3 priedas

TECHNOLOGINĖ INFORMACIJA

Category		Title
NFR:	**1.A.4.a.i, 1.A.4.b.i, 1.A.4.c.i, 1.A.5.a**	**Small combustion**
SNAP:	**020103a** **020103b** **020106** **020202a** **020202b** **020205** **020302a** **020302b** **020305**	**Commercial/institutional — Combustion plants 20–50 MW** **Commercial/institutional — Combustion plants < 20 MW** **Commercial/institutional — Other stationary equipments** **Residential — Combustion plants 20–50 MW** **Residential — Combustion plants < 20 MW** **Residential — Other stationary equipments** **Agriculture/forestry/aquaculture — Combustion plants 20–50 MW** **Agriculture/forestry/aquaculture — Combustion plants < 20 MW** **Agriculture/forestry/aquaculture — Other stationary equipments**
ISIC:		
Version	**Guidebook 2009**	

Coordinator
Carlo Trozzi

Contributing authors (including to earlier versions of this chapter)
Krystyna Kubica, Bostjan Paradiz, Panagiota Dilara, Zbigniew Klimont, Sergey Kakareka, B. Debsk, Mike Woodfield and Robert Stewart

Table 3-35 Tier 2 emission factors for non-residential sources, gas turbines burning natural gas

Tier 2 emission factors					
	Code	Name			
NFR Source Category	1.A.4.a.i 1.A.4.b.i	Commercial / institutional: stationary Residential plants			
Fuel	Natural Gas				
SNAP (if applicable)	020104	Comm./instit. - Stationary gas turbines			
Technologies/Practices	Gas Turbines				
Region or regional conditions	NA				
Abatement technologies	NA				
Not applicable	Aldrin, Chlordane, Chlordecone, Dieldrin, Endrin, Heptachlor, Heptabromo-biphenyl, Mirex, Toxaphene, HCH, DDT, PCB, HCB, PCP, SCCP				
Not estimated	NH3, PCDD/F, Total 4 PAHs				
Pollutant	Value	Unit	95% confidence interval		Reference
			Lower	Upper	
NOx	153	g/GJ	92	245	US EPA 2000, chapter 3.1
CO	39.2	g/GJ	24	63	US EPA 2000, chapter 3.1
NMVOC	1	g/GJ	0.3	3	US EPA 2000, chapter 3.1
SOx	0.281	g/GJ	0.169	0.393	US EPA 1998, chapter 1.4
TSP	0.908	g/GJ	0.454	1.82	US EPA 2000, chapter 3.1
PM10	0.908	g/GJ	0.454	1.82	US EPA 2000, chapter 3.1
PM2.5	0.908	g/GJ	0.454	1.82	US EPA 2000, chapter 3.1
Pb	0.234	mg/GJ	0.0781	0.703	US EPA 1998, chapter 1.4
Cd	0.515	mg/GJ	0.172	1.55	US EPA 1998, chapter 1.4
Hg	0.1	mg/GJ	0.05	0.15	van der Most & Veldt 1992
As	0.0937	mg/GJ	0.0312	0.281	US EPA 1998, chapter 1.4
Cr	0.656	mg/GJ	0.219	1.97	US EPA 1998, chapter 1.4
Cu	0.398	mg/GJ	0.199	0.796	US EPA 1998, chapter 1.4
Ni	0.984	mg/GJ	0.492	1.97	US EPA 1998, chapter 1.4
Se	0.0112	mg/GJ	0.00375	0.0337	US EPA 1998, chapter 1.4
Zn	13.6	mg/GJ	4.53	40	US EPA 1998, chapter 1.4
Benzo(a)pyrene	0.562	µg/GJ	0.187	0.562	US EPA 1998, chapter 1.4 "Less than value" based on method detection limits
Benzo(b)fluoranthene	0.843	µg/GJ	0.281	0.843	US EPA 1998, chapter 1.4 "Less than value" based on method detection limits
Benzo(k)fluoranthene	0.843	µg/GJ	0.281	0.843	US EPA 1998, chapter 1.4 "Less than value" based on method detection limits
Indeno(1,2,3-cd)pyrene	0.843	µg/GJ	0.281	0.843	US EPA 1998, chapter 1.4 "Less than value" based on method detection limits

Notes:

1. Concerning the respective heating value used to convert USEPA factors, the USEPA quotes higher heating value (HHV) = 1020 MMBtu/MM scf; derived lower heating value (LHV) = 920 MMBTU/MM scf (90 % of HHV). The derivation calculations are based on 1 lb/MMscf being equivalent to 0.468 g/GJ (LHV) (note 1 MM= 1x 10^6).
2. The SO2 emission factor refers to USEPA 1998 and not USEPA 2000, as this former factor was considered to more consistent with the other USEPA factors for natural gas.

Category		Title
NFR:	**6.D**	**Other waste**
SNAP:	**091003** **091005** **091006** **091008**	**Sludge spreading** **Compost production** **Biogas production** **Other production of fuel (refuse derived fuel, etc.)**
ISIC:		
Version	**Guidebook 2009**	

Coordinator
Carlo Trozzi

Contributing authors (including to earlier versions of this chapter)
Marc Deslauriers, David R. Niemi and Mike Woodfield

Table 3-1 Tier 2 emission factors for source category 6.D Other waste, compost production

Tier 2 emission factors					
	Code	Name			
NFR Source Category	6.D	Other waste			
Fuel	NA				
SNAP (if applicable)	091005	Compost production			
Technologies/Practices	Compost production				
Region or regional conditions					
Abatement technologies					
Not applicable	NOx, CO				
Not estimated	NMVOC, SOx, TSP, PM10, PM2.5, Pb, Cd, Hg, As, Cr, Cu, Ni, Se, Zn, Aldrin, Chlordane, Chlordecone, Dieldrin, Endrin, Heptachlor, Heptabromo-biphenyl, Mirex, Toxaphene, HCH, DDT, PCB, PCDD/F, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene, Total 4 PAHs, HCB, PCP, SCCP				
Pollutant	Value	Unit	95% confidence interval		Reference
			Lower	Upper	
NH3	0.24	kg/Mg organic waste	0.1	0.7	Guidebook (2006)

Table 3-2 Tier 2 emission factors for source category 6.D Other waste, sludge spreading

Tier 2 emission factors					
	Code	Name			
NFR Source Category	6.D	Other waste			
Fuel	NA				
SNAP (if applicable)	091003	Sludge spreading			
Technologies/Practices	Sludge spreading				
Region or regional conditions					
Abatement technologies					
Not applicable	NOx, CO				
Not estimated	NMVOC, SOx, TSP, PM10, PM2.5, Pb, Cd, Hg, As, Cr, Cu, Ni, Se, Zn, Aldrin, Chlordane, Chlordecone, Dieldrin, Endrin, Heptachlor, Heptabromo-biphenyl, Mirex, Toxaphene, HCH, DDT, PCB, PCDD/F, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene, Total 4 PAHs, HCB, PCP, SCCP				
Pollutant	Value	Unit	95% confidence interval		Reference
			Lower	Upper	
NH3	50	g/kg NH3 in the sludge	10	150	Guidebook (2006)

Table 3-3 Tier 2 emission factors for source category 6.D Other waste, car fire

Tier 2 emission factors					
	Code	Name			
NFR Source Category	6.D	Other waste			
Fuel	NA				
SNAP (if applicable)					
Technologies/Practices	Car fire				
Region or regional conditions					
Abatement technologies					
Not applicable	NH3				
Not estimated	NOx, CO, NMVOC, SOx, Pb, Cd, Hg, As, Cr, Cu, Ni, Se, Zn, Aldrin, Chlordane, Chlordecone, Dieldrin, Endrin, Heptachlor, Heptabromo-biphenyl, Mirex, Toxaphene, HCH, DDT, PCB, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene, Total 4 PAHs, HCB, PCP, SCCP				
Pollutant	Value	Unit	95% confidence interval		Reference
			Lower	Upper	
TSP	2.3	kg/fire	1	5	Aasestad (2007)
PM10	2.3	kg/fire	1	5	Aasestad (2007)
PM2.5	2.3	kg/fire	1	5	Aasestad (2007)
PCDD/F	0.047	µg/fire	0.02	0.1	Aasestad (2007)

3.3.3 Abatement

A number of add-on technologies exist that are aimed at reducing the emissions of specific pollutants. The resulting emission can be calculated by replacing the technology-specific emission factor with an abated emission factor as given in the formula:

$$EF_{technology,abated} = (1-\eta_{abatement}) \times EF_{technology,unabated} \qquad (3)$$

3.3.3.1 Compost production

This section provides the abatement efficiency for compost production using a bio filter.

Table 3-8 Abatement efficiencies ($\eta_{abatement}$) for source category 6.D Other waste, compost production

Tier 2 Abatement efficiencies						
	Code	Name				
NFR Source Category	6.D	Other waste				
Fuel	NA	not applicable				
SNAP (if applicable)	091005	Compost production from waste				
Abatement technology	Pollutant	Efficiency	95% confidence interval		Reference	
		Default Value	Lower	Upper		
Biofilter	NH3	90%	70%	97%	Guidebook (2006)	
Not applicable: NOx; CO; SOx; TSP; PM10; PM2.5; As; Cr; Cd; Cu; Hg; Ni; Pb; Se; Zn; Aldrin; Chlordane; Chlordecone; Dieldrin; Endrin; Heptachlor; Heptabromo-biphenyl; Mirex; Toxaphene; HCH; DDT; PCB; benzo(a)pyrene; benzo(b)fluoranthene; benzo(k)fluoranthene; indeno(1,2,3-cd)pyrene; PCDD/F; PCP; SCCP						
Not estimated: NMVOC; Total PAH						

3.3.4 Activity data

For compost production, the standard statistics on amounts of organic domestic waste produced may be used to estimate the emissions.

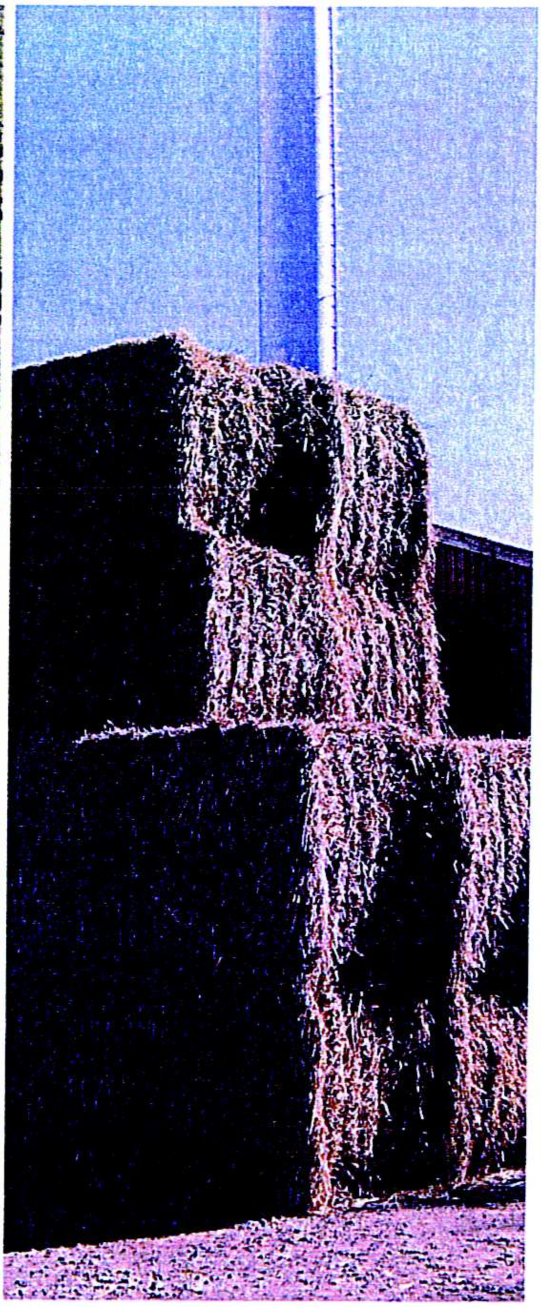
For sludge spreading, the relevant activity statistics are the standard statistics on sludge production and the fraction that is dried by spreading.

3.4 Tier 3 emission modelling and use of facility data

Not available for this source.

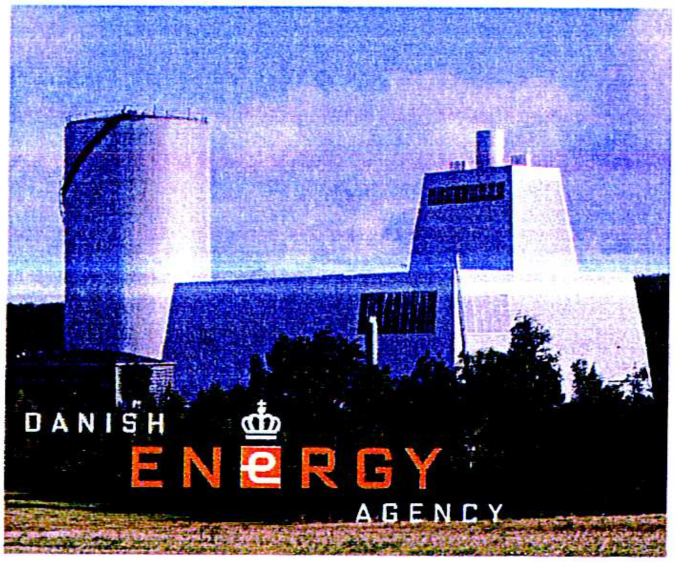
4 Data quality

No source specific issues are applicable to this source category.



Technology Data for Energy Plants

June 2010



13 CENTRALISED BIOGAS PLANTS

Brief technology description
Animal manure from a number of farms and organic waste from food processing and other industries are transported to a plant. The biomass is either transported by road or pumped in pipes. At the plant, the biomass is treated in an anaerobic process, which generates biogas. The biogas is converted into heat and power in a CHP plant. The CHP plant can either be located at the biogas plant, or it can be an external plant to where the gas is piped.

The biomass is received and stored in pre-storage tanks. Danish plants use continuous digestion in fully agitated digesters. This implies removing a quantity of digested biomass from the digesters and replacing it with a corresponding quantity of fresh biomass, typically several times a day. The digesters are heated to either 35 - 40 °C (mesophilic digestion) or 50 - 55 °C (thermophilic digestion).

This technology sheet does not include single-farm biogas digesters, biogas from wastewater treatment plants and landfill sites.

Input
Bio-degradable organic waste without environmentally harmful components. Typically, animal manure (80 - 90 %) and organic waste from industry (10 - 20 %). Sludge from sewage treatment plants and the organic fraction of household waste may also be used.

Rules for using animal products have been tightened by EU Directive 1774/2002 of 3 October 2002, amended by Directive 808/2003 of 12 May 2003.

Output
Biogas containing 60-70% methane (CH_4), 30-40% carbon dioxide (CO_2) and < 500 ppm H_2S (after gas cleaning).

Methane has a lower heating value 35.9 MJ/Nm^3. Biogas with 65% methane thus has a heating value of 23.3 MJ/Nm^3.

For biogas plants based on energy crops, the methane content may be as low as 50% (ref. 3).

The data presented in this technology sheet assume that the biogas is used as fuel in an engine, which produces electricity and heat, or sold to a third party. However, the gas may also be injected into the natural gas grid or used as fuel for vehicles, cf. Technology sheet no. 70 on biogas upgrading.

The digested biomass is used as fertiliser in crop production.

The output of biogas depends much on the amount and quality of supplied organic waste. For manure the gas output typically is 14 – 14.5 m^3 methane per tonne, while the gas output typically is 30 – 130 m^3 methane per tonne for industrial waste.

Typical capacities
There are about 20 centralised biogas plants in operation in Denmark. The average daily input is 50 – 600 tonnes raw material, typically delivered by 10 – 100 farms. The average daily yield is 1,000 – 25,000 Nm^3 biogas, which can be converted to 0.1 – 3 MW electricity. Due to economy-of-scale, the trend is towards larger plants.

Regulation ability
A typical biogas plant can regulate the production approximately +/- 15% within a day by adjusting the feed pumps (ref. 2). Also, a typical plant has a gas store of approximately a half day's production. Thus, gas supply can normally match demand variations within the day.

Biogas production may be increased during winter, when the energy demand is high, by adding organic materials with high methane potential, e.g. silage from energy crops, glycerol (residue from production of biodiesel), solid manure or garden waste. However, there is a biological limit to how fast the production can be regulated. A biogas plant digesting only animal slurry during summer, may thus increase the gas yield from 14-14.5 m^3 methane per tonne to about 45-50 m^3 methane per tonne during a period of 3 to 4 weeks (ref. 2).

The additional income from gas sales may not balance the extra costs of storing feedstock and digested biomass. Also, the emission of greenhouse gasses may increase (ref. 4).

Environment
The biogas is a CO_2-neutral fuel. Also, without biogas fermentation significant amounts of the greenhouse gas methane will be emitted to the atmosphere. For biogas plants in Denmark the CO_2 mitigation cost has been determined to approx. 5 € per tonne CO_2-equivalent (ref. 1).

The anaerobic treated organic waste product is almost odour free compared to raw organic waste.

Advantages/disadvantages
- The CO_2 abatement cost is quite low, since methane emission is mitigated.
- Saved expenses in manure handling and storage; provided separation is included and externalities are monetised.
- Environmentally critical nutrients, primarily nitrogen and phosphorus, can be redistributed from overloaded farmlands to other areas.
- The fertilizer value of the digested biomass is better than the raw materials. The fertilizer value is also better known, and it is therefore easier to distribute the right amounts on the farmlands.
- Compared with other forms of waste handling, biogas digestion of solid biomass has the advantage of recycling nutrients to the farmland – in an economically and environmentally sound way.

Research and development
Lack of sufficient organic industrial wastes can become a barrier as more centralised biogas plants are established. Therefore, the main objective of the Danish biogas R&D activities (ref. 5) is to improve

the plants to become economically attractive either digesting only manure or by adding less attractive organic wastes with more secure supplies in the long term.

References

1. Danish Climate Strategy, Ministry of Environment, February 2003.
2. Danish Energy Agency, 2009.
3. Danish Gas Technology Centre, 2009.
4. "Øget produktion og anvendelse af biogas i Danmark" (Increased production and use of biogas in Denmark; in Danish), Danish Gas Technology Centre, 2009.
5. "Forsknings- og udviklingsstrategi for biogas" (Research and development strategy for biogas; in Danish), Danish Energy Agency, Energy Technology Development Programme (EUDP) and Energinet.dk, August 2009.

Technology	Centralised Biogas Plant with CHP					
	2010	2020	2030	2050	Note	Ref
Energy/technical data						
Daily input of manure & organic waste in tonnes	300					1
Biogas output Nm3/m3 raw material	30 - 40	28 - 35	28 - 35		C	7
Electricity efficiency (%) net	40 - 45	43 - 48	45 - 50		E	
Electricity generating capacity (MW)	1.5	1.4	1.5		F	
Heat generation capacity (MJ/s)	1.7	1.4	1.4		E	
Availability (%)	98					4
Technical lifetime (years)	20					2
Construction time (years)	1					2
Own electricity consumption, kWh per ton biomass	6					1
Own heat consumption, kWh per m3 of raw material	34					5
Environment, biogas plant including co-generation						
SO2 (g per GJ fuel)	19.2	19.2	19.2	19.2		8;3;3;3
SO_2 (degree of desulphurisation, %)	0	0	0	0		3
NO_X (g per GJ fuel)	540	540	540	540		8;3;3;3
CH4 (g per GJ fuel)	323	323	323	323		8;3;3;3
N2O (g per GJ fuel)	0.5	0.5	0.5	0.5		8;3;3;3
Financial data						
Total plant investment, excl. transport equipment and co-generation plant (M€)	5.7	5.0	5.0		A+B;D	7
Total investment, co-generation plant (M€)	0.24	0.24	0.24		D	1
Specific investment, incl. co-generation plant (M€/MW)	5.9	5.2	5.2		D	
Total O&M (€/tonnes supplied raw material), excl. transport	2.9	2.9	2.9		D	7
Total O&M (€/MWh)	33	33	33		D	

References:

1 Samfundsøkonomiske analyser af biogasfællesanlæg 2002. Fødevareøkonomisk Institut. Rapport 136
2 "Teknologidata for vedvarende energianlæg, Del 2, Biomasseteknologier. Danish Energy Agency, 1996.
3 Danish Energy Agency, 2009.
4 Lemvig Biogas Plant
5 Ramboll estimates based on monthly biogas data from Danish Energy Agency
6 Varme Ståbi
7 Danish Energy Agency, 2003.
8 National Environmental Research Institute, Denmark, 2009 (data from 2007).

Notes:

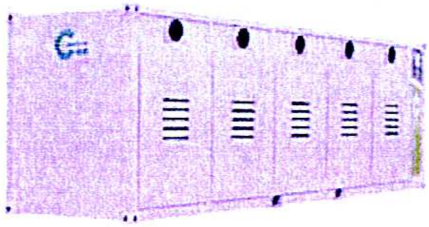
A Transport is typically 1.6-2.4 €/tonne; average distance between farms and plant 4-8 km.
B The deceasing investment costs presume an escalated market
C The output figures are estimated avarages for Danish conditions, recognizing the limited availability of industrial wastes
D Cost data are the same as in the 2005 catalogue, however inflated from price level 2002 to 2008 by multiplying by a factor 1.1876 for investment costs and 1.1672 for O&M costs.
E Assumed same efficiencies as Technology element '06 Gas engines'
F Assumed that 10% of the gas is used for process heating, and that the engine operates 6500 hours/year.

CR800 800kW Power Package
Renewable Fuels

Capstone

World's largest air-bearing turbine system produces 800kW of clean, green, and reliable power.

- High electrical efficiency over a very wide operating range
- Low-maintenance air bearings require no lube oil or coolant
- Ultra-low emissions
- High availability – part load redundancy
- Proven technology with tens of millions of operating hours
- Integrated utility synchronization and protection with a modular design
- 5 and 9 year Factory Protection Plans available
- Upgradable to 1MW with field installed Capstone 200kW power module
- Remote monitoring and diagnostic capabilities



CR800 Power Package

Electrical Performance[1]

Electrical Power Output	800kW
Voltage	400–480 VAC
Electrical Service	3-Phase, 4 wire
Frequency	50/60 Hz, grid connect operation
Maximum Output Current	1,160A RMS @ 400V, grid connect operation
	960A RMS @ 480V, grid connect operation
Electrical Efficiency LHV	33%

Fuel/Engine Characteristics[1]

Landfill Gas HHV	13.0–22.3 MJ/m³ (350–600 BTU/scf)
Digester Gas HHV	20.5–32.6 MJ/m³ (550–875 BTU/scf)
Inlet Pressure	517–552 kPa gauge (75–80 psig)
Fuel Flow HHV	9,600 MJ/hr (9,120,000 BTU/hr)
Net Heat Rate LHV	10.9 MJ/kWh (10,300 BTU/kWh)
H_2S Content	< 5,000 ppm

Exhaust Characteristics[1]

NOx Emissions @ 15% O_2[2]	< 9 ppmvd (18 mg/m³)
NOx / Electrical Output[2]	0.14 g/bhp-hr (0.4 lb/MWhe)
Exhaust Gas Flow	5.3 kg/s (11.7 lbm/s)
Exhaust Gas Temperature	280°C (535°F)
Exhaust Energy	5,680 MJ/hr (5,400,000 BTU/hr)

Reliable power when and where you need it. Clean and simple.

Dimensions & Weight[3]

Width x Depth x Height	2.4 x 9.1 x 2.9 m (96 x 360 x 114 in)
Weight - Grid Connect Model	12084 kg (32,300 lbs)

Minimum Clearance Requirements[4]

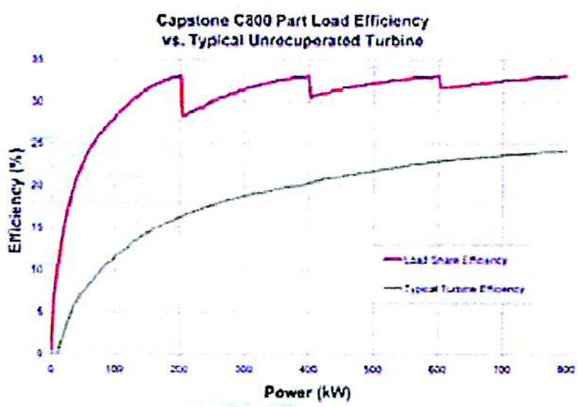
Vertical Clearance	0.6 m (24 in)
Horizontal Clearance	
Left & Right	1.5 m (60 in)
Front	1.5 m (60 in)
Rear	1.8 m (72 in)

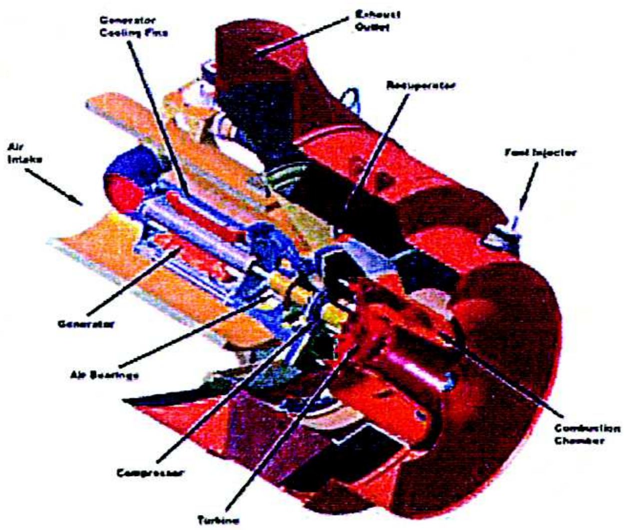
Sound Levels

Acoustic Emissions at Full Load Power	
Nominal at 10 m (33 ft)	65 dBA

Planned Certifications

- Will comply with UL 2200 and UL 1741 for raw natural gas and biogas operation under existing UL files[5]
- Will comply with IEEE 1547 and will meet statewide utility interconnection requirements for California Rule 21 and the New York State Public Service Commission
- Models will be available with optional equipment for CE marking
- Models will be available with optional 2008 CARB certification for waste gas





C200 Engine

(1) Nominal full power performance at ISO conditions: 59°F, 14.696 psia, 60% RH
(2) For surrogate landfill and digester gases. Please contact Capstone for additional details
(3) Approximate dimensions and weights
(4) Clearance requirements may increase due to local code considerations
(5) All models are planned to be UL Listed or available with optional equipment for CE marking

Specifications are not warranted and are subject to change without notice.

Capstone

21211 Nordhoff Street • Chatsworth • CA • 91311 • 866.422.7786 • 818.734.5300 • www.capstoneturbine.com
 P0911 CR800 800kW Power Package Renewable Fuels Data Sheet CAP160 | Capstone P/N 331055C