Sullivan County Nursing Home Biomass Combined Heat and Power Feasibility Study

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Final Report

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I. INTRODUCTION

A. Scope

Bonhag Associates has been retained by Sullivan County to investigate the feasibility of a biomass combined heat and power (CHP) system at the Sullivan County Nursing Home and Department of Corrections campus in Unity, New Hampshire. The intent of this study is to evaluate whether the incorporation of an on-site biomass CHP system can effectively reduce energy costs for the Sullivan County Nursing Home. Bonhag Associates will evaluate different combinations of biomass CHP systems and recommend which system type is most feasible for implementation based on cost, efficiency, reliability and ease of operation. The study will focus on the interconnection of a biomass CHP system to the facility's existing steam and electrical systems.

B. Resources

Information utilized in this study has been gathered from several sources including, but not limited to, owner provided empirical data, facility drawings, electrical trending information provided by the electrical utility (PSNH), on-site inspections to ascertain field conditions, various equipment manufacturers, Bonhag Associates' CHP screening tool, RET Screen, U.S. EPA CHP Reliability Benefit Screen, as well as our knowledge of and familiarity with various types of CHP technologies.

C. The Cogeneration Process

The concept of cogeneration, or combined heat and power, is to use a single fuel source, such as wood chips, to simultaneously produce electrical and thermal energy. Cogeneration has existed for more than 100 years and is a proven and widely used power generation technology. It provides efficiency advantages relative to the conventional means for independently producing either electric power or thermal energy. A combination of technological, economic and regulatory factors has caused many energy users to revisit the use of cogeneration, especially those with large facilities where the electrical and thermal loads occur concurrently and in balanced amounts.

There are two major types of biomass cogeneration systems that use wood as a biomass fuel source: combustion and gasification. A combustion type cogeneration system would consist of a wood fired burner that burns woodchips and produces a gas that can be used to fire steam boilers and then steam turbines, electrical generators or micro- turbines. A gasification type cogeneration system would consist of a gasifier that uses pyrolysis to control the oxygen rate when consuming wood chips resulting in the manufacture of a clean producer gas that can be used to fire steam boilers, coupled with steam turbines or electrical generators with heat recovery to produce electricity.

Electrical energy generated from the CHP system would be interfaced into the facility's existing electrical distribution system, reducing electrical consumption from the local utility.

II. EXECUTIVE SUMMARY

Sullivan County is considering implementing a biomass combined heat and power (CHP) system at the Sullivan County Nursing Home. The nursing home shares a site of approximately 1,400 acres with the Department of Corrections (DOC); a large portion of the site – approximately 1,200 acres – is wooded. Sullivan County would like to utilize the abundant wood (biomass) resources on site to reduce electrical and fuel oil operating costs.

This study indicates that the use of an on-site biomass CHP system utilizing gasifiers and reciprocating engine generators (System C) for both electric power and thermal energy for steam production is economically viable and should be explored in further detail during the design phase.

The optimum size of this system based on electrical and thermal loads for the site is a 250 KW electrical generator with steam stack heat recovery to offset one of the existing Cleaver Brooks boilers.

The biomass CHP system is viable based on the following:

1. The majority of the electricity required for the nursing home will be produced by the system, with the balance purchased from the local utility.
2. Actual consumption information concerning thermal and electrical use at the facility has been included in the analysis.
3. The base steam load for process steam is inconsistent over a twelve month period. The process steam load includes domestic hot water, kitchen and laundry equipment. Engineering presumptions were made regarding steam loads that are scheduled to be relocated or removed.
4. Steam produced by the system will be used year-round at the facility. Current load profiles are the basis for the analysis.
5. Low pressure steam can be connected into the existing steam header in the boiler room.
6. The system will be located in a new structure and will require on-site wood chip storage. The structures should be located a short distance from the boiler room.
7. Wood chip storage is designed for a minimum of 7 days due to the nature of the facility.
8. A rate of $26 per ton for 35% moisture content wood chips was used in this analysis based on 50% of the wood chips being harvested on site.
9. Depreciation on the project has been taken over a period of twenty (20) years.
10. Labor provided by the nursing home for on-site wood chip harvesting has been included as part of the operating costs.
11. Existing on-site electrical generators will operate during scheduled maintenance periods to prevent demand and other utility charges from being accrued.

III. EXISTING CONDITIONS

A. Mechanical Systems

Currently, there are three existing oil-fired steam boilers at the nursing home. The boilers are manufactured by Cleaver-Brooks and operate on #4 oil. The existing boilers are as follows:

Boiler 1
Installation Date: 02/26/1974
Burner Input: 3,347,000 Btu/h
Fuel Rate: 24 gph
Steam Output Pressure: 85 psig

Boiler 2
Installation Date: 11/11/1967
Burner Input: 3,350,000 Btu/h
Fuel Rate: 24 gph
Steam Output Pressure: 15 psig
Efficiency: 89%

Boiler 3
Installation Date: 07/03/1969
Burner Input: 3,350,000 Btu/h
Fuel Rate: 24 gph
Steam Output Pressure: 15 psig
Efficiency: 89%

The facility is in the process of modifying its high pressure steam requirements. At present, high pressure steam is produced for the laundry services and the production of domestic hot water in the kitchen. Our understanding is that the laundry services will be relocated to the Department of Corrections facility, and the domestic water production source will be modified. These are the only high pressure steam loads at the facility. Once the high pressure steam loads have been eliminated, the intent is to remove Boiler 1 from the system.

B. Current Fuel Consumption

Typical fuel oil deliveries to the facility are in increments of approximately 8,000 gallons. The delivery schedule is based on a manual measurement method. Current information indicates there is less than a 3% variation in fuel quantity per delivery. Refer to Table 1 for interpolated fuel consumption based on delivery schedule.

Table 1: Fuel Oil Consumption [1, 2]

Interpolated Fuel Delivery Data and Usage

Date	Delivery (gallons)	Days Between Deliveries	Gallons per Day	Daily Btu/h	Daily Steam [3] (lbs/hr)
7/14/2008	8,000				
8/27/2008	8,000	44	181.8	22,587,121	22,363
10/15/2008	8,000	49	163.3	20,282,313	20,081
11/20/2008	8,500	36	236.1	29,331,887	29,041
12/11/2008	8,000	21	381	47,325,397	46,857
1/5/2009	8,000	25	320	39,753,333	39,360
1/26/2009	8,000	21	381	47,325,397	46,857
2/20/2009	8,000	25	320	39,753,333	39,360
3/17/2009	8,000	25	320	39,753,333	39,360
4/15/2009	8,000	29	275.9	34,270,115	33,931
5/19/2009	8,000	34	235.3	29,230,392	28,941
7/14/2009	8,000	56	142.9	17,747,024	17,571
8/28/2029	7,814	45	173.6	21,571,705	21,358
10/16/2009	7,860	49	160.4	19,927,372	19,730
11/17/2009	7,867	32	245.8	30,540,964	30,239
12/14/2009	7,881	27	291.9	36,261,113	35,902
1/5/2010	7,894	22	358.8	44,575,684	44,134
		Min	142.9	17,747,024	17,571
		Max	381.0	47,325,397	46,857

Notes:

1. Typical of Boiler 2 and Boiler 3
2. Boiler input = 3,350,000 Btu/h, efficiency = 89%, fuel rate = 24 gph
3. Steam calculated at 1,010 Btu/lb enthalpy

C. Current Electrical Consumption

The electrical service at the nursing home is a 700 Amp, 120/208 VAC, three phase, four wire electrical system. The facility's utility meter measured a peak demand 304.3 KW during peak hours and a peak demand of 280.9 KW during off peak hours. The meter also measured a minimum demand of 226.0 KW during peak hours and a minimum demand of 193.1 KW during off peak hours. The current electrical loads are shown in Table 2.

We anticipate a 20.5KW increase in electrical load due to the Department of Corrections addition (Refer to "D. Department of Corrections" for additional information). We performed an analysis. with the 20.5KW increase in the demand history, that indicated that the Nursing Home would purchase a small amount of power from the electrical utility during Peak Demand periods (during the day period) and sell power to the utility during Off Peak Demand periods (during the night). Our analysis indicated these periods are approximately equal and will financially cancel each other out.

Table 2: Electrical Consumption [1, 2]

Bill Date	Peak Demand (KW)	Peak (KVA)	Off Peak Demand (KW)	Off Peak (KVA)	Billing Demand	Use (KWH)	Peak PF	Off Peak PF	Peak Amps	Off Peak Amps
1/10/2010	245.5	259.6	216.0	228.4	241	126,448	0.946	0.946	682.2	600.3
12/10/2009	244.5	258.6	213.1	225.1	240	115,837	0.945	0.947	379.6	592.2
11/10/2009	243.8	261.4	230.8	247.2	240	120,258	0.933	0.934	677.5	641.4
10/10/2009	250.1	270.3	208.1	223.1	246	111,415	0.925	0.933	695.0	578.3
9/10/2009	268.9	292.1	218.2	236.9	264	110,826	0.921	0.921	747.3	606.4
8/10/2009	288.4	311.2	244.7	270.3	283	134,111	0.927	0.905	801.5	680.0
7/10/2009	260.8	284.8	215.0	235.1	256	117,900	0.916	0.915	724.8	597.5
6/10/2009	247.9	269.9	213.8	233.8	244	113,184	0.918	0.914	688.9	594.2
5/10/2009	239.6	263.3	196.1	216.8	235	109,352	0.910	0.905	665.9	545.0
4/10/2009	237.4	255.2	200.0	219.5	233	111,415	0.930	0.911	659.7	555.8
3/10/2009	237.8	252.8	197.8	215.8	234	103,457	0.941	0.917	660.8	549.7
2/10/2009	226.0	241.5	213.0	229.4	222	119,963	0.936	0.929	628.1	591.9
1/10/2009	236.8	250.3	210.1	222.6	233	103,752	0.946	0.944	658.1	583.9
12/10/2008	243.5	257.6	214.9	226.8	239	131,753	0.945	0.948	676.7	597.2
11/10/2008	241.3	258.1	232.0	250.2	237	110,531	0.935	0.927	670.6	644.7
10/10/2008	258.0	279.4	228.7	244.5	253	114,068	0.923	0.935	717.0	635.6
9/10/2008	272.2	295.1	232.9	254.6	267	127,332	0.922	0.915	756.4	647.2
8/10/2008	279.2	303.2	223.9	245.3	274	122,911	0.921	0.913	775.9	622.2
7/10/2008	281.2	308.9	241.1	262.3	276	126,153	0.910	0.919	781.5	670.0
6/10/2008	285.7	310.2	234.0	256.1	281	125,858	0.921	0.914	794.0	650.3
5/10/2008	234.2	256.2	193.1	212.7	230	110,826	0.914	0.908	650.8	536.6
4/10/2008	238.7	258.0	208.1	223.8	235	117,900	0.925	0.930	663.4	578.3
3/10/2008	239.8	259.0	211.5	227.3	236	125,268	0.926	0.930	666.4	587.8
2/10/2008	273.7	291.1	246.2	265.7	269	135,880	0.940	0.927	760.6	684.2
1/10/2008	259.3	276.8	255.7	272.8	255	125,563	0.937	0.937	720.6	710.6
12/10/2007	257.6	274.7	216.7	230.7	253	126,742	0.938	0.939	715.9	602.2
11/10/2007	245.6	264.8	223.3	243.3	241	133,227	0.927	0.918	682.5	620.6
10/10/2007	300.8	328.1	217.1	236.4	296	120,258	0.917	0.918	835.9	603.3
9/10/2007	289.7	318.1	280.9	307.6	285	134,111	0.911	0.913	805.1	780.6
8/10/2007	304.3	332.8	264.0	288.7	299	134,111	0.914	0.914	845.7	733.7
Max	304.3	332.8	280.9	307.6	299	Max	0.946	0.948	845.7	780.6
Min	226.0	241.5	193.1	212.7	222	Min	0.910	0.905	628.1	536.6

Notes:

1. Sullivan County Nursing Home
2. PSNH account number 8004712-01

D. Department of Corrections

The Department of Corrections (DOC) acquires its electrical power after the nursing home's electrical utility meter, thus DOC electrical load requirements must be taken into account in the analysis. The facility is in a state of expansion and is currently in the midst of adding approximately 20,500 square feet to the facility. The increase in size of the DOC will have a significant impact on the electrical demand and loads. Due to the fact that the addition is currently under construction, an accurate electrical demand history that reflects the increase in load was not available. Bonhag Associates has approximated the electrical usage increase and has incorporated that load into our analysis. We expect the increase in the electrical load to be approximately 20.5 KW.

In addition, the DOC laundry services will be relocated from the nursing home to the DOC. This will impact the thermal loading requirements at the nursing home by eliminating the need for high pressure steam production.

IV. BIOMASS CHP SYSTEM EVALUATION

Utilizing gasification equipment to produce gas to fire a boiler or engine generator has many benefits, such as lower fuel throughput when compared to direct fired equipment and improved system efficiencies in excess of 80%. For these reasons, the systems analyzed in this study will utilize gasification equipment.

A. Site Growth

Plans for significant growth at the site are unclear. There is the potential of an additional facility being constructed in the northern lower field behind the nursing home. Preliminary documentation has been produced, but there is no advancement for the project foreseen in the immediate future. Analysis, therefore, encompasses the in progress DOC expansion only. The current expansion of the DOC will have an impact on the electrical loads. We anticipate that the additional loads will be approximately 20.5 KW for the DOC addition that is currently under construction.

The modifications to the boiler plant and removal of Boiler 1 at the nursing home will have a significant impact on steam requirements. Currently, the typical fuel delivery is approximately 8,000 gallons. We expect the oil consumption to be reduced to approximately 2,900 gallons per month in the summer and 4,000 gallons per month in the winter with the removal of high pressure steam loads.

B. Fuel Requirements

The primary fuel source for the CHP system is green wood chips having a moisture content ranging from 35% to 50% – the higher the moisture content, the greater the possibility for wood handling complication and lower efficiencies. The water within the wood chips promotes composting within chip storage, but more importantly requires additional fuel in the form of wood chips to add to the system to continue the CHP reaction. In addition, wet chips can freeze into clumps during cold weather resulting in hopper feeding and plugging issues. This study is based on the use of 35% moisture content, whole wood chips.

The study reflects that Sullivan County intends to harvest approximately 50% of its wood chip fuel from on-site sources. An off-site commercial supplier, such as Cousineaus, Inc., could provide and deliver the remaining wood chips. Cousineaus could provide whole wood chips at 35% moisture content at a rate of $40 per ton. A rate of $26 per ton was used in the analysis based on a blended rate of on-site produced chips and off-site procured chips.

C. Site Requirements

Each biomass system evaluated will require the construction of a new building to house the CHP system and ancillary equipment. The size of the building will vary with the equipment requirements for each system. On-site storage using a storage bunker or building will also be required. The size of the wood chip storage will vary based on the volume of chips required for each system as well as the number of days between deliveries. We recommend a minimum of 7 days of storage. Wood handling systems will be necessary to move wood chips from the storage bunker to the CHP system. We recommend that the wood storage be located as close to the system as possible.

The site was reviewed to determine a suitable location for the construction and operation of a new CHP building and wood storage building. The proposed location for the new buildings is shown in Figure 1.

Figure 1: Proposed Biomass CHP System Site Location

D. Utility Interface

In reviewing the site, it is feasible to construct the generation structure adjacent to the pad mount transformer on the South side of the facility. This would minimize the electrical costs of interfacing the CHP system into the existing on-site electrical distribution system. This will need to be coordinated with the utility to ensure that the appropriate electrical safeties are implemented at the site.

E. Permitting

The biomass CHP systems will require some level of permitting with the State of New Hampshire Department of Environmental Service (DES) for water and air quality permits, as well as other permits with the EPA. We anticipate that the following permits will be required:

- Air Emissions Permit
- Storm Water Permit
- Site Specific Permit: Alteration of Terrain Program

We are familiar with the required permitting for CHP systems; these will be addressed in depth during the design phase of the project. Costs associated with permitting have been included in the construction cost estimate for each system.

F. Renewable Energy Credits (RECs)

Renewable energy credits are the property rights to the environmental benefits from generating electricity from renewable energy sources, such as biomass. They can be sold and traded, and the owner of the REC can legally claim to have purchased renewable energy. The price of RECs is dependent upon many factors, including the location of the facility that is producing the renewable energy and the current demand for RECs. The price that is being used in this analysis for the REC is $0.06 per KWH of renewable energy produced over a period of ten years.

G. Carbon Credits

An additional venue for providing income to the project is from the sale of carbon credits. Burning of fossil fuels generates carbon dioxide, a greenhouse gas that has been determined to be detrimental to the earth's long term climate stability. Renewable energy sources including biomass are non-carbon producing energy sources, which are less harmful to the environment and reduce greenhouse gas emissions. Carbon credits were developed to mitigate global warming by providing a monetary value to the cost of polluting the air.

Technologies that reduce carbon emissions, such as renewable energy generation systems, earn a carbon credit based on the decrease amount of carbon emitted to the atmosphere when compared to carbon emissions from the burning of fossil fuels. The potential income from the carbon credits has not been included in this report.

H. Biomass Systems Evaluated

Three types of biomass CHP systems were evaluated for this study:

- System A – Biomass Gasifier with a Micro-turbine
- System B – Biomass Gasifier, Boiler and Steam Turbine
- System C – Biomass Gasifier and Reciprocating Engine Generator

Two types of alternate steam generating systems were evaluated for this study:

- System D – Biomass Gasifier with a Boiler
- System E – Biomass Boiler

Each system will operate continuously – 24 hours per day, 7 days a week, 365 days a year.

System A – Biomass Gasifier with a Micro-turbine

The use of a micro-turbine with a gasifier was evaluated. It was determined that this type of configuration is not feasible for the facility. The producer gas manufactured by a gasifier has a low heat value (LHV) of approximately 130 Btu/scf. Micro-turbines typically operate on gases with a minimum LHV of 350 Btu/scf; these types of micro-turbines are generally used in landfill gas reclamation projects. We researched manufacturers such as Capstone and Ingersol Rand and they indicated that it would not be possible to produce adequate power utilizing a gas with a LHV less than 350 Btu/scf. Therefore no further analysis was performed on this type of CHP system. This system was deemed not appropriate for this application.

System B – Biomass Gasifier, Boiler and Steam Turbine

For this application, a gasifier and steam boiler manufactured by Chiptec Wood Energy was evaluated in conjunction with a steam turbine manufactured by Skinner Power Systems. The turbine's steam requirement was the driving factor in sizing the steam boiler; Chiptec sized the steam boiler and corresponding gasifier to meet the operational requirements of the proposed steam turbine. Skinner indicates that a 250 KW steam turbine generator set will require a minimum of 400 BHP; Chiptec provided a proposal for a gasifier and boiler capable of producing up to 450 BHP.

The wood chip fuel consumption rate for the gasifier is approximately 2.18 tons/hr or 19,053 tons per year. The Chiptec system is capable of producing 15,000 lbs/hr of steam at 150 psig. The steam turbine will produce 250 KW of electricity and condense the output steam for thermal use. The output thermal energy that may be harvested is calculated at 15.15 MBH. Parasitic electric costs for this system will be larger than other systems evaluated due mainly to the steam condensing unit that is required in the system. The steam condensing unit can be eliminated from the system if the high pressure steam loads remain in place.

The drawback of this system is that the thermal energy generated is considerably more than can be utilized at the facility. The system produces approximately four times more steam then is currently used. The need to condense the excess steam in the system reduces the overall system efficiency. To increase the system efficiency, the excess steam could be used to make chilled water for air conditioning using an absorption chiller. This would increase the thermal load in the summer months and make the facility's thermal load more consistent though out the year. The cost for an absorption chiller has not been carried in the analysis because to implement this system into the nursing home would require significant rework of the existing air conditioning equipment, and we do not see that as being viable at this time.

A detailed construction cost estimate is shown in Table 3. A life cycle cost and simple payback analysis is shown in Table 4.

Table 3: Construction Cost Estimate
System B - Biomass Gasifier, Boiler and Steam Turbine

Description	Quantity	Units	Price/Unit	Total
Gasifiers, cooling & cleaning system, boiler & turbine	1	each	$1,017,500	$1,017,500
Condensate water pumps	4	each	$7,500	$30,000
Combined 8" steam & 4" condensate pipe	250	LF	$530	$132,500
Steam condensing unit	1	each	$125,000	$125,000
Wood handling system [1]	1	each	$196,000	$196,000
Truck scale (installed with security cameras)	1	each	$145,000	$145,000
Wood storage building - 7,500 SF	7,500	$/SF	$30	$225,000
Radiant slab in wood storage building	7,500	LF	$8	$56,250
Sitework	1	LS	$142,740	$142,740
Electrical installation and contractor	1	each	$40,000	$40,000
Mechanical contractor	1	each	$200,000	$200,000
Controls contractor	1	each	$75,000	$75,000
Miscellaneous, delivery and rigging	1	each	$45,000	$45,000
Building - 50' x 100' x 18' H	6,500	$/SF	$125	$812,500
Utility trenching	100	LF	$300	$30,000
Subtotal				$3,272,490
Contingency		10%		$327,249
Total				$3,599,739
Engineering, Architectural, Civil, Materials Handling, Structural (10%)				$359,974
Permitting				$200,000
Total Project Cost				**$4,159,713**
KWe produced				250
KWt produced				4,414
Price per KW(e+t)				$892

Notes:

1. Front loader cost is included in wood handling system.

Table 4: Life Cycle Cost and Simple Payback Analysis
System B - Biomass Gasifier, Boiler and Steam Turbine

LIFE CYCLE COST (LCC) ANALYSIS	
Investment Cost (IC)	
Installation of Biomass Gasifier Boiler/Turbine System	$4,159,713
Salvage Cost	$236,018
Investment Cost (first cost minus salvage)	$3,923,695
Maintenance and Repair Cost (MC)	
Annual Maintenance and Repair Cost	$65,700
Estimated Life of System	20
Maintenance and Repair Cost	$1,314,000
Operating Costs (OC)	
Annual Fuel	$495,378
Estimated Life of System (years)	20
Annual Estimated Labor	$43,800
Operating Cost	$10,783,560
Amortization Cost (AC)	
Replacement Cost	$0
LIFE CYCLE COST (LCC = IC + MC + OC + AC)	**$16,021,255**
SIMPLE PAYBACK ANALYSIS	
Initial Project Cost	$3,923,695
Maintenance and Repair Cost	$65,700
Operating Cost	$43,800
Before Tax Cash Flow	$0
Income From Project (Electrical Energy Savings)	$266,466
Income From Project (Mechanical Energy Savings)	$157,360
Energy RECs ($0.06/KWH)	$124,830
Initial Rate of Return (IRR)	
Annual Energy Savings From the Utility and Energy RECs	$548,656
Investment Cost	$3,923,695
Fuel Cost	$495,378
Initial Rate of Return (IRR = Annual Savings/Investment)	0.01
Simple Payback = 1 / Initial Rate of Return	
SIMPLE PAYBACK PERIOD (YEARS)	**73.65**

System C – Biomass Gasifier and Reciprocating Engine Generator

The evaluation of this system is based on a gasifier manufactured by AHT that will make producer gas to fuel a 250 KW reciprocating electrical generator to make electricity. Other quality gasifier manufacturers are REDONA and Omega Thermal Technologies, Inc. AHT uses a generator manufactured by Deutz. Other quality generator manufacturers that use "producer gas" are Jenbacher and Waukesha.

Thermal energy in the form of steam will be harvested from the generator stack. As an added benefit, the engine jacket and fuel scrubbing equipment also provide additional thermal energy that will be harvested and used to dry the wood chips via radiant tubing imbedded in the floor of the storage bunker.

The wood chip fuel consumption rate for the gasifier is approximately 0.29 tons/hr or 2,558 tons per year. The system will produce 869 lbs/hr of steam at 15 psig to interface with the nursing home's existing steam header. The output thermal energy that may be harvested from the heat recovery unit at the exhaust stack is calculated at 0.96 MBH.

A strong advantage of this system is that it consumes fewer tons of wood chips per combined Btu/h and KW output. The wood chip throughput is lower per hour, the ancillary equipment is less complicated, the thermal output is more closely matched to the facility's requirement. Also, the construction costs are lower when compared with System B. Additionally, since the smallest gasifier that AHT manufactures is 500 KW, this system has the added benefit of future expansion with the addition of one more 250 KW reciprocating electrical generator.

A detailed construction cost estimate is shown in Table 5. A life cycle cost and simple payback analysis is shown in Table 6.

Table 5: Construction Cost Estimate
System C - Biomass Gasifier and Reciprocating Engine Generator

Description	Quantity	Units	Price/Unit	Total
Gasifiers, cooling & cleaning system, engine gensets	1	each	$980,000	$980,000
Condensate water pumps	2	each	$7,500	$15,000
Stack heat recovery unit [1]	1	each	$0	$0
Steam condensing unit	1	each	$60,000	$60,000
Combined 8" steam and 4" condensate pipe	200	LF	$530	$106,000
Wood handling system [2]	1	each	$196,000	$196,000
Truck scale (installed with security cameras) [3]	1	each	$145,000	$145,000
Wood storage building - 5,000 SF	5,000	$/SF	$30	$150,000
Radiant slab in wood storage building	5,000	LF	$8	$37,500
Site work - road	1	LS	$142,740	$142,740
Electrical installation and contractor	1	each	$40,000	$40,000
Mechanical contractor	1	each	$200,000	$200,000
Controls contractor	1	each	$75,000	$75,000
Miscellaneous, delivery and rigging	1	each	$45,000	$45,000
Building - 42' x 47.5 x 30' H	2,000	$/SF	$125	$250,000
Utility trenching	100	LF	$300	$30,000
Subtotal				$2,472,240
Contingency		10%		$247,224
Total				$2,719,464
Engineering, Architectural, Civil, Materials Handling, Structural (10%)				$271,946
Permitting				$200,000
Total Project Cost				**$3,191,410**
KWe produced				250
KWt produced				270
Price per KW(e+t)				$6,137

Notes:

1. Provided with AHT package
2. Front loader cost is included in wood handling system.
3. Truck scale may be omitted if the owner can contractually weigh delivery truck loads at an off-site location.

Table 6: Life Cycle Cost and Simple Payback Analysis
System C - Biomass Gasifier and Reciprocating Engine Generator

LIFE CYCLE COST (LCC) ANALYSIS	
Investment Cost (IC)	
Installation of Biomass Gasifier/Reciprocating Engine Generator	$3,191,410
Salvage Cost	$108,548
Investment Cost (first cost minus salvage)	$3,082,862
Maintenance and Repair Cost (MC)	
Annual Maintenance and Repair Cost	$65,700
Estimated Life of System	20
Maintenance and Repair Cost	$1,314,000
Operating Costs (OC)	
Annual Fuel	$66,506
Estimated Life of System (years)	20
Annual Estimated Labor	$43,800
Operating Cost	$2,644,118
Amortization Cost (AC)	
Replacement Cost	$0
LIFE CYCLE COST (LCC = IC + MC + OC + AC)	**$7,040,980**

SIMPLE PAYBACK ANALYSIS	
Initial Project Cost	$3,082,862
Maintenance and Repair Cost	$65,700
Operating Cost	$43,800
Before Tax Cash Flow	$0
Income From Project (Electrical Energy Savings)	$266,466
Income From Project (Mechanical Energy Savings)	$101,500
Energy RECs ($0.06/KWH)	$124,830
Initial Rate of Return (IRR)	
Annual Energy Savings From the Utility and Energy RECs	$492,796
Investment Cost	$3,082,862
Fuel Cost	$66,506
Initial Rate of Return (IRR = Annual Savings/Investment)	0.14
Simple Payback = 1 / Initial Rate of Return	
SIMPLE PAYBACK PERIOD (YEARS)	**7.23**

Table 7: Life Cycle Cost and Simple Payback Analysis (Fuel @ $40/ton)
System C - Biomass Gasifier and Reciprocating Engine Generator

LIFE CYCLE COST (LCC) ANALYSIS	
Investment Cost (IC)	
Installation of Biomass Gasifier/Reciprocating Engine Generator	$3,191,410
Salvage Cost	$108,548
Investment Cost (first cost minus salvage)	$3,082,862
Maintenance and Repair Cost (MC)	
Annual Maintenance and Repair Cost	$65,700
Estimated Life of System	20
Maintenance and Repair Cost	$1,314,000
Operating Costs (OC)	
Annual Fuel	$102,317
Estimated Life of System (years)	20
Annual Estimated Labor	$43,800
Operating Cost	$2,644,118
Amortization Cost (AC)	
Replacement Cost	$0
LIFE CYCLE COST (LCC = IC + MC + OC + AC)	**$7,040,980**
SIMPLE PAYBACK ANALYSIS	
Initial Project Cost	$3,082,862
Maintenance and Repair Cost	$65,700
Operating Cost	$43,800
Before Tax Cash Flow	$0
Income From Project (Electrical Energy Savings)	$266,466
Income From Project (Mechanical Energy Savings)	$101,500
Energy RECs ($0.06/KWH)	$124,830
Initial Rate of Return (IRR)	
Annual Energy Savings From the Utility and Energy RECs	$492,796
Investment Cost	$3,082,862
Fuel Cost	$102,317
Initial Rate of Return (IRR = Annual Savings/Investment)	0.13
Simple Payback = 1 / Initial Rate of Return	
SIMPLE PAYBACK PERIOD (YEARS)	**7.90**

Table 7 is a representation of System C if 100% of the woodchip fuel supply was provided from an off site source. Compare Table 7 with Table 6 where the fuel is provided 50% on site and 50% from an offsite source to see how the fuel source impacts the analysis.

System D – Biomass Gasifier with a Boiler

In addition to the three cogeneration systems evaluated, we evaluated a thermal only system to produce steam consisting of a 100 BHP biomass gasifier and boiler. The intent of this configuration is to minimize the use of fossil fuels at the nursing home and utilize biomass fuel to reduce operating costs.

We reviewed a gasifier and boiler system manufactured by Chiptec Wood Energy. The gasifier and boiler were sized at 100 BHP, which is the size of each of the existing low pressure steam boilers, Boiler 2 and Boiler 3. Our calculations indicated that the nursing home can adequately operate utilizing one 100 BHP low pressure steam boiler. The second existing low pressure steam boiler could alternate operating time with the first low pressure steam boiler; in this manner there would be a level of redundancy if one boiler should fail and alternating boilers also extends the life of the boilers.

The wood chip fuel consumption rate for this system is approximately 0.5 tons/hr or 4,380 tons per year. The system will produce approximately 3,450 lbs/hr of steam at 15 psig to interface into the facility's steam header. The 3,450 lbs/hr of steam is calculated to have 3.35MBTUH of thermal energy.

The main detriment with this type of system is the lack of electrical production to minimize utility electrical demands and because there is no electrical power produced, there are no renewable energy credits (RECs) to provide an income benefit to the facility. Additionally, we feel the thermal demand is so low in the summer months, specifically in June, July and August, that it would be more cost effective to use the existing boilers for the facility's thermal requirements for the summer.

A detailed construction cost estimate is shown in Table 8. A life cycle cost and simple payback analysis is shown in Table 9.

Table 8: Construction Cost Estimate
System D - Biomass Gasifier with a Boiler

Description	Quantity	Units	Price/Unit	Total
Gasifiers, cooling & cleaning system, boiler	1	each	$525,000	$525,000
Condensate water pumps	2	each	$7,500	$15,000
Combined 8" steam and 4" condensate pipe	200	LF	$530	$106,000
Wood handling system [1]	1	each	$196,000	$196,000
Truck scale (installed with security cameras)	1	each	$145,000	$145,000
Wood storage building - 5,000 SF	5,000	$/SF	$30	$150,000
Radiant slab in wood storage building	5,000	LF	$8	$37,500
Site work - road	1	LS	$142,740	$142,740
Mechanical contractor	1	each	$200,000	$200,000
Controls contractor	1	each	$75,000	$75,000
Miscellaneous, delivery and rigging	1	each	$45,000	$45,000
Building - 42' x 47.5 x 30' H	2,000	$/SF	$125	$250,000
Subtotal				$1,887,240
Contingency		10%		$188,724
Total				$2,075,964
Engineering, Architectural, Civil, Materials Handling, Structural (10%)				$207,596
Permitting				$200,000
Total Project Cost				**$2,483,560**

Notes:
1. Front loader cost is included in wood handling system.

Table 9: Life Cycle Cost and Simple Payback Analysis
System D - Biomass Gasifier with a Boiler

LIFE CYCLE COST (LCC) ANALYSIS	
Investment Cost (IC)	
Installation of Biomass Gasifier/Boiler	$2,483,560
Salvage Cost	$108,548
Investment Cost (first cost minus salvage)	$2,375,012
Maintenance and Repair Cost (MC)	
Annual Maintenance and Repair Cost	$21,000
Estimated Life of System	20
Maintenance and Repair Cost	$420,000
Operating Costs (OC)	
Annual Fuel	$23,328
Estimated Life of System (years)	20
Annual Estimated Labor	$30,000
Operating Cost	$3,249,960
Amortization Cost (AC)	
Replacement Cost	$0
LIFE CYCLE COST (LCC = IC + MC + OC + AC)	**$6,044,972**
SIMPLE PAYBACK ANALYSIS	
Initial Project Cost	$2,375,012
Maintenance and Repair Cost	$21,000
Operating Cost	$30,000
Before Tax Cash Flow	$0
Income From Project (Electrical Energy Savings)	$0
Income From Project (Mechanical Energy Savings)	$142,960
Initial Rate of Return (IRR)	
Annual Energy Savings From the Utility	$142,960
Investment Cost	$2,375,012
Fuel Cost	$23,328
Initial Rate of Return (IRR = Annual Savings/Investment)	0.05
Simple Payback = 1 / Initial Rate of Return	
SIMPLE PAYBACK PERIOD (YEARS)	**19.85**

System E – Biomass Boiler

A biomass boiler system was another thermal only alternative option evaluated in lieu of cogeneration. A 100 BHP, direct-fired biomass steam boiler was reviewed. The intent is to minimize the use of fossil fuels at the nursing home and use a biomass fuel to minimize cost at the facility.

The biomass boiler was sized to be 100BHP, which is the size of each of the existing low pressure steam boilers, Boiler 2 and Boiler 3. Our calculations indicated that the nursing home can adequately operate utilizing one 100 BHP low pressure steam boiler. The second existing low pressure steam boiler could alternate operating time with the first low pressure steam boiler; in this manner there would be a level of redundancy if one boiler should fail and alternating boilers also extends the life of the boilers.

The wood chip fuel consumption rate for this system is approximately 0.65 tons/hr or 5,655 tons per year. The system will produce approximately 3,450 lbs/hr of steam at 15 psig to interface into the facility's steam header. The 3,450 lbs/hr of steam is calculated to have 3.35MBTUH of thermal energy.

The drawback to this system in this application is the lack of electrical production to minimize utility electrical demands and because there is no electrical power produced, there are no renewable energy credits (RECs) to provide an income benefit to the facility. Additionally, we feel the thermal demand is so low in the summer months, specifically in July and August, that it would be more cost effective to use the existing boilers for the facility's thermal requirements for the summer. This system was evaluated as a comparison to System D. The intent was to compare the reduction in capital costs to the operating costs, specifically the increase in fuel consumption. Typically a gasification system will consume 25-30% less fuel compared with a direct fired system.

A detailed construction cost estimate is shown in Table 10. A life cycle cost and simple payback analysis is shown in Table 11.

Table 10: Construction Cost Estimate
System E - Biomass Boiler

Description	Quantity	Units	Price/Unit	Total
Biomass boiler	1	each	$380,000	$380,000
Condensate water pumps	2	each	$7,500	$15,000
Combined 8" steam and 4" condensate pipe	200	LF	$530	$106,000
Wood handling system	1	each	$196,000	$196,000
Truck scale (installed with security cameras)	1	each	$145,000	$145,000
Wood storage building - 6,000 SF	6,000	$/SF	$30	$180,000
Radiant slab in wood storage building [1]	6,000	LF	$8	$45,000
Site work - road	1	LS	$142,740	$142,740
Mechanical contractor	1	each	$200,000	$200,000
Controls contractor	1	each	$75,000	$75,000
Miscellaneous, delivery and rigging	1	each	$45,000	$45,000
Building - 42' x 47.5 x 30' H	2,000	$/SF	$125	$250,000
Subtotal				$1,779,740
Contingency		10%		$177,974
Total				$1,957,714
Engineering, Architectural, Civil, Materials Handling, Structural (10%)				$195,771
Permitting				$200,000
Total Project Cost				**$2,353,485**

Notes:
1. Front loader cost is included in wood handling system.

Table 11: Life Cycle Cost and Simple Payback Analysis
System E - Biomass Boiler

LIFE CYCLE COST (LCC) ANALYSIS	
Investment Cost (IC)	
Installation of Biomass Gasifier/Boiler	$2,353,485
Salvage Cost	$108,548
Investment Cost (first cost minus salvage)	$2,244,937
Maintenance and Repair Cost (MC)	
Annual Maintenance and Repair Cost	$20,000
Estimated Life of System	20
Maintenance and Repair Cost	$400,000
Operating Costs (OC)	
Annual Fuel	$30,296
Estimated Life of System (years)	20
Annual Estimated Labor	$28,000
Operating Cost	$3,933,240
Amortization Cost (AC)	
Replacement Cost	$0
LIFE CYCLE COST (LCC = IC + MC + OC + AC)	**$6,578,177**
SIMPLE PAYBACK ANALYSIS	
Initial Project Cost	$2,244,937
Maintenance and Repair Cost	$20,000
Operating Cost	$28,000
Before Tax Cash Flow	$0
Income From Project (Electrical Energy Savings)	$0
Income From Project (Mechanical Energy Savings)	$142,960
Initial Rate of Return (IRR)	
Annual Energy Savings From the Utility	$142,960
Investment Cost	$2,244,937
Fuel Cost	$30,296
Initial Rate of Return (IRR = Annual Savings/Investment)	0.05
Simple Payback = 1 / Initial Rate of Return	
SIMPLE PAYBACK PERIOD (YEARS)	**19.93**

I. System Comparison

Of the five biomass systems that were evaluated, the following four deserve further comparison:

Table 12: Biomass System Comparison

System Description	Investment Cost	Simple Payback (Years)	Annual Savings and RECs	Annual System Costs	Fuel Consumption Rate
System B - Biomass Gasifier, Boiler and Steam Turbine	$4,159,713	78.08	$548,656	$670,578	2.18 ton/hr
System C - Biomass Gasifier and Reciprocating Engine Generator	$3,191,410	7.49	$492,796	$241,706	0.29 ton/hr
System C - Biomass Gasifier and Reciprocating Engine Generator [1]	$3,191,410	8.17	$492,796	$277,517	0.29 ton/hr
System D - Biomass Gasifier with a Boiler	$2,483,560	20.76	$142,960	$152,976	0.50 ton/hr
System E - Biomass Boiler	$2,353,485	20.89	$142,960	$159,944	0.65 ton/hr

Notes:

1. This alternate system "C" was added to compare 100% fuel supplied from an offsite source to 50% offsite source & 50% onsite supply.

The systems above utilize various combinations of proven, reliable technology – gasifiers, steam boilers, turbines, and engine generators – which will keep operating costs low. Each of the systems requires similar infrastructure, site work and construction. The difference in cost between the systems can be attributed to the differences in mechanical equipment mandated by each system.

All of the economic factors shown in Table 12 need to be taken into consideration when determining which biomass system is the most feasible for implementation at the Sullivan County Nursing Home. The ability for the system to adequately meet the electrical and thermal energy needs of the nursing home should be of primary concern if the objective of the system is to reduce annual operating costs and expenses. The combined heat and power (CHP) systems evaluated – System B and System C – will produce adequate quantities of electricity and steam. System B – Biomass Gasifier, Boiler and Steam Turbine, produces four times the steam required for the nursing home; this is a drawback to the system, as it reduces the overall system efficiency due to the quantity of steam that is wasted. The thermal only systems – System D and System E – take advantage of the relatively low cost biomass fuel source that is available to the nursing home. However, without the added benefit of an income stream from renewable energy credits (RECs) and avoided electrical costs, the economics simply do not justify the increased payback period, even though the initial investment costs are low.

V. RECOMMENDATIONS

Taking all of the above into consideration, System C – Biomass Gasifier and Reciprocating Engine Generator is the most economically viable biomass CHP system for implementation at the Sullivan County Nursing Home. The single biggest attribute of this system is it most closely matches the electrical and thermal energy requirements of the nursing home. System C generates electricity with a minimal surplus of thermal energy, especially when compared with System B which produces four times more steam than the nursing home requires. This system has the shortest calculated simple payback period of the four biomass systems evaluated at 6.43 years. Though it does not have the lowest capital cost of the four systems compared in Table 12, it does have the lowest initial cost of the two biomass CHP systems. The benefit of an income stream from RECs, as well as the avoided electrical and thermal costs, makes it stand out from the other systems.

Additionally, this system has the capability to expand to twice its capacity by adding one additional reciprocating engine generator. The biomass gasifier is sufficiently sized to provide fuel for two 250 KW engine generators. The system evaluated in this report has one 250 KW engine generator. However, we suggest Sullivan County consider procuring a second 250 KW generator for the project, which will enable the generators to be set up in a lead/lag configuration. This will assist in maintenance of the generators and provide a level of redundancy in case of equipment failure. If the electrical and thermal demand increases, both 250 KW reciprocating engine generators may be brought online to provide sufficient energy. This would allow the facility to expand and increase the load requirements but still mitigate the electrical transmission and demand charges from the utility.

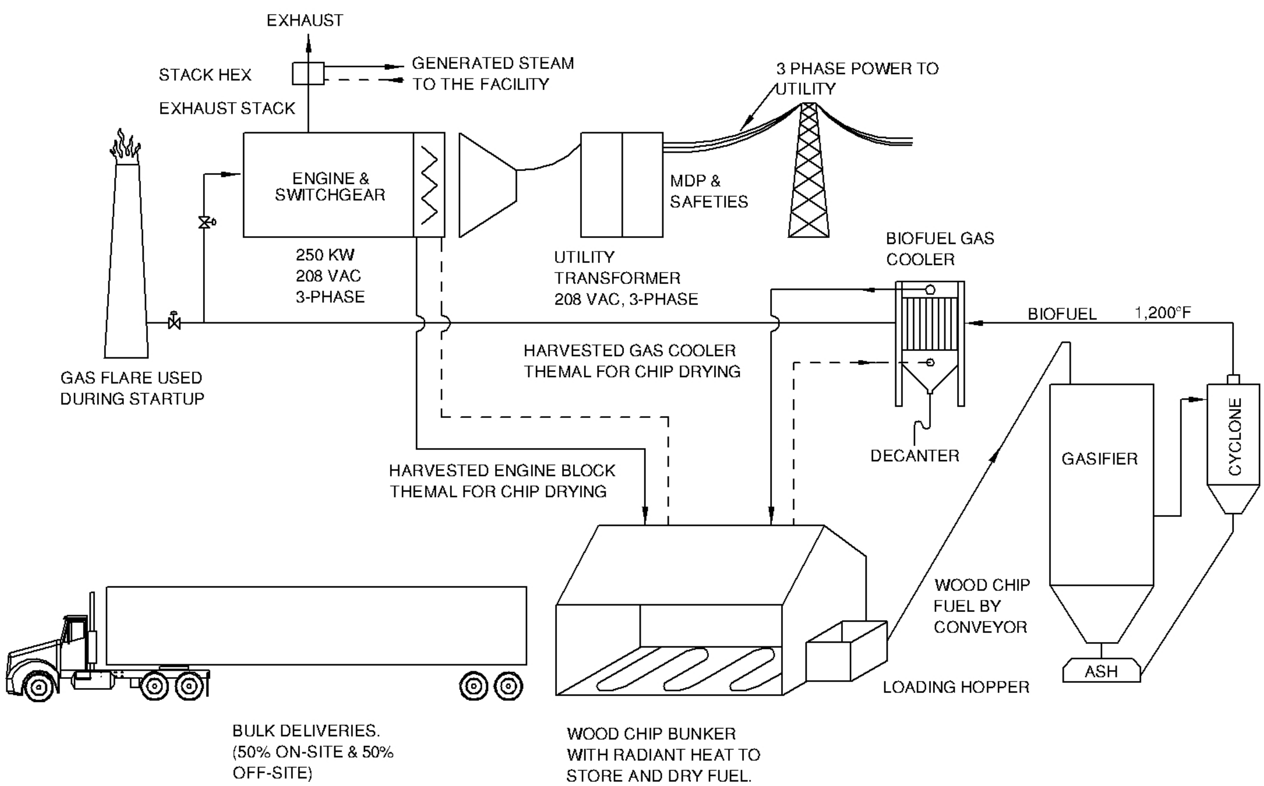


Figure 2: Proposed System C System Process Flow Diagram

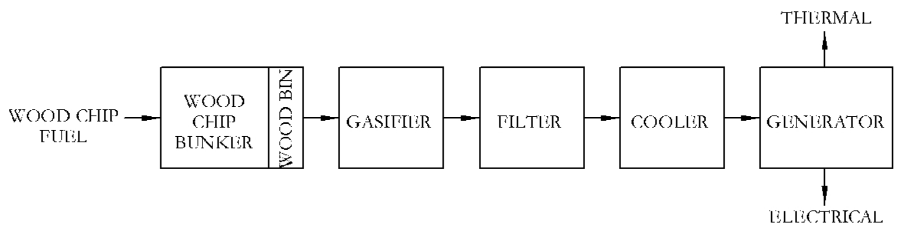


Figure 3: Proposed System C Simplified System Process Flow Diagram

VI. <u>OTHER CONSIDERATIONS</u>

A. Wood Harvesting Equipment and Considerations

The costs for wood harvesting were not included in this report. We determined what the cost of the site production of wood chips would be based on anticipated labor rates, and included that reduced cost in our analysis. When considering the prospect of implementing on-site wood harvesting equipment, there are significant variables to address, including:

- Wood chipping equipment location
- Fixed or portable equipment
- Size of equipment based on system selection
- Size and types of trees to be harvested
- Equipment type to remove tree

The report is based on a comparison of wood chips as a fuel source. We recommend the Morbark Beever M20R with loader to be considered for the facilities chipping needs. New, this chipper costs approximately $150,000. This chipper would take stock up to 20" in diameter and produce up to 20 tons per hour of wood chip fuel. Bonhag Associates additionally recommends that the owner pursue other feasible options regarding a chipping unit. The Nursing Home should examine, but not limited to, equipment upfront costing, reliability, ease of operation, operating costs, maintenance costs, warranty and fuel consumption items to evaluate the viability of used or rental equipment to ascertain what the most economically feasible solution for the facility.

Additionally, when using a chipper we recommend using a screener to remove any wood pieces not of suitable size for the biomass systems. A suitable screener costs approximately $10,000. As indicated above there are a plethora of variables involved when selecting the appropriate equipment for removing the logs from the forest to the chipper. We recommend Sullivan County confer with some local logging operation to obtain a better understanding of logging equipment suitable for the facility's terrain

Sullivan County will need to further explore how to best implement and employ on-site wood harvesting at the nursing home and DOC site. Equipment cost, reliability, ease of operation, maintenance costs, warranty and fuel consumption rates should be evaluated to ascertain what is most feasible for the facility. We recommend Sullivan County contact Dave Kent of New England Forestry Association and Chuck Hersey of the State of New Hampshire Extension Service to develop a forestry harvesting plan and replenishment.

Additional wood biofuel analysis shall be done in the preliminary design phase of the project to ascertain the best fuel characteristics suitable for the selected biomass system at the facility.

B. Standby Generator Power

When the 250 KW reciprocating engine generator that is part of System C is non-operational due to maintenance or repair, we recommend that Sullivan County should utilize its existing standby generators to make power temporarily until the maintenance is complete. This will mitigate the incidence of electrical transmission and demand charges from the local utility. Peak electrical demand is measured at fifteen minute intervals and billed on a ratcheted rate structure that will be applied to customer billings for a 12 month period. It is imperitative to avoid incurring these charges as they will significantly impact the facility's electrical costs. Further evaluation should be conducted during the design phase to minimize purchased electricity from the utility, especially electrical demand.

VII. CONCLUSION

It is economically feasible to construct and operate a biomass combined heat and power (CHP) system at the Sullivan County Nursing Home. The location for the project is ideal as there is sufficient land for the necessary CHP and wood storage structures, as well as ample on-site biomass resources to sustain the project. This location also provides minimal impact to the daily operation of the facilities during construction and operation.

A CHP system consisting of a biomass gasifier and reciprocating engine generator (System C) is the best choice of the five systems considered. It has the advantage of the fastest payback and lowest operating costs due to the reduction in electrical demand and transmission charges as well as the savings from the reduced consumption of #4 fuel oil. It is not our intent to isolate the facility from the electrical utility or to eliminate fossil fuel consumption entirely. Our objective is to generate energy to meet the greater part of the thermal and electrical loads of the nursing home facility; System C achieves that goal. The sale of renewable energy credits is an additional asset to the project.

Further attention to on-site wood harvesting is merited. A comprehensive review of the facility's surrounding terrain is required to determine the appropriate equipment and costs necessary to harvest the wood chips. This should be completed prior to the design phase of the project.

We strongly recommend that Sullivan County initiate the next step in the planning process.

APPENDIX I

EQUIPMENT AND ADDITIONAL INFORMATION

Energy from biomass
with wood gasification energy system

Energy from wood and wastes

As the cost of fuel oil, natural gas and electrical energy continue to escalate the search for alternative energy sources has intensified.
we have developed a method of economically converting wood and wood wastes to energy through biomass gasification.

Sources of biomass

Biomass is any fibrous material found in nature.
Many times great amounts of this material are available as waste products from various industries.
Readily available sources include:

- tree tops, branches and cull trees normally left in the forest after logging operations
- bark, slab wood, shavings and sawdust from the lumber and furniture industries
- cotton bolls, nutshells, bagasse, straw, husks and similar materials from agriculture
- packing material accumulating in supermarkets
- waste from the food industry

Production of energy by gasification

An economical form of energy production from this raw material, which has a relatively low cost, is the process of gasification. The gas produced in this manner has many applications, e.g. as fuel for gas engines.

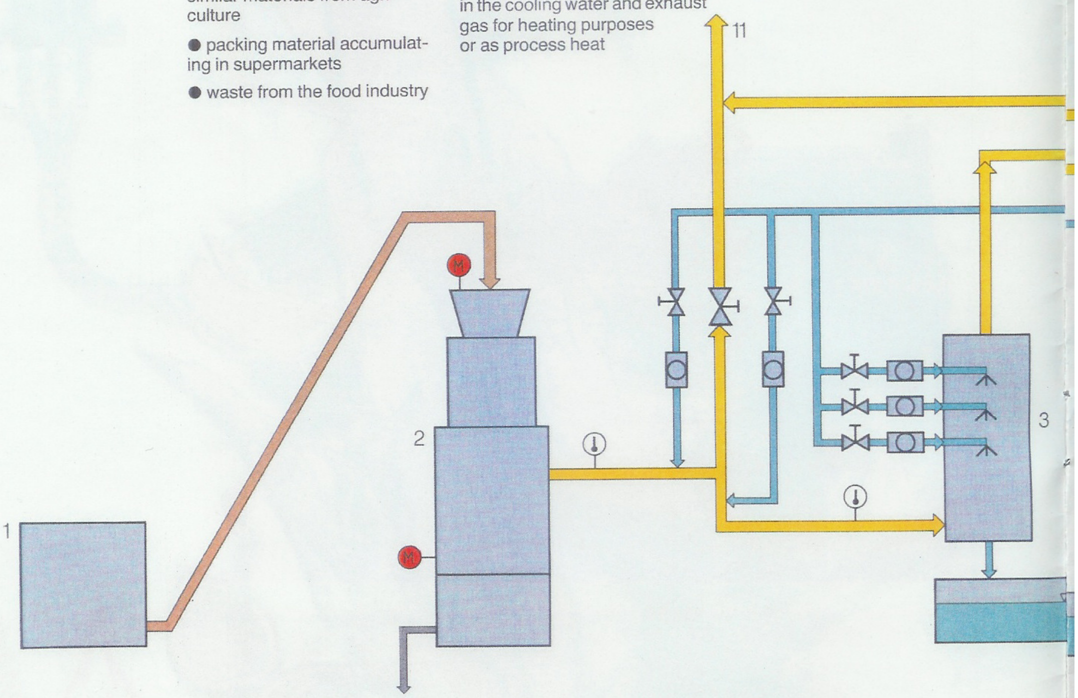
Three end products are generated:

- clean process gas – without phenols and tars
- electricity, provided by a KHD power plant connected to the gasifier
- utilization of heat contained in the cooling water and exhaust gas for heating purposes or as process heat

Similarly, the gas can be used for lean-gas burners installed in:

- boiler plants that generate steam and hot water
- kilns used in the ceramics industry
- drying plants

KHD has many years experience in the manufacture of biomass gasification plants; they can fall back on the know-how gained from some 10,000 plants constructed in the past and continuous research work in this area, which ensures that the KHD technology is the latest state of the art.



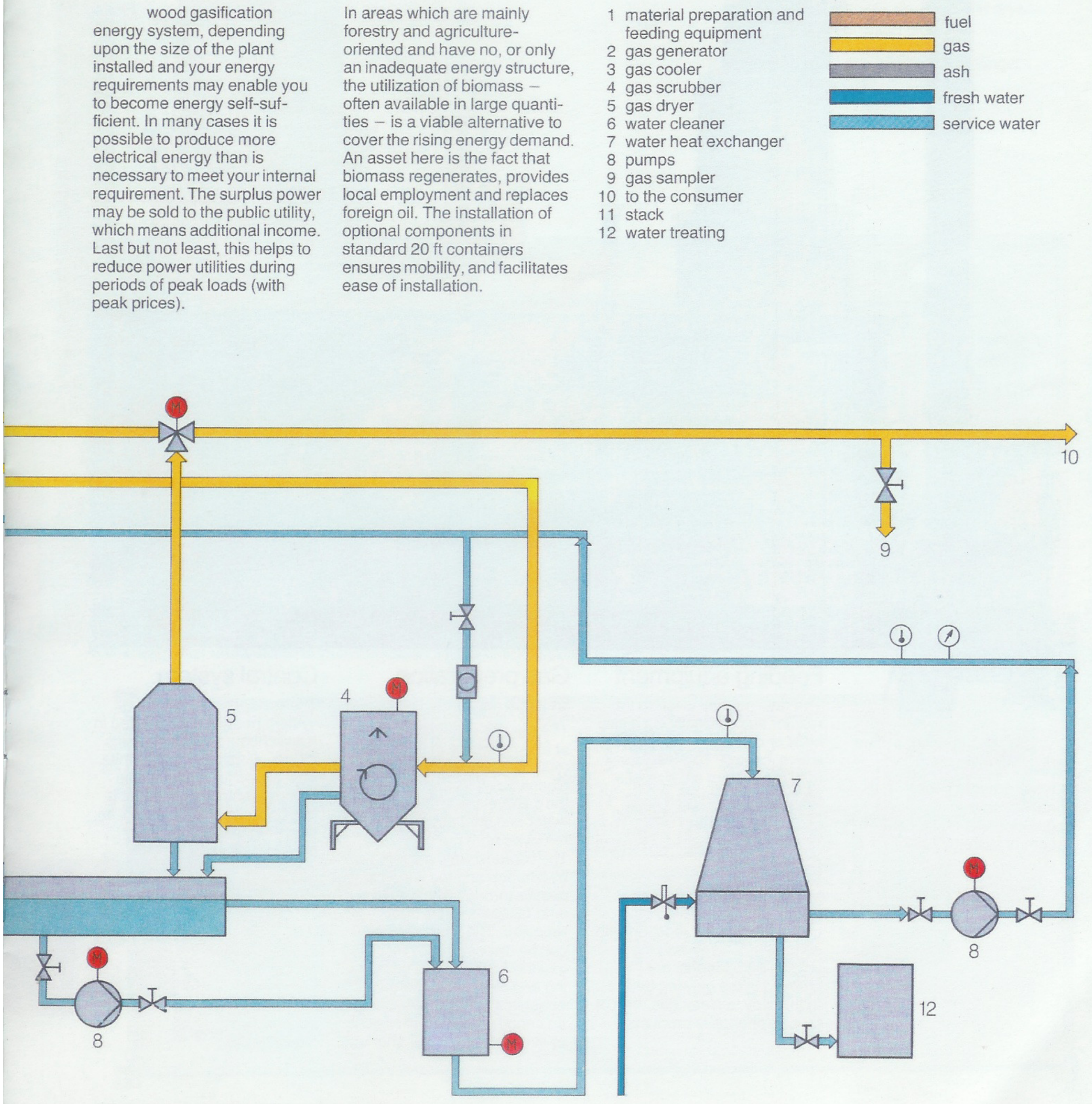
High economy

wood gasification energy system, depending upon the size of the plant installed and your energy requirements may enable you to become energy self-sufficient. In many cases it is possible to produce more electrical energy than is necessary to meet your internal requirement. The surplus power may be sold to the public utility, which means additional income. Last but not least, this helps to reduce power utilities during periods of peak loads (with peak prices).

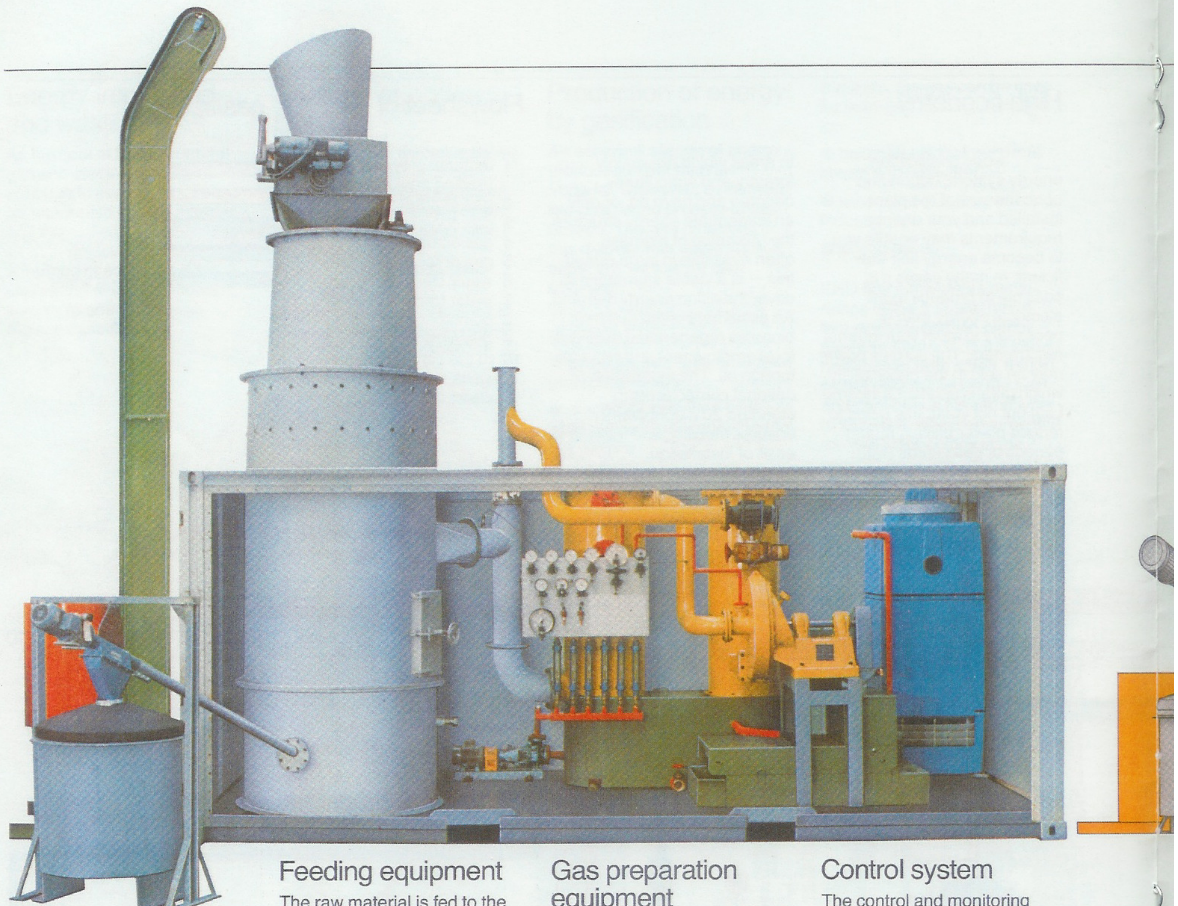
In areas which are mainly forestry and agriculture-oriented and have no, or only an inadequate energy structure, the utilization of biomass – often available in large quantities – is a viable alternative to cover the rising energy demand. An asset here is the fact that biomass regenerates, provides local employment and replaces foreign oil. The installation of optional components in standard 20 ft containers ensures mobility, and facilitates ease of installation.

Flowsheet of the gasifier plant

1 material preparation and feeding equipment
2 gas generator
3 gas cooler
4 gas scrubber
5 gas dryer
6 water cleaner
7 water heat exchanger
8 pumps
9 gas sampler
10 to the consumer
11 stack
12 water treating



Wood gasification plant and process



A wood gasification plant consists of four units:

- feeding equipment
- gasifier
- gas cleaning equipment
- control system

Feeding equipment

The raw material is fed to the reactor automatically via a skip hoist or conveyor, actuated by a level control. The feed stock may range from the size of a bean to a maximum of 2" × 4" × 15" and contain as high as 30 % fines.

Gasifier

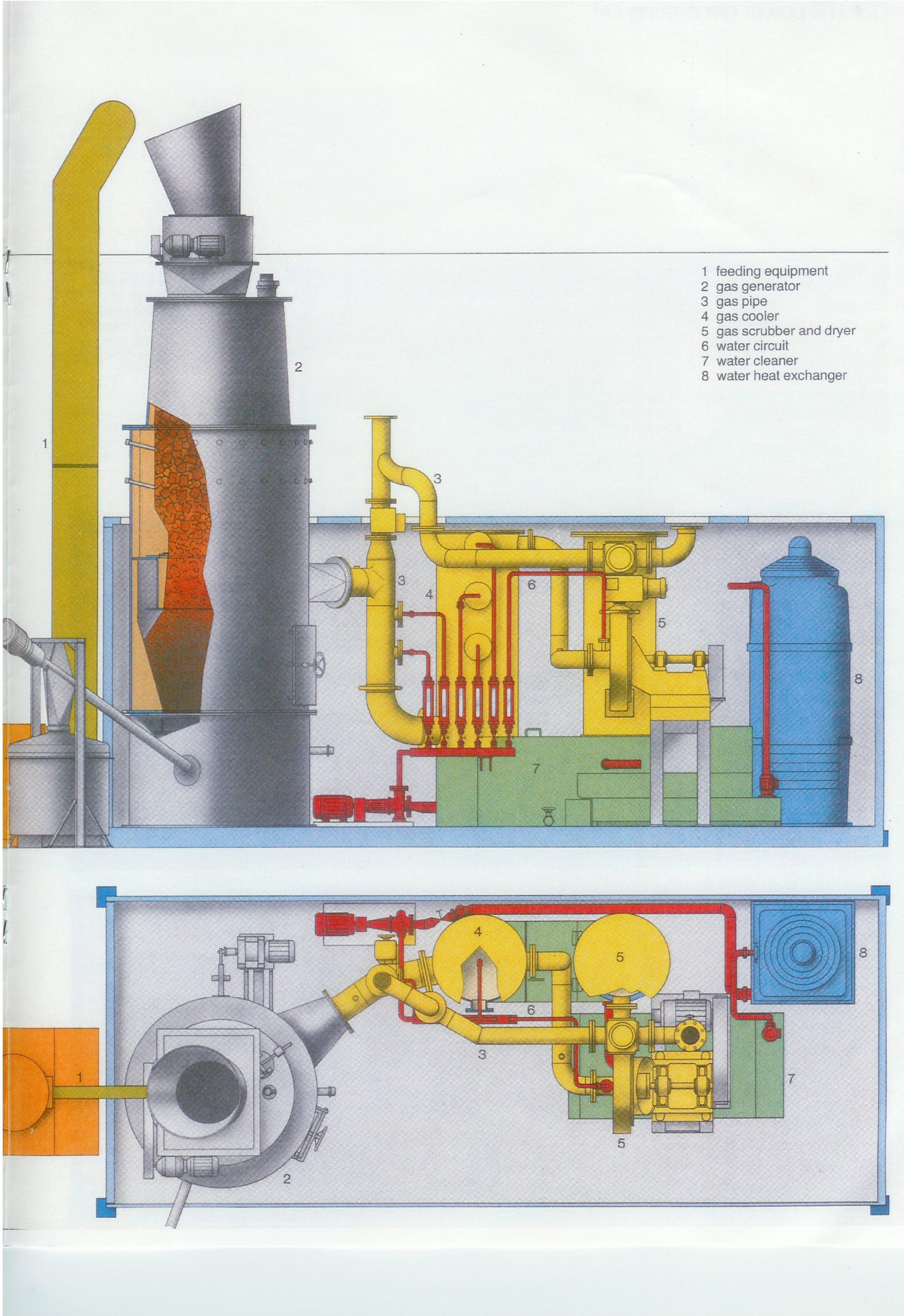
In this reactor, moisture is removed from the feed stock, gas is formed in a reaction with controlled feed air and the volatile components are cracked in the glowing bed. In this way, a clean gas, free of tar and phenol, is produced.

Gas preparation equipment

The hot gas exiting the gasifier at a temperature of 930 °F (500 °C) is cooled and then cleaned by injecting water into the gas system. In the separator, water and impurities are removed from the gas. The contaminants are removed by filtration and the water passes through a heat exchanger to facilitate waste heat recovery. The filter residues can be disposed of by recycling into the gasifier. This gas cooling and cleaning system enables a closed water circuit – an important aspect in regions of ever-existing water shortage.

Control system

The control and monitoring system has been centralized in a switchboard which contains all indicators and control units. This allows for automatic or manual control, as desired. If design limits are exceeded, an alarm signal or emergency shutdown is initiated.


1 feeding equipment
2 gas generator
3 gas pipe
4 gas cooler
5 gas scrubber and dryer
6 water circuit
7 water cleaner
8 water heat exchanger
1
2
3
4
5
6
7
8

DEUTZ power generating set

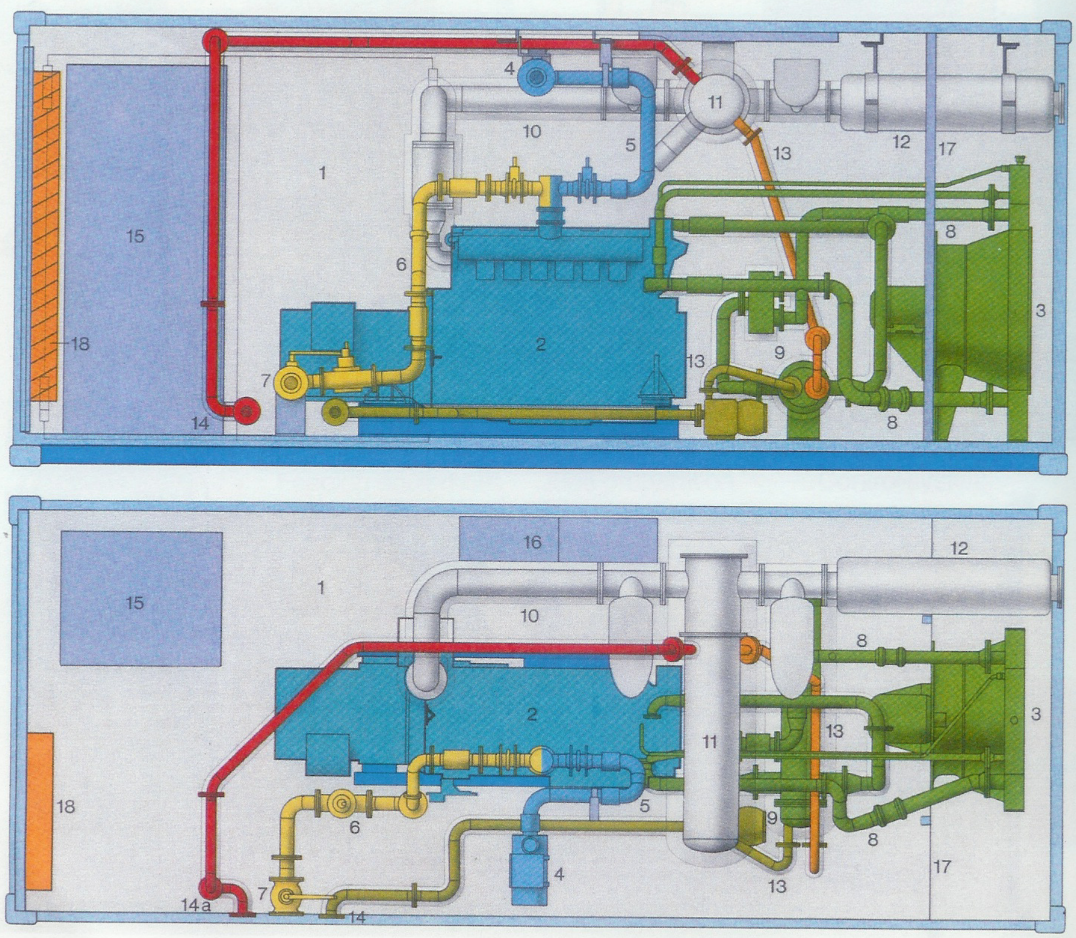
The engine, generator and accessories are installed in a standard 20 ft. container:

- gas engine and generator
- equipment for recovery of engine waste heat and ventilation of the container
- switchgear and, as required, equipment for feeding to the public utility

The prime mover of the generator is a DEUTZ gas engine from the B/GAM 816 family. This gas-burning 4 cycle engine is developed from the diesel series designed for heavy-duty operation at high mean effective pressures. The reduced output of the engine when redesigned to operate on biogas therefore ensures extremely long engine life.

The gas/air mixture is supplied to the engine via a gas mixing valve developed by KHD. An electronic governor keeps the speed of the engine constant under different load conditions.

When utilizing the waste heat, e.g. a hot water supply for process heat, building heat, or through an assorption machine for air conditioning the total efficiency of the plant can be increased to some 80 %.



DRESSER Waukesha **VHP3604GSI/GSID**

STANDARD EQUIPMENT

AIR CLEANER – Dry type with rain shield and service indicator.

AIR FUEL RATIO CONTROL (AFR) – Integrated ESM–AFR catalyst rich-burn control, main fuel gas regulators actuators, exhaust O_2 sensor(s), and post turbocharger exhaust thermocouple. Factory mounted and tested. AFR maintains emissions through load and speed changes. The ESM-AFR meets Canadian Standards Association Class 1, Division 2, Group D hazardous location requirements. Note: For dual fuel applications, ESM-AFR system will control the primary fuel source only.

BARRING DEVICE – Manual.

BEARINGS – Heavy duty, replaceable, precision type.

BREATHER – Closed system.

CONNECTING RODS – Forged steel, rifle drilled.

CONTROL SYSTEM - Waukesha Engine System Manager (ESM®) integrates spark timing control, speed governing, air/fuel ratio control, detonation protection, start-stop control, diagnostic tools, fault logging and engine safeties. The Engine Control Unit (ECU) is the central brain of the control system and main customer interface. Connection to the ESM is via a 25 foot (5.2 m) harness to a local panel, through MODBUS RTU slave RS-485 connection, and through the Electronic Service Program (ESP). Customer connections are only required to the local panel, fuel valve, and for 24V DC power supply. Compatible with Woodward load sharing module. ESM meets Canadian Standards Association Class I, Division 2, Group D, hazardous location requirements.

COOLING SYSTEM – Choice of mounted radiator with pusher fan, core guard and duct adaptor, heat exchanger with expansion tanks, or connection for remote radiator cooling. (One shutdown level switch for each circuit included on radiator and heat exchanger units).

CRANKCASE – Integral crankcase and cylinder frame.

CRANKSHAFT – Counterweighted, forged steel, dynamically balanced, with sealed viscous vibration damper.

CYLINDER HEADS – Six interchangeable valve–in–head type. Four valves per cylinder head, with water cooled exhaust valve seat. Roller valve lifters and hydraulic push rods. Flange mounted ignition coils.

CYLINDERS – 9.375" (238 mm) bore x 8.5" (216 mm) stroke; Removable wet type cylinder liners, chrome plated on outer diameter. Number of cylinders – Six.

ELECTRONIC SERVICE PROGRAM (ESP) - Microsoft® Windows-based program provided on CD-ROM for programming and interface to ESM. Includes E-Help for troubleshooting any ESM faults. A serial cable is provided for connection from a customer-supplied PC to the ECU's RS-232 port.

ENGINATOR BASE – Engine, generator and radiator or heat exchanger are mounted and aligned on a welded steel, wide flange base, designed for solid mounting on an inertia block, with standard base lifting eyes.

ENGINE MONITORING DEVICES – Factory mounted and wired sensors for lube oil pressure and temperature, intake manifold temperature and pressure, jacket water temperature, and Exhaust O_2 content, all accessible through ESM. ESM continually monitors combustion performance through individual knock sensors to provide detonation protection. Dual magnetic pick-ups are used for accurate engine speed monitoring. ESM provides advanced diagnostics of engine and all ESM sensors and logs any faults into non-volatile flash memory.

EXHAUST SYSTEM – Water cooled exhaust manifold with single vertical exhaust at rear. Flexible stainless steel exhaust connection; 8" (203 mm) long with 6" (152 mm) outlet flange.

FUEL SYSTEM (GSI) – One natural gas, 4" (102 mm) updraft carburetors and one mounted Mooney Flowgrid 250, 2 (51 mm) gas regulator, one 2" NPT flexible connection (shipped loose), and one 2" NPT Magnatrol gas solenoid valve (shipped loose). Fuel pressure – 30 PSIG minimum and 50 PSIG maximum.

FUEL SYSTEM (GSID) – One natural gas 4" updraft carburetor, one Fisher 133L gas regulator (shipped loose), one 3.5" 125 lb. flanged flexible connection (shipped loose), and one 3" NPT Magnatrol gas solenoid valve (shipped loose). Fuel pressure – 1 PSIG minimum and 50 PSIG maximum.

GENERATOR – Open, drip-proof, direct connected, fan cooled, 2/3 pitch, A.C. revolving field type, single bearing generator with brushless exciter, short circuit sustain (PMG type maintains 270% of rated generator current for up to 10 seconds on 105°C temperature rise generators; maintains 250% of current on 130°C rise generators) and damper windings. TIF and Deviation Factor within NEMA MG–1.32. Voltage 480/277, 3 phase, 4 wire, Wye 60 Hz and 400/230, 3 phase, 4 wire, Wye 50 Hz. Other voltages are available, consult factory. Insulation material NEMA Class F. Temperature rise within NEMA (105°C) for continuous power duty, within NEMA (130°C) for standby duty. All generators are rated 0.8 Power Factor, are mounted on the engine flywheel housing and have multiple steel disc flexible coupling drive. Includes space heater, 115/230 V, 1 phase.

GOVERNOR - Electric throttle actuator controlled by ESM with throttle position feedback. Governor tuning is performed using ESP. ESM includes option of a load-coming feature to improve engine response to predictable step loads.

IGNITION SYSTEM - Ignition Power Module Diagnostics (IPM-D) - controlled by ESM, with spark timing optimized for varying speed-load conditions. Dual voltage energy levels automatically controlled by ESM to maximize spark plug life and improve starting. The diagnostics feature of ESM can be used to help monitor spark plug life via predictive maintenance. Shielded ignition components that meet Canadian Standard Association Class 1, Division 2, Group D hazardous location requirements.

INTERCOOLER – Air to water.

JUNCTION BOXES – Separate AC and DC junction boxes for engine wiring and external connections.

LUBRICATION – Full pressure, positive displacement pump. Full flow oil filter (shipped loose) and flexible connections (shipped loose). Microspin® bypass filter and flexible connections. 50 or 60 Hz, 230 volt AC, single phase electric motor driven intermittent prelube pump with motor starter (other voltages can be specified).

OIL COOLER – Shell and tube type (mounted).

OIL PAN – Cast alloy iron base type with removable doors.

PAINT – Oilfield Orange.

PISTONS – Aluminum with floating pin. Oil cooled.

STARTING EQUIPMENT – Two 24V DC electric starting motors.

TURBOCHARGER – Water cooled bearing housing with adjustable wastegate.

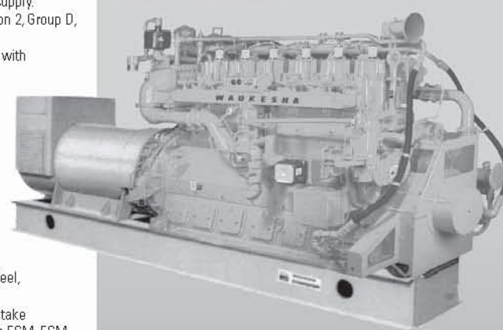
VOLTAGE REGULATOR (shipped loose) – SCR static automatic type providing 1% regulation from no load to full load, three phase sensing and automatic subsynchronous speed protection. Includes voltage adjustment rheostat (shipped loose).

WATER CIRCULATING SYSTEM, AUXILIARY CIRCUIT – Belt driven water circulating high capacity pump for intercooler and lube oil cooler. See S6543–19 performance curve for use with standard 10" diameter crankshaft pulley.

WATER CIRCULATING SYSTEM, ENGINE JACKET – Belt driven water pump, 175 – 180° F (79 – 82°C) thermostatic temperature regulation full flow bypass. Single 4" ANSI flange connections for inlet and outlet on water connect units.

VHP® Series Four® Gas Enginator® Generating System Featuring ESM® Technology

500 - 600 kW



Enginator shown with options, less Extender Series features.

Model VHP3604GSI/GSID

Turbocharged and Intercooled Gas Fueled Enginator

SPECIFICATIONS

Waukesha Engine
F3524GSI
Four Cycle
Overhead Valve

Cylinders
Inline 6

Piston Displacement
3520 cu. in.
(58 L)

Bore & Stroke
9.375" x 8.5"
(238 x 216 mm)

Compression Ratio
8:1

Jacket Water Capacity
48.5 gal.
(184 L)

Starting System
24V Electric

Fuel LHV
900 Btu/ft^3
(33.5 J/cm^3)

Lube Oil Capacity
66 gal.
(250 L)

PERFORMANCE DATA: VHP3604GSI GAS ENGINATOR® GENERATING SYSTEM

HEAT EXCHANGER COOLING Heat Exchanger Water Supply: 93°F (34°C) I.C. Water: 130°F (54°C)	CONTINUOUS POWER* 1200 rpm 60 Hz	1000 rpm 50 Hz
kW Rating	600	540***
Fuel Consumption x 1000 Btu/h (kW)	6762 (1982)	5876 (1722)
Jacket Water x 1000 Btu/h (kW)	2041 (598)	1772 (519)
Lube Oil x 1000 Btu/h (kW)	297 (87)	248 (73)
Intercooler x 1000 Btu/h (kW)	119 (35)	80 (23)
Heat Radiated x 1000 Btu/h (kW)	382 (112)	345 (101)
Exhaust Energy** x 1000 Btu/h (kW)	1906 (559)	1579 (463)
Exhaust Flow lb/h (kg/h)	5753 (2610)	4999 (2268)
Exhaust Temperature °F (°C)	1196 (647)	1144 (618)
Induction Air Flow scfm (nm³/hr)	1281 (2060)	1113 (1790)

WATER CONNECTION COOLING I.C. Water: 130°F (54°C)	CONTINUOUS POWER* 1200 rpm 60 Hz	1000 rpm 50 Hz
kW Rating	600	540***
Fuel Consumption x 1000 Btu/h (kW)	6762 (1982)	5876 (1722)
Jacket Water x 1000 Btu/h (kW)	2041 (598)	1772 (519)
Lube Oil x 1000 Btu/h (kW)	297 (87)	248 (73)
Intercooler x 1000 Btu/h (kW)	119 (35)	80 (23)
Heat Radiated x 1000 Btu/h (kW)	382 (112)	345 (101)
Exhaust Energy** x 1000 Btu/h (kW)	1906 (559)	1579 (463)
Exhaust Flow lb/h (kg/h)	5753 (2610)	4999 (2268)
Exhaust Temperature °F (°C)	1196 (647)	1144 (618)
Induction Air Flow scfm (nm³/hr)	1281 (2060)	1113 (1790)

RADIATOR CONNECTION COOLING I.C. Water: 130°F (54°C)	CONTINUOUS POWER* 1200 rpm 60 Hz	1000 rpm 50 Hz
kW Rating	560	500***
Fuel Consumption x 1000 Btu/h (kW)	6762 (1982)	5876 (1722)
Jacket Water x 1000 Btu/h (kW)	2041 (598)	1772 (519)
Lube Oil x 1000 Btu/h (kW)	297 (87)	248 (73)
Intercooler x 1000 Btu/h (kW)	119 (35)	80 (23)
Heat Radiated x 1000 Btu/h (kW)	382 (112)	345 (101)
Exhaust Energy** x 1000 Btu/h (kW)	1906 (559)	1579 (463)
Exhaust Flow lb/h (kg/h)	5753 (2610)	4999 (2268)
Exhaust Temperature °F (°C)	1196 (647)	1144 (618)
Induction Air Flow scfm (nm³/hr)	1281 (2060)	1113 (1790)
Radiator Air Flow scfm (nm³/hr)	57000 (91600)	54000 (86800)

Typical heat balance data is shown. Consult factory for guaranteed data.

*Continuous Power Rating: The highest electrical power output of the Enginator available for an unlimited number of hours per year, less maintenance. It is permissible to operate the 60 Hz Enginator units with up to 10% overload for two hours in each 24 hour period. NO overload is allowed for the 50 Hz units.

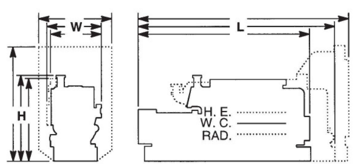
Rating Standard: The Waukesha Enginator power rating descriptions are in accordance to ISO 8528, DIN6271 and BS5514. It is also valid for ISO 3046/1-1995 with an engine mechanical efficiency of 90% and Tcra (clause 10.0) is limited to ±10° F (5° C).

**Heat rejection based on cooling exhaust gas to 85° F (29° C).

*** No overload allowed.

All natural gas engine ratings are based on a fuel of 900 Btu/ft³ (35.3 MJ/nm³) SLHV, with a 91 WKI®. For conditions or fuels other than standard, consult Dresser Waukesha Application Engineering Department.

Cooling Equipment	L in (mm)	W in (mm)	H in (mm)	Avg. Wt. lb (kg)
Heat Exchanger	205 (5180)	68 (1730)	106 (2690)	24750 (11225)
Water Connection	188 (4780)	66 (1680)	106 (2690)	23750 (10775)
Radiator	217 (5510)	85 (2160)	124 (3150)	27500 (12475)



Consult your local Waukesha Distributor for system application assistance. The manufacturer reserves the right to change or modify without notice, the design or equipment specifications as herein set forth without incurring any obligation either with respect to equipment previously sold or in the process of construction except where otherwise specifically guaranteed by the manufacturer.

Bulletin 8020 1008

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DRESSER Waukesha

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