The Penetration of Chemical Industry Technologies—Evidence from the 1991 and 1994 MECS

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ABSTRACT

This paper examines data on the penetration of industry-specific technologies into the chemicals industry. The data used are from the Manufacturing Energy Consumption Survey (MECS) in 1991 and 1994, the two years in which questions about specific technologies have been included in MECS. The MECS technology definitions and survey instructions provided by the Census Bureau to the respondents are reviewed, and specific commercial technologies identified and grouped according to these technology definitions. The review reveals substantial ambiguity in the technology definitions and overlap in the technology categories. The data are analyzed both according to the Census technology categories as well as using aggregated technology categories to account for the ambiguities and overlap in technology definitions. The results provide a description of the penetration of specific technologies into the chemicals industry, and also demonstrate the importance of precise categorization and definition of the technology categories. Suggestions are included to make these questions more valuable to industry analysts and technologists.

Introduction

The U.S. Department of Energy's Energy Information Administration has conducted the Manufacturing Energy Consumption Survey since 1985. The third survey conducted for the year 1991 was the first to include questions about the use of specific technologies by industry. These questions were both of a generic nature for all industry (which included four technologies) and industry specific for three industries – pulp and paper (SIC 26), chemical and allied products (SIC 28), and primary metals (SIC 33). Ten specific technologies were included for SIC 26 and 26 for SIC 33. For the chemical industry, 17 technologies were identified. Four technologies were identified first, followed by another 13 specific processing or separations technologies that were assumed to be adopted for one of three reasons: to reduce reliance on fossil feedstocks, improve overall process efficiency, or reduce environ-mental emissions.

The purpose of this paper is to explain the nature of this data and how it might be used in light of its potential to impact energy and resource efficiency. The paper also examines recent trends in technology penetration based on responses to the technology utilization portion of the Manufacturing Energy Consumption Survey (MECS) in 1991 and 1994. The strengths and limitations of the technology utilization data collected by the MECS are discussed, and some tentative suggestions on how the data might be improved are proposed.

Manufacturing Energy Consumption Survey Description

The Manufacturing Energy Consumption Survey (MECS) is the most comprehensive source of national data on the energy use characteristics of the manufacturing sector. The 1994 survey sample represented about 250,000 of the largest manufacturing sector establishments, which account for approximately 98 percent of the U.S. manufacturing output. The MECS has been conducted every three years from 1985 to 1994. The 1991 and 1994 surveys included for the first time questions on the utilization of industry-specific technologies for selected industries.

For the chemicals and allied products sector (SIC 28) and its subsectors, survey respondents are asked about the use of 17 specific chemical industry technologies. The survey results for each of the 17 specific technologies are published for the 1991 survey (EIA 1994), and are available on the EIA website for the 1994 Survey.[1] The survey results are presented in terms of the total inputs of energy for heat, power, and electricity generation for establishments signifying the use of the 17 specific technologies. Data are also presented for all establishments signifying the use of one or more technologies, as well as those with none present. Table 1 lists the 17 technologies used for the chemicals industry sector and the 1991 and 1994 energy use in establishments signifying the use of the technologies.

Table 1. Energy Use in Establishments Using Specific Technologies (Tbtu)

Chemicals Industry-Specific Technologies	1991	1994
Replacing Electrically Heated Platens in Thermoset Molding Process with Gas-Fired Central Thermal Fluid System	5	32
Processing Residuals as Alternative Feedstocks	900	898
Biomass Materials Used as Alternative Feedstocks	34	24
Bioprocessing of Petroleum, Natural Gas, Coal, or Other Fossil-Based Feedstocks	16	9
Direct Microbial	60	63
Bioprocessing	376	152
Gasification of Biomass Feedstocks	W	*
Fast Pyrolysis of Biomass Feedstocks	8	7
Immobilized Enzyme Processes	*	Q
Innovative Catalytic Processes	531	279
Recycling of Materials	1,381	1,263
Hydrolysis of Biomass Materials	Q	Q
Enhanced Bioprocessing with Genetically Engineered Feedstocks or Organisms	W	12
Fermentation	25	38
Fractionation of Biomass	*	5
Distillation Process Improvements	0	979
Hydrocarbon Cracking Enhancements	635	495
One or More Technologies Present	1,893	2,000
* Estimate less than 0.5.		
W Withheld to avoid disclosing data for individual establishments.		
Q Withheld because relative standard error is greater than 50 percent.		

[1] MECS table A56 (1994) can be found at http://www.eia.gov/emeu/mecs/mecs94/mecs5.html

While this table provides some interesting information, it needs to be pointed out that there is a lot it does not say. The table reports energy consumption by firms that report the use of one or more of these technologies. Thus of the 3040 trillion Btu used in SIC 28 for heat power and electricity generation in 1991, 1893 TBtu was used in firms that reported the use of one or more of these technologies. This reporting does not allow normalization of the data by output or even energy use. In 1994, this information was also reported by the number of firms that used these technologies, but again, the data are not tied to production data or other normalizing information. So while we know that nearly two-thirds of energy was consumed in chemical plants that used these technologies, we cannot track this use to the more energy intensive plants. Nor can we try to examine the impact of the use of these technologies on the energy efficiency of the plants without access to the Census records. While some work has been undertaken to examine this data, few results have been published to date.[2]

Assessment of Survey Quality

As part of an analysis of technology use trends in the chemicals industry, literature on industry products and processes was reviewed to identify and match these products and processes to the industry specific technology categories used in the MECS. Because 14 of the 17 categories are directly or indirectly related to bioprocessing or biomass based processes, the review essentially focused on identifying commercialized bioprocessing or biomass-based chemicals processes.

One of the first steps in the review process was to obtain definitions for the industry-specific technologies identified in MECS. The Census Bureau has developed definitions for most of the technologies and maintains an information line to answer questions that survey respondents may have during the survey period. A review of these definitions revealed substantial ambiguity and overlap in the technology categories. For example, the definition for fermentation is as follows:

> **Fermentation Definition**: An old word used to describe a chemical reaction in which a substrate is converted to products by whole microorganisms. The word is now general and is used to describe almost all biological processing that use [sic] microorganisms whether they are whole cells or not.

Because this definition is explicitly general, the category of fermentation overlaps with other technology categories such as bioprocessing, direct microbial, and immobilized enzyme processes.

While other technology definitions are more precise or more detailed, the usefulness of the technology definitions is, in general, questionable. It is also unclear that the survey respondents make wide use of the technology definitions. Finally, the substantial overlap and ambiguity in the technology categories themselves raises questions about the quality of the data, and the ability to draw conclusions about technology trends in the chemicals industry based on the data.

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[2] A report that characterizes the use of generic technology by size, industry, and age of plant will be submitted for publication this year. See Niefer, *et al.* (1999).

The second part of the review process involved identifying commercialized processes that fit within the Census Bureau definitions. A general review of bioprocessing literature was used to generate a list of possible products or processes in each technology category. From this list, a final set was generated for products and processes that are 1) commercialized, 2) in domestic production, and 3) that fall within the chemicals industry according to the Standard Industrial Classification Manual (OMB 1987). Major products are identified in Table 2.

Two major trends are apparent when comparing the results in Table 2 to the energy use values in Table 1. First, it is interesting to note that even for technologies for which no commercial chemicals industry products or process was identified, some positive response was received on the use of the technologies as early as the 1991 MECS. This either indicates that additional chemicals industry products and processes are currently in use, or that the technology definitions are not well understood.

Second, among the 5 most widely used technologies, declines in reported use of 3 of the technologies are offset by a dramatic increase (from 0 to 979 Tbtu for distillation process improvements) in one technology.

Analysis

Despite the fact that the questionnaire was divided into general (but industry specific) technologies and more specific technologies designed to reduce energy, improve process efficiency or reduce environmental emissions, clearly some confusion resulted.[3] Because of the ambiguity and overlap in the technology definitions and categories, several aggregation schemes were used to group the data according to major technology types. It is believed that this aggregation may tend to eliminate apparent trends due to inconsistent reporting of technology use from year to year. For example a bioprocess may be included under bioprocessing one year, and fermentation the next. By aggregating the categories the overall trend in bioprocessing technologies becomes more clear.

Two types of aggregation methods were used. In one method each technology was allowed to reside in only one technology group. In the second method technologies that span more than one group were allowed to reside in each group. The results of one scheme following the first method are presented in Table 3. Data withheld are treated as zeros.

The data suggest that the energy used in plants that report the use of these technologies has declined between 1991 and 1994 except in the case of the use of gas-fired systems in thermoset molding, and in separations processes. The increase in the latter group is due entirely to a jump from 0 to 979 Tbtu used in firms that reported the specific technology, distillation process improvements.

[3] The MECS form does not clearly explain the differences between the categories of technologies in either 1991 or 1994. An entirely different format is being used for the current survey. Other sources of confusion may arise as a result of different persons responding to the form, not having the previous form available, or because of confusion about the definitions of the technologies.

Table 2. Chemicals Industry Products

Industry-Specific Technologies	Chemicals Industry Processes	Notes
Replacing Electrically Heated Platens in Thermoset Molding Process with Gas-Fired Central Thermal Fluid System	Thermoset Molding	Well defined process
Processing Residuals as Alternative Feedstocks	Many	
Biomass Materials Used as Alternative Feedstocks	Alcohols, celluloses, gums, fats and oils, components of paints, varnishes, etc., (e.g. Glycerine)	Unclear what constitutes an alternative (versus conventional) feedstock
Bioprocessing of Petroleum, Natural Gas, Coal, or Other Fossil-Based Feedstocks	No commercial processes identified	One company is pursuing biocatalytic desulfurization
Direct Microbial	Antibiotics, vitamins, amino acids, alcohols	Category may be poorly understood
Bioprocessing	Same as fermentation and direct microbial	Category is very general and not distinct from other categories
Gasification of Biomass Feedstocks	No commercial processes identified	Could be used for a variety of chemical products
Fast Pyrolysis of Biomass Feedstocks	Hydroxyacetaldehyde	Probably falls in SIC 20 (food processing)
Immobilized Enzyme Processes	Penicillins	Acrylamide produced in Japan. Other products in research
Innovative Catalytic Processes	?	Unclear what meets distinction of innovative
Recycling of Materials	Many	
Hydrolysis of Biomass Materials	Furfural	Many potential uses
Enhanced Bioprocessing with Genetically Engineered Feedstocks or Organisms	No commercial processes identified	Potential production of erythromycin and 1,2-propanediol
Fermentation	Ethanol, acetic acid, beta carotene, lactic acid, xantham gum, linoleic acid, phenylalanine	Potential for polyester and polylactic acid
Fractionation of Biomass	Fatty acids, resins (for adhesives and waxes)	Only one commercial process identified
Distillation Process Improvements	Many	Unclear what meets this distinction
Hydrocarbon Cracking Enhancements	Olefins (ethylene, propylene, etc.)	Unclear what meets this distinction

Table 3. Energy Use for Aggregated Technology Groups (Tbtu)

Chemicals Industry-Specific Technology Groups	1991	1994	Difference
Replacing Electrically Heated Platens in Thermoset Molding Process with Gas-Fired Central Thermal Fluid System	5	32	27
Recycling of Materials	2,281	2,161	-120
Biomass Materials Used as Alternative Feedstocks	42	36	-6
Bioprocessing	477	274	-203
Innovative Catalytic Processes	531	279	-252
Separations Processes	635	1,474	839

While these trends in the data may reflect actual reductions in energy used in firms reporting the use of these technologies, there may be other explanations. One possible explanation is that there is confusion and ambiguity in the survey instrument, which results in inconsistent reporting. The change in the structure of the questionnaire for the MECS, currently underway, may allay these sources of confusion. These changes are mostly in the format of the questions, lengthening the form considerably, but making it much easier to answer the question set. If confusion remains, this issue needs to be addressed in the industry review process. The interaction mechanism developed through the "Vision Industry" program of OIT might serve to identify the proper set of technologies to include. Since the survey for 1998 is currently underway, they could be implemented for the 2001 survey.

Conclusions

The analysis of data collected on the use of industry specific technologies in the chemicals industry by the MECS suggests that there are several limitations to the data available for 1991 and 1994. While we recognize these shortcomings, we also recognize that the possibility exits that current and future survey results will be more useful.

First, it is clear that for the chemical industry questions, there are ambiguities in the survey as it has been developed. The technology categories used for the chemicals industry are in many cases unclear or overlapping and the technology definitions are also not particularly informative or precise. It is also unclear that survey respondents make wide use of the definitions.

Second, since the survey results are reported in terms of energy use in establishment that use the technologies, it is not possible to associate activity levels directly to the processes themselves. For example, an establishment may use a fermentation process as a small part of its operations, but all of the energy used at the establishment is recorded as associated with fermentation. Growth on decline in the resultant energy values may or may not be associated with any changes of the fermentation process technology. Without access to the individual census records, the use of the technologies cannot be associated with production levels, which might allow an estimate of how these technologies improve energy efficiency.[4]

Recognition of these shortcomings should not suggest that the effort is flawed or that the information collected could not be useful. On the contrary, this is the only technology

[4] Even with this information, it may not be possible to differentiate among the observations to measure the impact. Analysts that use the data indicate that the correlation between energy intensity and the use of these technologies may be too high to show an improvement in efficiency as a result of using the technologies.

game in town for energy intensive industries. But with only two years worth of data, it would be difficult to draw conclusions about the technology trends in the chemicals industry or the effect of the use of these technologies on energy efficiency. This last problem will be resolved with time, and the first two, mentioned above, may be addressed with changes in the current MECS survey format. Further, if these technology questions are to be of use to industry energy analysts, they must be broadened to allow a better understanding of how their adoption will effect energy consumption, process efficiency, or environmental emissions. The most direct way to address this need is to invite the industry panel that reviews the MECS questionnaire to indicate the industry segments to which these technologies (or possibly an improved list) might apply and how their usefulness could be assessed.

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