# Combined Heat and Power (CHP) Tool

## User Manual for  (Version 1.0.0)

**Effective from September 2004**

**Prepared For**
**Oak Ridge National Laboratory**

**By**

**E3M, Inc.**

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1. *Exhaust Gas Heat Recovery System for Heaters*
2. *"Duct Burner" System*
3. *Fluid Heating in Heat Exchange*
4. *New Turbine*

**APPENDIX 3 – MASTER TURBINE LIST**

## Installation Instruction:

The Program Package or CD content:

- **CHP Tool Setup**
- **User Manual**
- **Data Forms**

**System Requirements:**

1. A PC running Windows 2000 /Windows NT 4.0/Windows 98 with latest service pack
2. At least 50MB free space on hard disk
3. A processor (preferably Pentium) 133 MHz or faster.
4. A VGA or higher resolution video card and monitor.
5. A mouse or compatible tracking device.
6. A 12X or faster CD-ROM drive
7. Microsoft Office 2000 including MS Access, MS Word and MS Excel
8. Acrobat Reader

**Installation Instructions:**

1. Insert the Setup Disc in the CD ROM Drive OR Go to the instructed website
2. Follow the on screen instructions.
3. Unless otherwise changed/specified, the default path of the application is Start → Programs → CHP Tool → CHP Tool.
4. Open the Application (alternatively, the CHP Tool can be opened through the shortcut created on the Desktop)
5. If needed, restart the computer (It depends on the individual computer configuration of the user)

*Note: In case of problems during Installation:*

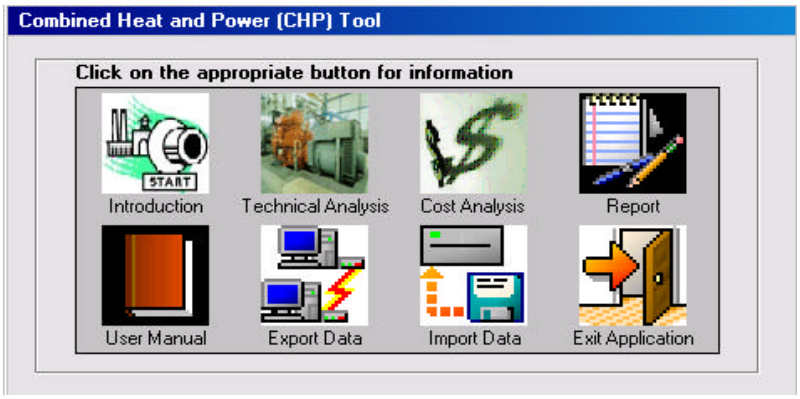
*Update the operating system with the latest service pack and run the* CHP Tool *Setup again.*
*Disable any memory resident programs and run the* CHP Tool *Setup again.*
*Contact your IT support personnel for permission/security issues.*

**General Notes:**

- *Do not use special characters (‘,”, &,*, #, etc.) while entering the data in different text boxes. This may cause problems when another user tries to import such data.*
- *While entering numbers with decimals, enter the prefix zero (0) before the decimal point (for example 0.03, 0.44).*
- *White colored boxes are for input data while yellow colored boxes are for results.*
- *Avoid duplicate names for Company, Application, and Turbine while entering data.*

## Summary:

This initial screen is used to start analysis of the Combined Heat and Power (CHP) application in process heating. Details of various functions of the tool and its possible use for analysis of the CHP application in commonly used industrial process heating systems are given in Appendix 1. The readers should review these details prior to the use of this application.




The Combined Heat and Power (CHP) Tool is designed to evaluate the feasibility of using heat from power generation equipment such as a gas turbine-generator in industrial heating applications. The results of the analysis give an approximate cost and payback period for the selected application based on the given data. This analysis is intended to provide a preliminary estimate for the payback period and help the user decide whether further detail engineering-economic analysis should be pursued.

The heating systems where this type of combined heat and power can be applied include fuel-fired furnaces, boilers, ovens, heaters, heat exchangers, etc. used by all major industries. The turbine exhaust gases are discharged at a temperature ranging from 800º F to 1100º F and have oxygen content of 14% to 16%. These gases can be used to supply sensible heat (through a temperature drop) and/or the use of oxygen for the combustion of fuel (such as natural gas) in the heating systems mentioned above. The tool analyzes the technical and economic feasibility of using gas turbine exhaust gases to supply heat to fluids (air, water, heating oils etc.), to boilers, or to an industrial furnace or oven. A further description of commonly used systems where CHP applications can be considered is given in Appendix 1.

The three specific cases where the tool can be used for application analysis include:

1. Use of fired heat exchangers to heat gases (i.e. air, process atmosphere) or liquids (i.e. water, heating liquids).
2. Use of the turbine exhaust gases into ovens or heat recovery boilers to recover sensible heat of the exhaust gases.
3. Use of the exhaust gases to supply oxygen (low oxygen content “air”) in fuel fired burners for furnaces or boilers as are commonly done in boilers using “duct-burners”.

The tool allows analysis of the amount of heat that can be obtained from the turbine exhaust gases and the approximate size of the turbine that can supply the required heat for the selected heating process. It is assumed that the turbine exhaust gases would be able to supply all or the required percentage of heat for the process. The system can be used for the design of a new system or as a modification of the currently used heating system. Results of the analysis and associated report include an estimate of the payback period for the application based on the fuel and electricity rates used for the analysis and the selected costs for the turbine, engineering, installation and other costs associated with the annual maintenance of the system. The results are meant to help the industry decide whether it is worthwhile to carry out further engineering studies for the project. The tool can also be used to estimate payback periods and a what-if analysis for various utility costs.

The tool includes the necessary performance data and default cost information for commonly used and available commercial gas turbines. It also allows the user to modify performance data for a selected turbine or to add data for turbines not included in the database.

Introduction:
This is the starting point of the tool. This section provides a quick overview of the tool, describing the various functionality, use and sequence of each piece. This section also has the data entry forms that can be used to collect and enter the required information before using the tool to perform an analysis.

Technical Analysis:
This section is used to collect data for analysis of an existing or new heating process used to analyze changes in energy requirement for the process with the use of the Combined Heat and Power (CHP) application. The results of this analysis give the approximate size of the turbine that should be used to meet the process heat requirements. This information can be used to select a commercially available turbine. A database of currently available turbines is incorporated in the tool and the user can select the appropriate turbine size from the database. If necessary, the user has the option of adding a new turbine if the database does not include the desired turbine. It is necessary to give appropriate performance information when a new turbine is used and added in the database. The user can also change the performance data for a turbine included in the database if necessary.

Cost Analysis:
This section is used to analyze the cost implication of using combined heat and power (CHP). It is used to calculate the total project cost, electric revenue, gas cost savings and payback period as a part of the analysis based on the default cost information included in the application or the information supplied by the user. The analysis helps in the decision making process of whether the use of CHP is economically viable and acceptable for the application being considered and analyzed.

Report:
The report shows a summary of data for the existing heating process, performance data for the selected turbine, avoided cost or revenue related to the electricity produced, changes in fuel

(natural gas) usage and cost, savings, and the payback period associated with the application of the combined heat and power system for the selected system.

User Manual:
This section provides step-by-step and detailed instructions for the use of tool. It also contains other technical details related to the tool.

Export Data
The complete information about the plant and the technical/cost analysis data can be exported as an MS Access database. Later, such information can be imported into the existing database through the "Import Data" feature, and new (imported) information can be analyzed, modified, or reviewed as discussed in the above section.

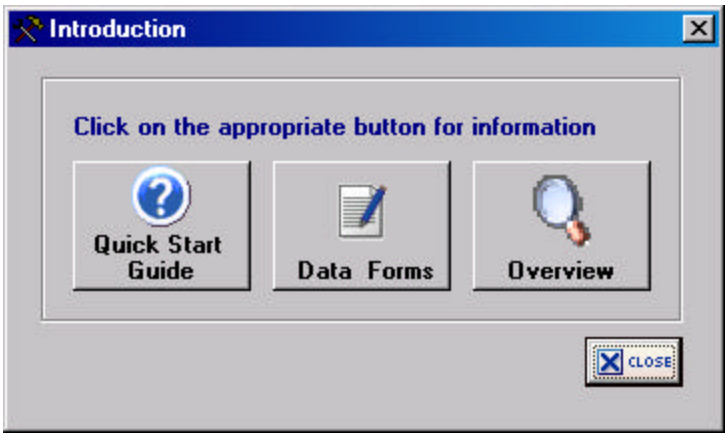
Import Data:
The complete information about the plant and the technical/cost analysis data can be imported into the existing database. Later, such information can be analyzed, modified, or reviewed as discussed in the above section.

Exit Application:
This will close the tool.

## Description and Use of Tool:

### Introduction:

Clicking **"Introduction"** on the main screen will open a screen as shown below. This section provides a quick overview of the tool, describing its functionality, use and sequence of each screen , and data forms required to collect data for the use of the tool.




Click on **"Quick Start Guide"** will open up a file in Adobe PDF that describes the salient features of the tool as well as brief steps to use the tool.

Click on **"Data Forms"** will display data entry forms that can be used to collect and enter the required information before using the tool to perform an analysis.

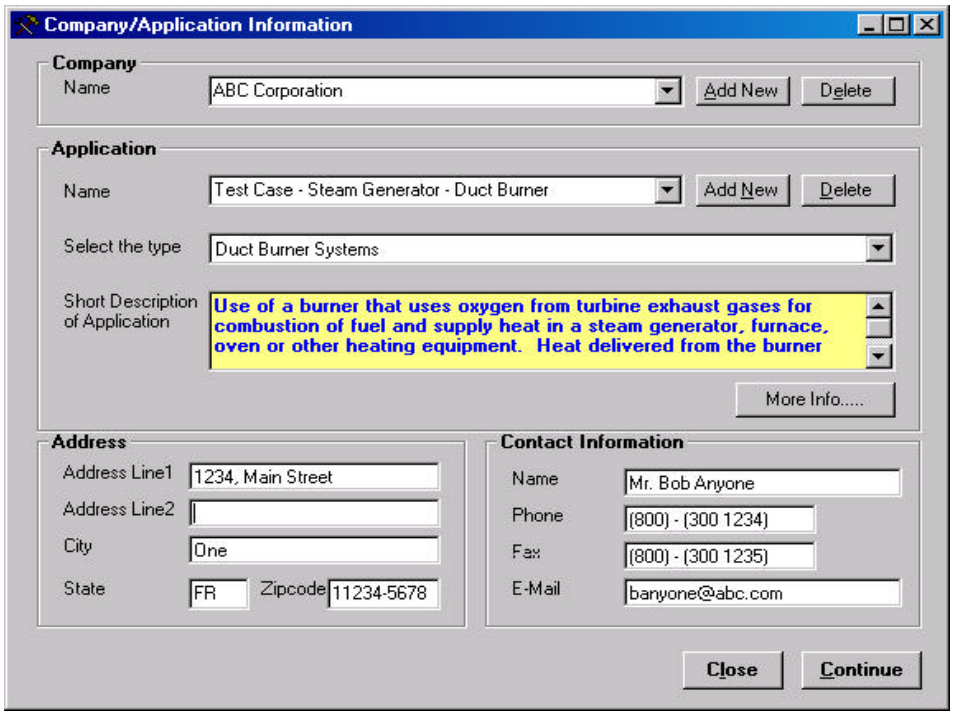
Click on **"Overview**" will display a technical presentation of most commonly used CHP systems and how this tool can be used to evaluate feasibility of using Combined Heat and Power (CHP) in industrial process heating systems.

Click on **"Close"** will close this screen and returns to main screen.

**Technical Analysis:**

*Company/Application Information:*

This section is used to enter general information about the company, including different applications, their types, the process description, and contact details.




For Existing Data:

- Select the Company from the drop down list.
- Select the Application from the drop down list.
- Note: The drop down list will be populated with applications that were analyzed previously for the selected company.
- Select the appropriate type of application from the drop down list for which the technical analysis is being carried out.

Clicking on the **"Continue"** button will save the existing data and will open a new screen depending upon the type of application. This is described in detail in a later part of the manual.

*Note: If analysis is not done for the selected type, a blank input form will pop up where technical data can be entered.*

Each Application can have a number of different heating systems associated with it. The current tool includes three types of possible heating systems:

1. Exhaust Gas Heat Recovery System for Heaters
2. Fluid Heating in Heat Exchanger
3. Duct Burner Systems

A schematic diagram of the heating system and a brief description can be viewed by clicking on the **"More Info…"** button. Additional details about this are given in a later section of this manual.

Clicking on **"Close"** will take the user back to the main screen with an option to save the data.

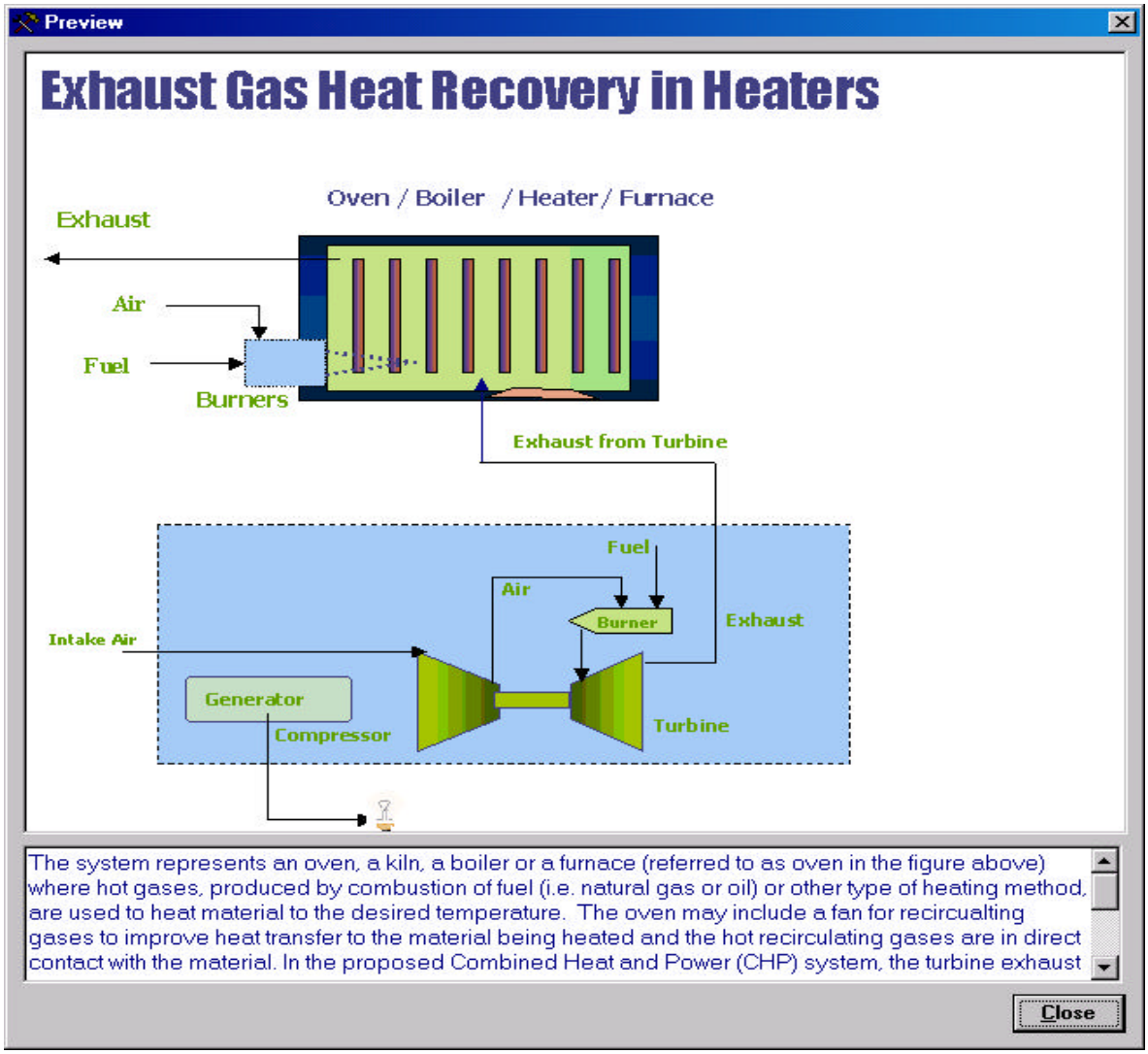
Click on **"Add New"** in the Company section to add new company information.

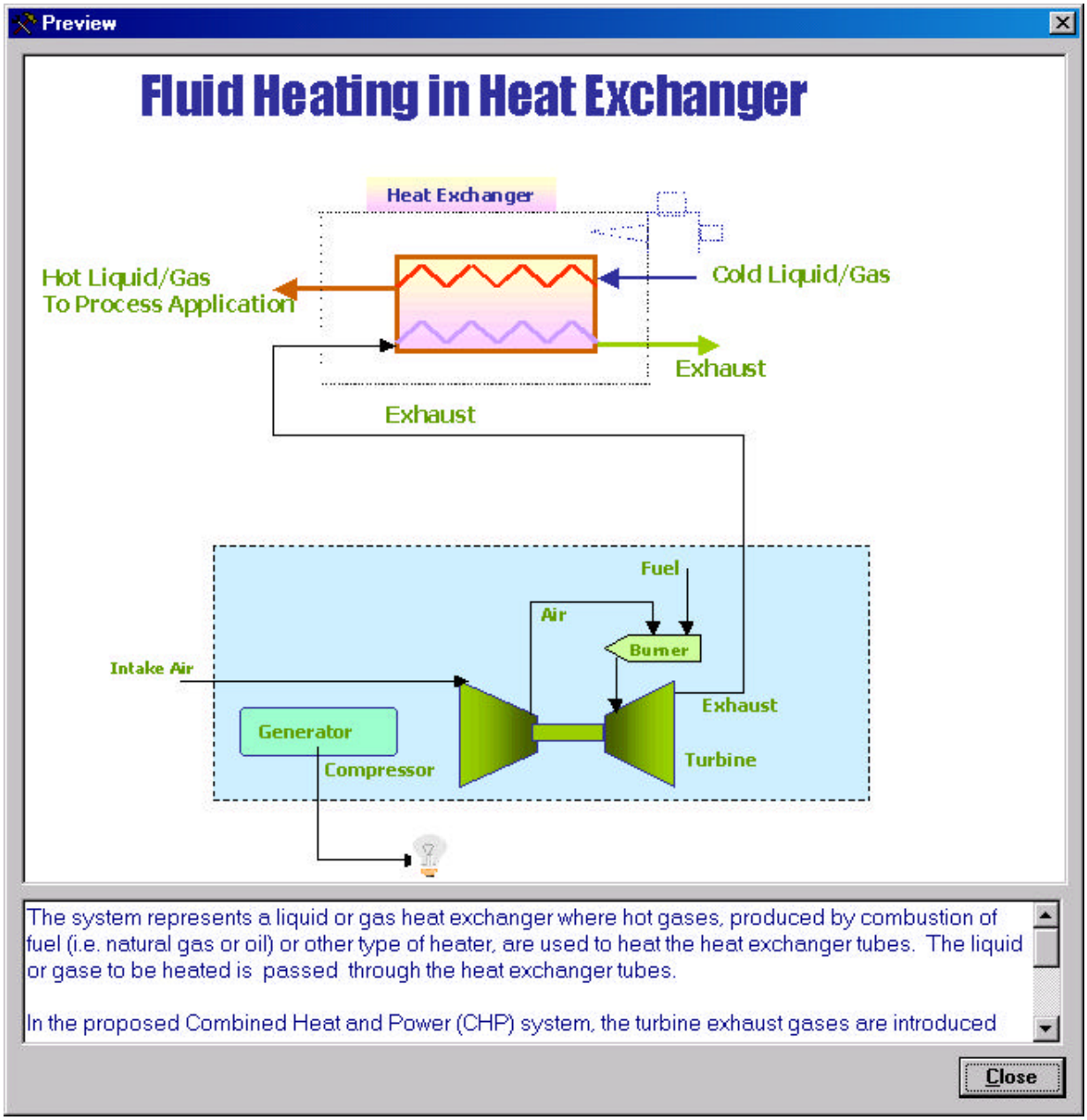
Clicking on **"Delete"** in the Company section will delete the currently selected company (as selected in the drop down list). All information, including all applications and their technical and cost data, will be deleted.

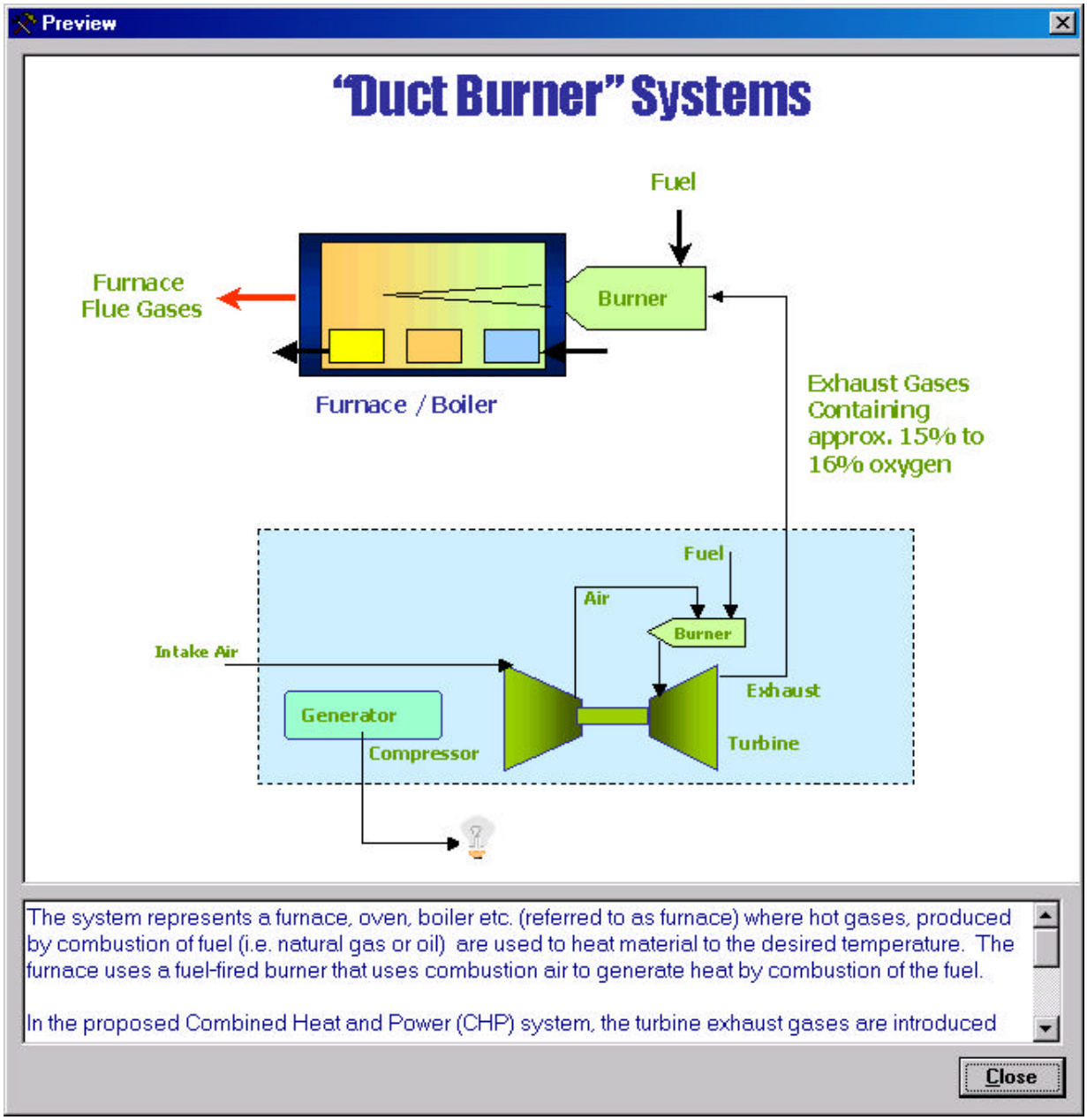
Click on **"Add New"** in the Application section to add a new application within the selected company (as selected in top drop down list) and information about it.

Clicking on **"Delete"** in the Application section will delete the currently selected application (as selected in the drop down list). The information for the application, including its technical and cost data, will be deleted.

Clicking on **"More Info…"** will display a picture and a short note on the selected application type. This screen contains only additional information – no data can be entered. An example of the type of information included in this section is shown below.


Preview
Exhaust Gas Heat Recovery in Heaters
Oven / Boiler / Heater / Furnace
Exhaust
Air
Fuel
Burners
Exhaust from Turbine
Fuel
Air
Burner
Exhaust
Intake Air
Generator
Compressor
Turbine
The system represents an oven, a kiln, a boiler or a furnace (referred to as oven in the figure above) where hot gases, produced by combustion of fuel (i.e. natural gas or oil) or other type of heating method, are used to heat material to the desired temperature. The oven may include a fan for recircualting gases to improve heat transfer to the material being heated and the hot recirculating gases are in direct contact with the material. In the proposed Combined Heat and Power (CHP) system, the turbine exhaust
Close


Preview
Fluid Heating in Heat Exchanger
Heat Exchanger
Hot Liquid/Gas
To Process Application
Cold Liquid/Gas
Exhaust
Exhaust
Fuel
Air
Burner
Intake Air
Exhaust
Generator
Compressor
Turbine
The system represents a liquid or gas heat exchanger where hot gases, produced by combustion of fuel (i.e. natural gas or oil) or other type of heater, are used to heat the heat exchanger tubes. The liquid or gase to be heated is passed through the heat exchanger tubes.
In the proposed Combined Heat and Power (CHP) system, the turbine exhaust gases are introduced
Close


Preview
"Duct Burner" Systems
Fuel
Furnace
Flue Gases
Burner
Furnace / Boiler
Exhaust Gases
Containing
approx. 15% to
16% oxygen
Fuel
Air
Burner
Intake Air
Exhaust
Generator
Compressor
Turbine
The system represents a furnace, oven, boiler etc. (referred to as furnace) where hot gases, produced by combustion of fuel (i.e. natural gas or oil) are used to heat material to the desired temperature. The furnace uses a fuel-fired burner that uses combustion air to generate heat by combustion of the fuel.
In the proposed Combined Heat and Power (CHP) system, the turbine exhaust gases are introduced
Close

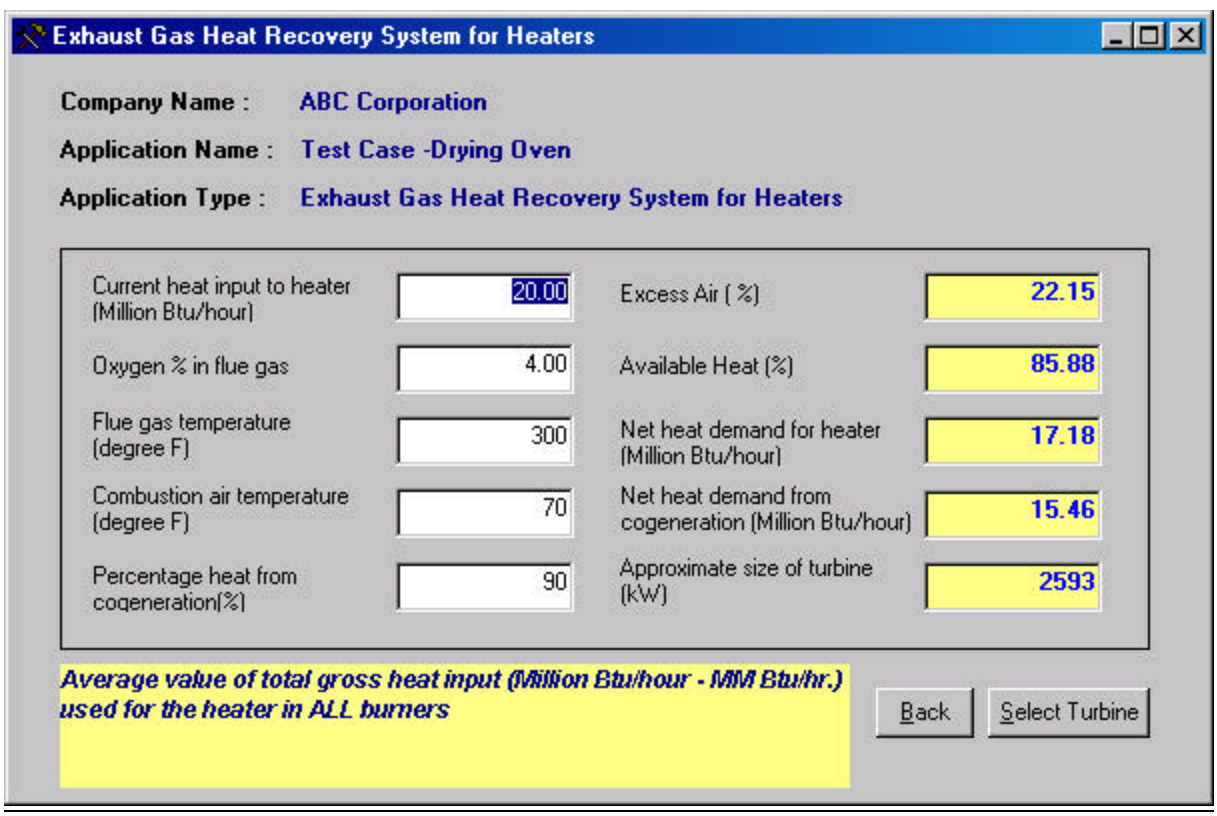
*Input Data Requirements:*
This section is used to collect data for a new or existing heating process and to analyze the effect of the use of combined heat and power (CHP). The result of the data input gives the approximate size of the turbine that should be used to meet the process heat requirements.

For an application, analysis can be performed for three different types of heating processes by selecting the appropriate type from the Application Type drop down list. A further description of each of the three applications is given in Appendix 1.

Here, appropriate process-system data such as heat input (use the average value of the average total or gross heat input value), percentage oxygen in flue gases on a dry basis, flue gas temperature, combustion air temperature at the currently used burners, etc… can be entered and turbine size is calculated as a first approximation. Note that the user can select the amount of heat to be derived from the turbine exhaust gases for the process. This is expressed as a percentage of the currently used gross or total heat input. The input screen for each type is displayed as shown below. Note that a brief description of the data input for each input is also displayed at the bottom of the form.

The analysis results are displayed in colored boxes with a bold, blue font.

Exhaust Gas Heat Recovery System for Heaters:
In this system, the turbine exhaust gases are used to supply sensible heat (through a temperature drop) to reduce heat input in the burners used in the heating system.



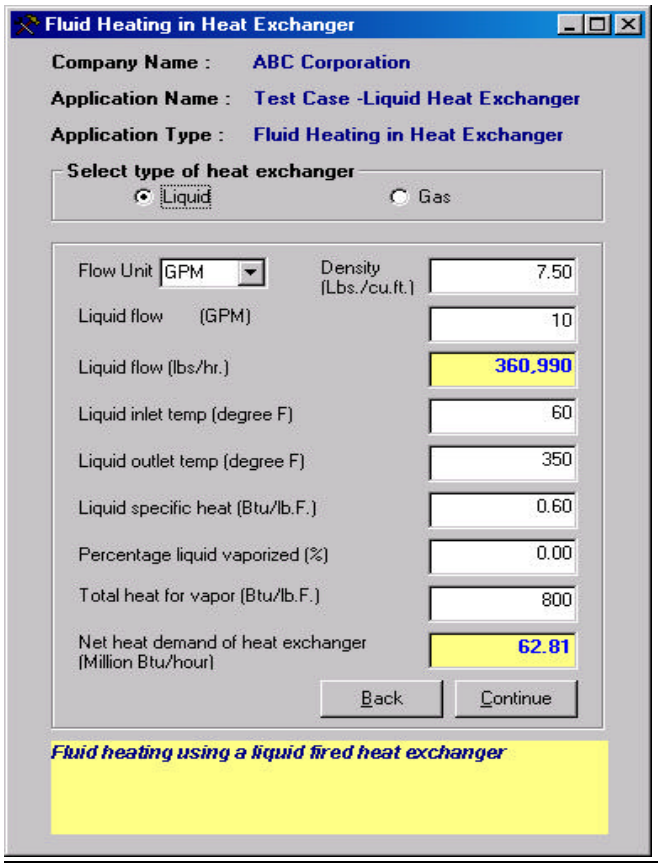
Fluid Heating in Heat Exchanger:
In this system, the turbine exhaust gases are used to supply sensible heat (through a temperature drop) to reduce heat input in the burners used in the fuel fired heat exchanger system.

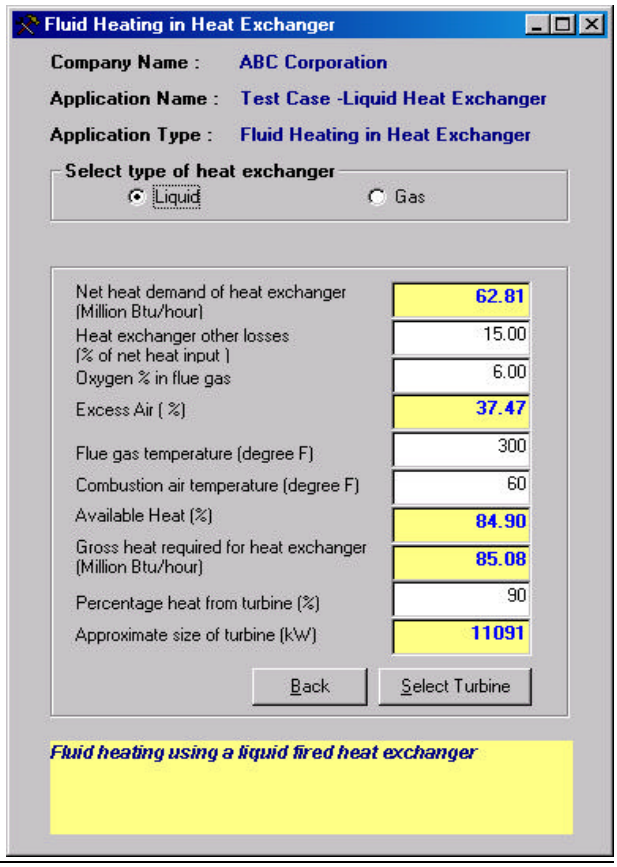
There are two available options:

(1) For liquid heating: The input for the liquid being heated can be given in terms of gallons per minute (GPM) with the liquid density, or in terms of lbs./hr. of the liquid being heated. In this case, the user can include data for vapor formation of the liquid to account for vaporization of all or a percentage of the liquid being heated.

(2) For gas heating: The input for the gas flow rate is given in Standard Cubic Feet Per minute (SCFM).

The data is used to calculate the total net heat required for the heating of the liquid or gas.



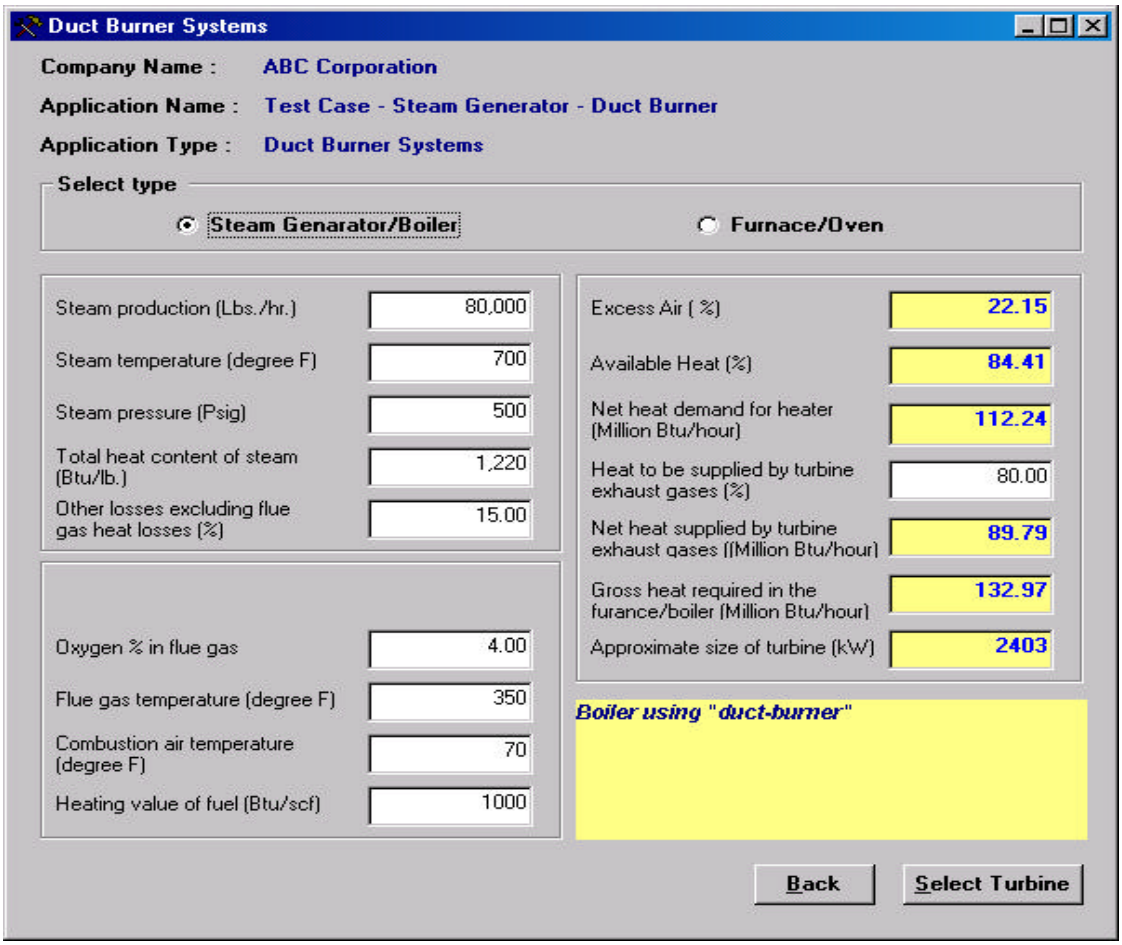




The user should provide data for heat losses from the heat exchanger – heater system as a percentage of the net heat input in the system. Typical values can be in the range of 15% to 40%.

Duct Burner Systems:

As mentioned in Appendix 1, in this type of system, the oxygen content of the turbine exhaust gases is used for the combustion of fuel in the heating system (boilers, heaters, furnaces, ovens etc.) while also deriving sensible heat from the flue gases.
There are two options available for this section.

(1) Steam Generation or Boilers: In this system, the data required is based on design or current steam demand. This and other boiler performance data is used to calculate the gross heat requirement of the system.
(2) Furnace/Oven application: In this system, the data required is the gross heat input used in the furnace/oven.

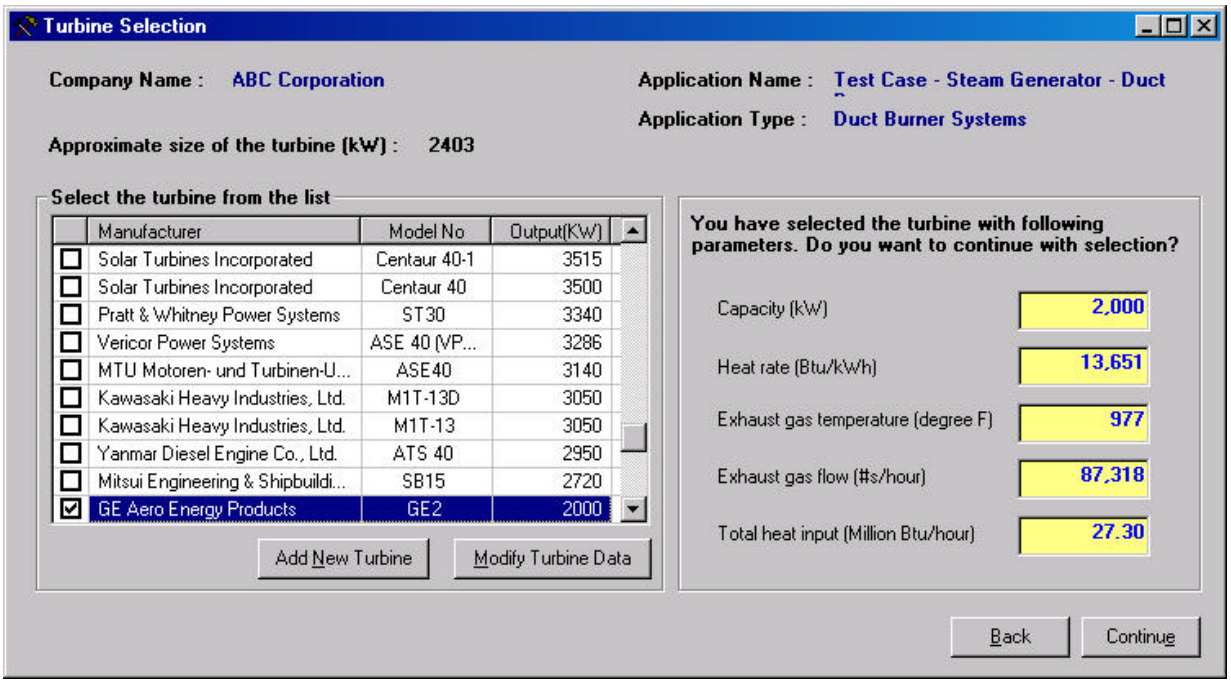



*Analysis Output – Results:*

For each type, the input data and analysis are used to estimate the approximate size of the turbine that would supply the necessary heat and exhaust gases. This estimate is based on the typical values of the gas turbine performance and should be used as a "first approximation" and starting point for further analysis.

The user can continue to refine the analysis by clicking on the **"Select Turbine"** button. Here, the user has the option to select a commercially available turbine from the list. By default, the turbine nearest to approximate size will be selected. The selection can be altered by clicking the appropriate checkbox. The operating parameters of the selected

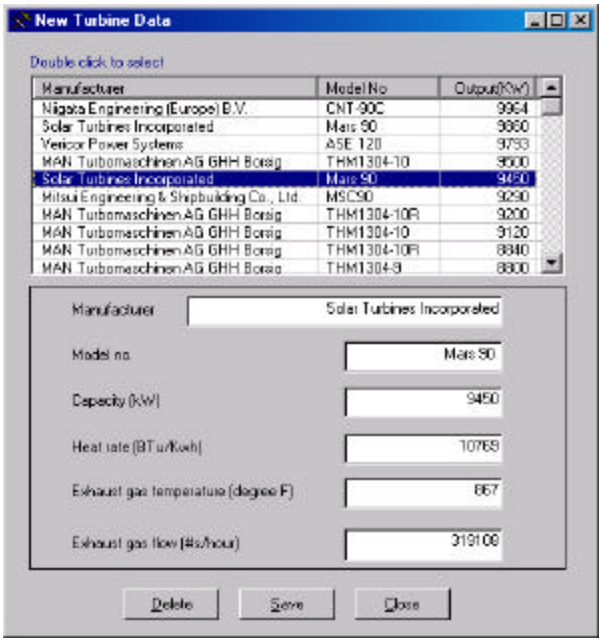
turbine are displayed in the adjoining screen and helps the user to select the appropriate turbine.




A master database of the turbine list is generated and displayed, as shown above.

*Add New Turbine:*

The user can add a new turbine by clicking on the **"Add New Turbine"** button. A separate screen will pop up, allowing the user enter to parameters for the new turbine.




***Note: The parameters shown above are mandatory for a new turbine entry.***

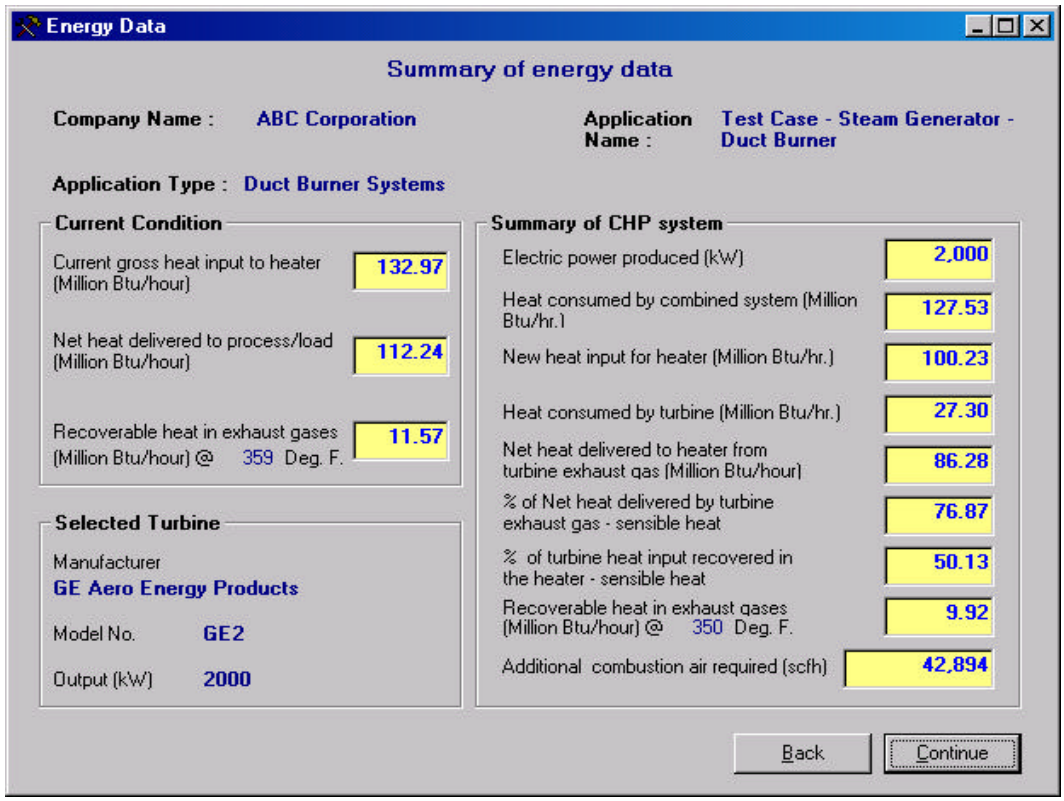
The same screen can be used to modify or delete the turbine data. Double click on the turbine in the list in order to select it (or make it current).

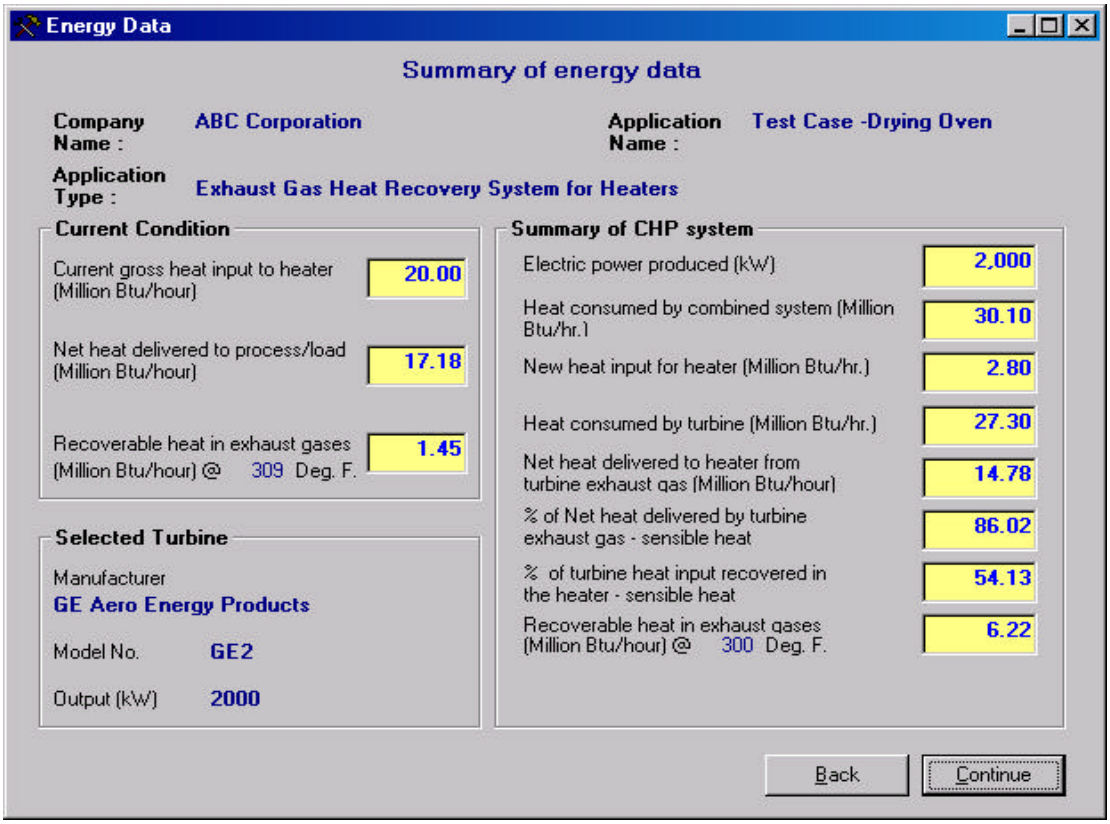
Click **"Save"** to save the data.

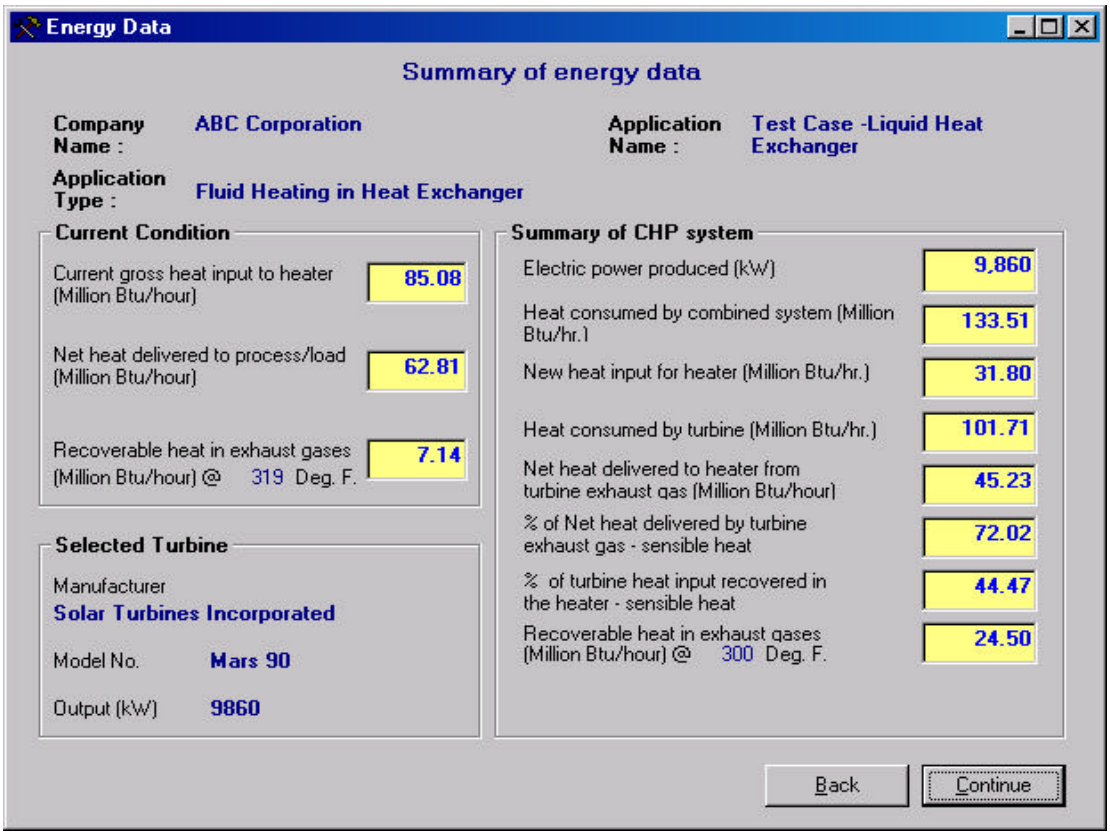
Click **"Close"** to go back to the turbine selection form and continue analysis.

Clicking **"Delete"** will delete the selected turbine from the list. The turbine will no longer be available for future selection.
*Note: The master database cannot be modified or deleted. Only turbine data entered by the user can be modified or deleted.*

*Clicking on **"Continue"** will recalculate the energy used data for the selected turbine and will display a summary of the analysis as shown below.*




Energy Data
Summary of energy data
Company Name : ABC Corporation
Application Name : Test Case -Drying Oven
Application Type : Exhaust Gas Heat Recovery System for Heaters
Current Condition
Current gross heat input to heater (Million Btu/hour) 20.00
Net heat delivered to process/load (Million Btu/hour) 17.18
Recoverable heat in exhaust gases (Million Btu/hour) @ 309 Deg. F. 1.45
Selected Turbine
Manufacturer
GE Aero Energy Products
Model No. GE2
Output (kW) 2000
Summary of CHP system
Electric power produced (kW) 2,000
Heat consumed by combined system (Million Btu/hr.) 30.10
New heat input for heater (Million Btu/hr.) 2.80
Heat consumed by turbine (Million Btu/hr.) 27.30
Net heat delivered to heater from turbine exhaust gas (Million Btu/hour) 14.78
% of Net heat delivered by turbine exhaust gas - sensible heat 86.02
% of turbine heat input recovered in the heater - sensible heat 54.13
Recoverable heat in exhaust gases (Million Btu/hour) @ 300 Deg. F. 6.22
Back
Continue

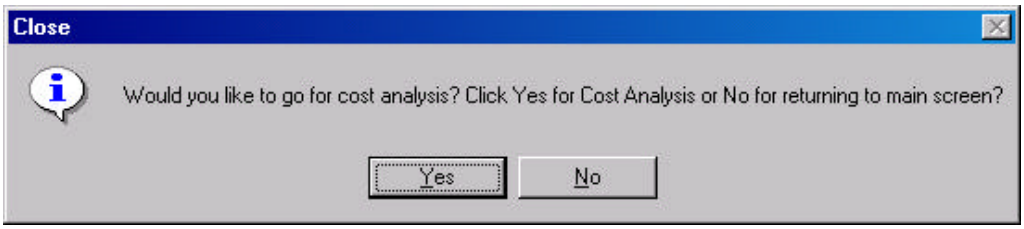

Energy Data
Summary of energy data
Company Name : ABC Corporation
Application Name : Test Case -Liquid Heat Exchanger
Application Type : Fluid Heating in Heat Exchanger
Current Condition
Current gross heat input to heater (Million Btu/hour) 85.08
Net heat delivered to process/load (Million Btu/hour) 62.81
Recoverable heat in exhaust gases (Million Btu/hour) @ 319 Deg. F. 7.14
Selected Turbine
Manufacturer
Solar Turbines Incorporated
Model No. Mars 90
Output (kW) 9860
Summary of CHP system
Electric power produced (kW) 9,860
Heat consumed by combined system (Million Btu/hr.) 133.51
New heat input for heater (Million Btu/hr.) 31.80
Heat consumed by turbine (Million Btu/hr.) 101.71
Net heat delivered to heater from turbine exhaust gas (Million Btu/hour) 45.23
% of Net heat delivered by turbine exhaust gas - sensible heat 72.02
% of turbine heat input recovered in the heater - sensible heat 44.47
Recoverable heat in exhaust gases (Million Btu/hour) @ 300 Deg. F. 24.50
Back
Continue

Note: These results should be reviewed to check the value of "% of Net heat delivered by turbine exhaust gas – sensible heat" The value of this term depends on the turbine performance and the user may not get the matching of what is required vs. what is possible by using the turbine size selected the first time. If this value is substantially different from the required value given in the previous screen then a different turbine should be selected to bring this value to the required value.

If a suitable turbine is not found from the database then the user can select a "new turbine" and provide data the "new" turbine or accept the % net heat delivered form the selected turbine.

It may be necessary to go through more than one iteration to obtain the required value.

Clicking on **"Continue"** will give the user the option to continue the cost analysis for the current application or to return to the main screen.



### Cost Analysis:

There are three distinct tabs where cost and operational data for the application can be entered or modified.

- Select company
- Select Application
- Select Application Type

*Note: If data was entered earlier, the boxes on all three tabs will already be filled with the previously entered data. The existing data can be changed/modified.*

If data was not entered earlier (for example, if the cost analysis is being performed for the first time), the boxes on all three tabs will be filled with the default numbers, as follows:

Turbine Cost/kW - $800
% Use of Rated Power (Load Factor) - 100
Fuel Cost ($/Million Btu) – 6.00
Electricity Cost ($/kWh) – 0.07
Operational Hour/Year (Turbine) – 8400
Operational Hour/Year (Heater) – 8400

This data can be changed or modified by the user as illustrated on the following tabs.

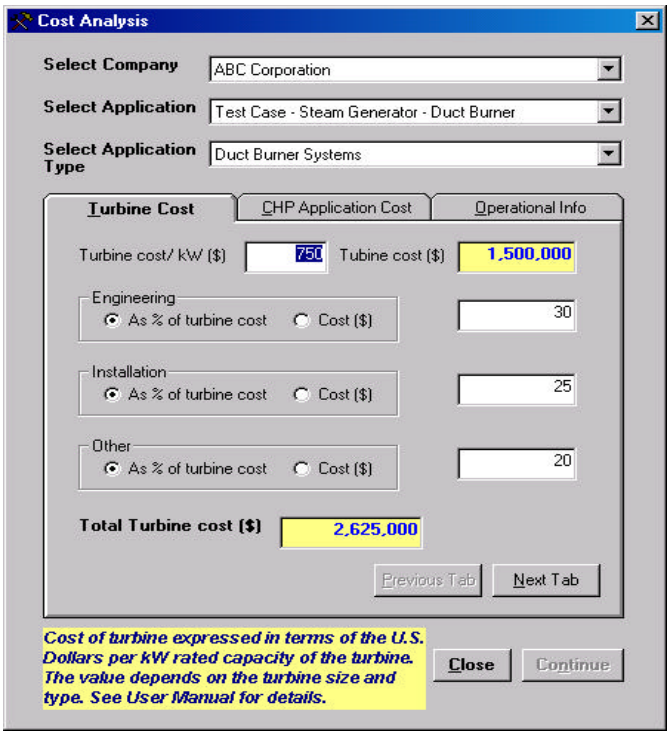
Following table illustrates estimated capital costs for typical Gas Turbine based CHP Systems ($000s)

| Cost Component | *System 1* | System 2 | System 3 | System 4 | System 5 |
|---|---|---|---|---|---|
| Nominal Turbine Capacity (MW) | 1 | 5 | 10 | 25 | 40 |
| Equipment (Thousands of $) | | | | | |
| Combustion Turbines | $675 | $1,900 | $4,000 | $8,500 | $15,800 |
| Heat Recovery Steam Generators | $250 | $450 | $590 | $1,020 | $1,655 |
| Water Treatment System | $30 | $100 | $150 | $200 | $225 |
| Electrical Equipment | $150 | $375 | $625 | $990 | $1,500 |
| Other Equipment | $145 | $315 | $575 | $1,150 | $1,875 |
| Total Equipment | $1,250 | $3,140 | $5,940 | $11,860 | $21,055 |
| Materials | $144 | $357 | $689 | $1,191 | $2,054 |
| Labor | $348 | $908 | $1,752 | $3,031 | $4,723 |
| Total Process Capital | $1,742 | $4,405 | $8,381 | $16,082 | $27,832 |
| Project/Construction Management | $125 | $314 | $594 | $1,186 | $2,105 |
| Engineering | $63 | $158 | $260 | $429 | $672 |
| Project Contingency | $87 | $220 | $419 | $804 | $1,392 |
| Project Financing | $129 | $326 | $618 | $1,184 | $2,048 |
| Total Plant Cost | $2,146 | $5,423 | $10,272 | $19,685 | $34,049 |
| Actual Turbine Capacity (kW) | 1,205 | 5,007 | 10,798 | 23,328 | 46,556 |
| Total Plant Cost per net kW ($) | $1,781 | $1,083 | $951 | $844 | $731 |

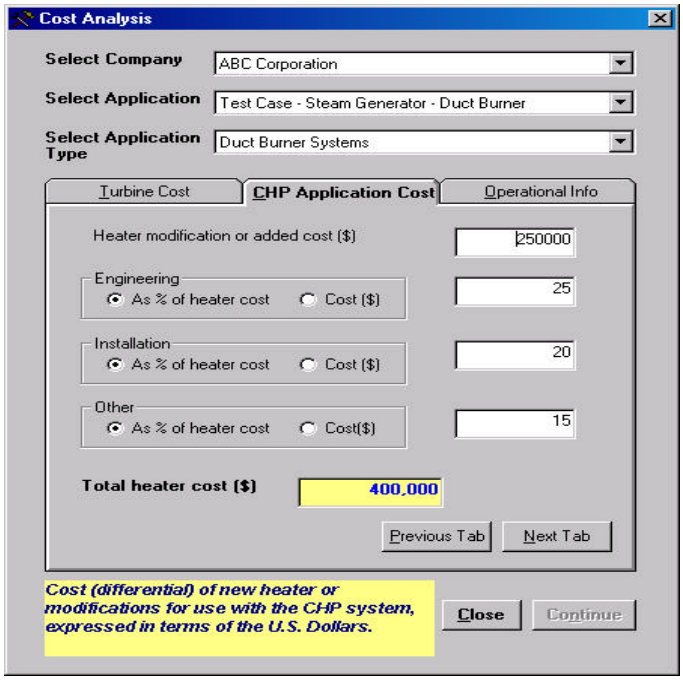
[12] Combustion turbine costs are based on published specifications and package prices. The total installed cost estimation is based in part on the use of a proprietary cost and performance model – SOAPP-CT.25 – (for state-of-the-art power plant, combustion turbine). The model output was adjusted based on Energy Nexus Group engineering judgment and experience and input from vendors and packagers. Actual costs can vary widely and are affected by site requirements and conditions, regional price variations, and environmental and other local permitting requirements.

*Note: It represents cost data for the years 2002.*
*The cost data table is taken from 'The Energy Solutions Center DG Applications Guide.' available at http://www.energysolutionscenter.org/DistGen/AppGuide/DGuideFrameSet.htm*

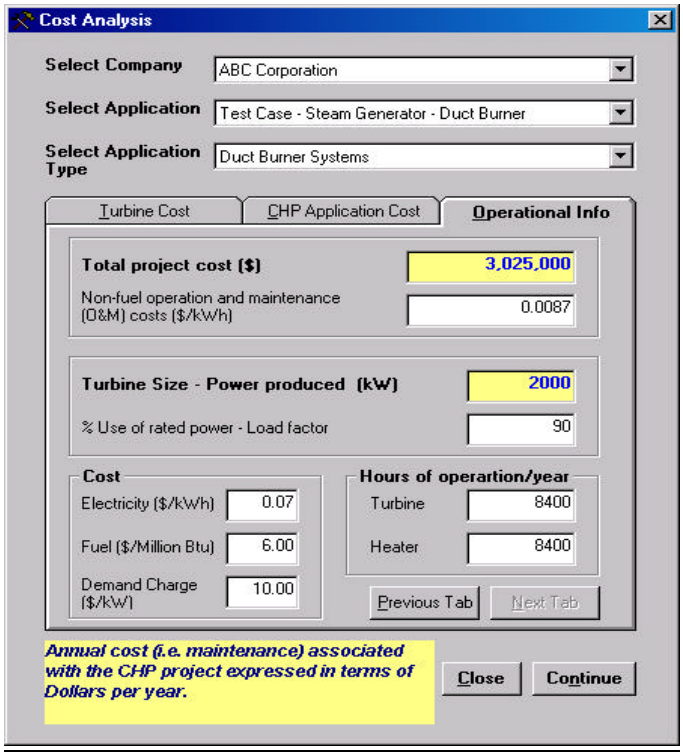
*Turbine Cost:*




*CHP Modification:*



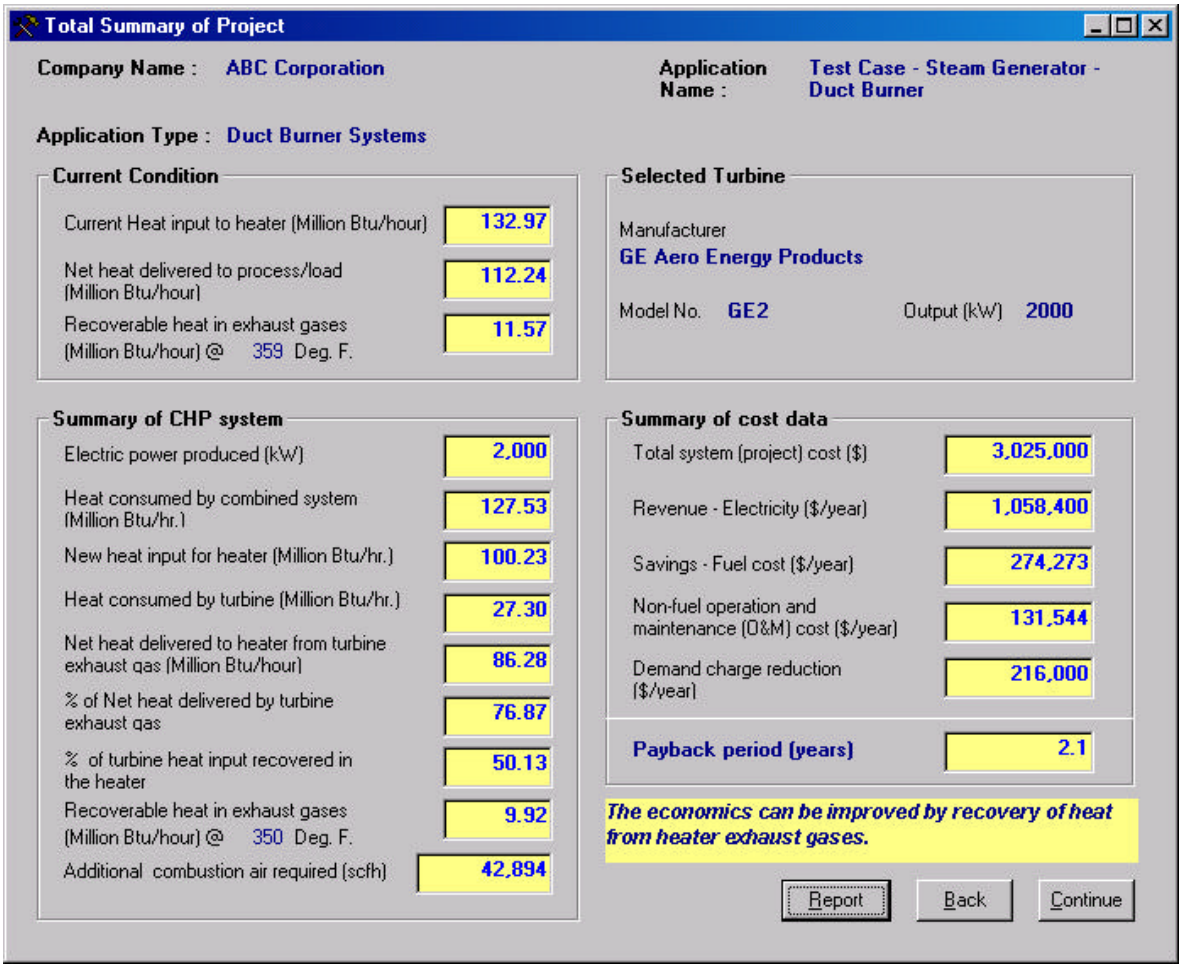
*Operational Info:*




**"Close"** will close the analysis form and will return the user to the Main Screen.

**"Continue"** will calculate the Electric Revenue, Fuel Savings (if any) and Payback period (of current application) as a part of the analysis. The summary of the complete analysis will be displayed as shown below.

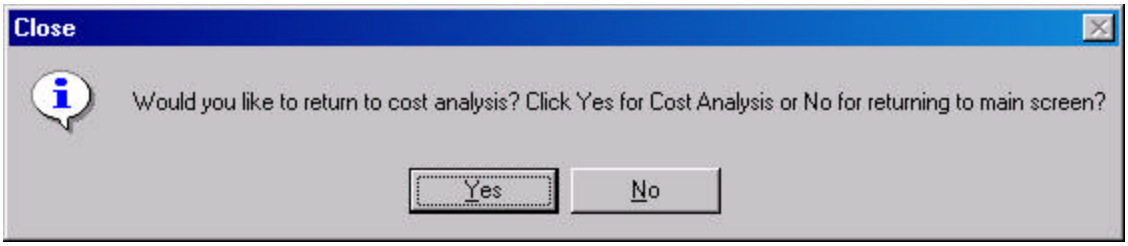
*Note: This button is enabled only for the third tab. The idea is to enter all of the data before performing calculations.*




**"Report"** will display the summary report for the current application. This is described in detail in a later portion of the Manual.

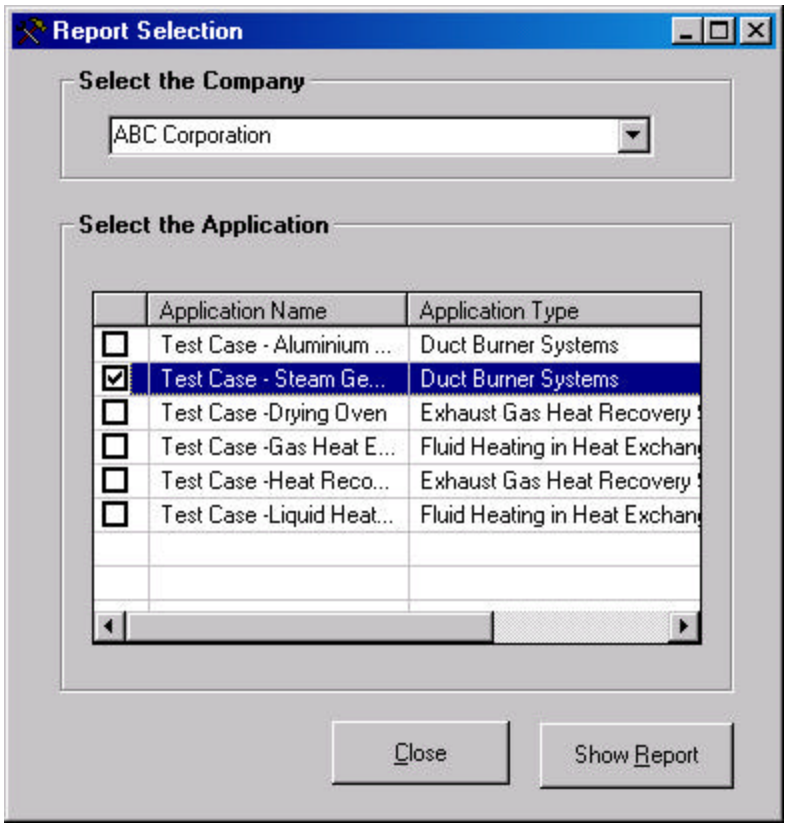
Clicking on **"Back"** will take the user back to the current cost analysis.

Clicking on **"Continue"** will give the user the option to continue with the cost analysis or return to the main screen.



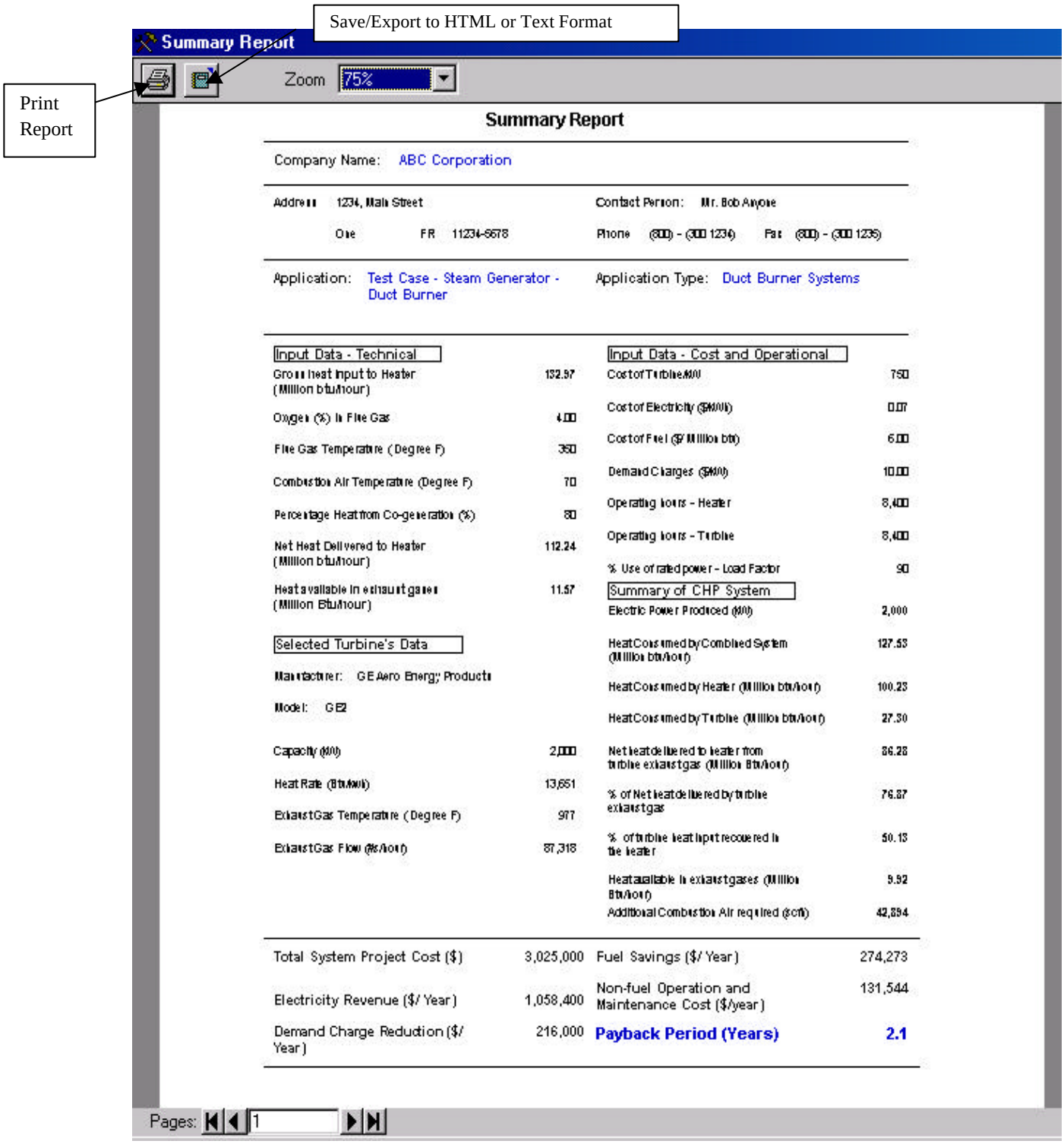
**Report:**

The report can also be viewed from the Main Screen by selecting Application from the list. Select the application to be reported on by clicking the appropriate checkbox.




**"Show Report"** will display the summary report for the selected Application as shown below. The user also has the option to print the report.

**"Close"** will take the user back to the main screen.




**Summary Report**

Company Name: ABC Corporation

Address: 1234, Main Street
City FR 11234-5678

Contact Person: Mr. Bob Anyone
Phone (800) - (300 1234) Fax (800) - (300 1235)

Application: Test Case - Steam Generator - Duct Burner

Application Type: Duct Burner Systems

| Input Data - Technical | |
|---|---|
| Gross heat input to Heater (Million btu/hour) | 132.97 |
| Oxygen (%) in Flue Gas | 4.00 |
| Flue Gas Temperature (Degree F) | 350 |
| Combustion Air Temperature (Degree F) | 70 |
| Percentage Heat from Co-generation (%) | 80 |
| Net Heat Delivered to Heater (Million btu/hour) | 112.24 |
| Heat available in exhaust gases (Million Btu/hour) | 11.57 |

| Selected Turbine's Data | |
|---|---|
| Manufacturer: | GE Aero Energy Products |
| Model: | GE2 |
| Capacity (kW) | 2,000 |
| Heat Rate (Btu/kWh) | 13,651 |
| Exhaust Gas Temperature (Degree F) | 977 |
| Exhaust Gas Flow (lbs/hour) | 87,318 |

| Input Data - Cost and Operational | |
|---|---|
| Cost of Turbine/kW | 750 |
| Cost of Electricity ($/kWh) | 0.07 |
| Cost of Fuel ($/ Million btu) | 6.00 |
| Demand Charges ($/kW) | 10.00 |
| Operating hours - Heater | 8,400 |
| Operating hours - Turbine | 8,400 |
| % Use of rated power - Load Factor | 90 |

| Summary of CHP System | |
|---|---|
| Electric Power Produced (kW) | 2,000 |
| Heat Consumed by Combined System (Million btu/hour) | 127.53 |
| Heat Consumed by Heater (Million btu/hour) | 100.23 |
| Heat Consumed by Turbine (Million btu/hour) | 27.30 |
| Net heat delivered to heater from turbine exhaust gas (Million Btu/hour) | 86.28 |
| % of Net heat delivered by turbine exhaust gas | 76.87 |
| % of turbine heat input recovered in the heater | 50.13 |
| Heat available in exhaust gases (Million Btu/hour) | 9.92 |
| Additional Combustion Air required (scfh) | 42,894 |

| | | | |
|---|---|---|---|
| Total System Project Cost ($) | 3,025,000 | Fuel Savings ($/ Year) | 274,273 |
| Electricity Revenue ($/ Year) | 1,058,400 | Non-fuel Operation and Maintenance Cost ($/year) | 131,544 |
| Demand Charge Reduction ($/ Year) | 216,000 | **Payback Period (Years)** | **2.1** |

*Notes:*

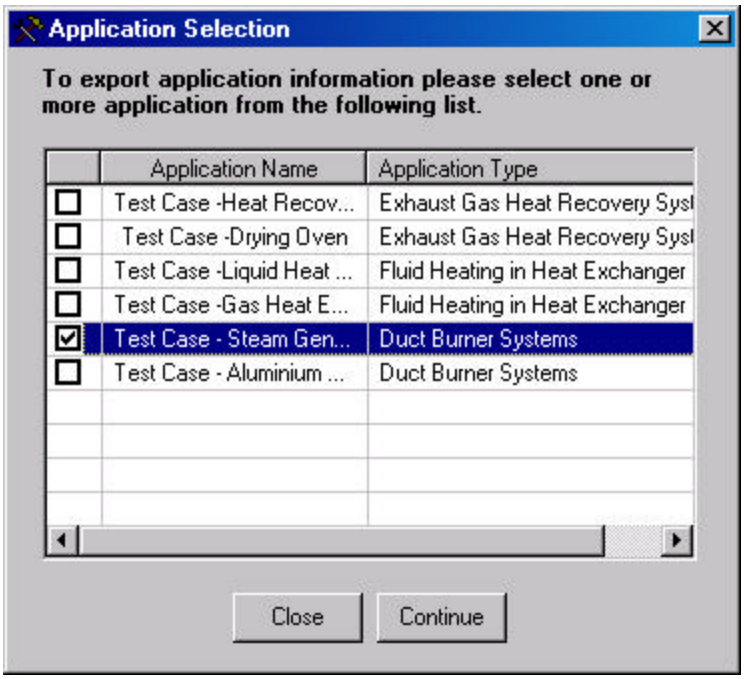
- *User has an option to print the report or save the report in HTML or Text format.*
- *While printing, a report can be saved or printed as PDF if Acrobat Distiller or Writer is installed as a printer on user computer and is selected as a printer name.*
- *The saved report can be stored on any electronic media or sent to other users through email.*

**Export Data:**

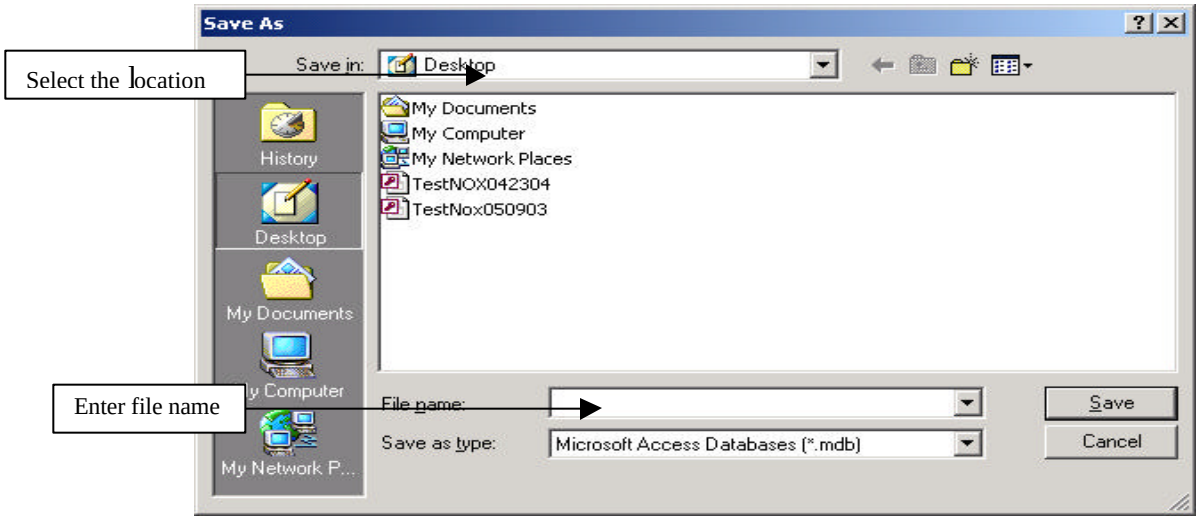
***This note is for the CHP TOOL user who is sending the file containing all information.***

This feature will create a Microsoft Access Application file (.mdb) of selected the Applications from all of the information available. This file can be sent to other CHP TOOL users through email or other forms of media.

Clicking on **"Export Data"** on the main screen will pop up a new interface as shown below.




This will display the list of Applications for which information was entered through the CHP TOOL (Version 1.0.0). The user can select one or more Applications from the list for which information is to be exported. The file can be saved and stored with any name and in any location.




The same file can be sent through email or via other media to other CHP TOOL users. Other users can import this file by using the import feature as discussed earlier.

### Import Data:

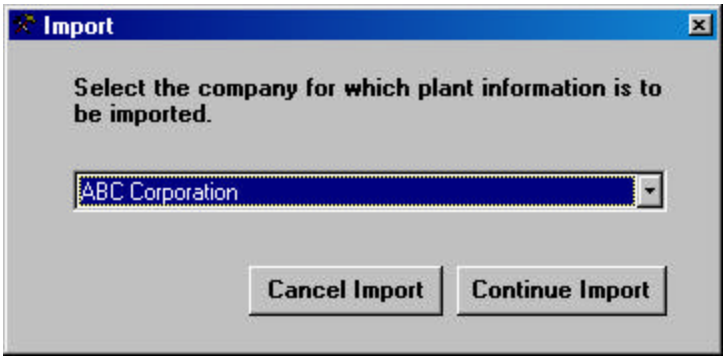
This section provides the capability of importing and integrating all information about other applications into the existing database of the CHP Tool. **This feature can be used once the user receives the Microsoft Access Application file (for example, Heater.mdb or any other named file sent by another user) from another source for which information is to be imported and integrated.** The Microsoft Access Application file can be received through email or other media and should be stored on the computer or local network from where it can be accessed later. (The user can save the received file with the same or a different name).

***Note:***
*This is a mandatory step and must be performed before using the "import data" feature.*

*Do not save the new database file with the name "Heater.mdb" in the default location. If this is done, the existing database will be replaced and deleted. Either save the new database with a different name or in a different location.*

*Do not save the database file as Read-Only.*

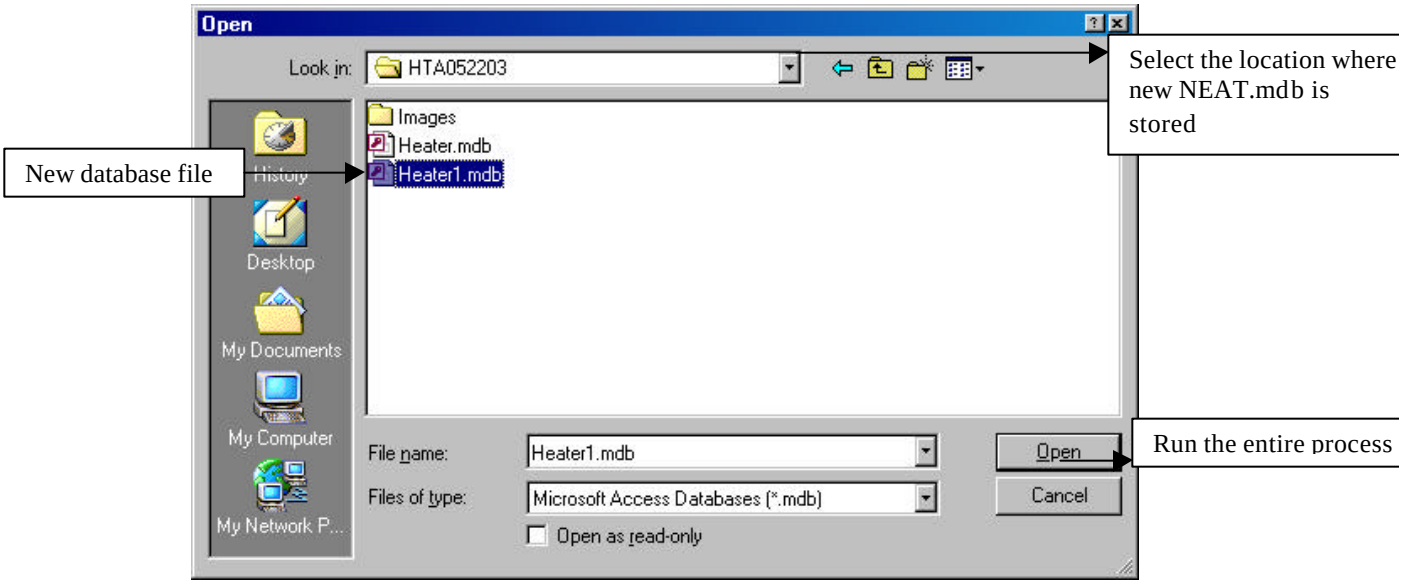
Click on the **Import Data** button on the main screen of the CHP Tool to open a new user interface.




- Select the company for which the Application information is to be imported.
- Click **"Continue Import"** to continue the import process.

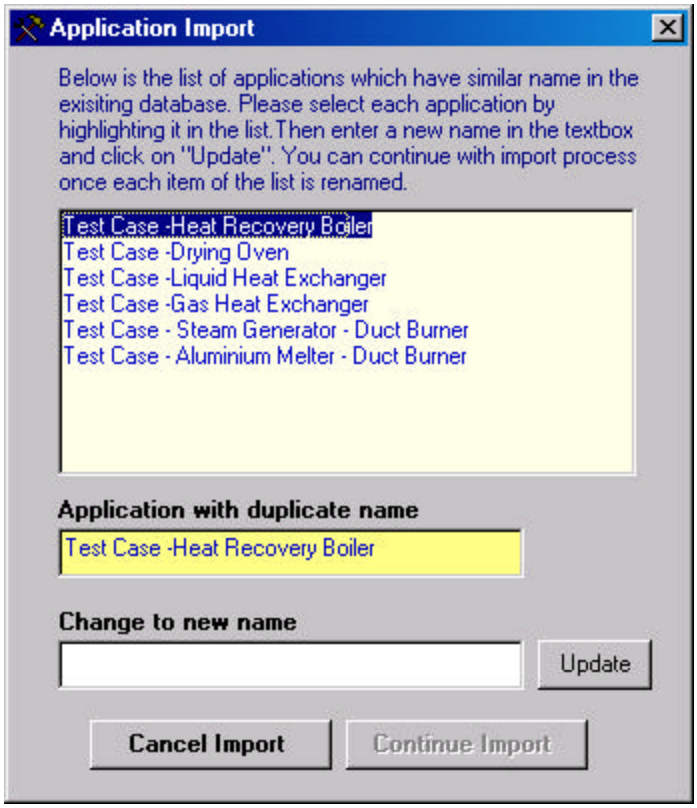
*Note: If there is no company available for selection, enter the information first through the Company/Application form, and then continue the import process.*

A New User interface will open up where the user can select the Microsoft Access Application file (Heater.mdb or a file with any other name) received from the other source and stored locally as mentioned above. This file contains the information for the Application to be imported and to be integrated with the existing database.




From the **Look-in** drop-down menu, the user can select the location where the new file was stored upon receipt (as described above) and select this file. Click on **"Open"** to carry out the entire process of importing the new database and integrating it with the CHP Tool's existing database.

If the new file information contains an Application with a name similar to one already in the database, the tool will display a list of the Applications with similar names, otherwise, the tool will continue the import process without interruption.



The user should select each duplicate Application from the list by clicking on it and changing the name by entering a new name into the text box provided. Clicking on the **'Update"** button will change the Application's name and remove it from the displayed list.

*Note: If the list has more than one Application with duplicate names, the user must change each name by entering a new name for the application and clicking "Update".*

Once all duplicate Applications have received new names, the **"Continue Import"** button will be enabled and the user will be able to continue the Import process by clicking on it.

The **"Cancel Import"** button will cancel the importing process and no information will be imported/integrated to the CHP TOOL.

Once the information is imported successfully, it can be viewed, analyzed, or modified as discussed in the earlier sections of the CHP TOOL manual. Reports can also be generated for the new Application's information.

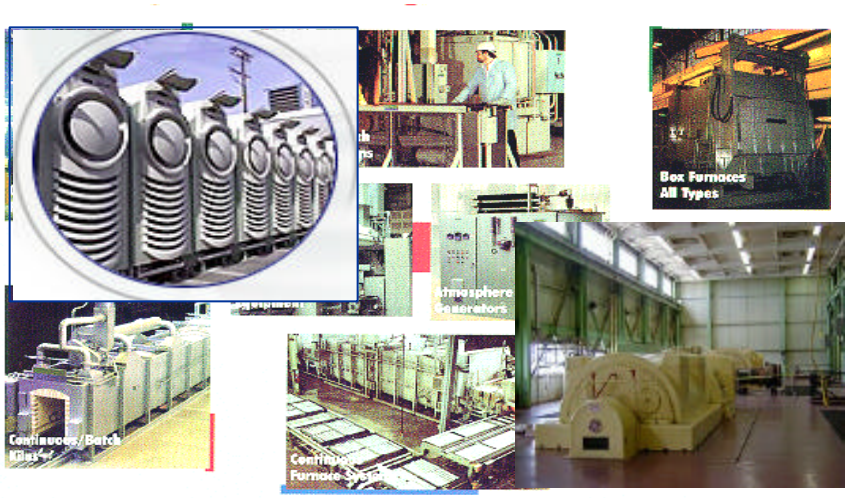
*Note:*
Do not open the saved database file as a Read-only.

# Appendix 1 - Awareness Presentation

# Overview

## Combined Heat and Power (CHP) Application Assessment Tool

## for Industrial Process Heating




**Prepared By**

**Arvind Thekdi**

**E3M, Inc.**

**August 2004**

# Combined Heat and Power (CHP) Application Assessment Tool for Industrial Process Heating

# Description and Function of the Tool

- The tool is designed to evaluate feasibility of using Combined Heat and Power (CHP) in industrial process heating systems.
- The heating systems include fuel fired furnaces, boilers, ovens, heaters, heat exchangers etc. used in the industry. The CHP systems use gas turbine exhaust gases to supply heat to the heating systems.
- The tool includes necessary performance data and cost information for commercially available gas turbines
- The results include “ball-park” estimate for payback period that will help the industry decide whether it is worth while to carry out further engineering study for the project.
- The tool can be used to estimate payback periods and what-if analysis for various utility costs

*Note: The current version includes three commonly used CHP systems most suitable for use in process heating and steam generation applications.*

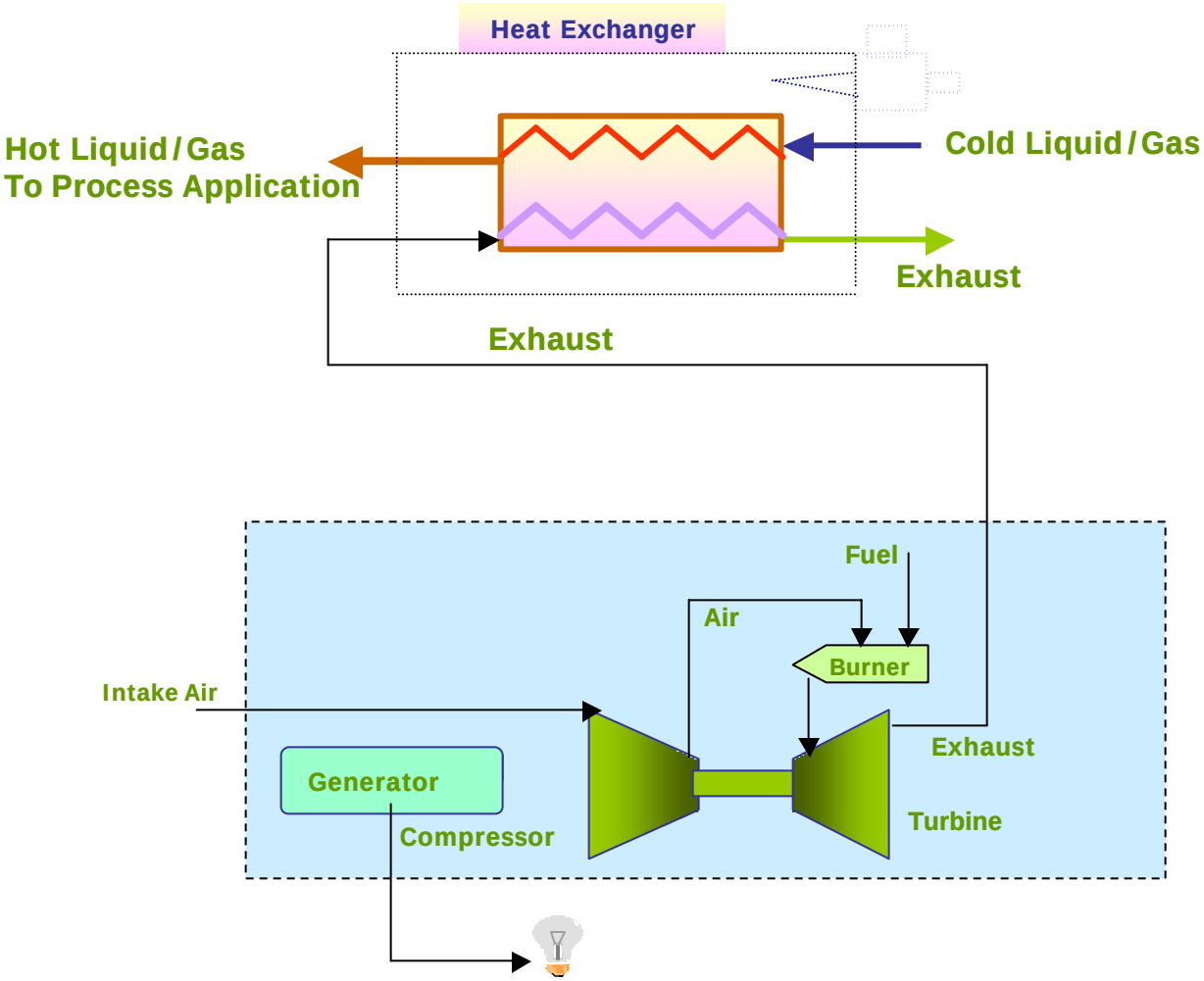
# Commonly Used CHP Systems

## 1. Fluid Heating in Heat Exchanger

Indirect heating of liquids or gases using gas turbine exhaust gases. The sensible heat of exhaust gases is transferred to liquid or gas being heated.

**Examples: Fired water (liquid) or air (gas) heaters**

# 1. Fluid Heating in Heat Exchanger



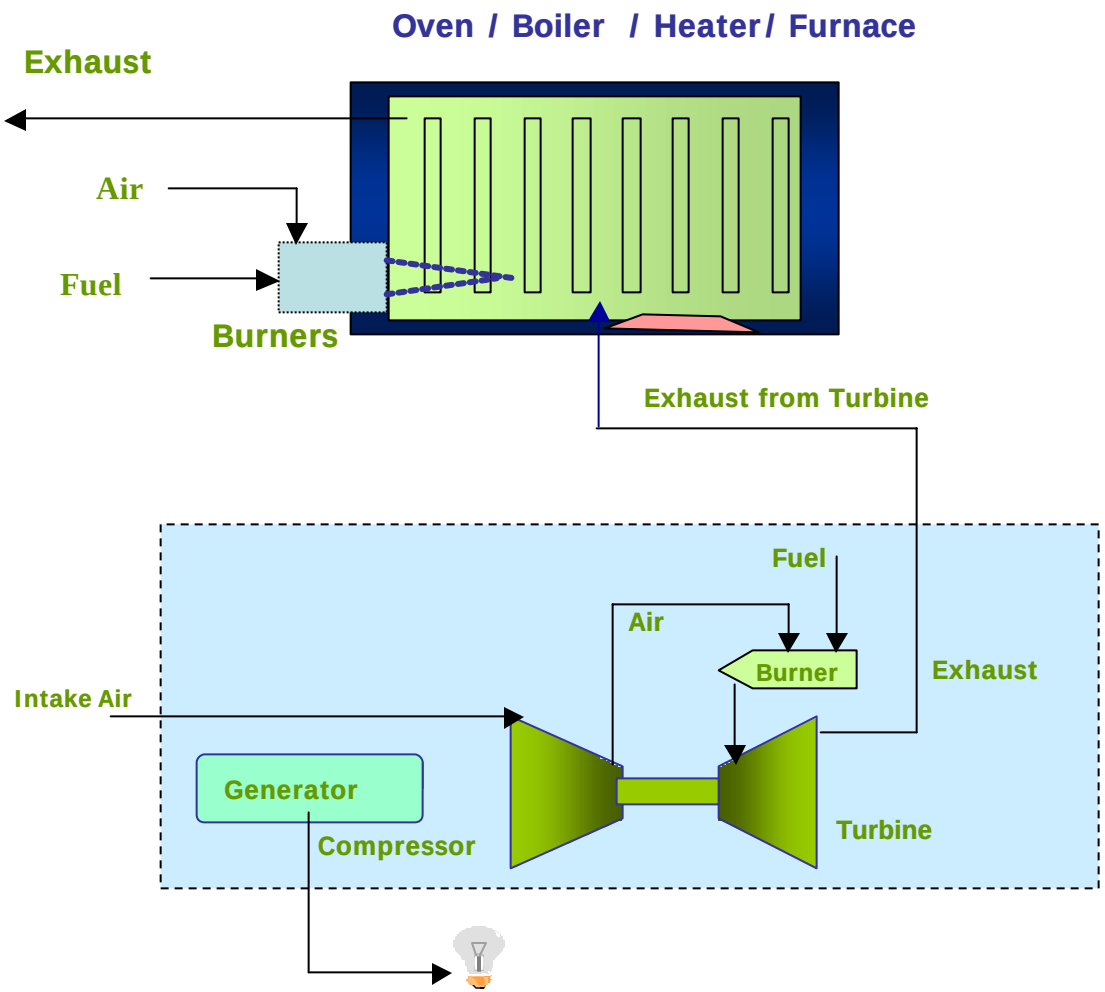
# Commonly Used CHP Systems

## 2. Exhaust Gas Heat Recovery in Heaters

Direct heating applications where the turbine exhaust gases are mixed or injected in a furnace, oven, heater, dryer or boiler. The sensible heat of exhaust gases is transferred to heat material in an oven or raise steam in a “heat recovery” boiler.

**Examples: Heat recovery boilers, drying ovens, low temperature furnaces/heaters**

# 2. Exhaust Gas Heat Recovery in Heaters



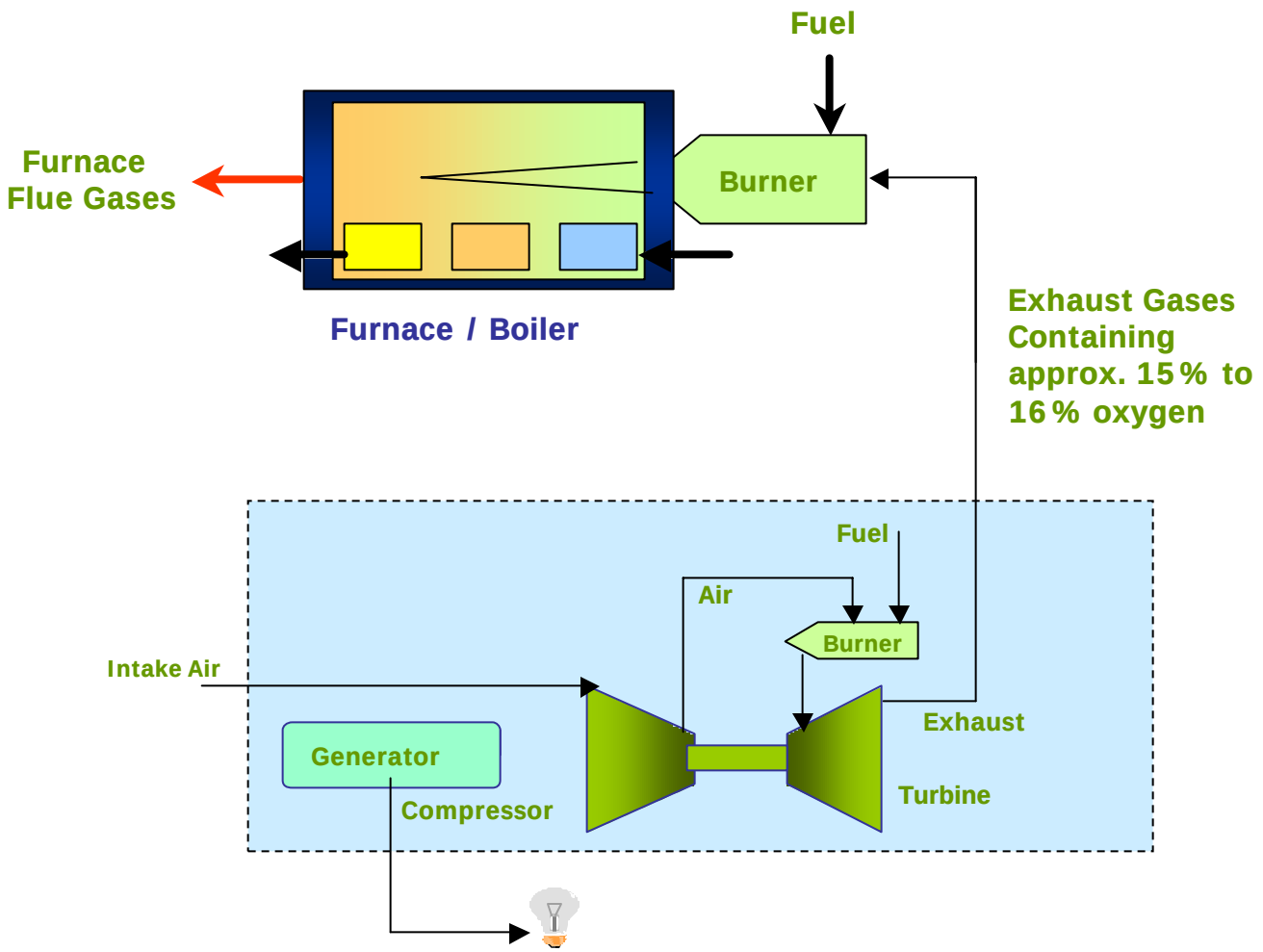
# Commonly Used CHP Systems

## 3. "Duct Burner" Systems

Use of the turbine exhaust gases for combustion of fuels such as natural gas, light oil, by-product gases in a furnace, heater, boiler etc. Most commonly used system is a boiler using a "duct-burner" where residual oxygen from the turbine exhaust gases is used for combustion of the fuel.

**Examples: Boilers, Direct fired furnaces and ovens**

# 3. "Duct Burner" Systems



# Data Requirement

| CHP Data Collection form - Duct Burner System | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Plant General Data** | | | | | | | |
| Company Name | | | | | | | |
| Application Name | | | | | | | |
| Application Type | Duct Burner System | | | | | | |
| Contact Address | Street | | | City | | Zip Code | |
| Contact Information | Name | | Email | | | | |
| | Phone | | Fax | | | | |

| Technical Analysis Data | |
|---|---|
| Current Heat Input to Heater ( Million Btu/hr.) *(For Furnace/Oven Only)* | |
| Oxygen % in flue gases from the boiler/furnace (heater) | |
| Flue gas temperature (degree F) | |
| Combustion air temperature (degree F) | |
| Heating Value of Fuel ( Btu /scf) | |
| Percentage of the net heat requirement of the heater delivered from turbine exhaust gases (%) | |
| *Data input for Steam Generator/ Boiler only* | |
| Steam Production ( lbs/hr.) | |
| Steam temperature (degree F) | |
| Steam Pressure (psig) | |
| Total heat content of Steam ( Btu /lb) | |
| Other losses excluding flue gas heat losses (%) | |
| **Turbine Data**(supply this information if known) | |
| Manufacturer | |
| Model No. | |
| Output ( kW) | |

| Cost and Operating Data | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Turbine cost ($/kW) | Engineering Cost | | | Installation Cost | | | Other Cost | | |
| | % of Turbine Cost | OR | ($) | % of Turbine Cost | OR | ($) | % of Turbine Cost | OR | ($) |
| | | | | | | | | | |
| CHP Application Cost ($) | Engineering Cost | | | Installation Cost | | | Other Cost | | |
| | % of Heater Cost | OR | ($) | % of Heater Cost | OR | ($) | % of Heater Cost | OR | ($) |
| | | | | | | | | | |

| Operational Information | | | | | | |
|---|---|---|---|---|---|---|
| Non-fuel operation and maintenance (O&M) cost ($/kWh) | Fuel Cost ($/MM Btu) | Electricity Cost ($/kWh) | Demand Charges ($/kW) | Use of power - % of the rated turbine power used | Turbine Operation (Hours/year) | Heater Operation (Hours/year) |
| | | | | | | |

- Use one data sheet - form for each application. There are three forms (one for each application) are available.
- Data forms are available and can be copied from
  - User Manual
  - Start section of the main screen
  - Help section located on the toolbar
- Most of the design and performance data can be obtained from the heating equipment supplier manuals, drawings or nameplates for the heating equipment.
- The cost data for utilities should be collected from current utility bills or projected costs at the time of project completion.
- Use this form to enter the required data in the CHP Tool application

# Summary Report

**Summary Report**

Company Name: ABC Corporation

Address: 1234 Main Street
First ON 11111-1111

Contact Person: Mr. Jack Anyone
Phone (111) - (111 1111) Fax (111) - (111 2222)

Application: Application 2
Description:

Application Type: Duct Burner Systems

| Input Data - Technical | |
|---|---|
| Gross heat input to Heater (Million btu/hour) | 175.18 |
| Oxygen (%) in Flue Gas | 4.00 |
| Flue Gas Temperature (Degree F) | 450 |
| Combustion Air Temperature (Degree F) | 100 |
| Percentage Heat from Co-generation (%) | 90 |
| Net Heat Delivered to Heater (Million btu/hour) | 144.00 |
| Heat available in exhaust gases (Million Btu/hour) | 18.92 |

| Selected Turbine's Data | |
|---|---|
| Manufacturer: Solar Turbines Incorporated | |
| Model: Centaur 40-1 | |
| Capacity (kW) | 3,515 |
| Heat Rate (Btu/kwh) | 12,241 |
| Exhaust Gas Temperature (Degree F) | 819 |
| Exhaust Gas Flow (lb/hour) | 147,647 |

| Input Data - Cost and Operational | |
|---|---|
| Cost of Turbine/kW | 800 |
| Cost of Electricity ($/kWh) | 0.07 |
| Cost of Fuel ($/ Million btu) | 6.00 |
| Demand Charges ($/kW) | 5.00 |
| Operating hours - Heater | 8,000 |
| Operating hours - Turbine | 8,000 |
| % Use of rated power - Load Factor | 100 |

| Summary of CHP System | |
|---|---|
| Electric Power Produced (kW) | 3,515 |
| Heat Consumed by Combined System (Million btu/hour) | 174.31 |
| Heat Consumed by Heater (Million btu/hour) | 131.28 |
| Heat Consumed by Turbine (Million btu/hour) | 43.03 |
| Net heat delivered to heater from turbine exhaust gas (Million Btu/hour) | 125.60 |
| % of Net heat delivered by turbine exhaust gas | 90.00 |
| % of turbine heat input recovered in the heater | 31.66 |
| Heat available in exhaust gases (Million Btu/hour) | 17.75 |
| Additional Combustion Air required (scfh) | 0 |

| | | | |
|---|---|---|---|
| Total System Project Cost ($) | 4,217,400 | Fuel Savings ($/ Year) | 41,891 |
| Electricity Revenue ($/ Year) | 1,968,400 | Non-fuel Operation and Maintenance Cost ($/year) | 205,276 |
| Demand Charge Reduction ($/ Year) | 210,900 | **Payback Period (Years)** | **2.1** |

The summary report includes

- Current energy input data for the furnace/Boiler
- Performance data for the selected turbine
- Energy use data for the CHP system
- Cost details for the of application of the CHP system
- Payback period based on the given cost data for the fuel – electricity and the equipment used in the CHP system

# Appendix 2 - Data Forms

## CHP Data Collection Form - Exhaust Gas Heat Recovery System for Heaters

| Plant General Data | | | | |
|---|---|---|---|---|
| Company Name | | | | |
| Application Name | | | | |
| Application Type | Exhaust Gas Heat Recovery System for Heaters | | | |
| Contact Address | | | | |
| Contact Information | Name | | Email | |
| | Phone | | Fax | |

| Technical Analysis Data | |
|---|---|
| Current heat input to heater (Million Btu/hour) | |
| Oxygen % in flue gases from the heater | |
| Flue gas temperature (degree F) | |
| Combustion air temperature (degree F) | |
| Percentage heat from cogeneration(%) | |

**Turbine Data**

(Based on the technical data entered, tool will appropriately select the available turbine. However if you want to select different turine, refer the attached turbine list and enter the following information. Use the "New Turbine Data Form" to enter the detail of a turbine that is not available in the list.)

| | |
|---|---|
| Manufacturer | |
| Model No. | |
| Output ( kW) | |

**Cost and Operating Data**

| Turbine cost ($/kW) | Engineering Cost | | | Installation Cost | | | Other Cost | | |
|---|---|---|---|---|---|---|---|---|---|
| | % of Turbine Cost | OR | ($) | % of Turbine Cost | OR | ($) | % of Turbine Cost | OR | ($) |
| | | | | | | | | | |

| CHP Application Cost ($) | Engineering Cost | | | Installation Cost | | | Other Cost | | |
|---|---|---|---|---|---|---|---|---|---|
| | % of Heater Cost | OR | ($) | % of Heater Cost | OR | ($) | % of Heater Cost | OR | ($) |
| | | | | | | | | | |

**Operational Information**

| Non-fuel operation and maintenance (O&M) cost ($/kWh) | Fuel Cost ($/MM Btu) | Electricity Cost ($/kWh) | Demand Charges ($/kW) | Use of power - % of the rated turbine power used | Turbine Operation (Hours/year) | Heater Operation (Hours/year) |
|---|---|---|---|---|---|---|
| | | | | | | |

## CHP Data Collection Form - Duct Burner System

| Plant General Data | | | | | | | |
|---|---|---|---|---|---|---|---|
| Company Name | | | | | | | |
| Application Name | | | | | | | |
| Application Type | Duct Burner System | | | | | | |
| Contact Address | Street | | | City | | Zip Code | |
| Contact Information | Name | | Email | | | | |
| | Phone | | Fax | | | | |

| Technical Analysis Data | | | | |
|---|---|---|---|---|
| Type (Select appropriate) | Steam Generator/Boiler | | Furnace/Oven | |

| *Data input for Steam Generator/ Boiler only* | |
|---|---|
| Steam Production ( lbs/hr.) | |
| Steam temperature (degree F) | |
| Steam Pressure (psig) | |
| Total heat content of Steam ( Btu /lb) | |
| Other losses excluding flue gas heat losses (%) | |
| Current Heat Input to Heater ( Million Btu/hr.) *(For Furnace/Oven Only)* | |

| *Common data input for both types* | |
|---|---|
| Oxygen % in flue gases from the boiler/furnace (heater) | |
| Flue gas temperature (degree F) | |
| Combustion air temperature (degree F) | |
| Heating Value of Fuel ( Btu /scf) | |
| Percentage of the net heat requirement of the heater delivered from turbine exhaust gases (%) | |

**Turbine Data**

(Based on the technical data entered, tool will appropriately select the available turbine. However if you want to select different turine, refer the attached turbine list and enter the following information. Use the "New Turbine Data Form" to enter the detail of a turbine that is not available in the list.)

| | |
|---|---|
| Manufacturer | |
| Model No. | |
| Output ( kW) | |

**Cost and Operating Data**

| Turbine cost ($/kW) | Engineering Cost | | | Installation Cost | | | Other Cost | | |
|---|---|---|---|---|---|---|---|---|---|
| | % of Turbine Cost | OR | ($) | % of Turbine Cost | OR | ($) | % of Turbine Cost | OR | ($) |
| | | | | | | | | | |

| CHP Application Cost ($) | Engineering Cost | | | Installation Cost | | | Other Cost | | |
|---|---|---|---|---|---|---|---|---|---|
| | % of Heater Cost | OR | ($) | % of Heater Cost | OR | ($) | % of Heater Cost | OR | ($) |
| | | | | | | | | | |

**Operational Information**

| Non-fuel operation and maintenance (O&M) cost ($/kWh) | Fuel Cost ($/MM Btu) | Electricity Cost ($/kWh) | Demand Charges ($/kW) | Use of power - % of the rated turbine power used | Turbine Operation (Hours/year) | Heater Operation (Hours/year) |
|---|---|---|---|---|---|---|
| | | | | | | |

## CHP Data Collection Form - Fluid Heating in Heat Exchanger

### Plant General Data

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Company Name | | | | | | | |
| Application Name | | | | | | | |
| Application Type | Fluid Heating in Heat Exchanger | | | | | | |
| Contact Address | Street | | | City | | Zip Code | |
| Contact Information | Name | | Email | | | | |
| | Phone | | Fax | | | | |

### Technical Analysis Data

| Gas Heat Exchanger | | Liquid Heat Exchanger | | | | |
|---|---|---|---|---|---|---|
| | | Liquid Flow | | | If Liquid Flow unit is GPM, provide Density | |
| | | GPM | OR | Lbs/hr. | | |
| Gas Flow ( scfm) | | | | | Density ( Lbs./Cu.ft) | |
| Gas Inlet Temperature ( Degree F.) | | Liquid Inlet Temperature ( Degree F.) | | | | |
| Gas Outlet Temperature ( Degree F.) | | Liquid Outlet Temperature ( Degree F.) | | | | |
| Gas Specific Heat ( Btu /scf. F.) | | Liquid Specific Heat ( Btu /scf. F.) | | | | |
| Total Heat for Vapor ( Btu /lb. F) | | Total Heat for Vapor ( Btu /lb. F) | | | | |
| | | Percentage Liquid Vaporized | | | | |

*Common data input for both type of heat exchangers*

| | |
|---|---|
| Heat Exchanger other losses (% of Net heat Input) | |
| Oxygen % in flue gases from the heater | |
| Flue gas temperature (degree F) | |
| Combustion air temperature (degree F) | |
| Percentage of the net heat requirement of the heater delivered from turbine exhaust gases (%) | |

**Turbine Data**

(Based on the technical data entered, tool will appropriately select the available turbine. However if you want to select different turine, refer the attached turbine list and enter the following information. Use the "New Turbine Data Form" to enter the detail of a turbine that is not available in the list.)

| | |
|---|---|
| Manufacturer | |
| Model No. | |
| Output ( kW) | |

### Cost and Operating Data

| | Engineering Cost | | | Installation Cost | | | Other Cost | | |
|---|---|---|---|---|---|---|---|---|---|
| Turbine cost ($/kW) | % of Turbine Cost | OR | ($) | % of Turbine Cost | OR | ($) | % of Turbine Cost | OR | ($) |
| | | | | | | | | | |
| | Engineering Cost | | | Installation Cost | | | Other Cost | | |
| CHP Application Cost ($) | % of Heater Cost | OR | ($) | % of Heater Cost | OR | ($) | % of Heater Cost | OR | ($) |
| | | | | | | | | | |

### Operational Information

| Non-fuel operation and maintenance (O&M) cost ($/kWh) | Fuel Cost ($/MM Btu) | Electricity Cost ($/kWh) | Demand Charges ($/kW) | Use of power - % of the rated turbine power used | Turbine Operation (Hours/year) | Heater Operation (Hours/year) |
|---|---|---|---|---|---|---|
| | | | | | | |

| CHP Data Collection Form - New Turbine | |
|---|---|
| **Manufacturer** | |
| **Model No.** | |
| **Output (kW)** | |
| **Heat Rate ( Btu/Kwh)** | |
| **Exhaust Gas Temperature ( Degree F)** | |
| **Exhaust Gas Flow( #s/hour)** | |

# Appendix 3 – Master Turbine List

| CHP Tool - Turbine list | | | | | | |
|---|---|---|---|---|---|---|
| **Sr. No.** | **Manufacturer** | **Model No** | **Output (kW)** | **Heat Rate (Btu/Kwh)** | **Exhaust Gas Temperature (Degree F)** | **Exhaust Gas Flow (#s/hour)** |
| 1 | Capstone Turbine Corporation | C30 | 30 | 13,082 | 527 | 2,461 |
| 2 | Capstone Turbine Corporation | C60 | 60 | 12,229 | 581 | 3,890 |
| 3 | Ingersoll Rand | 70S Series | 70 | 13,550 | 450 | 5,760 |
| 4 | Elliott Energy Systems | 100kW CHP | 100 | 12,183 | 535 | 6,840 |
| 5 | Ingersoll Rand | 250 Series | 250 | 10,700 | 500 | 15,840 |
| 6 | Pratt & Whitney Power Systems | ST5 | 395 | 14,504 | 1,089 | 18,257 |
| 7 | Pratt & Whitney Power Systems | ST5-1 | 457 | 10,428 | 689 | 17,622 |
| 8 | Pratt & Whitney Power Systems | ST6L-721 | 508 | 14,599 | 957 | 23,814 |
| 9 | Vericor Power Systems | ASE 8 | 525 | 15,658 | 909 | 28,577 |
| 10 | Pratt & Whitney Power Systems | ST6L-795 | 678 | 13,841 | 1,092 | 25,719 |
| 11 | Kawasaki Heavy Industries, Ltd. | S2A-01 | 680 | 16,362 | 885 | 40,484 |
| 12 | Pratt & Whitney Power Systems | ST6L-813 | 848 | 13,556 | 1,051 | 31,117 |
| 13 | Mitsui Engineering & Shipbuilding Co., Ltd. | SB5 | 1,080 | 13,395 | 918 | 39,690 |
| 14 | Pratt & Whitney Power Systems | ST6L-90 | 1,175 | 12,214 | 997 | 41,754 |
| 15 | Solar Turbines Incorporated | Saturn 20 | 1,210 | 14,025 | 940 | 51,900 |
| 16 | Kawasaki Heavy Industries, Ltd. | M1A-13 | 1,550 | 13,386 | 964 | 64,298 |
| 17 | Kawasaki Heavy Industries, Ltd. | M1A-13D | 1,550 | 13,518 | 984 | 63,504 |
| 18 | Pratt & Whitney Power Systems | ST18A | 1,961 | 11,281 | 990 | 63,266 |
| 19 | GE Aero Energy Products | GE2 | 2,000 | 13,651 | 977 | 87,318 |
| 20 | Mitsui Engineering & Shipbuilding Co., Ltd. | SB15 | 2,720 | 13,329 | 916 | 119,070 |
| 21 | Yanmar Diesel Engine Co., Ltd. | ATS 40 | 2,950 | 12,241 | 819 | 147,647 |
| 22 | Kawasaki Heavy Industries, Ltd. | M1T-13 | 3,050 | 13,604 | 964 | 128,596 |
| 23 | Kawasaki Heavy Industries, Ltd. | M1T-13D | 3,050 | 13,727 | 984 | 127,008 |
| 24 | MTU Motoren- und Turbinen-Union | ASE40 | 3,140 | 12,144 | 1,117 | 103,194 |
| 25 | Vericor Power Systems | ASE 40 (VPS3) | 3,286 | 12,073 | 1,108 | 100,813 |
| 26 | Pratt & Whitney Power Systems | ST30 | 3,340 | 10,712 | 955 | 103,194 |
| 27 | Solar Turbines Incorporated | Centaur 40 | 3,500 | 12,238 | 835 | 150,822 |
| 28 | Solar Turbines Incorporated | Centaur 40-1 | 3,515 | 12,241 | 819 | 147,647 |
| 29 | Mitsui Engineering & Shipbuilding Co., Ltd. | MSC40 | 3,520 | 12,243 | 819 | 147,647 |

| CHP Tool - Turbine list | | | | | | |
|---|---|---|---|---|---|---|
| Sr. No. | Manufacturer | Model No | Output (kW) | Heat Rate (Btu/Kwh) | Exhaust Gas Temperature (Degree F) | Exhaust Gas Flow (#s/hour) |
| 30 | Yanmar Diesel Engine Co., Ltd. | ATS 50 | 3,600 | 11,672 | 918 | 150,822 |
| 31 | MTU Motoren- und Turbinen-Union | ASE50 | 3,660 | 11,044 | 1,038 | 111,132 |
| 32 | Niigata Engineering (Europe) B.V. | CNT-30C | 3,716 | 12,419 | 815 | 149,234 |
| 33 | Vericor Power Systems | ASE 50 (VPS4) | 3,776 | 11,152 | 1,044 | 111,926 |
| 34 | Alstom Power | TB5000 | 3,942 | 13,247 | 910 | 168,127 |
| 35 | Rolls-Royce | 501-KB5S | 3,949 | 11,766 | 1,031 | 124,627 |
| 36 | Pratt & Whitney Power Systems | ST40 | 4,039 | 10,312 | 1,011 | 110,894 |
| 37 | Yanmar Diesel Engine Co., Ltd. | ATS 60 | 4,100 | 11,263 | 900 | 174,636 |
| 38 | Rybinsk Motors JSC | GTD-4RM | 4,110 | 4,491 | 727 | 172,255 |
| 39 | Alstom Power | TB5000 | 4,148 | 12,588 | 910 | 168,127 |
| 40 | Solar Turbines Incorporated | Mercury 50 | 4,180 | 8,297 | 694 | 129,389 |
| 41 | Alstom Power | TYPHOON | 4,343 | 11,371 | 982 | 140,106 |
| 42 | Mitsui Engineering & Shipbuilding Co., Ltd. | MSC50 | 4,350 | 11,675 | 934 | 150,822 |
| 43 | Solar Turbines Incorporated | Centaur 50 | 4,570 | 11,336 | 961 | 150,028 |
| 44 | Solar Turbines Incorporated | Centaur 50-1 | 4,600 | 11,631 | 948 | 151,616 |
| 45 | Solar Turbines Incorporated | Centaur 50L | 4,680 | 11,009 | 946 | 147,647 |
| 46 | Alstom Power | TYPHOON | 4,691 | 11,312 | 977 | 151,219 |
| 47 | Alstom Power | TYPHOON-1 | 4,932 | 10,666 | 1,013 | 142,408 |
| 48 | Niigata Engineering (Europe) B.V. | CNT-40C | 4,937 | 12,005 | 943 | 156,379 |
| 49 | Mitsui Engineering & Shipbuilding Co., Ltd. | MSC60 | 5,000 | 11,253 | 898 | 169,873 |
| 50 | Alstom Power | TYPHOON | 5,046 | 11,295 | 1,015 | 155,188 |
| 51 | Alstom Power | TYPHOON | 5,249 | 11,204 | 986 | 164,952 |
| 52 | Rolls-Royce | 501-KB7 | 5,273 | 11,204 | 982 | 165,110 |
| 53 | Kawasaki Heavy Industries, Ltd. | M7A-01D | 5,410 | 11,566 | 1,013 | 171,461 |
| 54 | Mitsui Engineering & Shipbuilding Co., Ltd. | SB30C | 5,410 | 13,139 | 946 | 214,326 |
| 55 | GE Aero Energy Products | GE5 | 5,500 | 11,117 | 1,060 | 158,760 |
| 56 | GE Aero Energy Products | GE5 | 5,500 | 11,117 | 1,060 | 158,760 |
| 57 | Solar Turbines Incorporated | Taurus 60 | 5,500 | 11,223 | 950 | 173,842 |
| 58 | Niigata Engineering (Europe) B.V. | CNT-50C | 5,531 | 11,516 | 903 | 176,224 |

| CHP Tool - Turbine list | | | | | | |
|---|---|---|---|---|---|---|
| Sr. No. | Manufacturer | Model No | Output (kW) | Heat Rate (Btu/Kwh) | Exhaust Gas Temperature (Degree F) | Exhaust Gas Flow (#s/hour) |
| 59 | Solar Turbines Incorporated | Taurus 60 | 5,740 | 10,661 | 914 | 169,873 |
| 60 | MAN Turbomaschinen AG GHH Borsig | THM1203A | 5,760 | 15,187 | 959 | 279,418 |
| 61 | Kawasaki Heavy Industries, Ltd. | M7A-01 | 5,900 | 11,092 | 982 | 176,224 |
| 62 | MAN Turbomaschinen AG GHH Borsig | THM1203A | 6,000 | 14,580 | 959 | 279,418 |
| 63 | Rybinsk Motors JSC | GTD-6RM | 6,000 | 7,754 | 779 | 381,024 |
| 64 | Rolls-Royce | 501-KH5 | 6,420 | 8,567 | 986 | 145,265 |
| 65 | Rolls-Royce | 601-K9 | 6,449 | 10,619 | 986 | 186,543 |
| 66 | Kawasaki Heavy Industries, Ltd. | M7A-01ST | 6,700 | 9,831 | 972 | 174,636 |
| 67 | Kawasaki Heavy Industries, Ltd. | M7A-02D | 6,700 | 11,130 | 963 | 211,151 |
| 68 | Alstom Power | TORNADO | 6,748 | 10,825 | 871 | 232,345 |
| 69 | Mitsui Engineering & Shipbuilding Co., Ltd. | MSC70 | 6,840 | 10,575 | 894 | 202,419 |
| 70 | Kawasaki Heavy Industries, Ltd. | M7A-02 | 7,150 | 10,731 | 950 | 215,914 |
| 71 | Mitsui Engineering & Shipbuilding Co., Ltd. | SB30E | 7,330 | 12,201 | 936 | 261,954 |
| 72 | Niigata Engineering (Europe) B.V. | CNT-60C | 7,500 | 10,601 | 900 | 210,357 |
| 73 | Solar Turbines Incorporated | Taurus 70 | 7,520 | 10,098 | 907 | 213,532 |
| 74 | Alstom Power | TORNADO | 7,670 | 10,187 | 912 | 233,774 |
| 75 | Solar Turbines Incorporated | Taurus 70 | 7,690 | 10,045 | 919 | 211,151 |
| 76 | Alstom Power | TEMPEST | 7,710 | 11,042 | 993 | 235,203 |
| 77 | Rolls-Royce | 601-K11 | 7,918 | 10,353 | 910 | 241,315 |
| 78 | Rybinsk Motors JSC | GTD-8RM | 8,000 | 10,082 | 869 | 381,024 |
| 79 | MAN Turbomaschinen AG GHH Borsig | THM1304-9 | 8,450 | 12,561 | 925 | 356,416 |
| 80 | MAN Turbomaschinen AG GHH Borsig | THM1304-9 | 8,800 | 12,059 | 925 | 356,416 |
| 81 | MAN Turbomaschinen AG GHH Borsig | THM1304-10R | 8,840 | 9,982 | 925 | 358,798 |
| 82 | MAN Turbomaschinen AG GHH Borsig | THM1304-10 | 9,120 | 12,428 | 946 | 359,591 |
| 83 | MAN Turbomaschinen AG GHH Borsig | THM1304-10R | 9,200 | 9,584 | 946 | 358,798 |
| 84 | Mitsui Engineering & Shipbuilding Co., Ltd. | MSC90 | 9,290 | 10,769 | 867 | 311,170 |
| 85 | Solar Turbines Incorporated | Mars 90 | 9,450 | 10,769 | 867 | 319,108 |
| 86 | MAN Turbomaschinen AG GHH Borsig | THM1304-10 | 9,500 | 11,935 | 946 | 359,591 |
| 87 | Vericor Power Systems | ASE 120 | 9,793 | 9,753 | 970 | 249,253 |

| CHP Tool - Turbine list | | | | | | |
|---|---|---|---|---|---|---|
| **Sr. No.** | **Manufacturer** | **Model No** | **Output (kW)** | **Heat Rate (Btu/Kwh)** | **Exhaust Gas Temperature (Degree F)** | **Exhaust Gas Flow (#s/hour)** |
| 88 | Solar Turbines Incorporated | Mars 90 | 9,860 | 10,315 | 867 | 319,108 |
| 89 | Niigata Engineering (Europe) B.V. | CNT-90C | 9,964 | 11,130 | 864 | 320,695 |

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