

# 2012 Hydrogen Student Design Contest

## Energy Savings and Environmental Analysis Guidelines

### *v. 1.2 – Sections 2 and 3 Updated*

The purpose of these guidelines, prepared by the EPA CHP Partnership<sup>1</sup>, is to provide a common basis for all teams participating in the 2012 Hydrogen Student Design Contest to respond to the energy savings and environmental analysis requirements in section 3.6 of the Official Rules and Design Guidelines v 1.0. These specific guidelines are designed to address the CHHP system outputs and applications most likely to be encountered in CHHP system design, but may not directly apply to all potential configurations. In those cases, it is recommended that your methodology parallel these guidelines as closely as possible and your submittal should include thorough documentation of assumptions, calculations and approach. The guidelines are based on calculating the fuel and carbon dioxide emissions savings over a twelve month period. If the proposed estimate is based on a different time period, please specify the period and modify the guidelines accordingly. The guidelines also include a section on estimating the amount of organic waste that would no longer require disposal through traditional means (e.g., landfills) for fuel derived from an organic waste streams.

## **Introduction**

The energy savings and CO<sub>2</sub> reduction benefits of a CHHP system are found in the aggregate reduction in overall fuel consumption. A CHHP system replaces a separate on-site thermal system (furnace or boiler), purchased power from the grid (typically electricity from a central station power plant), and additional energy services (e.g., transportation or additional thermal energy) that might be provided by hydrogen fuel, with a single, integrated system producing all of these products concurrently. To calculate the fuel use and CO<sub>2</sub> emissions saved by a CHHP system, all outputs of the CHHP system must be accounted for and compared to the fuel use and emissions from conventional energy sources providing these same services to the existing or proposed facility. The CHHP system's thermal output avoids the fuel normally consumed in and emissions from an on-site boiler or other form of heating equipment, the power output avoids the fuel consumed and emissions from grid-connected power plants, and the hydrogen avoids fuel currently used in vehicles and/or other applications that can be converted to hydrogen fuel. To quantify the fuel and CO<sub>2</sub> emissions savings of a CHHP system, the fuel used and emissions released from the CHHP system must be subtracted from the fuel use and emissions that would normally occur without the

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<sup>1</sup> The EPA CHP Partnership a voluntary program seeking to reduce the environmental impact of power generation by promoting the use of Combined Heat and Power. The Partnership works closely with energy users, the CHP industry, state and local governments, and other clean energy stakeholders to facilitate the development of new projects and to promote their environmental and economic benefits. For more information see: [www.epa.gov/chp/](http://www.epa.gov/chp/)

system (i.e., using conventional methods to produce heat, power, and other energy services). An equation showing this relationship for overall fuel savings is:

$$F_S = (F_T + F_G + F_H) - F_{CHHP}$$

Where:

- $F_S$  = total fuel savings,
- $F_T$  = fuel use from avoided on-site thermal production,
- $F_G$  = fuel use from avoided purchased grid electricity,
- $F_H$  = fuel use from avoided energy services provided by hydrogen, and
- $F_{CHHP}$  = fuel use by the CHHP system.

The equation for overall CO<sub>2</sub> emissions savings is:

$$C_S = (C_T + C_G + C_H) - C_{CHHP}$$

Where:

- $C_S$  = total CO<sub>2</sub> savings,
- $C_T$  = CO<sub>2</sub> emissions from avoided on-site thermal production,
- $C_G$  = CO<sub>2</sub> emissions from avoided purchased grid electricity,
- $C_H$  = CO<sub>2</sub> emissions from fuel avoided by hydrogen utilization, and
- $C_{CHHP}$  = CO<sub>2</sub> emissions from the CHHP system.

To complete the estimate of fuel and CO<sub>2</sub> savings, you will need to quantify the electricity generated by the CHHP system on an annual basis (kWh), the amount of parasitic power loads the system requires (including fuel processing and preparation, hydrogen compression and auxiliary power requirements of the system itself), the type and amount of fuel the system would consume, the amount of hydrogen and thermal output the system provides, and the types and amounts of conventional energy or fuels these outputs would avoid.

## Calculation Guidelines

### 1. Determine CHHP System Input Fuel

- a. Identify the CHHP system input fuel, energy content, and net CO<sub>2</sub> emissions rate. Table 1 contains energy content and CO<sub>2</sub> emissions rates for some common fuel types. You can provide your own estimate for energy content and net CO<sub>2</sub> emissions for the specific fuel in your design proposal (or if the fuel is not listed in Table 1), but you should provide documentation on how these values were derived.

If using a blended fuel mix (i.e., natural gas and biogas), then you will need to apply the appropriate energy content and net CO<sub>2</sub> emissions rates proportionally to get the total values for the blended fuel.

- b. Identify the estimated equivalent full load operating hours of the CHHP system. This is the number of hours that the CHHP system will operate per year at full load equivalent. This can be calculated by dividing the total annual kWh generated by the system by the maximum

capacity of the CHHP system<sup>2</sup>.

**Table 1 – Energy Content (HHV) and CO<sub>2</sub> Emissions Rates<sup>3</sup>**

<b>Fuel Type</b>	<b>Energy Content</b>	<b>CO<sub>2</sub> Emissions Rate (lb/MMBtu)</b>	<b>Net CO<sub>2</sub> Emissions Rate (lb/MMBtu)<sup>4</sup></b>
Natural Gas	1028 Btu/cf	116.8	116.8
Propane	91,000 Btu/gallon	135.5	135.5
Distillate Fuel Oil	138,000 Btu/gallon	163.1	163.1
Residual Fuel Oil	150,000 Btu/gallon	165.6	165.6
Motor Gasoline	125,000 Btu/gallon	154.8	154.8
Coal - Anthracite	25.09 MMBtu/short ton	228.3	228.3
Coal - Bituminous	24.93 MMBtu/short ton	205.9	205.9
Coal – Sub-bituminous	17.25 MMBtu/short ton	213.8	213.8
Coal - Lignite	14.21 MMBtu/short ton	212.4	212.4
Coke	24.8 MMBtu/short ton	224.9	224.9
Ethanol	84,000 Btu/gallon	150.8	0.0
Biodiesel	128,000 Btu/gallon	162.8	0.0
Agricultural Byproducts	8.25 MMBtu/short ton	260.5	0.0
Wood/Wood Residuals	15.38 MMBtu/short ton	206.8	0.0
Biogas	841 Btu/cf	114.8	0.0
Vegetable Oil	120,000 Btu/gallon	179.8	0.0
MSW Biogenic	9.95 MMBtu/short ton	199.9	0.0
Peat	8.0 MMBtu/short ton	246.5	0.0
Tires	26.87 MMBtu/short ton	189.5	189.5

- c. Calculate the CHHP system fuel consumption in MMBtu/year that would be needed to supply the CHHP system:

<sup>2</sup> The FuelCell Energy DFC 3000 molten carbonate fuel cell has a full load capacity of 2.8 MW and a 47% electrical efficiency (Lower Heating Value). Full technical specifications can be found at <http://www.fuelcellenergy.com/files/FCE3000%20Product%20Design-lo-rez%20FINAL.pdf>

<sup>3</sup> EPA Mandatory Green House Gas Reporting Rule. 40 CFR 98. <http://www.epa.gov/climatechange/emissions/downloads09/GHG-MRR-FinalRule.pdf>

<sup>4</sup> Biomass fuels such as wood, paper products, and agricultural waste, or fuels derived from organic matter such as biogas or landfill gas are considered for this analysis to be subject to the natural carbon cycle and, therefore, do not add carbon to the atmosphere. Thus, all biomass CO<sub>2</sub> are assigned a net CO<sub>2</sub> emissions value of zero because these organic materials would otherwise release CO<sub>2</sub> (or other greenhouse gases) through decomposition. “The Emissions & Generation Resource Integrated Database for 2007 (eGRID2007) Technical Support Document” September 2008, <http://www.epa.gov/cleanenergy/documents/egridzips/eGRID2007TechnicalSupportDocument.pdf>

$$\text{CHHP Fuel Consumption (MMBtu/year)} = \text{DFC 3000 Fuel Input Rate (MMBtu/hr)} * \text{Equivalent Full Load Hours (hr/year)}$$

- d. Calculate the CO<sub>2</sub> emissions associated with the CHHP system fuel consumption:

$$\text{CHHP CO}_2 \text{ Emissions (tons/year)} = (\text{Fuel Consumption (MMBtu/year)} * \text{Net CO}_2 \text{ Emissions Rate (lb/MMBtu)}) / 2000 \text{ lb/ton}$$

**2. Determine CHHP System Electricity Output and Avoided Central Station Fuel and Emissions**

- a. Determine the net electrical output of the CHHP system in kWh per year. Net electrical output is the annual gross generator output from the CHHP system minus parasitic electric loads including auxiliary electric loads for the CHHP system itself, any new electric requirements for fuel processing that are related to the CHHP system, and any new electric requirements for hydrogen compression, processing or storage. All parasitic requirements should be identified and estimated loads documented.

$$\text{Net Electrical Output (kWh)} = \text{Gross Electrical Output (kWh)} - \sum \text{Parasitic Loads (kWh)}$$

- b. Calculate the amount of electricity generation that is avoided at the central station including transmission and distribution (T&D) losses:

For that portion of the net electricity generated by the CHHP system that is used on site, the avoided central station generation needs to include the transmission and distribution (T&D) losses associated with delivering central station electricity to the site<sup>5</sup>. Regional-specific transmission and distribution loss percentages are presented in Table 2.

$$\text{Avoided Central Station Electricity (kWh)} = \text{Net Electrical Output}_{\text{Exported}} \text{ (kWh)} + (\text{Net Electrical Output}_{\text{Onsite}} \text{ (kWh)} / (1 - \text{T\&D Loss factor}))$$

**Table 2 - eGRID 2010 (Year 2007) Gross T&D Grid Loss Factors<sup>6</sup>**

Region	T&D Loss Factor (%)
Eastern Grid	6.47
Western Grid	4.84
Texas	6.42
Alaska	1.24
Hawaii	3.20

<sup>5</sup> Electricity sold and exported to the grid does not eliminate the losses inherent in the transmission and distribution grid

<sup>6</sup> EPA eGRID Technical Support Document.

<http://www.epa.gov/cleanenergy/documents/egridzips/eGRID2010TechnicalSupportDocument.pdf>

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- c. Find the heat rate and CO<sub>2</sub> emissions rate for avoided central station electricity at your location using EPA’s 2010 Emissions & Generation Resource Integrated Database (eGRID)<sup>7</sup>. The calculations should be based on the heat rate and emissions factors corresponding to a facility’s eGRID subregion because these regions consist of one or a portion of a power control area and generally represent sections of the grid that have similar emissions and resource mix characteristics (Figure 1)<sup>8</sup>. The calculations should also be based on the average fossil heat rates and CO<sub>2</sub> emissions rates as included in Table 3 because they most closely approximate the generation mix that is avoided by baseload technologies such as CHP.<sup>9</sup>

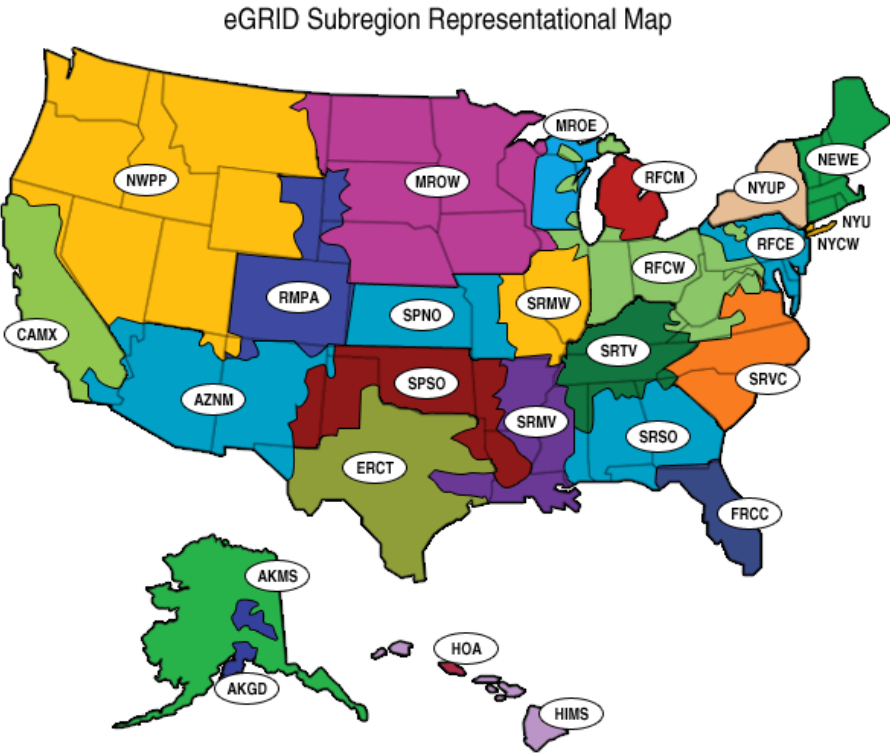


Figure 1 – EPA eGRID Subregions

- d. Calculate the total fuel avoided from central station generation:

<sup>7</sup> Environmental Protection Agency. Emissions and Generation Resource Integrated Database (eGRID). eGRID2010 Version 1.1. <http://www.epa.gov/cleanenergy/energy-resources/egrid/index.html>

<sup>8</sup> Diem, A. and Rothschild, S. "Total, Non-Baseload, eGRID Subregion, State, Guidance on the use of eGRID Output Emissions Rates." <http://www.epa.gov/ttn/chief/conference/ei18/session5/rothschild.pdf>

<sup>9</sup> "Fuel and CO<sub>2</sub> Emissions Savings Calculation Methodology for CHP", Hedman, B .A., Hampson, A.C., ASHRAE 2011, LV-11-029

$$\text{Avoided Fuel}_{\text{Central Station}} (\text{MMBtu/year}) = (\text{Avoided Central Station Electricity (kWh)} * \text{Average Fossil Heat Rate (Btu/kWh)}) / 1,000,000$$

e. Calculate the avoided central station CO<sub>2</sub> emissions in tons per year:

$$\text{Avoided CO}_2 \text{ Emissions}_{\text{Central Station}} (\text{tons/year}) = (\text{Avoided Central Station Electricity (kWh)} * 1000) * \text{Average Fossil CO}_2 \text{ Emission Rate (lb/MWh)} / 2000 \text{ lb/ton}$$

**Table 3 – EPA eGRID Average Fossil Heat Rate and Average Fossil CO<sub>2</sub> Emissions Rate by Subregion<sup>10</sup>**

eGRID Subregion Acronym	eGRID Subregion Name	Average Fossil Heat Rate (Btu/kWh)	Average Fossil CO <sub>2</sub> Emission Rate (lb/MWh)
AKGD	ASCC Alaska Grid	10,368	1,392.6
AKMS	ASCC Miscellaneous	9,449	1,396.1
ERCT	ERCOT All	8,935	1,471.0
FRCC	FRCC All	8,859	1,287.4
HIMS	HICC Miscellaneous	10,219	1,716.8
HIOA	HICC Oahu	9,426	1,601.0
MROE	MRO East	10,814	2,158.9
MROW	MRO West	11,055	2,236.6
NYLI	NPCC Long Island	10,137	1,359.0
NEWE	NPCC New England	8,950	1,236.1
NYCW	NPCC NYC/Westchester	9,099	1,101.2
NYUP	NPCC Upstate NY	8,922	1,545.2
RFCE	RFC East	9,715	1,593.6
RFCM	RFC Michigan	10,130	1,779.7
RFCW	RFC West	10,016	1,989.9
SRMW	SERC Midwest	10,344	2,085.7
SRMV	SERC Mississippi Valley	9,408	1,423.6
SRSO	SERC South	9,713	1,894.3
SRTV	SERC Tennessee Valley	10,364	2,067.1
SRVC	SERC Virginia/Carolina	9,585	1,833.5
SPNO	SPP North	10,904	2,156.4
SPSO	SPP South	9,998	1,781.6
CAMX	WECC California	8,284	1,076.4
NWPP	WECC Northwest	10,116	1,898.7
RMPA	WECC Rockies	10,661	2,006.9
AZNM	WECC Southwest	9,518	1,634.7

<sup>10</sup> Environmental Protection Agency. Emissions and Generation Resource Integrated Database (eGRID). eGRID2010 Version 1.1. <http://www.epa.gov/cleanenergy/energy-resources/egrid/index.html>

**3. Determine CHHP System Thermal Output(s) and Avoided Thermal Fuel and Emissions**

- a. Determine the useful thermal output of the CHHP system in MMBtu per year (i.e., the thermal output actually being used).

If the CHHP thermal energy is displacing more than one thermal application, then the avoided fuel and CO<sub>2</sub> emissions from each thermal application will need to be calculated and summed to complete this section.

- b. Identify the type(s) of thermal application that is being displaced
  - i. If displacing a boiler producing steam or hot water:
    - 1. Estimate the efficiency of the boiler that would normally provide the thermal energy being supplied by the CHHP system. Table 4 provides estimates of boiler efficiency based on the fuel type that can be used if the actual efficiency of the displaced boiler is not known.

**Table 4 – Boiler Efficiency Defaults<sup>11</sup>**

<b>Fuel Type</b>	<b>Boiler Efficiency</b>
Natural Gas	80%
Diesel Fuel	80%
Distillate Oil	80%
Coal	85%
Propane	80%
Woody Biomass	83%

- 2. Calculate the amount of boiler fuel that is avoided:

$$\text{Avoided Fuel}_{\text{Thermal}} \text{ (MMBtu/year)} = \frac{\text{Useful Thermal Output of CHHP System (MMBtu/year)}}{\text{Displaced Boiler Efficiency (\%)}}$$

- 3. Calculate the CO<sub>2</sub> emissions associated with the avoided boiler fuel:

$$\text{Avoided CO}_2 \text{ Emissions}_{\text{Thermal}} \text{ (tons/year)} = \frac{\text{Avoided Fuel}_{\text{Thermal}} \text{ (MMBtu/year)} * \text{Net CO}_2 \text{ Emissions Rate (lb/MMBtu)}}{2000 \text{ (lb/ton)}}$$

- ii. If displacing a thermal heating application other than a steam or hot water boiler:
  - 1. Estimate the efficiency and provide documentation for the equipment that normally provides the thermal energy being displaced.
  - 2. Calculate the fuel avoided by using the boiler equation above

<sup>11</sup> EPA CHP Emissions Calculator. <http://www.epa.gov/chp/basic/calculator.html>

3. Calculate the CO<sub>2</sub> emissions avoided by using the boiler equation above
- iii. If displacing thermal energy currently provided by electric resistance heating or a heat pump:
  1. Estimate the amount of electricity avoided by the thermal output of the CHP system

$$\text{Avoided Electricity}_{\text{Thermal}} (\text{kWh}) = (\text{Useful Thermal Output of CHHP System (MMBtu/year)} / \text{Efficiency of Electric Heating (\%)} / 3,412 (\text{Btu/kWh}) * 1,000,000 (\text{Btu/MMBtu}))$$

The point-of-use efficiency of electric resistance heating is 100%; the point-of-use heating efficiency for electric heat pumps is the heating COP \* 100%.

2. Calculate the avoided fuel and CO<sub>2</sub> emissions at the central station power plant by following the steps in Section 2 (b, c, d and e).
- iv. If displacing cooling with a thermally driven absorption chiller:
  1. Heat recovered from the fuel cell can provide cooling through the use of thermally driven absorption chillers. Estimate the annual amount of cooling provided by the CHHP system in tons of cooling, or refrigeration tons (RT), based on the amount of thermal energy used by the absorption chiller(s) and the performance specifications of the specific chiller proposed for the design<sup>12</sup>.

$$\text{Cooling (RT-hours/year)} = \text{Useful Thermal Output of CHHP System (MMBtu/year)} * \text{COP}_{\text{Absorption Chiller}} * (\text{RT} / 0.012 \text{ MMBtu/hours})$$

2. Determine the amount of purchased electricity displaced at the facility by the cooling output of the absorption chiller. This will require an estimate of the performance of the displaced electric chiller in terms of kW/RT or coefficient of performance (COP). The performance of electric chillers can vary widely depending on chiller type, size and vintage<sup>13</sup>. Any additional electrical requirements for the absorption chiller should be subtracted from the displaced electric chiller requirements<sup>14</sup>.

$$\text{Avoided Electricity}_{\text{Cooling}} (\text{kWh/year}) = (\text{Cooling (RT-hours/year)} * \text{Electric Chiller Electricity (kW/RT)}) - \text{Additional Absorption Chiller Electricity Requirements (kWh/year)}$$

<sup>12</sup> Absorption chiller performance is typically expressed as in terms of coefficient of performance (COP) which is cooling output / heat input in consistent units (12,000 Btu/hr = one ton of cooling). Single-effect absorption chillers using hot water as thermal input typically have coefficients of performance (COP) in the range of 0.6 to 0.7. Double effect absorption chillers driven by higher temperature steam have COPs in the range of 1.2 to 1.4.

<sup>13</sup> Electricity requirements of conventional vapor compression chillers can range from 0.45 kW/RT (COP = 7.8) for best available centrifugal compressor equipment (>150 RT) to 1.6 kW/RT (COP = 2.2) for 1980 vintage roof top units < 150 RT

<sup>14</sup> Absorption chillers typically have larger cooling tower requirements than electric chillers

3. Calculate the avoided fuel and CO<sub>2</sub> emissions at the central station power plant by following the steps in Section 2 (b, c, d and e).

#### 4. Determine CHHP System Hydrogen Output and Avoided Fuel and Emissions

- a. Identify the amount of hydrogen produced by the CHHP system (MMBtu per year).
- b. Identify the use of the hydrogen and the fuel that it would be displacing (e.g., hydrogen used in a vehicle would displace either gasoline or diesel fuel).
- c. Calculate the energy services provided (e.g., miles driven, MMBtu/year heat provided, etc) by utilizing the hydrogen in the identified application.
- d. Calculate the amount of conventional fuel avoided by utilizing hydrogen (in MMBtu/year).
  - i. Identify the conventional fuel use rate (MMBtu/hr) of the energy application that the hydrogen is displacing, as well as the consumption rate of hydrogen (MMBtu/hr) in the same application. Calculate the conventional fuel avoided based on the amount of hydrogen used:

$$\text{Avoided Fuel}_{\text{Hydrogen}} (\text{MMBtu/year}) = (\text{CHHP System Hydrogen Output (MMBtu or kg/year)} * \text{Hydrogen Consumption Rate (MMBtu or kg/applicable unit)}^{15}) / \text{Displaced Conventional Fuel Consumption Rate (MMBtu/applicable unit)}$$

An example calculation for 500 kg/year of hydrogen offsetting gasoline in a passenger vehicle is as follows:

Hydrogen contains approximately 116 MMBtu/kg, while gasoline contains 125 MMBtu/gallon. Therefore, if used in engines with the same efficiency, a kilogram of hydrogen would allow a vehicle to travel approximately the same distance as a gallon of gasoline<sup>16</sup>. The EPA estimates the average fuel efficiency of passenger vehicles is 23.9 miles/gallon<sup>17</sup>, and the EPA certified Mercedes F-Cell hydrogen vehicle has a fuel efficiency of 51.3 miles per kg hydrogen (52 miles/gallon gasoline equivalent).<sup>18</sup>

$$\text{Avoided Fuel}_{\text{Hydrogen}} (\text{MMBtu/year}) = ((\text{CHHP Hydrogen Output (500 kg/year)} * \text{Hydrogen Consumption Rate (51.3 miles/kg)}) / \text{Displaced Gasoline Rate (23.9 miles/gallon)}) * \text{Gasoline Heat Content (125 MMBtu/gallon)} = 134,153 \text{ MMBtu/year}$$

- e. Calculate the CO<sub>2</sub> emissions associated with the avoided conventional fuel:

<sup>15</sup> Examples of applicable units could be MMBtu/mile or kg/mile

<sup>16</sup> NREL. "Wind Energy and Production of Hydrogen and Electricity – Opportunities for Renewable Hydrogen." <http://www.nrel.gov/docs/fy06osti/39534.pdf>

<sup>17</sup> EPA. "Emission Facts: Greenhouse Gas Emissions from a Typical Passenger Vehicle." <http://www.epa.gov/otag/climate/420f05004.htm>

<sup>18</sup> <http://myautoworld.com/mercedes/cars/2011mercedes/mercedes-12-fCell/mercedes-12-fcell.html>

$$\text{Avoided } CO_2 \text{ Emissions}_{\text{Hydrogen}} \text{ (tons/year)} = (\text{Avoided Fuel}_{\text{Hydrogen}} \text{ (MMBtu/year)} * \text{Net } CO_2 \text{ Emissions Rate (lb/MMBtu)}) / 2000 \text{ (lb/ton)}$$

## 5. Determine Total Fuel and CO<sub>2</sub> Savings

- a. Calculate total fuel savings:

$$\text{Total Fuel Savings (MMBtu/year)} = (\text{Avoided Fuel}_{\text{Central Station}} \text{ (MMBtu/year)} + \sum \text{Avoided Fuel}_{\text{Thermal}} \text{ (MMBtu/year)} + \text{Avoided Fuel}_{\text{Hydrogen}} \text{ (MMBtu/year)}) - \text{CHHP Fuel Consumption (MMBtu/year)}$$

Where:

- Avoided Fuel<sub>Central Station</sub> (MMBtu/year) – calculated in Section 2,
- Avoided Fuel<sub>Thermal</sub> (MMBtu/year) - calculated in Section 3,
- Avoided Fuel<sub>Hydrogen</sub> (MMBtu/year) – calculated in Section 4, and
- CHHP Fuel Consumption (MMBtu/year) – calculated in Section 1.

- b. Calculate total CO<sub>2</sub> savings:

$$CO_2 \text{ Savings (tons/year)} = (\text{Avoided } CO_2 \text{ Central Station (ton/years)} + \sum \text{Avoided } CO_2 \text{ Thermal (ton/years)} + \text{Avoided } CO_2 \text{ Hydrogen (ton/years)}) - \text{CHHP System } CO_2 \text{ Emissions (tons/year)}$$

Where:

- Avoided CO<sub>2</sub> Emissions<sub>Central Station</sub> (tons/year) – calculated in Section 2,
- Avoided CO<sub>2</sub> Emissions<sub>Thermal</sub> (tons/year) - calculated in Section 3,
- Avoided CO<sub>2</sub> Emissions<sub>Hydrogen</sub> (tons/year) – calculated in Section 4, and
- CHHP System CO<sub>2</sub> Emissions (tons/year) – calculated in Section 1.

## 6. Determine Amount of Organic Waste Avoided

- a. Clean and renewable fuels can be produced from a number of sources. One such pathway is using wastewater, animal and organic waste, or landfills to create biogas for fuel. Biogas is a product of anaerobic digestion of organic materials, and typically consists of 60% methane and 40% carbon dioxide. Methane is a potent greenhouse gas if vented into the atmosphere, but can also be used to substitute for fossil fuels to produce energy. Fuels derived from organic wastes (e.g. biogas) typically reduce the amount of solid waste that needs to be disposed of through traditional methods (mainly landfills). The organic waste is processed in a fuel processor (i.e., digester, gasifier or other processing technology) producing a fuel gas and leaving behind a reduced amount of solid, non-digestible waste. This reduction in organic waste material is a noteworthy environmental benefit that should be documented. If your CHHP system uses a fuel derived from an organic waste stream, you need to calculate

the amount of organic waste materials that would no longer require disposal through traditional means.

- b. Documentation should include the following estimates and supporting calculations:
  - i. Identification of the waste material
  - ii. The amount of organic waste that is introduced into the fuel processor (e.g., digester or gasifier)
  - iii. The fuel gas flow that exits the fuel processor
  - iv. The amount of remaining solids that would need to be disposed of or used for other purposes.
- c. Calculate the amount of avoided organic waste in tons per year:

$$\text{Avoided Waste (tons)} = \text{Organic Waste Inflow to Fuel Processor (tons)} - \text{Solid Waste Outflow from Processor (tons)}$$