Output Measurement - Net vs Gross

This write-up summarizes some of the issues related to output measurement and separating net from gross output. It presents several examples of different kinds of electric and thermal generation systems with generic characterizations of how and where output could be measured.

Gross output is the total generation of thermal energy or electricity measured at the boiler header or generator terminals. Net output is the energy available for some use other than the generation itself. Net output is the gross output minus the output consumed in any way related to the generation. Examples of output that must be netted out include:

- Auxiliaries loads related to thermal or electric generation
- Pollution control devices
- Heat recovery
- House loads

The net output is always taken at the point of generation. It is not adjusted for line losses or for end use efficiency. Netting is only done for the energy type for which allocations are being awarded. For example, it is not necessary to net out net steam consumption for an electric-only generator and it is not necessary to net out electric loads for a steam-only generator. One issue that may need to be discussed is the recognition of electric parasitic loads or house loads for cogeneration systems that have no incremental electricity requirements. For example, if a pressure-reducing turbine is added to an industrial steam system to produce electricity, it creates no additional electric load. However, if the system must then net out parasitic electric loads in the boiler house, it could result in a negative number. This is a point that may require additional discussion.

In the examples below, the seasonal allocation is calculated for each option based on a 300 MMBtu/hr heat input and 80 percent capacity factor over a 5 month ozone season. Allowances are allocated at the rate of 0.15 lb/MMBtu input for electric generators, 0.17 lb/MMBtu input for thermal generators, 1.5 lb/MWh_e out for electric generators and 0.21 lb/$MMBtu_{th}$ out for thermal generators.

Example 1. Electric Generator (Figure 1)

Fuel is burned at A. Heat input can be measured there in various ways depending on fuel type. For liquid and gaseous fuel, fuel input can be measured directly. For solid fuel, Part 75 uses a back calculation from exhaust content. Gross electric output could be measured at the generator terminals (B). The nominal net output would be at the buss bar (C) but this may or may not account for all of the nettable loads. Electricity for auxiliary and house loads might come directly from the onsite generation (D) or might come from the grid (D^1) or both. In the former case, the net generation could be measured directly at the buss bar. In the latter cases, it might be easier to measure the gross (B) and subtract the total in house and parasitic electric loads, D and D^1. All steam use is internal to the generation of electricity and does not need to be addressed for either allocation. Assuming a heat rate of 10,000 Btu/kWh and 5 percent parasitic and house loads, the input and output numbers and allocation numbers are as follows:

Allocation Summary - Electric Generator Case

	Capacity	*Energy/Generation*	*Allowances*
Heat Input	300 MMBtu/hr	881,280 MMBtu	66
Gross Output	30 MW	88,128 MWh	66
Net Output	28.5 MW	83,711 MWH	63

Example 2. Industrial Boiler Plant (Figure 2)
Fuel is burned at A. Heat input measurement is assumed to be as in Part 75. Gross output could be measured at the steam header (B). Since only steam is netted and there is no central steam grid, all nettable loads would be drawing off of this steam source. The simplest situation

is where all nettable loads are drawn at one point allowing us to measure net steam at (C). In the alternative case (dotted lines), some house or other loads are drawn from beyond point C and must be measured and subtracted separately (C^1). Note that condensate return does not affect the output calculation. It actually affects the amount of heat *input* to the system. Since heat input is measured directly, condensate does not affect either the input or output measurement. Electricity used for auxiliaries or house loads does not need to be addressed since there is no electric output or allocations for electric generation. Assuming 80 percent boiler efficiency and 3 percent parasitic and house loads, the inputs, outputs and allocations would be as summarized below. The difference between the heat input allocation and the gross output allocation is simply due to round-off error in the two allocation factors (0.17 lb/MMBtu in vs 0.21 lb/MMBtu out).

Allocation Summary - Steam Generator Case

	Capacity	*Energy/Generation*	*Allowances*
Heat Input	300 MMBtu/hr	881,280 MMBtu	75
Gross Output	240 MMBtu/hr	705,024 MMBtu	74
Net Output	233 MMBtu/hr	683,873 MMBtu	

Example 3. Steam-Based CHP (Figure 3)
In this case, steam is generated in a boiler and sent to a steam turbine to generate electricity. Steam may be extracted from the turbine at various points or at the turbine outlet for other end uses. Because both electricity and steam are generated, both must be netted. Fuel input would be measured at A as in the other cases. Gross steam production of the boiler could be measured at the steam header (B), but this would be grossly overestimated since much of the energy goes to generation of electricity in the turbine. The gross available steam energy would need to be measured at the turbine exit and/or extraction points (C). In some cases, however, steam for auxiliary uses might be taken before the turbine inlet, so C would already be net of some internal uses. In some cases, C might be both the gross and net steam output. If some parasitic steam loads are served after the turbine exit, the net steam would be at D. In other cases, other loads such as house loads may be taken after C and would need to be netted out (D^1). Again, condensate return is an input factor that does not affect output or need to be measured for either input or output allocation.

Electricity is generated at the turbine and gross electricity can be measured at the terminals (E). In this case, it is more likely that at least some electric auxiliaries and house loads are supplied from another electricity source and would need to be metered separately to be netted out. Net internal energy could be measured at F and might need to be adjusted with electric house loads from the grid, measured at F^1. The allocations are calculated assuming 80 percent boiler efficiency and 3 percent parasitic loads for both steam and electricity. The power-to-heat ratio is 0.2 and the total system efficiency is 78 percent.

Allocation Summary - Steam Cogen Case

Capacity

Energy/Generation

Allowances

Heat Input

300 MMBtu/hr

881,280 MMBtu

75

Gross Output

195 MMBtu/hr

572,832 MMBtu

60

11.4 MW

33,568 MWh

25

Net Output

189 MMBtu/hr

538,978 MMBtu

57

10.9 MWh

32,561 MWh

24

Example 4. Combustion Turbine-Based CHP (Figure 4)
In this system, fuel goes into the combustion turbine at A and directly drives an electric generator. Gross electric output is measured at D. The exhaust gases generate steam in the heat recovery steam generator (HRSG) and the gross steam output can be measured at B. In the simplest case, net steam and electric generation can be measured by placing the meters after auxiliary and in-house loads are drawn (E and C). It may be that some internal steam loads will need to be measured separately (C^1) and some electric house loads from the grid may need to

be measured separately (E^1). The allocations are based on a turbine heat rate of 11,400 Btu/kWh and parasitic losses of 3 percent for both electricity and steam. The power to heat ratio is 0.67 and the total system efficiency is 75 percent.

Allocation Summary - Combustion Turbine Cogen Case

Capacity

Energy/Generation

Allowances

Heat Input

300 MMBtu/hr

881,280 MMBtu

75

Gross Output

135 MMBtu/hr

396,576 MMBtu

42

26.4 MW

77,464 MWh

58

Net Output

131 MMBtu/hr

373,138 MMBtu

39

25.6 MWh

75,140 MWh

56

Conclusion:
Net output can often be measured at one carefully placed metering point each for thermal and electric energy. In some cases two, or less often more meters may be required for each energy form. Calculating the net output does not require a full "heat balance" of the system and measurement of condensate is not required in any of the cases. The allocation impact of output measurement must be evaluated in the context of the total inventory. That said, the efficiency value of cogeneration and recognition of that value in an output-based system is clear.