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Determining Viable Contract-for-Difference Prices and Revenue Receipts for Gatton Solar Research Facility

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Abstract

In this paper, we investigate the role that a Contract-for-Difference (CFD) feed-in tariff might play in underpinning increased investment in renewable energy in Australia. We investigate two particular CFD designs: two-way and a one-way CFD. We develop a financial model that is capable of determining commercially viable CFD strike prices for different renewable energy projects. In this modelling, we take account of revenue from wholesale electricity market and renewable energy certificate sales. We also include capital and operational costs of the project including distribution of funds for holders of equity and debt. We present findings bases on analysis of the solar array located at UQ Campus Gatton Australia, employing a typical meteorological year framework. Our major findings are that Government's will prefer a two-way CFD design and Single-Axis tracking solar array technology. Project proponents, however, will strongly prefer a one-way CFD design.

Keywords: Contract for difference; feed-in tariff; solar PV; operation and maintenance costs; renewable energy policy

(1) Introduction

Policy support for renewable energy projects using a 'Contract-for-Difference' (CFD) feed-in tariff policy mechanism has gained prominence recently, in terms of public policy [(UK Government, 2015), (Victoria, 2015), (ACT, 2016), (CCA, 2016) and (QRET Expert Panel, 2016)] as well as academically [(Kozlov, 2014), (Bunn and Yusupov, 2015) and (Onifade, 2016)]. Contract for difference pricing mechanisms have been employed previously in energy applications, relating to transmission congestion contracts (Hogan, 1992) and the Nordic market (Kristiansen, 2004).

A CFD mechanism will require that renewable energy project proponents bid a strike price as part of some reverse auction process. Strike prices will typically be ranked in ascending order and projects with the lowest bid strike price will be chosen, moving up the ascending-order ranking until the desired renewable energy capacity of the auction round has been achieved. The strike price associated with the marginal project securing the final capacity increment will be the final successful project and associated strike price will be the highest price achieved by a successful project.

However, in conflict with the least cost methodology underpinning bidding strategies mentioned above, if the CFD price that is bid is set too low by the project proponent in order to secure success during the auction process, the project may run the risk of being economically unviable. This would occur if the revenue stream at the successful CFD strike price is not sufficient to cover operational and capital costs. This situation could emerge either separately or through the combined effects of: (1) price received for the energy produced by the project is too low; (2) energy produced by the project is too low compared with expected energy yield forecasts that underpinned the CFD strike price bid during the auction process.

A number of options exist for the structuring the CFD's that balance: (1) differing levels of revenue certainty for project proponents; (2) exposure to market prices; and (3) total cost of the CFD. Particular structures that have been proposed include (QRET Expert Panel, 2016):

- *Two-way CFD*: A set level of revenue is guaranteed for a project based on revenue collected through the wholesale market and revenue provided under the CFD up to an agreed strike price. If wholesale revenue exceeds that associated with the CFD strike price, the project proponent is required to pay back the difference to the CFD counter-party.

- *CFD with a collar*: This arrangement sets minimum and maximum limits on the total revenue that a project can receive. A project proponent receives additional revenue when the wholesale price exceeds the floor price, but this is capped by a price ceiling above which the proponent is required to make payments back to the counterparty in a manner similar to a two-way CFD.

- *One-way CFD*: Project proponents are guaranteed a minimum level of revenue, but maintain additional levels of revenue if wholesale market prices exceed the CFD strike price. By giving upside opportunities for successful projects, the expectation is for lower strike prices relative to a two-way CFD scheme.

In the case of a two-way CFD scheme, the need to get the bid price right gains more prominence because project proponents must pay back to the CFD counter-party, the amount of incremental revenue attributable to the project when wholesale market prices exceed the CFD strike price. As such, and in contrast with the one-way CFD design, it is not possible under a two-way CFD design to utilise super-normal economic profits associated with high wholesale electricity price events to provide revenue sufficient to cover capital and other fixed costs. Instead, the CFD strike price itself must be capable of fulfilling this requirement.

The structure of this paper is as follows. The next section contains an outline of the financial model that will be used as well as details about the Gatton solar array whose PV yields will be used to underpin the results in the paper. In Section 3, various inputs into financial modelling will be discussed, including Fixed Operation and Maintenance (FOM) costs, Overnight Capital Costs (OCC), output measure to be utilised and calculation of Typical Metrological Year (TMY) hourly output and wholesale electricity price data. In Section 4, the results of the modelling will be reported relating to both CFD strike prices and revenue payable for project proponents under two-way and one-way CFD pricing. Section 5 will address the public policy implications of our findings. Finally Section 6 will contain conclusions.

(2) Financial Model

To calculate CFD strike prices that are capable of generating revenue sufficient to cover operational and capital costs requires a detailed financial model. This model will calculate revenue receivable from wholesale electricity market sales, sale of eligible renewable energy certificates as well as payments *from (and to)* the CFD counter-party under one-way and two-way CFD schemes. From these revenue streams, various costs will be netted off including Operation and Maintenance (O&M) expenditure, annual network connection fees, depreciation allowance (for tax purposes), debt and equity service costs and tax allowances.

Details of the financial model used to calculate the CFD strike prices is documented in Table 1. In column four, example values are given for a Fixed Tilt (FT) array and assumed Large-scale Generation Certificates (LGC) strike price of 9.29 (c/kWh) for a two-way CFD design.

The output measure employed in the modelling denoted by variable 'Q' in Table 1 is the simulated sent-out energy produced by the Gatton Solar Research Facility (GSRF) located at the University of Queensland (UQ) Campus at Gatton. The GSRF was funded under the Federal Government's Education Investment Fund (EIF) scheme ($40.7M), and was part of the larger ARENA funded project Australian Gas and Light Pty Ltd (AGL) Nyngan and Broken Hill Solar Farms (UQ, 2015a).

The GSRF solar array is a 3.275 megawatt pilot plant that comprises three different solar array technologies: (1) a FT array comprising three identical 630 kW systems (UQ, 2015b); (2) a 630 kW Horizontal Single Axis Tracking (SAT) array utilising First Solar's SAT system (UQ, 2015c); (3) a 630 kW Dual Axis Tracking (DAT) array utilising the Degertraker 5000 HD system (UQ, 2015d).

In Table 1, variable 'P_WM' is the hourly transmission and distribution loss adjusted wholesale market price, converted to a (c/kWh) basis. Adjustment for transmission and distribution losses was made using a marginal loss factor of 0.9723 and distribution loss factor of 1.0262, determined as averages from published values over 2011/12 to 2015/16. Multiplying these two factors together produces a value of 0.9979 that was multiplied by each respective hourly wholesale price sourced from AEMO for the 'QLD1' regional reference node (AEMO, 2016).

In Table 2, annual (c/kWh) volume weighted average wholesale prices for the QLD1 market is presented, based upon the AEMO (2016) price and demand data for 2007-2015. This table indicates the lowest annual average prices arose over the period 2009 to 2011 whilst the highest average prices arose in 2007 and 2013, respectively. For the most recent time period 2014-2015, average wholesale prices were in the range of 5.62c/kWh and 5.80c/kWh. The average over the whole 2007-2015 period was 5.06c/kWh with the range between 2.81c/kWh and 7.27c/kWh.

Variable ‘P_LGC’ is the (c/kWh) LGC price that is assumed. Every MWh of electricity produced by the GSRF is eligible under the Large-Scale Renewable Energy Target (LRET) scheme (CER, 2016) and LGC revenue is calculated by multiplying this output by the assumed LGC (c/kWh) strike price. LRET non-compliance is assumed given the significant capacity deficit now existing in relation to the capacity required to meet the LRET target in forward years [Green Energy Markets (2015, 2016)]. In this situation, two LGC prices are relevant. The first is a strike price of 6.50 (c/kWh) which corresponds to the nominal shortfall LGC penalty price payable by eligible but non-compliant entities which do not have a tax liability. The second is a strike price of 9.29 (c/kWh) which equates to the tax-effective level of the shortfall LGC penalty price payable by non-compliant entities having a tax liability [Green Energy Markets (2016)]. We also adopt a contemporaneous value for the LGC spot price using the closing spot price of 8.92 (c/kWh), sourced as the mid-point of the ‘ask’ and ‘bid’ range of the LGC spot price values listed by Mercari (2016) on 10/10/2016, and converted to a (c/kWh) basis.

Variable ‘CP’ is the calculated (c/kWh) CFD strike price. The algorithm determining this is as follows: Given: (1) hourly wholesale electricity prices; (2) assumed LGC strike price; (3) hourly output from the representative solar PV sub-arrays; (4) other exogenous inputs outlined in Table 1, choose the CFD strike price that produces a (small) non-negative retained earnings after equity distribution value (i.e. in the last row of Table 1).

Note that in the above algorithm, while LGC prices are included in the determination of CFD strike price levels, the CFD strike price concept is not a combined wholesale market/LGC (e.g. black and green) bundled financial product. LGC’s are assumed to be managed separately by project proponents. A combined instrument, however, could be constructed by adding the assumed LGC and calculated CFD price together if this instrument is a superior financial instrument for securing project finance.

The determination of the CFD strike price under this methodology will ensure that enough revenue is earnt to cover operational and capital costs including annual payment of principal and required return on equity and principal and interest obligation on debt for each year under investigation. Note that the annual debt and equity allowances [items (19) and (20) in Table 1] are calculated by the excel PMT function using the costs of debt and equity [exogenous items (14) and (16) in Table 1], the amount of debt and equity principal [calculated in items (17) and (18) in Table 1] and an assumed 25 year lifespan for the project.

The '630' values in items (7) and (10) of Table 1 denotes the sent-out capacity of each of the five sub-arrays, e.g. 630 kW. Recall that there are three FT sub-arrays and individual SAT and DAT sub-arrays at GSRF. This value is combined with the FOM ($/kW-yr) cost estimates and the ($/kW) capital (construction) cost estimates to determine the $pa FOM cost [item (7)] and the $m OCC of each sub-array and for GSRF as a whole [e.g. item (10)]. The particular calculations involved are depicted in column three of Table 1 with numbers in '[ ]' denoting the item numbers involved in the calculations listed in Column two.

Finally, the prime cost method is used to calculate the depreciation allowance for company income tax purposes. Specifically, the annual depreciation rate is calculated as (100%/25) = 4.00% where '25' denotes the 25-year-lifespan of the project. Thus, for each year, the depreciation expense allocated for tax purposes for each sub-array component is 4.00% of the total capital cost of each sub-array as calculated in item (10) of Table 1.

For GSRF as a whole, FOM and CAPEX costs are calculated by multiplying the FT results by three and then adding this to the results associated with the SAT and DAT sub-arrays. On the other hand, both wholesale market and LGC revenue is calculated from PV yield simulations of the whole array itself, including the three individual (but separate) FT sub-arrays.[1]

More generally, the key variables in the financial model are:

- **Net Revenue (item 5)** – calculated as the sum of revenue from: (1) wholesale market sale of electricity; (2) sale of eligible LGC renewable certificates; (3) revenue received from the CFD counter-party when wholesale electricity

[1] In terms of the three FT sub-arrays, there will be some variation in PV yield related to differences in near-object shading effects primarily associated with the location of trees near each separate sub-array.

prices are lower than the CFD strike price bid by the project proponent; (4) *less* payments to the CFD counter party from the project proponent when wholesale electricity prices are greater than the CFD strike price bid by the project proponent (applicable only in the case of a two-way CFD tariff design).

- **EBITA (item 22)** – Net revenue less annual FOM costs and annual connection fees (items 7 and 8).

- **EBIT (item 23)** – EBITA less depreciation allowance calculated for tax purposes (item 12).

- **EBT (item 24)** – EBIT less annual interest payable on debt (item 19).

- **Income Tax Payments (item 25)** – Company income tax rate (item 21) multiplied by EBT.

- **Net Profit (item 26)** – EBT less income tax payments.

- **Cash Flow After Taxes (item 27)** – Net profit plus the depreciation allowance calculated for tax purposes. Note that tax depreciation is added back onto net profit in order to calculate cash flow after taxes because tax depreciation is a non-cash expense.

- **Retained Earnings After Equity Distribution (item 28)** – Cash flow after taxes less annual allocation to meet required return on equity invested in the project (item 20).

Table 1. Financial Model.

Item	Description	Formulae	Example: FT Value
1	Wholesale Market Revenue	P_WMxQ	$71,810
2	LGC Revenue	P_LGC*Q	$106,596
3	CFD Payments (e.g. to Government) – *applicable for two-way CFD tariff design*	(CP-P_WM)*Q if (CP >= P_WM), else 0	(-$28,169)

4	CFD *Receipts (e.g. from Government)*	(CP-P_WM)*Q if (CP< P_WM), else 0	$37,868
5	Net Revenue	[1]+[2]+[4]-[3]	$188,106
6	FOM ($/kW/year)	Exogenous input	20
7	Annual FOM Cost	[6]x630	$12,600
8	Annual Energex Connection Fee	Exogenous input	$6,568
9	($/kW) Overnight Capital Cost	Exogenous input	2151.19
10	CAPEX ($)	[9]*630	$1,355,249
11	Tax Depreciation Rate (Prime Cost Method Assuming 25 Year Lifespan)	Exogenous input	4.00%
12	Annual Tax Depreciation Allowance	[11]*[10]	$54,210
13	Debt Ratio	Exogenous input	0.70
14	Debt Cost	Exogenous input	5.82%
15	Equity Ratio	1.0-[13]	0.30
16	Equity Cost	Exogenous input	20.48%
17	Principal: Debt	[13]*[10]	$948,675
18	Principal: Equity	[15]*[10]	$406,575
19	Annual PMT Debt Payment	-PMT([14],25,[17])	$72,968
20	Annual PMT Allowance For Equity	-PMT([16],25,[18])	$84,059
21	Company Income Tax Rate	Exogenous input	28.5%
22	EBITDA	[5]-[7]-[8]	$168,938
23	EBIT	[22]-[12]	$114,728
24	EBT	[23]-[19]	$41,760
25	Income tax payments	[21]*[24]	$11,902
26	Net Profit	[24]-[25]	$29,858
27	Cash flow after taxes	[26]+[12]	$84,068
28	Retained earnings after equity distribution	[27]-[20]	$9

Table 2. (c/kWh) Volume Weighted Average Wholesale Prices for 'QLD1' Market

Year	Volume-weighted average QLD1 (c/kWh) Wholesale Price
2007	7.27
2008	4.88
2009	3.74
2010	2.81
2011	3.80
2012	4.40
2013	7.18
2014	5.62

2015	5.80
Average	5.06
Maximum	7.27
Minimum	2.81

The annual calculation of CFD strike prices by the above financial model will reflect variation in wholesale electricity prices, LGC strike prices and variations in renewable energy output arising on a year-on-year basis. In general, CFD strike prices will have to be higher if either wholesale electricity prices, LGC prices or output from the renewable energy project are lower than expected in order to offset the lower revenue streams flowing from wholesale electricity and LGC markets, respectively.

(3) Financial Modelling Inputs

(3.1) Treatment of FOM Costs

A key variable affecting the magnitude of CFD strike price bids by utility-scale renewable energy project proponents is the $pa FOM cost linked to the FOM ($/kW-yr) cost rates assumed in the financial modelling. For utility-scale solar PV farms, there are three main types of O&M [NREL (2015) and Sandia (2015)]: (1) *preventative maintenance* which encompasses routine inspection and servicing of equipment; (2) *corrective or reactive maintenance* which addresses equipment repair needs and breakdowns after their occurrence and unplanned downtime; (3) *condition-based maintenance* which uses real-time data to anticipate failures and prioritize maintenance activities and resources. Provisions for these three components are typically defined in an O&M contract.

Sandia (2015, p.10) cite USD cost estimates range of between $10/kW-yr and $45/kW-yr which equates to an equivalent AUD range of $14.29/kW-yr to $64.29/kW-yr, assuming an AUD/USD exchange rate of 0.77 and Goods and Services Tax (GST) of 10% applicable in Australia. In Figure 1 of Sandia (2015), approximate USD cost estimates developed by EPRI for CdTe FT, SAT and DAT arrays are estimated to be approximately $21.3/kW-yr, $22.8/kW-yr and $25.1/kW-yr.[2] In these calculations, a cost differential of (21.3/20.4) for CdTe FT systems was assumed relative to c-Si FT systems and then applying this cost differential to the SAT c-Si and DAT c-Si data reported in Figure 1 of Sandia (2015) to extrapolate SAT CdTe and DAT CdTe cost estimates. Converting from USD to AUD

[2] Note that these FOM cost estimates were derived by EPRI for conceptual 10-MW plants.

using the above exchange rate and GST rate produce AUD estimates of $30.43/kW-yr, $32.52/kW-yr and $35.80/kW-yr for CdTe FT, SAT and DAT arrays, respectively.

The FOM cost rates and AUD dollar costs utilised in the modelling are listed in Panels (A)-(B) of Table 3. To demonstrate how CFD strike prices may vary with FOM costs, three FOM cost scenarios are considered. The first, called the *low* FOM cost scenario is based on the average of private O&M contractor estimates cited in BREE (2013). These estimates range between $20/kW-yr to $33/kW-yr for each sub-array [Panel (A)], producing annual FOM costs between $12,600 and $20,790 for each respective sub-array and $74,970 in total for GSRF.

The *medium* and *high* FOM cost scenarios were calculated using ($/kW-yr) estimates cited for various FOM cost categories in Table 4 of Sandia (2015). The medium cost scenario is based on the lower range estimates whilst the high cost estimates are based the mid-range point estimates of the categories listed in that table. In both cases, the cost rate estimates were converted to an AUD basis again assuming an AUD/USD exchange rate of 0.77 and 10% GST rate.

The resulting FOM cost rates and AUD cost allocation for each FOM cost category is outlined in Table (4), Panel (A) for the medium FOM cost scenario and in Panel (B) for the high FOM cost scenario. Note that the FOM cost rates derived in the last rows of Table 4, Panels (A) and (B) are also included in rows three and four of Table 3, Panel (A), for completeness.

Table 3. ($/kW-yr) FOM Cost Scenarios

Panel A. ($/kW-yr) FOM cost rates				
FOM Cost Scenarios	FT	SAT	DAT	GSRF
Low	20.00	26.00	33.00	23.80
Medium	54.01	55.44	56.87	54.87
High	81.77	84.27	86.77	83.27
Panel B. ($) FOM costs				
FOM Cost Scenarios	FT	SAT	DAT	GSRF
Low	$12,600	$16,380	$20,790	$74,970
Medium	$34,025	$34,925	$35,825	$172,826
High	$51,516	$53,091	$54,666	$262,305

Special treatment was applied to certain FOM cost categories in Table 4. The first was panel washing. For the medium FOM cost scenario, it was assumed that the cost of washing modules was $0.68 AUD per panel, the mid-point of the range between the $0.35 USD and $0.6 USD cost cited in (Sandia, 2015, p.14), and converted to AUD. For the high FOM cost scenario, $0.86 AUD was assumed for cleaning per panel, with this corresponding to the upper bound $0.6 USD cited in (Sandia, 2015, p. 14) converted to AUD.

The next special case was monitoring costs. In this case, 50 days per year was allocated to this task payable at a $23.80 per hour pay scale for an administrative assistant. This produced a wage bill of $28,569 which was pro-rated equally across each of the five sub-arrays at GSRF.

The final cost category having special treatment was the insurance cost category. The USD $5000/MW-yr all-risk insurance product identified in (Sandia, 2015, p. 19) was adopted which produced an aggregate AUD $22,500 after converting to AUD. This produced an equivalent AUD $7,143/MW-yr rate insurance cost. We then pro-rated the $22,500 amount equally across the five sub-arrays.

In the case of the medium FOM cost scenario, the ($/kW-yr) FOM cost rates fell between $54.01/kW-yr and $56.87-yr (in Panel (A) of Tables 3 and 4), producing per annum AUD FOM costs of between $34,025 and $35,825 for each respective sub-array and $172,826 for GSRF as listed in Panel (B) of Table 3 and Panel (A) of Table 4. For the high FOM cost scenario, the equivalent FOM cost range was between $81.77/kW-yr and $86.77/kW-yr (e.g. see Panel (A) of Table 3 and Panel (B) of Table 4), producing AUD FOM cost estimates between $51,516 and $54,666 for each sub-array and $262,305 for GSRF as also reported in Panel (B) of Tables 3 and 4.

When compared with the earlier ($/kW-yr) FOM cost estimates listed at the start of this section (i.e. AUD $14.29/kW-yr to $64.29/kW-yr), the high FOM cost scenario estimates appear high in comparison. However, ($/kW-yr) O&M costs tend to decline as the size of the system increases because the FOM costs can be spread across a greater number of system components (Sandia, 2015, pp. 10-11). This could help explain the higher FOM cost estimates cited in Panel (A) of Tables 3 and 4 being derived for GSRF which is a relatively small utility-scale plant.

Table 4. ($/kW-yr) FOM Cost Rate Scenarios

Panel A. FOM cost itemisation: Medium cost scenario					
FOM Item	AUD ($/kW-yr)	FT	SAT	DAT	GSRF
General site maintenance	0.29	$180	$180	$180	$900
Wiring/electrical inspection	2.00	$1,260	$1,260	$1,260	$6,300
Panel washing	7.76	$4,886	$4,886	$4,886	$24,429
Vegetation management	6.80	$4,286	$4,286	$4,286	$21,429
Inverter maintenance	4.29	$2,700	$2,700	$2,700	$13,500
Inverter replacement	12.67	$7,980	$7,980	$7,980	$39,900
racking/tracker maintenance	2.86	$720	$1,620	$2,520	$6,300
Spares	2.86	$1,800	$1,800	$1,800	$9,000
Monitoring	9.07	$5,714	$5,714	$5,714	$28,569
all-risk insurance	7.14	$4,500	$4,500	$4,500	$22,500
Total		$34,025	$34,925	$35,825	$172,826
AUD ($/kW-yr)		54.01	55.44	56.87	54.87
Panel B. FOM cost itemisation: High cost scenario					
FOM Item	AUD ($/kW-yr)	FT	SAT	DAT	GSRF
General site maintenance	2.29	$1,440	$1,440	$1,440	$7,200
Wiring/electrical inspection	4.57	$2,880	$2,880	$2,880	$14,400
Panel washing	9.80	$6,171	$6,171	$6,171	$30,857
Vegetation management	6.80	$4,286	$4,286	$4,286	$21,429
Inverter maintenance	7.50	$4,725	$4,725	$4,725	$23,625
Inverter replacement	16.89	$10,640	$10,640	$10,640	$53,200
racking/tracker maintenance	5.00	$1,260	$2,835	$4,410	$11,025
Spares	15.71	$9,900	$9,900	$9,900	$49,500
Monitoring	9.07	$5,714	$5,714	$5,714	$28,569
all-risk insurance	7.14	$4,500	$4,500	$4,500	$22,500
Total		$51,516	$53,091	$54,666	$262,305
AUD ($/kW-yr)		81.77	84.27	86.77	83.27

(3.2) ($/kW) Capital Cost Estimates

Capital cost ($/kW) estimates for utility-scale solar PV have become quite fluid during 2016. At the beginning of 2016, capital cost estimates for FT and SAT technologies reflected costs associated with AGL's Nyngan and Broken Hill solar farms (AGL, 2015) and the Moree solar farm (ARENA, 2016a). These ($/kW) costs were $2,833/kW and $2,929/kW, respectively. With the release of details about the second ARENA large-scale solar PV competitive round in September 2016, average costs for these two technologies had declined significantly to between $2100/kW to $2210/kW with some individual costs as low as $1900/kW. Since then, however, Parkinson (2016) cites industry sources quoting cost estimates as low as $1600/kW.

The ($/kW) OCC estimates used are based on data cited in Table 3.5.2 of BREE (2012). Specifically, the following OCC estimates were listed in that table as:

- FT: $3380/kW;
- SAT: $3860/kW; and
- DAT: $5410/kW.

These (BREE, 2012) estimates are rebased to an average of the updated FT and SAT ($/kW) results linked to published information in (ARENA, 2016b). This was combined with private information sought from project proponents about the solar PV array technology intended to be used. The DAT estimate was determined by applying the original BREE cost shares between the SAT and DAT technologies listed above and pro-rating to the current SAT ($/kW) cost estimate. This led to the following ($/kW) estimates:

- FT: $2151/kW;
- SAT: $2204/kW; and
- DAT: $3089/kW = (5410/3860)*2204.

(3.3) Selection of Simulation Scenario According to 2015 Comparison of Actual and Simulated PV Yield

The output measure employed in the financial modelling is the hourly simulated output of the representative sub-arrays and the whole array obtained from the PVsyst simulation software (PVsyst, 2016) over years 2007-2015. To run simulations in PVsyst, various user supplied inputs are required. These relate to: (1) hourly solar, weather and surface albedo data; (2) technical information about modules, inverters and array sizing and design; (3) soiling effects; (4) shading effects; (5) DC and AC electrical losses. Further details can be found in (Wild, 2016).

Evidence for 2015 indicates that the PVsyst low soiling scenario most closely matches the actual solar PV yield performance of the FT and SAT sub-arrays at GSRF. Assessment of the DAT sub-array could not be undertaken during 2015 because solar tracking was not activated until early December 2015.

A close correspondence between the PVsyst low soiling scenario results and actual GSRF 2015 outcomes are established for two FT and SAT sub-arrays. These results are reported in Table 5. In this table, the difference between the simulated and actual Annual Capacity Factor (ACF) outcomes for these three sub-arrays is quite small in magnitude, between 0.1 and 0.3 percentage points, in absolute terms.

However, the results for one of the FT sub-arrays (i.e. FT-West) is significantly different. This outcome was subsequently attributed to blown fuses in a harness combiner box that was flagged as a defect but not quickly rectified. Therefore, the PVSyst low soiling simulation is used as the output measure for the CFD financial modelling performed in this paper, i.e. variable ‘Q’ in Table 1.

Table 5. Comparison of Actual and Simulated ACF Outcomes of GSRF in 2015

Array	FT-West	FT-East	Hybrid-FT	SAT
2015 Actual	18.1	20.2	19.5	23.7
2015 PVsyst	19.3	20.3	19.7	23.4
Difference	-1.2	-0.1	-0.2	0.3
PVsyst Scenario	HS	LS	LS	LS

(3.4) Calculation of Typical Meteorological Year (TMY)

We used the simulated hourly solar PV output data associated with the PVsyst low soiling scenario for years 2007 to 2015 as source data for TMY analysis. This was implemented by stacking each year's 8760 hourly PV yields across the top of a spreadsheet in chronological order commencing with 2007 and moving column-wise across the spreadsheet for years 2008 to 2015[3]. We then calculate the average of this data producing a series of 8760 values corresponding to each hour in a year.

To determine the empirical distribution function associated with TMY, we calculated the absolute value of the difference between the sequence of hourly average values applied column-wise across years 2007-2015 and the hourly production values of each year. These difference values were then aggregated over each month of each year in the interval 2007-2015. The month of PV yield data of a year that has the closest statistical match to the average monthly data would have the lowest magnitude associated with the aggregated monthly difference values. Using this criteria, the choice of month and year with the closest statistical match to TMY is reported in Table 6.

This year/month information was then used to construct the annual data series consistent with the TMY methodology from the original PVsyst simulations. This data will have 8760 individual hourly data points by construction. This data is used as the 'output' variable in the financial modelling, as represented by variable 'Q' in Table 1, when modelling TMY effects. This TMY methodology was applied to solar PV output data associated with the representative FT, SAT, DAT sub-arrays and total GSRF array, respectively.

The ACF's associated with the TMY threshold for each sub-array (and GSRF) were: (1) FT (20.9%); (2) SAT (24.3%); (3) DAT (28.3%); and (4) GSRF (23.0%).

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[3] Note that we dropped the 29th February from 2008 and 2012 to ensure that TMY based on a standard 365 day calendar year format.

Table 6. Year by Month Selections for Typical Meteorological Year (TMY) Calculation

Month	TMY
January	2009
February	2007
March	2011
April	2014
May	2012
June	2012
July	2009
August	2012
September	2012
October	2012
November	2011
December	2007

(4) Typical Metrological Year (TMY) Solar PV Profile

(4.1) One-way CFD strike price reductions relative to two-way CFD pricing

The financial model was used to calculate sets of two-way and one-way CFD prices for the PV yield associated with the TMY profile. The rationale for using the TMY profile is that, by construction, this concept provides a measure of average PV yield and average revenue streams for assumed wholesale electricity and LGC prices. For TMY analysis, we also applied the year/month selections in Table 6 to construct a wholesale electricity price index that is used to model wholesale market revenue.

To focus investigation, some homogenisation of the CFD price data for both CFD pricing schemes is utilised. Specifically, the CFD prices for each PV array type and GSRF were: (1) averaged across LGC price scenarios; (2) averaged across FOM cost scenarios; and (3) averaged across both LGC and FOM cost scenarios jointly. These results are reported in Table 7, Panels (A)-(C) for two-way CFD pricing, one-way CFD pricing and percentage change in one-way CFD prices relative to two-way CFD prices.

In Panel C of Table 7, the average two-way CFD pricing points indicate pricing levels of 7.7 (c/kWh) for the SAT sub-array, 9.5 (c/kWh) for GSRF, 9.8 (c/kWh) for the FT sub-array and 10.1 (c/kWh) for the DAT sub-array, averaged across both FOM costs and LGC price scenarios. In comparison, the equivalent average one-way CFD pricing points are lower in magnitude being 7.0 (c/kWh) for the SAT sub-array, 9.0 (c/kWh) for GSRF, 9.3 (c/kWh) for the FT sub-array and 9.6 (c/kWh) for the DAT-sub-array.

A number of observations can be drawn from Table 7. First, under all three different averaging schemes represented in Panels (A) to (C), the average percentage reduction rates in average one-way CFD prices relative to two-way pricing remain identical across the different array technologies and GSRF. These results are shaded in orange in Table 7. Second, percentage reductions in average one-way CFD prices reported in Table 7 are greatest in magnitude for the SAT sub-array (-9.1 per cent), followed by GSRF (-5.2 per cent), FT sub-array (-5.0 per cent) and finally the DAT sub-array (-4.2 per cent). Third, from Panel (A) the percentage reductions in one-way pricing relative to two-way CFD pricing decreases in magnitude as FOM costs increase. Fourth, from Panel (B), the magnitude of percentage reductions in one-way pricing relative to two-way CFD pricing increase as the LGC strike prices assumed in the financial modelling increase in magnitude.

These latter observations, in particular, indicate that securing adequate project revenue under both CFD pricing schemes becomes more prevalent under conditions of reduced competitiveness or tighter operating conditions associated with higher FOM costs or lower LGC revenues associated with lower LGC prices. In both of these situations, project proponents need to ensure that CFD strike prices are bid high enough under both pricing schemes to secure the required revenue.

Table 7. Percentage reduction in one-way CFD prices relative to two-way CFD prices

Panel A. Averaged across LGC Prices					Panel B. Averaged across FOM costs					Panel C. Averaged across both LGC Prices and FOM costs				
Two-way CFD					Two-way CFD					Two-way CFD				
FOM Cost	FT	SAT	DAT	GSRF	LGC Price	FT	SAT	DAT	GSRF		FT	SAT	DAT	GSRF
Low	8.1	6.4	9.0	8.0	6.50	11.6	9.5	11.8	11.2	Minimum				
Medium	9.9	7.7	10.0	9.5	8.29	9.2	7.0	9.4	8.8	Average	9.8	7.7	10.1	9.5
High	11.5	9.1	11.2	10.9	9.28	8.8	6.7	9.0	8.4	Median				
Average	9.8	7.7	10.1	9.5	Average	9.8	7.7	10.1	9.5	Maximum				
One-way CFD					One-way CFD					One-way CFD				
FOM Cost	FT	SAT	DAT	GSRF	LGC Price	FT	SAT	DAT	GSRF		FT	SAT	DAT	GSRF
Low	7.5	5.4	8.6	7.4	6.50	11.1	9.0	11.4	10.8	Minimum				
Medium	9.5	7.1	9.6	9.1	8.29	8.6	6.3	8.9	8.3	Average	9.3	7.0	9.6	9.0
High	11.0	8.6	10.8	10.5	9.28	8.2	5.8	8.6	7.9	Median				
Average	9.3	7.0	9.6	9.0	Average	9.3	7.0	9.6	9.0	Maximum				
% Change					% Change					% Change				
FOM Cost	FT	SAT	DAT	GSRF	LGC Price	FT	SAT	DAT	GSRF		FT	SAT	DAT	GSRF
Low	-7.2	-15.5	-5.1	-7.2	6.50	-3.6	-5.2	-3.1	-3.7	Minimum				
Medium	-4.8	-7.9	-4.2	-5.1	8.29	-5.7	-10.4	-4.7	-5.9	Average	-5.0	-9.1	-4.2	-5.2
High	-3.7	-5.7	-3.4	-3.9	9.28	-6.1	-13.2	-5.1	-6.4	Median				
Average	-5.0	-9.1	-4.2	-5.2	Average	-5.0	-9.1	-4.2	-5.2	Maximum				

(4.2) Implied revenue requirements and neutrality of two-way and one-way CFD pricing schemes over 2007-2015

The annual dollar ($AUD) payments owing to GSRF under both two-way and one-way CFD pricing for the TMY solar PV and wholesale price profiles are reported in Table 8. The values listed in this table for two-way CFD pricing is the net payment made by the CFD counter-party after netting off payments made by the project proponent to it when wholesale electricity prices exceed the CFD strike price. The results for each sub-array component and GSRF are listed in Panels (A)-(D) in Table 8. Revenue receipts are also reported for the three FOM cost scenarios column-wise and for the three LGC strike prices row-wise in Table 8 in each panel.

A number of observations can be drawn from Table 8. First, across all scenarios reported in Table 8, there is a close correspondence between revenue payable by the CFD counter-party under both CFD pricing schemes indicating that both pricing schemes are *revenue neutral*. Second, of the three sub-array components considered, greater revenue is payable to the DAT sub-array reflecting the role that higher operational and capital costs play in driving up economically viable CFD price bids relative to comparable price bids associated with particularly the SAT technology. Furthermore, the higher PV yield of this sub-array magnifies the CFD counter-party's revenue liability relative to the FT sub-array which has a similar CFD strike price level to the DAT sub-array reported in Table 7. Third, the SAT sub-array receives the lowest revenue payable from the CFD counter-party reflecting the role that lower operational and capital costs and superior PV yield plays relative to the situation confronting the DAT and FT sub-arrays, respectively. Note that the FT sub-array falls between the lower revenue receiving SAT sub-array and higher revenue receiving DAT sub-array. Fourth, for all four array components (including GSRF), revenue receivable from CFD counter-party *declines* as the LGC strike price employed in the financial modelling increases. This reflects the role of lower CFD price bids on the back of higher LGC revenue streams accompanying increases in the LGC strike price. Fifth, revenue receivable from the CFD counter-party across all array components also *increases* as FOM costs increase. This reflects the impact that increased operational (FOM) costs play in reducing project profitability requiring higher CFD price bids to ensure project viability. Finally, it should be noted that all values reported in Table 8 are per annum values, calculated from the TMY solar PV and wholesale electricity price profiles.

<u>Table 8. GSRF Revenue ($ pa) payable by CFD counter-party</u>

	Panel A. FT sub-array					
	Low FOM Costs		Medium FOM Costs		High FOM Costs	
LGC Price	Two-way	One-Way	Two-way	One-Way	Two-way	One-Way
6.50	58,917	58,917	80,344	80,341	97,831	97,832
8.92	31,087	31,087	52,515	52,512	70,002	70,001
9.29	26,812	26,812	48,240	48,238	65,727	65,726
	Panel B.SAT sub-array					
	Low FOM Costs		Medium FOM Costs		High FOM Costs	
LGC Price	Two-way	One-Way	Two-way	One-Way	Two-way	One-Way
6.50	45,123	45,123	63,671	63,672	81,835	81,834
8.92	12,684	12,684	31,231	31,231	49,395	49,393
9.29	7,700	7,700	26,248	26,247	44,411	44,411
	Panel C. DAT sub-array					
	Low FOM Costs		Medium FOM Costs		High FOM Costs	
LGC Price	Two-way	One-Way	Two-way	One-Way	Two-way	One-Way
6.50	96,213	96,212	111,251	111,248	130,088	130,087
8.92	58,450	58,449	73,486	73,487	92,324	92,323
9.29	52,648	52,648	67,685	67,687	86,523	86,523
	Panel D. GSRF					
	Low FOM Costs		Medium FOM Costs		High FOM Costs	
LGC Price	Two-way	One-Way	Two-way	One-Way	Two-way	One-Way
6.50	319,509	319,512	417,378	417,373	506,843	506,839
8.92	166,163	166,165	264,032	264,029	353,498	353,493
9.29	142,606	142,608	240,474	240,470	329,942	329,936

The results presented in Table 8 are predicated upon varying the CFD strike prices to achieve the same approximate results for retained earnings after equity distribution results under the two different CFD pricing schemes, that is, a small positive value for this financial model item. Under this particular circumstance, and optimised around the same TMY solar PV yield and wholesale market price profiles, the revenue results indicated in Table 8 are revenue neutral.

In practice, however, when applying CFD strike prices, revenue receivable by project proponents will vary with each CFD pricing scheme, reflecting differences in PV yield and wholesale prices. Under such circumstances, the CFD strike price that is bid cannot be changed or optimised to reflect the differing yield and wholesale price outcomes occurring over time and revenue neutrality between the two CFD pricing schemes will not eventuate.

To investigate this issue further, we set the CFD strike prices to the average values listed in Panel © of Table 7 for the two CFD pricing schemes and applied these pricing schemes to the simulated PV output profiles calculated by PVsyst for the 2007-2015 time period. The wholesale prices uses are those underpinning the average annual wholesale prices listed in Table 2 over the same time period. To focus analysis, we restricted the LGC price to the contemporaneous price of 8.29 (c/kWh), while continuing to consider the three FOM cost scenarios. Two key metrics are investigated. The first is the net outlay to be made to the project proponent by the CFD counter-party. The second is the retained earnings after equity distribution results received by the project proponent. Large positive values for this particular variable would point to 'super-normal' economic profits whilst negative values would indicate economic loss. Values that are small and positive would continue to point to normal economic profits.

Revenue receivable from the CFD counter-party is reported in Table 9 for the two-way and one-way CFD pricing schemes. Receipts under both pricing schemes tend to be higher in magnitude over 2009-2012 reflecting lower wholesale market prices as well as lower PV yields associated with La Nina weather events over 2010-2011. They tend to be smallest in magnitude in 2013 and 2007 on the back of higher wholesale prices occurring in those particular years. Note the negative value in 2013 of $3,305 associated with the SAT sub-array under two-way CFD pricing. In this case, the project proponent would have had to pay the CFD counter-party more money than they received because of the higher prices arising in 2013 following the introduction of the carbon price. Relatively lower payments also arise during 2008, 2014 and 2015 reflecting relatively higher average wholesale electricity prices. On the other hand, average to above average solar PV output would serve to increase the amount of revenue payable for a given price differential between the wholesale price and CFD strike price. This latter effect can be seen in two ways. First, higher payments accrue in 2014 relative to 2015 on the back of higher PV yield in 2014 relative to 2015 across all array technologies. Second, higher revenue payments accrues to the DAT sub-array relative to the FT sub-array, in part because of the better PV yield performance (e.g. output) of the DAT technology relative to the FT technology .

Examination of the last row of Table 9 indicates that the quantum of money payable by the CFD counter-party across all array technologies is lower under two-way CFD pricing compared with one-way CFD pricing. It should be recognised that with the selection of the CFD prices in row 3 this revenue receivable is independent of FOM cost. It is determined solely by the relative differences between the CFD strike price, the wholesale market price and the amount of output produced by each array technology. For example, the total revenue receivable over the nine year period 2007-2015 by the project proponent from the CFD counter-party for GSRF under a two-way CFD scheme is $1,984,756.00, 28.6 per cent lower than the equivalent one-way CFD scheme payment of $2,778,080.00. In this case, the payments to be made back to the CFD counter-party under a two-way scheme when wholesale prices exceed the CFD strike price is more than sufficient to reduce the total amount receivable by project proponents relative to a one-way CFD pricing scheme. This arises even with the lower CFD strike price operational under the one-way CFD scheme which would reduce the amount of payments that have to be made by the CFD counter-party relative to the equivalent payments arising under the two-way CFD scheme.

Examination of Table 9 also indicates lower payments are made by the CFD counter-party to the SAT sub-array relative to the FT and DAT array technologies. This reflects the relatively lower capital and operational costs and superior PV yield performance which produces the significantly lower CFD strike prices discernible in row 3 of Table 9. Highest payments are made to the DAT sub-array reflecting, in part, its greater output (e.g. PV yield) when compared to the FT technology which drives higher revenue outcomes in the case of the DAT sub-array. This is particularly noticeable when account is taken of the relatively close proximity of the CFD prices for the FT and DAT technologies listed in row 3 of Table 9.

Table 9. Revenue ($ pa) payable by CFD counter-party over 2007-2015

	Two-way CFD				One-way CFD			
	FT	SAT	DAT	GSRF	FT	SAT	DAT	GSRF
CFD Price (c/kWh)	9.80	7.70	10.10	9.50	9.30	7.00	9.60	9.00
2007	$22,253	$1,402	$40,921	$113,443	$42,449	$26,745	$63,972	$222,405
2008	$25,070	$6,102	$50,148	$135,275	$62,922	$45,381	$92,469	$332,448
2009	$66,599	$50,413	$99,034	$352,659	$68,089	$50,970	$99,880	$360,651
2010	$60,710	$45,694	$88,564	$319,197	$68,928	$53,109	$97,334	$362,169
2011	$50,641	$31,760	$76,384	$263,386	$67,026	$49,388	$95,172	$350,998
2012	$57,876	$39,533	$84,613	$301,853	$57,099	$37,231	$82,508	$297,232
2013	$24,843	-$3,305	$37,832	$113,724	$39,143	$18,113	$59,442	$201,051
2014	$41,059	$12,302	$59,270	$198,943	$63,515	$43,031	$91,984	$332,006
2015	$40,687	$9,100	$51,115	$186,276	$61,588	$42,292	$86,193	$319,119
Total	$389,738	$193,001	$587,880	$1,984,756	$530,759	$366,260	$768,956	$2,778,080

Table 10. GSRF Operating Surplus ($ pa) over 2007-2015

Panel A. GSRF Operating Surplus: Low FOM Cost								
	Two-way CFD				One-way CFD			
	FT	SAT	DAT	GSRF	FT	SAT	DAT	GSRF
2007	$19,025	$19,949	$20,660	$98,770	$33,465	$38,070	$37,142	$176,678
2008	$15,981	$17,983	$18,135	$85,249	$43,046	$46,067	$48,394	$226,228
2009	$16,987	$17,836	$19,356	$89,255	$18,053	$18,235	$19,961	$94,970
2010	$1,545	-$445	-$7,099	-$2,208	$7,421	$4,857	-$828	$28,517
2011	$11,888	$10,985	$7,741	$55,244	$23,603	$23,590	$21,175	$117,887
2012	$20,211	$22,403	$21,522	$106,152	$19,656	$20,757	$20,017	$102,848
2013	$22,752	$27,444	$29,092	$126,487	$32,977	$42,758	$44,543	$188,926
2014	$26,737	$28,776	$32,152	$142,444	$42,792	$50,747	$55,543	$237,585
2015	$19,120	$19,738	$14,972	$93,580	$34,064	$43,470	$40,053	$188,563
Total	$154,246	$164,670	$156,530	$794,974	$255,076	$288,551	$286,000	$1,362,201
Panel B. GSRF Operating Surplus: Medium FOM Cost								

	Two-way CFD				One-way CFD			
	FT	SAT	DAT	GSRF	FT	SAT	DAT	GSRF
2007	$3,705	$6,688	$9,908	$28,797	$18,145	$24,808	$26,389	$106,705
2008	$662	$4,722	$7,382	$15,276	$27,726	$32,806	$37,642	$156,255
2009	$1,667	$4,575	$8,604	$19,282	$2,733	$4,973	$9,209	$24,997
2010	-$13,774	-$13,706	-$17,852	-$72,181	-$7,899	-$8,405	-$11,581	-$41,456
2011	-$3,432	-$2,276	-$3,011	-$14,728	$8,283	$10,328	$10,422	$47,914
2012	$4,892	$9,142	$10,770	$36,179	$4,336	$7,495	$9,265	$32,875
2013	$7,433	$14,183	$18,340	$56,514	$17,657	$29,497	$33,791	$118,953
2014	$11,417	$15,514	$21,400	$72,471	$27,473	$37,486	$44,791	$167,612
2015	$3,800	$6,477	$4,219	$23,607	$18,744	$30,209	$29,300	$118,590
Total	$16,368	$45,319	$59,760	$165,218	$117,198	$169,199	$189,229	$732,445
Panel C. GSRF Operating Surplus: High FOM Cost								
	Two-way CFD				One-way CFD			
	FT	SAT	DAT	GSRF	FT	SAT	DAT	GSRF
2007	-$8,800	-$6,298	-$3,560	-$35,171	$5,640	$11,822	$12,921	$42,737
2008	-$11,843	-$8,264	-$6,086	-$48,692	$15,222	$19,820	$24,173	$92,287

2009	-$10,837	-$8,412	-$4,865	-$44,686	-$9,771	-$8,013	-$4,259	-$38,972
2010	-$26,279	-$26,693	-$31,320	-$136,149	-$20,403	-$21,391	-$25,049	-$105,424
2011	-$15,937	-$15,263	-$16,480	-$78,697	-$4,221	-$2,658	-$3,046	-$16,055
2012	-$7,613	-$3,845	-$2,698	-$27,790	-$8,169	-$5,491	-$4,203	-$31,094
2013	-$5,072	$1,197	$4,871	-$7,454	$5,152	$16,510	$20,323	$54,985
2014	-$1,088	$2,528	$7,932	$8,503	$14,968	$24,499	$31,322	$103,643
2015	-$8,705	-$6,510	-$9,249	-$40,361	$6,240	$17,223	$15,832	$54,622
Total	-$96,172	-$71,560	-$61,456	-$410,498	$4,658	$52,321	$68,013	$156,729

Total CFD revenue receivable over the nine year period 2007-2015 by the project proponent from the CFD counter-party for each sub-array technology is significantly lower under a two-way CFD scheme compared to a one-way CFD pricing scheme. Specifically, the amounts receivable for the SAT, FT and DAT technologies under the two-way CFD (e.g. $193,001, $389,738 and $587,880) are 47.3, 26.6 and 23.5 per cent lower than under one-way CFD (e.g. $366,260, $530,759 and $768,956).

Thus, the results in Table 9 point to the likelihood that Government attempting to minimise their financial obligations through the CFD counter-party will prefer a two-way CFD scheme to a one-way scheme. The technology of choice from their perspective would also be the SAT technology. Alternatively, from the perspective of project proponents attempting to maximise payments received from Government (i.e. from the CFD counter-party), the preferred scheme would be the one-way CFD pricing scheme across all of the solar PV array technologies considered.

GSRF retained earnings after equity distribution results for the period 2007-2015 are reported in Table 10 for two-way and one-way CFD schemes and by FOM cost scenarios listed in Panels (A)-(C). The results in Panel (A) for low FOM costs indicate a position of strong profitability across all solar array technologies and CFD pricing schemes considered. The only evidence of loss making is in year 2010 for the SAT, DAT and GSRF under two-way CFD pricing and only for the DAT sub-array under one-way CFD. Over the whole 2007-2015 period, the SAT sub-array is the most profitable array technology, followed by the DAT and then the FT sub-array. Overall profitability is greater under one-way CFD with cumulative surpluses of $288,511, $286,000 and $255,076 for the SAT, DAT and FT sub-arrays, respectively. These outcomes are 75.2, 82.7 and 65.4 per cent higher than the equivalent two-way CFD outcomes. For GSRF the one-way CFD result of $1,362,201 is 71.4 per cent higher than the equivalent two-way result of $794,974, calculated over the nine year period 2007-2015.

In the case of medium FOM costs, the results in Panel (B) indicate a continued position of profitability across all solar array technologies and CFD pricing schemes, although at a lower level compared to results in Panel (A). For example, for GSRF, the 2007-2015 cumulative surpluses of $165,218 and $732,445 in Panel (B) represent reductions of 46.2 and 79.2 per cent on the equivalent values cited in Panel (A) (of $794,974 and $1,362,201) respectively. Evidence of loss making is more evident over 2010-2011 across all technologies under two-way CFD, although only in 2010 for one-way CFD pricing. Over the 2007-2015 period, the DAT sub-array is now the most profitable array technology, followed by the SAT and then the FT sub-array. Overall profitability remains greater under one-way CFD with cumulative surpluses of $189,229, $169,199 and $117,198 for the DAT, SAT and FT sub-arrays. These outcomes are 216.6, 273.4 and 616.0 per cent higher than the equivalent two-way CFD outcomes reported in Panel (B). For GSRF as a whole, the one-way CFD result of $732,445 is 343.3 per cent higher than the equivalent two-way CFD result of $165,218. These results indicate a *marked increase* in profitability of project proponents in relative terms under one-way CFD compared with two-way CFD when viewed against the results reported in Panel (A).

High FOM cost scenario results are reported in Panel ©. These results point to a significant deterioration in overall profitability under a two-way CFD scheme. Positive economic profits are only observed in 2013 and 2014 and only for the DAT and SAT sub-arrays (and GSRF in 2014). For the 2007-2015 time period, each sub-array component and GSRF experience economic *losses* of between $61,456 and $96,172 (for the array technologies) and $410,498 for GSRF. The relative positions of DAT, SAT and FT sub-arrays remain the same in terms of competitive position with the DAT sub-array experiencing lower losses when compared with the other two array technologies.

In the case of one-way CFD reported in Panel ©, much lower but still positive economic profits are obtained over the whole 2007-2015 time period. Economic losses are experienced by all array components and GSRF over years 2009 to 2012, but profitability is secured in other years. As with the situation in Panel (B) and also with two-way CFD pricing in Panel (C), the DAT sub-array remains the most profitable array technology, followed by the SAT and then the FT sub-array. For GSRF as a whole, the overall surplus of $156,729 reported in Panel (C) is 88.5 and 78.6 per cent lower than the equivalent results reported in Panels (A) and (B), of $1,326,201 and $732,445, respectively.

The results in Table 10 strongly reinforce the proposition made in relation to the results in Table 9 that a one-way CFD scheme is likely to be the CFD scheme of choice for project proponents. This outcome rests on the ability of project proponents to fully leverage and appropriate super-normal profits that are available when wholesale prices exceed CFD strike prices. The results, more generally, indicate the requirement for and sensitivity to bidding appropriate CFD strike prices under two-way CFD. This will more generally be the situation for both CFD schemes when FOM costs are high and/or assumed LGC prices are low.

If the CFD strike price is bid too low under two-way CFD, then a situation similar to that documented in Panel © of Table 10 could emerge evolving over time into a loss making enterprise. Clearly, in the case of the two-way scheme, the results in Panel © indicate that the CFD pricing used was too low to secure economic profitability given the high FOM costs. This is demonstrated by the results in Table 11, Panels (A) and (B).

The results reported in Table 11 were calculated from the financial model assuming that the LGC price continued to be the contemporaneous price of 8.29 (c/kWh) but we now consider the high FOM cost scenarios only. The two-way and one-way CFD prices used in the modelling are reported in row 4 of Panel (A) and are now of higher magnitude than the CFD prices listed in row 3 of Table 9. For each respective CFD pricing scheme, the current CFD prices were calculated as the average of the high FOM cost prices listed in Panel (A) and the '6.5 (c/kWh) LGC price' outcomes listed in Panel (B) of Table 7. Because the CFD price levels have changed, the receipts flowing to project proponents from the CFD counter-party under both CFD schemes will change relative to the results in Table 9. Comparing the last row of Table 9 with the last row of Panel (A) of Table 11 indicates that the revenue receivable from the CFD counter-party has increased with the new set of higher CFD prices. This outcome primarily reflects the increased size of the gap between CFD strike prices and wholesale electricity prices emerging with the higher CFD prices when wholesale prices are less than CFD prices. This will increase the liability of the CFD counter-party towards the project proponent. In the case of two-way CFD, a narrowing of the gap between CFD and wholesale prices accompanying an increase in CFD prices when wholesale prices exceed CFD prices would reduce the liability of project proponents towards the CFD counter-party. Both factors would work to increase payments received from the CFD counter-party.

In Panel (B) of Table 11, the operating surplus of each component of GSRF is reported, based on the new set of higher CFD prices reported in Panel (A). In contrast to the situation in the last Panel of Table 10 for two-way CFD, each component and GSRF as a whole is now profitable over 2007-2015. Evidence of loss making is now restricted to years 2010 and 2011. Qualitatively, the results now more closely align with the patterns reported for the medium FOM cost scenario in Panel (B) of Table 10 although the magnitude of values is slightly higher in Panel (B) of Table 11. This same conclusion can also be extended to the results associated with the one-way CFD pricing scheme. Furthermore, the DAT sub-array remains the most profitable technology, followed by the SAT and then the FT sub-arrays. Moreover, overall profitability remains greater under one-way CFD compared with two-way CFD, thus confirming the proposition made earlier that one-way CFD pricing is likely to be the CFD scheme of choice of project proponents.

(5) Public Policy Issues

We observed in the previous section that revenue liability of the CFD counter-party and profitability of the project proponent for a specific CFD strike price can vary significantly with changes in LGC and wholesale electricity prices and solar PV output. We also saw that viable CFD strike prices depend crucially on both FOM and OCC costs of the project. Higher FOM and OCC costs would require higher CFD strike prices to secure project viability.

We also observed how the calculated CFD strike prices varied with the choice of array technology. This outcome could be extended more generally across a broader range of renewable energy technologies. More mature technologies such as hydro, onshore wind and solar PV would be expected to have lower capital and operational cost structures and thus require lower CFD strike prices to achieve commercial viability. Less mature technologies such as solar thermal, geo-thermal and wave technologies would be expected to have significantly higher construction and O&M costs, potentially placing significant upward pressure on the CFD strike price level needed to secure commercial viability relative to more mature technologies. Partially offsetting this, however, would be the more dispatchable nature of these emerging technologies (with and without storage) which would allow them to more readily fulfil baseload or intermediate production duties relative to intermittent mature wind and solar PV technologies. This would, in turn, allow the higher costs to be offset and amortised against larger annual and life-time production levels. Moreover, these emerging dispatchable technologies will be more readily able to appropriate super-normal economic profits particularly under one-way CFD through their ability to supply more power during high price peak load periods.

These considerations raise a number of important policy implications. First, the resulting size of Government expenditure on both two-way and one-way CFD feed-in tariff schemes will be significantly lower than Government support based on conventional feed-in

Table 11. Revenue ($ pa) payable by CFD counter-party and Operating Surplus over 2007-2015: High CFD Strike Prices

Panel A. CFD Counter-party Revenue Payments								
	Two-way CFD				One-way CFD			
	FT	SAT	DAT	GSRF	FT	SAT	DAT	GSRF
CFD Price (c/kWh)	11.55	9.30	11.50	11.05	11.05	8.80	11.10	10.65
2007	$42,329	$22,963	$62,920	$211,781	$60,174	$46,115	$85,078	$314,071
2008	$44,748	$27,398	$71,887	$232,021	$82,149	$68,388	$115,307	$433,007
2009	$86,409	$71,689	$120,899	$449,877	$87,329	$73,777	$122,739	$461,008
2010	$78,501	$64,509	$107,704	$405,647	$86,526	$73,895	$117,653	$453,157
2011	$69,784	$52,114	$97,053	$356,600	$85,664	$71,435	$116,810	$447,554
2012	$78,107	$61,425	$106,700	$401,060	$76,611	$60,569	$105,439	$399,065
2013	$45,407	$19,266	$60,699	$215,325	$58,068	$40,622	$82,116	$300,177
2014	$62,144	$35,052	$82,452	$302,422	$84,106	$67,750	$116,291	$439,507

2015	$60,775	$30,633	$72,528	$284,003	$80,721	$64,849	$108,050	$417,874
Total	$568,204	$385,048	$782,842	$2,858,736	$701,348	$567,401	$969,483	$3,665,421

Panel B. GSRF Operating Surplus: High FOM Costs								
	Two-way				One-way			
	FT	SAT	DAT	GSRF	FT	SAT	DAT	GSRF
2007	$5,555	$9,118	$12,169	$35,141	$18,314	$25,672	$28,012	$108,279
2008	$2,227	$6,962	$9,457	$20,482	$28,969	$36,270	$40,503	$164,186
2009	$3,327	$6,801	$10,769	$24,825	$3,985	$8,293	$12,084	$32,783
2010	-$13,559	-$13,240	-$17,635	-$74,337	-$7,821	-$6,529	-$10,521	-$40,367
2011	-$2,249	-$710	-$1,702	-$12,049	$9,105	$13,105	$12,424	$52,983
2012	$6,853	$11,808	$13,094	$43,143	$5,783	$11,196	$12,192	$41,717
2013	$9,631	$17,335	$21,221	$65,190	$18,683	$32,604	$36,534	$125,860
2014	$13,988	$18,794	$24,507	$82,490	$29,691	$42,173	$48,702	$180,506
2015	$5,659	$8,886	$6,061	$29,513	$19,920	$33,351	$31,459	$125,231
Total	$31,431	$65,754	$77,942	$214,398	$126,629	$196,136	$211,390	$791,178

tariff instruments [Cory et al. (2009) and Couture et al. (2010)] through their ability to leverage wholesale and LGC revenue streams.

Second, CFD feed-in tariff support levels can be tailored to reflect changes in market conditions, particularly in relation to changes in LGC and average wholesale electricity market prices over time.

Third, the potential role of learning and economies of scale and scope in component manufacturing and logistics over time would be expected to reduce both capital (installation) costs and operational costs. These trends would exert downward pressure on CFD strike prices required over time, thereby also reducing the required level of feed-in tariff support needed over time. This trend has been termed 'predetermined tariff degression' in the literature, for example, see Couture et al. (2010, pp. 36-42).

Fourth, capital and operating costs of a project still plays a key role in determining the required CFD strike price ensuring that a key policy objective of renewable energy project viability is achieved. This goal would be central to any broader policy objectives associated with promoting an innovative and viable renewable energy industry within the economy while contributing towards decarbonising the economy.

Fifth, least cost principles could be entrained in the design and implementation of the feed-in tariff scheme by: (1) choosing eligible projects on the basis of a competitive reverse auction process; and (2) allocating capacity segments of the scheme to be rolled out in parcels over time through the implementation of a sequence of tenders. These design characteristics would ensure that competitive cost advantages associated with technological innovation and economies of scale and scope are built into the bids of project proponents over time.

The CfD feed-in tariff scheme can easily be applied as a 'top-up' mechanism to other existing schemes such as a national carbon pricing mechanism or renewable energy certificate scheme based on a renewable energy obligation or target. For example, this is clearly seen with the inclusion of LGC prices associated with the LRET scheme (CER, 2016) in the financial modelling employed in this paper to determine commercially viable CFD strike prices. In this context, a carbon pricing mechanism would increase average wholesale electricity prices and could be factored into the model through a carbon pass-through mechanism as discussed in (Wild et al., 2015). By drawing on the revenue available from both of these types of policy mechanisms, the required CFD strike price needed to secure project feasibility would be reduced as would the level of Government expenditure needed to support the scheme.

The CFD scheme's implementation would not depend upon the availability of PPA instruments or the willingness of electricity retailers to underwrite projects with PPA instruments. However, it could also be constructed to act as a 'top-up' mechanism around commercial PPA instruments. More generally, the feed-in tariff scheme itself would provide a guaranteed and bankable revenue stream for the project.

(6) Conclusions

Policy support for renewable energy projects using a 'Contract-for-Difference' (CFD) feed-in tariff policy mechanism has gained prominence recently in Australia. A CFD mechanism requires that renewable energy project proponents bid a strike price as part of a reverse auction process. However, if the CFD price is set too low in order to secure success during the auction round, the project will run the risk of being commercially unviable.

In this paper, two CFD schemes are investigated. These are a two-way and a one-way CFD scheme. A two-way CFD guarantees a set level of revenue for a project based on revenue collected through the wholesale market and revenue provided under the CFD up to an agreed strike price. However, if wholesale market revenue exceeds that associated with the CFD strike price, the project proponent has to pay back the difference to the CFD counter-party. A one-way CFD ensures that project proponents receive a guaranteed minimum level of revenue, but they maintain additional levels of revenue if wholesale market prices exceed the CFD strike price.

A detailed financial model was used to calculate commercially viable CFD strike prices that are capable of generating revenue sufficient to cover operational and capital costs under both two-way and one-way CFD designs. The model calculates revenue receivable from wholesale electricity market sales, sale of eligible renewable energy certificates as well as net payments received from the CFD counter-party. From these revenue streams, various costs are netted off including operation and maintenance expenditure, annual network connection fees, debt and equity service costs and tax allowances.

Crucial inputs into the financial modelling include Fixed Operation and Maintenance costs, Overnight Capital Costs, hourly solar array output based upon the calculation of Typical Metrological Year output profile, LGC strike prices and wholesale electricity price data.

Assessment of modelling results indicated that the SAT sub-array was the most competitive technology, having the lowest required CFD price needed for commercial viability under both CFD schemes. This was followed by the FT sub-array and then the DAT sub-array. The required CFD prices tended to increase in magnitude with FOM costs and decline with increases in LGC prices. These trends reflect the role that higher FOM costs and lower LGC prices play in adversely affecting the profitability of the project.

Percentage reductions in average one-way CFD prices relative to average two-way CFD prices are greatest in magnitude for the SAT sub-array and smallest in magnitude for the DAT sub-array falling within the range of -4.2 to -9.1 per cent. More generally, the pricing results indicated the need for appropriate CFD price levels in order to secure adequate project revenue under both CFD schemes when conditions of reduced competitiveness or tightened operating conditions become prevalent.

When applying the same marginal analysis in the financial modelling, the revenue payable to project proponents under two-way and one-way CFD pricing was revenue neutral. In practice, however, when applying a given CFD strike prices, revenue receivable by project proponents will vary with each CFD pricing scheme, reflecting differences in solar PV output and wholesale prices. Under these circumstances, revenue neutrality between the two CFD pricing schemes will not be obtained.

Results pointed to Government attempting to minimise their financial obligations under the CFD scheme would prefer a two-way CFD pricing scheme. The technology of choice from their perspective would be the SAT technology. In contrast, on grounds of both project profitability as well as revenue receivable from Government, project proponents would strongly prefer a one-way CFD pricing scheme. This latter outcome, in part, rests on the ability of project proponents to fully leverage and appropriate super-normal economic profits that are available when wholesale prices exceed CFD strike prices.

CFD feed-in tariff support levels can be tailored to reflect changes in market conditions, particularly changes in LGC and average wholesale electricity market prices over time. Furthermore, technological innovation and economies of scale and scope in component manufacturing and logistics can also be accommodated over time through lower costs trends flowing through into lower CFD strike prices.

Finally, the CFD feed-in tariff scheme can be easily applied as a 'top-up' mechanism to other existing schemes such as a national carbon pricing mechanism or renewable energy certificate scheme based upon a renewable energy obligation or target. While it does not depend upon the willingness of electricity retailers to underwrite projects with PPA instruments, it could also be developed as a 'top-up' mechanism around commercially available PPA instruments.

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Determining Viable Contract-for-Difference Prices and Revenue Receipts for Gatton Solar Research Facility

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Abstract

In this paper, we investigate the role that a Contract-for-Difference (CFD) feed-in tariff might play in underpinning increased investment in renewable energy in Australia. We investigate two particular CFD designs: two-way and a one-way CFD. We develop a financial model that is capable of determining commercially viable CFD strike prices for different renewable energy projects. In this modelling, we take account of revenue from wholesale electricity market and renewable energy certificate sales. We also include capital and operational costs of the project including distribution of funds for holders of equity and debt. We present findings bases on analysis of the solar array at UQ Campus Gatton Australia, employing a typical meteorological year framework. Our major findings are that governments will prefer a two-way CFD design and Single-Axis tracking solar array technology. Project proponents, however, will strongly prefer a one-way CFD design.

Keywords: *Contract for difference; feed-in tariff; solar PV; operation and maintenance costs; renewable energy policy*

(1) Introduction

Policy support for renewable energy projects using a 'Contract-for-Difference' (CFD) feed-in tariff policy mechanism has gained prominence recently, in terms of public policy [(UK Government, 2015), (Victoria, 2015), (ACT, 2016), (CCA, 2016) and (QRET Expert Panel, 2016)] as well as academically [(Kozlov, 2014), (Bunn and Yusupov, 2015) and (Onifade, 2016)]. Contract for difference pricing mechanisms have been employed previously in energy applications, relating to transmission congestion contracts (Hogan, 1992) and the Nordic market (Kristiansen, 2004).

A CFD mechanism will require that renewable energy project proponents bid a strike price as part of some reverse auction process. Strike prices will typically be ranked in ascending order and projects with the lowest bid strike price will be chosen, moving up the ascending-order ranking until the desired renewable energy capacity of the auction round has been achieved. The strike price associated with the marginal project securing the final capacity increment will be the final successful project and associated strike price will be the highest price achieved by a successful project.

However, in conflict with the least cost methodology underpinning bidding strategies mentioned above, if the CFD price that is bid is set too low by the project proponent in order to secure success during the auction process, the project may run the risk of being economically unviable. This would occur if the revenue stream at the successful CFD strike price is not sufficient to cover operational and capital costs. This situation could emerge either separately or through the combined effects of: (1) price received for the energy produced by the project is too low; (2) energy produced by the project is too low compared with expected energy yield forecasts that underpinned the CFD strike price bid during the auction process.

A number of options exist for the structuring the CFD's that balance: (1) differing levels of revenue certainty for project proponents; (2) exposure to market prices; and (3) total cost of the CFD. Particular structures that have been proposed include (QRET Expert Panel, 2016):

- *Two-way CFD*: A set level of revenue is guaranteed for a project based on revenue collected through the wholesale market and revenue provided under the CFD up to an agreed strike price. If wholesale revenue exceeds that associated with the CFD strike price, the project proponent is required to pay back the difference to the CFD counter-party.

- *CFD with a collar*: This arrangement sets minimum and maximum limits on the total revenue that a project can receive. A project proponent receives additional revenue when the wholesale price exceeds the floor price, but this is capped by a price ceiling above which the proponent is required to make payments back to the counterparty in a manner similar to a two-way CFD.
- *One-way CFD*: Project proponents are guaranteed a minimum level of revenue, but maintain additional levels of revenue if wholesale market prices exceed the CFD strike price. By giving upside opportunities for successful projects, the expectation is for lower strike prices relative to a two-way CFD scheme.

In the case of a two-way CFD scheme, the need to get the bid price right gains more prominence because project proponents must pay back to the CFD counter-party, the amount of incremental revenue attributable to the project when wholesale market prices exceed the CFD strike price. As such, and in contrast with the one-way CFD design, it is not possible under a two-way CFD design to utilise super-normal economic profits associated with high wholesale electricity price events to provide revenue sufficient to cover capital and other fixed costs. Instead, the CFD strike price itself must be capable of fulfilling this requirement.

The structure of this paper is as follows. The next section contains an outline of the financial model that will be used as well as details about the Gatton solar array whose PV yields will be used to underpin the results in the paper. In Section 3, various inputs into financial modelling will be discussed, including Fixed Operation and Maintenance (FOM) costs, Overnight Capital Costs (OCC), output measure to be utilised and calculation of Typical Metrological Year (TMY) hourly output and wholesale electricity price data. In Section 4, the results of the modelling will be reported relating to both CFD strike prices and revenue payable for project proponents under two-way and one-way CFD pricing. Section 5 will address the public policy implications of our findings. Finally Section 6 will contain conclusions.

(2) Financial Model

To calculate CFD strike prices that are capable of generating revenue sufficient to cover operational and capital costs requires a detailed financial model. This model will calculate revenue receivable from wholesale electricity market sales, sale of eligible renewable energy certificates as well as payments *from (and to)* the CFD counter-party under one-way and two-way CFD schemes. From these revenue streams, various costs will be netted off including Operation and Maintenance (O&M) expenditure, annual network connection fees, depreciation allowance (for tax purposes), debt and equity service costs and tax allowances.

Details of the financial model used to calculate the CFD strike prices is documented in Table 1. In column four, example values are given for a Fixed Tilt (FT) array and assumed Large-scale Generation Certificates (LGC) strike price of 9.29 (c/kWh) for a two-way CFD design.

The output measure employed in the modelling denoted by variable 'Q' in Table 1 is the simulated sent-out energy produced by the Gatton Solar Research Facility (GSRF) located at the University of Queensland (UQ) Campus at Gatton. The GSRF was funded under the Federal Government's Education Investment Fund (EIF) scheme ($40.7M), and was part of the larger ARENA funded project Australian Gas and Light Pty Ltd (AGL) Nyngan and Broken Hill Solar Farms (UQ, 2015a).

The GSRF solar array is a 3.275 megawatt pilot plant that comprises three different solar array technologies: (1) a FT array comprising three identical 630 kW systems (UQ, 2015b); (2) a 630 kW Horizontal Single Axis Tracking (SAT) array utilising First Solar's SAT system (UQ, 2015c); (3) a 630 kW Dual Axis Tracking (DAT) array utilising the Degertraker 5000 HD system (UQ, 2015d).

In Table 1, variable 'P_WM' is the hourly transmission and distribution loss adjusted wholesale market price, converted to a (c/kWh) basis. Adjustment for transmission and distribution losses was made using a marginal loss factor of 0.9723 and distribution loss factor of 1.0262, determined as averages from published values over 2011/12 to 2015/16. Multiplying these two factors together produces a value of 0.9979 that was multiplied by each respective hourly wholesale price sourced from AEMO for the 'QLD1' regional reference node (AEMO, 2016).

In Table 2, annual (c/kWh) volume weighted average wholesale prices for the QLD1 market is presented, based upon the AEMO (2016) price and demand data for 2007-2015. This table indicates the lowest annual average prices arose over the period 2009 to 2011 whilst the highest average prices arose in 2007 and 2013, respectively. For the most recent time period 2014-2015, average wholesale prices were in the range of 5.62c/kWh and 5.80c/kWh. The average over the whole 2007-2015 period was 5.06c/kWh with the range between 2.81c/kWh and 7.27c/kWh.

Variable 'P_LGC' is the (c/kWh) LGC price that is assumed. Every MWh of electricity produced by the GSRF is eligible under the Large-Scale Renewable Energy Target (LRET) scheme (CER, 2016) and LGC revenue is calculated by multiplying this output by the assumed LGC (c/kWh) strike price. LRET non-compliance is assumed given the significant capacity deficit now existing in relation to the capacity required to meet the LRET target in forward years [Green Energy Markets (2015, 2016)]. In this situation, two LGC prices are relevant. The first is a strike price of 6.50 (c/kWh) which corresponds to the nominal shortfall LGC penalty price payable by eligible but non-compliant entities which do not have a tax liability. The second is a strike price of 9.29 (c/kWh) which equates to the tax-effective level of the shortfall LGC penalty price payable by non-compliant entities having a tax liability [Green Energy Markets (2016)]. We also adopt a contemporaneous value for the LGC spot price using the closing spot price of 8.92 (c/kWh), sourced as the mid-point of the 'ask' and 'bid' range of the LGC spot price values listed by Mercari (2016) on 10/10/2016, and converted to a (c/kWh) basis.

Variable 'CP' is the calculated (c/kWh) CFD strike price. The algorithm determining this is as follows: Given: (1) hourly wholesale electricity prices; (2) assumed LGC strike price; (3) hourly output from the representative solar PV sub-arrays; (4) other exogenous inputs outlined in Table 1, choose the CFD strike price that produces a (small) non-negative retained earnings after equity distribution value (i.e. in the last row of Table 1).

Note that in the above algorithm, while LGC prices are included in the determination of CFD strike price levels, the CFD strike price concept is not a combined wholesale market/LGC (e.g. black and green) bundled financial product. LGC's are assumed to be managed separately by project proponents. A combined instrument, however, could be constructed by adding the assumed LGC and calculated CFD price together if this instrument is a superior financial instrument for securing project finance.

The determination of the CFD strike price under this methodology will ensure that enough revenue is earnt to cover operational and capital costs including annual payment of principal and required return on equity and principal and interest obligation on debt for each year under investigation. Note that the annual debt and equity allowances [items (19) and (20) in Table 1] are calculated by the excel PMT function using the costs of debt and equity [exogenous items (14) and (16) in Table 1], the amount of debt and equity principal [calculated in items (17) and (18) in Table 1] and an assumed 25-year-lifespan for the project.

The '630' values in items (7) and (10) of Table 1 denotes the sent-out capacity of each of the five sub-arrays, e.g. 630 kW. Recall that there are three FT sub-arrays and individual SAT and DAT sub-arrays at GSRF. This value is combined with the FOM ($/kW-yr) cost estimates and the ($/kW) capital (construction) cost estimates to determine the $pa FOM cost [item (7)] and the $m OCC of each sub-array and for GSRF as a whole [e.g. item (10)]. The particular calculations involved are depicted in column three of Table 1 with numbers in '[ ]' denoting the item numbers involved in the calculations listed in Column two.

Finally, the prime cost method is used to calculate the depreciation allowance for company income tax purposes. Specifically, the annual depreciation rate is calculated as (100%/25) = 4.00% where '25' denotes the 25-year-lifespan of the project. Thus, for each year, the depreciation expense allocated for tax purposes for each sub-array component is 4.00% of the total capital cost of each sub-array as calculated in item (10) of Table 1.

For GSRF as a whole, FOM and CAPEX costs are calculated by multiplying the FT results by three and then adding this to the results associated with the SAT and DAT sub-arrays. On the other hand, both wholesale market and LGC revenue is calculated from PV yield simulations of the whole array itself, including the three individual (but separate) FT sub-arrays.[1]

More generally, the key variables in the financial model are:

- **Net Revenue (item 5)** – calculated as the sum of revenue from: (1) wholesale market sale of electricity; (2) sale of eligible LGC renewable certificates; (3) revenue received from the CFD counter-party when wholesale electricity

[1] In terms of the three FT sub-arrays, there will be some variation in PV yield related to differences in near-object shading effects primarily associated with the location of trees near each separate sub-array.

prices are lower than the CFD strike price bid by the project proponent; (4) *less* payments to the CFD counter party from the project proponent when wholesale electricity prices are greater than the CFD strike price bid by the project proponent (applicable only in the case of a two-way CFD tariff design).

- **EBITA (item 22)** – Net revenue less annual FOM costs and annual connection fees (items 7 and 8).

- **EBIT (item 23)** – EBITA less depreciation allowance calculated for tax purposes (item 12).

- **EBT (item 24)** – EBIT less annual interest payable on debt (item 19).

- **Income Tax Payments (item 25)** – Company income tax rate (item 21) multiplied by EBT.

- **Net Profit (item 26)** – EBT less income tax payments.

- **Cash Flow After Taxes (item 27)** – Net profit plus the depreciation allowance calculated for tax purposes. Note that tax depreciation is added back onto net profit in order to calculate cash flow after taxes because tax depreciation is a <u>non-cash</u> expense.

- **Retained Earnings After Equity Distribution (item 28)** – Cash flow after taxes less annual allocation to meet required return on equity invested in the project (item 20).

<u>Table 1. Financial Model.</u>

Item	Description	Formulae	Example: FT Value
1	Wholesale Market Revenue	P_WMxQ	$71,810
2	LGC Revenue	P_LGC*Q	$106,596
3	CFD Payments (e.g. to Government) – *applicable for two-way CFD tariff design*	(CP-P_WM)*Q if (CP >= P_WM), else 0	(-$28,169)

4	CFD *Receipts (e.g. from Government)*	(CP-P_WM)*Q if (CP< P_WM), else 0	$37,868
5	Net Revenue	[1]+[2]+[4]-[3]	$188,106
6	FOM ($/kW/year)	Exogenous input	20
7	Annual FOM Cost	[6]x630	$12,600
8	Annual Energex Connection Fee	Exogenous input	$6,568
9	($/kW) Overnight Capital Cost	Exogenous input	2151.19
10	CAPEX ($)	[9]*630	$1,355,249
11	Tax Depreciation Rate (Prime Cost Method Assuming 25 Year Lifespan)	Exogenous input	4.00%
12	Annual Tax Depreciation Allowance	[11]*[10]	$54,210
13	Debt Ratio	Exogenous input	0.70
14	Debt Cost	Exogenous input	5.82%
15	Equity Ratio	1.0-[13]	0.30
16	Equity Cost	Exogenous input	20.48%
17	Principal: Debt	[13]*[10]	$948,675
18	Principal: Equity	[15]*[10]	$406,575
19	Annual PMT Debt Payment	-PMT([14],25,[17])	$72,968
20	Annual PMT Allowance For Equity	-PMT([16],25,[18])	$84,059
21	Company Income Tax Rate	Exogenous input	28.5%
22	EBITDA	[5]-[7]-[8]	$168,938
23	EBIT	[22]-[12]	$114,728
24	EBT	[23]-[19]	$41,760
25	Income tax payments	[21]*[24]	$11,902
26	Net Profit	[24]-[25]	$29,858
27	Cash flow after taxes	[26]+[12]	$84,068
28	Retained earnings after equity distribution	[27]-[20]	$9

Table 2. (c/kWh) Volume Weighted Average Wholesale Prices for 'QLD1' Market

Year	Volume-weighted average QLD1 (c/kWh) Wholesale Price
2007	7.27
2008	4.88
2009	3.74
2010	2.81
2011	3.80
2012	4.40
2013	7.18
2014	5.62

2015	5.80
Average	5.06
Maximum	7.27
Minimum	2.81

The annual calculation of CFD strike prices by the above financial model will reflect variation in wholesale electricity prices, LGC strike prices and variations in renewable energy output arising on a year-on-year basis. In general, CFD strike prices will have to be higher if either wholesale electricity prices, LGC prices or output from the renewable energy project are lower than expected in order to offset the lower revenue streams flowing from wholesale electricity and LGC markets, respectively.

(3) Financial Modelling Inputs

(3.1) Treatment of FOM Costs

A key variable affecting the magnitude of CFD strike price bids by utility-scale renewable energy project proponents is the $pa FOM cost linked to the FOM ($/kW-yr) cost rates assumed in the financial modelling. For utility-scale solar PV farms, there are three main types of O&M [NREL (2015) and Sandia (2015)]: (1) *preventative maintenance* which encompasses routine inspection and servicing of equipment; (2) *corrective or reactive maintenance* which addresses equipment repair needs and breakdowns after their occurrence and unplanned downtime; (3) *condition-based maintenance* which uses real-time data to anticipate failures and prioritize maintenance activities and resources. Provisions for these three components are typically defined in an O&M contract.

Sandia (2015, p.10) cite USD cost estimates range of between $10/kW-yr and $45/kW-yr which equates to an equivalent AUD range of $14.29/kW-yr to $64.29/kW-yr, assuming an AUD/USD exchange rate of 0.77 and Goods and Services Tax (GST) of 10% applicable in Australia. In Figure 1 of Sandia (2015), approximate USD cost estimates developed by EPRI for CdTe FT, SAT and DAT arrays are estimated to be approximately $21.3/kW-yr, $22.8/kW-yr and $25.1/kW-yr.[2] In these calculations, a cost differential of (21.3/20.4) for CdTe FT systems was assumed relative to c-Si FT systems and then applying this cost differential to the SAT c-Si and DAT c-Si data reported in Figure 1 of Sandia (2015) to extrapolate SAT CdTe and DAT CdTe cost estimates. Converting from USD to AUD

[2] Note that these FOM cost estimates were derived by EPRI for conceptual 10-MW plants.

using the above exchange rate and GST rate produce AUD estimates of $30.43/kW-yr, $32.52/kW-yr and $35.80/kW-yr for CdTe FT, SAT and DAT arrays, respectively.

The FOM cost rates and AUD dollar costs utilised in the modelling are listed in Panels (A)-(B) of Table 3. To demonstrate how CFD strike prices may vary with FOM costs, three FOM cost scenarios are considered. The first, called the *low* FOM cost scenario is based on the average of private O&M contractor estimates cited in BREE (2013). These estimates range between $20/kW-yr to $33/kW-yr for each sub-array [Panel (A)], producing annual FOM costs between $12,600 and $20,790 for each respective sub-array and $74,970 in total for GSRF.

The *medium* and *high* FOM cost scenarios were calculated using ($/kW-yr) estimates cited for various FOM cost categories in Table 4 of Sandia (2015). The medium cost scenario is based on the lower range estimates whilst the high cost estimates are based the mid-range point estimates of the categories listed in that table. In both cases, the cost rate estimates were converted to an AUD basis again assuming an AUD/USD exchange rate of 0.77 and 10% GST rate.

The resulting FOM cost rates and AUD cost allocation for each FOM cost category is outlined in Table (4), Panel (A) for the medium FOM cost scenario and in Panel (B) for the high FOM cost scenario. Note that the FOM cost rates derived in the last rows of Table 4, Panels (A) and (B) are also included in rows three and four of Table 3, Panel (A), for completeness.

Table 3. ($/kW-yr) FOM Cost Scenarios

Panel A. ($/kW-yr) FOM cost rates				
FOM Cost Scenarios	FT	SAT	DAT	GSRF
Low	20.00	26.00	33.00	23.80
Medium	54.01	55.44	56.87	54.87
High	81.77	84.27	86.77	83.27
Panel B. ($) FOM costs				
FOM Cost Scenarios	FT	SAT	DAT	GSRF
Low	$12,600	$16,380	$20,790	$74,970
Medium	$34,025	$34,925	$35,825	$172,826
High	$51,516	$53,091	$54,666	$262,305

Special treatment was applied to certain FOM cost categories in Table 4. The first was panel washing. For the medium FOM cost scenario, it was assumed that the cost of washing modules was $0.68 AUD per panel, the mid-point of the range between the $0.35 USD and $0.6 USD cost cited in (Sandia, 2015, p.14), and converted to AUD. For the high FOM cost scenario, $0.86 AUD was assumed for cleaning per panel, with this corresponding to the upper bound $0.6 USD cited in (Sandia, 2015, p. 14) converted to AUD.

The next special case was monitoring costs. In this case, 50 days per year was allocated to this task payable at a $23.80 per hour pay scale for an administrative assistant. This produced a wage bill of $28,569 which was pro-rated equally across each of the five sub-arrays at GSRF.

The final cost category having special treatment was the insurance cost category. The USD $5000/MW-yr all-risk insurance product identified in (Sandia, 2015, p. 19) was adopted which produced an aggregate AUD $22,500 after converting to AUD. This produced an equivalent AUD $7,143/MW-yr rate insurance cost. We then pro-rated the $22,500 amount equally across the five sub-arrays.

In the case of the medium FOM cost scenario, the ($/kW-yr) FOM cost rates fell between $54.01/kW-yr and $56.87-yr (in Panel (A) of Tables 3 and 4), producing per annum AUD FOM costs of between $34,025 and $35,825 for each respective sub-array and $172,826 for GSRF as listed in Panel (B) of Table 3 and Panel (A) of Table 4. For the high FOM cost scenario, the equivalent FOM cost range was between $81.77/kW-yr and $86.77/kW-yr (e.g. see Panel (A) of Table 3 and Panel (B) of Table 4), producing AUD FOM cost estimates between $51,516 and $54,666 for each sub-array and $262,305 for GSRF as also reported in Panel (B) of Tables 3 and 4.

When compared with the earlier ($/kW-yr) FOM cost estimates listed at the start of this section (i.e. AUD $14.29/kW-yr to 64.29/kW-yr), the high FOM cost scenario estimates appear high in comparison. However, ($/kW-yr) O&M costs tend to decline as the size of the system increases because the FOM costs can be spread across a greater number of system components (Sandia, 2015, pp. 10-11). This could help explain the higher FOM cost estimates cited in Panel (A) of Tables 3 and 4 being derived for GSRF which is a relatively small utility-scale plant.

Table 4. ($/kW-yr) FOM Cost Rate Scenarios

Panel A. FOM cost itemisation: Medium cost scenario					
FOM Item	AUD ($/kW-yr)	FT	SAT	DAT	GSRF
General site maintenance	0.29	$180	$180	$180	$900
Wiring/electrical inspection	2.00	$1,260	$1,260	$1,260	$6,300
Panel washing	7.76	$4,886	$4,886	$4,886	$24,429
Vegetation management	6.80	$4,286	$4,286	$4,286	$21,429
Inverter maintenance	4.29	$2,700	$2,700	$2,700	$13,500
Inverter replacement	12.67	$7,980	$7,980	$7,980	$39,900
racking/tracker maintenance	2.86	$720	$1,620	$2,520	$6,300
Spares	2.86	$1,800	$1,800	$1,800	$9,000
Monitoring	9.07	$5,714	$5,714	$5,714	$28,569
all-risk insurance	7.14	$4,500	$4,500	$4,500	$22,500
Total		$34,025	$34,925	$35,825	$172,826
AUD ($/kW-yr)		54.01	55.44	56.87	54.87
Panel B. FOM cost itemisation: High cost scenario					
FOM Item	AUD ($/kW-yr)	FT	SAT	DAT	GSRF
General site maintenance	2.29	$1,440	$1,440	$1,440	$7,200
Wiring/electrical inspection	4.57	$2,880	$2,880	$2,880	$14,400
Panel washing	9.80	$6,171	$6,171	$6,171	$30,857
Vegetation management	6.80	$4,286	$4,286	$4,286	$21,429
Inverter maintenance	7.50	$4,725	$4,725	$4,725	$23,625
Inverter replacement	16.89	$10,640	$10,640	$10,640	$53,200
racking/tracker maintenance	5.00	$1,260	$2,835	$4,410	$11,025
Spares	15.71	$9,900	$9,900	$9,900	$49,500
Monitoring	9.07	$5,714	$5,714	$5,714	$28,569
all-risk insurance	7.14	$4,500	$4,500	$4,500	$22,500
Total		$51,516	$53,091	$54,666	$262,305
AUD ($/kW-yr)		81.77	84.27	86.77	83.27

(3.2) ($/kW) Capital Cost Estimates

Capital cost ($/kW) estimates for utility-scale solar PV have become quite fluid during 2016. At the beginning of 2016, capital cost estimates for FT and SAT technologies reflected costs associated with AGL's Nyngan and Broken Hill solar farms (AGL, 2015) and the Moree solar farm (ARENA, 2016a). These ($/kW) costs were $2,833/kW and $2,929/kW, respectively. With the release of details about the second ARENA large-scale solar PV competitive round in September 2016, average costs for these two technologies had declined significantly to between $2100/kW to $2210/kW with some individual costs as low as $1900/kW. Since then, however, Parkinson (2016) cites industry sources quoting cost estimates as low as $1600/kW.

The ($/kW) OCC estimates used are based on data cited in Table 3.5.2 of BREE (2012). Specifically, the following OCC estimates were listed in that table as:

- FT: $3380/kW;
- SAT: $3860/kW; and
- DAT: $5410/kW.

These (BREE, 2012) estimates are rebased to an average of the updated FT and SAT ($/kW) results linked to published information in (ARENA, 2016b). This was combined with private information sought from project proponents about the solar PV array technology intended to be used. The DAT estimate was determined by applying the original BREE cost shares between the SAT and DAT technologies listed above and pro-rating to the current SAT ($/kW) cost estimate. This led to the following ($/kW) estimates:

- FT: $2151/kW;
- SAT: $2204/kW; and
- DAT: $3089/kW = (5410/3860)*2204.

(3.3) Selection of Simulation Scenario According to 2015 Comparison of Actual and Simulated PV Yield

The output measure employed in the financial modelling is the hourly simulated output of the representative sub-arrays and the whole array obtained from the PVsyst simulation software (PVsyst, 2016) over years 2007-2015. To run simulations in PVsyst, various user supplied inputs are required. These relate to: (1) hourly solar, weather and surface albedo data; (2) technical information about modules, inverters and array sizing and design; (3) soiling effects; (4) shading effects; (5) DC and AC electrical losses. Further details can be found in (Wild, 2016).

Evidence for 2015 indicates that the PVsyst low soiling scenario most closely matches the actual solar PV yield performance of the FT and SAT sub-arrays at GSRF. Assessment of the DAT sub-array could not be undertaken during 2015 because solar tracking was not activated until early December 2015.

A close correspondence between the PVsyst low soiling scenario results and actual GSRF 2015 outcomes are established for two FT and SAT sub-arrays. These results are reported in Table 5. In this table, the difference between the simulated and actual Annual Capacity Factor (ACF) outcomes for these three sub-arrays is quite small in magnitude, between 0.1 and 0.3 percentage points, in absolute terms.

However, the results for one of the FT sub-arrays (i.e. FT-West) is significantly different. This outcome was subsequently attributed to blown fuses in a harness combiner box that was flagged as a defect but not quickly rectified. Therefore, the PVSyst low soiling simulation is used as the output measure for the CFD financial modelling performed in this paper, i.e. variable 'Q' in Table 1.

Table 5. Comparison of Actual and Simulated ACF Outcomes of GSRF in 2015

Array	FT-West	FT-East	Hybrid-FT	SAT
2015 Actual	18.1	20.2	19.5	23.7
2015 PVsyst	19.3	20.3	19.7	23.4
Difference	-1.2	-0.1	-0.2	0.3
PVsyst Scenario	HS	LS	LS	LS

(3.4) Calculation of Typical Meteorological Year (TMY)

We used the simulated hourly solar PV output data associated with the PVsyst low soiling scenario for years 2007 to 2015 as source data for TMY analysis. This was implemented by stacking each year's 8760 hourly PV yields across the top of a spreadsheet in chronological order commencing with 2007 and moving column-wise across the spreadsheet for years 2008 to 2015[3]. We then calculate the average of this data producing a series of 8760 values corresponding to each hour in a year.

To determine the empirical distribution function associated with TMY, we calculated the absolute value of the difference between the sequence of hourly average values applied column-wise across years 2007-2015 and the hourly production values of each year. These difference values were then aggregated over each month of each year in the interval 2007-2015. The month of PV yield data of a year that has the closest statistical match to the average monthly data would have the lowest magnitude associated with the aggregated monthly difference values. Using this criteria, the choice of month and year with the closest statistical match to TMY is reported in Table 6.

This year/month information was then used to construct the annual data series consistent with the TMY methodology from the original PVsyst simulations. This data will have 8760 individual hourly data points by construction. This data is used as the 'output' variable in the financial modelling, as represented by variable 'Q' in Table 1, when modelling TMY effects. This TMY methodology was applied to solar PV output data associated with the representative FT, SAT, DAT sub-arrays and total GSRF array, respectively.

The ACF's associated with the TMY threshold for each sub-array (and GSRF) were: (1) FT (20.9%); (2) SAT (24.3%); (3) DAT (28.3%); and (4) GSRF (23.0%).

[3] Note that we dropped the 29th February from 2008 and 2012 to ensure that TMY based on a standard 365 day calendar year format.

Table 6. Year by Month Selections for Typical Meteorological Year (TMY) Calculation

Month	TMY
January	2009
February	2007
March	2011
April	2014
May	2012
June	2012
July	2009
August	2012
September	2012
October	2012
November	2011
December	2007

(4) Typical Metrological Year (TMY) Solar PV Profile

(4.1) One-way CFD strike price reductions relative to two-way CFD pricing

The financial model was used to calculate sets of two-way and one-way CFD prices for the PV yield associated with the TMY profile. The rationale for using the TMY profile is that, by construction, this concept provides a measure of average PV yield and average revenue streams for assumed wholesale electricity and LGC prices. For TMY analysis, we also applied the year/month selections in Table 6 to construct a wholesale electricity price index that is used to model wholesale market revenue.

To focus investigation, some homogenisation of the CFD price data for both CFD pricing schemes is utilised. Specifically, the CFD prices for each PV array type and GSRF were: (1) averaged across LGC price scenarios; (2) averaged across FOM cost scenarios; and (3) averaged across both LGC and FOM cost scenarios jointly. These results are reported in Table 7, Panels (A)-(C) for two-way CFD pricing, one-way CFD pricing and percentage change in one-way CFD prices relative to two-way CFD prices.

In Panel C of Table 7, the average two-way CFD pricing points indicate pricing levels of 7.7 (c/kWh) for the SAT sub-array, 9.5 (c/kWh) for GSRF, 9.8 (c/kWh) for the FT sub-array and 10.1 (c/kWh) for the DAT sub-array, averaged across both FOM costs and LGC price scenarios. In comparison, the equivalent average one-way CFD pricing points are lower in magnitude being 7.0 (c/kWh) for the SAT sub-array, 9.0 (c/kWh) for GSRF, 9.3 (c/kWh) for the FT sub-array and 9.6 (c/kWh) for the DAT-sub-array.

A number of observations can be drawn from Table 7. First, under all three different averaging schemes represented in Panels (A) to (C), the average percentage reduction rates in average one-way CFD prices relative to two-way pricing remain identical across the different array technologies and GSRF. These results are shaded in orange in Table 7. Second, percentage reductions in average one-way CFD prices reported in Table 7 are greatest in magnitude for the SAT sub-array (-9.1 per cent), followed by GSRF (-5.2 per cent), FT sub-array (-5.0 per cent) and finally the DAT sub-array (-4.2 per cent). Third, from Panel (A) the percentage reductions in one-way pricing relative to two-way CFD pricing decreases in magnitude as FOM costs increase. Fourth, from Panel (B), the magnitude of percentage reductions in one-way pricing relative to two-way CFD pricing increase as the LGC strike prices assumed in the financial modelling increase in magnitude.

These latter observations, in particular, indicate that securing adequate project revenue under both CFD pricing schemes becomes more prevalent under conditions of reduced competitiveness or tighter operating conditions associated with higher FOM costs or lower LGC revenues associated with lower LGC prices. In both of these situations, project proponents need to ensure that CFD strike prices are bid high enough under both pricing schemes to secure the required revenue.

Table 7. Percentage reduction in one-way CFD prices relative to two-way CFD prices

Panel A. Averaged across LGC Prices					Panel B. Averaged across FOM costs					Panel C. Averaged across both LGC Prices and FOM costs				
Two-way CFD					Two-way CFD					Two-way CFD				
FOM Cost	FT	SAT	DAT	GSRF	LGC Price	FT	SAT	DAT	GSRF		FT	SAT	DAT	GSRF
Low	8.1	6.4	9.0	8.0	6.50	11.6	9.5	11.8	11.2	Minimum				
Medium	9.9	7.7	10.0	9.5	8.29	9.2	7.0	9.4	8.8	Average	9.8	7.7	10.1	9.5
High	11.5	9.1	11.2	10.9	9.28	8.8	6.7	9.0	8.4	Median				
Average	9.8	7.7	10.1	9.5	Average	9.8	7.7	10.1	9.5	Maximum				
One-way CFD					One-way CFD					One-way CFD				
FOM Cost	FT	SAT	DAT	GSRF	LGC Price	FT	SAT	DAT	GSRF		FT	SAT	DAT	GSRF
Low	7.5	5.4	8.6	7.4	6.50	11.1	9.0	11.4	10.8	Minimum				
Medium	9.5	7.1	9.6	9.1	8.29	8.6	6.3	8.9	8.3	Average	9.3	7.0	9.6	9.0
High	11.0	8.6	10.8	10.5	9.28	8.2	5.8	8.6	7.9	Median				
Average	9.3	7.0	9.6	9.0	Average	9.3	7.0	9.6	9.0	Maximum				
% Change					% Change					% Change				
FOM Cost	FT	SAT	DAT	GSRF	LGC Price	FT	SAT	DAT	GSRF		FT	SAT	DAT	GSRF
Low	-7.2	-15.5	-5.1	-7.2	6.50	-3.6	-5.2	-3.1	-3.7	Minimum				
Medium	-4.8	-7.9	-4.2	-5.1	8.29	-5.7	-10.4	-4.7	-5.9	Average	-5.0	-9.1	-4.2	-5.2
High	-3.7	-5.7	-3.4	-3.9	9.28	-6.1	-13.2	-5.1	-6.4	Median				
Average	-5.0	-9.1	-4.2	-5.2	Average	-5.0	-9.1	-4.2	-5.2	Maximum				

(4.2) Implied revenue requirements and neutrality of two-way and one-way CFD pricing schemes over 2007-2015

The annual dollar ($AUD) payments owing to GSRF under both two-way and one-way CFD pricing for the TMY solar PV and wholesale price profiles are reported in Table 8. The values listed in this table for two-way CFD pricing is the net payment made by the CFD counter-party after netting off payments made by the project proponent to it when wholesale electricity prices exceed the CFD strike price. The results for each sub-array component and GSRF are listed in Panels (A)-(D) in Table 8. Revenue receipts are also reported for the three FOM cost scenarios column-wise and for the three LGC strike prices row-wise in Table 8 in each panel.

A number of observations can be drawn from Table 8. First, across all scenarios reported in Table 8, there is a close correspondence between revenue payable by the CFD counter-party under both CFD pricing schemes indicating that both pricing schemes are *revenue neutral*. Second, of the three sub-array components considered, greater revenue is payable to the DAT sub-array reflecting the role that higher operational and capital costs play in driving up economically viable CFD price bids relative to comparable price bids associated with particularly the SAT technology. Furthermore, the higher PV yield of this sub-array magnifies the CFD counter-party's revenue liability relative to the FT sub-array which has a similar CFD strike price level to the DAT sub-array reported in Table 7. Third, the SAT sub-array receives the lowest revenue payable from the CFD counter-party reflecting the role that lower operational and capital costs and superior PV yield plays relative to the situation confronting the DAT and FT sub-arrays, respectively. Note that the FT sub-array falls between the lower revenue receiving SAT sub-array and higher revenue receiving DAT sub-array. Fourth, for all four array components (including GSRF), revenue receivable from CFD counter-party *declines* as the LGC strike price employed in the financial modelling increases. This reflects the role of lower CFD price bids on the back of higher LGC revenue streams accompanying increases in the LGC strike price. Fifth, revenue receivable from the CFD counter-party across all array components also *increases* as FOM costs increase. This reflects the impact that increased operational (FOM) costs play in reducing project profitability requiring higher CFD price bids to ensure project viability. Finally, it should be noted that all values reported in Table 8 are per annum values, calculated from the TMY solar PV and wholesale electricity price profiles.

Table 8. GSRF Revenue ($ pa) payable by CFD counter-party

	Panel A. FT sub-array					
	Low FOM Costs		Medium FOM Costs		High FOM Costs	
LGC Price	Two-way	One-Way	Two-way	One-Way	Two-way	One-Way
6.50	58,917	58,917	80,344	80,341	97,831	97,832
8.92	31,087	31,087	52,515	52,512	70,002	70,001
9.29	26,812	26,812	48,240	48,238	65,727	65,726
	Panel B.SAT sub-array					
	Low FOM Costs		Medium FOM Costs		High FOM Costs	
LGC Price	Two-way	One-Way	Two-way	One-Way	Two-way	One-Way
6.50	45,123	45,123	63,671	63,672	81,835	81,834
8.92	12,684	12,684	31,231	31,231	49,395	49,393
9.29	7,700	7,700	26,248	26,247	44,411	44,411
	Panel C. DAT sub-array					
	Low FOM Costs		Medium FOM Costs		High FOM Costs	
LGC Price	Two-way	One-Way	Two-way	One-Way	Two-way	One-Way
6.50	96,213	96,212	111,251	111,248	130,088	130,087
8.92	58,450	58,449	73,486	73,487	92,324	92,323
9.29	52,648	52,648	67,685	67,687	86,523	86,523
	Panel D. GSRF					
	Low FOM Costs		Medium FOM Costs		High FOM Costs	
LGC Price	Two-way	One-Way	Two-way	One-Way	Two-way	One-Way
6.50	319,509	319,512	417,378	417,373	506,843	506,839
8.92	166,163	166,165	264,032	264,029	353,498	353,493
9.29	142,606	142,608	240,474	240,470	329,942	329,936

The results presented in Table 8 are predicated upon varying the CFD strike prices to achieve the same approximate results for retained earnings after equity distribution results under the two different CFD pricing schemes, that is, a small positive value for this financial model item. Under this particular circumstance, and optimised around the same TMY solar PV yield and wholesale market price profiles, the revenue results indicated in Table 8 are revenue neutral.

In practice, however, when applying CFD strike prices, revenue receivable by project proponents will vary with each CFD pricing scheme, reflecting differences in PV yield and wholesale prices. Under such circumstances, the CFD strike price that is bid cannot be changed or optimised to reflect the differing yield and wholesale price outcomes occurring over time and revenue neutrality between the two CFD pricing schemes will not eventuate.

To investigate this issue further, we set the CFD strike prices to the average values listed in Panel © of Table 7 for the two CFD pricing schemes and applied these pricing schemes to the simulated PV output profiles calculated by PVsyst for the 2007-2015 time period. The wholesale prices uses are those underpinning the average annual wholesale prices listed in Table 2 over the same time period. To focus analysis, we restricted the LGC price to the contemporaneous price of 8.29 (c/kWh), while continuing to consider the three FOM cost scenarios. Two key metrics are investigated. The first is the net outlay to be made to the project proponent by the CFD counter-party. The second is the retained earnings after equity distribution results received by the project proponent. Large positive values for this particular variable would point to 'super-normal' economic profits whilst negative values would indicate economic loss. Values that are small and positive would continue to point to normal economic profits.

Revenue receivable from the CFD counter-party is reported in Table 9 for the two-way and one-way CFD pricing schemes. Receipts under both pricing schemes tend to be higher in magnitude over 2009-2012 reflecting lower wholesale market prices as well as lower PV yields associated with La Nina weather events over 2010-2011. They tend to be smallest in magnitude in 2013 and 2007 on the back of higher wholesale prices occurring in those particular years. Note the negative value in 2013 of $3,305 associated with the SAT sub-array under two-way CFD pricing. In this case, the project proponent would have had to pay the CFD counter-party more money than they received because of the higher prices arising in 2013 following the introduction of the carbon price. Relatively lower payments also arise during 2008, 2014 and 2015 reflecting relatively higher average wholesale electricity prices. On the other hand, average to above average solar PV output would serve to increase the amount of revenue payable for a given price differential between the wholesale price and CFD strike price. This latter effect can be seen in two ways. First, higher payments accrue in 2014 relative to 2015 on the back of higher PV yield in 2014 relative to 2015 across all array technologies. Second, higher revenue payments accrues to the DAT sub-array relative to the FT sub-array, in part because of the better PV yield performance (e.g. output) of the DAT technology relative to the FT technology .

Examination of the last row of Table 9 indicates that the quantum of money payable by the CFD counter-party across all array technologies is lower under two-way CFD pricing compared with one-way CFD pricing. It should be recognised that with the selection of the CFD prices in row 3 this revenue receivable is independent of FOM cost. It is determined solely by the relative differences between the CFD strike price, the wholesale market price and the amount of output produced by each array technology. For example, the total revenue receivable over the nine year period 2007-2015 by the project proponent from the CFD counter-party for GSRF under a two-way CFD scheme is $1,984,756.00, 28.6 per cent lower than the equivalent one-way CFD scheme payment of $2,778,080.00. In this case, the payments to be made back to the CFD counter-party under a two-way scheme when wholesale prices exceed the CFD strike price is more than sufficient to reduce the total amount receivable by project proponents relative to a one-way CFD pricing scheme. This arises even with the lower CFD strike price operational under the one-way CFD scheme which would reduce the amount of payments that have to be made by the CFD counter-party relative to the equivalent payments arising under the two-way CFD scheme.

Examination of Table 9 also indicates lower payments are made by the CFD counter-party to the SAT sub-array relative to the FT and DAT array technologies. This reflects the relatively lower capital and operational costs and superior PV yield performance which produces the significantly lower CFD strike prices discernible in row 3 of Table 9. Highest payments are made to the DAT sub-array reflecting, in part, its greater output (e.g. PV yield) when compared to the FT technology which drives higher revenue outcomes in the case of the DAT sub-array. This is particularly noticeable when account is taken of the relatively close proximity of the CFD prices for the FT and DAT technologies listed in row 3 of Table 9.

Table 9. Revenue ($ pa) payable by CFD counter-party over 2007-2015

	Two-way CFD				One-way CFD			
	FT	SAT	DAT	GSRF	FT	SAT	DAT	GSRF
CFD Price (c/kWh)	9.80	7.70	10.10	9.50	9.30	7.00	9.60	9.00
2007	$22,253	$1,402	$40,921	$113,443	$42,449	$26,745	$63,972	$222,405
2008	$25,070	$6,102	$50,148	$135,275	$62,922	$45,381	$92,469	$332,448
2009	$66,599	$50,413	$99,034	$352,659	$68,089	$50,970	$99,880	$360,651
2010	$60,710	$45,694	$88,564	$319,197	$68,928	$53,109	$97,334	$362,169
2011	$50,641	$31,760	$76,384	$263,386	$67,026	$49,388	$95,172	$350,998
2012	$57,876	$39,533	$84,613	$301,853	$57,099	$37,231	$82,508	$297,232
2013	$24,843	-$3,305	$37,832	$113,724	$39,143	$18,113	$59,442	$201,051
2014	$41,059	$12,302	$59,270	$198,943	$63,515	$43,031	$91,984	$332,006
2015	$40,687	$9,100	$51,115	$186,276	$61,588	$42,292	$86,193	$319,119
Total	$389,738	$193,001	$587,880	$1,984,756	$530,759	$366,260	$768,956	$2,778,080

Table 10. GSRF Operating Surplus ($ pa) over 2007-2015

Panel A. GSRF Operating Surplus: Low FOM Cost								
	Two-way CFD				One-way CFD			
	FT	SAT	DAT	GSRF	FT	SAT	DAT	GSRF
2007	$19,025	$19,949	$20,660	$98,770	$33,465	$38,070	$37,142	$176,678
2008	$15,981	$17,983	$18,135	$85,249	$43,046	$46,067	$48,394	$226,228
2009	$16,987	$17,836	$19,356	$89,255	$18,053	$18,235	$19,961	$94,970
2010	$1,545	-$445	-$7,099	-$2,208	$7,421	$4,857	-$828	$28,517
2011	$11,888	$10,985	$7,741	$55,244	$23,603	$23,590	$21,175	$117,887
2012	$20,211	$22,403	$21,522	$106,152	$19,656	$20,757	$20,017	$102,848
2013	$22,752	$27,444	$29,092	$126,487	$32,977	$42,758	$44,543	$188,926
2014	$26,737	$28,776	$32,152	$142,444	$42,792	$50,747	$55,543	$237,585
2015	$19,120	$19,738	$14,972	$93,580	$34,064	$43,470	$40,053	$188,563
Total	$154,246	$164,670	$156,530	$794,974	$255,076	$288,551	$286,000	$1,362,201
Panel B. GSRF Operating Surplus: Medium FOM Cost								

	Two-way CFD				One-way CFD			
	FT	SAT	DAT	GSRF	FT	SAT	DAT	GSRF
2007	$3,705	$6,688	$9,908	$28,797	$18,145	$24,808	$26,389	$106,705
2008	$662	$4,722	$7,382	$15,276	$27,726	$32,806	$37,642	$156,255
2009	$1,667	$4,575	$8,604	$19,282	$2,733	$4,973	$9,209	$24,997
2010	-$13,774	-$13,706	-$17,852	-$72,181	-$7,899	-$8,405	-$11,581	-$41,456
2011	-$3,432	-$2,276	-$3,011	-$14,728	$8,283	$10,328	$10,422	$47,914
2012	$4,892	$9,142	$10,770	$36,179	$4,336	$7,495	$9,265	$32,875
2013	$7,433	$14,183	$18,340	$56,514	$17,657	$29,497	$33,791	$118,953
2014	$11,417	$15,514	$21,400	$72,471	$27,473	$37,486	$44,791	$167,612
2015	$3,800	$6,477	$4,219	$23,607	$18,744	$30,209	$29,300	$118,590
Total	$16,368	$45,319	$59,760	$165,218	$117,198	$169,199	$189,229	$732,445

Panel C. GSRF Operating Surplus: High FOM Cost

	Two-way CFD				One-way CFD			
	FT	SAT	DAT	GSRF	FT	SAT	DAT	GSRF
2007	-$8,800	-$6,298	-$3,560	-$35,171	$5,640	$11,822	$12,921	$42,737
2008	-$11,843	-$8,264	-$6,086	-$48,692	$15,222	$19,820	$24,173	$92,287

2009	-$10,837	-$8,412	-$4,865	-$44,686	-$9,771	-$8,013	-$4,259	-$38,972
2010	-$26,279	-$26,693	-$31,320	-$136,149	-$20,403	-$21,391	-$25,049	-$105,424
2011	-$15,937	-$15,263	-$16,480	-$78,697	-$4,221	-$2,658	-$3,046	-$16,055
2012	-$7,613	-$3,845	-$2,698	-$27,790	-$8,169	-$5,491	-$4,203	-$31,094
2013	-$5,072	$1,197	$4,871	-$7,454	$5,152	$16,510	$20,323	$54,985
2014	-$1,088	$2,528	$7,932	$8,503	$14,968	$24,499	$31,322	$103,643
2015	-$8,705	-$6,510	-$9,249	-$40,361	$6,240	$17,223	$15,832	$54,622
Total	-$96,172	-$71,560	-$61,456	-$410,498	$4,658	$52,321	$68,013	$156,729

Total CFD revenue receivable over the nine year period 2007-2015 by the project proponent from the CFD counter-party for each sub-array technology is significantly lower under a two-way CFD scheme compared to a one-way CFD pricing scheme. Specifically, the amounts receivable for the SAT, FT and DAT technologies under the two-way CFD (e.g. $193,001, $389,738 and $587,880) are 47.3, 26.6 and 23.5 per cent lower than under one-way CFD (e.g. $366,260, $530,759 and $768,956).

Thus, the results in Table 9 point to the likelihood that Government attempting to minimise their financial obligations through the CFD counter-party will prefer a two-way CFD scheme to a one-way scheme. The technology of choice from their perspective would also be the SAT technology. Alternatively, from the perspective of project proponents attempting to maximise payments received from Government (i.e. from the CFD counter-party), the preferred scheme would be the one-way CFD pricing scheme across all of the solar PV array technologies considered.

GSRF retained earnings after equity distribution results for the period 2007-2015 are reported in Table 10 for two-way and one-way CFD schemes and by FOM cost scenarios listed in Panels (A)-(C). The results in Panel (A) for low FOM costs indicate a position of strong profitability across all solar array technologies and CFD pricing schemes considered. The only evidence of loss making is in year 2010 for the SAT, DAT and GSRF under two-way CFD pricing and only for the DAT sub-array under one-way CFD. Over the whole 2007-2015 period, the SAT sub-array is the most profitable array technology, followed by the DAT and then the FT sub-array. Overall profitability is greater under one-way CFD with cumulative surpluses of $288,511, $286,000 and $255,076 for the SAT, DAT and FT sub-arrays, respectively. These outcomes are 75.2, 82.7 and 65.4 per cent higher than the equivalent two-way CFD outcomes. For GSRF the one-way CFD result of $1,362,201 is 71.4 per cent higher than the equivalent two-way result of $794,974, calculated over the nine year period 2007-2015.

In the case of medium FOM costs, the results in Panel (B) indicate a continued position of profitability across all solar array technologies and CFD pricing schemes, although at a lower level compared to results in Panel (A). For example, for GSRF, the 2007-2015 cumulative surpluses of $165,218 and $732,445 in Panel (B) represent reductions of 46.2 and 79.2 per cent on the equivalent values cited in Panel (A) (of $794,974 and $1,362,201) respectively. Evidence of loss making is more evident over 2010-2011 across all technologies under two-way CFD, although only in 2010 for one-way CFD pricing. Over the 2007-2015 period, the DAT sub-array is now the most profitable array technology, followed by the SAT and then the FT sub-array. Overall profitability remains greater under one-way CFD with cumulative surpluses of $189,229, $169,199 and $117,198 for the DAT, SAT and FT sub-arrays. These outcomes are 216.6, 273.4 and 616.0 per cent higher than the equivalent two-way CFD outcomes reported in Panel (B). For GSRF as a whole, the one-way CFD result of $732,445 is 343.3 per cent higher than the equivalent two-way CFD result of $165,218. These results indicate a *marked increase* in profitability of project proponents in relative terms under one-way CFD compared with two-way CFD when viewed against the results reported in Panel (A).

High FOM cost scenario results are reported in Panel ©. These results point to a significant deterioration in overall profitability under a two-way CFD scheme. Positive economic profits are only observed in 2013 and 2014 and only for the DAT and SAT sub-arrays (and GSRF in 2014). For the 2007-2015 time period, each sub-array component and GSRF experience economic *losses* of between $61,456 and $96,172 (for the array technologies) and $410,498 for GSRF. The relative positions of DAT, SAT and FT sub-arrays remain the same in terms of competitive position with the DAT sub-array experiencing lower losses when compared with the other two array technologies.

In the case of one-way CFD reported in Panel ©, much lower but still positive economic profits are obtained over the whole 2007-2015 time period. Economic losses are experienced by all array components and GSRF over years 2009 to 2012, but profitability is secured in other years. As with the situation in Panel (B) and also with two-way CFD pricing in Panel (C), the DAT sub-array remains the most profitable array technology, followed by the SAT and then the FT sub-array. For GSRF as a whole, the overall surplus of $156,729 reported in Panel (C) is 88.5 and 78.6 per cent lower than the equivalent results reported in Panels (A) and (B), of $1,326,201 and $732,445, respectively.

The results in Table 10 strongly reinforce the proposition made in relation to the results in Table 9 that a one-way CFD scheme is likely to be the CFD scheme of choice for project proponents. This outcome rests on the ability of project proponents to fully leverage and appropriate super-normal profits that are available when wholesale prices exceed CFD strike prices. The results, more generally, indicate the requirement for and sensitivity to bidding appropriate CFD strike prices under two-way CFD. This will more generally be the situation for both CFD schemes when FOM costs are high and/or assumed LGC prices are low.

If the CFD strike price is bid too low under two-way CFD, then a situation similar to that documented in Panel © of Table 10 could emerge evolving over time into a loss making enterprise. Clearly, in the case of the two-way scheme, the results in Panel © indicate that the CFD pricing used was too low to secure economic profitability given the high FOM costs. This is demonstrated by the results in Table 11, Panels (A) and (B).

The results reported in Table 11 were calculated from the financial model assuming that the LGC price continued to be the contemporaneous price of 8.29 (c/kWh) but we now consider the high FOM cost scenarios only. The two-way and one-way CFD prices used in the modelling are reported in row 4 of Panel (A) and are now of higher magnitude than the CFD prices listed in row 3 of Table 9. For each respective CFD pricing scheme, the current CFD prices were calculated as the average of the high FOM cost prices listed in Panel (A) and the '6.5 (c/kWh) LGC price' outcomes listed in Panel (B) of Table 7. Because the CFD price levels have changed, the receipts flowing to project proponents from the CFD counter-party under both CFD schemes will change relative to the results in Table 9. Comparing the last row of Table 9 with the last row of Panel (A) of Table 11 indicates that the revenue receivable from the CFD counter-party has increased with the new set of higher CFD prices. This outcome primarily reflects the increased size of the gap between CFD strike prices and wholesale electricity prices emerging with the higher CFD prices when wholesale prices are less than CFD prices. This will increase the liability of the CFD counter-party towards the project proponent. In the case of two-way CFD, a narrowing of the gap between CFD and wholesale prices accompanying an increase in CFD prices when wholesale prices exceed CFD prices would reduce the liability of project proponents towards the CFD counter-party. Both factors would work to increase payments received from the CFD counter-party.

In Panel (B) of Table 11, the operating surplus of each component of GSRF is reported, based on the new set of higher CFD prices reported in Panel (A). In contrast to the situation in the last Panel of Table 10 for two-way CFD, each component and GSRF as a whole is now profitable over 2007-2015. Evidence of loss making is now restricted to years 2010 and 2011. Qualitatively, the results now more closely align with the patterns reported for the medium FOM cost scenario in Panel (B) of Table 10 although the magnitude of values is slightly higher in Panel (B) of Table 11. This same conclusion can also be extended to the results associated with the one-way CFD pricing scheme. Furthermore, the DAT sub-array remains the most profitable technology, followed by the SAT and then the FT sub-arrays. Moreover, overall profitability remains greater under one-way CFD compared with two-way CFD, thus confirming the proposition made earlier that one-way CFD pricing is likely to be the CFD scheme of choice of project proponents.

(5) Public Policy Issues

We observed in the previous section that revenue liability of the CFD counter-party and profitability of the project proponent for a specific CFD strike price can vary significantly with changes in LGC and wholesale electricity prices and solar PV output. We also saw that viable CFD strike prices depend crucially on both FOM and OCC costs of the project. Higher FOM and OCC costs would require higher CFD strike prices to secure project viability.

We also observed how the calculated CFD strike prices varied with the choice of array technology. This outcome could be extended more generally across a broader range of renewable energy technologies. More mature technologies such as hydro, onshore wind and solar PV would be expected to have lower capital and operational cost structures and thus require lower CFD strike prices to achieve commercial viability. Less mature technologies such as solar thermal, geo-thermal and wave technologies would be expected to have significantly higher construction and O&M costs, potentially placing significant upward pressure on the CFD strike price level needed to secure commercial viability relative to more mature technologies. Partially offsetting this, however, would be the more dispatchable nature of these emerging technologies (with and without storage) which would allow them to more readily fulfil baseload or intermediate production duties relative to intermittent mature wind and solar PV technologies. This would, in turn, allow the higher costs to be offset and amortised against larger annual and life-time production levels. Moreover, these emerging dispatchable technologies will be more readily able to appropriate super-normal economic profits particularly under one-way CFD through their ability to supply more power during high price peak load periods.

These considerations raise a number of important policy implications. First, the resulting size of Government expenditure on both two-way and one-way CFD feed-in tariff schemes will be significantly lower than Government support based on conventional feed-in

Table 11. Revenue ($ pa) payable by CFD counter-party and Operating Surplus over 2007-2015: High CFD Strike Prices

Panel A. CFD Counter-party Revenue Payments								
	Two-way CFD				One-way CFD			
	FT	SAT	DAT	GSRF	FT	SAT	DAT	GSRF
CFD Price (c/kWh)	11.55	9.30	11.50	11.05	11.05	8.80	11.10	10.65
2007	$42,329	$22,963	$62,920	$211,781	$60,174	$46,115	$85,078	$314,071
2008	$44,748	$27,398	$71,887	$232,021	$82,149	$68,388	$115,307	$433,007
2009	$86,409	$71,689	$120,899	$449,877	$87,329	$73,777	$122,739	$461,008
2010	$78,501	$64,509	$107,704	$405,647	$86,526	$73,895	$117,653	$453,157
2011	$69,784	$52,114	$97,053	$356,600	$85,664	$71,435	$116,810	$447,554
2012	$78,107	$61,425	$106,700	$401,060	$76,611	$60,569	$105,439	$399,065
2013	$45,407	$19,266	$60,699	$215,325	$58,068	$40,622	$82,116	$300,177
2014	$62,144	$35,052	$82,452	$302,422	$84,106	$67,750	$116,291	$439,507

	FT	SAT	DAT	GSRF	FT	SAT	DAT	GSRF
2015	$60,775	$30,633	$72,528	$284,003	$80,721	$64,849	$108,050	$417,874
Total	$568,204	$385,048	$782,842	$2,858,736	$701,348	$567,401	$969,483	$3,665,421
Panel B. GSRF Operating Surplus: High FOM Costs								
	Two-way				One-way			
	FT	SAT	DAT	GSRF	FT	SAT	DAT	GSRF
2007	$5,555	$9,118	$12,169	$35,141	$18,314	$25,672	$28,012	$108,279
2008	$2,227	$6,962	$9,457	$20,482	$28,969	$36,270	$40,503	$164,186
2009	$3,327	$6,801	$10,769	$24,825	$3,985	$8,293	$12,084	$32,783
2010	-$13,559	-$13,240	-$17,635	-$74,337	-$7,821	-$6,529	-$10,521	-$40,367
2011	-$2,249	-$710	-$1,702	-$12,049	$9,105	$13,105	$12,424	$52,983
2012	$6,853	$11,808	$13,094	$43,143	$5,783	$11,196	$12,192	$41,717
2013	$9,631	$17,335	$21,221	$65,190	$18,683	$32,604	$36,534	$125,860
2014	$13,988	$18,794	$24,507	$82,490	$29,691	$42,173	$48,702	$180,506
2015	$5,659	$8,886	$6,061	$29,513	$19,920	$33,351	$31,459	$125,231
Total	$31,431	$65,754	$77,942	$214,398	$126,629	$196,136	$211,390	$791,178

tariff instruments [Cory et al. (2009) and Couture et al. (2010)] through their ability to leverage wholesale and LGC revenue streams.

Second, CFD feed-in tariff support levels can be tailored to reflect changes in market conditions, particularly in relation to changes in LGC and average wholesale electricity market prices over time.

Third, the potential role of learning and economies of scale and scope in component manufacturing and logistics over time would be expected to reduce both capital (installation) costs and operational costs. These trends would exert downward pressure on CFD strike prices required over time, thereby also reducing the required level of feed-in tariff support needed over time. This trend has been termed 'predetermined tariff degression' in the literature, for example, see Couture et al. (2010, pp. 36-42).

Fourth, capital and operating costs of a project still plays a key role in determining the required CFD strike price ensuring that a key policy objective of renewable energy project viability is achieved. This goal would be central to any broader policy objectives associated with promoting an innovative and viable renewable energy industry within the economy while contributing towards decarbonising the economy.

Fifth, least cost principles could be entrained in the design and implementation of the feed-in tariff scheme by: (1) choosing eligible projects on the basis of a competitive reverse auction process; and (2) allocating capacity segments of the scheme to be rolled out in parcels over time through the implementation of a sequence of tenders. These design characteristics would ensure that competitive cost advantages associated with technological innovation and economies of scale and scope are built into the bids of project proponents over time.

The CfD feed-in tariff scheme can easily be applied as a 'top-up' mechanism to other existing schemes such as a national carbon pricing mechanism or renewable energy certificate scheme based on a renewable energy obligation or target. For example, this is clearly seen with the inclusion of LGC prices associated with the LRET scheme (CER, 2016) in the financial modelling employed in this paper to determine commercially viable CFD strike prices. In this context, a carbon pricing mechanism would increase average wholesale electricity prices and could be factored into the model through a carbon pass-through mechanism as discussed in (Wild et al., 2015). By drawing on the revenue available from both of these types of policy mechanisms, the required CFD strike price needed to secure project feasibility would be reduced as would the level of Government expenditure needed to support the scheme.

The CFD scheme's implementation would not depend upon the availability of PPA instruments or the willingness of electricity retailers to underwrite projects with PPA instruments. However, it could also be constructed to act as a 'top-up' mechanism around commercial PPA instruments. More generally, the feed-in tariff scheme itself would provide a guaranteed and bankable revenue stream for the project.

(6) Conclusions

Policy support for renewable energy projects using a 'Contract-for-Difference' (CFD) feed-in tariff policy mechanism has gained prominence recently in Australia. A CFD mechanism requires that renewable energy project proponents bid a strike price as part of a reverse auction process. However, if the CFD price is set too low in order to secure success during the auction round, the project will run the risk of being commercially unviable.

In this paper, two CFD schemes are investigated. These are a two-way and a one-way CFD scheme. A two-way CFD guarantees a set level of revenue for a project based on revenue collected through the wholesale market and revenue provided under the CFD up to an agreed strike price. However, if wholesale market revenue exceeds that associated with the CFD strike price, the project proponent has to pay back the difference to the CFD counter-party. A one-way CFD ensures that project proponents receive a guaranteed minimum level of revenue, but they maintain additional levels of revenue if wholesale market prices exceed the CFD strike price.

A detailed financial model was used to calculate commercially viable CFD strike prices that are capable of generating revenue sufficient to cover operational and capital costs under both two-way and one-way CFD designs. The model calculates revenue receivable from wholesale electricity market sales, sale of eligible renewable energy certificates as well as net payments received from the CFD counter-party. From these revenue streams, various costs are netted off including operation and maintenance expenditure, annual network connection fees, debt and equity service costs and tax allowances.

Crucial inputs into the financial modelling include Fixed Operation and Maintenance costs, Overnight Capital Costs, hourly solar array output based upon the calculation of Typical Metrological Year output profile, LGC strike prices and wholesale electricity price data.

Assessment of modelling results indicated that the SAT sub-array was the most competitive technology, having the lowest required CFD price needed for commercial viability under both CFD schemes. This was followed by the FT sub-array and then the DAT sub-array. The required CFD prices tended to increase in magnitude with FOM costs and decline with increases in LGC prices. These trends reflect the role that higher FOM costs and lower LGC prices play in adversely affecting the profitability of the project.

Percentage reductions in average one-way CFD prices relative to average two-way CFD prices are greatest in magnitude for the SAT sub-array and smallest in magnitude for the DAT sub-array falling within the range of -4.2 to -9.1 per cent. More generally, the pricing results indicated the need for appropriate CFD price levels in order to secure adequate project revenue under both CFD schemes when conditions of reduced competitiveness or tightened operating conditions become prevalent.

When applying the same marginal analysis in the financial modelling, the revenue payable to project proponents under two-way and one-way CFD pricing was revenue neutral. In practice, however, when applying a given CFD strike prices, revenue receivable by project proponents will vary with each CFD pricing scheme, reflecting differences in solar PV output and wholesale prices. Under these circumstances, revenue neutrality between the two CFD pricing schemes will not be obtained.

Results pointed to Government attempting to minimise their financial obligations under the CFD scheme would prefer a two-way CFD pricing scheme. The technology of choice from their perspective would be the SAT technology. In contrast, on grounds of both project profitability as well as revenue receivable from Government, project proponents would strongly prefer a one-way CFD pricing scheme. This latter outcome, in part, rests on the ability of project proponents to fully leverage and appropriate super-normal economic profits that are available when wholesale prices exceed CFD strike prices.

CFD feed-in tariff support levels can be tailored to reflect changes in market conditions, particularly changes in LGC and average wholesale electricity market prices over time. Furthermore, technological innovation and economies of scale and scope in component manufacturing and logistics can also be accommodated over time through lower costs trends flowing through into lower CFD strike prices.

Finally, the CFD feed-in tariff scheme can be easily applied as a 'top-up' mechanism to other existing schemes such as a national carbon pricing mechanism or renewable energy certificate scheme based upon a renewable energy obligation or target. While it does not depend upon the willingness of electricity retailers to underwrite projects with PPA instruments, it could also be developed as a 'top-up' mechanism around commercially available PPA instruments.

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