CYCLING CO2 EMISSIONS AND FUEL COST by Willem Post; dated June 30, 2011

Wind Energy Pene-tration	Wind Facility Capacity	Wind Energy	Cycling Energy	NEEG Annual Energy	NEEG Base-Loaded Energy Plus Wind & Cycling Energy	NEEG Non-Base Load Energy	NEEG Energy For Daily Load Following	NEEG Energy Available For Cycling	Alt No. 1 Cycling Facility CO2	Alt No.2 CCGT Facility CO2	CO2 Emission Decrease	Alt No. 1 Cycling Facility Fuel Cost	Alt No.2 CCGT Facility Fuel Cost	Fuel Cost Decrease	Fuel Cost Decrease Per kWh of Wind	Fuel Cost Decrease Per kWh of NEEG	Wind Energy Accom Fee	Wind Energy Accom Fee Per kWh of NEEG	Wind Energy W'sale Value	Wind Energy Retail Value	NEEG Energy W'sale Value	NEEG Energy Retail Value
%	MW	GWh/yr	GWh/yr	GWh/yr	GWh/yr	GWh/yr	GWh/yr	GWh/yr	millions lb/yr	millions lb/yr	millions lb/yr	millions $/yr	millions $/yr	millions $/yr	$/kWh	$/kWh	millions $/yr	$/kWh	millions $/yr	millions $/yr	millions $/yr	millions $/yr
0.5	239	650	1447	130000	72297	57703	39000	18703	1518	1551	33	52	53	1.1	0.0017	0.00001	2.1	0.00002	43	91	8502	18200
1	479	1300	2894	130000	74394	54306	39000	15306	3035	3101	66	104	106	2.3	0.0017	0.00002	4.2	0.00003	85	182	8502	18200
2	957	2600	5787	130000	78587	48813	39000	9813	6070	6202	132	208	212	4.5	0.0017	0.00003	8.5	0.00007	170	364	8502	18200
3	1436	3900	8681	130000	82781	43319	39000	4319	9105	9303	198	311	318	6.8	0.0017	0.00005	12.7	0.00010	255	546	8502	18200
4	1915	5200	11574	130000	86974	37826	39000	-1174	12140	12404	264	415	424	9.0	0.0017	0.00007	17.0	0.00013	340	728	8502	18200
5	2394	6500	14468	130000	91168	32332	39000	-6668	15175	15505	330	519	530	11.3	0.0017	0.00009	21.2	0.00016	425	910	8502	18200
6	2872	7800	17361	130000	95361	26839	39000	-12161	18210	18606	396	623	636	13.5	0.0017	0.00010	25.5	0.00020	510	1092	8502	18200
7	3351	9100	20255	130000	99555	21345	39000	-17655	21245	21707	462	726	742	15.8	0.0017	0.00012	29.7	0.00023	595	1274	8502	18200
8	3830	10400	23148	130000	103748	15852	39000	-23148	24280	24808	528	830	848	18.1	0.0017	0.00014	33.9	0.00026	680	1456	8502	18200
9	4308	11700	26042	130000	107942	10358	39000	-28642	27315	27910	594	934	954	20.3	0.0017	0.00016	38.2	0.00029	765	1638	8502	18200
10	4787	13000	28935	130000	112135	4865	39000	-34135	30350	31011	660	1038	1060	22.6	0.0017	0.00017	42.4	0.00033	850	1820	8502	18200
11	5266	14300	31829	130000	116329	-629	39000	-39629	33385	34112	726	1141	1166	24.8	0.0017	0.00019	46.7	0.00036	935	2002	8502	18200
12	5745	15600	34723	130000	120523	-6123	39000	-45123	36420	37213	793	1245	1272	27.1	0.0017	0.00021	50.9	0.00039	1020	2184	8502	18200
13	6223	16900	37616	130000	124716	-11616	39000	-50616	39455	40314	859	1349	1378	29.4	0.0017	0.00023	55.1	0.00042	1105	2366	8502	18200
14	6702	18200	40510	130000	128910	-17110	39000	-56110	42490	43415	925	1453	1484	31.6	0.0017	0.00024	59.4	0.00046	1190	2548	8502	18200
15	7181	19500	43403	130000	133103	-22603	39000	-61603	45525	46516	991	1556	1590	33.9	0.0017	0.00026	63.6	0.00049	1275	2730	8502	18200
16	7659	20800	46297	130000	137297	-28097	39000	-67097	48560	49617	1057	1660	1696	36.1	0.0017	0.00028	67.9	0.00052	1360	2912	8502	18200
17	8138	22100	49190	130000	141490	-33590	39000	-72590	51595	52718	1123	1764	1802	38.4	0.0017	0.00030	72.1	0.00055	1445	3094	8502	18200
18	8617	23400	52084	130000	145684	-39084	39000	-78084	54630	55819	1189	1868	1908	40.6	0.0017	0.00031	76.4	0.00059	1530	3276	8502	18200
19	9096	24700	54977	130000	149877	-44577	39000	-83577	57665	58920	1255	1971	2014	42.9	0.0017	0.00033	80.6	0.00062	1615	3458	8502	18200
20	9574	26000	57871	130000	154071	-50071	39000	-89071	60700	62021	1321	2075	2120	45.2	0.0017	0.00035	84.8	0.00065	1700	3640	8502	18200
20.9	10000	27156	60444	130000	157800	-54956	39000	-93956	63399	64779	1380	2167	2215	47.2	0.0017	0.00036	88.6	0.00068	1776	3802	8502	18200

The 0.5% penetration is the NEEG existing condition

The 20.9% penetration is the subject of the article 'Wind Power and CO2 Emissions"

							Alternative No.1		Alternative No. 2	
							Cycling		Base/Part-Load	
		Btu/kWh	Efficiency	Cycling	Part-Load		Heat	CO2	Heat	CO2
			Rated	Degrade	Degrade		Rate		Rate	
			Output	Factor	Factor					
Wind facility	130000*1000/(8760*0.31)*0.5/100 = 239									
Wind energy	239*8760*0.31/1000 = 650									
Cycling energy	239*8760*(1-0.31)/1000 = 1447									
Cycling facility CO2	1447*1000000*(0.3*1.426 + 0.7*0.908)/1000000 = 1518									
CCGT facility CO2	(650+1447)*1000000*0.739/1000000 = 1551									
Cycling facility fuel cost	1447*(0.3*13497+0.7*7023)*4/1000000) = 52									
CCGT facility fuel cost	(650+1447)*6320*4/1000000 = 53	CCGT	3413	0.60	0.90	0.90	7023	0.822	6320	0.739
		OCGT	3413	0.35	0.85	0.85	13497	1.579	11472	1.342
NEEG annual energy	130000									
Base-loaded energy + (wind and balancing). See notes	0.54*130000+650+1447 = 72297									
Not base-loaded energy, utility-owned	130000-72297 = 57703									
Energy for daily load following. See notes	0.30*130000 = 39000									
Variable energy available for cycling	57703-39000 = 18703									
Max wind energy penetration based on available cycling energy	3%									
Wind energy accommodation fee	650*(-0.0017+0.005) = 2.1	$0.005/kWh of wind energy is asumed owning and other O&M								
Wind energy wholesale, $	650*0.0654 = 43									
Wind energy retail, $	650*0.14 = 91									
NEEG energy wholesale, $	130000*0.0654 = 8502									
NEEG energy retail, $	130000*0.14 = 18200									

1- Energy exempt from cycling is base-loaded nuclear, coal, IPP-owned hydro and gas plants, Hydro-Quebec
2- Utility-owned load following energy, aka intermediate energy, is assumed at 40% of total NEEG power.
3- ISO-NE knows the exact ownership and service status of the 350 plants tied to the NEEG
4- http://www.hartfordbusiness.com/news18883.html
5- Energy available for cycling can be increased if utility-owned base-loaded plants reduce their outputs.
6- The 20.9% wind energy penetration corresponds with 27,156 GWh/yr of wind energy from the 10,000 MW wind turbine facility.
7- Wind+Cycling energy is seen by the grid as if from a base-loaded facility
8- With about 3% wind penetration the NEEG will have no more spare energy for cycling; new OCGTs and CCGTs will be needed, if more wind turbines are added.