Sustainable Energy, 2024, Vol. 12, No. 1, 1-5
Available online at http://pubs.sciepub.com/rse/12/1/1
Published by Science and Education Publishing
DOI:10.12691/rse-12-1-1

Techno-economic Evaluation of Power Generation from Industrial Wood Waste at Raiply Limited in Limbe, Malawi

Zaithwa Katuwa, Hope Baxter Chamdimba*

Energy Resources Management, Malawi University of Science and Technology, Thyolo, Malawi
*Corresponding author: hbchamdimba@gmail.com

Received February 28, 2024; Revised March 31, 2024; Accepted April 06, 2024

Abstract Amidst the rising cost of energy and unreliable power supply in Malawi, it is imperative that companies invest in alternative sources of energy. Industrial biomass waste should be considered first for economic and environmental reasons. This study was undertaken to assess the techno-economic potential of energy generation from industrial wood waste at Raiply Malawi Ltd in Blantyre. The methods used involved determining the energy demand of the company, quantifying and characterizing the wood waste, and using the System Advisor Model (SAM) to determine the techno-economic viability of the biopower system. The system's size, annual energy yield, installed cost, total installed cost per kW, levelized cost of electricity, carbon dioxide emissions per kWh, net present value, internal rate of return, and payback period were used to assess its feasibility. The study findings showed that the company generates 4,680 tons of sawdust, veneer waste, and offcut waste annually. The quantity and quality of the wood waste in terms of its physiochemical properties will allow the company to operate a biopower system with a 635-kW capacity that will generate 4,486.5 MWh of energy annually. The biopower system is expected to produce 643g of CO2 eq/kWh. The economic analysis showed that the proposed biopower plant will require an installation capital of $3,641,360 with a payback period of 9 years. The total installed cost per capacity was determined to be 5,735.40 $/kW. The proposed project has a net present value of $1,366,391, an internal rate of return of 15.45%, and a levelized cost of energy of 22.7¢//kWh. The techno-economic analysis of the project indicates that the project is viable, and Raiply Malawi must invest in the biomass power plant that in the long term will provide reliable power supply that meets 94.4% of the total energy demanded.

Keywords: *Industry, Wood waste, Energy, Techno-economic, System Advisor Model*

Cite This Article: Zaithwa Katuwa, and Hope Baxter Chamdimba, “Techno-economic Evaluation of Power Generation from Industrial Wood Waste at Raiply Limited in Limbe, Malawi.” *Sustainable Energy*, vol. 12, no. 1 (2024): 1-5. doi: 10.12691/rse-12-1-1.

1. Introduction

Available and reliable power is a necessity for economic growth but has not been adequate to drive the economic growth that Malawi desires [1,2]. Studies have shown that over the past years, the country has been experiencing substantial and consistent power outages, creating significant challenges for businesses [3,4]. In general, there is a lack of generation capacity; the existing power plants are deteriorating and aging, which are some of the key factors that cause high losses and frequent power outages [5]. These energy challenges cost businesses and households hundreds of millions of dollars per year in lost productivity [1]. In the absence of reliable energy supply, Malawi will not be able to achieve the objectives of the Malawi Vision 2063. Industrialization and the structural transformation of the economy are essential to maintaining rapid long-term economic growth, which demands an adequate and reliable power supply [4]. Over time, it has been noted that issues with the power sector have compelled businesses to give up on investments in Malawi, which is detrimental to the nation's goals for economic development. Already, it has been noted that Malawi’s ability to diversify its economy beyond agriculture is constrained by a lack of reliable electricity. To mitigate the effects of power outages, companies resort to costly alternative energy options, such as, diesel generators [6,7]. According to [6], 79% of the companies in Malawi indicated that persistent blackouts affect their production; 75% of the institutions use diesel-powered generators for power backup; and about 27% of the institutions planned to purchase diesel generators in the near future [6]. It is clear enough that private investment in power infrastructure will play a key role in resolving the challenges in the energy sector that Malawi is facing. In this case, onsite power generation by industries should be promoted. There is a need to diversify sources to meet the growing energy demand, and the generation of electricity and thermal energy from sustainable biomass has the potential to help meet national renewable energy goals [8]. However, with alternative fuel sources underdeveloped [4], unclean biomass will continue to form a significant part of Malawi's energy mix for the next few decades [9,10,11]. Unfortunately, the handling of forests in Malawi is not sustainable, which contributes to high levels of deforestation and inadequate supply of the much-needed firewood and charcoal.

Large volumes of waste are produced during the processing of wood by companies. These wood wastes have significant energy potential that remains untapped [12,13]. To address energy challenges, industries should consider using wood waste as a resource for power and heat generation instead of using planted energy crops that compete with food production [14,15]. It is widely accepted that the enhancement of the availability and utilization of forest biomass demands recovering wood from processing and end-life products [10,16,17]. The benefits of using biomass waste are stabilization of energy costs, enhancement of energy security, reduction of vulnerability to power grid interruptions, and the fact that biomass is carbon neutral, which makes it environmentally friendly when compared with fossil fuels [12].

Given the age of the industry, it is not surprising that the technologies for converting wood to energy in the form of heat or electricity are well established [14]. Boilers for wood waste are designed to produce heat energy in the form of steam and/or hot water by burning the crushed wood. In most industrial wood-to-energy applications, steam is produced in a boiler using standard stoker technology or newer. Wood waste, along with other biomass, is also used to generate electricity in combined heat and power plants (CHP). Therefore, the main objective of this study was to investigate the potential of electricity generation from industrial wood waste produced by Raiply Malawi Ltd, a company located in Limbe, Malawi.

2. Research Methodology

2.1. Study Area

The proposed study was undertaken at Raiply Malawi Limited, located in Blantyre City as shown in Figure 1. The company is one of the leading manufacturers of wood products in the country. The study area was chosen because the company generates a large amount of wood waste, like sawdust, wood offcuts, veneer waste, and wood chips. In addition, just like many other energy-intensive companies, Raiply Malawi Ltd demands more energy and continues to face many challenges related to energy supply. Therefore, exploring alternative sources of energy for the company is a priority.

2.2. Research Methods and Tools

This is the study's set of decisions that creates the foundation of the master plan that explains the methods and procedures for collecting and analysing data in research [18]. The study used both qualitative and quantitative research designs to assess the study objectives. The study design involved analysing the electric energy demand of Raiply Limited Malawi, quantifying the wood waste generated, characterizing the wood waste generated, and determining the recoverable energy from the available wood waste.

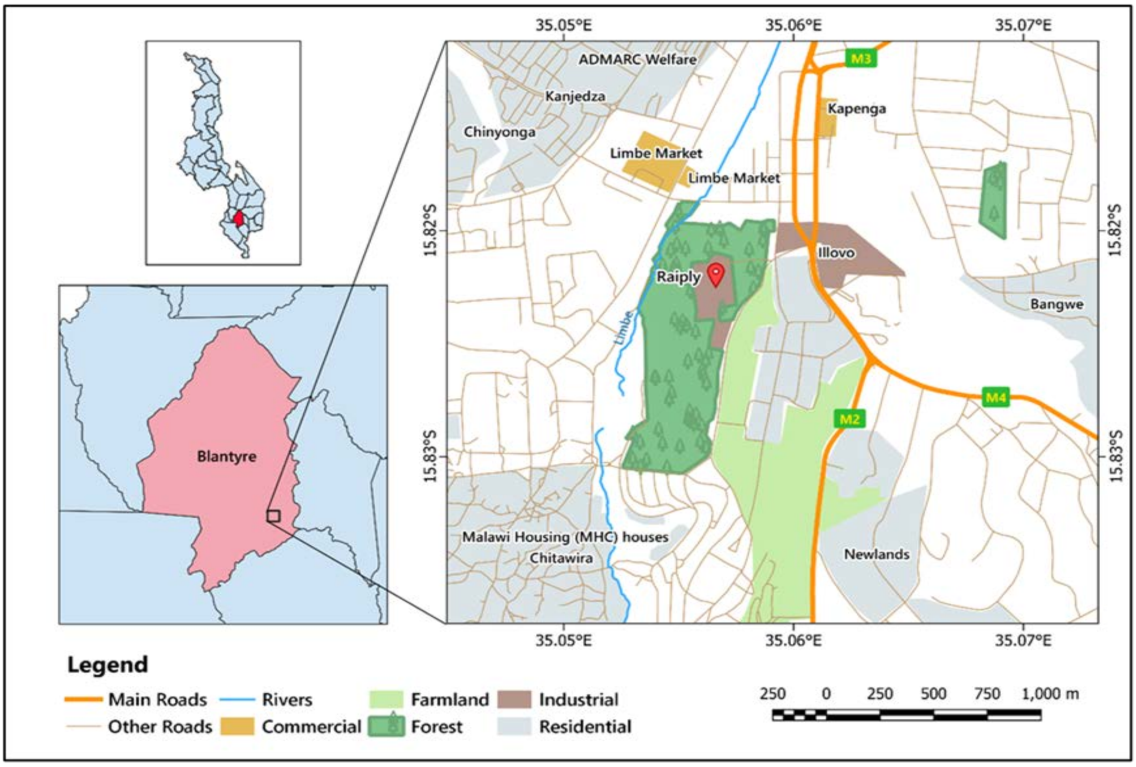

Figure 1. Map showing Raiply Ltd in Limbe, Malawi

2.2.1. Electric Energy Demand Assessment

An assessment of the electric energy demand was conducted to determine whether the available wood waste was enough for generating heat and electricity at Raiply Malawi Limited. The energy demand for the company was calculated using the end-use method, which involves direct recording of the power wattages and operating hours of the equipment in use. To achieve this, the company's records on monthly power consumption were used to provide the required data. Additional data was collected through a general inspection of the facilities at Raiply Malawi Ltd.

2.2.2. Characterization of Industrial Wood Waste

Quantification of the wood waste was done using data obtained from the company's records. Wood waste quantification was done based on the types of wood waste generated. In addition, the accumulative quantity of wood waste produced was determined. The physiochemical properties analyzed were Moisture Content (MC), total Solids (TS), Volatile Solids (VS) and Ash Content (AC). Tests were conducted at Malawi University of Science and Technology (MUST) biology laboratories and University of Malawi (UNIMA) laboratories. Figure 2 shows wood waste sample preparation for TS and VS analysis.

Figure 2. Physiochemical analysis of the wood waste at MUST biology laboratory

2.2.3. Techno-economic Analysis of the Power Plant using System Advisor Model

The physiochemical and thermal characteristics of the wood waste were used to calculate its energy potential. A thermal power plant that produces electricity from the available industrial wood waste was simulated using the System Advisor Model (SAM), a techno-economic computer model that evaluates renewable energy projects' financial and performance parameters [19]. The model is a decision-making tool for financial analysts, energy researchers, and developers of renewable energy projects, among others [20]. Biopower is one of the various renewable energy systems that SAM can model. In a normal study, simulations are performed, findings are reviewed, inputs are revised, and the process is repeated until the results are understood and you are confident in them [19]. SAM's performance models are intended for project pre-feasibility level analysis [20].

The recoverable energy from the industrial waste was calculated using the System Advisor Model (SAM). The plant specifics used were: wood waste fed as it has been received from different sources (i.e., without drying); a Grate Stoker Furnace combustion system considered; 2 boilers each having a capacity of 2131.093 lb/hr steam, a boiler overdesign capacity of 10%, and a percent excess fed air of 20% considered; and a biomass-fired Rankine Cycle Power Plant used. The simulation using SAM considered the monthly generation of the wood waste of 4,680 tons and the physiochemical and thermal properties of the wood waste (i.e., based on the laboratory test).

2.3. Data Analysis

The study collected both quantitative and qualitative data to determine the potential of using biomass waste for power generation. The Microsoft Excel statistical package was used to analyze the collected data on wood waste quantification and physiochemical characterization. The techno-economic performance of the system was analysed using SAM, which also has the capability to produce graphs.

3. Results.

3.1. Energy Demand of the Company

It was observed that the company has 17 main pieces of equipment, and these are the spindle veneer peeling lathe, spindle-less veneer peeling lathe, veneer clipper, veneer drier machine, veneer glue spreader, wood veneer cold press, plywood hot press machine, ply mill boiler, sawmill boiler, sizing machine, moulder, lit saw machine, compressor, cyclone machine, beam planer, bandsaw, wood-mizer, and kiln, together with their respective power usages. Most of this equipment operates 24 hours a day, considering that employees work in two shifts, i.e., day and night. Based on the total load and its operating hours it was determined that the company has an annual energy demand of 4,753 MWh (Figure 3).

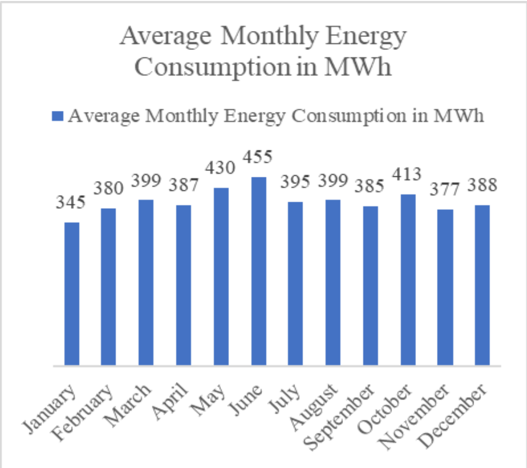

Figure 3. Energy Demand of Raiply Malawi Ltd in Limbe, Blantyre

Table 1. Energy Demand Statistics of Raiply Malawi Ltd in Blantyre

Statistical Analysis of the energy demand at Raiply Malawi Ltd	
Count, N:	12
Sum, Σx:	4,753
Mean, x̄:	396.08
Variance, s2:	766.27
Std.	27.68
Monthly Energy demand at 95% confidence level, margin error of ±3.95%	396.08 ±15.7

3.2. Generation and Characterization of the Industrial Wood Waste

The assessment results showed that the company generates three main types of industrial wood waste: sawdust, veneer waste, and offcuts. It was determined that the company generates 3,120 tons of sawdust, 936 tons of veneer waste, and 624 tons of offcut annually. In total, the company generates 4,680 tons of waste each year (Table 2). The company records showed that there was no significant variation in the generation of wood waste throughout the year.

Table 2. Types and quantities of Industrial Wood Waste Generated at Raiply Malawi Ltd in Limbe

Wood Waste Type	Quantities in Tons/Year	Percentage
Saw dust	3,120	67%
Veneer waste	936	20%
Offcuts	624	13%
Total	4,680	100%

Currently, a certain amount of wood waste is being used for the production of thermal energy that is used for industrial processes. Veneer waste and sawdust are the most commonly used types of wood waste. The findings showed that 42.3% of the offcuts, 61% of the veneer waste, and 88.50% of the sawdust are used; 46% of the offcuts, 30.8% of the veneer waste, and 9.2% of the sawdust are sold to the surrounding households and businesses, where the wood waste is mostly used for cooking, heating, and as a fire starter. The remaining 11.5% offcuts, 7.7% veneer waste, and 2.3% of the sawdust are unused (Figure 4).

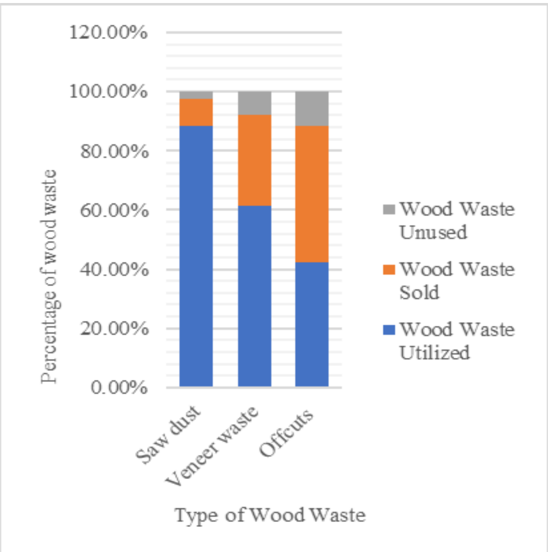

Figure 4. Wood waste generated by Raiply Malawi Ltd

Understanding the quantities of wood waste generated is not adequate to determine the recoverable energy for use. It is crucial that the physiochemical and thermal characteristics of the wood waste generated be determined. This helps to understand whether the available biomass waste is suitable for energy generation. In this case, MC, TS, VS, TS, AC, gross calorific value, Carbon (C) Hydrogen, (H) and Nitrogen (N) contents were tested, and the results are shown in Table 3.

Table 3. Physiochemical Characteristics of Wood Waste Generated

Parameter	Saw Dust	Veneer	Offcuts	Average
MC (%)	10.23	10.95	9.59	10.26
TS (%)	89.77	89.05	90.413	89.77
VS (%)	88.4	88.91	90.137	89.15
Ash (%)	1.524	0.16	0.305	0.67
Gross Calorific Value (Cal/g)	4,232.45	4325.56	4608.69	4388.9
Carbon (%)	46.83	46.83	46.83	46.83
Hydrogen (%)	6.88	6.88	6.88	6.88
Nitrogen (%)	0.28	0.28	0.28	0.28

3.3. Recoverable Energy Versus Demand and the Expected Carbon Emissions

SAM simulation results showed that a system with a capacity of 635 kW would be required (Figure 5). The actual amount of feedstock required annually is 3,480 dry tons. The feedstock will yield 4,486.5 MWh of energy annually at an annual capacity factor of 0.81, which is enough to meet 94.4% of the company's energy demand. On the other hand, the collection and processing of the wood waste for the biopower system will produce 643g of CO_2 eq/kWh.

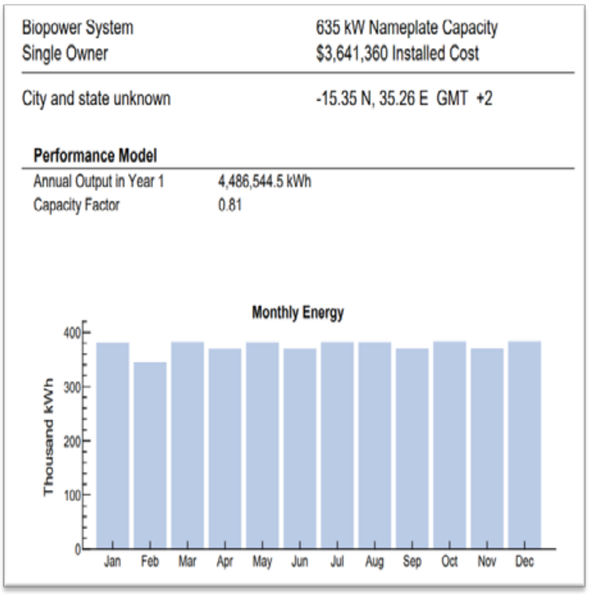

Figure 5. Recoverable Energy from wood waste

3.4. Economic Analysis of the Energy Recovery from the Wood Waste

The economic analysis results based on the SAM simulations considered the direct costs associated with the installation of the proposed power plant, and among others, these costs included the boiler, turbine, and generator; the balance of the plant; contingency as a percent of a direct cost; indirect costs, which included Engineer, Procure, and Construct (EPC); and taxes that are applicable locally. The simulation results showed that the proposed biopower plant will require an installation capital of $3,641,360 with a payback period of 9 years. The total installed cost per capacity was determined to be 5735.40 USD/kW. The proposed project has a net present value of $1,366,391, an internal rate of return of 15.45%, and a levelized cost of energy of 22.7¢/kWh.

4. Conclusions

Rising energy costs and an unreliable power supply affect the operations of all the industries in Malawi, which also reduces their competitive advantage. This requires that companies consider onsite power generation, where reliable and sustainable energy resources are used. Therefore, this study investigated the potential of using wood waste to generate power at Raiply Malawi Ltd in Blantyre. To achieve this objective, the study analysed the wood waste generated in terms of quantities and physiochemical characteristics and used the SAM model to analyze the techno-economic potential of power generation from the available wood waste resource. The study results showed that the wood waste available is enough to allow the company operate a 635-kW biomass plant that generates adequate power to meet 94% of the company's energy demand. The biopower system is expected to produce 643g of CO2 eq/kWh. The economic performance analysis of the biopower system showed that the cost of energy generated is on the higher side when compared with the average cost of electricity supplied by the Electricity Supply Corporation of Malawi in terms of ¢//kWh. However, onsite power generation offers the company an opportunity to reduce energy bills and ensure reliable power supply throughout the year. Therefore, the company should consider investing in biopower generation.

5. Recommendations

- Raiply Malawi Ltd should continuously record data related to the generation of different types of wood waste, which will help determine resource availability and variability throughout the year.
- The company should reconsider selling some wood waste; instead, all of it should be considered for power generation.

The waste generated by the company is enough to generate 94% of the total energy demanded by the company. Therefore, the company should seriously consider investing in power generation from wood waste.

References

[1] MCA, Star Report-Malawi. Millenium Challenge Account. 2020. [Online]. https:// assets.mcc.gov/.content/uploads/report-2020001236501-malawi-star.pdf.

[2] GoM, National Energy Policy. Government of Malawi. 2018. [Online]. https://npc.mw/wp-content/uploads/2020/07/National-Energy-Policy-2018.pdf.

[3] Oseni, M. (2019). Costs of unreliable electricity to African firms. Energy for Growth Hub, 1–2. http://www.enterprisesurveys.org.

[4] MIT, Malawi National Industry Policy. Ministry of Trade and Industry. 2014. https://mitc.mw/trade/images/Malawi-Trade-Policy.pdf.

[5] MCA, Improving Power Quality and Reliability in Malawi. Millenium Challenge Account. 2021. [Online]. https:// assets.mcc.gov/content/uploads/evalbrief-20200022490-malawi-idp.pdf.

[6] NSO, Final Energy Survey Report. National Statistical Office. 2014. [Online]. http:// conrema.org/ wp-content/ uploads/2019/01/Final-Energy-Survey-Report-August-2014.pdf

[7] Kim, D. C., Kim, H. J., & Yoo, S. H, Valuing improved power supply reliability for manufacturing firms in South Korea: Results from a choice experiment survey. Sustainability (Switzerland), 10(12). 2018. [Online].

[8] US. Department of Energy, Biopower: Power production from biomass can help meet renewable energy goals. 2010. [Online]. https://www.energy.gov/sites/prod/files/2014/04/f14/biopower_factsheet.pdf.

[9] Fullerton, D. G., Semple, S., Kalambo, F., Suseno, A., Malamba, R., Henderson, G., Ayres, J. G., & Gordon, S. B, Biomass fuel use and indoor air pollution in homes in Malawi. Occupational and Environmental Medicine, 66(11), 777–783. 2009. [Online].

[10] MoNR, National Charcoal Strategy. 1–44. Ministry of Natural Resources. 2017. [Online]. https://www.frim.org.mw/wp-content/uploads/2017/11/Malawi_Charcoal-Strategy-2017.pdf

[11] GoM, Malawi Biomass Energy Strategy. January, 151. 2009. [Online]. http:// conrema.org/ wp-content/ uploads/ 2019/01/Biomass-Strategy-2009.compressed.pdf.

[12] FEMP, Biomass Energy — Focus on Wood Waste. Federal Energy Management Program. 2004. [Online]. https://www.nrc.gov/docs/ML1409/ML14093A260.pdf.

[13] Veeyee, K.F., Bup, N.D., & Boldor, D, Potentials of sustainable electricity production from sawdust by small-scale wood transformation units: A case study in Cameroon. International Journal of Energy and Environmental Engineering. 2020. [Online]

[14] Racz, M. D., Darsy, A., Petrilean, D. C., & Irimie, S. I, The comparative analysis of the use of wood waste and natural gas in hot biogenerators from an energetic, economic and ecologic point of view. 00076. 2020. [Online].

[15] Sands, R. D., Malcolm, S. A., Suttles, S. A., & Marshall, E, Dedicated Energy Crops and Competition for Agricultural Land. ERR-223, U.S. Department of Agriculture, Economic Research Service, USDA ERS R (223), 72. 2017. [Online]. https://www.ers.usda.gov/webdocs/publications/81903/err-223.pdf?v=5200.6.

[16] Daian, G., & Ozarska, B, Wood waste management practices and strategies to increase sustainability standards in the Australian wooden furniture manufacturing sector. Journal of Cleaner Production, 2009. [Online].

[17] Mittlefehldt, S, Wood Waste and Race: The Industrialization of Biomass Energy Technologies and Environmental Justice Wood Waste and Race. 59(4), 875–898. 2019. [Online].

[18] Creswell, J. W, Research Design- Qualitative, Quantitative and Mixed methods Approaches (V. Knight (ed.); 3rd ed.). SAGE Publications, 2009. [Online].

[19] Blair, N., DiOrio, N., Freeman, J., Gilman, P., Janzou, S., Neises, T. and Wagner, M, System Advisor Model (SAM) General Description (Version 2017.9.5). Golden, CO: National Renewable Energy Laboratory, 2018, NREL/ TP-6A20-70414. https://www.nrel.gov/docs/fy18osti/70414.pdf.

[20] NREL, Reference Manual for the System Advisor Model's Wind Power Performance Model. National Renewable Energy Laboratory. 2014. [Online]. https:// www.nrel.gov/ docs/fy14osti/60570.pdf.