Appendix H – Shadow Flicker Impact Analysis

Shadow Flicker Impact Analysis for the Ashley Wind Energy Project

McIntosh County, North Dakota

Prepared for

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1.0 OVERVIEW

A wind turbine's moving blades can cast a moving shadow on locations within a certain distance of a turbine. These moving shadows are called shadow flicker, and can be a temporary phenomena experienced at nearby residences or public gathering places. The impact area depends on the time of year and day (which determines the sun's azimuth and altitude angles) and the wind turbine's physical characteristics (height, rotor diameter, blade width, and orientation of the rotor blades). Shadow flicker generally occurs during low angle sunlight conditions, typically during sunrise and sunset times of the day. However, when the sun angle gets very low (less than 3 degrees), the light has to pass through more atmosphere and becomes too diffused to form a coherent shadow. Shadow flicker will not occur when the sun is obscured by clouds or fog, at night, or when the source turbine(s) are not operating.

Shadow flicker intensity is defined as the difference in brightness at a given location in the presence and absence of a shadow. Shadow flicker intensity diminishes with greater receptor-to-turbine separation distance. Shadow flicker intensity for receptor-to-turbine distances beyond 1,500 meters (4,921 feet) is very low and generally considered imperceptible. In general, increasing proximity to turbines may make shadow flicker more noticeable, with the largest number of shadow flicker hours, along with greatest shadow flicker intensity, occurring nearest the wind turbines.

CPV Ashley Wind Energy Company, LLC (CPV) is proposing to install up to 87 wind turbines as part of the Ashley Wind Energy Project (the Project) in McIntosh County, North Dakota. Since the Project is using a minimum turbine siting setback requirement of 1,400 feet (427 meters to any residence), receptors (potentially occupied residences) are generally not located in potential shadow flicker impact zones, which ensures that shadow flicker impacts are minimized.

The two wind turbine models being considered for the Project, and evaluated for potential shadow flicker impacts, have the following characteristics:

- **General Electric (GE) 2.5xl** – 3-blade 103-meter diameter rotor, with a hub height of 85 meters. The GE 2.5xl has a normal high rotor speed of 14 rotations per minute (rpm) which translates to a blade pass frequency of 0.7 Hertz (Hz) which is less than 1 alternation per second.
- **Siemens Energy, Inc. (Siemens) SWT 2.3-101** – 3-blade 101-meter diameter rotor, with a hub height of 80 meters. The Siemens SWT 2.3-101 has a normal high rotor speed of 16 rpm which translates to a blade pass frequency of 0.8 Hz (less than 1 alternation per second).

Shadow flicker frequency is related to the wind turbine's rotor blade speed and the number of blades on the rotor. From a health standpoint, such low frequencies are harmless. For comparison, strobe lights used in discotheques have frequencies which range from about 3 Hz to 10 Hz (1 Hz = 1 flash per second). As a result, public concerns that flickering light from wind turbines can have negative health effects, such as triggering seizures in people with epilepsy are unfounded. The Epilepsy Action (working name for the British Epilepsy Foundation) states

that there is no evidence that wind turbines can cause seizures (Epilepsy Action 2008). However, they recommend that wind turbine flicker frequency be limited to 3 Hz. Since the proposed Project's wind turbine blade pass frequency is approximately 0.7-0.8 Hz (less than 1 alternation per second), no negative health effects to individuals with photosensitive epilepsy are anticipated.

Shadow flicker impacts are not regulated in applicable state or federal law, and there is no permitting trigger with regard to hours per year of anticipated impacts to a receptor from a wind energy project. Due to the significant growth of the wind energy industry in recent years, some states have published model bylaws for local governments to adopt or modify at their own discretion which sometimes includes guidance and recommendations for shadow flicker levels and mitigation. However, a general precedent has been established in the industry both abroad and in the United States that fewer than 30 hours per year of shadow flicker impacts is acceptable to receptors in terms of nuisance and well below health hazard concerns. In a German court case for example, a judge found 30 hours of actual shadow flicker per year at a certain neighbor's property to be tolerable (WindPower 2003). Thirty hours per year of shadow flicker or less at a receptor is well below any concern of nuisance or health impacts and has been widely used in the industry as a target value in the absence of formal guidelines. However, a value of 30 hours per year of shadow flicker or greater at a receptor does not necessarily create a nuisance and can still be well below concerns for impacts to health.

2.0 WINDPRO SHADOW FLICKER ANALYSIS

An analysis of potential shadow flicker impacts from the Project was conducted using the WindPro software package. The turbine array provided by CPV (Layout v4 dated June 13, 2010), which includes 87 turbines, was included in the analysis. The analysis evaluated the following two turbine scenarios:

- Scenario A – 87 GE 2.5xl turbines
- Scenario B – 87 Siemens SWT 2.3-101 turbines

The WindPro analysis was conducted to determine shadow flicker impacts under realistic impact conditions (actual expected shadow). This analysis calculated the total amount of time (hours and minutes per year) that shadow flicker could occur at receptors out to 1,500 meters (4,921 feet). The realistic impact condition scenario is based on the following assumptions:

- The elevation and position geometries of the wind turbines and surrounding receptors (potentially occupied residences). Elevations were determined using United States Geological Survey (USGS) digital elevation model (DEM) data. Positions geometries were determined using geographic information system (GIS) and referenced to Universal Transverse Mercator (UTM) Zone 14 (NAD83).
- The position of the sun and the incident sunlight relative to the wind turbine and receptors on a minute-by-minute basis over the course of a year.

- Historical sunshine hours availability (percent of total available). Historical sunshine rates for the area (as summarized by the National Climatic Data Center (NCDC 2008) for nearby Bismarck, North Dakota) used in this analysis are as follows:

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
53%	53%	58%	58%	61%	64%	73%	72%	65%	58%	43%	47%

- Estimated wind turbine operations and orientation (based on approximately 2 years of wind data from June 2008 through May 2010 (wind speed / wind direction frequency distribution) measured at on-site meteorological towers). The WindPro calculated wind direction frequency distribution for operating hour winds is as follows:

N	NNE	ENE	E	ESE	SSE	S	SSW	WSW	W	WNW	NNW
11.0%	5.3%	4.6%	4.3%	6.8%	11.1%	10.9%	5.8%	6.4%	6.8%	13.0%	14.0%

- Receptor viewpoints (i.e., house windows) are assumed to always be directly facing turbine to sun line of sight ("greenhouse mode").

WindPro incorporates terrain elevation contour information and the analysis accounts for terrain elevation differences. The sun's path with respect to each turbine location is calculated by the software to determine the cast shadow paths every minute over a full year. Sun angles less than 3 degrees above the horizon were excluded, for the reasons identified earlier in this section.

It should be noted however, that WindPro provides a conservative estimate of shadow flicker as obstacles such as trees, haze, and visual obstructions (window facing, coverings) are not fully accounted for and could possibly reduce or eliminate shadow flicker from receptors. A total of 15 receptor locations (potentially occupied residences) were identified within 1,500 meters of a proposed Project turbine. A receptor in the model is defined as a 1 meter squared area (approximate size of a typical window), 1 meter (3.28 feet) aboveground level. Approximate eye level is set at 1.5 meters (4.94 feet). Figure 1 shows the receptor locations and proposed Project turbines considered for both Scenario A and B.

3.0 SHADOW FLICKER ANALYSIS RESULTS

WindPro predicts that shadow flicker impacts will primarily occur near the wind turbines. Figures 2A and 2B describe the WindPro predicted expected shadow flicker impact areas for turbine Scenarios A and B, respectively. A detailed WindPro shadow flicker analysis results summary, for each of the modeling receptor locations, is provided in Attachment A. Tables 1A and 1B present the WindPro predicted expected shadow flicker impacts for the top ten worst case receptors for turbine Scenarios A and B, respectively. For both Scenario A and Scenario B, only 1 of the 15 receptors modeled had expected shadow flicker impacts predicted for more than 30 hours per year. The maximum predicted shadow flicker impact at a receptor is 38 hours 11 minutes per year (#3), which is approximately 0.9 percent of the potential available daylight hours.

Table 1A. **WindPro Predicted Shadow Flicker Impacts for Receptors with Maximum Expected Impacts – Turbine Scenario A (87 GE 2.5xl Turbines)**

Receptor ID*	Shadow Hours per Year (expected) [hh:mm / year]
3	38:11
2	27:12
7	26:09
11	25:07
8	24:50
6	16:32
12	13:10
4	10:24
13	10:02
1	8:27

Table 1B. **WindPro Predicted Shadow Flicker Impacts for Receptors with Maximum Expected Impacts – Turbine Scenario B (87 Siemens SWT 2.3-101 Turbines)**

Receptor ID*	Shadow Hours per Year (expected) [hh:mm / year]
3	35:00
7	24:29
2	24:23
11	21:12
8	19:32
6	14:44
12	10:55
4	9:31
13	8:08
1	7:26

The shadow flicker impact prediction statistics are as summarized in Table 2A and 2B.

Table 2A. Statistical Summary of WindPro Predicted Shadow Flicker Impacts at Modeled Receptor Locations – Turbine Scenario A (87 GE 2.5xl Turbines)

Cumulative Shadow Flicker Time (expected)	Number of Receptors
Total	15
= 0 Hours	3
> 0 Hours < 10 Hours	3
≥ 10 Hours < 20 Hours	4
≥ 20 Hours < 30 Hours	4
≥ 30 Hours < 40 Hours	1
≥ 40 Hours	0

Table 2B. Statistical Summary of WindPro Predicted Shadow Flicker Impacts at Modeled Receptor Locations – Turbine Scenario B (87 Siemens SWT 2.3 Turbines)

Cumulative Shadow Flicker Time (expected)	Number of Receptors
Total	15
= 0 Hours	3
> 0 Hours < 10 Hours	5
≥ 10 Hours < 20 Hours	3
≥ 20 Hours < 30 Hours	3
≥ 30 Hours < 40 Hours	1
≥ 40 Hours	0

The slightly higher shadow flicker impacts for Scenario A, can be explained by the difference in turbine design specifications.

Prior to finalizing the results of the WindPro analysis, Tetra Tech EC, Inc. (Tetra Tech) visited the Project location on July 19, 2010 with the objective of field verifying the existing conditions at receptor #3 which was the only receptor with expected shadow flicker impacts predicted for more than 30 hours per year. During the site visit Tetra Tech observed a stand of trees northwest of receptor #3 along with other various out building structures (barns, silos, etc.). These obstacles were added to the WindPro analysis to account for their potential mitigating effects for shadow flicker impacts. The results of the analysis are shown above in Table 1A and 1B. Tetra Tech confirmed the receptor is located on land under lease with CPV. Tetra Tech also determined that the receptor is an abandoned house which has been unoccupied since 1999 and has been described as no longer usable by the present landowner (Attachment B).

4.0 CONCLUSION

The analysis of potential shadow flicker impacts from the Project on nearby receptors shows that shadow flicker impacts within the area of study are expected to be minor and well within acceptable ranges that present no concerns for nuisance or health hazards. The one receptor that exceeds the target of 30 hours per year under the most conservative conditions is a participating landowner with the Project, with land under lease to CPV. The site verification field visit determined this receptor was an unoccupied home, confirmed by the landowner to be vacant since 1999 and no longer usable. The analysis assumes that the receptors all have a direct in-line view of the incoming shadow flicker sunlight and does not account for trees or

other obstructions which may block sunlight. In reality, the windows of many houses will not face the sun directly for the key shadow flicker impact times. In addition, potential shadow flicker impacts for wind turbines up to 1,500 meters (4,921 feet) away were determined. For these reasons, shadow flicker impacts are expected to be less than estimated with the conservative analysis, and shadow flicker is not expected to be a significant environmental impact. Mitigation measures such as strategic vegetative screening at receptors and/or installation of curtains and blinds on the windows facing the turbine casting the shadows are effective and economically viable options that CPV could consider on an individual basis with landowners, if necessary.

Notably, there is no state or federal regulatory threshold for shadow flicker hours per year at a given receptor; therefore, the Project in no way violates state or federal permitting requirements or conditions according to the results of this shadow flicker impact analysis. Finally, receptor #3 as identified in Section 3.0 is one of many receptors in this study located on land under lease with CPV for the development to the Project. This receptor has been unoccupied since 1999 and is no longer usable.

5.0 REFERENCES

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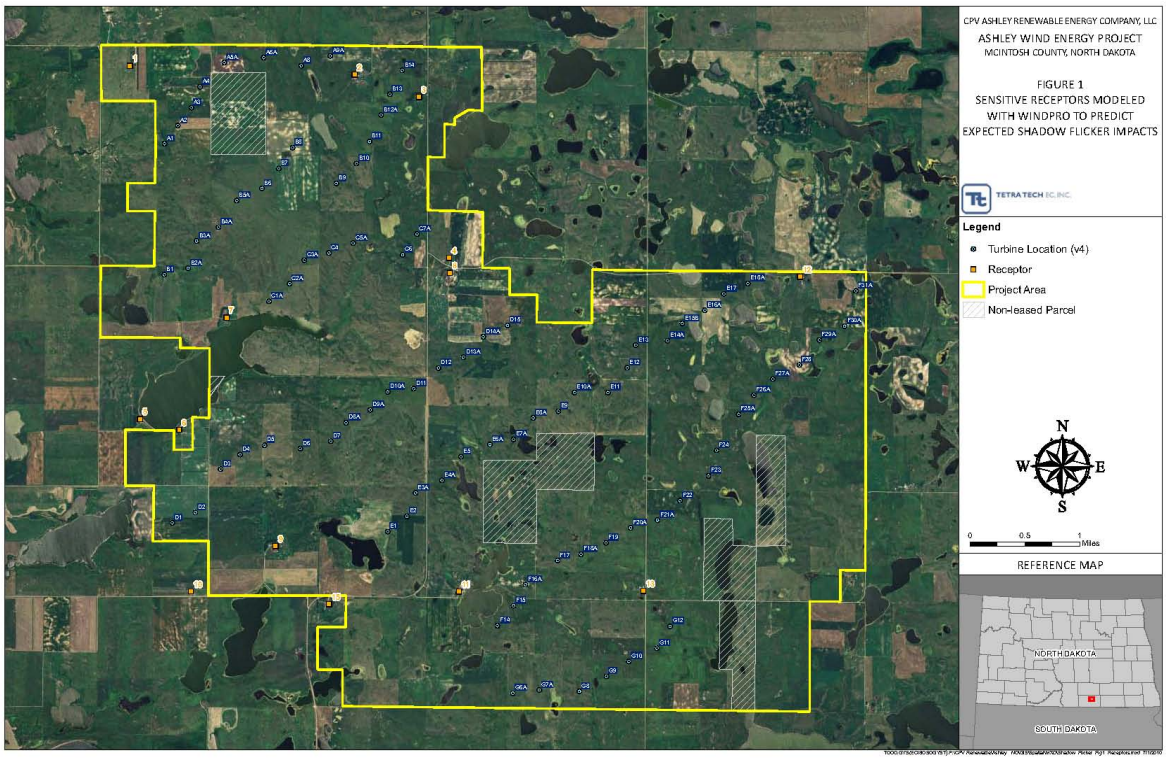
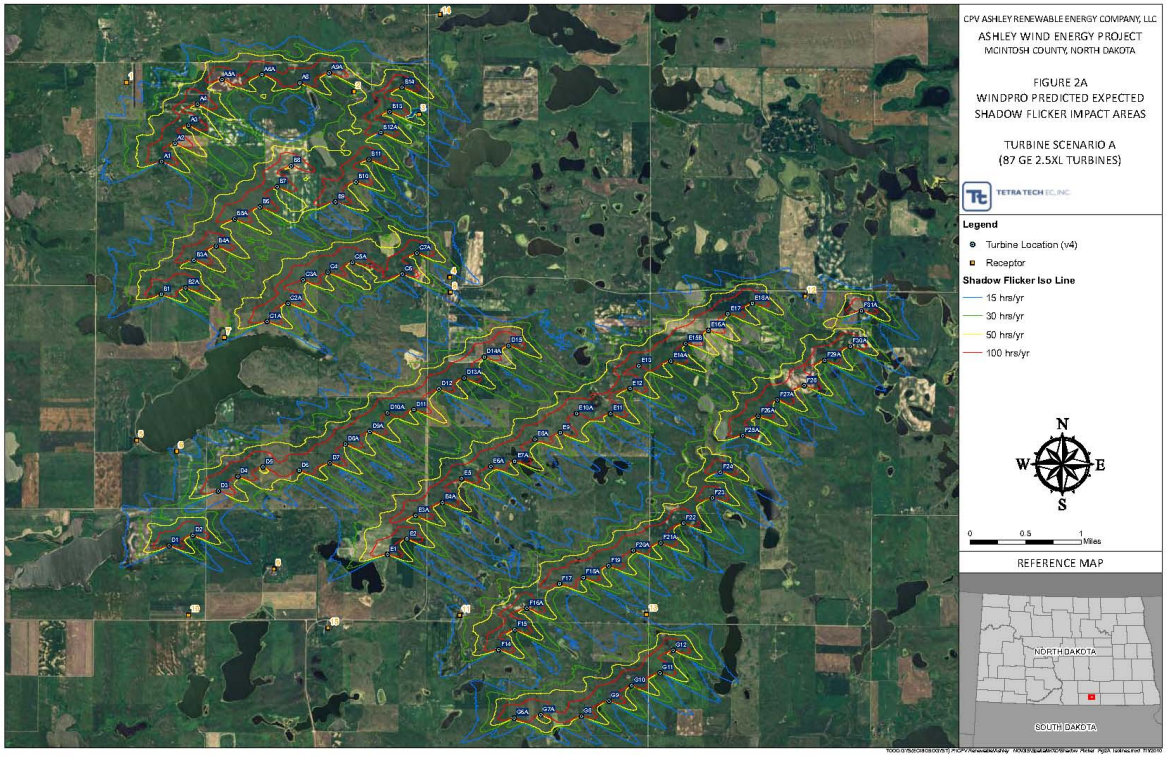
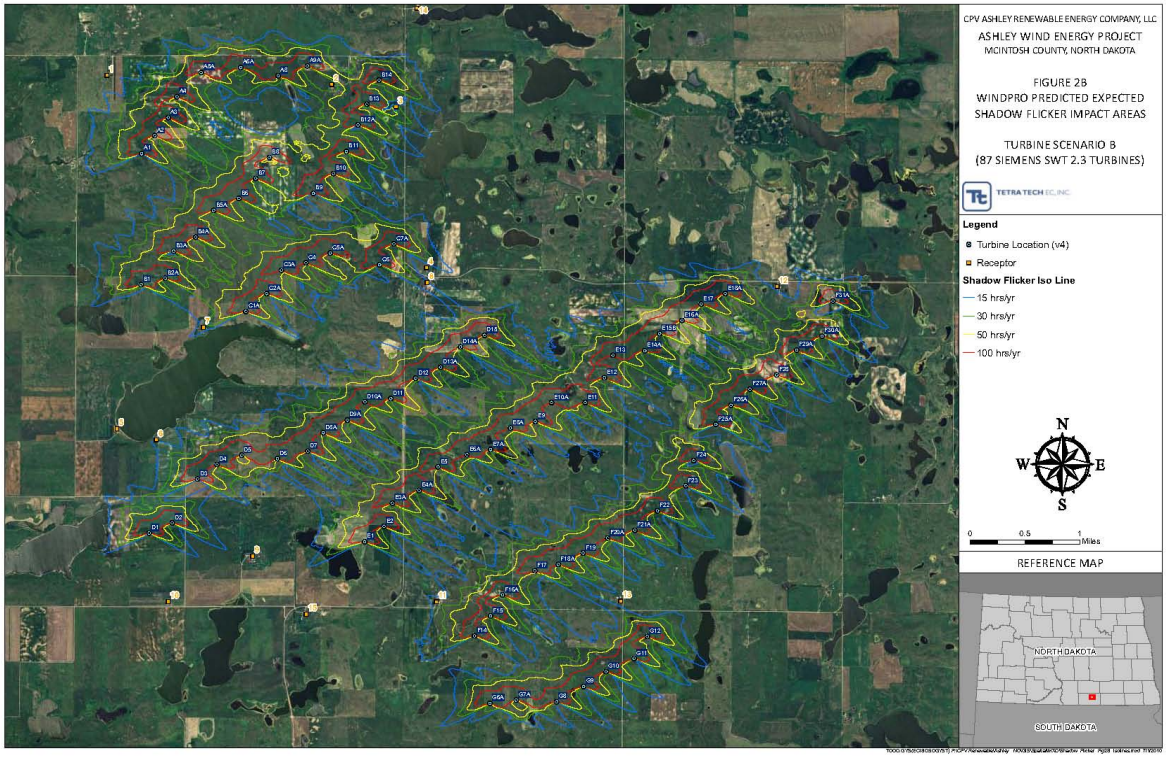
FIGURES


CPV ASHLEY RENEWABLE ENERGY COMPANY, LLC
ASHLEY WIND ENERGY PROJECT
MCINTOSH COUNTY, NORTH DAKOTA
FIGURE 1
SENSITIVE RECEPTORS MODELED WITH WINDPRO TO PREDICT EXPECTED SHADOW FLICKER IMPACTS
TETRA TECH EC, INC.
Legend
Turbine Location (v4)
Receptor
Project Area
Non-leased Parcel
N
W
E
S
0
0.5
1
Miles
REFERENCE MAP
NORTH DAKOTA
SOUTH DAKOTA


CPV ASHLEY RENEWABLE ENERGY COMPANY, LLC
ASHLEY WIND ENERGY PROJECT
MCINTOSH COUNTY, NORTH DAKOTA
FIGURE 2A
WINDPRO PREDICTED EXPECTED
SHADOW FLICKER IMPACT AREAS
TURBINE SCENARIO A
(87 GE 2.5XL TURBINES)
TETRA TECH EC, INC.
Legend
Turbine Location (v4)
Receptor
Shadow Flicker Iso Line
15 hrs/yr
30 hrs/yr
50 hrs/yr
100 hrs/yr
N
W
E
S
0
0.5
1
Miles
REFERENCE MAP
NORTH DAKOTA
SOUTH DAKOTA


CPV ASHLEY RENEWABLE ENERGY COMPANY, LLC
ASHLEY WIND ENERGY PROJECT
MCINTOSH COUNTY, NORTH DAKOTA
FIGURE 2B
WINDPRO PREDICTED EXPECTED
SHADOW FLICKER IMPACT AREAS
TURBINE SCENARIO B
(87 SIEMENS SWT 2.3 TURBINES)
TETRA TECH EC, INC.
Legend
Turbine Location (v4)
Receptor
Shadow Flicker Iso Line
15 hrs/yr
30 hrs/yr
50 hrs/yr
100 hrs/yr
N
W
E
S
0
0.5
1
Miles
REFERENCE MAP
NORTH DAKOTA
SOUTH DAKOTA

ATTACHMENT A.

Detailed Summary of WindPro Shadow Flicker Analysis Results

Ashley Wind Energy Project
WindPro Shadow Flicker Analysis Results Summary
Turbine Scenario A (87 GE 2.5xl Turbines)

Ashley Receptor ID	UTM-E (m)	UTM-N (m)	WindPro Predicted Expected Shadow Flicker (Hours per Year)
3	472,283	5,117,330	38:11
2	471,340	5,117,655	27:12
7	469,464	5,114,104	26:09
11	472,869	5,110,093	25:07
8	472,736	5,114,758	24:50
6	468,774	5,112,459	16:32
12	477,860	5,114,700	13:10
4	472,726	5,114,975	10:24
13	475,569	5,110,104	10:02
1	468,053	5,117,786	8:27
9	470,185	5,110,761	4:21
5	468,197	5,112,620	3:17
10	468,947	5,110,096	0:00
14	472,585	5,118,769	0:00
15	470,966	5,109,911	0:00

Ashley Wind Energy Project
WindPro Shadow Flicker Analysis Results Summary
Turbine Scenario B (87 Siemens SWT 2.3-101 Turbines)

Ashley Receptor ID	UTM-E (m)	UTM-N (m)	WindPro Predicted Expected Shadow Flicker (Hours per Year)
3	472,283	5,117,330	35:00
7	469,464	5,114,104	24:29
2	471,340	5,117,655	24:23
11	472,869	5,110,093	21:12
8	472,736	5,114,758	19:32
6	468,774	5,112,459	14:44
12	477,860	5,114,700	10:55
4	472,726	5,114,975	9:31
13	475,569	5,110,104	8:08
1	468,053	5,117,786	7:26
9	470,185	5,110,761	2:53
5	468,197	5,112,620	1:44
10	468,947	5,110,096	0:00
14	472,585	5,118,769	0:00
15	470,966	5,109,911	0:00

ATTACHMENT B.

Letter from Ruedow and Deloris Ulmer

August 3, 2010

To: John Hafner, CPV Ashley Renewable Energy Company LLC

From: Rnedon and Deloris Ilmer

Dear John,

The residence we own in Township 132 N, Range 69 W, Section 31 has been vacant since 1999 and is inhabitable

Sincerely,

Rnedon & Deloris Ilmer