Inland Empire Utilities Agency
A MUNICIPAL WATER DISTRICT

RP-5 Renewable Energy Efficiency Project (REEP)

Final Technical Report

July 12, 2002 – June 30, 2007

Submitted By:

Neil Clifton, P.E. - Manager of Engineering, Energy and Construction Management
Dave Wall, Deputy Manager of Engineering
Jamal Zughbi, P.E. - Project Manager

Date Report Submitted: September 27, 2007

DOE Award No. DE-FC26-02NT41475

Inland Empire Utilities Agency
6075 Kimball Ave
Chino, CA 91708

DISCLAIMER

ABSTRACT

This is the final technical report for the RP-5 Renewable Energy Efficiency Project (REEP). The report summarizes, in a comprehensive manner, all the work performed during the award period extending between July 12, 2002 and June 30, 2007. This report has been prepared in accordance with the Department of Energy (DOE) Guidelines and summarizes all of the activities that occurred during the award period.

The RP-5 Renewable Energy Efficiency Project, under development by the Inland Empire Utilities Agency (IEUA), is comprised of a series of full-scale demonstration projects that will showcase innovative combinations of primary and secondary generation systems using methane gas derived from local processing of biosolids, dairy manure and other organic material. The goal of the project is to create renewable energy-based generation systems with energy efficiencies 65% or more.

The project was constructed at the 15 MGD Regional Wastewater Treatment Plant No. 5 located in the City of Chino in California where the Agency has constructed its new energy-efficient (platinum-LEED rating) headquarters building. Technologies that were featured in the project include internal combustion engines (ICE), absorption chillers, treatment plant secondary effluent cooling systems, heat recovery systems, thermal energy storage (TES), Organic Rankine Cycle (ORC) secondary power generation system, the integration of a future fuel cell system, gas cleaning requirements, and other state-of-the-art design combinations.

The RP-5 REEP biogas source is coming from three manure digesters which are located within the RP-5 Complex and are joined with the RP-5 REEP through gas conveyance pipelines. Food waste is being injected into the manure digesters for digester gas production enhancement. The RP-5 REEP clearly demonstrates the biogas production and power generation viability, specifically when dealing with renewable and variable heating value (Btu) fuel.

The RP-5 REEP was challenged with meeting stringent utility, gas, power, and air quality rules and regulations. Coordination with the Southern California Gas Company (SCGC), Southern California Edison (SCE), and South Coast Air Quality Management District (SCAQMD) was continuous and extensive. The interconnecting agreement and the permit to construct and operate were major obstacles despite the early start and coordination with the utility companies and regulatory agencies.

The RP-5 REEP is part of a unique RP-5 Complex approach where several facilities are tied and connected with each other; where energy and gas can be transferred from one facility to another (see attached RP-5 Complex Ultimate Energy Balance Diagram). The REEP also incorporated new technologies, such as TES and ORC, along with using heat recovery for the platinum-LEED headquarter buildings' heating and cooling via efficient absorption chillers.

Through the conceptual design phase, numerous innovative technologies were researched and evaluated, with the most proven and efficient selected to be part of the RP-5 REEP.

TABLE OF CONTENTS

INTRODUCTION

The RP-5 REEP Award Agreement with the DOE states:

"Thorough research shall be conducted to establish the suitability of innovative power generation units and the sound basis of design for the power generation facility for both projects."

It was in this context that it became the understanding that the Agency should examine and evaluate a wide range of innovative technologies to create a project with the following criteria:

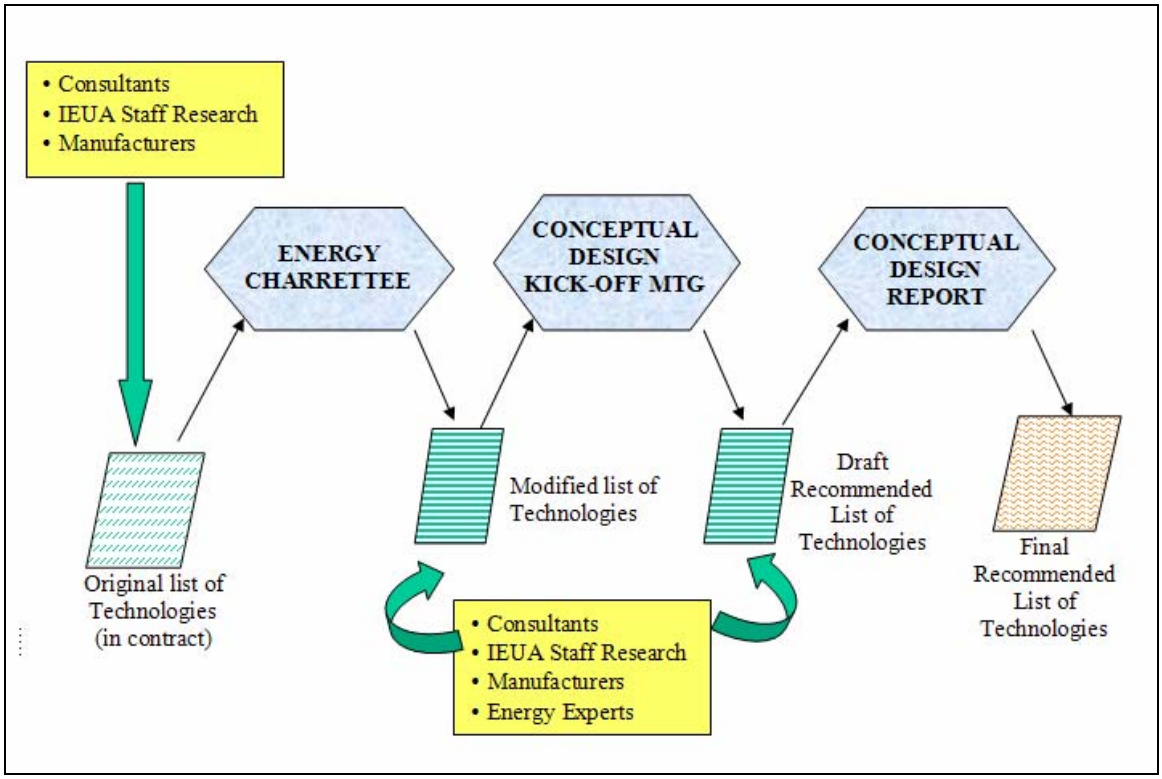
- Use digester gas from cow manure and/or biogas using wastewater biosolids
- Develop an R&D project that has not been done before to determine feasibility
- Design an energy efficient system based on the generation demands at RP-5 (match loads)
- Develop a project with a relatively low DOE cost share (19.47095 percent)
- Design a system that is cost effective and transferable to other public agencies/ private industry
- Design a system that provides power and recovered heat to the new platinum-LEED headquarters complex
- Have no environmental impacts and significant clean air / water quality benefits

The innovative technologies which the Agency proposed in the contract to evaluate project feasibility for possible implementations included a fuel cell, Stirling engine, and steam turbine associated with IC engine exhaust heat recovery. See **Figure 2** showing the schematic for the original project.

Research on Innovative Technologies

With the above listed criteria, the Agency went through a selection process in determining if the three innovative technologies which were originally proposed were viable. **Figure 1** below presents this process and includes three major milestones: 1) the Energy Charrette, 2) the Conceptual Design Kick-off Meeting and Workshop, and 3) the Conceptual Design Report. These milestones clarified the focus of the project and assisted the Agency in selecting only those technologies that met the project objectives.

IEUA Innovative Technology Selection Process
Figure 1



Innovative Technologies Evaluated

The following innovative technologies were evaluated during the Energy Charrette held on May 8-9, 2002, and at the energy workshop or the conceptual design kickoff meeting held on November 4, 2002:

- IC engines as primary power generation
- I.C. engine ceramic coating
- Stirling engines for primary and secondary (bottoming) power generation
- Direct fired Stirling engines
- Absorption chillers
- Thermal ice storage
- Fuel cells as primary power generation
- Organic Rankine Cycle
- Flexible microturbine
- Small and large scale ice storage
- Biogas Gasification
- Bio-reactor systems
- Steam turbine system

Revised Innovative Technologies

Between the first Quarterly Report and the Conceptual Design Kick-off meeting, the Agency worked with several Consultants to determine the technologies that should be included and evaluated in the Conceptual report. It was during this time that there were serious concerns regarding using a fuel cell as primary generation, and using either a steam turbine or a Stirling engine as a bottoming cycle, where the Stirling engine would run on the heat recovered from the engines exhaust. Gasification technology was also explored, and was determined not viable.

The Agency continued to work with several consultants on further evaluation of many other innovative technologies before the final selection for the RP-5 REEP. The California Energy Commission consultant, CH2M Hill, as well as Kennedy Jenks, conducted independent reviews of additional technologies. As a result, the following technologies were deemed unsuitable for this project:

- Stirling engines used as bottoming cycle (secondary power generation)
- Biogas Gasification
- Bio-Reactor systems that use green waste
- Fuel Cells as primary power generation
- Thermal Ice Storage

Criteria used to eliminate non viable technologies for the RP-5 REEP include one or more of the following elements:

- High and unjustifiable capital cost
- High maintenance cost
- Extensive maintenance frequency
- Significant environmental impact
- Poor performance
- Unproven technology

The attached **Figure 3** shows the modified and proposed schematic for project equipment.

Selected technologies and systems used in the RP-5 REEP include the following:

- Internal combustion (IC) engines with jacket water and exhaust heat recovery
  - Two (2) 1,500 kW engine generator sets
- Organic Rankine Cycle (ORC) bottoming cycle or secondary generation unit
  - One (1) 220 kW utilizing engines exhaust heat
- Thermal Energy Storage System to generate and store chilled water during the off peak hours for use during on peak daytime hours for significant energy savings
- Plant secondary effluent cooling system for the IC engines and ORC unit with zero flow rejection as cooling water returns to the RP-5 treatment process
- Multi-fuel capability including manure gas, municipal digester gas, supplemental natural gas, and diluted natural gas with air
- Manure gas generated in two different types of digesters
  - Modified full-mix plug flow digester
  - Vertical aboveground digesters based on European technology
- Interconnecting header joining the Regional Plant No. 2 (RP-2), Desalter Plant, RP-5 Solids Handling Facility (RP-5 SHF) and RP-5 REEP as shown in the attached RP-5 Complex Ultimate Energy Balance Diagram
- Fogging system for generator room cooling in lieu of the standard evaporative cooling
- Totally enclosed fresh lube oil and waste oil system involving tanks and pumps
- Sophisticated control system to shift energy, gas, and heat recovery as required for added flexibility, reliability and increased performance
- Net energy metering capability which enables the project to produce power in excess of the RP-5 plant demand and export the excess power to the utility grid. IEUA receives credit at other facilities interconnected with the RP-5 REEP equivalent to the amount of power exported.

RP-5 REEP Challenges

The RP-5 REEP throughout all of its phases from Energy Charrette and Conceptual Design to Final Design and construction experienced a tremendous amount of challenges that influenced the project schedule; however, the project team, including the Parsons

Water & Infrastructure, Inc. and the Agency's Engineering, Energy & Construction Management (EE&CM) Department overcame many unforeseen obstacles, and was able to maintain the project schedule on track with minimal delays. Some major challenges are summarized below:

- Energy analysis of six (6) engine generator configurations to select the best option for the project considering reliability, performance and payback
- Interconnecting agreement with local utility power company, Southern California Edison (SCE)
    - Stringent regulation
    - Repeated design drawing reviews
    - Numerous site visits
    - Strict relay settings with a very narrow margin
- Natural gas supply agreement with the local utility gas company, Southern California Gas Company
    - Early start and negotiation was required
    - Continuous correspondence and communications for complex requirements and timely installation(s)
- Permit to construct and operate from South Coast Air Quality Management District (SCAQMD)
    - Constant & continuous communication via telephone, emails, applications, and reports
    - According to the SCAQMD's definitions, the RP-5 Facility is considered a Title V facility, and therefore abides by the most stringent air quality regulations
    - Despite early coordination and application submittal, permitting language problems and issues arose requiring permit modifications
    - Project commissioning and startup was suspended due to ambiguity in the "gas cleaning system" described in the Permit to Operate issued by SCAQMD
    - The Agency is working with SCAQMD to modify the permit to correct the "gas cleaning system" description
    - Modifying a Title V Permit is an extensive task requiring approximately 6-8 weeks
- Delayed equipment delivery
    - Hurricanes Katrina and Rita shifted resources and efforts to the devastated areas; thus, affecting equipment/material delivery
    - The war in Iraq shifted power resources; thus effecting generating equipment delivery
- Material prices increased at unprecedented levels
- Rejection of the first project bid due to inconsistent and unrealistic pricing
- Re-bid and division of the project bid into thirteen bid packages
    - Resulted in about $2M cost savings
    - Eliminating the General Contractor role by self performing the project construction phase by the Agency for cost savings
    - Project construction became more difficult to manage and execute

    - Extensive experience due to complexity of the project
    - Thorough knowledge and experience by handling this multi-contract project from contract awards to commissioning
- Late cancellation of the Stirling engine project
    - Manufacturer (STM Power) went out of business and liquidated the company due to the lack of funds prior to Stirling engine testing
    - Stirling engine projects in the U.S may be taken over by another company
    - The Agency will continue to explore the Stirling engine project with the new company while maintaining acceptable terms & conditions
    - Stirling project is currently on hold, with no immediate activities in the near future
- Biogas sources, deliveries and production
    - Biogas produced from Agency's manure digesters is the primary source of fuel for the REEP engines
    - Manure handling from the dairies to the receiving tanks at the RP-5 SHF is a comprehensive and challenging process:
        - Manure deliveries loads should be consistent and timely
        - Debris, rocks, ropes and other trash in the manure cause process problems, specifically pumps plugging, mixing systems clogging, and other equipment being damaged
        - Effective screening equipment is required, along with frequent and extensive maintenance
        - Biogas has high hydrogen sulfide content, but very low siloxane levels
        - Food waste implementation is highly desirable to increase biogas production
        - Consistent and continuous feed of manure and food waste to the dairy digesters is required for acceptable biogas quality and consistent rate of production

Incentive Rebates

Since the Self-Generation Incentive Program (SGIP) application in 2005, the Agency has maintained constant communication with the Southern California Gas Company (SCGC) to receive a rebate for the RP-5 REEP. The project has qualified to receive up to $1M from the California Public Utilities Commission (through the SCGC) following inspection and startup. This will help defray the unexpected increase in materials cost. The main qualifying requirements include the following:

- Use of renewable fuel gas with no more than 25% natural gas blend
- Use of heat recovery in an efficient manner
- Generation and connection to the RP-5 facility electrical bus
- Rebate maximum power generation is 1,000 kW
- Valid interconnecting agreement and permit to construct and operate

EXECUTIVE SUMMARY

The RP-5 Renewable Energy Efficiency Project's (RP-5 REEP) primary objective is to make renewable energy more affordable in California and the U.S. The project involves innovative combinations of primary and secondary power generation systems using methane gas produced from local processing, dairy manure, and other organic materials. The project goal is to achieve a high system efficiency of at least 65% through heat recovery and supplying heating and cooling water to adjacent buildings and facilities.

The RP-5 REEP combines the conventional power generation system, such as the internal combustion engines (IC engines, two @ 1.5 MW each), an innovative bottoming (secondary) power generating unit (ORC @ 220 kW), and heat recovery system serving the platinum-LEED headquarters absorption chillers (four @ 30 tons each) and heating system. The RP-5 Complex consists of four interconnected facilities, where energy and gas resources are shifted for optimal performance and cost effectiveness (see attached RP-5 Complex Ultimate Energy Balance Diagram).

RP-5 REEP construction is complete, with initial operation and equipment testing in progress. Currently, the Agency is awaiting modifications to the facility permit to operate by the South Coast Air Quality Management District (SCAQMD). Project major highlights from inception to startup can be summarized as follows:

- RP-5 REEP is a true Research & Development (R&D) project, which can be used as an example and as guidelines for similar projects by other agencies in California and the U.S.;
- IEUA invited and conferred with the leaders and pioneers in the renewable energy fields, including research institutes, universities, scientists, power industry manufacturers and consulting engineers in the U.S. to help evaluate, research and analyze potential and viable innovative technologies
- Research was conducted for numerous innovative technologies such as fuel cells, gasification, thermal ice storage, bottoming cycles (including Stirling and ORC systems, etc.) for cost effectiveness, payback, efficiency, capital cost, and environmental impact
- The Agency avoided implementation of innovative technologies that have already been installed and evaluated by other agencies, and introduced new innovative technologies instead. An example is the replacement of the fuel cell with the innovative ORC bottoming unit, which has not been done previously
- RP-5 REEP was challenging from initial conception to end of construction and startup due to the high level of complexity including:
  - Number of technologies and facilities involved
  - Biogas source being manure
  - Interconnecting agreements
  - Permit to Operate and Emission compliance
  - Sophisticated control system for system optimization
- Large long lead equipment prepurchase is recommended for better quality control, saving money, and keeping schedule on track

- Extended 5 year internal combustion engines maintenance agreement with engine manufacturer provides the following advantages:
  - Guaranteed engine emission limits are maintained in compliance
  - Eliminate/reduce regulatory agency engine emission violations, which would result in project shutdowns
  - Extend engines life
  - Provide IEUA staff with engine maintenance experience during the 5 year maintenance warranty, which will be beneficial for future maintenance
- Surprises and Obstacles
  - Material abrupt and high increase in costs – IEUA incurred these unforeseen costs
  - High competition for the contractors in the area during the first bid resulted in high and inconsistent bids, causing IEUA to reject the two bids received and re-bid six months later to cut down the construction costs. This resulted in about a $2M savings.
  - Hurricane seasons (Katrina and Rita) – delayed equipment delivery
  - Iraq war – delayed equipment delivery
  - Lowest Achievable Emission Rate (LAER) is a new rule established by SCAQMD to enforce that an engine must meet the most stringent emission limitation that is achieved by any other engine within the SCAQMD service area. This impacted Caterpillar's (engine manufacturer) original emission guarantees, including NOx, CO and VOCs. Parsons, the design consultant, modified the design to include any future catalyst, if needed for compliance.
- Major concerns for attention include:
  - Early communication with the local power utility company to approve single line diagrams and establish the interconnecting agreement
  - Early communication with the regulatory agency (in the case of IEUA, SCAQMD) to ensure and secure timely approval
  - Permit language must be carefully reviewed prior to final issuance by the regulatory agency
  - Title V permits require a review and approval by the Environmental Protection Agency (EPA) for every permit modification. It may also require a public hearing depending on the nature of the modification
- Self-performing Construction
  - Provides extensive construction and commissioning experience for future projects
  - Saves money by eliminating the general contractor role
  - Required tremendous effort (telephone, email, reports, supervision, monitoring, coordination, permits, applications, etc.) by Engineering, Energy & Construction Management Department (EE&CM)
  - Self-performing the construction phase of a project requires a qualified and meticulous team. This task is not recommended for large sophisticated projects due to the amount of effort required, and the qualified staff necessary

EXPERIMENTAL

The RP-5 REEP throughout the conceptual design and research phase, and through the preliminary and final design phases, used standard research methods and equipment such as conferences, site visits, computers, phones, internet, etc. The methods and steps that have been utilized in this project include, but are not limited to the following:

- Manufacturer surveys, communications, literature, catalogues, etc.
- Technical workshops
- Communications with leading experts
- Communications with environmental control agencies
- Manufacturers' plant visits
- Other municipal agencies site visist
- Evaluation of specific factory test results for selected equipment
- Feedback from owners of existing installations
- Economic evaluation
- Life Cycle analysis
- Payback calculations

RESULTS AND DISCUSSION

The RP-5 REEP, with its configuration and features is considered one of the most innovative and unique projects in the U.S. The RP-5 REEP was thoroughly thought out and executed from inception to completion with the goal of making renewable energy projects affordable in California and the U.S. and transferable to other public agencies and private industry. The Agency worked vigorously from day one with the leading experts in the renewable power generation field to ensure that this project meets the goals set forth with no environmental impact and significant clean air/water quality benefits.

Based on the engine-guaranteed data provided by the engine manufacturer, Caterpillar, the engine efficiency when converting gas to electricity at full load is 35.9%. Also, when combining the heat recovery from the engine jackets and engine exhaust, the thermal efficiency is approximately 36%; therefore the total combined engine efficiency is in the order of 72%, which exceeds the project goal efficiency of 65% as stated in the Agreement. Moreover, the project control system allows the exhaust heat to be utilized for additional power generation via the ORC unit when the heat demand for the absorption serving the cooling water system for the platinum-LEED headquarters is low. In order to maximize and optimize performance, the Agency designed and installed the Thermal Energy Storage system, which generates about 65,000 gallons of chilled water during the night (off-peak period with lower energy costs) for use during the day (on-peak period with higher energy costs) for the headquarters cooling. This design lowers the heat demand of the absorption chiller during the day, and exhaust heat can be diverted to the ORC for additional power generation. ORC system efficiency is about 10%; however, ORC operation is based on waste heat recovery from engines exhaust which has to be wasted anyway. Heat recovery to absorption chillers has a priority over the ORC during the day in order to provide the needed chilled water for building cooling. If excess exhaust heat is not recovered and utilized buy the ORC, it will be dumped into the plant secondary effluent cooling water system. Reliability, flexibility, and optimum performance are the main benefiting features of the RP-5 REEP.

The engines use biogas derived from dairy manure processing as the primary fuel. Dairy manure is collected from six (6) dairy facilities in the Inland Empire area, which is then processed at the RP-5 Solids Handling Facility (RP-5 SHF) to produce biogas. The RP-5 SHF is designed to treat 615 wet tons of manure per day, and 90 tons of food waste per day, to produce about 3 MW using the RP-5 REEP power generation system. Collecting manure from the dairy facilities help clean the environment in two ways. First, when removing manure from the ground reduces emissions to the atmosphere and improves air quality. Secondly, preventing manure and acidic water from leaching into the ground protects the ground water from contamination. An environmental study performed by a professional consultant, Environmental Resources Trust, Inc. revealed the following average emission reductions:

Methane (CH4):	74 tons/year
Nitrogen Oxides (NOx):	21 tons/year
Ammonia (NH3):	164 tons/year

Project partners of the RP-5 REEP and dairy manure digestion projects include the U.S. Department of Energy, California Energy Commission, U.S. Department of Agriculture/Natural Resources Conservation Service, California Public Utilities Commission, Milk Producer Council and the South Coast Air Quality Management District. This large comprehensive partnership demonstrates the significance and urgency of the above stated projects, including the RP-5 REEP which is the main biogas consumer and power generator, and thus the heart of these projects. The RP-5 REEP places the Inland Empire Utilities Agency as a pioneer and innovative leader in the success and support of renewable energy projects. The Agency's success has received recognition and awards from Governmental, State and Federal Agencies.

Moreover, in order to demonstrate the Agency's dedication to promote innovative technologies and motivation to assist manufacturers in testing their new technologies, the RP-5 REEP includes a research room equipped with utilities such as digester and natural gas, water, power, and compressed and instrument air.

Along with providing a showcase of advancement and innovation, the RP-5 REEP path proved to be extremely experiential and will be a great addition to the Agency's support in energy efficiency and renewable energy applications.

Lessons Learned

- Regulatory agencies often require extended periods of time and abundant documentation to process/prepare permits (i.e. permit to operate application).
- Extended maintenance agreement and warranty from the engine and continuous emission monitoring system (CEMS) manufacturers is highly recommended to remain in compliance and avoid hefty fines and/or project shut downs by the regulatory agency. A minimum maintenance agreement and warranty of five years is recommended.
- Early and continuous communication with the power utility company is highly recommended. Plenty communication methods are recommended, and include meetings, e-mails, telephone conversations, etc. Constant correspondence helps prevent unseen project delays, especially in after the later stages of construction completion and when startup commences.
- Pre-purchasing long-lead equipment/items is cost saving and helps maintain a project schedule if performed and coordinated properly. However, along with pre-purchasing follows a tremendous amount of effort, coordination, documentation, etc. If not performed effectively and carefully, results are change orders, additional costs, and project delays.
- Self-performing the construction phase of a project is extremely difficult, time consuming, and requires a qualified and meticulous Engineering & Construction Management team. Although it was a successful experience for IEUA, self-performing task is not recommended for large sophisticated projects due to the amount of effort required, and the qualified staff necessary for efficiency.

- Consistency of manure and food waste feed to the digesters is the key for consistent biogas production with good quality. Slug-loading manure and/or food waste causes process upsets and results in low quality gas, which should not be used in the internal combustion engines.
- Grants are very beneficial to the project. However, along with grants comes a tremendous amount of effort, including applications, record documentation, reports, and other forms of communication. This is also true of incentive programs, such as the Self Generation Incentive Program (SGIP).
- Engineer and design Consultant's continuous and constant communication and involvement during the construction phase is absolutely critical, especially with modern projects. Consultants are the primary source of information (engineering, permits, etc.), having designed the system, and therefore can help clarify design issues, which can save on costs and avoid project delays. In addition to standard services during construction provided by consultants, preparing the overall plant Operation & Maintenance manual is highly recommended. Additional services should include training Owner's personnel on how to correctly operate the plant.

IEUA maintained close constant and continuous communication with the DOE through conference calls, e-mails, quarterly reports, design submittals, etc. This effective communication ensured the DOE was always up to date with all project activities. The DOE & National Energy Technology Laboratory's funding support was a key factor in the successful implementation of this energy efficient project, which is highly appreciated by IEUA.

CONCLUSIONS

Construction of the RP-5 Renewable Energy Efficiency Project is complete with initial operation and equipment testing in progress. The project's main highlights and conclusions are summarized below:

- The RP-5 REEP is a strong reference in the renewable energy and power generation field, as it tackled technology survey, scrutiny, evaluation and selection followed by actual implementation.
- The RP-5 REEP underwent detailed technical and economical evaluation and analysis based on the following criteria:
  - Feasibility
  - Reliability
  - Cost Effectiveness
  - Payback
- Projected cost savings using 100% manure biogas gas:
  - Project Cost: $18,500,000
  - Average Annual Cost Savings: $3,687,788
  - Payback: 5 years
- System Efficiencies:
  - Gas to electricity (engines): 36%

- Thermal efficiency (heat recovery): 36%
- Overall plant efficiency: 72%
- ORC efficiency: 10%

- Project Outcome and Benefits:
  - Proves that renewable energy projects of this magnitude are affordable and cost effective
  - Identified technologies that are not viable
  - Identified technologies that are not cost effective
  - First to use the ORC secondary power generation unit in conjunction with engines exhaust heat recovery
  - Hosted and tested several technologies such as Stirling engine and flexible microturbine to help manufacturers and researchers advance their technologies using digester gas. Outcome was as follows:
    - Both technologies are still struggling and not yet proven
    - Capital cost is high
    - Efficiency is low
    - Suitable material research is still advancing
    - Real applications of this equipment is not recommended at this time
- Public Benefits:
  - Use of findings and results achieved in the RP-5 REEP to avoid duplicating effort by other agencies
  - Improved air quality by reducing manure gaseous emissions to atmosphere
  - Improved ground water quality by reducing manure percolation into the ground
  - Lower electric rates due to onsite power generation which takes off the load from the grid. This maintains low utility company costs by not installing new power generation facilities

G:\EN\EN03029\ADMIN\STRATONIDOE GRANT\GRAPHICS\FIGURE 4-ORIGINAL SCHEMATIC

INLAND EMPIRE UTILITIES AGENCY
CONCEPTUAL POWER GENERATION AND HEAT RECOVERY SYSTEM

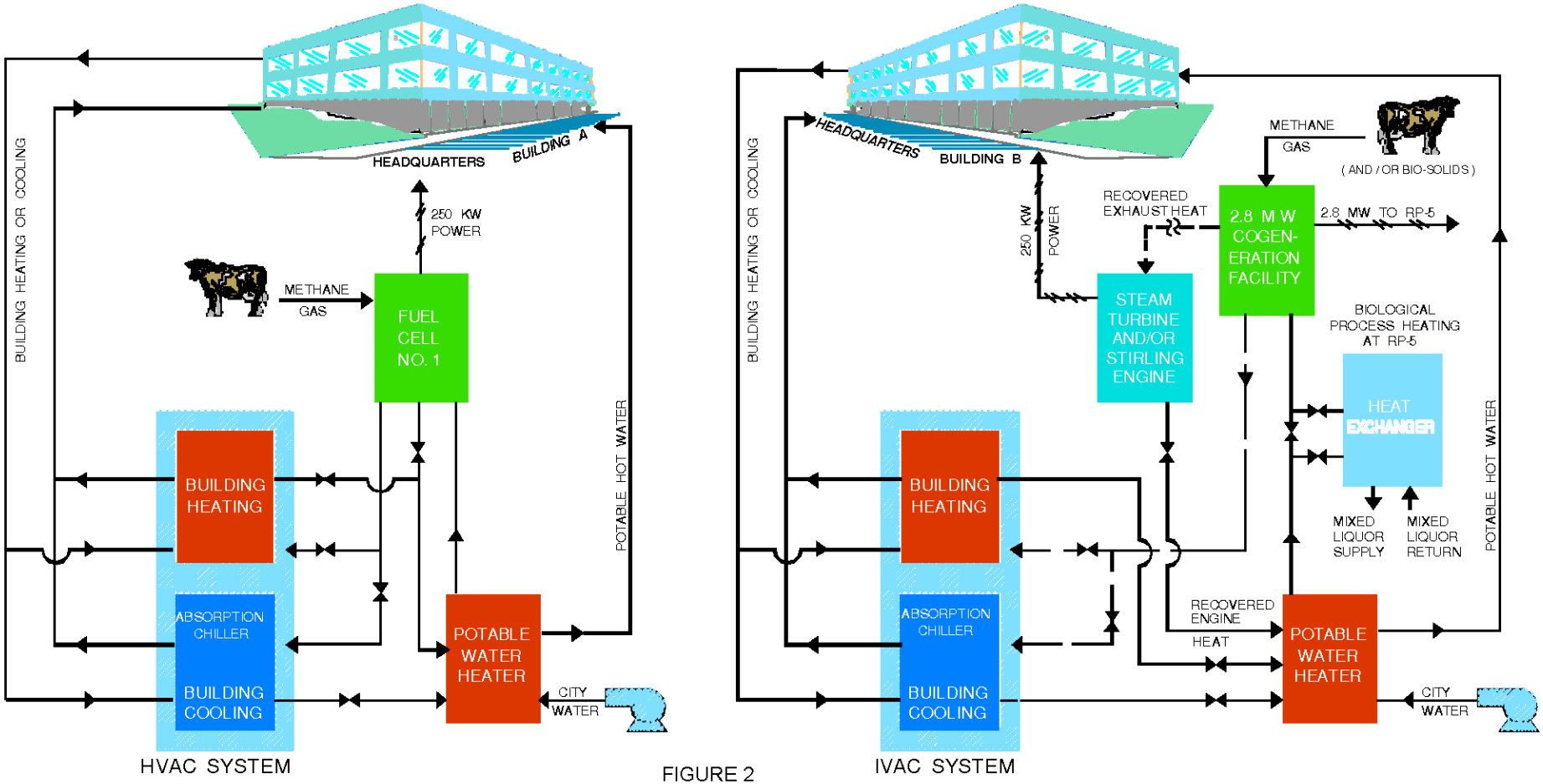


FIGURE 2

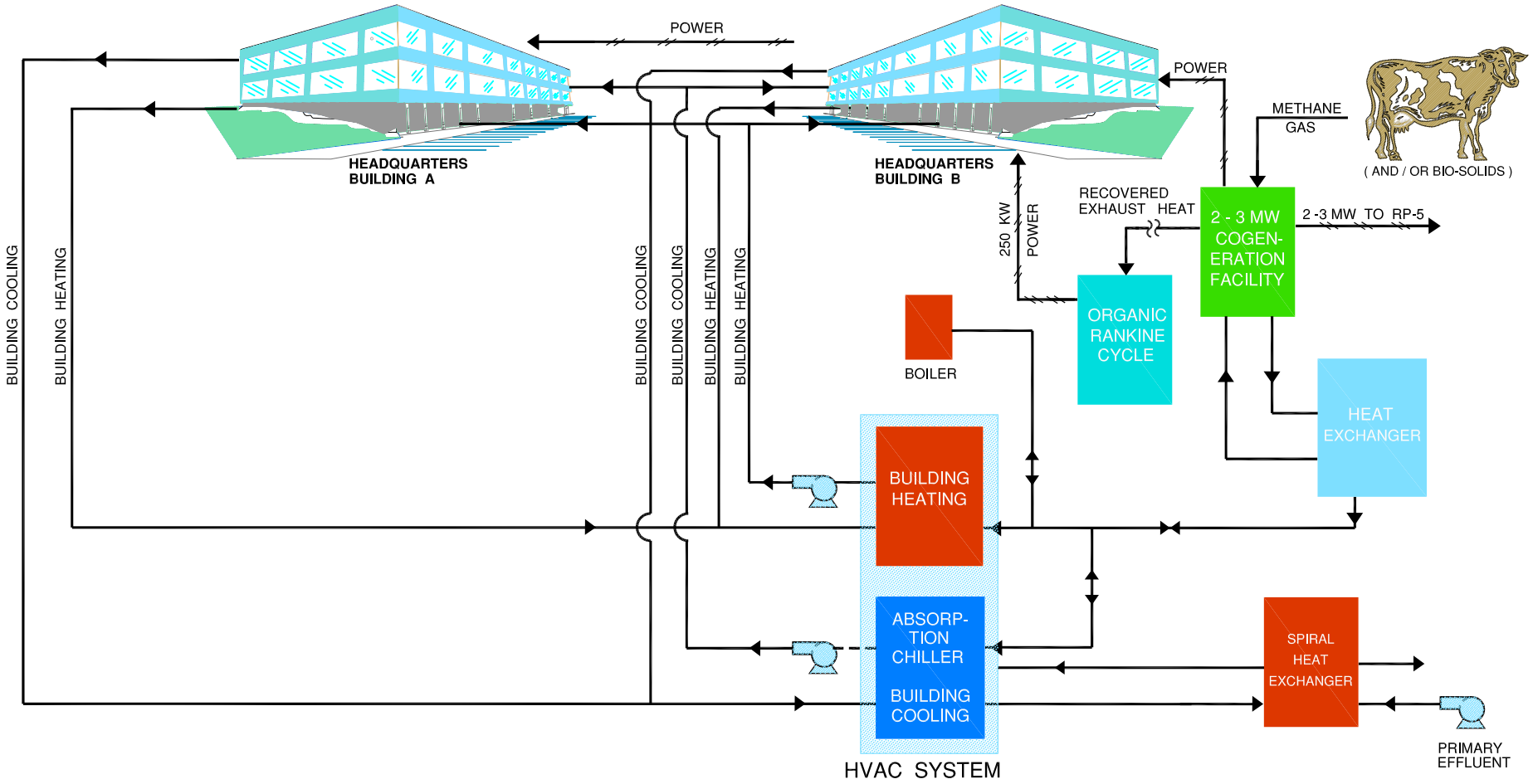
PROJECT 1
(Original)

PROJECT 2
(Original)

LEGEND
POWER
WATER

FIGURE 2

INLAND EMPIRE UTILITIES AGENCY
POWER GENERATION AND
HEAT RECOVERY SYSTEM



RP-5 RENEWABLE ENERGY EFFICIENCY PROJECT

(PROPOSED)

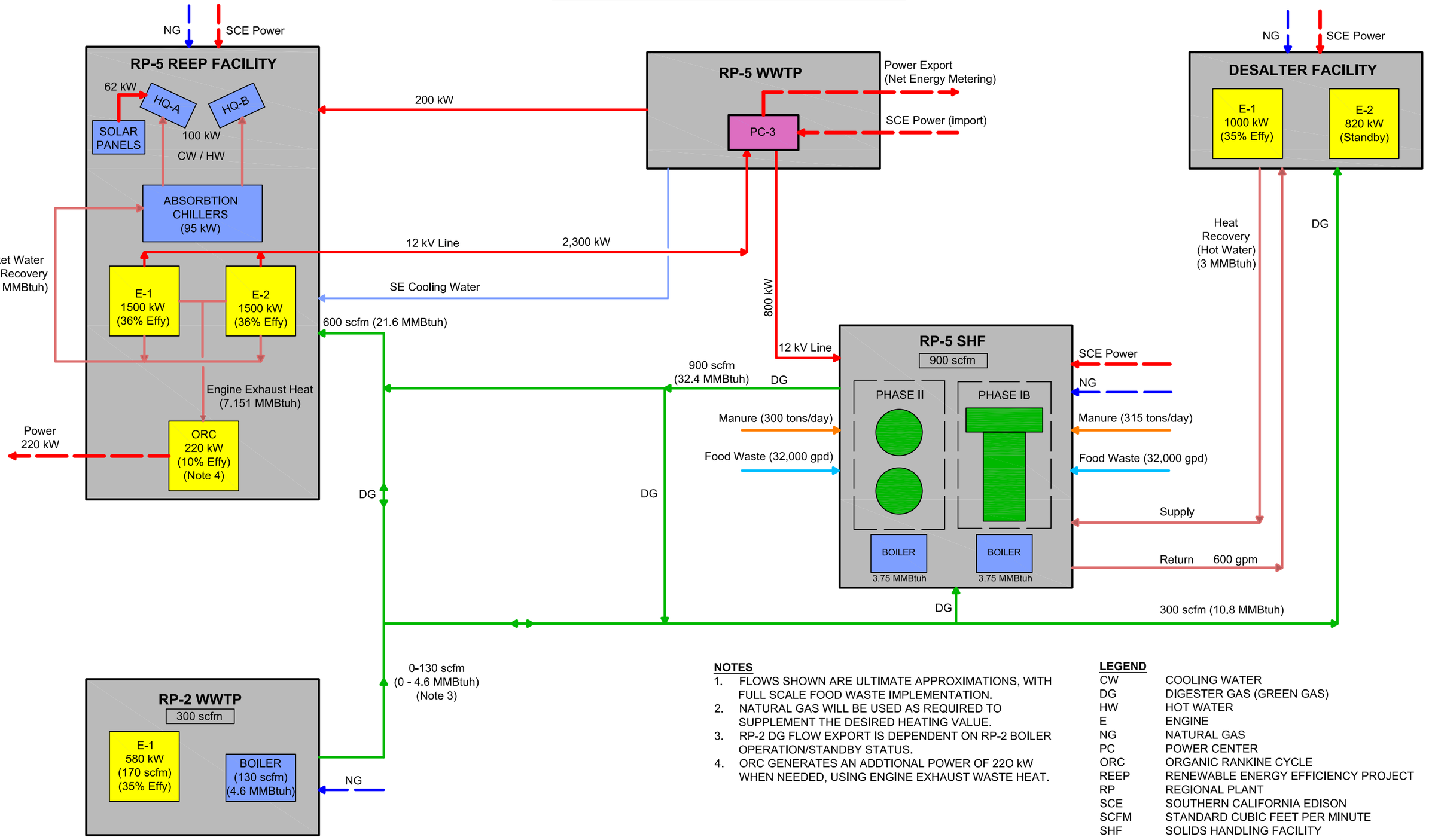
LEGEND

POWER

WATER

FIGURE 3

RP-5 COMPLEX
ULTIMATE ENERGY BALANCE DIAGRAM



NOTES

1. FLOWS SHOWN ARE ULTIMATE APPROXIMATIONS, WITH FULL SCALE FOOD WASTE IMPLEMENTATION.
2. NATURAL GAS WILL BE USED AS REQUIRED TO SUPPLEMENT THE DESIRED HEATING VALUE.
3. RP-2 DG FLOW EXPORT IS DEPENDENT ON RP-2 BOILER OPERATION/STANDBY STATUS.
4. ORC GENERATES AN ADDTIONAL POWER OF 22O kW WHEN NEEDED, USING ENGINE EXHAUST WASTE HEAT.

LEGEND

CW	COOLING WATER
DG	DIGESTER GAS (GREEN GAS)
HW	HOT WATER
E	ENGINE
NG	NATURAL GAS
PC	POWER CENTER
ORC	ORGANIC RANKINE CYCLE
REEP	RENEWABLE ENERGY EFFICIENCY PROJECT
RP	REGIONAL PLANT
SCE	SOUTHERN CALIFORNIA EDISON
SCFM	STANDARD CUBIC FEET PER MINUTE
SHF	SOLIDS HANDLING FACILITY
WWTP	WASTEWATER TREATMENT PLANT

Inland Empire Utilities Agency
A MUNICIPAL WATER DISTRICT

Final Technical Report Photos

Air-Start Compressors

1.5 MW Engine Generators w/ Heat Recovery

Chiller and Stirling Engine Pad

Heat Exchanger Room

Hot and Cold Water Piping

Motor Control Center (MCC)

12kV Switchgear

Natural Gas/Air Compressors (left), and Organic Rankine Cycle Unit (right)

REEP Building (background), and Thermal Energy Storage Tank (center)

REEP Site

Manure Collection at Manure Farms

RP-5 SHF Manure Receiving

RP-5 SHF Phase II Vertical Full Mix Manure Digesters

IEUA Platinum-LEED Headquarters Building