BEFORE THE
PUBLIC SERVICE COMMISSION OF WISCONSIN

Request for Comments on Draft Order Adopting Application Filing Requirements for Solar Generation Projects — Docket No. 5-AFR-700

COMMENT ON APPLICATION FILING REQUIREMENTS DRAFT

GRANT COUNTY INTERVENORS AND JEWELL JINKINS INTERVENORS

Grant County Intervenors and Jewell Jinkins Intervenors are informal associations of landowners, residents, and farmers who have intervened in the Grant County Solar docket (PSC Docket 9804-CE-100) and Badger Hollow dockets (PSC Dockets 9697-CE-100, 9697-CE-101, and 5-BS-228). In the process of participation in these dockets, we have learned much about solar, and Jewell Jinkins Intervenors that raised the issue of the need for rules for solar siting, PSC Docket 1-AC-254. This docket, 5-AFR-700, is a good first step by establishing filing requirements specifically for solar, and should be implemented quickly, and retroactively for those projects now in the solar CPCN process. We thank the Commission for the opportunity to comment on these AFR Draft proposals.

Grant County Intervenors and Jewell Jinkins Intervenors (hereinafter "Intervenors") note that on this docket's service list, there are no individuals or groups representing the interests and raising the concerns of landowners or groups, and no individuals or landowner groups who have intervened in solar dockets. We learned of this docket by accident, and have begun to spread word as best we can. The Commission should work to be more inclusive.

Rulemaking

As above, Jewell Jinkins Intervenors petitioned the Commission for a rulemaking, which was denied. PSC Docket 1-AC-254. In CPCN review, the Commission and the public have learned much about permitting large utility scale solar project and the potential impacts, and demonstrated impacts of large solar projects. This AFR docket begins to address important issues which should be promulgated into rules. Rules would have stronger impact, and a rulemaking proceeding would necessarily involve increased public input and consideration.

Grant County Intervenors and Jewell Jinkins Intervenors request that this AFR effort be implemented as soon as possible, and then also shifted into formal rulemaking for incorporation into PSC Code.

Substantive Comments

These substantive comments are not all inclusive – if an area is missed, it's likely due to time limitations.

Throughout, where an IPP is applying, but the project is under contract to be sold instantly on approval of the IPP CPCN, the project should be regarded as a utility project and should have to provide all the information a utility is required to provide. IPPs are circumventing review using the "site/acquire" model. NOT OK!

Draft Order, p. 1 – regarding Type I, II or III Action, the Commission should regard utility scale solar projects, using an acreage or megawatt threshold, as Type III and require environmental review, specifically an Environmental Impact Statement. The impacts of a project covering thousands of acres, with mitigation required, has admittedly substantial environmental impact and is comparable to those projects listed for Type I characterization. The experience of water issues in the Two Creeks and Badger Hollow projects is another demonstration of the substantial impacts. An Environmental Impact Statement is needed.

Completeness review is the "enforcement" of AFRs, and the Commission must take AFRs seriously. For example, the brownfield requirement for generation siting has not been taken seriously, and projects thus far do not give adequate consideration to siting on brownfields by ignoring the definition of brownfields, and only consider brownfields on the EPA list, and do not consider siting on brownfield if one brownfield cannot contain the entire project. Abandoned, idle, and underused sites, brownfields under Wisconsin law, are not considered. The Commission's AFRs should be binding, and applicants not providing a complete application should be required to request an exemption or variance, which should only be granted for good cause. The information is necessary to process an application, and considerable delay occurs when information is not forthcoming and must be unearthed through Data Requests.

In siting solar, shuttered coal and nuclear plant properties should receive priority, as infrastructure, particularly transmission, in this brownfield site is readily available. In closing coal plants and nuclear plants, the Commission should require siting of solar as a condition to approval of plant closure, and as a requirement in any decommissioning plan.

Draft AFR p. 2. During pre-application, the Commission should solicit names and contact information of interested parties, and add to notice and services lists, with service list winnowed down after application and intervention deadline has passed. Affected landowners and residents often do not have adequate notice of a project.

Draft AFR, p. 2-3. Draft plan to DNR should also be available publicly, because water, drainage, and erosion concerns are primary to landowners in a project area. Based on Two Creeks and Badger Hollow water issues, and failure of projects to take water concerns seriously, it is important for landowners in a project are to know of plans, and be able to contribute information – landowners are “on the ground” and know more about water in their area than anyone. Their expertise should be utilized.

Draft AFR, p. 3-4 – Notice of the Engineering Plan must be widely provided, by direct mail, newspaper, and radio PSAs. Requirement of this should be incorporated into the AFR. P. 5 refers to “property owners,” but notice should also be sent to “resident” where property owner address and property address are different. Renters such as Brianna and Henry Frear have been left out and not provided notice due to this “property owner” focus. The mailing list should also include interested parties who have contacted the applicants.

Draft p. 6 – CEII is a specific characterization that is misused. CEII is only information submitted to FERC, and does not include much of the MISO information that companies like to declare CEII. PSC should verify that any information classified by applicant as CEII is indeed CEII as defined legally. Odds are it is not.

Draft, p. 7 – Completeness. A completeness declaration starts the clock ticking towards Notice of Proceeding and time deadlines. If an application is not complete, it would be better to issue a letter with deficiencies listed, rather than declare it “complete” but for identified deficiencies.

Draft, p. 9 – There are people in the project area without internet access, by choice, or due to limited access – for example, cell service and internet service are very poor in the area of the Grant County Solar project. Each time I call my clients the signal is terrible and we are cut off regularly, several times per call. The morning of the Grant County Solar hearing, the Frears internet dropped off five times, and Frears were witnesses! In Cardinal-Hickory Creek, Old Order Amish participated, and they of course did not have internet access. Paper copies should be available to those without internet access.

Draft, p. 10 – Alternative Project Areas must include brownfield sites -- PLURAL. Applicants must be encouraged to group array sites together to include in the 25%, and for the project overall.

Draft, p. 11 – Applicants should be encouraged to break projects into small projects, but remain under the full project umbrella, to enable distributed generation siting.

Draft, p. 12 – Need and Purpose. The project MW should match the interconnection MW. In the Grant County solar project, the project is designed as 300MW, but only 200MW is approved by MISO for interconnection. What happens to that other 100MW?

Draft, p. 12, Need and Purpose – in this section, the project should disclose whether or not there is a direct link to reduction of greenhouse gas, i.e., is this project contractually replacing fossil fuel facility; is this project to be built on fossil fuel brownfield site; to address whether construction of the project will reduce greenhouse gas generation, or whether it is planned to just increase generation on the market.

Draft, p. 12 – Efficiency. Solar projects are inherently inefficient when compared to most other generation. In the efficiency section, the projects must provide energy loss information such as losses in conversion from DC to AC, losses inherent in the collector system, and energy losses in transmission over grid and cost of transmissions service (all projects should include information on losses). These losses are costs. Losses could be reduced by balancing loss cost with gains of distributed generation near load, with no transmission construction and no transmission service cost.

Draft, p. 13, brownfields – Applicant must address how brownfields were considered, including, as the statute includes, **ABANDONED, IDLE, AND UNDERUTILIZED INDUSTRIAL AND COMMERCIAL SITES.** Logically, any big box, warehouse, strip mall, etc. without solar on the roof could be an "underutilized industrial and commercial site." Closed fossil fuel plants would fall under the statutory brownfield definition, ditto with nuclear.

Draft, p. 13, setbacks – project application must provide basis for setback distances with support.

Draft, p. 14 – Good Neighbor Agreements – a full copy of good neighbor agreement used should be provided, and no good neighbor agreement should be allowed where signator must give up rights, waive, hold harmless, etc., as they have no idea of the possible impacts.

Draft, p. 14 – Easement Agreements/Leases – lease agreements should be scrutinized to determine whether lease has clause to transfer decommissioning to landowner if project owner fails to decommission or abandons project. This type of arrangement is against the public interest, and is assuredly against the landowners' interest! Any project with such a clause in the lease should not be approved.

Draft, p. 14, consistency with local setbacks – local setbacks should be disclosed and observed if distances are greater than project proposes.

Draft, p. 14 – Decommissioning. Decommissioning plans are not new. Both utilities and IPPs must provide decommissioning plans that include financial assurance and a commitment to recycle. Project must take full responsibility for decommissioning and must not have lease option of transferring decommissioning responsibility to landowner – financial assurance must be sufficient to preclude abdication of decommissioning responsibility. Decommissioning plans are available online, and these plans should be a part of the CPCN process for review and comment by the Commission, parties, and the public.

Draft, p. 15 – IPP Decommissioning. Same as above: Both utilities and IPPs must provide decommissioning plans that include financial assurance and a commitment to recycle. Project must take full responsibility for decommissioning and must not have lease option of transferring decommissioning responsibility to landowner – financial assurance must be sufficient to preclude abdication of decommissioning responsibility. Decommissioning plans are available online, and these plans should be a part of the CPCN process for review and comment by the Commission, parties, and the public. See attached Exhibit A -Two Creeks Decommissioning Plan.

Draft, p. 15 – DATCP – due to the large amount of acreage of a utility scale solar project, and siting common on Farmland Preservation land, an Agricultural Impact Statement must be required. Surveys must be sent out to all landowners, renters, farmers within (? 2 miles? 5 miles? 10 miles?) of the project area, with mailing list and affidavit of mailing filed on ERF, and responses filed on ERF. This survey process has been problematic in the past, with large landowners, and likely smaller landowners as well, excluded from the process. The survey should also be posted online for people who did not receive a survey to complete it, and for ease of response. The project applicant should also post notice of this survey with a link for local farmers' participation.

Draft, p. 16 – Identification of manufacturer and model of solar panel. This has not been done with the Grant County solar project, likely due to the monetary commitment required to order 700,000+ panels. Solar panels differ greatly in output, lifetime, and robustness of design. It is not reasonable for the Commission to grant a permit for a project when the panels are unknown. This must be declared prior to grant of a CPCN.

Draft, p. 16 – inverters and tracking system – noise characteristics of each must be disclosed – a manufacturer brochure with specifications would be helpful.

Draft, p. 16 – Perimeter fencing is a significant concern for a project with thousands of acres, both for wildlife and for those living in the area. See attached ungulate study.

Draft, p. 17 – Collector Circuits should all be underground, no overhead.

Draft, p. 17 – Foundations. Impact of long term foundations, 30-50 years, including concrete leachate, should be addressed, and how removal and restoration would be done.

Draft, p. 18 – Spill containment – Spill plan should be filed.

Draft, p. 18 – Construction Site Lighting – downward lighting should be required for temporary and permanent lighting.

Draft, p. 18 – Substation – stormwater holding ponds should be identified in or adjacent to substation area. Stormwater treatment should be addressed, including contaminants expected in substation stormwater runoff.

Draft, p. 18 – Security requirements, provide citation and link to source of requirements, i.e., NERC Critical Infrastructure. Shots were fired into a California substation a few years ago, and the applicant should address this type of threat.

Draft, p. 19 – Transmission and Distribution Interconnection – good requirements!

Draft, p. 20 – O & M Building – the applicant should disclose whether local land use plans allow an O&M building where applicants plan to put it.

Draft, p. 20 – Lighting – downward lighting should be required to limit disturbance to neighbors.

Draft, p. 20-21 – Battery storage – good to incorporate this into requirements, as battery storage has arrived and is alternative to transmission, per Wellinghoff testimony, Cardinal-Hickory Creek transmission docket. Specifications of batteries should be disclosed (mfg brochure with specs would be useful).

Draft, p. 21 – Construction Sequence & Schedule – Applicant should disclose influence of tax credits or other subsidies on construction schedule, likewise tariffs and embargos, etc.

Draft, p. 22 – Workforce – Applicant should address security and public health concerns associated with large workforce influx, including man camps, sex trafficking, etc., and what applicant will do to monitor and protect the public, and address increased needs for local law enforcement and emergency response.

Draft, p. 22 – Construction Equipment and Delivery Vehicles – Good details. This seems mostly a road agreement section, with details that should be considered in road agreement. Section should start with "identify local governments' road agreements" and include copy of such. See Exhibit C – Road Agreement. The road agreement should identify in narrative, and on a map with legend the roads to be used, with any limitations and conditions clearly stated.

Draft, p. 23 – Maps – the Application narrative should include a project map in the introduction, referencing detailed maps in Appendices.

Draft, p. 23, 4.1.1 – another bullet point – Identify local roads covered under road agreement.

Draft, p. 23, 4.1.2 – Collector systems should be underground, no overhead.

Draft, p. 24, Substation. "Adjacent landowners" should be defined. Contiguous? Within ½ mile? ?? Lighting ID'd on plan, and always downward lighting.

Draft, p. 24-25 – Identify "adjacent landowners," as above, and ID lighting, always downward.

Draft, p. 25, Battery Storage – Fencing – if barbed wire, say so. Are there security issues with battery storage?

Draft, p. 25 – 4.1.7.2 – Maps need to include drainage systems, including drain tile. Drain tile should be located and mapped and included in application.

Draft, p. 25, Land ownership maps – for "Current parcel boundaries and landowners – when landowner address differs from property address, applicant should determine whether it is used as residence, and add resident to lists, here and in notices, etc., even if just "resident" for mailing purposes. Non-owners residing in and near the project equation should be included, not left out. ID land in conservation programs.

Draft, p. 25, Public lands – looks good.

Draft, p. 25-26 Land cover – local roads should be on map, with roads AND road easements drawn in.

Draft, p. 26 – Community maps – show zoning, plus community areas, such as schools, hospitals, community centers, town halls, going out 2 miles.

Draft, p. 26 – Airport information is crucial, impacts of glare must be considered, not just in FAA required direct landing, but also for circling and non-standard approaches. Whether there is a tower at airports also determines whether FAA tower glare studies are required, so application must disclose this fact.

Draft, p. 26 – Communication infrastructure – looks good. But "line of site" should probably be "sight."

Draft, p. 26-29, GIS – not up to speed on GIS!

Draft, p. 29, Photo Simulations. Make sure photo simulations are simulations of view FROM properties (not from road TOWARDS properties). Simulations should have simulations of driving through project on local roads with fences and project shown, and birds eye view.

Draft, p. 29-30, site geology, good to include groundwater and infiltration rate measurements.

Draft, p. 30, include map to show all public and private wells within 2 miles.

Draft, p. 30, regarding grading activities, describe how grading activities will impact decommissioning and return to original state.

Draft, p. 30-31, it would be useful to know distance/length and acreage of land within setback from fence (outside of fence), i.e., 150 foot setback around 2,000 acres = how many acres, to provide additional information about how much land is affected.

Draft, p. 31, Invasive Species – Will sufficient vegetation management be utilized, sufficient seeding, to prevent invasive species of plants?

Draft, p. 31, Vegetation Mgmt, site restoration – Vegetation Management Plan should be public to greatest extent possible (see Grant Co. Solar, all but cost made public).

Draft, p. 31, Wildlife – criteria for determination of wildlife pre-construction studies should be stated. Final report/s and/or analyses should be reported, added to application, and ERF. Post-construction wildlife monitoring and response protocol should include posting results on ERF, an thresholds for putting in front of Commission.

Draft, p. 32, DNR and USFWS Comments and recommendations should be filed with application, and DNR testimony required, USFWS testimony encouraged (can't make them testify!).

Draft, p. 32 – Public Lands and Recreation – resources listed should also be on map with clearly defined boundaries.

Draft, p. 33, Contaminated Sites. Should also have section to list brownfield sites, including specific for EPA Brownfield sites, abandoned sites, idle sites, underutilized commercial and industrial, i.e., FoxConn, coal plant properties, nuclear plant properties, idle and/or abandoned frac sand mines, etc.

Draft, p. 33 – Local Zoning. In area with agricultural zoning, applicant should go through zoning process for change to industrial zoning.

Draft, p. 34 – Township road safety 5.12.4 and 5.12.6, 7 – road agreement should be required.

Draft, p. 34 – Land Use Plans – where project inconsistent with local land use plans, applicant should have to apply for exemption, variance, or local land use plan change.

Draft, p. 34 – Archaeological and Historic Resources. Where archaeological and/or historic resources are near or within the project siting area, applicant should contact entity overseeing that historical/archaeological site, particularly tribal entities, to assure project is respectful distance from site and that it does not interfere with use and preservation of the site.

Draft, p. 35 – Agricultural impacts. First and foremost, Farmland Preservation and land zoned agricultural should be identified.

Draft, p. 35, Drainage District – farm drainage patterns must also be identified, not only formal "Drainage Districts."

Draft, p. 36, Ag conservation and ag tax incentive programs – identify economic value of these programs for land in project area, and identify and itemize cost of loss in this section and in "cost" section of application.

Draft, p. 36, pre- and post-construction stray voltage testing is required. Applicant must submit stray voltage testing plan.

Draft, p. 36, Airports – information about airports is crucial for glare testing, required by FAA generally for approach, and also for testing of glare within airport towers. 5.16.3.3 seems unnecessary as solar projects aren't high. Application should include glare studies and FAA interference reports, if any.

Draft, p. 37, Communication towers – applicant should provide a complaint process and mitigation plan. If there is an issue requiring mitigation, the landowner/resident must not be required to sign waiver/hold harmless to receive mitigation.

Draft, p. 37, EMF. Applicant should disclose on a legible map the distances from collector systems and tie line of all residences within 300 feet.

Draft, p. 37, Noise. Applicant's pre-construction noise modeling should include substation, inverters, tracking motors, and any other noise producing components of the solar project.

Draft, p. 38, 5.19.3 – Applicant should also provide manufacturer's disclosure of component noise characteristics.

Draft, p. 38, 5.19.5 – Application should provide complaint process, including the discussion of mitigation measures.

Draft, p. 38, Glint or glare: FAA requires only approach glare studies, and applicant should model glare from project to more than that limited approach area. 5.20.3 – Application should include complaint process and mitigation options for glare.

Draft, p. 39 – Local Governments – 6.1.2 should specifically include "road agreement."

Draft, p. 39, 6.2 – should include any additional emergency response personnel, equipment, and training needs.

Draft, p. 39 – Landowners Affected – it's not just landowners. Project lists must include residents, as in 7.1.1. This has been an issue in solar project proposals.

Draft, p. 39 – Contact lists & Public Outreach – Notices of project open houses should be sent to landowners and residents, and not rely on a small ad with little information in a local paper, as was done for the first open house for Grant County Solar. Radio stations are hungry for local information, and Public Service Announcements (free) should be utilized by applicants.

Draft, p. 40 – Waterway/Wetland Permitting Activities. An important lesson learned is that waterway/wetland issues occur in projects not ostensibly requiring a DNR permit. DNR should be required to review all testimony and information in the docket regarding waterways, wetlands, drainage, soil erosion.

Draft, p. 45, Mapping Wetland and Waterway Locations, Impacts, and Crossings. This is absolutely necessary information, and should include agricultural drainage systems. This is crucial because water does not observe project boundaries, and non-participants can be severely affected by errant water, both above ground and below.

Draft, p 47-48, Erosion Control and Storm Water Management Plans. In addition to Erosion Control and Storm Water Management under DNR permits, the applicant should also be required to include a water complaint process and mitigation plan exclusive of DNR permits. This Complaint process should include a contact person, steps to take with water issues, and mitigation that applicants commit to performing, and steps if applicant response does not alleviate the problem.

The Commission should establish a filing requirement of a formal complaint process to cover all the above issues, with, as above, a contact person, steps to take with water issues, and mitigation that applicants commit to performing, and steps if applicant response does not alleviate the problem. There should be regular reporting to the Commission of all complaints, with details of steps taken, resolution, and that complainants have option to proceed to the Commission if problems are not resolved, with a designated Commission contact person for each project. Each CPCN Order should require this Complaint process and the Order be provided to those within and directly adjacent to the project area, and to parties in the CPCN docket.

At this time, Grant County Intervenors and Jewell Jinkins Intervenors have no further comments, due to the time constraint. We ask that in the future the Commission make an effort to be more inclusive and provide notice to landowners, residents, farmers near solar projects, and to all those commenting and intervening parties to solar dockets. Such notice could easily be provided online to those with an interest in solar project application requirements.

Thank you for the opportunity to comment.

Dated: February 15, 2021

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DNV·GL

TWO CREEKS SOLAR PROJECT

Decommissioning Costs Analysis

WISCONSIN PUBLIC SERVICE COMPANY

Document No.: 10153572-HOU-R-05
Issue: D, **Status:** FINAL
Date: 23 April 2020

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Task and objective:
Solar PV power project decommissioning analysis

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A	28 February 2020	Initial issue	N. Kautzer	A. Morrill	D. Pardo
B	4 March 2020	Inclusion of sensitivity analysis and scrap value adjustment	A. Morrill	D. Pardo	M. Cookson
C	13 March 2020	Correction of typos in section 3.4.1 and updates to Appendix A	A. Morrill	D. Pardo	M. Cookson
D	31 March 2020	Language updates	D. Pardo		
D	23 April 2020	Final issue	D. Pardo	N. Kautzer	M. Cookson

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Appendices

APPENDIX A – MAIN ASSUMPTIONS

List of tables

List of abbreviations

Abbreviation	Meaning
BoS	Balance of System
COD	Commercial Operation Date
DNV GL	DNV GL Energy USA, Inc.
O&M	Operations and Maintenance
PV	Photovoltaics

EXECUTIVE SUMMARY

At the request of Wisconsin Public Service Company ("WPS"), DNV GL Energy USA, Inc. ("DNV GL") performed a decommissioning analysis of the Two Creeks Solar Project (the "Project"). The study estimates the costs associated with the dismantling, removal, and salvage or disposal of the equipment. All costs in this study are provided in 2020 United States dollars (USD).

The Project is located in Manitowoc County and Kewaunee County, Wisconsin, approximately 25 miles southeast of Green Bay, and has a rated generating capacity of 212.99 MWdc and 150 MWac. Based on the current design, the Project consists of 22,776 JKM390M-72HL-V Jinko photovoltaic (PV) modules and 503,958 JKM400M-72HL-V Jinko PV modules, 48 3,270 kVA HEM FS3270M Power Electronics inverter stations, and associated infrastructure. The scheduled Project commercial operation date (COD) is Q4 2020. Per WPS's request, DNV GL has assumed that decommissioning of the Project will take place 30 years after COD. Other Project assumptions are presented in Appendix A.

DNV GL assumes that there are strong parallels between solar power project construction and decommissioning, and consequently bases estimates for decommissioning costs on its broad experience in solar power project construction and associated costs of labor, equipment, and materials. The complete decommissioning cost is calculated as the sum of the cost of disassembly, removal, and disposal of the PV modules and balance of system (BoS), as may be offset by gains from salvage value of materials. It is noted that the cost of disassembling PV arrays, racking, and piles is the most dominant cost factor for the disassembly, followed by transportation of the same components, which is reflected as costs of removal.

Assessments of salvage opportunities are based on the bill of quantities identified in this report. The average material weights, masses, and volumes for the pile and racking components are derived from previous DNV GL studies, WPS's documentation, and/or supplier technical specification sheets. Although DNV GL assumes certain commodity prices and disposal service rates based on present-day estimates, it does not forecast such future values. The reader is free to make those adjustments. The salvage value is calculated as the sum of parts resale and scrap revenue.

The net decommissioning cost is determined as the difference between: i) the sum of the disassembly cost, removal cost, and disposal cost; and ii) the sum of revenue from salvage material. The net decommissioning gain[1] or costs of Project assuming no resale (Scenario 1) and with partial resale of the Project's major components (Scenario 2) are presented in Table ES-1 and Table ES-2.

[1] Values in parentheses are negative values representing positive returns to the Project.

Table ES-1 Estimated Project decommissioning costs - no resale (Scenario 1)

Item	Disassembly (A)	Removal (B)	Disposal (C)	Total Costs (D=A+B+C)	Salvage (E)
PV modules, racking, and piles	$6,406,600	$3,429,000	$13,271,700	$23,107,300	($1,495,800)
Collection system	$2,661,000	$3,013,800	$622,200	$6,297,000	($1,489,100)
High-voltage substation	$484,000	$69,700	$71,800	$625,500	($215,300)
Transmission line	$494,100	$22,200	-	$516,300	($421,000)
Civil - Access roads & laydown area, reseeding and fencing	$2,774,900	$294,400	$1,628,000	$4,697,300	($32,000)
Mobilization/soft costs		$2,012,200		-	-
Project Totals	$12,820,600	$6,829,100	$15,593,700	$37,255,600	($3,653,200)
Total Project (D+E)	**$33,602,400**				
Total Project [$/kW dc]	**157.8**				
Total Project [$/kW ac]	**224.0**				

Table ES-2 Estimated Project decommissioning costs with partial resale (Scenario 2)

Item	Disassembly (A)	Removal (B)	Disposal (C)	Total Costs (D=A+B+C)	Resale/ Salvage (F)
PV modules, racking, and piles	$6,406,600	$3,429,000	$103,300	$9,938,900	($1,495,800)
Collection system	$1,842,800	$724,900	$0	$2,567,700	($1,202,700)
High-voltage substation	$484,000	$69,700	$71,800	$625,500	($948,500)
Transmission line	$494,100	$22,200	-	$516,300	($421,000)
Civil - Access roads & laydown area, reseeding and fencing	$1,423,700	$250,800	$1,312,000	$2,986,500	($32,000)
Mobilization/soft costs		$1,081,700		-	-
Project Totals	$10,651,200	$4,496,600	$1,487,100	$17,716,600	($4,100,000)
Total Project (D+F)	**$13,616,600**				
Total Project [$/kW dc]	**63.9**				
Total Project [$/kW ac]	**90.8**				

DNV GL notes that the net gains are highly sensitive to transportation and labor costs and, to a lesser degree, pricing of scrap materials. A high-level sensitivity analysis shows that a 20% fluctuation in the assumed cost of transportation could yield a variation of approximately $7/kWdc in the net decommissioning cost under Scenario 1. The same fluctuation in labor cost yields approximately the same result. A 20% fluctuation of only the assumed scrap value of steel yields a change close to $1.4/kWdc. However, it is noted that this simple sensitivity analysis does not take into account combined variations of costs/prices.

Technology for recycling or repowering of PV modules 30 years after the COD is likely to significantly improve compared to today's. Some private companies have already announced their interest in building businesses around PV module recycling [1]. As agreed with WPS, DNV GL has assumed that recycling technology will be fully available; therefore, the PV module disposal cost has been eliminated altogether in Scenario 2. Under Scenario 1, if the disposal cost of PV modules were to drop to a 25% of the current estimate, as presented in Section 5, the total project decommissioning cost would be $141.5/kWdc.

Also, as agreed with WPS, DNV GL has calculated the potential revenue to the Project if a second-hand market for PV modules is available at the time of decommissioning. DNV GL has limited information on a second-hand PV modules markets and considers it difficult to predict how one might develop/evolve within the next 30 years. For the purposes of determining such potential revenue to the Project, DNV GL has assumed that the PV modules could be sold at $0.08/Wdc, generating a revenue of $17M to the Project. Disassembly and Removal of the PV modules would still be required, at the costs presented in Table ES-2. A potential revenue of $17M from the resale of PV modules in a second-hand market would result in a total net decommissioning gain of $16.1/kWdc (representing revenue to the Project). Other assumptions incorporated into the analysis and presented in Scenario 2, as requested by WPS are presented further below.

Table ES-3 Scenario 2 cost analysis for varying PV modules final destinations

Total Project	Value
With zero disposal cost	$13,616,600
With 2^{nd}-hand market revenue	($3,422,600)

DNV GL notes that estimated costs reported herein are based on broad assumptions regarding the Project, the approach to decommissioning, and the market conditions at the time of decommissioning dictating labor costs, scrap value, and resale options. DNV GL recommends that estimated net costs of decommissioning be reviewed in detail near the end of the expected operating period (e.g., at operating year 27 assuming a 30-year operating life).

1 INTRODUCTION

The Project is located in Manitowoc County and Kewaunee County, Wisconsin approximately 25 miles southeast of Green Bay and has a rated generating capacity of 212.99 MWdc and 150 MWac. The Project consists of 503,958 JKM390M-72HL-V Jinko photovoltaic (PV) modules and 22,776 JKM400M-72HL-V Jinko PV modules, 48 3,270 kVA HEM FS3270M Power Electronics inverter stations, one substation, 4.6 miles of transmission line, 929 load break disconnects and associated infrastructure. PV modules are installed on single axis trackers, with each tracker holding either 52 or 78 modules in a single row. The Project also includes underground cabling making up the collection system and above ground facilities making up the generator tie line.. The scheduled Project COD is Q4 2020. Other Project assumptions are presented in Appendix A.

With the exception of a portion of the generation transmission line that extends north into Kewaunee County, the Project is located within Manitowoc County. The Project is subject to the decommissioning commitments made within the Project's Certificate of Public Convenience and Necessity (CPCN) application that was initially submitted on 31 May 2018, subsequently updated on 21 September 2018, and approved by the Wisconsin Public Service Commission (PSC) on 18 April 2019. The PSC's Final Decision Report includes Order Condition #14, which requires the Project to develop a decommissioning plan and submit to Commission staff for approval. The Final Decision Report also indicates that the lease agreements executed for the Project include stipulations that require land be restored to previous land use upon decommissioning [2].

Restoration commitments included within the CPCN application submissions include re-grading the disturbed areas, implementing stormwater and sediment control measures, and tilling the soil to support agricultural growth. In regard to infrastructure removal, the revised application states that all above-ground infrastructure will be removed, underground utilities will be abandoned, and concrete pads and foundations will be broken up and removed. No removal depth was specified as part of this commitment.

With the exception of the above-mentioned decommissioning requirements, there are no other local, state and federal decommissioning requirements currently applicable to the Project.

For Scenario 1 of this report, and in line with both industry standards and the commitments made within the CPCN application, the following assumptions have been applied:

- Decommissioning will start soon after the end of Project operating life (assumed to be 30 years after COD for purposes of this study), and all decommissioning work is performed in generally conducive weather conditions;
- Decommissioning includes the full removal of PV modules, PV support system, piles, electrical components, and any other associated facilities advised by WPS/as required by the Manitowoc County and Kewaunee County Order condition #14;
- Concrete foundations at the substation will be removed to a depth of 3 feet below grade;
- The Project substation, inverter stations, disconnect boxes, dc/ac underground collection system, and overhead power lines will be completely decommissioned; and
- Unless otherwise requested by the landowner(s), all Project roads and laydown area will be removed and reclaimed.

Other assumptions incorporated into the analysis and presented in Scenario 2, as requested by WPS [7], include:

- The technology and industry of PV modules recycling is fully evolved therefore the disposal cost of PV modules is nil;
- All underground collection system is abandoned in place;
- 50% of the project roads are left in place upon agreement with land owners; and
- No reseeding is necessary as land will be returned to agricultural use.

This report does not consider the time value of money; the results should, therefore, be adjusted to represent the real costs at the time of decommissioning (e.g., annual escalation). It should also be noted that commodity values are volatile and difficult to predict over the 30-year study horizon.

This report also does not consider the decommissioning scenarios from a legal or commercial perspective, which should be assessed by WPS.

1.1 Regulatory context

This decommissioning analysis for Scenario 1 has been prepared in accordance with the regulatory requirements set forth in CPCN Docket # 9696-CE-100 and 9696-CE-101. These commitments include:

- Dismantling and removal of all above ground equipment (solar panels, racking, transformers, substation, O&M building, etc.);
- Removal of all above ground cabling;
- Removal of posts;
- Break-up and removal of concrete pads and foundations;
- Pumping and break-up of any septic tank (backfilled with clean soil) and abandonment of leach field (if applicable);
- Abandonment of underground utilities; and
- Scarification of compacted areas within and contiguous to the Project (including but not limited to internal and external access roadways).

For Scenario 1, DNV GL has assumed that all underground cabling, even if below 4 feet, would be removed. This assumption exceeds CPCN's requirements.

2 STUDY ASSUMPTIONS

DNV GL's decommissioning study methodology assumes there are strong parallels between solar power project construction and decommissioning programs. DNV GL has used an internal bottom-up decommissioning model developed from experience in the solar industry to formulate these study results.

All costs are quoted in 2020 US dollars, and it should be noted that no specific quotes from third-party vendors were obtained in relation to this study, although the Project's location has been considered in the modeling with regards to transportation costs, labor costs and disposal costs. The study is broken down into three sections: i) disassembly, ii) removal, and iii) salvage/disposal. Due to the uncertainty associated with most cost categories assumed and modeled, DNV GL has rounded costs to the nearest $1,000, unless otherwise noted.

2.1 Initiation and mobilization

Before executing any decommissioning works, it is necessary to plan the work carefully, secure the appropriate permits and insurance, and manage the program of work and associated health and safety risks; all to ensure the successful completion of the work. DNV GL has considered mobilization and soft costs as overhead costs. Soft costs are assumed to include costs not specifically accounted for in the derivations presented later in this Report, including environmental studies, obtaining permits, environmental protection plans, hazardous material disposal, on-site administrative infrastructure and staff, utilities, off-site project management, and insurance/legal services. DNV GL has assumed that 5% of the total disassembly, removal and disposal costs would be required to cover soft costs.

In addition to soft costs, DNV GL has also assumed that an additional ~2% of total disassembly and removal costs will be needed for contractor mobilization. DNV GL has separately accounted for the costs of a temporary lay-down yard of 9.7 acres to house the required office trailers and staff parking and facilities for the decommissioning contractor.

2.2 Schedule

DNV GL has assumed that the decommissioning program will take 32 to 38 weeks. This timeline assumes a dismantling rate of PV modules, racking, and pile removal of approximately 85 single-axis tracker arrays per workday per subcontractor crew, and that two to three workdays of mobilization and demobilization are allowed before and after dismantling. While disassembly could, in theory, be done with slightly less care than during assembly (damage to PV modules and racking is not as much of a concern), safety and resale considerations will likely dictate that disassembly is accomplished in much the same fashion as installation, although in reverse order.

DNV GL has also assumed that other works across the site such as concrete foundation removal, underground collection systems disassembly, substation disassembly and reclaiming of roads, inverter stations, and other excavations will be done simultaneously and/or in concert with the PV module, racking, and pile removal.

3 DISASSEMBLY

The disassembly of the Project pertains to all work just prior to physical transportation of the infrastructure from the site. In the case of the PV modules, racking, and piles, it includes the dismantling and loading of the PV modules, racking, and piles onto trucks for transport. In the case of concrete foundations or roads and the temporary lay-down area, it pertains to the teardown, aggregate stripping, excavation and backfilling, all reclaiming as necessary, and reseeding of removed roads.

Although certain activities must be sequenced appropriately, based on DNV GL's knowledge of solar project construction considerations, DNV GL has assumed that many activities (e.g., PV modules, BoS, and substation disassembly) may be undertaken in parallel, facilitating an efficient decommissioning process.

3.1 PV modules

Once the site is mobilized, DNV GL has assumed that decommissioning of PV modules will start immediately and sequentially. These activities entail disconnecting module and string wiring and removing modules from the racking system.

For the Project, 526,734 modules and 1,815,287 feet of PV string cabling are to be removed. DNV GL has assumed that the scope of removing modules and string cabling includes the cost of labor, machinery, and tools required to perform the tasks, as well as costs of loading the dismantled material onto transport vehicles for removal from the site.

DNV GL has also assumed that all PV modules will remain fully intact for purposes of transport.

The costs presented in Table 3-1 below include labor cost to remove modules and strings from the support system, cost of equipment and tools needed to support module removal, labor and materials to secure modules for shipping.

Table 3-1 Summary of PV module disassembly costs

Cost item	Cost [$]
PV modules	2,300,600
PV strings	577,600
Subtotal	**2,878,200**

3.2 PV support system

DNV GL has assumed that the decommissioning of the racking system would start a week or two after PV module removal has commenced. Disassembly of a PV support system would typical entail the removal of all hardware in reverse order as installation. Staring with east-west rails, followed by A-frames, and ending with pile caps.

The Project consists of 6,483 three-string and 405 two-string PV single-axis tracker arrays. DNV GL has assumed that the scope of the disassembly work includes the cost of labor, machinery, and tools required to perform the tasks, as well as the loading of the dismantled material onto transport vehicles for removal from the site.

DNV GL has also assumed that the PV support system will be fully disassembled prior to loading onto transport trucks.

The costs presented in Table 3-2 below include the labor cost to remove and disassemble the PV support system from its respective pile foundations, cost of equipment and tools needed to disassemble the PV support system, labor, and materials to secure PV support system for shipping.

Table 3-2 Summary of PV support system disassembly cost

Cost item	Cost [$]
PV support system	1,562,300
Subtotal	**1,562,300**

3.3 Piles foundations

DNV GL has assumed that the full removal of pile foundations will start 1 – 2 weeks after the commencement of PV support system disassembly and removal. Based on the tracker manufacturer and DNV GL experience, DNV GL estimates a total of 74,553 piles at the Project.

The pile foundations in the current design of the Project are of the H-Beam driven pile type and a yank and pull methodology has been assumed for their removal.

DNV GL has assumed that each pile foundation will be fully removed from the Project site, that no material will be left in the subsoils, and that each foundation will remain fully intact for ease of loading into trucks.

The costs presented below include the labor cost to remove piles from the subsoils, cost of equipment and specialty tools needed to support in the removal of piles, labor, and equipment to load piles onto 53-feet long trucks.

Table 3-3 Summary of pile disassembly cost

Cost item	Cost [$]
Piles	2,543,700
Subtotal	**2,543,700**

3.4 Collection system

For Scenario 1 DNV GL has assumed the full decommissioning and removal of the collection system, even below 4 feet, as requested by WPS. DNV GL notes that the decommissioning requirements allow for the underground portion of the collection system to be abandoned in place. That said, due to the relatively high value of conductors, removal and resale of the underground cables may yield a positive return to the Project in 30 years from COD. Therefore, DNV GL has assumed that all underground cabling will be removed, and trenches restored.

For Scenario 2 DNV GL has assumed that all the collection system will be abandoned in place.

3.4.1 Underground collection system

According to WPS [3] the Project collection system is composed of a total amount of 2,955,097 feet of dc cable, and a total amount of 473,040 feet of ac three-phase cables buried along with 231,531 feet of bare copper grounding cable, and fiber cable. The decommissioning of underground collection system includes the excavation of buried conductors, and reclaiming. DNV GL has assumed that all conductors and cables will be damaged and cut into manageable sections during excavation and removal, and that all excavated material will be returned to trenches and covered with topsoil. The cost of reseeding has been accounted for in the civil work section of this report.

The cost of the disassembly and removal of underground conductors includes the cost of labor, equipment, and the loading of the dismantled material onto transport vehicles for removal from the site. DNV GL has assumed that work at the disconnect boxes, inverter stations, and substation will be performed as part of disconnect boxes, inverter station, and substation removal.

The results are reported in Table 3-4 below.

3.4.2 Disconnect boxes

According to WPS [3], the Project collection system will include 929 load break disconnect boxes that will require decommissioning and removal. The disconnect boxes will have to be disconnected by a licensed electrician prior to decommissioning. DNV GL has assumed that the decommissioning and removal of the disconnect boxes will start at approximately the same time as PV module decommissioning and be completed prior to pile removal, so as not to interfere with pile foundation removal and other ongoing work.

DNV GL has assumed that the scope of the disassembly includes the cost to disconnect the disconnect boxes from both the PV string and the dc homerun cables, cost of labor and loading the dismantled disconnect boxes onto transport vehicles for removal from the site.

The results are reported in Table 3-4 below.

3.4.3 Inverter stations

According to WPS [3], the Project collection system contains 48 3,510 kVA inverter stations that require decommissioning and removal. An inverter station includes one inverter section as well as a step-up transformer installed on a skid that is supported by ten steel piles surrounded by a gravel pad.

Once all inverter stations are disconnected from the collection system and decommissioned, a crane is required to assist with the transport loading onto flatbeds trucks before being removed from the site. DNV GL has assumed that the inverter station will be decommissioned at an appropriate time during the decommissioning activities so as not to interfere with other ongoing work.

DNV GL has assumed that the scope of the disassembly includes the cost of labor, equipment, and the cost of a crane for loading onto transport vehicles.

The results are reported in Table 3-4 below.

3.5 High-voltage substation

WPS has advised that the Project is equipped with one 138 kV/34.5 kV 170 MVA transformer. The remaining portion of the Project high-voltage (HV) substation is assumed to include typical equipment seen in North American solar power project substations for projects of this size, including grounding transformers, bus bars, relay switches, circuit breakers, disconnect switches, switchgear, and a control building. DNV GL has assumed that the substation decommissioning will occur at an appropriate time during the decommissioning activities so as not to interfere with other ongoing work.

DNV GL has assumed that the scope of the disassembly work includes the cost of labor and machinery required to perform the disassembly tasks, including disconnection work at the terminals, cost of crane, and the loading of the dismantled material onto transport vehicles for removal from the site. Table 3-4 below summarizes the costs to disassemble the Project's HV substations and control building.

Table 3-4 Costs to disassemble Project collection system and substation

Item	Cost [$]
Underground cabling	830,200
Disconnect boxes	216,400
Inverter stations	1,036,800
Substation and control building	484,000
Total	**2,567,400**

3.6 Transmission line

According to WPS, the Project will use a 4.6 mile overhead transmission line. Transmission line disassembly includes 36 poles teardown and reclaiming. The conductors would then need to be re-reeled for transport.

It is assumed that the scope of the disassembly includes the cost of labor and the loading of the dismantled material onto transport vehicles for removal from site.

The results are reported in Table 3-6.

3.7 Civil works and other

3.7.1 Site access roads and laydown area

Based on WPS's information, DNV GL has estimated that the entirety of the approximately 44,548 feet of total length of access roads and a 9.7 acre temporary lay-down area will be remediated and reclaimed. DNV GL has additionally assumed that inverter station pads will be remediated at the same time as the roads. Decommissioning of the site access roads will typically include stripping back the surfaces of project roads connecting the inverter stations and replacing them with topsoil in keeping with the surrounding environment. In the case of the Project, this phase also includes stripping and removing geotextile material used in the road base. The costs exclude reseeding with native grasses or regrading.

The results are reported in Table 3-5 below. Note the cost of aggregate transport off-site is captured in removal costs.

3.7.2 Re-seeding

The cost includes material and equipment required to reseed the Project area with native grasses. A secondary reseeding may be required if the initial work proves inadequate. DNV GL has, therefore, maintained a baseline assumption of one seeding.

3.7.3 Re-grading

The cost includes the equipment required to remove any culverts or stormwater management system and repair any equipment damage created during project decommissioning.

3.7.4 Fencing and security

The Project area is surrounded by a fence. DNV GL has assumed that all chain mesh, fence post, and eight access gates will be entirely removed for the Project area. These works typically require an excavator to pull out the post and general labor to remove the mesh. DNV GL has assumed that the fencing will be decommissioned at an appropriate time during the decommissioning activities so as not to interfere with other ongoing work.

DNV GL has assumed that the scope of the disassembly includes the cost of labor, equipment, and cost of loading material in dumpster trucks.

The results are reported in Table 3-5 below.

3.7.5 Weather stations

Three permanent weather stations are installed throughout the Project. DNV GL has assumed that these weather stations will be disassembled at the same time as the other work.

DNV GL has assumed that the scope of the disassembly works will be included in the cost of decommissioning the respectable inverter stations.

The results are reported in Table 3-5 below.

Table 3-5 Summary of civil disassembly costs

Item	Cost [$]
Access roads and laydown area	785,600
Reseeding	966,200
Regrading	624,800
Fencing and security system	398,300
Weather station	Included in Inverter Decommission
Total	**2,774,900**

3.8 Disassembly conclusion

The cost of the disassembly of the Project is summarized in Table 3-6.

Table 3-6 Summary of disassembly costs

Item	Cost [$]
PV modules	2,878,200
PV support system	1,562,300
Piles	2,543,700
Collection system and substation	2,567,400
Transmission line	494,100
Civil work and other	2,774,900
Total	**12,820,600**

4 REMOVAL FROM SITE

Removal of the Project in this study refers strictly to the transporting the equipment and material from the site to the appropriate landfill, aggregate rework facility, scrap yard, or recycling facility. Various distances and truck sizes are applied in the DNV GL decommissioning model, depending on which Project component is being calculated. Removal costs also include the costs of unloading the material once it reaches its destination. DNV GL notes that appropriate landfills and scrap yards appear to be located in the general region of the Project.

4.1 PV modules, PV support system, and pile foundations

DNV GL has assumed that the scope of the removal of the PV modules, PV support system, and piles includes the cost of labor and vehicles required to transport the dismantled equipment to an appropriate disposal, salvage, or recycling facility. DNV GL has assumed that the transport distances for general waste would be within a radius of 30 miles whereas the more complex and valuable material is assumed to be transported within a radius of 60 miles to 150 miles. These assumptions may be somewhat conservative considering there are recycling or salvage facilities near the Project site (e.g., Green Bay, WI). For the study DNV GL has assumed a similar methodology is used to remove the material as was initially used to transport to the site during construction, except that the PV support system and pile foundations are assumed to be transported in dumpster trucks instead of flatbed trucks.

Table 4-1 summarizes the costs for the removal of each of the solar components from the site.

Table 4-1 Solar components removal costs

Solar component	Cost [$]
PV modules	1,457,300
PV support system	629,400
Piles	1,342,300
Total	**3,429,000**

4.2 Collection system

4.2.1 Underground collection system

DNV GL has assumed that the scope of the removal works includes the cost of labor and vehicles required to transport the dismantled material to an appropriate salvage facility. The material will mainly include the dismantled and cut cables that will be removed by trucks.

The results are reported in Table 4-2 below.

4.2.2 Disconnect boxes

DNV GL has assumed that the scope of the removal works includes the cost of labor, shipping material, and vehicles required to transport the dismantled disconnect boxes to an appropriate salvage facility. The material will mainly include the disconnect boxes and related components all to be shipped on skids in transport trailers by trucks.

The results are reported in Table 4-2 below.

4.2.3 Inverter stations

DNV GL has assumed that the scope of the removal works includes the cost of labor and vehicles required to transport each inverter station off site to either be salvaged/dismantled or resold as second-hand equipment at an appropriate salvage facility. The inverter station is considered to be a self-contained unit, including both the inverter and an internal dry transformer all installed on a single steel skid all to be removed by flatbed trucks.

The results are reported in Table 4-2 below.

4.3 High-voltage substation

DNV GL has assumed that the transport distances for foundation rubble and general waste would be within a radius of 30 miles whereas the more complex and valuable material and substation components are assumed to be transported within a radius of 60 miles to 150 miles. DNV GL has assumed that local dump truck loads are 250 ft^3 in capacity.

The following table summarizes removal costs for the Project collection system and substation. As previously mentioned, the interconnection switchyards have not been considered in the present study.

Table 4-2 Project collection system and substation removal costs

Substation component	Cost [$]
Underground cabling	2,288,900
PV strings	408,000
Disconnect boxes	77,100
Inverter stations	239,800
Substation and control building	69,700
Total	**3,083,500**

4.4 Transmission line

It is assumed that the scope of the removal works includes the cost of labor and vehicles required to transport the dismantled material to an appropriate salvage or rework facility. The material will include the wound reels and/or cut cables as well as the dismantled poles (34 steel poles and 2 wood poles). The results are reported in Table 4-4.

4.5 Civil work and other

4.5.1 Site access roads and laydown area

For the purposes of the removal calculations, DNV GL has assumed that the entirety of the approximately 44,548 feet of access roads will be removed and 9.7 acres of temporary lay-down area will be remediated and reclaimed. Additional assumptions are that the width of the road is 12 feet and a depth of road removal is six inches. The laydown area is also assumed to be 12-inch deep. While this width attempts to capture any shoulder material as well, the assumption that all roads to be removed are 12 feet wide is likely conservative with respect to the Project design and is expected to therefore cover the cost of decompaction and reclamation of any additional work required by rock check dams, or grass roads. Dump truck capacity is assumed to be 250 feet^3 and all load trips are assumed to be local. The results are reported in Table 4-3 below.

4.5.2 Fencing, and security

DNV GL has assumed that the scope of the removal works includes the cost of labor and vehicles required to transport the dismantled material to an appropriate disposal, salvage or rework facility. The results are reported in Table 4-3 below.

4.5.3 Weather station

DNV GL has assumed that the scope of the removal works includes the cost of labor and vehicles required to transport the dismantled material to an appropriate disposal, salvage or rework facility. The results are reported in Table 4-3 below.

Table 4-3 Project civil works removal cost

Item	Cost [$]
Access roads and laydown area	225,600
Fencing and security system	67,300
Weather station	1,500
Total	**294,400**

4.6 Project removal conclusion

Table 4-4 summarizes the total anticipated costs for removing the solar equipment, collection system, substations, roadways, and met mast from the Project.

Table 4-4 Project removal conclusions

Item	Cost [$]
PV components	3,429,000
Collection system and substation	3,083,500
Transmission line	22,200
Civil work and other	294,400
Total	**6,829,100**

5 SALVAGE – DISPOSAL

While it is impossible to predict the exact evolution of an industry 30 years into the future, it is not unreasonable to assume that there may exist by that time consolidated centers that will fully recycle PV modules, given that many projects will have been decommissioned prior to that time. For example, DNV GL notes that significant attention is being placed by industry and academia alike into possible uses or methods for recycling the PV modules. DNV GL notes that in this section only, gains are shown as positive and costs to the Project are shown as negative.

While it may become easier to recycle PV modules in the future, DNV GL performed this study assuming only the application of present day means. Following the disassembly and removal of all materials from the Project site, four potential destinations for the material are typically envisaged by DNV GL when performing decommissioning studies. These scenarios may add extra cost to the decommissioning budget or offer an opportunity to reclaim some value from the solar power project components to offset against the cost of decommissioning.

1. Low-grade material such as contaminated aggregate, concrete rubble, wood, non-recyclable materials and other mixed general waste will likely be sent to landfill or incineration at cost to the Project. DNV GL notes that there is a relatively large volume of waste associated with the PV modules which are composed of aluminum, copper, glass, silicon, and other material. It is possible that, in 30 years, recycling PV modules will be an economical process reclaiming and repurposing the valuable materials and may be a net positive for the Project, or at least an offset to the cost, but no such projections have been made in the present study. PV modules have been considered waste with a fixed cost of $25 per module to cover the cost for proper disposal.
2. Medium-grade materials such as small- and medium-gauge cabling, cabinets of mixed electronics, and lighting may be sent to salvage centers to be stripped for parts and sold for re-use or re-processing. This may be done at a nominal, neutral, or negative cost (positive return) to the Project. However, this material may also be sent to landfill if an appropriate third party cannot be found. DNV GL notes that it is difficult to predict future returns of salvage due to the unpredictability of commodity prices.
3. High-grade materials such as large steel components (PV support systems and pile foundation and steel structures), large-gauge copper and aluminum cabling, will be sent to reprocessing centers at a net neutral cost or positive return to the Project. DNV GL notes that it is difficult to predict future returns of reprocessing due to the unpredictability of commodity prices.
4. Reusable components that are deemed to be undamaged, functional, and have not fulfilled their design life could be sold back to the manufacturer or its supply chain for a modest second-hand price for refurbishment. Some electrical infrastructure equipment as well as recently replaced solar components could fall into this category.

Applying a conservative approach, DNV GL only considered items 1, 3, and 4. No resale gains were assumed for item 2—only scrap/disposal value. Furthermore, item 4 was limited only to certain main components within a conservative age range.

5.1 Pricing assumptions

The following assessment is based on DNV GL's decommissioning model which estimates bill of quantities, typical material weights, masses, and volumes for racking components and piles acquired from the manufacturer's technical specifications, engineering drawings, or from DNV GL experience when such is not available. The model uses commodity prices and disposal service rates as inputs.

For the Project decommissioning, the following scrap commodity prices are assumed:

- Steel and cast iron: $150/ metric ton
- Copper: $4,535/ metric ton
- Aluminum: $1,070/ metric ton

Weights are in metric tons. It should be noted that the commodity price of metals is volatile and 30-year values are impossible to predict with any degree of certainty. The assumed prices are based on DNV GL's analysis of United States Geological Survey historical scrap metal costs statistics [4] and publicly available scrap costs for Wisconsin [5].

Because landfill costs are expected to keep rising, DNV GL used a different cost variable for the incineration, recycling, or disposal of PV modules. Although it is possible that in 30 years technology will be available to recycle silicon and other metals from PV modules and reuse at a net benefit, DNV GL assumed a fix cost to dispose/recycle PV modules as a separate cost to landfill. The following landfill costs are assumed [6]:

- PV modules (disposal or recycling): $25 per module
- Class 2 landfill, Construction waste: $75/ton

5.2 PV Modules, PV support system and piles foundation

5.2.1 Salvage and disposal

There should be considerable opportunity to reclaim scrap value from the PV support systems and the piles as they are manufactured from steel.

Table 5-1 summarizes the salvage and disposal costs per solar component. Component weights have been estimated by DNV GL, and/or obtained directly from manufacturer's documentation.

Table 5-1 PV components – Salvage and disposal values

Item	Disposal ($)	Salvage ($)
PV Modules	(13,168,400)	-
PV Support System	(103,300)	473,100
Piles	-	878,400
PV Strings	-	144,300
Total	**(13,271,700)**	**1,495,800**

Note: Negative values (those in parenthesis) are costs to the Project which represent disposal. Positive values are salvage associated revenue.

5.3 Collection system

5.3.1 Underground collection system

The underground conductor and ground cabling from the Project will be sold for scrap or disposed. Based on Project information, DNV GL has estimated at total of approximately 1,815,287 ft of PV string cabling, 912,922 feet of dc cabling, 473,040 feet ac cabling (3 Phase), 159,540 feet of fiber cabling and 231,531 feet bare copper grounding. For Scenario 1 DNV GL has assumed that all the collection system will be removed whereas for Scenario 2 the assumption has been that it will be abandoned in place.

The results are reported in Table 5-2 below.

5.3.2 Disconnect boxes

The disconnect boxes from the Project will be sold for scrap and/or salvaged as second-hand equipment.

The results are reported in Table 5-2 below.

5.3.3 Inverter stations

DNV GL has assumed that the inverter stations will either be fully salvaged for scrap or resold as second-hand equipment. DNV GL has estimated that an inverter station could be resold for 25% of its original value. This scenario has been taken into account in Section 6.

5.4 High-voltage substation

There should be opportunity to reclaim metal scrap value from electrical equipment. Yard equipment such as bus work, circuit breakers, grounding transformers, and main transformers contain a significant amount of conductive material such as copper and aluminum. Dead-end and other steel structures contain a significant amount of steel. The substation yard also contains aggregate, concrete rubble from the foundation demolition and all other materials would be sent to landfill at cost. The scrap value of the substation is presented in Table 5-2 below.

DNV GL considers that there is a resale market for substation transformers. Therefore, the transformers could be sold as operational second-hand equipment instead of being scrapped. This scenario has been taken into account in Section 6.

Table 5-2 Collection system - Salvage/disposal value (without resale of components)

Item	Disposal ($)	Salvage ($)
Underground cabling	(622,200)	458,900
Disconnect boxes	-	92,900
Inverter stations	-	937,300
Substation and control building	(71,800)	215,300
Total	**(694,000)**	**1,704,400**

5.5 Transmission line

The three-phase conductor cable can be sold for scrap and the poles could potentially be resold to an electric utility as second-hand parts. Based on Project details and specifications provided by WPS's, DNV GL has estimated at total of 36 transmission poles and approximately 13.8 miles of total conductor (3 phases). There is no disposal cost for the transmission line because it is assumed to be entirely salvaged. The results of this valuation are presented in Table 5-4.

5.6 Civil work and others

5.6.1 Site access roads and laydown area

For the purpose of disposal calculations, the Project's access roads and laydown area to be disposed at cost and have no salvage value as the material will be mixed with different screening material and unwanted contaminants.

The results of this valuation are presented in Table 5-3 below.

5.6.2 Fencing, and security

For the purpose of salvage and disposal calculations, the Project's fencing, and gates are assumed to have a net positive salvage value.

The results of this valuation are presented in Table 5-3 below.

5.6.3 Weather station

Although it is possible that the weather stations could be dismantled, resold, and reused at a different location, a 30-year old system may have limited reinstallation value (although it could very well be a candidate to remain for a repowering scenario). For conservatism in this study, DNV GL assumes a dismantling and removal with the intent of scrapping the material.

The results of this valuation are presented in Table 5-3 below.

Table 5-3 Civil – Salvage/disposal value (without resale of components)

Item	Disposal ($)	Salvage ($)
Access roads and laydown area	(1,628,000)	-
Fencing and security system	-	32,000
Total	**(1,628,000)**	**32,000**

Note: negative values, those in parenthesis, are costs to the Project.

5.7 Salvage – Disposal conclusions

Table 5-4 summarizes the opportunities from the salvage/disposal analysis. Please note that this table does not incorporate the resale scenarios of transformers. These will be included in Section 6.

Table 5-4 Salvage/disposal value (without resale of components) conclusion

Item	Disposal ($)	Salvage ($)
PV modules, PV support system and piles	(13,271,700)	1,495,800
Collection system and substation	(694,000)	1,704,400
Transmission line	-	421,000
Civil works and others	(1,628,000)	32,000
Total	**(15,593,700)**	**3,653,200**

Note: negative values, those in parenthesis, are costs to the Project.

6 NET DECOMMISSIONING COST

The net decommissioning cost for the Project is calculated by subtracting the salvage value from the total of the disassembly, removal, and disposal costs. This report presents two net decommissioning cost breakdowns: Scenario 1 assumes no resale of Project components, and Scenario 2 takes the more likely scenario for the possibility of partial resale of some of the components. As agreed with WPS, DNV GL has assumed that recycling technology will be fully available at the time of decommissioning; therefore, the PV module disposal cost has been eliminated altogether in Scenario 2. DNV GL considers that at the end of the Project's operating life, the main power transformers and the 48 inverter station transformers will still be serviceable and have positive value in the secondary parts market.

6.1 Net decommissioning cost – no resale

Table 6-1 summarizes the Project's net decommissioning costs assuming no resale of any Project components other than for scrap value.

Table 6-1 Project Net decommissioning costs – no resale (Scenario 1)

Item	Disassembly (A)	Removal (B)	Disposal (C)	Total Costs (D=A+B+C)	Salvage (E)
PV modules, racking, and piles	$6,406,600	$3,429,000	$13,271,700	$23,107,300	($1,495,800)
Collection system	$2,661,000	$3,013,800	$622,200	$6,297,000	($1,489,100)
High-voltage substation	$484,000	$69,700	$71,800	$625,500	($215,300)
Transmission line	$494,100	$22,200	-	$516,300	($421,000)
Civil - Access roads & laydown area, reseeding and fencing	$2,774,900	$294,400	$1,628,000	$4,697,300	($32,000)
Mobilization/soft costs		$2,012,200		-	-
Project Totals	$12,820,600	$6,829,100	$15,593,700	$37,255,600	($3,653,200)
Total Project (D+E)	**$33,602,400**				
Total Project [$/kW dc]	**157.8**				
Total Project [$/kW ac]	**224.0**				

6.2 Net decommissioning cost – partial resale of selected components

Table 6-2 summarizes the Project's net decommissioning costs inclusive of some plausible and conservative resale assumptions as well as the assumptions presented included at WPS's request:

- The technology and industry of PV modules recycling is fully evolved therefore the disposal cost of PV modules is nil;
- All underground collection system is abandoned in place;
- 50% of the project roads are left in place upon agreement with land owners; and
- No reseeding is necessary as land will be returned to agricultural use.

Table 6-2 Project Net decommissioning costs – partial resale and other assumptions (Scenario 2)

Item	Disassembly (A)	Removal (B)	Disposal (C)	Total Costs (D=A+B+C)	Resale/ Salvage (F)
PV modules, racking, and piles	$6,406,600	$3,429,000	$103,300	$9,938,900	($1,495,800)
Collection system	$1,842,800	$724,900	-	$2,567,700	($1,202,700)
High-voltage substation	$484,000	$69,700	$71,800	$625,500	($948,500)
Transmission line	$494,100	$22,200	-	$516,300	($421,000)
Civil - Access roads & laydown area, reseeding and fencing	$1,423,700	$250,800	$1,312,000	$2,986,500	($32,000)
Mobilization/soft costs		$1,081,700		-	-
Project Totals	$10,651,200	$4,496,600	$1,487,100	$17,716,600	($4,100,000)
Total Project (D+F)	**$13,616,600**				
Total Project [$/kW dc]	**63.9**				
Total Project [$/kW ac]	**90.8**				

As agreed with WPS[7], DNV GL has also calculated the potential revenue to the Project if a second-hand market for PV modules is available at the time of decommissioning. DNV GL has limited information on a second-hand PV modules market and considers it difficult to predict how one might develop/evolve within the next 30 years. For the purposes of determining such potential revenue to the Project, DNV GL has assumed that the PV modules could be sold at $0.08/Wdc, generating a revenue of $17M to the Project. Disassembly and Removal of the PV modules would still be required, at the costs presented in Table 6-2.

Table 6-3 Scenario 2 cost analysis for varying PV modules final destinations

Total Project	Value
With zero disposal cost	$13,616,600
With 2nd-hand market revenue	($3,422,600)

Table 6-3 shows that under the Scenario 2 assumptions presented above, a PV module resale in a second-hand market at a price of $0.08/Wdc would allow the Project to cover all disassembly, removal and disposal costs. In fact, it would allow the Project to generate a net revenue of approximately $5M, or $23.6/kWdc.

6.3 High-level sensitivity analysis

DNV GL notes that net decommissioning cost estimates for the Project are highly dependent on the cost of labor, transportation, and the price of scrap metal. Table 64 presents a high-level sensitivity analysis of net decommissioning costs where the labor, transportation and scrap metal- input costs/price assumptions were varied by ±20%. Labor is the most sensitive cost driver, and this is explained by the large number of hours that site staff is expected to invest on the disassembly and removal activities. The sensitivity analysis shows that a 20% fluctuation in the assumed cost of labor could yield a variation of approximately $7/kWdc in the net decommissioning cost under Scenario 1. However, it is noted that this simple sensitivity analysis does not take into account combined variations of costs/prices.

Table 6-4 Project net decommissioning costs – Sensitivity analysis (Scenario 1)

Cost input	% change	Total for Project [$]	Total for Project [$/kWdc]	Total for Project [$/kWac]
Labor	+20%	35,091,300	164.8	233.9
	-20%	32,112,500	150.8	214.1
Transportation	+20%	35,030,100	164.5	233.5
	-20%	32,174,400	151.1	214.5
Scrap steel	+20%	33,317,700	156.4	222.1
	-20%	33,886,800	159.1	225.9

6.4 Recommendations

It is stressed that this report is based on broad assumptions regarding the Project, the approach to the decommissioning, the market conditions for contracting costs, and the scrap value and resale options. DNV GL recommends that the net costs of decommissioning be reviewed closer to the end of the operating period (e.g., 2 to 4 years prior to the end of operations), when better visibility on these factors would be possible. The value of decommissioning after 30 years of operation could be reviewed at this time as well as the value of decommissioning at another point in the future, taking into consideration potential extended operational revenue as well as Project operations beyond the design life. The scenario would be easier to evaluate then and, if design and safety conditions warrant, it would be a viable alternative as long as future revenues outpace future expenditures.

7 REFERENCES

[1] https://www.pv-magazine.com/press-releases/pv-cycle-and-recycle-pv-solar-announce-integrated-partnership-for-recycling-in-the-usa/

[2] email from Richard OConor, WPS, to Michael Cookson, DNV GL, dated 25 February 2020.

[3] Two Creeks IFC electrical drawing sets, RRC: "2019.08.23 Two Creeks EE Design Dwgs Combined IFC-0.pdf", dated"23 August 2019; "Two Creeks Substation IFC package, dated 3 April 2020"; and "Two Creeks Transmission Line IFC package, dated 10 January 2020".

[4] USGS web site: http://minerals.usgs.gov/minerals/pubs/commodity/

[5] Wisconsin metal pricing http://www.cooleysscrap.com/services/pricing/ and https://iscrapapp.com/prices

[6] Wisconsin Waste management pricing, http://www.co.green.wi.gov/docview.asp?docid=19178&locid=148

[7] email from Doug Wetjen, WPS, to Michael Cookson, DNV GL, date 18 October 2019

APPENDIX A – MAIN ASSUMPTIONS

1000		**Special requirements**	
	1001	Decommissioning requirements applicable to the Project	WPS CPCN
1100		**Project basics**	
	1101	Solar Power Plant Name	Two Creeks
	1102	Construction Status	Under Construction
	1103	General Location	Manitowoc County and Kewaunee County
	1104	No. Solar Modules	526,734
	1105	Make and Model of Solar Module	Jinko JKM390M-72HL-V and JKM400M-72HL-V
	1106	Racking System style	Single axis tracker
	1107	Inverter Station Make	Power Electronics
	1108	Dc Project Capacity [MW]	212.99
	1109	Ac Project Capacity [MW]	150
	1110	dc/ac Ratio	1.42
	1111	Project Design Life [yr]	30
	1112	Decommissioning to Occur After Which Project Year	30
	1113	No. of Substations to Remove	1
	1114	No. of main project transformers	1
	1115	No. of Control buildings to Remove	1
	1116	Length of Underground Trenching to Remove [ft]	456,461
	1117	Length of Overhead Transmission System to Remove [mi]	4.6
	1118	No. of PV Support System [single-axis tracker array]	6,888
	1119	No. of Piles on project site [units]	74,553
	1120	Laydown Area to Reclaim [Acre]	9.7
	1121	Length of Project Access Roads to Reclaim [ft]	44,548
	1122	No. of Inverter Station to Remove [units]	48
1200		**Additional information**	
	1201	Commercial Operation Date	Q4 2020
	1202	Main step-up transformer voltage [kV/kV]	34.5/138
	1203	Main step-up transformer rating [MVA]	170
	1204	Inverter step-up transformer voltage [kV/kV]	2.5/34.5
	1205	Inverter step-up transformer rating [kVA]	3,510
	1206	Disconnect Boxes	929
	1207	Total ac Cables [ft]	473,040
	1208a	Total 500/600 kcmil dc Cables [ft]	912,922
	1208b	Total 350 kcmil dc Cables [ft]	226,888
	1209	Total PV String Cables [ft]	1,815,287
	1210	Ground Cables [ft]	231,531
	1211	Fiber Cables [ft]	159,540
	1212	No. of Overhead Steel Poles [units]	34
	1213	Pull Vaults and Junctions Boxes [units]	12

About DNV GL

Driven by our purpose of safeguarding life, property, and the environment, DNV GL enables organizations to advance the safety and sustainability of their business. We provide classification, technical assurance, software, and independent expert advisory services to the maritime, oil & gas, and energy industries. We also provide certification services to customers across a wide range of industries. Combining leading technical and operational expertise, risk methodology and in-depth industry knowledge, we empower our customers' decisions and actions with trust and confidence. We continuously invest in research and collaborative innovation to provide our customers and society with operational and technological foresight. Operating in more than 100 countries, we are dedicated to helping our customers make the world safer, smarter, and greener.

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RESEARCH ARTICLE

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Barrier Behaviour Analysis (BaBA) reveals extensive effects of fencing on wide-ranging ungulates

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Abstract

1. As human activities expand globally, there is a growing need to identify and mitigate barriers to animal movements. Fencing is a pervasive human modification of the landscape that can impede the movements of wide-ranging animals. Previous research has largely focused on whether fences block movements altogether, but a more nuanced understanding of animals' behavioural responses to fences may be critical for examining the ecological consequences and prioritizing conservation interventions.
2. We developed a spatial- and temporal-explicit approach, Barrier Behaviour Analysis (BaBA, available as an R package), to examine individual-level behaviours in response to linear barriers. BaBA classifies animal-barrier encounters into six behaviour categories: *quick cross*, *average movement*, *bounce*, *back-and-forth*, *trace* and *trapped*. We applied BaBA to wide-ranging female pronghorn *Antilocapra americana* and mule deer *Odocoileus hemionus* in an area of western Wyoming, USA, with >6,000 km of fencing.
3. We found both species were extensively affected by fences, with nearly 40% of fence encounters altering their normal movements, though pronghorn were more strongly affected than mule deer. On average, an individual pronghorn encountered fences 250 times a year—twice the encounter rate of mule deer. Pronghorn were more likely to bounce away from fences, whereas deer engaged in more *back-and-forth*, *trace* and *average movement* near fences.
4. We aggregated these behavioural responses to demonstrate how BaBA can be used to examine species-specific fencing permeability and to identify problematic fence segments in order to guide fence modification or removal.
5. *Synthesis and applications*. Our work provides empirical evidence on how fences affect wildlife movement. Importantly, Barrier Behaviour Analysis (BaBA) can be applied to evaluate other linear features (such as roads, railways and pipelines) and habitat edges, enhancing our ability to understand and mitigate widespread barrier effects to animal movement.

KEYWORDS

animal movement, BaBA package, barrier mitigation, conservation prioritization, fence, linear barriers, ungulate, wildlife migration

1 | INTRODUCTION

Animal movements connect disparate habitats in space and time, and sustain critical ecosystem functions and services (Bauer & Hoye, 2014; Lundberg & Moberg, 2003). Yet the movements of wide-ranging animals also render them vulnerable to landscape fragmentation caused by anthropogenic barriers (e.g. roads, pipelines). Fencing, which has been implemented since the beginning of human civilization, is among the most pervasive of these barriers (Jakes et al., 2018; Kotchemidova, 2008). The total length of fencing around the world may now exceed that of roads by an order of magnitude (Jakes et al., 2018), and continues to grow due to a global trend towards land partition and privatization (Linnell et al., 2016; Weldemichel & Lein, 2019; Yu et al., 2016).

Terrestrial wide-ranging mammals, such as migratory ungulates, are particularly susceptible to fence effects because fences directly block movement paths. Some of these effects are intentional and carry conservation benefits. For instance, fences are used to reduce roadway mortality (Clevenger et al., 2001), control disease transmission (Mysterud & Rolandsen, 2019) and facilitate endangered species recovery (e.g. woodland caribou, Cornwall, 2016). Fences also carry indirect conservation benefits in some systems, such as the US West, where maintaining livestock grazing as a viable land use may protect some wildlife habitat from exurban development (Cornwall, 2016; Jakes et al., 2018). However, fences also carry conservation costs. Impermeable fences, such as border and veterinary fences, completely block animal movement and often induce drastic population declines subsequently (Said et al., 2016; Woodroffe et al., 2014). Semipermeable fences allow a degree of connectivity, but may still reduce movement efficiency and compromise animals' ability to access valuable resources (Cozzi et al., 2013; Jakes et al., 2018). In some cases, animals avoid areas near fences altogether, such that high fence density significantly diminishes habitat effectiveness (Zhang et al., 2014). The nature and strength of fence effects vary by species, according to such factors as movement capacity, diet preference and adaptability to disturbance (Burkholder et al., 2018; Cozzi et al., 2013).

To date, most studies on fence effects have focused on measuring animal crossing rates (Bauman et al., 1999; Jones et al., 2020), mortality risk (Harrington & Conover, 2016) or population distribution (Said et al., 2016; Stabach et al., 2016; Zhang et al., 2014). While this information is valuable for basic management and land-use planning, animals' behavioural responses to fencing appear substantially more complex. For example, upon encountering a fence line, animals may 'patrol' along boundaries, seeking breaks for crossing opportunities (Gates et al., 2011; Nandintsetseg et al., 2019) or immediately deflect away (Vanak et al., 2010). Animals may also move more quickly in the immediate vicinity of fences (Mark Peaden et al., 2017). For animals less sensitive to fencing, there might be no visible changes in movement patterns at all (Cozzi et al., 2013). Identifying the full suite of behavioural responses, and how these vary by species, is a key step towards understanding the consequences for individual physiology, population demography and species interactions.

A better understanding of wildlife responses to fencing is also critical to conservation. Increasingly, land and wildlife managers seek to facilitate ungulate movement through fence removal (e.g. Alexander & Ferguson, 2010) or fence modification to meet 'wildlife-friendly' standards (Paige, 2015; Paige & Stevensville, 2008). Studies have shown that proper modification locations are critical for mitigation effectiveness (Burkholder et al., 2018; Jones et al., 2018, 2020). Given the sheer amount of fencing in some areas (e.g. Løvschal et al., 2017; Poor et al., 2014; Sun et al., 2020) and the costs of removal and modification (Huijser et al., 2009, B. Gray and A. Hemenway, pers. comm.), the ability to identify problematic fences is a major challenge for land and wildlife managers. Recent advances in animal tracking technology have created new opportunities to identify movement behaviours near fences, and to link behaviours to spatially explicit fence maps.

In this study, we examined near-fence behaviours of two migratory ungulate species which are of growing conservation concern across the western US, pronghorn *Antilocapra americana* and mule deer *Odocoileus hemionus*. Pronghorn ecology remains relatively poorly understood among North American ungulates, but the species is subject to intensive conservation and restoration efforts in some parts of the range (Jones, 2014; Sawyer et al., 2019), including habitat improvement and fence removal and modification (Jones et al., 2020). Meanwhile, mule deer is a species of conservation concern in a number of western US states, sometimes due to habitat loss and potentially barriers (Sawyer et al., 2017). We adopted a comparative approach because these species often co-occur, but exhibit different general responses to fences. Specifically, mule deer are known to jump over fences readily, whereas pronghorn prefer to crawl under fences (Jones, 2014; Jones et al., 2018). The reluctance to jump means that pronghorn movements can be completely blocked by woven-wire sheep or barbed-wire fences with low bottom wires (<40 cm)—the two most common types of fences across their home range in North America (Gates et al., 2011). To investigate these two species' behavioural responses to fences, we developed and applied a repeatable method that categorizes individual movement behaviours in response to linear barriers such as fences (Barrier Behaviour Analysis, BaBA). We conducted this work in western Wyoming, USA—a region known for some of the longest remaining ungulate migrations in North America and where fencing is a ubiquitous landscape feature (Middleton et al., 2020; Sayre, 2015). We identify extensive, complex behavioural responses of these wildlife to fences, examine spatial and temporal characteristics of these responses and demonstrate how BaBA might be used to inform conservation efforts.

2 | MATERIALS AND METHODS

2.1 | Study area

Our study area (17,420 km^2) is located in western Wyoming (110.03 W, 42.907 N, elevation 1,949–3,997 m, Figure 1). This semiarid region provides habitat for thousands of migratory pronghorn

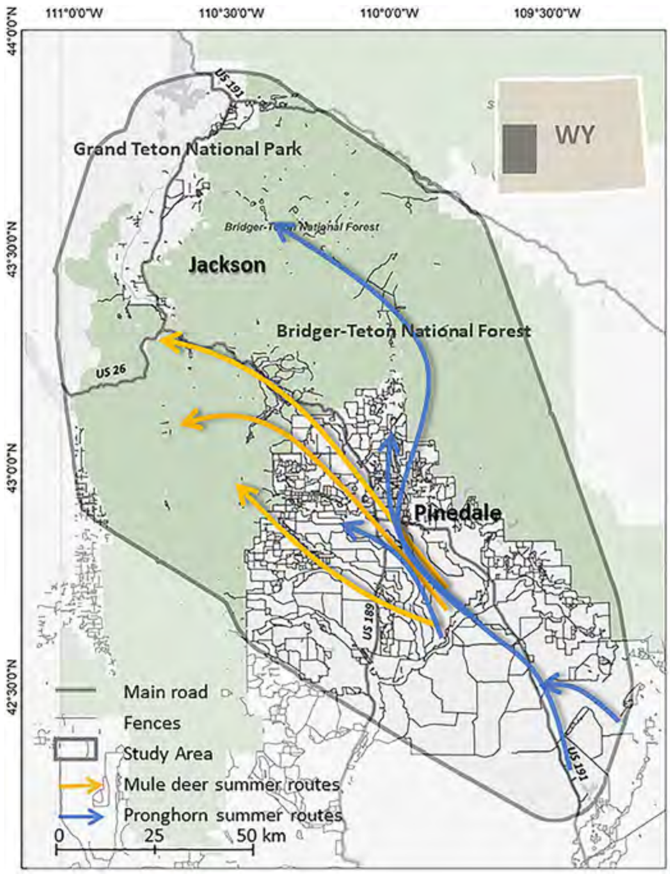

FIGURE 1 Study area and typical fence structure in the area. Upper right: four-strand barbed wire fence. Lower right: woven wire sheep fence

and mule deer that migrate 30–160 km between seasonal ranges (Sawyer et al., 2005). The southern part of the area is the lower elevation Green River Basin, characterized by sagebrush (*Artemisia* sp.) and sagebrush grasslands interspersed with riparian tributaries of the Green River. The landscape shifts into mountainous terrain as elevation increases towards the northern end, characterized by mid-elevation aspen *Populus tremuloides* and lodgepole pine *Pinus contorta*, and higher elevation Engelmann spruce *Picea engelmannii* and alpine fir *Abies lasiocarpa*. Most fencing in the study area is associated with livestock pastures, private property and right of ways along roads. Fence density is higher in the rangelands of Green River Basin compared to the forested areas to the north. Most fences in the region are four- or five-strand barbed wire, sometimes with woven-wire attached at the bottom (Figure 1). We refer readers to Sawyer et al. (2019) for a more detailed description of this area.

2.2 | Animal tracking data and fence data

For each species, we used GPS (Telonics) locations collected from 12 adult females in 2014 and 12 different adult females in 2016 (Xu et al., 2020). We focused on tracking females because they represent the reproductive segment of the population. We selected individuals that followed a variety of migration routes, which allows us to examine larger numbers of fences across the area (Figure S1). Data for each individual spanned January 1 to December 31. GPS positions were collected every 2 hr and each animal-year had fix rate success of ≥99% (refer to Sawyer et al., 2017, 2019 for detailed animal capture and data collection protocols). The 24 mule deer were all migratory and travelled from a shared winter range in the basin to three general summer ranges in higher elevation forest areas (Figure 1). In contrast, the 24 pronghorn varied across a migration behavioural continuum (Cagnacci et al., 2011) from long-distance migrants to residents. The two species shared a general winter range, but tended to spatially segregate in summer when mule deer migrated to higher elevation areas (Sawyer et al., 2005). For each species, we defined their home range using 95% kernel density estimation on all GPS points. We also calculated cumulative movement distances by summing all step lengths for each individual in the corresponding year.

We combined existing digital fence layers from the Bureau of Land Management, U.S. Forest Service and Wyoming Game of Fish Department. We validated our fence layer by manually checking fence lines against the submetre resolution (0.3–0.5 m) remote sensing imagery base maps in ArcGIS 10.5. To label each fence line, we dissolved all fence features before applying the 'multipart to single part' tool in ArcGIS (Xu et al., 2020). Our fence compilation process identified the location of fences but did not distinguish between fence types (e.g. woven wire vs. barbed wire).

2.3 | Fence Behaviours Analysis

Barrier Behaviour Analysis is a spatial- and temporal-explicit method to identify and classify barrier behaviours based on GPS tracking data relative to linear spatial features. We categorized each animal's response to a fence encounter into three general categories (Figure 2). The first was *normal movement*, wherein the encounter location is permeable enough for the animal to quickly cross the barrier (*quick cross*), or the animal does not change its movement pattern notably (*average movement*). Although *normal movement* may still cause extra energy expenditure, the barrier does not conspicuously influence animals' mobility. The second was *altered movement*, wherein the animal either quickly moves away from the barrier (*bounce*), stays close by going back and forth (*back-and-forth*) or moves along the barrier (*trace*). Note that *back-and-forth* and *trace* may sometimes lead to successful crossings, but the behavioural response caused a prolonged delay in the movement pattern, so we consider the event as an *altered movement*. The third was *trapped*, wherein animal locations are constantly near barriers, indicating the animal might be constrained, or choose to stay, in one enclosed area (*trapped*). *Trapped* also includes cases where the animal is able to cross one barrier line but only to enter in the proximity of another one.

With GPS data and fence location as input, BaBA identifies continuous GPS locations that fall within fence buffer area as encounter events. These events are subsequently classified into one of the six barrier behaviour types based on the encounter duration, straightness of the encounter movement segment and numbers of trajectory–fence intersections. The output of BaBA is a spatial data frame with each row representing an encounter event annotated with animal ID, time of occurring, duration of the event, numbers of intersections between fences and this movement segment and classified event type. A step-by-step BaBA guide can be found in Appendix S1.

For pronghorn and mule deer, we used BaBA with fence buffer distances every 10 m from 50 m to 150 m and used *quick cross* events as indicators to identify the optimal fence buffer distance that best captured animal crossing attempts (Appendix S1). To compare pronghorn and mule deer fence behaviours, we calculated the mean and the standard deviation of numbers of each type of fence behaviour across individuals, by species. We conducted a sensitivity analysis of BaBA results by adjusting parameter settings and GPS temporal intervals (Appendix S2).

2.4 | Identifying and prioritizing problematic fences

We spatially joined the BaBA result generated from the optimal fence buffer distance with the fence layer to create a fencing evaluation map. We characterized each fence line by the total number of animal encounters that occurred along it, the total number of unique individuals that interacted with it and the total number of each barrier behaviour along it. For each fence line, we calculated a permeability index to evaluate how often it alters animal movement, defined by the ratio of non-*normal movement* events (*bounce* + *trace* + *back-and-forth* + *trapped*) to total encounter events, weighted by numbers of unique individuals encountered and scaled to 0–1. Because not all mapped fences were encountered by animals equally, we only included ones with at least 10 encounters to ensure sufficient information exist for calculating the permeability index. All analyses were programmed in R (R Core Team, 2020), and the script is available in R package BaBA at https://github.com/wx-ecology/BaBA.

3 | RESULTS

3.1 | Fence and home range

Fencing digitization and correction generated 6,244.33 km of fence in the study area, with a density of 0.36 km/km^2 (Figure 1). Results of home range and movement distance calculations confirmed a widely dispersed movement pattern of pronghorn (Figure S1). The total range size of the 24 pronghorn was 5,726.7 km^2, with an accumulated movement distance of 1551.4 ± 201.0 km per year, 68% longer than that of a mule deer (991.8 ± 91.0 km). Deer were more migratory and the range of the 24 individuals (3,793.9 km^2) delineated their seasonal habitats and migration corridor. The average fence density in pronghorn range was 0.91 km/km^2, compared to 0.59 km/km^2 for mule deer.

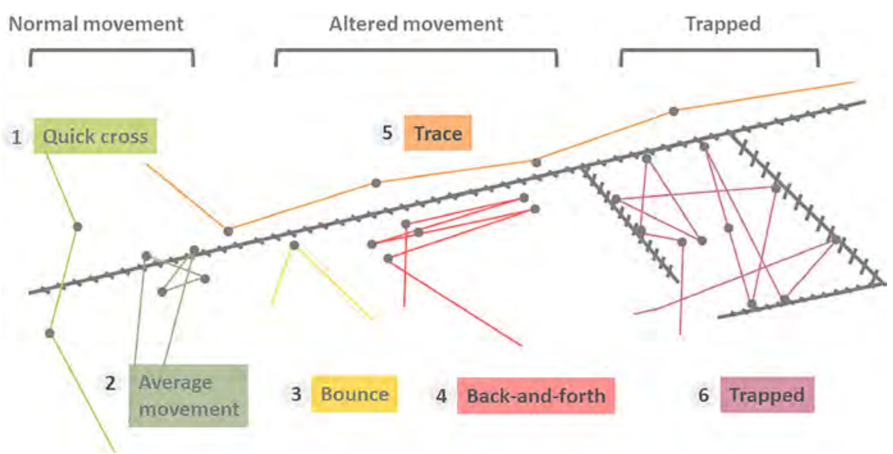

FIGURE 2 The six behavioural types identified in Barrier Behaviour Analysis. When a fence does not represent a significant barrier to movement, an animal can conduct *normal movement*, including (1) quick cross and (2) average movement. Otherwise, animals may (3) bounce away from fences or (4) move back-and-forth and (5) trace along the fence to seek a potential crossing. In some cases, an animal may become (6) trapped in a fenced area and forced to remain in proximity to fences for a prolonged period

3.2 | Fence Behaviours Analysis

For pronghorn, a 110-meter fence buffer best captured the *quick cross* events, while for mule deer, this optimal distance was 90 m (Figure 3; Appendix S1). Pronghorn encountered fences on an average of 248.5 ± 94.8 (mean ± *SD*, same below) times per year, twice the rate of mule deer (119.3 ± 86.2). Both species had similar *quick crossing* rates, with 51.0 ± 6.1% for pronghorn and 51.6 ± 10.5% for mule deer. Among non-crossing behaviours, pronghorn *bounced* away from fences (76.4 ± 7.6%) more frequently than mule deer (64.7 ± 12.5%; Mann–Whitney $p < 0.05$). When animals did spend time near fences and were not trapped (i.e. they were engaged in *average movement*, *back-and-forth* or *trace* behaviours), mule deer were more likely to maintain *average movement* patterns than pronghorn (63.8 ± 14.2% vs. 57.0 ± 13.1%, Mann–Whitney $p < 0.05$). For both species, the *back-and-forth* to *trace* ratio was about 3:2.

Pronghorn were impacted by fences more in summer than in winter (Figure 4), as fence encounters increased May through September

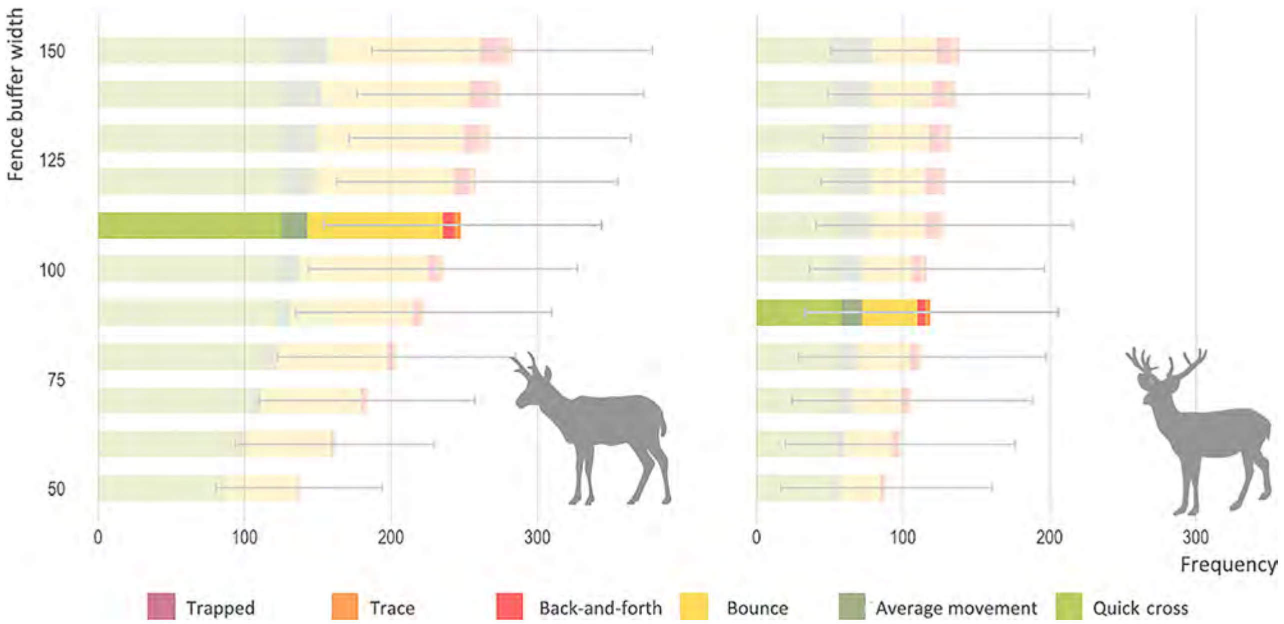

FIGURE 3 Annual individual frequency of barrier behaviours. Grey bars show the standard deviation of total fence encounters across the 24 individuals. The optimal distance for capturing fence crossing behaviours is 110 m for pronghorn, and 90 m for mule deer (highlighted bars)

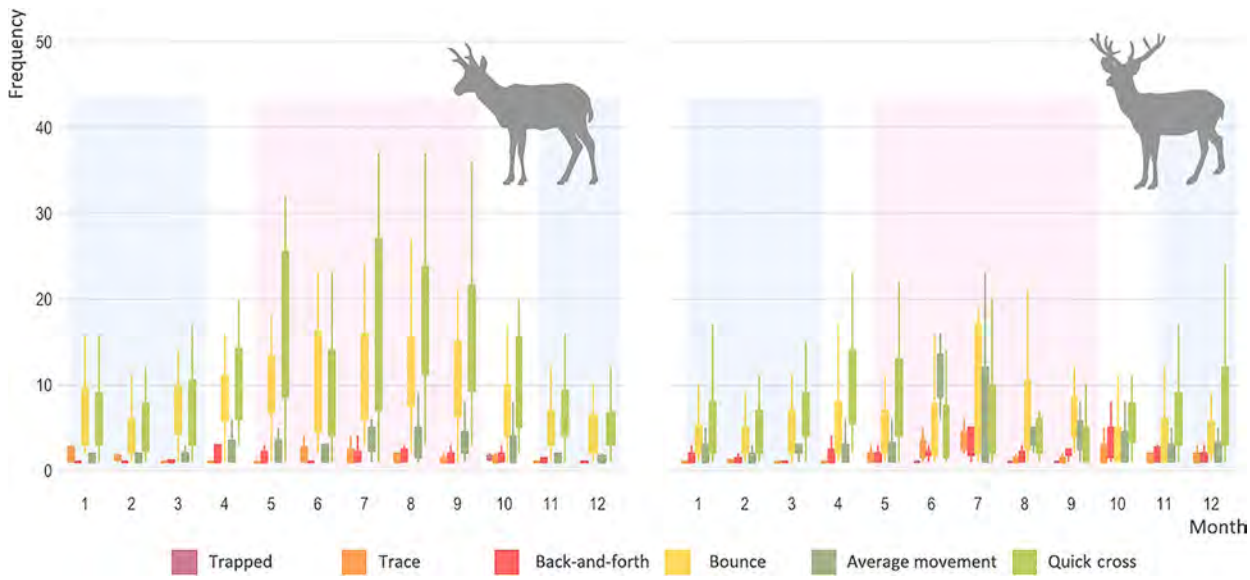

FIGURE 4 Seasonal variability of barrier behaviour. Pronghorn ($n = 24$) had a large, single peak seasonal variation in fence encounters with more bounce and quick cross behaviours during the summer (May–September, pink shade) compared to the winter (November–March, blue shade). Mule deer ($n = 24$) showed variable barrier behaviours throughout the year, with a slight, but not significant, increase in frequency during the summer

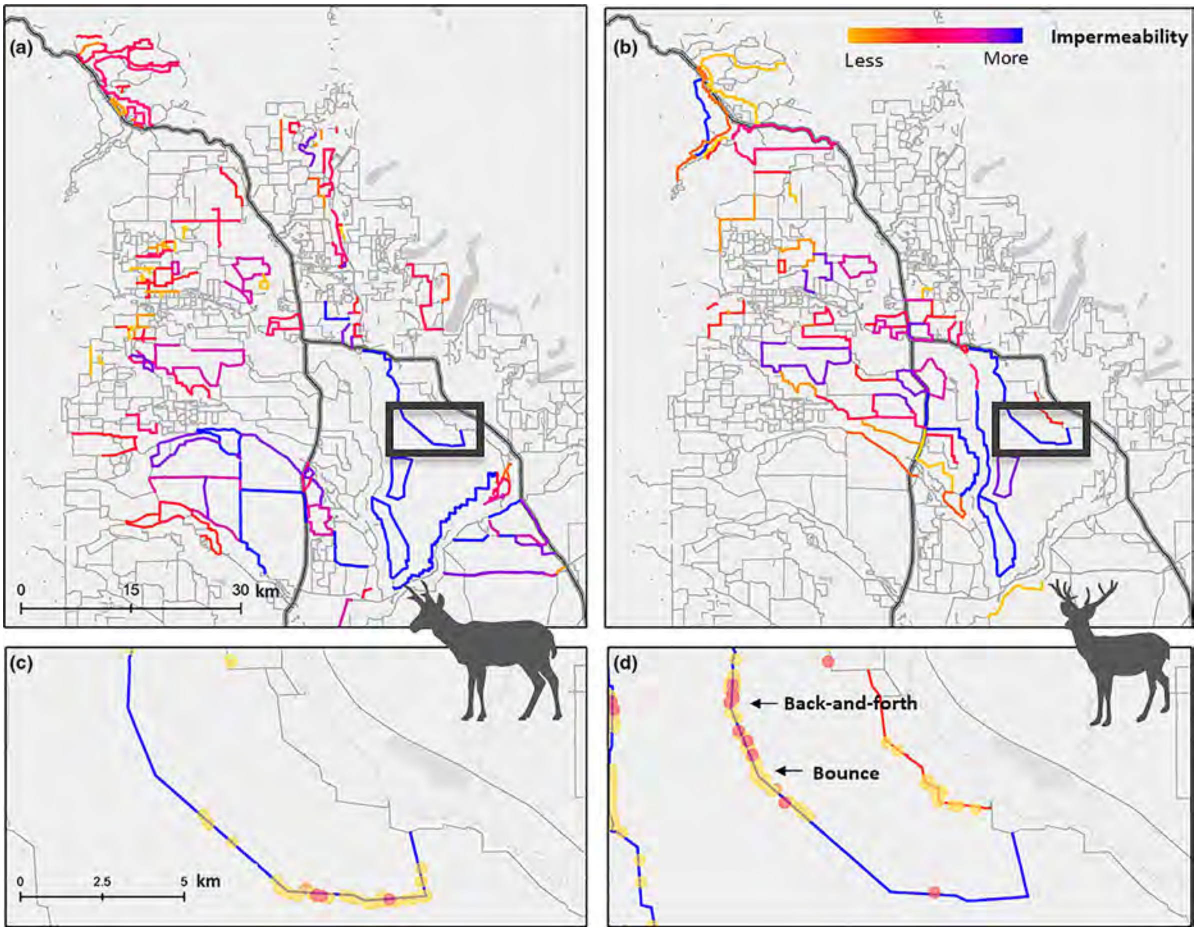

FIGURE 5 Fencing mitigation prioritization for (a) pronghorn and (b) mule deer movement. Only fence lines that had more than 10 total encounters are highlighted in colours. (c and d) show the zoom-in view of the boxed area in the top panels overlaid with classified fence encounter events

(summer encounters increased by 52.1 ± 46.5% compared to the winter encounters, Mann–Whitney $p < 0.05$). Specifically, pronghorn performed more *bounce* and *quick cross* behaviours, but other longer lasting behaviours did not increase as much. In contrast, some mule deer individuals even encountered fences less in the summer, and the changes were not significant across individuals between winter and summer (Mann–Whitney $p = 0.26$).

3.3 | Identifying and prioritizing problematic fences

Fence segments elicited different behavioural responses from pronghorn and mule deer, indicating some were more permeable than others. Cumulative levels of behavioural responses weighted by the number individuals detected at each fence segment provided a spatially explicit map, revealing a species-specific permeability landscape for pronghorn and deer. The highest concentration of problematic fences appeared to coincide with the central part of the study area that both pronghorn and deer utilize as winter range (Figure 5a,b). Notably, fences in the southeast corner of the study area with higher impermeability for mule deer also appeared to be problematic for pronghorn. Figure 5c,d showcase one fence that was problematic for both species and this zoom-in view further demonstrated species difference at a finer scale. Pronghorn often bounced at the southern section of this fence, yet mule deer encounters tended to happen at the west with high occurrences of *back-and-forth*.

4 | DISCUSSION

Scientists and conservationists increasingly recognize the ubiquity and potential impacts of fencing on global biodiversity, and have called for empirical studies of fence ecology to guide conservation and management (Durant et al., 2015; Jakes et al., 2018). Our work answers this call, revealing extensive effects of fencing on the movement behaviour of two wide-ranging ungulate species in western North America, effects which are expressed via a suite of specific behavioural responses. Specifically, the pronghorn and mule deer we studied crossed fences about half the time they encountered fences, but in the other half of these encounters mainly adopted *bounce*, *trace* and *back-and-forth* behaviours to avoid fences or find potential crossings. We show how fence effects vary in space and time and affected these two highly mobile ungulate species differently. Importantly, we demonstrate that when summed and mapped, these behaviours can aid in identifying problematic fence segments, potentially aiding in mitigation programmes. Our method, BaBA, is applicable to any linear barrier and habitat edges, illustrating how future work can harness tracking data to understand and ameliorate constraints on animal movements.

Importantly, our study shows that behavioural responses to fences are more complex than simply crossing or not crossing them. For both pronghorn and deer, nearly 40% of fence encounters altered their normal movement. Among the non-normal fence behaviours, *bounce* was the most common for both species, indicating that animals often move away from fences if they cannot quickly cross. Such avoidance of fences can drive animals away from high-quality resources and reduce habitat use effectiveness (Jones et al., 2019)—a barrier effect reported for a wide range of species including wildebeest *Connochaetes taurinus* (Stabach et al., 2016), African elephant *Loxodonta africana* (Vanak et al., 2010) and Przewalski's gazelle *Procapra przewalskii* (Zhang et al., 2014). The other two altered fence behaviours, *back-and-forth* and *trace*, could be particularly costly, especially when resources are not available along fences. For example, Mongolian gazelle *Procapra gutturosa* were observed to trace border fences for as long as 59 days (Nandintsetseg et al., 2019). Lastly, although not frequently detected in our study, *trapped* events often occurred in areas with high fence density—for example, near exurban properties or livestock pastures. Constraining animal movements for prolonged periods within limited areas may trigger human–wildlife conflicts (Zhang et al., 2014).

Our results are likely a conservative estimation of actual fencing impacts in our study area. For highly mobile animals like pronghorn and mule deer, our moderate 2-hr GPS interval might not capture nuanced movement changes caused by fencing in a shorter time period (Appendices S2 and S3). Fine-scale GPS tracking data manifest high spatiotemporal autocorrelation. While we focused on barrier behaviours of females in this study, males might be more constrained by fences because their large horns could prevent them from crossing underneath. Altogether, though the wildlife can still move across the study area, it is conceivable that connectivity and habitat function are substantially compromised across large portions of the landscape due to the cumulative effects of fence behaviours. Our future research will focus on evaluating potential ecological and demographic consequences of the different types of fence behaviours.

Our results also illuminate the species-specific nature of fence impacts on wildlife. Compared to mule deer, pronghorn encountered fences twice as often, which might be associated with their longer cumulative movement distance and dispersed movement patterns (Figure S1). It is possible that fences contribute to the relatively long movement distances of pronghorn by constantly redirecting them and making directed point-to-point movements difficult. Similarly, Ockenfels et al. (1997) found that fenced roads significantly constrain the shapes of pronghorn home range. At a broader scale, fence construction across the American West (Sayre, 2015) could shape the geographic distribution of pronghorn, confining them to a portion of their historical range. Pronghorn also exhibited larger seasonal variations in fence behaviours than mule deer, encountering fences 1.5 times more in summer than in winter. This pattern is likely a result of pronghorn simply moving more than deer during the summer and the spatial distribution of fences in our study area. Most pronghorn are an obligate to open plains and basins, whereas mule deer migrate into mountainous areas where fences are sparse, resulting in a much higher fence density in pronghorn year-round home range. It is generally recognized that winter is a critical season for pronghorn fitness and survival (Keating, 2002). However, our study underlines an unexpected conservation challenge that summer as well is a costly season for pronghorn considering energy spent interacting with fences. Given one recent estimate of over 1 million km of roadside fences and pasture fences in the American West (McInturff et al., 2020), fence modifications for conservation might be more urgent than currently recognized.

The spatial-explicit BaBA results, when viewed cumulatively, can be used to prioritize fence modification efforts (Figure 5). The distinctive distributions of problematic fences for the two species highlight the importance of the species-specific perspective when evaluating conservation needs in fenced landscapes. Pronghorn and deer shared several of the most problematic, or least permeable, fences, which highlight obvious areas to prioritize fence mitigation. The prioritization maps also highlight conservation challenges for conserving wide-ranging animals. Our map resulted from only 24 sampled animals. Additional animal tracking data might further expand the numbers and the distribution of problematic fences, especially for pronghorn because of their expansive movement pattern. Furthermore, problematic fences were dispersed widely across the study area, overlapping with a complex mosaic of public and private land ownerships (Middleton et al., 2020). Collaborative efforts and integrated land use management are likely necessary to ensure success of fence modifications for these wildlife.

Although we focus on fences here, BaBA can be widely applied to other types of linear barriers (e.g. roads, pipelines) and habitat edges (e.g. woody-cultivated ecotones). These applications can potentially aid in a wide range of conservation projects—such as constructing wildlife passages at optimal locations along highways and railroads (Xu et al., 2019). Yet, we caution that types of barrier behaviours classified by BaBA are solely based on physical characteristics of movement trajectories, and its application and interpretation should be informed by species movement characteristics, spatial precision of barrier locations and temporal resolution of GPS data (Appendix S1). For example, the *trace* behaviour can be extremely costly (Gates et al., 2011; Nandintsetseg et al., 2019) or can be a navigation tactic that boosts animal foraging and movement efficiency (e.g. Dickie et al., 2017; Rostro-García et al., 2015). Second, for demonstration purposes, we chose individuals that range over relatively large areas. Yet, when applied to management of populations, we recommend a more representative sampling design, ideally with multiple years of data to obtain sufficient encounter rates across fences.

To date, most fences on earth are still undocumented or unmapped (Jakes et al., 2018). Our study area alone contained 6,244 km fences, more than double the length of the US–Mexico border (3,145 km). Yet this only represents a small fraction of the total amount of fence in north America and beyond (McInturff et al., 2020). With the increasing availability of high-resolution remote sensing images and the rapid development of the field of computer vision, methods like deep learning can be applied in detecting fences systematically at a landscape scale (Christin et al., 2019). With the benefit of such technological advancement, we hope BaBA can be strengthened and play a significant role in generating synoptic knowledge across species and systems, underpinning the burgeoning subdiscipline of fence ecology and conservation.

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AUTHORS' CONTRIBUTIONS

W.X., N.D., H.S. and A.M. conceived the ideas; W.X. and V.H. designed the methodology; H.S. collected the data; W.X. analysed the data; W.X. led the writing of the manuscript. All authors contributed critically to the writing and editing, and gave final approval for publication.

DATA AVAILABILITY STATEMENT

Data available from the Dryad Digital Repository https://doi.org/10.6078/D1FB0R (Xu et al., 2020).

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REFERENCES

Alexander, A., & Ferguson, K. (2010). Delineating and decommissioning of park and veterinary fences. In K. Ferguson & J. Hanks (Eds.), *Fencing impacts: A review of the environmental, social, and economic impacts of game and veterinary fencing in Africa with particular reference to the Great Limpopo and Kavango Zambezi Transfrontier Conservation Areas* (pp. 223–227). University of Pretoria: Mammal Research Institute.

Bauer, S., & Hoye, B. J. (2014). Migratory animals couple biodiversity and ecosystem functioning worldwide. *Science*, *344*(6179), 1242552. https://doi.org/10.1126/science.1242552

Bauman, P. J., Jenks, J. A., & Roddy, D. E. (1999). Evaluating techniques to monitor elk movement across fence lines. *Wildlife Society Bulletin*, *27*(2), 344–352.

Burkholder, E. N., Jakes, A. F., Jones, P. F., Hebblewhite, M., & Bishop, C. J. (2018). To jump or not to jump: Mule deer and white-tailed deer fence crossing decisions. *Wildlife Society Bulletin*, *42*(3), 420–429. https://doi.org/10.1002/wsb.898

Cagnacci, F., Focardi, S., Heurich, M., Stache, A., Hewison, A. J. M., Morellet, N., Kjellander, P., Linnell, J. D. C., Mysterud, A., Neteler, M., Delucchi, L., Ossi, F., & Urbano, F. (2011). Partial migration in roe deer: Migratory and resident tactics are end points of a behavioural gradient determined by ecological factors. *Oikos*, *120*(12), 1790–1802. https://doi.org/10.1111/j.1600-0706.2011.19441.x

Christin, S., Hervet, É., & Lecomte, N. (2019, October 1). Applications for deep learning in ecology. In H. Ye (Ed.), *Methods in ecology and evolution*. British Ecological Society. https://doi.org/10.1111/2041-210X.13256

Clevenger, A. P., Chruszca, B., & Gunson, K. E. (2001). Highway mitigation fencing reduces wildlife-vehicle collisions. *Wildlife Society Bulletin*, *29*(2), 646–653.

Cornwall, W. (2016). To save caribou, Alberta wants to fence them in: Controversial proposal envisions the construction of a massive, predator-free pen. *Science*, *353*(6297), 333. https://doi.org/10.1126/science.353.6297.333

Cozzi, G., Broekhuis, F., Mcnutt, J. W., & Schmid, B. (2013). Comparison of the effects of artificial and natural barriers on large African carnivores: Implications for interspecific relationships and connectivity. *Journal of Animal Ecology*, *82*, 707–715. https://doi.org/10.1111/1365-2656.12039

Dickie, M., Serrouya, R., McNay, R. S., & Boutin, S. (2017). Faster and farther: Wolf movement on linear features and implications for hunting behaviour. *Journal of Applied Ecology*, *54*(1), 253–263. https://doi.org/10.1111/1365-2664.12732

Durant, S. M., Becker, M. S., Creel, S., Bashir, S., Dickman, A. J., Beudels-Jamar, R. C., Lichtenfeld, L., Hilborn, R., Wall, J., Wittemyer, G., Badamjav, L., Blake, S., Boitani, L., Breitenmoser, C., Broekhuis, F., Christianson, D., Cozzi, G., Davenport, T. R. B., Deutsch, J., … Pettorelli, N. (2015). Developing fencing policies for dryland ecosystems. *Journal of Applied Ecology*, *52*(3), 544–551. https://doi.org/10.1111/1365-2664.12415

Gates, C. C., Jones, P., Suitor, M., Jakes, A., Boyce, M. S., Kunkel, K., & Wilson, K. (2011). The influence of land use and fences on habitat effectiveness, movements and distribution of pronghorn in the grasslands of North America. In *Fencing for conservation: Restriction of evolutionary potential or a riposte to threatening processes?* (pp. 277–294). Springer New York. https://doi.org/10.1007/978-1-4614-0902-1

Harrington, J. L., & Conover, M. R. (2016). Characteristics of ungulate behavior and mortality associated with wire fences. *Wildlife Society Bulletin*, *34*(5), 1295–1305.

Huijser, M. P., Duffield, J. W., Clevenger, A. P., Ament, R. J., & McGowen, P. T. (2009). Cost-benefit analyses of mitigation measures aimed at reducing collisions with large ungulates in the United States and Canada: A decision support tool. *Ecology and Society*, *14*(2). https://doi.org/10.5751/es-03000-140215

Jakes, A. F., Jones, P. F., Paige, L. C., Seidler, R. G., & Huijser, M. P. (2018). A fence runs through it: A call for greater attention to the influence of fences on wildlife and ecosystems. *Biological Conservation*, *227*, 310–318. https://doi.org/10.1016/j.biocon.2018.09.026

Jones, P. F. (2014). Scarred for life: The other side of the fence debate. *Human–Wildlife Interactions*, *8*(1), 150–154. https://doi.org/10.26077/mppv-tt76

Jones, P. F., Jakes, A. F., Eacker, D. R., Seward, B. C., Hebblewhite, M., & Martin, B. H. (2018). Evaluating responses by pronghorn to fence modifications across the Northern Great Plains. *Wildlife Society Bulletin*, *42*(2), 225–236. https://doi.org/10.1002/wsb.869

Jones, P. F., Jakes, A. F., MacDonald, A. M., Hanlon, J. A., Eacker, D. R., Martin, B. H., & Hebblewhite, M. (2020). Evaluating responses by sympatric ungulates to fence modifications across the Northern Great Plains. *Wildlife Society Bulletin*, *44*(1), 130–141. https://doi.org/10.1002/wsb.1067

Jones, P. F., Jakes, A. F., Telander, A. C., Sawyer, H., Martin, B. H., & Hebblewhite, M. (2019). Fences reduce habitat for a partially migratory ungulate in the Northern Sagebrush Steppe. *Ecosphere*, *10*(7), https://doi.org/10.1002/ecs2.2782

Keating, K. A. (2002). *History of pronghorn population monitoring, research, and management in Yellowstone National Park* (pp. 1–70). U.S. Geological Survey. https://doi.org/10.3133/70159756

Kotchemidova, C. (2008). The culture of the fence: Artifacts and meanings. *Counterblast-The Journal of Culture and Communication*, *2*, 1–4.

Linnell, J. D. C., Trouwborst, A., Boitani, L., Kaczensky, P., Huber, D., Reljic, S., Kusak, J., Majic, A., Skrbinsek, T., Potocnik, H., Hayward, M. W., Milner-Gulland, E. J., Buuveibaatar, B., Olson, K. A., Badamjav, L., Bischof, R., Zuther, S., & Breitenmoser, U. (2016). Border security fencing and wildlife: The end of the transboundary paradigm in Eurasia? *PLoS Biology*, *14*(6), 1–13. https://doi.org/10.1371/journal.pbio.1002483

Løvschal, M., Bøcher, P. K., Pilgaard, J., Amoke, I., Odingo, A., Thuo, A., & Svenning, J. C. (2017). Fencing bodes a rapid collapse of the unique Greater Mara ecosystem. *Scientific Reports*, *7*. https://doi.org/10.1038/srep41450

Lundberg, J., & Moberg, F. (2003). Mobile link organisms and ecosystem functioning: Implications for ecosystem resilience and management. *Ecosystems*, *6*(1), 87–98. https://doi.org/10.1007/s10021-002-0150-4

Mark Peaden, J., Justin Nowakowski, A., Tuberville, T. D., Buhlmann, K. A., & Todd, B. D. (2017). Effects of roads and roadside fencing on movements, space use, and carapace temperatures of a threatened tortoise. *Biological Conservation*, *214*, 13–22. https://doi.org/10.1016/j.biocon.2017.07.022

McInturff, A., Xu, W., Wilkinson, C. E., Dejid, N., & Brashares, J. S. (2020). Fence ecology: Frameworks for understanding the ecological effects of fences. *BioScience*, biaa103. https://doi.org/10.1093/biosci/biaa103

Middleton, A. D., Sawyer, H., Merkle, J. A., Kauffman, M. J., Cole, E. K., Dewey, S. R., Gude, J. A., Gustine, D. D., McWhirter, D. E., Proffitt, K. M., & White, P. J. (2020). Conserving transboundary wildlife migrations: Recent insights from the Greater Yellowstone Ecosystem. *Frontiers in Ecology and the Environment*, *18*(2), 83–91. https://doi.org/10.1002/fee.2145

Mysterud, A., & Rolandsen, C. M. (2019). Fencing for wildlife disease control. *Journal of Applied Ecology*, *56*(3), 519–525. https://doi.org/10.1111/1365-2664.13301

Nandintsetseg, D., Bracis, C., Olson, K. A., Böhning-Gaese, K., Calabrese, J. M., Chimeddorj, B., Fagan, W. F., Fleming, C. H., Heiner, M., Kaczensky, P., Leimgruber, P., Munkhnast, D., Stratmann, T., & Mueller, T. (2019). Challenges in the conservation of wide-ranging nomadic species. *Journal of Applied Ecology*, *56*(8), 1916–1926. https://doi.org/10.1111/1365-2664.13380

Ockenfels, R. A., Carrel, W. K., & van Riper, C. (1997). Home ranges and movements of pronghorn in Northern Arizona. *Arizona Game and Fish Department Wildlife Bulletin*, *3*, 45–61.

Paige, C. (2015). *A Wyoming landowner's handbook to fences and wildlife: Practical tips for fencing with wildlife in mind* (pp. 1–56). Wyoming Community Foundation. https://westernlandowners.org/publication/a-wyoming-landowners-handbook-to-fences-and-wildlife/

Paige, C., & Stevensville, M. T. (2008). *A landowner's guide to wildlife friendly fences* (pp. 1–56). Montana Fish, Wildlife and Parks. https://www.nrcs.usda.gov/wps/PA_NRCSConsumption/download/?cid=nrcseprd1080608&ext=pdf

Poor, E. E., Jakes, A., Loucks, C., & Suitor, M. (2014). Modeling fence location and density at a regional scale for use in wildlife management. *PLoS ONE*, *9*(1), e83912. https://doi.org/10.1371/journal.pone.0083912

R Core Team. (2020). *R: A language and environment for statistical computing*. R Foundation for Statistical Computing. https://www.R-project.org/

Rostro-García, S., Kamler, J. F., & Hunter, L. T. B. (2015). To kill, stay or flee: The effects of lions and landscape factors on habitat and kill site selection of cheetahs in South Africa. *PLoS ONE*, *10*(2), https://doi.org/10.1371/journal.pone.0117743

Said, M. Y., Ogutu, J. O., Kifugo, S. C., Makui, O., Reid, R. S., & de Leeuw, J. (2016). Effects of extreme land fragmentation on wildlife and livestock population abundance and distribution. *Journal for Nature Conservation*, *34*, 151–164. https://doi.org/10.1016/j.jnc.2016.10.005

Sawyer, H., Beckmann, J. P., Seidler, R. G., & Berger, J. (2019). Long-term effects of energy development on winter distribution and residency of pronghorn in the Greater Yellowstone Ecosystem. *Conservation Science and Practice*, *1*(9). https://doi.org/10.1111/csp2.83

Sawyer, H., Korfanta, N. M., Nielson, R. M., Monteith, K. L., & Strickland, D. (2017). Mule deer and energy development—Long-term trends of habituation and abundance. *Global Change Biology*, *23*(11), 4521–4529. https://doi.org/10.1111/gcb.13711

Sawyer, H., Lindzey, F., & McWhirter, D. (2005). Mule deer and pronghorn migration in Western Wyoming. *Wildlife Society Bulletin*, *33*(4), 1266–1273. https://doi.org/10.1098/rspb.2001.1703

Sayre, N. F. (2015). The coyote-proof pasture experiment. *Progress in Physical Geography: Earth and Environment*, *39*(5), 576–593. https://doi.org/10.1177/0309133314567582

Stabach, J. A., Wittemyer, G., Boone, R. B., Reid, R. S., & Worden, J. S. (2016). Variation in habitat selection by white-bearded wildebeest across different degrees of human disturbance. *Ecosphere*, *7*(8), 1–17. https://doi.org/10.1002/ecs2.1428

Sun, J., Liu, M., Fu, B., Kemp, D., Zhao, W., Liu, G., Han, G., Wilkes, A., Lu, X., Chen, Y., Cheng, G., Zhou, T., Hou, G. E., Zhan, T., Peng, F., Shang, H., Xu, M., Shi, P., He, Y., … Liu, S. (2020). Reconsidering the efficiency of grazing exclusion using fences on the Tibetan Plateau. *Science Bulletin*, *65*(16), 1405–1414. https://doi.org/10.1016/j.scib.2020.04.035

Vanak, A. T., Thaker, M., & Slotow, R. (2010). Do fences create an edge-effect on the movement patterns of a highly mobile mega-herbivore? *Biological Conservation*, *143*(11), 2631–2637. https://doi.org/10.1016/j.biocon.2010.07.005

Weldemichel, T. G., & Lein, H. (2019). Fencing is our last stronghold before we lose it all. A political ecology of fencing around the Maasai Mara national reserve, Kenya: Authors. *Land Use Policy*, *87*, 104075. https://doi.org/10.1016/j.landusepol.2019.104075

Woodroffe, R., Hedges, S., & Durant, S. M. (2014). To fence or not to fence. *Science*, *344*(6179), 46–48. https://doi.org/10.1126/science.1246251

Xu, W., Dejid, N., Herrmann, V., Sawyer, H., & Middleton, A. (2020). Data from: Barrier Behavior Analysis (BaBA) reveals extensive effects of fencing on wide-ranging ungulates. *Dryad Digital Repository*, https://doi.org/10.6078/D1FB0R

Xu, W., Huang, Q., Stabach, J., Buho, H., & Leimgruber, P. (2019). Railway underpass location affects migration distance in Tibetan antelope (*Pantholops hodgsonii*). *PLoS ONE*, *14*(2), e0211798. https://doi.org/10.1371/journal.pone.0211798

Yu, C., Zhang, X., Zhang, J., Li, S., Song, C., Fang, Y., Wurst, S., & Wu, J. (2016). Grazing exclusion to recover degraded alpine pastures needs scientific assessments across the Northern Tibetan Plateau. *Sustainability (Switzerland)*, *8*(11), 1–6. https://doi.org/10.3390/su8111162

Zhang, L., Liu, J., McShea, W. J., Wu, Y., Wang, D., & Lü, Z. (2014). The impact of fencing on the distribution of Przewalski's gazelle. *Journal of Wildlife Management*, *78*(2), 255–263. https://doi.org/10.1002/jwmg.653

SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section.

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ROAD USE AND MAINTENANCE AGREEMENT

THIS ROAD USE AND MAINTENANCE AGREEMENT ("**Agreement**") is entered into as of this 13 day of July, 2020 ("**Effective Date**") by and between the Town of Potosi, whose address for purposes of this Agreement is 125 Cross Street, Potosi, WI 53820, Attn: Curtis Fetzek, Chairman ("**Township**") and Grant County Solar, LLC, a Delaware limited liability company, whose address for purposes of this Agreement is 700 Universe Boulevard, Juno Beach, FL 33408 ("**Operator**").

RECITALS

WHEREAS, Operator is developing a commercial solar electrical generation facility ("**Project**') on a site located in Grant County, Wisconsin, with an expected total nameplate capacity of approximately 200 megawatts ("**MW**"); and

WHEREAS, Operator intends to obtain the necessary approvals to build, operate and maintain the Project; and

WHEREAS, in connection with the construction, operation and maintenance of the Project, the Parties desire to address certain issues relating to the roads owned, operated and maintained by the Township (collectively, the "**Roads**") over which it will be necessary for Operator and Operator's Representative(s) to, among other things: (i) transport heavy equipment and materials which may be in excess of local design limits of certain Roads, (ii) transport locally sourced materials, such as concrete and gravel, on the Roads; (iii) make specific modifications and improvements (both temporary and permanent) to the Roads (including various associated culverts, bridges, road shoulders and other fixtures) to permit such equipment and materials to pass; and (iv) place overhead and underground electrical and communication cables (collectively "**Cables**") for the Project adjacent to, along, and under or across such Roads; and

WHEREAS, Operator and the Township wish to set forth their understanding and agreement relating to the use of Roads during the construction and operation of the Project; and

NOW, THEREFORE, in consideration of the mutual terms and conditions set forth in the Agreement, and for other good and valuable consideration, receipt of which is hereby acknowledged, the Parties agree as follows:

TERMS AND CONDITIONS

1. Operator will undertake the following activities in accordance with the terms of this Agreement:

a. Designate a company representative with authority to represent Operator. As of the date of the Agreement, the company representative is Toni Darwish (561) 304-5493.

b. At least sixty (60) days prior to beginning construction of the Project, provide the Township with a preliminary site plan identifying solar panel locations, site access points, and road crossings, to be attached as **Exhibit A**, along with the preliminary transportation route for the Project equipment attached as **Exhibit B**, subject to amendment;

c. Provide plans to the Township for the widening of any corner radius necessary to facilitate the turning movements of the transport trucks used by Operator during construction of the Project; make any necessary improvements; and at the conclusion of construction, remove any such improvements as the Township directs and restore the affected property to its original condition. The Township shall not be required to obtain any additional easements (whether permanent or temporary) for the Project;

d. Erect permanent markers indicating the presence of the Cables and install tape in any trench in which Operator has placed or will place Cables in a Township right-of-way. All Cables shall be buried at a minimum depth of forty-eight (48) inches below the road surface;

e. Notify the Township Highway Commissioner in advance of all oversize transportation and crane crossings over, across or along any Road;

f. Transport or cause to be transported the tower segments and other oversize loads in a reasonable effort to minimize adverse impact on the local traffic;

g. Provide reasonable advance notice to the Township when it is necessary for a Road to be closed due to a crane crossing or for any other reason relating to the construction of the Project. Notwithstanding the foregoing, Operator will provide no less than twenty-four (24) hours' notice and will provide all materials necessary to close the road;

h. Provide signage of all road closures and work zones in compliance with the Manual on Uniform Traffic Control Devices and as may be required by the Township;

i. Purchase and deliver applicable road materials for repairs to Roads that are damaged by Operator and/or an Operator Representative during the hauling of materials and/or construction of the Project and bear costs to restore any Roads that are damaged by Operator and/or Operator Representative during the hauling of materials and/or construction of the Project to the condition enjoyed immediately prior to such damage occurring, to the extent possible. Operator will restore significant damage to any Roads within sixty (60) days after the date the damage occurs, but will restore any minor damage to Roads within sixty (60) days after the commercial operations date of the Project

j. Cables must cross a road, in which case, these Cables will be bored under the road, buried at a minimum depth of forty-eight (48) inches below the road surface and the crossing shall be restored promptly to its pre-construction condition;

k. Pay to the Township the annual amount of $6,500.00. The first payment will be made within sixty (60) days after the Effective Date and thereafter the annual payment will be made on or before February 28th of every year that Operator is operating the Project.

2. The Township, in accordance with the terms of this Agreement, agrees that it shall:

a. Within fifteen (15) days following the Effective Date of this Agreement, designate a Township representative with authority to represent the Township at (608) 763-2841;

b. Perform routine and regular maintenance of the Roads (as needed to not impede access) including; grading, snow removal, striping, routine signage, and regularly scheduled maintenance of the Roads, as necessary.

c. Review and approve all Project-related access points and road crossings, which are submitted by Operator in **Exhibit A** within fifteen (15) days after submission;

d. Timely review and approve plans for all Project-related utility encroachments on Township rights-of-way; which are submitted by Operator in accordance with **Exhibit A**;

e. Authorize the designated Township representative to agree on behalf of Township to revisions to **Exhibit A** and the final location of Road crossings, access points, and utility encroachments as revisions are submitted to the Township by or on behalf of Operator.

3. Planning Inventory

a. Road Inventory

1. Pre-Construction Inventory. No later than thirty (30) days prior to the start of construction, the Parties shall jointly perform a survey to record the condition of the pavement surface of the Roads which will be used in the transport of equipment to the Project. During this survey, the entire length of the roads shall be videotaped if deemed necessary by the parties, photographs may also be taken. In addition, the Township will provide Operator, if available, with copies of any plans, cross-sections and specifications relevant to the existing Roads structure. Copies of all pre-construction documentation shall be provided to each of the Parties. Operator will reimburse the Township for all costs associated with the Pre-Construction Inventory.

2. Post-Construction Inventory

i. Upon completion of construction of each phase of the Project, representatives of the Township and Operator will perform a post-construction inventory, the methods of which shall be similar to those of the Pre-Construction Inventory described above. The two sets of pre and post-construction data will be compared and if there is any wheel lane rutting, cracking or other damage in excess of the original survey, the Township and Operator will determine the extent of the repairs or improvements needed to return the roads to a pre-construction condition. All costs associated with the Post-Construction Inventory shall be solely by Operator.

ii. Operator shall be obligated to, make any or all repairs necessary to return the roads to a pre-construction condition, at its sole cost and expense. Within five (5) calendar days following the completion of the Post-Construction Inventory, Operator shall provide notice to the Township identifying those repairs which Operator agrees to undertake and the expected date by which such repairs shall be completed.

b. Routing and Access Approval. As soon as practical after execution of this Agreement and as necessary throughout the construction of the Project, Operator and Township shall meet to discuss routing for the transportation of equipment to the Project, Project-related access points, road crossings and Cable locations and the Township shall review and approve the same in accordance with Sections 2.

4. Mutual Indemnification/Hold Harmless and Liability Insurance Provisions.

a. Indemnity. Each Party (the "**Indemnifying Party**") agrees to indemnify, defend and hold harmless the other Party and such other Party's mortgagees, Lenders, officers, employees and agents (the "**Indemnified Party**") against any and all losses, direct or indirect damages (including consequential damages), claims, expenses, and other liabilities, including, without limitation, attorney's fees, resulting from or arising out of (i) any negligent act or negligent failure to act on the part of the Indemnifying Party or anyone else engaged in doing work for the Indemnifying Party, or (ii) any breach of this Agreement by the Indemnifying Party. This indemnification shall not apply to losses, damages, claims, expenses and other liabilities to the extent caused by any negligent or willful act or omission on the part of the Indemnified Party. Nothing in this paragraph or in this Agreement shall be construed as a waiver or limitation of Township's rights under Wis. Stat. § 893.80 or of the statutory damage limitations provided therein.

b. Limitations of Liability. In no event shall Operator or any of its members, officers, directors or employees of the Township or any of its Boards, officers or employees be liable (in contract or in tort, involving negligence, strict liability, or otherwise) to any other Party or their contractors, suppliers, employees, members and shareholders for indirect, incidental, consequential or punitive damages resulting from the performance, non-performance or delay in performance under this Agreement.

c. Required Insurance. Operator shall upon commencement of construction of the Project and for the period of construction of the Project, maintain in full force and effect commercial general liability insurance, in the aggregate amount equal to Three Million Dollars ($3,000,000). Operator may utilize any combination of primary and/or excess insurance to satisfy this requirement and may satisfy this requirement under existing insurance policies for the Project.

5. Miscellaneous

a. Remedies and Enforcement. The Parties acknowledge that money damages would not be an adequate remedy for any breach or threatened breach of this Agreement. Each of the parties hereto covenant and agree that in the event of default of any of the terms, provisions or conditions of this Agreement by any Party (the **"Defaulting Party"**), which default is not caused by the Party seeking to enforce said provisions (the **"Non-Defaulting Party"**) and after notice and reasonable opportunity to cure has been provided to the Defaulting Party, then in such an event, the Non-Defaulting Party shall have the right to seek specific performance and/or injunctive relief to remedy or prevent any breach or threatened breach of this Agreement. The remedies of specific performance and/or injunctive relief shall be exclusive of any other remedy available at law or in equity.

b. Due Authorization. Operator hereby represents and warrants that this Agreement has been duly authorized, executed and delivered on behalf of the Operator. The Township hereby represents, and warrants that this Agreement has been duly authorized, executed and delivered on behalf of the Township.

c. Severability. If any provision of this Agreement proves to be illegal, invalid, or unenforceable, the remainder of this Agreement will not be affected by such finding, and in lieu of each provision of this Agreement that is illegal, invalid, or unenforceable a provision shall be deemed added as may be possible to accurately reflect the intentions of the Parties and so as to make the unenforceable provision legal, valid, and enforceable.

d. Amendments. This Agreement constitutes the entire agreement and understanding of the parties and supersedes all offers, negotiations and other agreements. There are no representations or understandings of any kind not set forth herein. No amendment or modification to this Agreement or waiver of a Party's rights hereunder shall be binding unless it shall be in writing and signed by both Parties to this Agreement.

e. Notices. All notices shall be in writing and sent (including via facsimile transmission) to the Parties hereto at the addresses set forth in the Preamble (or to such other address as either such Party shall designate in writing to the other Party at any time).

f. Counterparts. This Agreement may be executed in any number of counterparts, each of which shall be deemed an original, with the same effect as if the signatures thereto and hereto were upon the instrument. Delivery of an executed counterpart of a signature age to this Agreement by electronic mail shall be as effective as delivery of an originally signed counterpart to this Agreement.

g. Governing Law. This Agreement shall be governed by and interpreted in accordance with the laws of the State of Wisconsin, irrespective of any conflict of laws provisions. Both parties desire that the transactions contemplated hereby be effected and carried out in a manner that is in compliance with all laws.

h. Successor and Assigns. This Agreement shall inure to the benefit of and shall be binding upon the Parties hereto, their respective successors, assignees, and legal representatives.

i. If any Term of this Agreement is found to be void or invalid, such invalidity shall not affect the remaining Terms of this Agreement, which shall continue in full force and effect.

j. Failure of Township or Operator to insist on strict performance of any of the conditions or provisions of this Agreement, or to exercise any of their rights hereunder, shall not waive such rights.

k. Whenever in this Agreement the approval or consent of either Township or Operator is required or contemplated, unless otherwise specifically stated, such approval or consent shall not be made the subject of a demand for additional compensation, nor otherwise unreasonably conditioned, withheld or delayed.

l. In any litigation arising from or related to this Agreement, the parties hereto each hereby knowingly, voluntarily and intentionally waive the right each may have to a trial by jury with respect to any litigation based hereon, or arising out of under or in connection with this Agreement.

[*Signatures on Next Page*]

IN WITNESS WHEREOF, the Parties have caused this Agreement to be executed in their respective names by their duly authorized officers.

Operator:

Grant County Solar, LLC
a Delaware limited liability company

By: ______________________________
Anthony Pedroni, Vice President

Township:

By: ______________________________
Curtis Fetzek, Chairman

ATTEST:

By: ______________________________
Peggy Udelhoven, Township Clerk

Approved as to Form:

By: ______________________________
Eileen A. Brownlee
Boardman & Clark, LLP
Township Attorney