1. INTRODUCTION

1.1 BACKGROUND

Under the President's Hydrogen Fuel Initiative, the U.S. Department of Energy (DOE) Hydrogen Program works with industry, academia, national laboratories, and other Federal and international agencies to overcome critical technology barriers, address safety issues and facilitate the development of model codes and standards, validate hydrogen fuel cell technologies in real world conditions, and educate key stakeholders that have a role in the transition to a hydrogen economy.

A hydrogen economy requires an educated human infrastructure – trained safety and code officials, an educated workforce, state and local government officials who understand the near-term realities and long-term potential of the technology, and a public that is familiar and comfortable with using a new fuel. The DOE Hydrogen Program education key activity was developed to address the training and informational needs of these key target audiences that have a role in the near-term transition as well as the long-term development of a hydrogen economy.

The purpose of the Baseline Knowledge Assessment for the DOE Hydrogen Program was to measure the current level of awareness and understanding of hydrogen and fuel cell technologies and the hydrogen economy. The information collected will help guide DOE efforts to formulate an effective education campaign about hydrogen and also will provide a baseline for comparison of future evaluations of public awareness, knowledge, and opinion.

1.2 PURPOSE

For an education program to be effective, it must have a logical starting point or baseline. In 2003, DOE initiated an effort to ascertain the familiarity of the population of the United States with hydrogen and fuel cell concepts. DOE tasked the National Transportation Research Center at the Oak Ridge National Laboratory (ORNL) to identify and characterize previous or ongoing attempts to determine this knowledge level (Truett, 2003). The ORNL literature review revealed that very few scientific surveys had been conducted to evaluate public knowledge and familiarity with hydrogen and fuel cell technology, and no results of national scientific surveys conducted within the United States had been published at the time. DOE determined, therefore, that there was a need for a statistically-designed survey of knowledge and opinions about hydrogen, fuel cells, and the hydrogen economy in the United States.

Four target populations were selected to be surveyed: (1) the general public, (2) students, (3) personnel in state and local governments, and (4) potential large-scale end users of hydrogen fuel and fuel cell technologies in business and industry. The goal of the 2004 hydrogen surveys was a statistically-valid, nationally-based measurement of awareness and understanding of hydrogen, fuel cells, and the hydrogen economy for each of these target populations. The results of the 2004 surveys will be the baseline assessment. The same processes for conducting the survey in 2004 will be used in follow-on surveys in 2008 and 2011, and the same methods of data analysis will be used.

DOE will use these baseline results to design a hydrogen education program for the public, state and local governments, teachers and students, and the community of potential large-scale end users of hydrogen. Over time, when the surveys are periodically repeated, measures of changes in awareness and understanding will be taken, and this information will be used to modify the educational program as necessary.

1.3 TIMELINE OF EVENTS

Prior to development of the survey instruments, a literature review was conducted by Oak Ridge National Laboratory (ORNL) to ascertain the types of hydrogen and fuel cell surveys that had been conducted, where they had been conducted, and the relevant results (Truett, 2003). Although a few scientific surveys had been conducted in Europe, including some student surveys, no comprehensive, scientifically designed knowledge-based survey of the general public had been conducted in the United States. While some U.S. surveys on alternative fuels had contained attitude and opinion questions on hydrogen and some surveys had contained questions on specific aspects of fuel cells or the hydrogen economy, a new set of surveys that contained both knowledge and opinion questions was needed. This literature review was completed and published in October 2003.

Concurrent with the literature review, questions were being formulated and a basic format for the questionnaire was decided upon. These draft questionnaires were reviewed by the National Hydrogen Association, the U.S. Fuel Cell Council, and by personnel in the DOE Hydrogen Program office. The basic design of the questionnaires was completed in December 2003.

The Paperwork Reduction Act of 1995 required DOE to obtain Office of Management and Budget (OMB) approval prior to conducting the surveys. A 60-day Federal Register Notice was issued on August 20, 2003, requesting public input and comments to the proposed data collection. No comments were received. Formal application was made to OMB in January 2004 requesting approval to conduct the surveys. On January 12, 2004, a 30-day Federal Register Notice was issued, again requesting public input. No comments were received. Copies of the Federal Register Notices are provided in Appendix B. Approval of the OMB for the General Public Survey was received in March 2004. OMB approval for the Student Survey was received in May 2004. Approval for the State and Local Government Agencies Survey was received in July 2004, and approval for the Large-scale End User Survey was received in September 2004.

A contract was let with a public opinion research firm, Opinion Research Corporation (ORC), on May 11, 2004. The public and student surveys were initiated in June 2004. The government survey was initiated in August 2004, and the end user survey was initiated in September 2004.

A preliminary report with interim results was produced on September 30, 2004. The current document, *Results of the 2004 Knowledge and Opinions Surveys for the Baseline Knowledge Assessment of the U.S. Department of Energy Hydrogen Program,* includes the final results and analyses of the four survey components. Results will also be published on the DOE Hydrogen Program website.

The same survey instruments and survey methodology will be used again in 2008 and 2011. At this time it is expected that an additional survey population, safety and code officials, will be added to the out-year collections (individuals representing this target audience are included in both the state and local government and potential large-scale end user surveys in the 2004 collection). The results of the repeated data collections will be compiled as for the 2004 data collection. In addition, the data in follow-on years will be compared with 2004 baseline data. The education program will be modified as needed, on the basis of this comparison.

2. SURVEY APPROACH

The following sections describe the four surveys, the rational for their design, and the survey methodology.

2.1 RESPONDENT POPULATIONS

There were four populations to be surveyed – the general public, students, state and local government agencies, and large-scale end users. The general scope and temper of the four collections were the same; however, the numbers of respondents differed for each of the populations.

The general public was surveyed first. Eligible respondents were adults 18 and older living in private households in the 50 states and the District of Columbia. A random (probability) sample of 1,000 completed interviews was the goal.

The second survey population consisted of a random sample of students between the ages of 12 and 17 living in private households in the 50 states and the District of Columbia. The goal was 1,000 completed surveys.

The third population included three state government agencies (State Energy Offices, Departments of Transportation, and Departments of Environmental Protection) in all 50 states, plus the twelve largest cities and the twelve largest counties in each of the four census regions. Completion of 246 total interviews was the goal, consisting of 150 interviews with state government agencies and 96 interviews with local government agencies.

The fourth population included a limited number (99) of large-scale energy users that were grouped into three categories: transportation, energy users who required an uninterrupted power supply, and industrial end users who had large power requirements.

2.2 FORMAT AND DESIGN OF THE QUESTIONNAIRES

To facilitate the data analysis, the survey questionnaires were prepared in a closed-end format. For every question, answer options were read to the interviewee, who was asked to choose one of the options. In every case, one of the options was "I don't know" or "I have no opinion." Prior to asking any questions, the respondent was assured that there were no trick questions and that an "I don't know" response was perfectly acceptable. Two sections, which were common to all questionnaires, contained knowledge-based questions. One of the knowledge-based sections was a true-false section; the other was a multiple choice section. Another section contained opinion questions ("How do you feel about …?"). This section was also common to all of the surveys. In each survey, one section was specific to the population being surveyed. Copies of each of the survey instruments in their final survey format are found in Appendix A.

The questionnaire for the public and student surveys was translated into Spanish prior to the start of each survey period. The Spanish version was coded into the computer system of the opinion research firm conducting the interviews. Respondents to the General Public and Student Surveys had the option of completing the interview in either English or Spanish.

The content of the knowledge-based sections of the surveys included questions on hydrogen, fuel cells, and the hydrogen economy. Questions about the relative safety of hydrogen and fuel cell technologies were included in every section of the survey.

The length of the surveys was kept to under 15 minutes (averaging 10-15 minutes), including the introduction, screening process, and demographic questions (age, etc.).

2.3 DATA COLLECTION METHODOLOGY

Early in the design of the survey instruments and determination of the survey process, it was clearly established that the survey needed to be statistically defensible.

The computer-assisted telephone interviewing (CATI) methodology was selected for conducting the survey because the questions and potential responses could be programmed into the system, and for other reasons discussed below. The responses needed no interpretation by the interviewer and were automatically logged into a database. Because the CATI telephone interviewer reads the "script" from the computer monitor, there is less chance of skipping questions or making other similar errors.

Other methods of data collection were considered and rejected. Web survey responses are not statistically valid because the sample is self-selecting rather than random; in addition, the results could be "stacked" by a single individual who completed the survey multiple times. Surveys handed out at events (e.g., county fairs) are also not statistically valid for essentially the same reason; the population cannot be considered random or representative of the entire United States at a specific event or set of events. In addition, such surveys of the same population may not be repeatable in 2008 or 2011. Written surveys were considered because they can be designed to be statistically valid. The use of written surveys was rejected, however, because of the timeframe involved, as well as cost. In a cost and time comparison, CATI surveys had an advantage over written responses.

All data collection efforts took place at the telephone facilities of ORC. All ORC interviewers complete intensive training. Interviewers are continuously supervised, monitored, and reviewed in order to maintain the highest quality interviewing standards. ORC's CATI system is state-of-the-art and offers full-screen control which allows multi-question screens, fully-programmable help and objection screens to aid interviewing, a flexible telephone number management system and powerful data checking facilities.

One of the greatest advantages of CATI systems is their ability to accurately and efficiently handle large numbers of scheduled appointments. Callbacks are queued by continuously comparing station sample activity and the index of definite callback records. When a definite appointment time arrives, the system finds the next available station and delivers the record as the next call. The call history screen that accompanies each record informs the interviewer that the next call is a definite appointment and describes the circumstances of the original contact.

The following protocols were followed in an effort to maximize response rate for the general public and students (ORC 2004).

- A minimum of 15 attempts was used to reach an eligible household for each telephone number in the sample frame.
- Each call attempt was a minimum of five rings. The automated CATI software cycled the attempts weekday day, weekday evening, Saturday day, and Sunday evening shifts to maximize coverage of the residential population.
- Persistent "ring-no-answers" were attempted a minimum of four times at different times and days of the week. Each number was called a minimum of 15 times over 14 calling periods or until a completed interview was achieved.
- Lines that were busy were called back a minimum of five times at 10-minute intervals. If the line was still busy after the fifth attempt, the number was attempted again on different calling occasions until the record was resolved. As with no-answers, if a shift closed before an automatically rescheduled busy was attempted, the number was cycled to the next available calling time.
- Callbacks to specific respondents were entered into the computer by interviewers and handled automatically by the CATI program. They were held out of the sample until the appointed hour, when they were sent to a station with an open slot for that call. These calls had a higher system priority than returning no-answer and busy records, but lower priority than definite callbacks.
- A non-response conversion staff attempted to call back all initial refusals, other than those households who expressly prohibited such an attempt – for example, "take me off your calling list."

The CATI process was also used for the calls to government agencies and large-scale end users, and similar procedures were used to maximize response rates. In addition, an advance letter was sent to a named representative of each government agency (Appendix D) to encourage response. The letter was sent less than two weeks prior to interviewing. A similar letter was prepared for the large-scale end users (Appendix D) but was not sent in advance. If the respondent requested verification of the legitimacy of the survey, the letter was emailed or faxed.

2.4 SAMPLE SELECTION

2.4.1 General Public

A national sample (50 states and the District of Columbia) of telephone numbers was randomly generated by ORC using GENESYS, a custom random digit dialing (RDD) sample generation system developed by Marketing Systems Group. GENESYS samples include both listed and unlisted residential telephone numbers. As noted by the contractor conducting the surveys (ORC, 2004), GENESYS samples include the following features:

- GENESYS RDD sampling (referred to as "list assisted") provides for a single stage, Equal Probability of Selection Method (EPSEM) sample of residential telephone numbers. The system gives any unlisted number the same chance of selection as a listed one. The system is updated twice a year.
- When a national probability sample is needed, a random selection is made from approximately 40,000 exchanges in two million working banks.
- In GENESYS sampling, telephone prefixes are implicitly stratified by Census Division and metropolitan area status. (This affects the data analysis—see Section 3.[1])
- Each telephone number is transferred to a separate call record. The record shows the computer-generated telephone number to be called, as well as the county, state, and time zone into which the telephone number falls.

For the General Public Survey, replicates of approximately 250 records were created from this sample.[2] Initially 26 replicates (6,500 records) were released for dialing. Subsequent releases were made on June 24 (10 replicates; 2,748 records) and July 15 (2 replicates; 498 records), for a total of 38 replicates and 9,746 records. As has become typical with an unscreened RDD residential sample, over half these records were determined to be disconnected or not in use, business numbers, or otherwise unusable.

RDD methodology was used to produce the sample. Random selection (most recent birthday) was used to select the respondent from each household.

2.4.2 Students

A national sample of telephone numbers was randomly generated as described in Section 2.4.1 for the General Public Survey. A much lower proportion of these numbers were eligible, however, because only students age 12-17 were interviewed.

Initially 28 replicates (7,000 records) were released for dialing. Subsequent releases were made on June 22 (10,943 records) and June 24 (17,023 records), for a total of 34,966 records. The results of the student pretest (see Section 2.5) were used in the final results.

For the main survey of students, replicates of approximately 250 records were created from the sample for the first three releases, with replicates of approximately 1,000 records for the fourth release. Initially 14 replicates (3,514 records) were released for dialing. Subsequent releases were made on July 15 (4,514 records), July 19 (42,026 records) and July 23 (36,179 records), for a total of 86,233 records.

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[1]See also http://www.m-s-g.com/reference/genmeth.htm (Marketing Systems Group, "GENESYS Methodologies") for a discussion of the GENESYS implicit stratification.
[2]A replicate is a conveniently sized subsample (e.g., 100-500 records) of a larger sample of records, selected in conformance with the larger sample's statistical design (e.g., stratification) so as to represent the target population.

2.4.3 State and Local Government Agencies

The state agencies of interest were State Energy Offices (SEOs), Departments of Environmental Protection (DEPs),[3] and Departments of Transportation (DOTs). Functionally similar personnel were sampled in cities and counties (local governments). Because small cities or counties were not expected to be actively planning for hydrogen and fuel cells applications now or in the near future, the target populations for cities were the twelve largest cities in each census region, and the target populations for counties were the twelve largest counties in each census region.[4] For each census region, all twelve largest cities and all twelve largest counties were sampled. When county and city governments were combined into a single government entity, only one call was made to that office, and the next largest county in that census region was selected for interviewing.

The targeted sample size was 246 completed interviews. All offices in the component populations were sampled. As noted in Section 2.3, an advance letter was sent to a named person within each organization. Sampling was accomplished by calling the appropriate office and requesting the person to whom the advance letter had been addressed. The designated respondent could assign someone else in the office to represent the agency if need be.

2.4.4 Large-scale End Users

For the purpose of this survey, large-scale end users were defined as businesses and industries with potential large-scale commercial uses of hydrogen and/or fuel cells. Respondents to the Large-Scale End User Survey did not need to be using hydrogen or fuel cells at the time of the survey interview. Although respondents could have global corporate operations, it was required that they have facilities in the United States, and only personnel in the United States were interviewed. Potential persons to be interviewed included chief executive officers, chief financial officers, facility managers, energy managers, fleet managers, and information/security managers.

Respondent businesses, identified by North American Industry Classification System (NAICS) or Standard Industrial Classification (SIC) codes, were stratified into three sectors of hydrogen usage or potential hydrogen usage:

- Transportation: private and public fleets that use trucks, buses, or other ground-based vehicle types; these are the end users (not developers) of hydrogen-powered vehicles.
- Business types for which energy usage is primarily for facility heating/cooling and localized power requirements and for which on-site power generation is important because of the need for an uninterrupted power supply. These business types include large agricultural

[3]For the purposes of this document, state environmental offices are called Departments of Environmental Protection. The agency name, however, varies by state. Equivalent agency names include Department of Environmental Quality, Department of Environment, or Department of Natural Resources.
[4] The four census regions are Northeast, South, Midwest, and West. A map showing the states in each of the census regions may be found at U.S. Census Bureau, http://www.census.gov/geo/www/us_regdiv.pdf .

productions; hospitals and other healthcare institutions; education institutions; and financial institutions.

- Industrial sectors that have large power requirements—examples include processing, manufacturing, and fabrication plants; mills and refineries; and industrial machinery and equipment plants.

Component population numbers for each of these three categories are shown in Table 2.1.

Table 2.1. Populations and Interview Plans for the Three Sectors in the Large-scale End User Category

Hydrogen Usage Sector	Number in Component Population*	Number in Target Population**	Number of Completed Interviews	Number of Attempted Interviews
Transportation (i.e., end users)	282,866	849	33	66
Businesses needing uninterrupted power supplies	891,817	2,675	33	66
Industrial sectors with large power requirements	344,188	1,033	33	66
Total	**1,518,871**	**4,587**	**99**	**198**

*Based on the Census Bureau's 2002 Economic Census.
**Sampling was restricted to the largest 0.3% of the component populations.

Lists of businesses meeting the above criteria were purchased from Dun & Bradstreet, (specifically the D&B Market Place database). In addition to the NAICS (or SIC) code, the lists included the number of employees and revenues for each listed business. The contact lists were the most recently available for this type of data.

For each NAICS (or SIC) category, businesses in the compiled lists were ranked by either number of employees or revenue, depending on which was considered more appropriate for the category. For the transportation stratum and for the stratum of businesses needing uninterrupted power supplies, the number of employees was used primarily as the ranking criterion for NAICS (or SIC) categories (revenue was used for a few subcategories); for the stratum of industrial businesses with large power requirements, revenue was used for all categories. The largest 0.3% of businesses were then selected from each category and used to represent the subcategory in the strata. The largest businesses were selected because they represent the greatest potential for hydrogen usage. The choice of 0.3% as the cutoff was somewhat arbitrary but was made because the target population so defined is restricted to the largest businesses and yet still represents a large number (thousands) of businesses. For each strata, these largest businesses were then sampled randomly to obtain samples of 66, as indicated in Table 2.1. Appendix E lists the numbers of businesses in the various NAICS-coded (or SIC-coded) subpopulations.

There was one sample release, which consisted of 153 pieces within the transportation segment, 194 within the uninterrupted power supply segment, and 141 within the large power requirement segment.

2.5 PRETESTING

During the development of the survey, various drafts were tested in a limited environment. In addition, drafts were reviewed by National Hydrogen Association and U.S. Fuel Cell Council personnel as well as by management at the DOE Hydrogen Program office.

Finally, an official pretest of the public survey was conducted by the contractor selected to administer the survey. Fifty interviews were conducted. The results seemed to indicate that the knowledge questions were too simple. Knowledge-based questions were revised to increase the difficulty of the questions. The basic structure of the questionnaire was not changed. The pretest results were not used in the final survey. Sample replicates that had been dialed during the pretest were discarded.

A pretest of the Student Survey was also conducted by the contractor. Thirty-seven interviews were completed. The knowledge questions from the public questionnaire (the more difficult version) were used. For the student pretest, replicates of approximately 250 records (i.e., telephone numbers) were created from the sample. Unlike the General Public Survey pretest, no changes were made to questions on the Student Survey after the student pretest. Therefore the student pretest results were incorporated with the final results.

Because the questionnaires for the State and Local Government and Large Scale User Surveys were substantially similar to the questionnaires for General Public and Student Surveys, which were pretested, no pretesting was conducted for the State and Local Government or Large Scale User Surveys.

2.6 INTRODUCTIONS AND PROTOCOL

When a potential respondent answered the phone, there was an introduction and a screening protocol to ensure that the appropriate respondent would be selected. For each survey, the protocol was slightly different.

For the Student Survey, parental permission was acquired (per OMB specification) for each interview. When requesting this permission, it was realized (after pretesting) that selection of the teen based on gender (e.g., “the 16-year-old female”) resulted in a high frequency of hang-ups. Therefore, the screening protocol was revised to request permission to speak with the teen with the most recent birthday, omitting any reference to age or gender. This change resulted in a higher rate of parental permissions, which resulted in a higher rate of completed interviews.

One additional change was made to the original introduction of the general public and student surveys. The original introduction for the general public and student surveys contained the terms "fuel cells" and "hydrogen economy." During administration of the Student Survey, the number of children initially being reported in households was substantially lower than expected from Census Bureau data for households with children in various age ranges. A plausible explanation was that the introduction was causing parents to exclude their children from taking the survey. That is, it appeared that parents were screening their children from technical questions, which the parents felt their children might not understand. Therefore, the introductory words on both the general public and the student surveys were changed to use the terms "energy" and "alternative fuels." (The student and public surveys were being conducted concurrently when the introductory words were revised.) This change affected essentially all of the Student Survey results, but only part of the General Public Survey results.[5] So as not to introduce bias in estimates of changes, future versions of the General Public Survey will incorporate the same before/after mix of introductions that was used in the baseline version.

Survey interviewers always had certain information available to provide, upon request, to respondents: the OMB control number (1910-5124, per OMB specification) and a DOE website [Uniform Resource Locator (URL) = http://www.eere.energy.gov/hydrogenandfuelcells]. The interviewers were also instructed to tell respondents that their responses were completely voluntary but very important, that their responses would not be associated with their household or specific organization in any way, and, if asked, that there were no trick questions on the survey.

While the specific protocol for each of the surveys is shown in the questionnaires, which are in Appendix A, the most significant protocols are as follows:

- For the general public, the adult over 18 years of age with the most recent birthday was selected.
- For the students (after parental permission was obtained), the child age 12-17 with the most recent birthday was selected.
- For the state and local government agencies, a letter was sent to the head of a particular agency (e.g., Director State DOT; city mayor; county executive) requesting participation. A copy of this letter is contained in Appendix D. The designated interviewee could at his/her option assign a surrogate to take the survey.
- For the large-scale end users, the person most responsible for energy-related decisions was selected.

[5]Before the change of wording in the introduction in the General Public Survey, there were 540 respondents, and after the change there were 349 respondents. After the introduction was changed, the technical scores decreased slightly, on average, from 34.7% correct (before) to 30.2% correct (after). Apparently the general public was in fact self-screening for knowledge about hydrogen and fuel cells; that is, before the change in wording, some people refused to take the survey, possibly because they assumed that they could not answer the questions; therefore, a greater percentage of those who did take the survey really did have an understanding of hydrogen and fuel cells. After the change in wording, fewer individuals refused based on the introduction; therefore, the population taking the survey after the change in wording may have had less of an understanding about hydrogen and fuel cells, which is one possible explanation for the lower scores.

3. DATA ANALYSIS METHODS

The General Public Survey and Student Survey are implicitly stratified RDD surveys with sampling weights calculated by post-stratification and iterative proportional fitting. The proper analysis of RDD surveys requires (1) proper use of sampling weights to adjust for both a priori differences in sample selection probabilities and a posteriori differences between known demographic characteristics of the population sampled and the selected sample itself, and (2) proper accounting for the survey design, including stratification and clustering. A priori differences in selection probabilities can be caused, for example, by differences in the number of telephones households have. A posteriori differences between the population and the sample can be caused, for example, by variations in nonresponse (e.g., females more likely to respond). Sampling weights, which can be calculated more than one way, affect both survey estimates, their standard error calculations, and, consequently, confidence levels for them or significance levels for tests about them. Stratification and clustering in the survey design also affect how standard errors should be calculated.

The proper analysis of RDD surveys is generally complicated and requires approximations, many of which are current research issues beyond the scope of this report. See, for example, Lu and Gelman (2003) for a general discussion and references. The analyses performed for this report (Sections 4-7) are adjusted for sampling weights computed (by iterative proportional fitting) by ORC to adjust for differences in household numbers of telephones and a posteriori differences in age, gender, race, and census region. Because the GENESYS RDD samples are implicitly stratified by Census Division and metropolitan area status, the General Public and Student survey data are handled in the analysis as stratified by Census Division and metropolitan area status. This is essentially the approach taken for the Bureau of Transportation Statistics (BTS) Omnibus Survey (BTS, 2002).[6]

The State and Local Government Survey is not an RDD survey, though it is stratified by Census Region and government function (largest cities and counties, and state departments of energy, environmental protection, and transportation). This survey was intended as a census (complete sample); there were, nevertheless, a few nonrespondents. In the analysis, the nonrespondents were treated as random, so that the responders composed a (nearly complete) random sample.

The Large-Scale End User Survey is not an RDD survey, but it is randomly sampled within three strata (transportation, businesses needing uninterrupted power supplies, industrial sectors with large power requirements). Thus, all four survey components are stratified or weighted or both. Whereas the general public and student populations are huge and treated as essentially infinite in the statistical analysis, the state and local government and large-scale end user populations are much smaller, and are treated as finite in the analysis.[7]

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[6]See also http://www.m-s-g.com/reference/genmeth.htm (Marketing Systems Group, "GENESYS Methodologies") for a discussion of the GENESYS implicit stratification.

[7]The state and local populations are all of the states (9, 12, 16, and 13 states respectively in the Northeast, Midwest, South, and West Census Regions) and the twelve largest cities and counties in each Census Region. The large-scale end user populations are the largest 0.3% of transportation businesses, businesses

The Statistical Analysis System (SAS) Version 9.1 software (SAS, 2004) was used to perform the analysis of the infinite-population, stratified, and weighted General Public and Student Surveys, and the finite-population, stratified State and Local Government and Large-Scale End User Surveys. The SAS surveymeans procedure was used to compute means of (essentially) continuous response variables such as the collective percentage of correct answers to the technical questions, and the SAS surveyfreq procedure was used to compute frequency estimates for categorical responses (such as answers to "Which of the following would you MOST closely associate with the word 'hydrogen'?"). The surveyfreq procedure was also used to perform cross-tab analyses to explore relationships between responses and respondent characteristics such as sex, age, and educational degree. In addition to computing properly weighted estimates, the SAS procedures compute standard errors (and thus confidence levels and test significance levels), which account for both stratification and sampling weights, using a method based on Taylor series approximations (Woodruff, 1971; Fuller, 1975). Alternative methods for computing standard errors (e.g., balanced repeated replication or jackknife methods) are not considered here.

Other data analysis issues such as missing values (of which there are very few) and response rates are discussed in Sections 4-7 for the individual survey components. In Section 8, results are compared across survey components using essentially the same methodology discussed in this section. In three-year intervals (2008 and 2011), the surveys will be repeated, and subsequent results will be compared with the baseline results, again using the same methods. These comparisons will be fairly straightforward, because the surveys conducted at different times and the different survey components are all statistically independent.

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needing uninterrupted power supplies, and industrial businesses with large power requirements. The largest 0.3% amounted to 849, 2,675, and 1,033 businesses in each of the respective business categories.

4. RESULTS: GENERAL PUBLIC SURVEY

4.1 INTRODUCTION

This section summarizes the results of the General Public Survey. A copy of the survey is provided in Appendix A.1. Please note that the question numbering is not always consecutive; however, the results displayed in this chapter correlate to the question numbers in the questionnaire given in Appendix A.1. A total of 889 interviews with the general public were completed. The average interview length was 12.3 minutes. The results of this survey are provided in Appendix C.1.

Appendix C.1 and Section 4.2 contain tables and charts for "one-way" statistics; that is, categories for these summaries are defined in terms of one survey variable such as sex, region, or response to a specific question. Weighted frequencies and weighted means are used for the summaries, and standard deviations and confidence bounds (that account for the sampling weights) are also given to quantify the statistical variability of the frequencies and means.

Obviously there are also myriad relationships and interactions between the survey variables that could be investigated (for example, "Does the respondent's sex or geographic region affect his/her responses to Question 4d?"). Although no such interactions were of particular interest a priori, a few of the more pronounced response interactions are investigated in Section 4.3.

Section 4.4 is about outcome rates – particularly, response rates. Response rates are of interest in all sample surveys, because low response rates suggest the possibility of response bias. Response rates are also of interest in the sense that interest in and awareness of hydrogen can affect response rates in this and future hydrogen surveys.

For the sake of simplicity, several variables are reduced to a higher level form in some analyses, particularly in Section 4.3. The thirteen age categories are sometimes also considered in terms of just two categories: 18-44 and 45+. Urbanization is indicated with two classes, urban (city) and non-urban (suburban, metropolitan with no central city, and non-metropolitan areas). Degree is defined as associate degree or higher. A variable "Above Average?" indicates whether respondents scored above or below the mean for all respondents on the survey's eleven technical knowledge questions. See Appendix A.1 for a copy of the questionnaire; the eleven knowledge questions are 1a, 1b, 1c, 1d, 1e, 1g, 1h (all true-false questions), and 3a, 3b, 3c, 3f (all multiple choice questions).

In addition to the technical knowledge questions, other questions asked for opinions or reactions to certain statements. These questions included Question 2, which asked respondents to rank the importance of certain features, and Questions 3d, 3e, 4, 5, and 6. Questions 7 and 8 asked about sources of information. Questions 9-12 were demographic questions.

4.2. SUMMARY TABLES

The frequencies of the various responses (called response values) to the various questions in the General Public Survey are listed in Appendix C.1. Both weighted and unweighted frequencies are given. Unweighted frequencies are the raw counts. Weighted frequencies are adjusted to more accurately reflect actual U.S. demographic characteristics. A standard deviation of the weighted frequency measures the statistical variability of the frequency. (The range defined by taking plus or minus two standard deviations from the frequency is an approximate 95% confidence interval for the expected frequency.) The weighted frequencies are also expressed as percentages, with standard errors similarly reflecting statistical variability.

Figure 4.1 shows the responses graphically for the survey question about the safety of hydrogen relative to gasoline and diesel (survey Question 4d). The options that were provided to respondents were "Disagree," "Are neutral," "Agree," or "No opinion." As can be seen in Figure 4.1, most people agreed with the statement "Hydrogen is as safe as gasoline and diesel fuels." Many respondents, however, provided a "No opinion" response.

General Public Perception of the Safety of Hydrogen as a Fuel

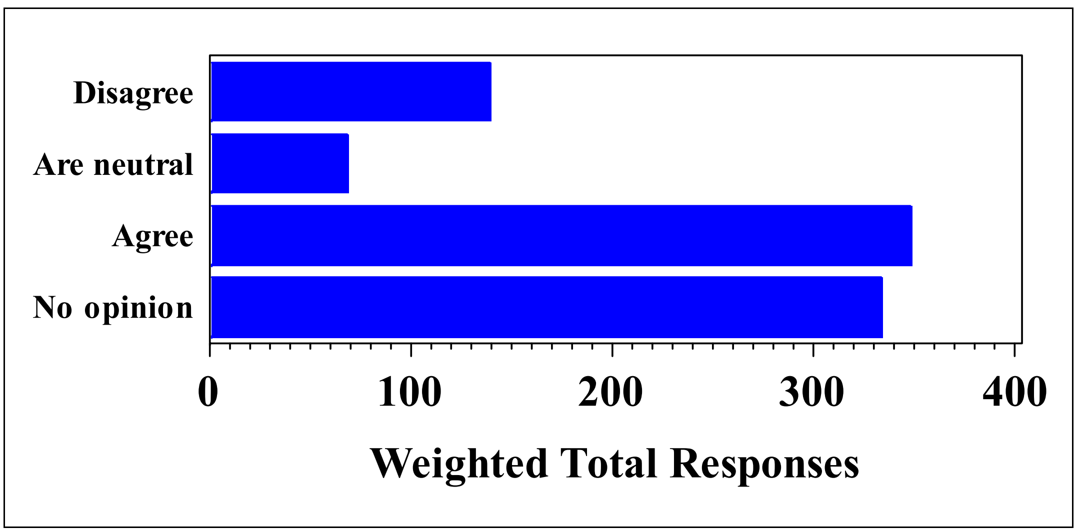

Figure 4.1. Responses to Question 4d, "Hydrogen is as safe as gasoline and diesel fuels," General Public Survey.

The rank scores for the question asking respondents to rank the importance of safety, cost, environment, and convenience (Question 2) are summarized in Table 4.1 as the weighted averages of the ranks (1-4) assigned by each survey subject. In this ranking, "1" ranks as more important than "2," etc. Therefore, the lower the weighted average rank, the more important is the "Value." On average, the rankings were in the order "Safety" is more important than "Cost" is more important than "Environment" is more important than "Convenience," though many individuals departed from that exact order. Figure 4.2 also illustrates this pattern. The last six "Value" entries in Appendix C.1 are for pairwise comparisons based on the safety, cost, environment, and convenience preference rankings. Each possible pair (e.g., safety and cost) is considered separately.

Table 4.1. Weighted Average Preference Ranks for the General Public

Question	Number of Responses*	Weighted Average Rank	Lower 95% Confidence Bound	Upper 95% Confidence Bound
Safety	874	1.9	1.9	2.0
Cost	874	2.2	2.1	2.2
Environment	874	2.4	2.4	2.5
Convenience	874	3.1	3.1	3.2

*15 respondents did not rank the alternatives.

Note that the lower the rank, the greater the importance that was attributed to the value; for example, safety was ranked as more important than cost.

The order in which the options – safety, cost, environment, or convenience – were presented to respondents taking the survey was variable. In other words, the four options were rotated by the CATI system to prevent the influence of order on the selection of a "first choice." Another way of looking at the ranking is to look at which factor was selected as most important (i.e., which option was selected first) out of all four options.[8]

[8] This perspective does not take into consideration tied responses. For example, safety and environment might both be ranked number 1.

Figure 4.2 shows the share of respondents selecting each factor as most important. As shown in Figure 4.2, safety and low cost were chosen by respondents as most important 38.7% and 32.7% of the time, respectively; environmental protection was selected as most important by 18.7% of the respondents, and convenience was most important to 8.2% of the respondents. Almost 1.7% of the respondents had no opinion or were not able to name a first choice.

Value Rankings by the General Public

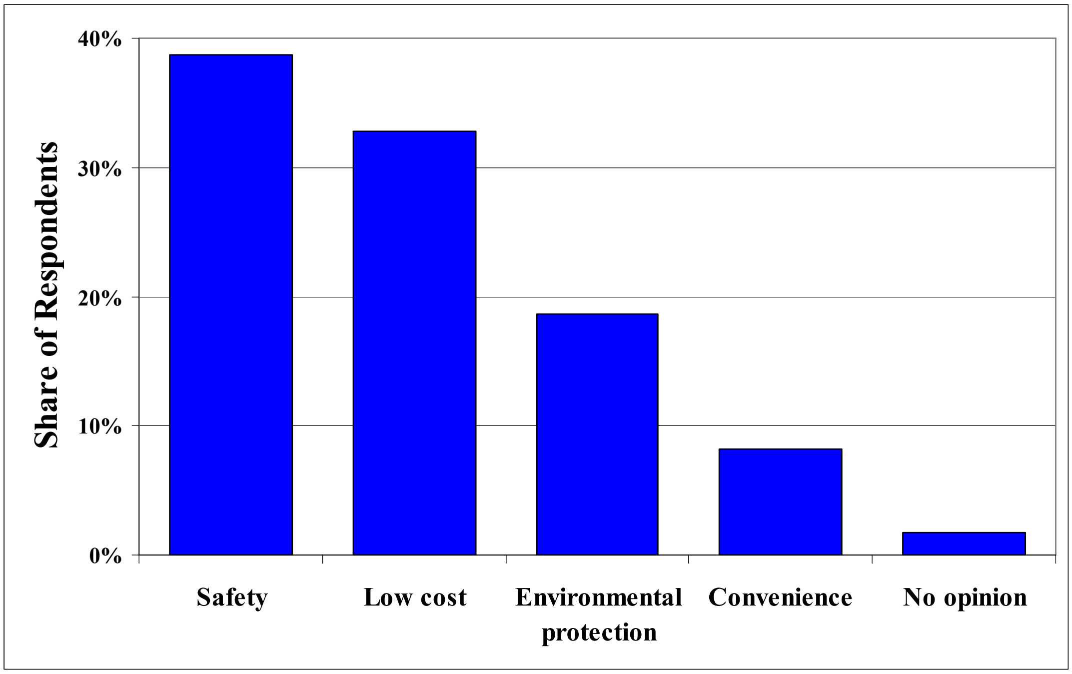

Figure 4.2. Share of respondents ranking each factor as most important when all four factors were read, Question 2, General Public Survey.

Results for technical knowledge questions (along with the other questions) can be summarized as in Appendix C.1. However, the technical questions can also be summarized in terms of whether they were answered correctly. In this summary, “Don’t know” can be handled either as an incorrect response (i.e., a failure to give the correct response) or as a separate kind of response. Table 4.2 summarizes the technical questions in terms of whether they were answered correctly or incorrectly with “Don’t know” treated as an incorrect response. (Table 4.2 is similar to Table 4.1, except that the average weighted percentages of correct responses are given rather than average weighted ranks.)

Table 4.2. Summary of Results for the General Public on the Technical Knowledge Questions (Correct/Incorrect)				
Question	**Number of Responses**	**Weighted Percent Correct**	**Lower 95% Confidence Bound**	**Upper 95% Confidence Bound**
1a. Hydrogen pipelines exist nationwide (false)	889	32.4	29.1	35.7
1b. In a hydrogen economy, hydrogen replaces fossil fuels as the dominant form of energy (true)	889	44.0	40.4	47.6
1c. Hydrogen gas is toxic (false)	889	37.1	33.6	40.6
1d. Fuel cells produce electricity through hydrogen combustion (false)	889	11.8	9.4	14.2
1e. Hydrogen is too dangerous for everyday use by the general public (false)	889	41.9	38.4	45.4
1g. Hydrogen is lighter than air (true)	889	57.3	53.8	60.9
1h. Hydrogen has a distinct odor (false)	889	47.0	43.4	50.6
3a. In which state or condition can hydrogen be stored? (chemical compound and liquid)	889	29.4	26.2	32.7
3b. When using pure hydrogen, fuel cell vehicles generate electricity, water, and what else? (heat)	889	18.5	15.8	21.2
3c. Hydrogen can be produced using which of the following sources of energy? (natural gas, sunlight, organic matter)	889	38.4	34.9	41.9
3f. Which of the following represents a type of fuel cell? (PEM)	889	3.4	2.1	4.7
Overall Average	**889**	**32.8**	**31.3**	**34.4**

The fewest number of correct responses was to Question 3f, which asked respondents about their knowledge of a specific type of fuel cell. Other questions with low percentages of correct responses were 1d and 3b, both concerning fuel cells. The greatest number of correct responses was to Question 1g, which was a question about hydrogen.

The correct/incorrect perspective used in Table 4.2 is conventional, since “Don’t know” is generally considered an incorrect response. However, “Don’t know” was a very common response to the survey technical questions. Figure 4.3 shows the responses broken down according to type: Correct, Incorrect, and “Don’t know.” On average, 32.8% of questions were answered correctly, 24.2% were answered incorrectly, and 43.0% were answered with “Don’t know.”

Technical Knowledge Scores for the General Public

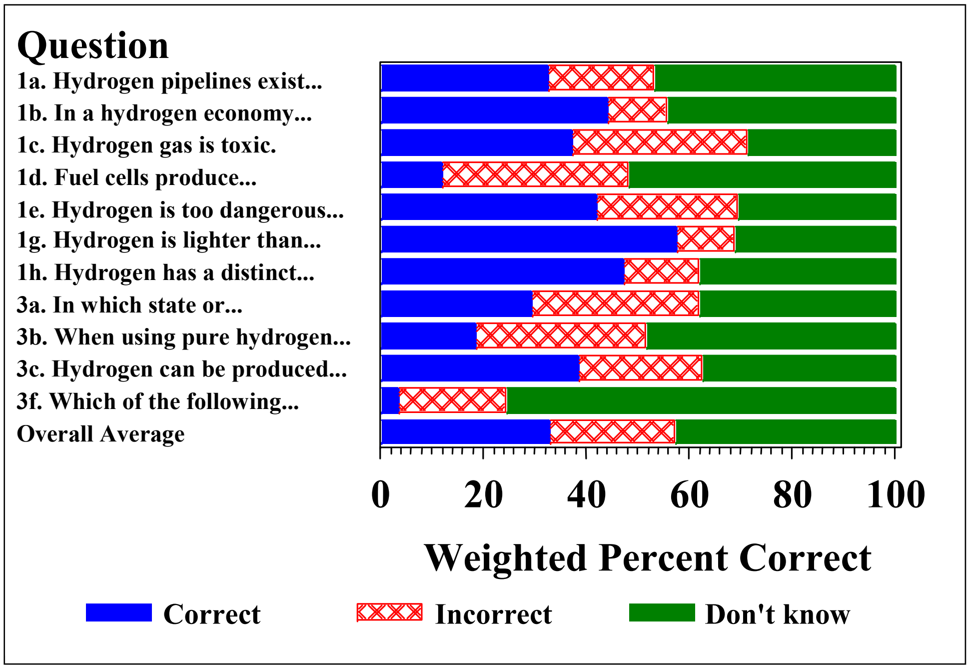

Figure 4.3. Weighted percent correct, incorrect, and “Don't know” for the technical knowledge questions, General Public Survey.

Figure 4.4 shows the distribution of responses. The dispersion about the mean score (32.8%) is substantial, as might be expected, given the varied backgrounds of general public respondents. The distribution is skewed towards fewer correct answers, with 11.5% of respondents answering zero technical questions correctly and 0.3% of respondents answering all eleven technical questions correctly.

Distribution of Technical Question Responses from the General Public

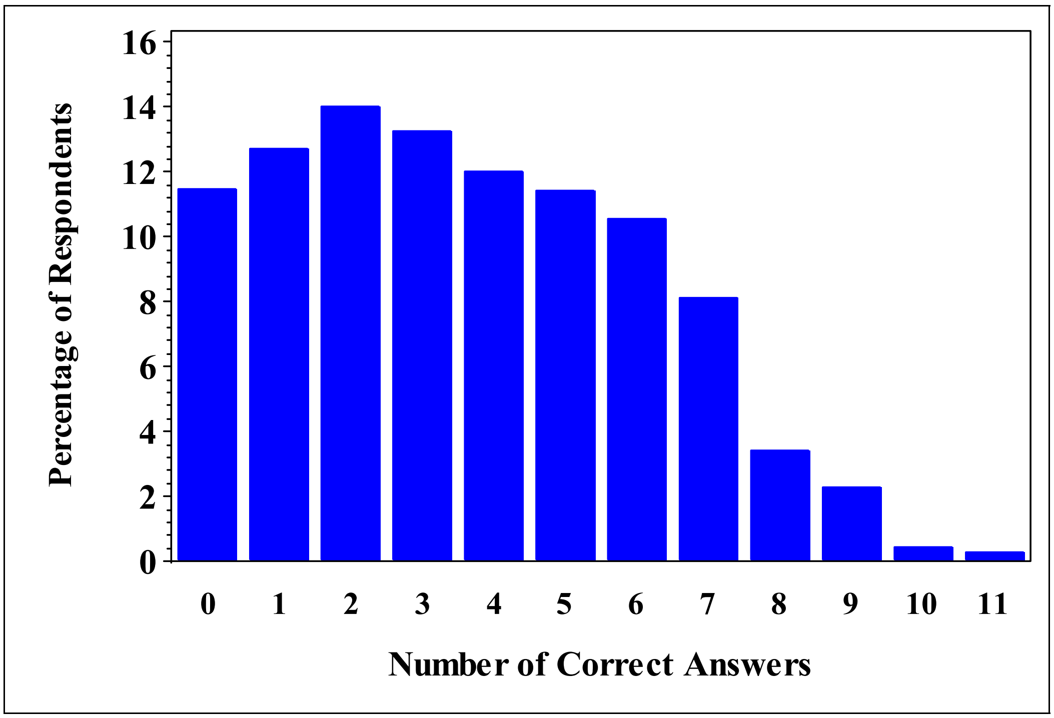

Figure 4.4. The distribution of the number of correct answers to the eleven technical questions, General Public Survey.

Figure 4.5 shows responses to Questions 5 and 6. Question 5 asked respondents to rate the likelihood of widespread commercial availability for hydrogen and fuel cells in the next five years for six separate potential applications. Figure 4.5 shows the percentage of respondents rating the likelihood as "High." Question 6 asked about the safety of using hydrogen and fuel cells, in comparison with technology in use today, for the same applications. Figure 4.5 shows the percentage of respondents who ranked hydrogen and fuel cells as "Equally as safe" or "Safer."

General Public Perceptions of Safety and Availability of Hydrogen Applications

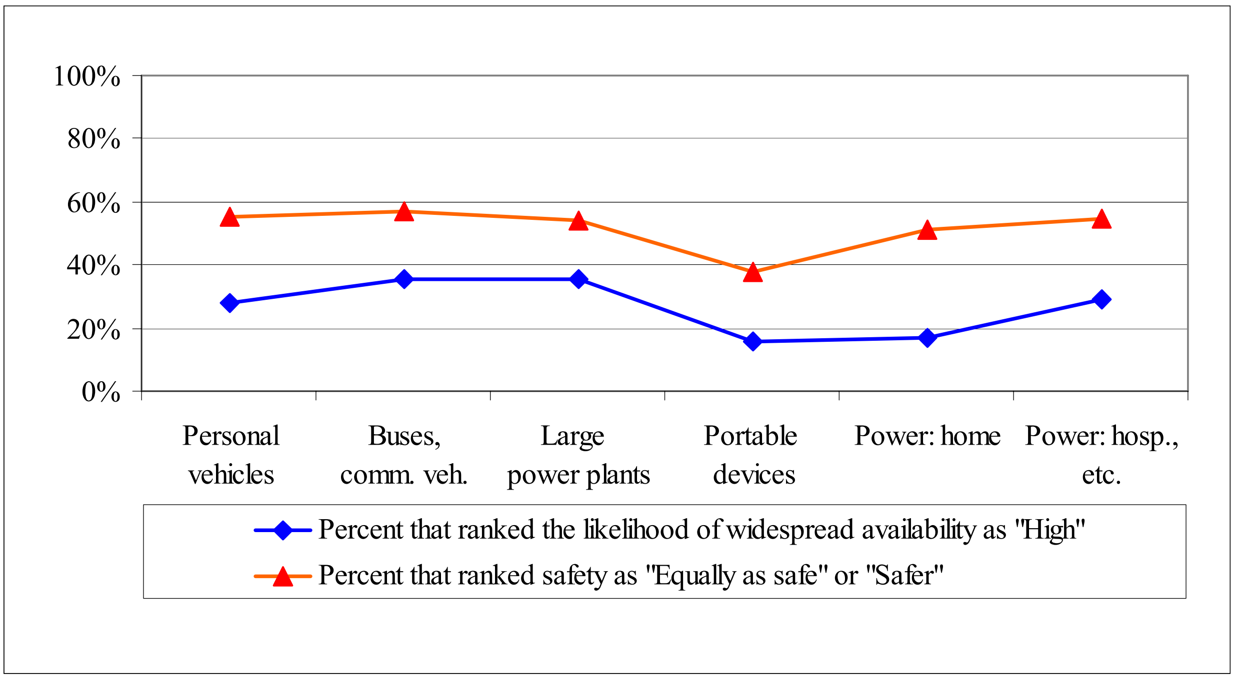

Figure 4.5. Weighted percent of responses to Questions 5 and 6 concerning widespread commercial availability within the next five years and perception of safety for specific applications, General Public Survey.

The general public considers buses and commercial vehicles and large power plants as being the most likely applications for widespread availability in the next five years. The general public also considers small portable devices as being the least likely application.

The adults responding to the General Public Survey were asked two questions about information sources. Question 7 asked about the frequency of use ("Never," "Sometimes," "Frequently") of information sources to make decisions about energy costs and safety. As shown in Figure 4.6, the source marked "Frequently" most often was utility companies or brokers such as gas or electricity providers (21.1% of respondents indicated frequent use of this source), followed by friends and family. These sources were also used "Sometimes" more often than the other sources. All other sources (teachers/schools, environmental groups, and the three government sources) received more "Never" responses than either "Sometimes" or "Frequently."

Comparison of Energy Information Source Use by the General Public

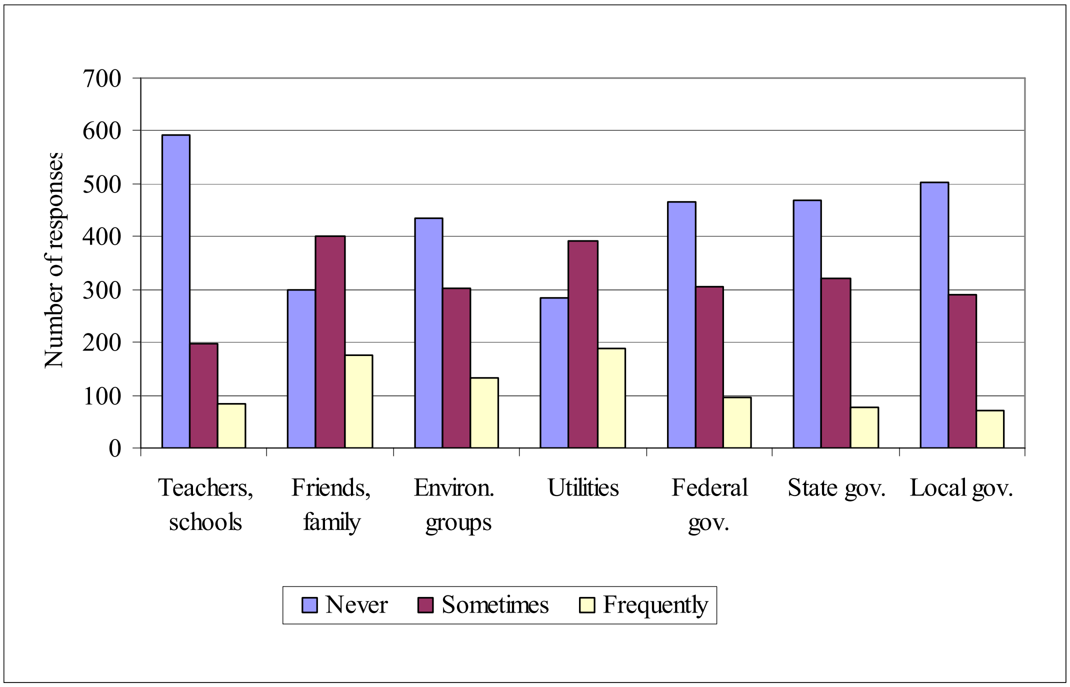

Figure 4.6. Weighted frequency of responses to Question 7 regarding the use of information for making decisions about energy costs and safety, General Public Survey.

Question 8 also asked about use of information sources but from a different perspective. Question 8 asked about the frequency of use of different types of mass media for obtaining energy information (Figure 4.7). As shown in the figure, the Internet and technical magazines are not generally used by the general public to obtain energy information. The general public indicated that television is the media source used most frequently for obtaining energy information.

Use of Mass-Media Sources for Energy Information by the General Public

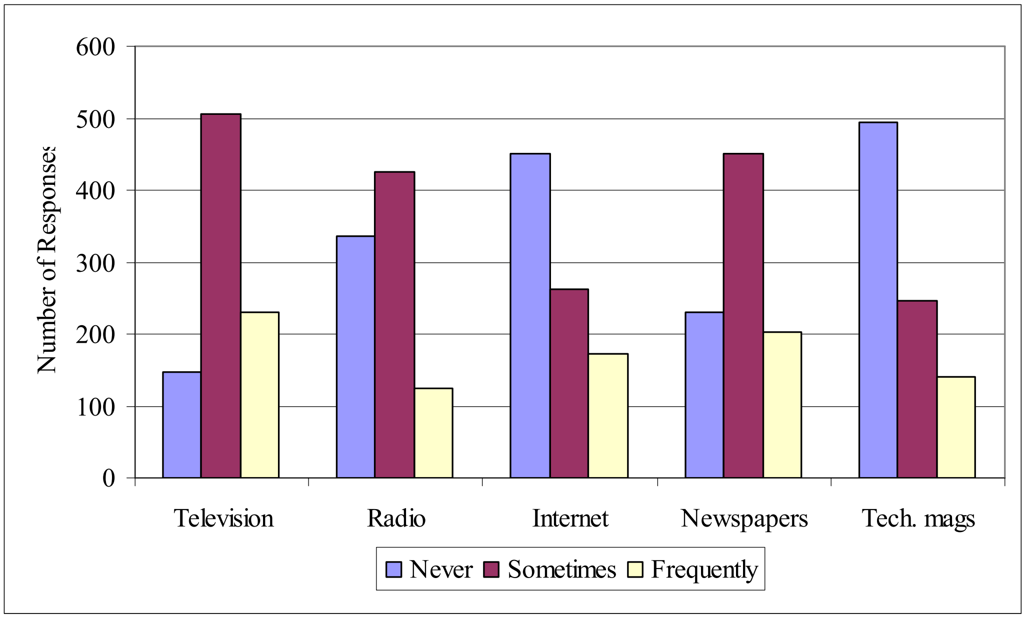

Figure 4.7. Weighted frequency of responses to Question 8, "How often do you get ENERGY information from different types of mass media," General Public Survey.

4.3. RELATIONSHIPS

The summary statistics in Section 4.2 are "one-way" statistics in the sense that the response categories are defined in terms of one variable such as sex, region, or response to an opinion question (e.g., Question 4d, "Hydrogen is as safe as gasoline and diesel fuels"). However, relationships in the responses determined by two or more variables may also be of interest. Although no relationships were of particular interest a priori, in this section a few of the more statistically significant ones are illustrated. Interactions that are considered are with the survey variables and sex, age (18-44, and 45+), region, urban/non-urban, degree (no degree/associate or above), and the score "Above Average." The statistical significance is the significance level (p) of a chi-square test that accounts for the sampling weights.[9]

[9]Measures could also be based on odds ratios or combinations of odd ratios and significance levels as well as other metrics. Significance levels alone were used for simplicity and because sample sizes are essentially the same for all survey questions.

For example, the most statistically significant response difference between the sexes was for True-false Question 1b (Figure 4.8), “In a hydrogen economy, hydrogen replaces fossil fuels as the dominant form of energy.” Males tended to answer “True” for this question much more frequently than females, and females indicated “Don’t know” much more often ($p < .0001$).

General Public Responses to Hydrogen Economy Question by Gender

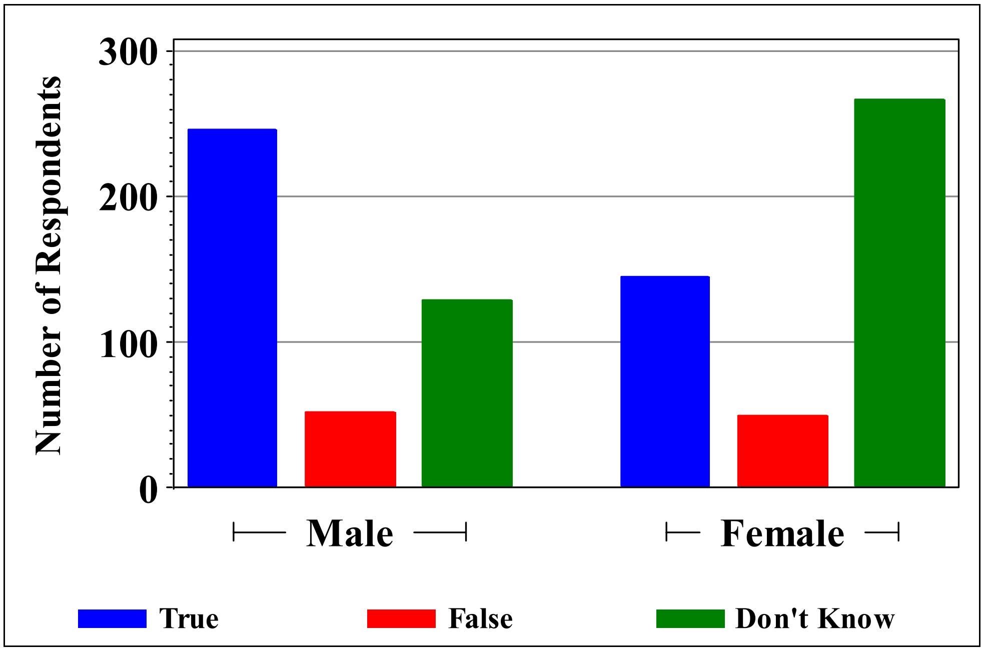

Figure 4.8. Responses to Question 1b, “In a hydrogen economy, hydrogen replaces fossil fuels as the dominant form of energy,” General Public Survey.

The most statistically significant interaction with respect to age (18-44 and 45+) was in the responses to Question 3d ($p < .0001$), “Which of the following would you MOST closely associate with the word ‘hydrogen’?” Younger respondents answered “Chemistry class” more often, whereas older respondents answered “The H-bomb” (and “The Hindenburg”) more often (Figure 4.9). For both age groups, the least frequent association (other than the “Don’t know” response) was “Fuel.”

General Public Word Associations with Hydrogen by Age Group

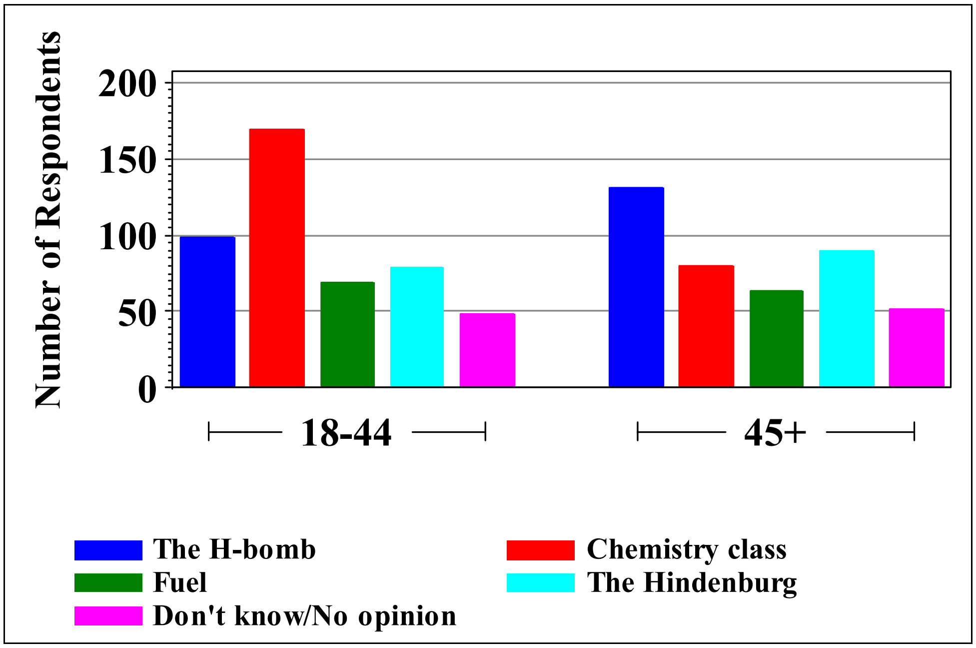

Figure 4.9. Responses by age to Question 3d, “Which of the following would you MOST closely associate with the word ‘hydrogen’,” General Public Survey.

It is also interesting to note (Figure 4.9) that although the 18-44 group scored slightly better on the technical questions, the difference between the two age groups was not statistically significant ($p=.15$; the overall technical score average was 34.1 ± 1.2 (one standard error) for the 18-44 group, and 31.7 ± 1.0 for 45+ group).

There were statistically significant regional differences, one of which was in the preference of safety over convenience. Respondents from the Northeast and South showed a stronger relative preference for Safety than respondents from the Midwest and West (p=.006), as illustrated in Figure 4.10.

General Public Preferences for Safety or Convenience by Census Region

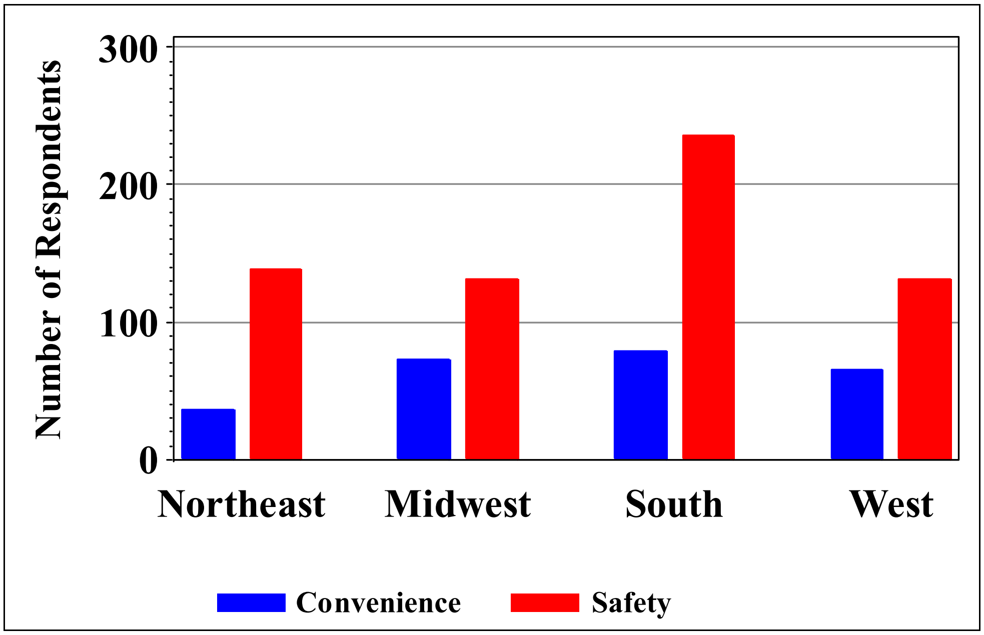

Figure 4.10. Preferences of safety or convenience, by Census Region, General Public Survey.

The most significant difference between respondents with a college degree (associate, bachelors, post-graduate) and those having no college degree was in responses to Question 3e, "How would you feel if your local gas station also sold hydrogen?" As seen in Figure 4.11, respondents with a college degree were much more comfortable with the idea of a local hydrogen filling station ($p < .0001$) than respondents with no degree.

General Public Response to Hydrogen at Gas Stations by Education

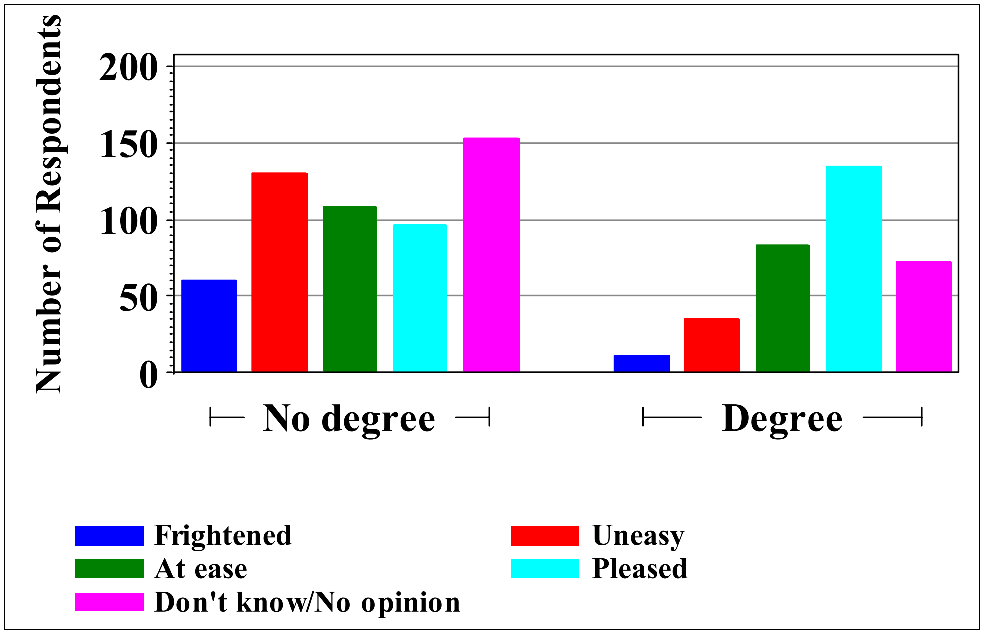

Figure 4.11. Responses by college degree/no-degree to Question 3e, "How would you feel if your local gas station also sold hydrogen," General Public Survey.

In addition (Figure 4.11), persons without a college degree were more likely to indicate that they would feel frightened or uneasy with a locally available hydrogen refueling station. They also responded with a "Don't know" or "No opinion" response more often.

The most significant associations with the below/above-average score differences (on the technical questions) were with answers to individual technical questions. This is not surprising, because the average score is functionally dependent on scores to individual questions. The most significant association of below/above-average score differences with a response other than to a technical question was again with Question 3e, "How would you feel if your local gas station also sold hydrogen?" As with more educated respondents, respondents who did better on the technical questions were much more likely ($p < .0001$) to say they would be comfortable with a local hydrogen filling station (Figure 4.12).

General Public Response to Hydrogen at Gas Stations by Technical Knowledge Score

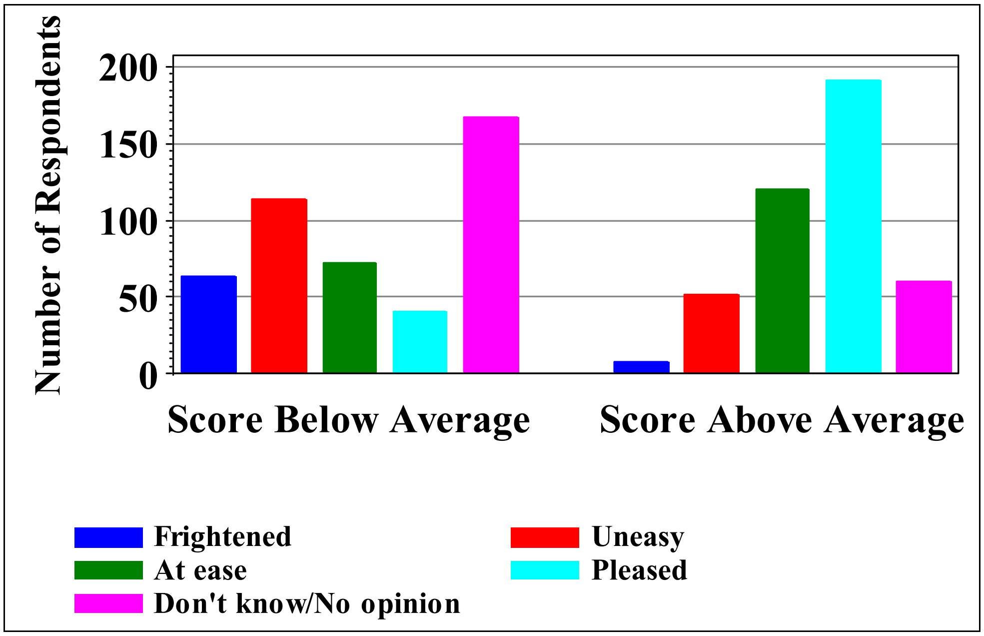

Figure 4.12. Responses by technical score above/below average to Question 3e, "How would you feel if your local gas station also sold hydrogen," General Public Survey.

4.4. OUTCOME RATES

Various outcome rates are of interest in characterizing survey data results. The *response rate* is the proportion of sampled eligible subjects for whom complete survey interview information was obtained. The *refusal rate* is the proportion of sampled eligible subjects who refused to be interviewed or who terminated their interviews before completion. The *contact rate* is the proportion of sampled eligible subjects that were contacted at all. In general the number of eligible subjects must be estimated, and there are various ways to estimate this number and to define, in turn, estimates of the rates. The American Association for Public Opinion Research (AAPOR) gives various definitions (AAPOR, 2004) for the rates and provides a spreadsheet calculator for computing them.

Estimates of the rates are computed from outcome frequencies, as shown in the following table for the General Public Survey.

Table 4.3. Outcome Frequencies for the General Public Survey	
Outcome Type	**Frequency**
Complete interviews (I)	889
Partial interviews (P)	61
Refusals and break offs (R)	1,047
Non-contacts (NC)	17
Other eligible, non-interviews (O)*	856
Known eligible	**2,870**
Unknown households (UH)	491
Unknown others (UO)	1,451
Eligibility unknown	**1,942**
Known ineligible	**4,934**
Total phone numbers used	**9,746**
*This category is a catchall for various kinds of eligible non-interviews. See AAPOR (2004, page 39) for a complete listing of outcome categories.	

The eligibility rate can be estimated as

e = Known eligible / (Known eligible + Known ineligible).

The eligibility rate estimate **e** can be applied to cases of unknown eligibility to estimate the number of those cases that were actually eligible. The response rate can then be estimated (there are other ways) as

Response rate = I/(I + P + R + NC + O + e × (UH + UO)).

For the General Public Survey

e = 2,870/(2,870 + 4,934) = .3678,

and the response rate estimate is

Response rate estimate = 889/(889+61+1,047+17+856+.3678 × (491+1,451)) = .2480.

In comparing survey results over time or across survey components, it is important to consider the response rates and other outcome rates. Contact rates may decline, for example, as cell phone use increases and land line use decreases. From the perspective of hydrogen technology awareness, the rates are of independent interest. For example, it is likely that the response rate would increase and the refusal rate would decrease, for a population that becomes more enthusiastic about hydrogen technology. However, subjects might self-select for the very reason that they are knowledgeable about hydrogen, and a low response rate might upwardly bias estimates of awareness.

5. RESULTS: STUDENT SURVEY

5.1 INTRODUCTION

This section summarizes the results of the Student Survey. A copy of the survey is provided in Appendix A.2. Please note that the question numbering is not always consecutive; however, the results displayed in this chapter correlate to the question numbers in the questionnaire given in Appendix A.2. A total of 1,000 interviews were completed (37 in the pilot and 963 in the full survey). The average interview length was 14.1 minutes, which included the protocol for getting parental permission to interview the student. The results of this survey are provided in Appendix C.2.

Appendix C.2 and Section 5.2 contain tables and charts for "one-way" statistics; that is, categories for these summaries are defined in terms of one survey variable such as sex, region, or response to a specific question. Weighted frequencies and weighted means are used for the summaries, and standard deviations and confidence bounds (that account for the sampling weights) are also given to quantify the statistical variability of the frequencies and means.

Obviously there are also myriad relationships and interactions between the survey variables that could be investigated. (For example, "Does the respondent's sex or geographic region affect his/her responses to Question 3d?") Although none of the interactions were of particular interest a priori, a few of the more pronounced response interactions are investigated in Section 5.3.

Section 5.4 is about outcome rates – particularly, response rates. Response rates are of interest in all sample surveys, because low response rates suggest the possibility of response bias. Response rates are also of interest in the sense that interest in and awareness of hydrogen can affect response rates in this and future hydrogen surveys.

For the sake of simplicity, several variables are reduced to a higher level form in some analyses, particularly in Section 5.3. Grade in school, which ranged from fourth up, was reduced to just two categories: 8^{th} and below and 9^{th} and above. (Two home-schooled individuals and five "refused" were excluded in the reduced classification.) Urbanization is indicated with two classes, urban (city) and non-urban (suburban, metropolitan with no central city, and non-metropolitan areas). A variable "Above Average?" indicates whether respondents scored above or below the mean for all respondents on the survey's eleven technical questions. See Appendix A.2 for a copy of the questionnaire; the eleven knowledge questions are 1a, 1b, 1c, 1d, 1e, 1g, 1h (all true-false questions), and 3a, 3b, 3c, 3f (all multiple choice questions).

In addition to the technical knowledge questions, other questions requested opinions or reactions to certain statements. These questions included 3d, 3e, 4, 5, and 6. Questions 7 and 8 asked about sources of information. Questions 9-11 were questions related to science topics and the educational experience, and Questions 12-14 were demographic questions.

5.2. SUMMARY TABLES

The frequencies of the various responses (called response values) to the various questions in the Student Survey are listed in Appendix C.2. Both weighted and unweighted frequencies are given. Unweighted frequencies are the raw counts. Weighted frequencies are adjusted to more accurately reflect actual U.S. demographic characteristics. A standard deviation of the weighted frequency measures the statistical variability of the frequency. (The range defined by taking plus or minus two standard deviations from the frequency is an approximate 95% confidence interval for the expected frequency.) The weighted frequencies are also expressed as percentages, with standard errors similarly reflecting statistical variability. Figure 5.1 shows the distribution of student grades (answers to Question 12, "What was the last grade of school you completed?").

Distribution of Students by Grade Level

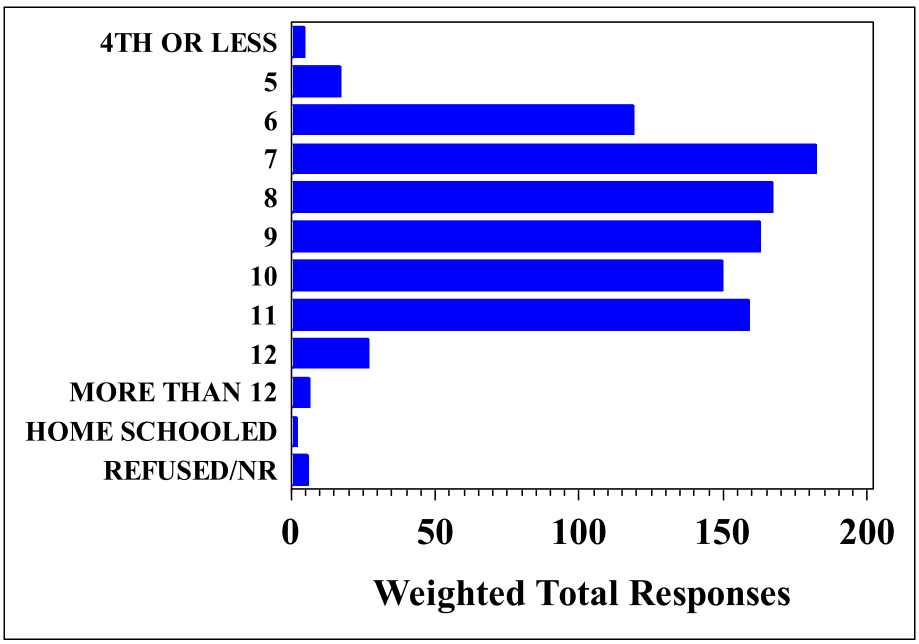

Figure 5.1. Responses of students to Question 12, "What was the last grade of school you completed," Student Survey.

Figure 5.2 shows the responses to Question 3d, "Which of the following would you MOST closely associate with the word 'hydrogen'?"

Student Word Associations with Hydrogen

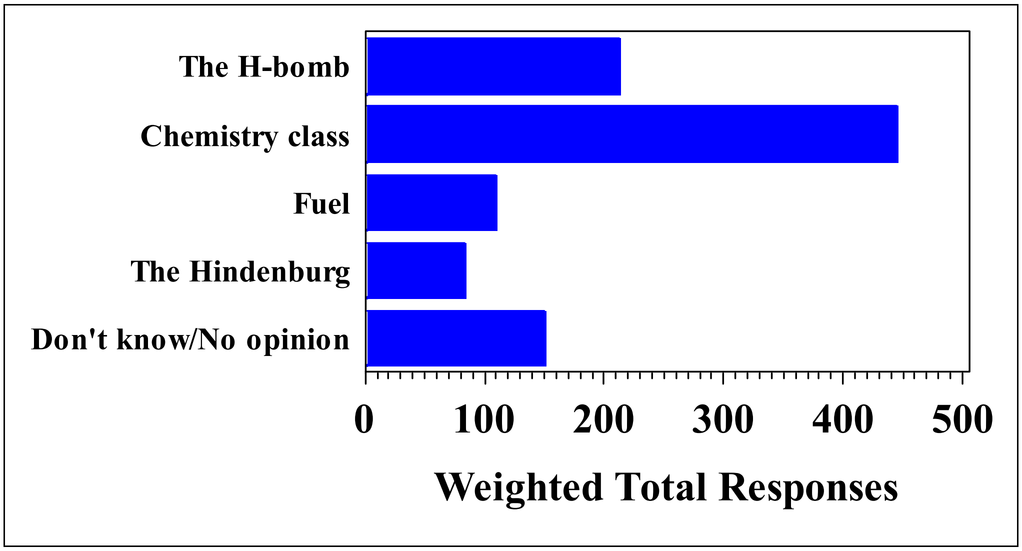

Figure 5.2. Responses of students to Question 3, "Which of the following would you MOST closely associate with the word 'hydrogen'," Student Survey.

It is interesting to compare the responses of students to this question with those of the general public. Adults, ages 18-44, have a similar pattern to their responses – that is, they associate the word "hydrogen" with chemistry class more often that with any of the other terms. Adults over 45, however, were more likely to respond with an association of "the H-bomb" or "the Hindenburg."

Results for technical knowledge questions (along with the other questions) can be summarized as in Appendix C.2. However, the technical questions can also be summarized in terms of whether they were answered correctly. In this summary, "Don't know" can be handled either as an incorrect response (i.e., a failure to give the correct response) or as a separate kind of response. Table 5.1 summarizes the technical knowledge questions in terms of whether they were answered correctly or incorrectly with "Don't know" treated as an incorrect response.

Table 5.1. Summary of Results for the Students on the Technical Knowledge Questions (Correct/Incorrect)

Question	Number of Responses	Weighted Percent Correct	Lower 95% Confidence Bound	Upper 95% Confidence Bound
1a. Hydrogen pipelines exist nationwide (false)	1,000	25.3	22.5	28.0
1b. In a hydrogen economy, hydrogen replaces fossil fuels as the dominant form of energy (true)	1,000	43.2	40.0	46.3
1c. Hydrogen gas is toxic (false)	1,000	37.9	34.8	41.1
1d. Fuel cells produce electricity through hydrogen combustion (false)	1,000	13.4	11.2	15.7
1e. Hydrogen is too dangerous for everyday use by the general public (false)	1,000	44.8	41.6	48.0
1g. Hydrogen is lighter than air (true)	1,000	52.1	48.9	55.3
1h. Hydrogen has a distinct odor (false)	1,000	46.7	43.5	49.9
3a. In which state or condition can hydrogen be stored? (chemical compound and liquid)	1,000	35.4	32.4	38.5
3b. When using pure hydrogen, fuel cell vehicles generate electricity, water, and what else? (heat)	1,000	16.7	14.3	19.1
3c. Hydrogen can be produced using which of the following sources of energy? (natural gas, sunlight, organic matter)	1,000	35.4	32.4	38.5
3f. Which of the following represents a type of fuel cell? (PEM)	1,000	2.7	1.6	3.7
Overall Average	**1,000**	**32.2**	**31.0**	**33.3**

As with the general public, the fewest correct responses were for Questions 3f, 1d, and 3b, all on the subject of fuel cells.

The correct/incorrect perspective is conventional, since “Don’t know” is generally considered an incorrect response. However, “Don’t know” was a very common response to the survey technical questions. Figure 5.3 shows the responses broken down according to type: Correct, Incorrect, and “Don’t know.” On average, 32.2% of the questions were answered correctly, 36.2% were answered incorrectly, and 31.6% were answered with “Don’t know.”

Student Technical Knowledge Scores

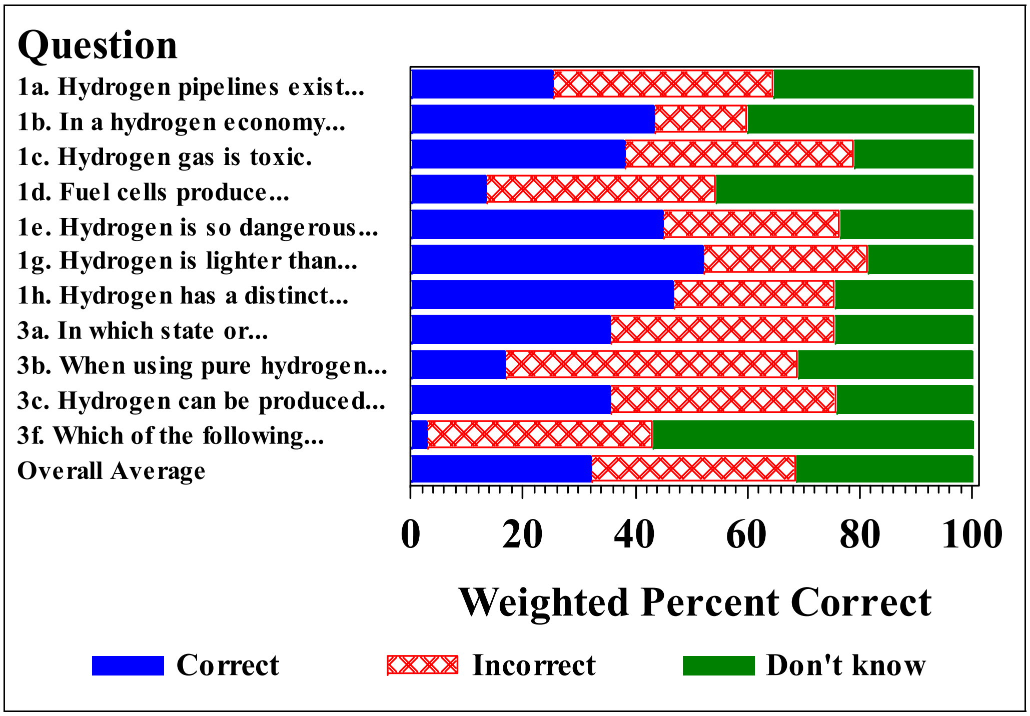

Figure 5.3. Weighted percent correct, incorrect, and “Don't know” for the technical questions, Student Survey.

Figure 5.4 shows the distribution of scores for the Student Survey. The dispersion about the mean score (32.2% correct) is substantial, but tighter than for the general public (Figure 4.4), which is more heterogeneous in age than is that of the students. About 5.1% of the students answered no technical questions correctly, and no students were able to answer more than nine questions correctly.

Distribution of Student Responses to Technical Questions

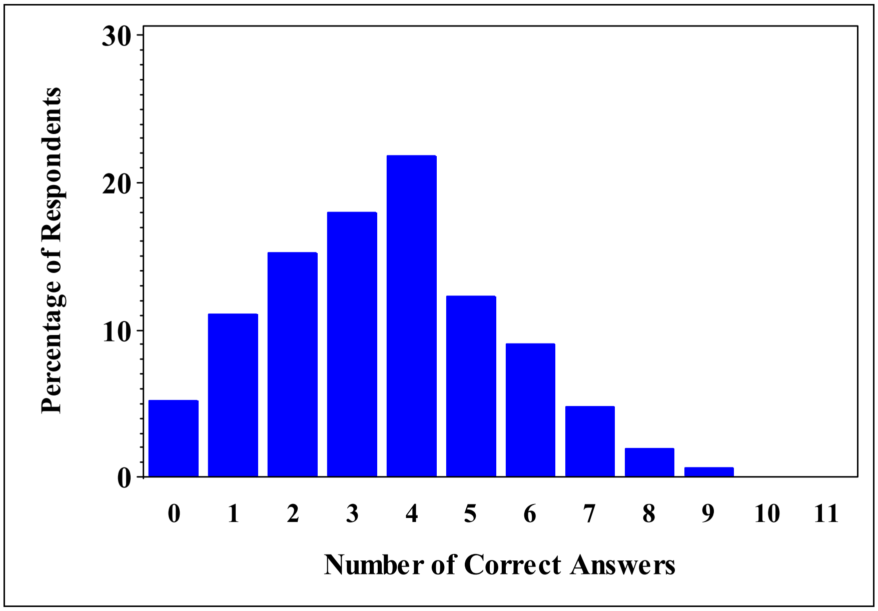

Figure 5.4. The distribution of the number of correct answers to the eleven technical questions, Student Survey.

Figure 5.5 shows responses to Questions 5 and 6. Question 5 asked students to rate the likelihood of widespread commercial availability for hydrogen and fuel cells in the next five years for six separate potential applications. Figure 5.5 shows the percentage of respondents rating the likelihood as “High.” Question 6 asked about the safety of using hydrogen and fuel cells, in comparison with technology in use today, for the same applications. Figure 5.5 shows the percentage of students who ranked hydrogen and fuel cells as “Equally as safe” or “Safer.”

Student Perceptions of Safety and Availability of Hydrogen Applications

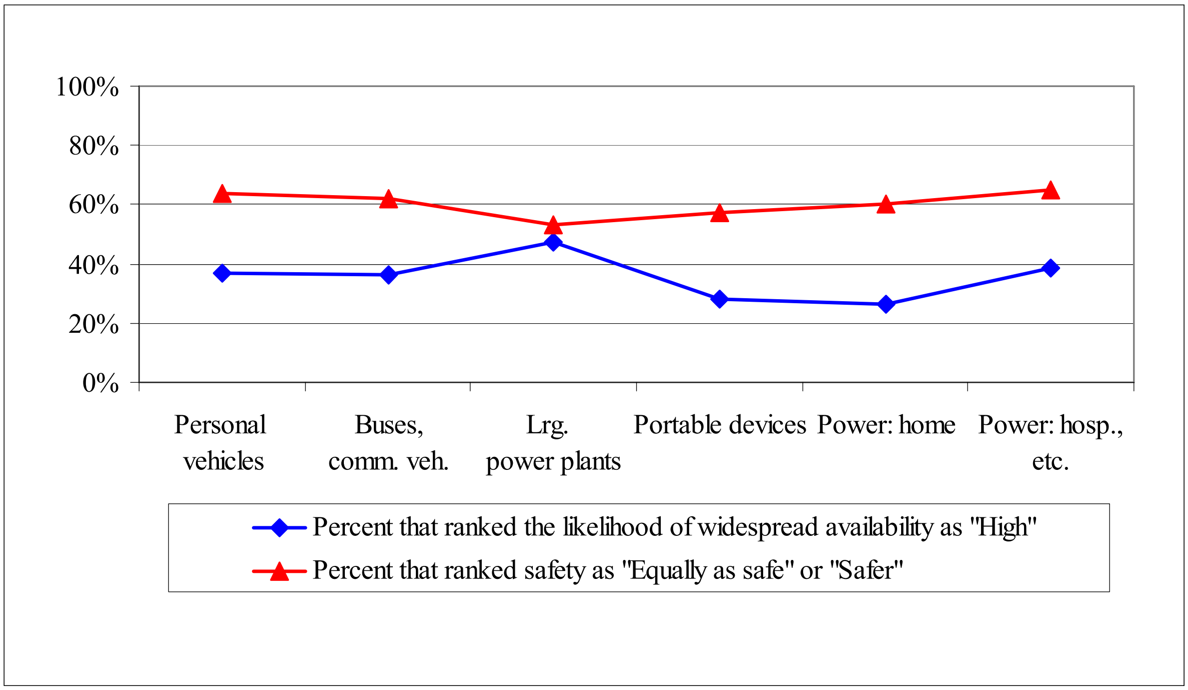

Figure 5.5. Weighted percent of responses to Questions 5 and 6 concerning widespread commercial availability within the next five years and perception of safety for specific applications, Student Survey.

The students were asked about their information sources, using a scale of "Never," "Sometimes," and "Frequently" to indicate usage. Students most often obtain energy information from the classroom; 33.5% of the student responses were "Frequently" and 46.0% of the responses were "Sometimes" for this source. A fifth of the students, however (20.5%), indicated that they "Never" obtain energy information in the classroom. Students rarely obtain energy information from family and friends; over half (50.3%) of the responses were "Never" for this source.

Question 8 asked about the frequency of use of different types of mass media for obtaining energy information (Figure 5.6).

Use of Mass-Media Sources for Energy Information by Students

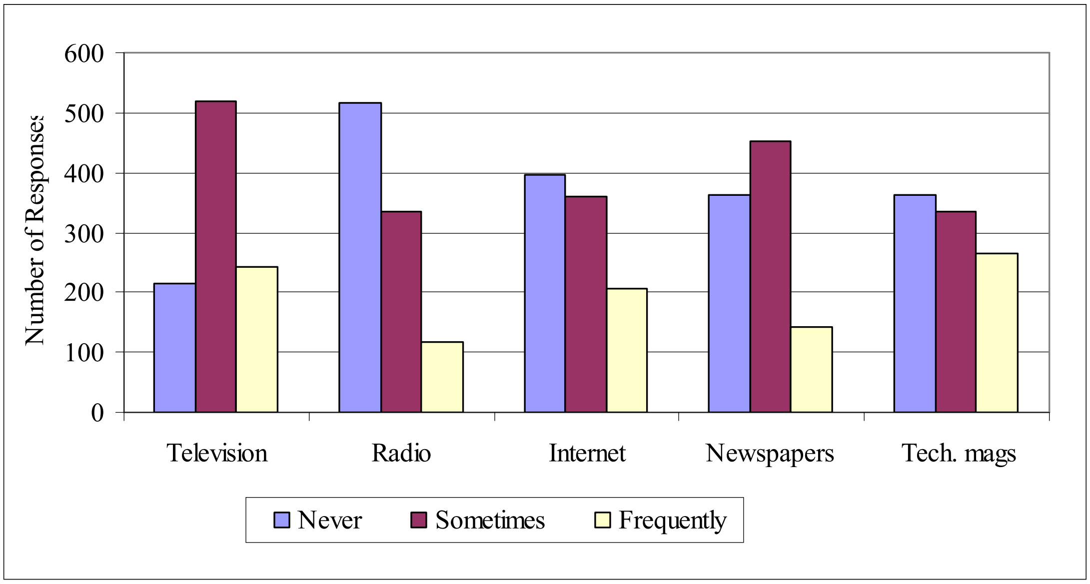

Figure 5.6. Weighted frequency of responses to Question 8, "How often do you get ENERGY information from different types of mass media," Student Survey.

As shown in Figure 5.6, the source indicated most often by students as being used "Frequently" is science and technology magazines, followed closely by television. When considering responses of both "Frequently" and "Sometimes," the most often used source is television (78.0% of the student responses), followed by technical magazines (62.4%) and newspapers (62.1%). The radio is the mass media source used least to obtain energy information (53.3% of the students responded that they "Never" use this source).

Figure 5.7 shows the percentages of students responding "Yes" to various questions concerning their participation in specific hydrogen education or science activities (Questions 9a-g). Many more students have learned about energy and fuels, including hydrogen, and had experience with these topics than have learned about or had experiences with fuel cells.

Student Participation in Educational Fuel Cell Activities

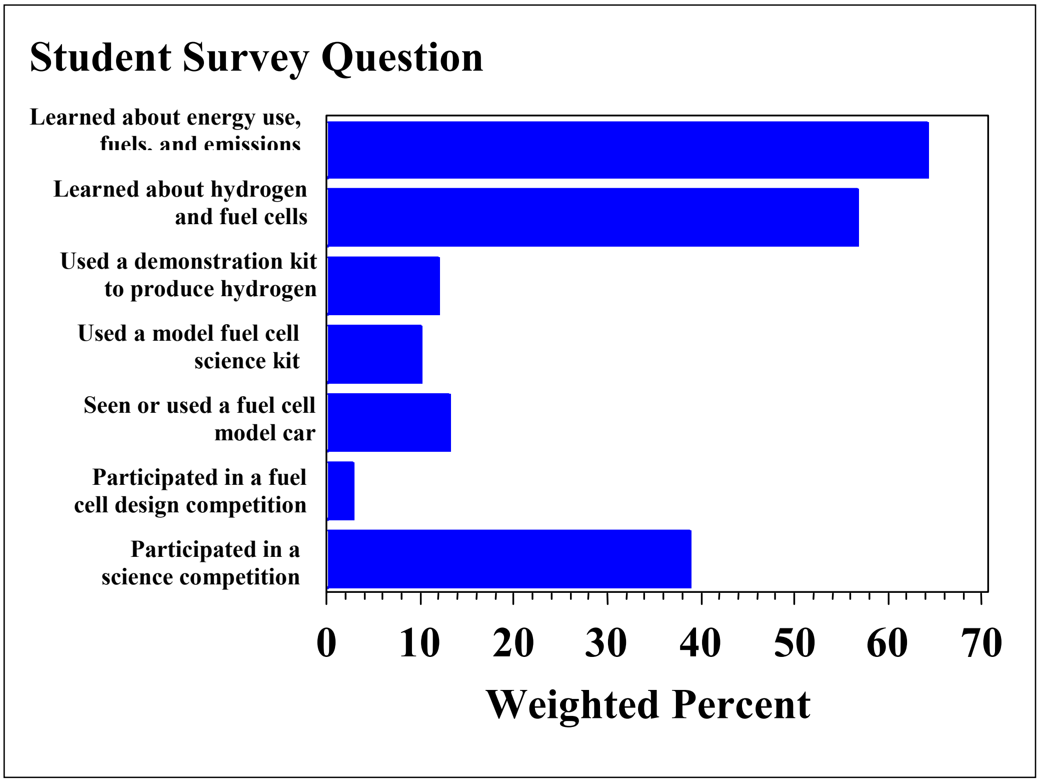

Figure 5.7. Percentages of students responding "Yes" to the various "Have you ever…" science activity Questions 9a-g, Student Survey.

If the students responded positively about their participation in a particular science activity, then they were asked where the learning took place. Most educational experiences took place at school. The next most common response was that the learning took place at home. It should be noted that students that were home schooled were instructed to consider their home schooling experiences as school, not home. The question concerning where students had seen or used a hydrogen fuel cell model car showed the greatest variety concerning where the experience took place. Only 57.3% indicated that this experience took place at school; 13.0% responded that the experience took place at home; 4.6% responded with the Internet; and 19.8% indicated that there was some other provider of the experience. Table 5.2 provides the counts for all students who responded "Yes" to the experience questions.

Table 5.2. Number of Students Receiving Instruction in or Participating in Various Science Topics and Activities, with an Indication of the Source of the Learning Activity								
Question: Have you …	**Number Responding "Yes"[a]**	**Where Learning Took Place (% of total number responding "Yes," if that value is over 4.5%)**						
		School	**Home**	**Relig. org.**	**Scouts**	**Inter-net**	**Other**	**Un-known**
Received instruction on or otherwise learned about energy use, fuels, and emissions	641	589 (91.9%)	24	0	2	6	15	6
Received instruction on or otherwise learned about hydrogen and fuel cells	567	524 (92.4%)	22	1	0	6	13	1
Ever used a demonstration kit to produce hydrogen	120	111 (92.5%)	3	0	2	0	0	3
Ever used a model fuel cell science kit	100	88 (88.0%)	8 (8.0%)	0	1	1	1	1
Ever seen or used a hydrogen fuel cell model car	131	75 (57.3%)	17 (13.0%)	1	2	6 (4.6%)	26 (19.8%)	5
Participated in a fuel cell vehicle design competition	29	22 (75.9%)	2	0	0	0	1	3
Participated in a science bowl or other science competition	387	377 (97.4%)	1	1	1	0	7	1

Note: Results are the weighted frequency and have been rounded to the nearest whole number. See also Appendix C.2.

[a]Because of rounding, the sums may not add up to the numbers in this column.

5.3. RELATIONSHIPS

The summary statistics in Section 5.2 are "one-way" statistics in the sense that the response categories are defined in terms of one variable such as sex, region, or response to Question 3d. However, relationships in the responses determined by two or more variables may also be of interest. Although no relationships were of particular interest a priori, in this section a few of the more statistically significant interactions are illustrated. Interactions that are considered are with the survey variables and sex, region, grade (8th and below, 9th and above), urban/non-urban, and the score "Above Average?" The statistical significance is the significance level (p) of a chi-square test that accounts for the sampling weights.[10]

For example, the most statistically significant response difference between the sexes was for Question 3b, "When using pure hydrogen, fuel cell vehicles generate electricity, water, and what else?" Girls were far more likely than boys to answer either "Don't know" or "All of these" to this question. The second most significant response difference between the sexes was for Question 3e, "How would you feel if your local gas station also sold hydrogen?" Responses are

[10]Measures could also be based on odds ratios or combinations of odd ratios and significance levels as well as other metrics. Significance levels alone were used for simplicity and because sample sizes are essentially the same for all survey questions.

summarized in Figure 5.8. Girls were much more likely to be either uncertain or uneasy about the premise of the question ($p < .0001$).

Student Response to Hydrogen at Gas Stations by Gender

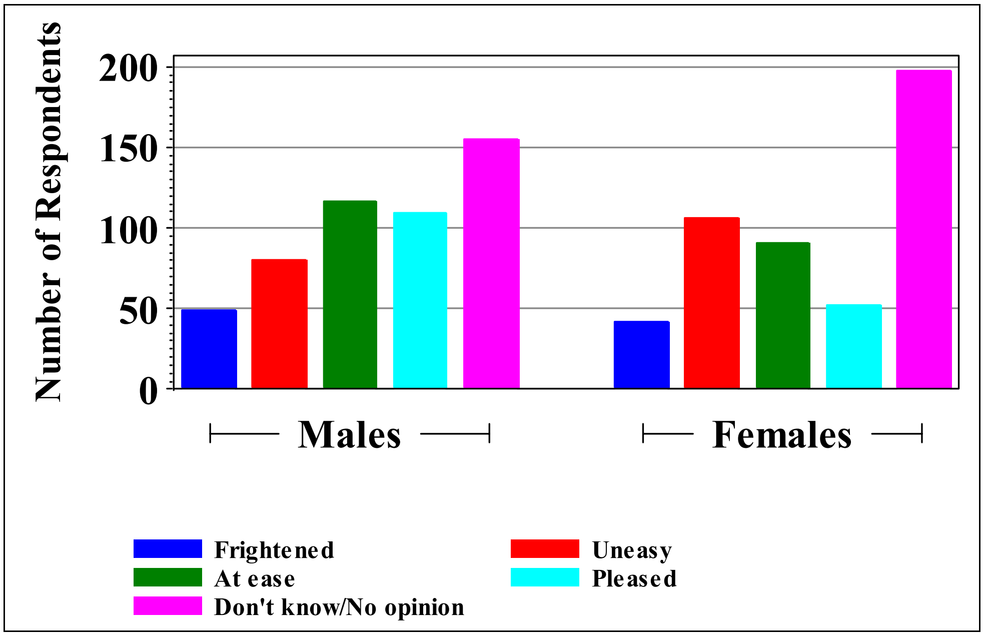

Figure 5.8. Differences between male and female students in response to Question 3e, "How would you feel if your local gas station also sold hydrogen," Student Survey.

There were statistically significant differences with respect to region, one of which was in the responses to how often ENERGY information is obtained from television (Question 8a). Figure 5.9 shows the difference. Students in the South and West were more likely than students in the Northeast and Midwest to indicate they got energy information from television ($p = .002$).

Student Use of Television as an Energy Information Source by Census Region

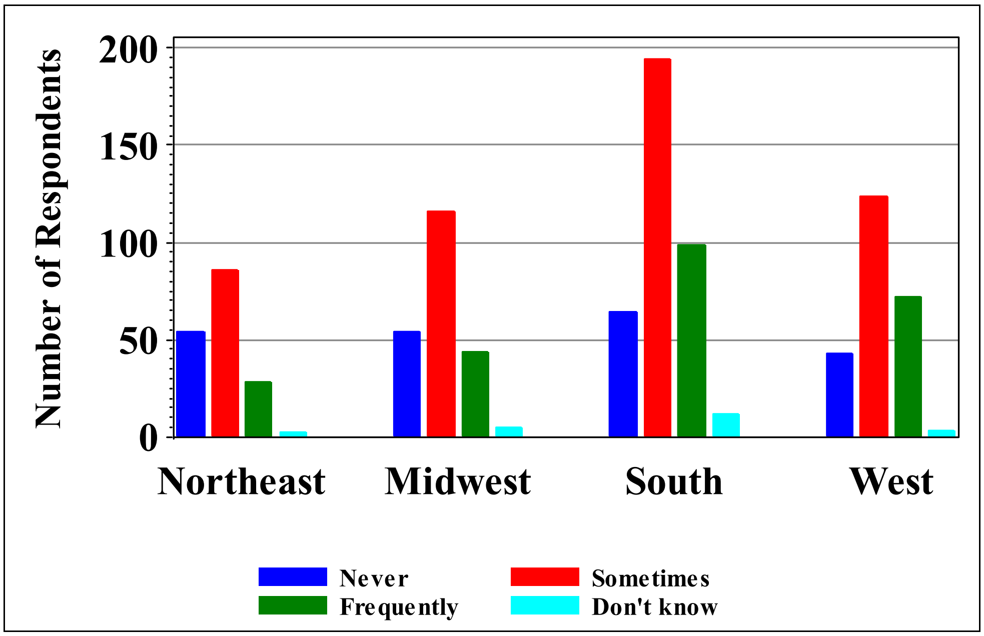

Figure 5.9. Regional differences in responses to Question 8a, "How often do you get ENERGY information from television," Student Survey.

The most statistically significant difference with respect to grade (8th and below, 9th and above) was in the responses to Question 3d, "Which of the following would you MOST closely associate with the word 'hydrogen'?" Younger students were far less likely to associate hydrogen with chemistry class ($p < .0001$). This is no doubt because younger students have not yet taken chemistry in school (Figure 5.10).

Student Word Associations with Hydrogen by Grade Level

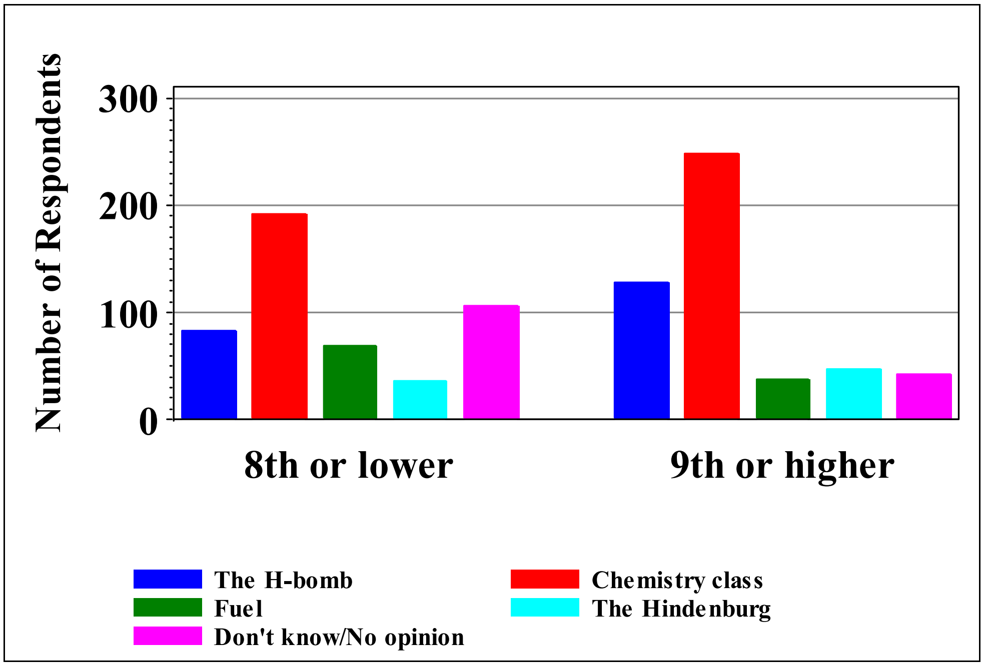

Figure 5.10. Differences between grade levels (8th and below, 9th and above) in responses to Question 3d, "Which of the following would you MOST closely associate with the word 'hydrogen'," Student Survey.

The most statistically significant difference between students scoring above average and below average on the technical questions (other than on any of the technical questions themselves) is in the responses to Question 3e, "How would you feel if your local gas station also sold hydrogen?" Students who demonstrated more technical understanding were much more likely both to have an opinion and to be pleased or at ease with the premise of the question ($p < .0001$). This is illustrated in Figure 5.11.

Student Response to Hydrogen at Gas Stations by Technical Score

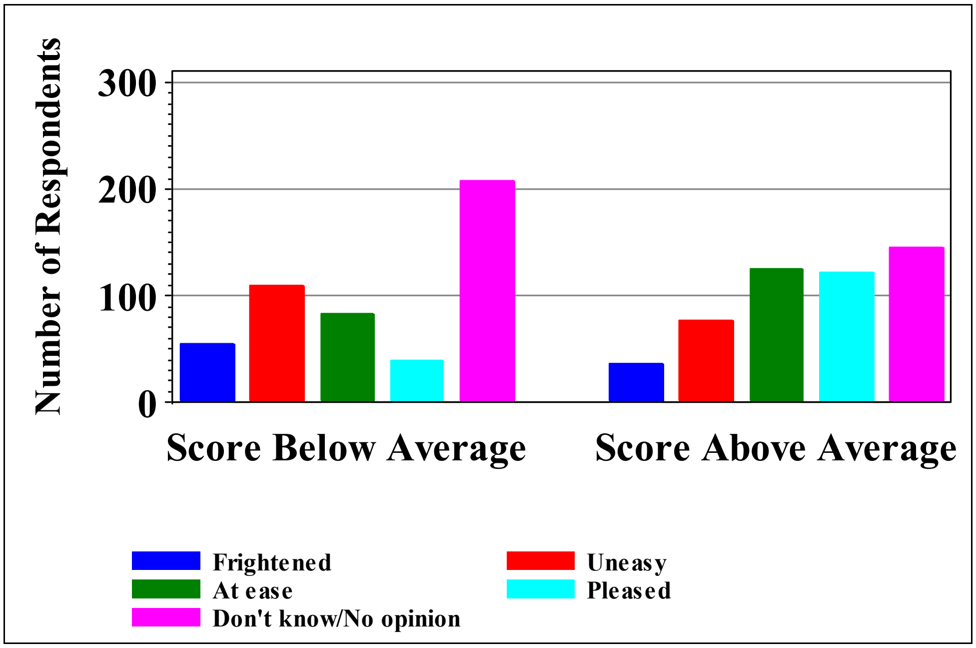

Figure 5.11. Differences between students scoring above and below average in responses to Question 3e, "How would you feel if your local gas station also sold hydrogen," Student Survey.

5.4. OUTCOME RATES

Various outcome rates are of interest in characterizing survey data results. The *response rate* is the proportion of sampled eligible subjects for whom complete survey interview information was obtained. The *refusal rate* is the proportion of sampled eligible subjects who refused to be interviewed or who terminated their interviews before completion. The *contact rate* is the proportion of sampled eligible subjects that were contacted at all. In general the number of eligible subjects must be estimated, and there are various ways to estimate this number and to define, in turn, estimates of the rates. The AAPOR gives various definitions (AAPOR, 2004) for the rates and provides a spreadsheet calculator for computing them.

Estimates of the rates are computed from outcome frequencies, as shown in the following table for the student survey:

Table 5.3. Outcome Frequencies for the Student Survey	
Outcome Type	**Frequency**
Complete interviews (I)	1,000
Partial interviews (P)	28
Refusals and break offs (R)	493
Non-contacts (NC)	463
Other eligible, non-interviews (O)*	0
Known eligible	**1,984**
Unknown households (UH)	48,284
Unknown others (UO)	6,700
Eligibility unknown	**54,984**
Known ineligible	**64,231**
Total phone numbers used	**121,199**
*This category is a catchall for various kinds of eligible non-interviews. See AAPOR (2004, page 39) for a complete listing of outcome categories.	

The eligibility rate can be estimated as

$$\mathbf{e = Known\ eligible / (Known\ eligible + Known\ ineligible).}$$

The eligibility rate estimate **e** can be applied to cases of unknown eligibility to estimate the number of those cases that were actually eligible. The response rate can then be estimated (there are other ways) as

$$\mathbf{Response\ rate = I/(I + P + R + NC + O + e \times (UH + UO)).}$$

For the student survey

$$\mathbf{e = 1{,}984/(1{,}984 + 64{,}231) = .02996,}$$

and the response rate estimate is

$$\mathbf{Response\ rate\ estimate = 1{,}000/(1{,}000+28+493+463+0+.02996 \times (48{,}284+6{,}700)) = .2754.}$$

In comparing survey results over time or across survey components, it is important to consider the response rates and other outcome rates. Contact rates may decline, for example, as cell phone use increases and land line use decreases. From the perspective of hydrogen technology awareness, the rates are of independent interest. For example, it is likely that the response rate would increase and the refusal rate would decrease, for a population that becomes more enthusiastic about hydrogen technology. However, subjects might self-select for the very reason that they are knowledgeable about hydrogen, and a low response rate might upwardly bias estimates of awareness.

6. RESULTS: STATE AND LOCAL GOVERNMENT SURVEY

6.1 INTRODUCTION

This section summarizes the results of the State and Local Government Survey. A copy of the survey is provided in Appendix A.3. Please note that the question numbering is not always consecutive; however, the results displayed in this chapter correlate to the question numbers in the questionnaire given in Appendix A.3. A total of 236 interviews were completed. The average interview time was 10.0 minutes. The results of this survey are provided in Appendix C.3.

As noted in Section 2.4.3, there were three state and two local sub-groups selected for this population. These included State Energy Offices (SEOs), Departments of Environmental Protection (DEPs),[11] and Departments of Transportation (DOTs). Local government agencies included the twelve largest cities and twelve largest counties in each of the four census regions (see Section 2.4.3). When the city and county governments were combined into a single entity, only one call was made to that office, and the next largest city or county was contacted.

Appendix C.3 and Section 6.2 contain tables and charts for "one-way" statistics; that is, categories for these summaries are defined in terms of one survey variable such as census region, government function (city, county, state DOT, etc.) or response to a specific question. Standard deviations and confidence bounds that account for the survey stratification by census region and government function are given to quantify the statistical variability of the frequencies and means.

There are also many relationships and interactions between the survey variables that could be investigated. (For example, "Does the respondent's government function affect his/her responses to Question 3d?") Although no relationships were of particular interest a priori, a few of the more pronounced response interactions are investigated in Section 6.3.

Section 6.4 is about outcome rates – particularly, response rates. Response rates are of interest in all sample surveys, because low response rates suggest the possibility of response bias. Response rates are also of interest in the sense that interest and awareness in hydrogen can affect response rates in this and future hydrogen surveys.

A new variable "Above Average?" was created for the State and Local Government Survey to indicate whether respondents scored above or below the mean for all respondents on the survey's eleven technical questions. The eleven technical questions are 1a, 1b, 1c, 1d, 1e, 1g, 1h (all true-false questions), and 3a, 3b, 3c, 3f (all multiple choice questions). See Appendix A.3 for a copy of the questionnaire. The mean percentage of correct answers was 65.8%.

In addition to the technical knowledge questions, other questions asked for opinions or reactions to certain statements. These questions included 3d, 3e, 4, 5, and 6. Questions 7 and 8 asked about sources of information. Questions 9-17 were about hydrogen and fuel cell activities in the

[11] For the purposes of this document, state environmental offices are called Departments of Environmental Protection. The agency name, however, varies by state. Equivalent agency names include Department of Environmental Quality, Department of Environment, or Department of Natural Resources.

respondents' respective geographic jurisdictions. Question 18 was about a possible DOE-sponsored hydrogen class or workshop.

6.2. SUMMARY TABLES

The frequencies of the various responses (called response values) to the various questions in the State and Local Government Survey are listed in Appendix C.3. All frequencies in this survey are raw counts, because there is no probability weighting (i.e., all weights are 1). The standard deviation of the frequency measures its statistical variability. (The range defined by taking plus or minus two standard deviations from the frequency is an approximate 95% confidence interval for the expected frequency.) The frequencies are also expressed as percentages, with standard errors similarly reflecting statistical variability.

Figure 6.1 shows the distribution of respondents by government function. The response frequencies are nearly uniform across the functional types.

Distribution of Respondents by Government Function

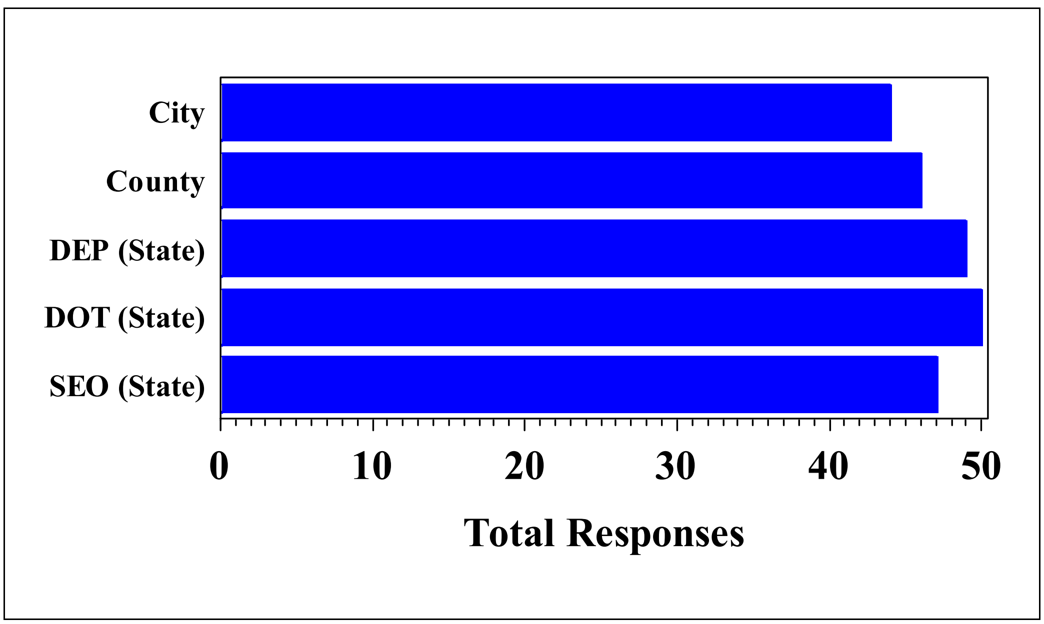

Figure 6.1. Numbers of respondents to the State and Local Government Survey by government function.

Figure 6.2 shows the distribution of responses to Question 5a about the likelihood of widespread commercial availability in the next five years of hydrogen and fuel cells for use in personal cars and trucks. Evidently, respondents are skeptical about this likelihood.

Government Respondent Perception of Availability of Fuel Cells for Personal Vehicles

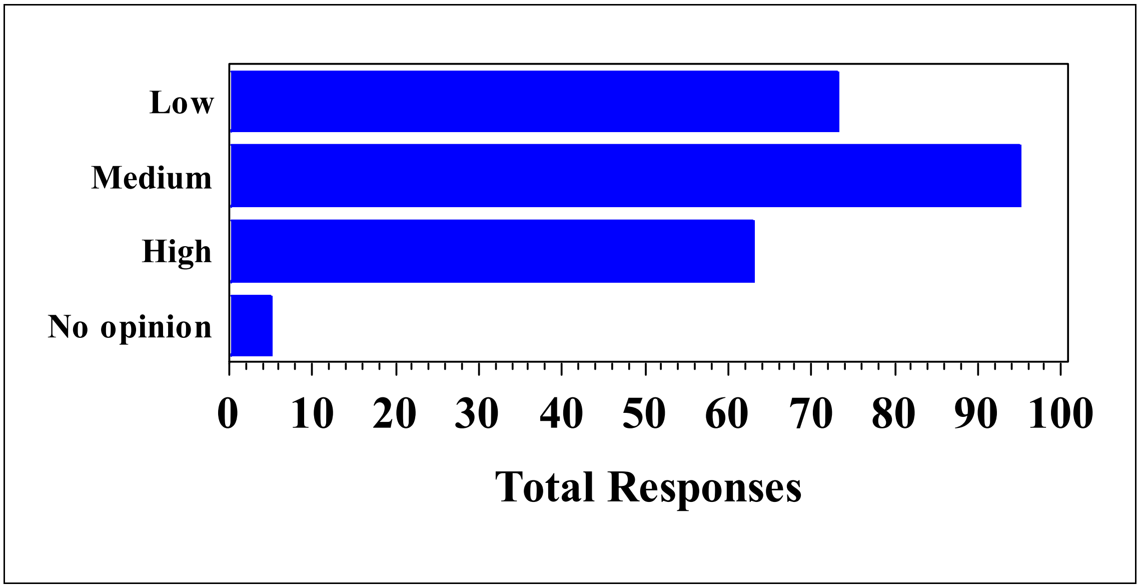

Figure 6.2. The distribution of responses to Question 5a about the likelihood of widespread commercial availability in the next five years of hydrogen and fuel cells for use in personal cars and trucks, State and Local Government Survey.

Results for the technical knowledge questions (along with the other questions) can be summarized as in Appendix C.3. However, the technical questions can also be summarized in terms of whether they were answered correctly. In this summary, “Don’t know” can be handled either as an incorrect response (i.e., a failure to give the correct response) or as a separate kind of response. Table 6.1 summarizes the technical knowledge questions in terms of whether they were answered correctly or incorrectly with “Don’t know” treated as an incorrect response. On average, 65.8% of the technical questions were answered correctly. This is much higher than the percentage of correct answers for either the general public (32.8%), students (32.2%), or end users (44.4%). Still, about a third of the time the state and local government respondents did not give the correct answer.

Table 6.1. Summary of Results for the State and Local Officials on the Technical Knowledge Questions (Correct/Incorrect)

Question	Number of Responses	Percent Correct	Lower 95% Confidence Bound	Upper 95% Confidence Bound
1a. Hydrogen pipelines exist nationwide (false)	236	72.0	70.9	73.2
1b. In a hydrogen economy, hydrogen replaces fossil fuels as the dominant form of energy (true)	236	68.6	67.6	69.7
1c. Hydrogen gas is toxic (false)	236	72.0	71.0	73.1
1d. Fuel cells produce electricity through hydrogen combustion (false)	236	37.3	36.2	38.4
1e. Hydrogen is too dangerous for everyday use by the general public (false)	236	78.4	77.5	79.3
1g. Hydrogen is lighter than air (true)	236	79.2	78.4	80.1
1h. Hydrogen has a distinct odor (false)	236	81.4	80.4	82.3
3a. In which state or condition can hydrogen be stored? (chemical compound and liquid)	236	64.8	63.8	65.9
3b. When using pure hydrogen, fuel cell vehicles generate electricity, water, and what else? (heat)	236	52.5	51.4	53.7
3c. Hydrogen can be produced using which of the following sources of energy? (natural gas, sunlight, organic matter)	236	67.0	65.8	68.0
3f. Which of the following represents a type of fuel cell? (PEM)	236	50.8	49.7	52.0
Overall Average	**236**	**65.8**	**65.4**	**66.2**

The fewest correct responses (37.3%) were for Question 1D. The other fuel cell questions, 3f and 3b, received the next fewest correct responses.

While Table 6.1 presents correct versus incorrect responses (where incorrect responses include the "Don't know" response), Figure 6.3 shows the responses broken down according to type: Correct, Incorrect, and "Don't know." On average, 65.8% of the questions were answered correctly, 15.9% were answered incorrectly, and 18.3% of the responses were answered with "Don't know."

Technical Knowledge Scores for Government Respondents

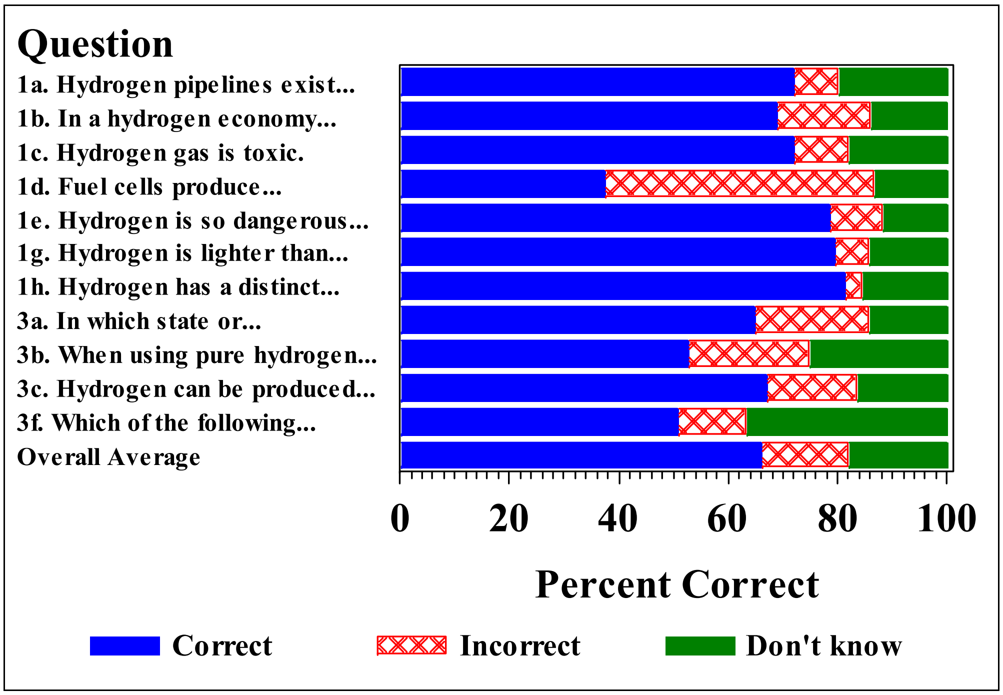

Figure 6.3. Weighted percent correct, incorrect, and "Don't know" for the technical knowledge questions, State and Local Government Survey.

Figure 6.4 shows the distribution of scores for the State and Local Government Survey. Although some respondents responded with fewer than six correct answers, more than 80% had six or more correct answers, and there is less dispersion about the mean score (65.8%) than for the general public (Figure 4.4), which is more heterogeneous than the state and local officials.

Distribution of Technical Question Responses from Government Respondents

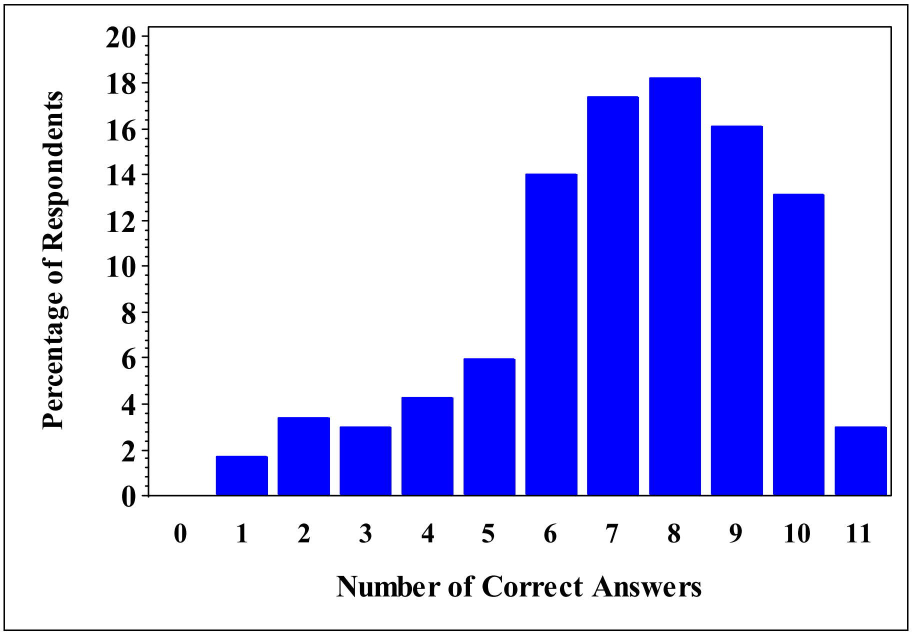

Figure 6.4. The distribution of the number of correct answers to the eleven technical questions, State and Local Government Survey.

Figure 6.5 shows responses to Questions 5 and 6. Question 5 asked government agency respondents to rate the widespread commercial availability for hydrogen and fuel cells in the next five years for six separate potential applications. Question 6 asked about the safety of using hydrogen and fuel cells, in comparison with technology in use today, for the same applications. Figure 6.5 shows the percentages who responded to each of these questions. The huge discrepancy between a perception of *safety* of hydrogen and the belief that hydrogen application will not be widespread in the near future is interesting and very different from the other surveys.

Government Respondent Perceptions of Safety and Availability of Hydrogen Applications

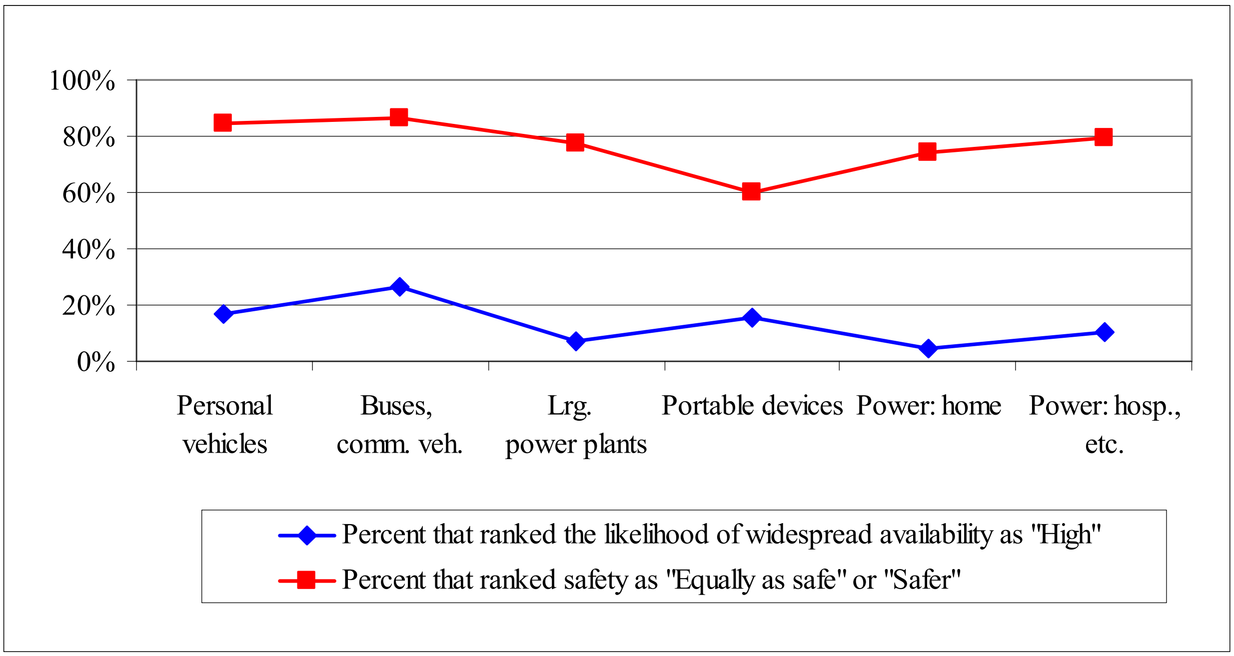

Figure 6.5. Weighted percent of responses to Questions 5 and 6 concerning widespread commercial availability within the next five years and perception of safety for specific applications, State and Local Government Survey.

Government officials were asked two questions about information sources. Question 7 (see Appendix A.3) asked about the use of information sources (based on a scale of “Never,” “Sometimes,” and “Frequently”) to help make decisions about energy costs and safety. The most common source of information used by government agencies to make energy-related decisions (i.e., the source most often chosen as “Frequently” used) was the Federal government. The next most frequently used source was the state government. Local government sources were used the least as an information source for making decisions about energy costs and safety. Figure 6.6 shows the responses of government officials for the frequency of their use for selected sources.

Comparison of Energy Information Source Use by Government Respondents

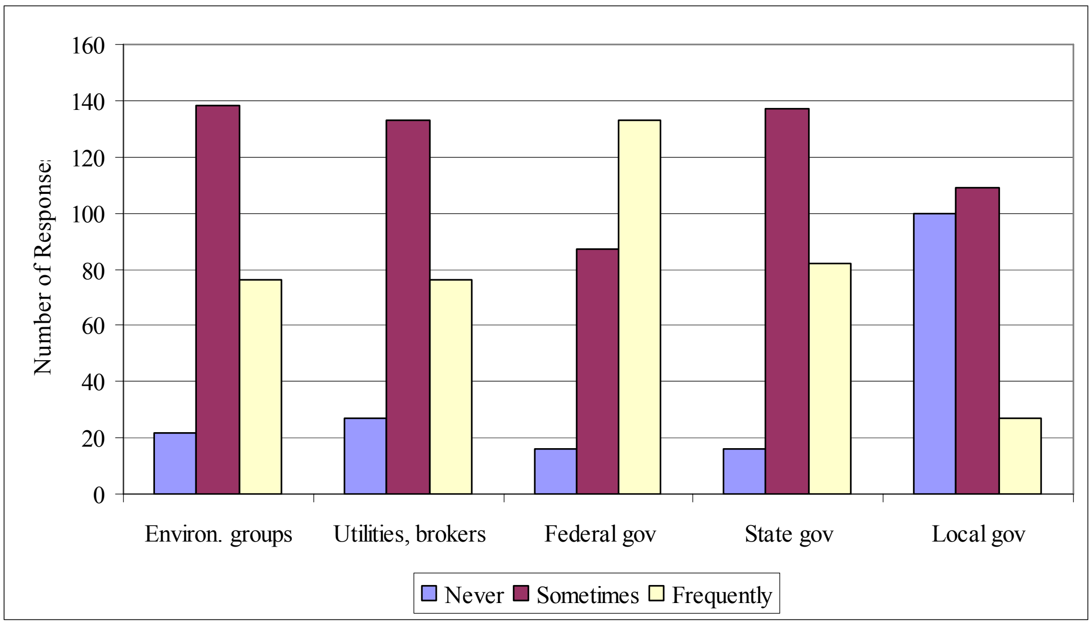

Figure 6.6. Weighted frequency of responses to Question 7 regarding the use of information for making decisions about energy costs and safety, State and Local Government Survey.

Question 8 also asked about the use of information sources but from a different perspective. Question 8 asked about the frequency of use of different types of mass media to get energy information. Almost 60% (57.6%) of government officials indicated that they use the Internet to obtain energy information on a frequent basis. The next source that government officials indicated they use frequently is technology magazines and journals, with 47.5% of respondents indicating that they use this source on a frequent basis. Figure 6.7 shows the responses to this question.

Use of Mass-Media Sources for Energy Information by Government Respondents

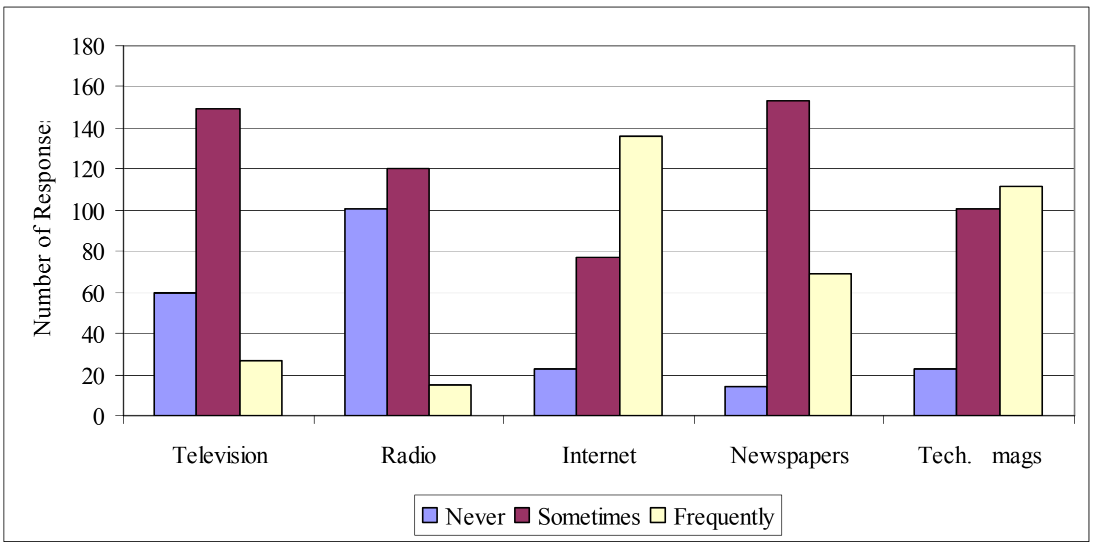

Figure 6.7. Weighted frequency of responses to Question 8 regarding the frequency of obtaining ENERGY information from different types of mass media, State and Local Government Survey.

Questions 9-13 were about respondents' awareness of hydrogen and fuel cell technology penetration. Figure 6.8 shows the percentages of state and local officials responding "Yes" to Questions 9-13. Only a few respondents indicated that their own agencies are using hydrogen vehicles (5.1%) or stationary fuel cells (8.5%). A greater number of respondents knew of other agencies in their geographic jurisdiction that are using hydrogen-powered vehicles (22.9%) or stationary fuel cells (30.1%).

Government Respondent Perception of Hydrogen Technology Penetration

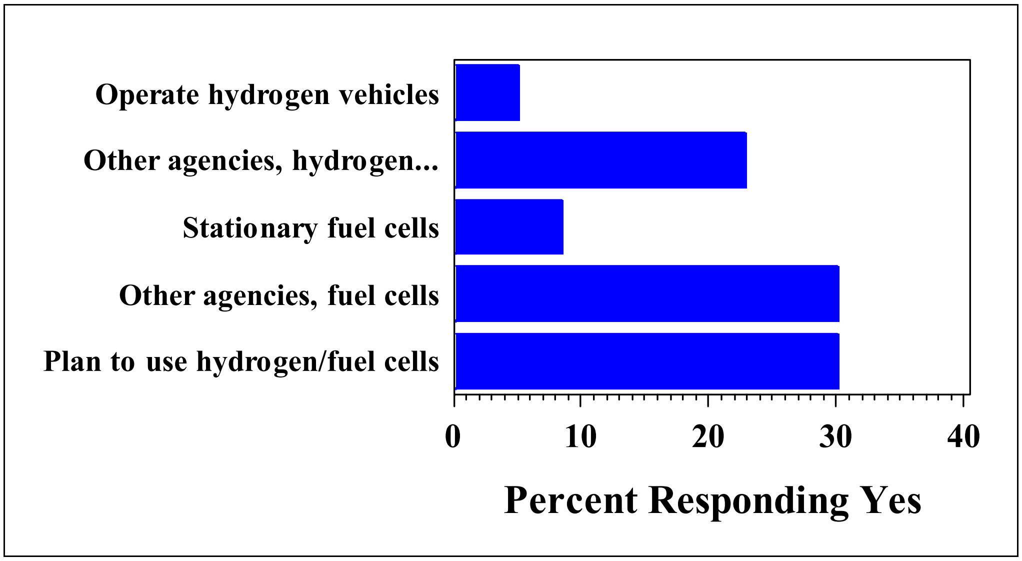

Figure 6.8. Percentages of state and local officials who responded "Yes" to Questions 9-13 about hydrogen and fuel cell technology penetration, State and Local Government Survey.

Officials were asked if their agencies had plans to use hydrogen and/or fuel cells in the future. Those responding "Yes" were then asked the time frame for implementation. As can be seen in Figure 6.9, about half of the respondents indicated that their agencies had no plans to use hydrogen or fuel cells in the near future. An additional 19.5% of the agency officials did not know what their agency's plans were for hydrogen and fuel cells. About 30.1% of the agency officials indicated plans to use hydrogen and/or fuel cells. Of those agencies with plans for the future use of hydrogen and fuel cells, most agencies plan to implement within the 1-5 years time frame.

Time Frame for Hydrogen Use as Noted by Government Respondents

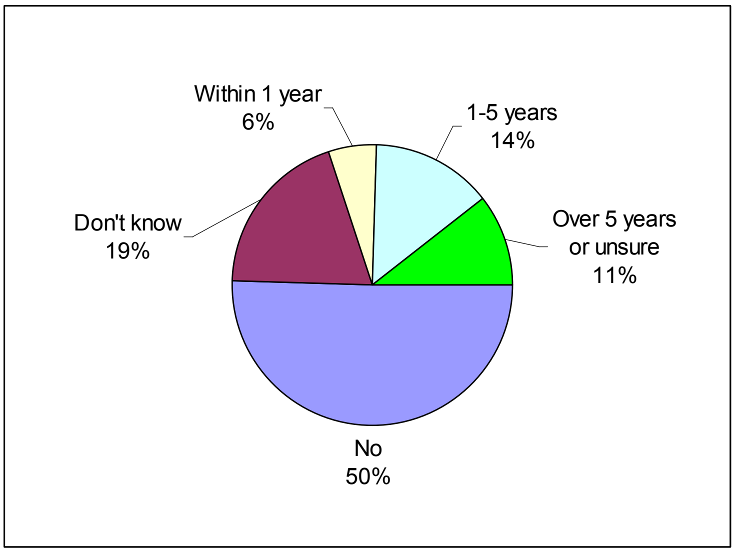

Figure 6.9. Responses to Questions 13 and 14, "Does your agency have plans to use hydrogen or fuel cells in the future," and "What is the time frame for plans to use hydrogen or fuel cells," State and Local Government Survey.

Questions 16-18 asked agency officials about receipt of information on hydrogen and fuel cells at the workplace (Figure 6.10), including attendance at specific events. Eighty-six percent responded that they thought a DOE-sponsored class, conference, or workshop on hydrogen and fuel cells would be of value.

Hydrogen Education Event Attendance by Government Respondents

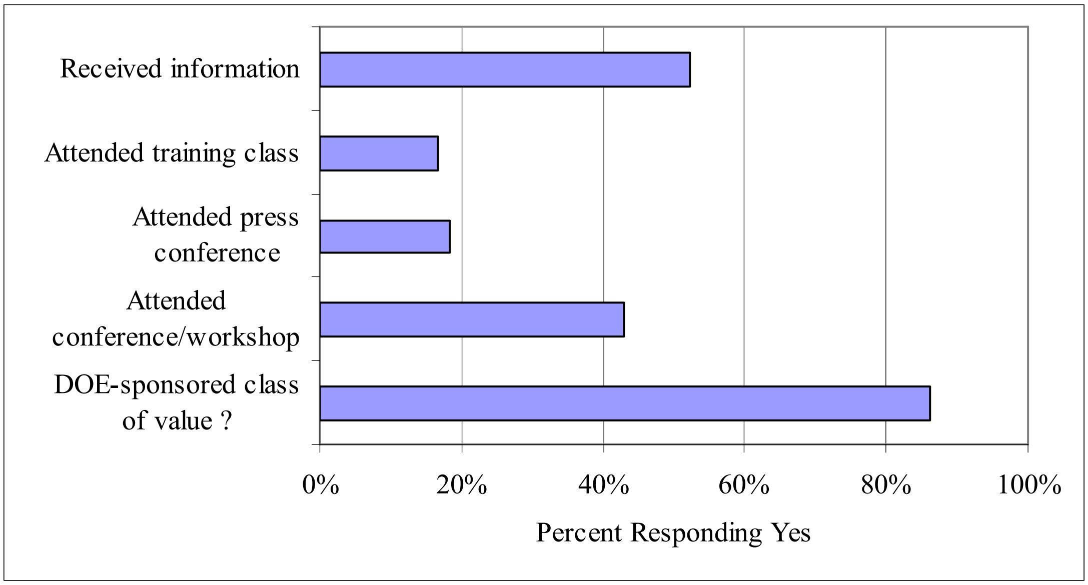

Figure 6.10. Responses to Questions 16-17 concerning receiving information about hydrogen and/or fuel cells at the workplace and attendance at a training class, press conference, or workshop and Question 18 about the potential value of a DOE-sponsored class, State and Local Government Survey.

6.3. RELATIONSHIPS

The summary statistics in Section 6.2 are "one-way" statistics in the sense that the response categories are defined in terms of one variable (for example, responses to Question 5a). However, relationships in the responses determined by two or more variables may also be of interest. Although no such relationship was of particular interest a priori, in this section a few of the more statistically significant ones are illustrated. Interactions that are considered are with the survey variables and Census Region, government function, and the "Above Average?" score indicator. The statistical significance is the significance level (p) of a chi-square test that accounts for the stratification in the survey design.

Fewer significant ($p < .01$) relations were discovered among the results for the State and Local Government Survey than for the Student or General Public Surveys, possibly because the Student and General Public Surveys both had bigger sample sizes. Also, scores on the technical questions for state and local officials are generally higher than for the other populations (see Sections 4, 5, 7), and state and local responses to the safety questions were also generally positive and did not vary as much between groups scoring above and below average on the technical questions. Nevertheless, a number of significant ($p < .01$) differences were found.

As illustrated in Figure 6.11, responses to Question 17c indicate that state energy office personnel were significantly ($p < .0001$) more likely to have attended a hydrogen workshop than personnel in the other government functions. The same pattern can also be seen in the responses to question 17a, "Have you attended a training class on hydrogen or fuel cells?" ($p=.0007$).

Attendance at Hydrogen Education Events by Government Function

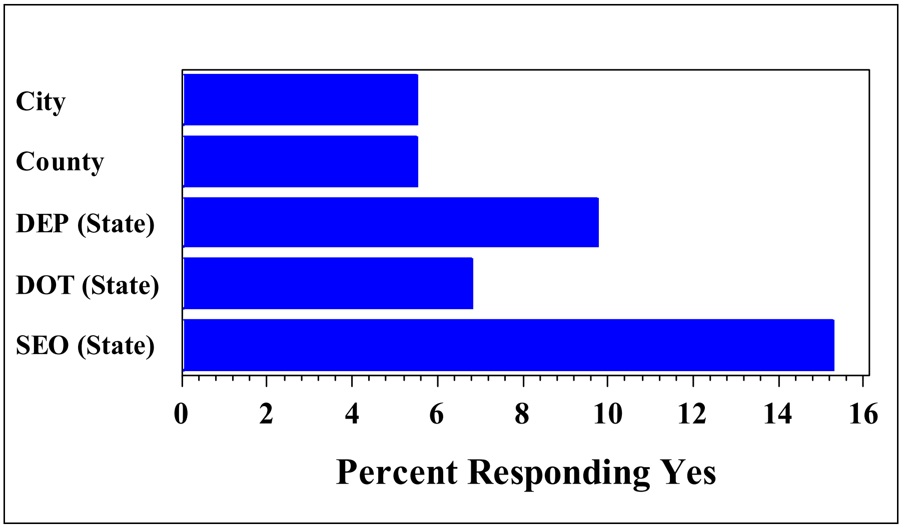

Figure 6.11. Government functional differences in response to Question 17c, "Have you attended a conference or workshop that included a session on hydrogen or fuel cells," State and Local Government Survey.

Statistically significant ($p < .0001$) differences across functional areas were also found in the responses to Question 1d, "Fuel cells produce electricity through hydrogen combustion." These responses are shown in Figure 6.12.

Fuel Cell Knowledge by Government Function

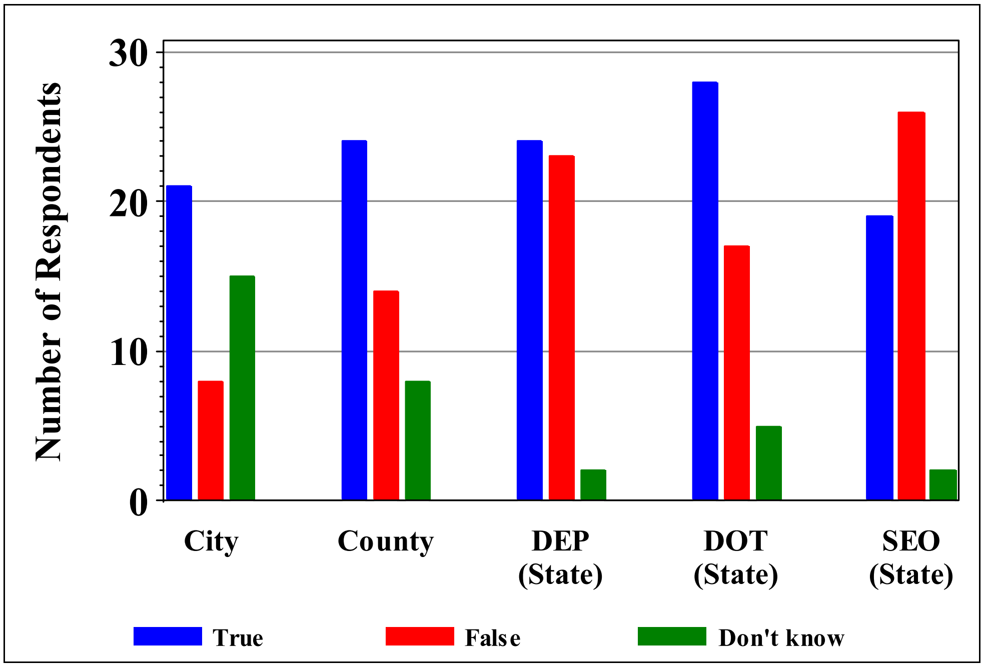

Figure 6.12. Government functional differences in the pattern of responses to true/false Question 1d, "Fuel cells produce electricity through hydrogen combustion," State and Local Government Survey.

Figures 6.13-6.15 show response differences between respondents scoring above and below average on the eleven technical questions. Not surprisingly, responses to Question 17a, "Have you attended a training class on hydrogen or fuel cells?" and Question 8c, "How often do you get ENERGY information from the Internet?" both differed significantly between those scoring above and below average on the technical questions ($p < .0001$ in either case). Above average scorers are more likely to have had training (Figure 6.13) and to use the Internet as a source of energy information (Figure 6.14).

Government Respondent Attendance at Hydrogen Training Class by Technical Knowledge Score

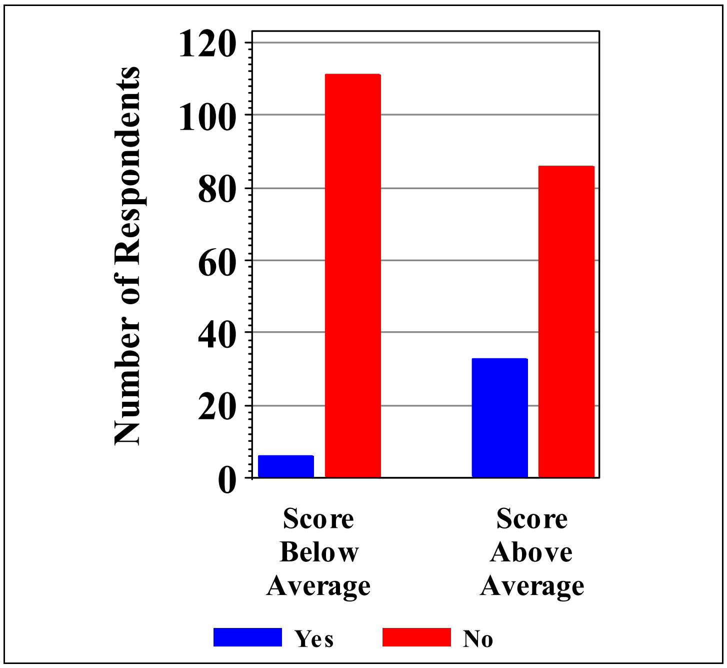

Figure 6.13. Differences between respondents scoring above and below average on the technical questions in responses (Yes/No) to Question 17a, "Have you attended a training class on hydrogen or fuel cells," State and Local Government Survey.

Government Respondent Use of Internet for Energy Information by Technical Knowledge Score

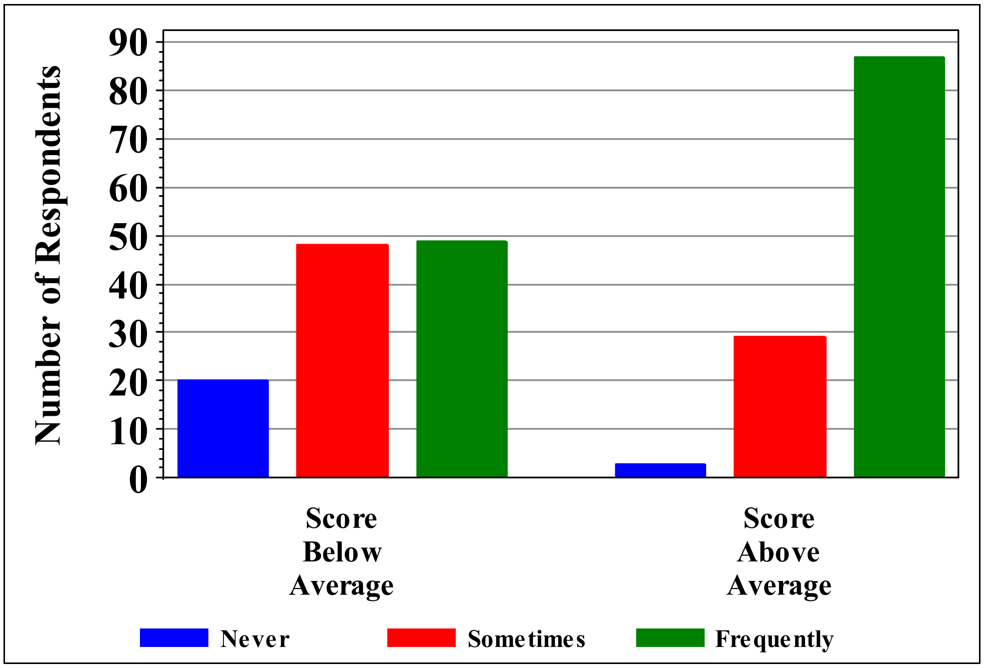

Figure 6.14. Differences between respondents scoring above and below average on the technical questions in response to Question 8c, "How often do you get energy information from the Internet," State and Local Government Survey.

Responses to Question 5c about the likelihood of widespread commercial availability of large hydrogen power plants in the next five years also showed significantly differences ($p < .0001$) between those scoring above and below average on the technical questions. Far fewer responders with above-average scores indicated that large hydrogen power plants were likely (Figure 6.15).

Government Respondent Perception of Hydrogen Availability by Technical Knowledge Score

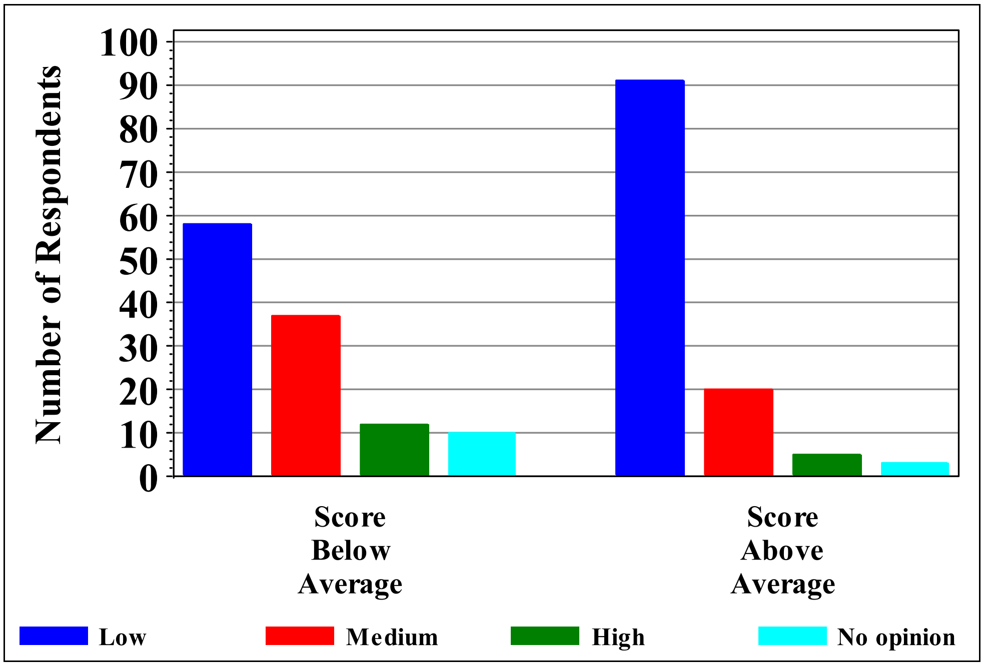

Figure 6.15. Differences between respondents scoring above and below average on the technical questions in response to Question 5c about the likelihood of widespread commercial availability of large hydrogen power plants in the next five years, State and Local Government Survey.

Finally, Figure 6.16 shows statistically significant (p=.004) regional differences in responses to Question 10, “Do you know of any other organization that operates hydrogen-powered buses or other fleet vehicles in the area covered by your geographic jurisdiction?” Relatively more respondents in the Western Census Region answered “Yes” to this question.

Government Respondent Knowledge of Hydrogen Use By Census Region

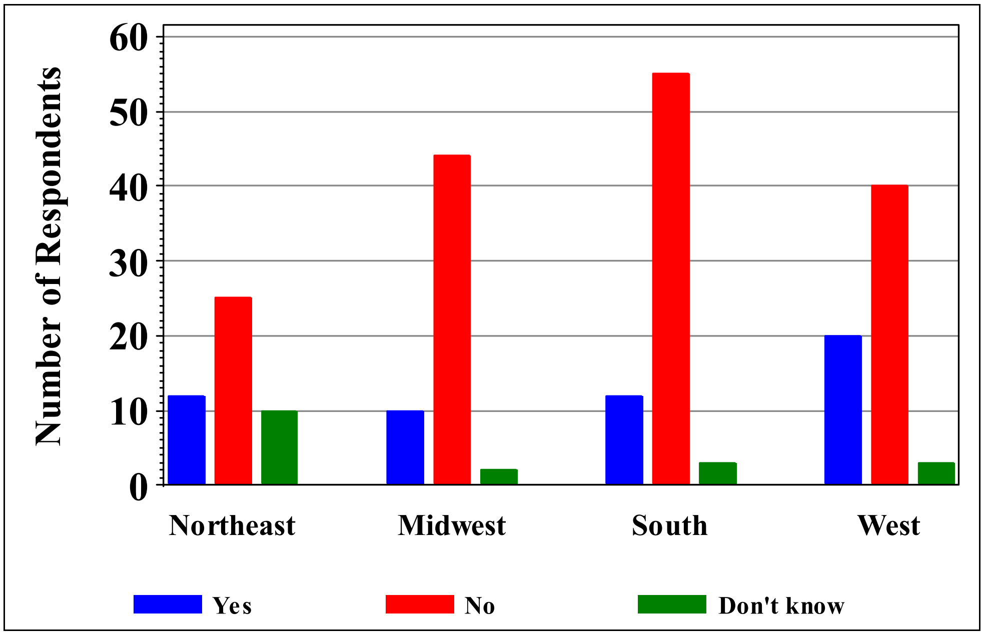

Figure 6.16. Regional differences in patterns of responses to Question 10, “Do you know of any other organization that operates hydrogen-powered buses or other fleet vehicles in the area covered by your geographic jurisdiction,” State and Local Government Survey.

6.4. OUTCOME RATES

The State and Local Government Survey differs from the other survey components in that attempts were made to sample the entire target population. That is, an attempt was made to contact fifty SEOs, fifty state DOTs, fifty state DEPs, and the twelve largest cities and twelve largest counties in each of the four Census Regions. As Table 6.2 shows, that attempt nearly succeeded.

Table 6.2. Outcome Frequencies for the State and Local Government Survey

Government Function	Number Targeted	Number Sampled	Response Rate (%)
Cities	48	44	91.6
Counties	48	46	95.8
DEP	50	49	98.0
DOT	50	50	100.0
SEO	50	47	94.0
Total	**246**	**236**	**95.9**

Had the entire target population been sampled (100% response), there would be no statistical error (at least no sampling error) in the survey estimates. As the survey stands, its estimation standard errors are very small. The near-100% response rate is accounted for in the statistical computations by applying finite population correction factors (Cochran, 1977, p 24), which are applied in the SAS surveymeans and surveyfreq procedures (SAS, 2004, p 165).

7. RESULTS: LARGE-SCALE END USER SURVEY

7.1 INTRODUCTION

This section summarizes the results of the Large-Scale End User Survey. A copy of the survey is provided in Appendix A.4. Please note that the question numbering is not always consecutive; however, the results displayed in this chapter correlate to the question numbers in the questionnaire given in Appendix A.4. Although questions common to all four surveys had the same numbering in the General Public, Student, and State and Local Government Survey components, these questions are numbered differently in the Large-Scale End User Survey. A total of 99 interviews were completed. The average interview time was 12.5 minutes. The results of this survey are provided in Appendix C.4.

The Large-Scale End User Survey had three sampling strata: transportation (i.e., end users), businesses needing uninterrupted power supplies, and industrial sectors with large power requirements. Various NAICS- or SIC-coded subpopulations were identified for each of these strata, and the largest 0.3% from each subpopulation represented the subpopulation in the strata, where, depending on the subpopulation, size was measured in terms of either revenue or number of employees (see Section 2.4.4 and Appendix E, Table E.1).

Appendix C.4 and Section 7.2 contain tables and charts for "one-way" statistics; that is, categories for these summaries are defined in terms of one survey variable such as census region or response to a specific question. Standard deviations and confidence bounds that account for the survey stratification by census region and government function are given to quantify the statistical variability of the frequencies and means. There are also many relationships and interactions between the survey variables that could be investigated, although no relationships were of particular interest a priori.

Unlike the State and Local Government Survey, the Large-Scale User Survey is of only a small proportion of its target population. Further, the sample size for the Large-Scale User Survey is much smaller than the General Public or Student Survey sample sizes. Therefore, there are fewer statistically significant relationships for the Large-Scale User Survey than for the other survey components. Nevertheless, a few of these relationships are illustrated in Section 7.3.

As with the other survey components, a new variable "Above Average?" was created for the Large-Scale End User Survey to indicate whether respondents scored above or below the mean for all respondents on the survey's eleven technical questions. (The eleven technical questions are the true-false questions, 12a, 12b, 12c, 12d, 12e, 12g, 12h, and the multiple choice questions, 13a, 13b, 13c, 13f.) The mean percentage of correct answers was 44.4%, though a bimodal score distribution complicates the interpretation of the scores. Unlike the score distributions for the other survey components, the distribution for the large-scale users has a spike at the low end. This distribution is illustrated in Section 7.2 and discussed further in Section 7.3.

In addition to the technical questions, questions were also posed to learn interviewee opinions about the likelihood of hydrogen technology applications in the future, about safety, about power usage of his/her business, etc. (See Appendix A.4 for a copy of the questionnaire.)

7.2. SUMMARY TABLES

The frequencies of the various responses (called response values) to the various questions in the Large-Scale End User Survey are listed in Appendix C.4. All frequencies in this survey are raw counts, because there is no probability weighting. The standard deviation of the frequency measures its statistical variability. (The range defined by taking plus or minus two standard deviations from the frequency is an approximate 95% confidence interval for the expected frequency.) The frequencies are also expressed as percentages, with standard errors similarly reflecting statistical variability.

Thirty-three potential end users were surveyed in each of three strata – transportation, businesses needing an uninterrupted power supply, and industrial sectors with large power requirements. The segments within these strata were defined by NAICS or SIC codes and are described more fully as follows:

1. Transportation:
    - Trucking (250 or more employees),
    - Transit (500 or more employees),
    - Postal service (employee/revenue totals not available),[12]
    - Couriers and messengers (1,000 or more employees),
    - Automotive rental/leasing (revenue over $20 million),
    - Police (250 or more employees),
    - Fire (1,000 or more employees),
    - Private fleets (250 or more employees),
    - Airports (250 or more employees);
2. Businesses needing an uninterrupted power supply:
    - Farms (sales over $250,000),
    - Financial institutions excluding insurance (500 or more employees),
    - Educational services (1,000 or more employees),
    - Hospitals/residential care (1,000 or more employees),
    - Wired communications (250 or more employees),
    - National security (500 or more employees),
    - Utilities (500 or more employees),
    - Government services (1,000 or more employees); and
3. Industry (industries with revenue over $1 billion).

There were no additional segments within the industrial stratum. Additional information on these strata and sectors is provided in Appendix E.

[12] Target populations were selected randomly by taking 0.3% from the Dun and Bradstreet list of postal service entries.

One-third of the respondents were from each of the three strata – transportation, businesses needing an uninterrupted power supply, and industrial sectors with large power requirements. Figure 7.1 shows the distribution of survey respondents by strata subcategory.

Distribution of Large-Scale End User Respondents by Business Subcategory

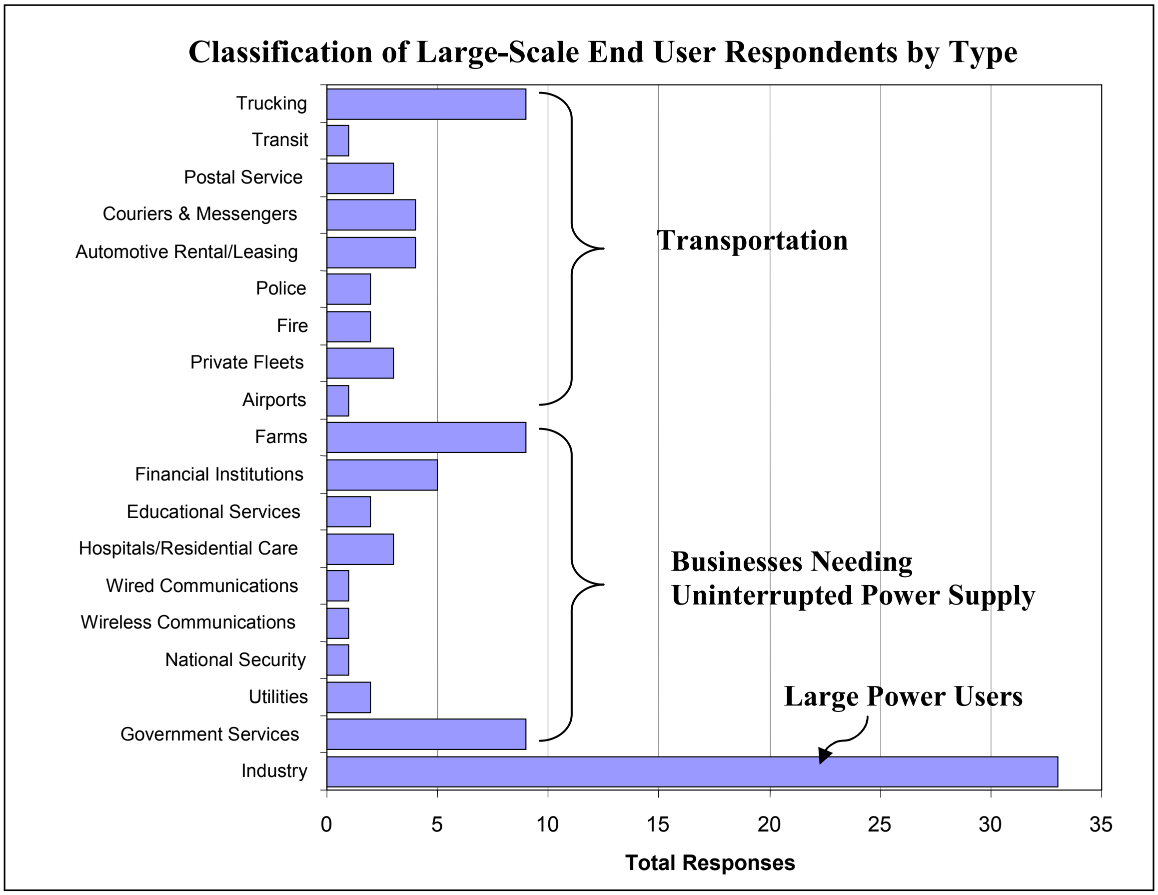

Figure 7.1. Numbers of respondents to the Large-Scale End User Survey by business subcategories.

Figure 7.2 shows the distribution of responses to Question 5, "Does your organization use hydrogen and/or fuel cells for any purpose?" Very few respondents answered "Yes" to Question 5. Consequently, very few interviewees responded at all to Question 6, "What is the PRIMARY function of the hydrogen and/or fuel cells used by your organization?"

Use of Hydrogen by Large-Scale End Users

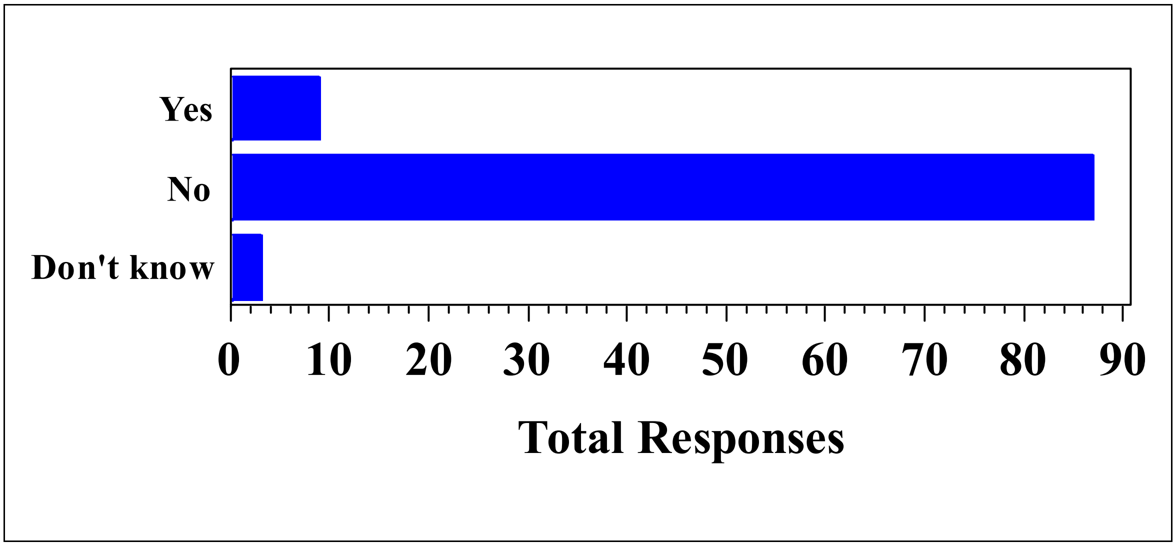

Figure 7.2. Responses to Question 5, "Does your organization use hydrogen and/or fuel cells for any purpose," Large-Scale End User Survey.

Figure 7.3 shows the distribution of responses to Question 7, "Does your organization have plans to use hydrogen or fuel cells in the future?" Most of the businesses do not have plans to use hydrogen or fuel cells. Should hydrogen technology become widespread, however, future responses to Questions 5-7 will likely depart greatly from these baselines.

Planned Use of Hydrogen by Large-Scale End Users

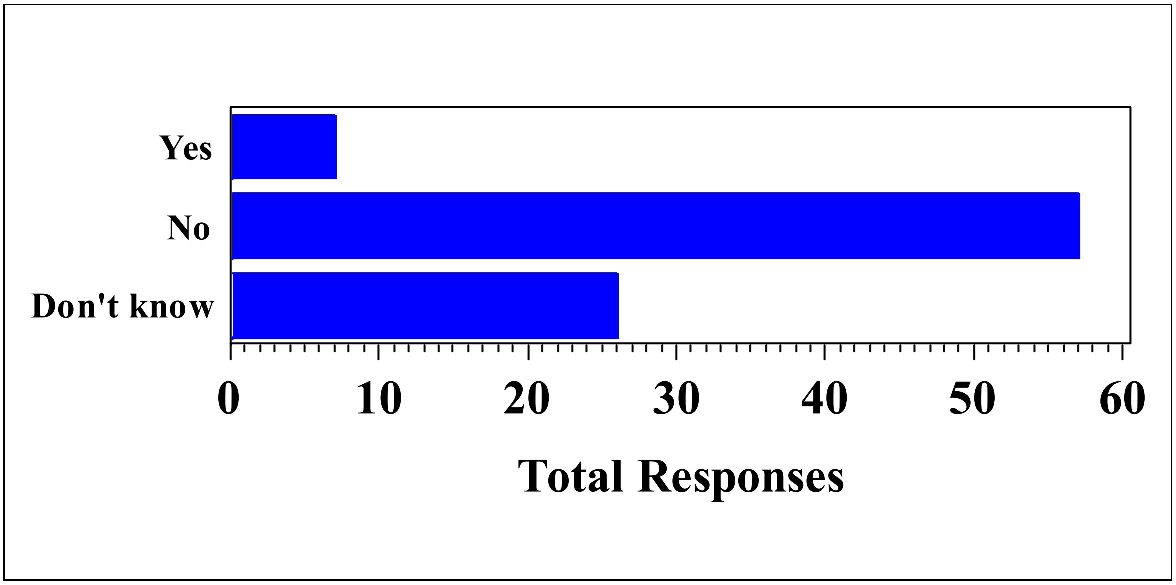

Figure 7.3. Responses to Question 7, "Does your organization have plans to use hydrogen or fuel cells in the future," Large-Scale End User Survey.

On first glance, the responses to these two questions may seem contradictory; that is, if there are nine respondents (Figure 7.2) who indicated that they currently use hydrogen or fuel cells, how can there be only seven respondents (Figure 7.3) who have future plans for hydrogen or fuel cells. Although there is no clear-cut explanation, it is possible that respondents answered the questions based on knowledge of current technologies (the respondent knows what currently exists) and a lack of knowledge about the future (there are no plans for additional usage).There were only three "Don't know" responses to Question 5 (current usage), but there were 26 "Don't know" responses to Question 7 (future plans).

Results for the technical knowledge questions (along with the other questions) can be summarized as in Appendix C.4. However, the technical questions can also be summarized in terms of whether they were answered correctly. In this summary, "Don't know" can be handled either as an incorrect response (i.e., a failure to give the correct response) or as a separate kind of response. Table 7.1 summarizes the technical knowledge questions in terms of whether they were answered correctly or incorrectly with "Don't know" treated as an incorrect response. On average, 44.4% of the technical questions were answered correctly. This is higher than the percentage of correct answers for either the general public (32.8%) or students (32.2%) and lower than the percentage of correct answers for the state and local government agencies (65.8%).

Question	Number of Responses	Percent Correct	Lower 95% Confidence Bound	Upper 95% Confidence Bound
Table 7.1. Summary of Results for the Large-Scale End Users on the Technical Knowledge Questions (Correct/Incorrect)				
12a. Hydrogen pipelines exist nationwide (false)	99	48.5	38.6	58.4
12b. In a hydrogen economy, hydrogen replaces fossil fuels as the dominant form of energy (true)	99	50.5	41.3	59.7
12c. Hydrogen gas is toxic (false)	99	54.6	44.9	64.2
12d. Fuel cells produce electricity through hydrogen combustion (false)	99	17.2	9.6	24.7
12e. Hydrogen is too dangerous for everyday use by the general public (false)	99	60.6	51.3	69.9
12g. Hydrogen is lighter than air (true)	99	62.6	53.2	72.0
12h. Hydrogen has a distinct odor (false)	99	59.6	50.4	68.8
13a. In which state or condition can hydrogen be stored? (chemical compound and liquid)	99	46.5	36.9	56.0
13b. When using pure hydrogen, fuel cell vehicles generate electricity, water, and what else? (heat)	99	29.3	20.2	38.4
13c. Hydrogen can be produced using which of the following sources of energy? (natural gas, sunlight, and organic matter)	99	40.4	30.8	50.0
13f. Which of the following represents a type of fuel cell? (PEM)	99	19.2	11.4	27.0
Overall Average	**99**	**44.4**	**38.9**	**50.0**

The fewest number of correct answers (17.2%) were for Question 12d, concerning fuel cells. The other fuel cells questions (13f and 13b) received the next fewest correct responses.

While Table 7.1 presents correct versus incorrect responses (where incorrect responses include the “Don’t know” response), Figure 7.4 shows the responses broken down according to type: Correct, Incorrect, and “Don’t know.” On average, 44.4% of the technical questions were answered correctly, 13.4% were answered incorrectly, and 42.2% were answered with “Don’t know.”

Technical Knowledge Scores of Large-Scale End Users

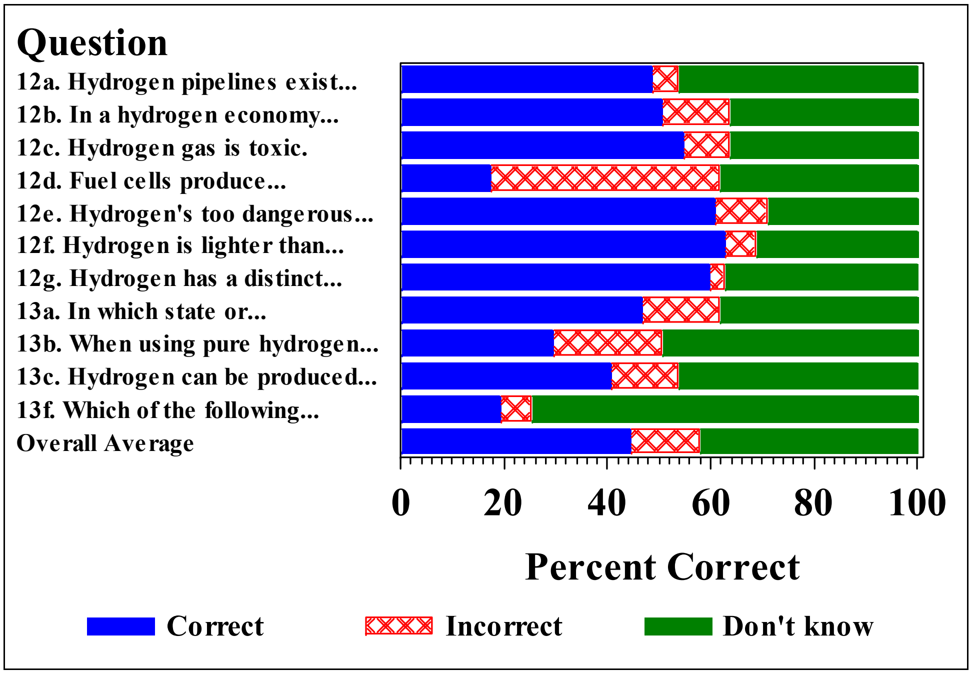

Figure 7.4. Weighted percent correct, incorrect, and “Don't know” for the technical knowledge questions, Large-Scale End User Survey.

Figure 7.5 shows the distribution of scores for the Large-Scale End User Survey. Unlike the score distributions for the other survey components, the distribution for the large-scale end users is bimodal. Most of these respondents (69 of 99; 69.7%) correctly answered three or more of the eleven technical questions, but a substantial proportion (30 of 99; 30.3%) correctly answered fewer than three, and the most frequent score, the score for 16.2% of the respondents, was zero. The high proportion of zeros may reflect indifference or reticence or impatience among some of the end user respondents in dealing with the technical questions.

Distribution of Technical Question Responses from Large-Scale End Users

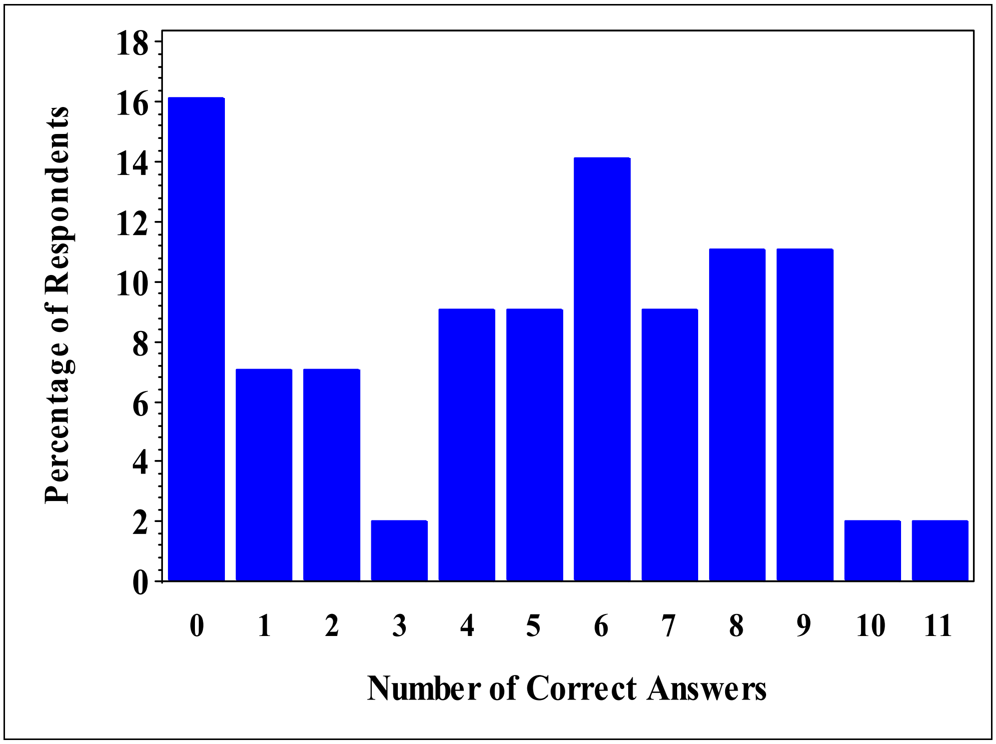

Figure 7.5. The bimodal distribution of the number of correct answers to the eleven technical questions for the Large-Scale End User Survey.

Figure 7.6, which contrasts the correct, incorrect, and "Don't know" response frequencies for those respondents who correctly answered fewer than three technical questions, is analogous to Figure 7.4 for ***all*** of the end-user respondents. The high proportions of "Don't know" responses – even among respondents who answered fewer than three technical questions correctly – suggest that these respondents may have been dismissive with the technical questions, for whatever reason, not even wanting to bother with them. Because these respondents represent a substantial (30.3%) and clearly separate subpopulation of the large-scale end users, an education program might be designed to treat them separately. Differences between this subpopulation and the higher scorers are explored further in Section 7.3.

Distribution of Responses for Large-Scale End Users with Low Technical Knowledge Scores

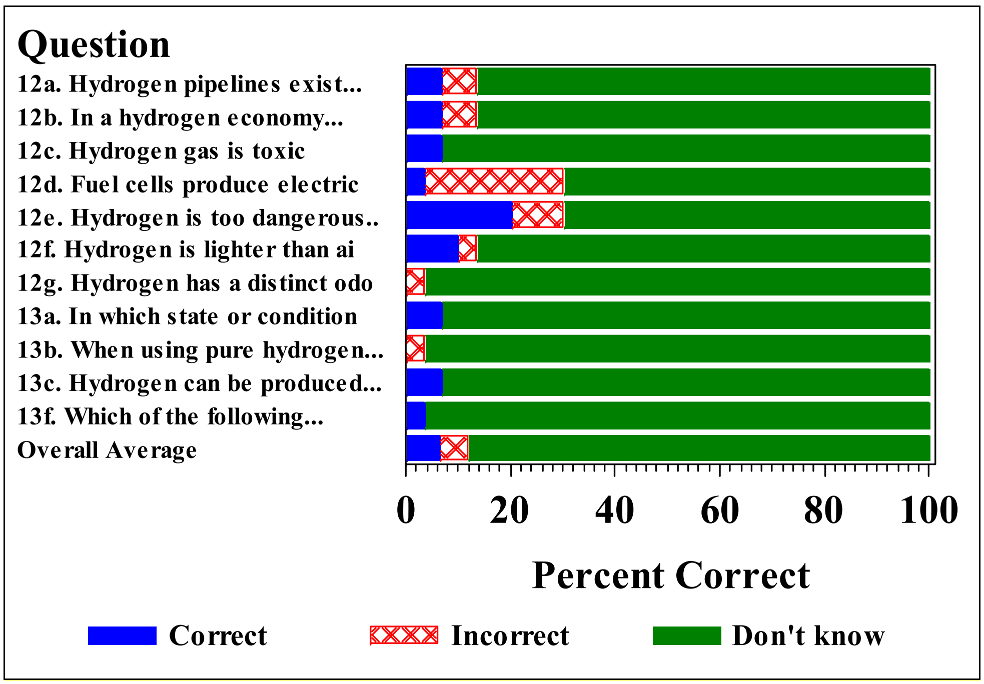

Figure 7.6. Percentages of correct, incorrect, and "Don't know" answers to the technical knowledge questions, for large-scale end-users with fewer than three correct answers to the eleven technical questions, Large-Scale End User Survey. The high proportions of "Don't knows" may reflect reticence or impatience of these respondents.

Respondents were asked (Question 5) whether their organizations currently used hydrogen and/or fuel cells for any purpose. Only nine respondents (9.1%) indicated that they did. Of these respondents, about a third indicated that the primary function of the hydrogen or fuel cell usage was to power vehicles.

When asked whether their organizations plan to use hydrogen or fuel cells in the future, 57 respondents (57.6%) responded that they did not have plans. Another 26 respondents indicated that they did not know, and only about seven respondents indicated that they did have future plans for the use of hydrogen or fuel cells. Of these respondents most indicated that their implementation plans were for the next five years. (See Appendix C.4 for specific information.)

Figure 7.7 shows responses to Questions 15 and 16. Question 15 asked respondents to rate the widespread commercial availability for hydrogen and fuel cells in the next five years for six separate potential applications. Question 16 asked about the safety of using hydrogen and fuel cells, in comparison with technology in use today, for the same applications. Figure 7.7 shows the percentages who responded to each of these questions. These respondents generally did not believe that small portable devices are safe; nor do they believe that small devices will be widely available in five years.

Large-Scale End User Perceptions of Safety and Availability of Hydrogen Applications

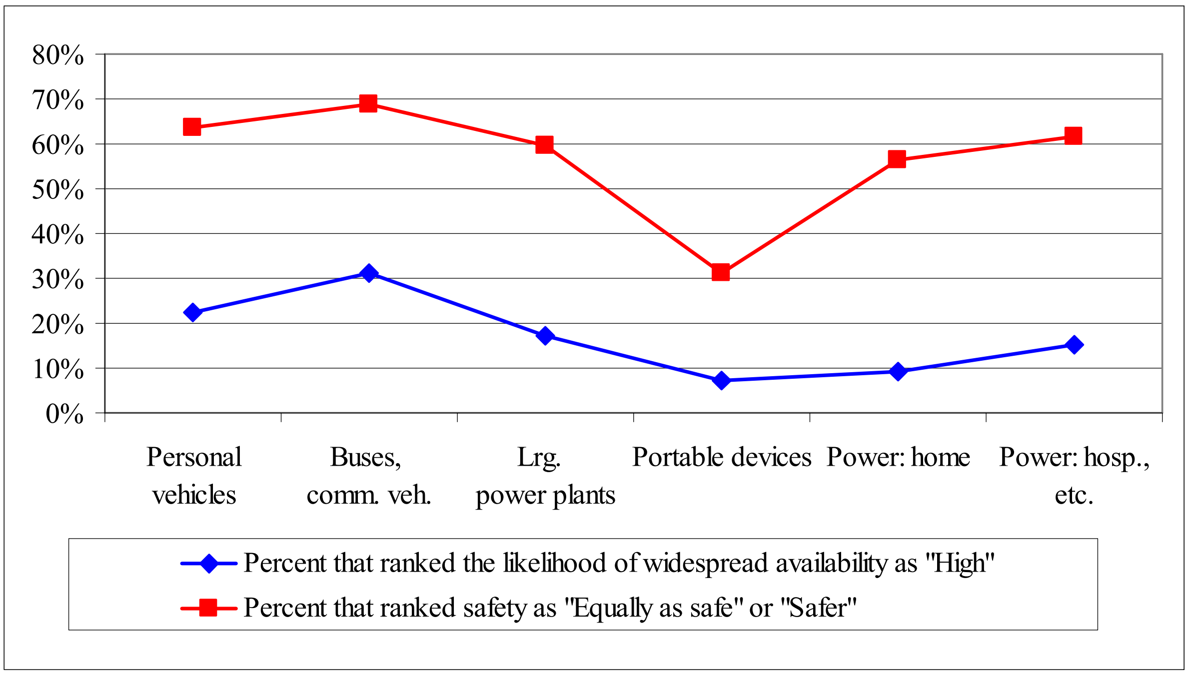

Figure 7.7. Weighted percent of responses to Questions 15 and 16 concerning widespread commercial availability within the next five years and perception of safety for specific applications, Large-Scale End User Survey.

Two questions were asked about information sources. Question 17 (see Appendix A.4) asked about the use of information sources (based on a scale of “Never,” “Sometimes,” and “Frequently”) to help make decisions about energy costs and safety. As shown in Figure 7.8, the most common source of information used by potential large-scale end users of hydrogen and fuel cells to make energy-related decisions (i.e., the source most often chosen as “Frequently” used) was utility companies or brokers. The next most frequently used source was the Federal government. Sources not used, as indicated by a response of “Never,” included friends and family members, local government, and trade shows.

Comparison of Energy Information Source Use by Large-Scale End User

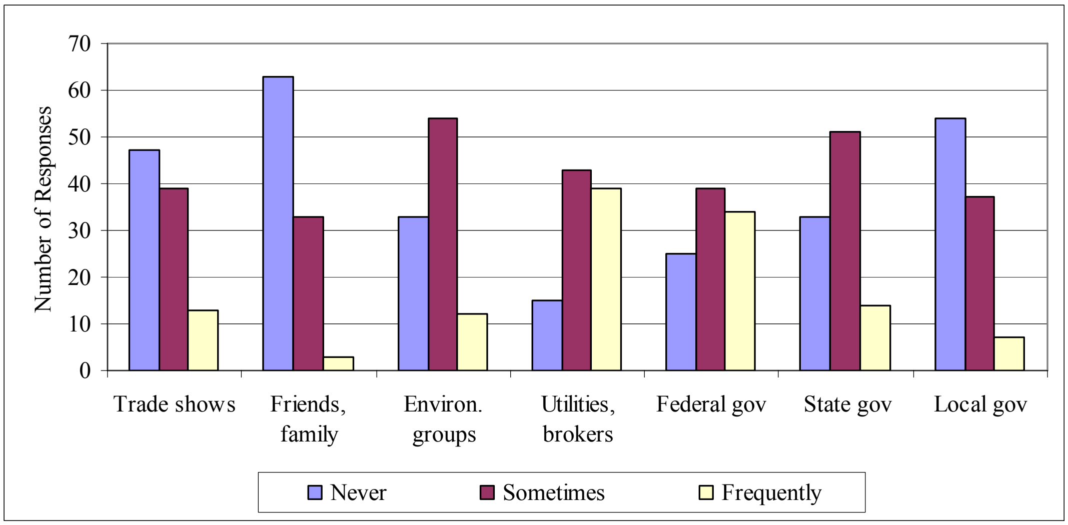

Figure 7.8. Weighted frequency of responses to Question 17 regarding the use of information for making decisions about energy costs and safety, Large-Scale End-User Survey.

Question 18 also asked about the use of information sources but from a different perspective. Question 18 (see Appendix A.4) asked how often respondents get energy information from different types of mass media. The media source that potential large-scale end users cited most often (i.e., the source most often chosen as "Frequently") was the Internet, followed closely by business or trade magazines (Figure 7.9).

Use of Mass-Media Sources for Energy Information by Large-Scale End Users

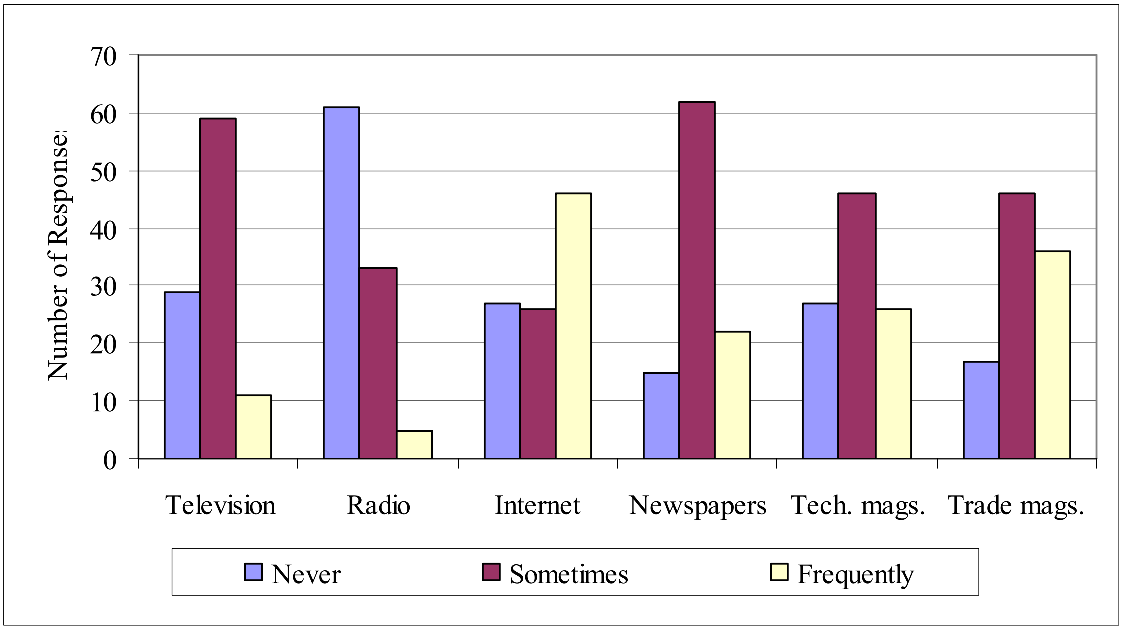

Figure 7.9. Weighted frequency of responses to Question 18 regarding the frequency of obtaining ENERGY information from different types of mass media, Large-Scale End User Survey.

Questions 9-11 asked large-scale end user executives about receipt of information on hydrogen and fuel cells at the workplace (Figure 7.10), including attendance at specific events. While only six respondents (6.1% of the total respondents) indicated that they had attended a training class on hydrogen or fuel cells, 70 respondents (70.1%) indicated that a DOE-sponsored class, conference, or workshop on hydrogen and fuel cells would be of value.

Hydrogen Education Event Attendance by Large-Scale End Users

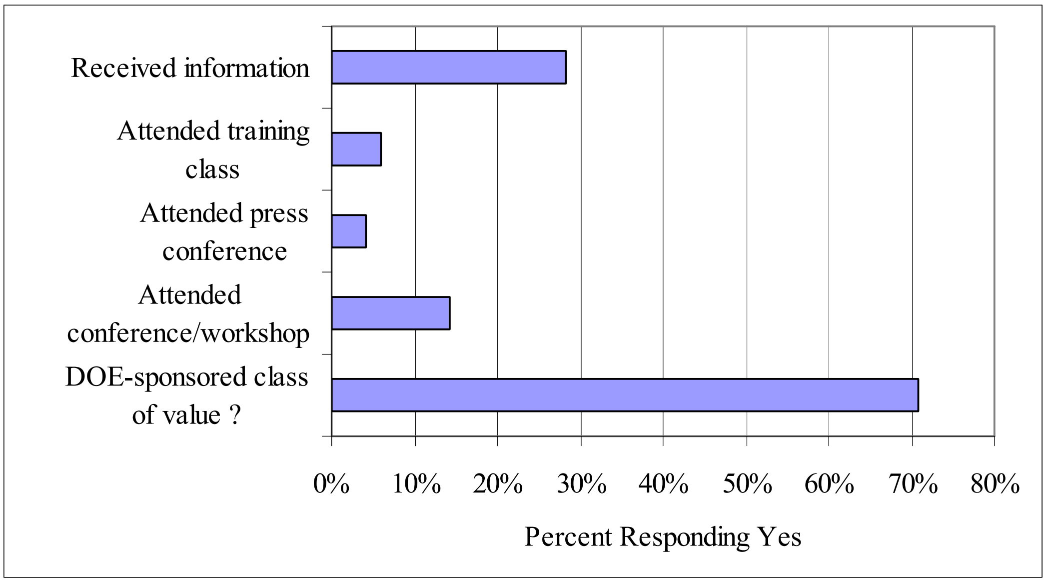

Figure 7.10. Responses to Questions 9-11 concerning receiving information at the workplace and attendance at a training class, press conference, or workshop and Question 18 about the potential value of a DOE-sponsored session, Large-Scale End User Survey.

7.3. RELATIONSHIPS

The summary statistics in Section 7.2 are "one-way" statistics in the sense that the response categories are defined in terms of one question (such as responses to Question 5). However, relationships in the responses determined by two or more variables may also be of interest. Although no such relationship was of particular interest a priori, in this section a few statistically significant ones are illustrated. Interactions that are considered are with the survey variables and Census Region, business strata, urban/non-urban status, and the "Above Average?" score indicator. The statistical significance is the significance level (p) of a chi-square test that accounts for the stratification in the survey design. Relatively few of these interactions are statistically significant ($p < .01$), however, because of the relatively small number of responses to the Large-Scale End User Survey, though quite a few significant interactions occurred for the above-average-score indicator.

Responses to each of the Questions 16a-f about safety depended significantly on whether the respondent's technical score was above or below average ($p < .0001$ in each case), with lower-scoring respondents much more likely to have no opinion, and above-average scorers more likely to believe that hydrogen power is as safe as or safer than technology in use today. Examples of this relationship are shown in Figures 7.11-7.13.

Figure 7.11 shows that respondents with above average technical scores were much more comfortable with the idea of onsite hydrogen power for the home (Question 16e, $p < .0001$).

Large-Scale End User Perception of Hydrogen Safety for Onsite Power for the Home by Technical Knowledge Score

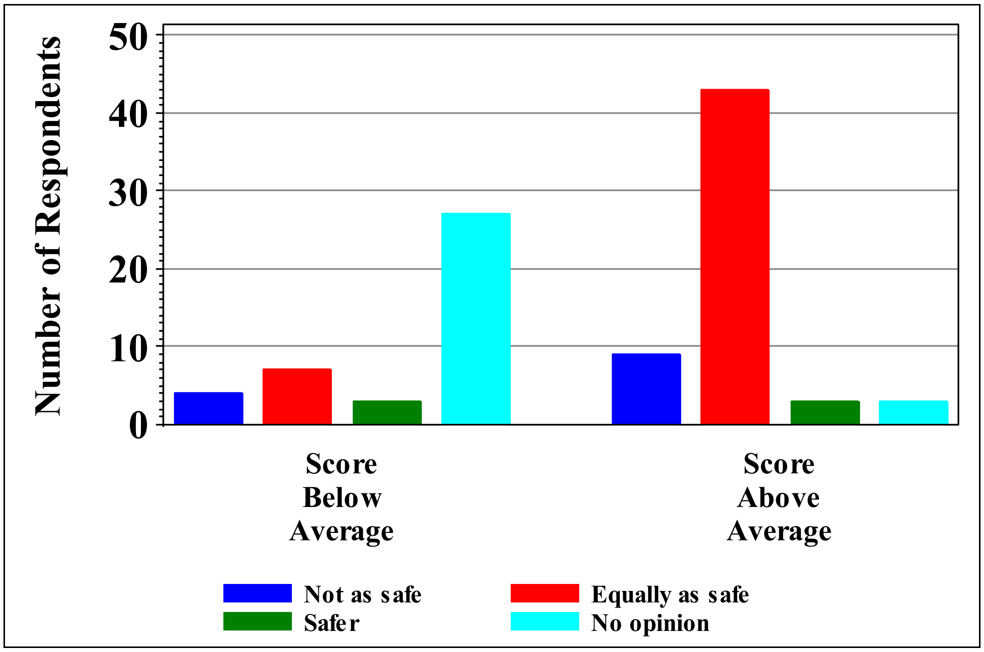

Figure 7.11. For respondents with above and below average scores on the technical questions, responses to Question 16e, "In comparison with technology in use today…is it not as safe, equally as safe or safer to use hydrogen and fuel cells for onsite power for the home," Large Scale End-User Survey.

Figure 7.12 shows that respondents with above average technical scores were much more comfortable with the idea of hydrogen-powered cars and trucks (Question 16a, $p < .0001$).

Large-Scale End User Perception of Hydrogen Safety for Personal Vehicles by Technical Knowledge Score

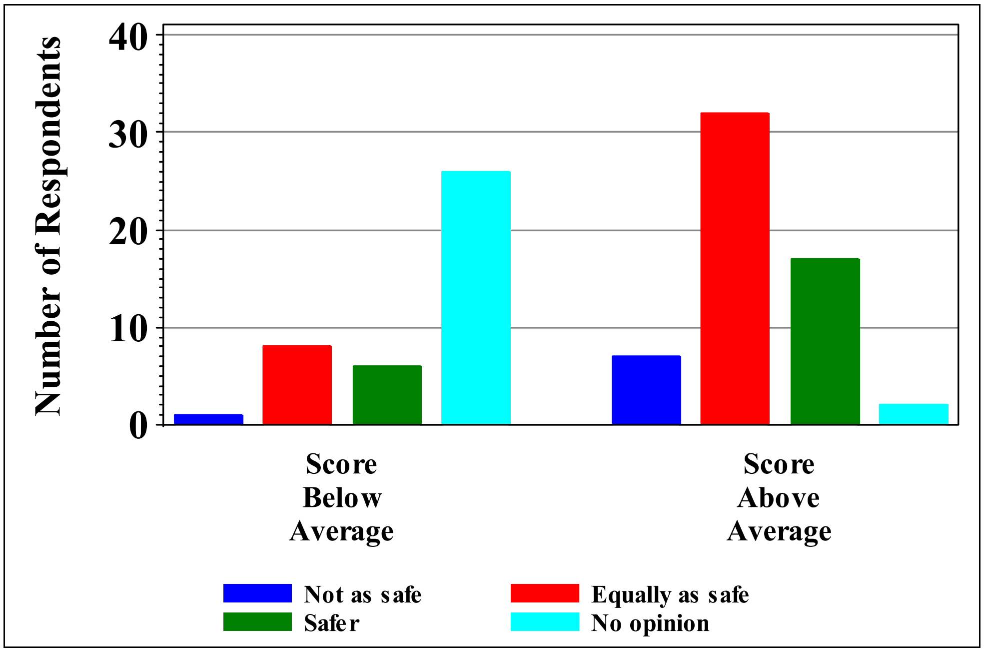

Figure 7.12. For respondents with above and below average scores on the technical questions, responses to Question 16a, "In comparison with technology in use today…is it not as safe, equally as safe or safer to use hydrogen and fuel cells for personal cars and trucks," Large-Scale End User Survey.

Figure 7.13 shows that respondents with above average technical scores were much more skeptical of the likelihood that hydrogen fuel cell technology would be commercially available to meet large power requirements in the next five years (Question 15c; $p < .0001$).

Large-Scale End User Perception of Availability of Hydrogen Power by Technical Knowledge Score

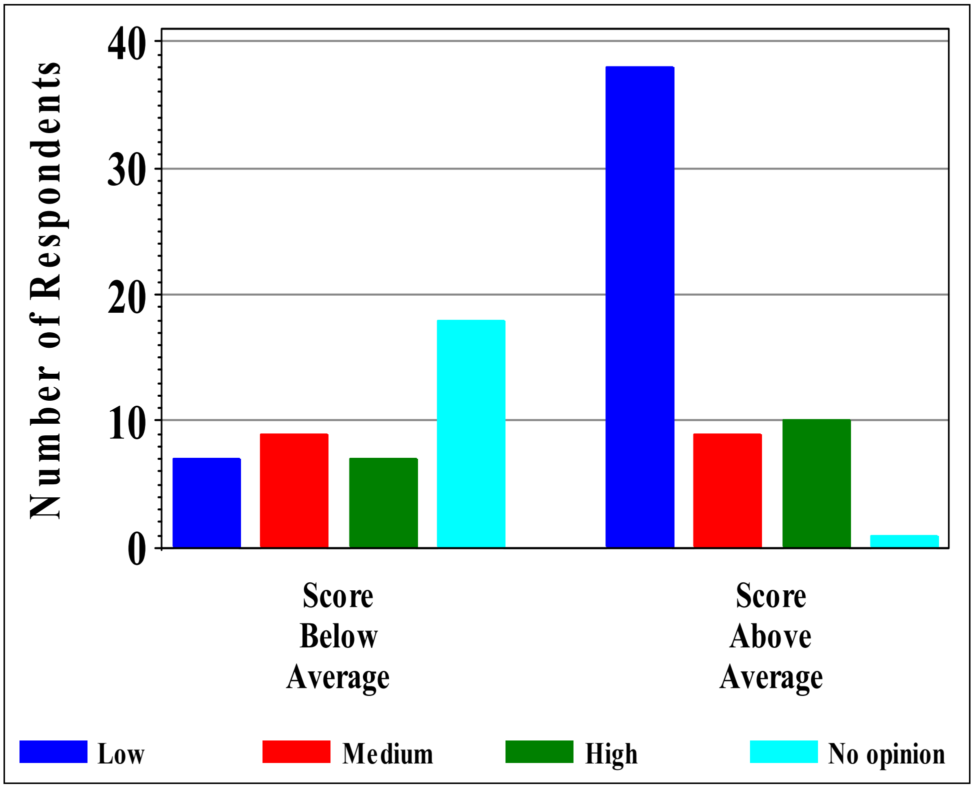

Figure 7.13. For respondents with above and below average scores on the technical questions, responses to Question 15c, "Please rate the likelihood of widespread commercial availability in the next five years…of large [hydrogen-fueled] power plants," Large-Scale End User Survey.

The discussion in Section 7.2 (including Figure 7.5) suggests that large-scale end users with fewer than three correct answers seem to represent a natural subpopulation, on which designers of an education program might focus separately. Thus, in this bimodal case, classifying respondents according to whether they correctly answered fewer than three of the eleven technical questions would also be useful, perhaps more so than classifying them according to whether they scored above or below average.

Figure 7.14 shows the frequencies of business categories (transportation, uninterrupted supply users, large power users) for respondents with fewer than three and at with three or more correct answers to the technical questions. Respondents in the higher scoring group were much more likely to be large power users, whereas lower scorers were more likely to be from the uninterrupted supply user category. Twenty (29.0%) of the 69 higher scorers were large power users, whereas only five (16.7%) of the 30 lower scorers were large power users. Fifteen (50.0%) of the lower scorers were from the uninterrupted supply category, whereas only eighteen (26.1%) of the higher scorers were from that category.[13]

Business Categories of Large-Scale End Users by Technical Knowledge Scores

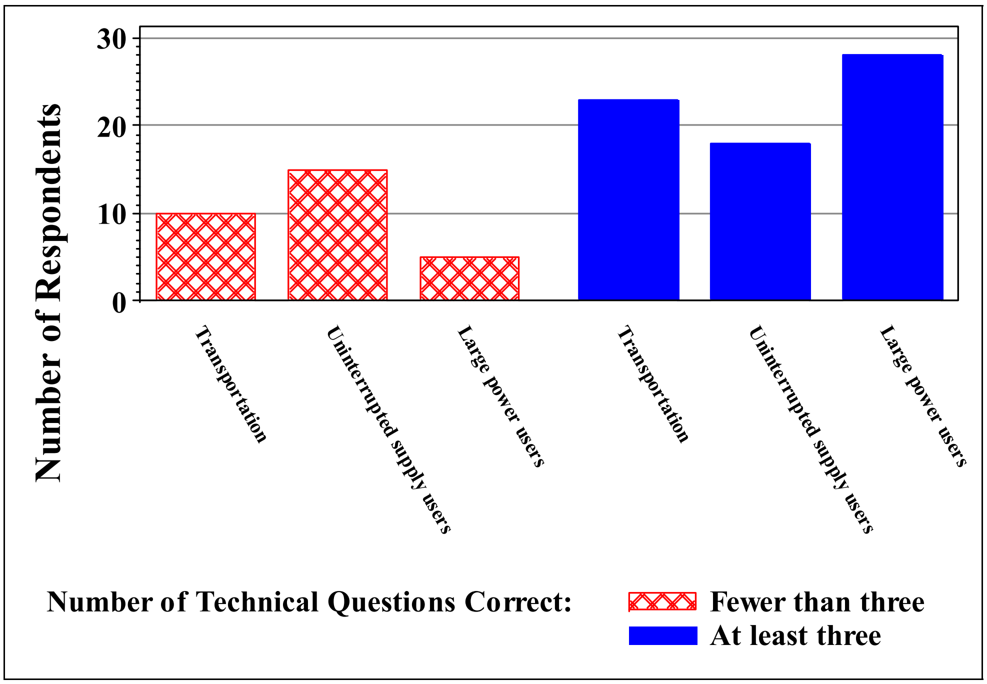

Figure 7.14. Business categories of the large-scale end user respondents who correctly answered fewer than three and at least three of the eleven technical questions, Large-Scale End User Survey.

Figure 7.15 shows responses to "How would you feel if your local gas station also sold hydrogen?" for respondents with fewer than three or at least three correct answers to the technical questions. Of the 30 respondents with fewer than three correct answers, only four (13.3%) said they would be "at ease." Among the 69 respondents with at least three correct answers, 36 (52.2%) said they would be at ease.

[13]Among the uninterrupted supply users, six of the fifteen lower scorers were classified as farms, whereas only three of the eighteen higher scorers were classified as farms.

Large-Scale End User Response to Hydrogen at Gas Stations by Technical Knowledge Scores

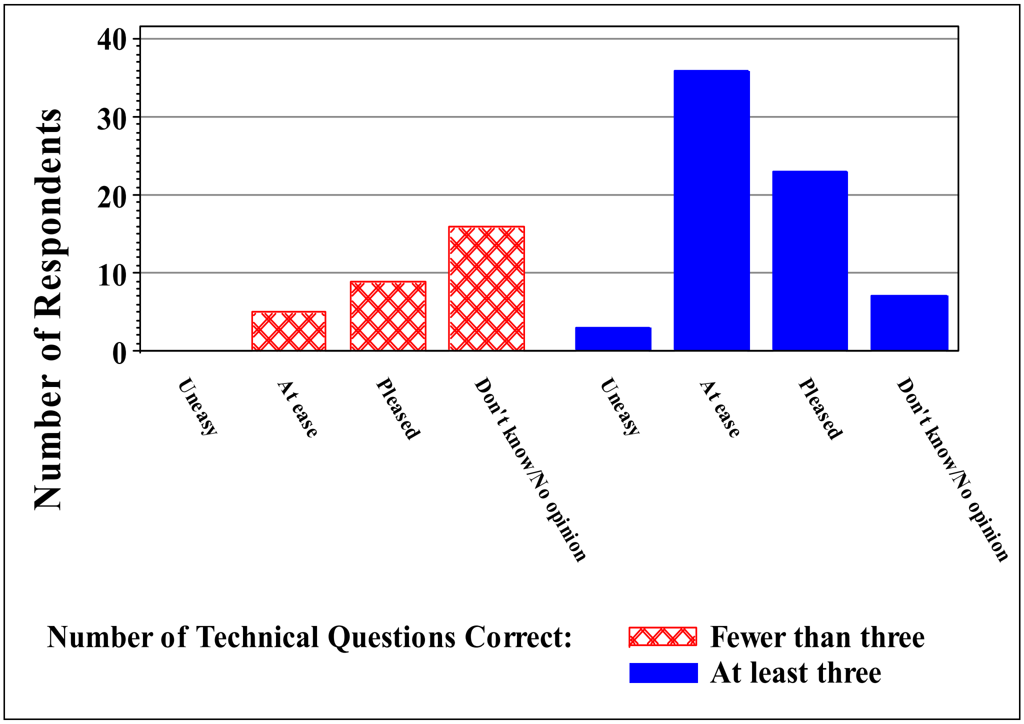

Figure 7.15. Responses to "How would you feel if your local gas station also sold hydrogen?" by whether or not respondents correctly answered at least three of the eleven technical questions, Large-Scale End User Survey.

Many of the other survey questions also reveal differences between the 69 respondents who correctly answered at least three technical questions and the 30 who did not. Among the 69 higher scorers 25 (36.2%) said yes to "Have you received information at your workplace concerning hydrogen and/or fuel cells?" Among the 30 lower scores, only three (10.0%) said yes. To the question inquiring about the value of training at a conference or workshop sponsored by the U.S. Department of Energy on hydrogen and fuel cells, 16 (53.3%) of the lower scorers responded "Yes," while 54 (78.3%) of the higher scores responded "Yes."

Among the lower scorers, "H-Bomb" was the most frequent (30.0%) response to "Which of the following would you MOST closely associate with the word 'hydrogen'?" "Chemistry Class" was the most frequent response among the 69 higher scorers, with only 10 (14.5%) of the higher scorers answering "H-bomb." Only three (10.0%) of the lower scorers agreed with the statement "Hydrogen is as safe as gasoline and diesel fuels" whereas 49 (71.0%) of higher scorers agreed. Only eight (26.7%) of the lower scorers said they frequently get energy information from the internet, whereas 38 (55.1%) of the higher scorers said they do.

The subpopulation of lower-scoring large-scale end users seems well-defined, both in its statistical distribution and in the mindset of its membership. Although lower scoring individuals are an obvious target for any education program, the lower-scoring large-scale end users seem especially appropriate.

7.4. OUTCOME RATES

Various outcome rates are of interest in characterizing survey data results. The *response rate* is the proportion of sampled eligible subjects for whom complete survey interview information is obtained. The *refusal rate* is the proportion of sampled eligible subjects who refuse to be interviewed or who terminated their interviews before completion. The *contact rate* is the proportion of sampled eligible subjects that were contacted at all. In general the number of eligible subjects must be estimated, and there are various ways to estimate this number and to define, in turn, estimates of the rates. AAPOR gives various definitions (AAPOR, 2004) for the rates and provides a spreadsheet calculator for computing them.

Estimates of the rates are computed from outcome frequencies, as shown in the following table for the Large-Scale End User Survey.

Table 7.2. Outcome Frequencies for the Large-Scale End User Survey

Outcome Type	Frequency
Complete interviews (I)	99
Partial interviews (P)	1
Refusals and break offs (R)	10
Non-contacts (NC)	0
Other eligible, non-interviews (O)*	0
Known eligible	**110**
No Answer (UB)	80
Other non-contact (UO)	250
Eligibility unknown (non-contact)	**330**
Quota Filled (QF)**	45
Other known ineligible (UO)	3
Known ineligible	**48**
Total phone numbers used	**488**

*This category is a catchall for various kinds of eligible non-interviews. See AAPOR (2004, page 39) for a complete listing of outcome categories.

** After 33 respondents were obtained for any strata, further potential respondents in that strata were regarded as ineligible.

The eligibility rate can be estimated as

e = Known eligible / (Known eligible + Known ineligible).

The eligibility rate estimate **e** can be applied to cases of unknown eligibility to estimate the number of those cases that were actually eligible. The response rate can then be estimated (there are other ways) as

$$\textbf{Response rate} = I/(I + P + R + NC + O + e \times (UB + UO)).$$

For the Large-Scale End User Survey

$$e = 110/(110 + 48) = .6962,$$

and the response rate estimate is

$$\textbf{Response rate estimate} = 99/(99+1+10+0+0+.6962 \times (80+250)) = .2914.$$

In comparing survey results over time or across survey components, it is important to consider the response rates and other outcome rates. Contact rates may decline, for example, as cell phone use increases and land line use decreases. From the perspective of hydrogen technology awareness, the rates are of independent interest. For example, it is likely that the response rate would increase and the refusal rate would decrease, for a population that becomes more enthusiastic about hydrogen technology. However, subjects might self-select for the very reason that they are knowledgeable about hydrogen, and a low response rate might upwardly bias estimates of awareness.

8. COMPARISON OF RESULTS FOR THE FOUR POPULATIONS

Sections 4-7 summarize the results for the General Public, Student, State and Local Government, and Large-Scale End User Surveys, respectively. In these summaries, very few comparisons are made among these four survey component populations. The results of the surveys of the four different populations are compared in the paragraphs below. It must be stressed that a comparison of the results is **NOT** the primary purpose of these surveys. Each of the populations is very different, and each population will require a different approach for the education program. Therefore, the primary impact of the information gained in the hydrogen surveys is in the results from each individual survey.

The comparisons are of interest, however, and may be used to point out the differences in the four populations. One of the most interesting comparisons is that of the average scores for the eleven technical knowledge questions. It was noted in Sections 4-7 that the state and local officials are more likely to know the answers to the technical questions than the other populations.

Overall, the technical questions were answered correctly about one-third of the time by either the general public or students, and about two-thirds of the time by the state and local officials. Thus, the state and local officials answered the questions correctly about twice as often as the general public or students. Large-scale end user respondents answered the technical questions correctly 44.4% of the time, although their distribution of responses was bimodal (Figure 7.5) and different from the distributions for the other survey components.[14]

Figure 8.1 illustrates the differences in correct technical responses among the four populations. The figure also shows differences between the percentage of correct scores for fuel cell questions and for hydrogen technical questions. The three questions about fuel cells were Question 1d ("Fuel cells produce electricity through hydrogen combustion"), 3b ("When using pure hydrogen, fuel cell vehicles generate electricity, water, and what else"), and 3f ("Which of the following represents a type of fuel cell"), based on numbering on the General Public Survey (see Appendix A for copies of the complete questionnaires).[15]

The fuel cell questions were answered correctly by only 11.2% of the general public and 10.9% of the students. These groups were over three times more likely to respond correctly to a hydrogen-related technical question than a fuel cell question. Large-scale end users were about twice as likely to respond correctly to a hydrogen-related technical question as to a fuel cell question. The state and local officials correctly answered the hydrogen technical questions about 40.4% more often than the fuel cell questions. Thus, it might be assumed that either

[14] Additional information on these distinct subpopulations of the end users is provided in Section 7.
[15]The numbering of the technical questions is the same for all survey components except for the Large-Scale End User Survey. Large-Scale End User Survey Questions 12a-e correspond to Question 1a-e, respectively, on the other surveys; Large-Scale End User Survey Questions 1f and 1g correspond to Questions 1g and 1h, respectively, on the other surveys; and Large-Scale User Survey Questions 13a, b, and f correspond to Questions 3a, b, and f, respectively, on the other surveys.

(1) knowledge about fuel cells is not as prevalent as technical knowledge about hydrogen and the hydrogen economy, particularly so for the general public and students, or (2) the fuel cell questions were more difficult questions (see Figure 8.1).

Correct Technical Responses by Survey Population

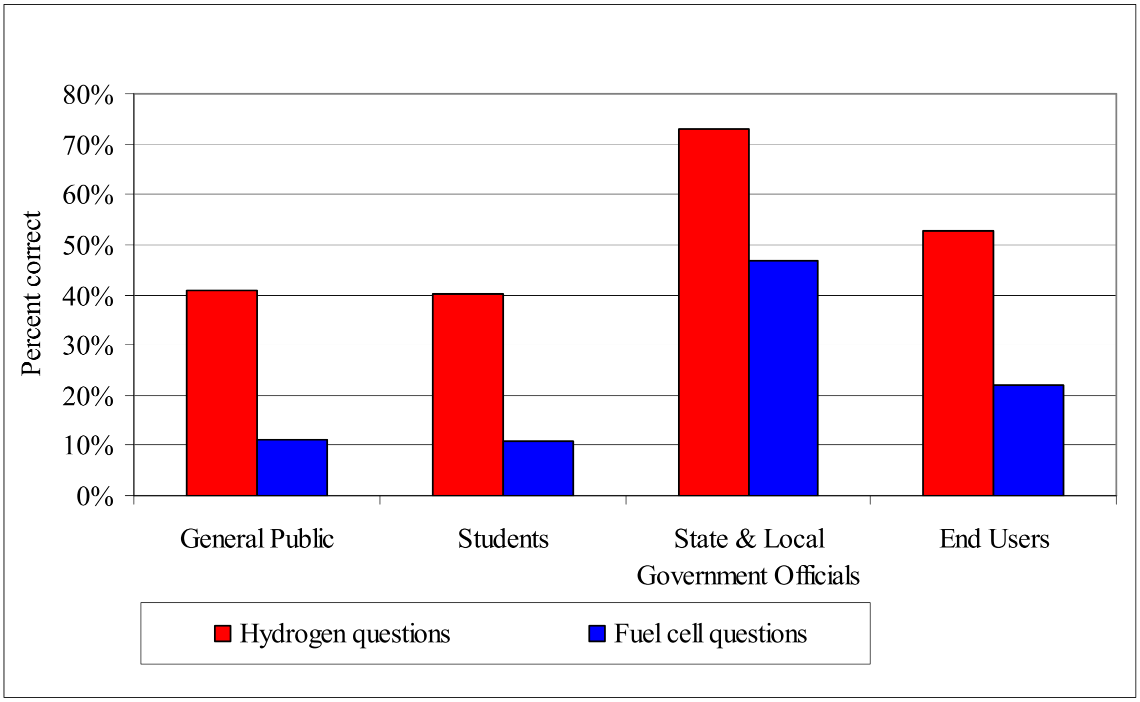

Figure 8.1. The distribution of the average percentage of correct responses to the eleven technical questions, for hydrogen (eight questions) and fuel cells (three questions), General Public Survey, Student Survey, State and Local Government Survey, Large-Scale End User Survey.

Another way of looking at responses to the technical knowledge questions is to look at the number of “Don’t know” responses. Figure 8.2 shows the percentage of respondents in each category that responded “Don’t know” to the eleven technical questions. The population with the highest percentage of “Don’t know” responses was the general public, followed closely by the large-scale end users. The large-scale end users group had a higher overall average number of correct answers (44.4) than the general public (32.8), but the percentage of “Don’t know” responses was very similar for the two groups.

“Don’t Know” Responses by Survey Population

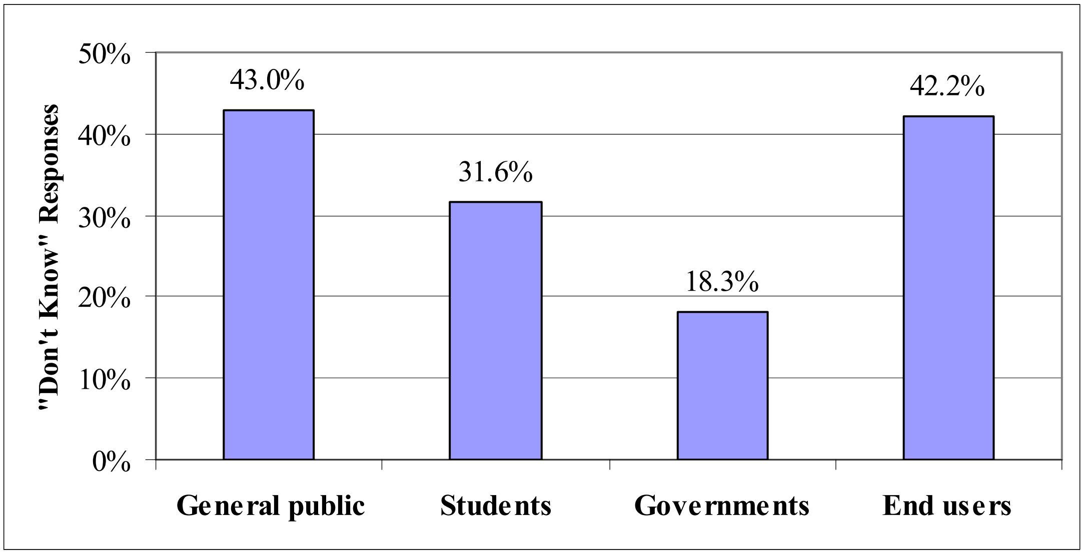

Figure 8.2. Percentage of respondents in each population who answered “Don’t know” to the eleven technical questions assessing knowledge of hydrogen and fuel cells, General Public Survey, Student Survey, State and Local Government Survey, Large-Scale End User Survey.

Figure 8.3 contrasts the responses to the opinion assertions "Using hydrogen will reduce U.S. dependence on foreign oil," "Using hydrogen will reduce emissions and improve air quality," and "Hydrogen is as safe as gasoline and diesel fuels." These are Questions 4a, 4b, and 4d on the General Public Survey questionnaire (Appendix A.1).[16] From the figure, the state and local officials are apparently more optimistic than either the general public or students about the benefits of hydrogen technology. The large-scale end user respondents are between the government and general public or students. The figure represents the percentage of respondents in each population saying they agree with the assertions. Similar figures (with generally higher chart bars) result if respondents who said they are neutral are combined with those saying they agree with the assertions.

Agreement with Hydrogen Technology Assertions by Survey Population

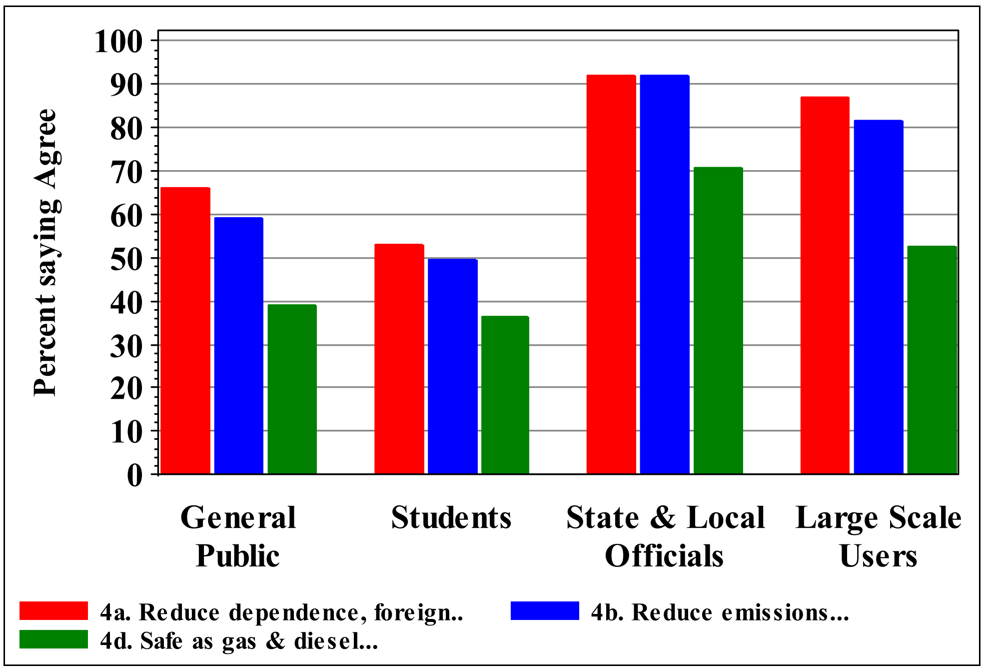

Figure 8.3. Distribution of respondents agreeing with the hydrogen technology assertions, General Public Survey, Student Survey, State and Local Government Survey, Large-Scale End User Survey.

[16]Questions 14a, 14b, and 14c on the Large-Scale End User Survey.

Figure 8.4 contrasts the survey components in the respondent ratings of the likelihood of widespread commercial availability in the next five years of various hydrogen technologies (Question 5).[17] State and local officials and large-scale end user respondents are less optimistic than either students or the general public, perhaps because they have a more realistic understanding of technical barriers.

Perception of Future Hydrogen Technology Availability by Survey Population

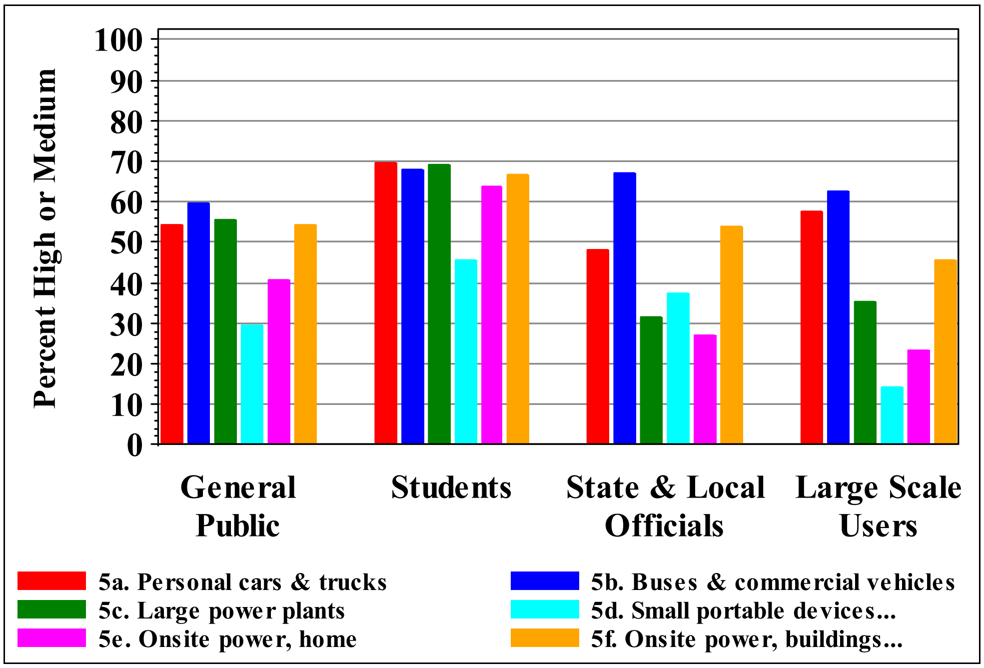

Figure 8.4. Distribution of respondents rating the likelihood as either "medium" or "high" for widespread commercial availability in the next five years for various hydrogen technologies, General Public Survey, Student Survey, State and Local Government Survey, Large-Scale End User Survey.

Responses of "Medium" and "High" are combined in Figure 8.4, but a similar conclusion can be inferred from a chart based only on the "High" responses. (See, for example, Figures 4.5, 5.5, 6.5, and 7.6.) Table 8.1 shows the percentages of respondents in each population group that rank the likelihood of widespread availability as "High" for each specific application.

[17] Question 15 on the Large-Scale End User Survey.

Table 8.1. Percentages of Respondents Ranking the Likelihood of Widespread Availability as "High" for Specific Applications						
Population	**Personal Cars & Trucks**	**Buses & Commercial Vehicles**	**Large Power Plants**	**Small Portable Devices**	**Onsite Power, Home**	**Onsite Power, Buildings**
General public	27.9	35.7	35.7	15.9	16.7	28.9
Students	36.7	36.0	47.2	28.1	26.1	38.8
State/local officials	16.9	26.7	7.2	15.3	4.2	10.2
Large-scale users	22.2	31.3	17.2	7.1	9.1	15.2

For these same technologies, Figure 8.5 contrasts safety ratings relative to the corresponding current technologies (Question 6).[18] The state and local officials tended more often than the other groups to rate the hydrogen technology as at least as safe as the current technology.

Perception of Hydrogen Technology Safety by Survey Population

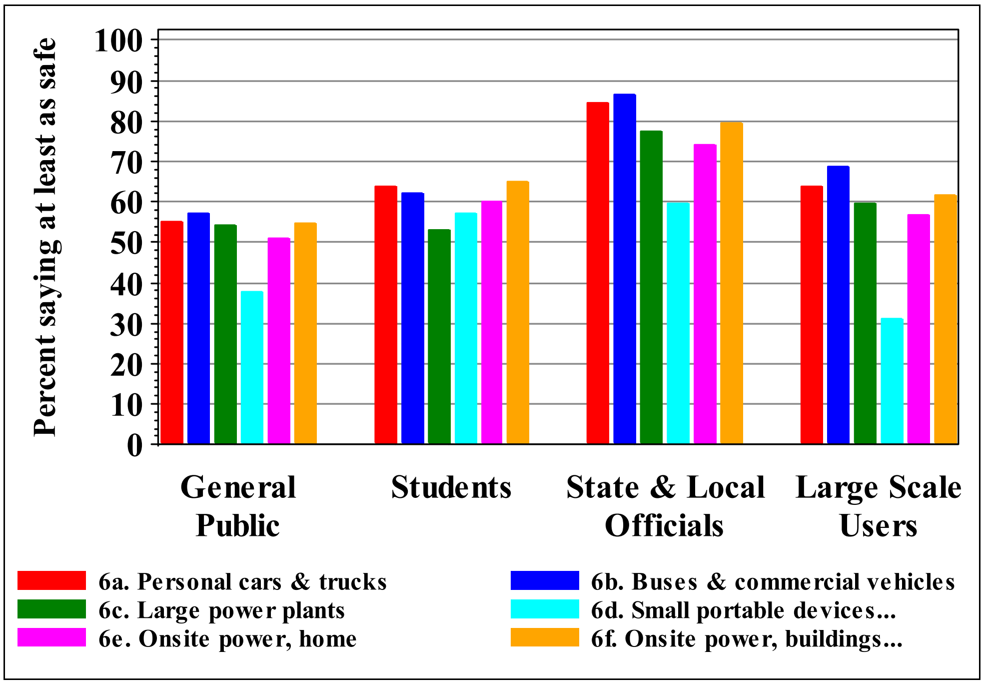

Figure 8.5. The distribution of respondents who rated the safety of hydrogen for various technologies as at least as safe as the corresponding current technology, General Public Survey, Student Survey, State and Local Government Survey, Large-Scale End User Survey.

[18] Question 16 on the Large-Scale End User Survey.

Figure 8.6 shows differences in the use of mass media sources by the respondents for obtaining energy information (Question 8).[19] Figure 8.6 is based on total responses of both "Sometimes" and "Frequently." Not surprisingly state and local officials and large-scale end users indicated that they get energy information more often from newspapers, the Internet, and science and technology journals. Large-scale end users also indicated that they use business and trade magazines to obtain energy information. Television is a media source used by all populations to obtain energy information.

Mass-Media Use for Energy Information by Survey Population

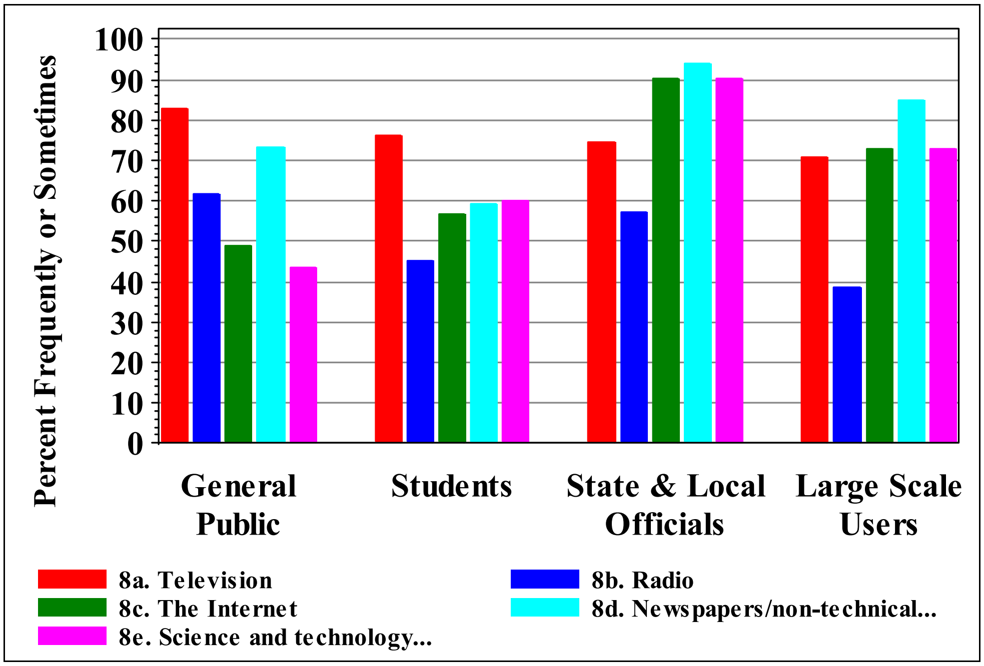

Figure 8.6. The distribution of respondents indicating either "Sometimes" or "Frequently" for how often they use various information sources for energy information, General Public Survey, Student Survey, State and Local Government Survey, Large-Scale End User Survey.

[19] Question 18 on the Large-Scale End User Survey.

Figure 8.7 is a slightly different view of the data shown in Figure 8.6. The percentages of the responses ("Frequently," "Sometimes," or "Never") by media source for each of the populations are shown in Figure 8.7 for the frequency of use of each source for obtaining energy information. When considering a combination of both "Frequently" and "Sometimes" responses, all four populations use television as a major source. At least 70% of respondents in the general public, government, and end user groups indicated that newspapers are used "Frequently" or "Sometimes." The radio is used less than the other media sources by all of the populations surveyed for obtaining energy information (i.e., there was a greater percentage of "Never" responses).

Frequency of Mass-Media Use for Energy Information by Survey Population

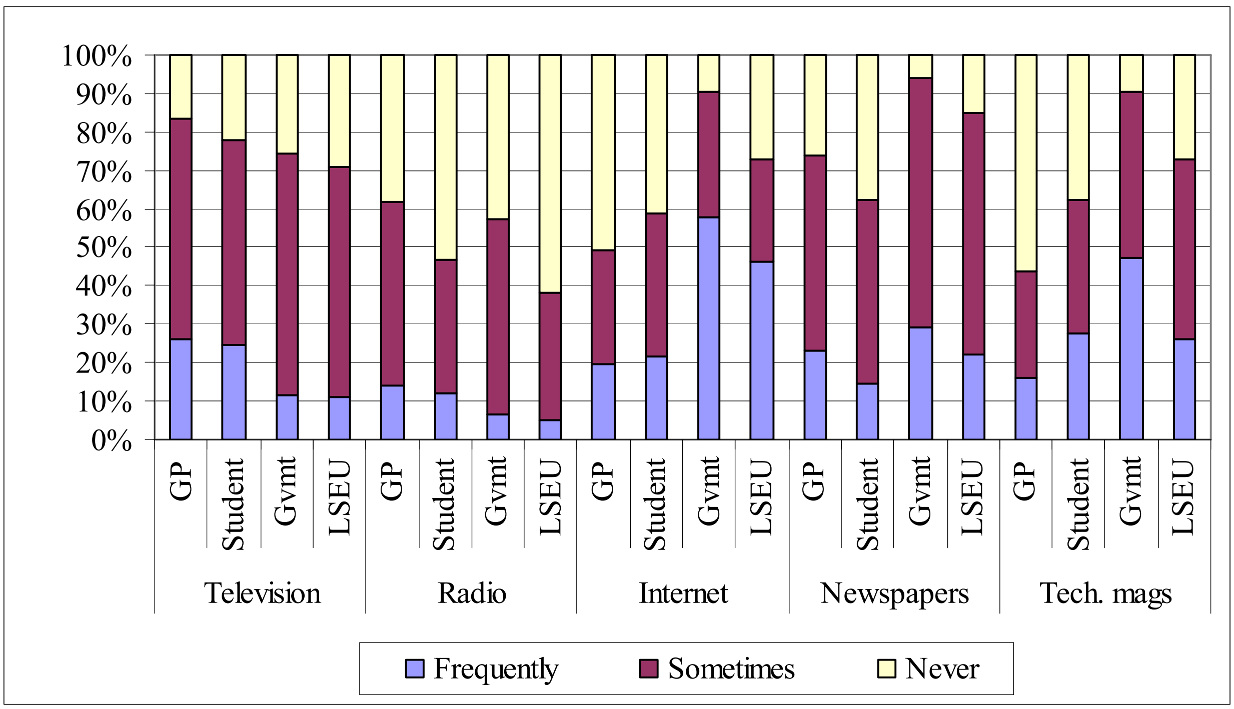

Figure 8.7. The frequency by which each media source is used by each of the survey populations, General Public Survey, Student Survey, State and Local Government Survey, Large-Scale End User Survey. (Note: GP = general public; Gvmt = government; and LSEU = large-scale end users.)

Figure 8.8 contrasts responses to survey Questions 1e and 4d.[20] Question (or proposition) 4d is "Hydrogen is too dangerous for everyday use by the general public." Question 4e is "Hydrogen is as safe as gasoline and diesel fuels." In addition to measuring opinions about safety, these two questions also measure consistency of the respondents with survey components. The figure shows the percentage of respondents that (1) disagreed with the statement "Hydrogen is too dangerous for everyday use by the general public" and, thus, felt that hydrogen is NOT too dangerous to use and (2) agreed with the statement "Hydrogen is as safe as gasoline and diesel fuels." The figure shows that state and local officials are more confident about safety than either students or the public in general, and that, again, large-scale end users fall between the state and local officials and either the students or the general public. The figure also shows that the responses to these two questions are consistent within the survey components.

Perception of Hydrogen Safety by Survey Population

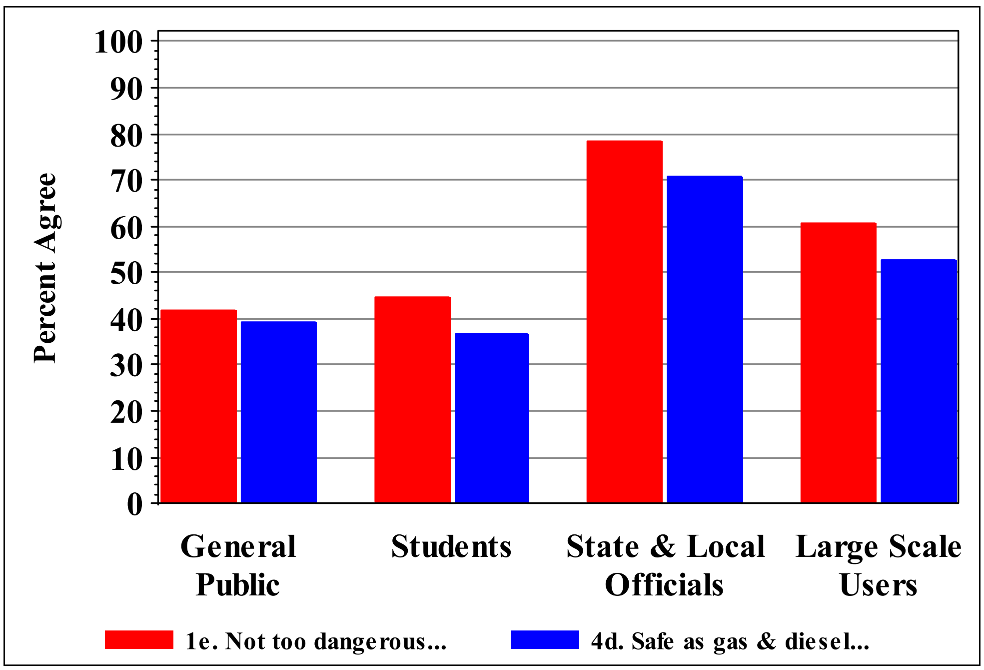

Figure 8.8. Distribution of responses to safety questions about everyday use of hydrogen, General Public Survey, Student Survey, State and Local Government Survey, Large-Scale End User Survey.

A similar conclusion follows when the number of respondents saying they are "neutral" is included.

[20]These are questions 12e and 14c on the Large-Scale End User Survey.

One specific question was posed to assess the "not in my backyard" attitude toward hydrogen. Question 3e in the public survey asked, "How would you feel if your local gas station also sold hydrogen?" Figure 8.9 shows the distribution of responses for each population surveyed.

Attitudes on Local Hydrogen Availability by Survey Population

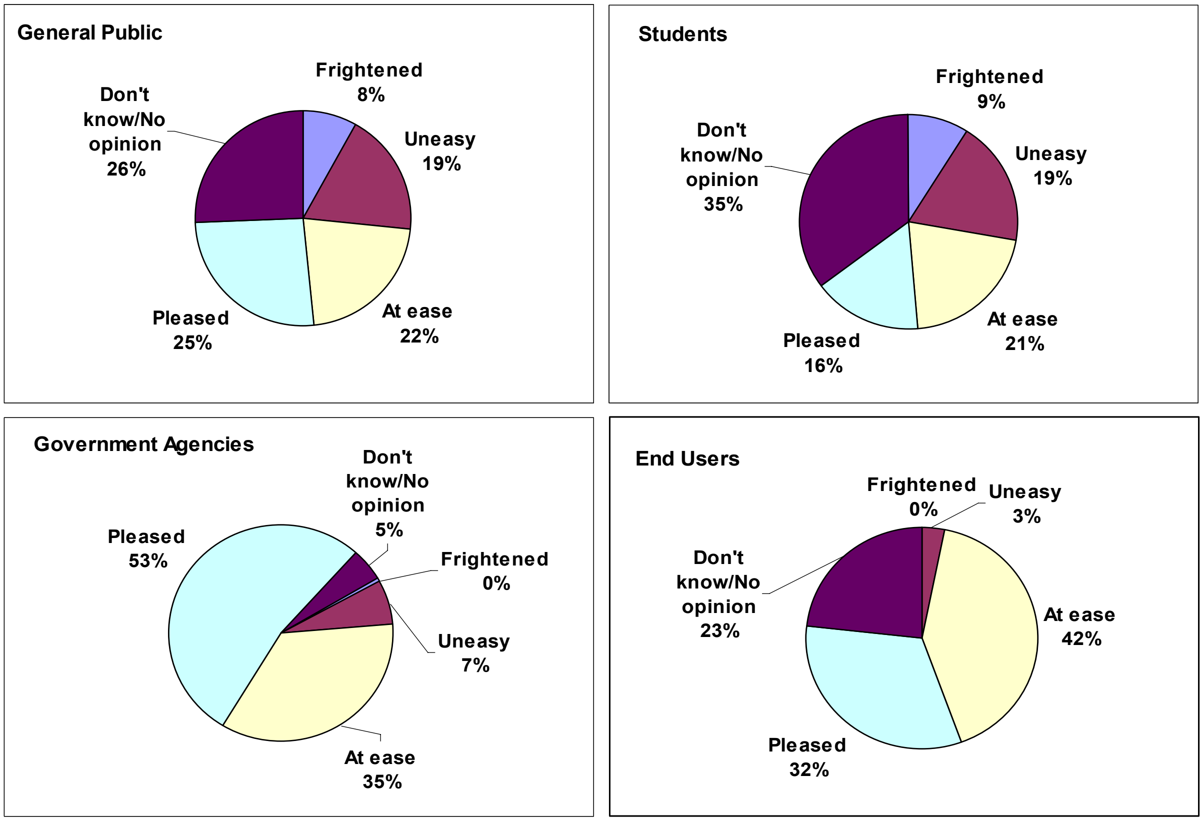

Figure 8.9. Responses to Question 3e on attitudes about a near-by hydrogen refueling station, General Public Survey, Student Survey, State and Local Government Survey, Large-Scale End User Survey.

9. NON-SURVEY METRICS

During 2003 and 2004, five large, geographically dispersed United States newspapers (*New York Times, Chicago Tribune, Dallas Morning News, Denver Post,* and *Los Angeles Times*) were searched regularly for articles about hydrogen. In 2004, another newspaper, the *Washington Post,* was added. These newspapers were available on the web and had search engines available. Four hydrogen-related keywords (fuel cell, hydrogen economy, hydrogen infrastructure, and hydrogen storage) were used as search criteria.

The number of articles that appeared in each newspaper was counted. No distinction was made for the length of the article, whether it had a positive or negative connotation, its position in the paper (i.e., front page or back page), or the day of the week (i.e., weekday or weekend); the measure was strictly a count. Each article in each paper was counted even if it was essentially the same article that was in one of the other papers. Articles were not double counted over time in the same paper.

The count of the number of feature articles by newspaper is given in Table 9.1. As can be seen in the table, the number of articles for four of the five newspapers that were searched both years dropped. The only newspaper with more hydrogen-related articles in 2004 than in 2003 was the *Denver Post*, which had no articles in 2003.

Table 9.1. Number of Articles Appearing in each Newspaper during 2003-2004

Newspaper	January-December 2003	January-September 2004
New York Times	27	8
Chicago Tribune	31	10
Dallas Morning News	10	6
Denver Post	0	6
Los Angeles Times	21	17
Washington Post	Not searched	9
Totals (excluding *Washington Post*)	89 (72, Jan-Sept; 17, Oct-Dec)	47

The number of articles by keyword is given in Figure 9.1. There were almost three times the number of articles on fuel cells as there were on hydrogen (i.e., articles on the hydrogen economy, hydrogen infrastructure, and hydrogen storage).

Newspaper Articles Related to Hydrogen

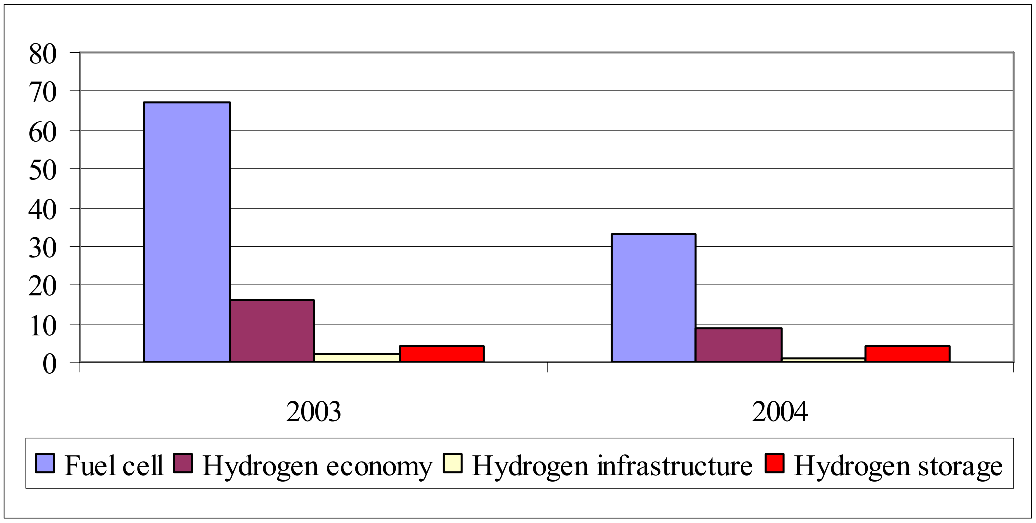

Figure 9.1. Number of articles found by count of specific hydrogen-related keyword.

10. SUMMARY AND CONCLUSIONS

10.1 SUMMARY

Four scientifically designed surveys were conducted during 2004 to assess the current knowledge and opinions of certain populations concerning hydrogen and fuel cells and the hydrogen economy. This report documents the data and results of these surveys. DOE will use the baseline data as a reference in designing an education program and will compare it with future survey results to measure changes in understanding and awareness. It is envisioned that the same statistical surveys will be fielded again in three years.

Scientific sampling was used to survey four populations: (1) the general public, ages 18 and over; (2) students, ages 12-17; (3) state and local government officials from state departments of transportation and environmental protection, state energy offices, and functionally similar personnel from cities and counties; and (4) potential large-scale hydrogen end users in three business categories: transportation, businesses requiring uninterrupted power supplies, and industries with large power requirements.

The surveys were conducted using CATI technology; closed-end questions were used. There were both technical knowledge and opinion questions. The total number of responses for each population and the average score on the eleven technical questions are shown in Table 10.1.

Table 10.1. Number of Responses and Average Score for Each of the Four Survey Populations

Population	Total Completed Interviews	Average Percent Correct on Technical Questions
General public	889	32.8
Students	1,000	32.2
State and local government officials	236	65.8
Large-scale end users	99	44.4

10.2 CONCLUSIONS

The data collected for the four component populations are intended (1) as a reference for designing the DOE Hydrogen Program education key activity, and (2) as a baseline for measuring changes in understanding and awareness over time. Design of an education program itself is beyond the scope of this report and comparisons of the baseline data with future results will not be made until the survey is fielded again. The report, therefore, is essentially a data book – a digest of the survey data collected for the four survey populations. Many conclusions can be made from the survey data, however. The purpose here is not to draw the conclusions, but rather to summarize the data in a way that facilitates drawing them.

A few observations about the data summaries are salient:

- Technical understanding appears to influence opinions about safety. For the General Public, Student, and Large-Scale End User Surveys, respondents with above-average scores on the eleven technical questions were more likely to have an opinion about hydrogen technology safety, and for those respondents who expressed an opinion, their opinion was more likely to be positive. These differences were statistically significant.

- On the technical knowledge questions, over 40% of the general public (43.0%) and large-scale end user (42.2%) responses were “Don’t know.” These responses were not unexpected for the baseline survey. It is expected that there will be fewer “Don’t know” responses when the survey is repeated in 2008 and 2011.

- State and local officials expressed more confidence about hydrogen safety than large-scale end users, and they were much more confident than either the general public or students. State and local officials also scored much higher on the technical questions. Even those government officials whose technical knowledge scores were below average (among government officials) felt that hydrogen and fuel cells were safe.

- The general public ranks safety first in importance, then cost, then the environment, and, last, convenience.

- For every population group, average scores on the technical knowledge questions were lower for the fuel cell questions than for the other technical questions.

- The Large-Scale End User Survey suggests that there is presently little penetration of hydrogen technology; nor is there much planning for it.

- Buses and commercial vehicles are considered the most likely area for the application of hydrogen and fuel cell technology in the next five years by government officials and large-scale end users. Students consider large power plants as the most likely application. The general public considers both large power plants and buses and commercial vehicles as equally likely.

- At least for the general public, perceptions about hydrogen technology can vary with age, education level, geographic region, urban/non-urban status, and sex.

- All populations except students were asked about sources of information used to make decisions about energy costs and safety. Using the criteria of “Never,” “Sometimes,” and “Frequently,” the general public and large-scale end users responded “Frequently” most often for the category of utilities as a source of information; state and local officials responded “Frequently” most often for the Federal government.

- Students obtain energy information most often from classroom situations.

- Using criteria of "Sometimes" or "Frequently" to describe usage, respondents rated mass media sources for obtaining energy information. The general public and students responded that television is the primary *media* source of energy information. State and local officials and large-scale end users indicated that their primary media sources are newspapers, the Internet, and science and technology journals. Radio is used least by all groups except the general public.

- In addition to the formal survey documented in this report, non-survey metrics were collected using the Internet. A search was conducted for articles about fuel cells and/or hydrogen appearing in five major newspapers in the United States during 2003 and 2004. The number of articles decreased between 2003 and 2004, and more articles were about fuel cells than about hydrogen topics.

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