Exhibit No. 124

Staff – Exhibit 124
Claire M. Eubanks, PE
Surrebuttal/True-Up Direct Testimony
File No. ER-2022-0337

Exhibit No.:
Issue(s): High Prairie and Rush Island
Witness: Claire M. Eubanks, PE
Sponsoring Party: MoPSC Staff
Type of Exhibit: Surrebuttal/True-Up Direct Testimony
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MISSOURI PUBLIC SERVICE COMMISSION

INDUSTRY ANALYSIS DIVISION

ENGINEERING ANALYSIS DEPARTMENT

SURREBUTTAL/TRUE-UP DIRECT TESTIMONY

OF

CLAIRE M. EUBANKS, PE

UNION ELECTRIC COMPANY, d/b/a AMEREN MISSOURI

CASE NO. ER-2022-0337

Jefferson City, Missouri
March 2023

******* Denotes Highly Confidential Information *******

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Q. Please state your name and business address.

A. My name is Claire M. Eubanks and my business address is Missouri Public Service Commission, P.O. Box 360, Jefferson City, Missouri, 65102.

Q. By whom are you employed and in what capacity?

A. I am employed by the Missouri Public Service Commission ("Commission") as the Manager of the Engineering Analysis Department of the Industry Analysis Division.

Q. Are you the same Claire M. Eubanks who previously filed direct and rebuttal testimony in this case?

A. Yes.

EXECUTIVE SUMMARY

Q. What is the purpose of your surrebuttal and true-up direct testimony?

A. The purpose of my surrebuttal testimony is to respond to Union Electric Company, d/b/a Ameren Missouri ("Ameren Missouri" or "Company") witnesses Andrew Meyer, Ajay K. Arora, and John J. Reed; and Missouri Industrial Energy Consumers ("MIEC") witness Greg R. Meyer. The two issues covered in my surrebuttal testimony are Staff's recommended adjustments related to Rush Island and High Prairie. My true-up direct testimony updates these adjustments based on Staff's fuel model and market price updates for True-up.

Q. Do other Staff witnesses discuss the issues with Rush Island and High Prairie?

A. Yes, Staff witness Keith Majors responds to John Reed regarding Rush Island and Staff witness Shawn E. Lange, PE responds to Mr. Arora regarding the modeling of High Prairie in Staff's production cost modeling.

SURREBUTTAL TESTIMONY

Rush Island

Q. Please summarize the issue with Rush Island and the witnesses involved.

A. Ameren Missouri has been involved in litigation regarding environmental permits at Rush Island since 2011. Rather than installing air pollution equipment at Rush Island, Ameren Missouri made the decision to retire the plant. The witnesses providing testimony related to Rush Island in this case include:

Staff

- Claire M. Eubanks, PE – direct, rebuttal
- Keith Majors – rebuttal
- Shawn E. Lange, PE – direct, rebuttal

Ameren Missouri

- Jeffrey R. Holmstead – direct
- Karl R. Moor – direct
- Matt Michels – direct
- Mark Birk – direct
- John J. Reed – rebuttal
- Andrew Meyer- rebuttal

Q. On page 3, lines 6-8 of his rebuttal testimony Andrew Meyer claims Staff failed to give Ameren Missouri credit for Rush Island Units 1 and 2 clearing the MISO Planning Resource Auction, is this accurate?

A. No. Staff's recommended adjustment only reduces the remaining rate base associated with Rush Island. Staff included Rush Island's expected operations in its fuel modeling which is used in setting the Net Base Energy Costs (NBEC). Staff made no negative adjustment that would impact the existing treatment of capacity revenues through the FAC.

Q. On page 4, lines 14, in his rebuttal testimony, Andrew Meyer discusses instances where units have not operated near their historic capacity factors, is this relevant to the Rush Island discussion?

A. No. Staff is not suggesting that every instance of a less than historic capacity factor warrants an adjustment. However, Staff is recommending an adjustment to Rush Island because the Company has made decisions that have affected its ability to operate Rush Island as it would otherwise. Utilities make investments on behalf of its customers, customers pay that cost plus a reasonable rate of return. This investment becomes dedicated to customers for its useful life. Ratepayers have a reasonable expectation that their utility respect this regulatory compact by making reasonable decisions. The Eastern District Court found that Ameren Missouri was not reasonable in its actions with regard to Rush Island. Ameren Missouri, the Commission, and its customers, expected Ameren Missouri to operate Rush Island through 2045[1] but Ameren Missouri failed to take the necessary actions to allow it to do so.

Q. In a similar vein, Ameren Missouri witness Mr. Reed, on page 24, lines 10-11 of his rebuttal testimony, presents historic capacity factors from Rush Island, arguing capacity factors vary year to year. How do you respond?

A. Capacity factor is simply the ratio of electrical energy output over a given time period compared to the theoretical maximum over that period. Staff's production cost modeling provides a reasonable expectation of the energy output over the test-year for Rush Island

[1] Until the retirement date was updated to 2039 in the 2020 IRP.

Unit 1 and 2 under two scenarios – with normalized Rush Island operations and with Rush Island operating as a System Support Resource. No Ameren Missouri witness disputed Staff's production cost modeling related to the Rush Island SSR operations.

Q. On page 23, line 20-21 Mr. Reed claims Staff compared the "forecasted reduction" in the two units' capacity "as compared to its capacity factor for a historical period." Is that accurate?

A. No. Staff uses a production cost model to perform a simulation of a utility's energy generation, energy sales, and energy purchases. Staff's results are not a forecast as the production cost model is used to develop a normalized level of net energy costs. Staff did not compare the Rush Island SSR simulation to "its capacity factor for a historical period." Staff compared the results of the production cost modeling of Rush Island as an SSR to its normalized simulation. In other words, Staff compared Rush Island as an SSR to what Staff would typically do in any other rate case for modeling Rush Island.

Q. On page 3, lines 12 and 13, Mr. Reed states that Staff's adjustment is due to the fact that Rush Island is "merely because it is producing less than Staff desires." Is this a fair characterization of Staff's position?

A. No. Staff's position is that due to the decisions of Ameren Missouri's management, the Rush Island facility will not operate as it was intended. It is artificially constrained by the MISO operating guide and as such, it is Staff's position that the shareholders should bear some of the consequences of management decisions.

Q. On page 6, lines 9-12, in his rebuttal testimony, Andrew Meyer discusses the energy, ancillary and capacity sales from the 1,195 hours and 583,461 MWhs of Rush Island operation as an SSR. How do the hours and generation levels compare to how Rush Island would operate if it were economically dispatched versus as a SSR?

A. Staff's fuel model results comparing Rush Island Units 1 and 2 operating as normal and as dispatched per the MISO operating guide resulted in Rush Island Unit 1 operating ** [redacted]

[redacted]

[redacted]

[redacted]

**

Q. On Page 23, lines 4-5 Mr. Reed argues that the bases for Staff's recommended adjustment are factually incorrect, how do you respond?

A. Ameren Missouri has clearly explained in testimony in this case, in its recent Boomtown CCN request, and in its status updates in EO-2022-0215 that the Rush Island units will only operate for reliability purposes and that Ameren Missouri anticipates the units will run primarily in summer and winter.[2]

In Boomtown testimony Mr. Arora attempts to bolster the Company's position with regard to the planned addition of Boomtown by pointing out the risks of losing Rush Island:

> As the Commission knows from the reports filed each month in File No. EO-2022-0215, and from testimony filed in the Company's pending rate review, the two Rush Island Units are now System Support Resources ("SSR") in the MISO market. This means they are only dispatched for reliability reasons under an "operating guide" issued by MISO. **Consequently, these units run far less than they would if they were dispatched economically, and this means they provide far less energy.** So, while it is true that for the next year or two those two units will be fully available **to backstop reliability**, we are, even today, exposed to greater market price risk when our energy needs spike given Rush Island's status as an SSR. [Emphasis Added.]

Ameren Missouri witness Andrew Meyer includes in his Direct Testimony the suggested language it provided to the court for a proposed order related to Rush Island operations (schedule AMM-D4):

> 2. Operation for Reliability Purposes: Ameren may operate the Rush Island units pursuant to a System Support Resource ("SSR") agreement so long as those operations are limited as follows:
>
> a. Operation of the Rush Island units must be subject to orders issued by this Court.
>
> b. The Rush Island units may be committed by MISO, whether concurrently or interchangeably on a single unit basis, to ensure system reliability depending upon circumstances of the grid.

[2] EO-2022-0215, February 15, 2023 "Since the agreement began, the Rush Island SSR reliability commitments have been as expected, with the units only running during times of MISO need, mostly anticipated to be during summer or winter conditions."

> c. Because their cost profile is such that MISO would normally seek to dispatch the Rush Island units in the normal course of business, for the avoidance of doubt, **the Rush Island units may not be committed by MISO based on economics**.
>
> d. The Rush Island units may be committed by MISO to serve the reliability conditions identified in the Rush Island Attachment Y Study Report based on such measures as forecasted weather conditions and forecasted daily demand levels in the geographic areas for which the reliability service is intended as described in the Report.
>
> e. The Rush Island units may be committed by MISO, as needed, in the event that MISO declares an Energy Emergency or MISO determines that commitment of the Rush Island units would respond to unstable conditions on the transmission system.
>
> f. If not already committed, the Rush Island units may be committed by MISO, as needed, for freeze protection (i.e., according to predetermined weather conditions) to maintain their integrity so that they continue to be available to provide reliability service. [Emphasis Added.]

It is clear that Rush Island will not operate as it has in the past because it will not be economically dispatched by MISO except in times of MISO system needs. Staff's capacity factor calculation takes into account the drastic change in Rush Island dispatch. While the MISO market did not exist when Rush Island was originally constructed, the plant was constructed and operated as a baseload unit providing energy and capacity to serve Ameren Missouri customers, not to solely "backstop reliability". Rush Island is no longer being used to serve customers as it was intended to, and in that manner, it is not fully used for serving Ameren Missouri customers.

The decisions of Ameren Missouri have resulted in the Rush Island plant being artificially constrained from legally operating to its full potential. Mr. Reed's rebuttal testimony indicates that "Both units are fully available to serve customers and are required to be by the terms of the MISO SSR contract." However, Ameren Missouri and its customers did not build Rush Island under the context of being available under the terms of the MISO SSR contract. Without Staff's recommended adjustment, ratepayers are inappropriately held solely accountable for the lost revenues while Ameren Missouri's shareholders are unscathed by the decisions of Ameren Missouri's management. Staff's adjustment appropriately accounts for the lost use of the plant to Ameren Missouri's customers, while still providing credit to Ameren Missouri's shareholders for a portion of the plant.

Q. On page 9, lines 1 and 2, Mr. Reed states that "the law is clear that utility property is properly includable in rates when it is "fully operational and used for service." Is Rush Island fully operational?

A. No, it will not be dispatched except to backstop reliability.

Q. On page 13, lines 5 – 8, Mr. Reed states, "The Commission relies on a pre-approval approach today because it requires prior approval, via obtaining a certificate of convenience and necessity (CCN), before new generation can be built,…" Is this an accurate statement?

A. No. It is my understanding that, just because a CCN is required does not mean that the Commission has pre-approved the building of the facility. That being said; the current CCN rule gives the Commission the discretion to decide decisional prudence but without that specific finding, the granting of a CCN does not "pre-approve" projects. A CCN case is not the appropriate time to determine whether or not a utility has acted imprudently. The appropriate time for those decisions are generally in a rate case proceeding where all factors can be reviewed, and more recently, in any securitization case where a utility is requesting to securitize the costs of retiring generation facilities.

Q. Further on page 13, Mr. Reed dips into hyperbole. He states that the adoption of his so-called economic used and useful standard "could go so far as to inappropriately permit cost disallowances whenever load unexpectedly changed, or fuel prices unexpectedly changed, or even when environmental or tax policies unexpectedly changed,…" Is this what Staff's position is?

A. No. Staff is not contemplating any type of cost disallowance for these types of events. Generally speaking, those items are out of the control of the utility and thus would not be subject to any disallowance. However, if the utility made decisions after a facility was already included in rates that caused costs to be imprudent, then those decisions have to be reviewed to ensure that they were not detrimental to the ratepayers. The regulatory compact does not work if the game is "heads the utility wins, tails the ratepayers lose." Every and all decisions that the utility management makes must be subject to scrutiny by the regulator to ensure that all costs that the captive ratepayers must pay are just and reasonable. Under Mr. Reed's argument, the utility would always be shielded from its decisions. In Mr. Reed's own words, this is an asymmetrical, unpredictable, and unquantifiable risk on ratepayers and is inefficient and highly inequitable.

Q. Is it Staff's opinion that Ameren Missouri acted imprudently when it failed to evaluate the Rush Island modifications for applicability of the New Source review standards?

A. Yes.

Q. Please summarize Staff's position on Rush Island.

A. Ameren Missouri's decisions have left its customers in limbo – unable to retire Rush Island now because Ameren Missouri failed to prepare for its premature retirement – and unable to continue to rely on Rush Island as they have in the past except when the MISO system needs it most. Ameren Missouri is requesting the Commission set rates and allow recovery of and on the full remaining balance of Rush Island rate base – a plant whose dispatch is drastically altered - and has attempted to justify its positon by presenting arguments the Eastern District

Court rejected and the Court of Appeals upheld. Staff is reasonably recommending to the Commission that Ameren Missouri customers continue to pay a portion of the rate base of Rush Island and a reasonable rate of return – just not the full cost – until a further decision is made by the Commission in a future securitization case.

High Prairie

Q. Please explain the issue around High Prairie wind farm and the witnesses involved.

A. As the Commission is aware, Ameren Missouri voluntarily curtailed operations overnight from April through October at High Prairie as a result of bat takes.[3] The following witnesses discuss this issue:

Staff
- Claire M. Eubanks – direct, rebuttal
- Shawn E. Lange, PE [4] – direct

Ameren Missouri
- Andrew Meyer- direct
- Ajay K. Arora - rebuttal
- John J. Reed – rebuttal

MIEC
- Greg R. Meyer- direct

OPC
- Geoff R. Marke- direct

Q. Mr. Arora claims that the Company is closing the gap on its RES compliance shortfall by constructing Huck Finn and that the RES compliance shortfall is not relevant to this case. Do you agree?

[3] In footnote 11, Mr. Arora notes the number of bat takes listed in my direct testimony is incorrect for the number of Indiana bat takes. However, I did not specify the species of bats. Attached as Schedule CME-s1 is detailed information provided in ER-2021-0240 regarding the bat takes at the facility.

[4] As it relates to production cost modeling.

A. No. First, Huck Finn is not expected to be operational and producing RECs until December 1, 2024. Ameren Missouri's REC shortfall is relevant because it is greater than it otherwise would be because of the lost production at High Prairie resulting in additional actual REC purchases.

Q. On page 5, line 4 of his rebuttal testimony, Mr. Arora further argues the only relevant question is whether Ameren Missouri imprudently signed the Build Transfer Agreement ("BTA"). Do you agree?

A. No. First, as Mr. Arora correctly points out, Staff is not alleging the signing of the BTA was imprudent but what is relevant to this issue is the decisions Ameren Missouri has made which resulted in lower production at High Prairie.

Q. In footnote 5, page 4 of Mr. Arora's rebuttal testimony, he argues that Staff "should not be allowed to, in effect, make an end run around its commitments in the CCN stipulation". Is Staff arguing the decisional prudence of acquiring High Prairie under the terms of the BTA as presented by Ameren Missouri in the CCN case?

A. No.

Q. What is the language from the CCN stipulation with regards to decisional prudence?

A. Paragraph 12, page 3 of the Third Stipulation and Agreement states:

> 12. Prudence: The Signatories agree that they shall not challenge the prudence of the decision to acquire the facility under the terms of the BTA, including Non-Compliant wind turbine generators under the terms of the BTA, and to merge TG High Prairie, LLC into Ameren Missouri if the acquisition of the facility closes pursuant to the BTA. Nothing in this Stipulation limits the ability of any Signatory or other party from challenging the prudency of the design, construction costs, interconnection costs, and all other project related costs, including costs impacted by construction duration.

Q. Did the terms of the BTA change since parties agreed not to challenge the prudence of the decision to acquire the project under the terms of the BTA?

A. *** [redacted][5] ***

Q. Did Staff support the High Prairie project in the CCN case?

A. Yes. I, on behalf of Staff, recommended the Commission find the project under the terms of the BTA in the public interest. Staff recognized that certain mitigation measures, such as operating at a higher cut-in speed, would impact generation (and REC) output and therefore the economics of the project.[6] However, Staff noted that Ameren Missouri considered these risks in it RFP selection process and contract negotiations.

Q. Mr. Arora criticizes Staff for basing its adjustment on use of a 5.0 m/s cut in speed because "everyone understood when the CCN was granted that operations at night from April to October might very well have to be conducted using a 6.9 m/s minimum cut-in speed" How do you respond?

A. Staff is using the same profiles that Ameren Missouri witnesses Andrew Meyer and Mark Peters used in its fuel modeling, only netting the difference to determine the lost production, so criticizing Staff's use of the wind profiles necessarily undermines the Company's own fuel modeling. Further, in response to Staff Data request 572, Ameren Missouri provided a report by DNL-GL titled *Technical Note: Long-term Energy Production* ("Post-Closing Wind Resource Assessment") that analyzed the post-project generation

[5] Response to Staff data request 78 in EA-2018-0202 related to Staff's construction audit.
[6] Case No. EA-2018-0202, Surrebuttal of Claire M. Eubanks, P.E. Page 8, lines 4-13.

assuming a 5.0 m/s cut-in speed. This report is Ameren Missouri's support for releasing the $3 million production holdback to the Seller.

Ameren Missouri modeled only two capacity factors in its economic modeling for the CCN. ** [redacted] ** *** [redacted] *** The operating profile Staff utilized for High Prairie's expected generation with nighttime operations falls within this range. Staff's profile for the scenario that no overnight generation occurs from April through October is also reasonable given the historic generation at High Prairie as discussed later in my testimony and by Staff witness Shawn E. Lange, PE.

Q. Can you provide additional information regarding the wind resource assessments from the CCN case?

continued on next page

A. Yes. *** [redacted] ***

Q. On Page 22, lines 9-12 of his rebuttal testimony, Mr. Arora criticizes Staff's adjustment for not using the worst-case scenario in its adjustment. What are Staff's results using the worst-case from the CCN case for High Prairie?

A. The worst-case scenario Ameren Missouri actually used in its economic modeling in the CCN case was a ** [redacted] **

Staff estimated the impact of the worst-case scenario Ameren Missouri utilized in the CCN case (a 8,760 time series reflecting a ** [redacted] ** net capacity factor was not provided in the CCN case). Staff averaged the two available bat curtailment scenarios

[7] 8,760 is the number of hours in a year.

resulting in ** [redacted] ** Recalculating Staff's adjustment[8] using the average of the 5.0 m/s cut-in speed and the 6.9 m/s cut-in speed shapes results in:

Lost Revenue	$13,572,435
Lost PTCs	$13,819,910
Lost RECs	$2,707,817

Q. Given the above calculation is Staff reducing its recommended adjustment?

A. No, the table above is provided for Commission reference. The profile Staff utilized for its recommended adjustment reasonably falls within the range of production assumed by Ameren Missouri for purposes of its testimony in the High Prairie CCN case and is being used by Ameren Missouri as a part of its 50/50 profile. Staff witness Shawn E. Lange, PE discusses the 50/50 profile as it relates to Staff's production cost modeling in his surrebuttal testimony.

Q. On Page 22, lines 4-5 of his rebuttal testimony, Mr. Arora argues Staff's profile is not a reasonable representation of the normalized output of High Prairie, do you agree?

A. No. Ameren Missouri's witnesses Andrew Meyer and Mark Peters do not even use a 6.9 m/s wind shape for Ameren Missouri's 50/50 wind profile. The 50/50 profiles is the average of the 5.0 m/s wind shape and the 5.0 m/s wind shape without overnight generation. It appears Mr. Arora is intending to rebut Staff Witness Shawn E. Lange, PE regarding Staff's use of the 5.0 m/s shape with no overnight generation in Staff's fuel modeling. Staff's wind profile represents 938,737 MWh of generation and is certainly more representative of

[8] True-up Direct market prices were utilized.

Ameren Missouri's actual production (801,249 in 2021 and 937,059 MWh in 2022)[9] than Ameren Missouri's 50/50 shape (1,163,435 MWh).

Q. On Page 24, lines 7-8 of Mr. Arora's rebuttal testimony he criticizes Staff's adjustment because if production is restored customers would receive a "windfall". Is that a reasonable concern?

A. No. Mr. Arora is discussing the interplay between Staff's High Prairie adjustment and the Renewable Energy Standard Rate Adjustment Mechanism ("RESRAM"). The RESRAM is a periodic adjustment mechanism to recover RES compliance costs and pass-through to the customers the benefits related to RES compliance. If the Commission does not order an adjustment related to High Prairie there is no accountability for Ameren Missouri to regain production.

The base amount for the RESRAM in Staff's case reflects Staff's modeled fuel run using the operating profile for High Prairie assuming no overnight operations. Staff is recommending the Commission set the base amount for the RESRAM at this level as it is a reasonable expectation based on historic generation at High Prairie. All else being equal, lower generation reflected in the base amount means that the expected revenues are lower. In other words, all else being equal, we expect there to be less benefits from High Prairie to offset renewable costs. After rates are in effect from this case, Ameren Missouri will track the actual costs and benefits against the base amount (converted to the Monthly Base Amount) over the accumulation period. At the end of the accumulation period, the RESRAM rate will change based on whether there was an over or under recovery. If the base amount in the RESRAM is artificially low (Ameren's positon), there would more likely be an under recovery and the

[9] As reported by Ameren Missouri per 20 CSR 4240-3.190, includes negative generation.

RESRAM rate will be adjusted for it in the next accumulation period. In other words, customers may see a RESRAM credit for a few months but then later be hit with a RESRAM charge. Either way customers pay the costs and receive the benefits from renewable resources. Staff's position in this case is simply that customers are seeing less benefits because Ameren Missouri voluntarily curtailed High Prairie overnight.

In the next rate case, if the bat mitigation measures result in higher production, Staff would expect to see that in generation data and would reflect it in its production cost modeling and in the base amount for the RESRAM.

Further, Ameren Missouri customers have been paying the return of and on Ameren Missouri's investment in High Prairie since its inclusion in rates. Customers will have to continue to bear the cost of the lost REC production through additional REC purchases until production of High Prairie increases or until Huck Finn is constructed and operational.

Q. Switching momentarily to Mr. Greg Meyer's rebuttal testimony on this issue, he claims to support Staff's position that the Fuel Adjustment Clause ("FAC") could be used to capture the energy and PTC revenue stream from High Prairie; is this an accurate representation of Staff's position in this case?

A. No. Mr. Greg Meyer is presumably referencing my Direct Testimony on page 4, line 11 which mentions the Fuel Adjustment Clause. Staff's adjustment in this case is not intended to be returned to customers through the FAC or the RESRAM.

Q. Mr. Greg Meyer criticizes Staff for the inclusion of the capital cost associated with the bat mitigation measures while Mr. Arora compares Staff to the Great and Powerful Oz for "giving" the Company return on and of its investment while "taking away" on the other hand. How do you respond?

A. Regarding Mr. Greg Meyer's argument, Staff's adjustment for High Prairie and its support for the capital costs associated with bat mitigation efforts are intended purposefully. Staff wants to ensure that Ameren Missouri is taking all reasonable actions to regain lost production at High Prairie. Mr. Arora discusses the status of its efforts: "Early testing results are promising but we have not done enough testing to draw any definitive conclusions. We intend to begin implementing and testing a third measure… in 2023." Staff included the plant investments because there was sufficient evidence in data request responses that the equipment installed are supporting the efforts to regain production. However, Staff is also addressing the lost production because it has a known impact to customers that occurred during the test-year. Mr. Arora seems to be arguing that Staff should not be allowed to make a revenue adjustment. Again, Staff is reasonably recommending to the Commission, to ensure just and reasonable rates, that Ameren Missouri shareholders bear some, not all, of the detriment from its decisions related to the issues at High Prairie.

Q. Returning to Mr. Arora's rebuttal testimony, on page 13, lines 7-8, Mr. Arora notes that the BTA included provisions "that would compensate us (and ultimately customers) if an ITP could not be obtained." Did those BTA provisions fully compensate customers?

A. No. ** [redacted] ** on June 21, 2021, Ameren Missouri voluntarily ceased all nighttime operations.

Q. On page 8, lines 13-15, Mr. Arora attributes the ** [redacted] **; what else went into that calculation as represented by Ameren Missouri in the CCN case?

A. ** [redacted] **

Q. Were there other provisions of the BTA related to energy production?

A. Yes. Ameren Missouri held back $3 million from the purchase price related to energy production and released the $3 million hold back to the Seller on January 19, 2023. The energy production provision of the BTA contemplated comparing 18-months of generation data to calculate the P50 energy production that would then be compared to the P95 expected generation pre-construction.

Q. Did Ameren Missouri represent that the nighttime operations could impact the Production Guarantee?

A. When asked that question in a data request in the last case, Ameren Missouri stated: ** [redacted] ** CME-s5, includes the response to Staff Data Request 573.2 from ER-2021-0240 and ** [redacted] **

Q. Did Ameren Missouri agree to utilize the 5.0 m/s wind profile for purposes of releasing the Production Guarantee holdback?

A. Yes. As stated on page 20 of the Post-Closing Wind resource Assessment[10], Ameren Missouri agreed to utilize the 5 m/s cut in wind profile:

continued on next page

[10] CME-s6 includes the public response to Staff data request 572.

> Bat curtailment: Actual bat curtailment averaged 36.9%, based on program of stopping all turbines every night regardless of wind speed. As noted in the build transfer agreement, this operational analysis is to be based on operational data, but the assumptions of the preconstruction estimate. The preconstruction estimate included two bat curtailment scenarios, and **during bi-weekly progress calls,** Terra-gen and **Ameren representatives agreed to base the comparison required in the build transfer agreement on the bat curtailment scenario with 5 m/s cut in wind speed.** The future loss factor for bat curtailment **is based on the program assumptions from the preconstruction report**, but estimated from operational data. [Emphasis added.]

Q. On page 17, line 8 of his rebuttal testimony Mr. Arora claims the facility's actual production in 2022 exceeded the P99 assessment of 939,000 MWh.[11] Please explain how that relates to the Post-closing wind resource assessment.

A. It doesn't. Ameren Missouri negotiated its BTA to base the production holdback release on comparing the post-closing P50 assessment to the pre-construction P95 assessment. Later, in phone calls, Ameren Missouri agreed to exclude its voluntary bat curtailment program from that comparison.

The post-closing P50 assessment (1,347.4 GWh/year) reflects not the historical operations (833.8 GWh/year), rather it reflects the calculated bat curtailment loss had Ameren Missouri operated at a 5.0 m/s cut-in speed[12] as shown in Table 5-3 from the Post-Closing Wind Resource Assessment:

[11] It appears that Staff was not provided the P99 assessment referenced by Mr. Arora in the CCN case. *** [redacted] ***

[12] Page 23, Post-closing Wind Resources Assessment: "Historical bat curtailment has been 36.9% annually, based on a program that turns off all turbines every night from 30 minutes before sunset to 30 minutes after sunrise, from 1 April to 31 October, regardless of wind speed. The bat curtailment assumption from the preconstruction report was based on a cut-in wind speed of 5.0 m/s for the same time and calendar period. DNV has therefore used historical SCADA production data and calculated the loss had it operated under with this cut-in setpoint."

Table 5-3 Energy loss factors and projected net energy output

		Preconstruction estimate [1]	Historical[a]	Future	
	Wind farm rated power	400.0	400.0	400.0	MW
	Gross energy output[a]	1,745.8	1,528.0	1,480.0	GWh/annum
1	Wake effect	92.4	100.0	100.0	%
1a	Wake effect internal	92.4	100.0	100.0	% *Inherent*
1b	Wake effect external	100.0	100.0	100.0	% *Inherent*
1c	Future wake effect	100.0	100.0	100.0	% *Not considered*
2	Availability	94.0	92.6	95.5	
2a	Turbine availability (years 3 to 20)	95.2	92.6	96.2	% *Project-Specific*
2b	Balance of plant availability	99.0	100.0	99.3	% *DNV standard*
2c	Grid availability	99.8	100.0	99.8	% *DNV standard*
3	Electrical efficiency	97.5	100.0	100.0	
3a	Operational electrical efficiency	97.5	100.0	100.0	% *Inherent*
3b	Wind farm consumption	100.0	100.0	100.0	% *Inherent*
4	Turbine performance	95.9	97.1	98.0	
4a	Generic power curve adjustment	100.0	100.0	100.0	% *Inherent*
4b	High wind speed hysteresis	100.0	100.0	100.0	% *Inherent*
4c	Site-specific power curve adjustment	97.9	100.0	100.0	% *Inherent*
4d	Suboptimal performance	99.0	97.1	99.0	% *Project-Specific*
4e	Blade and turbine degradation (years 3 to 20)	99.0	100.0	99.0	% *Partially Inherent*
5	Environmental	98.5	100.0	98.5	
5a	Performance degradation – icing	99.5	100.0	99.5	% *Project-Specific*
5b	Icing shutdown	99.0	100.0	99.0	% *Project-Specific*
5c	Temperature shutdown	100.0	100.0	100.0	% *Inherent in 2a*
5d	Site access	100.0	100.0	100.0	% *Inherent in 2a*
5e	Tree growth / felling	100.0	100.0	100.0	% *Not considered*
6	Curtailments	99.2	61.4	99.0	
6a	Grid curtailment[b]	100.0	97.6	100.0	% *Not considered*
6b	Bat curtailment[c]	99.2	63.1	99.0	% *Customer requested*
6c	Noise, visual and environmental curtailment	100.0	100.0	100.0	% *Not considered*
	Net Energy Output	1,387.8	833.8	1,347.4	GWh/annum
	Net Capacity Factor	39.6	23.8	38.2	%

a. Historical values represent the period of data analyzed by DNV: 1 January 2021 through 30 June 2022.
b. Grid curtailment based on preconstruction report assumption.
c. Bat curtailment estimated from operational data based on preconstruction report assumptions.

In this case, Mr. Arora is arguing that the 5.0 m/s profile is not the appropriate comparison for rate making purposes[13] - but it is a reasonable profile to release the production holdback to the Seller. Mr. Arora argues that signatories are bound to the Stipulation and

[13] Contradicting other Ameren Missouri witnesses.

Agreement – which was based on a BTA *** [redacted] *** Mr. Arora argues that the Commission can only consider what Ameren Missouri knew or reasonably should have known at the time it signed the BTA[14] – but that positon ignores its decisions related to voluntary curtailments and ** [redacted]. **

Q. On pages 19-21 of Mr. Arora's rebuttal testimony, he criticizes Staff's position on High Prairie and its recent testimony in the Boomtown[15] CCN case. How do you respond?

A. Staff has recommended an adjustment related to High Prairie and Rush Island in this case. Both issues are similar in that Ameren Missouri has made decisions that have impacted its ability to operate both facilities – reducing the energy produced directly by Ameren Missouri and the revenues received from the MISO market for that energy.

Staff is not the Great and Powerful Oz, the man behind the curtain.[16] Staff's role is to provide the Commission an unbiased recommendation based on the facts and circumstances of each particular case. Mr. Arora is right - there is a connection to the arguments presented in the Boomtown case and this rate case related to High Prairie and also Rush Island. In the Boomtown CCN case, Mr. Arora argued need for the Boomtown project is demonstrated by the Company's purported need for energy - driven by the early retirement of Rush Island.[17] The overall energy position of the Company is also impacted by its voluntary curtailment of High Prairie. Staff's recommendations in this case are not in direct contradiction as Mr. Arora alleges. Staff is questioning the reasonableness of the Company's decisions that have resulted in lower generation at both facilities while at the same time asking the Commission to grant it a CCN for approval of another resource on the basis of energy needs. Further, Staff's testimony

[14] Mr. Arora rebuttal testimony page 5, lines 3-5.
[15] Ameren Missouri also cites to Staff's testimony in Evergy's Persimmon Creek wind farm CCN case.
[16] Mr. Arora rebuttal testimony in this case page 21, line 9.
[17] Surrebuttal of Ajay Arora in EA-2022-0245, page 6 line 15 and 21.

in Boomtown is clearly discussing the economic risks that are outside the control of the Company, not the risks brought on by the Company's own decisions.

TRUE-UP DIRECT TESTIMONY

Q. What is the purpose of your True-up direct testimony?

A. The purpose of my True-up direct testimony is to update Staff's recommended adjustments related to High Prairie and Rush Island with known and measurable changes through December 31, 2022.

Q. How have you updated the High Prairie adjustment?

A. Staff's market prices have been updated which are an input into my adjustment. The table below presents Staff's quantification of the lost off-system sales revenue, PTCs, and RECs at true-up direct[18] due to Ameren Missouri's voluntary curtailment at High Prairie:

Lost Off-system sales Revenue	$14,526,194
Lost PTCs	$14,754,013
Value of lost RECs	$2,890,841

Q. How have you updated the Rush Island adjustment?

A. As part of its production cost modeling in this case, Staff modeled the Ameren Missouri generating resources (1) with Rush Island units operating as normal and (2) with Rush Island operating as a SSR. As discussed by Staff witness Shawn E. Lange, PE, the production cost model has been updated to incorporate known and measurable changes as of December 31, 2022. The results of the production cost model provide the expected generation from these two scenarios.

[18] July 2021 was the first full month of nighttime curtailment at High Prairie.

Staff then calculated a net capacity factor for each unit under these scenarios (i.e. the modeled generation for the test year divided by the expected generation at the average net capability). The comparison of these two scenarios results in a reduction in the units capacity factor of ** [redacted] ** when operating as an SSR. Staff reduced the rate base associated with Rush Island by this percentage.

Q. Is it Staff's understanding that Ameren Missouri will receive compensation from MISO under Schedule 43K for operating Rush Island as a reliability backstop?

A. Yes. Based on the response to Staff data request 459, Ameren Missouri records the SSR settlements in FERC account 555. Staff expects these settlements will flow through the FAC. At this time, it appears Ameren Missouri has not proposed MISO Schedule 43K to be listed in its FAC tariff.

Q. Does this conclude your Surrebuttal and True-Up Direct Testimony?

A. Yes it does.

BEFORE THE PUBLIC SERVICE COMMISSION

OF THE STATE OF MISSOURI

In the Matter of Union Electric Company d/b/a Ameren Missouri's Tariffs to Adjust Its Revenues for Electric Service	)))	Case No. ER-2022-0337

AFFIDAVIT OF CLAIRE M. EUBANKS, PE

STATE OF MISSOURI)
) ss.
COUNTY OF COLE)

COMES NOW CLAIRE M. EUBANKS, PE and on her oath declares that she is of sound mind and lawful age; that she contributed to the foregoing *Surrebuttal/True-Up Direct Testimony of Claire M. Eubanks, PE*; and that the same is true and correct according to her best knowledge and belief.

Further the Affiant sayeth not.

Claire M Eubanks

CLAIRE M. EUBANKS, PE

JURAT

Subscribed and sworn before me, a duly constituted and authorized Notary Public, in and for the County of Cole, State of Missouri, at my office in Jefferson City, on this 10th day of March 2023.

D. SUZIE MANKIN
Notary Public - Notary Seal
State of Missouri
Commissioned for Cole County
My Commission Expires: April 04, 2025
Commission Number: 12412070

D Suzie Mankin

Notary Public

MISSOURI PUBLIC SERVICE COMMISSION

INDUSTRY ANALYSIS DIVISION

ENGINEERING ANALYSIS DEPARTMENT

CLAIRE M. EUBANKS, PE

SURREBUTTAL/TRUE-UP DIRECT

SCHEDULE CME-s1

through

SCHEDULE CME-s7

UNION ELECTRIC COMPANY,
d/b/a AMEREN MISSOURI

CASE NO. ER-2022-0337

Jefferson City, Missouri
March 2023

*** Denotes Highly Confidential Information ***

** Denotes Confidential Information **

SCHEDULE CME-s1

HAS BEEN DEEMED

CONFIDENTIAL

IN ITS ENTIRETY

SCHEDULE CME-s2

HAS BEEN DEEMED

HIGHLY CONFIDENTIAL

IN ITS ENTIRETY

SCHEDULE CME-s3

SCHEDULE CME-s4

and

SCHEDULE CME-s5

HAVE BEEN DEEMED

CONFIDENTIAL

IN ENTIRETY

Ameren Missouri's
Response to MPSC Data Request - MPSC
ER-2022-0337
In the Matter of Union Electric Company d/b/a Ameren Missouri's Tariffs to Adjust Its Revenues for Electric Service

No.: MPSC 0572

(1) Please provide the payment date, payment reason, and journal entries for payments Ameren Missouri has made post-closing to the developer for the High Prairie Renewable Energy Center.
(2) Did Ameren Missouri Release the Production Holdback of $3 million pursuant to Article 8 of the BTA? Provide all supporting documentation related to the performance assessment.
Requested by Claire Eubanks Claire.Eubanks@psc.mo.gov

RESPONSE

Prepared By: Christine Brinkmann
Title: Manager, Renewables Construction
Date: March 3, 2023

(1) Ameren Missouri made two (2) post-closing payments to the developer for the High Prairie Renewable Energy Center. The two (2) payments are detailed below.

- **a.** The first post-closing payment made to the developer for the High Prairie Renewable Energy Center was made on **January 19, 2021, in the amount of $645,224.85 for Test Power generated prior to Ameren Missouri's project acquisition and Commercial Operations.**
  See attached journal entry "TG High Prairie post-close payment (Test Power) 1-19-21"

- **b.** The second post-closing payment made to the developer for the High Prairie Renewable Energy Center was made on **January 12, 2023, in the amount of $3,000,000 for Production Holdback.**
  See attached journal entry "TG High Prairie post-close payment (Production Holdback) 1-12-23"

(2) Ameren Missouri released the Production Holdback of $3 million pursuant to Article 8 of the BTA on January 12, 2023.

- a. Please refer to the response above for journal entry information.

b. The supporting documentation, specifically the "Post-Close Wind Resource Assessment" performed by the developer's third-party engineer, DNV, is attached and reflects the P50 Energy Production of the Project (as identified in the Post Closing Wind Resource Assessment) is equal to or greater than the P95 Energy Production identified in the Initial Wind Resource Assessment (the “Purchase Price Production Guarantee”) thereby achieving the Purchase Price Production Guarantee.

HIGH PRAIRIE WIND PROJECT

Technical Note: Long-term Energy Production

TG High Prairie Holdings, LLC

Document No.: 10371653-HOU-T-01
Date: 21 December 2022
Issue: D, **Status:** Final

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Project name:	High Prairie Wind Project	DNV Energy USA Inc.
Technical note title:	Technical Note: Long-term Energy Production	101 Station Landing, Suite 520,
	TG High Prairie Holdings, LLC	Medford, MA 02155 USA
Customer:	11455 El Camino Real Ste 160,	Tel: +1 518-530-6973
	San Diego, CA	Enterprise No.: 23-2625724
Contact person:	Yuanlong Hu	
Date of issue:	21 December 2022	
Proposal reference.:	231263-HOU-P-01-B	
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Issue:	D	
Status:	Final	

Task and objective:

This technical note presents the results of an operating assessment for the High Prairie wind energy project.

Prepared by:	Verified by:	Approved by:
Brian Kramak Senior Energy Analyst	Elizabeth Traiger Team Lead, Wind Energy Assessments	Adnan Shah Team Lead, Wind Energy Assessments
	Arthur Burden Energy Analyst	Onur Kaprol Head of Section, Wind Energy Assessment

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Version	Date	Reason for Issue	Prepared by	Verified by	Approved by
A	09 November 2022	Initial release	B. Kramak	A. Burden, E. Traiger	A. Shah, O. Kaprol
B	15 November 2022	Address client comments	B. Kramak	E.Traiger	O. Kaprol
C	6 December 2022	Typographical edits	B. Kramak	E.Traiger	O. Kaprol
D	21 December 2022	Final release	B. Kramak	E.Traiger	O. Kaprol

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1 INTRODUCTION

This technical note is issued to TG High Prairie Holdings, LLC ("TG High Prairie") pursuant to a written agreement arising from proposal 231263-HOU-P-01-B High Prairie Operational Energy Assessment, dated 9 May 2022.

The High Prairie project ("High Prairie" or the "Project") in Missouri has been operational since December 2020. TG High Prairie has engaged DNV to carry out an analysis of the long-term energy production of the Project based on the Project's historical production and the assumptions in the preconstruction report [1] regarding bat and grid curtailment. The results of the work are reported herein.

The location of the High Prairie site is shown in Figure 1-1. The Project consists of 163 Vestas V120-2.2 MW turbines, and 12 Vestas V112-3.45 MW turbines, for a total of 175 turbines and an installed capacity of 400 MW.

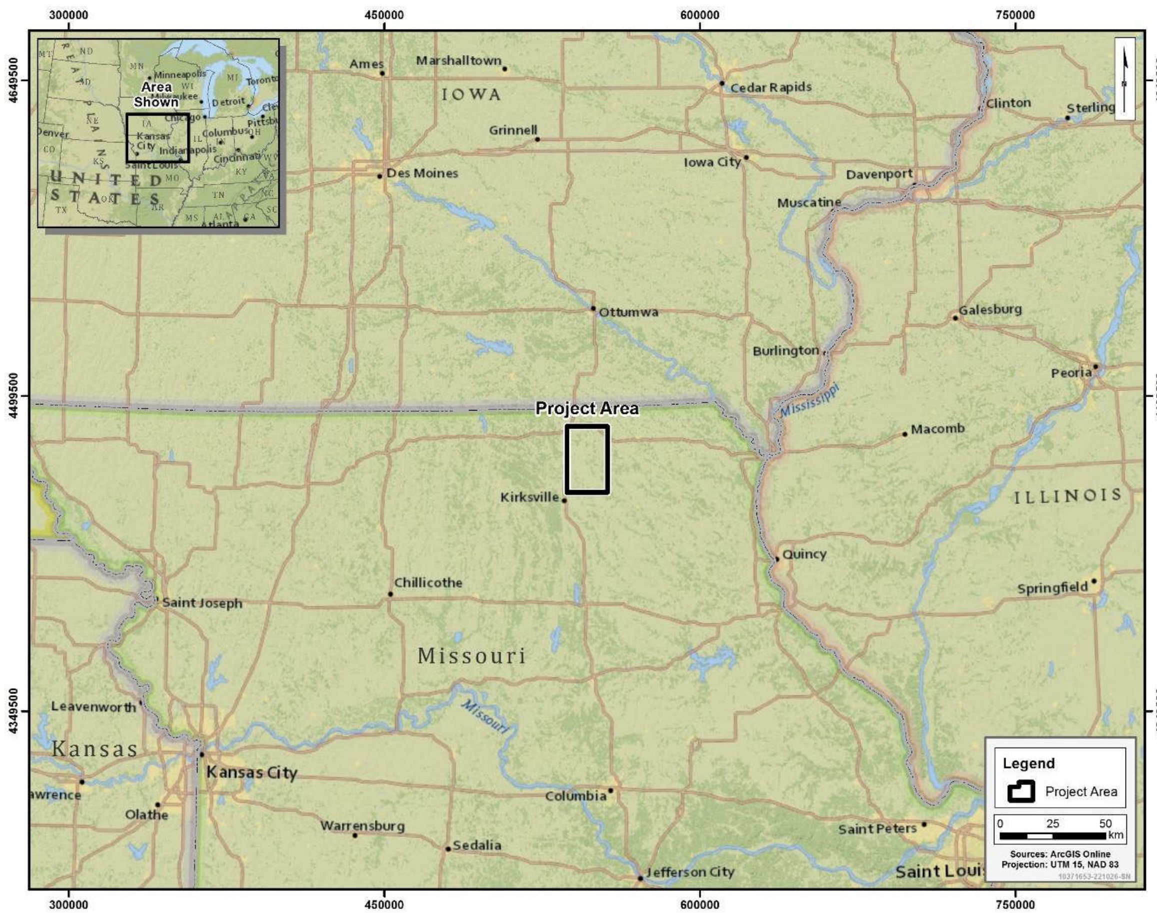

Figure 1-1 Location of the High Prairie site

The wind farm production has been combined with regional long-term wind speed datasets to extend the period of reference. DNV has obtained and analyzed data from several meteorological stations. Analysis of the reference data is discussed in Section 5.2.

2 DESCRIPTION OF THE WIND FARM

The High Prairie site is located in Adair and Schuyler counties, Missouri, approximately 220 km northeast of Kansas City. The Project site is located on relatively simple terrain with low rolling hills. Turbine base elevations range from approximately 255 m to 305 m above sea level, with elevations decreasing gradually from the northwest to the southeast. Ground cover comprises crops, grassland, and forested streambeds with average tree heights of 10 m. The Project consists of 175 Vestas turbines: 12 V112-3.45 MW turbines at a hub height of 94 m and 163 V120-2.2 MW turbines at a hub height of 92 m. The Project commenced commercial operation 20 December 2020.

A map of the Project layout is presented in Figure 2-1, showing the turbine and permanent met mast locations. These masts were used for performance testing, and also for the nacelle transfer functions discussed in section 3.1.5.

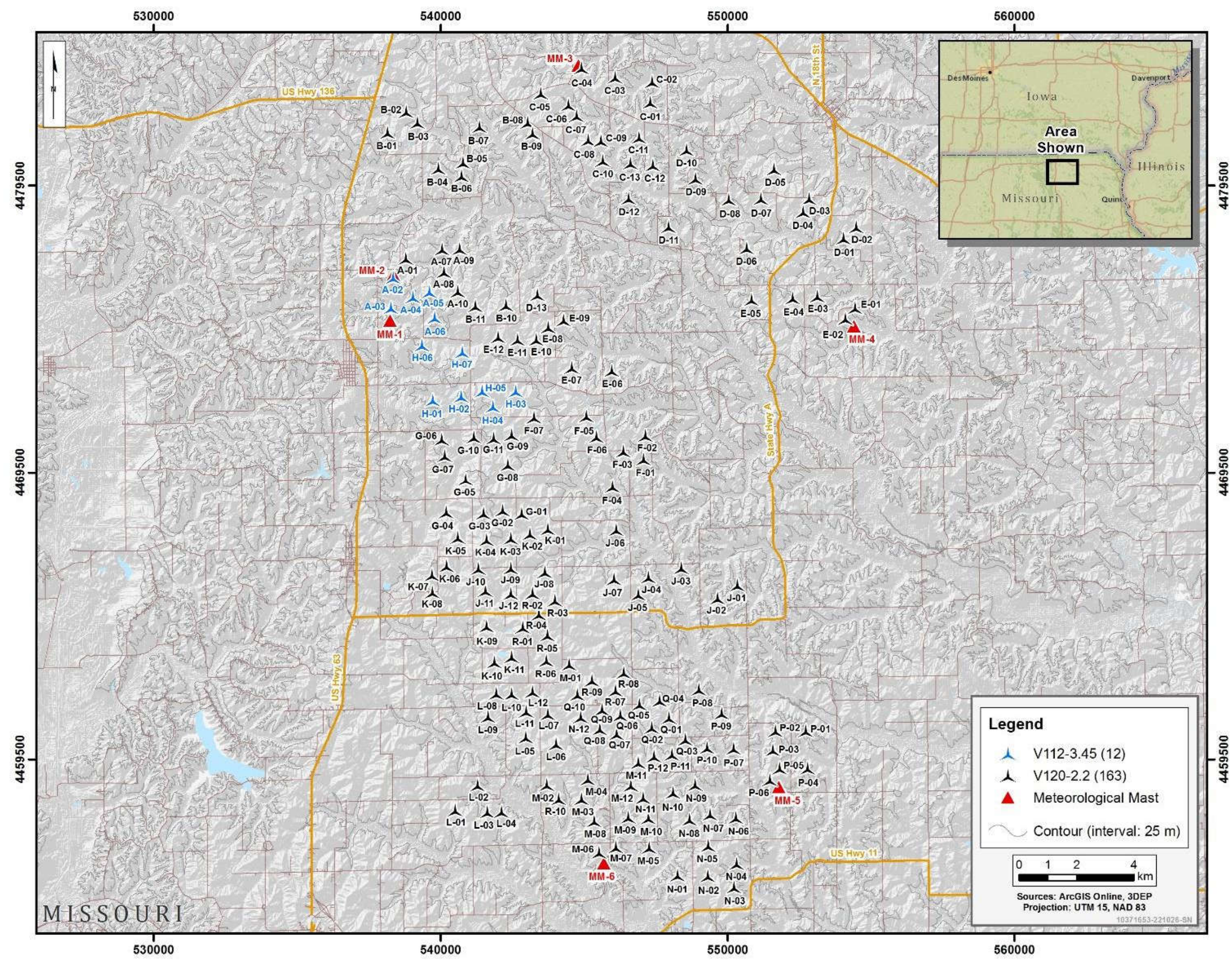

Figure 2-1 Layout of the High Prairie site

DNV has reviewed publicly available data sources [6] and has not identified any installed or planned wind farms that pose external wake risk that impact the results of this analysis.

3 DESCRIPTION OF ON-SITE DATA SUPPLIED

3.1 Production data supplied

TG High Prairie has supplied the following Project data for this review [4]:

- PDF and xlsx files of manufacturer monthly operating reports from January 2021 through June 2022;
- CSV files with raw 10-minute SCADA data providing average values for power, nacelle wind speed 1 and 2 and absolute wind direction, blade pitch, nacelle position, rotor speed, and generator speed from 1 January 2021 through 30 June 2022;
- CSV file with average windspeed from Vestas controllers
- CSV files with event logs for each turbine, with event start/stop time;
- CSV file with site curtailment signal (separate from curtailment events in event logs) indicating plant output limit in MW (0-400);
- CSV files with met mast 10-minute wind speed, direction, ambient temperature and air pressure at multiple levels for 6 masts paired to 8 turbines undergoing performance testing by DNV;
- CSV files with 15-minute utility-metered production at the point of interconnection with the grid from 23 December 2020 through 30 June 2022.

The monthly operating reports summarize the wind farm performance from the manufacturer's perspective and generally agree with DNV aggregate data values. The reports were not otherwise relied upon in this analysis, which focused on the SCADA data.

To consistently consider full months, only data from 1 January 2021 through 30 June 2022 were considered in the SCADA analysis.

3.1.1 Turbine SCADA data cleaning

The turbine SCADA signals have been subject to DNV's quality control method to identify records that were affected by measurement equipment malfunction or other anomalies.

Initial estimates of missing wind speed data based on nacelle anemometer 1 and 2 readings ranged from 2.1% for the southern group of V120 turbines to 5.2% for the V112 turbines. When DNV expressed concern about the high data loss, Ameren provided the windspeed_avg signal that includes logic for filling in missing data. Nacelle wind speed for the remainder of the analysis is based on this windspeed_avg signal, not windspeed_1 or windspeed_2 signals, also provided.

The turbine state in each 10-minute period was classified through a review of the turbine power and nacelle wind speed. SCADA measurements that fell into the following categories were noted and excluded from the analysis:

- **Null or out of range values –** Periods where the turbine nacelle wind speed or power values were outside the expected normal range.
- **Repeated samples at the same time stamp –** Multiple SCADA records were available for each time stamp per turbine when only one was expected. DNV randomly retained only one record during such periods and excluded all other samples.

- **Signal repeating over consecutive time stamps** – Periods where the same wind speed or power signal repeated for three or more 10-minute records.

Through this process, approximately 0.1% of the data were removed from the dataset. **Errant and missing wind speed measurements were replaced with a site average wind speed measurement, adjusted to the turbine location.**

3.1.2 Data coverage

Turbine SCADA data coverage was calculated by dividing the total number of valid wind speed and power records by the expected 10-minute periods in the analysis. The wind farm data coverage averaged across all turbines between 1 January 2021 through 30 June 2022, was 98.3%. SCADA data coverage on operating wind farms is typically between 97% and 100%.

Monthly wind farm data coverage is listed in Table 3-1.

Table 3-1 Turbine SCADA data coverage

Month	Data coverage [%]
Jan 2021	96.5
Feb 2021	95.8
Mar 2021	94.7
Apr 2021	98.2
May 2021	99.4
Jun 2021	98.4
Jul 2021	95.4
Aug 2021	99.5
Sep 2021	99.7
Oct 2021	99.4
Nov 2021	99.7
Dec 2021	98.5
Jan 2022	95.3
Feb 2022	98.7
Mar 2022	99.7
Apr 2022	99.7
May 2022	99.3
Jun 2022	98.7
Average	**98.3**

3.1.3 Data processing

DNV has identified periods when turbines were not performing as expected through a detailed review of the turbine SCADA data. DNV's standard turbine performance analysis includes an inspection of the turbine's nacelle wind speed, power, rotor speed, blade pitch, and turbine status signals, when available. The turbine performance in each 10-minute period is then classified as normal, unavailable, suboptimal, or over-rated as follows:

- **Normal** – Turbine was behaving as expected.
- **Unavailable** – Periods between cut-in and cut-out wind speed when the turbine was not producing power. This represents periods of downtime regardless of the source. If a curtailment signal is available, curtailed downtime will be re-classified as curtailment.
- **Suboptimal** – Turbine was generating power at a lower level than expected for the given wind speed.

During preconstruction estimates for this site, DNV is aware that Vestas V120-2.0 and Vestas V120-2.2 turbine options were both considered, but the V120-2.2 was finally selected and installed. It appears from a cursory review of the SCADA data that many of the installed V120 turbines operated with a 2.0 MW maximum power rating for extended periods of time. DNV estimates the expected gross energy based on 2.2 MW turbines being installed.

The major periods of unavailability, suboptimal and over-rated power are described in the availability and performance statistics presented in Section 4.1.

3.1.4 Establishing expected turbine production

For every period when turbines were not operating normally, the expected production for the 10-minute record was calculated. With this measure, DNV calculates the energy loss associated with abnormal performance as well as the production of the wind farm had the turbines all been performing normally. The expected production and energy loss for each 10-minute record of non-normal performance was established through the following steps:

- Typically, a monthly binned Nacelle Anemometer Power Curve (NAPC) is developed for each turbine based on all 10-minute periods of normal performance. The NAPCs are established using density-adjusted nacelle anemometer wind speeds and the corresponding turbine power.
- For this analysis DNV followed an alternative process, first creating nacelle transfer functions (NTFs) which allowed adjusting nacelle anemometer measured wind speed to free-stream wind speed. Second, the NTF and density adjusted wind speed is used to look up expected power on the average wind turbine performance test result power curve for this site. We will refer to these as performance test average power curves (PTAPCs). This method was used as more than 11% of the V120 2.2 MW turbines do not reach the rated power of 2.2 MW for several months of the evaluation period. DNV’s method for creating NTFs is explained in section 3.1.5 and A.4.2.
- The expected power was estimated for each record when the turbine production was not normal. The free stream adjusted nacelle wind speed of the concurrent record was used to look up the expected power from the PTAPCs.
- The power loss of non-normal performance was calculated as the expected power from the monthly NAPC minus the actual turbine power for the 10-minute record.

By this method, DNV calculated the energy lost or gained from under- or over-performance of each turbine as well as the Project’s gross energy for the SCADA review period. These topics are discussed in greater detail in subsequent sections.

3.1.5 Nacelle transfer function

The turbines used to create the NTFs are the turbines undergoing performance testing, summarized in Table 3-2 below.

Table 3-2 Test turbine pairs

Test pair	Met Mast	Turbine model	Turbine	Valid sector start [°]	Valid sector end [°]
1	1	V112	A03	275	325
2	2	V112	A02	165	225
3	3	V120	C04	275	25
4	4	V120	E02	155	225
5	4	V120	E01	155	192
6	5	V120	P05	105	205
7	5	V120	P06	115	192
8	6	V120	M06	115	225

DNV considered both linear and non-linear models and selected the generalized additive model (GAM) with the lowest error for use in this analysis. The GAM selected yields a 2.0% to 4.5% improvement in R-squared over simple linear models.

The NTF and air density adjusted wind speeds were used with the average wind turbine performance testing results per turbine model to estimate possible power for all turbines, for the entire operating period.

4 AVAILABILITY AND PERFORMANCE REVIEW

The availability, turbine performance, grid and bat curtailment imposed at the Project have been reviewed over the SCADA review period from 1 January 2021 through 30 June 2022.

4.1 Availability

Monthly reported availability figures for the 18-month period from January 2021 through June 2022 were provided in the turbine manufacturer monthly operational reports. Based on information provided by Vestas, DNV understands that the reported availability is energy-based and reflects turbine downtime without grid or bat curtailment. Monthly reported availability figures are shown in Table 4-1.

Also, shown in Table 4-1 is the energy-based availability which was calculated by DNV using the provided 10-minute SCADA data. These availability calculations and results are discussed in the following two sub-sections.

4.1.1 Energy-based availability

In DNV's energy-based availability, the energy loss associated downtime, is measured using the PTAPC, as defined in Section 3.1.4. For every 10-minute period when the turbine is shut down, the loss in energy at the given wind speed of the outage is estimated using the PTAPC. By this method, all non-curtailment downtime was calculated based on the following definition.

Energy-based availability is defined as:

$$\text{Energy-based availability} = \frac{\text{Estimated total energy} - \text{Estimated lost energy due to downtime}}{\text{Estimated total energy}}$$

where:

- **Estimated lost energy due to downtime** is the sum of energy that could have been produced had the turbine been running normally based on the nacelle wind speed.
- **Estimated total energy** is the ideal energy that could have been produced had the turbine been operating with expected efficiency and no curtailment based on the nacelle wind speed.

Energy-based availability, per the equation above, was calculated by aggregating the energy across all turbines for each month of the operational/SCADA review period.

To account for lower SCADA coverage in some months, the above availability was adjusted based on the difference between the energy production measured by the SCADA system and the production at the utility meter where data coverage is assumed to be 100% as described in Appendix A.

The average energy-based availability adjusted for data coverage over the operational/SCADA review period was 92.6% for the period from 1 January 20211 through 30 June 2022. Monthly energy-based availability values are presented in Table 4-1 and Figure 4-1 below. Note that losses due to curtailment where turbines were shut down are not included in these availability numbers. Curtailment is further discussed in Section 4.3.

4.1.2 Availability summary

Monthly availability figures are shown in Table 4-1.As can be seen in Figure 4-1, energy-based availability tracks closely with manufacturer reported availability.

Table 4-1 Reported and estimated availability

Month	Vestas reported turbine availability [%]	DNV Energy-based availability[a] [%]
Jan 2021	74.2	76.4
Feb 2021	83.3	85.5
Mar 2021	87.5	88.1
Apr 2021	88.7	89.8
May 2021	93.8	95.1
Jun 2021	92.5	91.6
Jul 2021	85.9	87.7
Aug 2021	94.5	94.3
Sep 2021	94.1	95.5
Oct 2021	95.0	96.6
Nov 2021	95.9	95.7
Dec 2021	97.0	93.2
Jan 2022	96.6	90.6
Feb 2022	98.0	94.5
Mar 2022	97.5	95.9
Apr 2022	97.1	95.0
May 2022	96.2	95.1
Jun 2022	93.8	93.1
Average[b]	**93.1**	**92.6**

a. DNV availability is adjusted for data coverage.
b. Average considers all data from 1 January 2021 through 30 June 2022 and is seasonally normalized.

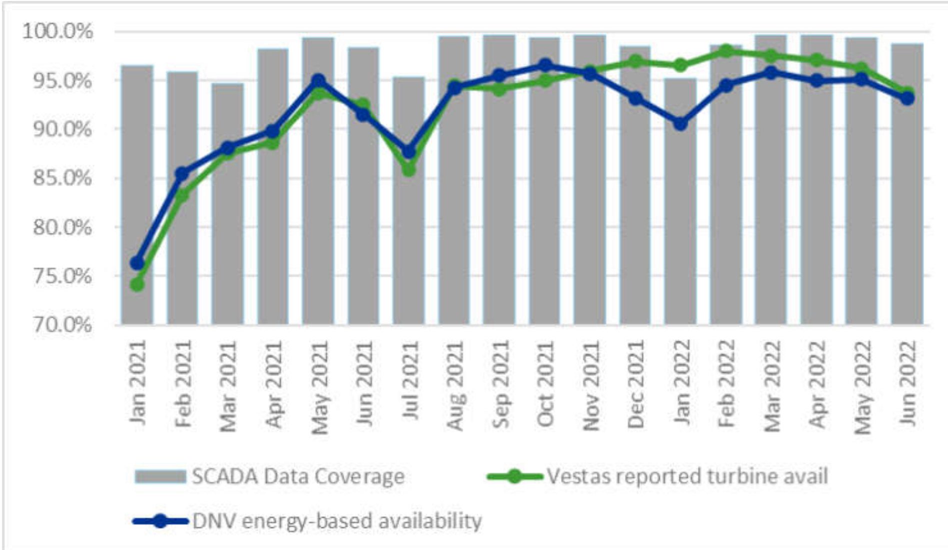

Figure 4-1 Availabilities and data coverage at the High Prairie site

4.1.3 Downtime review

The main sources of downtime were noted by DNV through a review of the monthly operating reports and SCADA data. The main source of downtime is bat curtailment, under "pause without curtailed" Vestas tracking category. Turbine specific issues have decreased from COD through the first six months of operation. Vestas excludes "Pause without curtailed" from their reported availability. The bat and grid curtailment portions of this are not included in the DNV availability, but other time under "pause without curtailed" is included as downtime.

A review of the Vestas monthly reports shows other significant downtime is associated with control signals:

- 703: Grid voltage outside defined tolerances (Dec 2021, Feb 2022)
- 975: Slip ring temp differential (Jan 2022)
- 3621: Converter disconnected during production (Jan 2022)
- 556: Grid inverter filter overload (June 2022)
- 6290,3009, 5067, 6293: Hydraulic pitch system issues (throughout evaluation period)

4.2 Turbine performance

In the review of the NAPCs at each turbine, any period of non-normal operation was identified, and the amount of energy lost or gained was calculated using the procedures outlined in Section 3.1.4. The issues identified through this review include icing, derating, and wind turbine parameter changes.

DNV has identified icing, derating, and wind turbine parameter changes amounting to a total of 2.9% loss in expected production, or a loss factor of 97.1%, between 1 January 2021 through 30 June 2022 across the entire Project. The overall production loss factor is summarized by month in Table 4-2.

Icing was identified on multiple occasions within the winter months of 2021 and 2022. Icing resulted in both turbine shutdown and performance degradation, which are factored into the overall availability and performance degradation. Icing is identified when ambient temperatures are near or below freezing and multiple turbines experience a decline in turbine efficiency. Additional characteristics of icing are identified and differentiated from other forms of underperformance. DNV first applied Vestas event log “environmental” for offline availability and online performance impact, then added DNV estimated icing shutdown and performance degradation impact. The total environmental losses (primarily icing) were 1.0% loss or 99.0% loss factor.

Turbine derating occurs when the turbine maximum power is reduced below the turbine’s standard rated power. Derating may result from multiple factors, either internal or external to the turbine. Turbines may be derated to comply with a wind farm curtailment command. If curtailment is the known cause of derating, DNV will re-classify the event accordingly. Derating may also be implemented by the turbine control system or a technician in response to a turbine malfunction or to prevent overheating or damage to turbine components.

For this analysis, derating also includes times when the V120-2.2 turbines were operated with a maximum power of 2.0 MW. At the end of the evaluation period in June 2022, all turbines were operating at 2.2 MW. As more than 11% of the V120 turbines operated for several months during the evaluation period at 2.0 MW instead of 2.2 MW, DNV opted to use calculated NTFs described in section 3.1.5 and the actual average results of performance testing for power curves as a basis for expected power, as noted in section 3.1.4. DNV has estimated that derating has amounted to an energy loss of 1.9% over the SCADA review period, or a loss factor of 98.1%.

The following turbines were impacted by issues including derating:

- C06, L06, M09 – did not operate at 2.2 MW until Q2 2022. Up until then, they are limited to 2.0 MW, a 10% shortfall.
- A01, A09, A10, B08, D07, D11, E02, E09 – operate at 2.0 MW for Q2, 3, 4 2021, including all of Q3
- C03 did not go online until Q2 2021
- F05, G10, K06, K11, M05, were limited to 1.25 MW for the entirety of one or two quarters
- R04 didn’t operate more than a few hours in Q4-2021
- L05 derated to 50% of rated power for 4 of 6 quarters for significant periods of time

Examples of derating and degradation at turbine A01 are shown in Figure 4-2 below, along with normal performance.

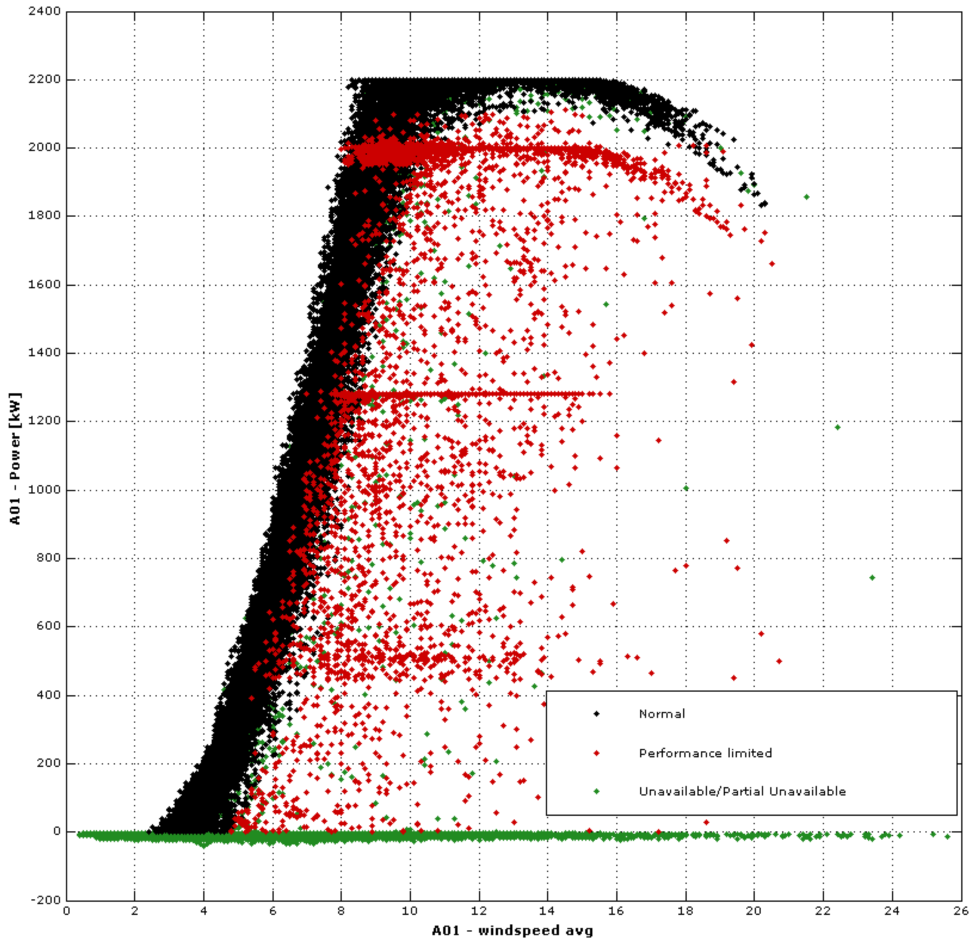

Figure 4-2 Derating and general degraded performance at turbine A01

Table 4-2 Monthly performance loss factors

Month	Total performance related losses [%]	Environmental [%]	Derated/degraded [%]
Jan 2021	93.9	97.7	96.1
Feb 2021	91.0	94.5	96.3
Mar 2021	97.0	99.7	97.3
Apr 2021	97.1	99.5	97.6
May 2021	97.5	99.9	97.6
Jun 2021	96.2	99.7	96.5
Jul 2021	98.2	99.1	99.0
Aug 2021	98.5	99.1	99.4
Sep 2021	98.6	99.4	99.2
Oct 2021	96.4	97.3	99.0
Nov 2021	98.6	99.3	99.2
Dec 2021	97.8	99.8	97.9
Jan 2022	97.4	99.4	98.0
Feb 2022	96.6	98.3	98.3
Mar 2022	96.4	99.4	97.0
Apr 2022	95.7	99.2	96.5
May 2022	98.3	99.7	98.6
Jun 2022	98.7	99.9	98.8
Average[a]	**97.1**	**99.0**	**98.1**

a. Average considers all data from 1 January 20211 through 30 June 2022 and is seasonally normalized.

4.3 Curtailment

Curtailment signals were provided per turbine in the event log as well as in a separate signal at the plant level, which indicated the MW limit of output to the grid. DNV used these signals separately and in tandem to identify offline or underperformance related periods of curtailment.

Significant curtailment was observed within the data for the Project, including 2.4% annual grid curtailment, but primarily bat curtailment at 36.9%, where all turbines were stopped every night from 30 minutes before sunset to 30 minutes after sunrise, from 1 April to 31 October, regardless of wind speed. Table 4-3 below includes the actual grid/bat curtailment compared to the bat curtailment calculated from SCADA data, had the site followed a program where turbines were only offline from cut-in wind speed to 5 m/s during the same period.

Table 4-3 Curtailment

Month	Actual bat curtailment [%]	Actual grid curtailment [%]	Estimated bat curtailment for 5 m/s cut-in wind speed [%]
Jan 2021	0.0	5.5	0.0
Feb 2021	0.0	5.9	0.0
Mar 2021	5.5	5.3	0.0
Apr 2021	37.3	2.5	1.2
May 2021	34.2	11.8	1.8
Jun 2021	39.1	12.4	3.1
Jul 2021	69.5	0.5	5.2
Aug 2021	71.5	4.0	1.0
Sep 2021	77.5	0.0	1.3
Oct 2021	74.7	1.1	2.2
Nov 2021	33.8	0.0	0.0
Dec 2021	0.0	0.0	0.0
Jan 2022	0.0	0.1	0.0
Feb 2022	0.0	1.2	0.0
Mar 2022	19.0	3.8	0.0
Apr 2022	58.0	2.3	0.8
May 2022	54.7	0.2	1.4
Jun 2022	61.9	0.3	1.7
Average loss[a]	**36.9**	**2.4**	**1.0**

a. Average considers data from 1 January 20211 through 30 June 2022 and is seasonally normalized.

5 LONG-TERM ENERGY PRODUCTION

The analysis of the long-term energy production for the site involved several steps which are summarized below:

- Monthly production for the SCADA review period was adjusted to estimate the wind farm production had it operated at 100% availability.
- The wind speeds from the selected reference stations were correlated on a monthly basis to the monthly production data. These correlations were used to derive the predicted long-term gross energy production.
- The net energy production of the wind farm was calculated taking account of availability, bat curtailment, turbine performance, and environmental losses expected over the long-term period. DNV notes that internal wake effects and electrical losses are inherent in the gross energy prediction. A portion of the environmental and turbine performance losses are inherent.
- An assessment of the uncertainty in the predicted wind farm energy production was undertaken.

A more complete description of the methods employed is included in Appendix A. Results for each step of the process are provided in the following sections.

5.1 Adjusted historical gross energy production timeseries

In order to adjust the monthly production of the operating/SCADA review period of the site to estimate the wind farm production had it operated at 100% availability, the following analysis steps were undertaken:

- 10-minute SCADA production data for the operational period of January 2021 through June 2022 were adjusted for any availability or performance gain or loss in each record.
- This 10-minute time series was aggregated to a monthly wind farm metered production time series for 1 January 2021 through 30 June 2022.
- DNV normally filters months with availability or data coverage of less than 85% or curtailment greater than 15%. Applying the typical filters would result in only three months of data to use in the regression, therefore DNV considered all data, without any filter, to have a sufficient operational data period for the analysis. There is therefore elevated uncertainty in the analysis.
- These adjusted production values were normalized by the number of days in each month to provide a monthly time series of mean daily energy production values.
- The mean of the predicted production for each calendar month was determined from the averages of monthly production. Summing the resulting values for every month in the year yields the annual estimate of gross energy production.

The resulting adjusted historical gross energy production is 1,528.3 GWh/year.

5.2 Extension of the site period to the reference period

When assessing the wind regime at a wind farm, it is desirable to correlate the production data recorded on site with wind speed data recorded at a nearby long-term reference meteorological station. Production data are often only available for a short period and such correlation is required to ensure that the estimates of the production of the Project are representative of the long term.

5.2.1 Reference data considered

DNV has undertaken an extensive review of sources of meteorological data surrounding High Prairie in order to choose the most appropriate sources of long-term reference data for the energy assessment. Listed in Table 5-1 are the locations of potential sources of long-term reference wind speed data for this analysis.

Table 5-1 Potential sources of long-term reference wind speed data

Meteorological data source	Network	Distance from site	Start date	End date
MERRA2 40.5N, 92.5W	NASA	10 km	Jan 2000	July 2022
MERRA2 40.5N, 91.875W	NASA	50 km	Jan 2000	July 2022
MERRA2 40.0N 92.5W	NASA	45 km	Jan 2000	July 2022
MERRA2 40.0N, 91.875W	NASA	70 km	Jan 2000	July 2022
MERRA2 40.0N, 92.125W	NASA	70 km	Jan 2000	July 2022
MERRA2 40.5N,93.125W	NASA	55 km	Jan 2000	July 2022
ERA5 40.5N, 92.4W	ECMWF	10 km	Jan 2000	June 2022
ERA5 40.2N, 92.4W	ECMWF	25 km	Jan 2000	June 2022
ERA5 40.2N, 92.7W	ECMWF	30 km	Jan 2000	June 2022
ERA5 40.5N, 92.7W	ECMWF	20 km	Jan 2000	June 2022
Vortex MERRA2	Vortex	On-site	Jan 2000	June 2022
Vortex ERA5	Vortex	On-site	Jan 2000	June 2022

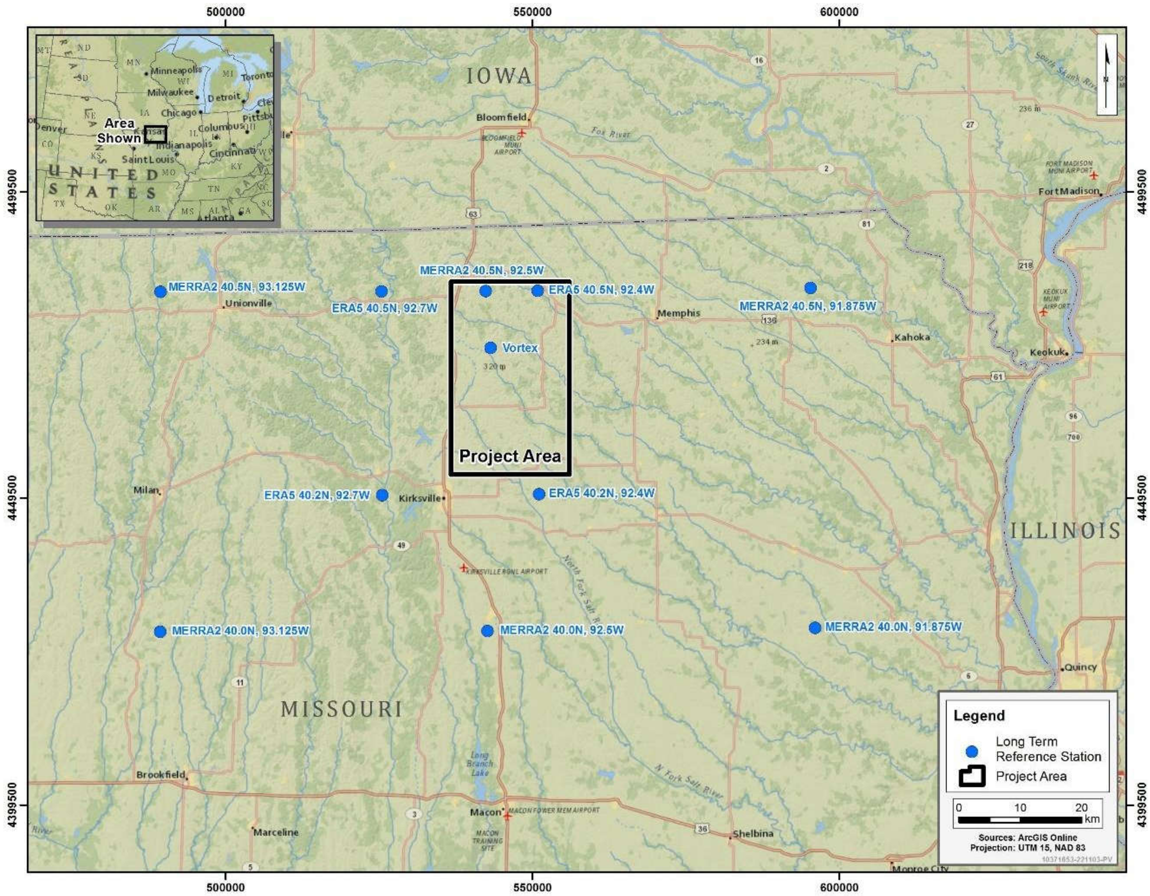

Figure 5-1 Long term references

Further information regarding long-term reference data sources typically used by DNV is included in Appendix C. A review of the suitability and use of these sources of data referenced in the analysis is provided below.

5.2.2 Reference station consistency

The consistency of each source of reference data was evaluated through a comparison to the regional trends and a statistical change point analysis. Figure 5-2 shows a plot of seasonally normalized 12-month moving average wind speeds from example reference data sources considered. The reference sources not included in Figure 5-2 were similar to the sources shown.

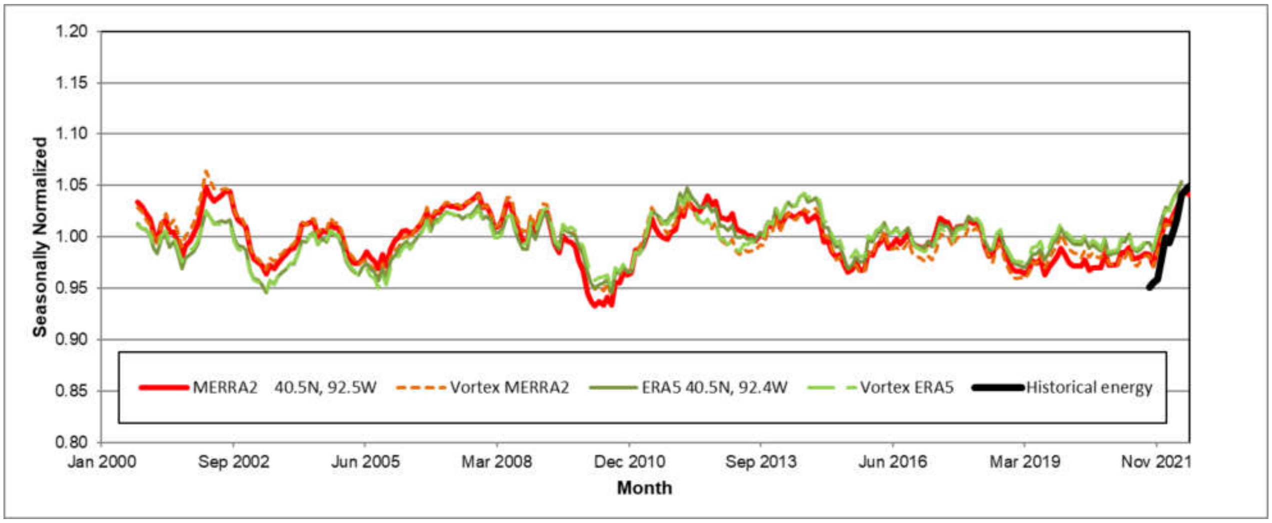

Figure 5-2 Reference data seasonally normalized 12-month moving average wind speeds

A review of general trends for other work in this area, and the relationship between ERA5 and MERRA-2 show consistency issues in relation to ERA5 over time and Vortex MERRA-2 deviations resulted in the selection of only MERRA-2 for a long-term reference.

5.2.3 Quality of correlation

A correlation of monthly mean wind speeds between each relevant reference station and the site production data, corrected for data coverage, availability, curtailment, and performance, has been undertaken, resulting in coefficients of determination (R^2) ranging between 0.94 and 0.97. A procedure was used in an attempt to remove seasonal bias from the correlations as mentioned in Appendix A.4.3.

A summary of the correlations is shown in Table 5-2.

Table 5-2 Summary of correlations to site data

Reference station	Coefficient of determination, R^2
	Monthly
MERRA2 40.5N, 92.5W	0.94
MERRA2 40.5N, 91.875W	0.94
MERRA2 40.0N 92.5W	0.94
MERRA2 40.0N, 91.875W	0.94

DNV's analysis of these results and assessment of the consistency of the measurement period, proximity to the site, and the associated uncertainty corresponding to each potential long-term reference station concludes that the most suitable source of long-term reference data for the High Prairie site is MERRA-2 40.5N, 92.5W. A This data source, representing 22.7 years of valid wind data, have been used in the analysis to define the long-term period.

The long-term reference data indicated the region's wind speeds during the filtered SCADA review were higher than average. The historical gross energy production was therefore adjusted downward by 3.2% to determine the long-term annual gross energy production.

By these methods, the long-term gross annual energy production of the wind farm was calculated as shown in Table 5-3. This value forms the basis of the net projected energy production of the wind farm described in Section 5.3. The uncertainty associated with assuming this period to be representative of the long term is considered in Section 5.4 and Appendix A.

5.3 Long-term net energy production

The projected net energy production of the wind farm under the assumptions of the preconstruction report [1] for grid and bat curtailment is shown in Table 5-3 and has been calculated by applying a number of energy loss factors to the gross energy production calculated in Section 5.2. The predictions represent the estimate of the annual production expected over the next 18 years of operation under the assumptions of the preconstruction report [1] for grid and bat curtailment. A detailed definition of loss factors, including any time dependency, is provided in Appendix B.

DNV

Table 5-3 Energy loss factors and projected net energy output

		Preconstruction estimate [1]	Historical[a]	Future	
	Wind farm rated power	400.0	400.0	400.0	MW
	Gross energy output[a]	1,745.8	1,528.0	1,480.0	GWh/annum
1	Wake effect	92.4	100.0	100.0	%
1a	Wake effect internal	92.4	100.0	100.0	*% Inherent*
1b	Wake effect external	100.0	100.0	100.0	*% Inherent*
1c	Future wake effect	100.0	100.0	100.0	*% Not considered*
2	Availability	94.0	92.6	95.5	
2a	Turbine availability (years 3 to 20)	95.2	92.6	96.2	*% Project-Specific*
2b	Balance of plant availability	99.0	100.0	99.3	*% DNV standard*
2c	Grid availability	99.8	100.0	99.8	*% DNV standard*
3	Electrical efficiency	97.5	100.0	100.0	
3a	Operational electrical efficiency	97.5	100.0	100.0	*% Inherent*
3b	Wind farm consumption	100.0	100.0	100.0	*% Inherent*
4	Turbine performance	95.9	97.1	98.0	
4a	Generic power curve adjustment	100.0	100.0	100.0	*% Inherent*
4b	High wind speed hysteresis	100.0	100.0	100.0	*% Inherent*
4c	Site-specific power curve adjustment	97.9	100.0	100.0	*% Inherent*
4d	Suboptimal performance	99.0	97.1	99.0	*% Project-Specific*
4e	Blade and turbine degradation (years 3 to 20)	99.0	100.0	99.0	*% Partially inherent*
5	Environmental	98.5	100.0	98.5	
5a	Performance degradation – icing	99.5	100.0	99.5	*% Project-Specific*
5b	Icing shutdown	99.0	100.0	99.0	*% Project-Specific*
5c	Temperature shutdown	100.0	100.0	100.0	*% Inherent in 2a*
5d	Site access	100.0	100.0	100.0	*% Inherent in 2a*
5e	Tree growth / felling	100.0	100.0	100.0	*% Not considered*
6	Curtailments	99.2	61.4	99.0	
6a	Grid curtailment[b]	100.0	97.6	100.0	*% Not considered*
6b	Bat curtailment[c]	99.2	63.1	99.0	*% Customer requested*
6c	Noise, visual and environmental curtailment	100.0	100.0	100.0	*% Not considered*
	Net Energy Output	1,387.8	833.8	1,347.4	GWh/annum
	Net Capacity Factor	39.6	23.8	38.2	%

a. Historical values represent the period of data analyzed by DNV: 1 January 2021 through 30 June 2022.
b. Grid curtailment based on preconstruction report assumption.
c. Bat curtailment estimated from operational data based on preconstruction report assumptions.

Table 5-3 includes potential sources of energy loss that have been calculated, estimated, assumed, or not considered. The background and general basis for all loss estimates is provided in Appendix B. Project specific aspects of the loss estimates which are not included in the Appendix B are listed below:

- External wake effect: There are no external wake considerations for High Prairie at this time.

- Future wake effects: Public records do not indicate new wind farm development in the vicinity of High Prairie.
- Turbine availability: Based on a review of the SCADA data, historical turbine availability has averaged 92.6% since January 2021. Due to the limited period of historical data available at the Project, the projected availability is based on DNV's expectations for the turbine technology and the expectation that availability will be the highest during the next few years before decreasing over the later years of operation. DNV has therefore assumed that turbine availability at High Prairie is 96.5% in 2022 and decreases gradually to 95.3% in 2039, with an average availability of 96.2%. The availability projection is shown in Table B-1.
- Balance of Plant (BoP) and grid availability: Due to the limited period of historical data available at the Project, DNV has determined that standard loss factors of 99.25% and 99.8% are appropriate for the estimation of future BoP and grid availability, respectively.
- Suboptimal performance: Based on a review of the SCADA data, the historical turbine performance loss factor has averaged 99.4% since January 2021. Considering this and given limited period of historical data available at the Project, DNV has instead considered its standard suboptimal loss factor of 99.0% for the future.
- Blade and turbine degradation: DNV applied a loss factor of 99.0%, which accounts for reduced aerodynamic performance caused by continued degradation of the turbine blade surface. This adjustment represents the performance of the turbines in the years 2022-2039 relative to the historical performance; the minor historical loss due to performance degradation is inherent in the gross energy prediction. The performance degradation projection is shown in Table B-1.
- Icing shutdown: Due to the limited period of historical data available at the Project, DNV has used the same environmental loss factor of 98.5% as was used in the preconstruction estimate. Actual environmental losses including icing were 98.9% and are thought to be understated as turbines only operated 60% of the time during the period analyzed.
- Grid curtailment: Based on the data provided by TG High Prairie, High Prairie has experienced decreasing levels of curtailment, with an estimated average loss of approximately 2.4% from January 2021 through June 2022. A comprehensive transmission study would aid in the estimation of future curtailment levels. DNV has made no assumptions regarding future curtailment as historical curtailment levels are not necessarily an accurate predictor of future levels for cases where curtailment decreases continuously over the evaluation period, and not included in the preconstruction estimate, to which this analysis is being compared.
- Bat curtailment: Actual bat curtailment averaged 36.9%, based on program of stopping all turbines every night regardless of wind speed. As noted in the build transfer agreement, this operational analysis is to be based on operational data, but the assumptions of the preconstruction estimate. The preconstruction estimate included two bat curtailment scenarios, and during bi-weekly progress calls, Terra-gen and Ameren representatives agreed to base the comparison required in the build transfer agreement on the bat curtailment scenario with 5 m/s cut in wind speed. The future loss factor for bat curtailment is based on the program assumptions from the preconstruction report, but estimated from operational data.

Other loss factors, such as internal wake effects, existing external wake effects, and electrical losses, are inherent in the production data.

5.4 Uncertainty analysis

The main sources of deviation from the central estimate of the energy prediction for the Project have been quantified and are detailed in Table 5-4. A description of each category and applied methodology is provided in Appendix A.

Table 5-4 Uncertainty in the projected energy output for the High Prairie wind project

Source of uncertainty	[% of net energy]			[GWh/annum]		
Consistency of long-term reference data	1.6			21.8		
Variability of 22.7-year historical period	1.6			22.0		
Availability adjustments	2.6			34.4		
Power curve performance adjustments	0.6			7.8		
Correlations to long-term reference data	2.7			36.5		
Curtailment	0.3			3.9		
Loss factor assumptions	2.0			26.9		
Data resolution	3.0			40.4		
Historical wind rose	1.6			22.0		
Future period under consideration	*1 year*	*10 year*	*18 year*	*1 year*	*10 year*	*18 year*
Future energy variability	8.2	2.6	1.9	110.4	34.9	26.0
Overall energy uncertainty	10.1	6.5	6.2	136.4	87.3	84.1

The sensitivity ratio shows how sensitive the net energy production is to changes in wind speed and is dependent mainly upon the wind speed distribution and power curve of the turbine. For example, with a sensitivity ratio of 1.50, a 2.0% reduction in wind speed at all masts would lead to a 3.0% reduction in net energy production. The calculated sensitivity ratio used to convert wind speed uncertainties to uncertainties on energy is 1.73.

6 CONCLUSIONS AND RECOMMENDATIONS

DNV has reviewed the operational history and available reference wind data at High Prairie. The turbine production data have been reviewed for a 1.5-year period from 1 January 2021 through 30 June 2022. The following conclusions are made regarding the site operational history and long-term wind regime, under the assumptions of the preconstruction estimate [1]:

1. The projected energy capture of the wind farm over the next 18 years of operation is presented in Table 6-1.

Table 6-1 Energy loss summary for High Prairie

Wind farm rated power	**400.0**	**MW**
Gross energy output	1,480.0	GWh/annum
Wake effect [a]	100.0	%
System availability and environmental shutdown	95.2	%
Electrical efficiency [a]	100.0	%
Turbine performance [b]	98.0	%
Environmental [b]	98.5	%
Curtailment [c, d]	99.0	%
Net energy output	**1,347.4**	**GWh/annum**
Net capacity factor	**38.4**	**%**

a. Inherent in the metered production data.

b. Turbine power curve losses are inherent in the metered production. Value shown represents additional suboptimal losses estimated from SCADA data and blade degradation.

c. Historic grid curtailment of 2.4% is not included in this estimate based on the assumptions in the preconstruction report [1].

d. Historic bat curtailment is 36.9%. Future bat curtailment is based on the assumptions in the preconstruction report for the 5 m/s cut-in scenario [1].

This includes the actual wake, electrical, and air density effects and assumptions for long-term availability, turbine performance, environmental, and bat curtailment losses.

There are a number of other losses that could affect the net energy output of the wind farm, as detailed in Table 5-3, but these have not been considered herein. It is recommended that TG High Prairie consider each of these losses and the possible effect they may have on the net energy production.

The net energy prediction presented above represents the long-term mean, P50 exceedance level, for the annual energy production of the wind farm. This value is the best estimate of the long-term mean value to be expected from the Project. There is therefore a 50% chance that, even when taken over very long periods, the mean energy production will be less than the value given.

2. The standard error associated with the prediction of energy capture has been calculated and the confidence limits for the prediction are given in Table 6-2.

Table 6-2 Confidence Limits for High Prairie

Probability of Exceedance [%]	Net Energy Output [GWh/annum]		
	1-year average	10-year average	18-year average
50	1,347.4	1,347.4	1,347.4
75	1,255.5	1,288.6	1,290.7
90	1,172.7	1,235.6	1,239.7
95	1,123.2	1,203.9	1,209.1
99	1,030.2	1,144.4	1,151.8

There are a number of losses and uncertainties for which only pragmatic assumptions have been made at this stage, as detailed in Section 5.4.

As a result of this work, DNV makes the following notes and recommendations:

- The average system availability for the 18-month period, which represents the energy loss while shut down for all sources except for curtailment, has been 92.6% based on the SCADA analysis. Due to the limited period of historical data available at the Project, the projected availability is based on the turbine technology and the expectation that availability will be the highest during the next few years before decreasing over the later years of operation. DNV has not reviewed any changes to the contractual provisions or operations and maintenance details of the Project in order to inform the availability projection. DNV recommends that such a review is undertaken to confirm the availability projections in this technical note.
- Historic grid curtailment has averaged 2.4% during the 18-month operational period. Given the decreasing pattern of grid curtailment over time and that it is not included in the preconstruction estimate to which this analysis is being compared, DNV has not included the impact of future grid curtailment in this analysis.
- Historical bat curtailment has been 36.9% annually, based on a program that turns off all turbines every night from 30 minutes before sunset to 30 minutes after sunrise, from 1 April to 31 October, regardless of wind speed. The bat curtailment assumption from the preconstruction report was based on a cut-in wind speed of 5.0 m/s for the same time and calendar period. DNV has therefore used historical SCADA production data and calculated the loss had it operated under with this cut-in setpoint.
- Turbine under/suboptimal performance was estimated from operational data, after backing out all known causes of “off curve” operation.
- Historic environmental losses including icing were 1.0%. Due to the limited period of historical data available at the Project, future losses are based on preconstruction estimate [1] values of 1.5%.
- There are no neighboring wind sites that might impact external waking. Internal wake losses are inherent in the revenue meter data.
- DNV recommends establishing a program to monitor turbine settings for changes that impact output. A review of the SCADA data suggests more than 11% of the V120-2.2 MW turbines operated at 2,000 kW maximum output (90% of rated), rather than 2,200 kW, for extended periods of time.

- Based on TG High Prairie's instruction, the primary purpose for this scope of work was to establish a P50 annual net energy that could be compared to the 20-year P95 estimate from the preconstruction assessment [1] for the 5 m/s bat curtailment scenario. The operational P50 of 1,347.4 GWh/year is 15.3% higher than the preconstruction 20-year P95 of 1,168.9 GWh/yr. The operational P50 is approximately 2.9% below the preconstruction P50 of 1,387.8 GWh/year with the 5 m/s bat curtailment scenario.

7 REFERENCES

[1] 5.1.3.29 - 27 - Exhibit BB - Initial Wind Resource Assessment.pdf, bat curtailment scenario and associated preconstruction loss assumptions.

[2] 5.1.3.30 - 28 - Exhibit CC - Wind Assessment Methodology (Execution Copy).pdf.

[3] Amended and Restated High Prairie Build Transfer - Blackline.pdf.

[4] DNV High Prairie Data room - https://dnv-my.sharepoint.com/:f:/r/personal/david_deluca_dnv_com/Documents/External/Terra-Gen/High%20Prairie?csf=1&web=1&e=MI9FM2, data uploaded to OneDrive by Kevin Schartner and David Meiners of Ameren, from 4 August 2022 to 16 September 2022.

[5] An Introduction to Statistical Learning (statlearning.com).

[6] Federal Aviation Administration. Circle search for cases, retrieved 14 October 2022 using internal Huracan tool. https://oeaaa.faa.gov/oeaaa/external/searchAction.jsp?action=showCircleSearchForm.

[7] Vestas monthly operating reports May 2021 to July 2022.

APPENDIX A – ANALYSIS METHODOLOGY

The analysis of the long-term energy production of the Projects involved several steps which are summarized below and shown in Figure A-1.

- Monthly metered production data for the SCADA review period of the Project was adjusted by the reported project availability, turbine performance and curtailment factors. This has been done to estimate the 'gross' energy production, as though the Project operated at 100% availability and 100% relative performance, with no curtailment, for the entire period.
- A long-term adjustment was calculated and applied based on correlations of gross energy to monthly wind speeds at the reference stations. The long-term adjustment was applied to the gross metered data to estimate the long-term gross energy.
- The net energy production of the project was calculated considering long-term expectations for sources of downtime not inherent in the grossed-up energy production (assuming 100 availability) including:
  - Future site availability – Due to the limited period of historical data available at the Project, the projected availability is based on DNV's expectations for the turbine technology and the expectation that availability will be the highest during the next few years before decreasing over the later years of operation. DNV has therefore assumed that turbine availability at the High Prairie is 96.5% in 2022 and decreases gradually to 95.3% in 2039, with an average availability of 96.2%, which combined with BoP and grid availability of 99.5% and 99.8% average 95.5%.
  - Performance degradation – DNV applied a loss factor that accounts for reduced aerodynamic performance caused by degradation of the turbine blade surface. This loss also considers suboptimal turbine performance from our previous preconstruction estimate.
  - Environmental losses - This loss factor includes downtime associated with environmental shutdowns, such as icing events and other environmental losses included in our previous preconstruction estimate.
  - Curtailment – A future bat curtailment loss has been estimated for the Project based 5 m/s cut-in wind speed, April 1 to October 31, 30 minutes before sunset to 30 minutes after sunrise, calculated from SCADA data. The estimate is slightly higher than the previous preconstruction estimate.

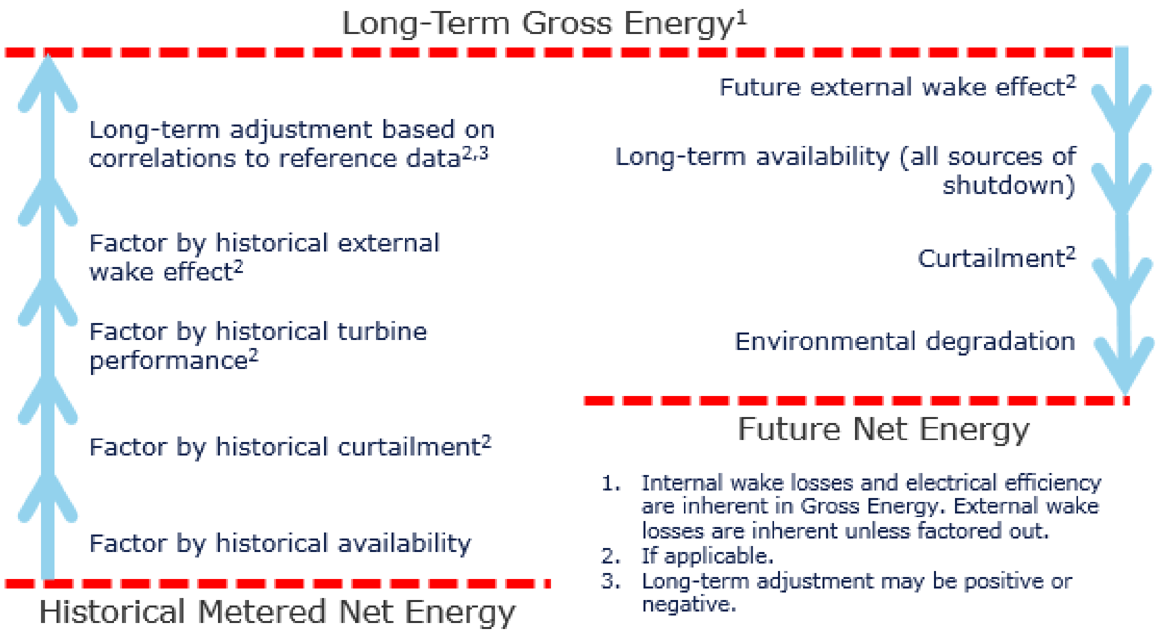

Figure A-1 Flowchart of energy analysis process

A.1 Availability during loss of SCADA communication

It is commonly assumed that the average turbine availability over loss of SCADA communications is the same as for the average during full SCADA communications. In DNV's experience this is often not the case and there are many situations where data loss may result as a consequence of turbine down-time.

DNV has investigated the amount of production observed during periods of loss of SCADA communications by investigating the production metered at the point of grid connection. The data coverage of the metered data at the point of grid connection is assumed to be 100%.

If it is assumed that in a given month that wind speeds, and hence production, are averaged over the period of data loss, an indicative estimate of availability over periods of data loss can be made. It is considered reasonable to assume that SCADA data loss is not strongly correlated to wind speed.

Availability over periods of data loss has been estimated based on a comparison of the sum of the production measured at the base of the turbines, over the period of SCADA data coverage, to the monthly meter readings (100% data coverage). The sum of production at the turbine bases was multiplied by the measured electrical efficiency to ensure that the two measures are comparable.

A.2 Adjusted system availability

The following equations illustrate the calculation made by DNV to estimate the availability during loss of SCADA communications.

If it is assumed that wind speeds and turbine power performance were the same over periods of SCADA communications and periods of no SCADA communications, it would be reasonable to say that the following would be true.

$$\frac{\left(\frac{P_c}{D}\right)}{A_c} = \frac{\left(\frac{P_{lc}}{1-D}\right)}{A_{lc}} \qquad \text{Equation A-1}$$

where:

P_c = sum of turbine production during periods of full SCADA communications [MWh]

D = data coverage of the SCADA system as a percentage of total time [%]

A_c = Availability measured over period of full communications [%]

P_{lc} = sum of turbine production during periods of loss of SCADA communications [MWh]

A_{lc} = availability estimated during periods of loss of SCADA communications [%]

$P_{lc}$and A_{lc} are both unknowns. However, P_{lc} can be estimated by calculating the electrical efficiency of the network and applying the production measured at the point of grid connection. The assumption made is that there is 100% data coverage of the data metered at the point of grid connection.

Plc can be estimated using the following formula:

$$P_{lc} = G_{100} / E - P_c \qquad \text{Equation A-2}$$

where:

G_{100} = production measured at the point of grid connection (100% data coverage) [MWh]

E = Measured electrical efficiency of the internal wind farm network [%]

By incorporating Equation A-2 into Equation A-1 and rearranging, the following equation is derived:

$$A_{lc} = \frac{A_c \cdot D \cdot \left(\frac{G_{100}}{E} - P_c\right)}{P_c \cdot (1-D)} \qquad \text{Equation A-3}$$

The above equation is valid within the following limits because availability is always a positive number and is less than 100%:

$$0\% \leq A_{lc} \leq 100\% \qquad \text{Equation A-4}$$

Equations A-3 and A-4 were applied on a monthly basis and showed a positive correlation between data loss and production loss. Therefore, it is concluded when data are missing from the SCADA system the wind farm in general has lower availability than when the SCADA is fully communicating.

A.3 Calculation of electrical efficiency

The derivation of adjusted availability requires the calculation of the electrical efficiency of the wind farm internal network (E). DNV has estimated this by comparing the production at the substation to the sum of the production measured at the turbines when there was 100% data coverage of the 10-minute SCADA database. In lieu of high-resolution revenue meter data, monthly utility-metered generation data from the US Energy Information Administration [A-1] was compared to monthly SCADA production.

It is noted that this estimate is a relative measure of the electrical efficiency based on turbine and grid metering systems that are subject to uncertainty. This factor should therefore only be considered as a relative conversion factor to estimate the production at the grid connection point from the production measured at the turbines and not an absolute and accurate measure of the true electrical efficiency.

A.4 Projected energy production

A.4.1 Expected Energy

For analyses based on SCADA data, expected energy can be estimated from nacelle anemometer-based power curves, or free stream warranted power curves or free stream power curves that result from performance testing. For the cases where a free stream power curve is used, an NTF or nacelle transfer function must be created to account for the differences between free stream wind speed and nacelle anemometer measured wind speed.

A.4.2 Nacelle Transfer Function

A typical nacelle transfer function is the scaling of the nacelle anemometer measured wind speed to a measurement in front of the rotor, or “free-stream,” not impacted by rotor wake using a simple linear model, $Y = mx + b$. NTFs adjust for the impact of the rotor wake, but not machine-to-machine variation in anemometer settings, or terrain influences.

DNV will assess several potential NTF models, including simple linear models of all data, separate linear models for online/offline, and generalized additive models with inputs including nacelle wind speed, turbine power, blade pitch, absolute wind direction, nacelle position, mismatch between absolute wind direction and nacelle position, hour of day, month of year, and ambient temperature.

The models are created from turbine anemometer/met mast test pairs for turbines undergoing performance testing.

In general, the linear nacelle transfer function with separate online/offline models did better than the linear model based on both online and offline data together, and the generalized additive models did better than the separate online/offline linear models. The parameter compared between models was mean squared error, where 9/10th of the data was used to train the model, and 1/10th of the data was used to test the models for accuracy. The final generalized additive model had four terms – nacelle wind speed, turbine power, blade pitch, and mismatch between absolute wind direction and nacelle position. Figure A-2 provides an example graphical summary of the model for turbine A03. The process was repeated twice for the V112 turbines, and six times for the V120 turbines, once per turbine/mast test pair undergoing performance testing. Resulting wind speeds from application of the models were averaged such that each test turbine for a given model contributed equally to the estimated free-stream wind speed for all turbines of that model type.

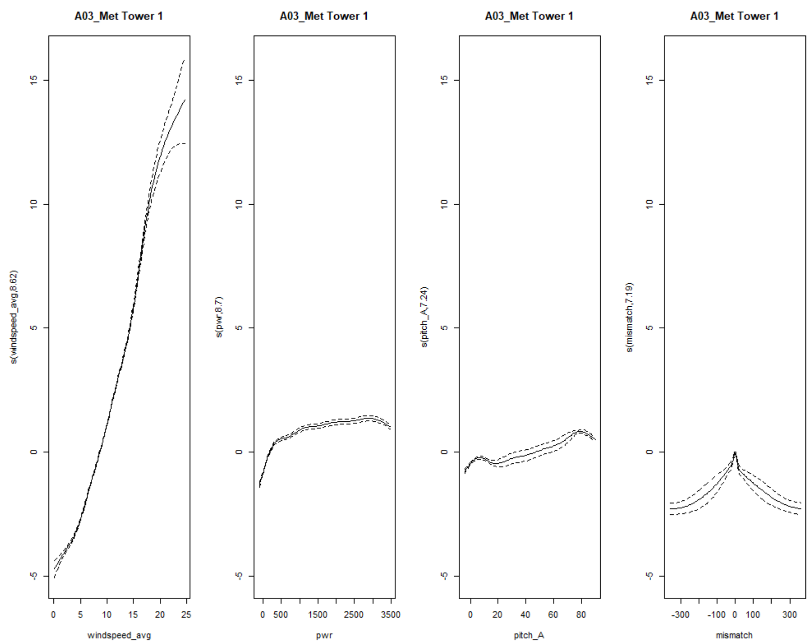

Figure A-2 Example of a typical non-linear nacelle transfer function

Generalized additive models (GAMs) provide a general framework for extending a standard linear model by allowing non-linear functions of each of the variables, while maintaining "additivity" [5][1]

Where a linear regression can be represented by $Y = mx + b$, with m is a scaling factor and b is the intercept, a single term generalized additive model would be represented by $Y = f(x) + b$, where the first term is now any function – linear or non-linear - not just a simple linear scalar m as in linear regression. An additive model can have many terms; the model used here has four terms. An illustrative version of the formula for the plot above would be $Y = f(x_1) + f(x_2) + f(x_3) + f(x_4) + b$ where each panel in the plot represents the non-linear functions for each term – nacelle wind speed, turbine power, blade pitch and mismatch between absolute wind direction and nacelle position.

The model above is interpreted for any individual parameter by considering the other parameters held constant. That is, when power, pitch and mismatch are held constant, we see that the relationship between nacelle and met mast wind speed is nearly linear, as expected. The dashed lines represent the error bars of +/- 2 standard deviations and are narrowest for nacelle wind speed as it is the most important indicator of free-stream wind speed, and widest for blade pitch and mismatch where there are the fewest measurements. As these are the additive influences of each term, the Y axis 0-point represents the average met mast wind speed value of around 7.7 m/s, representing the b intercept term in the simplified formula above.

GAMs, which are non-linear, will typically yield an improvement in R-squared over simple linear models.

The NTF and air density adjusted wind speeds were used with the average wind turbine performance testing results per turbine model to estimate possible power for all turbines, for the entire operating period.

1

A.4.3 Factoring of monthly metered production to derived gross long-term energy production

The Factoring Approach adjusts the historical metered energy production to the gross energy production by scaling the production to 100% availability, performance, and curtailment from the availability, performance, and curtailment losses. This method provides an estimate which is inclusive of all operational and power performance effects.

The gross monthly production is divided by the number of days in each month to calculate the gross daily average production in each month. A regression is developed between the gross daily average production in each month over the operational period and the concurrent month's average wind speeds from a nearby reference station. This relationship is employed to synthesize the production at the site for the historical period of record of the reference station. The synthesized and measured gross production figures are combined by averaging the synthesized or measured gross production for each month in the year. The gross long-term energy production is calculated from the sum of the long-term monthly production.

A.4.4 Energy losses

DNV uses a standard detailed set of energy loss factors, which aims to ensure that all potential sources of energy loss are considered by the relevant parties. For some projects, certain loss factors will not be relevant, in which case an efficiency of 100 is assumed. Additionally, some losses may only be sensibly estimated when comprehensive information is available from a project and review of such documentation is within the scope of DNV's work. The comprehensive list of potential losses included within Appendix B allows clarity on what losses have and have not been considered within the analysis, and what assumptions have been made.

Six main sources of energy loss are considered: wake effect, availability, electrical efficiency, turbine performance, environmental, and curtailments. Each source is fully described and further subdivided into more detailed loss factors in Appendix B.

The energy loss factors are applied to the gross energy production to estimate the wind farm net energy output production.

A.5 Uncertainty analysis

Six broad categories of uncertainty associated with the methodology are used to estimate the long-term production for the Project:

- **Consistency of long-term reference data** - There is an uncertainty associated with the consistency of long-term reference data. A value is assigned based on the level of regional validation available and the nature of the long-term reference data, i.e. ground station with documented traceability or various forms of virtual meteorological data.
- **Historical wind speed variability** – There is an uncertainty associated with the assumption made here that the historical period of wind speed at a site is representative of the climate over longer periods. A study of historical wind records indicates a typical variability of 4.5% in the annual mean wind speed. This figure is used to define the uncertainty in assuming the long-term mean wind speed is defined by a period of 22.7 years.
- **Applicability of wind farm power curve** – There is a degree of uncertainty associated with the assumption that power performance and its relationship to the reference wind speed has remained consistent over the operational period and that the WFPC is representative of future project production. This uncertainty is evaluated based on the scatter of the WFPC and the quantity of data used in the WFPC.
- **Power curve performance adjustments** – There is a degree of uncertainty associated with the assumption that power performance has remained consistent over the operational period as well as with the calculation of the benefit of the adjusted turbine controls.

- **Applied correlation to long-term reference** – The long-term energy production was derived from a correlation analysis. The uncertainty associated with correlating and extrapolating between reference and production data is evaluated from the statistical scatter in the correlation plots.
- **Loss factor uncertainty** – There is an uncertainty associated with the assumption that the loss factors that have been applied including future availability, future grid curtailment, and future turbine performance will be representative of long-term production. A pragmatic uncertainty of 2.0 has been applied for this factor.
- **Future wind speed variability** – Additionally, even if the long-term mean wind speeds were perfectly defined, there would be variability in future mean wind speeds observed at the wind farm site. The variability in future mean wind speeds is dependent on the period considered.

The uncertainties described above are assumed to be normally distributed and added as independent errors on a root-sum-square basis to give the total uncertainty in the projected energy output.

The probability of exceedance levels has been derived from the total uncertainties that represent one standard error of what is assumed to be a Gaussian distribution. The probability of exceedance is reported for 50 (the central estimate), 75, 90, 95 and 99 for 1-year, 10-year and 15-year periods.

A.6 References

[A-1] "Annual Electric Utility Data," United States Energy Information Administration, http://www.eia.gov/electricity/data/eia923/.

APPENDIX B – ENERGY LOSS FACTORS

DNV uses a standard detailed set of loss factors that aims to ensure that all potential sources of energy loss are considered by the relevant parties. For some projects, certain loss factors will not be relevant in which case an efficiency of 100 is assumed. Additionally, some losses may only be sensibly estimated when comprehensive information is available from a project and review of such documentation is not within the scope of DNV's work.

Six main sources of energy loss are considered: wake effect, system availability, electrical efficiency, turbine performance, environmental, and curtailments. For each loss factor, a general description is given. It is noted that the system availability, non-icing performance degradation, and the influence of tree growth on energy production may be time-dependent factors.

B.1 Wake effect

As wind turbines extract energy from the wind, an area of wake forms downstream of the turbine rotor where wind speed is reduced. As the flow proceeds downstream, the wake dissipates, and the wind recovers until it reaches its free-stream conditions. The wake effect is the aggregated influence on the energy production of the wind farm which results from the changes in wind speed caused by the impact of the turbines on each other.

For operational wind farms, the impact of wake losses can be estimated by developing a pattern of production that compares relative production levels between turbines when they are online and producing. Often, the turbine production is benchmarked against a select group of turbines that can be predicted well from pre-construction masts. The relative variation in production captures the effect of wake as seen in operational data and is considered the most accurate measure of such losses. For all energy assessments derived from actual wind farm production, wake effects are inherent in the calculation of the long-term production.

In the absence of any significant operational data, wake effects are calculated using the WindFarmer computational model 5.2.11.0 [B-1].The eddy viscosity model within WindFarmer is employed using a site-specific definition of the turbulence intensity as an input.

1a Wake effect internal

This is the effect that the wind turbines within the wind farm being considered have on each other.

1b Wake effect external

This is the effect that the wind turbines from neighboring wind farms (if any) have on the wind farm being considered.

1c Future wake effect

Where future wind farms are to be constructed in the vicinity of the project under consideration, the wake effect of these has been estimated and considered. If appropriate, this factor can be derived as a profile over the project lifetime.

B.2 Availability

Wind turbines, the balance of plant infrastructure, and the electrical grid will not be available the whole time. Estimates are included for likely levels of availability for these items averaged over the next 18 years of operation.

2a Turbine availability

This factor defines the expected average turbine availability of the wind farm over the next 18 years of operation of the project. It represents, as a percentage, the factor which needs to be applied to the gross energy to account for the loss of energy associated with the amount of turbine downtime.

2b Balance of plant availability

This factor defines the expected availability of the turbine transformers, the on-site electrical infrastructure, and the substation infrastructure up to the point of connection to the grid of the wind farm. It represents, as a percentage, the factor which needs to be applied to the gross energy to account for the loss of energy associated with the downtime of the Balance of Plant.

2c Grid availability

This factor defines the expected grid availability for the wind farm in mature operation. It is stressed that this factor relates to the grid being outside the operational parameters defined within the grid connection agreement as well as actual grid downtime. This factor also accounts for delays in the wind farm coming back to full operation following a grid outage. It represents, as a percentage, the factor which needs to be applied to the gross energy to account for the loss of energy associated with the downtime of the Balance of Plant.

B.2.1 Reconciliation of availability from operational wind farms with pre-construction loss factors

When considering operational wind farms, the metrics used for assessing the overall wind farm availability can be different from those described above. This is because a number of the issues that impact availability sometimes cannot be discretely quantified due to, for example, the concurrency of downtime events.

Also, production data from wind farms may be recorded on a variety of temporal resolutions, for example from 1 minute to 1 month. The metric that is used to assess the availability of an operational wind farm is dependent upon the type of data that are available for the analysis.

The common metric used to assess operational wind farm availability is System Availability (SA). The SA is a measure of the availability that counts any downtime against the availability regardless of the cause.

Due to the indivisibility of some of the loss factors that will impact availability, the following line items are included when assessing the SA:

- 2a: Turbine availability;
- 2b: Balance of Plant availability;
- 2c: Grid availability;
- 5c: Icing shutdown;
- 5d: Temperature shutdown;
- 5e: Site access;
- 6a: Wind sector management;
- 6b: Grid curtailment; and
- 6c: Noise, visual and environmental.

It should be noted that the inclusion of line items 6a, 6b and 6c is dependent on the details of the curtailment strategies applied. Forensic analysis of detailed SCADA data may allow a reasonable subdivision of downtime into the loss factors defined above in some cases.

B.3 Electrical efficiency

Electrical losses will be experienced between the low-voltage terminals of each of the wind turbines and the wind farm Point of Connection, which is usually located within a wind farm switching station.

3a Operational electrical efficiency

This factor defines the electrical losses encountered when the wind farm is operational and will manifest as a reduction in the energy measured by an export meter. This is presented as an overall electrical efficiency and is based on the long-term average expected production pattern of the wind farm.

3b Wind farm consumption

This factor defines the electrical efficiency due to the electrical consumption of the non-operational wind farm due to transformer no load losses and consumption by electrical equipment within the turbines and substation. For most wind farms this value is set to 100 within the table and this impact on wind farm energy production is considered as a wind farm operational cost rather than an electrical efficiency factor. However, for some metering arrangements it may be appropriate to include this as an electrical efficiency factor rather than an operational cost and therefore this factor is included within the table.

B.4 Turbine performance

In an energy production calculation from operational data, the efficiency of each turbine's power curve is inherent in the analysis of the long-term production.

4a Generic power curve adjustment

It is usual for the supplied power curve to represent accurately the power curve which would be achieved by a wind turbine on a simple terrain test site, assuming the turbine is tested under an IEC power curve test. For certain turbine models there may be reason to expect that the supplied power curve does not accurately represent the power curve which would be achieved by a wind turbine on a simple terrain site under an IEC power curve test. In such a situation a power curve adjustment is applied. This may be thought of as estimating that a turbine would not meet the turbine sales power curve in an IEC power curve test on a simple terrain turbine test site.

4b High wind speed hysteresis

Most wind turbines will shut down when the wind speed exceeds a certain limit. High wind speed shut-down events can cause significant fatigue loading. Therefore, to prevent repeated start-up and shut-down of the turbine when winds are close to the shut-down threshold, hysteresis is commonly introduced into the turbine control algorithm. Where a detailed description of the wind turbine cut-in and cut-out parameters are available, this is used to estimate the loss of production due to high wind hysteresis by repeating the analysis using a power curve with a reduced cut-out wind speed. If such information is unavailable, then a realistic assumption is made.

4c Site-specific power curve adjustment

When 10-minute SCADA production data are available, a site-specific performance adjustment may be applied for turbines experiencing persistent and unresolved power performance issues. Issues in power performance are estimated from a review of the Nacelle Anemometer Power Curves (NAPC). Such analysis only provides information on relative changes in power performance from turbine to turbine and over time, rather than how the turbines compare to the warranted power curve for the site. An estimate of the energy gain or loss due to power performance issues is derived by comparing the individual turbine power for periods of good operation and quantified as a percentage of the annual gross production.

Site-specific power curve adjustment may be made if a standard IEC power performance test indicates that the turbine performance is substantially different from the warranted power curve.

4d Suboptimal turbine performance

DNV typically assumes that wind turbine power curves will be controlled and operated with minimal deviations from their sales power curve output. However, for large periods of time and for significant numbers of wind turbines on any given wind farm, in DNV’s experience material performance deviations from the expected sales power curve can be observed.

4e Blade and turbine degradation

The performance of wind turbines can be affected by blade degradation, which includes the accretion of dirt, which may be washed off by rain from time to time, as well as physical degradation of the blade surface over prolonged operation. This is a time dependent phenomenon which DNV models as increasing linearly at a rate of 0.1% per year for 20 years, resulting in an average 1% loss over 20 years. In dry climates, these values are increased 0.3% to account for the reduced frequency with which precipitation will periodically clean the blades.

4f Aerodynamic device degradation

Aerodynamic devices, such as vortex generators, are expected to become detached or damaged as the project ages. This is a time-dependent phenomenon beginning in Year 6. To account for the decreased turbine performance due to aerodynamic device degradation, DNV applies a loss that begins in Year 6 and increases linearly such that by Year 20 there is no material benefit of these devices. In the absence of turbine-specific information, the performance loss in Year 20 is estimated to be 1.0%. This loss is higher in environments that experience significant amounts of icing.

B.5 Environmental

In certain conditions, dirt can accumulate on the blades and over time the surface of the blades may degrade. Also, ice can build up on a wind turbine. These influences can impact the energy production of a wind farm in ways which are described in 5a, 5b, and 5c below. Extreme weather events can also impact the energy production of a wind farm, as described in 5d and 5e below. Tree growth and tree felling may impact the production of a wind farm in a time varying manner; this impact is not considered herein. However, a line item is included here to define, where appropriate, the impact from trees at a given year of project operation.

5a Performance degradation - icing

Small amounts of icing on the turbine blades can change the aerodynamic performance of the machine resulting in loss of energy.

5b Icing shutdown

As ice accretion becomes more severe, wind turbines will shut down or will not start. Icing can also affect the anemometer and wind vane on the turbine nacelle, which also may cause the turbine to shut down.

5c Temperature shutdown

Turbines are designed to operate over a specific temperature range. For certain sites this range may be exceeded and for periods when the permissible temperature range is exceeded the turbine will be shut down. For such sites an assessment is made to establish the frequency of temperatures outside the operational range and the correlation of such conditions with wind speed. From this, the impact on energy production is estimated.

5d Site access

Severe environmental conditions can influence access to more remote sites which can impact availability. An example of this might be an area prone to severe snow drifts in winter. As the impact on energy will be dependent on the operation and maintenance (O&M) arrangements, a factor will only usually be included where DNV has reviewed the O&M arrangements for the wind farm.

5e Tree growth / felling

For wind farm sites located within or close to forestry or areas of trees, the impact of how the trees may change over time and the effect that this will have on the wind flow over the site and consequently the energy production of the wind farm must be considered. The impact of future felling of trees, if known, may also need to be assessed. The results presented within the table identify whether tree modeling is required for the site and whether or not this has been carried out. Such analyses may not be required where nearby trees are considered to be mature.

B.6 Curtailments

Some or all of the turbines within a wind farm may need to be shut down to mitigate issues associated with turbine loading, export to the grid, or certain planning conditions.

6a Wind sector management

Turbine loading is influenced by the wake effects from nearby machines. For some wind farms with particularly close machine spacing, it may be necessary to shut down certain turbines under certain wind conditions. This is referred to as wind sector management and will generally result in a reduction in the energy production of the wind farm.

6b Grid curtailment

Within certain grid connection agreements, it may be necessary to curtail the output of the wind farm at certain times. This will result in a loss of energy production. This factor also includes the time taken for the wind farm to become fully operational following grid curtailment.

6c Noise, visual and environmental curtailment

In certain jurisdictions, there may be requirements to shut down turbines during specific meteorological conditions to meet defined noise emission, shadow flicker criteria at nearby dwellings, or environmental conditions due to such aspects as birds or bats.

B.7 Specific assumptions

B.7.1 Time-dependent loss factors

The results presented represent annual average energy production values for a wind farm averaged over the remaining years of operation. However, for some wind farms there will be loss factors which change over time such as the turbine availability and non-icing performance degradation.

Table B-1 Time-varying losses and annual net energy

Year	Availability (2) [%]	Blade and turbine degradation (4e) [%]	Net energy [GWh/a]
3	95.6%	99.8	1364.4
4	95.6%	99.7	1363.1
5	95.6%	99.6	1361.7
6	95.6%	99.5	1360.3
7	95.6%	99.4	1358.9
8	95.6%	99.3	1357.6
9	95.6%	99.2	1356.2
10	95.6%	99.1	1354.8
11	95.5%	99.0	1351.7
12	95.4%	98.9	1348.6
13	95.2%	98.8	1345.5
14	95.1%	98.7	1342.4
15	95.0%	98.6	1339.3
16	94.9%	98.5	1336.2
17	94.8%	98.4	1333.1
18	94.6%	98.3	1330.0
19	94.5%	98.2	1326.9
20	94.4%	98.1	1323.8
Loss Factor averaged Years 3-20	**95.2**	**99.0**	**1347.5**

B.8 References

[B-1] "V5 WindFarmer, Theory Manual", GL Garrad Hassan, January 2011.

[B-2] "V5 WindFarmer, User Manual", GL Garrad Hassan, January 2012.

APPENDIX C – REFERENCE WIND DATA

C.1 MERRA-2 data

The Modern Era Retrospective-analysis for Research and Applications, Version 2 (MERRA-2) data set has been produced by the National Aeronautics and Space Administration (NASA) by assimilating satellite observations with conventional land-based meteorology measurement sources using the Goddard Earth Observing System, Version 5.12.4 (GEOS-5.12.4) atmospheric data assimilation system. The analysis is performed at a spatial resolution of 0.625° longitude by 0.5° latitude. DNV typically procures hourly time series of two-dimensional diagnostic data, at a surface height of 50 m for suitable grid cells near the project site [C-1].

C.2 ERA5 data

ERA5 is the fifth generation of ECMWF atmospheric reanalysis of the global climate. It provides data at a considerably higher spatial and temporal resolution than its predecessor ERA-Interim: hourly analysis fields are available at a horizontal resolution of 31 km and include wind data at 100 m above ground level, as well as surface air temperature and air pressure. ERA5 incorporates vast amounts of historical measurement data, including both satellite-based, commercial aircraft, and ground-based data [C-2][C-3].

C.3 Vortex Data

Vortex SERIES is a commercially sold long-term reference data source, primarily based on the Weather Research and Forecasting (WRF) model, a mesoscale model developed and maintained by a consortium of more than 150 international agencies, laboratories, and universities. Its downscaling system uses a number of high-resolution inputs such as MERRA-2 or ERA5, as well as analyses of soil temperature and moisture, sea surface temperature, sea ice, and snow depth. Data are typically produced as a virtual hourly time series on a 3 km horizontal resolution, centered on the subject wind farm and at heights between 50 and 300 m above ground.

C.4 References

[C-1] National Aeronautics and Space Administration, MERRA-2, MDISC website: http://disc.sci.gsfc.nasa.gov/mdisc/, MERRA-2 tavg1_2d_slv_Nx: 2d,1-Hourly,Time-Averaged,Single-Level,Assimilation,Single-Level Diagnostics V5.12.4 (M2T1NXSLV), 1980-present.

[C-2] European Centre for Medium Range Weather Forecasting, “ERA5 data documentation”, https://confluence.ecmwf.int/display/CKB/ERA5+data+documentation

[C-3] Copernicus, “Climate reanalysis”, https://climate.copernicus.eu/products/climate-reanalysis

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