Commonwealth Energy's PIER Renewables Affordability Mini-Grid Program

Final Report

Prepared Under Contract No. 500-00-036
Project 1.1 – Task 1.1.1
Technical Potential Assessment Review

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September 16, 2002

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Technical Potential Assessment Review

1.1 Overview

This Commonwealth Energy Planning and Analysis Project Task 1.1.1 report reviews and summarizes key results from previous technical and market potential assessments of electricity that may be generated from renewable resources in California, both statewide and those in Southern California. Within California, there is significant potential for generating electricity from renewable energy resources. One recent study (RER 2002) examined all major renewable resources in the state and found the net technical potential[1] to be nearly 91,000 megawatts (MW) of electric generation capacity. Most (83%) of the reported renewable potential is from direct solar resources – using photovoltaic and solar thermal electric technology. The California ISO peak demand in 2001 was approximately 43,000 MW.[2] It is apparent from these previous assessments that electric generation from renewable energy resources has the potential in the future to provide a significant portion of the electricity needs in California.

The renewable resources selected for development under the Commonwealth Energy (Commonwealth) PIER Renewables Mini-Grid Program include four derivatives of biogas (landfill gas, biogas from livestock and food processing waste, and biogas from wastewater treatment facilities) and building-integrated photovoltaics. One of the overall goals of the Commonwealth Program is the development and implementation of an approach for tailoring resource development to the specific needs and resources of localized areas of the electric distribution system, or "mini-grids." The specific renewable resources selected are particularly well suited to this goal. Unlike geothermal or wind resources, these selected resources tend to be located close to populated areas, relatively close to electric transmission and distribution facilities, and may be found in concentrated pockets near electric system load centers. These features make them attractive to this research and development program's sub-regional perspective on renewable resource development.

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1 Net Technical Potential for electricity generation from renewable resources is considered to be the maximum potential generation purely from a technical feasibility perspective, minus any existing renewable resource based electricity generation.

2 Obtained from California Energy Commission website: http://www.energy.ca.gov/electricity/2001_peak_demand.html.

This review of prior resource assessments is a necessary step in meeting the objectives of the Commonwealth Program's planning and analysis project. It would not be prudent to undertake the program planning and analysis project without first reviewing any relevant previously completed work. During the course of carrying out this first task under Project 1.1, Regional Economic Research, Inc (RER) reviewed 14 studies.[3] Eight of the reports provide estimates of the technical or market potential of electricity generation from renewable resources and generation technologies including photovoltaic systems and select biogas utilization (i.e., landfill gas, animal waste, and municipal solid waste). Two of the eight studies briefly discuss technology market barriers. The other six reports did not address the objectives of this report. The following sections briefly summarize the results of the eight renewable resource assessments of interest in California.

1.2 Technical Potential Studies

Technical Potential Statewide

Technical potential is considered to be the maximum generating capacity that could be developed purely from a technical feasibility perspective, and it does not take into consideration any economic, political, market or consumer awareness/acceptance issues. It represents the upper limit of electric generation capacity achievable, assuming all available resources are fully exploited and current technology is used.

A thorough examination of the literature makes it clear that there is no consensus among researchers of the definition of technical potential. The inclusion of currently developed and operating generation resources within the technical potential estimates is one area where differences exist. For example, RER (2002) includes existing renewable generation potential from animal waste-based biogas, while the Moser (1997) study does not.

Five studies that addressed technical potential of the Commonwealth PIER Mini-Grid Program resources were identified and reviewed in detail.[4] All of these studies provide technical potential estimates for at least one biogas technology, while two studies provide estimates for solar photovoltaics. Table 1-1 presents the statewide estimates of net technical potential[5] from these studies, except where noted.

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3 See Appendix A for a list of the reports reviewed and a brief summary of each.

4 Envirosphere 1984, Regional Economic Research 1991, Mark A. Moser 1997, SCS Engineers 2002, and Regional Economic Research 2002.

5 ***Net Technical Potential*** is defined as the sum of electricity generation, in megawatts, that could be produced by a renewable resource using existing generation technology, less what is currently being produced from operational projects using the same resource/technology.

Table 1-1: Estimates of Statewide Biogas and Photovoltaic Net Technical Potential (MW)

Study	Solar Photovoltaics	Animal Waste Biogas	Food Processing Waste Biogas	Municipal Solid Waste (Landfill) Biogas	Municipal Sludge Waste Biogas
Envirosphere Co. (1988)	NA	16*	NA	NA	34*
Regional Economic Research (1991)	34,015*	17*	NA	843*	178*
Moser, Mark A. (1997)	NA	57*	NA	NA	NA
SCS Engineers (2002)	NA	NA	NA	382*	NA
Regional Economic Research (2002)	34,378* 9,450*[6] 9,442**	210	33	755	138

* Gross technical potential estimates (installed capacity plus undeveloped capacity).
**Lower photovoltaic net capacity includes estimated effects of current distribution system reverse power flow constraints.

Table 1-1 illustrates that the estimates of technical potential for these technologies can vary significantly from one study to another. This can be caused by the availability of more refined baseline data over time, different authors making different assumptions about the amount of available fuel, the number of available sites (for biogas) or usable square footage (solar photovoltaic), and conversion efficiency rates (from tons of waste or amount of sunlight to electricity). These major differences in resource assumptions are discussed in more detail below.

Comparison of Photovoltaic Resource Estimates

RER developed both of the solar photovoltaic potential studies. There are some very significant differences between them. The first study (RER 1991) developed estimates for the residential and nonresidential markets using two primary limiting factors. These criteria included available roof area and matching photovoltaic system size to customer load. Although there will clearly be energy exchange with the grid, the net effect of the second factor is that there should be no net sale of on-site generation back to the electric utility on an annual basis.

[6] Lower estimate (9,450 MW) of photovoltaic gross technical potential includes the current estimated impacts of reverse power flows on the distribution system.

In the second study (RER 2002), estimates were developed for residential, nonresidential, and parking structures using two primary limiting factors. Again, the first factor included usable roof area, but the second factor pertained to the ability of the electric distribution system to accept all of the potential generation. Most of the existing distribution system cannot accommodate reverse power flows, which would exist at certain times of the year (i.e., mild and clear spring and fall days). This second factor currently has a very pronounced impact on the gross technical potential for photovoltaic. In fact, had this constraint not existed, the two studies would have had very similar results. The 2002 update study estimated gross technical potential for photovoltaic to be 34,378 MW compared to the initial 1991 study's estimate of 34,015 MW. There were other differences in the assumptions made between these two studies, such as system efficiency and capacity factor, but these did not result in significant differences in the technical potential estimates.

Comparison of Animal Waste Biogas Resource Estimates

The differences in the results across the three animal waste biogas potential studies are varied. The first two studies (Envirosphere 1988 and RER 1991) are based on data from an earlier market potential study (Quok et al. 1984). The two RER studies (1991 and 2002 update) differ in several ways. The livestock population for the 1991 study was based on a 1981 survey of farm types suitable for biogas and expanded by 10% to estimate the 1991 livestock population. However, the 1981 survey only looked at farm operations that could support existing technologies, which required relatively large volumes of manure waste. The livestock population for the 2002 study is based on agricultural statistics at the county level from the U.S. Department of Agriculture. Since new waste processing and energy conversion technologies, such as microturbines, can now be applied to smaller manure producing sites, there was no need to exclude smaller farm operations. This factor was the most significant in understanding the difference in the technical potential of biogas from animal waste.

The Moser (1997) study and the most recent RER (2002) study differ in several areas. The first important difference is that Moser estimated biogas production only for dairy farms. RER developed biogas production estimates for dairy farms, chicken farms, beef feedlots, and swine operations. However, the single most important difference was in the method used to estimate biogas production. The Moser study based its estimates on the types of manure management schemes across the state. The RER study based its estimates on livestock type and the digester technology to be used. This study's assumptions were based on a review of numerous case studies of actual digester gas operations. Overall, the RER study assumed a biogas production rate that was approximately three times as great as that used by Moser.

Food Processing Waste Biogas Resource Estimates

Only one study (RER 2002) addresses the use of food processing waste as a source of biogas. Food processing is generally a water-intensive operation. The wastewater from these operations contains high levels of dissolved or suspended solids. Energy recovery can be accomplished through anaerobic digestion to produce methane, or through pryolitic thermo-chemical gasification. In this study, food production data were obtained from the California Department of Food and Agriculture. It was assumed that 3% of the total production is residue or waste suitable for conversion to a biogas fuel.

Comparison of Landfill Biogas Resource Estimates

The recent two studies on landfill biogas technical potential (SCS 2002 and RER 2002) were published in the same year, yet differ in their estimates of landfill gas (LFG) technical potential by more than a factor of two. SCS listed 79 landfills as potential LFG-to-energy projects and used the EPA Landfill Gas Emissions Model to estimate annual biogas production. The EPA model is classified as a *first-order decomposition rate* equation where the user may supply site-specific data for all the information needed to calculate LFG, or they may use one of two different sets of default values. One set of defaults will result in more conservative estimates of LFG production than the other. In addition, the model assumes that 50% of the LFG produced is methane. The SCS study did not discuss the specifics of how the model was used to derive estimates of technical potential and the report did not list the estimated LFG production at each landfill site.

RER (2002) used an EPA database of landfills that included 108 landfills in the state. The database contained estimates of LFG production based on the amount of waste in place and the age of the waste. Landfill gas generation is often predicted using a first order decay model, which takes into account the changing rate of biogas generation over time. However, RER used results from a simpler model for the profiles contained in the EPA database. This model assumes a constant (average) rate of landfill gas generation over time. RER developed estimates of gross technical potential from these estimates of LFG production. Net technical potential was then estimated by subtracting the existing generation, if any exists, at those sites. This study also assumed the LFG is composed of 50% methane.

The lack of information on how the SCS study developed its estimates of technical potential has made it impossible to determine exactly why these two studies differ so significantly – although the landfill decay/biogas generation model used by SCS does result in lower current biogas production estimates for 2002. Clearly, the RER study included additional landfills (79 versus 108), but the differing methodologies for estimating LFG production over time are another key factor impacting the current 2002 technical potential.

Comparison of Municipal Sludge Waste Biogas Resource Estimates

The primary determinant of municipal sludge waste-biogas-to-energy technical potential is the in-flow of wastewater into a municipal sewage treatment system. The first study (RER 1991) used a listing of active wastewater treatment plants, including design flow rates obtained from the State Water Resources Control Board. Eliminated from the analysis were the numerous waste treatment facilities with design flows below one million gallons per day (MGPD). Based on an assessment of 18 digester gas facilities at various types of municipal wastewater treatment facilities in California, a general relationship of 45 kW per MGPD was developed and used to estimate the county level and statewide technical potential. In addition, a generation capacity factor of 100% was assumed in the calculation of MW potential.

The second RER (2002) study used the same basic methodology. A database of treatment plants was obtained from a 1995 U.S. Geological Survey database. Wastewater treatment volumes for 2000 were calculated as the product of 2000 U.S. Census population totals and the 1995 per-person wastewater generation rates. Data from three California municipal sewage system digester gas electric generating facilities were used to estimate the relationship between wastewater treatment volumes and digester electric generation capacity. The capacity weighted average value estimated was 40 kW per MGPD. To calculate the potential capacity (MW) of generation from this resource an average annual capacity factor of 80% was assumed for operation of the generation facilities.

The Envirosphere (1988) study used a slightly different method for calculating the technical potential. This study provides an assumption for the amount of biogas produced per capita per day and then expands this factor to the total population. The next step was to assume a certain heat content and generation conversion efficiency. Unfortunately, the basis for the assumptions was not discussed and the data[7] are not readily available.

Technical Potential in Southern California

Four of the studies identified were mined for estimates of technical potential in Southern California. While only one study divided the state along large geographical boundaries, several reported the results by county, or cities in the case of landfills, making it possible to isolate (or aggregate) the potential within Southern California.

In two of the studies (RER 1991 and RER 2002), technical potential estimates were provided at the county level. The county-level results for photovoltaic, animal waste biogas, food processing waste biogas and municipal sludge biogas were presented only as gross technical potential and did not have existing generation subtracted. To obtain consistent results for

[7] California Energy Commission PEAD database.

Southern California, the following counties were included: Imperial, Los Angeles, Orange, Riverside, San Bernardino, San Diego, Santa Barbara, and Ventura. Table 1-2 presents these estimates. In addition, the percent of the statewide estimate from the corresponding study is displayed in parentheses.

Moser (1997) aggregates farm types by region. This made it possible to calculate the potential for animal waste biogas in Southern California by applying the same methodology used for the entire state.

SCS (2002) presents a list of currently operational landfill gas generation sites in California, a list of landfills throughout the state for which generation is currently being planned, and sites for which generation is not currently planned. To obtain results for Southern California, the county in which each landfill is located was identified. Landfills in Southern California were combined to develop the technical potential estimates in Table 1-2.

The differences between the studies previously discussed hold true when the results are isolated for Southern California.

Table 1-2: Estimates of Southern California Biogas and Photovoltaic Gross Technical Potential (MW)

Study	Solar Photovoltaic	Animal Waste Biogas	Food Processing Waste Biogas	Municipal Solid Waste (Landfill) Biogas	Municipal Sludge Waste Biogas
Regional Economic Research (1991)	16,543 (49%)	5 (29%)	NA	487 (58%)	103 (58%)
Moser, Mark A. (1997)	NA	9 (16%)	NA	NA	NA
SCS Engineers (2002)	NA	NA	NA	89 (23%)	NA
Regional Economic Research (2002)	5,507* (58%)	58 (23%)	1 (3%)	480** (64%)	79 (46%)

Values in parenthesis represent the percent of the statewide estimate from the corresponding study.
* Includes estimated effects of current distribution system reverse power flow constraints.
** Net technical potential.

1.3 Market Potential Studies

Market potential is the most important aspect of these studies and the most relevant to the needs of the Commonwealth PIER Mini-Grid Program. Reviewing the previous approaches employed and then determining the most appropriate methodology for this program is a key element of this first Task 1.1.1 deliverable. As with technical potential, market potential also does not have a uniform definition. Determining market potential usually starts with a review of the technical potential, and then takes into consideration various market barriers and markets conditions. These market conditions include the economics of the technologies of interest, the available alternative options, and barriers to market entry. In general terms, market potential takes the view of what is practical given certain conditions in the marketplace.

Three market potential studies were identified and reviewed for this planning and analysis project. Among these studies, two estimate market potential for solar photovoltaic and one estimates market potential for biogas technologies. Table 1-3 presents these market potential estimates. A significant shortcoming was uncovered; there are very few market potential studies and two of the three studies reviewed (Arthur D. Little 1995 and Hoff 1996) are localized studies and not of a statewide nature.

Table 1-3: Estimates of Market Potential by Resource Type (MW)

Study	Geographic Scope	Solar Photovoltaic	Animal Waste Biogas
Linda Quok (1984)	All California	NA	89 MW
Arthur D. Little, Inc. (1995)	Los Angeles	568 MW[8]	NA
Tom Hoff et al. (1996)	Sacramento	400 MW	NA

The methodologies used in each of these market potential studies starts with an assessment of the technical potential of the resource, either implicitly or explicitly. The technologies considered in developing the market potentials are first identified. A few differences exist in the focus of the market assessments. One study (Quok et al. 1984) examined both current and emerging technologies, whereas the other two studies focused on current technologies.[9]

The costs associated with the technologies under consideration are developed in much the same manner. The only difference is how rigorously the authors develop the costs. For example, Quok et al. (1984) recognizes that there are economies of scale. In this study, cost curves were developed where costs decline in a non-linear fashion as system capacity (kW) increases.

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8 Estimate assumes savings under direct distribution and takes into account average market rates for electricity at the date of publication. The geographical area of interest for this study was termed " Pacific Southwest," and is representative of Los Angeles, CA, and used PG&E price data.

9 One study (Arthur D. Little 1996) briefly explored an emerging technology under a niche market scenario.

Differences in the benefits considered exist across these reports. One study (Hoff et al. 1996) placed significantly more emphasis on the electric utility T&D benefits than the others did. This study considered the value of reduced gas price risk, electric line loss reduction, distribution system equipment investment deferral, subtransmission capacity investment deferral, transmission system equipment investment deferral, avoided marginal cost of system-wide generation capacity, avoided marginal cost of system-wide energy production, as well as the impact of net metering. Only Quok et al. (1984) did not consider environmental externalities.

The estimates of market penetration varied between the studies, as well. One study (Quok et al., 1984) assumed the potential to be all systems that met a predetermined threshold[10] for being cost effective.[11] Another study (Arthur D. Little, Inc. 1995) developed market penetration curves relative to payback periods at differing technology maturity levels. This allowed for changing levels of market penetration over time due to reduced technology costs as well as increased customer acceptance.

1.4 Conclusions

This review focuses on two renewable energy generation technologies: biogas and solar photovoltaics. Four biogas feedstocks were identified: municipal solid waste (landfill gas), municipal sludge waste, animal waste, and food processing waste. The technical and market potential estimates found in the studies identified as part of this report are summarized in Table 1-4. This table represents what is believed to be the best available estimates of technical and market potential. Generally, RER has greater confidence in its own estimates for technical potential and, therefore, closely aligns with them for most of the resources.

[10] Economical is defined as having or exceeding an internal rate of return of 20% and a payback of less than or equal to five years.

[11] This is sometimes referred to as economic potential.

Table 1-4: Net Technical and Market Potential in California (MW)

		Solar Photovoltaic	Animal Waste Biogas	Food Processing Waste Biogas	Municipal Solid Waste (Landfill) Biogas	Municipal Sludge Waste Biogas	Photovoltaic/ Biogas Total
Technical Potential in California	Potential	9,442*	210	33	755	138	10,578
	% of Cal. Peak[12]	22%	< 1%	< 1%	2%	< 1%	25%
Technical Potential in Southern California	Potential	2,219**	58**	1**	480	79**	2,405
	% of So. Cal. Peak[13]	8%	< 1%	< 1%	2%	< 1%	9%
Market Potential in California	Potential	NA	90	NA	NA	NA	NA
	% of Cal. Peak	NA	< 1%	NA	NA	NA	NA

* Includes estimated effects of current distribution system reverse power flow constraints.
** Gross technical potential data available

The literature also points out that market barriers, such as high initial capital costs, and several institutional barriers[14] make the proliferation of renewable electricity generation difficult.

Southern California's peak demand was approximately 28,000 MW in 2001. The studies reviewed demonstrate that a significant portion of the potential for electric generation from biogas and photovoltaic resources in California is located within the southern part of the state and, furthermore, that these resources could be utilized to satisfy much of this demand.

These market potential studies shed light on the requirements for the market assessment[15] to be performed in Project 1.1 of the Commonwealth PIER Renewables Mini-Grid Program. This market assessment should examine both current as well as emerging technologies. This will allow for the inclusion of expected cost reductions and efficiency improvements resulting from the emerging technologies developed through the Commonwealth PIER Program. The market assessment must also fully consider T&D system impacts, since this is

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12 The percentage of California Peak Demand was calculated by dividing the technical and market potential estimates by the Statewide Peak Value of 43,000MW.

13 The Southern California Peak Demand estimate of 28,000MW represents the sum of SDG&E, LADWP, and SCE Peak Demand forecasts for 2001. The percentage of Southern California Peak Demand was calculated by dividing the technical potential estimates for Southern California by the Southern California Peak Value

14 For example, electric grid interconnection and environmental permit requirements.

15 Project 1.1, Task 1.1.7.

an important element of the program. Given the sub-regional aspect of the mini-grid, it will be important to consider local market penetration and the market barriers that affect it. Finally, the mini-grid market assessment will need to consider the specific environmental benefits that apply[16] and any synergistic benefits associated with the Commonwealth mini-grid concept.

[16] For example, reduced ground water contamination.

Appendix A

Bibliography

1. Arthur D. Little, Inc. "Building Integrated Photovoltaics (BIPV) – Analysis and U.S. Market Potential." U.S. Department of Energy Office of Building Technologies. February 1995.

   This study attempted to determine the market potential for grid-connected, building-integrated photovoltaics (BIPV). The report discusses options for reducing the cost of BIPV systems, the effect of BIPV on residential and commercial building load profiles, different commercial (rooftop and curtainwall) and residential (rooftop) configurations and their associated load impacts, allowable system price with and without integrated resource planning (IRP) benefits, and the impact of BIPV on national energy savings. Conclusions are then drawn from the data.

2. Blackburn, William. "Evaluation of Biomass-to-Ethanol Fuel Potential in California: A Report to the Governor and the Agency Secretary, California Environmental Protection." California Fuels and Transportation Committee. December 1999.

   This paper was prepared as part of California Executive Order D-5-99, issued by Governor Gray Davis, which calls for the phase-out of methyl tertiary-butyl ether (MTBE), a fuel additive suspected to be contributing to groundwater and surface water pollution. The author looked at past efforts to produce ethanol from bio-waste, which concluded that in-state production of ethanol was not economically competitive with ethanol produced in the Midwestern United States. The study also reviewed government incentive programs (typically in the form of tax breaks) aimed at making ethanol a more feasible substitute to MTBE, California's biomass resources for producing ethanol (51 million bone dry tons of gross waste and residual biomass annually), potential biomass crops in California, regulatory requirements for siting biomass-to-ethanol facilities in California, ethanol production potential from biomass resources, biomass-to-ethanol project economics, potential investment risks, and potential public benefits. The authors also provided recommendations for actions the state should undertake to develop a longer term policy.

3. Bureau of Land Management. "Assessing the Potential for Renewable Energy on Federal Lands." 2002. Draft.

This report assesses the potential for geothermal, wind, solar, biomass, and low-impact hydropower resources on BLM lands, and attempts to identify planning units in the Western United States with the highest potential for private-sector development of power production facilities. The report makes note of areas with high resource availability, but does not go so far as to estimate the potential (either technical or market) for harnessing these resources. Hence, this report is of little interest to the present study.

4. Envirosphere Company. "Non Utility Supply Curves Project: Subcontractor Report of Tasks 1, 2, 3, and 4 for Biogas, MSW, Landfill Gas and Digester Gas Recovery/Power Generation, Geothermal, Electric and Wind Technologies." California Energy Commission. February 1988.

This report looks at biomass, municipal solid waste, landfill gas, digester gas, geothermal, binary, dual-flashed steam, and wind power generation in terms of each technology's gross technical potential and development of prototype facility characteristics for modeling purposes. In addition, the report discusses the market assumptions used in the analysis and contains a cash flow analysis for each technology.

5. Hoff, Tom, J. Pepper, and H. Wenger. "Photovoltaic Economics and Markets: The Sacramento Municipal Utility District as a Case Study." Sacramento Municipal Utility District, California Energy Commission, and U.S. Department of Energy. September 1996.

This report evaluates the grid-connected photovoltaic applications within the Sacramento Municipal Utility District's service area for utility- and customer-sited applications. The report looks at utility benefits, the performance of photovoltaic systems, the impact of net metering, the market potential for residential rooftop photovoltaic systems, and commercialization strategies (the multi-megawatt IPP strategy and the niche market strategy).

6. Heavner, Brad, D. Jacobson, and M. Zugel. "Affordable, Reliable Renewables: The Pathway to California's Sustainable Energy Future." California Public Interest Research Group Charitable Trust. July 2001.

This paper gives an overview of renewable technologies that exist, or, in the author's opinion, ought to exist, in California. The authors give their assessments of energy potential from certain renewable technologies (wind, geothermal, and solar) on a statewide level, and bolster their argument by siting reliability issues, cost issues, and potential environmental impacts, which, in their view, make renewable generation options particularly attractive. In addition, the authors make recommendations for policy changes

to increase the amount of California's electric generation produced from renewable resources.

7. Kaye, R.J., I. MacGill, D. Travers, and M. Watt. "An Analysis of the Australian Market for Building Integrated Photovoltaic." Photovoltaic Special Research Centre University of New South Wales. Sydney, Australian. 1997.

   This paper presents the results of a project that assessed the potential of different photovoltaic products in each of a number of markets. The objectives of the study were to assess and rank the potential of different photovoltaic products in each of a number of markets (by building type and region), identify the key barriers to the realization of that potential and outline possible remedies, and provide information to the photovoltaic industry, the building industry and policy makers on the most promising building integrated photovoltaic products and their applications. Together, it was hoped that these objectives would satisfy the overall objective, which was to match products to markets across Australian state of New South Wales. This involved matching both technical performance and economic criteria using a model, which estimated hourly photovoltaic output over the study period from databases of climate and from photovoltaic system parameters for specified installations on the building envelope.

8. Kulkarni, Pramod, and M. Smith. "1996 Energy Technology Status Report: Chapter 8 – Biomass Fired Plants." California Energy Commission. March 1999.

   This report is a biennial response from the CEC to the Governor and Legislator of the State of California, as mandated by Public Resources Code Section 25604 (1988). The report's intention is to shed light on energy development trends in the state, including the status of new and existing technologies. In the case of Chapter 8: Biomass Fired Plants, the report focuses on three types of biomass fired plants: direct combustion, gasification, and anaerobic digestion of livestock manure. For each of these plant types, the report provides a description of the technology, discusses the commercial availability, research and development goals, deployment issues, and project economics. Each section includes references for materials used in the report, and the section on gasification technologies includes a background section.

9. Kulkarni, Pramod, and M. Smith. "1996 Energy Technology Status Report: Report Summary." California Energy Commission. December 1997.

   This report is a biennial response from the Commission to the Governor and Legislature of the State of California, as mandated by Public Resources Code Section 25604 (1988). The report's intention is to shed light on energy development trends in the state, including the status of new and existing technologies. The report summarizes the status of fuel cycles technologies, electric generation technologies, end-use technologies, and transmission and

distribution technologies in terms of their commercial availability. Each section also contains general conclusions regarding the particular technology groupings. The end of the report provides a technology evaluation summary, which contains a technology evaluation matrix and a competitive cost analysis.

10. Moser, Mark A. "Resource Potential and Barriers Facing the Development of Anaerobic Digestion of Animal Waste in California." California Energy Commission. December 1997.

This report addresses production, recovery, and use of methane from animal manures and the associated costs and benefits in California. The report estimates that under current animal waste management practices, California dairies have a potential of generating over 20 million cubic feet of methane per day (or, over 34 million cubic feet of biogas, assuming biogas contains 60% of methane), which, if fully utilized in the production of electric power, would potentially generate 57 net megawatts. The authors developed the California Methane Estimation Model (CMEM) to estimate costs and benefits of methane recovery and use, which uses animal numbers, farm location, farm characteristics, and waste management techniques. From this model, it is possible to select an appropriate digester type, assess project costs, and calculate potential revenues from biogas potential. The authors estimate that many anaerobic digester systems could be built in California that would have a positive net present value, and that energy prices (in 1997) could justify many profitable digesters in California. Among the barriers to commercialization of biogas technologies, the authors draw particular attention to a history of poor performance, a lack of people and institutions familiar with successful projects, high capital costs, limited financing opportunities, and disadvantageous electric utility rate structures.

11. Regional Economic Research, Inc. "Technical Potential of Renewable Energy Technologies." California Energy Commission. Draft Report, June 2002.

This report is an update of the 1991 RER technical potential study and addresses the resource potential from all major renewable energy resources in California, including those of interest to this PIER Program: photovoltaics, biomass, and biogas resources. Topics include methodology for derivation of technical potential, renewable-based utilization technologies and their applications, availability of resources, transmission constraint issues, updated technical potential estimates at the state and county level, and estimates of potential on State-owned Lands.

12. Regional Economic Research, Inc. "Technical Potential of Alternative Technologies." California Energy Commission. December 1991.

This report addresses the resource potential from cogeneration and renewable energy sources including photovoltaic, biomass, and biogas resources. Topics

include methodology, utilization technologies and applications, availability of resources, transmission constraints, and technical potential estimates at the state and county level.

13. Quok, Linda, J. Chandler, and S. Schellenbach. "Potential of Biogas Systems for California Farms with Confined Animals." California Energy Commission. January 1984.

    This study attempts to estimate the potential market for biogas systems, with the following assumptions: a 20% minimum rate of return, a five-year maximum payback period for potential installations, and benefits calculated solely on electricity-generated revenues. With these assumptions as a guide, the technical potential for biogas systems was calculated. In addition, two case studies of commercial biogas systems funded by a Commission program are included in the study in order to illustrate the actual benefits associated with these systems.

14. SCS Engineers. "Economic and Financial Aspects of Landfill Gas to Energy Project Development in California." Public Interest Energy Research (PIER). California Energy Commission. April 2002.

    This report provides an overview of available technologies for the utilization of landfill gas, discusses technical and performance issues associated with those technologies, and discusses the capital and operating costs that an operator of a landfill gas generation facility might expect to incur. In addition, the report addresses project development issues including permitting, financing, ownership, energy sales opportunities, and potentially available grants, tax credits, and other financial incentives available for LFG utilization projects. The report contains some interesting information about landfill sites in California that have potential as landfill gas to energy projects.