HUD CHP GUIDE #2:
FEASIBILITY SCREENING FOR COMBINED HEAT AND POWER IN MULTIFAMILY HOUSING

Prepared for
U.S. Department of Housing and Urban Development
by
U.S. Department of Energy, Oak Ridge National Laboratory

May 2009

Introduction

The U.S. Department of Housing and Urban Development's (HUD) *2002 Energy Action Plan[1]* includes an initiative to promote the use of combined heat and power (CHP) in multifamily housing. The primary target is existing buildings.

The average efficiency of the fossil-fueled power plants in the U.S. is 33% and has remained virtually unchanged for 40 years. This means that two-thirds of the energy in the fuel is lost as heat, and 8% of the remainder is lost in transmission and distgribution over wires. Combined Heat and Power (CHP)--also known as "cogeneration"—is the sequential production of two or more useful forms of energy from a single fuel consuming device. CHP systems recycle waste heat and convert it to useful energy, and they can achieve overall efficiencies of over 80%.

CHP can significantly reduce a multi-family building's annual energy costs. Instead of buying all the building's electricity from a utility and separately purchasing fuel for its heating (mechanical) equipment, most--or even all--of the electricity and heat can be produced for less money by a small on-site power plant operating at a higher combined efficiency. The best economic prospects for CHP are single buildings with at least 100 units, master metered for utilities, with access to natural gas. The type of CHP system commonly applied to multi-family housing uses a "prime mover," that is, a reciprocating engine similar to that found in a car or truck, or a microturbine, that drives a generator to produce electricity. The heat (thermal energy) produced by this process is recovered and used to produce hot water or steam, operate a chiller or serve as a desiccant, instead of being exhausted from the engine and transferred through the engine radiator. CHP systems also often lead to increased ability to handle electric loads during power outages.

HUD, the U.S. Department of Energy (DOE) and the Environmental Protection Agency (EPA) have been working together to help implement the HUD CHP initiative. The activities include providing CHP guides for apartment building owners, working with the eight DOE-funded Regional CHP Application Centers (RACs)[2], preparing case studies, undertaking market analysis and promoting peer exchanges on CHP among the owners and managers of housing developments. For further information, see:

DOE- http://www.eere.energy.gov/de
EPA- http://www.epa.gov/chp
USCHPA- U.S. Clean Heat and Power Association - http://www.uschpa.org/

Two CHP guides have been put on the HUD website at:

http://www.hud.gov/offices/cpd/library/energy/index.cfm

CHP Guide #1: "Q&A on Combined Heat and Power for Multifamily Housing" explains the basics of CHP for apartment building owners and managers.

CHP Guide #2 (this Guide): "Feasibility Screening for Combined Heat and Power in Multifamily Housing" describes EPA's preliminary screening exercise and shows the

---

[1] See http://www.hud.gov/energy// for a copy of the HUD *Energy Action Plan.*

[2] The RACs were designated "Clean Energy Centers" by Section 451 of the 2007 Energy Independence and Security Act, P.L. 110-140. It authorized appropriations of $10 million a year for fiscal years 2008 through 2012 for five-year grants "to ensure their continued operations and effectiveness."

screens for the feasibility screening tool, computer software prepared for HUD by the Oak Ridge National Laboratory (ORNL).

The American Recovery and Reinvestment Act of 2009 contains several tax incentives and billions of dollars in funding opportunities for CHP and waste energy recovery. A summary of the combined heat and power provisions is available from the web site of the U.S. Clean Heat and Power Association.

Stimulus funds for HUD public and assisted housing will provide another source for funding housing improvements that can include CHP. These will be announced during April 2009. Watch the HUD web site for information on them: http://www.hud.gov

The 2008 Energy Improvement and Extension Act provides for a 10-percent investment tax credit (ITC) for the costs of the first 15 megawatts (MW) of CHP property under Section 48(a)(3)(A)(v) of the Internal Revenue Code of 1986.   The definition of CHP systems as "energy property" under the act might also qualify CHP for a five- year accelerated depreciation schedule under Section 168 of the Internal Revenue Code. The act also extended the existing 30-percent ITC for fuel cell property and the 10-percent ITC for microturbine property though December 31, 2016.   For details, see:
    http://www.epa.gov/chp/documents/chp_itc.pdf

 For the software tool prepared by the Oak Ridge National Laboratory and the User's Manual see:
    http://eber.ed.ornl.gov/HUD_CHP_Guide_version _2.1

 For a profile of CHP installed in a 100 unit public housing project, see:
    http://www.hud.gov/offices/cpd/energyenviron/energy/library/index.cfm

For a web-cast summary of HUD's promotion of CHP go to:
    http://www.hud.gov/webcasts/archives/envirhealth.cfm
(Bring up Part 2. CHP begins after the 51 minute point and runs about 20 minutes.)

The HUD contact for information on CHP-- and editor of this Guide-- is Robert Groberg, Office of Environment and Energy, robert.groberg@hud.gov

The ORNL contact for questions on the CHP Guide is J. Michael (Mike) MacDonald, macdonaldjm@ornl.gov , Energy and Transportation Science Division
http://www.ornl.gov/sci/ees/division_etsd.shtml

For further information on the RAC program, contact Merrill Smith, USDOE CHP Program Manager merrill.smith@hq.doe.gov, Patti Garland-ORNL Program Technical Assistance garlandpw@ornl.gov, and Ted Bronson-PEA, Program Technical Assistance. tlbronsonpea@aol.com .

For further information on the EPA CHP Partnership contact Felicia Ruiz, CHP Partnership Team Lead, at Ruiz.Felicia@epa.gov or the CHP Partnership Hotline at chp@epa.gov , or call (703) 373-8108.

How do you determine whether it is appropriate to consider installing combined heat and power in multifamily housing? Here are two levels of screening available to owners and managers of apartment buildings. The first is a "qualifications screening" provided by the Environmental Protection Agency. The second is a form of Level 1 feasibility screening tool provided for HUD by the Oak Ridge National Laboratory. It can be used with very limited data as well as with detailed utility expenses for a year.

1. The Environmental Protection Agency (EPA) has included in its web site descriptions of five stages for developing CHP: 1) Qualifications; 2) Level 1 Feasibility; 3) Level 2 Feasibility; 4) Procurement; and 5) Operations and Maintenance. See: http://www.epa.gov/chp/project-development/index.html [3]

For Stage 1, Qualifications, EPA has a simple questionnaire with eleven questions, designed for industry and commercial--including residential-- buildings. No special data inputs are required. You will find this questionnaire on the EPA Web site:

http://www.epa.gov/chp/project-development/qualifier_form.html

It is slightly modified below for "buildings." If three are answered "yes," EPA will offer more detailed analysis. The next step in assessing the potential of an investment in CHP is to perform a Level 1 Feasibility analysis to estimate the preliminary return on investment. The EPA CHP Partnership offers comprehensive Level 1 analysis services for qualifying projects and can provide contact information to others who perform these types of analyses. The contact information is included on the EPA Web site.

IS MY BUILDING A GOOD CANDIDATE FOR CHP?

STEP 1	Check the points that apply to your building.

- **Do you pay more than $.07/ kWh on average for electricity (including generation, transmission and distribution)?**

- **Are you concerned about the impact of current or future energy costs on your building?**

- **Is your building located in a deregulated electricity market?**

- **Are you concerned about power reliability? Is there a substantial financial impact to your building or residents if the power goes out for 1 hour? For 5 minutes?**

- **Do you have thermal loads throughout the year (including hot water, chilled water, hot air, steam, etc.)?**

- **Does your building have an existing central plant?**

---

[3] The times and cost figures here are for larger megawatt installations compared to the kilowatt sized systems needed to serve apartment buildings. The HUD focus on preliminary or initial screening falls somewhere between EPA Stages 1 and 2.

- **Do you expect to replace, upgrade or retrofit central plant equipment within the next 3-5 years?**

- **Do you anticipate a building expansion or new construction project within the next 3-5 years?**

- **Have you already implemented energy efficiency measures and still have high energy costs?**

- **Are you interested in reducing your building's impact on the environment?**

STEP 2	If you have answered "yes" to 3 or more of these of these questions, your facility may be a good candidate for CHP.

The next step in assessing the potential of an investment in CHP is to have a Level 1 Feasibility Analysis performed to estimate the preliminary return on investment. EPA's CHP Partnership offers a comprehensive Level 1 analysis service for qualifying projects and can provide contact information to others who perform these types of analyses.

If you would like the EPA CHP Partnership to contact you with more information on its technical support services, fill out the form following the questionnaire on the EPA website and click "Submit." You can also contact EPA at (703) 373-8108.

2. The Oak Ridge National Laboratory (ORNL)
HUD CHP FEASIBILITY SCREENING TOOL

The Oak Ridge National Laboratory has created a computer software Tool for HUD that enables managers and owners of apartment buildings to do an initial screening of the potential for installing combined heat and power (cogeneration) in a building.[4]   It will roughly calculate the potential return on investment for installing CHP in a multifamily building. This is a form of Level 1 screening that is less-detailed than the EPA one cited above.   The computerized worksheets contain nine screens: three for the input of information and six that display intermediate and final results for the three Methods of calculation.

Version 1 of the software considered use of recovered heat from the engine-generator to be used only for domestic hot water. Version 2.1 builds on Version 1 by considering the use of recovered heat for energy savings for space heating and cooling as well as for domestic hot water. The calculations provide the user with a range of estimated simple payback periods for installing and operating CHP in the building. Buildings with acceptable payback periods are candidates for more serious consideration that includes a detailed economic evaluation. Those with unacceptable paybacks can avoid further consideration of CHP.

The Tool will not do the calculations for all electric buildings, but there are examples of all electric buildings that converted a portion of the space heating to hot water and successfully installed combined heat and power. Wooster Manor in Danbury CT is one. See the profile of this development cited above.

Preliminary Checklist: The best prospects for installing CHP are buildings with at least 80 dwelling units, with access to natural gas needed to run the system, master-metered for utilities. Before going further, fill out the "Preliminary Checklist" found on the last page of the Guide. Buildings with fewer than 80 units or "No" answers to Questions 11-14 indicate obstacles to proceeding. These should be discussed with HUD, EPA, a Clean Energy Application Center or other source for advice on whether and how to proceed.

With limited data: Without entering detailed utility consumption data for a whole year, a quick, more theoretical assessment can be made with Method 3 of the Tool. Skip over the Monthly Utility Data screen, Figure 1. Enter in Figure 2, Utility Rate Data, only the utility rates0. In Figure 3, Intermediate Input Information, enter the location of the building, square footage to be heated and cooled, number of occupants and level of Hot Water Usage based on the type of occupancy. Method 3 uses space conditioning loads estimated from the DOE Energy Information Agency (EIA) degree day algorithms and hot water use estimated from ASHRAE publications. A payback based on this information will give a rough idea of whether it may be worthwhile to prepare more refined estimates by entering twelve months of utility bills and fuel costs and quantities.

---

[4]   The Oak Ridge software drew on the worksheets in the 1989 "Cogeneration Manual" prepared for the Energy Conservation Division of the New York City Office of Rent and Housing Maintenance under contract to the New York State Energy Research and Development Authority by Hirschfeld and Stone Consulting Engineers, Glen Cove, NY. The original manual had three purposes: It explained the concept of CHP in multi-family buildings. It presented guidelines to evaluate technical and economic considerations. It provided guidelines for equipment installation and operation. It has been modified by HUD for use in other states.

With a year's utility consumption and costs: To run the software program for all three Methods, in addition to the limited data cited above, the user must enter in the Monthly Utility Data screen information from the twelve most recent months utility bill data for cost and level of consumption. The screen will show the Annual Totals and the Average Cost per kWh for electricity and per unit of gas or other fuel consumed.

If only total monthly cost is known, that is entered on the first data screen. Then see the instructions starting on page 7 for the approach to use in entering Utility Rate Data on the second screen.

Figure 1 Monthly Utility Data

The monthly electricity consumption (kWh) and demand (kW) are used in sizing an on-site generator to provide heat and power so that it does not exceed the amount of electricity that can be used by the apartment building. (Although many people would like to, it rarely makes sense to sell excess power back to the utility because the price paid is so low). In states where net metering is allowed (e.g. CA, CT) the meter may run backwards when the system generates more electricity than it needs. That means that the price "paid" by the utility is the same retail price charged by the utility. This generally is a favorable rate for the CHP system.

The consumption, type, and cost of fuels used on-site are used to estimate hot water loads and potential savings from producing hot water using engine heat. Some facilities use more than a single fossil fuel, perhaps to qualify for interruptible gas rates, so space is provided for two different fuels. Many people will not have to use the second set of columns for fuel data.

The second screen of the program, Utility Rate Data, requires the user to enter some information about the electricity and gas rates at the facility. This form is shown in the figure below. The best results are obtained if the user can provide current information for the electricity charges ($/kWh consumption charge and $/kW demand charge) and the cost of natural gas. (It is assumed that any CHP or cogeneration equipment would use natural gas as its primary fuel; almost any other fuel would be difficult to permit because of NOx and SOx emissions.) If the electric utility uses a block rate structure where the usage and demand charges are set for multiple levels of consumption (e.g. first 100,000 kWh cost $0.89/kWh, the next 100,000 cost $0.056/kWh) or demand charges vary with time of day, the numbers entered should be for the last block used (the highest quantity consumption block, with associated energy and demand charges, seen by the facility, which may also be the lowest block rate).

Some of these electric rates, such as the declining block rates mentioned above, are tremendously confusing. As an alternative, users can enter the Average Cost calculated at the bottom of the Monthly Utility Data screen for the Energy Charge on this screen and leave all other components of the electric rate (Adjustment, Demand and Standby Charges) as zero. This approach will lead to simplified average cost results, but this approach is preferable to making other mistakes with input data to approximate complicated rate structures.

The Natural Gas Units selections on the Utility Rate Data Form are used in the calculations to estimate the amount of space heating and hot air produced by the fuel consumed.

Figure 2 **Utility Rate Data**

The best way for building managers to secure utility consumption and rate data is to request it from the utility by letter. The request should be sent on the letterhead of the organization that has the utility relationship. Ask for the following site specific data:

> **"To: Utility Account Rep**, **Utility, Address, Account Number, Account Address,**
>
> **"(Name of organization)** requests that you provide historic billing data for the accounts and addresses listed above. Please provide us data for the most recent 12 months.
>
> You may be contacted by **(name of contact person).** Thank you."

Miscellaneous Input Information

Figure 3 requires Site Information for Estimating Heating and Cooling Loads.
-The user identifies the state and nearest city location of the building, enters the square footage to be heated and cooled and the approximate number of occupants.
-To help with the calculations for domestic hot water, the user chooses among three levels of use ranging from 27 to 54 gallons per day per person.
-Equipment Operating Assumptions show 75% and may be adjusted for the running time of the generator and the efficiency of the boiler.
-The Site Information for Estimating Equipment and Installation Costs permits a choice of the type of equipment, generally reciprocating engine or microturbine.
-The choice of Installation Difficulty—ranging from "low" to "retrofit"-- will have a major impact on the length of time for payback shown later under Results.

CHP calculations are performed using three different methods for estimating the building thermal loads. Method 3 employs a table of information for heating and cooling degree days that has been built into the Tool. The corresponding heating and cooling degree days selection for a typical year are based on the choice of location. These are correlated to "energy intensity factors" to estimate space heating and cooling loads using items 3a and b on this tab. The "Prime Mover" box at the bottom has different technology types "grayed out" depending on the size of system needed. If microturbines are an appropriate choice for the building, they will be available as a prime mover, but the Sample Data building load is over 400 kW (Figure 4), so microturbines are not allowed as a reasonable screening choice for this building (a later more detailed analysis could include them). The most common type of Prime Mover has been reciprocating engines, but the use of microturbines is increasing. Full size gas turbines require a load of at least a Megawatt and fuel cells are currently too expensive for use in this type of installation.

Figure 3 Miscellaneous Input Information

"Energy Plots" provides graphs showing the results of the entries in the first screen: The graphs above show monthly power consumption, monthly electrical demand, and monthly fuel consumption As entered in Figure 1. A review of these graphs may reveal a spike or gap that indicates an error in an entry for Monthly Utility Data. The graphs below show the monthly data for the same three categories, and they including on-site generation calculated with Method 2 and corresponding reduced purchases from the utilities.
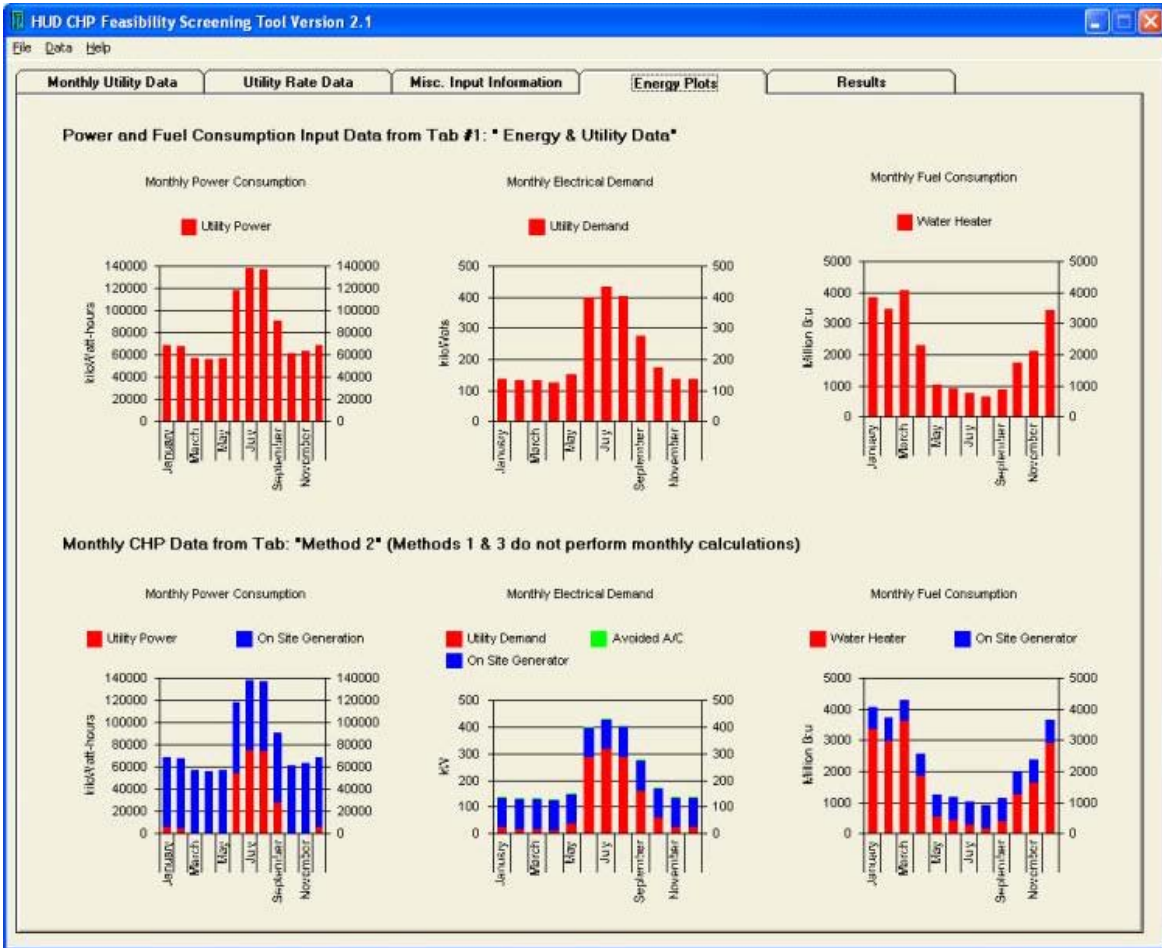
Figure 4 Energy Plots

Results are shown on five screens, (as well as on Figure 4, Energy Plots) and they may be printed following instructions found under the "File" heading above the screens.

Building owners and managers may only be interested in the level of detail shown under "Summary of Results" as shown below. The key elements in each of the three sets of calculations are included in the lower part of the screen.
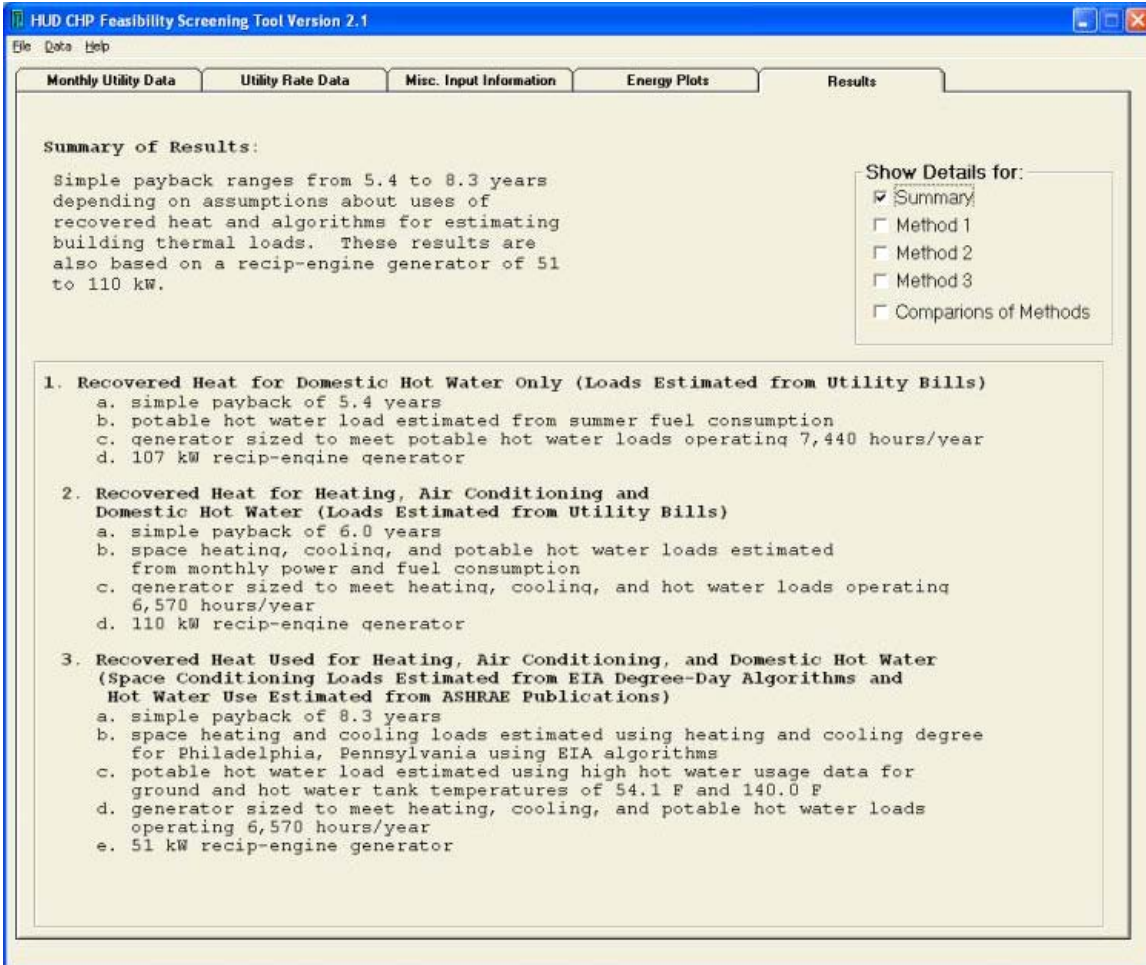
Figure 5 Results

Another array that may be useful for building owners and managers is found in the "Side-by-Side" Results **Comparison of Methods** screen. It lists data for eleven components of the analysis. When the software program is open, the user can change the settings, e.g. shifting from "Low" to "Retrofit" for Installation Difficulty and immediately go to the Comparison screen to see the differences in installation costs and simple payback periods.
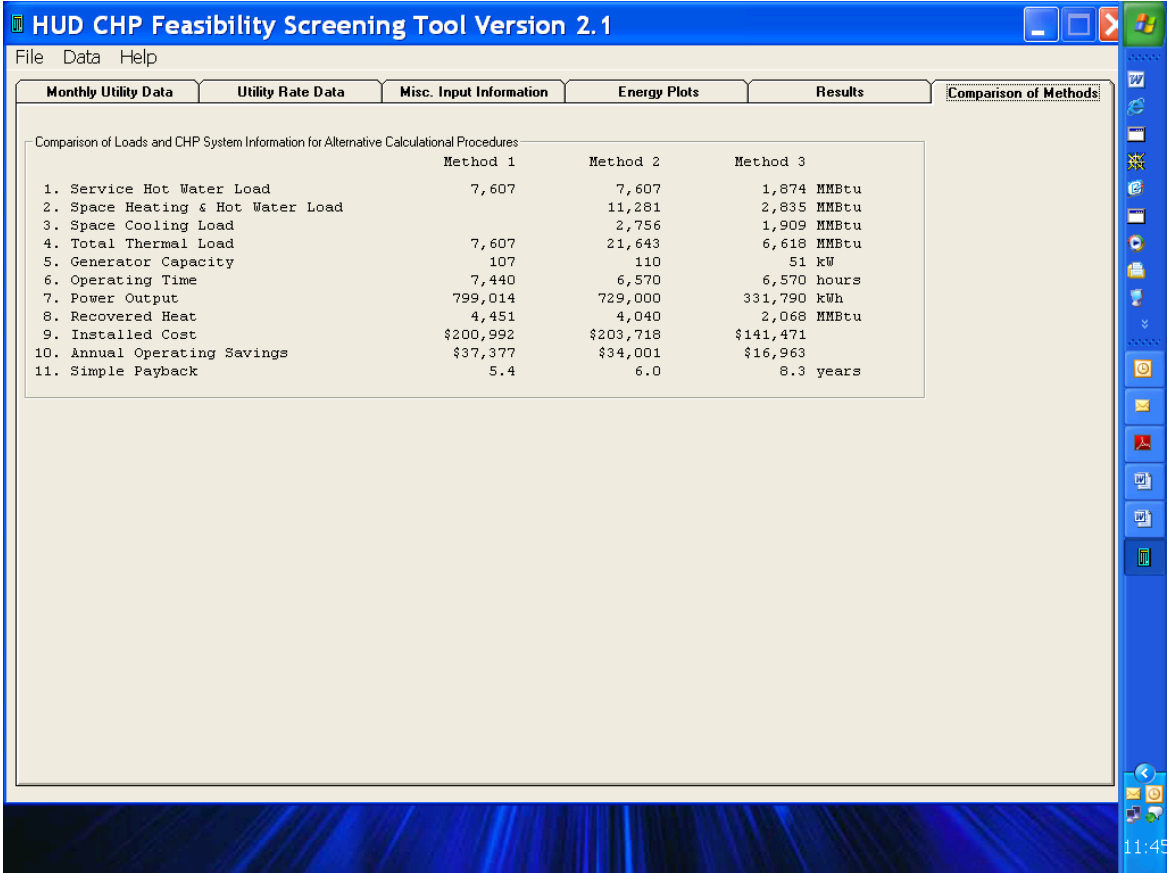

Figure 6 Comparison of Methods

The details behind these conclusions are found on the screens for Methods 1, 2 and 3.

Below is one page of the very detailed material in the algorithms that backs up the calculations for **Method 3**. They may be of interest to engineers for checking assumptions and methodology, such as efficiency levels and value of recovered heat.
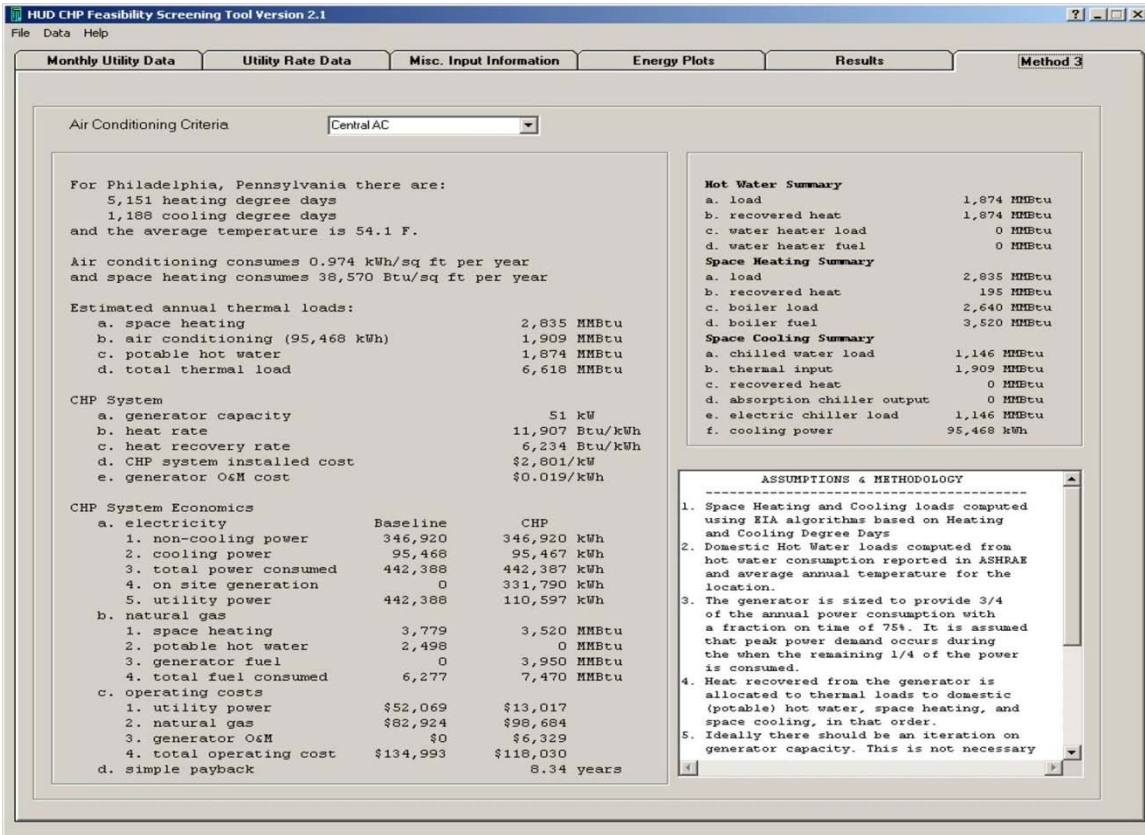

Figure 7 Method 3 Results

File Heading
 The following actions may be taken once you open the "File" heading on the Task Bar
        -"New" enables you to create a new file by entering data on the screens which are saved as Program Files.:
                -"Print" gives you the option to print one or more of the five screens:
                        --Input data and Summary of Results
                        --Side-by-Side comparison of the results for all 3 methods.
                        --Methods 1, 2 or 3 "Intermediate results"
            -"Capture Screen Shots" creates a Word file with the images of six screens
             showing the data you entered and all results. Add a header identifying the
building and save it in Screen Shots.

Data Heading
 You can bring up Sample Data to illustrate how the screens look when filled.
 You can clear data to prepare for entering new data.
Opening a file with data previously entered automatically switches and replaces the earlier entries.

Help Heading User's Manual
 The software contains a lengthy and detailed Help file that can be downloaded in the form of the "User's Manual". It explains the following:

        -Getting Started
                Overview; Monthly Utility Data, Utility Rate Data, Energy Plots,
                Intermediate Information, Results.
        -Menu Bar
                File, Data and Help Menus
        -General Parameters
                Reciprocating Engine-Driven Generators; microturbine generators;
                gas turbine generators
        -Algorithms & Methodology for Methods 1, 2 and 3
        -Additional Information on Building Loads
                Electric Loads, Space Heating and Hot Water Loads

Conclusions
Users should bear in mind that the analysis performed by this program is adequate for a coarse screening to let building operators know whether or not they should consider CHP seriously. A short payback may fit the financing strategy for privately-owned properties. Public housing can finance such installations with energy performance contracting that can have a twenty-year term. Both may be affected by the availability of the ten percent investment tax credit. The calculations can be reviewed annually as utility costs and other economic factors change. Despite the payback calculated, some CHP developers may reach other conclusions. In any event, encouraging results are only a prelude to a more rigorous analysis to be performed by engineering professionals using much more detailed information on building heating and electricity loads and CHP equipment.

<div align="center">###</div>

Combined Heat and Power for Multifamily Housing:
A Preliminary Checklist

Before running data through the HUD CHP Feasibility Screening Tool you should complete this checklist.   Buildings with fewer than 80 units or "No" answers to Questions 11-14 indicate there may be obstacles to proceeding. You may seek advice from HUD or one of the other sources cited on pages 2 and 3 of the Guide.

1. **Property Name** _____ Year built _____
2. **Location: Address)**_____
3. **(City, State)** _____
4. **Contact Name: _____ _____**
5. **Contact Telephone: _____ email _____**
6. **Number of buildings with 80+ units _____**
7. **Number of stories per building _____**
8. **Number of dwelling units and occupants per building:_____**
9. **Square footage to be heated _____ and cooled _____**
10. **Annual Total Utility Cost and Consumption:**

    10.1 Electricity: $_____   kWh _____

    10.2 Natural Gas: $_____ (   ) therms (   ) CCH_____

    10.3 Oil: $ _____   gallons _____

		Yes	No
11.	Natural gas is available.	( )	( )
12.	Domestic Hot Water is centrally produced.	( )	( )
13.	Electricity is master metered for each building	( )	( )
14.	Space heating is centrally provided	( )	( )
15.	"Spark Spread" is greater than $12 MMBTU	( )	( )

   [See the following page for calculations.]

Comments: _____
_____
_____
_____
_____
_____

Is the "spark spread" sufficient?

For a CHP system, spark spread is the difference between the cost of gas to produce power and heat on site and the reduced amount of electricity purchased from the grid. A common rule of thumb puts it at no less than $12 per million Btus (MMBtu), but it can vary. Spark spread is highly dependent on the efficiency of conversion. It is expressed in terms of the maximum cost differential between electricity and fuel cost in dollars per MMBtu. What works in New York may not work in California.

A good format for calculating spark spread is found in the Midwest Regional Application Center "CHP Resource Guide".[5]

For a quick way to calculate spark spread for a particular building, use the data that appears on Monthly Utility Cost screen once you have entered your 12 months of utility consumption and cost:

A. *For electricity:* Multiply the Average Annual Electric Cost *($/kWh)* by 293 to convert to $/MMBtu.

B. *For gas:* Multiply average annual gas cost $/therm by 10 to convert to /MMBTU.

C. *To determine Spark Spread:* Subtract B from A.

Is the *"Spark Spread"* **>$12/MMBtu?**   If **Yes,** then CHP has the potential for favorable payback.

See the following page for MWRAC's worksheet Table 3-1 or these calculations.

---

[5] http://www.chpcentermw.org/pdfs/Resource_Guide_10312005_Final_Rev5.pdf
Table 3-1 Estimating "Spark Spread" is found in Section 3 of the "CHP Resource Guide" (page 39).
Table 3-2 "Rules-of-Thumb for acceptable Average Annual Fuel Cost."

Table 3-1   Estimating "Spark Spread"

1.	**Determine the Average Annual Electric Cost** *($/MMBtu)*:			
a.	**Sum** the total cost for electricity from the *last 12 months* of bills (including demand charge): **Total Cost**	$		
b.	**Sum** the number of kWh utilized over the *last 12 months* of bills: **Total kWh**			kWh
c.	**Divide** the Total Cost by the Total kWh: **Average Annual Electric Cost**	$		/kWh
d.	**Multiply** the **Average Annual Electric Cost** *($/kWh)* by 293 to convert to $/MMBtu: **Average Annual Electric Cost**	**$**		**/MMBTU**
2.	**Determine the Average Gas Cost** *($/MMBtu)*:			
a.	**Sum** the total cost for gas from the *last 12 months* of bills: **Total Cost**	$		
b.	**Sum** the number of Therms utilized over the *last 12 months* of bills: **Total Therms**	$		Therms
c.	**Divide** the Total Cost by the Total Therms: **Average Annual Gas Cost**	$		/Therm
d.	**Multiply** the **Average Annual Gas Cost** *($/Therms)* by 10 *(for NG)* to convert to $/MMBTU: **Average Annual Gas Cost**	**$**		**/MMBTU**
3.	**Determine** the *"Spark Spread"*:			
a.	Average Annual Electric Cost (1.d.)	$		/MMBTU
b.	**Minus** Average Annual Gas Cost (2.d)	$		/MMBTU
	"Spark Spread"	**$**		
4.	**Is** the *"Spark Spread"* **>$12/MMBtu?**			**Yes / No**

If **Yes,** than CHP has the potential for favorable payback.