New Resource Options

STAKEHOLDER MEETING #2
GPA INTEGRATED RESOURCE PLAN 2021

March 2021

Why do we have Resource Options?

- Meet projected customer demands/loads
  - Historical growth rates
  - Project developments in discussion
- Reduce operating costs
  - Efficiency
  - Manpower
  - Maintenance Costs
- Replace aged equipment
  - Reliability
  - Increased Costs
- Meet reserve requirements
  - Backup requirements to support planned and forced outages (island system)

New Resource Options

- Power Production
  - Ocean Thermal Energy Conversion (OTEC)
  - Waste to Energy (WTE)
  - Fuel Cell
  - Dual-Fuel Reciprocating Engines
  - Additional Renewable Contracts (Phase IV+)
- Energy Reduction & Grid Support
  - Sea Water Air Conditioning (SWAC)
  - Fuel Cell Cogen
  - Battery Energy Storage (BESS)
  - Pumped-Storage Hydropower (PSH)
  - Compressed Air Energy Storage (CAES)+
  - Flywheels
  - Synchronous Condenser

Assumptions

- Construction related costs and O&M costs are presented in 2019$
- Non-union labor will be used
- Construction costs include 7 percent contingency as part of the direct costs
- The plant direct construction costs include costs for plant side switchgear and transformer to increase the voltage to 34.5 KV, as well as a 34.5 KV breaker, 3 disconnects, 34.5 KV switchgear and control panel, control house and fencing
- Construction costs include owner costs at 15 percent of direct costs
- Cost estimates have been adjusted to include a 20 percent uplift from mainland pricing to account for working on Guam, unless noted otherwise
- O&M costs represent non-fuel production related costs, including subcategories for variable O&M (VOM), Fixed O&M (FOM), and major maintenance
- FOM does not include owner costs such as property taxes, insurance, or finance related costs
- New installation construction schedule information is based on permitting starting in July 2020

Power Production

Ocean Thermal Energy Conversion (OTEC)

- Utilizes the temperature differences between deep sea water at the surface to condense and evaporate the fluid of a closed-loop organic rankine cycle (“ORC”) while passing it through a turbine to generate electricity.
- Scaled from Hawaii 100KW Makai Ocean Engineering’s project located in the National Energy Laboratory of Hawaii Authority (NELHA)
  - 10MW plant
  - Staff of 12 people
- The high capital costs and potential environmental impacts of OTEC deployments has inhibited commercial scale development of the technology

Waste to Energy (WTE)

- Uses waste for combustion to generate steam that passes through a turbine to create electricity.
    - 5 MW Firm / dispatchable output
    - Fuel from approximately 40,000 and 140,000 tons of municipal solid waste
    - Staff 12-15 people Issues exist
- Local legislation and ongoing litigation will impact project development.

Fuel Cell

- Produces electricity and heat through an electrochemical reaction between a fuel (generally hydrogen) and oxygen.
- Technology is considered mature with significant deployments in both the residential and utility space worldwide.
- Solid Oxide Fuel Cell (SOFC)
  - 4x250KW SOFC for 1 MW facility
- Degrades over time and would require cell replace process at least five years after initial use

Dual-Fuel Reciprocating Engines

- Small piston – cylinder engines. Fuel injected in piston chamber and its combustion move piston linked to a crankshaft creating electricity.
- Quick start (full load in 2 mins) to assist with production support after and ESS has been activated to discharge for grid stability.
- Based on Wärtsilä Model 20V34DF-B unit
  - 3 units x 9.3 MW (27.9 MW)
  - Emergency/limited hours (300 hrs/yr)
  - Ultra-Low Sulfur Fuel and Natural Gas

Power Production Characteristics

Plant Description		OTEC	WTE	Fuel Cell	Diesel Recip
Technology		Land Based ORC	MSW	SOFC	Fast start for outage
Nominal Capacity	MW	10	5	1	28
Space Required	Acres	0.5 to 1	10 to 15	0.1	5 to 10
Capital Cost	$000	$ 99,794	$ 65,550	$ 8,280	$ 40,514
Capital Cost	$/kW	$ 9,979	$ 13,110	$ 8,280	$ 1,446
Total Schedule Duration	Months	48	48	24	24
Max Net Capacity	MW	10.0	5.0	1.0	27.9
Min Net Capacity	MW	5.0	2.5	0.25	4.6
HR @ Max	Btu/kWh (HHV)	NA	16,240	6,100	8,383
HR @ Min	Btu/kWh (HHV)	NA	16,850	6,200	9,389
Mature FOR	%	6.0	8.0	0.5	0.5
Scheduled Maintenance	%	6.0	8.0	0.5	0.0
Max Capacity Factor	%	88.0	84.0	99.0	99.5
Water Consumption	gpm	440,000	NA	NA	0
Primary Fuel		Seawater	MSW	LNG	ULSD
Generation	MWh	76,703	36,424	8,672	8,364
VOM	$/MWh	$ 15.64	$ 32.95	$ -	$ 2.34
MM	$/MWh	$ 18.25	$ 17.57	$ -	$ -
FOM	$/kW-yr	$ 361.81	$ 606.06	$ 318.00	$ 10.76

Additional Renewable Energy (PV) Contracts

- Renewable bids are generally open to all renewable technologies unless specified (i.e. Phase III)
  - Bidders propose technology and in most cases will identify site and interconnection
  - Bids are compared against current fossil fueled variable production costs which is made up of primarily fuel costs (heavy oil/ultra-low sulfur fuel oil)
- 60 MW PV project increments to reach RPS mandates for modeling purposes (BESS for dispatchable output)
- Recent bid price references (1^{st} year)
  - Phase II – \$0.082/kWh & \$.0855/kWh
  - Phase III - \$0.11/kWh

Energy Reduction & Grid Support

Sea Water Air Conditioning (SWAC)

- Cool sea water is pumped to a land-based heat exchanger, where it extracts heat from the closed fresh water loop that is used in air conditioning services.
- Based on 2006 Makai study for SWAC in Tumon Bay area
  - 16,000 tons of cooling (8.4MW electrical equivalent at 25% CF)
  - Staff of 6-8 people
- Modeled as an energy reduction project
- High capital costs and potential environmental impacts limit development

Fuel Cell Cogen

- Uses waste heat from a Fuel Cell (1 MW) system for building heat use (i.e. heating water)
- Energy Reduction System
  - 1 MW electrical equivalent
  - 23.76 MWH energy reduction

Battery Energy Storage (BESS)

- Lithium-ion technology similar to BESS in our Agana and Talofofo BESS sites
- Storage System
  - 5 MW, 20MWH
  - 4 hour application
  - Remote/unmanned operations
- Model for load shifting/flattening
- Other grid support benefits are not modeled (emergency/reserve capacity, frequency and Volt/VAR support)

Pumped-Storage Hydropower (PSH)

- Type of hydroelectric energy storage
  - Two water reservoirs at different elevations
  - Water pumped up to upper level reservoir typically during low loads
  - Water flows down to lower reservoir through a turbine to generate power during peak periods
- Mature technology, but deployed in limited capacity due to the siting requirement
- Storage System
  - 25 MW, 50MWH
  - Constant speed with 2 hr operation requires 2-200 acre-ft reservoirs
  - Staff of 6-8 people

Compressed Air Energy Storage (CAES)

- Air is compressed into a storage tank and released through combustion turbine to produce electrical energy.
- Compression using lower cost power and stored energy used during peak or high cost production periods.
- Storage System
  - 5 MW, 10 MWH
  - Diabatic CAES system utilizing a large, high-pressure (1,000psi or 70 Bar) storage tank with a volume of approximately 300,000 gallons, or 1,000 cubic meters
- Model for load shifting/flattening

Flywheels

- A flywheel consists primarily of a hub, permanent magnet motor generator ("PMMG"), rim, two angular contact/rolling element bearings, a magnetic bearing, and housing. A flywheel is designed to convert electric energy to kinetic energy and kinetic energy to electric energy. (Uses momentum of large rotating mass.)
- Storage System
  - 5 MW, 1.25 MWh (15 min.)
  - 50 modules at 100KW
  - Unmanned/Remote operations
- Model for load shifting/flattening

Synchronous Condenser

- DC-excited synchronous motor which is used to either generate or absorb reactive power as needed to adjust the grid voltage or to improve power factor.
  - Installation and operation is identical to large electric motor and generator (shaft is allowed spin freely)
  - The kinetic energy stored in the rotor of the machine can help stabilize a power system during rapid fluctuations of loads such as those created by short circuits or large intermittent loads.
- Retrofit of existing combustion turbine plant
- Modeled for capital cost impact

Energy Reduction & Grid Support Characteristics

Plant Description		SWAC	Fuel Cell Cogen	Li-Ion BESS	Pumped Hydro	CAES	Flywheels	Sync Cond
Technology		Once Through	CHP - 100 gpm of	Time shift / Peak	Dual 20 Acre	Tank - with LNG		Retrofit Macheche
Nominal Capacity	MW	8.4	1	5	25	5	5	20
Space Required	Acres	1 to 3	0.1	0.25	50 to 60	5 to 10	3 to 5	0.1
Capital Cost	$000	$ 152,315	$ 9,039	$ 15,870	$ 139,380	$ 20,010	$ 29,523	$ 4,830
Capital Cost	$/kW	$ 18,133	$ 9,039	$ 3,174	$ 5,575	$ 4,002	$ 5,905	$ 242
Total Schedule Duration	Months	60	30	18	48	48	36	30
Max Net Capacity	MW	8.4	1.0	5	25.0	4.9	5.0	20.0
Min Net Capacity	MW	4.2	0.25	0.3	10.0	2.4	0.0	10.0
HR @ Max	Btu/kWh (HHV)	NA	6,100	NA	NA	8,250	NA	NA
HR @ Min	Btu/kWh (HHV)	NA	6,200	NA	NA	12,000	NA	NA
Mature FOR	%	3.0	0.5	0.5	2.0	3.0	8.0	0.5
Scheduled Maintenance	%	4.0	0.5	0.5	4.0	6.0	8.0	0.5
Max Capacity Factor	%	93.0	99.0	99.0	94.0	91.0	84.0	99.0
Water Consumption	gpm	NA	NA	NA	NA	NA	NA	NA
Primary Fuel		Seawater	LNG	Grid	Grid	LNG	Grid	Grid
Generation	MWh	68,091	8,672	7,300	18,250	3,541	36,718	173,448
VOM	$/MWh	$ 7.05	$ 1.66	$ 30.00	$ 16.44	$ 25.42	$ 16.34	$ -
MM	$/MWh	$ 10.57	$ 1.38	$ 3.29	$ 16.44	$ 35.02	$ 10.95	$ -
FOM	$/kW-yr	$ 215.36	$ 360.00	$ 12.00	$ 72.00	$ 247.42	$ 33.67	$ -

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