Distributed Generation (DG) MSBACT (HBL Feb 2004)

Concept: Update MSBACT for DG to meet limits required in CARB DG certification program starting 1/1/2007.
New subcategory: ICE, Stationary, Non-Emergency On-Site Electricity Generation
New subcategory: Gas Turbine, Natural Gas Fired, Non-Emergency On-Site Electricity Generation
Add footnotes-does not apply to plants intended primarily for sale of power to the electrical grid.
Set ppm limits based on following lb/MWh: Nox-.07, CO-0.1, VOC-.02 and give CHP credit at 1 MWh per 3.4 MMBtu.
Keep NH3 limit at 10 for ICE and 9 for gas turbine. For ICE keep references to Clean Fuels Policy for Sox and PM10.
Technical basis will be KHI 1.5 MW gas turbine and fuel cell for smaller needs.
Base Nox, CO and VOC ppm limits and CHP ppm credits on KHI efficiency: 16 MMBtu/MWh (HHV)

	lb/MWh	ppm	ppm-25%CHP	ppm/%CHP
Nox	0.07	1.17	2.54	0.055
CO	0.1	2.74	5.96	0.129
VOC	0.02	0.96	2.09	0.045

KHI Gas Turbine:
Brochure: Output-1423 kW (at 59F amb.), fuel-20.7MMBtu/hr (LHV, 59F), heat recovery-53.7%, Nox<3, CO<10, UHC<2
Sales Dept. (Sept 2002): will guarantee 2.5 Nox, 6 CO down to 70% load.
CEC RAMD test (Phase III, last 700 hrs): Nox 1.5, CO 5.5, THC 3.5
CARB Precertification (6-mo. test): Nox 2.5, CO 6 (98+ load)
USEPA test (2-day test): 1.15 Nox (98+% load)

	ppm-15	lb/MWh	Required	% Heat Recov. Needed
Nox	2.5	0.150	0.07	26.7
CO	6	0.219	0.1	27.8
VOC	2	0.042	0.02	25.4

Conclusion: CHP version of KHI should meet CARB 2007 certification requirements (large cogen plants ok too).
To meet the requirements without CHP would require Nox, CO, VOC of about 1, 3, 1 ppm.

Cost Analysis:

Technology	Unc ICE	Rich, 3-way	Fuel Cell	Unc ICE	Rich, 3-way	KHI	Unc ICE	SCR+CatOx	KHI
MW	0.5	0.5	0.5	1.5	1.5	1.5	3	3	3
hrs/yr	8760	8760	8760	8760	8760	8760	8760	8760	8760
Installed Cost	650,000	672,500	2,156,981	1,425,000	1,492,500	2,190,750	2,700,000	2,983,144	4,381,500
Maintenance	65,700	76,889	65,700	197,100	230,668	174,105	394,200	458,809	348,210
Elec Effic HHV	33	33	40	33	33	21.3	33	33	21.3
Thermal Effic HHV	41.5	41.5	37.2	41.5	41.5	48.8	41.5	41.5	48.8
Fuel Cost	119,778	119,778	109,968	261,335	261,335	328,456	522,669	522,669	656,911
10-yr PV (Avg)			**1,424,183**			**1,138,173**			**2,426,346**
10-yr PV (Incr)			**1,307,244**			**787,356**			**1,597,904**
lb/MWH:									
NOx	8	0.466	0.07	3	0.466	0.150	2	0.349	0.150
CO	8	1.864	0.04	8	1.864	0.219	8	0.779	0.219
VOC	2	0.466	0.01	2	0.466	0.042	2	0.337	0.042
NH3	0	0	0	0	0	0	0	0.143	0
10-yr tons:									
Nox	175.2	10.21	1.53	197.1	30.62	9.86	262.80	45.87	19.71
CO	175.2	40.82	0.88	525.6	122.47	14.39	1051.20	102.37	28.78
VOC	43.8	10.21	0.22	131.4	30.62	2.76	262.8	44.32	5.52
NH3	0	0	0	0	0	0	0	18.83	0.00
Boiler NOx, 10-yr tons	-1.76	-1.76	-1.30	-5.29	-5.29	-9.63	-10.58	-10.58	-19.27
Boiler CO, 10-yr tons	-4.47	-4.47	-3.31	-13.42	-13.42	-24.43	-26.85	-26.85	-48.86
Total 10-yr tons:									
NOx	173.44	8.44	0.23	191.81	25.33	0.22	252.22	35.28	0.44
CO	170.73	36.35	-2.43	512.18	109.05	-10.04	1024.35	75.52	-20.08
VOC	43.80	10.21	0.22	131.40	30.62	2.76	262.80	44.32	5.52
NH3	0	0	0	0	0	0	0	18.83	0.00
Max 10-yr (Avg)			**4,257,837**			**6,466,704**			**10,423,669**
Max 10-yr (Incr)			**1,122,322**			**3,269,596**			**4,716,162**
Pass/Fail (Avg)			**PASS**			**PASS**			**PASS**
Pass/Fail (Incr)			**FAIL**			**PASS**			**PASS**

Notes: Next Sheet

Effect of 50% Increase in Price of Gas:			
10-yr PV (Avg)	**1,382,783**	**1,421,423**	**2,992,846**
10-yr PV (Incr)	**1,265,844**	**1,070,607**	**2,164,405**
Pass/Fail (Avg)	**PASS**	**PASS**	**PASS**
Pass/Fail (Incr)	**FAIL**	**PASS**	**PASS**

Conclusion:
The concept is ok for 1.5 MW and above but cannot be required for systems smaller than this threshhold.
In cases where there is no opportunity for CHP, the 2007 limits cannot be met by any proven, cost-effective technology.

Notes:

Costs for ICE and gas turbine are from "Analysis of Cost Effectiveness of Future Compliance with Proposed 2007 Emission Limits for Distributed Generation", The Energy Foundation, September 2003, Appendix 1, Exhibit 4 (Installed Costs, Incl CHP

Cost of 3-way cat for ICE from "Analysis of…", Exhibit 9: $45/kW. Assume rich-burn engine cost same as lean-burn engine based on Exhibit 4.

Cost of SCR and CatOx system for ICE: from "Analysis of…", App 3, $/kW (installed) =111@2000, 135@1350, 169@800

Cost of catalytic combustion unit for 1.5 MW gas turbine from same reference, Appendix 3: $240,750 (installed)

Cost of fuel cell system: $4000/kW installed w/o CHP (UCI Fuel Cell Collaborative cost study)
plus $160,000 for CHP system based on AQMD microturbine project (480 kW heat recov)…scale to (Heat Recovery)^0.6

Maintenance costs for base equipt, "Distributed Generation: A Non-Technical Guide", Ann Chambers, PennWell 2001, page 5
mils/kWh: 15 for ICE, 10 for turbines, 15 for fuel cells

Maintenance costs of add-on emission controls from "Analysis of…", Appendix 3
3-way catalyst for 375 kW engine/gen: $.083/hr + $6563 cat replacement ev 20,000 hrs….scale to kW
SCR + CatOx for 2 MW engine: $58,539 cat replacement ev 20,000 hrs, $0.17/hr mntnc, $1.82/hr urea…scale to k
Catalytic combustor for 1.5 MW gas turbine: $0.5/hr + $52,500 cat replacement ev 12,000 hrs

Electrical efficiency of ICE and fuel cell, from "Analysis of…", Exhibit 5

Electrical efficiency of gas turbine, from KHI brochure: 21.3% (HHV)

Thermal efficiency of KHI CHP system, from brochure: 48.8% (HHV) (62% of waste heat is recovered).

Thermal efficiency of ICE and fuel cell CHP systems, assume same waste heat recovery efficiency as KHI system (62%)

Fuel cost: $/MMBtu-assume $4 for >= 1 MW and $5.50for <1 MW (as in "Analysis of…")
and recovered waste heat displaces gas from 80%-efficient boiler.

Ten-year present value calculation: used 4% discount rate.

Emission rates (lb/MWH) from uncontrolled ICE and fuel cell: from "Analysis of…", Exhibits 6, 7, 8

Emission rates (lb/MWH) from controlled ICE: based on MSBACT for gas engine, assuming 95% mechanical efficiency.
For <2064 bhp: 0.15 Nox, 0.15 VOC, 0.6 CO (g/hp-hr)
For >=2064 bhp: 9 ppm Nox, 25 ppm VOC, 33 ppm CO, 10 ppm NH3 (ppmvd@15%O2)

Emission rates (lb/MWH) from KHI system: based on ppm guarantees now offered (2.5 Nox, 6 CO, 2 VOC) and electrical efficiency from brochure.

Emission reductions from boiler assume boiler emission rates of 12 ppm Nox and 50 ppm CO (ppmvd@3%O2).

Max 10-yr present values are based on AQMD BACT cost effectiveness criteria ($/ton pollutant reduction):
NOx-19,100, CO-400, VOC-20,200, PM10-4,500.

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