Alaska Department of Transportation & Public Facilities

Review of Power Sources for Alaska DOT & PF Road Weather Information Systems (RWIS): Phase I

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This report documents the findings related to a review of power sources for six off-grid Road Weather Information Systems (RWIS) in Alaska. Various power sources were reviewed as a means of reliably operating the off-grid RWIS sites throughout the year. Based on information collected on current power sources and equipment used at the off-grid RWIS sites, and visits to off-grid installations in Alaska, some viable methods of reliable operation were discovered. Power sources included in the study were solar photovoltaics (PV), small wind turbines, fuel cells, and thermoelectric generators, all charging a battery bank which powers the weather sensors, cameras, and communication equipment. The results showed that while solar PV provides enough standalone power to keep the sites operational from early spring to late fall with wind supplementing this somewhat during the transition seasons, a fossil fuel based source is necessary to maintain operation through the winter. These findings suggest that a combination of power sources is required for reliable RWIS operation throughout the year and is dependent on the location of the site.

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
^oF	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	^oC
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2 m^2
square meters	10.764	square feet	ft^2 m^2	square
meters	1.195	square yards	yd^2	
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3 m^3
	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
^oC	Celsius	1.8C+32	Fahrenheit	^oF
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.
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Lastly, the authors would like to thank Jack Stickel and Lisa Idell-Sassi of the Alaska Department of Transportation Juneau office for providing information about the equipment and state of current RWIS sites.

Abstract

This report documents the findings related to a review of power sources for six off-grid Road Weather Information Systems (RWIS) in Alaska. Various power sources were reviewed as a means of reliably operating the off-grid RWIS sites throughout the year. Based on information collected on current power sources and equipment used at the off-grid RWIS sites, and visits to off-grid installations in Alaska, some viable methods of reliable operation were discovered. Power sources included in the study were solar photovoltaics (PV), small wind turbines, fuel cells, and thermoelectric generators, all charging a battery bank which powers the weather sensors, cameras, and communication equipment. The results showed that while solar PV provides enough standalone power to keep the sites operational from early spring to late fall with wind supplementing this somewhat during the transition seasons, a fossil fuel based source is necessary to maintain operation through the winter. These findings suggest that a combination of power sources is required for reliable RWIS operation throughout the year and is dependent on the location of the site.

Summary of Findings

The ultimate question that this project seeks to answer is, "Are power sources available to reliably operate off-grid Road Weather Information Systems (RWIS) through the winter in Alaska?" The results of this project show that a combination of generation sources charging deep-cycle lead-acid batteries is required to keep the RWIS sites operational through the winter season. These sources include combinations of solar photovoltaics (PV), small wind generators, and fuel cells or thermoelectric generators, depending on the solar and wind resources available at the site and the demand of the camera, weather sensors, and communications equipment.

The current propane generators used at the sites have reliability issues, either coming online and never shutting off until the propane tank runs dry or never coming online resulting in an inoperable system once the propane generator and/or solar PV are not able to keep the system charged. Alternative fossil-based power sources such as fuel cells and thermoelectric generators which use propane or natural gas and have no moving parts investigated as part of this study are still under evaluation for a number of small remote power applications such as the Coast Guard, FAA, and even DOT off-grid meteorological sites.

The findings also suggest that upgrading weather sensors, cameras, and communication equipment such as single or multi-view cameras to maintain operation in inclement weather conditions is critical to receiving accurate data and does not increase the power demand on the system. However, heaters on cameras to maintain a clear lens normally double or triple the power usage and must be left on when the occurrence of condensation (moisture) on the lens results. One critical component that affects demand is the operating scenario used at the site. Simply decreasing the frequency of the camera image and turning the camera and heater off at night can increase the energy storage potential and allow for operation on solar PV for a larger portion of the year.

Overall, the project findings suggest that a combination of power sources is required for reliable RWIS operation throughout the year (in particular, the winter season) and the selection and capacity of renewable power sources is dependent on the location of the site. This research study finds that a combination of the existing solar PV array and either an EFOY 1600 fuel cell or Global 5060 Thermoelectric Generator (TEG) would serve to power the off grid RWIS sites. However, the long term reliability of the fuel cell and TEG units remains to be seen.

CHAPTER 1 - INTRODUCTION AND RESEARCH APPROACH

Problem Statement and Research Objective

Alaska Department of Transportation and Public Facilities (AKDOT&PF) has a specific research need for evaluating the power sources for six off-grid Road Weather Information Systems (RWIS) in Alaska. RWIS require reliable remote electric power sources to operate video cameras, heating elements to prevent lens icing and fogging, and on-board electronics for weather data acquisition and transmission to a central server for display on the web. While the required power levels are not large, generally less than 500 W, in terms of a grid connected system, they are significant for small remote off-grid power sources. There are also issues with sudden increases in power consumption when the camera is operated or when data is being polled by the central server. The research objective of this project was to explore current power generation sources, weather sensors, cameras, and communication equipment for off-grid RWIS sites and to make recommendations for replacement of those power sources with reliable generation that will power the stations throughout the year.

Scope of Study

This research project surveyed the existing off-grid RWIS power sources and explored the use of state-of-the-art power generation sources, weather sensors, cameras, and communication equipment for these sites. The UAF team, lead by Professor Richard Wies, addressed both methods of reliable remote power generation and power utilization for six off-grid RWIS sites in Alaska.

For each site the researchers reviewed and made recommendations for improvement of four specific components of the RWIS system.

These four components included:

1) the replacement of internal combustion (IC) generators,
2) the use of current state-of-the-art alternative power sources such as wind, solar, fuel cells, thermoelectric generators, and batteries,
3) the use of cameras, weather sensors, and communication equipment with lower power consumption ratings and better cold weather reliability including video cameras and on-board electronics for data acquisition and transmission, and

4) operating scenarios that could allow for more efficient and optimal use of the available power. (Ex: In a situation with solar charging the batteries during the day, does the video camera, which takes a considerable amount of the available power, need to operate continuously or at night when no solar is available to charge the batteries?)

Expected outcomes from this project were: (1) a review of state-of-the-art remote power sources, cameras, weather sensors, communication equipment, and operating scenarios for off-grid RWIS systems, (2) recommendations for more efficient IC generators, alternative power sources, and operating scenarios for possible improvement of off-grid RWIS sites, (3) a planned implementation to develop and test a prototype off-grid RWIS system for a specific site in Phase II based on recommendations in Phase I, (4) improved roadway safety with reliable and up-to-date RWIS sites, and (5) reduced maintenance costs at off-grid RWIS sites.

Research Approach

The UAF team, lead by Professor Richard Wies, reviewed the current off-grid RWIS systems installed in Alaska from both the power generation and power utilization sides and make recommendations for system improvements. One off-grid RWIS site that is currently not operational and two sites that are currently operational were visited and evaluated in the study. The non-operational site was Turnagain Pass (MP 63 on Seward Highway). The operational sites were Jean Lake Hill (MP 62.3 on the Sterling Highway) and Little Coal Creek (MP 163.2 on the Parks Highway).

The following research and evaluation plan was executed in this project.

1) A literature review of current and previous power sources and available weather sensors, cameras, and communication equipment for RWIS systems was performed.

2) The current power sources, weather sensors, cameras, communication equipment, and operating scenarios with site visits were reviewed.

3) Suitable capacity fossil-fuel based generators and alternative power sources were recommended based on the needs, climate, and available energy resources.

4) Possible improvements to weather sensors, cameras, and communication equipment were recommended to reduce power consumption.

5) Possible operating scenarios were recommended that could allow for more efficient and optimal use of the available power.

This final report will be issued to AKDOT&PF containing the results of our literature and on-site reviews and our recommendations for strategies to design, construct and deploy updated RWIS systems at the off-grid sites. Implementation of the recommendations in this report would be to implement the strategies at each off-grid RWIS site.

Power Source, Cameras, Weather Sensors, and Communication Equipment Evaluation Method

The power sources, cameras, weather sensors, and communication equipment at the current RWIS sites were evaluated using a combination of site visits to observe and collect data and from information provided by AKDOT&PF personnel, Jack Stickel and Lisa Idell-Sassi, in Juneau. Specific power data from each site was not collected, but estimated based on manufacturer's specifications for power usage from the cameras, weather sensors, and communication equipment. The amount of power available from the renewable sources such as solar and wind was estimated using solar insolation maps and archived wind data from each RWIS site. An energy budget was then developed to estimate the amount of power that would be required from wind and fossil fuel based sources such as propane-fired generators, fuel cells, or thermoelectric generators to operate through the winter months. Based on this evaluation method recommendations (see Chapter 3) were provided for implementing power sources at off-grid RWIS sites in Alaska. This first required an assessment of the current and potential new power sources, cameras, weather sensors, and communication equipment used at the off-grid RWIS sites (see Chapter 2).

CHAPTER 2 - FINDINGS

Current Power Sources, Cameras, Weather Sensors, and Communication Equipment at Off-Grid RWIS Sites

The following sections document the current power sources, cameras, weather sensors, and communication equipment at the six off-grid RWIS sites listed in Table I below.

Table I: Off-Grid RWIS Sites

Site	Operation
Parks Hwy @ Little Coal Creek MP 163.2	Converted to DC system with PV only
Klondike Hwy @ US/Canada Border MP 14.9	In-Situ test of fuel cell underway
Sterling Hwy @ Jean Lake Hill MP 61.8	Converted to DC system with PV only
Seward Hwy @ Turnagain Pass MP 69.9	Not operational
Seward Hwy @ Divide MP 11.7	Not operational
Richardson Hwy @ Stuart Creek MP 45.6	Converted to DC system with PV only

Current Power Sources

The current power sources are listed in Table II with representative pictures from Turnagain Pass shown in Figure 1 and specification sheets in Appendix A.

Table II: Power Sources and Converters at Off-Grid RWIS Sites

Power Source	Sites	Operational
Minotaur 2.5 kW propane-fired electric generator	All sites	NO
6-Kyocera 120 W solar photovoltaic (PV) panels	All sites	YES
4-Rolls 12 V, 275 A-hr deep cycle marine batteries	Jean Lake, Turnagain Pass	YES
4-Trojan 12 V, 230 A-hr deep cycle marine batteries	Coal Creek	YES
2-Xantrex solar PV charge/load controllers	All sites	NO
Outback Flexmax 80 Charge Controller	Jean Lake, Little Coal Creek	YES
Outback VFX2812 (2.8 kW, 12V) inverter	Jean Lake, Little Coal Creek	NO; DC System
Acumentrics RP500 500 W Fuel Cell DC Generator	Klondike	In-situ test

(a) (b) (c)

Figure 1: RWIS Site and Power Sources at Turnagain Pass Off-Grid RWIS Site [1]: a) overall site b) propane electric generator, and c) 6 Kyocera 120 solar PV panels [2].

The propane-fired electric generators (mainly the controllers) have been unreliable, either never coming on to supplement battery charging or running continuously until empty.

Current Cameras, Weather Sensors, and Communication Equipment

The cameras, weather sensors, and communication equipment, and their location and power demand are listed in Table III with representative pictures from Jean Lake shown in Figure 2 and specification sheets in Appendix B.

Table III: Current Cameras, Weather Sensors, and Communication Equipment

Cameras, Weather Sensors, and Communication Equipment	Site	Power Demand
Cohu ER-8546 Color Camera	Jean Lake, Little Coal Creek, Stuart Creek	13 W; 27 W (w/ heater)
Cohu iDome 3920, pan-tilt-zoom	Turnagain Pass, Divide	27 W; 104 W (w/ heaters & PTZ)
Axis P1343	Klondike	6.4 W; 12.8 W (w/ heater)
RM Young 05103L Wind Monitor	Jean Lake, Turnagain Pass, Little Coal Creek, Stuart Creek, Divide	0.48 W
RM Young 58000 Ultrasonic Wind Monitor	Klondike	0.36 W
Adolf Theis Hygro-Thermo Transmitter	Jean Lake, Turnagain Pass, Little Coal Creek, Klondike, Stuart Creek, Divide	1.5 W
Quixote FP 2000 Pavement Temp Sensor	Turnagain Pass, Klondike, Stuart Creek	0.01 W
SSI Thermoscan 1000 Pavement Temp Sensor	Jean Lake, Little Coal Creek, Divide	0.01 W
MRC Temperature Data Probe TP101	Jean Lake, Turnagain Pass, Little Coal Creek, Klondike, Stuart Creek, Divide	0.01 W
SSI Hawk Eye Optical Infrared Y/N Precipitation Sensor	Jean Lake, Turnagain Pass, Little Coal Creek, Klondike, Stuart Creek, Divide	0.78 W
Judd Ultrasonic Snow Depth Sensor	Turnagain Pass, Little Coal Creek, Stuart Creek, Divide	0.60 W
Nova Lynx 260-2500 Rain Gauge	Little Coal Creek, Klondike	3 W
Nova Lynx 260-2500E Heated Rain Gauge	Stuart Creek	3 W; 400 W (w/ heater)
Communications interface and Ku-band transmitter[1]	Jean Lake, Turnagain Pass, Stuart Creek, Divide	25 W
Airlink Raven 4221 3G Cellular Modem	Little Coal Creek, Klondike	*Transmit/Receive (Typical/Max) 2.87/3.21 W; Idle 1.25 W; Dormant 1.02 W*

[1]Ku-band transmitters (11-18 GHz) are capable of transmitting large amounts of data at high speeds via satellite links with fairly low power requirements. Ku stands for K-under, or under the K band (20-40 GHz).

(a) (b) (c)

Figure 2: RWIS Site and Power Sources at Jean Lake Off-Grid RWIS Site: a) meteorological tower b) satellite dish, c) communications antenna (Jean Lake).

State-of-the-Art Power Sources, Weather Sensors, Cameras, and Communication Equipment for Off-Grid RWIS Sites

The following sections document state-of-the-art RWIS power sources, weather sensors, cameras, and communication equipment.

State-of-the-Art Power Sources

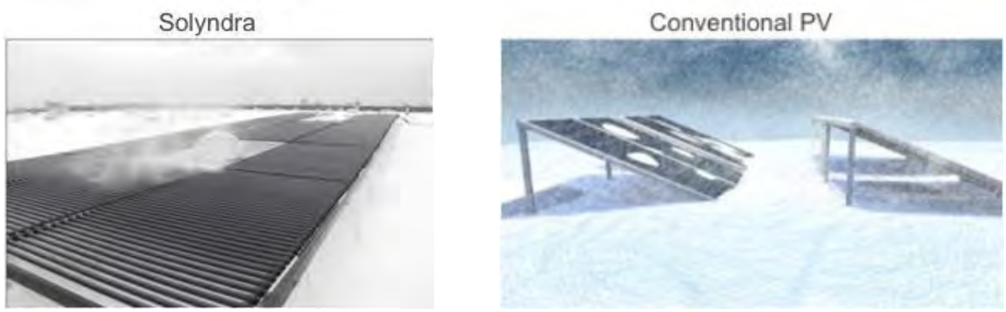
State-of-the-art power sources such as thin film solar PV, small-scale harsh weather resistant wind turbines, fuel cells, and thermoelectric generators were evaluated for possible use as RWIS power sources. The power sources reviewed in this study, their power capacity, capital cost, and fuel use rates are listed in Table IV.

Table IV: State-of-the-Art Power Sources, Power Capacity, Cost, and Fuel Rates

Power Source	Power Capacity (W)	Capital Cost ($)	Fuel Use Rate (gal/kWh)
Stion STN130 Thin Film CIGS Solar PV Panels	130 W	$105	NA
APRS World WT-10 Wind Turbine (24V with rectifier)	75 W @ 40 mph & 12 VDC	$4,000	NA
Acumentrics RP500 Fuel Cell	500 W @ 12 VDC	$28,531	0.12
Efoy Pro 800 Fuel Cell	45 W @ 12 VDC	$21,500	0.24
Global 5060 Thermoelectric Generator	54 W @ 12 VDC	$6,500	1.16

Thin Film Solar PV

Thin film Copper, Indium, Gallium, Selenide (CIGS) solar PV modules offer the improved performance in capturing the available solar energy due to a higher efficiency (15-18%) than standard polycrystalline or amorphous silicon based modules (10-14%). The current Kyocera PV modules used at the site are multi-crystalline and offer an upper bound efficiency of 14 %. The small efficiency improvement with thin-film CIGS panels does not offer enough additional power suggesting replacement of the current PV modules at the point of failure. A new cylindrical thin film CIGS technology allows snow and dirt to fall through and receives more reflected light than conventional flat panel PV (See Figure 3). These cylindrical thin film CIGS modules or even the flat panel version are suggested as power sources for the development of any new off-grid RWIS sites or as a point of failure replacement at an existing site.



(a) **(b)**

Figure 3: Thin Film CIGS PV Modules: a) Cylindrical and b) Flat Panel [3].

Harsh Weather Wind Turbines

A small harsh weather wind turbine, APRS World WT-10, shown in Figure 4 could be installed at the sites with good wind potential. The turbine is similar to the one used by the FAA on their remote meteorological modules designed for Alaska applications.

The output of this turbine is three-phase AC, so a rectifier would be needed to convert the AC output to DC as well as a regulator for the output voltage and current to the batteries. The turbine can be configured by the manufacturer to charge a 24 V or 48 VDC system through an appropriate rectifier, but the 24 VDC version can also be used to charge a 12 VDC system with a lower regulated DC output voltage.

(a) (b) (c)

Figure 4: APRS World WT-10 Wind Turbine [4]: a) on FAA module b) brochure view, c) a successful remote mountain top application.

The cost of the basic turbine ranges from $3,000 to $3,500 depending on the blade, yaw, and mast connection types. A detailed price list for the turbines and accessories is available at http://www.aprsworld.com/wtaprs/WT10/pricing/. Quick coupler mounts range from $300-$500. Cabling ($100-$150) for power output to the module and an associated mast for mounting the turbine would also have to be installed given that the current anemometer is already mounted on top of the meteorological sensor mast.

Fuel Cells and Thermoelectric Generators

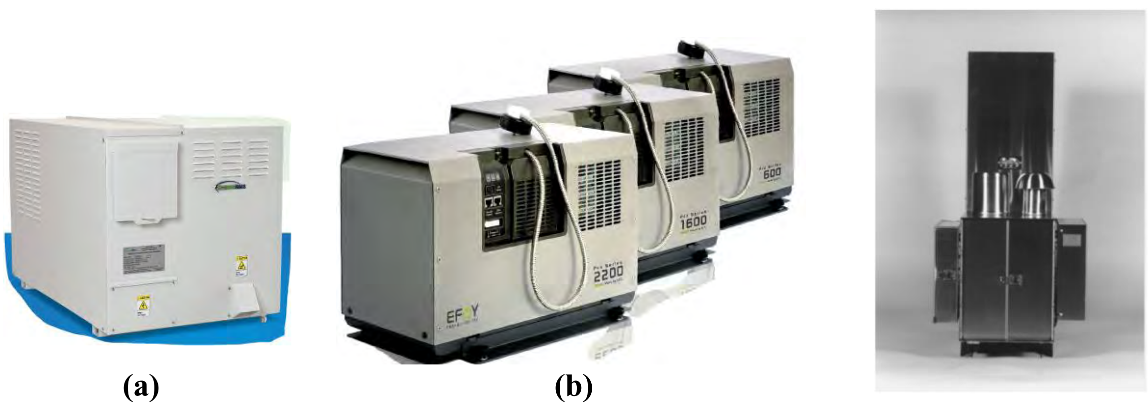
A small fuel cell or thermoelectric generator which is fueled by propane could be added to keep the system operational when both solar PV and wind do not produce enough energy to maintain the battery charge. Although fuel cells offer a non-mechanical low power fossil fuel source, there have been challenges with fuel cells shutting off and freezing up. Fuel cells have to be heated in order to remain operational and also the ceramic cells are more sensitive to shock from transportation.

Figure 5 shows two fuel cells and a thermoelectric generator that are currently being tested as power sources on remote meteorological platforms. While the Acumentrics RP500 fuel cell (Figure 5a) is a 500 W maximum capacity, the EFOY 1600 fuel cell (Figure 5b) and Global ThermoElectric Model 5060 thermoelectric generator (Figure 5c) are 65 W and 54 W capacity, respectively.

The Acumentrics RP500 fuel cell is fueled by propane or natural gas. It is currently being tested at the Klondike Highway RWIS site on the US/Canada border after a failure in December

2012 due to a fractured ceramic cell during shipment. The current problem with the site is a fuel relay problem which should be resolved this summer. The cost of the RP500 is $28,531 as provided by the current maintenance contractor for the off-grid RWIS sites.

The EFOY 1600 is fueled by methanol. It was deployed a season and half ago at Fourth of July Pass in Idaho and has been operational ever since. It is also used in a variety of remote applications in Alaska and Northern Canada, such as remote oil platforms and communication sites. The EFOY pro series fuel cells are rated to -40 °C with heat regulation in a special insulated enclosure provided by the manufacturer. The first generation EFOY pro series (600, 1600, 2200) was replaced in June 2013 by a second generation EFOY pro series (800 & 2400). The EFOY 800 Pro offers a maximum power output of 45 W and would be suitable for the off-grid RWIS application. The cost of the EFOY 800 Pro fuel cell with a cold climate enclosure ranges from $15,600 to $21,000 and depends on the amount of fuel required to achieve the desired autonomy in terms of refueling.



(a) (b) (c)

Figure 5: Fuel Cells: a) Acumentrics RP500 [5] and b) EFOY 1600 [6, 7]; and Thermoelectric Generator: (c) Global Thermo Electric Generator [8].

The Global ThermoElectric Model 5060 thermoelectric generator is fueled by propane. It is currently being deployed by the FAA on their remote meteorological platforms (discussed in the next section) in Alaska to provide a small ~50W of power to keep the batteries charged during the winter season when sunlight for PV arrays is minimal and wind speeds are low. The cost of the thermoelectric generator is $5,850.00 with an additional $662.00 for a pole mount stand.

FAA Off-Grid Meteorological Module

The FAA has designed a complete off-grid power module (see Figure 6) for monitoring flight weather (mainly via web-based cameras) employing a 54-W thermoelectric generator fueled by propane (Figure 5c), a 500-W thin film tube CIGS solar PV array (Figure 6a), and a 400-W APRS World military-grade wind-turbine generator (Figure 6c) for power sources to charge 8-Odyssey 12 V, 200 A-hr AGM batteries. Although ten times overpowered for the application and using relatively expensive components these modules offer the reliability of operating throughout the winter season and in harsh climates. These are being deployed at a number of remote airport sites in Alaska.

(a) (b) (c)

Figure 6: FAA Remote Power Module: (a) thin-film solar PV tube array, (b) control cabinet and satellite dish, and (c) wind turbine and weather sensors.

State-of-the-Art Cameras, Weather Sensors, and Communication Equipment

State-of-the-art low power cameras, weather sensors, and communications equipment were evaluated for possible use at RWIS sites. These include Power over Ethernet (POE) Mobotix cameras, all-in-one weather sensors, Ku-band transmitters, and 3G cellular communications equipment. The power demand of cameras, weather sensors, and communication equipment similar to that used on the FAA module is shown in Table V.

Table V: Power Demand of State-of-the Art Cameras, Weather Sensors, and Communication Equipment

Cameras, Weather Sensors, and Communication Equipment	Power Demand
4-Mobotix M24 Power over Ethernet (POE) cameras	3 W; 6 W (w/ heater) each
Vaisala WXT520 Multi Weather Sensor	2-6 W
Ku-Band Transmitter with 1.2 m dish	20 W
Raven X Airlink 3G Modem	Transmit/Receive (Typical/Max) 2.87/3.21 W; Idle 1.25 W; Dormant 1.02 W

This state-of-the-art cameras, weather sensors, and communication equipment including Mobotix POE cameras and the Raven X Airlink 3G Modem could offer the low power consumption required for off-grid RWIS sites to operate with lower demand on the power sources than in the current configuration. This could result in operation with non-fossil fuel based sources such as solar PV and wind for longer periods over the year.

Mobotix M24 Cameras

The Cohu ER-8546 color and Cohu iDome 3920, pan-tilt-zoom (PTZ) cameras used at the sites could be replaced with two Mobotix M24 POE cameras (see Figure 7) that have been equipped with heaters for winter operation. This significantly reduces the power demand from the cameras.

(a) **(b)**

Figure 7: Cameras for Off-grid RWIS Sites: a) Cohu iDome 3920, pan-tilt-zoom [9], b) Mobotix M24 [10].

The basic version of the M24 camera would also require some special modifications for Alaska applications per its use on the FAA remote weather modules. A heated lens cover would need to be added and the entire camera coated (minus the glass lens cover) for protection against the elements. This work is currently performed for the FAA by TecPro in Anchorage. A higher resolution version of the camera is also available if needed.

The cost of the basic M24 camera is about $900 with a lens costing about $100, and additional modifications mentioned above for Alaska applications of about $1800, resulting in a total cost of $2800 per camera. A price list for the basic camera and accessories can be found at http://www.mobotix.com/eng_US/Products/Cameras/Allround-M24.

Airlink Raven X V4221 3G Modem

The Airlink Raven X V4221 3G modem (see Figure 8) offers cellular communications with the RWIS sites with a much lower power demand, decreasing power consumption during transmit and receive from 20 - 30 W to 2.87 (typical) - 3.24 W (peak) at 12 VDC, with idle power at 1.25 W.

These devices are a previous generation that have been discontinued, but have been purchased awaiting installation at the off-grid RWIS sites. The original cost was about $600.

A power generation and demand analysis for off-grid RWIS sites is illustrated in the next section.

(a) **(b)**

Figure 8: Airlink Raven X V4221 3G Cellular Modems for RWIS sites [11]: a) front view and b) rear view.

Power Generation and Demand Analysis

The following sections contain analysis of the estimated power generation and demand for all six off-grid RWIS sites. All generation is used to charge the batteries in the power modules, while the batteries are used to meet the demand on the system. Any solar PV and wind generation in excess of demand is assumed to be stored in the battery bank if not fully charged. Any demand in excess of generation, including stored energy in the batteries is assumed to be picked up by fossil fuel based sources using fuel cells or thermoelectric generators. A sample analysis for the Turnagain Pass site is provided at the end of this section to describe the process.

Power Generation Analysis

The estimated power generation capacity from solar PV and wind was conducted for each off-grid RWIS site using solar and wind data available from both AKDOT&PF archived data for some sites and FAA and NOAA weather data provided online for nearby locations.

Solar PV

The available solar energy at all six off-grid RWIS sites has been estimated based on the average daily insolation and the specifications of the current solar panels (see Appendix A) used at the sites. The dimensions, surface area, and efficiency of one Kyocera 120 W solar PV panel are used with the average daily insolation for each site to determine the available daily solar energy as:

$$\text{Available Daily Solar Energy} = \text{Average Daily Insolation} * \text{Module Efficiency} * \text{Module Surface Area} * \text{Number of Modules} \quad (1)$$

The solar module specifications are:

Dimensions: (1425 x 653 x 59 mm)

Surface Area: 1.425 m x 0.653 m = 0.9305 m^2

Solar Panel Efficiency: 14%

The average daily insolation values for each site are provided in Table VI as calculated from data in [2] and [12].

Table VI: Monthly Averaged Solar Insolation for Off-Grid RWIS Sites [2, 12]

Monthly Averaged Insolation Incident On A Horizontal Surface ($kWh/m^2/day$)													
22-Year Average	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann. Avg.
Parks Hwy @ Little Coal Creek MP 163.2	0.27	0.93	2.19	3.84	5.01	5.61	4.79	3.76	2.5	1.3	0.43	0.11	**2.57**
Klondike Hwy @ US/Canada Border MP 14.9	0.39	1.04	2.14	3.67	4.87	5.13	4.76	3.83	2.42	1.37	0.56	0.23	**2.54**
Sterling Hwy @ Jean Lake Hill MP 61.8	0.34	1.04	2.45	4.05	5.22	5.65	5	3.97	2.67	1.39	0.5	0.19	**2.71**
Seward Hwy @ Turnagain Pass MP 69.9	0.41	1.01	2.24	3.73	4.88	5.43	4.8	3.86	2.54	1.37	0.59	0.23	**2.59**
Seward Hwy @ Divide MP 11.7	0.41	1.01	2.24	3.73	4.88	5.43	4.8	3.86	2.54	1.37	0.59	0.23	**2.59**
Richardson Hwy @ Stuart Creek MP 45.6	0.36	0.97	2.17	3.85	5.22	5.75	5.35	4.2	2.67	1.37	0.53	0.19	**2.72**

The available average daily solar energy for all six RWIS sites was calculated as shown in Table VII based on daily solar insolation values averaged over 22 years provided in Table VI.

Table VII: Available Solar Energy (kWh/day) for RWIS Sites

Available Solar Energy (KWh/day)												
Site	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Parks Hwy @ Little Coal Creek MP 163.2	0.21	0.73	1.71	3.00	3.92	4.38	3.74	2.94	1.95	1.02	0.34	0.09
Klondike Hwy @ US/Canada Border MP 14.9	0.30	0.81	1.67	2.87	3.81	4.01	3.72	2.99	1.89	1.07	0.44	0.18
Sterling Hwy @ Jean Lake Hill MP 61.8	0.27	0.81	1.91	3.17	4.08	4.42	3.91	3.10	2.09	1.09	0.39	0.15
Seward Hwy @ Turnagain Pass MP 69.9	0.32	0.79	1.75	2.92	3.81	4.24	3.75	3.02	1.99	1.07	0.46	0.18
Seward Hwy @ Divide MP 11.7	0.32	0.79	1.75	2.92	3.81	4.24	3.75	3.02	1.99	1.07	0.46	0.18
Richardson Hwy @ Stuart Creek MP 45.6	0.28	0.76	1.70	3.01	4.08	4.49	4.18	3.28	2.09	1.07	0.41	0.15

Wind Turbine

The available wind energy at all six off-grid RWIS sites has been estimated based on the archived wind speed data collected at the sites and the specifications of the APRS World WT-10 wind turbine. Table VIII shows the average monthly wind speeds for each month at each site. The power versus wind speed curve in Figure 9 for the 24 V wind turbine charging a 12 VDC system through a rectifier was determined in a July 2013 field test by the manufacturer.

Table VIII: Average Monthly Wind Speeds (mph) for Off-Grid RWIS Sites

Average Monthly Wind Speeds (mph)												
Site	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Parks Hwy @ Little Coal Creek MP 163.2	2.6	2.9	3.4	2.9	2.9	3.6	2.9	2.1	1.9	2.7	3.4	3.0
Klondike Hwy @ US/Canada Border MP 14.9	30.5	22.2	12.8	11.7	10.7	7.9	6.6	13.6	12.7	11.7	14.4	11.3
Sterling Hwy @ Jean Lake Hill MP 61.8	3.9	4.4	4.9	4.6	5.3	4.8	4.5	4.5	6.5	6.5	4.0	4.0
Seward Hwy @ Turnagain Pass MP 69.9	4.3	5.1	4.6	5.4	4.5	4.6	8.7	4.3	4.4	5.7	5.1	4.1
Seward Hwy @ Divide MP 11.7	3.9	3.5	3.9	3.0	3.3	3.3	3.3	2.9	2.5	2.5	2.9	1.7
Richardson Hwy @ Stuart Creek MP 45.6	2.1	3.0	2.8	3.6	4.3	4.9	3.9	2.8	2.1	2.4	2.4	2.1

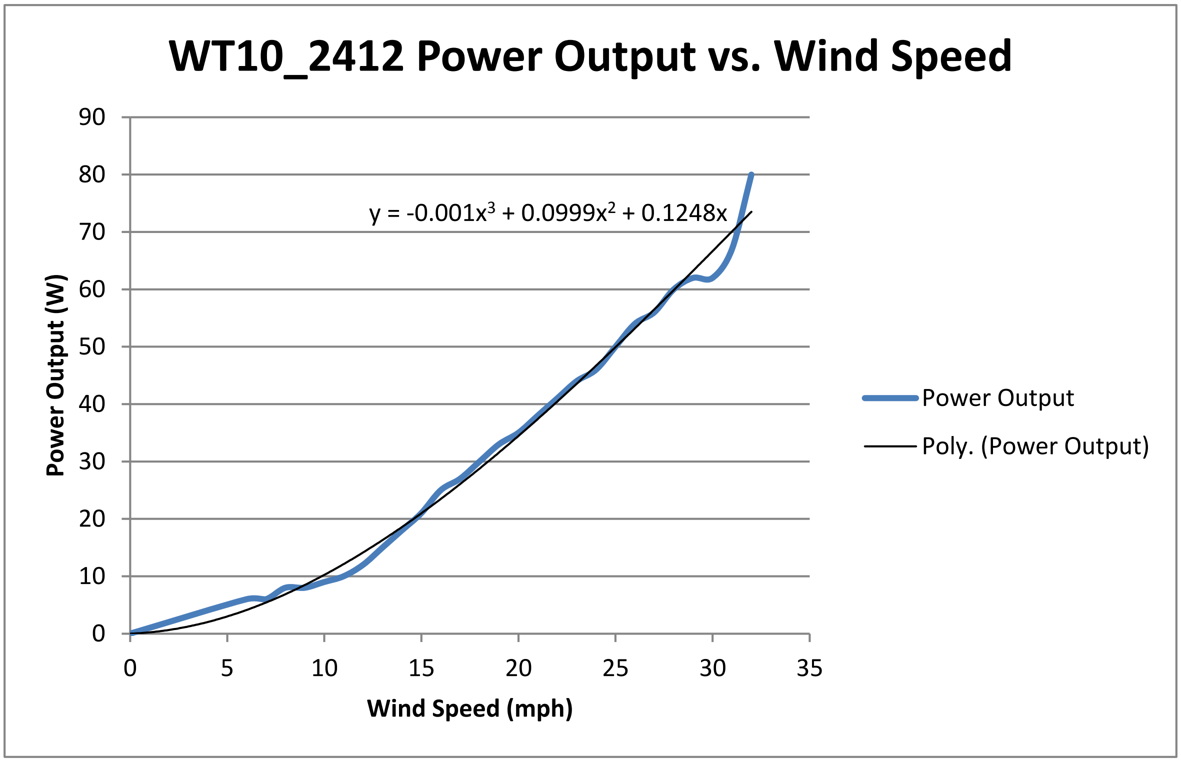


Figure 9: Power versus Wind Speed Curve for APRS World WT-10 24 V Turbine Charging a 12VDC System [4].

The wind analysis was performed by taking wind speed data sampled at 30-minute intervals and then determining the power output from the curve in Figure 9. The average daily wind energy generation shown in Table IX was then calculated by multiplying the power output by the sample time (0.5 hrs), averaging over 24 hours (48 samples), then averaging over each month.

Table IX: Available Wind Energy ($x10^{-3}$ kWh/day) for RWIS Sites

Available Wind Energy ($x10^{-3}$ kWh/day)[2]												
Site	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Parks Hwy @ Little Coal Creek MP 163.2	1.39	2.64	2.19	1.22	1.24	1.21	0.86	0.57	0.82	1.10	3.04	1.86
Klondike Hwy @ US/Canada Border MP 14.9	23.3	44.3	26.8	16.7	14.0	14.0	15.0	23.1	17.2	13.9	23.9	18.9
Sterling Hwy @ Jean Lake Hill MP 61.8	6.84	4.64	5.11	3.13	2.90	3.27	2.46	2.65	4.43	3.75	3.56	3.25
Seward Hwy @ Turnagain Pass MP 69.9	1.63	4.35	1.92	6.67	1.73	2.06	2.38	1.60	2.29	2.86	3.32	3.22
Seward Hwy @ Divide MP 11.7	0.92	0.92	1.04	0.78	0.71	0.79	0.72	0.44	0.62	1.23	2.06	1.89
Richardson Hwy @ Stuart Creek MP 45.6	1.16	1.05	1.07	1.50	2.24	1.96	1.61	0.82	0.56	1.27	1.32	1.89

[2]Note: Values of wind energy are expressed in $x10^{-3}$ kWh/day for comparison with solar energy in Table VII.

Demand Analysis

The estimated demand for the RWIS sites visited was determined using power consumption data provided by the manufacturer. The demand was assumed to be relatively constant at two levels with and without the heater on the camera based on continuous operation of all the cameras, weather sensors, and communication equipment.

For demonstration purposes, the following section provides a power capacity and demand analysis for the Turnagain Pass RWIS site. Since this site is currently not operational, generation and demand data was not collected from the site. A visit on June 26, 2013 at 1:30 PM to the Little Coal Creek RWIS site which is similarly configured showed demand at about 65 W. Our demand estimates for this site as currently outfitted are about 39 W without the camera heater on. Some of the discrepancy could be due to losses in the converter, underestimating the power drawn by the communications equipment and sensors, and the fact that the propane generator controller was active even though the generator was not operational. *Given this discrepancy, we have* ***added 15 W*** *to our* ***total demand*** *requirement at each site to account for other random loads and losses in the system.*

Turnagain Pass

The current power capacity of the Turnagain Pass RWIS site was used in a demand analysis to determine the additional power capacity required to operate the site through the winter months. Based on this analysis additional power sources will be recommended likely including some type of fossil fuel based generator.

Power Capacity

The current estimated maximum power capacity of the Turnagain Pass RWIS site based on information provided in Table II is 720 W at 12 VDC using the six solar PV panels that are in place, but not currently operating and assuming that the propane generator will be removed from the system. However, the 720 W maximum capacity is only achievable with a clear sky and with sun light directly incident on the panel surfaces. The surface area and efficiency of each Kyocera 120 W solar PV panel was used with the monthly average insolation values in Table VII shown in the previous section to determine the available solar energy (kWh/day) using (1).

The demand analysis in the next section clearly illustrates that additional power sources will be required to operate the site through the winter season from mid-November to mid-February.

Demand Analysis

The current continuous power demand of the Turnagain Pass RWIS site (if operational) based on manufacturer's power specifications provided in Table X is 53.5 and 130.5 W without and with the camera heater, respectively. The analysis was performed using 32 °F as the set point for turning on the camera heaters based on temperature data from each site as shown in Table XI.

Table X: Power Demand of Current Weather Sensors, Cameras, and Communication Equipment at Turnagain Pass Site

Weather Sensors, Cameras, and Communication Equipment	Power Demand (W)
Cohu iDome 3920, pan-tilt-zoom	27 W; 104 W (w/ heaters & PTZ)
RM Young 05103L Wind Monitor	0.48 W
Adolf Theis Hygro-Thermo Transmitter	1.5 W
Quixote FP 2000 Pavement Temp Sensor	0.01 W
SSI Thermoscan 1000 Pavement Temp Sensor	0.01 W
MRC Temperature Data Probe TP101	0.01 W
SSI Hawk Eye Optical Infrared Y/N Precipitation Sensor	0.78 W
Judd Ultrasonic Snow Depth Sensor	0.60 W
Communications interface and Ku-band transmitter	25 W
TOTAL DEMAND	53.5 W; 130.5 W (w/heater)

Table XI: Average Monthly Temperatures (°F) for Off-Grid RWIS Sites

Average Monthly Temperatures (°F)												
Site	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Parks Hwy @ Little Coal Creek MP 163.2	10.8	15.6	18.1	32.7	45.3	54.0	55.9	52.8	44.3	30.4	11.7	11.6
Klondike Hwy @ US/Canada Border MP 14.9	10.3	9.4	13.3	28.1	37.0	43.4	46.9	39.9	40.7	31.9	11.7	10.0
Sterling Hwy @ Jean Lake Hill MP 61.8	14.0	20.4	23.9	32.4	47.9	53.3	56.6	55.0	51.6	36.8	22.4	20.6
Seward Hwy @ Turnagain Pass MP 69.9	22.8	24.4	30.9	41.5	45.9	54.3	57.4	55.3	50.5	43.0	17.5	28.7
Seward Hwy @ Divide MP 11.7	18.9	22.3	25.7	34.3	43.7	47.5	53.8	53.0	48.3	35.5	28.1	23.6
Richardson Hwy @ Stuart Creek MP 45.6	4.8	16.4	16.2	35.1	45.5	54.1	55.8	53.9	44.5	36.0	14.5	11.8

In the winter months with heaters "on" requires 130.5 W * 6 hours = 783 Wh or 0.783 kWh for daylight operation which is clearly more than the daily energy provided in December and January assuming operation is only during daylight hours. Since the values in Table VII are daily averages based over a month the available energy will also likely be below the required level in late November and early February.

If the current Cohu 3920 PTZ cameras are replaced with two Mobotix M24 cameras, the power demand is reduced from 53.5 and 130.5 W without and with the camera heater, respectively, to 32.5 and 38.5 W. A comparison of the power demand for the two cameras with and without heaters is shown in Table XII. With the new cameras in the winter months with heaters "on" requires 38.5 W * 6 hours = 231 Wh or 0.231 kWh for daylight operation which is still more than is available from solar in December, but would likely also be below the required levels in most of January and even parts of late November and early February.

Table XII: Comparison of Power Demand for Cohu PTZ and Mobotix M24 Cameras

Camera	Power Demand (W)
Cohu iDome 3920, pan-tilt-zoom	27 W; 104 W (w/ heaters & PTZ)
2-Mobotix M24 Power over Ethernet (POE) cameras	6 W; 12 W (w/ heaters) includes two cameras

If the current communications interface which uses a Ku-band transmitter is replaced with the Raven 4221 Airlink 3G cellular modem gateway with the power requirements shown in Table XIII, the power demand for data transmit and receive functions is reduced from 25W to about 3W. However, the timing of the modem for transmitting data at 10 minute intervals indicates that the modem would not draw 3W continuous, but only during times when data was transmitted and received. In this analysis a demand of 3W for 1 min every 10 min, and 1.25 W for the remaining idle time as the minimum was used based on information from the Vaisala field service engineer.

Table XIII: Power Requirements for Airlink Raven 4221 3G Cellular Modem

Current @ 12VDC	Power Demand (W)
Transmit/Receive (Typical/Max) 239/270 mA	2.87/3.21 W
Idle 104 mA	1.25 W
Dormant 85 mA	1.02 W

The power demand of the Turnagain Pass RWIS site with the new POE camera and cellular modem based on manufacturer's power specifications provided in Table XIV is 10.54 W and 16.54 W without and with the camera heater, respectively.

Table XIV: Power Demand of Recommended Weather Sensors, Cameras, and Communication Equipment at Turnagain Pass Site

Weather Sensors, Cameras, and Communication Equipment	*Power Demand (W)*
2-Mobotix M24 Power over Ethernet (POE) cameras	6 W; 12 W (w/ heaters) includes two cameras
RM Young 05103L Wind Monitor	0.48 W
Adolf Theis Hygro-Thermo Transmitter	1.5 W
Quixote FP 2000 Pavement Temp Sensor	0.01 W
SSI Thermoscan 1000 Pavement Temp Sensor	0.01 W
MRC Temperature Data Probe TP101	0.01 W
SSI Hawk Eye Optical Infrared Y/N Precipitation Sensor	0.78 W
Judd Ultrasonic Snow Depth Sensor	0.60 W
Airlink Raven 4221 3G Cellular Modem	Transmit/Receive (Typical/Max) 2.87/3.21 W; Idle 1.25 W; Dormant 1.02 W
TOTAL DEMAND	10.54 W; 16.54 W (w/heater)

Tables XV-XVIII on pages 20-23 contain the average monthly demand analysis results for the Turnagain Pass RWIS site under continuous and daylight operation with different combinations of power sources including either of the two fuel cells or the TEG.

1) Table XV shows the energy required for continuous operation with solar PV alone.
2) Table XVI shows the energy required for continuous operation combining solar PV and wind.
3) Table XVII shows the energy required for daylight operation plus an hour before sunrise and after sunset with solar PV alone.
4) Table XVIII shows the energy required for daylight operation plus an hour before sunrise and after sunset with combinations of solar PV and wind.

Negative kWh values for demand indicate that surplus generation is available from the combination of generation sources. The optimal generation system would meet the demand with some extra generation to keep the batteries charged and to meet the demand during years when the available solar energy is low due to increased cloudiness. Clearly, another energy source is required for this site to operate continuously through the winter months and even for strict daylight operation. This would come from the addition of a fossil fuel based source such as the EFOY Duo Pro 800 fuel cell or the Global 5060 TEG and the replacement of the existing camera with two Mobotix cameras and the Ku-band transmitter with a Raven Airlink 3G modem. Wind is not sufficient at this site to supply the additional demand.

Table XV: Demand Analysis for Continuous Operation of Turnagain Pass RWIS Site (Solar PV + Fuels Cells or TEG)

Demand Analysis (Continuous Operation): Seward Highway @ Turnagain Pass MP 69.9						
Month	Current Energy Demand (kWh)	Energy Demand After Replacing Cameras and Communications Equipment (kWh)	Energy Demand After Incorporating Solar (kWh)	Energy Demand: Solar & Acumentrics Fuel Cell (kWh)	Energy Demand: Solar & Efoy Fuel Cell (kWh)	Energy Demand: Solar & Thermoelectric Generator (kWh)
January	109.7	22.6	12.7	-359.3	-20.8	-27.5
February	93.5	20.0	-2.1	-338.1	-32.4	-38.4
March	98.6	21.7	-32.5	-404.5	-66.0	-72.7
April	56.2	18.0	-69.5	-429.5	-101.9	-108.4
May	52.4	18.1	-100.1	-472.1	-133.6	-140.3
June	50.7	17.6	-109.8	-469.8	-142.2	-148.6
July	52.4	18.1	-98.2	-470.2	-131.6	-138.3
August	52.4	18.1	-75.4	-447.4	-108.9	-115.6
September	50.7	17.6	-42.0	-402.0	-74.4	-80.9
October	59.8	18.7	-14.5	-386.5	-48.0	-54.6
November	106.1	21.9	8.0	-352.0	-24.4	-30.8
December	109.7	22.6	17.0	-355.0	-16.4	-23.1

Table XVI: Demand Analysis for Continuous Operation of Turnagain Pass RWIS Site (Solar PV + Wind + Fuel Cells or TEG)

Demand Analysis (Continuous Operation): Seward Highway @ Turnagain Pass MP 69.9						
Month	Current Energy Demand (kWh)	Energy Demand After Replacing Cameras and Communications Equipment (kWh)	Energy Demand After Incorporating Solar & Wind (kWh)	Energy Demand: Solar,Wind & Acumentrics Fuel Cell (kWh)	Energy Demand: Solar, Wind & Efoy Fuel Cell (kWh)	Energy Demand: Solar, Wind & Thermoelectric Generator (kWh)
January	109.7	22.6	12.6	-359.3	-20.8	-27.5
February	93.5	20.0	-2.2	-338.1	-32.4	-38.4
March	98.6	21.7	-32.6	-404.5	-66.0	-72.7
April	56.2	18.0	-69.7	-429.5	-101.9	-108.4
May	52.4	18.1	-100.1	-472.1	-133.6	-140.3
June	50.7	17.6	-109.8	-469.8	-142.2	-148.6
July	52.4	18.1	-98.2	-470.2	-131.6	-138.3
August	52.4	18.1	-75.4	-447.4	-108.9	-115.6
September	50.7	17.6	-42.1	-402.0	-74.4	-80.9
October	59.8	18.7	-14.6	-386.5	-48.0	-54.6
November	106.1	21.9	7.9	-352.0	-24.4	-30.8
December	109.7	22.6	16.9	-355.0	-16.4	-23.1

Table XVII: Demand Analysis for Daylight Operation of Turnagain Pass RWIS Site (Solar PV + Fuels Cells or TEG)

Demand Analysis (Daylight Operation): Seward Highway @ Turnagain Pass MP 69.9						
Month	Current Energy Demand (kWh)	Energy Demand After Replacing Cameras and Communications Equipment (kWh)	Energy Demand After Incorporating Solar (kWh)	Energy Demand: Solar & Acumentrics Fuel Cell (kWh)	Energy Demand: Solar & Efoy Fuel Cell (kWh)	Energy Demand: Solar & Thermoelectric Generator (kWh)
January	42.0	8.7	-1.3	-373.3	-34.7	-41.4
February	44.9	9.6	-12.5	-348.5	-42.8	-48.8
March	57.5	12.7	-41.6	-413.6	-75.1	-81.8
April	42.6	13.6	-73.8	-433.8	-106.2	-112.7
May	42.6	14.8	-103.5	-475.5	-137.0	-143.7
June	44.3	15.3	-112.0	-472.0	-144.4	-150.9
July	42.7	14.8	-101.5	-473.5	-135.0	-141.7
August	38.4	13.3	-80.2	-452.2	-113.7	-120.4
September	33.2	11.5	-48.1	-408.1	-80.5	-86.9
October	31.9	10.0	-23.2	-395.2	-56.7	-63.4
November	47.5	9.8	-4.0	-364.0	-36.4	-42.9
December	42.0	8.7	3.1	-368.9	-30.4	-37.1

Table XVIII: Demand Analysis for Daylight Operation of Turnagain Pass RWIS Site (Solar PV + Wind + Fuel Cells or TEG)

Demand Analysis (Daylight Operation): Seward Highway @ Turnagain Pass MP 69.9						
Month	Current Energy Demand (kWh)	Energy Demand After Replacing Cameras and Communications Equipment (kWh)	Energy Demand After Incorporating Solar & Wind (kWh)	Energy Demand: Solar,Wind & Acumentrics Fuel Cell (kWh)	Energy Demand: Solar, Wind & Efoy Fuel Cell (kWh)	Energy Demand: Solar, Wind & Thermoelectric Generator (kWh)
January	42.0	8.7	-1.3	-373.3	-34.7	-41.4
February	44.9	9.6	-12.6	-348.5	-42.8	-48.8
March	57.5	12.7	-41.6	-413.6	-75.1	-81.8
April	42.6	13.6	-74.0	-433.8	-106.2	-112.7
May	42.6	14.8	-103.5	-475.5	-137.0	-143.7
June	44.3	15.3	-112.0	-472.0	-144.4	-150.9
July	42.7	14.8	-101.6	-473.5	-135.0	-141.7
August	38.4	13.3	-80.3	-452.2	-113.7	-120.4
September	33.2	11.5	-48.1	-408.1	-80.5	-86.9
October	31.9	10.0	-23.3	-395.2	-56.7	-63.4
November	47.5	9.8	-4.1	-364.0	-36.4	-42.9
December	42.0	8.7	3.0	-368.9	-30.4	-37.1

Tables XX-XXXIX in Appendix C contain the average monthly demand analysis results for the remaining five off-grid RWIS sites.

Operating Scenarios

Demand analysis using the existing solar PV and either the EFOY Pro 800 fuel cell or Global Thermoelectric 5060 generator to power POE cameras, existing weather sensors, and Airlink 3G modems provides enough power to maintain operation for continuous or daylight operation at the Turnagain RWIS site. However, the demand depends on the operating scenario. An operating scenario that could potentially save energy over the current configuration includes turning the cameras, weather sensors, and communications equipment off while not in use. Specific exceptions to turning off cameras and communication equipment are: 1) when camera heaters are required to keep the lens free of ice and condensation, and 2) transmitter links must stay connected to the central server in order to poll data at set intervals. Currently the communications system is designed to poll meteorological data and a camera image from the site every 10 minutes. It is beneficial to have 24 hour meteorological data, but it may not be necessary to have camera images during the night time hours. An infrared camera or infrared illuminators with existing cameras may be installed if it is necessary to have nighttime images.

The following chapter provides recommendations for power sources, weather sensors, cameras, and communication equipment at the six off-grid RWIS sites.

CHAPTER 3 – RECOMMENDATIONS

General Recommendations

The following sections provide recommendations for the Alaska off-grid RWIS power sources, cameras, weather sensors, communication equipment, and operating scenarios. A summary of the results and recommendations for all six off-grid RWIS sites is provided in Table XIX.

RWIS Power Sources

Based on research of power sources for similar off-grid systems and site visits to Alaska off-grid RWIS sites conducted during this project, it is recommended that the AK DOT consider the use of fuel cells or thermoelectric generators as power sources for operating through the winter season when solar PV outputs are low. Based on discussions with DOT personnel operating a similar off-grid RWIS site in Idaho using the EFOY Pro 1600 fuel cell, and the current testing of the Acumentrics RP500 fuel cell at the Alaska Klondike Highway site, fuel cells could prove to be viable options for Alaska DOT off-grid RWIS sites. The Global 5060 TEG used on the FAA remote modules could also provide the additional reliable power required to operate through the winter months.

The Global 5060 TEG offers the lowest cost fossil-fuel based power source at 1/4 of the initial cost of the EFOY Pro 800 fuel cell, but with approximately five times the fuel use to provide enough power to meet the demand at five of the six off-grid RWIS sites. The Stuart Creek RWIS site requires the Acumentrics RP500 fuel cell to meet the demand throughout the year due to the heated rain bucket. Given a 20 year life cycle, the initial cost of $21,500 and a cost of methanol at $1.60 per gallon for the EFOY Pro 800, and the initial cost of $6500 and a cost of propane at $4.00 per gallon for the Global 5060 TEG, ***the TEG is the lower cost option for 300 gallons per year or less of fuel use over the life cycle***. The life cycle expectations and reliability of these power sources remains to be evaluated through in-situ testing.

It is also recommended that the AK DOT work closely with the FAA to explore the use of a scaled-down version (1/3 power capacity) of the off-grid power module which employs a thermoelectric generator, a small harsh weather resistant wind turbine, and a thin-film solar PV array. The military grade wind turbine costing over $25K would need to be replaced by a commercially available turbine (APRS World WT-10) costing around $3.5K.

Table XIX: Summary of Results and Recommendations for Off-Grid RWIS Sites

Legend:
- ● Currently Installed
- ○ Recommended Equipment
- x Analyzed Generators

	Retrofit Equipment								Retrofit Cost		EFOY Pro 800 Fuel Cell					Global ThermoElectric Generator				
	Acumentrics RP500 Fuel Cell	Efoy Pro 800 Fuel Cell	Global ThermoElectric Generator Model 5060	6-Kyocera 120 W Solar Photovoltaic (PV) Panels	APRS World WT-10 Wind Turbine	Mobotix M24 Power over Ethernet (POE) Camera	Axis P1343 Camera	Raven X Airlink 3G Modem	Capital Cost of Retrofit with Efoy Fuel Cell ($)	Capital Cost of Retrofit with TEG ($)	Annual Energy Generation (Continuous) kWh	Annual Energy Demand (Continuous) kWh	Annual Energy Demand (Daylight) kWh	Annual Fuel Usage - Continuous (Gallons Methanol)	Annual Fuel Usage - Daylight (Gallons Methanol)	Annual Energy Generation (Continuous) kWh	Annual Energy Demand (Continuous) kWh	Annual Energy Demand (Daylight) kWh	Annual Fuel Usage - Continuous (Gallons Propane)	Annual Fuel Usage - Daylight (Gallons Propane)
Parks Highway @ Little Coal Creek MP 163.2		x	x	●		○		●	$26,600	$12,100	1087.2	278.2	162.9	14.4	1.6	1206.0	278.2	162.9	70.2	7.8
Klondike Highway @ US/Canada Border MP 14.9	●	x	x	●			●	●	$21,000	$6,500	1076.5	277.3	168.7	11.2	1.1	1198.2	277.3	168.7	54.7	5.1
Sterling Highway @ Jean Lake Hill MP 61.8		x	x	●		○		○	$27,200	$12,700	1126.7	263.7	147.9	11.6	0.9	1247.3	263.7	147.9	56.5	4.3
Seward Highway @ Turnagain Pass MP 69.9		x	x	●		○		●	$26,600	$12,100	1092.1	235.1	142.7	8.5	0.4	1214.4	235.1	142.7	41.3	2.1
Seward Highway @ Divide MP 11.7		x	x	●		○		○	$27,200	$12,700	1092.1	236.0	143.5	8.3	0.4	1092.1	236.0	143.5	40.4	2.1
Richardson Highway @ Stuart Creek MP 45.7	○	x	x	●		○		○	$27,200	$12,700	1130.3	540.4	285.3	56.2	8.4	1251.4	540.4	285.3	273.6	41.1

Power Demand of Cameras, Weather Sensors, and Communication Equipment

Based on research of current cameras, weather sensors, and communication equipment it is recommended that the AK DOT use the existing weather sensors, but replace the cameras with two POE Mobotix M24 cameras. One exception to the use of the existing weather sensors is the replacement of the Nova Lynx 2500E heated tipping bucket at Stuart Creek with a rain gauge and visibility sensor with a much lower power demand such as the Vaisala PWD 12. It is also recommended that Raven Airlink 3G modems be used in place of the Ku-band transmitters for communications. The use of the POE cameras and Airlink modems significantly reduces the power demand when compared to the current off-grid RWIS configurations.

Operating Scenarios for Energy Savings

Although the RWIS sites use very little power, it is important to operate the sites such that enough stored energy is available in the batteries to power the site when solar PV is not available. Demand analysis using the existing solar PV and either the EFOY Pro 800 fuel cell or Global Thermoelectric 5060 generator to power POE cameras, existing weather sensors, and Airlink 3G modems provides enough power to maintain operation for continuous or daylight operation at all RWIS sites except for Stuart Creek. The Stuart Creek RWIS site demand could be significantly reduced with the replacement of the heated tipping bucket as mentioned above.

An operating procedure that could potentially save energy over the current configuration includes leaving the cameras off while not in use, except for when the heater needs to be on to keep the camera lens free of ice and condensation. This same operating procedure could be followed for weather sensors and communication equipment, except for the communications interface (transmitter). The link must stay connected to the central server in order to poll data. The communications system is designed to poll meteorological data and a camera image from the site every 10 minutes. It is beneficial to have 24 hour meteorological data, but it may not be necessary to have camera images during the night time hours. An infrared camera or infrared illuminators such as the Cantronic CSI-IR Infrared Illuminators with existing cameras may be installed if it is necessary to have nighttime images. The additional power demand would range from 5-50 W depending on the distance and angle of view to be illuminated, but could be operated only when the camera is operational at night. The result would be an average increase in annual energy demand from 14.6-146 kWh for continuous nighttime operation averaging 8 hours per night over the year.

RWIS Locations

The location of the RWIS sites is critical for determining weather conditions along Alaska roadways where safety for vehicles is the major concern. AK DOT maintenance personnel recommended moving the RWIS location for at least one off-grid site, Little Coal Creek. While convenient and easy to access on a highway pull out, the location of the Little Coal Creek RWIS site at MP 163.2 on the Parks Highway is in a weather dead zone from about MP 158 to MP 169. One possible new location would be at or near the railroad crossing about 6 miles north of the current site where the Alaska Railroad has a remote power module for the crossing gates and signal flashers. The time to make this change in location would be during an upgrade of the RWIS module or simply placing a new module at the new location.

Also, five of the six off-grid RWIS sites are not in an ideal location for the use of a wind turbine. While the wind turbine could save on fossil fuel use (propane), it does not offer a significant amount of energy, particularly in the winter months at the off-grid sites.

Overall Recommendations

Based on research and evaluation of current off-grid RWIS sites, the following overall recommendations were reached:

1) Fossil-fuel based generators such as fuel cells or thermoelectric generators with non-moving parts like internal combustion engines could be used at the off-grid RWIS sites to supplement the existing solar PV system for continuous or daylight operation through the winter months.
2) Cameras using POE and Airlink 3G modems could be used to reduce power demand, increase the stored energy, and decrease the fuel used by fossil-fuel based power sources.
3) Cameras could be timed to come on at specified intervals and turned off during nighttime hours to reduce power demand, increase the stored energy, and decrease the fuel used by fossil-fuel based power sources.
4) An off-grid power module similar to the FAA module, but with 1/3 the capacity could be employed for new off-grid RWIS applications.

Conclusions and suggestions for future research work from the review, evaluation, results and recommendations for the six off-grid RWIS sites are provided in Chapter 4.

CHAPTER 4 - CONCLUSIONS AND SUGGESTED RESEARCH

Conclusions

This report documented the findings of a review of current off-grid RWIS power sources, weather sensors, cameras, and communication equipment and provided recommendations for improving the power sources at these sites for reliable year round operation.

Three distinct conclusions can be drawn from these findings:

1) Off-grid RWIS sites require a combination of the existing solar PV array and fossil-fuel based sources such as the Acumentrics RP500 or EFOY Pro 800 fuel cell, or the Global Thermoelectric 5060 generator for continuous or daylight operation throughout the year.
2) The use of low-power cameras, weather sensors, and communication equipment employing POE can reduce power demand and dependence on fossil-fuel sources.
3) The operating scenario used at the site is critical to energy savings, and is largely dependent on continuous versus daylight operation and the duty cycle of the camera, heaters, and communications equipment.

In general these findings suggest that RWIS power sources need to be configured as a combination of alternative and fossil-fuel based power sources with low-power cameras, weather sensors, and communications equipment for reliable year round operation.

Suggested Research

Further investigation and testing in the area of off-grid RWIS power sources includes:

1) Evaluation through in-situ testing of similar off-grid power modules for meteorological data using fuel cells and thermoelectric generators by the Coast Guard, FAA, and DOT.
2) Further and more detailed analysis of the energy generation, storage, and demand at off-grid RWIS sites through data logging by the operation and maintenance contractor.
3) Cold and harsh weather testing of both power sources, weather sensors, cameras, and communication equipment.
4) Development of a scaled-down version of the FAA off-grid power modules.

This research could be conducted as a Phase II project with AKDOT&PF and could include the development and in-situ testing of off-grid RWIS power modules.

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APPENDIX A: RWIS Power Source Specification and Data Sheets

Marathon Minotaur 2.5

Kyocera 120-1 Solar PV Panels

Rolls Series 4000 12 V, 275 A-hr deep cycle marine batteries (12 HHG 8DM)

Trojan 8D-AGM 12 V, 230 A-hr deep cycle battery

APRS World WT-10 Wind Turbine

Acumentrics RP500 (formerly RP 20) Fuel Cell

EFOY 1600 Pro Series Fuel Cell (1st Generation)

EFOY 800 Pro Series Fuel Cell (2nd Generation)

Global ThermoElectric Model 5060 Thermoelectric Generator

Marathon Minotaur 2.5

Minotaur™ 2.5 — This venerable workhouse is used for unattended prime power applications.

Minotaur™

NOTE:

The Minotaur line is being upgraded and a release date will be announced.

LONG-LIFE PRIME POWER

The Minotaur™ 2.5 Electric Power System has been specifically engineered to deliver high quality, reliable, unattended prime power with a unique long-life engine designed for long hours of continuous operation.

LOW MAINTENANCE

Long routine maintenance intervals of up to 4,000 hours translate into a low maintenance cost that is particularly important for remote, often difficult to reach locations. A well-engineered cabinet design provides easy service access for quick, efficient, simple servicing.

SUPERIOR RELIABILITY

Highly engineered components and electronics give a superior degree of reliability that translates into long operating periods with minimal downtime. The Minotaur™ 2.5 Electric Power System provides the highest degree of reliability of any small internal combustion engine based system available today.

HIGH QUALITY POWER 120/240 VAC

The output of the Minotaur™ 2.5 Electric Power System is high quality power of 120/220 VAC delivered at 50/60 Hz, or 24/48 VDC. With tight voltage and frequency specifications, the Minotaur™ 2.5 Electric Power System is compatible with electric equipment worldwide.

UNIVERSAL APPLICATION

The use of widely available natural gas or LPG (propane) coupled with world wide power compatibility makes the Minotar™ 2.5 Electric Power System truly unique, resulting in prime power availability to any location throughout the world. The versatility of the Minotaur™ 2.5 Electric Power System can be further enhanced with the availability of a wide range of custom options.

Kyocera 120-1 Solar PV Panels

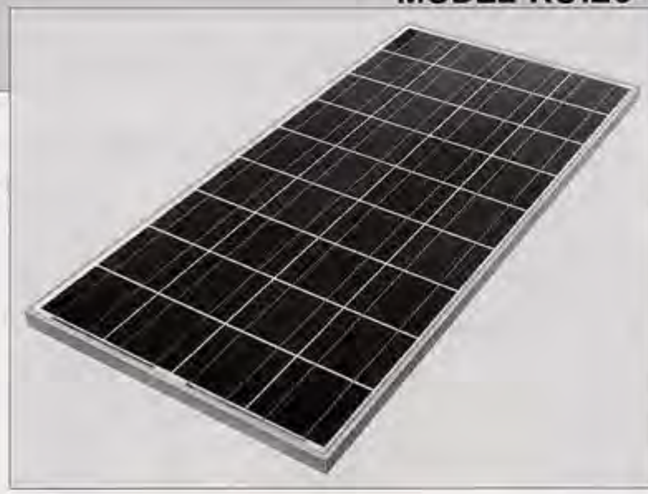
MODEL KC120-1

KYOCERA

KC120-1

HIGH EFFICIENCY MULTICRYSTAL PHOTOVOLTAIC MODULE

TYPICAL OUTPUT 120 Wp



HIGHLIGHTS OF KYOCERA PHOTOVOLTAIC MODULES

Kyocera's advanced cell processing technology and automated production facilities have produced a highly efficient multicrystal photovoltaic modules.
The conversion efficiency of the Kyocera solar cell is over 14%.
These cells are encapsulated between a tempered glass cover and an EVA pottant with PVF back sheet to provide maximum protection from the severest environmental conditions.
The entire laminate is installed in an anodized aluminum frame to provide structural strength and ease of installation.

APPLICATIONS

- Microwave/Radio repeater stations
- Electrification of villages in remote areas
- Medical facilities in rural areas
- Power source for summer vacation homes
- Emergency communication systems
- Water quality and environmental data monitoring systems
- Navigation lighthouses, and ocean buoys
- Pumping systems for irrigation, rural water supplies and livestock watering
- Aviation obstruction lights
- Cathodic protection systems
- Desalination systems
- Recreational vehicles
- Railroad signals
- Sailboat charging systems

SPECIFICATIONS

■ Electrical Specifications

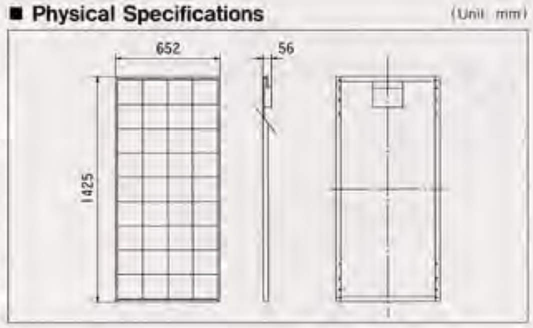
MODEL	KC120-1
Maximum Power	120 Watts
Maximum Power Voltage	16.9 Volts
Maximum Power Current	7.10 Amps
Open Circuit Voltage	21.5 Volts
Short-Circuit Current	7.45 Amps
Length	1425mm (56.1in.)
Width	652mm (25.7in.)
Depth	56mm (2.2in.)
Weight	11.9kg (26.3lbs.)

Note: The electrical specifications are under test conditions of Irradiance of 1kW/m², Spectrum of 1.5 air mass and cell temperature of 25°C

Kyocera reserves the right to modify these specifications without notice.

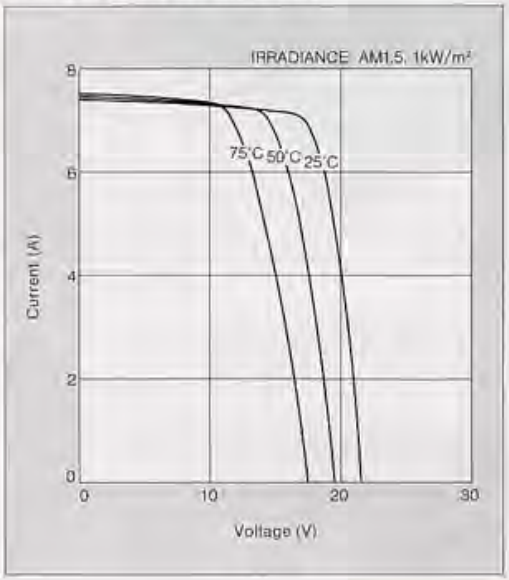
■ Physical Specifications

(Unit: mm)

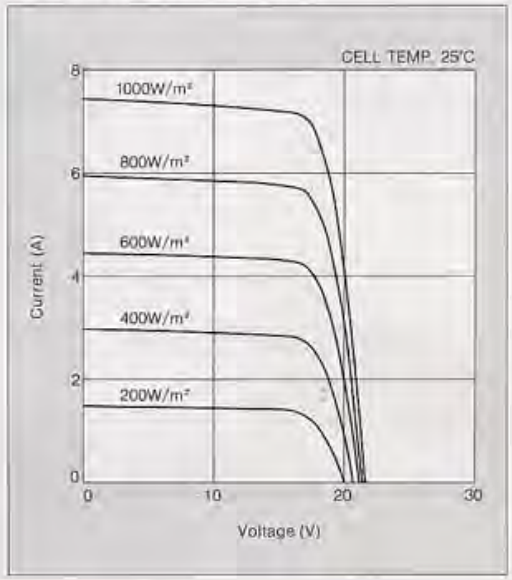


ELECTRICAL CHARACTERISTICS

Current-Voltage characteristics of Photovoltaic Module KC120-1 at various cell temperatures



Current-Voltage characteristics of Photovoltaic Module KC120-1 at various irradiance levels



QUALITY ASSURANCE

Kyocera multicrystal photovoltaic modules exceed government specifications for the following tests.

- Thermal cycling test
- Thermal shock test
- Thermal/Freezing and high humidity cycling test
- Electrical isolation test
- Hail impact test
- Mechanical, wind and twist loading test
- Salt mist test
- Light and water-exposure test
- Field exposure test

Please contact our office to obtain details without hesitation.

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22780 280, Recreio, Rio de Janeiro, Brazil
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Rolls Series 4000 12 V, 275 A-hr deep cycle marine batteries (12 HHG 8DM)

ROLLS MARINE BATTERIES – TECHNICAL SPECIFICATIONS

Part No.	Capacity@ 20 Hr	Reserve Minutes	CCA	Dimensions (mm)	Weight (Kg)
Series 3000 – 12Volt – Heavy Duty Marine Starting / Cycling					
24 90 XJM	90	165	520	279 x 171 x 241	22.7
27 112 XJM	112	190	600	318 x 171 x 241	26.8
Series 4000 – 6Volt – Heavy Duty Marine Deep Cycle					
HT 1M	105	203	472	229 x 173 x 222	20.0
EHG 210M	210	390	875	259 x 179 x 264	30.8
EIGH 225M	225	414	658	259 x 179 x 275	33.6
EIGH 262M	262	483	768	312 x 181 x 286	40.8
NS 305M	305	560	992	312 x 181 x 362	49.4
CH 375M	350	761	1066	312 x 181 x 425	53.1
Series 4000 – 6Volt – 'Dual Container' Heavy Duty Marine Deep Cycle					
6 HHG 31PM	344	696	1444	527 x 203 x 302	56.7
6 EHG 31PM	410	830	1721	527 x 203 x 324	60.3
Series 4000 – 8Volt – 'Dual Container' Heavy Duty Marine Deep Cycle					
8 HHG 21PM	230	464	963	540 x 187 x 283	53.5
8 HHG 25PM	275	557	1155	622 x 187 x 292	59.0
8 M 23PM	240	530	1138	686 x 184 x 305	57.6
8 HHG 29PM	300	603	1350	686 x 184 x 305	68.0
8 HHG 31PM	344	696	1444	686 x 203 x 302	75.7
8 EHG 31PM	410	830	1721	686 x 203 x 324	80.7
Series 4000 – 12Volt – Heavy Duty Marine Deep Cycle					
24 HT 80M	80	163	324	279 x 171 x 241	22.7
27 HT 90M	90	183	405	318 x 171 x 241	28.1
30 H 108M	108	203	394	335 x 171 x 248	32.7
T12 136M	136	277	512	335 x 171 x 286	40.8
12 HHG 185PM	185	344	800	527 x 222 x 254	55.3
T12 250M	200	435	648	391 x 178 x 365	63.5
HT 8DM	221	489	1050	527 x 279 x 254	74.4
12 HHG 8DM	275	557	1155	527 x 279 x 254	78.0

12 HHG 8DM

Rolls marine batteries are exactly that . . . batteries for marine use – *not just automotive batteries with a marine label*

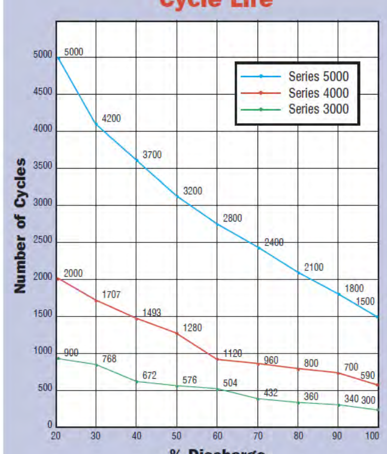
ROLLS MARINE BATTERIES – TECHNICAL SPECIFICATIONS

Part No.	Capacity@ 20 Hr	Reserve Minutes	CCA	Dimensions (mm)	Weight (Kg)
Series 4000 – 12Volt – 'Dual Container' Heavy Duty Marine Deep Cycle					
12 EHG 210PM	210	390	875	527 x 222 x 314	62.6
12 HHG 325BSM	325	650	1350	622 x 381 x 330	90.7
12 HHG 325PM	325	650	1350	552 x 337 x 287	90.7
12 EHG 375PM	375	775	1530	552 x 337 x 319	104.3
12 MD 325PM	325	650	1350	464 x 383 x 281	90.7
12 MD 375PM	375	775	1530	464 x 383 x 310	104.3
Series 5000 – 2Volt – 'Dual Container' Premium Marine Deep Cycle					
2 KS 33PM	1766	4915	4952	392 x 211 x 630	94.3
Series 5000 – 4Volt – 'Dual Container' Premium Marine Deep Cycle					
4 CS 17PM	546	1083	1689	365 x 210 x 464	66.7
4 KS 21PM	1104	3575	3095	400 x 238 x 629	121.1
4 KS 25PM	1350	4290	3714	400 x 270 x 629	142.9
Series 5000 – 6Volt – 'Dual Container' Premium Marine Deep Cycle					
6 CS 17PM	546	1083	1357	559 x 210 x 464	100.2
6 CS 21PM	683	1353	1740	559 x 248 x 464	122.9
6 CS 25PM	820	1624	2088	559 x 286 x 464	144.2
Series 5000 – 8Volt – 'Dual Container' Premium Marine Starting / Deep Cycle					
8 NS 23PM	430	716	1520	718 x 210 x 464	109.8
8 CH 23PM	582	969	1866	718 x 210 x 464	116.1
8 NS 33PM	625	1042	2204	718 x 286 x 464	159.7
8 CH 33PM	846	1410	2648	718 x 286 x 464	187.8
Series 5000 – 8Volt – 'Dual Container' Premium Marine Deep Cycle					
8 CS 17PM	546	1083	1351	718 x 210 x 464	133.4
8 CS 25PM	820	1624	2027	718 x 286 x 464	192.3
Series 5000 – 12Volt – 'Dual Container' Premium Marine Deep Cycle					
12 CS 11PM	357	677	845	559 x 286 x 464	123.4

Choosing the right battery for your particular application will save you money and give you years of trouble-free service

- Robust construction to handle the largest inverter systems
- Numerous sizes and voltage configurations to suit your requirements
- Enhanced proven technology assures long cycle life
- Modular design provides easy installation of larger batteries
- Long life expectancy, coupled with the industry's best warranty

Cycle Life



Trojan 8-D AGM Battery (12V, 230 A-hr)

BCI GROUP SIZE	TYPE	CAPACITY[A] Minutes		CRANKING Performance		CAPACITY[B] Amp-Hours (AH)				ENERGY (kWh)	VOLTAGE	TERMINAL Type	DIMENSIONS[C] Inches (mm)			WEIGHT lbs. (kg)
		@25 Amps	@75 Amps	C.C.A.[E] @0°F	C.A.[E] @32°F	5-Hr Rate	10-Hr Rate	20-Hr Rate	100-Hr Rate	100-Hr Rate			Length	Width	Height[F]	
MARINE/RV DEEP-CYCLE BATTERIES - with T2 TECHNOLOGY™																
24	SCS150	150	36	530	650	80	92	100	111	1.33	12 VOLT	10	11-1/4 (286)	6-3/4 (171)	9-3/4 (248)	50 (23)
27	SCS200	200	52	620	760	95	105	115	128	1.54	12 VOLT	10	12-3/4 (324)	6-3/4 (171)	9-3/4 (248)	60 (27)
30H	SCS225	225	57	665	820	105	118	130	144	1.73	12 VOLT	10	13-15/16 (355)	6-3/4 (171)	9-7/8 (251)	66 (30)
DEEP-CYCLE AGM BATTERIES																
U1	U1-AGM	42	-	240	306	29	31	33	34	0.408	12 VOLT	13	8-3/16 (207)	5-3/16 (132)	6-13/16 (174)	27 (12)
GC12	12-AGM	280	-	825	900	112	127	140	144	1.72	12 VOLT	13	13-9/16 (345)	6-13/16 (174)	10-15/16 (278)	100 (45)
22	22-AGM	79	-	280	336	43	47	50	52	0.624	12 VOLT	13	9 (229)	5-1/2 (139)	8-1/16 (205)	40 (18)
24	24-AGM	137	-	500	600	67	70	76	84	1.01	12 VOLT	6	10-3/4 (274)	6-13/16 (174)	8-11/16 (220)	54 (24)
27	27-AGM	158	-	550	660	77	82	89	99	1.19	12 VOLT	6	12-9/16 (318)	6-13/16 (174)	8-3/4 (221)	64 (29)
31	31-AGM	177	-	600	720	82	92	100	111	1.33	12 VOLT	6	13-7/16 (341)	6-13/16 (174)	9-3/16 (233)	69 (31)
31	OverDrive AGM 31™	180	-	730	875	84	93	102	112	1.34	12 VOLT	11	13-7/16 (341)	6-13/16 (174)	9-1/4 (234)	69 (31)
STARTING AGM BATTERY																
31	TransPower™ ST1000 AGM 31	200	-	1000	1200	88	93	102	105	1.26	12 VOLT	11	13-7/16 (341)	6-13/16 (174)	9-1/4 (234)	74 (34)
DUAL PURPOSE AGM BATTERIES																
GC2	6V-AGM	385	-	1100	1400	154	184	200	221	1.33	6 VOLT	6	10-1/4 (260)	7-1/8 (181)	10-3/4 (274)	65 (29)
8D	8D-AGM	460	-	1450	1850	179	210	230	254	3.05	12 VOLT	6	20-1/2 (521)	10-9/16 (269)	9-3/16 (233)	167 (76)

* Polyon™ Case

A. The number of minutes a battery can deliver when discharged at a constant rate at 80°F (27°C) and maintain a voltage above 1.75 V/cell. Capacities are based on peak performance.
B. The amount of amp-hours (AH) a battery can deliver when discharged at a constant rate at 77°F (25°C) for Signature Line, Deep-Cycle AGM & Deep-Cycle Gel, 80°F (27°C) for Premium & Industrial Lines and maintain a voltage above 1.75 V/cell. Capacities are based on peak performance.
C. Dimensions are based on nominal size. Dimensions may vary depending on type of handle or terminal. Batteries to be mounted with .5 inches (12.7 mm) spacing minimum.
D. Dimensions taken from bottom of the battery to the highest point on the battery. Heights may vary depending on type of terminal.
E. C.A. (Cranking Amps) - the discharge load in amperes which a new, fully charged battery can maintain for 30 seconds at 32°F at a voltage above 1.2 V/cell. This is sometimes referred to as marine cranking amps @ 32°F or M.C.A. @ 32°F.
F. Dimensions taken from bottom of the battery to the highest point on the battery. Heights may vary depending on type of terminal.

Terminal Configurations

1 ELPT Embedded Low Profile Terminal
2 EHPT Embedded High Profile Terminal
3 EAPT Embedded Automotive Post Terminal
4 EUT Embedded Universal Terminal
5 LT L-Terminal
6 DT Automotive Post & Stud Terminal
7 UT Universal Terminal
8 AP Automotive Post Terminal
9 WNT Wingnut Terminal
10 DWNT Dual Wingnut Terminal
11 ST Stud Terminal
12 Cable & Plug
13 IT Insert Terminal
14 IND Ind Terminal

Trojan BATTERY COMPANY
Clean energy for life.

Your Local Trojan Battery Representative:

For more information, call 800.423.6569 or + 1.562.236.3000 or visit www.trojanbattery.com

TRJN0111_CSTM_06/13 — TRJN_ProdSpecGuide_0613

APRS World WT-10 Wind Turbine

Introduction

APRS World's WT10 micro wind turbine is the premiere wind generator for extreme wind enviroments. We have spent years developing and testing the WT10 in ***downright brutal*** locations and applications. Regular 150+ MPH winds, ice, and lightning. Every component of the WT10 has been repeatedly revised to make it as tough as possible and work in the most demanding enviroments. ***Simply put, there isn't a tougher micro wind turbine on the market.***

A complete system

APRS World can supply you with a complete integrated and tested micro wind turbine or hybrid wind / solar power and control system. We manufacture turbine control panels, output cables, dump loads, tower components, specialized installation tools, and even highly innovative mounting structures for ISO shipping containers. With our 8 years of experience in data acquisiton and control systems for small wind, we can offer both the most advanced and the most cost effective instrumentational, control, or telemetry systems.

MADE IN USA

Made in USA — with pride

The WT10 is assembled in the USA with as many USA made components as possible. The only major non-USA components are the European designed and molded blades and the Asian made bearings. While other companies continue to move manufacturing overseas, APRS World has invested heavily to bring the generator manufacturing to the USA. See a complete breakdown of country of origin information in our documents section.

WT10 Design

The WT10 is designed to be strong and power through anything mother nature can throw at it. Nearly every component on the WT10 is designed by APRS World and custom manufactured for us. Off the shelf components neither fit nor provided the reliability we require. Most components are machined from solid metal or engineered plastic. All components are sealed, plated, or otherwise designed to provide the most reliable service. Read more about each part of the WT10 turbine in our WT10 design section.

Specifications

	TURBINE
Configuration	3 blades, horizontal axis, upwind
Rated power @ 11 m/s	24 volt battery charging: TBD watts 48 volt battery charging: TBD watts
Applications	Battery charging
Cut-in wind speed	4.5 m/s (10 MPH)
Survival wind speed	70 m/s (157 MPH)
Overall weight	10 kg (23 lbs)
	ROTOR
Rotor diameter	1.0 m (3.3 ft)
Swept area	0.79 m^2 (8.45 ft^2)
Blade Length	0.47 m (18.6 in)
Blade Material	Nylon 6/6, black, 33% glass filled
	GENERATOR
Drive	Direct drive
Type	Permanent magnet generator, radial flux
Configuration	3Ø, 10 pole Variable frequency and voltage
Maximum power output	1 kW
	ELECTRONICS
See turbine control panel for more information.	
	WARRANTY
Complete system	5 years
	TOWERS
Factory supplied mounting systems for	Rohn 25G & 45G. Bergey GL. Most monopoles. Others available upon request.
See towers for more information.	

Acumentrics RP500 Fuel Cell

RP250/RP500*

250/500W NATURAL GAS OR PROPANE FUELED REMOTE POWER SYSTEM

The RP Series of high efficiency, natural gas or propane fueled Remote Power Systems are based on fuel cell technology developed by Acumentrics and is an excellent option for supply of DC Power to several Off Grid application areas:

- **Natural Gas Pipeline & Wellhead**
  Cathodic Protection, SCADA, RCVs, Chemical Injection Pumps, Gas Analyzers
- **Off Grid Telecom**
  Cellular Basestations, Radio Transmitters, Microwave Repeaters
- **Off Grid Homes**
  Cabins, Vacation Homes, Security Systems
- **Wind Energy Assessment**
  LIDAR, SODAR, Met-Tower Heating/Lighting

Reliable, Low Maintenance Operation

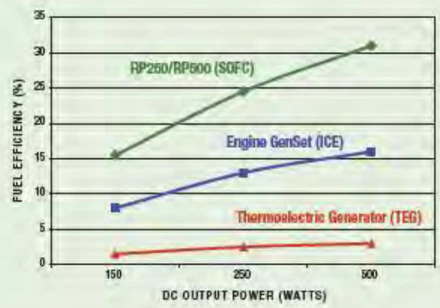
The core of the RP is a solid state, ceramic tubular fuel cell. The system has few moving parts with no motor oil, coolant or hydraulic fluids to change or potentially spill. The system is compact, easy to install. Standard maintenance is an annual site visit to change air and fuel filters. It's scalable and modular so install only as much power as needed, with the option to add more as required.

Efficient

The RP fuel cell electrochemically converts a fuel's energy directly into DC electric power. It consumes natural gas or propane, but it does not burn or combust the fuel as in an Internal Combustion Engine (ICE) or a TEG. The combustion process in an ICE or a TEG creates significant waste heat as well as several byproducts that contribute to air pollution. This electrochemical conversion allows the RP to be inherently more efficient than combustion generators so that it can deliver more useable energy from the same amount of fuel. The user benefit is significant fuel/cost savings (see chart below).

Whisper Quiet, Clean, Green & Tax Credit Eligible

Unlike loud, noxious engine generators, the RP's virtually silent fuel cell core enables the direct generation of DC power without emitting NOx and SOx pollutants. RP CO_2 emissions are significantly lower than combustion based generators. By switching to an RP from a Thermoelectric Generator (TEG), a user can reduce carbon footprint by up to 50 tons/year or the equivalent of removing 10 cars from the road for a year. Fuel cell products like the RP are defined as renewable energy sources by the US government and are eligible for state and federal tax credits that can be $3,000 per system or more.



High efficiency RP Power Systems achieve significant fuel savings vs. incumbent technologies.

The Acumentrics RP Series is a family of quiet, clean and reliable DC power systems based on proprietary tubular ceramic fuel cell technology to serve remote or off grid applications.

CLEAN
RELIABLE
POWER™

RP250/RP500*

250/500W NATURAL GAS OR PROPANE FUELED REMOTE POWER SYSTEM

OUTPUT

Fuel Cell Capacity: 1.0 kW (RP500) or 0.5 kW (RP250) Peak Power from Fuel Cell Bundle

Electrical Efficiency:
> 30% @ 500W DC Output Power (RP500)
> 25% @ 250W DC Output Power (RP250)

DC Output Power: 500W (RP500) or 250W (RP250) Maximum Continuous

DC Output Voltage: 10 to 60 VDC, User Adjustable

DC Output Current: 100A Maximum Continuous
Note: Current will also be limited by maximum output power of 500W (RP500) or 250W (RP250)

Operating/Control Modes:
Current Control Mode
Voltage Control Mode
Battery Charge Mode

Start-up Time to Max Output Power: <60 minutes

FUEL

RP500N or RP250N: Natural Gas

RP500P or RP250P: Propane (LP Vapor)

Fuel Supply Pressure:
2 to 5 psig for std system;
2 to 125 psig with High Pressure Gas (Option -H)

Maximum Sulfur Content:
<60ppmw (42mg/m³) for std system;
High Sulfur Content Gas (Option -S) available

Maximum Water Content:
<5000ppmv for std system;
Self draining coalescing filter available for High Water Content Gas (Option -W)

Fuel Consumption:

@ 500W DC Output Power:
RP500N: 5.70 ft³/hr (0.16 m³/hr)
RP500P: 0.06 gals/hr (0.24 liters/hr)

@ 250W DC Output Power:
RP250N: 3.51 ft³/hr (0.10 m³/hr)
RP250P: 0.04 gals/hr (0.14 liters/hr)

ENVIRONMENTAL

Operating Temperature:
-30°C to +50°C (-22°F to +122°F)

Storage Temperature:
-40°C to +55°C (-40°F to +131°F)

Humidity:
5% to 95% (non-condensing)

Operating Altitude:
0 to 10,000 ft (3,048m)

Storage Altitude:
0 to 40,000 ft (12,192m)

MECHANICAL

Nominal Envelope Dimensions (H x W x D):
22in x 22in x 39in (556mm x 556mm x 991mm)

Weight: 300lbs (136kg)

COMMUNICATIONS

Local control and monitoring of system status and performance data is standard and can be accessed through an Ethernet cable connection. With Satellite Dish (Option -D) or Cellular Network (Option -C) the system can be monitored and controlled remotely.

PREVENTIVE MAINTENANCE

Annual Service:
Air and fuel filters – Replace
Desulfurizer canister – Replace
Batteries, fans, valves, etc. – Inspect, clean or replace as necessary

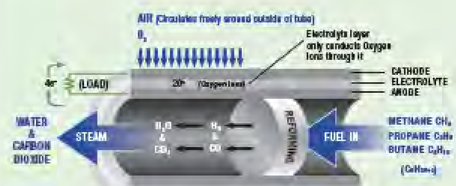
WARRANTY

Standard Warranty: 1 year
An extended warranty is available as an option.

***Note: The RP500 used to be designated the RP20**

SOLID OXIDE FUEL CELL

SOLID STATE (CERAMIC) CONSTRUCTION



Acumentrics' tubular SOFC technology enables clean, reliable power for your off grid applications.

CLEAN RELIABLE POWER™

MODELS

RP500N-C48-ACDEHSW

- RP — Base Model
- Max System DC Output Power: **250** = 250 watts; **500** = 500 watts
- Fuel: **N** = Natural Gas (Methane); **P** = Propane (LP Vapor)
- Operating/Control Mode: **C** = Current Control Mode; **V** = Voltage Control Mode; **B** = Battery Charge Mode
- Nominal System Output Voltage: **12** = 12 VDC; **24** = 24 VDC; **48** = 48 VDC
- System Options:
  - **A** = Auxiliary Output (+12VDC @ max of 100 watts)
  - **C** = Cellular Network Communications
  - **D** = Satellite Dish Communications
  - **E** = E-Stop Button
  - **H** = High Pressure Gas (Allows Max Fuel Inlet pressure up to 125psi)
  - **S** = High Sulfur Content Gas
  - **W** = High Water Content Gas (Recommended for hi water content in gas)

- **Continuous Power for Remote or Off Grid Applications**
- **High Energy Efficiency Yields Significant Fuel Savings**
- **Available Fuel Options — Natural Gas & Propane**
- **Low Maintenance — Solid State Construction**
- **Safe, Quiet and Clean — Electrochemical Fuel Conversion Minimizes Emissions**

RP250-500-1212

Acumentrics
20 Southwest Park • Westwood, MA 02090
Tel: 800-332-0277 • FAX: 781-461-1261
www.acumentrics.com\fuel-cell-generators.html

EFOY 1600 Pro Series Fuel Cell (1st Generation)

Data Sheet – EFOY Pro Series Fuel Cells

EFOY ENERGY FOR YOU

Fuel Cells	EFOY Pro 600	EFOY Pro 1600	EFOY Pro 2200	EFOY Pro 2200 XT
Max. charging power per day	600 Wh/day	1560 Wh/day	2160 Wh/day	2160 Wh/day
Nominal power	25 W	65 W	90 W	90 W
Nominal voltage	12 V / 24 V	12 V / 24 V	12 V / 24 V	12 V / 24 V
Nominal charging current at 12 V /24 V	2.1 A / 1.05 A	5.4 A / 2.7 A	7.5 A / 3.75 A	7.5 A / 3.75 A
Recommended battery capacity[1] at 12 V at 24 V	10 to 100 Ah 5 to 50 Ah	40 to 250 Ah 20 to 120 Ah	60 to 350 Ah 30 to 175 Ah	60 to 350 Ah 30 to 175 Ah
Weight	6.8 kg (15 lbs)	8.3 kg (18.3 lbs)	8.6 kg (19 lbs)	8,95 kg (19,7 lbs)
Warranty	24 months / 3000 hours	24 months/ 3000 hours	24 months / 3000 hours	24 months/ 4500 hours
Switching threshold for automatic battery charging at 12 V /24 V[2]	On: ‹12.3 V / ‹24.6 V Off: ›14.2V / ›28.4 V			
Required start-up voltage at 12 V /24 V	›9 V / ›18.5 V			
Noise level (at 1m / 7m distance)	39 / 23 dB(A)			
Nominal consumption[3]	0.9 l/kWh			
Quiescent current draw	15 mA			
Operating temperature	-20 °C to +45 °C (-4°F to +113°F)			
Start-up temperature	+5 °C to +45 °C (41°F to 113°F)			
Storing temperature	+1 °C to +45 °C (34°F to 113°F)			
Recommended altitude	Up to 1500 m (4920 ft)			
Dimensions L x W x D	433 x 188 x 278 mm (17 x 8 x 11 in)			
Inclination along the roll axis	Permanent: max. 35°; temporary (‹10 min): max. 45°			
Inclination along the lateral axis	Permanent: max. 20°			
User-Interface	At the unit or via Remote Control with text display			
Data-Interface	RJ-45 plug for accessories (e.g. Interface adapter)			
Electrical Interface	MNL-plug 4-pins (e.g. Tyco Electronics Universal Mate-N-Lok – Nr. 350779)			

[1] Depends on battery type and application - bigger batteries possible, if charging current sufficient (e.g. solar battery)
[2] Factory Setting - can be modified with Interface Adapter and PC
[3] Effective consumption depends on operating conditions

Standard Accessory Set
• Remote control with cable • Mounting plate for EFOY Pro • Charge line for battery connection • Fuel cartridge holder with belt • Off heat duct • Exhaust hose • Service fluid and user manual

Accessories
M28 adapter
EFOY ProCube
DuoCartSwitch DCS1
GSM modem GSM-2-SMS
Fuel cartridge sensor FS1
Interface adapter IA1
USB adapter
Cluster controller CC1

Fuel Cartridges	M5	M10	M28 (only with M28-Adapter)
Volume	5 l (1.32 gallons)	10 l (2.64 gallons)	28 l (7.4 gallons)
Weight	4.3 kg (9.5 lbs)	8.4 kg (18.5 lbs)	22 kg (48.5 lbs)
Nominal capacity	5.5 kWh	11.1 kWh	31.1 kWh
Dimensions L x W x D	190 x 145 x 283 mm	230 x 193 x 318 mm	420 x 280 x 360 mm

SFC Energy AG
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Web: www.sfc.com

Valid from 27.07.2010

Direct methanol fuel cells

All SFC fuel cells use DMFC (direct methanol fuel cell) technology. Inside the cells, an environmentally-friendly catalytic process directly converts methanol alcohol into electricity, efficiently and without any intermediate steps. This technology is one of cleanest methods available for generating electricity.

Direct methanol fuel cells are the ideal energy solution for remote and mobile applications.

Connect it – switch it on – no worries

The EFOY Pro is an intelligent electricity generator. It is directly connected to the battery supplying your power consumers and automatically recharges it when necessary. The user does not need to look after anything. The user can use the remote monitoring to check that the fuel cell is working properly. The electricity generation is very efficient, quiet and maintenance-free because the process has no moving parts.

100 % availability – weather independent

A perfect solution for ensuring 100% availability is to use the EFOY Pro as a backup system in a solar power station. The fuel cell automatically comes into operation as soon as the solar system is not able to provide enough power. This allows expensive solar systems to be of smaller dimensions and greatly increases the reliability of the system as a whole.

Precisely stated: The advantages of methanol as an energy source

Methanol as a fuel offers a number of decisive advantages compared to classical fuels:

Extremely high energy density:
10 l of methanol has a capacity of 11.1 kWh of electricity at a weight of only 7.9 kg – corresponding to about 1,400 Wh/kg.

Safety tested
EFOY fuel cartridges are designed to the highest levels of safety and carry the TÜV GS seal of tested safety and UN approval for air transport. Their construction ensures that the user can never come into contact with the contents.

Environmentally-friendly
Methanol can be generated from renewable resources (e.g. from biomass and even household waste), does not damage the groundwater or the ozone layer and exists naturally (in small concentrations) in the environment and the human body.

EFOY 800 Pro Series Fuel Cell (2nd Generation)

EFOY ENERGY FOR YOU

Data Sheet – EFOY Pro Fuel Cells

Fuel Cells	EFOY Pro 800	EFOY Pro 800 Duo	EFOY Pro 2400	EFOY Pro 2400 Duo
Max. nominal power	45 W	45 W	110 W	110 W
Min. nominal power [1]	25 W	25 W	80 W	80 W
Nominal voltage	12 V dc / 24 V dc	12 V dc / 24 V dc	12 V dc / 24 V dc	12 V dc / 24 V dc
Charging current at 12 V / 24 V max.: min.:	3,75 A / 1,88 A 2,1 A / 1,05 A	3,75 A / 1,88 A 2,1 A / 1,05 A	9,17 A / 4,58 A 6,7 A / 3,3 A	9,17 A / 4,58 A 6,7 A / 3,3 A
Recommended battery capacity [2] at 12 V (Lead acid, gel and AGM) at 24 V	40 to 160 Ah 10 to 100 Ah	40 to 160 Ah 10 to 100 Ah	60 to 350 Ah 30 to 175 Ah	60 to 350 Ah 30 to 175 Ah
Weight	8,0 kg / 17.6 lbs	8,3 kg / 18.3 lbs	9,0 kg / 19.8 lbs	9,3 kg / 20.5 lbs
Warranty [3]	24 Month / 4.500 hours	24 Month / 4.500 hours	24 Month / 4.500 hours	24 Month / 4.500 hours
Connectable cartridges (with DCS1)	1 (2)	2 (4)	1 (2)	2 (4)
Length fuel cartridge connector	70 cm / 27.6 in			
Switching threshold for automatic battery charging at 12 V / 24 V [4]	On: ‹12,3 V / ‹24,6 V Off: ›14,2 V / ›28,4 V			
Required start-up voltage at 12 V /24 V	›9 V / ›18,5 V			
Maximum battery voltage	‹16 V / ‹32 V			
Noise level (at 1m / 7m distance)	42 dB(A) / 25 dB(A)			
Nominal consumption [5]	0,9 l/kWh			
Quiescent current draw at 12 V	20 mA			
Operating temperature	-20 °C to +50 °C / -4°F to +122°F			
Start-up temperature	+3 °C to +50 °C / +37.4 °F to +122°F			
Storing temperature	+1 °C to +50 °C / +34°F to +122°F			
Recommended altitude [4]	Standard: ≤1500 m / ≤4920 ft (up to 2000m / 6561 ft)			
Dimensions L x W x H	433 x 188 x 278 mm / 17 x 8 x 11 in			
International Protection (IP-Class)	IP 21			
Inclination along the roll axis	Permanent: max. 35°; temporary (‹10 min): max. 45°			
Inclination along the lateral axis	Permanent: max. 20°			
User-Interface	At the unit or via Operating Panel OP2 with text display			
Data-Interface	RJ-45 plug for accessories (e.g. Interface adapter)			
Electrical Interface	MNL-plug 4-pins (e.g. Tyco Electronics Universal Mate-N-Lok – Nr. 350779)			
Certificates				
Standard Equipment	• Operating panel OP2 with cable • Mounting plate for EFOY Pro • Charge line for battery connection • Fuel cartridge holder with belt		• Exhaust hose • Off heat duct • Service fluid and user manual	

Headquaters Europe:
SFC Energy AG
Tel.: +49 89 673 592 - 0
Fax: +49 89 673 592 - 369

USA:
SFC Energy Inc.
Phone: +1 240 328 6688
Fax: +1 240328 6694

Email: sales@sfc.com
Web: www.efoy-pro.com

All technical data at test conditions of 20 °C / 68 °F
Data sheet only valid in USA and Canada
Subject to modifications and errors
Valid from: 03rd April 2013

1 / 2

Data Sheet – EFOY Pro Fuel Cells

EFOY ENERGY FOR YOU

Accessories [6]		
DuoCartSwitch DCS1	Dimensions L x W x H	174 x 119 x 96 mm / 6.9 x 4.7 x 3.8 in
	Weight	0,7 kg / 1.54 lbs
	International Protection (IP-Class)	IP 20
	Quiescent current draw	7.5 mA
GSM modem GSM-2-SMS	Dimensions L x W x H	72 x 32 x 65 mm / 2.8 x 1.3 x 2.6 in
	Weight	0,5 kg / 1.1 lbs
	Input Voltage	8 – 30 V dc
	Max. peak current	3,2 A
	Average current draw (Quiescent / SMS / GPRS)	30 / 100 / 100 mA
Fuel cartridge sensor FS1	Dimensions L x W x H	50 x 20 x 5 mm / 19.7 x 7.9 x 2.0 in
Interface adapter IA1	Dimensions L x W x H	60 x 33 x 16 mm / 2.4 x 1.3 x 0.6 in
Cluster controller CC1	Dimensions L x W x H	149 x 77 x 270 mm / 58.7 x 30.1 x 106.3 in
	Weight	0,16 kg / 1.3 lbs
M28 adapter	Dimensions L x W x H	70 x 70 x 61 mm / 2.8 x 2.8 x 2.4 in

Fuel Cartridges	M5	M10	M28 (only with M28-Adapter)
Volume	5 litre / 1.32 US gallons	10 litre / 2.64 US gallons	28 litre / 7.4 US gallons
Weight	4,3 kg / 9.5 lbs	8,4 kg / 18.5 lbs	22 kg / 48.5 lbs
Nominal capacity	5,5 kWh	11,1 kWh	31,1 kWh
Dimensions L x W x H	190 x 145 x 283 mm / 7.5 x 5.7 x 11.1 in	230 x 193 x 318 mm / 9.1 x 7.6 x 12.5 in	370 x 285 x 395 mm / 14.6 x 11.2 x 15.6 in with M28 Adapter: 370 x 285 x 425 mm / 14.6 x 11.2 x 16.7 in

[1] Nominal power varies by ±10 %, decreases with the operation hours. Specification valid within warranty period.
[2] Depends on battery type and application - bigger batteries possible, if additional energy source available (e.g. solar)
[3] Regional warranty conditions for EFOY Pro fuel cells apply.
[4] Factory Setting - can be modified with Interface Adapter and PC or operating panel OP2.
[5] Effective consumption depends on operating conditions.
[6] All EFOY Pro accessories are for operating in following temperature ranges: -20 °C to +50 °C / -4 °F to +122°F

Global ThermoElectric Model 5060 Thermoelectric Generator

Model 5060 Thermoelectric Generators

Global Thermoelectric's Model 5060 Thermoelectric Generator contains no moving parts. It is a reliable, low maintenance source of DC electrical power for any application where regular utilities are unavailable or unreliable.

Power Specifiations

Power Rating at 20ºC
60 Watts at 6.7 Volts
54 Watts at 12 Volts
54 Watts at 24 Volts
54 Watts at 48 Volts

Electrical

Adjustment:	6.7V	up to 11 Volts
	12 V	12 -18 Volts
	24 V	24 - 30 Volts
	48 V	48 - 60 Volts

Reverse current protection included.

Output: Terminal block which accepts up to 8 AWG wire. Opening for 3/4" conduit in the base of the cabinet.

Fuel

Natural Gas:	4.4 m^3/day (155 Sft^3/day) 1000 BTU/Sft^3 (37.7 MJ/SM^3) gas max 7 mg/Sm^3 H_2S max 120 mg/Sm^3 max 1% free O_2
Propane:	5.7 l/day (1.5 US gal/day)
Max. Supply Pressure:	1724 kPa (250 psi)
Min. Supply Pressure:	103 kPa (15 psi)
Fuel Connection:	1/4" MNPT

Environmental

Ambient Operation Temperature: Max. 45ºC (115ºF) Min. -40ºC (-40ºF).
Operating Conditions: Unsheltered operation
Please contact Global for operating conditions below -40ºC or above +40ºC.

Materials of Construction

Cabinet:	304 SS
Cooling Type:	Natural Convection
Fuel System:	Brass, Aluminum & SS

Standard Features

- Automatic Spark Ignition (SI)
- Fuel Filter
- Low Voltage Alarm Contacts (VSR)
- Volt & Amp Meter

Optional Features

- Cathodic Protection Interface
- Pole Mount or bench stand
- Automatic Fuel Shut-off (SO)
- Corrosive Environmental Fuel System
- Flame Arrestor

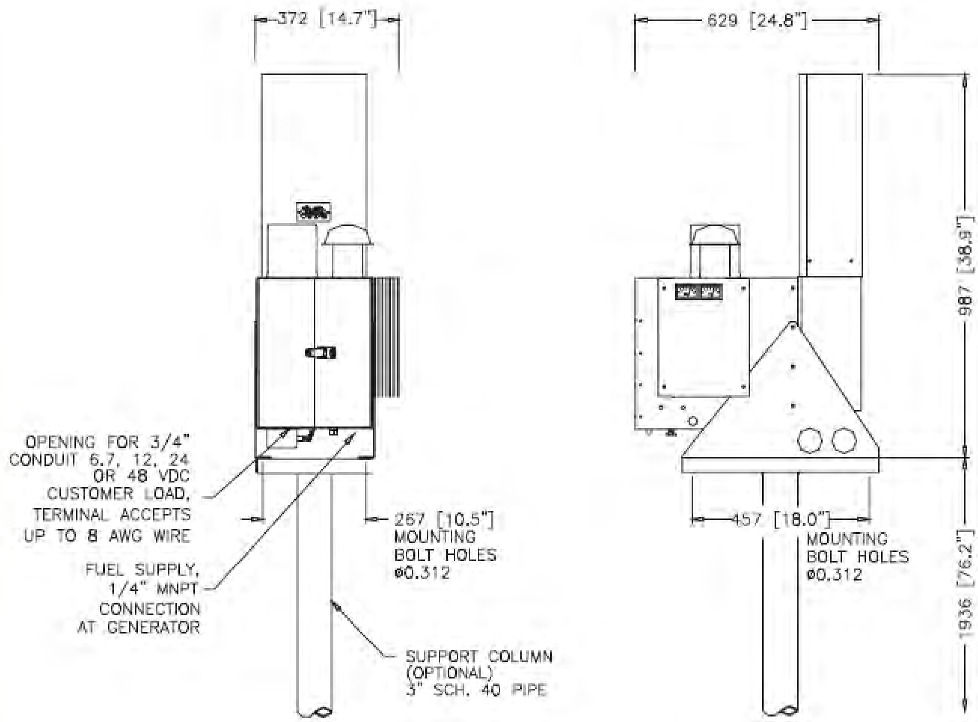
Note: Specifications shown are for standard configurations. Global Thermoelectric's Applications Engineering Department is available to design custom voltages, fuel supply systems and non-standard operating temperatures.

Global Thermoelectric

Power where you need it.

Rev 03-09

Typical Installation



NOTES:
1. GENERATOR WEIGHT: 41 kg [100 lb]
2. DIMENSIONS IN mm [INCHES].

Global Thermoelectric

Power where you need it.

Corporate Office
#9, 3700 - 78 Avenue SE
Calgary, Alberta T2C 2L8
CANADA
Phone: (403) 236-5556
Fax: (403) 236-5575

US Sales
P.O. Box 38624
Houston, TX 77238
Phone: (281) 445-1515
Fax: (281) 445-6060
Toll Free: 1 800 848-4113

Model 5060 Thermoelectric Generator

APPENDIX B: RWIS Cameras, Weather Sensors, and Communication Equipment Specification and Data Sheets

SSI Cohu ER-8546 Single View Camera

Cohu 3920 PTZ Camera

Mobotix M24 Allaround Camera

Cantronic CSI-IR Infrared Illuminators

RM Young 05103 Wind Monitor

SSI Adolf Theis Hygro-Thermo Transmitter

Quixote FP 2000 Pavement Temp Sensor

SSI Thermoscan 1000 Pavement Temp Sensor

SSI MRC Temperature Data Probe TP101

SSI Hawk Eye Optical Infrared Y/N Precipitation Sensor

Judd Ultrasonic Snow Depth Sensor

Nova Lynx 260-2501 Rain Gauge

Vaisala PWD12

Decibel Products DB498 Directional Antenna

Cohu ER-8546 Single View Camera

Surface Systems, Inc.

SSI Zoom Camera

SSI P/N: 56213010
(Part of Fixed Low Light Color Camera Kit, SSI P/N: 56218550)

FEATURES

- ¼" Progressive Scan Color Sensor
- Horizontal Resolution of 470 TV Lines
- 23:1 (3.6mm to 82.8mm) optical zoom lens
- Auto Focus
- Long term integration available to 1/2 second
- Composite video output; NTSC format
- Automatic color balance
- Internal phase adjust line-lock, software adjustable
- Programmable on screen character generator
- Wide Dynamic Range (WDR) by use of dual shutter exposure technique.
- RS-232 serial control
- Internal heater wired separately from the camera power
- Sealed enclosure pressurized with dry nitrogen
- 16 zoom, focus, preset positions, each with a unique user programmable preset ID

SSI Zoom Camera
021903

Surface Systems, Inc. 11612 Lilburn Park Road St. Louis, MO 63146
A Quixote Company Phone: (314) 569-1002 Fax(314) 569-3567

CAMERA SPECIFICATIONS

Imager:	Interline transfer Progressive Scan CCD with mosaic-type color compensating filter.
Image Area:	¼" Format 3.6mm (H) x 2.7mm (V)
Resolution:	470 horizontal; 350 vertical
Picture Elements:	758 (H) x 504 (V)
Video Output:	NTSC, 1 V p-p @ 75 ohms, unbalanced.
Maximum Lens Aperture:	f/1.6 (wide) to f/3.7 (tele)
Optical Zoom Range:	23X, 3.6mm to 82.8mm
Effective Digital Focal Length:	82.8mm to 828mm
Horizontal Angle of View:	Optical: 54° to 2.5°; At 10X Digital: 54° to 0.25°.
Minimum Focus Distance:	40" in tele, 0.4" in wide angle
Zoom & Focus Presets:	16 preset positions, focus is auto, if programmed, displays the preset caption.
Flash Memory:	Update firmware and new features via serial communication.
Long Term Integration Range: (Short Shutter)	Provides manual selection of integration duration for enhanced sensitivity. Integration times are 1/2 second, 1/4 second, 1/8 second, 1/15 second, 1/30 second. Frame Store video output provides continuous video output, updated at the integration rate.
Auto Iris:	Iris automatically adjusts to compensate for changes in scene illumination to maintain constant video level output within sensitivity specifications.
Gamma:	0.45
AGC:	0 to 50 dB
Color Balance:	Auto Tracking Color Balance
Signal to Noise Ratio:	>50 dB
Synchronization:	Phase-Adjust Line Lock on 60Hz.
Sensitivity:	(3200K): Scene Illumination @ F1.6, Wide Angle 3.0 Lux @ 1/60Sec.,F1.6, Shutter, Color I.R Cut On 0.2 Lux @ 1/4Sec., F1.6, Shutter, Color I.R.Cut On 0.3 Lux@ 1/60Sec. F1.6, Shutter, monochrome mode I.R. Cut Off 0.02 Lux@ 1/4Sec., F1.6, Shutter, monochrome mode I.R. Cut Off

COMMUNICATION AND CAMERA ADDRESSING PROTOCOL

Control and addressing is via RS-232 serial communications.

Upon receipt of any given command, the camera responds in 1.0 second or less.

All programmable functions are stored in non-volatile memory and are lost if a power failure occurs.

Surface Systems, Inc. 11612 Lilburn Park Road St. Louis, MO 63146
A Quixote Company Phone: (314) 569-1002 Fax(314) 569-3567

POWER REQUIREMENTS

Camera Power Input Requirements: 12VDC. (±10%)

Power consumption: 13W – Camera (no zoom motor); 27W - Heater

MECHANICAL SPECIFICATIONS

Weight:	4.2 lbs.
Dimensions:	Length (less connectors): 12.0" Housing Diameter: 3.5" Height (Including Mounting Base): 5.13"
Mounting:	3 ¼-20 mounting nuts on the bottom of base

ENVIRONMENTAL SPECIFICATIONS

Ambient Temperature Limits (Operating):	-40°C to +74°C (-40°F to 165°F)
Ambient Temperature Limits (Storage):	- 40°C to +85°C (-40°F to 185°F)
Humidity:	Up to 100% relative humidity (per MIL-E-5400T, paragraph 3.2.24.4)
Other:	Withstands exposure to sand, dust, fungus, and salt atmosphere per MIL-E-5400T, paragraph 3.2.24.7, 3.2.24.8, and 3.2.24.9.

Surface Systems, Inc. 11612 Lilburn Park Road St. Louis, MO 63146
A Quixote Company Phone: (314) 569-1002 Fax(314) 569-3567

Cohu 3920 PTZ Camera

Surface Systems, Inc.

SSI PTZ Camera

SSI P/N: 56213011
(Part of PTZ Camera Kit, SSI P/N: 56218549)

FEATURES

¼" Progressive Scan Color Sensor
Horizontal Resolution of 470 TV Lines
23:1 (3.6mm to 82.8mm) optical zoom lens
Auto Focus
Long term integration available to 1/2 second with frame store video output
Composite video output; NTSC format
Automatic color balance
Internal phase adjust line-lock, software adjustable
Programmable on screen character generator
Wide Dynamic Range (WDR) by use of dual shutter exposure technique.
RS-232 serial control
Internal heater and blower wired separately from the camera power
Sealed enclosure pressurized with dry nitrogen
No mechanical pan limits, continuous rotation capability in either direction
Variable pan speed from 0.1°/sec. to >250°/sec. (Preset Mode)
180° continuous tilt movement through 90° down. Auto image rotation at 90° down.
Variable tilt speed from 0.1°/sec. to 60°/sec
64 zoom, focus, pan & tilt preset positions, each with a unique user programmable preset ID

Surface Systems, Inc. 11612 Lilburn Park Road St. Louis, MO 63146
A Quixote Company Phone: (314) 569-1002 Fax(314) 569-3567

CAMERA SPECIFICATIONS

Imager:	Interline transfer Progressive Scan CCD with mosaic-type color compensating filter.
Image Area:	¼" Format 3.6mm (H) x 2.7mm (V)
Resolution:	470 horizontal; 350 vertical
Picture Elements:	758 (H) x 504 (V)
Video Output:	NTSC, 1 V p-p @ 75 ohms, unbalanced.
Maximum Lens Aperture:	f/1.6 (wide) to f/3.6 (tele)
Optical Zoom Range:	23X, 3.6mm to 82.8mm
Effective Digital Focal Length:	82.8mm to 828mm
Horizontal Angle of View:	With Optical Zoom: 54° to 2.5°
Minimum Focus Distance:	40" in tele, 0.4" in wide angle
Zoom & Focus Presets:	16 preset positions, focus is auto, if programmed, displays the preset caption.
Flash Memory:	Update firmware and new features via serial communication.
Long Term Integration Range: (Short Shutter)	Provides manual selection of integration duration for enhanced sensitivity. Integration times are 1/2 second, 1/4 second**,** 1/8 second, 1/15 second, 1/30 second.
Auto Iris:	Iris automatically adjusts to compensate for changes in scene illumination to maintain constant video level output within sensitivity specifications.
Gamma:	0.45
AGC:	0 to 50 dB
Color Balance:	Auto Tracking Color Balance
Signal to Noise Ratio:	>50 dB
Sensitivity:	(3200K): Scene Illumination @ F1.6, Wide Angle 3.0 Lux @ 1/60Sec.,F1.6, Shutter, Color I.R Cut On 0.2 Lux @ 1/4Sec., F1.6, Shutter, Color I.R.Cut On 0.3 Lux@ 1/60Sec. F1.6, Shutter, monochrome mode I.R. Cut Off 0.02 Lux@ 1/4Sec., F1.6, Shutter, monochrome mode I.R. Cut Off

COMMUNICATION AND CAMERA ADDRESSING PROTOCOL

Control and addressing is via RS-232 serial communications.

Upon receipt of any given command, the dome camera responds in 1.0 second or less.

All programmable functions are stored in non-volatile memory and are lost if a power failure occurs. System configurations such as video privacy zones, preset text and sector I.D. are able to be stored in a computer file and a camera personality can be cloned or uploaded into a camera in the event that a camera replacement is necessary.

Surface Systems, Inc. 11612 Lilburn Park Road St. Louis, MO 63146
A Quixote Company Phone: (314) 569-1002 Fax(314) 569-3567

POWER REQUIREMENTS

Operating Voltage: 21.6VAC to 26.4VAC, 24VAC Nominal 50/60 Hz. (±3.0 Hz)

Power consumption: 27W – Camera (no motors); 131W - Heater

ENVIRONMENTAL SPECIFICATIONS

Ambient Temperature Limits (Operating):	-34°C to +74°C (-30°F to 165°F)
Ambient Temperature Limits (Storage):	- 45°C to +85°C (-50°F to 185°F)
Humidity:	Up to 100% relative humidity (per MIL-E-5400T, paragraph 3.2.24.4)
Other:	Withstands exposure to sand, dust, fungus, and salt atmosphere per MIL-E-5400T, paragraph 3.2.24.7, 3.2.24.8, and 3.2.24.9.
Shock:	Up to 5G's, 11ms, in any axis under non-operating conditions, MIL-E-5400T, para 3.2.24.6
Vibration:	Sine vibration from 5 to 60 Hz with 0.082 inch total excursion without damage. Random vibration from 60 to 1000 Hz, 5 G's RMS ($0.027g^2$/Hz) without damage

MECHANICAL SPECIFICATIONS

Weight:	Not to exceed 13 lbs.
Dimensions:	13" (h) x 11" (w)

MOUNTING CONFIGURATIONS

The dome camera includes three possible mounting configurations, a wall mount, pole mount, or pendant mount version.

3920 Series Specifications

SYSTEM

Pan/Tilt Drive
Pan Range: 360° continuous rotation
Tilt Range: -90° to +5°
Pan Speed
Max Speed: 250°/sec
Preset: 250° movement (start to stop) <2 sec
Manual: 0.1° to >80°/sec
Tilt Speed
Max Speed: 120°/sec
Preset: 80° movement (start to stop) <2 sec
Manual: 0.1° to >40°/sec
Accuracy: <0.1°
Repeatability: <0.1°
Absolute Positioning
Set Position: 0.1° precision
Get Position: 0.1° precision

Presets
64 preset positions (each preset includes pan, tilt, zoom, focus and 24 character ID label)

Video Tours
8 tours, each consisting of 32 presets with dwell time per preset per tour

Sector Zones
Up to 16 programmable zones in the horizontal plane

Privacy Zones
8 programmable zones can be set for video blanking

Compass Direction
8 or 16 direction points (i.e.: north, NE, east, SE, south, SW, west, and NW) can be displayed. Function can be on/off, 3-sec. time out or permanent

Absolute Position
Displayed in 0-359° AZ and +95° to -95° EL. Function can be on/off, 3-sec. time out or permanent

Title Generation
Camera ID: 2 lines of 24 characters
Preset ID: 1 Line of 24 characters
Sector ID: 1 line of 24 characters per zone
Privacy ID: 1 line of 24 characters per zone
Low Pressure: 1 line of 24 characters
Compass ID: 1 line, includes compass direction and absolute position

CAMERA

Image Sensor
1/4" Sony Ex-View HAD™

Total Pixels
NTSC: 811 x 508
PAL: 795 x 596

Resolution
Typical 540 HTVL; 400 VTVL

Day/Night Method
Removable IR cut filter

Sensitivity (F1.4 @ 50IRE, Progressive Scan Mode)
0.1 fc (1.0 lx) @ 1/60 shutter (color mode)
0.01 fc (0.10 lx) @ 1/4 shutter (color mode)
0.005 fc (0.05 lx) @ 1/2 shutter (color mode)
0.001 fc (0.01 lx) @ 1/4 shutter (mono mode)

Video Output
1.0 V p-p @ 75 ohms, Progressive Scan

Integration Settings
1/30, 1/15, 1/8, 1/4, 1/2 fields

Shutter Speed Settings
1/60, 1/120, 1/180, 1/250, 1/500, 1/1000, 1/2000, 1/4000, 1/10,000, 1/30,000

Wide Dynamic Range
Two shutter speeds in alternative video fields combined into one progressive scan frame

Electronic Image Stabilization
5hz Mode: 16db suppression @ 3-13hz
16hz Mode: 16db suppression @ 7-17hz

Sync
Crystal

LENS

Integrated Zoom: 35X optical zoom
Focal Range: 3.4mm to 119mm (±15%);
Aperture: f1.4 to f4.2
AFOV: 56° to 1.7° (±15%)

Lens Focus
Auto/manual

Digital Zoom
Up to 12X with smooth transition produces an effective focal length from 3.4mm to 1428mm (±15%)

OPERATIONAL CONTROL

Day/Night Mode
Auto, Color or Monochrome

Zoom
Zoom In/Out
Magnification: 1-35X Setting
Lens speed mode (Fast/Slow)

Lens Focus
Auto/manual selectable

Iris Control
Auto/manual selectable

Digital Zoom
Selectable digital zoom depth (OFF, 2x, 5x, 10x, 12x)

Electronic Image Stabilization
On/Off; 5hz/16hz selectable

Wide Dynamic Range
On/Off selectable

White Balance
Auto, Manual (Blue/Red), Indoor, Outdoor Modes

Shutter/Integration
Auto/manual selectable

Video Modes
Live/Freeze; Selectable
Freeze Video between Preset Movements; On/Off

ELECTRICAL

Power Input
89 VAC to 135 VAC
Conforms to NEMA TS2 para. 2.1.2.
24 VAC ±15%

Power Consumption
104 W max with p/t and heaters operating

Power Interruption
Conforms to NEMA TS2 para. 2.1.4

Power Transients
Conforms to NEMA TS2 para 2.1.6

COMMUNICATIONS

Data Format
Half-duplex RS-422 (4-wire) or RS-232 (3-wire), 300 to 19.2K baud

Camera Protocol
Cohu, Pelco-D, Pelco-P, Bosch, Vicon

Firmware
Stored in flash memory; upload via serial port

(continued next page)

3920 Series
i-dome high performance dome cameras

MECHANICAL

Construction / Finish
Powder Coated 1100 aluminum
External parts corrosion protected with stainless steel fasteners. Internal screws/ fasteners nylon or loctite thread-locking

Weight
14 lbs (6.3 kg)

Dimensions
see diagram

Field Connector
18-pin MS
Mating connector included

ENVIRONMENTAL

Protection Rating
IP-67 / NEMA 4X / ASTM-B117

Operating Temperature Limits
Standard: -29.2° to 131°F
(-34° to 55°C)
TS2: -29.2° to 165°F
(-34° to 74°C)
Per NEMA TS2, para. 2.1.5.1, using fig. 2.1 test profile

Humidity
Up to 100% relative humidity

Vibration
Conforms to NEMA TS2, para. 2.1.9

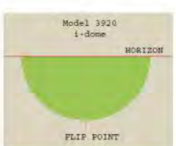
Shock
Conforms to NEMA TS2, para. 2.1.10

Wind
Survivability: 120 mph (193 km/h) with 25% gust factor. Mounting connector not included.

EMI
FCC rules, Part 15, Subpart J, for Class B devices

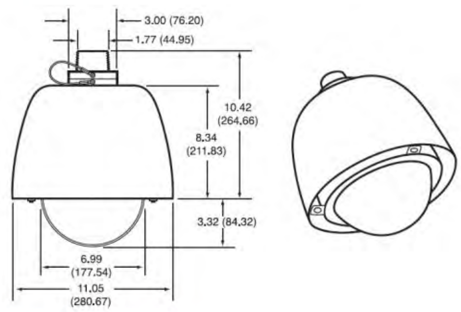
FAST POSITIONING

A high-speed positioner with up to 0.1° accuracy provides 360° continuous rotation and up to 64 user-defined preset positions, each with a two-line, 24-character title. The Auto-Flip feature can track objects moving under the Model 3920 i-dome.



NEW *For IP-enabled video systems, this camera is available as 3940 Series.*

DIMENSIONS *in inches (mm)*



ORDERING INFORMATION

392X-XX0X/XXXX

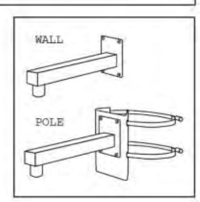
Power
4 - 24 VAC
5 - 115 VAC

Video
5 - NTSC Day/night with 35x zoom and EIS
8 - PAL Day/Night with 35x zoom and EIS

Protocol
1 - Standard (Contact Cohu for current list of protocols supported)
2 - NTCIP 1205 Camera Control

Dome
0 - Clear dome
1 - Smoke dome

Mount
WALL - Wall mount
POLE - Pole mount
PEND - Pendant mount



SHIPPING INFORMATION

Weight 18 lbs (8.2 kg)
Volume 15" x 15" x 20" (381 mm x 381 mm x 508 mm)

www.cohu-cameras.com

COHU
Cohu, Inc. / Electronics Division
COHU ELECTRONICS
12367 Crosthwaite Circle
Poway CA 92064-1245
Tel. +1 (858) 277-6700
Fax: +1 (858) 277-0221

3920 01-10 Printed in USA

Mobotix M24 Allaround Camera

M24

Camera Series M24

Allround M24M

More Camera For Less. Guaranteed!

The M24M enables smooth video frames rates of up to 30 fps, even at a megapixel resolution (3MEGA: up to 20 fps). The M24M is accompanied by five interchangeable standard lenses with image angles ranging from 15° to 90° and a model with CS mount and a manual adjustable Vario lens. MOBOTIX provides night models with a particularly light-sensitive B/W image sensor for use in poor lighting conditions. The M24M can also be configured for high-resolution, distortion-free panorama images using a hemispheric L11 lens.

The M24M can be installed and rotated in just a few minutes using the standard, flexibly adjustable VarioFlex Wall and Ceiling Mount. The weatherproof camera can operate in temperatures ranging from -30°C to +60°C (-22°F to +140°F) and does not require a heater or a fan. Thanks to the high-quality microphone/speaker combination, which eliminates echoes during handsfree operation, the camera can transmit lip-synchronous sound alongside high-resolution video and can record on a 4 GB card integrated as standard. MicroSD cards of up to 64 GB are also supported.

Highlights

- Outdoor camera (IP65) with wall mount and weather protection
- Integrated microphone + speaker
- Bidirectional IP telephony
- Audio transmission to the browser
- Definable exposure zones
- Integrated video motion detection
- Alarm management with pre- & post-alarm images
- Digital pan/tilt/zoom
- IP telephony with video stream (H.264)
- Camera-controlled recording on Windows/ Linux/Mac systems
- Power supply via Ethernet cable

Video Management

- Software installation on PC not necessary
- Convenient administration via web browser
- Complete video management software and recording integrated in camera software
- User-definable access levels
- Optional: Free of charge video management
  - MxControlCenter (Windows)
  - MxEasy (Windows/Macintosh/Linux)
- Event triggered by
  - time-controlled masking of image areas
  - event and/or time-controlled recording
  - temperature, brightness
  - motion in definable video sensor areas
  - definable time functions/repetition

Features

M24 IT	M24 Sec
• Adjustable PoE classes (1 to 3)	
• waterproof connections to the camera	
• Full image recording at live PTZ	
• Power consumption typ. 3 watt	
• Echo suppression during hands-free operation	
• Web server	
• FTP client	
• E-mail	
• Multiview	
• Recorder/Player	
• Softbuttons	
• IP-Notify (Send, Receive) for external management system	
	• integrated VoIP from/to browser
• SIP video telephony	
• IP announcement	
• PDA web pages	
• MxPEG live	
• Logo generator	
• Snapshot recording (10 pre-, 10 post-alarm images	• Snapshot recording (50 pre-, 50 post-alarm images
• Video-Audio-Recording with bis zu 30 B/s in VGA	
• Event- and time-controlled storage: internal, via FTP on web server or PC on the LAN (Windows/Linux NFS/Mac)	
• Direct access to images, therefore, no FTP required (although possible)	
	• scheduled privacy zones
	• flexible event logic
	• Master/slave arming

Back Panel M24 (mm)

Rotation Angle

MOBOTIX.com

Cantronic CSI-IR Infrared Illuminators

CANTRONIC SYSTEMS INC.

CSI-IR Infrared Illuminators

www.cantronics.com

Overview

The CSI-IR series of infrared illuminators for CCTV applications is designed to produce clear night vision images for security surveillance. Cantronic's proprietary design allows for evenly distributed illumination with viewing distances over 200 meters (660ft). Another advantage of these Illuminators is the low power consumption, ranging from 6W to 55W only. The CSI-IR infrared illuminators are weather resistant and come in 850nm (semi-covert) or 940nm (covert) wavelength versions.

The result of these innovations is a high-performance infrared illuminator that delivers the farthest viewing distance and longest life of any infrared illuminator currently available on the market. The CSI-IR series of illuminators can be purchased separately or as part of a complete infrared CCTV camera system. They can also be retrofitted to existing CCTV cameras.

Outstanding Features

- Illumination distance range up to 200m (660ft)
- Available in semi-covert (850nm) and covert (940nm) wavelength
- Available in 30° and 60° illumination angle
- Constructed in light weight rugged extruded aluminum weatherproof housing
- Long lifespan LED of 10,000+ hours
- Automatic ON/OFF photocell control as standard for 30m, 50m, 100m & 200m models
- Produce no infrared glare
- Operating temperature range -30℃ to 55℃
- Available in industry standard 24VAC, 24VDC or 110/220 VAC power input

Dimensional Diagram

Housing Type	Dimension A x B x C
1 *	69 x 69 x 89 mm (2.7" x 2.7" x 3.5")
2	130 x 130 x 165 mm (5.1" x 5.1" x 6.5")
3	130 x 130 x x195 mm (5.1" x 5.1" x 7.8")
4	130 x 130 x 215 mm (5.1" x 5.1" x 8.5")
5	165 x 165 x 215 mm (6.5" x 6.5" x 8.5")

* Type 1 Housing is in different shape.

Product Image

CSI-IR Infrared Illuminator

Applications

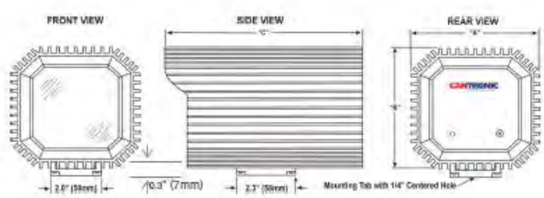
- Night time or Covert Surveillance
- Airport Perimeter
- Government Facilities
- Border and Harbor Patrols
- Prison Surveillance
- Police Surveillance
- Facilities that require a high level of security

Performance Options & Accessories

- Mounting Bracket, support up to 9kg (20lbs)
- Power Adapter AC to AC or AC to DC
- Integrated with CIRP CCTV Camera System for viewing distance up to 800m

Certifications / Compliance

CSA Standard C22.2 (No 250.0-00)	Luminaires
UL Standard No 1598	Luminaires
US Patent #6902299B2 Other Patents Pending	Illuminators



CANTRONIC SYSTEMS INC.

CSI-IR Infrared Illuminators

Specifications

Model	Illumination Distance	Angle	LED	Input Voltage	Power	Weight kg (lbs)	Housing Type
Semi-Covert (850nm wavelength)							
CSI-IR18m30	18m (60ft)	30°	42	12VDC	6W	0.4 (0.9)	1
CSI-IR30m30	30m (100ft)	30°	90	24VAC, 24VDC	12W	1.2 (2.6)	2
CSI-IR30m60	30m (100ft)	60°	150	24VAC, 24VDC	20W	1.3 (2.9)	3
CSI-IR50m30	50m (165ft)	30°	150	24VAC, 24VDC	20W	1.3 (2.9)	3
CSI-IR50m60	50m (165ft)	60°	300	24VAC, 24VDC, 110/220VAC	30W	1.5 (3.3)	4
CSI-IR100m30	100m (330ft)	30°	300	24VAC, 24VDC, 110/220VAC	30W	1.5 (3.3)	4
CSI-IR100m60	100m (330ft)	60°	588	24VAC, 110/220VAC	55W	1.9 (4.2)	5
CSI-IR200m30	200m (660ft)	30°	588	24VAC, 110/220VAC	55W	1.9 (4.2)	5
Covert (940nm wavelength)							
CSI-IR30m30N	30m (100ft)	30°	150	24VAC, 24VDC	20W	1.3 (2.9)	3
CSI-IR30m60N	30m (100ft)	60°	300	24VAC, 24VDC, 110/220VAC	30W	1.5 (3.3)	4
CSI-IR50m30N	50m (165ft)	30°	300	24VAC, 24VDC, 110/220VAC	30W	1.5 (3.3)	4
CSI-IR50m60N	50m (165ft)	60°	588	24VAC, 110/220VAC	55W	1.9 (4.2)	5
CSI-IR100m30N	100m (330ft)	30°	588	24VAC, 110/220VAC	55W	1.9 (4.2)	5

How to Order

CSI-IR100m30 – 24AC

Model
See above for details

Input Voltage
12DC : 12VDC
24AC : 24VAC
24DC : 24VDC
110/220 : 110V or 220VAC

Upper Mount Bracket
Model: 631-0003

Bottom Mount Bracket
Model: 631-0025

CIRP-800M System

c UL us LISTED SP c us
*on selected models

GSA Schedule

Application Examples:
Pictures shown with optional mounting brackets and CIRP-800M CCTV Camera System

Specifications subject to change without notice

 ISO9001 Certified

Cantronic Systems Inc.
www.cantronics.com
63A Clipper Street
Coquitlam, BC V3K 6X2, Canada
Telephone: +1.604.516.6667
Facsimile: +1.604.516.6618
Toll Free: +1.866.391.6970
Email: irsales@cantronics.com

Dealer/Distributor

DS-CSI-IR-08A

RM Young 05103 Wind Monitor

YOUNG — Model 05103 Wind Monitor

The Wind Monitor is a high performance, rugged wind sensor. Its simplicity and corrosion-resistant construction make it ideal for a wide range of wind measuring applications.

The wind speed sensor is a four blade helicoid propeller. Propeller rotation produces an AC sine wave voltage signal with frequency directly proportional to wind speed. Slip rings and brushes are eliminated for increased reliability.

The wind direction sensor is a rugged yet lightweight vane with a sufficiently low aspect ratio to assure good fidelity in fluctuating wind conditions. Vane angle is sensed by a precision potentiometer housed in a sealed chamber. With a known excitation voltage applied to the potentiometer, the output voltage is directly proportional to vane angle. A mounting orientation ring assures correct realignment of the wind direction reference when the instrument is removed for maintenance.

The instrument is made of UV stabilized plastic with stainless steel and anodized aluminum fittings. Precision grade, stainless steel ball bearings are used. Transient protection and cable terminations are in a convenient junction box. The instrument mounts on standard 1 inch pipe.

For offshore and marine use, the **Model 05106, Wind Monitor-MA** features special waterproof bearing lubricant and a sealed, heavy-duty cable pigtail in place of the standard junction box. Separate signal conditioning for voltage or current outputs is available.

The Wind Monitor is available with two additional output signal options. **Model 05103V** offers calibrated 0-1 VDC outputs (0-5 VDC optional), convenient for use with many dataloggers. **Model 05103L** provides a calibrated 4-20 mA current signal for each channel, useful in high noise areas or for long cables (up to several kilometers). Signal conditioning electronics are integrated into the sensor junction box.

Ordering Information

	MODEL
WIND MONITOR	**05103**
WIND MONITOR 0-1 VDC OUTPUTS	**05103V***
WIND MONITOR 4-20 mA OUTPUTS	**05103L***
WIND MONITOR-MA (MARINE MODEL)	**05106**
WIND SENSOR INTERFACE (FOR USE WITH 05106) 0-1 VDC	**05603B***
WIND LINE DRIVER (FOR USE WITH 05106) 4-20 mA	**05631B***

** SPECIFY SUFFIX FOR DESIRED WIND SPEED SCALE:*

0-50 M/S	*ADD SUFFIX "M"*
0-100 MPH	*ADD SUFFIX "P"*
0-100 KNOTS	*ADD SUFFIX "N"*
0-200 KM/HR	*ADD SUFFIX "K"*

Specifications

Range:
Wind speed: 0-60 m/s (134 mph)
Gust survival: 100 m/s (220 mph)
Azimuth: 360° mechanical, 355° electrical (5° open)

Accuracy:
Wind speed: ±0.3 m/s (0.6 mph)
Wind direction: ±3 degrees

Threshold:*
Propeller: 1.0 m/s (2.2 mph)
1.1 m/s (2.4 mph) 05106
Vane: 1.1 m/s (2.4 mph) 05103

Dynamic Response:*
Propeller distance constant (63% recovery) 2.7 m (8.9 ft) Vane delay distance (50% recovery) 1.3 m (4.3 ft)
Damping ratio: 0.3
Damped natural wavelength: 7.4 m (24.3 ft)
Undamped natural wavelength: 7.2 m (23.6 ft)

Signal Output:
Wind speed: magnetically induced AC voltage, 3 pulses per revolution. 1800 rpm (90 Hz) = 8.8 m/s (19.7 mph)
Azimuth: analog DC voltage from conductive plastic potentiometer- resistance 10K Ω, linearity 0.25%, life expectancy- 50 million revolutions

Power Requirement:
Potentiometer excitation: 15 VDC maximum

Dimensions:
Overall height: 37 cm (14.6 in)
Overall length: 55 cm (21.7 in)
Propeller: 18 cm (7 in) diameter
Mounting: 34 mm (1.34 in) diameter (std. 1 inch pipe)

Weight:
Sensor weight: 1.0 kg (2.2 lbs)
Shipping weight: 2.3 kg (5 lbs)

*Nominal values, determined in accordance with ASTM standard procedures.

MODEL 05103V 0-1 VDC outputs

Power Requirement:
8-24 VDC (5 mA @ 12 VDC)

Operating Temperature:
-50 to 50° C

Output Signals:
0-1.00 VDC full scale
0-5.00 VDC optional

MODEL 05103L 4-20 mA outputs

Power Requirement:
8-30 VDC (40 mA max.)

Operating Temperature:
-50 to 50° C

Output Signals:
4-20 mA full scale

YOUNG
R.M. YOUNG COMPANY
2801 Aero Park Drive
Traverse City, Michigan 49686 U.S.A.
TEL: (231) 946-3980 FAX: (231) 946-4772
E-mail: met.sales@youngusa.com
Web Site: www.youngusa.com

SSI Adolf Theis Hygro-Thermo Transmitter

Surface Systems, Inc.

Thies Relative Humidity/Air Temperature Sensor

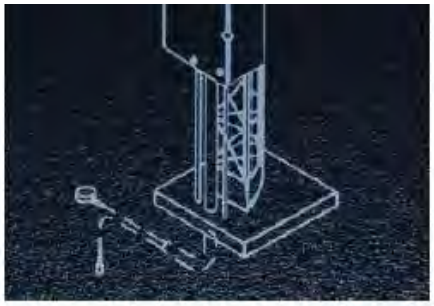
SSI P/N 72657501

Thies Relative Humidity Sensor	
Measuring Range	10 to 100% relative humidity
Accuracy at 70°F	+/- 5% relative humidity
Measurement method	Human hair
Ambient Temperature	-31 to 158°F (-35°C to 70°C)
Output	10K Ohm precision potentiometer
Air Temperature Sensor	
Temperature range*	-60 to +176°F (-51°C to 80°C)
Sensor element accuracy*	±0.5°F (±0.28°C) from -22 to +176°F (-30°C to 80°C) ±0.9°F (±0.5°C) from –40 to –22°F (-40°C to –30°C) ±1.8°F (±1°C) from –60 to –40°F (-51°C to –40°C)
Weather and Thermal Radiation Shield	
Material	Anodized aluminum
Cover treatment	Clear varnish
Dimensions	Height: 19 ½ inches (49.53cm) Diameter: 6 ¼ inches (15.86cm)
Weight, shield & both sensors	6.5 lbs (2.9kg)
General	
Maximum cable length	150 feet (45.72 meters)

* Requires the proper revision of SSI ESS-NTCIP RPU. Otherwise, the temperature range is less.

Surface Systems, Inc. 11612 Lilburn Park Road St. Louis, MO 63146
A Quixote Company Phone: (314) 569-1002 Fax(314) 569-3567

Quixote FP 2000 Pavement Temp Sensor



FP 2000®

Pavement Sensor

SSI's durable FP 2000 pavement sensor sets the standard for excellence, reliability, and long-lasting performance for in-pavement sensors. The sensor uses four-point conductivity to passively measure chemical concentrations of the water/ice/de-icer solution on the sensor surface. The unique indented well in the FP 2000 offers enhanced performance to collect sufficient moisture and provides an accurate analysis of the surface solution.

Pins on top of the sensor, along with another set of pins in the indented well, provide a system to check and balance the measurement of chemical concentration. When there is slush or residual moisture of 2ml or more in the well, the sensor provides accurate freeze point temperatures. When the moisture in the well diminishes, the remote processing unit relies upon the top set of pins to measure thin film situations.

Since the FP 2000 is the only sensor with two sets of pins, it is the only sensor that can accurately measure liquid depth. Its durability and reliability make it the cost-effective choice in passive sensors.

Benefits

Passive sensor with no maintenance requirements

Uses 2 sets of four-point sensing nodes

Durable electrodes withstand tire compression, chains and temperature fluctuations

Flush mounting unaffected by traffic and snowplows

Operates at cable lengths up to 2500 feet (763 meters)

Lifetime warranty

Specifications

Range	
Surface Temperature	-60°F to 176°F (-52°C to 80°C)
Depth of Solution	0.01" to 0.50" (0.03 to 1.27 cm)
Solution Freeze Point	-40°F to 32°F (-40°C to 0°C)
Percent of Ice	0 to 100%
Operating Temperature	-40°F to 176°F (-40°C to 80°C)
Physical	
Diameter	5.25" (13.34 cm)
Height	1.75" (4.5 cm)
Weight (without cable)	2.75 lbs (1.25 kg)
Cable Length	150 ft (45.7m) standard
Mean Time Between Failures	40,000 hours

SSI Thermoscan 1000 Pavement Temp Sensor

Surface Systems, Inc.

Thermo Scan1000

SSI Part Number #7281XXXX*

Specifications

Manufacturer	Surface Systems, Inc.
Operating temperature range	-60° F to 176° F (-51° C to 80° C)
Temperature sensing element accuracy	±0.36° F (±.20° C) over the range of -40° F to 176° F (-40° C to 80° C) ±0.72° F (±.40° C) over the range of -60° F to -40° F (-51° C to -40° C)
Physical Size	1 inch (2.54cm) Wide Top, 1 1/4 inch (3.17 cm) Wide Base by 3 7/8 inch (9.8 cm) Long Top, 4 inch (10.16cm) Long Base X Height 1 3/16"(3.02cm)
Cable	Special SSI Type IIA attached and molded into sensor with non-removable water proof cable entrance
Cable Length	150 feet (45.72 meters) standard, attached to sensor 300 feet (91.44 meters) optional, attached to sensor 500 feet (152.40 meters) optional, attached to sensor
Maximum Cable Length from RPU	5000 feet (1524 meters)
Reliability	MTBF of 87,600 hours
Maintenance	Sealed unit, none required

* SSI Part Numbers

72810150	150ft grey
72810300	300ft grey
72810500	500ft grey
72811150	150ft black
72811399	300ft black
72811500	500ft black

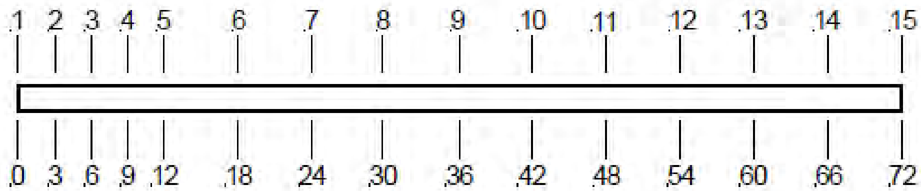
ThermoScan 1000
092005

Surface Systems, Inc. 11612 Lilburn Park Road St. Louis, MO 63146
A Quixote Company Phone: (314) 569-1002 Fax(314) 569-3567

MRC Temperature Data Probe TP101

"TDP"
6 Foot Thermistor Probe
Model TP101 "SHRP"

SENSOR CHANNEL NUMBERS



TEMPERATURE SENSOR LAYOUT IN INCHES

SPECIFICATIONS:

Manufacturer:	Measurement Research Corporation
Total Thermistors:	15, plus one fixed reference resistor (equal to 35.1°F)
Accuracy:	± 0.18° F @ -4° F to +167° F, as delivered Range expanded in SSI ESS-RPU software to: ±0.36° F @ –40° F to –4° F ±1.8° F @ –60° F to –40°F [Note 1]
Operating Temperature	-40° F to +167° F [Note 1]
Operating Humidity:	0 to 100%
Spacing:	3" spacing first 12", 6" spacing from 12" to 72"
Dimensions:	72" x 1" dia.
Cable:	Side mounted, 100' underwater cable/connector, 1.25" dia.

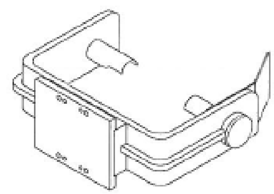
Note 1: The electronic switches necessary for probe operation are guaranteed to operate from –40°F to +167°F but frequently function at lower temperatures. The SSI ESS software accepts and reports temperatures down to –60°F. Temperatures outside the range of –60 to +167°F are not allowed and cause blank display values.

Surface Systems, Inc. 11612 Lilburn Park Road St. Louis, MO 63146
A Quixote Company Phone: (314) 569-1002 Fax(314) 569-3567

SSI Hawk Eye Optical Infrared Y/N Precipitation Sensor

Surface Systems, Inc.

SSI Hawk Eye Optical Infrared Y/N Precipitation Sensor
SSI P/N 72657103



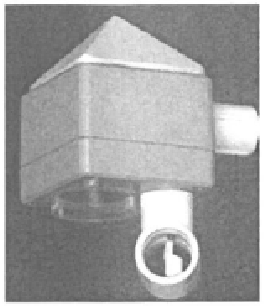
SPECIFICATIONS:

Precipitation State Detected	Yes/No (Over specified operating temperature range)
Sensing Type	Dual beam infrared
Sensing Area	22 x 150 mm
Detectable particle size	0.010" (0.10mm) to large hail stones
Precipitation Onset	Programmable pulses per minute
Sampling Time Frame	Sliding one minute window
Output	Precipitation state Yes/No: Analog 2.2 VDC Sensor state: Operable -Non Precip <>.2 VDC Inoperable - Blocked <> 4.2 VDC
Operating Temperature	-20 to +60°C
Enclosure	Anodized aluminum
Size	15 ½ x 12 ½ x 6 inches (39.37 x 31.75 x 15.24 cm)
Input Voltage	+12 to 15 VDC
Amperage	65 ma
Maximum cable length	150 feet (45.72 meters)

Surface Systems, Inc. 11612 Lilburn Park Road St. Louis, MO 63146
A Quixote Company Phone: (314) 569-1002 Fax(314) 569-3567

Judd Ultrasonic Snow Depth Sensor

Ultrasonic Depth Sensor



View ANALOG Output manual as PDF file
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View DIGITAL Output manual as PDF file
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Transducer Replacement Instructions

The Judd Communications ultrasonic depth sensor is an inexpensive solution for remotely measuring snow depth or water levels. The sensor works by measuring the time required for an ultrasonic pulse to travel to and from a target surface. An integrated temperature probe with solar radiation shield, provides an air temperature measurement for properly compensating the distance measured. An embedded microcontroller calculates a temperature compensated distance and performs an error checking routine.

Both distance and air temperature are output as an analog signal between 0 to 2.5 Volts or 0 to 5 Volts. Measurements can also be output digitally as serial ASCII. Specify Analog or Digital output at time order.

Due to the simplified interface, the depth sensor can interface with any datalogger or control system that can delay at least 3 seconds after powering up before measuring the output.

Specifications

Power: +12 to 24 VDC, 50 mA (maximum sample time 2.6 seconds)

Analog Output: 0 to 2.5 or 0 to 5 VDC

Digital Output: 1200 baud serial ASCII

Range: .5 to 10 meters (1.6 to 32.8 feet)

Beamwidth: 22 degrees

Accuracy: 1 cm or .4 % distance to target

Resolution: 3 mm (.12 inches)

Temp. range: -40 to + 70C (-40 to 158F)

Size: 8 x 8 x 13 cm (3 x 3 x 5 inches)

Weight: .6 kg (1.3 lbs.)

Mounting: 1/2 inch galvanized threaded pipe

Cable length: 7.6 meters (25 feet)

Nova Lynx 260-2501 Rain Gauge

260-2501 Rain Gauge

The **Model 260-2501 Tipping Bucket Rain Gauge** was designed for the National Weather Service to provide a reliable, low-cost tipping bucket rain sensor. Its simplicity of design assures trouble-free operation, yet provides accurate rainfall measurements. The tipping bucket mechanism activates a sealed reed switch that produces a contact closure for each 0.01", 0.25 mm, or 1 mm of rainfall. The gauge has an 8" orifice and is manufactured of powder coated and anodized aluminum. The funnel screen prevents debris from entering the gauge. Shipped complete with mounting brackets and 25' of signal cable.

Specifications

Sensor type: Tipping bucket
Output: 0.1 second switch closure
Switch: Sealed reed switch
Sensitivity: 1 tip per 0.01", 1 tip per 1 mm, or 1 tip per 0.25 mm
Accuracy: ±2% up to 2"/hr
Contact rating: 3 watts, 0.25 amps, 24 Vdc
Size: 8" dia x 13.75" high
Mounting: 3 legs, ¼" diameter bolt holes on 9½" diameter bolt circle
Weight/shipping: 3.5 lbs/5 lbs

Ordering Information

260-2501	8" Tipping Bucket Rain Gauge, 0.01"/tip, incl 25' cable
260-2501M	8" Tipping Bucket Rain Gauge, 1 mm/tip, incl 25' cable
260-2501M.25	8" Tipping Bucket Rain Gauge, 0.25 mm/tip, incl 25' cable
330-0220	Additional Signal Cable, per foot
260-2595	Rain Gauge Calibrator
260-2596	Digital Event Counter
260-950	Rain Gauge Mounting Plate
260-952	Rain Gauge Wind Screen, 24" legs
260-953	Rain Gauge Wind Screen, 36" legs
260-954	Leg Extender Kit, converts 260-952 to 260-953
260-955	Wind Screen Mounting Kit, flange adapters and #12 x 1-1/4" wood screws

260-2501 Rain Gauge with 260-950 Mounting Plate

Rain Gauge Accessories

The **Model 260-952 Rain Gauge Wind Screen** minimizes the formation of strong updrafts that can distort the trajectories of precipitation particles falling toward a gauge. The screen also generates turbulent air motions over the gauge orifice to break up streamlines and thus improve the catch. Use of a wind screen is recommended with all precipitation gauges located in windy areas. The screen consists of 32 free-swinging galvanized metal leaves, evenly spaced around a 48" diameter. Each leaf is fabricated from 22-gauge sheet metal, 16" long, 3" wide at the top and 2" wide at the bottom. One of the quadrants swings out to permit easy access to the gauge. Two lengths of legs (2' and 3') are available due to variations in gauge height. A mounting kit is available for mounting to a wooden platform.

The **Model 260-950 Rain Gauge Mounting Plate** is an easy and convenient way to mount your rain gauge. The mounting plate is sized to fit the 260-2500 and 260-2501 rain gauges. Welded to the bottom of the plate is a hub that will accept a standard 1" (1.34" o.d.). pipe. Hardware is supplied for mounting the rain gauge to the plate. The plate should be leveled prior to installing the gauge.

Specifications

260-952
Material: 22-gauge sheet metal, galvanized
Size: 48" Dia x 24" H (1219 x 610 mm)
Weight/shipping: 45 lbs/48 lbs

260-950
Material: Aluminum
Size: 10.75" Dia
Weight/shipping: 2 lbs/3 lbs

260-952 Precipitation Gauge Wind Screen

Vaisala PWD12

VAISALA www.vaisala.com

PWD10, PWD12, PWD20 and PWD22 Present Weather and Visibility Sensors

Vaisala PWD-series of present weather detectors and visibility sensors provide you off-the-shelf accuracy and realiability. They are a sensor family that grows with your needs.

Features and Benefits

All models:

- Accurate measurement of prevailing visibility
- Compact and light-weight
- Easy to install

Additionally PWD12 and PWD22 models:

- Indicate the cause of prevailed visibility
- Detect precipitation type
- Measure the intensity and accumulation of precipitation
- Estimate snow accumulation

Thousands of Vaisala present weather and visibility sensors are installed around the world, working reliably and accurately in diverse applications and climates. In the Vaisala PWD-series of present weather detectors and visibility sensors, you will find the mix you require of visibility measurement range (MOR), characterization of reduced visibility, precipitation type identification, precipitation accumulation/intensity measurement, and report formats (WMO, NWS code tables).

Proven Measurement Principles for Present Weather

The Vaisala Present Weather Detectors PWD12 and PWD22 identify precipitation type by accurately estimating the water content of precipitation with a capacitive device (Vaisala RAINCAP® sensor element) and combining this information with optical forward scatter and temperature measurements. These three independent measurements are processed through sophisticated algorithms in order to produce an accurate evaluation of the weather type according to the WMO and NWS code tables.

Accurate Visibility Measurement

Calibrated with reference to a highly accurate transmissometer, Vaisala PWD-series sensors use the proven forward-scatter measurement principle to measure Meteorological Optical Range (MOR). The visibility sensor is well-protected against contamination: the optical components point downwards and hoods protect the lenses against precipitation, spray and dust. This weather-proof design of the PWD sensors provides accurate measurement results and reduces the need for maintenance. The optional hood heaters are recommended for wintry conditions to prevent ice and snow accumulation.

Economical Visibility Measurement for Road Weather Applications

With a measurement range of 10...2,000 meters, the Vaisala Visibility Sensor PWD10 offers economical and reliable visibility measurement for road weather applications. The PWD10 is recommended for road weather systems which alert drivers to e.g. reduced visibility.

For Sophisticated Road Weather Applications

The Vaisala Present Weather Detector PWD12 provides accurate visibility and present weather measurement in the road environment, where low visibility is a serious safety hazard and significantly reduces traffic flow rates. With a visibility measurement range of 10...2,000 meters, the Vaisala Present Weather Detector PWD12 is ideal for road weather applications. The PWD12 also indicates the cause of reduced visibility to give you a full picture of weather conditions. Its ability to detect precipitation and identify precipitation type gives the road authority valuable information for the short-range planning of road maintenance operations.

The PWD22 is recommended for Automatic Weather Observation Systems (AWOS).

PWD12 is ideal for road weather applications.

For Meteorological and Aviation Applications

With a visibility measurement range of 10...20,000 meters, the Vaisala Present Weather Detector PWD22 is a two-in-one forward scatter visibility and present weather sensor. The PWD22 is recommended for automatic weather stations (especially low-power AWSs) that are used for general meteorological and aviation applications.

The Vaisala Present Weather Detector PWD22.

The PWD22's ability to detect freezing precipitation makes it possible to issue warnings when the weather presents safety hazards for road and air traffic.

The PWD22 is equipped with two Vaisala RAINCAP® sensor elements to improve detection sensitivity during light precipitation events – even light drizzle is detected. The PWD22 also reports present weather in WMO METAR code format so it is easily integrated with AWOS systems.

PWD-series sensors can be used in planning the road maintenance.

Wherever Visibility Measurement is Needed

With a measurement range of 10...20,000 meters, the Vaisala Visibility Sensor PWD20 offers long-range visibility measurement for diverse applications covering harbors, coastal areas, heliports, windmill parks – indeed, any locations or areas where visibility measurement is necessary.

Easy Installation

PWD sensors are less than one meter long. All are compact, light-weight, come with a cable and connector for easy installation, and can be mounted in many ways on any existing mast.

Expandable Measurement Capabilities

The measurement capabilities of the Vaisala PWD-series sensors can be extended when your measurement needs grow. All PWD-series sensors can be economically upgraded to ensure that your PWD sensor gives full value for many years to come.

On a day like this, the Vaisala Present Weather Detector PWD22 can only report clear present weather and visibility to 20 km.

The PWD22 is a two-in-one forward scatter visibility and present weather sensor. It is ideal for automatic weather stations used for general meteorological and aviation applications.

In the Vaisala PWD-series of present weather and visibility sensors, you will find the mix you need of:

- Visibility measurement range (MOR)
- Characterization of reduced visibility
- Precipitation type identification
- Precipitation accumulation / intensity measurement
- Report formats WMO 4680 (SYNOP) and 4678 (METAR)

The Vaisala Present Weather Detector PWD10 is recommended for road weather systems, which alert drivers to e.g. reduced visibility, the PWD12 for sophisticated road weather applications that involve activities such as road maintenance planning.

The Vaisala Present Weather Detector PWD20 is recommended for measuring Visibility in other places such as harbors, coastal areas, heliports and windmill parks.

The measurement capabilities of the Vaisala PWD-series sensors can be extended when your measurement needs grows.

All PWD-series can be economically upgraded to ensure that your PWD sensor gives full value for many years to come.

Technical Data

Present Weather

PWD12	
Identifies	4 different types of precipitation (rain, drizzle, mixed rain/snow, snow) fog, mist, haze (smoke, sand) or clear
Reports	WMO 4680 (SYNOP) and NWS code tables 39 different codes supported from WMO 4680 code table
PWD22	
Identifies	7 different types of precipitation (rain, freezing rain, drizzle, freezing drizzle, mixed rain/snow, snow, ice pellets) Fog, mist, haze (smoke, sand) or clear
Reports	WMO 4680 (SYNOP), 4678 (METAR) and NWS code tables 49 different codes supported from WMO 4680 code table

Precipitation Measurement

Measures	precipitation intensity, accumulation and amount of new snow
Precipitation detection sensitivity	0.05 mm/h or less, within 10 minutes

Visibility Measurement

Operating principle	forward scatter measurement
PWD10 and PWD12	
Measurement range (MOR)	10...2000 m (32...6500 ft)
PWD20 and PWD22	
Measurement range (MOR)	10...20 000 m (32...65 600 ft)
Accuracy	±10%, range 10...10 000 m±15%, range 10...20 km

Electrical

Power supply	12 V DC...50 V DC (electronics) 24 V AC or 24 V DC for heater option
Power consumption	
PWD10 and PWD20	3 W (electronics with dew heater @12VDC)
PWD12 and PWD22	6 W
Options	2 W (luminance sensor with dew heater) 65 W (heater option)
Outputs	RS-232, RS-485 Three programmable relay controls, visibility alarm threshold and delays configurable, fault alarm relay 0 ... 1mA, 4 ... 20 mA analog current

Mechanical

Dimensions	40.4 (w) x 69.5 (l) x 19.9 (h) cm(15.91" (w) x 27.36" (l) x 7.83" (h))
Weight	3 kg (6.61 lb)

Environmental

Operating temperature	-40 ... +60 °C
Operating humidity	0 ... 100 %RH
Protection class	IP66

Electromagnetic Compatibility

CE-compliant

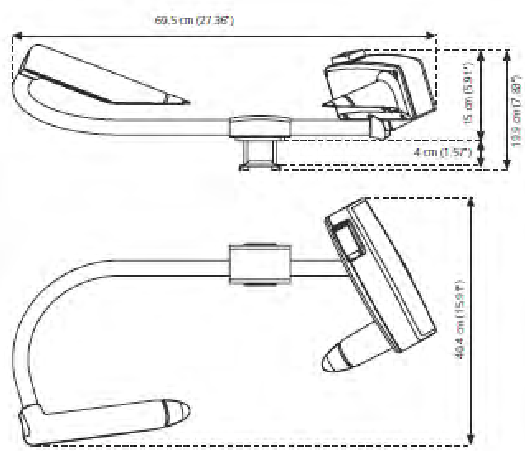
Compliance has been verified according to the following EMC directives

Verification subject	standard
Radiated emissions	CISPR 16-1,16-2
Radiated susceptibility	IEC 61000-4-3,10 V/m
Conducted emissions	CISPR 16-1,16-2
Conducted susceptibility	IEC 61000-4-6
EFT immunity	IEC 61000-4-4
ESD immunity	IEC 61000-4-2
Surge	IEC 61000-4-5

Accessories/Options

Luminance sensor PWL111 for AWOS applications
Hood heaters for winter conditions
Support arm for mast installations
Pole clamp kit for mast top installations
Calibration set PWA12
Maintenance cable 16385ZZ

Dimensions



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Decibel Products DB498 Directional Antenna

DECIBEL PRODUCTS

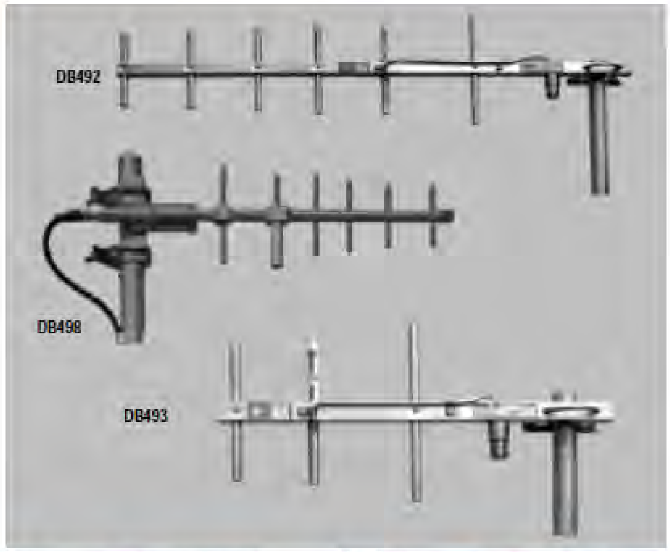
806 - 960 MHz

Yagi Antenna

DB492, DB493, DB498, 6-15 dBd gain

- **Light Duty** – DB492 and DB493 are excellent for control or point-to-point communications, well suited for temporary or portable use.
- **Heavy Duty** – DB498, for permanent installation, is gold anodized and has a radome cover for the radiator to prevent corrosion and ice build-up. It resists winds to 150 mph (241 km/hr).
- **Stacked Array** – Two DB498 antennas increase gain to 12 dBd.
- **All Metal** – Components in the support boom and elements are made of high strength aluminum alloys; brackets and hardware of galvanized or stainless steel.
- **Easy Mount** – A unique mounting arrangement facilitates rapid azimuth orientation.
- **No Field Tuning** – Antennas are assembled and tested for minimum VSWR at the factory; pruning or adjusting is unneeded.
- **Lightning Resistant** – Protection provided by direct ground.

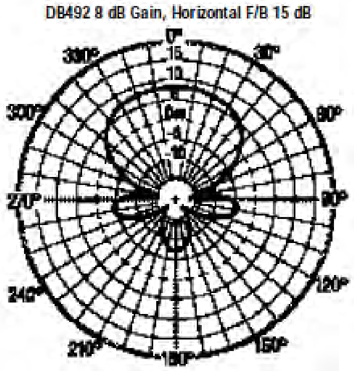
Ordering Information – Use model number for correct frequency. Mounting clamps are included. **Example:** DB492-A for 806-866 MHz.



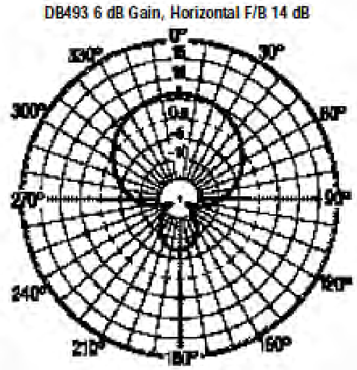
Gain	Order – Light Duty
8 dB	1 ea. DB492 Antenna
6 dBd	1 ea. DB493 Antenna

Gain	Order – Heavy Duty
9 dB	1 ea. DB498 Antenna
12 dBd	2 ea. DB498 Antenna 1 ea. 14498/9-2 Dual Phasing Harness
15 dBd	4 ea. DB498 Antenna 1 ea. 15499-4 Quad Phasing Harness

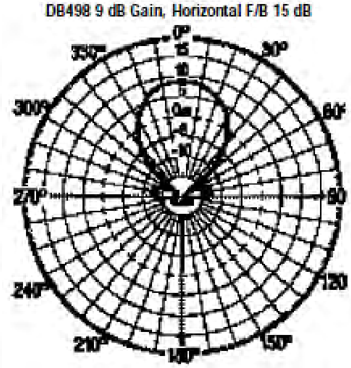
DB492 8 dB Gain, Horizontal F/B 15 dB



DB493 6 dB Gain, Horizontal F/B 14 dB



DB498 9 dB Gain, Horizontal F/B 15 dB



Electrical Data	
Frequency Ranges – MHz	
DB492, DB493	A = 806-866, K = 920-960
DB498	A = 806-866, C = 824-896, K = 896-960
Bandwidth – MHz	Same as above
VSWR	1.5 to 1 or less
Nominal impedance – ohms	50
Forward gain (over half-wave dipole) – dBd	
DB492	8
DB493	6
DB498	9
Polarization	Vertical
Maximum power input – watts	100
Lightning protection	Direct ground
Standard Termination	Captive Type N-Female

Mechanical Data		
Support boom		Aluminum
Elements		Aluminum
Dimensions (HxL) – in. (mm)		
DB492		7.5 (190.5)x25.5 (647.7)
DB493		7.5 (190.5)x13 (330.2)
DB498		7.5 (190.5)x25.5 (647.7)
Shipping weight – lbs. (kg)		Net weight – lbs. (kg)
DB492	6 (2.72)	3.5 (1.59)
DB493	3 (1.36)	.7 (.32)
DB498	8 (3.63)	5 (2.27)
Mounting brackets		Galvanized steel

APPENDIX C: Demand Analysis Results for RWIS Sites

Table XX: Demand Analysis for Continuous Operation of Little Coal Creek RWIS Site (Solar PV + Fuels Cells or TEG)

Demand Analysis (Continuous Operation): Parks Highway @ Little Coal Creek MP 163.2						
Month	Current Energy Demand (kWh)	Energy Demand After Replacing Cameras and Communications Equipment (kWh)	Energy Demand After Incorporating Solar (kWh)	Energy Demand: Solar & Acumentrics Fuel Cell (kWh)	Energy Demand: Solar & Efoy Fuel Cell (kWh)	Energy Demand: Solar & Thermoelectric Generator (kWh)
January	37.1	25.9	19.4	-352.6	-14.1	-20.8
February	33.5	23.4	3.0	-333.0	-27.2	-33.2
March	37.1	25.9	-27.2	-399.2	-60.6	-67.3
April	30.5	22.8	-67.3	-427.3	-99.7	-106.2
May	26.6	21.4	-100.0	-472.0	-133.4	-140.1
June	25.8	20.7	-110.8	-470.8	-143.2	-149.7
July	26.6	21.4	-94.6	-466.6	-128.1	-134.8
August	26.6	21.4	-69.7	-441.7	-103.1	-109.8
September	25.8	20.7	-37.9	-397.9	-70.3	-76.8
October	31.4	23.5	-8.0	-380.0	-41.5	-48.2
November	35.9	25.1	15.0	-345.0	-17.4	-23.9
December	37.1	25.9	23.2	-348.8	-10.2	-16.9

Table XXI: Demand Analysis for Continuous Operation of Little Coal Creek RWIS Site (Solar PV + Wind + Fuel Cells or TEG)

Demand Analysis (Continuous Operation): Parks Highway @ Little Coal Creek MP 163.2							
Month	Current Energy Demand (kWh)	Energy Demand After Replacing Cameras and Communications Equipment (kWh)	Energy Demand After Incorporating Solar & Wind (kWh)	Energy Demand: Solar,Wind & Acumentrics Fuel Cell (kWh)	Energy Demand: Solar, Wind & Efoy Fuel Cell (kWh)	Energy Demand: Solar, Wind & Thermoelectric Generator (kWh)
January	37.1	25.9	19.3	-352.6	-14.1	-20.8
February	33.5	23.4	3.0	-333.0	-27.2	-33.2
March	37.1	25.9	-27.2	-399.2	-60.6	-67.3
April	30.5	22.8	-67.3	-427.3	-99.7	-106.2
May	26.6	21.4	-100.0	-472.0	-133.4	-140.1
June	25.8	20.7	-110.8	-470.8	-143.2	-149.7
July	26.6	21.4	-94.7	-466.6	-128.1	-134.8
August	26.6	21.4	-69.7	-441.7	-103.1	-109.8
September	25.8	20.7	-37.9	-397.9	-70.3	-76.8
October	31.4	23.5	-8.1	-380.0	-41.5	-48.2
November	35.9	25.1	14.9	-345.0	-17.4	-23.9
December	37.1	25.9	23.2	-348.8	-10.2	-16.9

Table XXII: Demand Analysis for Daylight Operation of Little Coal Creek RWIS Site (Solar PV + Fuels Cells or TEG)

Demand Analysis (Daylight Operation): Parks Highway @ Little Coal Creek MP 163.2						
Month	Current Energy Demand (kWh)	Energy Demand After Replacing Cameras and Communications Equipment (kWh)	Energy Demand After Incorporating Solar (kWh)	Energy Demand: Solar & Acumentrics Fuel Cell (kWh)	Energy Demand: Solar & Efoy Fuel Cell (kWh)	Energy Demand: Solar & Thermoelectric Generator (kWh)
January	12.4	8.6	2.1	-369.9	-31.4	-38.1
February	16.1	11.2	-9.1	-345.1	-39.4	-45.4
March	21.6	15.1	-38.0	-410.0	-71.4	-78.1
April	23.1	17.2	-72.8	-432.8	-105.2	-111.7
May	22.0	17.7	-103.7	-475.7	-137.2	-143.9
June	23.2	18.6	-112.9	-472.9	-145.3	-151.8
July	22.1	17.8	-98.3	-470.3	-131.8	-138.5
August	19.5	15.7	-75.4	-447.4	-108.9	-115.6
September	16.9	13.6	-45.0	-405.0	-77.4	-83.9
October	15.2	11.3	-20.2	-392.2	-53.6	-60.3
November	12.4	8.6	-1.4	-361.4	-33.8	-40.3
December	10.5	7.3	4.7	-367.3	-28.8	-35.5

Table XXIII: Demand Analysis for Daylight Operation of Little Coal Creek RWIS Site (Solar PV + Wind + Fuel Cells or TEG)

Demand Analysis (Daylight Operation): Parks Highway @ Little Coal Creek MP 163.2						
Month	Current Energy Demand (kWh)	Energy Demand After Replacing Cameras and Communications Equipment (kWh)	Energy Demand After Incorporating Solar & Wind (kWh)	Energy Demand: Solar,Wind & Acumentrics Fuel Cell (kWh)	Energy Demand: Solar, Wind & Efoy Fuel Cell (kWh)	Energy Demand: Solar, Wind & Thermoelectric Generator (kWh)
January	12.4	8.6	2.0	-369.9	-31.4	-38.1
February	16.1	11.2	-9.2	-345.1	-39.4	-45.4
March	21.6	15.1	-38.0	-410.0	-71.4	-78.1
April	23.1	17.2	-72.8	-432.8	-105.2	-111.7
May	22.0	17.7	-103.8	-475.7	-137.2	-143.9
June	23.2	18.6	-112.9	-472.9	-145.3	-151.8
July	22.1	17.8	-98.3	-470.3	-131.8	-138.5
August	19.5	15.7	-75.4	-447.4	-108.9	-115.6
September	16.9	13.6	-45.1	-405.0	-77.4	-83.9
October	15.2	11.3	-20.2	-392.2	-53.6	-60.3
November	12.4	8.6	-1.5	-361.4	-33.8	-40.3
December	10.5	7.3	4.6	-367.3	-28.8	-35.5

Table XXIV: Demand Analysis for Continuous Operation of Klondike RWIS Site (Solar PV + Fuels Cells or TEG)

Demand Analysis (Continuous Operation): Klondike Highway @ US/Canada Border MP 14.9						
Month	Current Energy Demand (kWh)	Energy Demand After Replacing Cameras and Communications Equipment (kWh)	Energy Demand After Incorporating Solar (kWh)	Energy Demand: Solar & Acumentrics Fuel Cell (kWh)	Energy Demand: Solar & Efoy Fuel Cell (kWh)	Energy Demand: Solar & Thermoelectric Generator (kWh)
January	26.0	25.4	15.9	-356.1	-17.6	-24.3
February	23.4	22.9	0.1	-335.9	-30.1	-36.1
March	26.0	25.4	-26.5	-398.5	-60.0	-66.7
April	23.4	23.0	-63.1	-423.1	-95.5	-102.0
May	21.2	20.9	-97.1	-469.1	-130.6	-137.3
June	20.5	20.2	-100.1	-460.1	-132.5	-139.0
July	23.2	22.8	-92.6	-464.6	-126.0	-132.7
August	21.2	20.9	-71.9	-443.9	-105.4	-112.1
September	21.0	20.7	-36.1	-396.1	-68.5	-75.0
October	26.0	25.4	-7.8	-379.8	-41.3	-48.0
November	25.1	24.5	11.4	-348.6	-21.0	-27.5
December	26.0	25.4	19.8	-352.2	-13.7	-20.4

Table XXV: Demand Analysis for Continuous Operation of Klondike RWIS Site (Solar PV + Wind + Fuel Cells or TEG)

Demand Analysis (Continuous Operation): Klondike Highway @ US/Canada Border MP 14.9						
Month	Current Energy Demand (kWh)	Energy Demand After Replacing Cameras and Communications Equipment (kWh)	Energy Demand After Incorporating Solar &Wind (kWh)	Energy Demand: Solar, Wind & Acumentrics Fuel Cell (kWh)	Energy Demand: Solar, Wind & Efoy Fuel Cell (kWh)	Energy Demand: Solar, Wind & Thermoelectric Generator (kWh)
January	26.0	25.4	15.2	-356.1	-17.6	-24.3
February	23.4	22.9	-1.1	-335.9	-30.1	-36.1
March	26.0	25.4	-27.3	-398.5	-60.0	-66.7
April	23.4	23.0	-63.6	-423.1	-95.5	-102.0
May	21.2	20.9	-97.5	-469.1	-130.6	-137.3
June	20.5	20.2	-100.5	-460.1	-132.5	-139.0
July	23.2	22.8	-93.0	-464.6	-126.0	-132.7
August	21.2	20.9	-72.6	-443.9	-105.4	-112.1
September	21.0	20.7	-36.6	-396.1	-68.5	-75.0
October	26.0	25.4	-8.3	-379.8	-41.3	-48.0
November	25.1	24.5	10.7	-348.6	-21.0	-27.5
December	26.0	25.4	19.8	-352.2	-13.7	-20.4

Table XXVI: Demand Analysis for Daylight Operation of Klondike RWIS Site (Solar PV + Fuels Cells or TEG)

Demand Analysis (Daylight Operation): Klondike Highway @ US/Canada Border MP 14.9						
Month	Current Energy Demand (kWh)	Energy Demand After Replacing Cameras and Communications Equipment (kWh)	Energy Demand After Incorporating Solar (kWh)	Energy Demand: Solar & Acumentrics Fuel Cell (kWh)	Energy Demand: Solar & Efoy Fuel Cell (kWh)	Energy Demand: Solar & Thermoelectric Generator (kWh)
January	9.9	9.7	0.3	-371.7	-33.2	-39.9
February	11.2	11.0	-11.8	-347.8	-42.0	-48.1
March	15.1	14.8	-37.1	-409.1	-70.5	-77.2
April	17.8	17.4	-68.7	-428.7	-101.1	-107.5
May	16.6	16.4	-101.6	-473.6	-135.1	-141.8
June	17.7	17.4	-102.9	-462.9	-135.3	-141.8
July	19.3	19.0	-96.4	-468.4	-129.8	-136.5
August	15.5	15.3	-77.5	-449.5	-111.0	-117.7
September	13.7	13.5	-43.2	-403.2	-75.6	-82.1
October	13.8	13.5	-19.7	-391.7	-53.2	-59.8
November	11.2	11.0	-2.1	-362.1	-34.5	-41.0
December	9.9	9.7	4.1	-367.9	-29.3	-36.0

Table XXVII: Demand Analysis for Daylight Operation of Klondike RWIS Site (Solar PV + Wind + Fuel Cells or TEG)

Demand Analysis (Daylight Operation): Klondike Highway @ US/Canada Border MP 14.9						
Month	Current Energy Demand (kWh)	Energy Demand After Replacing Cameras and Communications Equipment (kWh)	Energy Demand After Incorporating Solar &Wind (kWh)	Energy Demand: Solar, Wind & Acumentrics Fuel Cell (kWh)	Energy Demand: Solar, Wind & Efoy Fuel Cell (kWh)	Energy Demand: Solar, Wind & Thermoelectric Generator (kWh)
January	9.9	9.7	-0.5	-371.7	-33.2	-39.9
February	11.2	11.0	-13.0	-347.8	-42.0	-48.1
March	15.1	14.8	-37.9	-409.1	-70.5	-77.2
April	17.8	17.4	-69.2	-428.7	-101.1	-107.5
May	16.6	16.4	-102.1	-473.6	-135.1	-141.8
June	17.7	17.4	-103.3	-462.9	-135.3	-141.8
July	19.3	19.0	-96.8	-468.4	-129.8	-136.5
August	15.5	15.3	-78.2	-449.5	-111.0	-117.7
September	13.7	13.5	-43.7	-403.2	-75.6	-82.1
October	13.8	13.5	-20.1	-391.7	-53.2	-59.8
November	11.2	11.0	-2.9	-362.1	-34.5	-41.0
December	9.9	9.7	3.6	-367.9	-29.3	-36.0

Table XXVIII: Demand Analysis for Continuous Operation of Jean Lake RWIS Site (Solar PV + Fuels Cells or TEG)

Demand Analysis (Continuous Operation): Sterling Highway @ Jean Lake Hill MP 61.8						
Month	Current Energy Demand (kWh)	Energy Demand After Replacing Cameras and Communications Equipment (kWh)	Energy Demand After Incorporating Solar (kWh)	Energy Demand: Solar & Acumentrics Fuel Cell (kWh)	Energy Demand: Solar & Efoy Fuel Cell (kWh)	Energy Demand: Solar & Thermoelectric Generator (kWh)
January	51.9	24.8	16.6	-355.4	-16.9	-23.6
February	46.9	22.4	-0.3	-336.3	-30.6	-36.6
March	49.9	24.0	-35.4	-407.4	-68.9	-75.6
April	43.5	21.2	-73.8	-433.8	-106.2	-112.7
May	41.5	20.4	-106.1	-478.1	-139.6	-146.3
June	40.2	19.7	-112.8	-472.8	-145.2	-151.6
July	41.5	20.4	-100.8	-472.8	-134.3	-140.9
August	41.5	20.4	-75.8	-447.8	-109.3	-116.0
September	40.2	19.7	-42.9	-402.9	-75.3	-81.8
October	44.9	21.8	-11.9	-383.9	-45.3	-52.0
November	50.2	24.0	12.3	-347.7	-20.1	-26.6
December	51.9	24.8	20.2	-351.8	-13.2	-19.9

Table XXIX: Demand Analysis for Continuous Operation of Jean Lake RWIS Site (Solar PV + Wind + Fuel Cells or TEG)

Demand Analysis (Continuous Operation): Sterling Highway @ Jean Lake Hill MP 61.8						
Month	Current Energy Demand (kWh)	Energy Demand After Replacing Cameras and Communications Equipment (kWh)	Energy Demand After Incorporating Solar & Wind (kWh)	Energy Demand: Solar, Wind & Acumentrics Fuel Cell (kWh)	Energy Demand: Solar, Wind & Efoy Fuel Cell (kWh)	Energy Demand: Solar, Wind & Thermoelectric Generator (kWh)
January	51.9	24.8	16.4	-355.4	-16.9	-23.6
February	46.9	22.4	-0.5	-336.3	-30.6	-36.6
March	49.9	24.0	-35.5	-407.4	-68.9	-75.6
April	43.5	21.2	-73.9	-433.8	-106.2	-112.7
May	41.5	20.4	-106.2	-478.1	-139.6	-146.3
June	40.2	19.7	-112.9	-472.8	-145.2	-151.6
July	41.5	20.4	-100.8	-472.8	-134.3	-140.9
August	41.5	20.4	-75.9	-447.8	-109.3	-116.0
September	40.2	19.7	-43.0	-402.9	-75.3	-81.8
October	44.9	21.8	-12.0	-383.9	-45.3	-52.0
November	50.2	24.0	12.2	-347.7	-20.1	-26.6
December	51.9	24.8	20.1	-351.8	-13.2	-19.9

Table XXX: Demand Analysis for Daylight Operation of Jean Lake RWIS Site (Solar PV + Fuels Cells or TEG)

Demand Analysis (Daylight Operation): Sterling Highway @ Jean Lake Hill MP 61.8						
Month	Current Energy Demand (kWh)	Energy Demand After Replacing Cameras and Communications Equipment (kWh)	Energy Demand After Incorporating Solar (kWh)	Energy Demand: Solar & Acumentrics Fuel Cell (kWh)	Energy Demand: Solar & Efoy Fuel Cell (kWh)	Energy Demand: Solar & Thermoelectric Generator (kWh)
January	17.3	8.3	0.0	-372.0	-33.4	-40.1
February	22.5	10.8	-12.0	-348.0	-42.2	-48.3
March	29.1	14.0	-45.4	-417.4	-78.9	-85.6
April	33.0	16.0	-78.9	-438.9	-111.3	-117.8
May	33.8	16.6	-109.9	-481.9	-143.4	-150.1
June	35.1	17.3	-115.2	-475.2	-147.6	-154.1
July	23.5	11.5	-109.6	-481.6	-143.1	-149.8
August	20.1	9.8	-86.3	-458.3	-119.8	-126.5
September	26.3	12.9	-49.7	-409.7	-82.1	-88.6
October	23.9	11.6	-22.0	-394.0	-55.5	-62.2
November	22.5	10.8	-1.0	-361.0	-33.4	-39.8
December	17.3	8.3	3.7	-368.3	-29.8	-36.5

Table XXXI: Demand Analysis for Daylight Operation of Jean Lake RWIS Site (Solar PV + Wind + Fuel Cells or TEG)

Demand Analysis (Daylight Operation): Sterling Highway @ Jean Lake Hill MP 61.8						
Month	Current Energy Demand (kWh)	Energy Demand After Replacing Cameras and Communications Equipment (kWh)	Energy Demand After Incorporating Solar &Wind (kWh)	Energy Demand: Solar, Wind & Acumentrics Fuel Cell (kWh)	Energy Demand: Solar, Wind & Efoy Fuel Cell (kWh)	Energy Demand: Solar, Wind & Thermoelectric Generator (kWh)
January	17.3	8.3	-0.2	-372.0	-33.4	-40.1
February	22.5	10.8	-12.1	-348.0	-42.2	-48.3
March	29.1	14.0	-45.5	-417.4	-78.9	-85.6
April	33.0	16.0	-79.0	-438.9	-111.3	-117.8
May	33.8	16.6	-110.0	-481.9	-143.4	-150.1
June	35.1	17.3	-115.3	-475.2	-147.6	-154.1
July	23.5	11.5	-109.7	-481.6	-143.1	-149.8
August	20.1	9.8	-86.4	-458.3	-119.8	-126.5
September	26.3	12.9	-49.8	-409.7	-82.1	-88.6
October	23.9	11.6	-22.2	-394.0	-55.5	-62.2
November	22.5	10.8	-1.1	-361.0	-33.4	-39.8
December	17.3	8.3	3.6	-368.3	-29.8	-36.5

Table XXXII: Demand Analysis for Continuous Operation of Divide RWIS Site (Solar PV + Fuels Cells or TEG)

Demand Analysis (Continuous Operation): Seward Highway @ Divide MP 11.7						
Month	Current Energy Demand (kWh)	Energy Demand After Replacing Cameras and Communications Equipment (kWh)	Energy Demand After Incorporating Solar (kWh)	Energy Demand: Solar & Acumentrics Fuel Cell (kWh)	Energy Demand: Solar & Efoy Fuel Cell (kWh)	Energy Demand: Solar & Thermoelectric Generator (kWh)
January	109.7	22.6	12.7	-359.3	-20.8	-27.5
February	91.7	19.8	-2.3	-338.3	-32.5	-38.5
March	107.8	22.5	-31.8	-403.8	-65.3	-72.0
April	67.3	18.9	-68.6	-428.6	-101.0	-107.5
May	52.4	18.1	-100.1	-472.1	-133.6	-140.3
June	50.7	17.6	-109.8	-469.8	-142.2	-148.6
July	52.4	18.1	-98.2	-470.2	-131.6	-138.3
August	52.4	18.1	-75.4	-447.4	-108.9	-115.6
September	50.7	17.6	-42.0	-402.0	-74.4	-80.9
October	59.8	18.7	-14.5	-386.5	-48.0	-54.6
November	98.7	21.3	7.5	-352.5	-24.9	-31.4
December	109.7	22.6	17.0	-355.0	-16.4	-23.1

Table XXXIII: Demand Analysis for Continuous Operation of Divide RWIS Site (Solar PV + Wind + Fuel Cells or TEG)

Demand Analysis (Continuous Operation): Seward Highway @ Divide MP 11.7						
Month	Current Energy Demand (kWh)	Energy Demand After Replacing Cameras and Communications Equipment (kWh)	Energy Demand After Incorporating Solar & Wind (kWh)	Energy Demand: Solar, Wind & Acumentrics Fuel Cell (kWh)	Energy Demand: Solar, Wind & Efoy Fuel Cell (kWh)	Energy Demand: Solar, Wind & Thermoelectric Generator (kWh)
January	109.7	22.6	12.6	-359.3	-20.8	-27.5
February	91.7	19.8	-2.3	-338.3	-32.5	-38.5
March	107.8	22.5	-31.8	-403.8	-65.3	-72.0
April	67.3	18.9	-68.6	-428.6	-101.0	-107.5
May	52.4	18.1	-100.1	-472.1	-133.6	-140.3
June	50.7	17.6	-109.8	-469.8	-142.2	-148.6
July	52.4	18.1	-98.2	-470.2	-131.6	-138.3
August	52.4	18.1	-75.4	-447.4	-108.9	-115.6
September	50.7	17.6	-42.0	-402.0	-74.4	-80.9
October	59.8	18.7	-14.5	-386.5	-48.0	-54.6
November	98.7	21.3	7.4	-352.5	-24.9	-31.4
December	109.7	22.6	17.0	-355.0	-16.4	-23.1

Table XXXIV: Demand Analysis for Daylight Operation of Divide RWIS Site (Solar PV + Fuels Cells or TEG)

Demand Analysis (Daylight Operation): Seward Highway @ Divide MP 11.7						
Month	Current Energy Demand (kWh)	Energy Demand After Replacing Cameras and Communications Equipment (kWh)	Energy Demand After Incorporating Solar (kWh)	Energy Demand: Solar & Acumentrics Fuel Cell (kWh)	Energy Demand: Solar & Efoy Fuel Cell (kWh)	Energy Demand: Solar & Thermoelectric Generator (kWh)
January	42.0	8.7	-1.3	-373.3	-34.7	-41.4
February	44.0	9.5	-12.6	-348.6	-42.8	-48.9
March	62.9	13.1	-41.2	-413.2	-74.7	-81.3
April	51.0	14.3	-73.2	-433.2	-105.6	-112.1
May	42.6	14.8	-103.5	-475.5	-137.0	-143.7
June	44.3	15.3	-112.0	-472.0	-144.4	-150.9
July	42.7	14.8	-101.5	-473.5	-135.0	-141.7
August	38.4	13.3	-80.2	-452.2	-113.7	-120.4
September	33.2	11.5	-48.1	-408.1	-80.5	-86.9
October	31.9	10.0	-23.2	-395.2	-56.7	-63.4
November	44.2	9.5	-4.3	-364.3	-36.7	-43.2
December	42.0	8.7	3.1	-368.9	-30.4	-37.1

Table XXXV: Demand Analysis for Daylight Operation of Divide RWIS Site (Solar PV + Wind + Fuel Cells or TEG)

Demand Analysis (Daylight Operation): Seward Highway @ Divide MP 11.7							
Month	Current Energy Demand (kWh)	Energy Demand After Replacing Cameras and Communications Equipment (kWh)	Energy Demand After Incorporating Solar & Wind (kWh)	Energy Demand: Solar, Wind & Acumentrics Fuel Cell (kWh)	Energy Demand: Solar, Wind & Efoy Fuel Cell (kWh)	Energy Demand: Solar, Wind & Thermoelectric Generator (kWh)
January	42.0	8.7	-1.3	-373.3	-34.7	-41.4
February	44.0	9.5	-12.6	-348.6	-42.8	-48.9
March	62.9	13.1	-41.2	-413.2	-74.7	-81.3
April	51.0	14.3	-73.2	-433.2	-105.6	-112.1
May	42.6	14.8	-103.5	-475.5	-137.0	-143.7
June	44.3	15.3	-112.0	-472.0	-144.4	-150.9
July	42.7	14.8	-101.5	-473.5	-135.0	-141.7
August	38.4	13.3	-80.2	-452.2	-113.7	-120.4
September	33.2	11.5	-48.1	-408.1	-80.5	-86.9
October	31.9	10.0	-23.2	-395.2	-56.7	-63.4
November	44.2	9.5	-4.4	-364.3	-36.7	-43.2
December	42.0	8.7	3.0	-368.9	-30.4	-37.1

Table XXXVI: Demand Analysis for Continuous Operation of Stuart Creek RWIS Site (Solar PV + Fuels Cells or TEG)

Demand Analysis (Continuous Operation): Richardson Highway @ Stuart Creek MP 45.7						
Month	Current Energy Demand (kWh)	Energy Demand After Replacing Cameras and Communications Equipment (kWh)	Energy Demand After Incorporating Solar (kWh)	Energy Demand: Solar & Acumentrics Fuel Cell (kWh)	Energy Demand: Solar & Efoy Fuel Cell (kWh)	Energy Demand: Solar & Thermoelectric Generator (kWh)
January	350.0	73.2	64.5	-307.5	31.0	24.3
February	316.1	66.1	44.9	-291.1	14.6	8.6
March	340.1	71.6	19.0	-353.0	-14.5	-21.2
April	101.9	31.7	-58.6	-418.6	-91.0	-97.5
May	44.2	22.6	-103.9	-475.9	-137.4	-144.0
June	42.8	21.9	-112.9	-472.9	-145.3	-151.8
July	44.2	22.6	-107.0	-479.0	-140.5	-147.2
August	44.2	22.6	-79.2	-451.2	-112.6	-119.3
September	42.8	21.9	-40.7	-400.7	-73.1	-79.6
October	162.6	42.2	9.0	-363.0	-24.5	-31.2
November	338.7	70.8	58.4	-301.6	26.0	19.5
December	350.0	73.2	68.6	-303.4	35.1	28.4

Table XXXVII: Demand Analysis for Continuous Operation of Stuart Creek RWIS Site (Solar PV + Wind + Fuel Cells or TEG)

Demand Analysis (Continuous Operation): Richardson Highway @ Stuart Creek MP 45.7						
Month	Current Energy Demand (kWh)	Energy Demand After Replacing Cameras and Communications Equipment (kWh)	Energy Demand After Incorporating Solar & Wind (kWh)	Energy Demand: Solar,Wind & Acumentrics Fuel Cell (kWh)	Energy Demand: Solar, Wind & Efoy Fuel Cell (kWh)	Energy Demand: Solar, Wind & Thermoelectric Generator (kWh)
January	350.0	73.2	64.4	-307.5	31.0	24.3
February	316.1	66.1	44.9	-291.1	14.6	8.6
March	340.1	71.6	19.0	-353.0	-14.5	-21.2
April	101.9	31.7	-58.6	-418.6	-91.0	-97.5
May	44.2	22.6	-103.9	-475.9	-137.4	-144.0
June	42.8	21.9	-113.0	-472.9	-145.3	-151.8
July	44.2	22.6	-107.1	-479.0	-140.5	-147.2
August	44.2	22.6	-79.2	-451.2	-112.6	-119.3
September	42.8	21.9	-40.7	-400.7	-73.1	-79.6
October	162.6	42.2	9.0	-363.0	-24.5	-31.2
November	338.7	70.8	58.4	-301.6	26.0	19.5
December	350.0	73.2	68.5	-303.4	35.1	28.4

Table XXXVIII: Demand Analysis for Daylight Operation of Stuart Creek RWIS Site (Solar PV + Fuels Cells or TEG)

Demand Analysis (Daylight Operation): Richardson Highway @ Stuart Creek MP 45.7						
Month	Current Energy Demand (kWh)	Energy Demand After Replacing Cameras and Communications Equipment (kWh)	Energy Demand After Incorporating Solar (kWh)	Energy Demand: Solar & Acumentrics Fuel Cell (kWh)	Energy Demand: Solar & Efoy Fuel Cell (kWh)	Energy Demand: Solar & Thermoelectric Generator (kWh)
January	116.7	24.4	15.7	-356.3	-17.8	-24.5
February	151.7	31.7	10.5	-325.5	-19.7	-25.8
March	198.4	41.7	-10.8	-382.8	-44.3	-51.0
April	72.0	22.4	-67.9	-427.9	-100.3	-106.8
May	34.1	17.4	-109.0	-481.0	-142.5	-149.2
June	38.1	19.5	-115.3	-475.3	-147.7	-154.2
July	36.4	18.6	-111.0	-483.0	-144.5	-151.2
August	32.4	16.6	-85.2	-457.2	-118.7	-125.4
September	28.0	14.3	-48.3	-408.3	-80.7	-87.2
October	86.7	22.5	-10.7	-382.7	-44.2	-50.9
November	151.7	31.7	19.3	-340.7	-13.1	-19.6
December	116.7	24.4	19.8	-352.2	-13.7	-20.4

Table XXXIX: Demand Analysis for Daylight Operation of Stuart Creek RWIS Site (Solar PV + Wind + Fuel Cells or TEG)

Demand Analysis (Daylight Operation): Richardson Highway @ Stuart Creek MP 45.7						
Month	Current Energy Demand (kWh)	Energy Demand After Replacing Cameras and Communications Equipment (kWh)	Energy Demand After Incorporating Solar & Wind (kWh)	Energy Demand: Solar,Wind & Acumentrics Fuel Cell (kWh)	Energy Demand: Solar, Wind & Efoy Fuel Cell (kWh)	Energy Demand: Solar, Wind & Thermoelectric Generator (kWh)
January	116.7	24.4	15.6	-356.3	-17.8	-24.5
February	151.7	31.7	10.5	-325.5	-19.7	-25.8
March	198.4	41.7	-10.9	-382.8	-44.3	-51.0
April	72.0	22.4	-68.0	-427.9	-100.3	-106.8
May	34.1	17.4	-109.1	-481.0	-142.5	-149.2
June	38.1	19.5	-115.4	-475.3	-147.7	-154.2
July	36.4	18.6	-111.1	-483.0	-144.5	-151.2
August	32.4	16.6	-85.2	-457.2	-118.7	-125.4
September	28.0	14.3	-48.3	-408.3	-80.7	-87.2
October	86.7	22.5	-10.7	-382.7	-44.2	-50.9
November	151.7	31.7	19.3	-340.7	-13.1	-19.6
December	116.7	24.4	19.7	-352.2	-13.7	-20.4