Colegio Nacional Galápagos

Puerto Ayora, Santa Cruz Island, Galápagos, Ecuador.

Photovoltaic System

In the context of the specific Work Agreement that will soon be established among Colegio Nacional Galápagos (CNG), SolarQuest® and the Dirección Provincial de Educación de Galápagos (DPEG), based on the already signed Work Agreement between the DPEG and SolarQuest®, SolarQuest® is proposing a project to repair and improve the extant Photovoltaic System installed at CNG.
The equipment to be installed as well as the technical support will be provided by SolarQuest®. This document describes the current system and the proposed modifications.
SolarQuest® is requesting Colegio Nacional Galápagos to coordinate the following activities for this initial phase of the project:

1. Make this document of public knowledge for all teachers working at CNG.
2. The Program of Activities for this reparation and improvement project is under development. The preliminary starting date is June 21st, 2004. The Program of Activities will be forwarded to CNG for review and comment as soon as it is ready.
3. The Program of Activities includes an **informative workshop** about the existing System and the planned improvements, and a **practical workshop** aimed to promote a permanent maintenance and troubleshooting team. The informative workshop is open to all CNG community interested in learning the basics of the Photovoltaic System installed at CNG and the proposed modifications. The estimated duration of this workshop is 4 to 6 hours in two sessions.
   The practical workshop is more specific and it is aimed to the persons that will eventually hold the responsibility to maintain and troubleshoot the improved Photovoltaic System. This workshop will explore relatively advanced topics on photovoltaic systems. The attendees will also be directly involved in the reparations work under the guidance of SolarQuest®'s technician. The estimated duration of this workshop is 60 hours.
4. This initial phase requires a remote coordinating mechanism between CNG personnel and SolarQuest® technical support in the US. We urge to every person interested in attending in any of the previously mentioned workshops to obtain an e-mail account and to learn the "Virtual Schoolhouse" program available at: **http://galapagos.solarquest.com/escuelas/**
5. All persons interested in participate in any of the workshops please communicate with SolarQuest SolarQuest®'s authorized technician responsible for this project, Alfonso Tovar Fonseca, as soon as possible: **alfonso@solarquest.com**.

REPORT

1: Existing Photovoltaic System

Installed during 1998 in accordance with the "*Convenio para Implementar Sistemas Fotovoltaicos en los Colegios Alejandro Humboldt y Nacional Galapagos*" (agreement to implement photovoltaic systems in the Alejandro Humbolt and Nacional Galapagos schools) signed by the Ecuatorian Ministry of Education, the Instituto Ecuatoriano de Electrificación (INECEL) and the representative of UNESCO in Ecuador.
The project was financed by the British government through UNESCO, the Global Environment Facility (GEF) and United Nations Development Program (UNDP)*
The systems began operating in October 1998.

* I was provided with a copy of the original agreement signed in Quito in April 1998

System Description

a. Photovoltaic Panels:

Brand: BP Solar
Model: BP585
Power: 85 W max (18 Vp – 4.72 A) 22.03 V open circuit
Number of panels: 40 Note: The frame has space for 42 panels.
Connection: 13 sets connected in parallel. Each set has 3 panels connected in series. There is one panel not in use.

b. Batteries:

Brand: BP Solar.
Model: Powerblocs
Voltage: 2 V
Capacity: 900 AH/100
Number of Batteries: 24

c. Charge Controller:

Brand: Trama Tecno Ambiental, Barcelona, España.
Model: TApS C-8648 (Centralita)
Current: 48 V system – 70 A

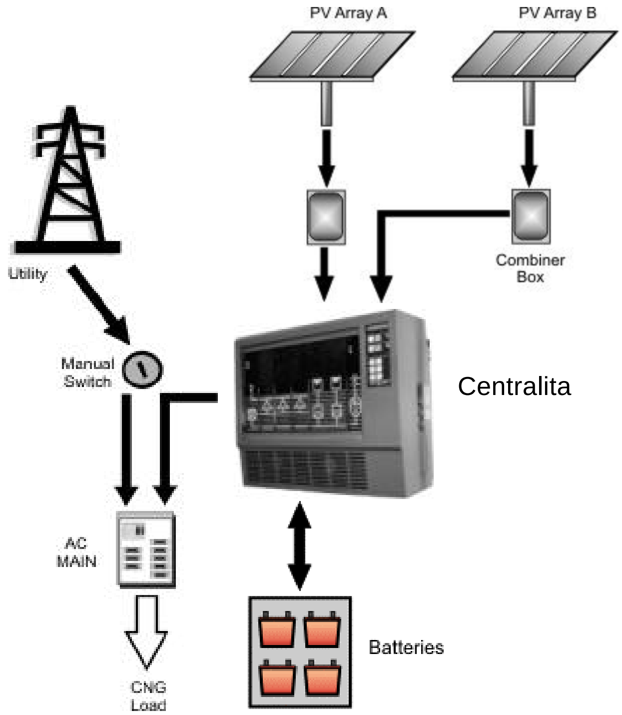
d. Inverter:

Brand: Trama Tecno Ambiental, Barcelona, España.
Model: TApS C-8648 (Centralita)
Power: 3 modules, 1.1 KW each.

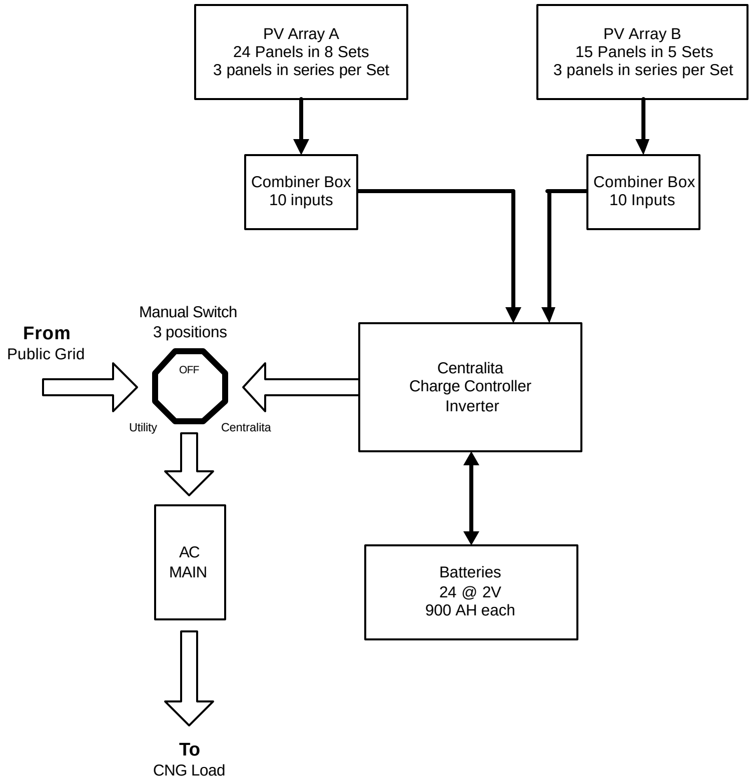
e. Battery Charger:

Brand: Trama Tecno Ambiental, Barcelona, España.
Model: Unknown
Power: Unknown

f. System Diagram:



Schematic of Existing Photvoltaic System installed at CNG



Block Diagram of Existing Photvoltaic System installed at CNG

2: Recommended Improvements to the Existing System

a. Photovoltaic Panels:

- Re-wire the system for 48 Volts. Create sets of 4 panels connected in series. Each group of 4 panels connected in series is a Set. Total power per Set: 4@85 W = 340W **:** 72V-4.7A

- Create two arrays of 5 Sets connected in parallel (20 panels per each array). Total power per array: 5@340 = 1700 W **:** 72V-23.6A

- Check all interconnections between panels. Make a careful evaluation of the connectors in the connector box at the back of the PV panels. Verify conductivity and state of the part. Replace with new connectors as needed. Check state of the insulator in the cables. Replace as needed. Use cable **12** or **10 AWG** for outdoors (the cables are not exposed to direct solar radiation though). Cable gauge **12 AWG** is adequate enough to interconnect the PV panels in series – parallel, carrying 5 Amps in lengths of about 5 meters, with a 3% voltage drop maximum at 48 Vdc or more.

- Replace the two combiner boxes. Use one box per each array. Use NEMA-4 enclosures for outdoors.

b. Batteries:

- Perform various tests to verify state of the batteries.
- Clean terminals with sodium bicarbonate. Check connector cables and tighten if needed.

c. Charge Controllers:

- Install two charge controllers Outback MX60 in parallel.
  http://www.outbackpower.com/MX60_temp.htm

d. Inverter and Battery Charger:

- Replace both pieces of equipment.

The alternative we have considered is to use 2 inverter/chargers **Outback FX2548** (sealed, 2.5 KW) connected in parallel or in series:

http://www.outbackpower.com/FX/fx_page.htm

The OutBack is a sealed FX sine wave inverter/charger. Each inverter/charger is a complete power conversion system: DC to AC inverter, battery charger and automatic AC transfer switch. The FX inverter/charger is designed for stand-alone or back-up power applications with battery energy storage. Additional units can be connected at any time in either parallel (120 VAC), series (120/240 VAC), or three-phase (120Y208 VAC) configurations. This allows a system to be tailored to meet the specific power conversion requirements of the application, both at the time of the installation and in the future. The sealed FX series are designed to survive harsh environments around the world. The sealed die-cast aluminum chassis protects and keeps the power conversion components cool in very hot environments even when operated at high power for extended periods. The FX2548 can be used in high ambient applications up to 60 °C (with reduced output ratings).

SPECIFICATIONS	SEALED VERSIONS			VENTED VERSIONS		
	FX 2012T	FX 2024	FX 2548	VFX 2812	VFX 3524	VFX 3648
Continuous Power Rating at 25 degrees C	2000 VA (std TURBO)	2000 VA	2500 VA	2800 VA	3500 VA	3600 VA
Nominal DC Input Voltage	12 VDC	24 VDC	48 VDC	12 VDC	24 VDC	48 VDC
Nominal AC Input Voltage / Frequency	120V 60 Hz	120V 60 Hz	120V 60 Hz	120V 60 Hz	120V 60 Hz	120V 60 Hz
Continuous AC RMS Output current at 25 C	17amps	17amps	21amps	23.3 amps	29.2 amps	30 amps
Idle Power (typical at no AC load) (sleep – 3 watts)	18-20 Watts	18-20 Watts	21-23 Watts	19-21 Watts	18-20 Watts	21-23 Watts
Efficiency (typical at 25 degree C and 75% resistive load)	90%	92%	93%	>90%	>90%	>90%
Total Harmonic distortion voltage (typical / max)	2% / 5%	2% / 5%	2% / 5%	2% / 5%	2% / 5%	2% / 5%
Output Voltage Regulation	+/- 2% typ.	+/- 2% typ.	+/- 2% typ.	+/- 2% typ.	+/- 2% typ.	+/- 2% typ.
Surge Power Capability Peak (1mSec)	56 amps AC	70 amps AC	70 amps AC	56 amps AC	70 amps AC	70 amps AC
Surge Power Capability RMS (100mSec)	40 amps AC	50 amps AC	50 amps AC	40 amps AC	50 amps AC	50 amps AC
Overload Capability (from 25 C start) 5 second	4000 VA	4800 VA	4800 VA	4000 VA	5000 VA	5000 VA
Overload Capability (from 25 C start) 30 minutes	2500 VA	3200 VA	3200 VA	3200 VA	4000 VA	4000 VA
Automatic AC transfer Relay (at nominal AC)	60 amps AC	60 amps AC	60 amps AC	60 amps AC	60 amps AC	60 amps AC
AC Input Current (adjustable limits)	60 amps AC	60 amps AC	60 amps AC	60 amps AC	60 amps AC	60 amps AC
AC Input Voltage Range (adjustable limits)	90-140VAC	90-140VAC	90-140VAC	90-140VAC	90-140VAC	90-140VAC
Frequency Range – AC Input	54-67.4 Hz	54-67.4 Hz	54-67.4 Hz	54-67.4 Hz	54-67.4 Hz	54-67.4 Hz
DC Input Range (adjustable low battery cut-out)	10-16.5 VDC	20-33 VDC	40-66 VDC	10-16 VDC	20-33 VDC	40-66 VDC
Recommended DC Breaker	OBDC-250	OBDC-175	OBDC-100	OBDC-250	OBDC-250	OBDC-175
Continuous Battery Charger Output amps DC	80 amps DC	55 amps DC	35 amps DC	125 amps DC	85 amps DC	45 amps DC
Shipping Weight	65 lbs	60 Lbs	60 Lbs	62 Lbs	62 Lbs	62 Lbs

e. Wiring:

- Re-wire and replace cables as need as indicated in section a).

- Currently a pair of double-conductor 6 AWG cables, 18 mts. each, are being used to transmit the power generated by the PV panels to the Control Room. Check the state of the insulator. Consider the implementation of a structure for the power cables to travel from the roof where the PV panels are, to the nearby control room. The entrance of the cables to the control room would be through the wall. Modifying the actual path of the cables would be beneficial if it shortens the distance from the PV panels to the control room without representing a high cost or technical challenge. I would propose an aerial path from the roof where the PV panels are, to the control room.

- The existing two power lines to transmit the energy to the charge controllers may be reused. The gauge of the power cables is 2×6 AWG. Evaluate the state of the insulator. Cable gauge **6 AWG** is adequate for currents of 25 Amps in lengths of up to 25 meters, with a 3% voltage drop maximum, at 48 Vdc or more.

- The existing AC cable is about 34 m long, 3×6 AWG at 600 V type and it runs from the Control Room to the Computer Lab building. The cable is adequate to transmit the AC power generated by the PV system to the computer laboratory. The end of the existing cable is connected to a breaker in the building. This breaker is part of the local electrical installation which shows serious impediments to distribute the energy with control and organization. To avoid interfering with the local electrical installation but, furthermore, to preserve a solid control and monitoring of the PV system and the load it serves, I suggest to isolate the AC grid in the computer laboratory from any source of power. The new grid will only be powered by the PV system (which has a public grid backup in addition to the battery bank).

- Once isolated from any other source of power, the computer laboratory will represent a load for the PV system of approximately 1.5 KW.

f. DC/AC Power Switches and Breakers:

- Install a central panel for DC power. It will add safety and proper administration to the system to install dc switches/breakers to isolate the PV panels from the rest of the system when needed. Install a switch/breaker for the batteries.

- Install an AC panel switch to control the AC provided by the public grid to the system, and to control the AC power generated by the PV system and delivered to the load.

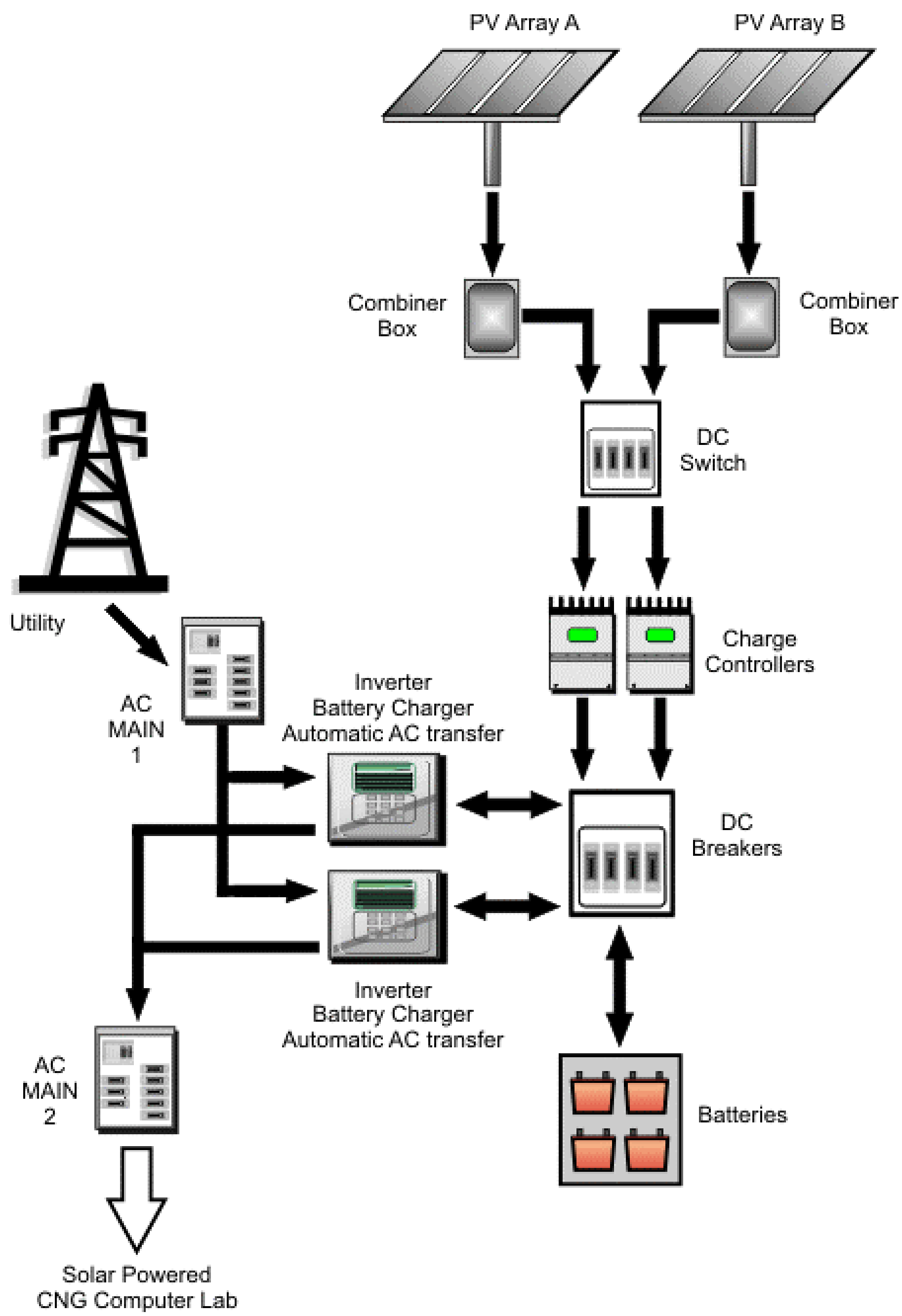
g. Human Capacity Building for Technology Appropriation:

- It is necessary to create a local team that fully understands the PV system. Only if a core group of persons get involved and committed to the PV system, will it be possible to guarantee a sustainable operation and efficient use/administration of the resource. Financial constraints for maintenance will remain though.

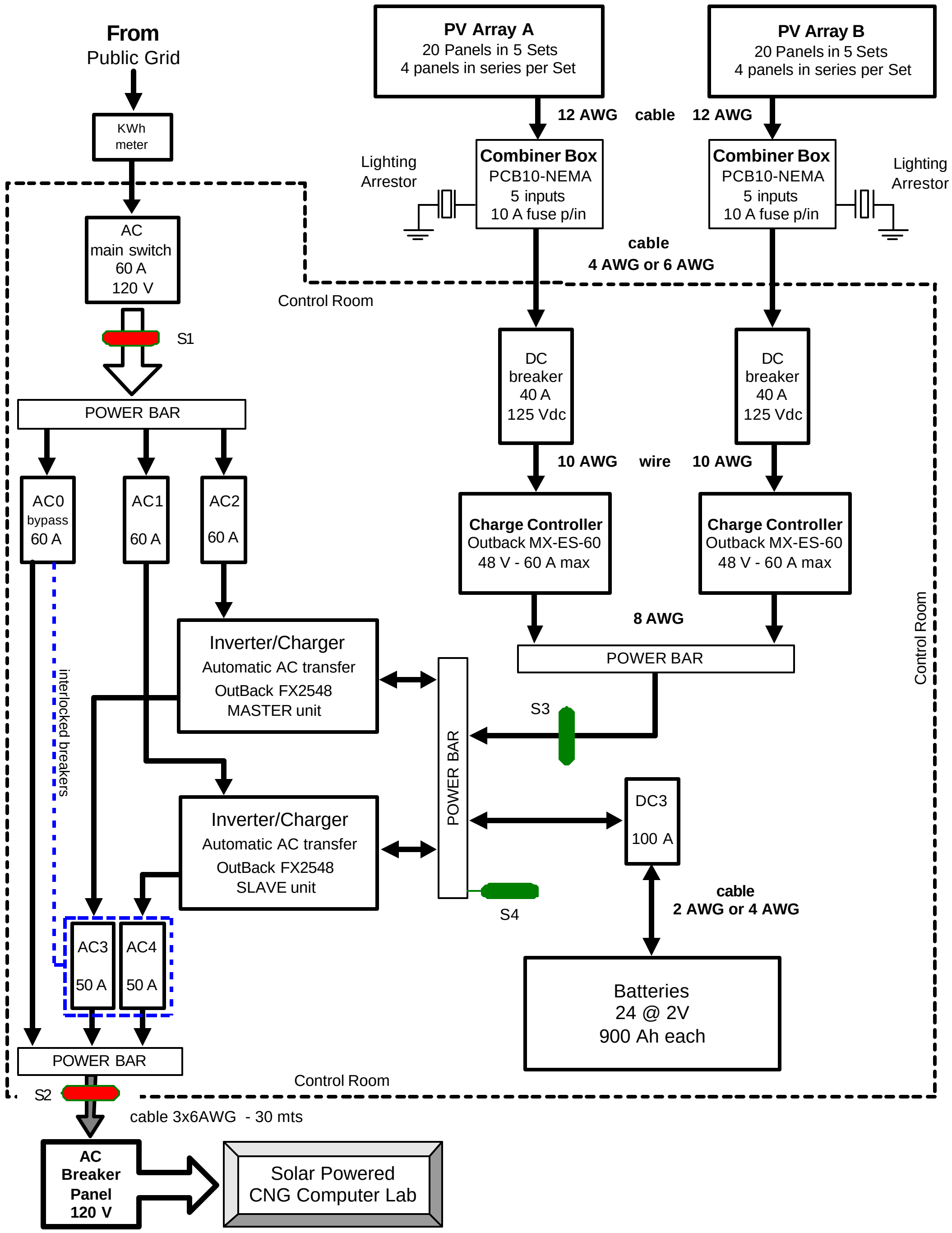
- My observations indicate that the school teachers involved with the system lacked some vital information about the operation of the system. The responsibility to provide maintenance and supervision of the system was also concentrated to one teacher and not to an extended group. I gathered the sense that the PV system hasn't been completely assimilated as part of the school infrastructure.

- SolarQuest® will work to identify and motivate the interest of various teachers to promote the creation of a core group responsible for the PV system. SolarQuest® will provide an intensive training course to teach the fundamentals of the system and the equipment. One of the advantages of PV systems is their straightforward maintenance so there are good chances that no specialized technical support will be needed often. Remote support can be established. Remote monitoring will be implemented.

h. System Diagram:



Schematic of the modifications to the Photovoltaic System at Colegio Nacional Galapagos.



Block Diagram for the PV system improvements at CNG

PV array A

Number of panels: **20** (power of Array A: 20 @ 85 W = 1,700 W)
Configuration:

- Sets of 4 panels connected in series
- Number of sets connected in parallel: **5**
- Power per set: 4 panels @ 85 W each = **340 W** (72 Vp – 4.72 A)
- Array power: 5 sets @ 340 W each = **1,700 W** (72 Vp – 23.6 A)

PV array B

Idem

3: Parts List

Component	Qty	Model
Inverter/Battery Charger/Automatic AC transfer relay Features: 48 Vdc input (40-66 Vdc range) 60 A rms max AC input for battery charging plus AC load supply. 2.5 KVA output (75% resistive load) 21 A rms Continuous output current at 120 Vac -25 ^{o}C 15 A rms continuous for battery charger	**2**	Outback FX 2548T SEALED Turbo model: (external-fan cooled)
Charge Controller Features: Spanish language menu Maximum Power Point Tracking (MPPT) Battery System Voltage: 12, 24, 36, 48 or 60 Vdc (adjustable) PV open circuit voltage: 120 Vdc (max) Temperature compensation	**2**	Outback MX-ES-60
Control Devices for the OutBack System MATE System Controller and Display HUB-4 System Communication Manager Temperature sensor	**1** **1**	Outback MATE Outback HUB-4
Combiner Box Features: NEMA-4 lockable enclosure 5 circuit breakers (6 Adc, 125 Vdc input max)	**2**	
DC PV Breakers kit Features: PV array A & PV array B disconnect 40 A, 125 Vdc Lighting arrestors	**2** **2**	Outback accessories: OBDC-40 Delta
DC Power Breakers kit **Features:** Inverter/Battery circuit breaker – 100 A dc, 125 Vdc Charge Controllers breakers – 40 A dc Bus bars	**1** **2** **3**	Outback accessories: OBDC-100 OBDC-40 TBB – TBR - GBB
AC Input/Output Breakers Features: Bypass: Single 60 Amps breaker Output: Dual 50 Amps breaker for output/bypass Input: Dual 60 Amps breaker. Main: Single 60 Amps switch Bus Bars	**1** **1** **1** **1** **4**	Outback accessories: AC-IOB-60 AC-IOB-50D OBAC-60D Square-D QOU 2 TBB & 2 TBW
Sensors Features: AC Energy/Power sensors: 0 – 100 Aac, single phase DC current sensor: 0 - 75 Adc S3 DC voltage sensor: 0 - 100 Vdc S4	2 1 1	H8051-100-2 CR-5220-75 CR-5320-100