Griffith School of Engineering Griffith University

7405ENG – Renewable Energy Systems

5MW PV Plant-Grid Connected

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Summary

The proposed 5 MW grid-connected solar PV plant in Wallsend, NSW, is set to take advantage of the region's ample solar resources, supporting Australia's push towards net-zero emissions by 2050. The plant will benefit from unobstructed solar exposure and an optimal north-facing orientation, ensuring it operates at peak efficiency. High-performance Sunpower mono-crystalline silicon modules, with an efficiency of 18.5%, will be used, mounted at a fixed tilt to maximize energy generation throughout the year.

The financial outlook for this project is notably enhanced by a feed-in tariff (FiT) of AUD 140/MWh, which increases by 2.5% annually over the plant's projected 25-year lifespan. On top of this, a government incentive of AUD 250,000 further supports the project's economic feasibility. The plant is expected to generate 6,783 MWh of electricity per year, and with the added benefit of Large-scale Generation Certificates (LGCs), it will secure additional revenue of approximately AUD 271,320 annually, based on an LGC market price of AUD 40. The financial viability is further reinforced by revenue from GHG reduction credits, contributing to the overall profitability.

One periodic cost involves the replacement of inverters every 10 years, an expense factored into the financial model. The Operational and Maintenance (O&M) costs, estimated at AUD 122,311 annually, will cover the necessary upkeep and management costs over the plant's lifetime.

In terms of environmental benefits, the project is expected to reduce greenhouse gas (GHG) emissions by 4,630 tCO_2 annually, which is comparable to removing 848 cars from the road each year. This aligns directly with the New South Wales Net Zero Plan, which aims to achieve 50% renewable electricity by 2030 and reduce GHG emissions by 50% from 2005 levels by the same year.

Financial analysis reveals a Net Present Value (NPV) of AUD 2,342,233 and a payback period of 9.2 years, with a strong Internal Rate of Return (IRR) indicating a solid financial performance. Key factors such as debt financing, taxation, and straight-line depreciation are carefully considered in the financial model to provide a comprehensive view of the project's long-term financial outlook.

In conclusion, this project delivers substantial economic and environmental benefits. By contributing to Australia's renewable energy goals, reducing dependence on fossil fuels, and providing robust returns for investors, the plant will play a critical role in the country's transition to clean energy.

1.Introduction

Australia is strongly committed to reducing its carbon footprint and transitioning to a **low-carbon economy**, with a particular emphasis on boosting its **renewable energy capacity**. The nation has set an ambitious **renewable energy target** to generate **33 GWh** of electricity from renewable sources by **2030**, which would make up approximately **20% of its total electricity supply**. This target has been a significant driver of Australia's energy policies, spurring the growth of **solar, wind, and hydro projects** across the country. Additionally, Australia is working towards achieving **net-zero emissions by 2050**, in line with global goals established under the **Paris Agreement**.

The chart below illustrates the progress made since **1 January 2016**, showcasing probable, committed, and accredited projects that contribute to the **2020 Renewable Energy Target**.

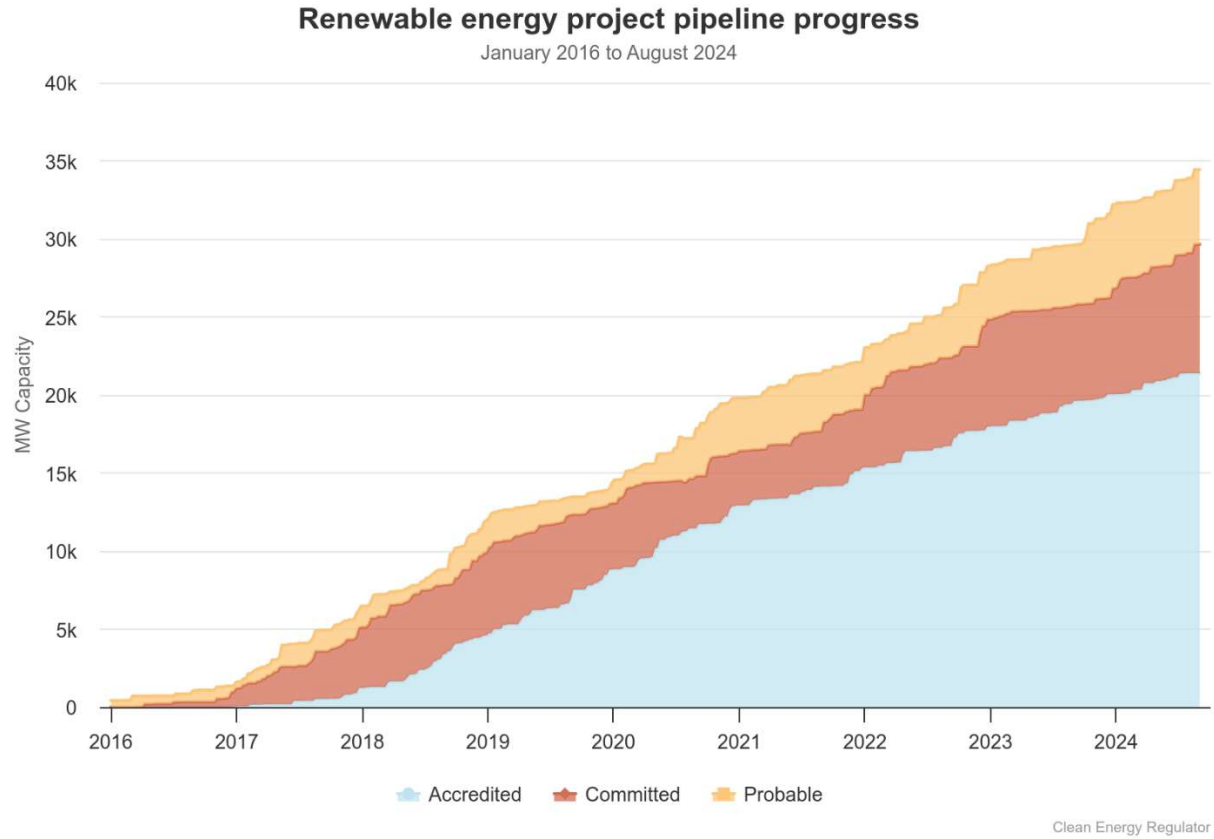

Figure 1 : Renewable Energy Pipeline Progress [1]

New South Wales (NSW) Renewable Energy Goals:

New South Wales (NSW), as one of Australia’s largest energy-consuming states, has set ambitious targets as part of its NSW Net Zero Plan. This plan aims to:

- Achieve 50% renewable electricity by 2030, making a substantial contribution to Australia's overall renewable energy goals.
- Establish dedicated Renewable Energy Zones that are expected to attract $32 billion in investment and create over 6,500 construction jobs in the next decade.
- Reduce greenhouse gas (GHG) emissions by 50% below 2005 levels by 2030, with a long-term goal of reaching net-zero emissions by 2050[2].

Australia’s Non-Renewable Energy Mix

Australia remains heavily reliant on non-renewable resources, primarily coal and natural gas, and to a lesser extent, fossil fuels to meet its energy demands. These traditional fuels have long been the backbone of the country’s energy supply. However, the share of renewable resources is steadily increasing as the nation transitions towards a more sustainable energy mix. The graph below illustrates Australia’s updated energy mix, reflecting the current distribution between renewable and non-renewable energy sources.

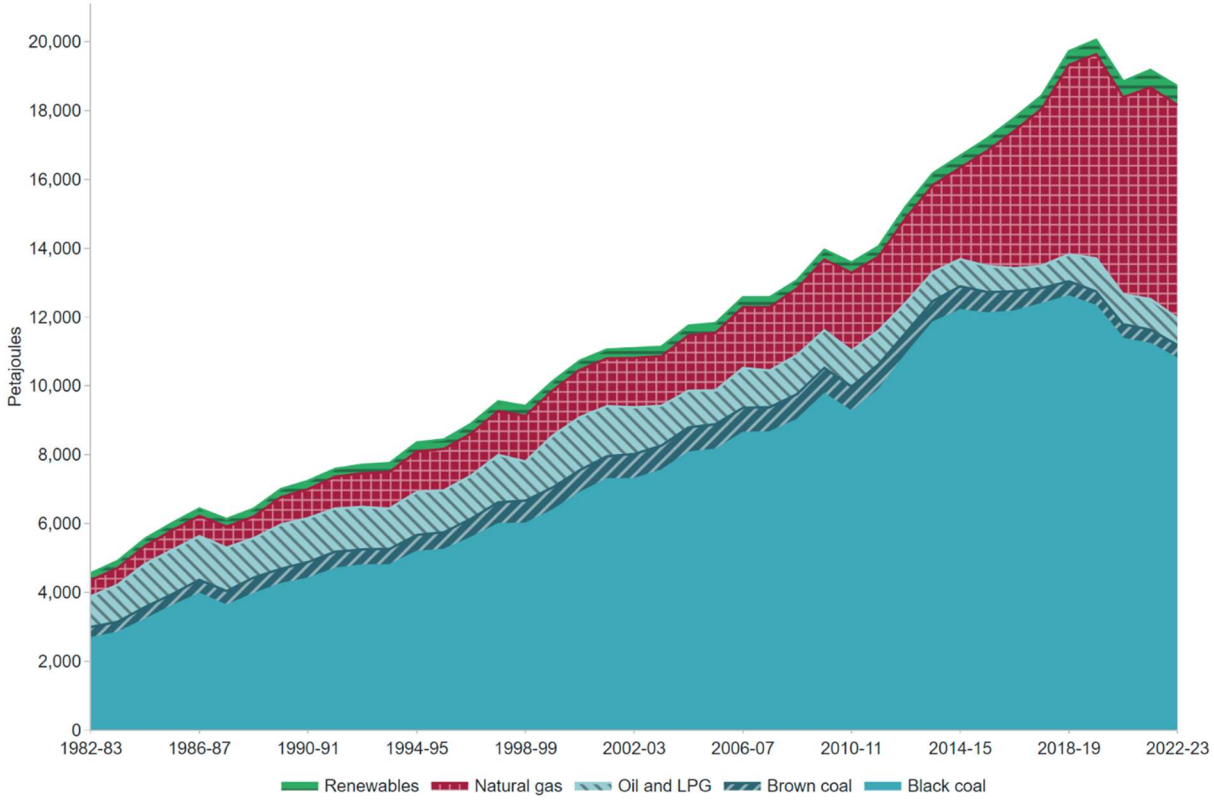

Figure 2 : Non-Renewable & Renewable Energy Mix Over 40 years [3]

Challenges and Transition:

Here’s a refined, professional version of the text:

Australia's reliance on **non-renewable resources** presents several key challenges:

- **High GHG Emissions**: Coal-fired power plants remain the largest source of Australia's energy, but they are also the greatest contributors to **greenhouse gas (GHG) emissions**.
- **Energy Transition**: Australia has committed to achieving **net-zero carbon emissions by 2050**, which requires a significant reduction in the use of non-renewable resources and a shift towards **renewable energy sources**.
- **Economic Impact**: Coal and natural gas are among Australia's major export industries. The transition away from these resources will have economic implications, especially for regions that are heavily dependent on **fossil fuel industries**[4].

2.Design Criteria

The following table details all the design criteria :

Location and Site Information Criteria	
Criteria	**Details**
Location	Near Wallsend, NSW, Australia; Newcastle Airport weather station reference
Site Characteristics	Unrestricted solar exposure; Suitable for north-facing modules; No shading issues
Design Implication	Optimized for maximum solar energy capture; Minimal terrain adjustments
Module Specifications Criteria	
Module Type	Mono-crystalline silicon (Sunpower mono-Si-SPR-230-WHT)
Efficiency	18.5%
Capacity	230 W per module
Tilt and Orientation	Optimized tilt close to latitude (~32-33 degrees)
Quantity	Approximately 21,739 modules needed for 5 MW
Inverter and Transformer Specifications Criteria	
Inverter Type	250 kW capacity inverters with MPP tracking and multi-input strings
Transformer Capacity	High-capacity transformer suitable for 5 MW
Efficiency	92% efficiency including losses
Cost	$700,000 for the transformer
Electrical Infrastructure Criteria	
DC Wiring	$25 per module for DC wiring

Mounting Rack	$7 per module for mounting racks
Transmission Line	5 km of transmission line required at $30,000 per km
Civil Infrastructure	$250,000 for access and service roads
Financial Criteria Criteria	
Project Life	25 years with inverter replacement every 10 years
Inflation Rate	2.8%
Discount Rate	9.5%
Feed-in Tariff	$140/MWh increasing by 2.5% annually
Debt Financing	50% debt financing over 15 years at 7.5% interest rate
Government Incentive	$250,000 government grant
Regulatory and Compliance Criteria	
Grid Integration	Must comply with local grid standards for connection
Environmental Impact	Necessary EIAs completed to assess impact
Regulatory Approvals	All required governmental approvals must be secured prior to construction

2.1. Energy Model

This is the most important step in modelling. Modelling your system is a crucial step as it sets the stage of all the process next. The energy model is based on the criteria detailed in the design criteria.

Steps of Modeling:

Modeling Parameters and Setup:

- **Level 2 Analysis**: Employed for comprehensive modeling of the 5MW PV plant, ensuring detailed accuracy in simulation outputs.
- **Feed-in Tariff Negotiations**: Successfully secured an initial electricity feed-in price of AUD 140 per MWh, escalated annually by 2.5% over the project's 25-year lifespan, integrated within the financial analysis framework.

Resource Assessment:

- **Solar Tracking and Orientation**: The system is configured with fixed solar tracking, optimized at a slope of 330 degrees latitude and an azimuth of 180 degrees, appropriate for the Southern Hemisphere's solar exposure.
- **Module Specifications**: Utilized SunPower solar PV modules, model mono-Si-SPR-230-WHT, each with a 230 W capacity. The plant comprises 21,740 modules, achieving a high efficiency of 18.5% and covering a total solar collector area of 27,042 m².

Energy Conversion and Efficiency:

- **Inverter Configuration**: The plant employs 20 units of 250 kW inverters, each equipped with Maximum Power Point (MPP) trackers, enhancing the efficiency of energy conversion from the solar panels to the grid.
- **System Losses**: Miscellaneous losses, primarily from power conditioning, are conservatively estimated at 1%, ensuring realistic projection of net energy output.

Energy Output and Performance Metrics:

- A detailed monthly breakdown of daily solar radiation and electricity exportation demonstrates the plant's expected performance and energy contribution to the grid across varying seasonal conditions.

The RETScreen Energy Model is given in Appendix A for reference.

Results from Energy Model:

Refer to Appendix A

- Annual Solar Radiation horizontal = 1.69 MWh/m^2.
- Annual Solar Radiation tilted = 1.85 MWh/m^2.
- Capacity Factor = 15.5 %
- Electricity exported to grid , annually = 6783 MWh
- Electricity Export Revenue= AUD 949,604

2.2.Cost Analysis

The **Cost Analysis** for this project was conducted at **Level 3**, which represents the highest level of detail. All provided costs, as well as assumed estimates, are included in the analysis. For detailed cost tables and verification of the data, refer to **Appendix B**, where the corresponding table screenshots are presented for review.

Cost Assumptions

Salary Assumptions:

Many assumptions related to salaries of different professionals were made . Below is the description and some calculations for salary assumption [5][6].

Engineering Design

The **average salary of an engineer**, for the purposes of this analysis (assuming an **Electrical Engineer**), is approximately **AUD 462 per day** (median salary). Since this is a one-time job, the professional fee will include a **markup**. Typically, a **40% markup** is applied to one-time professional fees. Therefore, the project-day professional fee for an engineer is calculated as follows:

$$\text{Salary per day} = 462\text{AUD} \times (1+0.40) = 646.8\text{AUD/day} \approx 650\text{AUD/day}$$

Using this formula, we can calculate the costs for all **design-related tasks** by applying the same markup structure to the respective daily rates.

Preliminary Design & Investigation related costs

The **average salary** of a **data entry clerk** is **25 AUD/hour**. After applying the necessary markup for professional services, their **professional fee** comes to approximately **280 AUD per day**.

Similarly, the **site investigator** has a base salary of **41 AUD/hour**, and with the markup applied, their **professional fee** amounts to around **460 AUD per day**.

For an **environmental consultant**, the base rate is **35 AUD/hour**, which, after including the markup, brings their **professional fee** to **400 AUD per day** (rounded from an original calculation of 392 AUD for simplicity)[5][6].

Legal & Contract related Costs

A **contract negotiator** typically has a professional fee of **40 AUD/hour**. After applying the markup, the **project-day fee** comes to approximately **450 AUD per day**.

A **lawyer** charges a professional fee of around **70 AUD/hour**. With the markup applied, their **legal services** are estimated to cost **780 AUD per day**.

For an **accountant**, the professional fee is around **32 AUD/hour**, and with the markup, the **daily fee** for their services amounts to approximately **360 AUD per day**.

A **management consultant** generally charges **80 AUD/hour**, and after applying the markup, the **project-day fee** for their services is around **800 AUD per day**.

Costs of remaining can be estimated this way [5][6].

O&M Costs (Annual)

To provide a background for the **Operations and Maintenance (O&M) costs** for the 5 MW solar PV plant in **Wallsend, NSW**, we can break down each cost category and explain the rationale behind the estimations, supported by industry standards.

Land lease & resource rental

Land lease costs are generally determined by the value of the land and terms of the lease agreement .For 5MW PV plant , the land requirement is around 10 to 15 acres , depending on panel density and spacing.

- Market rates for Land lease in regional NSW varies between AUD 300 to 1000 per acre per year, depending upon the location and proximity to urban centers [7].
  Assuming an average lease rate of AUD 400 per acre and an estimated land requirement of 13 acres:

  Land Lease Cost= 13 acres × 400 AUD/acre/year= 5200 AUD/year

Property Taxes

In NSW , the average rate for commercial property taxes can vary between 1 % & 1.5% of the property's value annually [7].

If we estimate the land value for 13 acres plot at around AUD 500,000:

Property Tax Cost= 500,000 × 1.25%= 6250 AUD / year

We can estimate this value to 6200 AUD/year

Insurance Premium

The **insurance premium** for solar projects is typically calculated based on the **capital expenditure (CAPEX)** of the plant and the associated risks. A common range for these premiums is **0.1% to 0.3%** of the total capital expenditure.

For a **5 MW solar plant**, the typical **capital expenditure** is approximately **AUD 12 million** (based on an average installation cost of **AUD 2,400 per kW** for large-scale projects). However, in our specific case, the value is approximately **AUD 1,565.28 per kW**, as calculated in the **Energy Model** section .Refer to Appendix A .

Insurance Premium= (1565.28 AUD/kW x 5000kW) (0.2%)=15,650 AUD / year

We can round off this value to around 15,700 AUD/year.

Parts & Labour

This is a annual regular maintenance cost , inspections , cleaning and minor repairs. For a 5MW solar plant generally between AUD 10,000 to AUD 30,000 per MW per year, depending upon maintenance intensity and age of the system [8][9].

Given the project's scale :

Parts & Labour = 5MW x 15,000 AUD/MW/year=60,000 AUD/year

GHG monitoring & Verification

GHG monitoring costs are based on the compliance and reporting requirements under local regulations and international standards for renewable energy credits.Typical Range for GHG verifaction for a PV plant is around 2500 to 50000 AUD/year [8][9].

GHG monitoring & Verification = 2500 AUD/year

Community Benefits

Community benefits are usually project specific and depend on agreements made with local authorities or communities . These contributions involve supporting local initiative , educational programs etc. Typical range is around AUD 10 ,000 to AUD 50,000 [9].

Periodic Costs

A periodic cost is associated with the replacement of inverters, which will occur every 10 years. Over the plant's total lifespan of 25 years, this cost will be incurred twice. The financial impact of these replacements is accounted for and can be seen in the finance section.

Periodic Cost = 3,150,000 AUD/decade

Item	Unit	Quantity	Unit Cost (AUD)	Amount (AUD)	Description
Feasibililty Study					
Site investigation	p-d	10	500	5000	2 field Engineer fee for 5 days
Resource assessment	project	1	1500	1500	One time fee for a data entry assistant for preliminary design resources
Environmental assessment	p-d	7	400	2800	2 Environmental consultants will conduct assessment in 4 days.
Preliminary design	p-d	8	650	5200	2 Design Engineers will give a preliminary design in 4 days
Detailed cost estimate	p-d	10	360	3600	2 Accountants will give detailed Cost estimate in 5 days.
GHG baseline study & MP	project	1	10000	10000	One time GHG baseline fee study fee to a third party organization
Report preparation	p-d	20	400	8000	5 men project management team will work for 4 days to prepare report
Project management	p-d	40	650	26000	5 project managers will oversee for 8 days the preparation and completion of preliminary design
Travel Accomodation	p-trip	8	2000	16000	2 surveyers will visit site 4 times during preliminary design preparation
Development					
Contract negotiations	project	1	6000	6000	One time fee will be paid to the consulting negotiator
Permits & approvals	project	1	10000	10000	One time fee paid for permits and approvals
Site survey & land rights	project	1	10000	10000	One time fee paid for land survey and land rights
GHG validation & registration	project	1	12000	12000	One time fee paid for GHG validation to a third party organization
Project financing	project	1	3000	3000	One time fee paid to a accountant for financing
Legal & accounting	project	1	3500	3500	One time legal is give to a lawyer to oversee development
Project management	project	1	250000	250000	Fee for Project Manager
Travel & accommodation	p-trip	8	2000	2000	8 trip were made by manager during development phase
Engineering					
Site & Building Design	project	3	16000	48000	1 Architectural Engineer work for three days on site design
Civil design	project	3	60000	180,000	1 Civil Engineer work on the civil design
Mechanical design	project	3	70000	210,000	Fee for mechanical Engineer
Electrical design	project	3	90000	270,000	Fee for Electrical Engineer
Tenders & contracts	project	2	45000	90,000	Different types of tenders & contracts done on two separate occasions
Construction supervision	project	2	30000	60,000	2 construction supervisors will oversee engineering construction phase
Power System					
Photovoltaic	kW	5000	1565.28	7,826,400	Cost of PV modules

Road construction	km	4	62500	250,000	Cost of contruction for nearest main road to the powerplant
Transmission Line	km	5	30000	150,000	Cost of Transmission Line
Energy efficiency measures	project	1	80000	80000	Cost for Different energy efficient measure
Substation	project	1	700000	700,000	Cost of Transformer in Substation
Balance of System & Miscellaneous					
Inverter	kW	5000	630	3,150,000	Collective Inverters cost
Collector Support Structure	m^2	27,042	5.60	151,435	Mounting rack cost
Installation	project	21,740	6.50	141,310	Installation of modules cost
Buildings & yard construction	m^2	50000	150	7,500,000	Nearby building & yard construction cost according to local estimates
Spare Parts	%	10	8,141,400	814,140	Spare parts for different modules cost
Transportation	project	1	50000	50000	Transportation of modules cost based on local estimates
Training & commissioning	project	5	1500	7500	Training of individuals of different fields to work on plant
Electrical infrastructure	project	21,740	25	543500	DC wiring Cost
Office infrastructure	project	1	80000	80000	Tables , Chair , lights etc cost for office.
Hardware & Software	project	1	70000	70000	Computers & their softwares Cost
Contingencies	%	20	20,018,685	4,003,737	Emergency Resources Estimation
O & M (Annual)					
Land lease & resource rental	project	1	5200	5200	Land lease Cost per Year
Property taxes	project	1	6200	6200	Property Tax per year
Insurance premium	project	1	15700	15700	Insurance premium per year
Parts & labour	project	1	60000	60,000	Parts & labour needed for different O & M jobs estimated cost per year
GHG monitoring & verification	project	1	8000	8000	GHG monitoring cost per year by third party organization
Community benefits	project	1	10000	10,000	Community help estimated cost
General administration	%	2	104600	2092	General engineering works cost
Office O&M	project	1	4500	4500	Office maintenance cost
Contingencies	%	10	111,192	11,119	Office contingencies
Periodic Costs					
Inverter	cost	10 (year)	3,150,000	3,150,000	After every ten years , new inverters will be installed
LGC					
LGC Credit Revenue (1LGC=1MWH)	project	67830	40	-2,713,200	LGC is a revenue generated against each MWh of clean energy.

2.3.Emission Analysis

According to the **updated fuel energy mix in Australia**, as shown in **Figure 3**, it is evident that **NSW** still relies heavily on **coal** to meet its energy demands. This reliance remains significantly high, which underscores the urgent need to reduce coal usage to align with Australia's commitments under the **Paris Agreement**. Consequently, whenever a new plant is established, it is crucial to conduct a comprehensive **emission analysis** to assess and mitigate its environmental impact.

For further details, please refer to **Appendix C**, where the relevant **RETScreen tables** related to the emission analysis are presented.

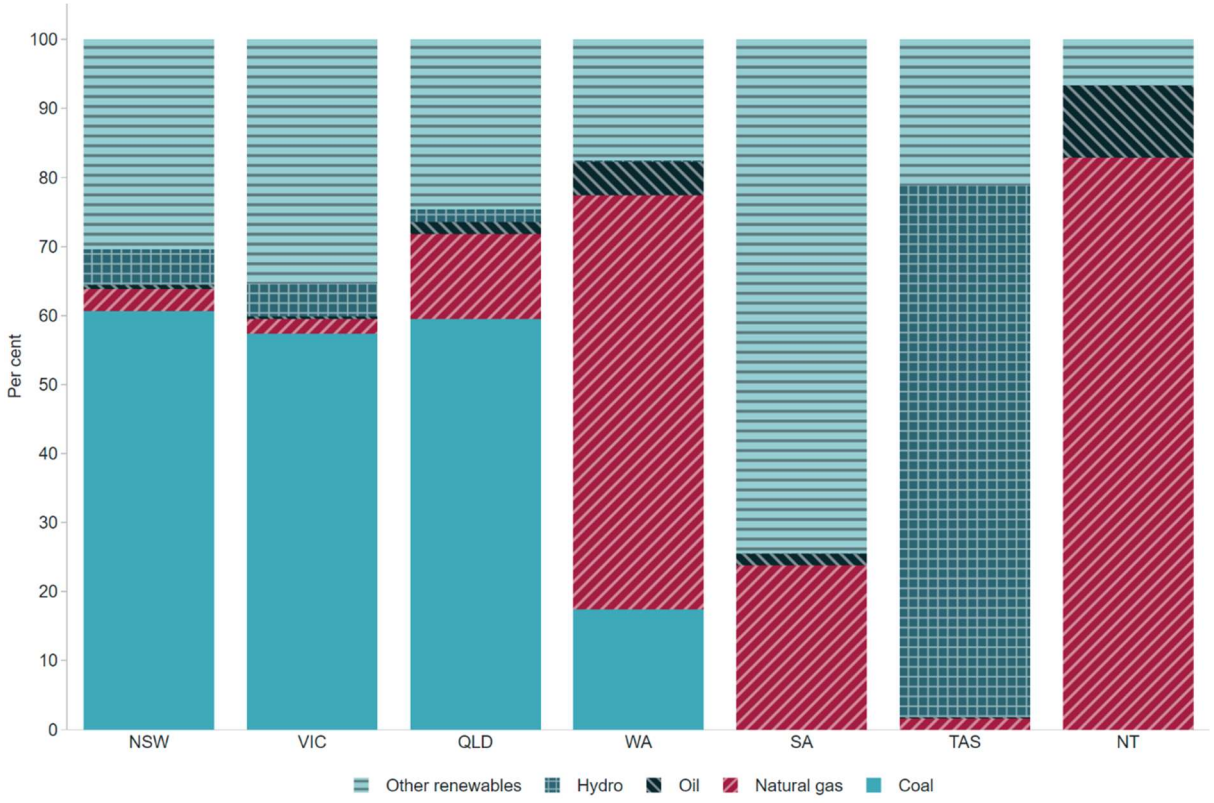

Figure 3 : Australia's Fuel Mix Updated across States (2024)[10]

Fuel Mix

Refer to Appendix C to see RETScreen breakdown of Fuel Mix for Wallsend , NSW , Australia [10].

GHG Emissions Graph

Base Case

For base Case GHG emissions are 4774tCO_2

Proposed Case

For Proposed Case Gross Annual GHG Reduction rate is 4630t CO_2

Annual GHG Emissions for proposed case are 143tCO_2

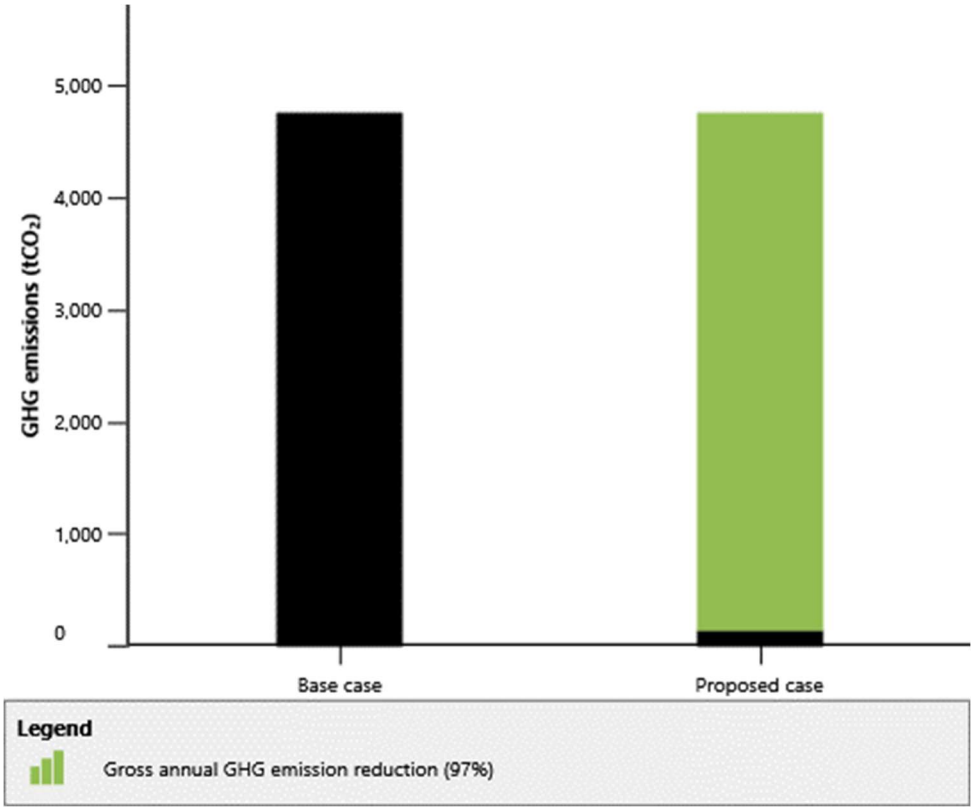

Figure 4 : GHG Emission Graph Comparison between Base & Proposed Case

GHG Reduction Revenue

GHG reduction revenue refers to the financial benefits generated from projects that reduce greenhouse gas emissions. This revenue is typically earned through the sale of **carbon credits**, which are awarded to projects based on the amount of CO2 (or equivalent gases) they prevent from entering the atmosphere. These credits can be sold to entities looking to offset their emissions, providing a valuable revenue stream for green projects.

In Australia, the primary unit for carbon credits is the **Australian Carbon Credit Unit (ACCU)**, where each unit represents **1 tonne of CO2-equivalent** avoided or reduced.

The market price for ACCUs (Australian Carbon Credit Units) currently ranges from **AUD $33.75 to AUD $36.30 per tonne**, depending on supply and demand in the carbon market [11].Refer to Appendix C

Carbon Offsets Rate

Australia's **shadow carbon price** in 2024 is **AUD $70 per tonne of CO_2-equivalent emissions**. Unlike a direct cost paid by businesses or individuals, a shadow price serves as an estimate for the environmental impact of emissions. It is used in cost-benefit analyses to influence decisions in industries like energy and infrastructure, ensuring that emissions reductions are accounted for when making policy changes.Refer to Appendix C.

The shadow price is projected to rise to **AUD $420 per tonne by 2050**, aligning with Australia's target to achieve **net-zero emissions**. This framework encourages the transition to cleaner energy sources by quantifying the cost of greenhouse gas emissions, making the environmental benefits of renewable energy projects more visible in economic terms.

This pricing mechanism helps guide investments and decisions towards reducing emissions and promoting sustainability as part of the broader effort to meet international climate goals [12].

2.4.Financial Analysis

Refer to Appendix D to see the RETScreen details of Financial Analysis.

Financial Parameters

1. Fuel Cost Escalation Rate (2%):

- The **fuel cost escalation rate** of **2%** reflects the anticipated annual increase in fuel-related expenses. Even though renewable projects like solar PV plants typically don't have significant fuel costs, this escalation rate may apply to ancillary energy sources or fuel-related services tied to project operations, such as transportation or maintenance that rely on fossil fuels.

2. Inflation Rate (2.8%):

- The **inflation rate** of **2.8%** indicates the expected yearly rise in the general price level of goods and services. This affects the project's future operating and maintenance costs. Incorporating this rate ensures that future cash flows are adjusted for inflation, enabling a more accurate prediction of real-term earnings.

3. Discount Rate (9.5%):

- A **9.5% discount rate** is applied to future cash flows to determine their present value. It reflects both the risk level of the project and the opportunity cost of capital. A higher discount rate suggests greater perceived risk or a higher return required by investors to justify their investment.

4. Reinvestment Rate (9%):

- The **reinvestment rate** of **9%** refers to the rate at which any returns or intermediate cash flows from the project can be reinvested. A high reinvestment rate implies that cash generated by the project will earn relatively strong returns when reinvested in similar projects or financial instruments.

Incentives & Grants

For the project , 250,000 AUD was approved as incentives .

Debt

Our Debt ratio is 50% . Debt term is 15 yr. Yearly debt payments are
Debt = 1,545,057 AUD/yr.

Annual Savings & Revenue

Electricity Revenue

Annual Electricity export to the grid is 6783 MWh at 140AUD/MWh rate.Total Electricity export Revenue is :

Electricity Export Revenue = 949,604 AUD/yr at 2.5% export escalation rate

GHG Reduction Revenue

GHG Reduction Revenue= 149,096 AUD/yr

Clean Energy Production Revenue

In Australia, the **Clean Energy Production Credit Rate** is linked to incentives such as the **Renewable Energy Target (RET)**, which provides **Large-scale Generation Certificates (LGCs)** for renewable energy productionAs of **2024**, the average **credit rate** for renewable electricity, including sources like **solar, wind, and biomass**, was approximately **2.9 cents per kilowatt-hour (kWh)** for certain qualifying energy types. For other renewable sources, such as solar, the credit rate generally ranges between **0.6 and 1.5 cents per kWh**, depending on the technology and specific eligibility requirements.
These incentives play a crucial role in supporting renewable energy projects by helping to offset operational costs and enhancing financial feasibility. The rates fluctuate based on factors like **inflation adjustments** and changing **market conditions**, ensuring that **clean energy** remains a competitive option within the broader energy market [13].

CE Production Revenue=6783 (1000)kWh (0.29AUD/kWh)=1,967,037 AUD/yr

LGCs(Large-scale Generation Certificate)

A **Large-scale Generation Certificate (LGC)** is a key component of Australia's **Renewable Energy Target (RET)** framework. Renewable energy power stations earn **1 LGC** for every **1 MWh of renewable electricity** they generate and export to the grid. These certificates can be traded or sold to entities that are required to purchase LGCs in order to meet their **renewable energy obligations**. This trade offers an additional revenue source for renewable energy projects, enhancing their financial sustainability.These are provided for the first ten years of the project [13].

1MWh= 1 LGC

Calculation for LGC

Since you earn **1 LGC per MWh**, the number of LGCs generated annually would be:

Number of LGCs/year=6,783 MWh/year

Over **10 years**, the total number of LGCs would be:

Total LGCs in 10 years=6,783×10=67,830 LGCs

Assuming the market price of **AUD $40 per LGC**, the LGC revenue over 10 years would be:

LGC Revenue=67,830 LGCs×40 AUD/LGC=2,713,200 AUD over 10 years

Since there was no column for LGC in the finance section. This credit was included as -negative cost in the cost Analysis

Financial Viability

The financial metrics for 5 MW solar PV project reveal several important insights into its viability:

- **Pre-tax IRR - Equity (16.7%)**: Indicates that the project will deliver a solid return on the equity investment before taxes, reflecting good profitability.
- **Pre-tax IRR - Assets (8.4%)**: This shows the return on all assets (both equity and debt) before tax, indicating overall performance efficiency.
- **After-tax IRR - Equity (13.5%)**: Reflects the return after taxes, which is naturally lower than the pre-tax IRR but still strong.
- **Simple Payback Period (8.1 years)**: Represents the time needed to recover the initial investment, which is a reasonable duration for such projects.
- **Net Present Value (NPV)** of **AUD 4,739,340**: This figure confirms that the project is expected to generate more value than the initial investment.
- **Annual Life Cycle Savings (AUD 509,178/year)**: Shows the recurring financial benefits each year, contributing to overall profitability.
- **Benefit-Cost Ratio (1.4)**: Indicates that the benefits outweigh the costs, making it financially favorable.
- **Debt Service Coverage (0.41)**: This low ratio suggests that the project may struggle to meet debt repayments from its operating cash flows alone, highlighting a potential financing risk.
- **GHG Reduction Cost (-150 AUD/tCO_2)**: Demonstrates the project's efficiency in reducing greenhouse gas emissions at a negative cost, meaning it's both environmentally and financially beneficial.
- **Energy Production Cost (459 AUD/MWh)**: Represents the cost of generating electricity per megawatt-hour.

Overall, the project shows strong potential for profitability, but the low **Debt Service Coverage** indicates that careful financial planning may be needed to manage debt obligations. The **NPV**

and **life cycle savings** reflect significant long-term financial gains, while the environmental benefits are also noteworthy The graph below encapsulates all discussed above.

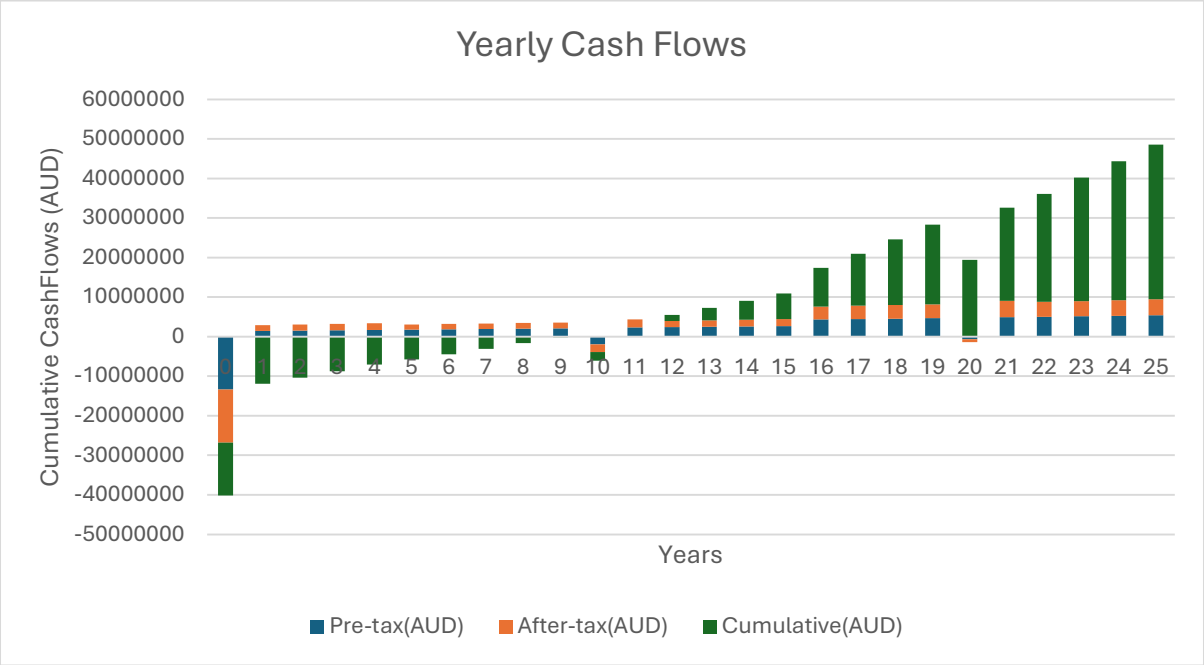

Figure 5 : Yearly Cash Flows

4.Results and Discussion

1. Energy Production and Efficiency

The 5 MW solar PV plant proposed for Wallsend, NSW, is expected to produce approximately **6,783 MWh** of electricity annually. With high-efficiency mono-crystalline solar panels, the plant will operate at its peak potential, ensuring minimal energy loss. Unlike fossil-fuel-based plants, the PV system benefits from **100% electricity generation efficiency**, as there is no combustion process. This efficiency, paired with optimal sunlight exposure, contributes to the high energy output of the plant.

2. Greenhouse Gas Emission Reductions

One of the standout benefits of this project is its significant reduction in greenhouse gas (GHG) emissions. The current grid electricity mix, heavily reliant on coal (62.8%) and natural gas (4.6%), results in approximately **4,774 tCO_2 emissions** annually. In stark contrast, the solar PV plant will emit **zero tCO_2**, aside from a minor contribution of **143 tCO_2** from transmission and distribution losses. This leads to a **gross annual reduction of 4,630 tCO_2**, which is equivalent to removing **848 cars and light trucks** from the roads every year. This remarkable decrease in emissions showcases the environmental impact of transitioning to renewable energy.

3. Financial Viability

From a financial standpoint, the project is highly attractive. The **Net Present Value (NPV)** of **AUD 2,342,233** shows the project's strong financial potential over its **25-year life span**. With a **pre-tax Internal Rate of Return (IRR) of 13.9%** and an **after-tax IRR of 11.3%**, the project not only promises significant environmental benefits but also provides attractive returns for investors. Additionally, the **payback period of 9.2 years** means the initial investment can be recovered well within the first decade, further supporting the project's long-term viability and profitability.

4. Revenue from Large-scale Generation Certificates (LGCs)

A significant part of the project's financial return comes from **Large-scale Generation Certificates (LGCs)**. For every **megawatt-hour** of renewable energy produced, the plant earns one LGC. With an annual energy output of **6,783 MWh**, the plant is expected to generate **6,783 LGCs** each year. At a rate of **AUD 40 per LGC**, this results in an additional yearly revenue of **AUD 271,320**. This steady and predictable income, supported by the **Renewable Energy Target (RET)**, greatly enhances the project's financial outlook and contributes to its long-term economic sustainability.

5. Carbon Offset and GHG Reduction Credits

Alongside revenue from LGCs, the project qualifies for **carbon credits** thanks to its significant reduction in **GHG emissions**. With an annual net reduction of **4,260 tCO_2** and a market value of **AUD 35 per tonne**, the project earns approximately **AUD 149,096** each year from these credits. This additional income strengthens the project's financial position, showcasing its ability to deliver both **environmental benefits** and **economic returns**.

6. Operational and Maintenance Costs

The **Operational and Maintenance (O&M) costs** for the project are estimated at **AUD 122,311 annually**. These expenses include key items such as **land lease fees**, **property taxes**, **insurance premiums**, and routine maintenance. Thanks to the relatively low O&M costs, which are typical of solar PV projects, the ongoing expenses have a minimal effect on profitability. Solar plants, in particular, have lower maintenance requirements compared to traditional power stations, making them a more **cost-effective solution** over time.

7. Energy Export Revenue

In addition to revenue from **LGCs** and **carbon credits**, the solar plant will also earn income by exporting clean energy to the grid. With an estimated annual export of **6,783 MWh**, the plant is projected to generate **AUD 949,640** in its first year. This amount will increase by **2.5% each year** due to price escalation, providing a stable and reliable revenue stream. This steady income from energy sales further strengthens the plant's financial outlook, contributing to its overall success

8. Environmental and Social Impact

Beyond the financial benefits, this solar PV plant is crucial in helping Australia lessen its dependence on fossil fuels. By replacing electricity generated from coal and natural gas with clean solar energy, the project makes a significant contribution to reducing greenhouse gas emissions. This effort directly supports Australia's renewable energy targets and aligns with

global initiatives to combat climate change. As a result, the project not only offers value to investors but also benefits the broader community and environment.

5. Conclusion

The 5 MW solar PV plant in Wallsend, NSW, proves to be a financially sound and environmentally impactful project. The inclusion of LGCs at AUD 40 per certificate adds a considerable boost to the annual revenue, bringing in AUD 271,320 each year. When combined with revenue from energy exports and GHG credits, the project achieves an impressive Net Present Value (NPV) of AUD 2,342,233 and a payback period of 9.2 years. Furthermore, with an annual reduction of 4,630 tCO_2, the project not only contributes to Australia's energy transition but also plays a critical role in addressing global climate challenges.

By merging environmental benefits with strong financial returns, this solar PV project sets a benchmark for future renewable energy investments. The combination of LGC revenue, carbon credits, and energy export income makes it a prime example of how clean energy can deliver both sustainability and profitability in today's energy market

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Appendix (RETScreen Tables)

Appendix A (Energy Model)

Table 1

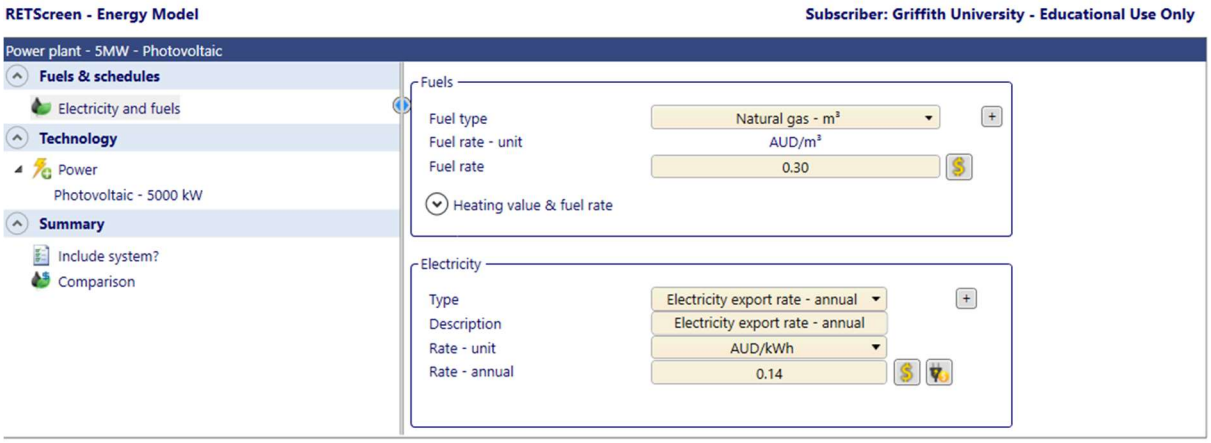


Table 2

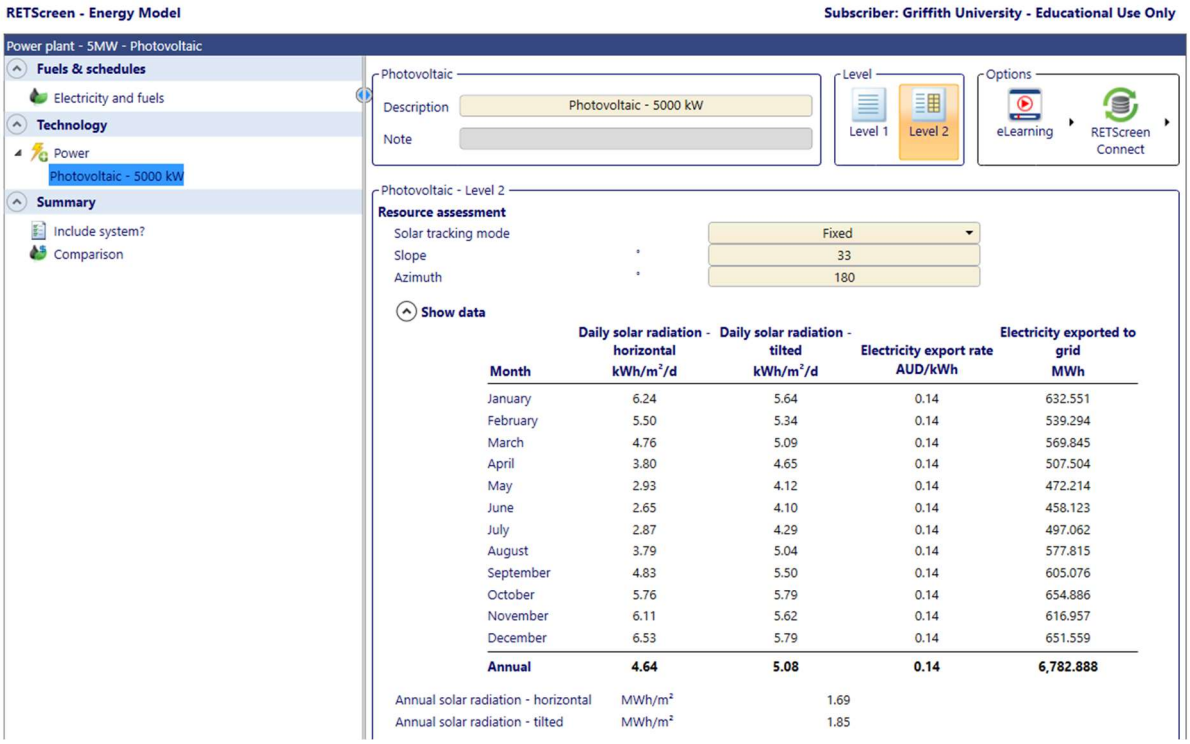


Table 3

Photovoltaic		
Type		mono-Si
Power capacity	kW	5,000
Manufacturer		Sunpower
Model		mono-Si - SPR-230-WHT
Number of units		21,740
Efficiency	%	18.49%
Nominal operating cell temperature	°C	45
Temperature coefficient	% / °C	0.4%
Solar collector area	m²	27,042
Bifacial cell adjustment factor	%	0%
Miscellaneous losses	%	15%
Inverter		
Efficiency	%	92%
Capacity	kW	250
Miscellaneous losses	%	1%
Summary		
Capacity factor	%	15.5%
Initial costs	AUD/kW	1,300
	AUD	6,500,000
O&M costs (savings)	AUD/kW-year	1
	AUD	5,000
Electricity export rate		Electricity export rate - annual
	AUD/kWh	0.14
Electricity exported to grid	MWh	6,783
Electricity export revenue	AUD	949,604

Appendix B (Cost Analysis)

Table 1

RETScreen - Cost Analysis

Initial costs (credits)	Unit	Quantity	Unit cost		Amount
Feasibility study					
Site investigation	p-d	3	AUD 500	AUD	1,500
Resource assessment	project	2	AUD 280	AUD	560
Environmental assessment	p-d	1	AUD 400	AUD	400
Preliminary design	p-d	2	AUD 650	AUD	1,300
Detailed cost estimate	p-d	1	AUD 360	AUD	360
GHG baseline study & MP	project	1	AUD 460	AUD	460
Report preparation	p-d	2	AUD 280	AUD	560
Project management	p-d	2	AUD 800	AUD	1,600
Travel & accommodation	p-trip	3	AUD 200	AUD	600
User-defined	cost			AUD	-
Subtotal:				**AUD**	**7,340**

Table 2

Development					
Contract negotiations	project	2	AUD 450	AUD	900
Permits & approvals	project	2	AUD 500	AUD	1,000
Site survey & land rights	project	2	AUD 450	AUD	900
GHG validation & registration	project	1	AUD 800	AUD	800
Project financing	project	2	AUD 360	AUD	720
Legal & accounting	project	2	AUD 780	AUD	1,560
Project management	project	2	AUD 800	AUD	1,600
Travel & accommodation	p-trip	3	AUD 600	AUD	1,800
User-defined	cost			AUD	-
Subtotal:				**AUD**	**9,280**
Engineering					
Site & building design	project	3	AUD 600	AUD	1,800
Mechanical design	project	3	AUD 650	AUD	1,950
Electrical design	project	3	AUD 650	AUD	1,950
Civil design	project	3	AUD 600	AUD	1,800
Tenders & contracting	project	2	AUD 450	AUD	900
Construction supervision	project	2	AUD 650	AUD	1,300
User-defined	cost			AUD	-
Subtotal:				**AUD**	**9,700**

Table 3

Power system							
Photovoltaic - 5000 kW	kW	5,000	AUD	1,565.28	AUD	7,826,400	
Road construction	km	4	AUD	62,500	AUD	250,000	
Transmission line	km	5	AUD	30,000	AUD	150,000	
Substation	project	1	AUD	700,000	AUD	700,000	
Energy efficiency measures					AUD	-	
DC Wiring	cost	21,740	AUD	25	AUD	543,500	
Subtotal:					**AUD**	**9,469,900**	45.6%
Balance of system & miscellaneous		Specific project costs					
Photovoltaic							
Inverter	kW	5,000	AUD	630	AUD	3,150,000	
Collector support structure	m^2	27,042	AUD	5.60	AUD	151,435	
Installation	project	21,740	AUD	6.50	AUD	141,310	
Building & yard construction	m^2	50,000	AUD	150	AUD	7,500,000	
Spare parts	%	3.0%	AUD	8,119,145	AUD	243,574	
Transportation	project	1	AUD	50,000	AUD	50,000	
Training & commissioning	p-d	5	AUD	1,500	AUD	7,500	
Electrical infrastructure	project	1	AUD	35,000	AUD	35,000	
User-defined	cost				AUD	-	
Contingencies	%		AUD	20,775,040	AUD	-	
Interest during construction			AUD	20,775,040	AUD	-	
Subtotal:					**AUD**	**11,278,820**	54.3%
Total initial costs					**AUD**	**20,775,040**	100.0%

Table 4

O&M						
Show data					AUD	5,000
Land lease & resource rental	project	1	AUD	5,200	AUD	5,200
Property taxes	project	1	AUD	6,200	AUD	6,200
Insurance premium	project	1	AUD	15,700	AUD	15,700
Parts & labour	project	1	AUD	60,000	AUD	60,000
GHG monitoring & verification	project	1	AUD	2,500	AUD	2,500
Community benefits	project	1	AUD	10,000	AUD	10,000
General & administrative	%		AUD	104,600	AUD	-
User-defined	cost				AUD	-
Contingencies	%		AUD	104,600	AUD	-
Subtotal:					**AUD**	**104,600**

Annual savings	Unit	Quantity	Unit cost		Amount
User-defined	cost			AUD	-
Subtotal:				**AUD**	**-**

Periodic costs (credits)	Unit	Year	Unit cost		Amount
Inverter	cost	10	AUD 3,150,000	AUD	3,150,000
End of project life	cost			AUD	-

Appendix C (Emission Analysis)

Table 1

RETScreen - Emission Analysis — **Subscriber: Griffith University - Educational Use Only**

Base case electricity system (Baseline)

Fuel type	Fuel mix %	CO_2 emission factor kg/GJ	CH_4 emission factor kg/GJ	N_2O emission factor kg/GJ	Electricity generation efficiency %	T&D losses %	GHG emission factor tCO_2/MWh
Coal	62.8%	92.7	0.0145	0.0029	33.8%	7.0%	1.073
Natural gas	4.6%	49.6	0.0010	0.0009	40.8%	7.0%	0.473
Solar	11.0%	0.0	0.0000	0.0000	100.0%	7.0%	0.000
Wind	9.6%	0.0	0.0000	0.0000	100.0%	7.0%	0.000
Hydro	5.4%	0.0	0.0000	0.0000	100.0%	7.0%	0.000
Biomass	6.0%	0.0	0.0299	0.0037	23.3%	7.0%	0.030
Oil (#6)	0.6%	74.1	0.0029	0.0019	28.6%	7.0%	1.012
Electricity mix	100.0%	192.6	0.0374	0.0070		7.0%	0.704

☐ Baseline changes during project life

Base case system GHG summary (Baseline)

Fuel type	Fuel mix %	CO_2 emission factor kg/GJ	CH_4 emission factor kg/GJ	N_2O emission factor kg/GJ	Fuel consumption MWh	GHG emission factor tCO_2/MWh	GHG emissions tCO_2
Electricity	100.0%	192.6	0.0374	0.0070	6,783	0.704	4,774
Total	100.0%	192.6	0.0374	0.0070	6,783	0.704	4,774

Table 2

Proposed case system GHG summary

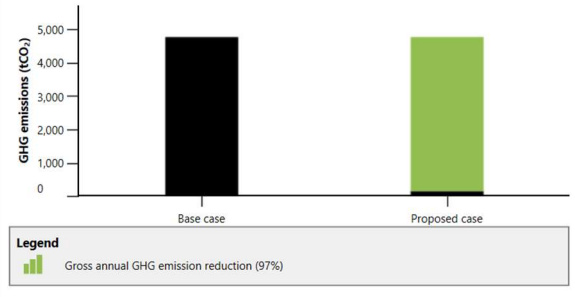
Fuel type	Fuel mix %	CO_2 emission factor kg/GJ	CH_4 emission factor kg/GJ	N_2O emission factor kg/GJ	Fuel consumption MWh	GHG emission factor tCO_2/MWh	GHG emissions tCO_2
Solar	100.0%	0.0	0.0000	0.0000	6,783	0.000	0
Total	100.0%	0.0	0.0000	0.0000	6,783	0.000	0
				T&D losses			
Electricity exported to grid	MWh	6,783		3.0%	203	0.704	143.2
						Total	143.2

Table 3

GHG emission reduction summary

GHG emissions		
Base case	tCO_2	4,774
Proposed case	tCO_2	143
Gross annual GHG emission reduction	tCO_2	4,630

97%



4,630 tCO_2 **is equivalent to** **848**

Cars & light trucks not used

Table 4

Carbon shadow price | GHG reduction revenue

			Gross annual GHG emission reduction	GHG credits transaction fee	Net annual GHG emission reduction	GHG reduction revenue
GHG reduction credit rate	AUD/tCO_2	35	tCO_2	%	tCO_2	AUD
GHG reduction credit duration	yr	25	4,630	8%	4,260	149,096
GHG reduction credit escalation rate	%	2%				

Carbon offsets

Remaining GHG emission reduction required	tCO_2	143	143
Net annual GHG emission reduction	tCO_2	4,773	100%
Carbon offsets rate	AUD/tCO_2	70	
Carbon offsets cost	AUD	10,010	

Appendix D (Finance Analysis)

Table 1

RETScreen - Financial Analysis — **Subscriber: Griffith University - Educational Use Only**

Financial parameters

General

Fuel cost escalation rate		2%
Inflation rate	%	2.8%
Discount rate	%	9.5%
Reinvestment rate	%	9%
Project life	yr	25

Finance

Incentives and grants	AUD	250,000
Debt ratio	%	50%
Debt	AUD	13,638,399
Equity	AUD	13,638,399
Debt interest rate	%	7.5%
Debt term	yr	15
Debt payments	AUD/yr	1,545,057

Income tax analysis ☑

Effective income tax rate	%	30%
Loss carryforward?		Yes
Depreciation method		Straight-line
Depreciation tax basis	%	80%
Depreciation period	yr	25
Tax holiday available?	yes/no	No

Annual savings and revenue

Electricity export revenue

Electricity exported to grid	MWh	6,783
Electricity export rate	AUD/MWh	140
Electricity export revenue	AUD	949,604
Electricity export escalation rate	%	2.5%

GHG reduction revenue

Net GHG reduction	tCO_2/yr	4,260
Net GHG reduction - 25 yrs	tCO_2	106,497
GHG reduction credit rate	AUD/tCO_2	35
GHG reduction revenue	AUD	149,096
GHG reduction credit duration	yr	25
Net GHG reduction - 25 yrs	tCO_2	106,497
GHG reduction credit escalation rate	%	2%

Other revenue (cost) ☐

Clean Energy (CE) production revenue ☑

CE production	MWh	6,783
CE production credit rate	AUD/kWh	0.29
CE production revenue	AUD	1,967,037
CE production credit duration	yr	25
CE production credit escalation rate	%	2.5%

Fuel type	Electricity exported to grid MWh	Clean energy
Solar	6,783	Yes

Costs | Savings | Revenue

Initial costs

Feasibility study	0.28%	AUD	76,880
Development	1%	AUD	281,500
Engineering	3.1%	AUD	858,000
Power system	33%	AUD	9,006,400
Balance of system & miscellaneous	62.5%	AUD	17,054,018
Total initial costs	**100%**	AUD	**27,276,798**
Incentives and grants		AUD	250,000

Yearly cash flows - Year 1

Annual costs and debt payments

O&M	AUD	122,311
Carbon offsets cost	AUD	10,010
Debt payments - 15 yrs	AUD	1,545,057
Total annual costs	**AUD**	**1,677,378**

Annual savings and revenue

Electricity export revenue	AUD	949,604
GHG reduction revenue - 25 yrs	AUD	149,096
CE production revenue - 25 yrs	AUD	1,967,037
Total annual savings and revenue	**AUD**	**3,065,738**
Net yearly cash flow - Year 1	**AUD**	**1,388,360**

Periodic costs (credits)

Inverter - 10 yrs	AUD	3,150,000

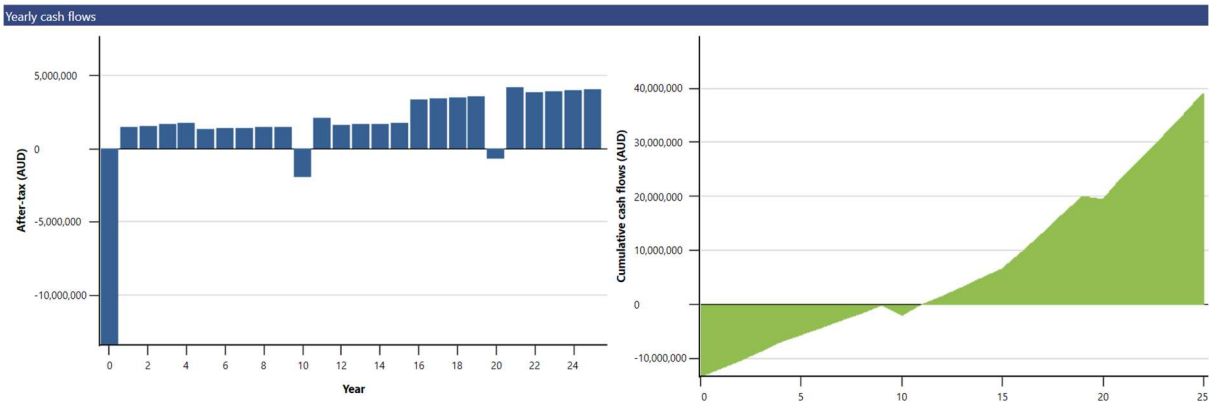
Financial viability

Pre-tax IRR - equity	%	13.9%
Pre-tax MIRR - equity	%	10.9%
Pre-tax IRR - assets	%	6.7%
Pre-tax MIRR - assets	%	8%
After-tax IRR - equity	%	11.3%
After-tax MIRR - equity	%	9.9%
After-tax IRR - assets	%	4.7%
After-tax MIRR - assets	%	7%
Simple payback	yr	9.2
Equity payback	yr	11.1
Net Present Value (NPV)	AUD	2,342,233
Annual life cycle savings	AUD/yr	248,182
Benefit-Cost (B-C) ratio		1.2
Debt service coverage		-0.27
GHG reduction cost	AUD/tCO_2	-75.61
Energy production cost	AUD/MWh	513

Yearly cash flows

Year #	Pre-tax AUD	After-tax AUD	Cumulative AUD
0	-13,398,409	-13,398,409	-13,398,409
1	1,460,553	1,460,553	-11,937,856
2	1,534,525	1,534,525	-10,403,331
3	1,610,319	1,610,319	-8,793,011
4	1,687,981	1,687,981	-7,105,030
5	1,767,557	1,313,272	-5,791,758
6	1,849,094	1,331,327	-4,460,431
7	1,932,639	1,372,942	-3,087,489
8	2,018,244	1,414,733	-1,672,756
9	2,105,958	1,456,641	-216,115
10	-1,956,017	-1,956,017	-2,172,133
11	2,287,924	2,088,858	-83,274
12	2,382,283	1,582,374	1,499,100
13	2,478,968	1,624,022	3,123,122
14	2,578,036	1,665,386	4,788,508
15	2,679,546	1,706,361	6,494,869
16	4,328,613	3,291,887	9,786,755
17	4,435,188	3,366,489	13,153,244
18	4,544,389	3,442,929	16,596,173
19	4,656,281	3,521,254	20,117,427
20	-701,406	-701,406	19,416,022
21	4,888,407	4,156,021	23,572,043
22	5,008,779	3,768,002	27,340,045
23	5,132,117	3,854,339	31,194,384
24	5,258,495	3,942,804	35,137,188
25	5,387,988	4,033,449	39,170,637

Table 2


Yearly cash flows
After-tax (AUD)
5,000,000
0
-5,000,000
-10,000,000
0
2
4
6
8
10
12
14
16
18
20
22
24
Year
Cumulative cash flows (AUD)
40,000,000
30,000,000
20,000,000
10,000,000
0
-10,000,000
0
5
10
15
20
25