ENERGY CONSERVATION SOLUTIONS

IN THE UPSTREAM OIL AND GAS INDUSTRY

AN ECO-EFFICIENCY PILOT
2002-2005

APPENDIX 2

Benchmarking Results

CETAC-WEST

August 2005

A2 Benchmarking

A2.1 Indicator Format and Units

All indicators developed as part of the Key Performance Indicator portion of the Benchmarking Program were consistently based on the Energy Equivalent Production (EEP) of a facility. This practice follows the example of the World Business Council on Sustainable Development's method for benchmarking, and is somewhat different than the practice of the Voluntary Challenge Registry (VCR) as the VCR does not include fuel gas as production. EEP includes the energy content of all product streams including sales gas, fuel gas, gas liquids, oil, sulphur and exported heat and electric power.

Energy Equivalent Production is calculated using production flow rates and higher heating values (HHV) for each product stream. Reasons for including fuel gas in EEP are related to market place realities where midstream-processing plants dispose of sales gas back to upstream activities as fuel and in other operations where a facility may receive or provide gas to a totally unrelated activity to meet fuel needs.

For energy intensities, all energy consumed by an activity was converted to gigajoules (GJ) again using HHVs for fuel gas and the direct conversion of electrical energy (MWh) metered at the plant site to GJ using a conversion factor of 3.6 GJ/MWh. Power plant and transmission efficiencies were not addressed. Energy intensities were expressed as GJ (consumed) per e^3GJ (EEP) and as GJ (consumed) per GJ (EEP) as a percent (10 GJ/ e^3GJ = 1%).

For all environmental intensity indicators, the indicators were calculated as tonnes or cubic meters per thousand units of EEP. Some scaling adjustments were appropriate and applied on a case-by-case basis. Carbon Dioxide Equivalent and sulphur dioxide emissions intensity indicators were expressed as t/e^3GJ and produced water, fresh water and produced sand intensity indicators were expressed in units of m^3/e^3GJ.

The performance indicators developed are outlined in the following table:

Table A2.1: Facility Level Indicators and Definitions

KPI Name	Definition
Plant Total Energy Index (PTEI)	The sum of plant fuel gas and electric energy consumed including flaring and venting per unit of total energy production in units of GJ/10^3 GJ.
Processing Energy Index (PEI)	The sum of plant fuel gas energy and electric power purchases per unit of total energy production in units of GJ/10^3GJ.
Plant Flare Index (PFI)	The sum of raw and residue gas flared per unit of total production in units of GJ/10^3GJ.
Plant Vent Index (PVI)	Fugitive emissions from leaking and non-leaking equipment components per unit of total production in units of GJ/10^3GJ.

KPI Name	Definition
Plant Compression Index (PCompI)	Total fuel gas and electrical energy used for inlet and sales gas compression at the plant site per unit of total production in units of GJ/10^3GJ.
Processing Carbon Index (PCI)	The sum of the carbon dioxide equivalent of plant fuel gas, vent and fugitive emissions, plant flare, residual gas flared and electrical power purchases per unit of total production in units of t $CO_2E/10^3$GJ using factors provided in CAPP Pub. #2000-0004.
Plant Total Carbon Index (PTCI)	The sum of the acid gas carbon dioxide released and the carbon dioxide equivalent of plant fuel gas, vent and fugitive emissions, raw gas flared, residue (sales) gas flared and electrical power purchases per unit of total production in units of t $CO_2E/10^3$GJ using factors provided in CAPP Pub. #2000-0004.
Plant Total CO_2 Emissions	The absolute tonnes of carbon dioxide equivalent emitted at actual total production.
Plant Sulphur Index (PSI)	Emission of sulphur dioxide from all incinerators and from acid gas flaring per unit of total production in units of t $SO_2/10^3$GJ.
Plant Produced Water Index (PWpI)	The total produced water per unit of total production in units of $m^3/10^3$GJ.
Plant Fresh Water Index (PWfI)	The total fresh water consumed per unit of total production in units of $m^3/10^3$GJ.
Total Production (energy equivalent)	The energy equivalent of all residue (sales) gas, C_2, C_3, C_4 & C_5^+ liquids, sulphur and electric power exported based on plant specific energy values for all HC products and 9.24 GJ/t for sulphur. Production may be converted to oil equivalent production using 38.5 GJ/m^3OE (CAPP Pub. #2000-0004).

A2.2 Benchmarking Cluster Results

A total of 23 facilities were benchmarked and they are most appropriately discussed as clusters of plants of similar production types. For each cluster a common set of performance indicators was applied to characterize energy and environmental performance. For those facilities that participated in the pilot audit program, the fugitive emission or vent energy intensity was included in the data set.

A2.2.1 Sour Gas Facilities

The sour gas facility data set includes ten facilities with sulphur recovery and one without (Facility 22). Of these, five participated in the audit program. The facilities ranged in size from very small to very large, from basic to complex and exhibited a wide range in raw gas composition resulting in very different equipment types and gas liquid product yields.

The benchmarking results for the sour gas plants are summarized in Table A2.2.

Table A2.2: Benchmarking Results for Sour Gas Facilities

Facility	Size E^3GJ/d	PTEI GJ/GJ%	PEI GJ/GJ%	CompEI GJ/GJ%	PFI GJ/GJ%	PVI GJ/GJ%	PCI tCO_2/e^3GJ	PSI tSO_2/e^3GJ	PWpI m^3/e^3GJ	PWfI m^3/e^3GJ
1	107.6	2.934	2.605	0.725	0.199	0.0580	2.28	0.0038	1.630	0.880
2	91.3	9.110	6.914	1.921	0.250	0.0245	3.80	0.124	0.695	0.567
3	456.6	3.131	2.625	0.406	0.098	0.0018	1.45	0.077	0.200	0.153
4	317.7	2.851	2.698		0.153		1.58	0.043	0.233	
5	371.2	3.923	3.912		0.011		3.13	0.029		
6	180.5	11.603	11.260	0.109	0.234		6.86	0.168		
7	349.9	4.242	4.170	0.007	0.065		2.17	0.0039	1.169	5.300
8	162.1	3.797	3.509	0.203	0.085		2.54	0.039	0.218	0.379
12	118.0	3.092	3.030	0.060	0.0018		1.61	0.057	0.009	
13	74.7	3.038	1.911	0.687	0.312	0.0127	1.49	0.053	1.050	
22	50.2	6.340	5.010	1.110	0.220		10.02	0.0099	0.0	0.0
Average	207.3	4.405	4.049	0.382	0.112	0.014	2.690	0.053	0.489	1.751

Notes: 1. Blanks mean no production data available for item
2. Zero means no consumption or production of item
3. Averages are production weighted

Table A2.2 results demonstrate that each plant operates as an independent entity and its performance is not related to that of another plant. Each plant's performance is defined by is own characteristics even though each plant is processing sour gas and recovering sulphur (except for Facility 22).

As a group or cluster, the range in performance and the production-weighted average for the cluster can be observed. It should not be concluded that all plants could be optimized to achieve the same level of energy or environmental intensity. However, for a selected item such as flaring, one can use average performance as a guide to set a target for improved performance for facilities with high Plant Flare Intensities (PFI).

Plant Total Energy Intensity (PTEI), Processing Energy Intensity (PEI) and Plant Flare Intensity (FEI) for this cluster are shown in the following figures.

Figure A2.1: Sour Gas Cluster Plant Total Energy Index

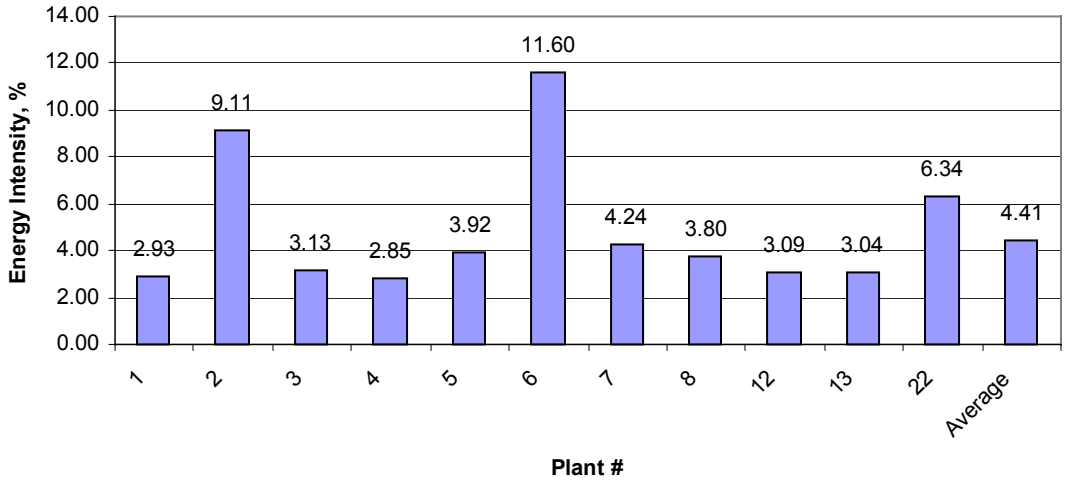


Figure A2.2: Sour Gas Cluster Processing Energy Index

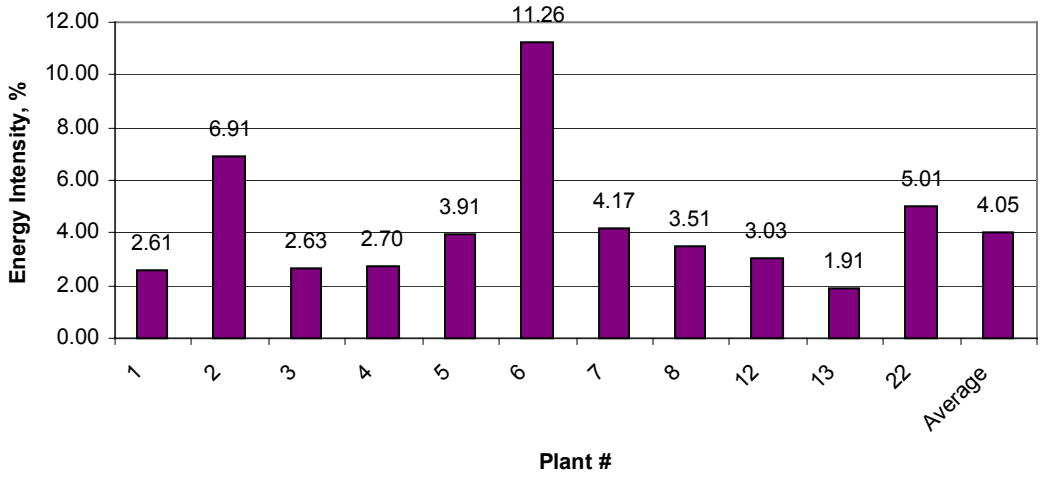
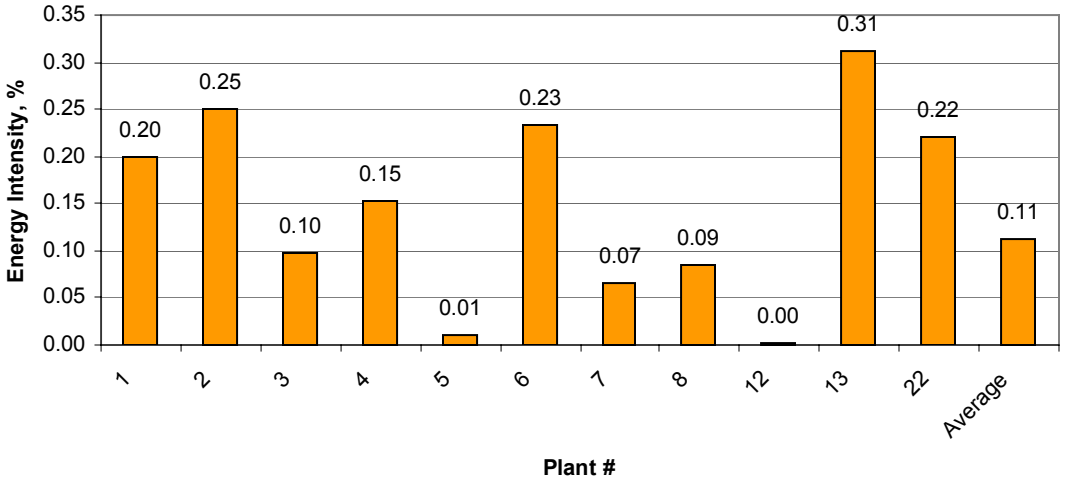


Figure A2.3: Sour Gas Cluster Plant Flare Intensity



A2.2.2 Sweet Gas Facilities

The sweet gas facility data set includes two facilities and of these one participated in the audit program. The sample size is very small.

The benchmarking results for these plants are summarized in Table A2.3.

Table A2.3: Benchmarking Results for Sweet Gas Facilities

Facility	Size e^3GJ/d	PTEI GJ/GJ%	PEI GJ/GJ%	CompEI GJ/GJ%	PFI GJ/GJ%	PVI GJ/GJ%	PCI tCO_2/e^3GJ	PSI tSO_2/e^3GJ	PWpI m^3/e^3GJ	PWfI m^3/e^3GJ
9	111.5	2.782	2.718		0.063		1.55	0.0		
21	25.0	2.210	0.000	2.21	0.000	0.09	1.22	0.0	0.0	0.0
Average	68.3	2.677	2.220	0.405	0.051	0.090	1.490	0.0	0.0	0.0

Note: 1. Blanks mean no production data available for item
2. Zero means no consumption or production of item
3. Averages are production weighted

Plant Total Energy Intensity (PTEI), Processing Energy Intensity (PEI) and Flare Energy Intensity (FEI) for this cluster are shown in the following Figures.

Table A2.4: Sweet Gas Cluster Plant Total Energy Intensity

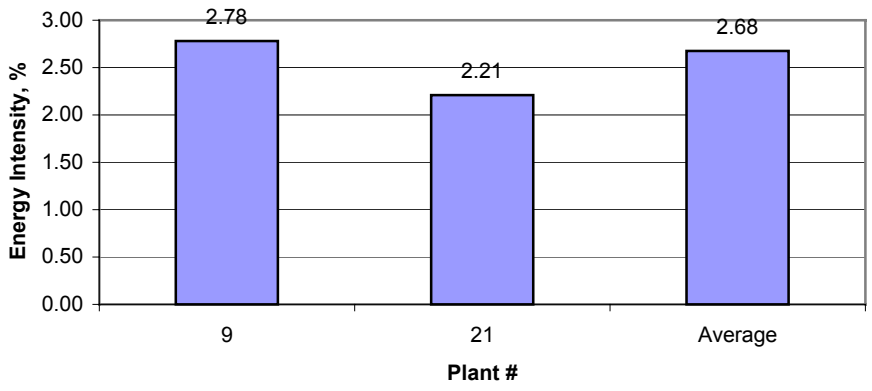


Table A2.5: Sweet Gas Cluster Processing Energy Intensity

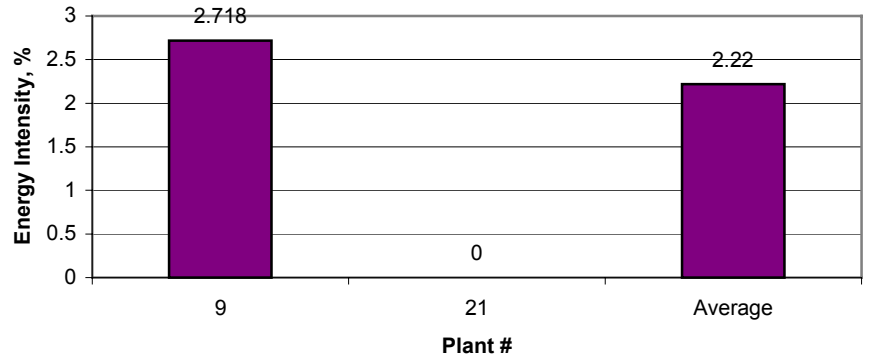
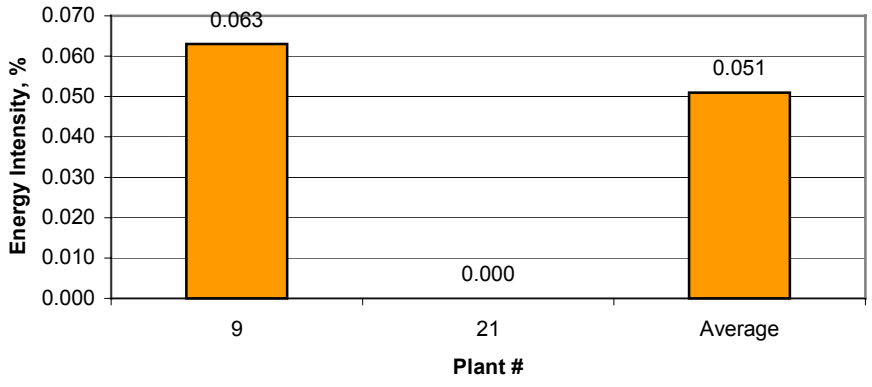


Figure A2.6: Sweet Gas Cluster Plant Flare Intensity



A2.2.3 Conventional Oil and Solution Gas Facilities

The conventional oil and gas facility data set includes eight facilities and of these seven participated in the audit program. The facilities are very diverse; they ranged in size from very small to large, from basic to complex and exhibited a wide range in oil content and raw gas composition resulting in very different equipment types and gas liquid product yields. Some of these facilities included gas re-injection to maintain reservoir pressure for oil recovery as required by provincial regulators. This activity has a significant impact on energy intensity.

The benchmarking results for these plants are summarized in Table A2.4.

Table A2.4: Benchmarking Results for Conventional Oil and Gas Facilities

Facility	Size e^3GJ/d	PTEI GJ/GJ%	PEI GJ/GJ%	CompEI GJ/GJ%	PFI GJ/GJ%	PVI GJ/GJ%	PCI tCO_2/e^3GJ	PSI tSO_2/e^3GJ	PWpI m^3/e^3GJ	PWfI m^3/e^3GJ
10	6.3	6.89	4.32	2.39	0.039	0.144	2.65		0.258	0.0
11	171.9	4.93	3.62	1.11	.019	0.025	2.96		50.4	22.6
16	4.0	0.85	0.85		0.0		1.06	0.0005	1306.0	0.0
17	8.3	4.90	2.07	1.47	1.37	0.0026	6.46	0.031	421.5	0.0
19	5.2	6.05	3.14	1.76	2.91	0.00004	3.23	0.0	0.0	0.0
20	5.8	2.86	2.76		0.0	0.09	1.50	0.0	0.13	0.0
23	10.7	5.94	1.12	0.67	3.23	0.91	6.03	0.00007	111.4	0.0
24	30.8	3.70	1.16	2.25	0.16	0.13	4.56	0.0	0.0	0.0
Average	254.6	4.484	4.163	0.366	0.108	0.014	2.615	0.054	0.516	1.826

Note: 1. Blanks mean no production data available for item
2. Zero means no consumption or production of item
3. Averages are production weighted

Plant Total Energy Intensity (PTEI), Processing Energy Intensity (PEI) and Flare Energy Intensity (FEI) for the Conventional Oil and Solution Gas Cluster are displayed in the following figures.

Figure A2.7: Oil and Sol'n Gas Cluster Plant Total Energy Intensity

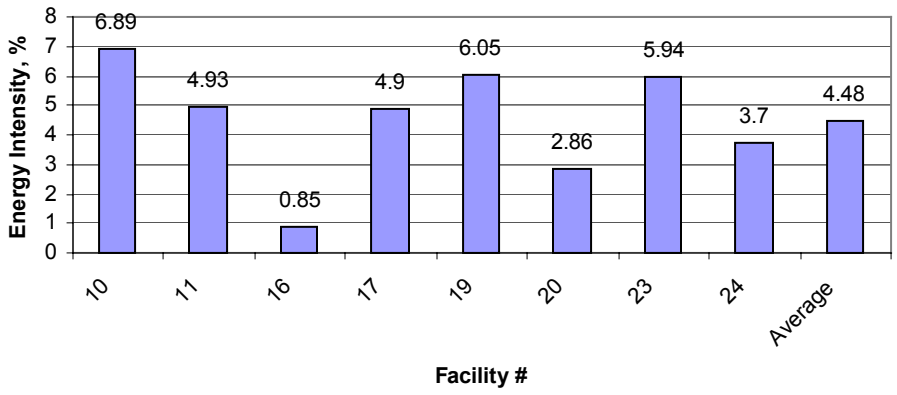


Figure A2.8: Oil and Sol'n Gas Cluster Processing Energy Intensity

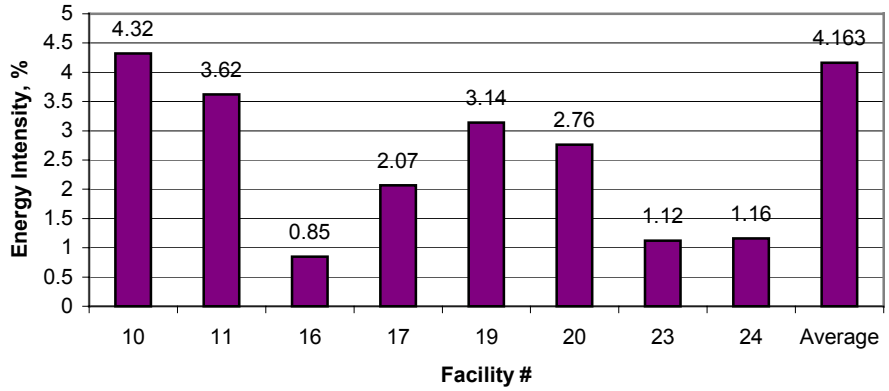
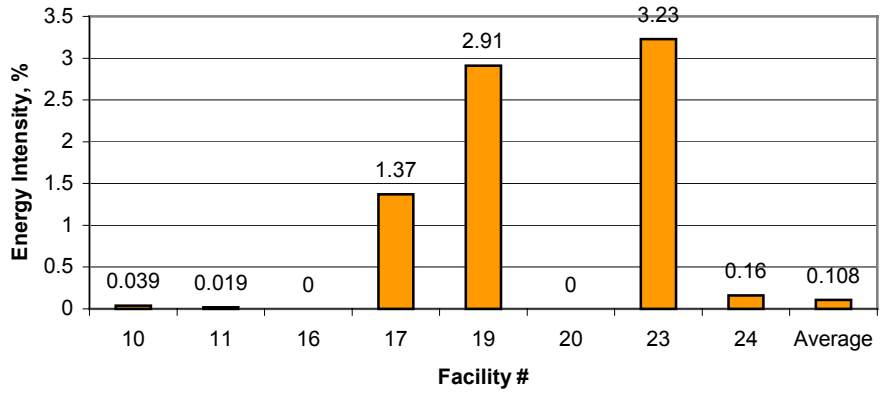


Figure A2.9: Oil and Sol'n Gas Cluster Plant Flare Intensity



A2.2.4 Heavy Oil Facilities (Conventional and Enhanced Oil Recovery (EOR))

The heavy oil facility data set includes two heavy oil-processing batteries and both participated in the audit program. One is a conventional heavy oil-processing unit and the other is a combination cyclic steam and steam-assisted-gravity-drainage (SAGD) oil-processing unit. Energy intensities incurred outside of the oil processing battery limits are not included here but are addressed in Section A2.2.3.

Table A2.5: Benchmarking Results for Heavy Oil Battery Facilities

Facility	Size e^3GJ/d	PTEI GJ/GJ%	PEI GJ/GJ%	CompEI GJ/GJ%	PFI GJ/GJ%	PVI GJ/GJ%	PCI tCO_2/e^3GJ	PSdI m^3Sd/e^3GJ	PWpI m^3/e^3GJ	PWfI m^3/e^3GJ
14	112.1	0.50	0.50	0.00	0.000	0.0022	0.33	0.149	8.1	0.0
15	68.5	0.66	0.49	0.00	0.174	0.013	0.62	0.024	82.0	67.7
Average	99.500	0.561	0.496	0.000	0.066	0.006	0.440	0.102	36.130	25.678

Note: 1. Blanks mean no production data available for item
2. Zero means no consumption or production of item
3. Averages are production weighted

Plant Total Energy Intensity (PTEI), Processing Energy Intensity (PEI) and Flare Energy Intensity (FEI) for this cluster are shown in Figures A2.10 through A2.12.

Figure A2.10: Heavy Oil Cluster Plant Total Energy Intensity

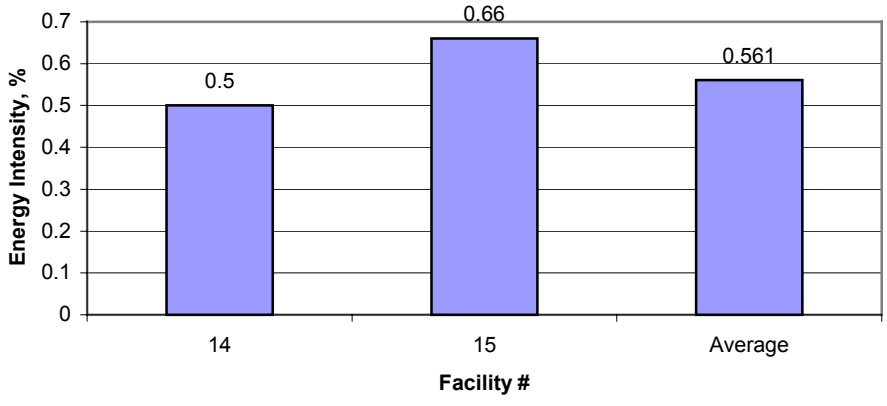


Figure A2.11: Heavy Oil Cluster Plant Total Energy Intesity

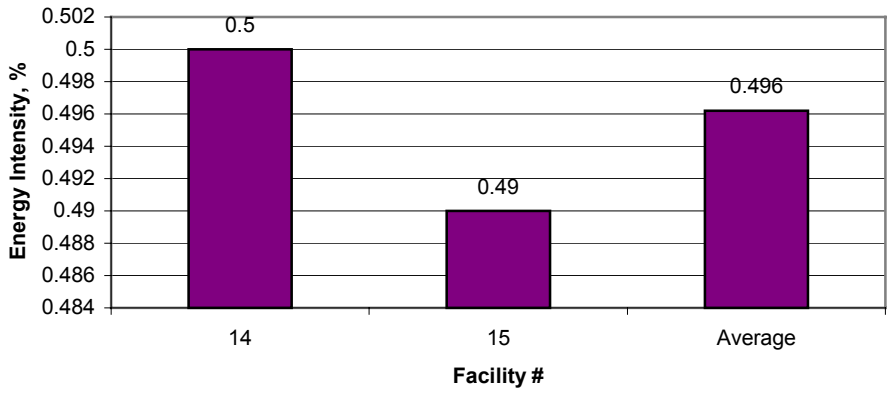
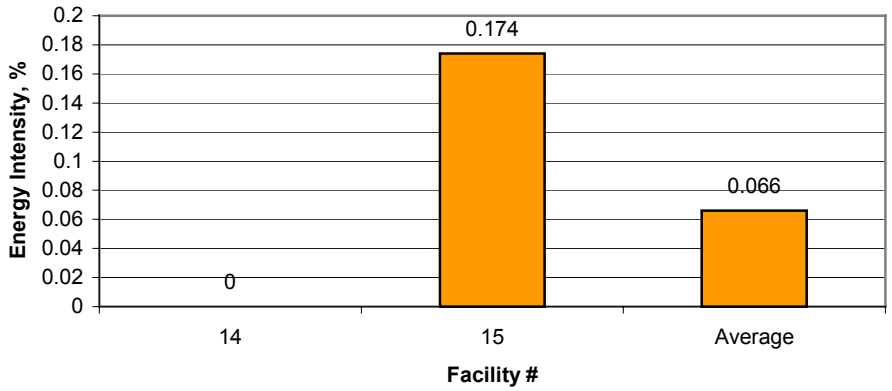


Figure A2.12: Heavy Oil Cluster Plant Flare Intensity



A2.2.5 Integrated Field Gathering and Processing Facilities

For five facilities sufficient decoupled energy consumption data was obtained to establish a complete wellhead to point of sale energy and environmental intensity profile. The data set includes one sour gas plant with sulphur recovery, two heavy oil facilities, one conventional oil-and-gas facility, and one conventional oil production system (several integrated batteries).

Table A2.6: Benchmarking Results for Integrated Field Gathering and Processing Facilities

Facility	Size e^3GJ/d	Fld/PTEI GJ/GJ%	FldEI GJ/GJ%	PTEI GJ/GJ%	PEI GJ/GJ%	CompEI GJ/GJ%	PFI GJ/GJ%	PVI GJ/GJ%	Fld/PCI tCO_2/e^3GJ	PCI tCO_2/e^3GJ
13	74.7	5.36	2.31	3.05	1.91	0.69	0.31	0.1270	2.62	1.49
14	112.1	9.09	8.59	5.01	5.01	0.00	0.00	0.0002	19.98	0.33
15	68.5	19.20	18.54	0.66	0.47	0.00	0.17	0.0013	9.93	0.62
19	5.2	9.62	1.81	6.05	3.14	1.76	2.91	0.0004	5.86	3.23
24	30.8	5.25	1.56	3.69	1.16	2.24	0.16	0.1300	7.22	4.53
Average	58.3	10.114	8.455	3.363	2.707	0.445	0.188	0.047	11.564	1.162

Note: 1. Blanks mean no production data available for item
2. Averages are production weighted

Field Gathering plus Plant Total Energy Intensity (Fld/PTEI) as well as Plant (only) Total Energy intensity are shown in Figure A2.13. This cluster includes a mix of facilities and points out the need to understand the total energy profile of an operation for each and every one of them. For several of these operations as much, or more, energy is spent in field gathering and well production as there is spent in the processing plant, the greatest example of this being Facility 11.

Figure A2.13: Field Gather + Plant Cluster
Shows Plant and Field Total Energy Intensity and Plant Energy Intensity Only