HVAC Modeling for Cost of Ownership Assessment in Biotechnology & Drugs Manufacturing

Peter Broomes
Sponsored by LMA

Abstract— Heating, ventilation, and air conditioning (HVAC) systems used in the clean room environment of biotechnology and drug development and manufacturing, are extremely energy and water intensive and represent a significant operating cost for these facilities [1]. HVAC systems are also the primary source of environmental emissions for the majority of companies operating within the biotechnology and drugs sector. While the processes used in drug manufacture have negligible environmental impact, the power plants, and water treatment facilities which annually provide the billions of kilowatt hours (kWh) of required electricity and hundreds of billions of gallons of make up water [5], also produce tons of CO_2, CO, VOC, PM_{10}, SO_2, NO_X, and in some cases Hg [3]. These issues of water and air emissions, key concerns of the California Department of Toxic Substance Control (DTSC) and the Environmental Protection Agency (EPA), are increasingly shared by the CEOs of leading pharmaceutical and biological products companies, and are appearing in their annual Environmental Health and Safety (EHS) reporting [4] with greater frequency and detail. The HVAC system used in the clean room manufacturing environment has been modeled with a functional unit of $/CFM. Economic and environmental impacts as a function of specified performance criteria have been captured, allowing for cost of ownership assessment of both existing and future systems of varying configurations serving a variety of clean room conditions. The opportunities for increased efficiency and cost savings of HVAC systems used in clean rooms are considerable, as much as 50% [5]. The HVAC model developed may lead to these savings through estimated results, which are considerably accurate, within 25% of several industry and government organized case study results [6]. The following report details a discussion of the HVAC system model, the methodology behind its development, its capabilities, and limitations.

1. Methodology

The development of the HVAC model included several phases. The biotechnology and drugs sector, Standard Industrial Code (SIC) 283 was first defined based on the categorizations made by the United States Census Bureau [7], and by Ernst & Young in their 2000 industry report [8].

Table 1. Biotechnology & Drugs Sector Industry Composition [9].

Biotechnology & Drugs Sector	**(SIC) 283**
Medicinal Chemicals and Botanical Products	**(SIC) 2833**
Pharmaceutical Preparations	**(SIC) 2834**
In Vitro and In Vivo Diagnostic Substances	**(SIC) 2835**
Biological Products, Except Diagnostic Substances	**(SIC) 2836**

A study of the environmental emissions of companies within the biotechnology and drugs sector relative to other well-known industries was then carried out [9]. From information collected from literature, and in interviewing several individuals from within the biotechnology and drugs sector, it was determined that water, and energy consumption were among the major sources of environmental emissions resulting from drug development and manufacture.

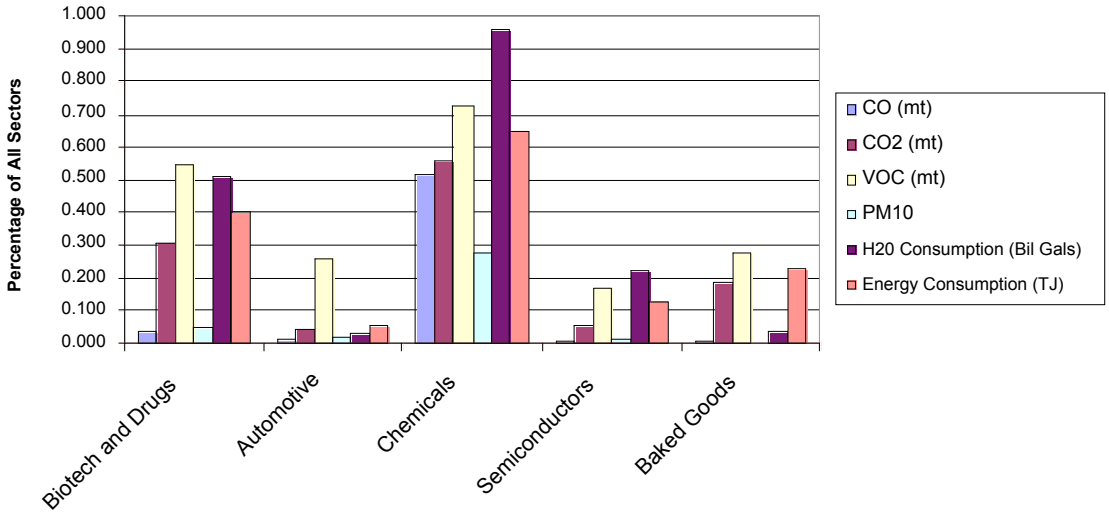

Figure 1. Environmental Impact as % of Total Value Chain [9].

HVAC systems were targeted as a major source of energy and water consumption in biotechnology and drug industries. These systems were also targeted because of their independence from the drug manufacturing process as viewed by the FDA. They were therefore perceived as more flexible to efficiency improvement measures than process impacting systems.

A methodology and metrics most useful for comparing these systems over widely varying configurations, and operating conditions was first developed. A functional unit of $/CFM of treated air was used to remove facility size from system considerations, and allow for the inclusion of a variety of cost drivers such as those attributed to water consumption, consumables, utilities, employee salaries, and installation, maintenance and operation costs into the cost accounting for a specified required cubic feet per minute of treated air.

2. Capabilities

The HVAC model was then developed providing varying levels of detail in the modeling of existing or planned systems, requiring varying degrees of involvement by the user. The model was designed in such a way that results could be obtained from entering basic parameters indicating the required CFM of air, clean room temperature, and humidity desired in the clean rooms, to the altering of the characteristics for every system component down to the number of coils desired on a re-heat coil.

The EIOLCA database [10] and the EPA's EGRID2000PC database [11] were used to capture the use and lifecycle environmental emissions of the HVAC system used in the biotechnology and drugs sector industries. The EIOLCA database provides life cycle environmental impacts as a function of the life cycle cost of the HVAC system. The EGRID2000PC database provides state specific environmental emissions data for the power mix for each state. The HVAC model operates under the assumption that the majority of power used to supply electricity to the HVAC system is provided from power plants within the state. This allows for a comparison of location impact on HVAC environmental performance. The location and life cycle impacts on HVAC economic performance have also been calculated, and will be discussed in this paper.

The impact of people, equipment, and lights in the clean room on energy consumption were intentionally ignored because of the relatively low impact they have on the overall system performance, 1 – 5% of building energy load [1]. It was also believed that these factors could be calculated separate from the model, and taken into account when sizing the different system components, and clean room requirements.

3. Limitations

The underlying objective of the HVAC model was to develop a tool that owners and decision makers could use to understand the performance of their HVAC systems. Facility size, and CFM limitations were placed on the model in order to control the accuracy of the results. The 550,000 CFM of total treated air, 10 primary air handler units, and 40 clean rooms used in the model were based on the maximum facility size, and facility requirements observed in the pharmaceutical industry.

The HVAC model was constructed with industry and experiential based estimates as well as back of the envelope based calculations representing each component of the system.

The industry based estimates were generally used for energy efficiency ratios used to capture the consumption of each system, experiential based estimates were used in cases where no industry data was available, and where the level of confidence in experiential based data as being representative of a majority of systems was high. The back of the envelope based calculations used to model each individual system were referenced from several industry, and academic texts and handbooks used for HVAC system sizing and design.

4. Conclusion

Based on preliminary testing of the model against several industry and laboratory led case studies, it appears that the HVAC model developed is accurate to a degree well within the requirements for estimating HVAC system performance. It allows for much flexibility in HVAC system customization. It performs satisfactorily in accounting for each of the metrics, performance, economic, and environmental, identified. Currently the model developed is applicable to the biotechnology and drugs sector. An area for future work is on expanding its capabilities for use in all sectors utilizing clean rooms such as the electronics industry.

References

[1] Tschudi, William. et. al., "Clean Room Energy Benchmarking in High-Tech and Biotech Industries," April 2001

[2] Broomes, Peter, "Preliminary Research: Biotechnology Industry," November, 2002

[3] EPA, The Emissions & Generation Resource Integrated Database, EGRID2000PC, December 2002

[4] Broomes, Peter, et. al., "Environmental Impacts of the Biotechnology and Drugs Sector," May, 2002

[5] Sartor, Dale, et. al., "Strategies for Energy Benchmarking in Clean Room and Laboratory Type Facilities.", August, 2000

[6] Broomes, Peter., "HVAC Results Comparison", April, 2003

[7] U.S. Census Bureau, http://www.census.gov/, 1997, Accessed April, 2003

[8] Ernst & Young, "The Economic Contributions of The Biotechnology Industry to the U.S. Economy", May 2000

[9] Broomes, Peter., "HVAC Modeling for Cost of Ownership Assessment in Biotechnology & Drugs Manufacturing LMA Presentation", November, 2002

[10] Carnegie Mellon Green Design Initiative, Economic Input Output Life Cycle Assessment, 1997, Accessed April, 2003

[11] EPA, The Emissions & Generation Resource Integrated Database, EGRID2000PC, December 2002.