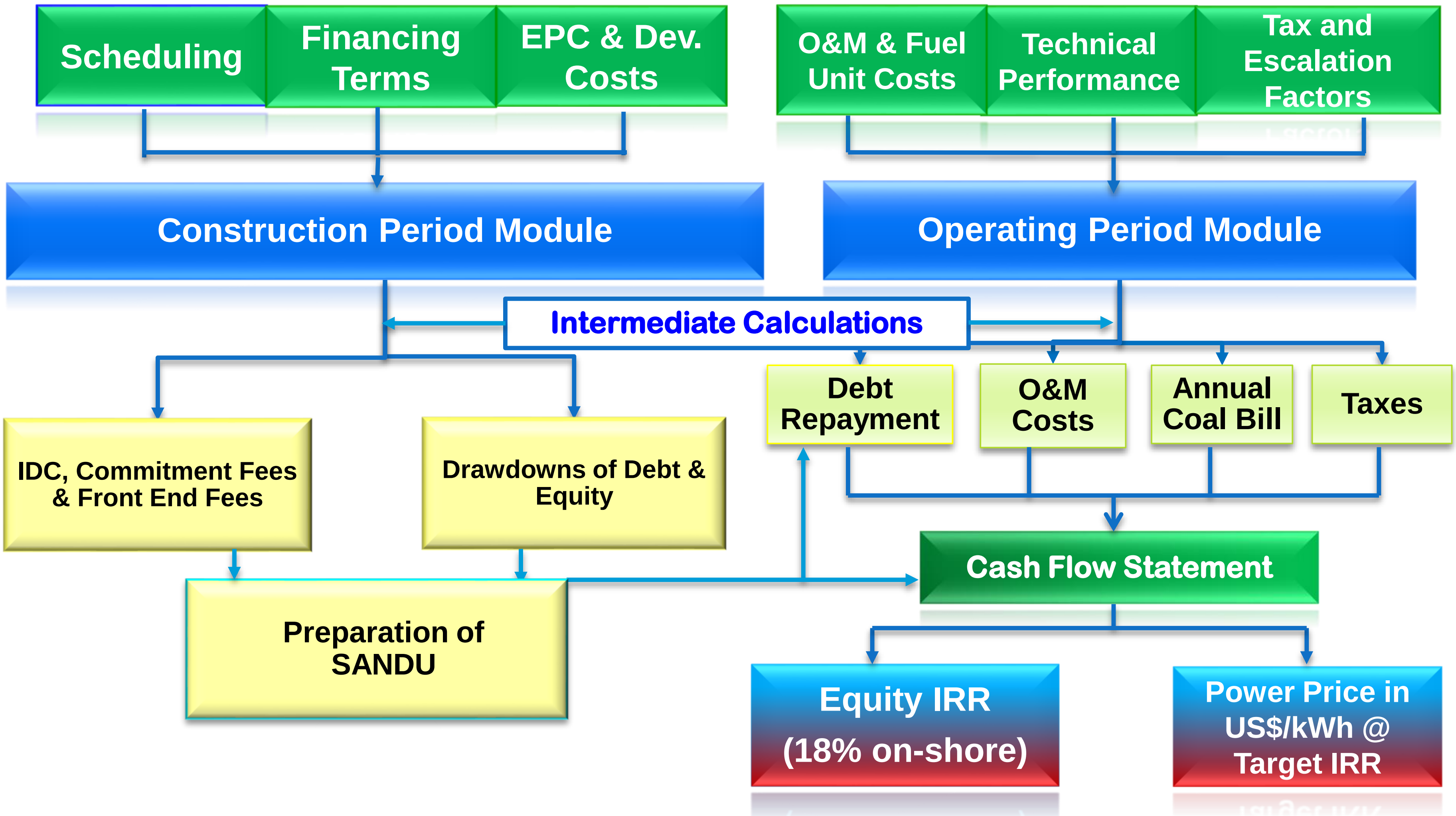
DCF Model's Methodology (cont.)

- Initial gross revenues and operating period costs are entered into an Income Statement from which a Cash Flow statement is generated.

- An initial equity IRR is calculated using the XIRR function in EXCEL with the annual Net Cash Dividends over the operating period and the annual equity infusions over the construction period as the data inputs to that calculation.

- The "Goal Seek" function is then used to determine the "all-in" tariff that will generate the target equity IRR.

Structure of a Full DCF Model for Assessing Projects



Gas-fired CCGT Plant Inputs for Two Options

Model Inputs	Units	F Class (4-4-2)	H Class (3-3-3)	Remarks
Plant Capacity (net)	MW	1512	1512	3% Aux Power; 2.6% output degradation
Plant Capacity Factor	%	83%	83%	EAF x DF = .92 x .90 = .83
Net Plant Heat Rate	kJ / kWh	LHV 6300	6150	w/cooling tower. HR degradation of 1.6% over 25 years; Max HR Degrade = 2.5%
		HHV 6930	6765	
EPC Price (net installed KW)	USD / KW	$630	$670	EPC price based on average site, 2014 EPC prices, Japanese EPC contractor, LNG as fuel
Contingency	% of EPC Price	30%	30%	Same as for coal plants
Construction Period	months	36	36	Average site conditions
Fixed O&M Cost	$000 / MW	10	10	O&M cost estimates function of owner's O&M philosophy and fixed: variable split.
Variable O&M Cost	USD / MWh	3.00	3.00	

Coal-fired Power Plant Options under Consideration

Description of Model Inputs	Units	Coal Ultra SC 2x1000 MW (gross)	Coal SC 2x600 MW (gross)	Remarks
Plant Capacity (net)	MW	1890	1134	3% aux power and 3% output degradation for both plants
Capacity Factor	%	78%	78%	CF +EAF x DF = .87 x .9 = .78
Net Plant Heat Rate (HHV) (includes degradation allowance)	kJ / kWh	9300	9530	USC plant: 3.2% HR degrade SC Plant: 3.5% HR degrade. Range: 2.8% -3.5% Coal CV range = 4800-5700 kcal/kg, gar; TM max = 25% (arb).
EPC Price	USD / KW (net)	$1,365	$1,439	2014 EPC prices for average site, Melawan coal and non-Chinese EPC contractor
Contingency	% of EPC	30%	30%	Range: 20% - 40%, includes major spares, development costs
Construction Period	months	51	51	Assumes average site
Fixed O&M Cost	USD '000 / MW	25	25	Fixed Range: $25-$30/MW Var. Range: $0.80 - $1.40/MWh Fixed-Variable split:75:25 to 85:15
Variable O&M Cost	USD / MWh	0.80	0.80	

Performance characteristics for the 2 coal-fired power plants have been set based on KPC's Melawan coal

Melawan Partial Quality Specification		
Calorific Value	kcal/kg, GAR	5100
Total Moisture	% by weight, arb	22.5
Inherent Moisture	% by weight, adb	16
Ash	% by weight, adb	6.5
Total Sulfur	% by weight, adb	0.4
AFT	IDT, Red. Atms. ^{o}C	1130
$Na_2O + K_2O$	% by weight, db	2.4

Financing Assumptions Provided by Financial Advisor

Debt	75%
Equity	25%
Upfront Fees (% of EPC and Development Cost)	1.00%
Commitment Fee	0.75%
Interest Rate During Construction Period:	
LIBOR (6 mo. July 2015)	0.46%
Interest rate premium during construction	5.54%
All-in Lending Rate During Construction	6.00%
Interest Rate During Operating Period:	
LIBOR (6 mo. April 2012)	0.46%
Interest rate premium during operating period	5.54%
All-in Lending Rate During Operating Period	6.00%
Term of Debt (maximum of 20 years)	12
Grace Period for 1st Principal Payment after COD	6
Method & Timing of Principal and Int. Payments (1 = equal annual payments; 2 = equal semi-annual payments; 4 = equal, quarterly)	2

…. and there are Other Inputs to consider

Other Inputs	Gas	Coal
GCV of Fuels	1000 Btu / ft3 (HHV)	5100 kcal/ kg, GAR
Price of Fuels (US$ / mmbtu (HHV or GCV); delivered at power plant)	$8.90 - 9.13	$2.56 - $3.18 (Melawan Coal)
Depreciation Period	25	25
Inflation Adjustments (Local/Foreign) (not applied for this case study)	Local CPI/US CPI	
FOREX Adjustments (US$:Local Currency X-rate changes) (not applied for this case study)	Used mainly for sensitivity analysis	
Decommissioning Costs / Salvage Value	-NIL-	

Assumed Values: (a) COD and SOC dates; (b) construction & operating periods and (c) start date for modeling period

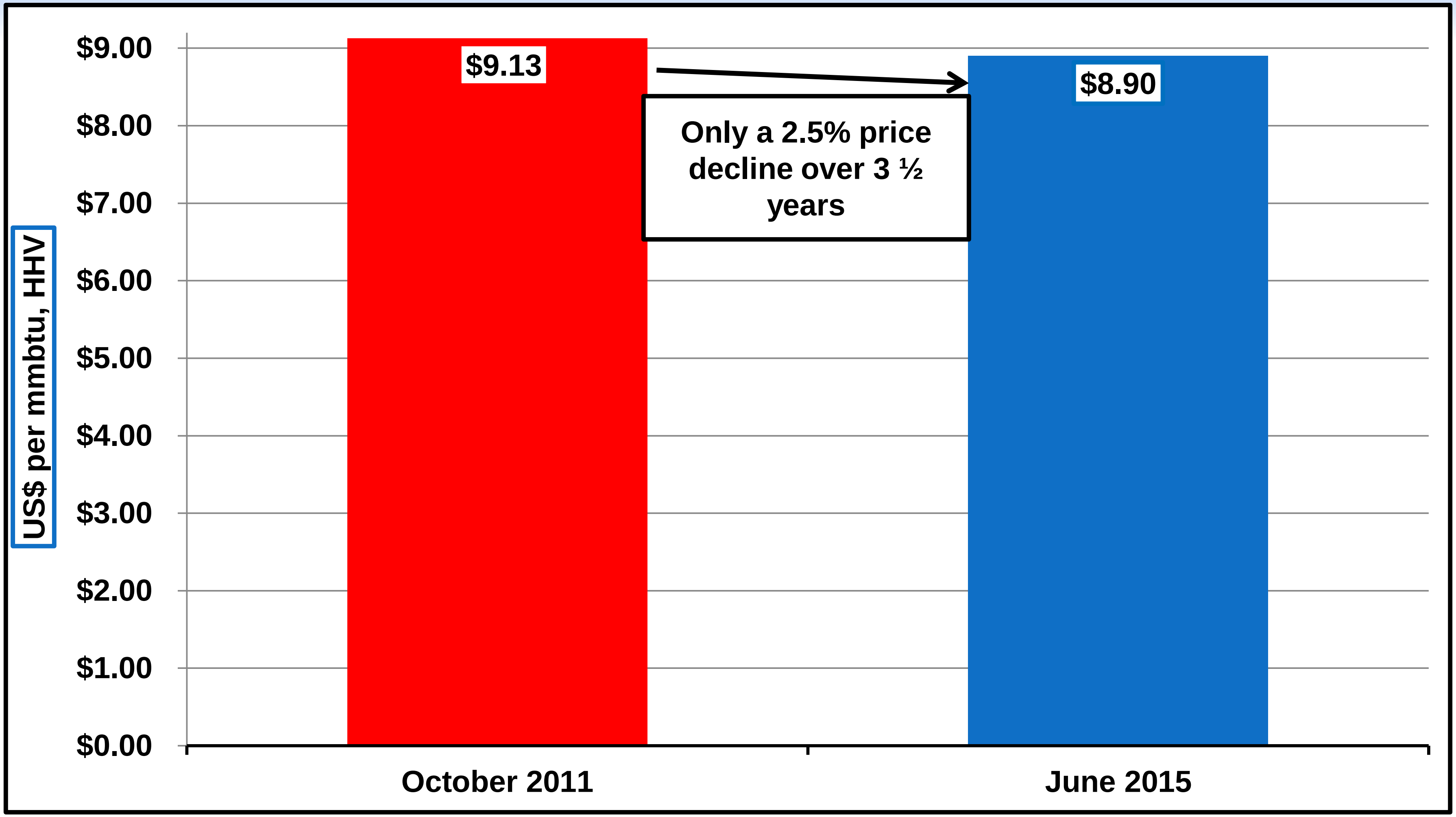
Calculated Values: (a) Start of Ops, (b) End of Ops, and (c) End of Modeling Period

Time Period	Gas CCGT 4x375 MW	Coal Ultra Super Critical 2x950 MW	Coal Super Critical 2x575 MW
Financial Closing Date	Jan-16	Jan-16	Jan-16
Start of Construction	Jan-16	Jan-16	Jan-16
Start of Operations	Jul-19	Apr-20	Oct-19
End of Operations	Jul-44	Apr-50	Oct-49
Start Modeling Period	Dec-16	Dec-16	Dec-16
End Modeling Period	Jun-45	Mar-51	Sep-50

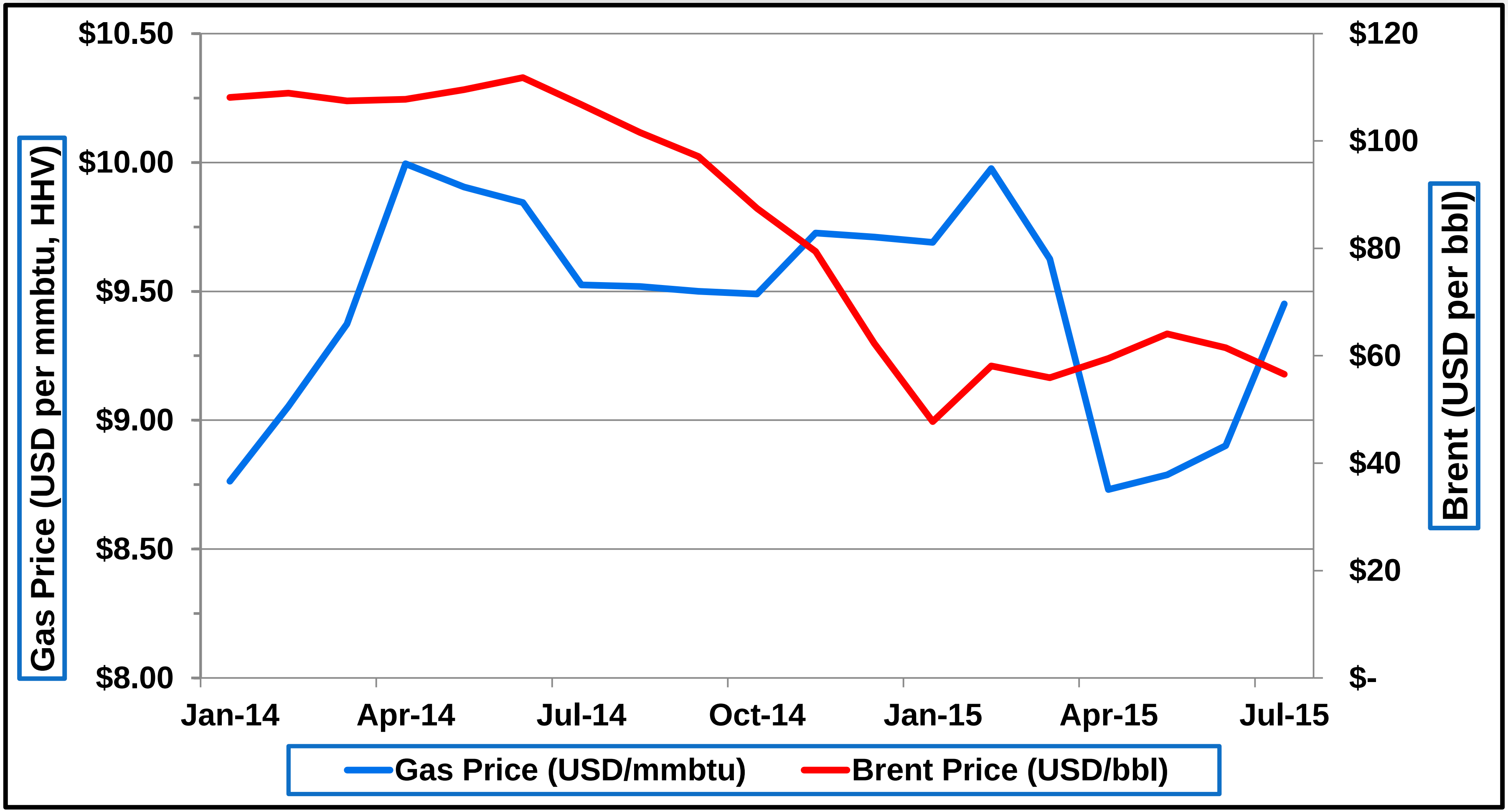
Regional Gas Price for IPPs (in US$/mmbtu, HHV)

Country	Jan 2010	Mar 2011	Oct 2011	Mar 2012
Singapore	$10.20	$ 18.00	$ 16.30	$16.75
Thailand	$ 6.85	$ 7.35	$ 9.13	n/a
Indonesia	$ 5.60	$ 5.60	n/a	n/a
Philippines	$ 9.26	$ 12.24	$ 11.49	$12.31

Thailand's pipeline gas price has decreased by only 2.5% over the past 3 ½ years while the Brent Oil price has decreased by 44%- from $110/bbl in Oct. 2011 to $62/bbl in June 2015

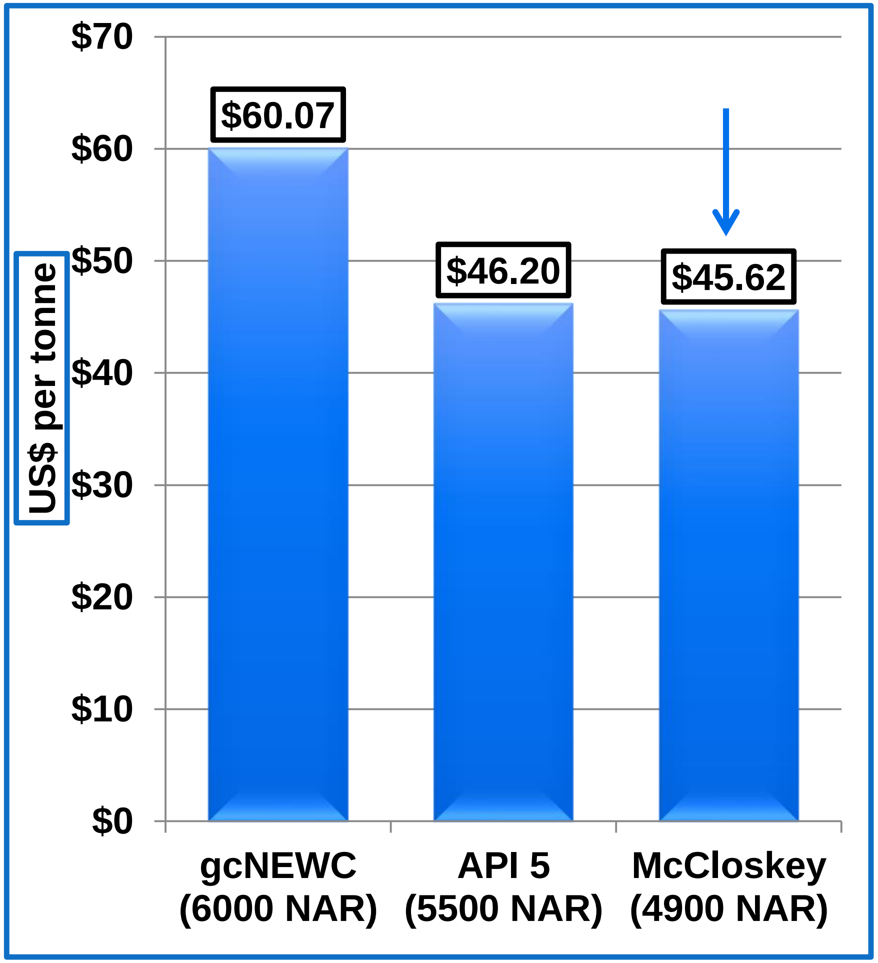


Monthly IPP gas price when plotted against Dated Brent shows a very weak correlation, even if one lagged the response of the gas price by 1 quarter or more

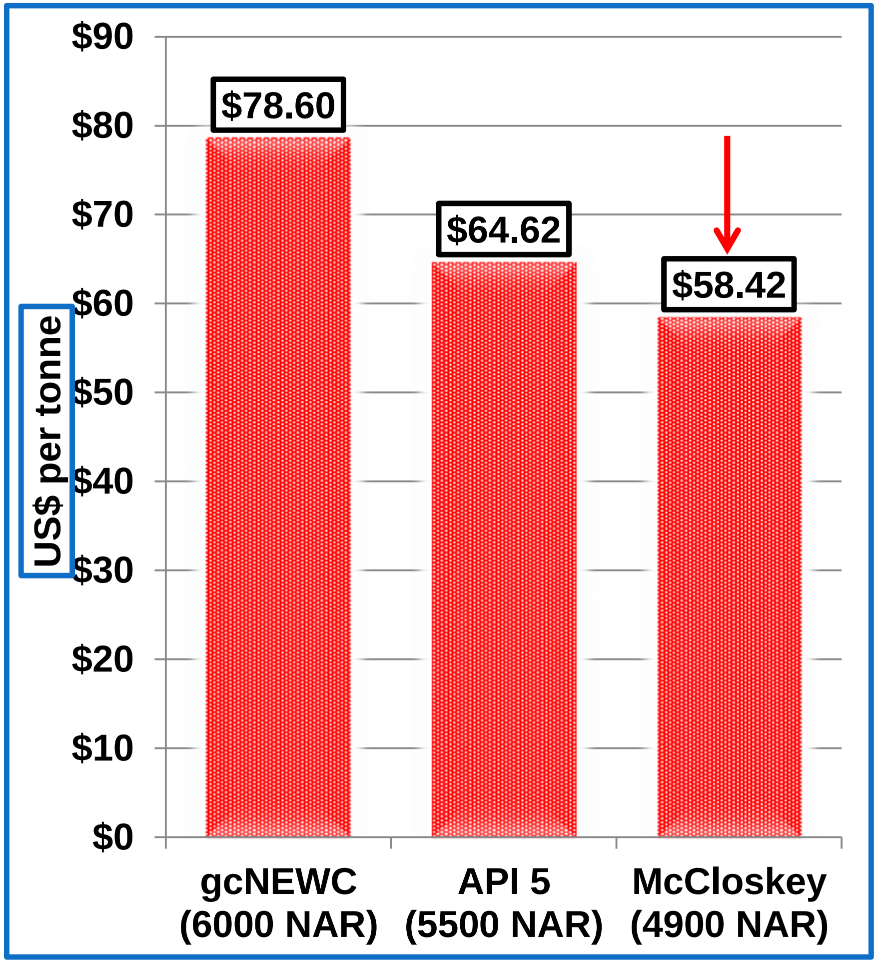


FOB Coal Price Data for Case Study Analysis (US$ per Tonne)

May 2015 Prices

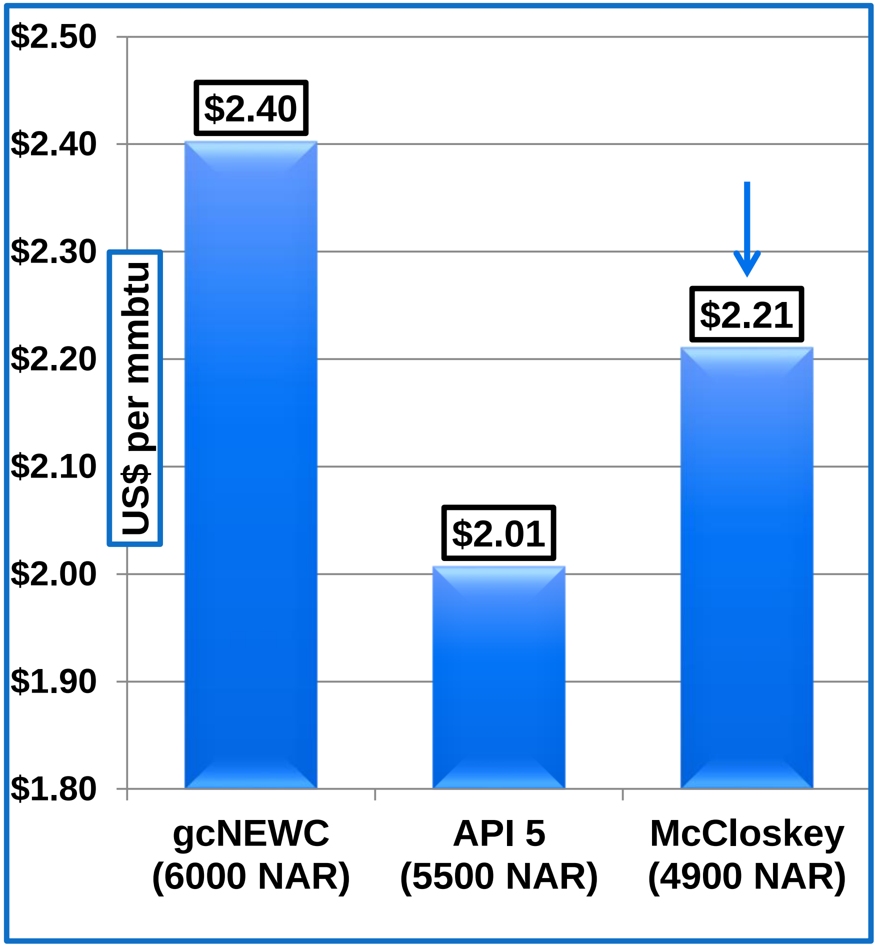


3 Year Average Prices (May 2012- May 2015)



FOB Coal Price Data for Case Study Analysis (in US$ per mmbtu, GAR)

May 2015 Prices



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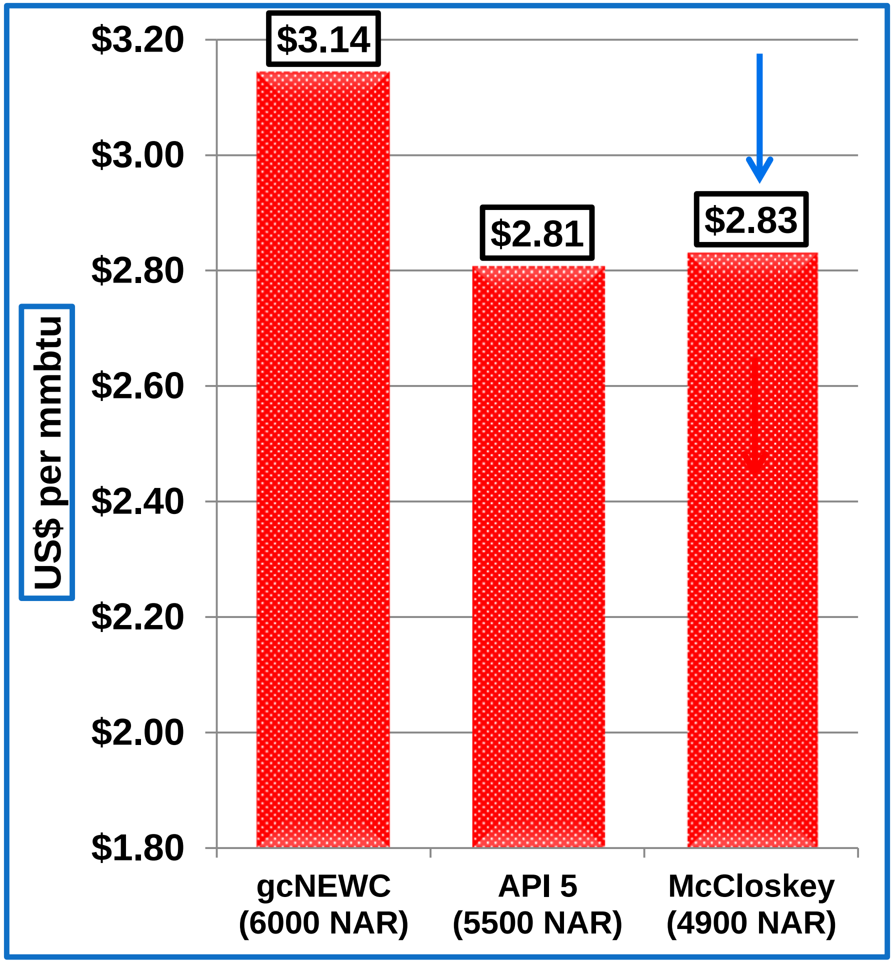


Hypothetical Journey from North Pulau Laut Cola Terminal to Rayong, the Power Plant Site

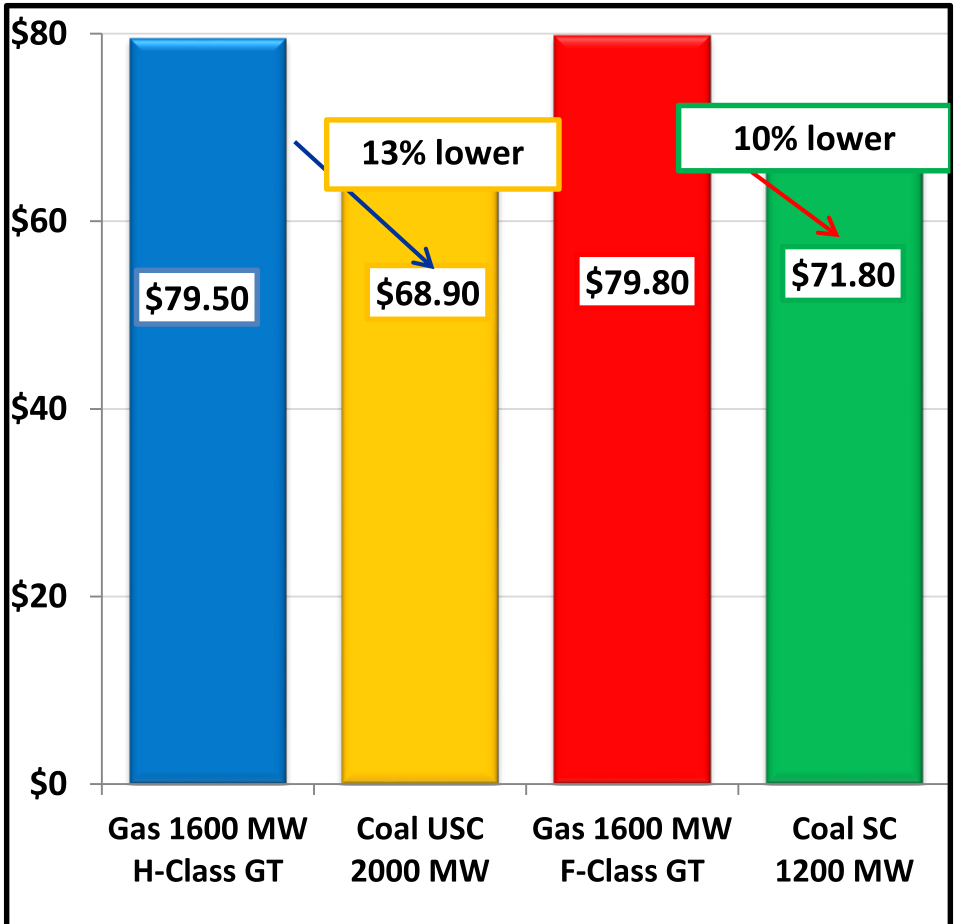
Loading Port	North Pulau Laut CT

Voyage Time Calculation	
Vessel Name	**TBN**
Vessel Type	**Panamax**
DWT/Built	**74,000**
Open Position	**Keelung**
Ballast Distance (miles)	1,852
Laden Distance (miles)	1,578
Laden Speed (Knots)	14.00
Ballast Speed (Knots)	14.00
Laden sea-time (days)	**4.70**
Ballast sea-time (days)	**5.51**
Total Sea-Voyage (days)	**10.21**
Sea Margin (%)	5.0%
Total Sea Time (days)	**10.72**
Estimated Cargo Intake (tonnes)	**72,500**
Load Rate (tonnes/day)	25,000
Load Port Turn-time (days)	0.50
Load Port Laytime (days)	**3.40**
Discharge Rate (tonnes/day)	25,000
Discharge Port Turn-time (days)	0.50
Discharge Port Laytime (days)	**3.40**
Bunker Port Time	**0.50**
Total Days in Port (days)	**7.30**
Total Voyage Time (days)	**18.02**

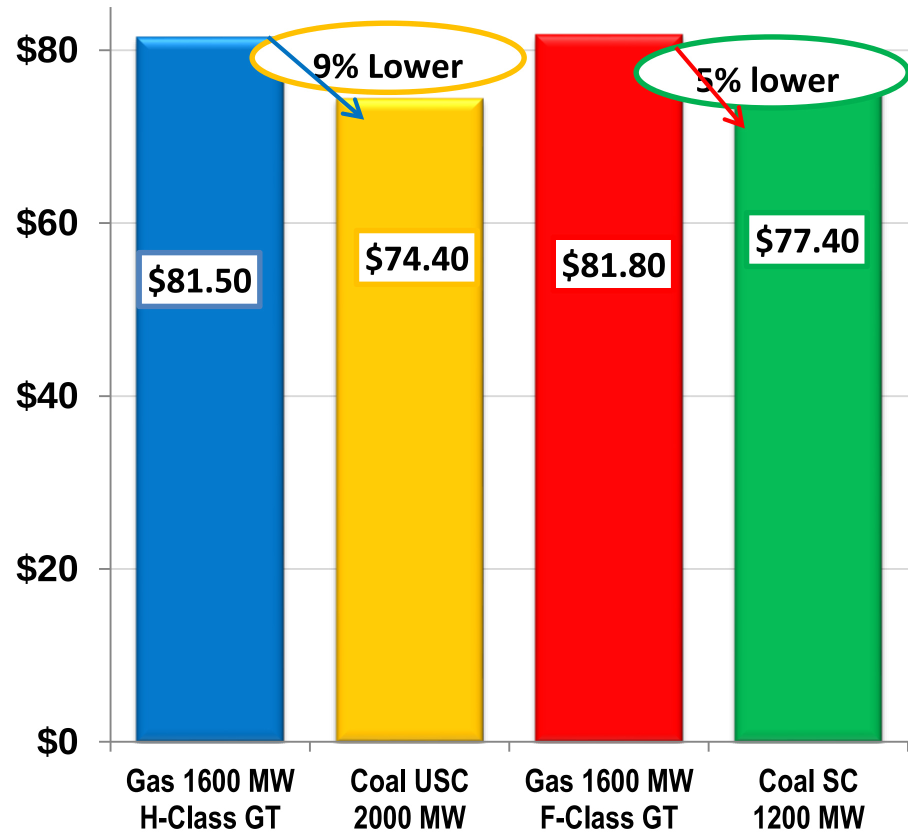
Discharge Port	Rayong	
Freight Rate Calculation (10 yr term contract)		
Daily Charter Rate ($)	**5-Aug-15**	16,000
Brokerage	(%)	
Total Voyage Charter Cost		**288,300**
Load Port Costs ($)		60,000
Discharge Port Costs ($)		-
Total Port Costs ($)		**60,000**
Laden IFO cons (tonnes/ sea-day)		32.0
Ballast IFO cons. (tonnes/sea-day)		28.0
Port IFO Cons (tonnes/port-day)		3.0
MDO consumption (tonnes/sea-day)		0.3
MDO consumption (tonnes/port-day)		0.3
IFO cost $/tonne		400.00
MDO cost $/tonne		600.00
Laden IFO cost ($)		**63,120**
Ballast IFO cost ($)		**64,820**
Port IFO cost ($)		**8,760**
Total MDO cost ($)		**3,243**
Total IFO & MDO Costs ($)		**139,943**
Freight Tax	0.00%	-
MISC Costs ($)		12,000
Total Voyage Cost ($)		**500,243**
Net Freight Rate ($/tonne)		**6.90**
Net Freight Rate ($/GJ)		**0.32**

Coal is cheaper than gas for supplying base load power in Thailand but the cost advantage is not that great – only 5% to 13%

US$ / MWh based on gas price =$8.90 per mmbtu, HHV and coal price = $2.56 per mmbtu, GAR



US$ / MWh based on gas price = $9.13 /mmbtu, HHV and coal price = $3.18 / mmbtu, GAR



Sensitivity Analysis # 1
Carbon Tax = $25 per tonne of CO2(e) emitted is imposed on power plants in Thailand

Impact of $25/t Carbon Tax on Coal Price

Atomic Weight Basics:

- Carbon (C) =12; Oxygen (O) =16
- 1 molecule of CO_2 = 12 + (2*16) = 44

… or 1 tonne of C will combine with 2.667 tonnes of O to produce 3.667 tonnes of CO_2.

If Melawan Coal has 54.3% C (arb), then:

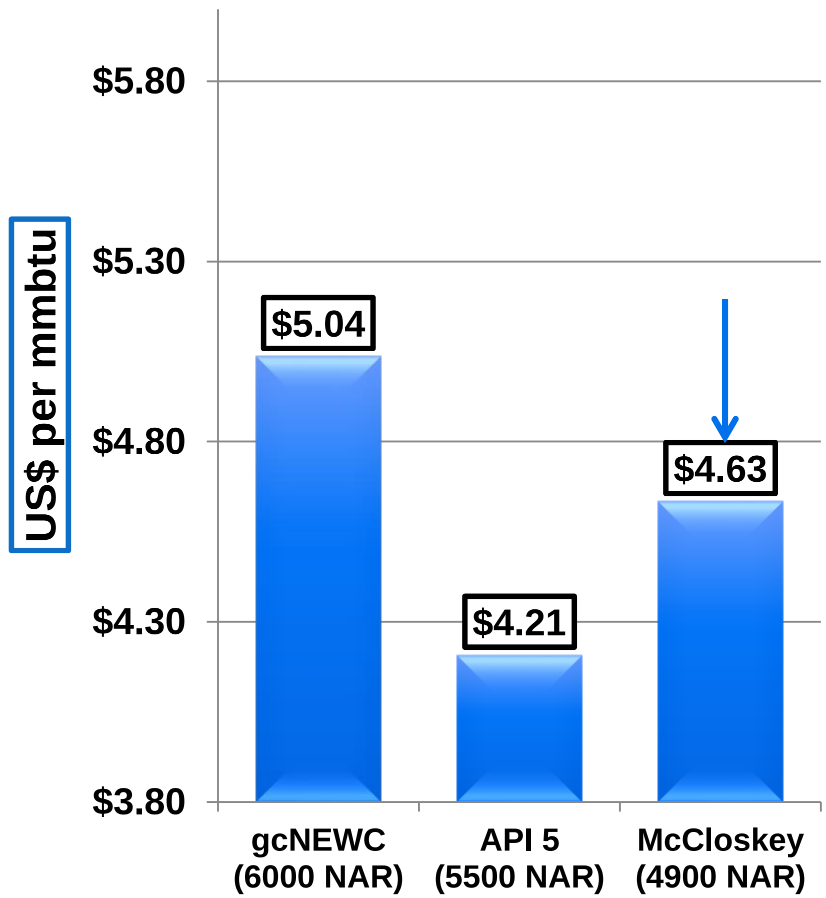
- 1 tonne of Melawan coal produces ~2 tonnes of CO2 (0.543 x 3.667) when combusted.
- A $25/t carbon tax = **<u>$50/t increase</u>** in consumer's perceived price for coal

Impact of $25/t Carbon Tax on Gas Price

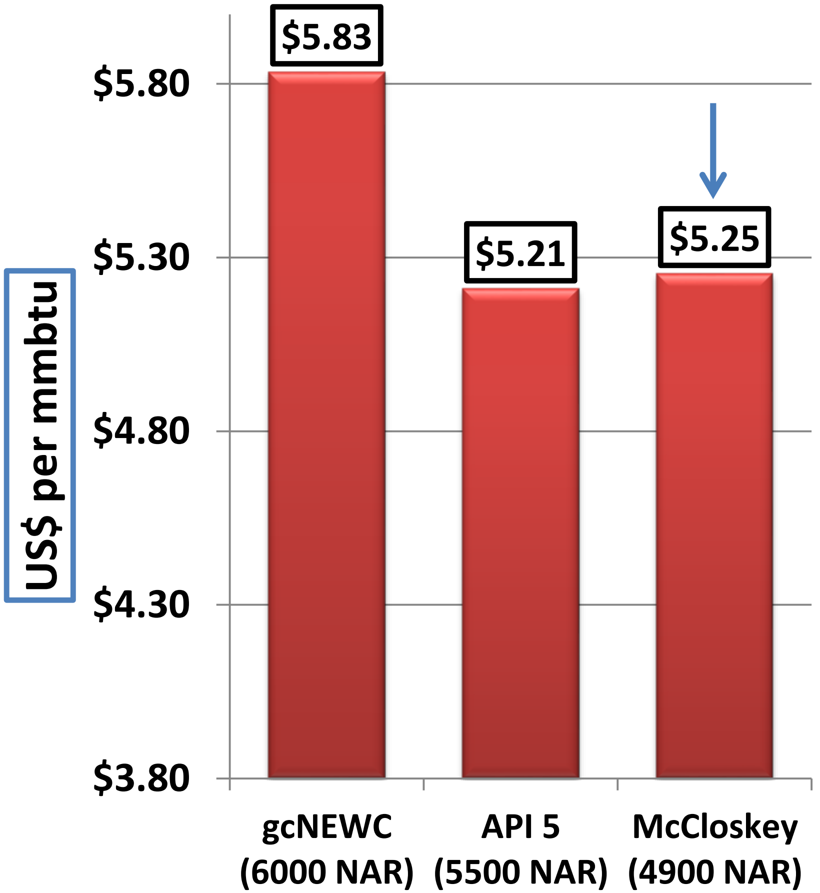
- 1 mmbtu of methane produces 53 kgs of CO_2 (US EIA), which would lead to a 5.3% price adder per $1 C tax (53/1000)
- A $25 /t carbon tax = $25 x .053 **<u>$1.33/mmbtu adder</u>** to price of gas in Thailand.

CFR Coal Price for Carbon Tax Case Study Analysis (in US$ per mmbtu)

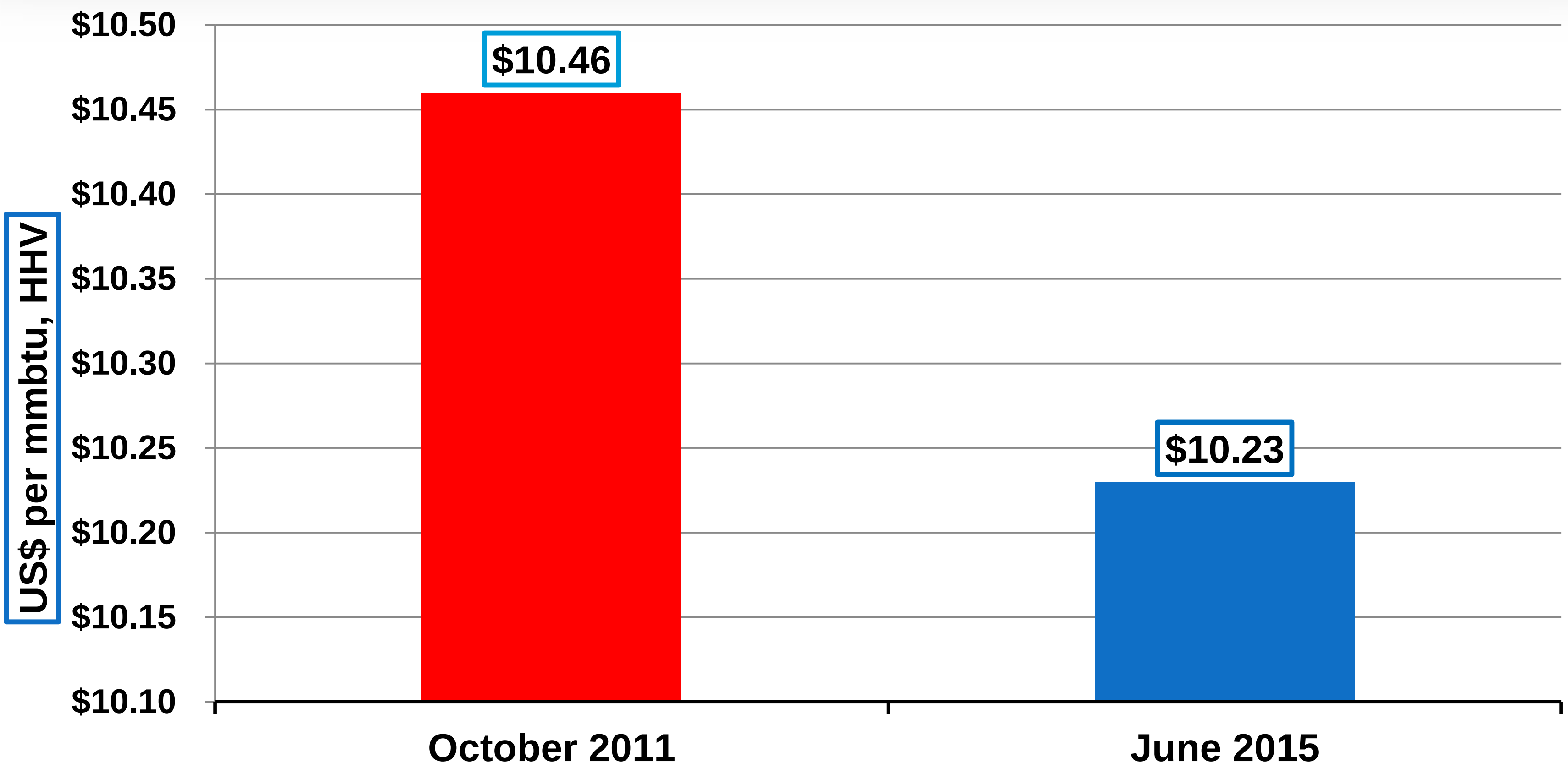
May 2015 Prices



3 Year Average Prices (May 2012- May 2015)

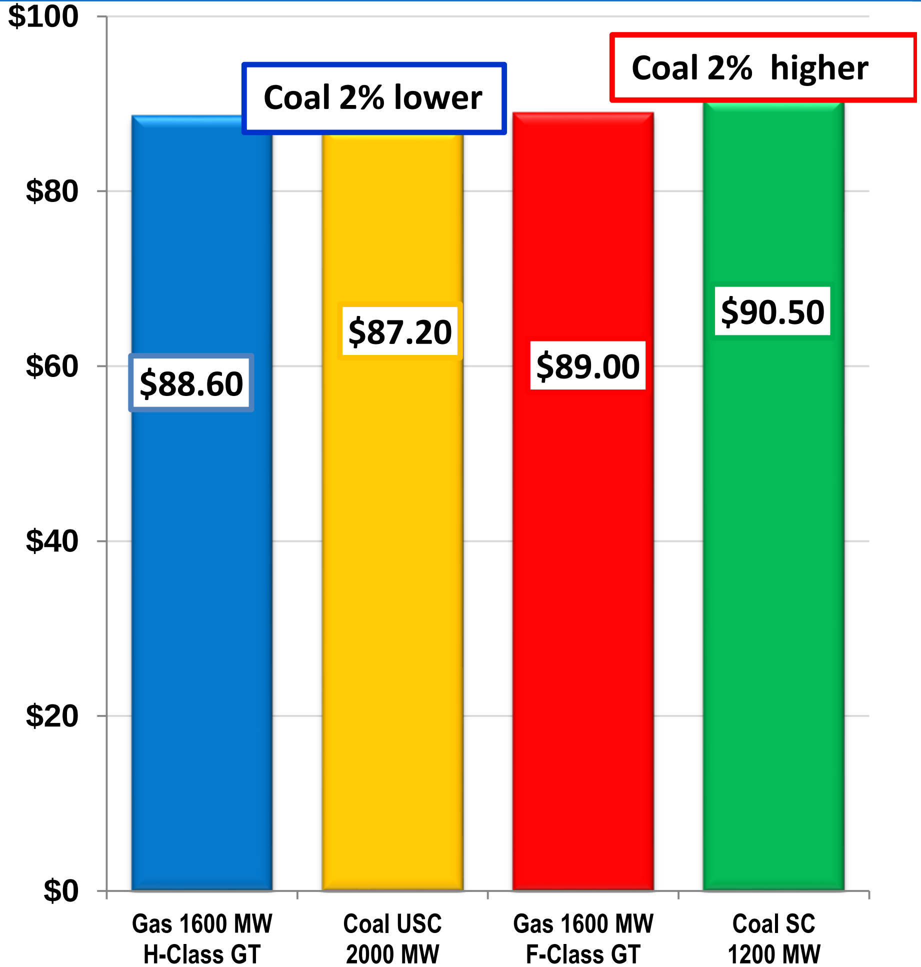


Thailand's pipeline gas prices for October 2011 and June 2015 after adjustment for $25 per tonne CO2 emissions tax.



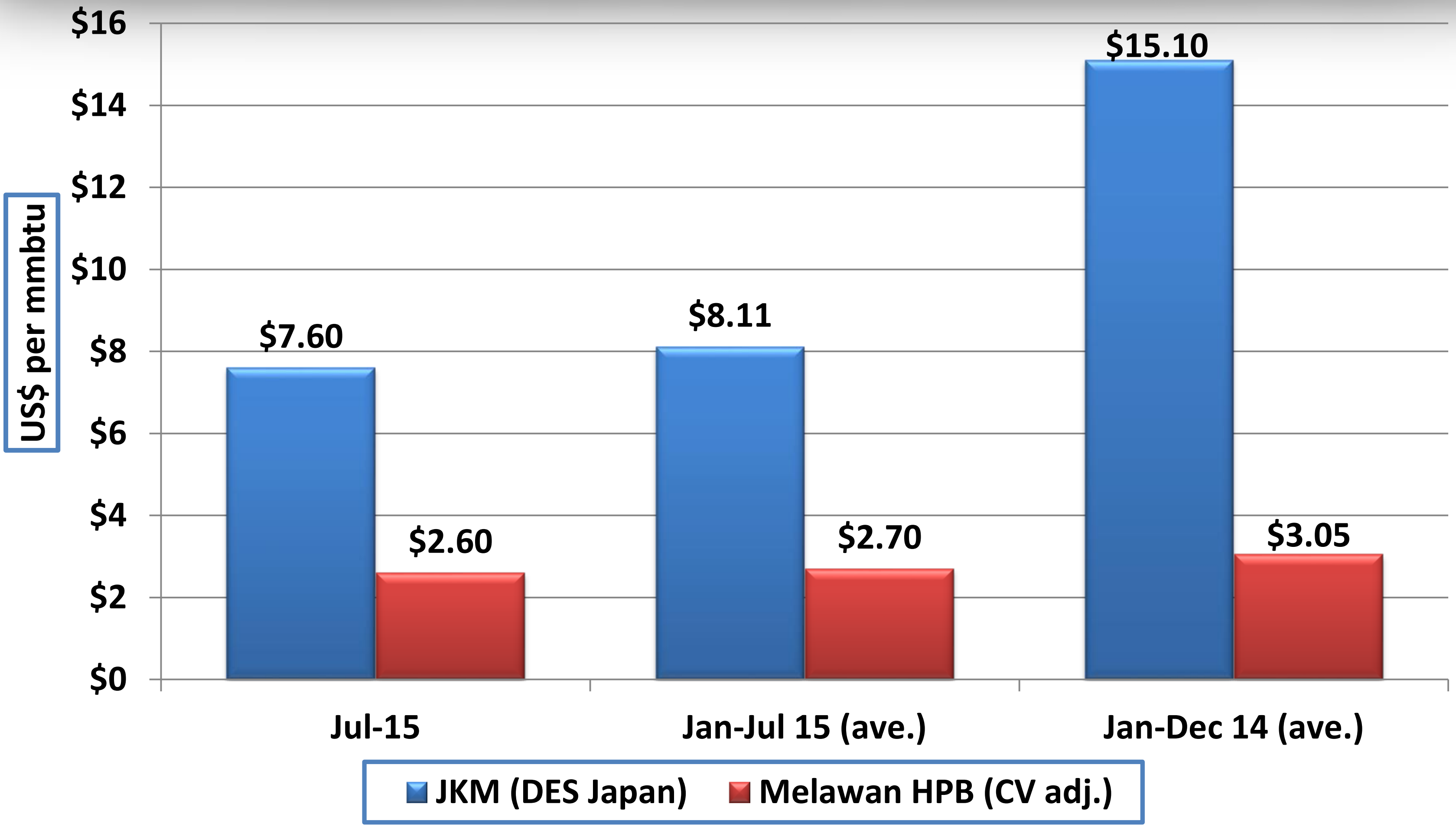
If $25/t carbon tax is imposed, new CFPPs lose their cost advantage over gas-fired CCGT plants under all plausible fuel price scenarios

US$ / MWh with gas price = $10.23 per mmbtu, HHV and coal price = $4.63 per mmbtu, GAR



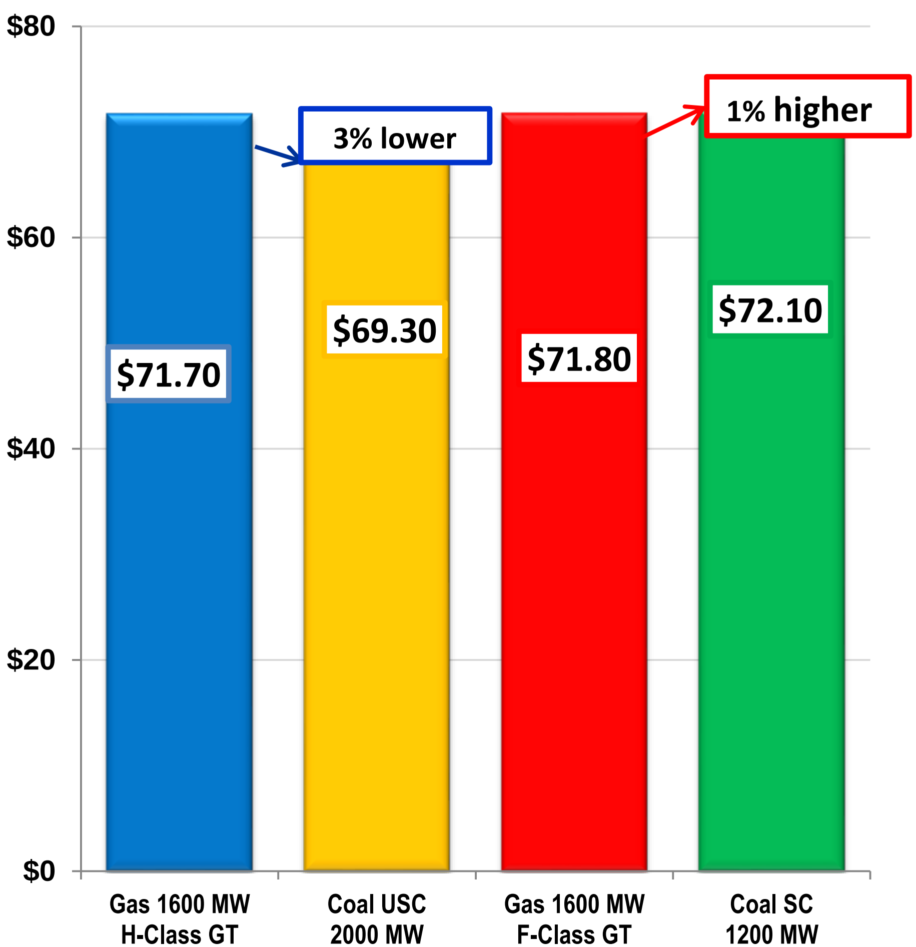
US$ / MWh with gas price = $10.46 per mmbtu, HHV and coal price = $5.25 per mmbtu, GAR

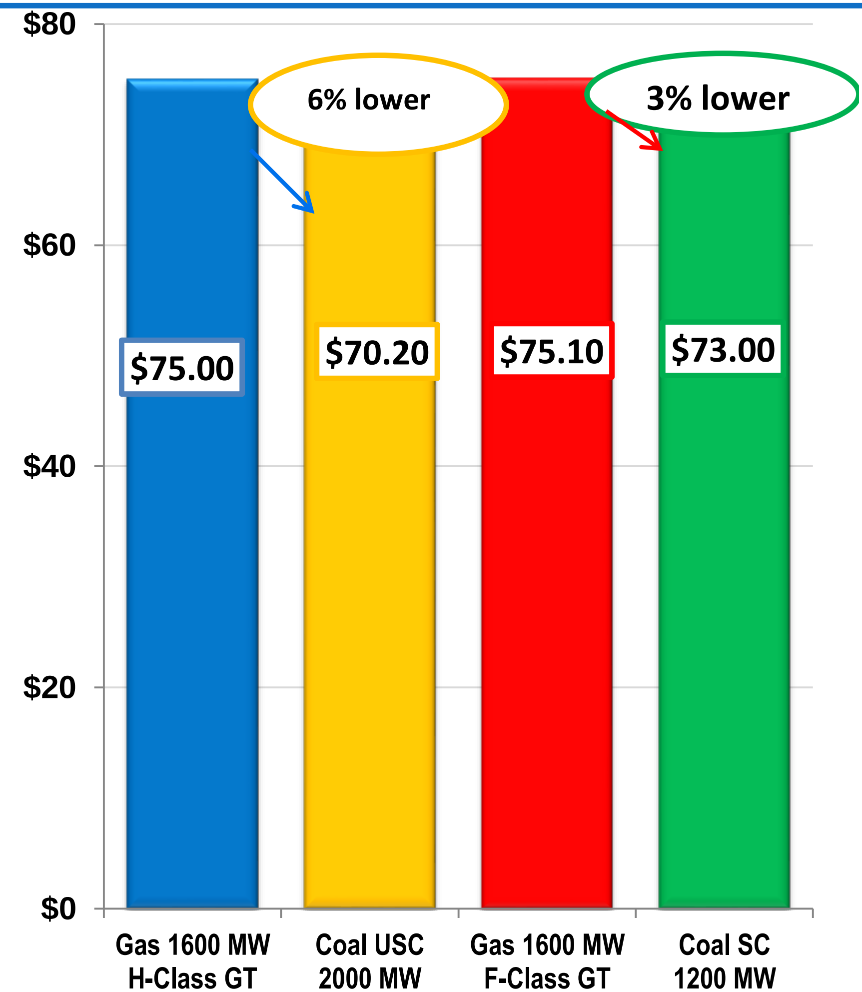
Sensitivity Analysis # 2
JKM LNG & Melawan Coal Prices for July 2015, Jan-July 15 and Jan-Dec 14 (US$ per mmbtu, HHV/GAR, delivered but no C Tax)



Power Prices for 2 periods – July 2015 and Jan-July 2015- on assumption that LNG will be procured for new gas-fired CCGT plants.

US$ / MWh based on an LNG price =$7.60 per mmbtu, HHV (DES) and Melawan price = $2.60 per mmbtu, GAR, CFR	US$ / MWh based on gas price = $8.11 per mmbtu HHV, (DES) and coal price = $2.70 per mmbtu, GAR, (CFR)





Summary of Case Study Results for Thailand

- **Based on May 2015 Thai IPP Gas Prices and No Carbon Tax**: Coal-fired power was at most 13% cheaper than a gas-fired CCGT plant of comparable size.

- **Based on 3 year Average Coal Prices, October 2011 IPP Gas Price and No Carbon Tax**: Coal-fired power was only 5% - 9% cheaper.

- **Results assume coal shipments from Indonesia to Rayong by Panamax vessel at a cost of $0.35 per mmbtu.**

- **A big risk to coal-fired power plants in SE Asia is the imposition of a carbon tax on all fossil fuels.** With a moderate carbon tax of $25 per tonne CO_2, both gas and coal will suffer but coal will suffer by a much greater margin due to its higher carbon content.

- Given the coal and LNG prices that have prevailed over past 1 ½ years, coal-fired power plants would have lost all of their cost advantage over gas-fired CCGT plants if a moderate Carbon Tax of $25 per tonne of CO_2 emission was imposed on power producers.

Summary of Case Study Results for Thailand

- Another risk facing IPPs who wish to build coal-fired power plants in Asia is the risk that an extended oversupply of LNG will lead to a prolonged continuation of today's relatively low LNG prices.

- The high LNG prices that Asia experienced between 2011 and 2014 are now viewed as temporary price increases unlikely to be repeated unless there is another natural disaster similar to the Fukushima tsunami that shut down Japan's nuclear power plants.

- With Asia now likely to be in for an extended period where LNG supplies are in surplus, the cost advantage of coal-fired power is likely to be reduced dramatically – if not wiped out completely –for the remainder of this decade.

- In summary, if I were an IPP developer in Asia, I would be turning my attention away from coal and toward gas-fired power plants with a focus on using LNG supplied from an FSRU.