Distributed Generation and Combined Heat and Power Case Study Protocol

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Prepared For:

Association of State Energy Research and Technology Transfer Institutions (ASERTTI)
The U.S. Department of Energy (DOE)
The Illinois Department of Commerce and Economic Opportunity (DCEO)

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Foreword

Distributed generation (DG) technologies are emerging as a viable supplement to centralized power production. Independent evaluations of DG technologies are required to assess performance of systems, and, ultimately, the applicability and efficacy of a specific technology at any given site. A current barrier to the acceptance of DG technologies is the lack of credible and uniform information regarding system performance. Therefore, as new DG technologies are developed and introduced to the marketplace, methods of credibly evaluating the performance of a DG system are needed. This protocol was developed to meet that need.

This interim protocol describes the procedure to conduct case studies of the performance of microturbine generators (MTG), reciprocating internal-combustion engine (IC) generators, and small turbine generators. It also provides information for transmitting this information to a national database at the National Renewable Energy Laboratory (NREL). The protocol is applicable to systems with and without combined heat and power (CHP). The case study protocol is designed to report data on the electrical, thermal (if applicable), emissions, financial, and operational performance of DG/CHP systems. Application of this protocol will provide uniform data of known quality that is obtained in a consistent manner. Therefore, this protocol will allow for comparisons of the performance of different systems, facilitating purchase and applicability decisions. In addition to this protocol, there are parallel interim protocols for:

- laboratory applications of these systems (Gas Technology Institute)
- field applications of these systems (Southern Research Institute)
- long term monitoring of these systems (Connected Energy Corporation)

The performance results of DG systems tested and/or monitored with the protocols will be housed in a free searchable database managed by NREL. A list of Meta Data is included in an appendix. The list defines the database structure to support the searchable database.

The case study protocol is intended for use by those evaluating new technologies (research organizations, technology demonstration programs, testing organizations), those purchasing DG equipment (facility operators, end users), and manufacturers. It is intended solely to provide consistent, credible case study data. It is not intended to be used for certification, regulatory compliance, or equipment acceptance testing.

The Gas Technology Institute (GTI) and Underwriters Laboratory (UL) have initiated an effort through UL's Standards Process to offer a certification service that allows testing at any qualified laboratory. UL is adopting the laboratory performance protocol as part of its certification development process.

This protocol was developed as part of the *Collaborative National Program for the Development and Performance Testing of Distributed Power Technologies with Emphasis on Combined Heat and Power Applications*, co-sponsored by the U.S. Department of Energy and members of the Association of State Energy Research and Technology Transfer Institutions (ASERTTI). The ASERTTI sponsoring members are the California Energy Commission, the Energy Center of Wisconsin, the New York State Energy Research and Development Authority, and the University of Illinois-Chicago. Other sponsors are the Illinois Department of Commerce and

Economic Opportunity and the U.S. Environmental Protection Agency Office of Research and Development. The program is managed by ASERTTI.

The protocol development program was directed by several guiding principles specified by the ASERTTI Steering Committee:

- The development of protocols uses a stakeholder driven process.
- The protocols use existing standards and protocols wherever possible.
- The protocols are cost-effective and user-friendly, and provide credible, quality without excessive implementation costs.
- The interim protocols will become final protocols after review of validation efforts and other experience gained in the use of the interim protocols.

The case study protocol was developed based on input and guidance provided by the ASERTTI Stakeholder Advisory Committee (SAC). The SAC consisted of 27 stakeholders representing manufacturers, end-users, research agencies, regulators, and demonstrators.

The ASERTTI Steering Committee directed the project and provided review and final approval of this protocol. Figure 1 shows the program management structure and individuals that were involved in the protocol development.

The protocol development process consisted of several steps following ASERTTI's guiding principles. First, a list of performance parameters for which laboratory and field testing protocols should be written was completed. The parameters selected provide performance data for electrical generation, electrical efficiency, thermal efficiency, atmospheric emissions, acoustic emissions, and operational performance.

The laboratory, field, long term monitoring and case study protocols' development was based on existing standards, protocols, and the experience of the committees. Existing standards and protocols potentially applicable to DG systems were reviewed and evaluated. The existing standards and protocols form the basis for instrument specifications, acceptable test methods, QA/QC procedures, calculations, and other requirements of this protocol. The laboratory protocol allows for the controlled evaluation of the effects of several parameters on performance of the unit which can not be reasonably verified in field testing. Laboratory testing also allows testers to determine performance under conditions that can not be practically controlled in a field setting, such as ambient conditions, response to upsets, and grid isolated (stand alone) operation for determining transient response characteristics.

Reasonable compromises were sought to provide a balance between the requirement for credible, quality data, and requirements that these protocols be user-friendly and result in minimizing cost to implement testing, such that they can be widely and consistently implemented and reported on the Search Database at NREL.

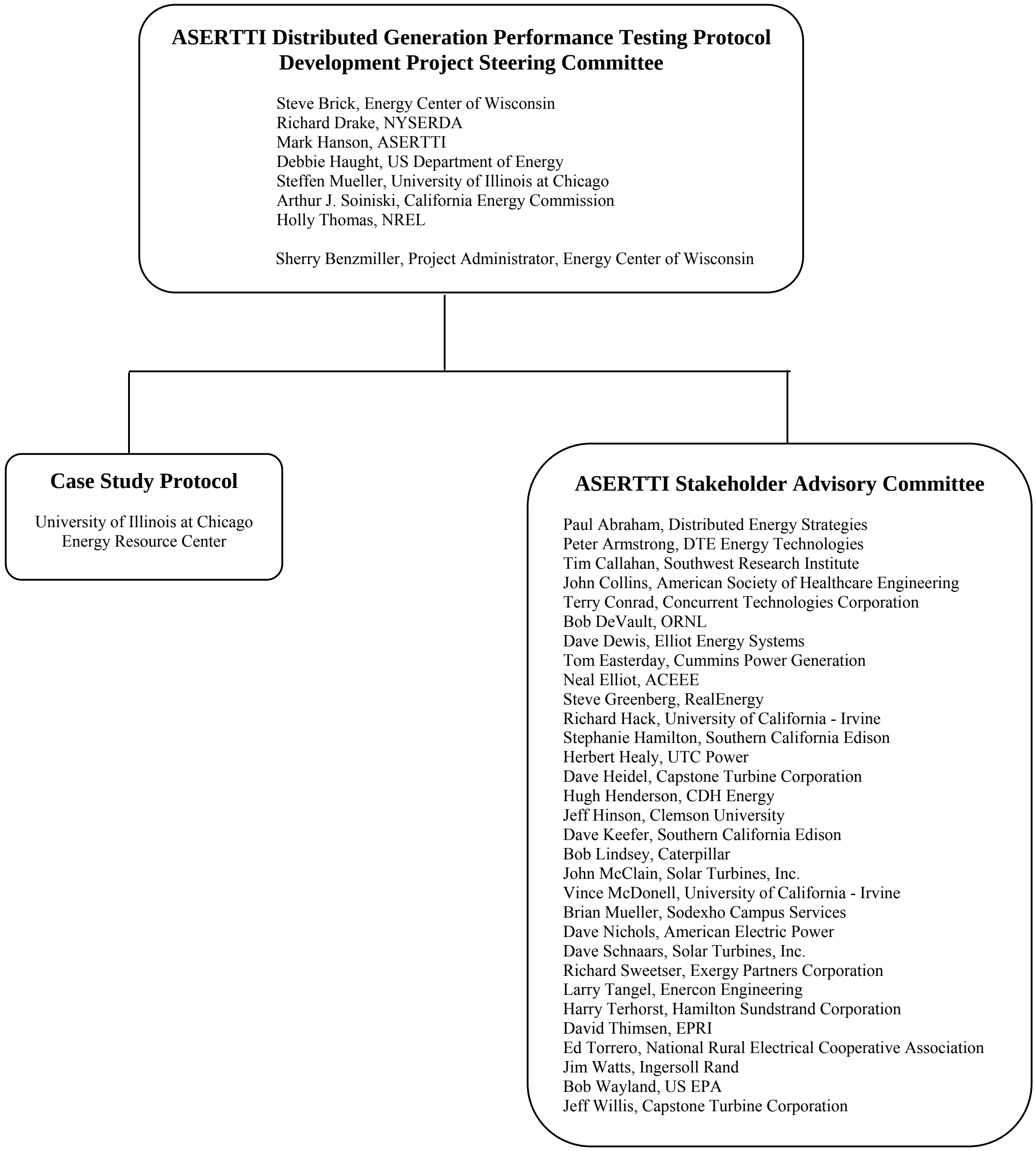

Figure 1. Case Study Protocol Development Contributors

This case study protocol follows the general format for qualitative research of this type [1]:

a) Case Study Field Procedures
   The field procedures discuss the required preparation and training of the case study investigator prior to the data collection process. Furthermore, the field procedures address the criteria to be utilized when selecting the appropriate people to be interviewed as part of the case study protocol.

b) Data Collection Procedures
These procedures provide guidelines that assure a comprehensive collection of data relevant to the case study.

c) Case Study Reports
Case studies cater to a variety of audiences. This section provides report templates for two potential audiences. Report A, the "Detailed Site Report," is based on a fourteen-page template that provides a comprehensive analysis of a DG/CHP facility with in-depth financial and descriptive analyses of the facility. The advantage of this report form is its thoroughness and high quality of the data analysis. The disadvantage of Report A is the relatively high research cost that may range between $5,000 and $10,000 per report (where the lower cost is usually associated with newer facilities with more readily available information).

d) Report B, the "Project Profile," is based on a two-page template. It is a much shorter and succinct analysis of a DG/CHP site than the Detailed Site Report. The Project Profile is limited to the key financial facts of the installation as well as the key motivations and lessons learned. The research cost associated with Report B is approximately $2,000 per report.

The case study protocol incorporates the generally accepted quality principals for case studies, which call for "construct validity" and "external validity" of the research. Construct validity refers to the correctness of the employed measurements [2]. For the present DG/CHP case study protocol, construct validity is enhanced by using multiple data sources (where possible). For example, data collected from case study informants on the efficiency of DG/CHP equipment should be compared to data from the engine manufacturer. Construct validity also refers to the comprehensiveness of the assessment. Therefore, a review of existing CHP case studies has been conducted to assure that the current protocols reflect current "best-practices" in the field.

External validity, on the other hand, refers to the extent of which it is possible to generalize from the data and context of the research study. External validity for the purpose of CHP case studies can be achieved by comparing the results from a particular case against a database of other cases. One component of the ASERTTI collaborative program calls for the development of a centralized database system for all laboratory testing, field performance, and case study results, which will be based at NREL. This case study protocol provides for interaction with this database through a Meta Data file. The Meta Data file consists of key search criteria that users of the database can select to assess the key financial and qualitative findings of the case studies.

This protocol is an interim protocol. A final protocol will be issued in 2006 with any revisions based on feedback from various users and stakeholders. This feedback and results of the validation process will be reviewed by the SAC, and forwarded to the Steering Committee for approval of a final protocol.

The ASERTTI Steering Committee provided final approval of this interim protocol on September 30, 2004. For additional information regarding this protocol and the associated DG performance evaluation program, please contact the following:

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1 Purpose

1.1 Objective

The objective of this case study protocol is to establish a uniform methodology to conduct DG/CHP case studies including the required field procedures, the data collection procedures, and the reporting formats. The intent of this case study protocol is to balance flexibility in terms of how the investigator conducts a case study with the objective for consistency across different case studies. This protocol should be viewed as a set of minimum requirements for an investigator; other formats are possible.

1.2 Scope

This document is intended for use by individuals and organizations to conduct case studies of DG/CHP systems. Results of these case studies are ultimately intended for use by end users, manufacturers, utilities, system integrators, engineers, and regulators. The scope of this document covers case studies for gas turbines, internal combustion engines, and microtubine-based products and may be applied to such products containing heat recovery and thermally activated cooling technologies.

1.3 Review and Amendment

This document is subject to review and amendment as the marketplace and technology further development.

2 Review of Current CHP Case Studies and Case Study Approaches

This section reviews research based on case studies in the field of distributed generation and combined heat and power technologies. The intent is to provide an overview of the various case study approaches and their reporting and data verification procedures.

A report sponsored by NREL titled "Making Connections - Case Studies of Interconnection Barriers and their Impact on Distributed Power Projects" summarizes a total of 26 cases with respect to their experience with the electric interconnection process [3]. Particularly interesting and informative about the report is that it lists the "interview guide" used to collect the information from the individual distributed generation systems. Besides using a structured interview guide, the collected information from the distributed generation projects was verified by also contacting the incumbent utility companies. The results from each case study are described using a five line summary table detailing the system's electric generating technology, the current interconnection status, the major interconnection barrier, and the current back-up power arrangements. The report does not address any financial considerations of the systems.

Another report sponsored by NREL titled "The Impact of Air Quality Regulation on Distributed Generation" is based on 51 case studies focusing on air emissions permitting experiences [4]. The "approach" section of the report details that each case study consisted of an initial data gathering process through contacts with air regulators and developers, followed by detailed phone interviews. Data gathered during the initial phone interview was verified using follow-up phone calls and public records; using multiple data sources thereby enhances "construct validity" of the case studies. Also, each case is described by a five line case summary and a three paragraph case description addressing the main permitting issue and critique.

The Department of Defense issued a report on their fuel cell CHP program, which includes the installation of 30 fuel cells with heat recovery across various military sites across the United States [5]. The report presents three cases in more detail, consisting of a one paragraph project description with details on the use of thermal energy from the CHP systems, the project experience, a brief summary of the savings in dollars, and a one-line system diagram. Details on the basis of the savings calculations are not given in the report. The overall focus of the report, however, is to detail the variety of thermal applications from fuel cell based CHP systems.

The New York State Energy Research and Development Authority (NYSERDA) posts several case study reports on its website (www.nyserda.org). The case study reports list the application type, the employed CHP technology and electric capacity, as well as the annual energy savings in dollars from the CHP system. The reports are one-page in length and provide a good snapshot of the various installations.

DynCorp Meridian prepared a report titled "Assessment of Biomass Cogeneration in the Great Lakes Region – A Great Lakes Casebook" for the Council of Great Lakes Governors, which details a total of 10 CHP applications [6]. Each case is described in approximately 4 page reports, consisting of project background, the project financials, the waste heat use, a one-line power plant/process operation diagram, and a section titled "success and challenges." The key strength of this report is its good analysis of the case financials, including current power sales and purchase arrangements backed by cost and revenue estimates. All key financial figures list the base year when cost and revenues were incurred.

While the above case studies were sponsored by governmental entities, many manufacturers of distributed generating/CHP equipment have also conducted studies, usually detailing the benefits of their own equipment.

Capstone Microturbine Corporation, a manufacturer of small, natural gas fired combustion turbines, has conducted several case studies, which are posted on the company's website (www.capstoneturbine.com). One case study focuses on the installation of a Capstone CHP system to heat a school's swimming pool. The case study promotes primarily the financial advantages as well as the educational benefits of the system. Another case study focuses on a microturbine used to burn coal mine methane and promotes primarily the environmental benefits. Another case study of a CHP system installed at a plastics plant centers on the reliability of the equipment. Capstone's case studies are particularly interesting because they cover a wide range of non-financial benefits of CHP systems.

Solar Turbine Inc., a division of Caterpillar, Inc., has conducted several case studies that detail the various applications and the reliability record of their equipment [7]. The one-page case study reports describe the utilized technology and capacity, the waste heat use, and sometimes staffing needs. The case study reports present particularly well the individual CHP plant configurations by employing one-line flow diagrams. The reports do not generally detail any financial considerations of the projects.

The Midwest CHP Application Center has performed several case studies. Some of these case studies are reported in two different formats, an approximately twenty page long "site report" and an approximately two page long "project profile" [8]. The "site reports" provide a very detailed overview of the energy supply arrangements (electricity and fuel) before and after the CHP installation and the net financial savings of the system. The "project profiles" provide a brief synopsis of the financials and a brief project description.

The project profiles are, however, not consistent with respect to their outline structure and they do not always detail the baseline scenario against which CHP savings are assessed. However, both report forms address the "key barriers and lessons learned" from the CHP project. The reports are also posted in a searchable database thereby increasing the "external validity" of the case studies. Finally, contact information to obtain additional information is provided in the reports both for the author(s) of the case study as well as the studied facility.

In summary, good DG/CHP case studies contain several elements: They are based on a structured data collection process such as the interview guide used in the NREL study. Furthermore, the more detailed case studies back-up data derived from interviews with other documented data sources. Also, case studies can incorporate multiple report forms depending on the audience. Shorter report forms show the key facts up-front in a brief summary table. Good reports also show one-line diagrams of the plant detailing the equipment configuration. Exact definition for all financial parameters assessed in the case studies should be provided. Besides financial parameters the case studies should detail other benefits from the DG/CHP system (i.e. environmental benefits, increased reliability etc.). Most case studies detail the lessons learned and challenges from the project. Finally, good reports should provide contact points to obtain further information about the studied DG/CHP facility.

3 Field Procedure

The field procedure discusses the required preparation and training of the case study investigator prior to the data collection process. Furthermore, the field procedure addresses the selection criteria of the informant(s) for the case study.

3.1 Training the Investigator

Training assures that the investigator can adequately collect, analyze, and report the required information for a case study. Training of the investigator should cover:

a) The technical aspects of DG/CHP systems. This includes an understanding of electric prime-mover technologies, thermal heat recovery technologies, heat utilization equipment types, electric interconnection and emissions reduction technologies.

b) The key financial concepts of DG/CHP systems. This includes the calculation of direct savings over an existing baseline system. Since many baseline systems are based on electricity provision by the electric utility company a basic understanding of the interpretation of utility rate structures is required. Also, basic familiarity with capital budgeting calculations, specifically payback period and internal rate of return calculations needs to be assured. Furthermore, the investigator needs to have the capability to assess less tangible savings from, for example, increased reliability from DG/CHP or decreased volatility in energy supply arrangements.

c) Review of this protocol.

3.2 Selection of the Informant(s)

The selection of the informant(s) should follow Campbell's selection criteria, which means the person or persons to be interviewed have to be "well informed and exceptionally observant" as well as "communicatively gifted" [9]. While job descriptions and job titles vary widely by company, for DG/CHP case studies it is recommended to chose the highest ranking manager or managers that are still directly involved with the DG/CHP operation; their generic job titles are usually "manager power plant operations," or "manager, facilities operation," or "manager of utilities." Other titles are, however, possible.

4 Data Collection Procedure

The data collection procedure employs a set of questions that serve the investigator as a tool and guide during the data collection process. The investigator should review the list of questions before the start of the case study.

Since this case study protocol generates two types of reports, Report A and Report B, two different investigator guides are necessary. Table 4-1 lists the key questions that should be addressed during an in-depth DG/CHP case study for presentation in Report A form. Table 4-2 lists questions that should be addressed during a succinct assessment of the key facts of a DG/CHP installation, which are ultimately presented in Report B form. It should be noted that these are recommended templates; the templates may be adjusted to fit the scope and the budget of the individual case study.

Table 4-1: Case Study Investigator Guide to Create Report Form A

Question	Sources of Data	Comment
What are the site characteristics?	Walk-through and Facility Files	What is the address and location of the site? What is the type, construction method, age, size, occupancy level of the building(s) and/or industrial facilities?
When was the DG/CHP facility installed?	Walk-through and Facility Files	How long did the construction phase take? Commissioning? Start-Up? What were the specific dates?
What are the current electricity supply arrangements of the facility?	Last 12 months of electric bills	Do bills contain monthly demand value? Do bills detail on-peak and off-peak consumption? Name of rate schedules used?
What are the current gas supply arrangements?	Last 12 months of gas bills	Do bills contain energy use? Is gas purchased under long-term contract? Name of rate schedules used?
What are the current fuel oil supply arrangements?	Last 12 months of fuel oil bills	What type (i.e. No.2 or No.6) fuel oil is used?

Question	Sources of Data	Comment
What is the current operating schedule of the facility?	Facility Files	What are the weekday and weekend operating hours.
What is the DG/CHP recovered heat used for?	Walk-through and Facility Files	Is the recovered heat used for heating, cooling, dehumidification, hot water, chilled water, steam, or other uses?
What are the current total electricity and thermal loads?	Facility Files, Generator Instrumentation/Controller	What approximate percentage of total electricity and thermal load is met by DG/CHP facility?
What is the current equipment configuration?	Plant-floor walk-through, Equipment data sheets	What is the capacity/make of the DG/CHP system electric generator prime-mover? What is the capacity/make of the DG/CHP thermal recovery systems (HRSG)? What is the capacity of the heat utilization equipment (absorption chillers, desiccant wheels etc)? What is the capacity/make of the remainder of the energy plant equipment (additional boilers, electric chillers etc.)?
What is the demand for reliable and quality power of the facility?	Facility Files	Has the facility experienced problems with power quality such as low voltage, low frequency from the incumbent electricity provider? Does the facility have any significant need for UPS systems?

Question	Sources of Data	Comment
What were the key reasons to install DG/CHP facility	Plant Manager, Finance Manager	Were the reasons purely financial considerations, environmental, power quality, political?
DG/CHP Capital Requirements	Accounting Records	What were the initial cost for: equipment, instrumentation/controls, engineering and installation. What is the current cost of capital of the facility?
What are the annual DG/CHP-related maintenance requirements?	Accounting Records	What are the scheduled and unscheduled maintenance procedures and costs including major overhauls of the equipment?
What is the reliability of the facility?	Plant Files, Plant Manager	How many outages did the DG/CHP facility experience during one year (number and duration)? What were the reasons for the outages?
What are other O&M costs?	Accounting Records	What are the DG/CHP-related labor costs, water-costs, consulting services costs?
What did the environmental permitting process entail?	Plant Files, Plant Manager, Environmental Permitting Agency	What was the initial duration of the permitting process; who performed it (in-house, outsourced?). What were the initial permitting costs? What are the annual permitting costs? What are the emission limits per permit? What are the actual emissions of the plant?
What is the electric interconnection status of the facility?	Plant Files, Plant Manager, Local Utility Company	Is the facility interconnected? If yes, how long did the interconnection process take; what were the costs?

Question	Sources of Data	Comment
What were the other regulatory requirements such as siting, zoning, other local codes (OSHA, Noise etc.)	Plant Files, Plant Manager, Local Regulatory Agencies	How long did regulatory approval take and what were the costs?
How can the experience with DG/CHP be summarized?	Plant Files, Plant Manager, Facility Financial Manager	What are the major lessons learned? What were the major barriers? Did the DG/CHP installation meet expectations? What improvements could be made to current DG/CHP operation?
Who can be contacted for further information?	Plant Manager	Can the plant manager be contacted, the engineering firm, the local utilities, the regulatory jurisdictions?

Table 4-2: Case Study Investigator Guide to Create Report Form B

Question	Sources of Data	Comment
What are the site characteristics?	Walk-through	What is the address and location of the site? What is the age, size, and number of the building(s) and/or industrial facility?
When did the DG/CHP facility become operational?	Plant Files, Plant Manager	Date?
What is the DG/CHP recovered heat used for?	Plant Files, Plant Manager	Is the recovered heat used for heating, cooling, dehumidification, hot water, chilled water, steam, or other uses?
What is the current equipment configuration?	Walk-through, Equipment data sheets	What is the capacity/make of the DG/CHP system prime-mover? What is the amount of total thermal recovery.

Question	Sources of Data	Comment
What were the key reasons to install DG/CHP facility?	Plant Manager	Were the reasons purely financial considerations, environmental, power quality, political?
What were the DG/CHP Capital Requirements?	Accounting Records	What were the initial costs of the installed facility?
What are the annual DG/CHP-related estimated savings?	Accounting Records	Absent the DG/CHP system, how would the facility meet its energy needs (i.e. define the baseline energy supply arrangement)? What are the total annual estimated savings of the DG/CHP system over the baseline energy supply taking into account fuel cost, maintenance, labor, annual regulatory fees?
What were the other regulatory requirements such as siting, zoning, other local codes (OSHA, Noise etc.)	Plant Files, Plant Manager	How long did the regulatory approval take and what were the costs?
How can the experience with DG/CHP be summarized?	Plant Manager	What are the major lessons learned? What were the major barriers? What improvements could be made to current DG/CHP operation? Did the DG/CHP installation overall meet expectations? Can the collected information be used as a direct quote in the case study report?
Who can be contacted for further information?	Plant Manager	Can the plant manager be contacted, the engineering firm, the local utilities, the regulatory jurisdictions?

5 Case Study Reports

As discussed in the overview section, this protocol generates two types of report forms. Case study Report A is a very detailed assessment of all major aspects of a DG/CHP installation. The first sections of Report A focus on the site characteristics and application of the DG/CHP system, followed by a technical description of the installed equipment, the electricity and thermal generation and the fuel uses. Later sections of Report A describe the financial and regulatory situation of the DG/CHP facility. Report A concludes with a summary of the experience and lessons learned form the installation.

Report B is much shorter and limited to two pages in length. The first page of Report B focuses on the reasons to install a DG/CHP system and provides a brief summary table of the DG/CHP financials. The second page of Report B presents more technical detail of the system.

In the following both report forms are detailed. Based on the relatively high research costs to create Report A for a facility, Report B is more likely to be used in practice. It should be noted that these are recommended templates; the templates may be adjusted to fit the scope and the budget of the individual case study.

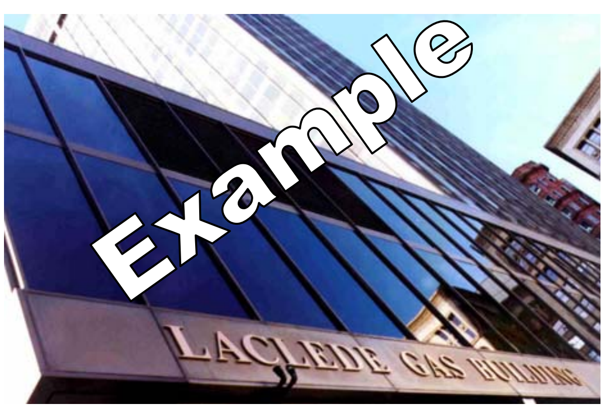
5.1 Case Study Report A (Detailed Site Report)

5.1.1 Title Page

Provide name of organization conducting case study, and name of studied facility.

5.1.2 Site Description

Provide a general description about the site and building type and use (i.e. is the DG/CHP system installed at a hospital, school, etc.). Show a picture of the facility. Describe the initial reasons for installing a DG/CHP system.



List the number of buildings, the size in square-feet, and the size in square-feet covered by the DG/CHP system. Include general occupancy and operating schedules of the building(s), building(s) age, construction method (number of floors, slab-on-grade construction or basement).

5.1.3 Market Sector Discussion

Discuss the potential market for DG/CHP in the particular sector for this building use [10]. Include market penetration and an overview of other installations if information is available [11]. Discuss any regional benefits and concerns.

5.1.4 Technical Description

5.1.4.1 Baseline System Description

The baseline energy system is defined as the energy supply arrangement that would be in place absent of the DG/CHP system, which is most likely the equipment configuration at the facility prior to DG/CHP installation.

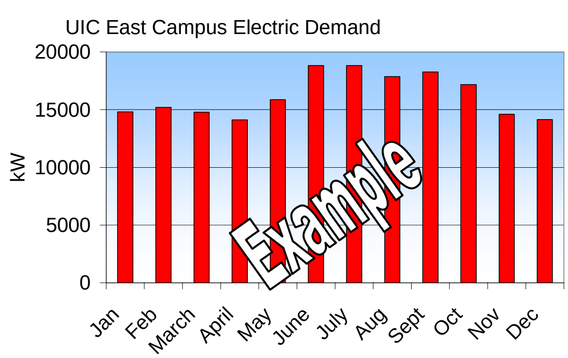
Describe the electric generating system, such as emergency generators etc. deemed appropriate for the baseline installation. List all types of mechanical chiller systems. Describe all thermal generating systems (boilers etc.), and all thermal utilization equipment (absorption chillers, desiccant systems) deemed appropriate for a baseline system.

Describe the electricity and fuel supply arrangements that accommodate the baseline system. For regulated states this may most likely include electricity and fuel provision by the incumbent utility company; for deregulated states this may include electricity and fuel supply from energy marketers.

5.1.4.2 DG/CHP System Description

a) Electrical Parameters

Discuss the building(s)' electrical energy requirements including a 24-hour demand profile and a description of any seasonal variations. Provide tabulated or graphical presentation of this information.

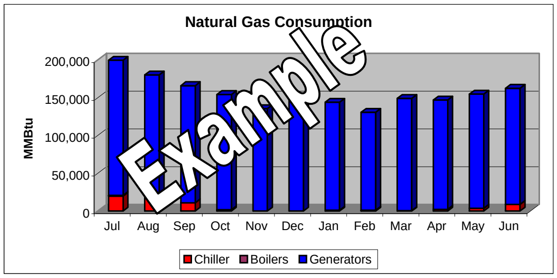


Provide the make and type of power supply equipment (i.e microturibine, natural gas fired engine, etc.) including the required fuel type. Provide a description of the waste heat profile (i.e. jacket water parameters, exhaust heat quality and temperature).

Explain any supplemental electric supply arrangements (i.e. from the incumbent utility company, or alternative electricity suppliers), any backup-power arrangements, and any sales arrangements of excess DG/CHP capacity. Describe the type of metering in place for these arrangements, as well as electric equipment requirements.

b) Fuel Supply Description

Provide a general description of the fuel supply arrangements including fuel used for generation and supplemental thermal requirements. The fuel supply description should name or describe the fuel seller and the types of arrangements (i.e. firm transportation, duration of contracts, other hedging arrangements).

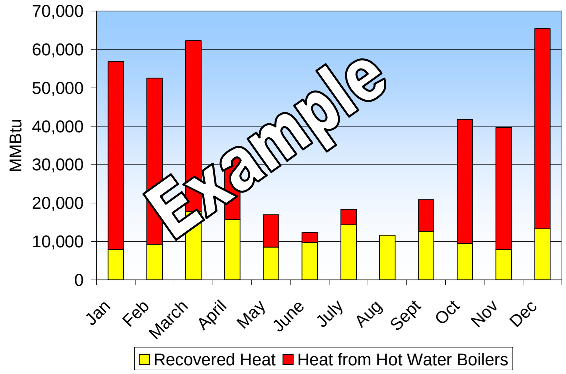


c) Thermal Utilization Systems

Describe the heat utilization systems in place if waste heat is recovered

- for process steam (list make, model and capacity)
- for building hot water heating or other uses such as laundry, pool, heating, or some other heating and drying processes.
- to drive a compression chiller.
- for use in an absorption chiller.
- to dry /preheat a desiccant wheel.

Provide a summary of the above waste heat uses in tabulated or graphical form.

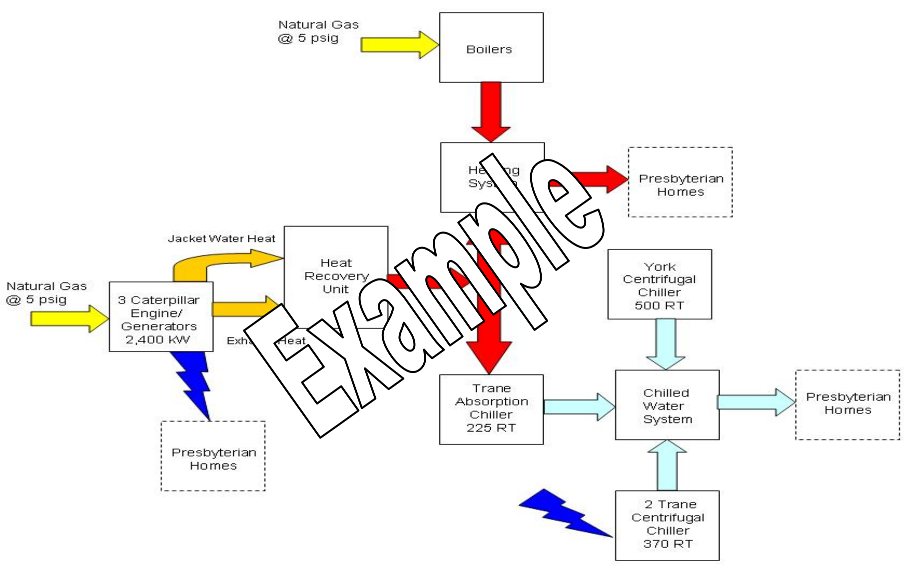


d) Non-Recovery Thermal Systems

Provide a description of any supplemental or redundant thermal system to the DG/CHP system described above.

e) Summary DG/CHP System Description

Provide a one-line diagram of the DG/CHP plant components.



5.1.5 Comparative Analysis – DG/CHP vs. Baseline Energy Supply System.

a) Electricity Supply Comparison

The information in this section provides a comparison of the electricity in kWh generated with the DG/CHP system to the electricity generated with the baseline system. Information in this section should be presented in tabulated or graphical form. If useful, the information should be shown for on-peak and off-peak conditions as well as monthly and yearly averages.

Description	Units	DG/CHP System	Baseline
Electric Load	kWh		
Electric Peak	kW		
Annual Electrical Consumption	kWh		

b) Thermal Supply Comparison

The information in this section provides a comparison of the thermal energy production in Btu from the DG/CHP system to the thermal generation from the baseline system. Information in this section should be presented in tabulated or graphical form. The information should be shown for each type of thermal utilization system. If useful, the information should be shown for peak and off-peak conditions as well as monthly and yearly averages.

Description	Units	DG/CHP System	Baseline
Thermal Capacity	Btu		
Heating	Btu		
Cooling	Btu		
Annual Thermal Use	Btu		

c) Fuel Usage Comparison

The information in this section provides a comparison of the fuel requirements in Btu of the DG/CHP system to the fuel requirements of the baseline system. Information in this section should be presented in tabulated and graphical form. The information should be shown for each type of thermal fuel. If useful, the information should be shown for peak and off-peak conditions as well as monthly and yearly averages.

Description	Units	DG/CHP System	Baseline
(Fuel Type 1)			
Average Daily Fuel Consumption	Btu		
Winter	Btu		
Summer	Btu		
Peak Daily Fuel Consumption	Btu		
Annual Fuel Consumption	Btu		Example
Annual Fuel Consumption	Btu		
(Fuel Type 2)			
Average Daily Fuel Consumption	Btu		
Winter	Btu		
Summer	Btu		
Peak Daily Fuel Consumption	Btu		
Annual Fuel Consumption	Btu		

5.1.6 Financial Analysis

a) Procurement of Capital

This section should discuss the initial procurement of financing for the DG/CHP facility as well as the baseline system. This should describe the methods used to access capital (i.e. issuance of debt, equity, or grants).

b) Initial Project Cost

Equipment:

This section compares DG/CHP equipment costs to the costs of the baseline system. The description should include all costs for instrumentation, interconnection upgrades, controls, and installation of the equipment. At a minimum the costs for the entire project should be listed.

Equipment	DG/CHP System	Baseline
Power Generation Equipment		
Cooling Equipment		
Desiccant		
Heating Equipment		
System Instrumentation		
System Controls		
Installation		
Interconnection Equipment		
TOTAL COSTS	$0	$0

Engineering**:**

This section should provide a comparison of the initial feasibility, design, and engineering cost.

	DG/CHP System	Baseline
Design		
Drawing		
Labor		
Site Preparation/Modification		
TOTAL COST	$0	$0

One-Time Regulatory Fees:

This section should list the costs associated with one-time regulatory fees such as initial siting fees, construction permitting fees, initial environmental permitting fees, interconnection fees, and others.

	DG/CHP System	Baseline
Sitting Fees		
Construction Permit		
Exit Fee		
Interconnection Fee		
TOTAL COST	$0	$0

c) Annual Cost

Maintenance Costs:

This section should detail the annual maintenance costs both for the DG/CHP system as well as the baseline system. Maintenance costs should list routine as well as special/major maintenance overhauls. If maintenance is performed through a service agreement, the details should be listed.

	DG/CHP System	Baseline
Service Contract		
Routine Maintenance		
Monthly		
Quarterly		
Yearly		
Special Maintenance *(yearly average cost)*		
Overhaul		
Replacements		
TOTAL COST	$0	$0

Electricity Costs:

This section compares the annual electricity costs of the DG/CHP system to the annual electricity costs of the baseline system. Annual electricity costs of the DG/CHP system in this case include backup-power arrangements and electricity purchases to supplement DG/CHP generated electricity.

	DG/CHP System	Baseline
January		
February		
March		
April		
May		
June		
July		
August		
September		
October		
November		
December		
TOTAL	$0	$0

Example

Fuel Costs:

This section compares the fuel costs between the two energy supply systems.

	DG/CHP System	Baseline
January		
February		
March		
April		
May		
June		
July		
August		
September		
October		
November		
December		
TOTAL	$0	$0

Operator Costs:

This section provides a comparison of the annual personnel costs between the DG/CHP system and the baseline system.

	DG/CHP System	Baseline
January		
February		
March		
April		
May		
June		
July		
August		
September		
October		
November		
December		
TOTAL	$0	$0

Example

d) Total Annual Cost and Energy Consumption Summary

This section summarizes the key cost components of both the DG/CHP system and the baseline system as well as the energy consumption of both systems.

Operating Savings with CHP	Utility and O&M Cost		Annual Energy Consumption	
	Baseline	CHP	Baseline	CHP
Electricity				
Utility Electricity	$655,696	$0	12,868,233 kWh	--
Generated Electricity	--	$0	--	12,868,233 kWh
Natural Gas				
Boilers	$424,340	$0	65,775 MMBtu	--
Engine	$0	$928,642	--	179,771 MMBtu
Maintenance	$0	$137,808		
Total Operating Cost	**$1,080,036**	**$1,066,450**		
Annual Savings from CHP		**$13,585**		

5.1.7 Capital Budgeting Analysis

The capital budgeting analysis performed as part of the case study depends on whether the DG/CHP system constitutes a replacement or a retrofit of the baseline system. In the first case it is assumed that the baseline system is at the end of its useful life and needs to be replaced, in which case the capital cost of the baseline system are considered a credit towards the capital cost of the DG/CHP system. In the retrofit case the DG/CHP capital cost will not receive this credit for capital budgeting purposes.

While several capital budgeting methods exists, the following two measures are most commonly used for DG/CHP systems:

a) Payback Time

The payback time is defined as the ratio of the extra capital cost (whether for replacement or retrofit) over first year savings [12].The inverse of this ratio is often referred to as "return on investment." Neglecting any discounting of future cash flows or the possibility that future cash flows do not equal the first year savings, the payback time provides a rough approximation of the number of years it takes for a DG/CHP installation to "pay for itself."

b) Internal Rate of Return

The internal rate of return (IRR) takes into account the uncertainty risk associated with projected future annual savings and applies a discount rate to these cash flows. The IRR is defined as the value of the discount rate at which the total savings from the DG/CHP installation equal zero. All commonly used spreadsheet software programs can calculate IRR values. The discount rate used for IRR calculations should be the cost of capital of the particular facility. If this information is not available a discount rate of 11.5% has been cited in the literature as an appropriate rate for the risk associated with this type of investment [13].

IRR calculations require an estimation of the total life of the project (i.e. how many years of savings should be considered for calculation purposes). Since the actual lifetime of electric generation and HVAC systems vary from equipment to equipment general assumptions need to be made. This case study protocol recommends following the ASHRAE equipment service life estimates, which estimate the service life for a reciprocating engine-based DG/CHP system to be 20 years [14].

5.1.8 Performance Measures

This section summarizes the performance measures of the DG/CHP system.

a) Efficiency

Efficiency calculations should be performed in accordance with the laboratory performance and field test protocols. At a minimum for DG systems the net electrical efficiency should be calculated. As defined in the laboratory performance test protocol "the net electrical efficiency is the indication of fuel to electricity conversion efficiency of the DG product considering internal and external parasitic losses." For natural gas-fired systems the fuel used per year should be stated in Btu of lower heating value [15]. The derived efficiency values should be compared to the values listed by the equipment manufacturers.

At a minimum for CHP systems the net electrical efficiency and the system efficiency should be calculated. As defined in the laboratory performance test protocol "the system efficiency is based on the total energy input in the form of fuel to the total usable energy available at the customer electric and mechanical interconnection locations in the form of electricity and heat."

b) Reliability

The reliability measure should be calculated for the DG/CHP as well as for the baseline installation. For the DG/CHP system the annual reliability in percent should be calculated by dividing the unscheduled outage times (in hours) by the total scheduled operating time (in hours) of the DG/CHP system during the study year. Reliability should also be described in terms of number of total outages per year. A qualitative assessment of the reasons for any major outages should also be provided.

For the baseline system, reliability should be calculated by dividing the electric outage times (in hours) by 8760.

5.1.9 Installation Analysis

This section should provide a comparison of the siting and space requirements of the DG/CHP system versus the baseline system. Secondly, this section should address the time requirements to install the systems and detail the delays encountered during the installation processes.

5.1.10 Regulatory Considerations

This section should compare the major regulatory requirements for environmental permitting, electric interconnection, and local code compliance between the DG/CHP system and the baseline system. For example, this section should point out pollutants that are close to the permitting limits, major interconnection issues, or unexpected local code requirements.

5.1.11 Summary and Lessons Learned

This section should detail the lessons learned from the DG/CHP installation in terms of the experience gained from the technical, financial, and regulatory process. This section should also list names and addresses of the key parties involved with the DG/CHP system. For example the contact list may include the current facility manager, the architect and engineering company, and key regulatory contacts.

5.2 Case Study Report B (Project Profile)

5.2.1 First Page

The first paragraph should list a brief synopsis of the DG/CHP system consisting of the main application (i.e. hospital, school etc.), the type of waste heat utilization, and the experience (level of satisfaction) with the system.

The second paragraph should summarize the key financial parameters in a table.

Installed Cost:	$ X
Annual Savings:	$ X
Payback:	X Years
Generator Size:	X kW
Facility Size:	X Square-feet
Operational Since*:	200X

*First full calendar year of operation

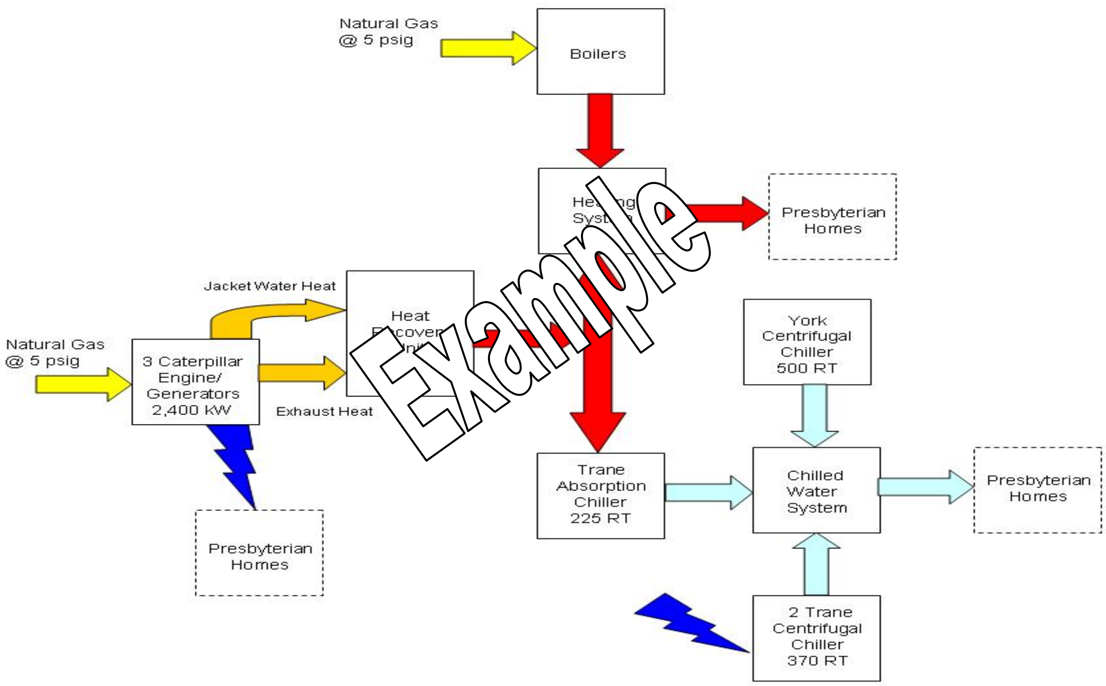
The third paragraph provides an overview of the key reasons for the installation of the DG/CHP system (i.e. assurance against outages, hedging against energy cost spikes etc.).

5.2.2 First Page – Side Bar

The side bar should provide a quote from the plant manager that relates to the key experience/key lessons learned from the DG/CHP installation.

5.2.3 Second Page

The first half of the second page summarizes the technical characteristics of the system, possibly providing a one-line flow diagram of the facility.



The second half of the second page discusses the lessons learned during and from the DG/CHP installation. For example, this can include a comparison between the expected benefits of the DG/CHP system and the actual benefits, a discussion on the experience dealing with regulatory agencies, or a discussion on the technical experience with the installed equipment. The bottom of the second page should list a contact for further information on the DG/CHP system.

5.3 Meta Data File

The intent of the collaborative effort for the development and performance testing of distributed power technologies is to create a centralized database where users can quickly locate lab test reports, field test reports, case studies and long-term monitoring sites. Each site will be required to submit an electronic report incorporating all of the performance parameters defined by the protocol and a separate electronic file containing the Meta Data.

The purpose of the Meta Data is to define the available search criterion for users of the database to quickly locate lab test reports, field test reports, case studies and long-term monitoring sites. Users will also be able to get a snapshot of the performance of different groups of DG/CHP facilities organized by technology, application, location, etc. The same list of Meta Data, or search criterion, will be used for each of the 4 site types – lab test, field test, case study, and long-term monitoring sites. Based on the cost to maintain the database the size of the Meta Data needs to be relatively small. Listed in Appendix B are the Meta Data that may result from the case studies.

6 Summary

This protocol aims to provide guidance for parties that perform a financial and qualitative assessment of individual CHP facilities. In turn, using this protocol assures that these assessments are done in a uniform and consistent way.

The literature for qualitative research states that case study protocols should consist of field procedures, data collection guidelines, and reporting procedures. This protocol follows this approach. The field procedures, data collection guidelines, and reporting procedures were developed based on an assessment of the strength and weaknesses of published case studies in the DG/CHP field.

Since available budget and research capabilities vary among parties interested in performing case studies, this protocol provides for the generation of two forms of reports. One report form is based on a very detailed, in-depth assessment of the CHP facility; the second report form is more succinct and presents the major facts of the installation. Consistent with this approach the data collection guidelines and investigator guides are tailored accordingly.

Appendix A: Acronyms and Abbreviations

A	ampere
acfh	actual cubic feet per hour
ASERTTI	Association of State Energy Research and Technology Transfer Institutions
ASTM	American Society for Testing and Materials
Btu	British thermal unit
Btu/h	Btu per hour
Btu/kWh	Btu per kiloWatt-hour
Btu/lb	Btu per pound
Btu/scf	Btu per standard cubic foot
BoP	balance of plant
c_p	specific heat (constant pressure)
CARB	California Air Resources Board
CEC	California Energy Commission
CH_4	methane
CHP	combined heat and power
cm	centimeter
CO	carbon monoxide
CO_2	carbon dioxide
CoP	coefficient of performance
CSV	comma-separated value
CT	current transformer
dB	decibel
DG	distributed generation
DOE	US Department of Energy
DUT	device under test
DVM	digital volt meter
dscfh	dry standard cubic feet per hour
ECW	Energy Center of Wisconsin
EPA	US Environmental Protection Agency
EPS	electric power system
ETV	Environmental Technology Verification
FID	flame ionization detector
FS	full scale
GC/FID	gas chromatography with flame ionization detector
GHG	greenhouse gas
gph	gallons per hour
gpm	gallons per minute
gr/dscf	grains per dry standard cubic foot
GTI	Gas Technology Institute
h	hour
HHV	higher heating value
Hz	Hertz
IC	reciprocating internal-combustion engine
ID	induced draft
ISO	International Organization for Standardization
kAIC	kiloampere interrupt current
kVA	kilovolt-ampere (apparent power)
kVAR	kilovolt-ampere reactive (reactive power)
kW	kilowatt (real power)
kWh	kilowatt-hour
LHV	lower heating value
lb	pound
lb/gal	lb per gallon
lb/h	lb per hour
lb/kWh	lb per kWh
lb/lb.mol	lb per lb-mole
M	motor
mA	milliamp
ml	milliliter
mph	miles per hour
m/s	meters per second
MTG	microturbine generator
MTG-CHP	MTG with CHP
NDIR	non-dispersive infra-red
NIST	National Institute of Standards and Technology
NO_2	nitrogen dioxide
NO_x	nitrogen oxides
NREL	National Renewable Energy Laboratory
NYSERDA	New York State Energy Research and Development Authority
O_2	oxygen
PC	personal computer

PCC	point of common coupling
PF	power factor
PG	propylene glycol
ppm	parts per million
ppmv	ppm, volume basis
psia	pounds per square inch, absolute
psig	pounds per square inch, gage
PT	potential transformer
QA/QC	quality assurance / quality control
rms	root-mean-square
RT	refrigeration ton
SAC	Stakeholder Advisory Committee
scf	standard cubic feet
scfh	scf per hour
SO_2	sulfur dioxide
SUT	system under test
THC	total hydrocarbons
THD	total harmonic distortion
THCD	total harmonic current distortion
THVD	total harmonic voltage distortion
TPM	total particulate matter
UIC	University of Illinois at Chicago
V	volt
VA	volt-ampere (apparent power)
VAR	volt-ampere reactive (reactive power)
w	Watt
^oC	degree Centigrade
^oF	degree Fahrenheit
^oR	degree Rankine, absolute
ΔT	absolute temperature difference, ^oR or ^oF
η	efficiency, percent
ρ	density, lb/gal

Notation for References, Tables etc.

All Figures and Tables in the Protocol document are numbered using the Section number followed by a sequential digit. Appendices replace the Section number with the Appendix letter. Example references within the test are:

Figure 3-2	The second figure in Section 3
Table 6-1	The first table in Section 6
Eqn. D18	The 18th equation occurring in Appendix D

References within the main text appear as a sequential number within square brackets, or [4] (fourth reference in the document) and may be found at the back of the document. References within the appendices appear as [D4] (fourth reference in Appendix D) and may be found at the back of the indicated appendix.

Appendix B: Meta Data List

Meta Data	Definition	Domain	Applicable Test Types	Data (select from domain codes where applicable)
Site Data				
Organization Name	Name of the organization (company, test site) where DG system was installed and tested. This name must also identify the system if the site has tested more than 1 system (e.g., lab test sites).		All	
City	City in which the test was performed		All	
State	State in which the test was performed		All	
Description	Type of facility in which distributed energy system was installed; select 1	Agriculture, Commercial - hotel, Commercial - ice arena, Commercial - office-high rise, Commercial - office-low rise, Commercial - refrigerated warehouse, Commercial - restaurant, Commercial - retail store, Commercial - supermarket, Commercial - theater, Commercial - other, Industrial - food processing, Industrial - plastics processing, Industrial - wood/wood products, Industrial - other, Institutional - hospital/healthcare, Institutional - school/university, Institutional - nursing home, Institutional - other, Residential - multifamily-single building, Residential - multifamily–multibuilding, Residential - single family, Testing Laboratory, Water Utility, Other Utility, Other	All	
Altitude - feet	Altitude of site, in feet		All	

Meta Data	Definition	Domain	Applicable Test Types	**Data** (select from domain codes where applicable)
System Data				
DG System Enclosure	Describes whether/how the system is enclosed; select 1	Indoor (I), Dedicated Shelter (DS), Outdoor (O)	All	
System Application	Defines whether the distributed generation system is used to produce power only or for combined heat and power; select 1	Electric Power Only (E), Combined Heat and Power (C)	All	
Number of prime movers	Number of prime movers for generating electricity in the distributed energy system		All	
Stand-alone Capability	Ability of system to operate in stand-alone mode and type of transfer between stand alone and grid connected mode; select 1	No (N), Seamless Transfer (YS), Manual Transfer (YM), Auto Transfer <=10sec Delay (YAL), Auto Transfer >10sec Delay (YAM)	All	
Power Rating - kW	Power generation rating of the system, in kW (total combined rating if the distributed energy system has more than one prime mover)		All	
Nominal Voltage - V	Voltage output normally generated, in Volts		All	
Heat Recovery - BTU	Heat recovery rating, in BTU/hr; (total combined heat recovery rating if multiple units)		All	
Cooling Capacity - RT	Total rated cooling capacity in refrigeration tons		All	
Component Integration	Party responsible for integrating system components; select 1	Factory Integrated (F), Customer Assembled (C)	Field, Long-term, Case Study	
Controller	Origin of controller; select 1	Manufacturer Integrated (M), Third Party Off-the-shelf (OTS), Third Party Custom (CUST)	All	
System Installer	General contractor for the installation of the distributed energy system		Field, Long-term, Case	

Meta Data	Definition	Domain	Applicable Test Types	Data (select from domain codes where applicable)
			Study	
Point of Contact Data				
Name	Name of the individual responsible for meta data and test report, and point of contact for the quality checking process.		All	
Organization	Organization with which the POC is affiliated		All	
Email	Email address of the individual responsible for meta data and test report		All	
Telephone	Telephone number of the individual responsible for meta data and test report		All	
Prime Movers (fill in as many sets of prime mover data as you have prime movers)				
Prime Mover 1				
Technology Type	Type of prime mover technology; select 1	Internal Combustion Engine (ICE), Microturbine (MT), Gas Turbine (GT), Fuel Cell-PEM (FCP), Fuel Cell-Solid Oxide (FCSO), Fuel Cell-Phosphoric Acid (FCPO), Fuel Cell-Carbonate (FCC)	All	
Manufacturer Name	Company that manufactured the prime mover		All	
Model Number	Model number assigned by the manufacturer to the prime mover		All	

Meta Data	Definition	Domain	Applicable Test Types	Data (select from domain codes where applicable)
Invertor-Synchronous-Induction	select 1	Inverter (INV), Synchronous Generator (SG), Induction Generator (IG)	All	
Rated Power - kW	Power output rating of the prime mover, in kW		All	
Prime Mover 2				
Technology Type	Type of prime mover technology; select 1	Internal Combustion Engine (ICE), Microturbine (MT), Gas Turbine (GT), Fuel Cell-PEM (FCP), Fuel Cell-Solid Oxide (FCSO), Fuel Cell-Phosphoric Acid (FCPO), Fuel Cell-Carbonate (FCC)	All	
Manufacturer Name	Company that manufactured the prime mover		All	
Model Number	Model number assigned by the manufacturer to the prime mover		All	
Invertor-Synchronous-Induction	select 1	Inverter (INV), Synchronous Generator (SG), Induction Generator (IG)	All	
Rated Power - kW	Power output rating of the prime mover, in kW		All	
Prime Mover 3				
Technology Type	Type of prime mover technology; select 1	Internal Combustion Engine (ICE), Microturbine (MT), Gas Turbine (GT), Fuel Cell-PEM (FCP), Fuel Cell-Solid Oxide (FCSO), Fuel Cell-Phosphoric Acid (FCPO), Fuel Cell-Carbonate (FCC)	All	
Manufacturer Name	Company that manufactured the prime mover		All	
Model Number	Model number assigned by the manufacturer to the prime mover		All	
Invertor-Synchronous-Induction	select 1	Inverter (INV), Synchronous Generator (SG), Induction Generator (IG)	All	

Meta Data	Definition	Domain	Applicable Test Types	Data (select from domain codes where applicable)
Rated Power - kW	Power output rating of the prime mover, in kW		All	
Heat Recovery Equipment (fill in as many sets of heat recovery data as you have heat recovery units)				
HR Unit 1				
Technology Application	Type of heat recovery technology	Domestic Hot Water/Space Heating/HVAC Reheat (DHW), Cooling/Dehumidification (CD), Process Heat (PH), Combustion Air Preheat (CAP), Other (O)	All	
Manufacturer Name	Company that manufactured the heat recovery unit		All	
Model Number	Model number assigned by the manufacturer to the heat recovery unit; select or insert 1 or more		All	
Heat Recovery Rating	Heat recovery rating of the unit		All	
HR Unit 2				
Technology Type	Type of heat recovery technology	Domestic Hot Water/Space Heating/HVAC Reheat (DHW), Cooling/Dehumidification (CD), Process Heat (PH), Combustion Air Preheat (CAP), Other (O)	All	
Manufacturer Name	Company that manufactured the heat recovery unit		All	
Model Number	Model number assigned by the manufacturer to the heat recovery unit; select or insert 1 or more		All	
Heat Recovery Rating	Heat recovery rating of the unit		All	
HR Unit 3				

Meta Data	Definition	Domain	Applicable Test Types	Data (select from domain codes where applicable)
Technology Type	Type of heat recovery technology	Domestic Hot Water/Space Heating/HVAC Reheat (DHW), Cooling/Dehumidification (CD), Process Heat (PH), Combustion Air Preheat (CAP), Other (O)	All	
Manufacturer Name	Company that manufactured the heat recovery unit		All	
Model Number	Model number assigned by the manufacturer to the heat recovery unit; select or insert 1 or more		All	
Heat Recovery Rating	Heat recovery rating of the unit		All	
System Operation				
Name	Unique short name to identify the report.		All	
URL	Internet address of the detailed long-term monitoring data		Long-term	
Test Type	The type of test or study that was performed; select 1	Lab (LT), Field (FT), Long-term (LTM), Case Study (CS)	All	
Date Commissioned	Date on which the system became operational		All	
Monitoring Termination Date	Date on which the DG system monitoring was terminated		All	
Fuel	Fuel used during the test/study period; select 1 or more (separated by commas)	Natural Gas (NG), Biogas (BG), Propane (P), Diesel (D), Biodiesel (BD), Other (O)	All	
Primary Power Application	Primary use of generated power; select 1	Based Load (BL), Peak Shaving (PS), Backup (BU), VAR Support (VAR), Other (O)	Field, Long-term, Case Study	
Secondary Power Application	If applicable, secondary use of the generated power; select 1	Based Load (BL), Peak Shaving (PS), Backup (BU), VAR Support (VAR), Other (O)	Field, Long-term, Case Study	

Meta Data	Definition	Domain	Applicable Test Types	Data (select from domain codes where applicable)
Primary Heat/Cooling Application	Primary use of recovered heat; ie, end use to which the highest amount of recovered energy is directed; select 1	Space Heat and/or Cooling (SHC), Process Heat and/or Cooling (PHC), Domestic Hot Water (DHW), Refrigeration (R), Other (O)	All	
Secondary Heat/Cooling Application	If applicable, secondary use of the recovered heat; ie, end use to which the second highest amount of recovered energy is directed; select 1	Space Heat and/or Cooling (SHC), Process Heat and/or Cooling (PHC), Domestic Hot Water (DHW), Refrigeration (R), Other (O)	All	
Average Fuel HHV	Average Higher Heating Value of the fuel(s) used during the period of operation covered by the report		All	
Average Fuel LHV	Average Lower Heating Value of the fuel(s) used during the period of operation covered by the report		All	
Heating Value Units	Units in which heating values are presented; select 1	BTU/std cu ft (BTU_per_SCF), BTU/gal (BTU_per_Gal)	All	
Highest Combustion Intake Air Temp - F	Highest temperature of the combustion intake air during the testing or monitoring period; degrees F		All	
Lowest Combustion Intake Air Temp - F	Lowest temperature of the combustion intake air during the testing or monitoring period; degrees F		All	
NOx Emissions Data Available	Does the report include NOx emissions data?	Y/N	All	
CO Emissions Data Available	Does the report include CO emissions data?	Y/N	All	

Meta Data	Definition	Domain	Applicable Test Types	Data (select from domain codes where applicable)
Capacity Factor	The ratio of the gross electricity generated, for the period of time considered, to the energy that could have been generated at continuous full-power operation during the same period.		Long-term, Case Study	
Availability	The number of hours in a given time period that the unit was in the available state (the state in which a unit is capable of providing service at any capacity, whether or not it actually is in service), divided by the total number of possible operating hours in that time period.		Long-term, Case Study	
Electrical Efficiency - HHV	Average net electrical efficiency over period covered by the report and over all load levels; based on fuel higher heating value; calculated as 100 x kWh net electrical output / kWh fuel input		All	
Electrical Efficiency - LHV	Average net electrical efficiency over period covered by the report and all load levels based on fuel lower heating value; calculated as 100 x kWh electrical output / kWh fuel input		All	
Run Hours	Total hours of operation during the most recent 12-month period, in hours		Long-term, Case Study	
12-Month Energy Savings	If available, value of energy saved during most recent 12-month period due to the distributed energy system, in $		Case Study	
DG System Cost	Total installed first cost of the distributed energy system, in $		Case Study	

Endnotes

[1] See: Robert K. Yin. Case Study Research - Design and Methods. Sage Publications, 1994.

[2] See: Hedrick et al. Applied Research Design. A Practical Guide. Sage Publications, 1993.

[3] The report was prepared by Brent Alderfer and Monika Eldridge with Competitive Utility Strategies LLC, and Thomas Starrs with Kelso, Starrs & Associates LLC.

[4] The report was prepared by Joel Bluestein with Energy and Environmental Analysis Inc., Susan Hogan with Distributed Utilities Associates, and Monika Eldridge with Competitive Utility Strategies. The report was published by NREL, October 2002.

[5] See: Holcomb, Franklin et. al. Cogeneration Case Studies of the DoD Fuel Cell Demonstration Program. Presented at the IQPC F-Cells Stationary Conference, London, February 20, 2000.

[6] Published May, 1995 by DynCorp Meridian.

[7] For more information see www.solarturbines.com.

[8] The case studies are posed on www.chpcentermw.org

[9] See: Campbell, Donald T. The Informant in Quantitative Research. American Journal of Sociology, Volume 60, 1955.

[10] Two publications that are good sources of information for this section are: a)Onsite Sycom Energy Corporation. The Market and Technical Potential for Combined Heat and Power in the Commercial/Institutional Sector. Onsite Sycom Energy Corporation, 2000, and b) Valenti, Gianluca. An Assessment of Combined Heat and Power for Medium-Sized Commercial Applications. University of Illinois at Chicago, 2001.

[11] Good information on non-utility related distributed generation equipment is available on the Energy Information Administration Website at www.eia.doe.gov. Information on installed combined heat and power systems for a particular region is listed on the regional Combined Heat and Power Application Center websites. The website for the Midwest CHP Application Center is www.chpcentermw.org.

12 Borbely, Anne-Marie, and Jan F. Kreider. Distributed Generation – The Power Paradigm for the New Millennium. CRC Press, 2001.

[13] Sutherland, Ronald J. Market Barriers to Energy-Efficient Investments. Energy Journal, Volume12, Issue 3, 1991.

[14] American Society of Heating, Refrigerating and Air-Conditioning Engineers. ASHRAE Handbook HVAC Applications, 1995.

[15] The lower heating value calculations do not take into account the latent heat of vaporization of the water vapor formed by combustion. While latent heat can be captured by condensing appliances (furnaces, boilers) it cannot be captures by natural gas fired turbines or engines.