Executive Summary

PCRWRD Regional Wastewater Reclamation Department (PCRWRD) commissioned the development of a master plan to identify the optimal strategy for managing current and projected biosolids and biogas production from its wastewater reclamation facilities.

PCRWRD owns and operates two major wastewater reclamation facilities and a smaller wastewater reclamation facility in the metropolitan area of Tucson. In addition, PCRWRD owns and operates seven Non-Metropolitan (Sub-regional) wastewater reclamation facilities which serve population centers outside of metropolitan Tucson.

PCRWRD's system is undergoing significant changes through the implementation of the Regional Optimization Master Plan (ROMP). The ROMP Study recommended significant changes to PCRWRD's facilities in order to meet more stringent effluent standards with respect to ammonia and nitrogen. As part of this study effort, capacity expansion was also considered to meet growing demand for wastewater service within PCRWRD's service area. The most significant recommendations to evolve from the ROMP included:

- Expanding the Ina Road Wastewater Reclamation Facility (Ina Road WRF) capacity to 50 million gallons per day (mgd).
- Decommissioning the existing Roger Road Wastewater Treatment Plant (Roger Road WWTP) and replacing with a new Water Reclamation Campus (WRC) to treat 32 mgd.

The ROMP also recommended that the processing of biosolids produced at Ina Road WRF and the new WRC be consolidated at Ina Road WRF. This includes an expansion of the current anaerobic digestion process for solids stabilization, and thickening of digested solids as preparation for haul to agricultural land application sites. The ROMP acknowledged that PCRWRD's current biosolids management program of agricultural land application of thickened Class B biosolids (slurry) was currently viable. However, the ROMP also acknowledged the current biosolids management program to be one-dimensional and vulnerable to changes, such as reduction in available agricultural land for land application within cost-effective hauling distances. Consequently, the ROMP recommended a comprehensive study to develop a long-term and sustainable plan for managing biosolids produced from PCRWRD facilities, including the Sub-regional facilities. This study is a result of this ROMP recommendation.

In addition, the management of biogas – the methane rich byproduct from the anaerobic digestion of raw wastewater solids – requires consideration as part of this study. Currently, the Ina Road WRF uses biogas produced on-site to produce electric power in an on-site power generation facility. It is PCRWRD's desire to decommission the existing power generation facility (due to age and because on-site power generation as currently configured is not beneficial to PCRWRD) and replace with another form of biogas utilization that will benefit PCRWRD economically, as well as support PCRWRD's goals for energy efficiency and sustainability. Further, the consolidation of solids processing at Ina Road WRF will result in significantly more biogas production than what is currently produced. Therefore, the biogas utilization planning must also account for this increase in production.

Managing biosolids produced from the Sub-regional facilities is also a component of the Master Plan. Currently, for all except the Green Valley Wastewater Reclamation Facility (Green Valley WRF), biosolids from these Sub-regional facilities are hauled as a liquid slurry and discharged into the collection system of the Roger Road Wastewater Reclamation Facility (WRF) or Ina Road WRF (some of the very small facilities utilize drying beds and haul their dried to a landfill). Once combined, and processed through anaerobic digestion and thickening, all solids are sent to land application as described above. Only the Green Valley WRF currently processes biosolids on-site.

Biosolids and Biogas Projections

In evaluating biosolids and biogas projections, two conditions were considered in order to bracket the production estimates over the planning horizon:

- WRC start-up, 2014.
- Full capacity, 2030.

Biosolids projections were developed based on previous studies completed as part of the ROMP and the Ina Road WRF Capacity and Effluent Upgrade Project, plus discussions with CH2MHill, the consultant for the design of the plant expansion as well as the WRC (see discussion in Section 2). Biosolids projections resulting from these evaluations and discussions are summarized in Table ES-1.

Table ES-1. Solids to Digestion and Beneficial Use – Ina Road WRF

Year	Estimated Total Solids to Digestion dry lbs/day	Estimated Total Volatile Solids to Digestion dry lbs/day	Estimated Total Liquid to Digestion gals/day	Estimated Total Biosolids to Beneficial use dry lbs/day (2)	Estimated Total Liquid to Beneficial Use gals/day (3)	Estimated Total Cake to Beneficial use wet lbs/day (4)
2014 (1)	**160,800**	**125,800**	**307,300**	**81,900**	**163,600**	**372,100**
2030 (1)	**238,500**	**186,500**	**478,300**	**122,300**	**244,500**	**556,100**

(1) WRC start-up and Full Capacity – all solids to Ina

(2) BC estimates assumes 55% VSR and 90% capture in centrifuges

(3) Assumes digested solids thickened to 6% TS

(4) Assumes digested solids dewatered to 22% TS

Biogas projections evolve from projections of raw solids to digestion, and assumptions regarding performance of the digesters in terms of converting volatile solids to biogas and other constituents. Table ES-2 presents biogas projections; these are presented in terms of a range to reflect some uncertainty regarding various factors influencing biogas production including the unit volume of gas produced per pound of volatile solids destroyed.

Table ES-2. Biogas Projections – Ina Road WRF

Year	Estimated Total Volatile Solids (VS) to Digestion lbs/day	Aggregate Volatile Solids percent	Estimated Volatile Solids Reduction percent	Estimated Cubic Feet Biogas Per lb VS Destroyed	Estimated Gas Production cf per day average (1)	Estimated Biogas BTU Content BTU/cubic feet	Estimated Biogas Energy Production million BTU/day
WRC Start-up 2014	125,800	78.5	55	12 - 15	830,000 - 1,038,000	600	500 - 623
Full Capacity 2030	186,500	78.2	55	12 – 15	1,231,000 -- 1,539,000	600	738 - 923

(1) Range reflects potential range in unit gas production, cubic feet of gas per pound of volatile solids destroyed (12 cu ft per lb VS destroyed was used in ROMP and in Ina Road WRF Energy Master Plan).

Biosolids Market Assessment and Technology Screening

PCRWRD's current biosolids management program has been reliable and cost-effective for over 20 years. The program is based on land application of Class B biosolids in slurry form. Though the current biosolids program has been reliable and cost-effective, it is vulnerable to potential changes, including the following:

- Loss of Agricultural Land Due to Urbanization.
- Loss of Public Acceptance
- Political Pressure
- Loss of Viable Contractor.

Therefore, the primary objective of the biosolids utilization master plan is to improve the long-term reliability of PCRWRD's biosolids management program through assessing and potentially expanding the market for biosolids products, and identifying technologies to support the expanded market. The approach to the biosolids market assessment was to determine the following:

- Who are the likely users of biosolids products in the greater PCRWRD area?
- What are the product characteristics that enhance market interest and demand?

The data gathered through the market assessment was used to develop answers to these questions, and provide direction for features of PCRWRD's current biosolids program that should be retained and changes that may be warranted to enhance long-term reliability (see Section 3).

The market assessment provides direction for developing a long-term plan biosolids utilization program for PCRWRD. Based on the results of the market assessment, the following summarize recommendations to achieve the goal of long-term reliability (more complete recommendations are provided in Section 6):

1. PCRWRD's current biosolids program remains cost-effective and reliable in the short-term. However, in order to achieve long-term reliability, PCRWRD should diversify both the biosolids products it produces as well as the outlets to receive and utilize those products.
2. Diversifying biosolids outlets will require an investment by PCRWRD to develop these markets. PCRWRD should begin immediately to develop demonstration scale projects to produce diverse products. Opportunities include field demonstrations at the Freeport McMoran, Inc. Sierrita mine and PCRWRD-owned Canoa Ranch or other PCRWRD-owned ranch lands (for example, biosolids could be used to support ranch land restoration or other open space preservation and enhancement projects; PCRWRD staff noted the availability of Federally Funded Environmental Quality Incentives Program (EQUIP) that can help pay for up to 80 percent of land restoration through the United States Department of Agriculture Natural Resource Conservation program). For mine reclamation, the objectives of the demonstration project would include not only logistical considerations for the quantity and timing of biosolids delivery, but also investigation and documentation of the performance of biosolids in tailings reclamation. It is anticipated that these demonstration projects would be conducted using Class B biosolids.
3. There is significant interest in Class A products, especially from other PCRWRD departments and the City of Tucson. However, the market assessment did not reveal an immediate need to shift completely from Class B to Class A product at this time. Pilot-scale production of Class A material in the short-term will help build interest and diversity for PCRWRD's biosolids program.
4. The market assessment concluded that using biosolids as a fuel source is not viable for PCRWRD at this time; this may change over time, but it is not recommended that PCRWRD spend resources to develop this market unless approached by a potential user.

5. Currently, there is no requirement to upgrade PCRWRD biosolids to Class A in order to maintain reliability and viability. There appears to be no current regulatory pressure to require Class A biosolids. And there has been virtually no public scrutiny of the current Class B land application program. That said, experience in other areas of the United States has indicated that conditions may change, and Class A may be required in the future. Therefore, it is recommended that PCRWRD adopt a plan to produce Class A biosolids, if required in the future.

Using the results of the market assessment as a guide, biosolids treatment/processing alternatives were considered. A wide range of alternatives were considered and narrowed, through a series of evaluations and workshops with PCRWRD staff, to a short list of those that could be tailored and applied to Ina Road WRF. Those alternatives evaluated in detail for application to Ina Road WRF include the following:

- Alternative 1: Thermophilic Anaerobic Digestion, Class A.
- Alternative 2: Solar-dried Product (utilizing solar greenhouse driers) with Class A feed stock, Class A.
- Alternative 3: Solar-dried Product (utilizing solar greenhouse driers) with Class B feed stock, Class A and B.
- In addition, the base case of continuation of the current biosolids program was evaluated for purposes of comparison.

These alternatives were developed specifically for Ina Road WRF, and compared on the basis of life cycle costs (capital plus present value of annual operating and maintenance costs) and non-cost considerations. In addition, the sensitivity of each alternative was evaluated against various cost factors that could vary over the life of the project. The results of the evaluation indicated that the base case is the lowest cost option on the basis of capital costs and life cycle costs. However, on the basis of non-cost considerations, Alternative 1 ranked highest. Also, the base case, though cost effective currently, is most vulnerable to increases in the cost of hauling and application (see Section 3 for more complete discussion of analysis).

Biogas Market Assessment and Technology Screening

In developing a comprehensive biogas management and utilization strategy PCRWRD, the following primary goals and objectives were considered:

- Beneficially utilize biogas.
- No flaring; beneficially utilize 100 percent of biogas produced.
- Accommodate increased biogas production from WRC solids without flaring.
- Facilitate air permit modification; avoid major modification.

Biogas marketability differs from biosolids marketability in that biogas has one primary use – conversion to usable energy. That energy conversion can take several forms – thermal, electric, fuel for vehicles, or sale of the gas itself as a commodity. There are several factors that contribute to the marketability of biogas, including:

- Proximity of the point of use (or transfer of custody).
- The timing of the gas use (i.e. use in a boiler, which may be intermittent) relative to the production of the gas from the digester (which is constant, but varies somewhat in flow).
- Quality of the biogas (biogas can be “upgraded” to be the near equivalent to natural gas in quality, but at a cost).

In addition, the technology(ies) that enable biogas utilization are a significant factor in assessing the viability of biogas for a particular market. These factors and others have been taken into account in the assessment of the marketability of biogas produced at the Ina Road WRF.

Potential uses, or markets, for biogas include the following:

- Use as a fuel to generate electric power.
- Use as a fuel to generate steam.
- Use as a fuel for vehicles.
- Use as a fuel in some other process.
- Sale as a commodity, i.e. the equivalent to natural gas.

For this study, potential uses of biogas were considered together with potential technologies for biogas use in order to determine viable markets for biogas. A total of 17 biogas utilization options and technologies were considered, including multiple options in all of the above categories.

These 17 options were subjected to a fatal flaw analysis to determine those options most viable for PCRWRD. Then, viable options were further culled in a workshop format with PCRWRD staff to a short list for more detailed evaluation (see discussion in Section 4).

The results of this evaluation led to three alternatives for further consideration:

- Alternative A - Cogeneration with Internal Combustion Engine-Generators.
- Alternative B - Gas Upgrading and Sale to Premium Markets (premium markets are primarily in California where renewable fuels carry a premium price due to mandated renewable energy portfolios).
- Alternative C - Gas Upgrading with Partial Implementation of Vehicle Fuel.

Detailed life cycle cost evaluations were performed on these alternatives, including an estimation of potential revenue/savings that PCRWRD could realize from each alternative.

The evaluation of short listed Alternatives A, B and C indicate that there is potential for a significant positive net present value through implementation of Alternative B. However, this comes with significant risk associated with volatility in the premium biogas market in California. The other alternatives carry less opportunity for positive net present value, but with somewhat lower risk of market volatility. On the other hand, Alternative A – where power is generated on-site – continues to carry the risk of compromising the attractive tariff with Tucson Electric Power (TEP), the commercial electric power provider at Ina Road WRF.

Green Valley WRF Biosolids and Odor Control Evaluation

In developing a comprehensive biosolids management and utilization strategy for PCRWRD, the biosolids management and utilization at the Green Valley WRF was evaluated. Due to severe odor complaints received from neighbors to this facility, odor control capabilities and treatment options at the solids treatment portion of Green Valley WRF were included with the evaluation of biosolids management.

The solids treatment processes at the Green Valley WRF are intended to produce a Class B biosolids product and include thickening, aerated storage (storage tanks were designed to operate as aerobic digesters; however, mixing and aeration are insufficient to achieve effective digestion), dewatering, and drying in open-air drying beds. The dried biosolids product is hauled to the ASARCO Mission Mine for surface application; however, current utilization availability at that mine site has been inconsistent and future utilization opportunities are uncertain. When the ASARCO site is not available, solids are stored on-site. Other options for surface application of Class B biosolids will likely include an increased hauling distance.

The solids treatment facility at Green Valley WRF is not equipped with odor containment or odor control. Based on discussions with Green Valley WRF Operations staff, the lack of odor control system combined with difficulties related to the current solids processing activities at Green Valley WRF are causing odor

control issues. Processing difficulties, which are responsible for generating excessive odors, include insufficient aeration of the biosolids in the drying beds and the sludge in the aerated sludge holding tanks.

To address the biosolids management and odor issues at the Green Valley WRF, three alternatives were developed for further evaluation (see Section 5), including:

- Improved Solids Holding with Solar Greenhouse Dryers.
- Aerobic Digestion with Solar Greenhouse Dryers.
- Hauling Unclassified Sludge to the Ina Road WRF.

The capital costs and annual operations costs were estimated at a planning level of detail for the three alternatives at both the current BNROD flow rating of 2.0 mgd and the expected future flow of 4.0 mgd.

Alternatives were evaluated on the basis of life cycle costs (capital and annual costs) and non-cost considerations. Hauling of unclassified solids to Ina Road WRF was shown to have the lowest life cycle cost primarily due to the low capital costs compared to the other alternatives. However, it was also demonstrated that this alternative was most sensitive to potential increases in the cost of hauling (e.g. increased fuel costs). On the other hand, this alternative has the advantages of minimizing solids handling at Green Valley WRF; thereby reducing odor potential, and consolidating solids treatment and distribution at Ina Road WRF.

Summary of Recommendations

Biosolids. Retaining the current biosolids management program is recommended due to its proven reliability and cost-effectiveness. However, recognizing program vulnerability, it is recommended that PCRWRD move toward diversification in terms of products and users. Figure ES-1 summarizes the current program and one recommended scenario for diversification.

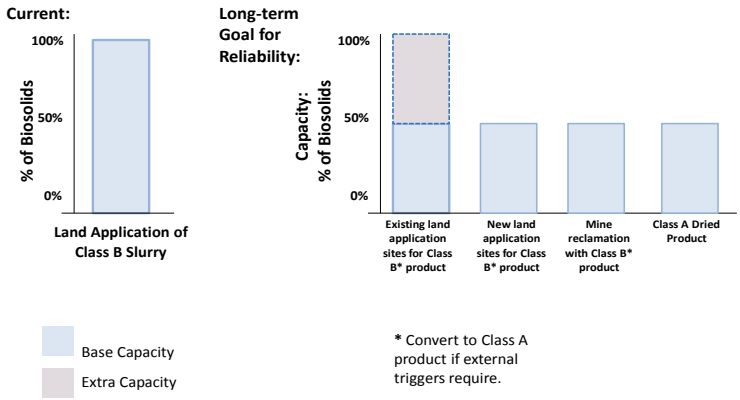

Figure ES-1 Recommended Plan for Biosolids Program Diversification

While the current program relies nearly 100 percent on land application of Class B slurry using one contractor, the recommended plan for diversification, once fully implemented, would include biosolids outlets with capacity to accommodate at least 200 percent of PCRWRD's biosolids production. By developing biosolids outlets equal to 200 percent of production, PCRWRD is protected against the loss of one outlet, as those biosolids could be shifted to other outlets which together would have the capacity to accept the increased load.

Figure ES-1 depicts one plan for diversification; other plans are possible and viable. However as represented in the figure, a diversified plan would include the following elements:

- Existing land application sites, available through the current contractor.
- New land application sites for Class B product.
- Mine reclamation with Class B product.
- Class A dried product (could also include compost).

It was determined that there is no immediate need to produce all Class A biosolids in order to maintain program reliability. Therefore, investing in a wholesale conversion to Class A production is not recommended at this time. However, it is recommended that PCRWRD adopt a plan to convert to a Class A process in case at some time in the future production of Class A biosolids is mandated.

As a result of evaluations conducted as part of this study, PCRWRD developed an interest in side stream treatment; specifically, a potential new process for the Ina Road WRF to help manage nitrogen (and ultimately phosphorus) loads that are returned to the liquid treatment process at the Ina Road WRF from solids dewatering. Separate side stream treatment – where ammonia and/or phosphorus loads could be reduced - could provide the following additional advantages:

- Reduced cost of operations of the liquid treatment processes.
- More reliable operation of the liquid treatment process, in terms of consistently meeting permit limits.
- Potential recovery of nutrients as a marketable product (this depends on the process selected for side stream treatment).
- Potential increase in capacity at the Ina Road WRF.

It is recommended that PCRWRD investigate further whether side stream treatment could be cost effective and beneficial for Ina Road WRF.

Biogas. The conclusions from the evaluation in Section 4, including substantial input from PCRWRD is that gas upgrading and sale is the recommended alternative for biogas produced at the Ina Road WRF. The following were identified as the most significant advantages that gas upgrading and sale offers PCRWRD:

- Best potential for positive economic return on PCRWRD's capital investment in gas upgrading facilities, provided gas is sold to a premium market (i.e. a market like California where a premium is placed on biogas and other renewable fuels due to state mandated percentages of renewables in energy utility portfolios), and assuming that this market for out of state biogas remains strong in California and other states (thereby keeping the value of biogas high).
- Least complicated impact on air permitting for the Ina Road WRF.
- Provides flexibility for use of upgraded gas for other uses, such as vehicle fuel; once the biogas is upgraded to pipeline quality it can be used for any purpose that natural gas is used for. PCRWRD is interested in converting a portion of their fleet vehicles to operate on compressed natural gas (CNG), and by upgrading biogas to pipeline quality, PCRWRD will have the opportunity to divert a portion of their upgraded biogas for use as vehicle fuel.
- Unlike on-site generation of electric power using biogas as a fuel, gas upgrading and sale does not compromise PCRWRD's negotiated power purchase tariff with TEP.
- From the perspective of design, equipment delivery and construction (and permitting) this alternative is the simplest and likely the quickest to implement. This is an important consideration so as to minimize the time that biogas will be flared at Ina Road WRF (after the existing Energy Recovery Facility is shut down and prior to full-implementation of gas utilization).
- Properly designed, the gas upgrading system will have the capability to accommodate a wide range in biogas production rates without flaring.

As stated above, PCRWRD is very interested in converting at least a portion of its vehicle fleet to CNG. As PCRWRD currently has very few CNG compatible vehicles, it is expected that this conversion will occur over time as vehicles are replaced. By implementing the gas upgrading system as described above, PCRWRD retains the flexibility to use upgraded biogas as vehicle fuel (termed BioCNG).

PCRWRD's decision on whether to invest in fleet conversion to CNG is independent of PCRWRD's decision to invest in biogas upgrading to pipeline quality. Given PCRWRD's interest in vehicle fleet conversion to CNG, it is recommended that this proceed independently from PCRWRD's biogas utilization implementation. If both are implemented – biogas upgrading to pipeline quality, and vehicle fleet conversion the CNG – then the decision whether to divert upgraded biogas to vehicle fuel can be made on its own merit at the time.

It is further recommended that PCRWRD implement biogas upgrading to pipeline quality biomethane using a Design-Build-Finance-Own-Operate (DBFOO) delivery method. The basis for this recommendation is provided in Section 6 where multiple options for project delivery and biomethane marketing were considered for the recommended biogas upgrading project. Besides being responsible for financing, designing, building and operating the biogas upgrading facilities, the DBFOO contractor would also be responsible for marketing the biomethane product and providing PCRWRD with a negotiated revenue stream in return for accepting the raw biogas. The primary advantages for proceeding with DBFOO for biogas upgrading project delivery are summarized below:

- Based on the assumptions used, this approach is projected to provide the highest net present value, and thus the highest potential return to PCRWRD for the biogas.
- The contract with the DBFOO company can be written to virtually eliminate PCRWRD's exposure to financial loss resulting from inability to recover the capital investment and operating costs through the sale of the biomethane.
- PCRWRD has less exposure to volatility in the biomethane and natural gas markets.
- PCRWRD can maintain focus on its core business of treating wastewater.

Green Valley WRF. The results of the evaluation in Section 5 demonstrated that consolidating the treatment and management of biosolids from Green Valley WRF with biosolids at Ina Road WRF would require less capital costs, and have somewhat lower life cycle costs than making improvements to biosolids treatment at Green Valley WRF. Consequently, the following are recommendations for biosolids and related odor control improvements at the Green Valley WRF (see Section 6 for a more complete listing of recommendations):

- Treatment (stabilization and air drying) of biosolids produced from the Biological Nutrient Removal Oxidation Ditch (BNROD) process will be discontinued.
- Biosolids produced from the BNROD process will be thickened and hauled to the Ina Road WRF for treatment and dewatering or thickening prior to land application (assuming the current land application program continues). A new liquid biosolids slurry load-out facility will be provided for loading tanker trucks for hauling to Ina Road WRF (or to the conveyance system upstream of the Water Reclamation Campus).
- The existing solids aeration tanks will be used for short-term storage of biosolids prior to thickening and/or hauling to Ina Road WRF. The existing solids holding tanks will be retrofitted with improved aeration and improved mixing in order to hold solids while minimizing odor production.
- Recognizing that the solids storage tanks may still be a source of odor, tanks will be covered and the head space ventilated to odor control (biofiltration).
- A new odor treatment system will be provided for the new foul air streams generated through these improvements; a biofilter is the recommended odor control process.

As discussed in Section 5, the results of the Green Valley WRF evaluation discussed above has significant implications for these other facilities. These are summarized below:

- The Green Valley WRF evaluation demonstrated hauling liquid-slurry, unclassified solids to Ina Road WRF for treatment and incorporation into the larger PCRWRD biosolids management program is cost effective and has other benefits, such as consolidating solids treatment and distribution at one location.
- Converting to on-site solids handling at the other Sub-regional facilities, with biosolids haul and application to beneficial use at these sites, will require considerable investment in new processes, odor control and management of biosolids product in order to avoid the issues encountered at Green Valley WRF.
- The other Sub-regional facilities already have in place the solids thickening, truck load-out facilities recommended for Green Valley WRF; by retaining this approach for solids management at these plants, no further capital investment is needed.

For these reasons, it is recommended that the Sub-regional facilities that currently haul solids to Ina Road WRF continue this as their process for solids management. Specifically, these include the Avra Valley WRF, the Corona de Tucson WRF and the Mt. Lemmon WRF.

Section 6

Summary of Recommended Plans

This section presents a summary of the recommended plans for biosolids and biogas utilization for Pima County Regional Wastewater Reclamation Department (PCRWRD). The development of these recommendations has drawn upon the following:

- Results of alternative development and evaluation as described in the preceding sections.
- Discussions and input from PCRWRD staff during multiple workshops conducted throughout the development of this Master Plan (see Appendix G for a compilation of workshop notes and presentation material).
- Results of the Request for Expressions of Interest (RFEI) process conducted by PCRWRD in support of this Master Plan (see Appendix B for summary of RFEI process and responses).
- For biogas recommendations, input from subconsultants who are specialists in the natural gas and renewable gas marketplace, as well as financial consultants providing analysis and input on the economic considerations associated with project delivery options.

Consequently, the recommendations presented in this section represent a compilation and melding of data and information received from various sources, including input from PCRWRD staff. As a result, in order to best meet the long and short term needs of PCRWRD, the recommended plans for both biosolids and biogas utilization have been tailored from the alternatives evaluated previously to reflect input from these multiple sources, as well as meet the specific objectives of PCRWRD.

The paragraphs that follow present the recommended plans for biosolids utilization, managing biosolids from Sub-regional facilities, and utilization of biogas produced at the Ina Road Water Reclamation Facility (WRF). In all cases, it is assumed that the Regional Optimization Master Plan (ROMP) program has been completed with recommended facilities constructed and in operation. This includes the upgrade and expansion of the Ina Road WRF, including conversion of the solids dewatering facility to allow for continued production of slurry or the production of dewatered cake; it is also assumed that the construction and start-up of the Water Reclamation Campus (WRC) is complete and solids transfer to Ina Road WRF has been implemented and is operational. Finally, it is assumed that the existing Energy Recovery Facility at Ina Road WRF has been de-commissioned and a new Central Plant has been implemented to meet the plant's thermal energy demands.

6.1 Biosolids – Improve Long Term Reliability

As stated in Section 3, PCRWRD's current biosolids management program has been cost-effective and reliable for over 20 years. The current system relies on a single contractor for land application of Class B biosolids, in slurry form, to agricultural lands, mostly within 10 miles of the Ina Road WRF. This is one of the most cost-effective biosolids programs in the country. It is compliant with state and federal regulations, and public scrutiny of the program has not been an issue for PCRWRD or the contractor. However, as also stated in Section 3, the current program is vulnerable to potential changes that could increase the cost of biosolids management and/or severely curtail the current program. Therefore, recommendations for biosolids management are focused on actions necessary to improve the long term reliability of PCRWRD's biosolids program, while continuing to utilize biosolids beneficially as in the current program, and maintaining the relative cost-effectiveness of the program.

There are two over-arching recommendations for biosolids utilization:

1. Retain the current land application program (contractor and land application sites) for as long as the program remains viable and cost-effective.
1. Begin to diversify the biosolids program in terms of biosolids products produced, and potential users of those products.

Consequently, recommended near term capital investments in biosolids treatment and disposal are limited; however, some short term actions by PCRWRD are recommended in order to provide a foundation for long term reliability. In addition, it is recommended that PCRWRD be prepared to convert to production of a Class A biosolids product should regulations and/or biosolids market conditions (such as public perception) change significantly. The time line for this conversion to Class A is not defined as no current drivers for Class A have been identified. Indeed, the requirement for Class A may never evolve; however, it is recommended that PCRWRD include this potential conversion in its long term capital and biosolids management planning.

The specifics of these recommendations are discussed in the following paragraphs.

6.1.1 Recommendations for Biosolids Program Diversification

As discussed above, retaining the current biosolids management program is recommended due to its proven reliability and cost-effectiveness. However, recognizing program vulnerability, it is recommended that PCRWRD move toward diversification in terms of products and users. Figure 6-1 summarizes the current program and one recommended scenario for diversification.

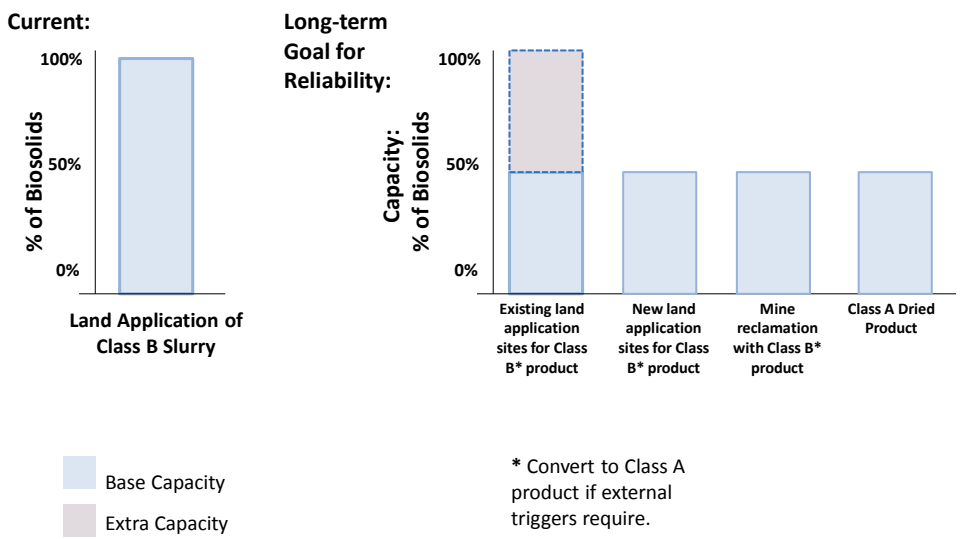

Figure 6-1 Recommended Plan for Biosolids Program Diversification

While the current program relies nearly 100 percent on land application of Class B slurry using one contractor, the recommended plan for diversification, once fully implemented, would include biosolids

outlets with capacity to accommodate at least 200 percent of PCRWRD's biosolids production. By developing biosolids outlets equal to 200 percent of production, PCRWRD is protected against the loss of one outlet, as those biosolids could be shifted to other outlets which together would have the capacity to accept the increased load.

Figure 6-1 depicts one plan for diversification; other plans are possible and viable. However as represented in the figure, a diversified plan would include the following elements:

- Existing land application sites, available through the current contractor.
- New land application sites for Class B product.
- Mine reclamation with Class B product.
- Class A dried product.

Each element is discussed in sub sections 6.1.3.1 through 6.1.3.4. The potential for conversion to an all Class A product is discussed in a later subsection.

6.1.2 Planned Modifications to Ina Road WRF Solids Dewatering Process

It should be noted that the current plans for upgrading and expanding the Ina Road WRF already includes one feature that contributes to diversification – modification of the centrifuge dewatering process to allow production of either slurry (similar to current) or dewatered cake. The recommendations below assume that these modifications will be implemented and therefore dewatered cake is a biosolids product that PCRWRD can produce per the Ina Road Capacity and Effluent Quality Upgrade Final Design Report by CH2MHill (January 2011). The expected cake dryness (based on dewatering facility design criteria) is 22 percent solids.

Though capability will exist to produce slurry and cake, input from PCRWRD staff indicates that their operational plan will be to produce one or the other. The effort necessary to convert from slurry production to cake production to slurry production makes frequent conversion prohibitive.

6.1.3 Recommended Actions for Program Diversification

Recommended short term actions are discussed in the paragraphs below. It should be noted that given the current viability of the current biosolids management program, there is no strong schedule driver that compels PCRWRD to take action by a given date. However, from other agencies' experience, fully developing alternative markets will take time, possibly years. Therefore, it is recommended that PCRWRD begin as early as next fiscal year in implementing some or all of these recommendations so that the benefits of program diversification can begin to realize and enhance overall biosolids management reliability in case an unexpected change occurs in the current program.

6.1.3.1 Retain Existing Land Application

It is recommended that the current land application program be retained and supported for as long as it remains viable and cost-effective. The reason is to continue to take advantage of the cost-effectiveness of the program; virtually any other means of biosolids disposal or beneficial use will be more expensive than the current program.

The existing land application program handles nearly 100 percent of the PCRWRD biosolids production, and there are sufficient lands to accommodate more than 100 percent of PCRWRD projected production. Therefore, this provides PCRWD with a reliable, high capacity outlet provided it remains viable and cost-effective. Section 3 provides a summary of some longer term factors that could compromise the viability of the current program. In addition, the following factors, each of which is related, may also impact the cost-effectiveness and/or reliability in the short term:

- Re-bid of biosolids haul and application contract – periodically, PCRWRD must re-bid these services. The current contractor – AvraGro – has been the successful bidder for years. However, this could change in an open bid environment. Any new contractor must live-up to the high standards of reliability provided by AvraGro; otherwise, the reliability of the program may be compromised.
- Conversion to dewatered cake – whether or not PCRWRD decides to convert to dewatered cake production after the modifications are completed may depend on the re-bidding of haul and application services. It is likely PCRWRD will provide bidders the option of working with either product, and this could influence the competitive landscape between rival bidders, including AvraGro. For example, AvraGro currently only has equipment suitable for slurry application. Another contractor who already has equipment suitable for cake application could be at a competitive advantage to bid against AvraGro.
- Growth and development in the current land application area may reduce land availability or create public pressure to find alternatives.

Regardless, it is anticipated that haul and agricultural land application of Class B biosolids will remain viable and cost-effective on some level and should continue to as one element of the overall program.

6.1.3.2 Develop New Agricultural Land Application Sites

The current biosolids contractor has access to agricultural land in excess of current needs for 100 percent of projected biosolids production. However, some of this land is unavailable from year to year due to conflicts with crop management schedules. Also, some of the land would require a much longer haul distance and could impact the cost-effectiveness of the program. And as stated previously, some of the close-in land is vulnerable to loss to urbanization. Therefore, it is recommended that additional land application sites be developed and permitted. Further, it is recommended that PCRWRD begin to use some of these sites for a percentage of the biosolids production. The exact percentage of biosolids to be diverted depends on the amount of land available and location of the land (cost of hauling).

These new sites could be developed unilaterally by PCRWRD, in partnership with the biosolids program contractor, or through another contractor. Using the same contractor to develop new sites is administratively simpler; however, program diversity and hence reliability is improved if PCRWRD or another contractor is responsible for these new sites.

The biosolids market survey identified PCRWRD owned ranches with active agricultural operations that could be developed into biosolids land application or reclamation sites. In addition, other lands could be identified and developed. In all likelihood, the cost of hauling to these new lands will be more than the current haul costs. However, from a reliability perspective, it is recommended that PCRWRD make this investment in the short term to promote long term diversity and reliability.

6.1.3.3 Develop Mine Reclamation

Conversations with Freeport McMoran, Inc (FMI; see Appendix A) indicated an interest in accepting biosolids for mine tailings reclamation. Specifically, biosolids could be used on tailings piles to promote permanent vegetation establishment, stabilize slopes, reduce dust, etc. Also, tailings are typically not open to public access and therefore the quality of biosolids used for reclamation could be Class B rather than Class A (must be confirmed with FMI). The timing of FMI's need for biosolids relative to PCRWRD's production of biosolids is an important consideration. Biosolids are produced continuously from the Ina Road WRF. FMI is implementing a program of "concurrent reclamation" whereby a portion of active tailings piles would be reclaimed each year. Thus, through a partnership between PCRWRD and FMI a portion of each year's biosolids production could be sent to FMI for tailings reclamation providing an

additional outlet for biosolids for PCRWRD, and a viable and cost-effective material to assist FMI in their tailings reclamation program.

Developing mine tailings reclamation into a viable outlet for PCRWRD biosolids will require investment in establishing a working relationship with FMI (and other mining companies who may be interested). It is recommended that the first step in establishing that relationship is a tailings reclamation demonstration project using Ina Road WRF biosolids at the FMI Sierrita mine site. The demonstration project would include a small percentage of the potential biosolids capacity of the tailings reclamation, but sufficient to achieve the following objectives:

- Gain Arizona Department of Environmental Quality (ADEQ) approval for tailings reclamation with biosolids. This is a very important consideration for FMI, and would likely require numerous discussions with ADEQ prior to, during and after the demonstration project.
- Determine the most beneficial and cost-effective form of biosolids application – slurry or dewatered cake. The haul distance to the FMI-Sierrita mine suggests that dewatered cake will be more cost-effective than slurry.
- Test application rates to determine optimum performance for local conditions.
- Test biosolids application equipment and operational methods. Varying terrain of reclamation sites, and the fine texture of the tailings, may influence the choice of application equipment.
- Confirm that odors will not be an issue. Some tailings piles have advanced toward the Town of Green Valley; therefore, FMI wants to confirm that future application of biosolids will not result in an odor issue with nearby residents.

Assuming that the demonstration project yields positive results for both FMI and PCRWRD, the relationship can be expanded and mine reclamation can become a reliable outlet for PCRWRD biosolids into the future.

It should be noted that PCRWRD has been providing biosolids to the ASARCO mine for tailings reclamation off and on for several years. The biosolids have come from the Green Valley Wastewater Reclamation Facility (WRF). The results of the market survey indicate that ASARCO will not likely be an outlet for PCRWRD biosolids in the future. Nonetheless, it is recommended that PCRWRD periodically make contact with ASARCO and other mining operations in Southern Arizona in order to continually explore the potential benefits to both the mines and PCRWRD in mine reclamation using biosolids.

A successful demonstration with FMI will help stimulate demand for biosolids in mine reclamation. It is important for PCRWRD to have technical support for designing and monitoring the demonstration. Support could be provided by the University of Arizona, a consultant with specific experience in mine tailings reclamation using biosolids, or a combination of the two organizations. Design considerations include determining the best operational approach from application of biosolids through tillage and planting. Two to three application rate variables plus a control plot with commercial fertilizer should be provided. Biosolids application rates will be in the range of 10-20 times higher than a typical agricultural rate on a one-time basis. Monitoring environmental effects including nutrients, metals, and possibly bacteria will be a critical part of the study.

6.1.3.4 Develop Class A Dried Product

It is recommended that PCRWRD also begin to diversify the biosolids products it produces. One opportunity for diversification is to produce a Class A product that could be recycled within the local community as a soil amendment. A Class A product could be produced by thermophillic digestion, solar drying, or a combination of the two.

It is recommended that production of Class A dried product be considered for inclusion in PCRWRD's plan for biosolids program diversification. This recommendation is based on the interest in Class A product expressed by multiple potential users of biosolids during the market survey portion of this study. Development of a robust market for dried biosolids product provides another outlet for biosolids which contributes to program diversity and long term reliability. However, development of a robust market for dried product requires an investment in 1) technology/facilities to product the dried product, and 2) marketing of the product to potential users. Therefore, it is further recommended that PCRWRD invest in a demonstration scale project to produce sufficient dried product to provide to potential users on a trial basis. There are two primary objectives of a demonstration scale dried product project:

1. Develop interest and demand for the dried product.
2. Demonstrate the technology at a small scale, for a modest capital investment, in order to better define design criteria for a larger, production scale system.

Each is discussed below.

Develop Demand for Dried Product. Potential users of dried biosolids include municipal parks, golf courses, turf farms, nurseries, etc. In all cases, potential users will want to "try-out" the material to confirm that it will be beneficial to their operations and/or more cost-effective than commercial fertilizer, topsoil, etc. Production of a small quantity of dried product through a demonstration scale project provides samples for distribution to potential users. It is recommended that between 300 and 400 cubic yards of dried product be produced per year in order to distribute sufficient material to demonstrate the value to potential users. If the dried biosolids product performs well, then presumably the user will be interested in more. If multiple users have a positive experience using the dried product, then the demand will likely justify a larger investment in facilities to produce dried product. On the other hand, if demand for the product fails to materialize, PCRWRD's investment in drying facilities is limited to just the demonstration scale facilities, and further investment is not justified.

Demonstration Scale Technology/Facilities for Dried Product Production. The objectives of implementing a demonstration scale drying facility are 1) produce sufficient quantity of dried product to distribute to potential users on a trial basis, and 2) demonstrate the technology in order to develop sound design criteria for potential development of a production-scale drying facility. Also, operation of the demonstration scale facility will also provide valuable information on key operational parameters. This is especially important in terms of confirming the operational requirements necessary to achieve a Class A dried product.

The detailed evaluation of short-listed alternatives in Section 3 considered the production of Class A dried product for part of PCRWRD's biosolids output using enhanced solar greenhouse drying. As shown in the detailed evaluation of short-listed alternatives in Section 3, the capital costs for enhanced solar greenhouse drying is high. Other types of drying are available, namely thermal drying using an external fuel source (e.g. natural gas), or biogas produced at Ina Road WRF. The cost of thermal drying is also high, both in terms of capital costs and operational costs (or in the case of using biogas, the lost potential for other beneficial uses of biogas). Also, thermal drying based on the combustion of a fuel, regardless of source, has air permitting implications that could further increase the cost of thermal drying. Therefore, it is recommended that solar green house drying technology be explored first for implementation at a demonstration scale at Ina Road WRF. If solar greenhouse drying proves to not be cost-effective, then thermal drying should be considered. At that time the cost in terms of fuel can be better evaluated.

It is recognized that production of a Class A dried product at any scale will be significantly more expensive, on a unit cost basis (i.e. dollars per dried ton), than the current program costs or the costs of

the other potential diversification options. As such, this can be considered a lower priority than developing the other options. Nonetheless, in the long term the development of a robust market for dried product will contribute to the diversity and reliability of PCRWRD's biosolids management program.

Note also that any drying technology will require dewatered cake as a feedstock to the dryer; it is not practical to feed slurry to a dryer to produce a dried product as too much energy will be required to evaporate the additional water in a slurry product. Therefore, PCRWRD's decision to produce only dewatered cake, or slurry will determine whether it is practical to implement a drying demonstration project.

6.1.4 Future Conversion to Class A Digestion

The current program of land application of biosolids requires only Class B quality biosolids. The recommended actions for diversification discussed above also require only Class B biosolids (it is assumed the process to produce Class A dried biosolids starts with Class B feed stock).

However, as discussed previously, various changes in the regulatory and/or public perception arena may require production of Class A biosolids at some time in the future. Under these circumstances, it is recommended that all biosolids produced from the Ina Road WRF be Class A. By making this conversion, biosolids outlets will not be constrained by product classification, and program reliability – in terms of outlets for biosolids - can be maintained.

One method to achieve Class A quality is conversion of the anaerobic digestion process at Ina Road WRF to a thermophilc batch process, as described in Section 3. Specifically, the digesters would be operated at thermophilic temperatures (over 130 deg F), and the flow scheme of solids through the process would be changed so that at least 3 tanks are operated in a batch mode so that the regulatory time-temperature requirements of the 40CFR, Part 503 regulations are met (specifically, Class A Alternative 1 for sewage sludge less than 7 percent solids). This process modification offers the following advantages to PCRWRD:

- By converting the base solids treatment system at Ina Road WRF to a Class A process, all solids produced will meet Class A standards. This should remove many restrictions for most if not all biosolids beneficial use outlets.
- Biosolids beneficial use options available to PCRWRD will remain viable after conversion to Class A.
- Existing infrastructure investment at the Ina Road WRF is fully utilized; preliminary evaluations indicate that the 4 existing digester tanks, plus the 2 new digester tanks being constructed as part of ROMP will be sufficient to provide thermophilic digestion, and provide batch operation to meet Class A standards, for projected 2030 biosolids production.

Implementing this process modification will require capital improvements to the digesters and support facilities; these modifications are described in Section 3, and include:

- Additional and/or higher capacity heat exchangers.
- Solids transfer pumping and piping between digesters.
- Conversion of floating covers to fixed covers.
- Insulation on the 4 existing digesters.

In addition, operation at thermophilic temperatures will require more heat energy input to the digestion process. This will result in either:

- Use of more biogas for meeting the higher thermal needs of thermophilic digestion, making less biogas available for beneficial use and revenue production; or

- Purchase of an alternative fuel (e.g. natural gas) to meet the thermal demands, which adds operating cost to the biosolids program.

Due to the capital costs involved, and the additional thermal energy demands, it is recommended that conversion to Class A digestion not be implemented until circumstances indicate this will be required. Examples of these "triggers" to move to Class A include the following:

- Regulatory changes, most likely at the state level, that would require Class A biosolids for the beneficial use outlets used by PCRWRD.
- Change in public perception/expectations of the biosolids program such that conversion to Class A biosolids is considered mandatory in order to retain the beneficial use outlets being relied upon by PCRWRD. This has been the most common scenario in other states where public agencies have been forced to convert to a Class A process in order to continue to utilize biosolids outlets (i.e. land application) in another agency's jurisdiction.

Fortunately, there is no current evidence to indicate that a conversion to Class A will be required anytime in the foreseeable future. Further, by maintaining a well-managed biosolids program, with appropriate public outreach to continually demonstrate the value of PCRWRD's program using Class B biosolids, PCRWRD can proactively avoid being put in a position where conversion to Class A is required due to public pressure. Nonetheless, it is recommended that PCRWRD continually monitor regulatory trends, and public opinion trends in order to identify as early as possible a potential shift in requirements.

If and when conversion to Class A is required, it is recommended that PCRWRD re-consider technologies for producing Class A biosolids. Other options besides thermophilic batch operation which could offer operational and cost advantages. Regardless, it is estimated that full implementation of a conversion to Class A digestion will require 3–4 years (including design and staged construction while maintaining the Class B digestion process). Therefore, early identification of changes requirements will be important to avoiding disruption to the biosolids program while the conversion to Class A is in progress.

6.1.5 Side Stream Treatment

During the course of this master planning effort, information has been developed/presented that has led to PCRWRD's interest in improvements not directly related to biosolids utilization, but potentially important to PCRWRD's overall wastewater treatment operations. Side stream treatment has been identified as a potential new process for the Ina Road WRF to help manage nitrogen (and ultimately phosphorus) loads that are returned to the liquid treatment process at the Ina Road WRF.

Currently, digested solids are thickened to approximately 8 percent solids using the existing centrifuges at the Ina Road WRF. The anaerobic digestion process results in the conversion of organic nitrogen and phosphorus to soluble forms which pass into the centrate through the dewatering process. Centrate is returned to the liquid treatment process for treatment. The high concentration of ammonia and phosphorus compounds in the centrate imposes a significant burden on the liquid treatment processes at the Ina Road WRF. The loads will be greater if/when Ina Road WRF converts to digested solids dewatering (rather than thickening) resulting in more liquid and loads being returned to the Ina Road WRF.

According to CH2MHill, the designers of the Ina Road WRF upgrade and expansion, the process design for the Ina Road WRF accommodates these side stream loads. A centrate storage system has been included in the design to "dampen" out the loads over time, especially when solids dewatering is occurring for only part of each day. However, separate side stream treatment – where ammonia and/or phosphorus loads could be reduced - could provide the following additional advantages:

- Reduced cost of operations of the liquid treatment processes.
- More reliable operation of the liquid treatment process, in terms of consistently meeting permit limits.
- Potential recovery of nutrients as a marketable product (this depends on the process selected for side stream treatment).

These potential benefits must be weighed against the added capital and operating cost of side stream treatment.

For these reasons it is recommended that PCRWRD investigate side stream treatment through an independent study. The objectives of the study will include:

- Assess the cost-effectiveness of side stream treatment for Ina Road WRF; that is, to what degree will liquid stream treatment be improved through the implementation of side stream treatment.
- Evaluate alternative processes for side stream treatment.
- Determine the timing for implementation; that is, will side stream treatment be more cost effective later when flows and loads to Ina Road WRF have increased closer to design loads.

There are many process options for side stream treatment. The following are only a few of the potential process categories that could be considered in a side stream treatment study:

- Physical/chemical (Struvite recovery via a proprietary process marketed by Ostara, or others).
- Biological nitrogen removal based on specialized Anammox bacteria.
- More conventional processes, such as Sequencing Batch Reactors and activated sludge, modified specifically for application to side stream treatment.

Some process options are proprietary. Therefore, consideration of project delivery options (alternative delivery versus conventional Design-Bid-Build) should also be included in the study.

6.1.6 Summary of Biosolids Recommendations

Table 6-1 below summarizes the master plan recommendations for biosolids management, including recommendations for program diversification and future improvements to implement Class A digestion. For capital funding purposes, capital cost estimates are provided where appropriate; not all recommendations have a capital cost associated with them – see comments in the table. In addition, side stream treatment is included as a recommendation and a capital cost estimate is provided as an allowance. A separate study is recommended initially to determine whether side stream treatment is feasible and beneficial for Ina Road WRF, and what process is most appropriate. Once this is completed, and side stream treatment is confirmed, then a more accurate estimate of capital costs can be provided.

Finally, it is recommended that PCRWRD consider assigning a person or group to direct and manage the diversification of PCRWRD's biosolids beneficial use program. The specific assignments of this position may include the following:

- Manage re-bidding current biosolids haul and agricultural land application contract, with inclusion of dewatered cake as a product option.
- Development of demonstration projects as discussed above for purposes of diversification.
- Manage public outreach to highlight the benefits of PCRWRD's biosolids program to rate payers and the regional environment.
- Marketing of biosolids products to potential users (in addition to current and re-bid agricultural land application program).
- Maintain dialogue with ADEQ to stay abreast of any potential changes in regulations that could impact biosolids management in the future.

Table 6-1. Summary of Biosolids Utilization Master Plan Recommendations with Estimated Capital Cost Allocation

Recommendation	Estimated Capital Cost dollars (see note)	Recommended Timing	Comments
Recommendations for Program Diversification			
Retain Existing Land Application	See Comment	Ongoing	There is no capital cost associated with this recommendation assuming the current system of haul and application through a contractor is retained.
Develop New Land Application	$1 Million	Implement over 5 years	Capital cost should be considered an allowance, and assumes PCRWRD purchases equipment for new land application sites. Cost does not include purchase of land. Capital costs will vary depending on the capacity of sites quantity of biosolids allocated to these sites. Capital costs may be zero if haul and application is contracted similar to current.
Develop Mine Reclamation	See Comment	Initiate dialogue with FMI immediately; target pilot program starting 2013	It is assumed that haul of biosolids to mine site for pilot program can be accomplished using current contractor, or use equipment for new land application sites.
Develop Class A Dried Product (demonstration project)	$2.5 Million	Implement demonstration scale project in 2013	Estimated cost based on 150 dry ton per year (300 – 350 cubic yards per year) demonstration scale solar greenhouse dryer system. An equivalent sized thermal dryer for demonstration purposes is estimated to cost approximately $4-5 million.
Future Conversion to Class A	$10 Million	Undefined; when needed	Capital costs are to convert existing digesters to operate thermophically in a Class A digestion mode (partial batch).
Implementation of Side Stream Treatment	$2.5 Million	Timing to be defined by side stream treatment evaluation	Capital cost shown is a placeholder allowance; separate study of side stream treatment options will determine 1) if side stream treatment is feasible and cost effective, and 2) capital cost, assuming PCRWRD led project delivery.

Note: Capital cost estimates were developed in 2011; escalation has not been included. These are planning level cost estimates, not based on detailed design development.

6.2 Biogas Utilization – Gas Upgrading and Sale Preserves Opportunities for Other Future Uses

In Section 4 a wide range of biogas utilization alternatives were considered, including using conditioned biogas as fuel for on-site cogeneration, upgrading the gas to pipeline quality and selling the gas for revenue, and using a portion of the upgraded gas as vehicle fuel. The conclusions from the evaluation in Section 4, including substantial input from PCRWRD is that gas upgrading and sale is the recommended alternative for biogas produced at the Ina Road WRF. Further, with input from a team of gas consultants, a financial consultant, and input from PCRWRD, it is recommended that this system be implemented through the engagement of a third party private entity that would Design-Build-Finance-Own-Operate the facility while providing PCRWRD revenue for the raw biogas. The paragraphs below further describe these recommendations.

6.2.1 Advantages of Gas Upgrading and Sale

The evaluation in Section 4 identified the following as the most significant advantages that gas upgrading and sale offers PCRWRD:

- Best potential for positive economic return on PCRWRD's capital investment in gas upgrading facilities, provided gas can be sold at a premium price over the commodity cost of natural gas.
- Least complicated impact on air permitting for the Ina Road WRF.
- Provides flexibility for use of upgraded gas for other uses, such as vehicle fuel; once the biogas is upgraded to pipeline quality it can be used for any purpose that natural gas is used. PCRWRD is interested in converting a portion of their fleet vehicles to operate on compressed natural gas (CNG), and by upgrading biogas to pipeline quality. PCRWRD will have the opportunity to divert a portion of their upgraded biogas for use as vehicle fuel.
- Unlike on-site generation of electric power using biogas as a fuel, gas upgrading and sale does not compromise PCRWRD's negotiated power purchase tariff with Tucson Electric Power.
- From the perspective of design, equipment delivery and construction (and permitting) this alternative is the simplest and likely the quickest to implement. This is an important consideration so as to minimize the time that biogas will be flared at Ina Road WRF (after the existing Energy Recovery Facility is shut-down and prior to full-implementation of gas utilization).
- Properly designed, the gas upgrading system will have the capability to accommodate a wide range in biogas production rates without flaring.

The following section provides a brief overview of the proposed configuration of a biogas upgrading facility for Ina Road WRF.

6.2.2 Gas Upgrading Facilities – Proposed System Configuration

The gas upgrading system will be configured around a vendor designed and provided gas upgrading technology. Likely technologies include Pressure Swing Absorption (PSA), water solvent systems, membrane systems, and amine systems. Selection of the most appropriate upgrading technology will be made at the time of implementation. Each type of technology will likely be provided as a vendor-engineered, pre-packaged system that would be installed at the Ina Road WRF and connected to raw biogas supply. Connection and integration of the gas upgrading system with the Ina Road WRF would require site-specific engineering and construction.

It is further recommended that the gas upgrading facilities be designed to treat all biogas produced at the Ina Road WRF. Though some biogas may be required for use at the Ina Road WRF Central Plant in order to meet the plant's thermal energy demands, there are advantages for having all biogas treated to pipeline quality and then diverted to the Central Plant. These include the following:

1. Use of biogas in boilers requires some treatment in order to remove hydrogen sulfide, moisture and siloxanes so as to reduce the frequency and cost of boiler maintenance.
2. Having separate gas conditioning process dedicated to boiler operation adds another separate process to the plant that must be operated and maintained.
3. Though boilers do not require removal of carbon dioxide, removal of carbon dioxide is not detrimental to the boiler; in fact, natural gas is provided as a back-up fuel for the boiler.
4. Due to the expected wide fluctuations in Central Plant fuel demand (due in part to seasonal variation in thermal demands), the gas upgrading facilities will need to be designed for full gas production in order to accommodate periods when biogas production is high and Central Plant fuel demand is low. Consequently, there is no capital cost advantages for the gas upgrading process by diverting some biogas to the Central Plant prior to gas upgrading; that is, the gas upgrading facilities must be sized for the maximum biogas production regardless.

The Central Plant design is being completed concurrently with the completion of this master plan; it is understood that the Central Plant design includes the ability to use either raw biogas or natural gas as the boiler fuel. Due to item 4 above, this design decision does not materially impact the recommendations or sizing of the biogas upgrading facilities recommended in this report.

Key features of the recommended gas upgrading system include the following:

- Raw biogas pre-conditioning, including hydrogen sulfide removal. Hydrogen sulfide must be removed either upstream or downstream of the gas upgrading system to meet pipeline quality. Some gas upgrading systems require removal upstream to prevent damage to downstream components. Likely technologies include iron sponge or other chemical treatment systems. Multiple units, plus a spare, are recommended so that units may be taken out of service and maintained periodically without impacting gas upgrading capacity.
- Gas upgrading equipment. The proprietary gas upgrading systems are designed to remove carbon dioxide, but will also remove moisture and siloxanes. The gas quality specification for the final upgraded gas product will be determined by the company who owns and operates the pipeline into which the upgraded biogas will be injected. Multiple gas upgrading units are recommended so that units may be taken out of service and maintained periodically while maintaining at least partial biogas upgrading capacity. As a minimum, two gas upgrading systems are recommended to be installed each with a capacity of one half of the peak day gas flow in 2040 (assuming a 1.3 multiplier of average gas production). This would provide an upgrading capacity of 65 percent of the average gas production in 2040 with one system offline for maintenance.
- A small thermal oxidizing flare is provided with the PSA systems or membrane systems to remove residual methane in the off-gas released from the cleaning process. The water solvent system or amine system would emit very small quantities of methane similar to an enclosed flare.
- Odorizing station. Prior to discharging into the utility pipeline, the upgraded biogas must be odorized similar to natural gas.
- Gas quality monitoring equipment. The quality of the upgraded biogas must be continually monitored to ensure it meets pipeline specifications.
- Compression station and pipeline for delivery to the natural gas pipeline. Each gas upgrading technology includes compression to drive the upgrading process. Additional compression is required

to raise the pressure at or slightly above pipeline pressure (350 pounds per square inch gauge (psig) for Southwest Gas). Similar to the gas upgrading system, a minimum of two compressors are recommended each with a capacity of one half of the peak day gas flow in 2040 (assuming a 1.3 multiplier of average gas production).

- Various utilities necessary to support the gas upgrading process – electric power, controls, plant water, and process and stormwater drains. The gas upgrading facilities can be located outdoors. Road access to the location of the gas upgrading facilities should be designed to accommodate heavy equipment for lifting and maintaining the largest pieces of the system.

The estimated capital costs for implementing the gas upgrading system is summarized in Table 6-2 below. It should be noted that the estimated capital costs shown in Table 6-2 are lower than those developed for biogas utilization alternatives development presented in Section 4. During development of the financial modeling and risk assessment (see Appendix F), and with input from gas consultants (see section 6.2.4. below), it was noted that the estimated capital costs developed in Section 4 may be high relative to industry experience. Based on this feedback, the assumptions used in developing the capital cost estimates were re-evaluated, and modified. The major changes to capital cost estimating assumptions are summarized below:

- Changed staging configuration from installing 3 gas upgrading units at 650,000 standard cubic feet per day (scfd) capacity each in 2014 and 1 additional unit in 2024, to installing 2 units at 1,000,000 scfd capacity each in 2014. Total installed capacity in 2014 will be 2,000,000 scfd. No additional units are required in the future.
- Changed staging configuration from installing 3 final compressors at 430,000 scfd capacity each in 2014 and 1 additional unit in 2024, to installing 2 units at 580,000 scfd capacity each in 2014. Total installed capacity in 2014 will be 1,160,000 scfd. No additional units are required in the future.

Installing fewer but larger units reduce overall capital costs somewhat. These modifications reduce redundancy and peak capacity. The changes also reduce capital cost significantly and are deemed acceptable based on the following reasons:

- The average gas production in 2024 is expected to be 1,539,000 scfd. The installed system will be able to handle peak productions up to 1.3 times the average gas production in 2024 with both gas upgrading systems and both final compressors on line.
- With one of the gas upgrading systems or final compressors off line, the system will still have capacity for 65 percent of the average gas flow in 2024.
- Based on observations in the industry, most gas upgrading systems do not have full redundancy. Redundancy of compressors or lead/lag type installation like that described above is common.

Table 6-2. Estimated Capital Costs for Digester Gas Separation Equipment in 2014

Equipment Costs	Water Solvent (Flotech – Greenlane), $
Equipment Costs	
Packaged biogas upgrading systems cost (2 x 1,000,000 scfd) [a, d]	$3,500,000
Product gas compressors cost (to 350 psig) [b]	$460,000
Gas analyzer and odorizer	$100,000
H_2S removal [c]	$550,000

Table 6-2. Estimated Capital Costs for Digester Gas Separation Equipment in 2014	
Equipment Costs	Water Solvent (Flotech – Greenlane), $
Additional valves and instruments for pipeline connection	$100,000
Instrument air compressor	$10,000
Total equipment	$4,720,000
Equipment Installation Costs (no electrical)	$150,000
Earthwork, Concrete, Cover and Piping Costs (including 12% contractor mark-up,)	$270,000 [d]
Electrical and I&C Cost (20% of equipment subtotal, 18% of earthwork, etc)	$990,000
Total Installed Cost	$6,130,000
Contractor general conditions (10% of Subtotal)	$610,000
Start-up testing, bonds, insurance (7% of Subtotal)	$470,000
Sales tax (6% of Subtotal)	$430,000
Contingency (20% of Subtotal)	$1,160,000
Total Estimated Construction Cost	$8,810,000

(a) Estimated cost for two 1,000,000 scfd Greenlane systems from Flotech

(b) Estimated cost for two, 580,000 scfd compressor packages

(c) Budgetary for two dual 11 foot diameter iron sponge removal systems from Marcab

(d) Assumes 2-inch steel pipe to convey biomethane to Southwest Gas Corporation (SWG) distribution main in Ina Road. SWG would "wheel" biomethane to El Paso NG pipeline for conveyance to premium markets (must be confirmed with SWG)

Note that this summary includes the assumption that gas upgrading equipment would not be installed in stages. As described above, two gas upgrading systems with final compressors would be installed in a single stage to provide sufficient capacity into 2040. Two units are expected to provide sufficiently high turndown capabilities when first brought online, but turndown capacity should be verified during detailed design.

In addition, annual operations and maintenance costs were estimated for the proposed biogas upgrading system. These are presented in Table 6-3 below.

Table 6-3. O&M Costs for 2014	
Category	Annual Cost
Gas Separation Maintenance	76,509
Hydrogen Sulfide Removal	150,000
Gas Sep and Compression Elec	187,450
Final Compression Maintenance	3,982
Operator Cost	51,675
Total Annual O&M Costs	$496,616
General O&M Inflation	2.28%
Energy Inflation	2.28%

6.2.3 Flexibility for Future Use of Upgraded Biogas as Vehicle Fuel (BioCNG)

Pima County is very interested in converting at least a portion of its vehicle fleet to CNG. As Pima County currently has very few CNG compatible vehicles, it is expected that this conversion will occur over time as vehicles are replaced. PCRWRD is in turn very interested in diverting some of its biogas to use as vehicle fuel. By implementing the gas upgrading system as described above, PCRWRD retains the flexibility to use upgraded biogas as vehicle fuel (termed BioCNG).

Besides acquiring vehicles that are compatible for use on CNG (and BioCNG), PCRWRD will need to invest in the following to implement BioCNG for vehicles:

- Construct fueling stations for dispensing the BioCNG. These include not only the actual fuel dispensing equipment but also compression equipment (typically CNG is compressed to over 3600 pounds per square inch for storage in cylinders at the dispensing location).
- To make the BioCNG most available to PCRWRD vehicles, multiple dispensing locations, at strategic locations around Pima County would be needed. There is currently a liquid fuel dispensing station at Ina Road WRF; this is one likely location of a BioCNG dispensing station. However, not all Pima County vehicles have convenient access to the Ina Road WRF site. Other locations are needed and upgraded biogas would need to be "wheeled" through gas utility pipelines to these other locations. [Note: "wheeling" refers to putting a certain quantity of a commodity – in this case upgraded biogas – into the pipeline at one location and removing an equivalent quantity of the commodity at another location.]
- Pipelines to convey the CNG (BioCNG equivalent) from the utility pipelines to each fuel dispensing station. Obviously, minimizing the distance from the distribution pipeline to the dispensing station is strongly preferred to decrease the cost of implementing the vehicle fueling system.

The commodity price of natural gas is currently very low. This makes conversion of fleet vehicles to CNG attractive. However, with such low natural gas prices, the cost to upgrade biogas for use as BioCNG in vehicles may be higher than the cost to buy natural gas for use as CNG. On the other hand, the positive public relations value of PCRWRD "advertising" that a portion of its fleet is fueled with biogas from its wastewater treatment operations may be substantial.

PCRWRD's decision on whether to invest in fleet conversion to CNG is independent of PCRWRD's decision to invest in biogas upgrading to pipeline quality. Given PCRWRD's interest in vehicle fleet conversion to CNG, it is recommended that this proceed independently from PCRWRD's biogas utilization implementation. If both are implemented – biogas upgrading to pipeline quality, and vehicle fleet conversion the CNG – then the decision whether to divert upgraded biogas to vehicle fuel can be made on its own merit at the time.

6.2.4 Considerations in Implementing Biogas Upgrading and Sale to Balance PCRWRD's Risk With Potential Economic Gain

The evaluations summarized in Section 4 and 6.2.1 above lead to the recommendation for PCRWRD to implement biogas upgrading to pipeline quality (termed biomethane, or renewable natural gas - RNG) at the Ina Road WRF. In order for PCRWRD to follow through on this recommendation, consideration of both the marketing of the biomethane product as well as the delivery method of actually constructing and operating the biogas upgrading facility must be considered. The objectives in evaluating marketing and project delivery options is to achieve an appropriate balance between potential economic gain for PCRWRD through the sale or beneficial use of biomethane and the risk associated with implementing this type of a system (i.e. capital cost).

- In order to develop and evaluate marketing and delivery alternatives, the following specialty consultants were engaged: natural gas and biomethane marketing consultants:
  - Mr. Dave Jones, DMJ Gas Marketing Consultants, LLC
  - Ms. Diane L. Saber, Ph.D., REEthink, Inc.
- Financial modeling and risk consultant, Raftelis Financial Consultants, Inc.

In addition, legal input on delivery options was provided by Hawkins, Delafield and Wood, Inc under a separate agreement with PCRWRD.

The results of the consultant input and evaluations demonstrated that biomethane marketing and project delivery are linked, and in order to achieve PCRWRD's objectives of balancing economic return with risk each must be considered together. The sections that follow summarize the input received from consultants, the marketing/delivery alternatives developed and evaluated, and the recommendations that evolve from the results of these evaluations.

6.2.4.1 Biomethane Marketing Considerations

Mr. Dave Jones and Ms. Diane Saber were retained to provide input on the marketability of biomethane, potential markets for biomethane, and considerations that may impact the marketability of biomethane produced by PCRWRD. Each consultant is active in the natural gas and biomethane marketplace; working with natural gas and biomethane producers, buyers, and transmission companies is the core business for each consultant.

Each consultant was asked to provide responses to various questions related to the marketability of biomethane, and the factors that influence the value and demand for biomethane in the marketplace. The questions were developed jointly by Brown and Caldwell and PCRWRD. The questions and responses are provided in Appendix E.

Key input received from the consultants and impacting PCRWRD's decision of how to implement biogas upgrading and sale are summarized below:

- The interest in biomethane as a commodity of value appears to be growing.
- The interest is driven 1) by state mandates to meet renewable portfolio standards for power generation; 2) mandates to meet renewable fuel standards for vehicle fleets; and 3) desire by corporations and public agencies to "go green" for the public relations value.
- Interest in using biomethane as vehicle fuel appears to be growing.
- Where biomethane "competes" against natural gas as a fuel source, the value for the biomethane is low, largely because the commodity value of natural gas is low; where biomethane "competes" against other forms of renewable energy (e.g. wind power, geothermal power, etc) the value of biomethane is higher, due to the higher cost to produce power from these other renewable sources.
- Prior to March 2012, California represented the most robust market for biomethane; prices paid for biomethane to meet state mandated renewable portfolio standards was several times the commodity price for natural gas; see below for changes since March 2012.
- The most important factor impacting the marketability and value of biomethane is gas quality; in order to inject biomethane into the gas transmission companies' pipelines, strict gas quality specifications must be met; continual monitoring of gas quality is required.
- Biomethane purchase arrangements and agreements vary substantially with the producers and buyers; there is no "standard" agreement in the marketplace, each agreement is negotiated independently.

- An important consideration in any agreement is the cost to transport biomethane through natural gas transmission pipelines from the point of production to the point of use. Termed "wheeling" the cost of transmission can vary between $0.10 and $0.70 per million British Thermal Unit percent of the value of the biomethane.

The Consultant's responses were provided in February 2012. In March 2012, the California Energy Commission (CEC) issued a moratorium on imported biomethane being used as a fuel source for power generation for meeting California state mandated renewable portfolio standards. The effect of this moratorium was to eliminate one significant and viable market for biomethane, at least for the foreseeable future. Further consultation with Ms. Saber and Mr. Jones provided some clarification of how the CEC moratorium might impact the marketability of PCRWRD's biomethane once implemented, as summarized below:

- The high prices being paid in California for biomethane prior to the CEC moratorium cannot be relied upon moving forward.
- There remains a market for biomethane due to reasons stated above, i.e. desire for public relations value for using green energy, renewable standards in states other than California, continued interest in biomethane for use as vehicle fuel.
- The marketplace for biomethane may still provide a premium value over the commodity price for natural gas due to the reasons stated above.

6.2.4.2 Potential Biomethane Delivery and Marketing Scenarios

The following paragraphs summarize the project delivery and biomethane marketing scenarios evaluated for the implementation of the recommended biogas utilization system. These are described more completely in Appendix D.

Historically, under the general alternative project delivery methods, many PCRWRD projects began as traditional Design-Bid-Build projects and were subsequently implemented using Design-Build or Design-Build-Operate methods for a variety of reasons. The most common reasons appear to be the need to reduce costs or accelerate schedules. In the recent past, state or local legislation has prohibited the use of alternative project delivery, but this is not the current situation in Arizona where alternative Design-Build project delivery has been successfully employed. PCRWRD has had recent experience and success with alternative project delivery methods.

Alternative project delivery methods are being considered for the Design-Build-Finance-Operate, and ownership of a biogas upgrading facility (Facility). Accelerated schedules or reduced costs are not the motivating factors in this project; however, alternative approaches are being considered because of the nature of the project which ultimately results in the marketing and sale of biomethane. PCRWRD is considering alternative delivery approaches to evaluate the estimated revenue potential of biomethane against the inherent risk of such an operation. This project is less capital intensive; instead it combines a process, namely cleaning raw biogas to the level of market grade natural gas (biogas upgrading), and a marketing element, selling biomethane to potential users.

Potential alternative project delivery methods were reviewed and narrowed to two approaches for the financing and operation of the Facility. Since this project is a multi-faceted project including a marketing of biomethane component, the first approach, PCRWRD financed approach, is evaluated in two separate ways. The project delivery methods are described in the following sections.

6.2.4.3 PCRWRD Financed Approach – Design-Bid-Build or Design-Build with PCRWRD Operations

This structure is the traditional method of project delivery being used successfully for most water and wastewater capital projects in the U.S. This method involves three basic participants: the design

professional, the general contractor, and PCRWRD (the operating agency). Facilities are then operated by PCRWRD staff.

In the first step of this method, a design professional is retained through a qualifications based submittal process. Its responsibilities include determining facility requirements for PCRWRD, including (implicitly) many of the risk elements of the project. The design professional is responsible for the engineering design of the facility and the development of contract documents for competitive bidding by PCRWRD.

In the second step, bids are tendered in conformance with the contract documents and the lowest responsive, responsible bidder is selected, without negotiations, to construct the facilities. Either the design professional, an independent engineer, or PCRWRD staff assures that the builder's performance is in compliance with the contract documents and assists in resolving any issues and/or conflicts. PCRWRD retains design liability.

Relationships of responsible Design-Bid-Build parties are illustrated in Figure 6-2.

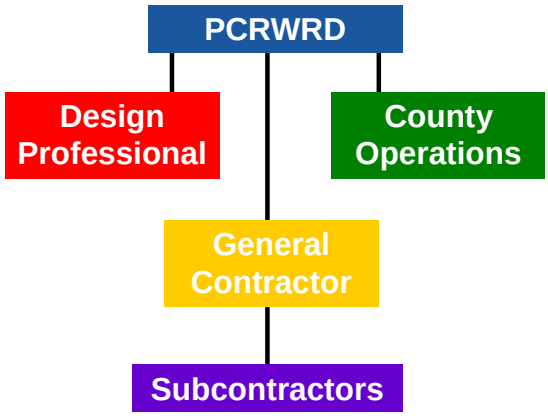

Figure 6-2 Traditional Design-Bid-Build Project Delivery Method with PCRWRD Operations

For this particular project, Brown and Caldwell in association with the natural gas consultants, Dave Jones of DMJ Gas Marketing and Diane Saber, Ph. D. of REEthink inc. advised that the Facility may be more of a packaged turn-key facility with relatively little construction on site that would require design and construction by subcontractors. Therefore, the traditional two-step process of Design-Bid-Build described above may be simplified by the implementation of such a facility.

The facility may be more expeditiously and effectively designed and built if there is a single entity contracted to provide both design and construction services. PCRWRD usually develops performance requirements for use in securing a design-builder. The design-builder contracts directly with subcontractors and is responsible for delivery and performance of the project, and specifically assumes design as well as construction liability. Selection of the design-builder is based on the proposal offering the best value to PCRWRD, in terms of qualifications, technical and business merit, and project costs. Independent technical, legal and/or financial consultant(s) may serve as PCRWRD's agent(s) in managing the procurement process, establishing performance criteria, and monitoring performance. A conceptual to preliminary design (10 to 30 percent) may be prepared at the direction of PCRWRD to detail the prescriptive and performance requirements of the project. The Design-Build contract is negotiated based on a formal Proposal.

This delivery method requires PCRWRD to be knowledgeable of its needs and objectives for the project and be directly involved in the process. A key element to success is trust between PCRWRD and the design-builder, and the opportunity and necessity for the designer and builder to work closely together to develop the winning Proposal. For this method, the design-builder is provided with a description of the desired end product. The design-builder is responsible for developing the detailed design and specifications, selection of material and equipment, constructing the Facility, and meeting performance requirements.

Relationships of responsible design-builder parties are illustrated in Figure 6-3.

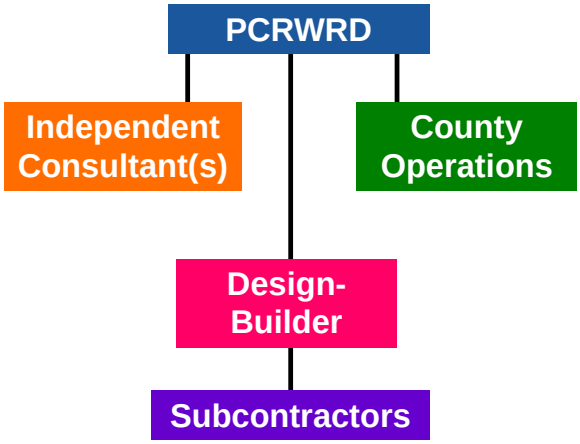

Figure 6-3 Basic Design-Build Project Delivery Method with PCRWRD Operations

PCRWRD approach is summarized above as either a combination of bids for design and construction or a company capable to serve PCRWRD in both roles. PCRWRD retains ownership and is responsible for daily operation of the facility. PCRWRD will then be responsible to sell the upgraded natural gas product, biomethane, on the renewable energy market.

6.2.4.4 Marketing the Biomethane Product

PCRWRD has determined it will evaluate two delivery approaches for PCRWRD financed design, construction, and operation of the Facility. The two are:

- PCRWRD (Local)
- PCRWRD (Regional/National)

As previously stated, this project is unique in that PCRWRD is undertaking an entrepreneurial activity of either selling the raw biogas or an upgraded, renewable natural gas product (biomethane). Under the first set of delivery approaches, PCRWRD retains control over the whole operation and will sell the biomethane, locally or regionally/nationally.

PCRWRD (Local). This alternative delivery approach will involve a Design-Bid-Build or Design-Build process in which PCRWRD will oversee the design and construction of the facility and PCRWRD staff will operate the facility. PCRWRD will upgrade the raw biogas to the market grade natural gas and sell the product in the local renewable energy market to either local vendors or buyers. PCRWRD would hire a Full Time Equivalent employee to market and sell the natural gas in or around Pima County, most likely

within the state of Arizona. PCRWRD would retain all revenue after wheeling fees were paid to transport the biomethane through local transmission lines.

PCRWRD (Regional/National). PCRWRD (Regional/National) alternative delivery approach is very similar to PCRWRD (Local) model in that PCRWRD owns and operates the facility. However, the major difference between these models is how PCRWRD markets the biomethane. Under this approach, PCRWRD would enter into a contract with a nationally reputable third party broker who sells the biomethane in a regional or national market. In return, the third party retains a portion of the revenue from the sale of the biomethane.

6.2.4.5 Private Financed Approach – Design-Build-Finance-Own-Operate

Design-Build-Finance-Own-Operate method is a method in which a private corporation has complete control over the design, construction and operation of the facility. The private corporation will own the facility and any other assets involved. The facility will be built on property owned or leased by the company, not by PCRWRD. For this delivery method, the project is financed by the Design-Build-Finance-Own-Operate entity. Independent technical, legal and/or financial consultant(s) may serve as PCRWRD's agent(s) in managing the procurement process, establishing performance criteria, and monitoring performance.

The Design-Build-Finance-Own-Operate contract, as the tax beneficial owner, will depreciate the project and contribute equity, which will reduce the amount of debt needed to finance the project. As a tradeoff, the contractor will own the project when the service contract expires, and PCRWRD must thereafter purchase or rent the facilities at fair market value if it wishes to continue to receive service from the facility.

Relationships of responsible Design-Build-Finance-Own-Operate parties are illustrated in Figure 6-4.

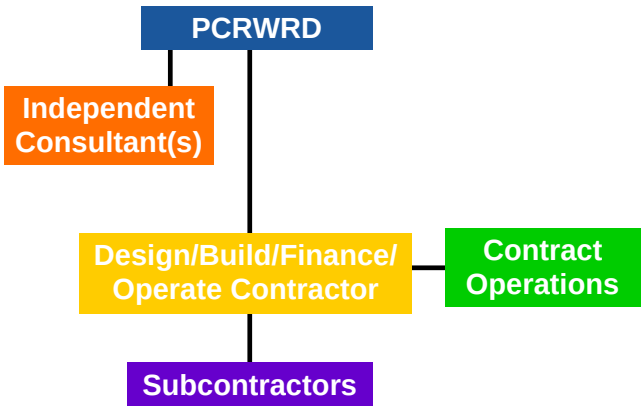

Figure 6-4 Design-Build-Finance-Own-Operate Project Delivery Method

Ordinarily under a Design-Build-Finance-Own-Operate, PCRWRD would pay the private company a monthly charge for providing the public service PCRWRD has chosen to privatize. However, since this project does not provide a public service, and is instead an entrepreneurial activity, the private company will agree to take the captured raw biogas and will most likely pay PCRWRD a particular amount for it, as measured in Million British Thermal Units (MMBTU).

PCRWRD will have no direct bond or debt service liability. For the purpose of this analysis, it is assumed that if the contractor fails to take PCRWRD's biogas, PCRWRD can terminate the service contract, in

many cases with the project ownership reverting to PCRWRD without cost. The potential for such a provision could take the place of a service contract guarantee by the contractor.

6.2.4.6 Marketing Raw Biogas Product

The third alternative delivery approach described above assumes PCRWRD will enter into a long-term contract with a private company to supply it raw biogas for a fee per MMBTU. The private company will finance the design and construction of the Facility. The company will own (or lease) the land and all assets related to the Facility and the company will operate the Facility with their own staff. It is assumed that the company will pay PCRWRD for the biogas, upgrade it, and then sell the biomethane in a regional or national market.

6.2.4.7 Summary of Alternative Delivery Approaches

For this financial and risk analysis, PCRWRD is considering three alternative delivery approaches.

1. **PCRWRD (Local)** – Facility is PCRWRD built, owned, operated and financed; PCRWRD markets/sells biomethane locally.
2. **PCRWRD (Regional/National)** – Facility is PCRWRD built, owned, operated and financed; PCRWRD partners with third party to market/sell biomethane in a regional or national market.
3. **Private** – Facility is built, operated, financed, and owned by private entity; private entity markets/sells biomethane in a regional or national market.

These three approaches have been evaluated based on cost, risk, and revenue potential. The next section presents the financial assumptions and baseline analysis.

6.2.5 Evaluation of Alternative Delivery Approaches

Each of the delivery approaches identified above were evaluated using a financial model incorporating risk factors designed to reflect the uncertainty inherent in any decision making process. A complete description of the financial model, methodology of evaluation and assumptions used is provided in Appendix F. The following sections provide a summary of the results of the financial risk evaluation and recommendations for implementing the biogas upgrading project. Capital cost and annual operations and maintenance costs used in the financial model are based on the system configuration developed by Brown and Caldwell – see section 6.2.2. above.

In order to conduct this analysis, key assumptions were made, including the following as baseline assumptions (see Appendix F for a more complete discussion):

- The private model could take advantage of an accelerated depreciation tax advantage over the first 7 years of operation.
- Baseline value of natural gas will follow projections obtained from the natural gas industry NYMEX index.
- A premium value for biomethane is assigned, reflecting the potentially higher value of this renewable energy resource: a 10 percent premium is applied for PCRWRD Local model, and 35 percent premium is assumed for PCRWRD Regional/National model, and the Private model; the higher premium reflects the potential for more robust demand for biomethane in the regional and national market.
- Some loss of biomethane product between Ina road WRF and the point of use is assumed; termed “shrinkage”, this was assumed to be 1 percent for PCRWRD Local model and 5 percent for the other models reflecting the longer travel distances and higher potential for losses in longer transmission distances.

- The cost of "wheeling" the biomethane through privately owned transmission systems was estimated; it was assumed the cost for local "wheeling" would be significantly less than for wheeling to regional or national users.
- A cost of marketing the biomethane was assumed as a percentage of the value of the biomethane; the marketing cost for the PCRWRD owned options was higher (7.5 percent) than the Private model (5.0 percent) reflecting the assumption that PCRWRD would need to hire a marketing consultant or a dedicated employee to provide this function.
- PCRWRD's share of the net present value over and above costs and private companies return on investment (assumed as 75 percent for baseline).
- Interest rate on capital – 3.5 percent for PCRWRD financed; 4.75 percent for private financed.
- Discount rate – 6.0 percent.
- Escalation for annual operations and maintenance costs – 2.28 percent.
- Sinking fund for repair and replacement of capital - $175,000 per year.

In addition, the financial modeling assigned certain assumptions as risk factors, i.e. assumptions whose value vary from the baseline over a range in the analysis. These risk factors are summarized below (see Appendix F) for a more complete description):

- Interest rate on capital
- Operations and maintenance escalation
- Sinking fund allocation for repair and replacement
- Cost of construction
- Premium for renewable gas
- PCRWRD's portion of the net revenue shared with the third party broker or private developer.

The financial modeling initially evaluates each option using baseline assumptions, then re-evaluates the alternatives by running multiple scenarios by varying risk factors. The results of the baseline and risk evaluation are summarized below:

- Baseline:
  - Each delivery option shows a positive net present value (NPV) over 20 years; key to this outcome is the assumed escalation of natural gas values, as forecast by NYMEX, and the premiums assigned to biomethane over the NYMEX value. The Private model shows the highest NPV and the PCRWRD Local model shows the lowest NPV.
  - For the first several years in each option, there is a negative cash flow; the positive NPVs noted above are the result of future positive cash flows. The private model cash flow appears least negative in the early years due to the opportunity for accelerated depreciation.
  - A break-even analysis demonstrates that the sale value of the biomethane can be slightly below the 20 year composite value of natural gas (using NYMEX projections) for the PCRWRD Local option; the break even sale value for the other two options are somewhat above the 20 year composite value of natural gas.

- Risk Analysis:
  - Using the risk analysis results, the NPV for both PCRWRD Local and PCRWRD Regional/National models are significantly reduced, reflecting the greater uncertainty associated with the key assumptions used to develop these models.
  - In each of the PCRWRD owned models, there is a chance that the ultimate outcome will be negative; that is, PCRWRD will not recover sufficient revenue to cover debt service on the capital investment and operating expenses, even over 20 years.
  - The results for the Private model also show a reduction in the NPV over the baseline; however, it is the highest (i.e. most positive) risk adjusted NPV of the three options.
  - A key consideration from PCRWRD's perspective is that the private financed model cannot result in a negative outcome; that is, PCRWRD will not enter into an agreement that results in PCRWRD paying a private entity to take their raw biogas.

The results of this financial evaluation are summarized below:

Table 6-4. Summary of Key Findings from Financial Modeling of Delivery and Marketing Options

PCRWRD Financed Approaches	Private Financed Approach
Facility/Operation/Sales	
• PCRWRD has full control over assets, operation and sale of biomethane	• PCRWRD transfers risks related to operation and sale of biomethane to Private company
Advantages for PCRWRD	
• PCRWRD has most flexibility for sale and uses of biomethane	• PCRWRD should never lose money in this venture • Highest risk adjusted NPV
Disadvantages for PCRWRD	
• PCRWRD is responsible for debt service and operating expenses regardless of health of biomethane market	• PCRWRD's involvement is limited to negotiated contract

6.2.6 Recommendations for Biogas Upgrading Delivery and Marketing

The recommendation based on the discussions, risks, and results of the financial analysis presented above is that PCRWRD should explore a turn-key private financed delivery option (i.e. the Private Model). This approach appears to maximize revenue potential while minimizing risk to PCRWRD. PCRWRD should pursue a contract that requires, at a minimum, for a private partner to take PCRWRD's raw biogas at all times.

Results of the Private analysis that support the adoption of the Private delivery approach are:

- Private approach has the highest NPV in both the baseline and risk adjusted analysis.
- PCRWRD has no exposure to negative value, based on assumed contractual language.
- PCRWRD has less exposure to the volatility of the natural gas market.
- By pursuing a privately developed and operated project, PCRWRD can continue to focus primarily on its core service, i.e. treating wastewater.

- Risk analysis has highlighted the broad uncertainty of forecasting the value of biomethane, particularly as it's predicated on receiving a premium above the NYMEX future price of natural gas. Therefore, the private option helps to mitigate this risk.
- Quantitative and qualitative risk/benefit analysis shows the potential cash flows of this endeavor includes significant uncertainty; therefore, the private option mitigates this risk by allowing PCRWRD to only enter into an agreement if the revenue potential to PCRWRD is positive.

6.3 Green Valley WRF and Sub-regional Facilities

Section 5 presented the evaluation of alternatives for changing and improving biosolids management at the Green Valley WRF, with a primary objective of improving odor control at this facility. The results of this evaluation demonstrated that consolidating the treatment and management of biosolids from Green Valley WRF with biosolids at Ina Road WRF would require less capital costs, and have somewhat lower life-cylce costs than making improvements to biosolids treatment at Green Valley WRF. Consequently, the following are recommendations for biosolids and related odor control improvements at the Green Valley WRF:

- Treatment (stabilization and air drying) of biosolids produced from the Biological Nutrient Removal Oxidation Ditch (BNROD) process will be discontinued.
- Biosolids produced from the BNROD process will be thickened and hauled to the Ina Road WRF for treatment (anaerobic digestion) and dewatering or thickening prior to land application (assuming the current land application program continues).
- A new liquid biosolids slurry load-out facility will be provided for loading tanker trucks for hauling to Ina Road WRF.
- The existing solids aeration tanks will be used for short term storage of biosolids prior to thickening and/or hauling to Ina Road WRF.
- The existing solids holding tanks will be retrofitted with improved aeration and improved mixing in order to hold solids while minimizing odor production.
- Recognizing that the solids storage tanks may still be a source of odor, tanks will be covered and the head space ventilated to odor control.
- The existing gravity belt thickeners will be retrofitted with odor control covers; the space under the covers will be ventilated to odor control.
- A new odor treatment system will be provided for the new foul air streams generated through these improvements; a biofilter is the recommended odor control process.
- Various utility, site and electrical and control improvements will be made to support the improvements described above.

The improvements described above can be implemented via a stand alone project, utilizing the Job Order Contracting or Design-Bid-Build delivery process.

Construction costs for the above improvements, including contingencies and allowances for unforeseen project elements is estimated to be approximately $2,000,000. In addition, it is anticipated that up to three dedicated liquid slurry hauling tanker trucks will be required and dedicated to Green Valley WRF.

As discussed in Section 5, the results of the Green Valley WRF evaluation discussed above has significant implications for these other facilities. These are summarized below:

- The Green Valley WRF evaluation demonstrated hauling liquid-slurry, unclassified solids to Ina Road WRF for treatment and incorporation into the larger PCRWRD biosolids management program is cost-

effective and has other benefits, such as consolidating solids treatment and distribution at one location.

- Converting solids handling at the other Sub-regional facilities will require considerable investment in new processes, odor control and management of biosolids product in order to avoid the issues encountered at Green Valley WRF.
- The other Sub-regional facilities already have in-place the solids thickening, truck loadout facilities recommended for Green Valley WRF; by retaining this approach for solids management at these plants, no further capital investment is needed.

For these reasons, it is recommended that the Sub-regional facilities that currently haul solids to Ina Road WRF continue this as their process for solids management. Specifically, these include the Avra Valley WRF, the Corona de Tucson WRF and the Mt. Lemmon WRF.

Likewise, it is recommended that the Randolph Park WRF continue to discharge solids back to the interceptor sewer for conveyance downstream to the regional water reclamation facilities (ultimately the WRC due to go on-line in 2014). Finally, it is recommended that those small water reclamation facilities that currently air dry solids and haul to landfill continue this practice. The quantities of solids from these very small facilities do not justify significant capital investment to change biosolids management practices at these facilities.