INFORMATION BENEFITS: TOWARD A COMPREHENSIVE ANALYSIS OF R&D PROGRAM IMPACTS

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Abstract

The evaluation of energy-related programs historically has focused on assessing the direct quantitative costs and benefits of tangible products and services. However, many programs generate information-based products whose benefits must be indirectly quantified. Because information-based products do not apparently produce "hard" economic benefits, the evaluator faces additional burdens beyond the methodological rigors of a credible program evaluation. An evaluator must recognize and solve the difficulties of disseminating results to disparate audiences that may tend to view the quantification of the benefits of information programs with skepticism. This paper explores the evaluation of information programs from a methodological perspective as well as from an "evaluation transfer" perspective. Techniques used in three information-product benefits analyses conducted at the Gas Research Institute (GRI) are the focus of this paper.

Introduction

The Gas Research Institute (GRI) is a not-for-profit research and development management organization that works on behalf of the natural gas industry and its customers. It funds R&D in gas end use, supply, and gas operations. Members of GRI include natural gas pipeline companies, local distribution companies, municipal utilities, and natural gas producers.

Conducted in cooperation with gas industry partners, GRI's R&D program has brought 170 new items to the marketplace since its inception in 1976. GRI R&D items fall into two general categories: (1) products, processes, and techniques; and (2) key research information. The first category includes tangible products, such as advanced gas-fired equipment; improved processes and techniques for producing, transporting, or using gas; and advanced analytical tools and measurement techniques that improve the understanding of the physics, chemistry, and economics of supplying, transporting, and using natural gas.

For the first category of items, benefits can generally be estimated by comparing a scenario without the GRI product to a scenario with the product. Some measurable change—such as fuel cost savings, a reduction in maintenance or labor costs, or a reduction in installed equipment costs—can be used to calculate potential benefits. Calculation of economic benefits from products in this category has been the primary thrust of GRI's benefits analysis effort.

The second category of items include information such as databases, analytical studies, and new design procedures. The benefits from these information items usually result from an action taken by a user based on the knowledge gained from the information. Because of the difficulty in establishing and quantifying chains of cause-effect relationships between use of the items and the benefits, benefits resulting from GRI information items have not generally been calculated. However, calculations of the benefits of information R&D is now the focus of analytical efforts to make it more comparable to direct benefits analysis of products, processes, and techniques.

Impetus for Quantifying Information Benefits

The need to understand and place a value on the benefits of information items is recognized by GRI as being critical to providing a comprehensive picture of GRI's R&D program. Several factors have led GRI to pursue the quantification of information program benefits. They include:

To provide a level playing field between encouraging development of both information products and hardware products. In most R&D organizations, there is a built-in bias towards funding hardware products, and the development of information in many cases does not receive equal consideration. Decision makers can more easily conceptualize and understand "hard" benefits produced by tangible products than they can conceptualize the inherent complex mechanics of information flow and transfer, and hence the benefits of information items.

Moreover, many evaluators and program managers are not able to establish defensible benefits analysis methods to lend credibility to the process or to the value of the information, itself.

To provide support in the planning process. Planners and management need an estimation of the value of specific information products and information programs in general to assess the future directions of various R&D projects. The ability to quantify information programs will have an impact on the planning process and the future allocation of funds within an organization.

Regulatory oversight. GRI R&D projects are funded primarily by gas customers based upon a rate applied to interstate sales of natural gas, which is approved by the Federal Energy Regulatory Commission (FERC). Use of all revenues is restricted to FERC-approved research and development expenses, general expenses, and equipment and leasehold improvement expenses. An important element of the expenditure justification process of the FERC for GRI R&D involves the quantification of the impact and benefits of the R&D to ratepayers. Since the benefits of information products historically have not been fully quantified, they are essentially scored as having conservatively low benefits.

Support of GRI member company evaluation and technology transfer activities. GRI member companies play an important role in planning GRI's R&D program by providing both formal and informal recommendations to GRI. In addition, member companies promote the transfer of new gas technologies into the marketplace by using R&D results intended for gas industry use and by informing their customers of new end-use products. Evaluations of the benefits of R&D products have proven to be an important source of information for member company staff in terms of benefits assessment of R&D and technology transfer.

Case Study Methodologies

GRI is in the process of developing a methodology for evaluating the benefits of its information products. Alternative methodologies are being tested in a set of case studies for R&D programs with significant information product results. This paper discusses methodological and anecdotal aspects of three GRI information programs. The three case studies are: (1) Information Benefits Produced at the Center for Advanced Materials (CAM) at Pennsylvania State University; (2) Information Benefits Produced from Plastic Pipe R&D; and (3) Benefits Produced from Proper Venting of Mid-efficiency Furnace Systems.

A variety of analytical techniques were used in conducting the three information-product benefits analyses. Multi-attribute choice analysis, decision analysis, production function approach, demand and supply curve approach, utility function approach, diffusion paths, and technology benefit assessment techniques were among the methods attempted to assess the information benefits of the case studies. A flexible "best fit" or "trial and error" approach for each case study was preferred due to the innovativeness and uncertainty involved with the quantification of information benefits.

Center for Advanced Materials (CAM)

CAM was established by GRI in 1986 at Pennsylvania State University. CAM's mission is to provide a focal point for high-performance materials R&D and to help ensure the timely application of state-of-the-art advanced materials in such areas as waste heat recovery systems, direct and indirect heating and melting systems, solid oxide fuel cell systems, and gas-fired prime movers.

CAM is an interdisciplinary unit within the College of Earth and Mineral Science which draws upon expertise in various departments, colleges, and laboratories within Pennsylvania State University. It is structured in three units: Research; Analytical and Engineering Services; and Technology Assessment and Transfer.

Improvements in advanced materials such as ceramics, high-temperature metallic alloys, and composite materials technology are occurring at a rapid pace. However, the communication and transfer of developments are difficult because of the fragmented relationships between the researcher, material supplier, equipment manufacturer, and end-use communities. The diverse nature of these groups has resulted in the existence of various obstacles to the beneficial use of advanced materials in gas-fired applications. CAM's role is to help eliminate these obstacles, and to more effectively coordinate and direct advanced materials research activities for the benefit of the natural gas industry and its customers.

Information products from CAM are transferred to users by workshops, newsletters, databases, journal publications, reports, and by collaborative efforts with material suppliers, equipment manufacturers, and end users.

Benefits analysis methodology. The cost-benefit characteristics of advanced materials makes it difficult to use established analytical tools in assessing economic benefits. Physical, chemical, and other fundamental properties, rapid technology changes in the advanced materials industry, and the uncertainty of being able to assess all the applications to which the materials could be used, create methodological barriers in assessing this new frontier of information products.

Due to the problems with applying traditional economic assessments to advanced materials, a combination analytical and anecdotal approach was taken. Numerical estimates of CAM information benefits and an associated error band were calculated based on the extrapolation of information product diffusion combined with assumptions about ultimate market penetration.

Substantial gross benefits exist from GRI funding of CAM. However, economic benefits directly associated with increased gas utilization for industry end users are mostly 3 to 10 years in the future. Currently, relatively few CAM information products appear to have directly influenced day-to-day industrial operations.

Significant information benefits accrue to engineering designers from careful measurement of key properties of materials samples and associated components. For example, due to GRI-sponsored R&D, much uncertainty has been removed surrounding the performance of ceramic radiant tubes. As these information-related benefits become embodied in new products or increase product sales, benefits also accrue to natural gas customers and to the advanced materials industry since many information products developed at CAM would not have been economically or technically feasible for individual companies to perform within a desirable time frame.

Benefits of Plastic Pipe R&D Information

Plastic materials have been used for gas distribution pipe for local utilities since the early 1960's. In the last three decades, plastic pipe has experienced steady growth as the material of choice for distribution system expansion and replacement. In recent years, on a national basis, polyethylene (PE) pipe has been used in over 85 percent of new and replacement distribution pipe installations. The decision to install PE pipe can be attributed to its significant cost advantages over steel, in terms of both material and installation cost, and its superior corrosion resistance. A significant portion of the growth in plastic pipe use can be attributed to research efforts that addressed several unknowns that could have retarded industry acceptance of plastic materials for distribution pipe. Questions in areas such as: potential chemical reactions between flowing gas and the plastic pipe; specific material selection; and expected service life of the pipes required answers.

GRI has been directly involved in plastic pipe research since the company's inception through to the present time. Objectives of GRI's plastic pipe research include: (1) to find methods to reduce costs of gas operations and investments in capital; (2) to develop cost effective tools for use in construction and maintenance of distribution systems; and (3) to maintain the present high level of safety. Research, conducted in both basic and applied areas, has resulted in numerous hardware and information advances in a spectrum of plastic pipe technical areas—from material selection, to evaluation of joining procedures, to increasing the pressure capacity of new PE pipe distribution systems. These results are transferred to the gas industry and manufacturers through numerous topical reports, periodic publications, and personal interactions and presentations.

Benefits analysis methodology. Quantification of the direct benefits of hardware developments, such as improved PE joint integrity inspection devices, is a straightforward application of conventional engineering economics. However, there are numerous indirect benefits of both hardware introduction, and more particularly, information development that traditional evaluation approaches do not consider. Thus, an alternative analysis was undertaken to account for these indirect benefits of PE pipe research. Evaluation of the information-based benefits required a broad view of trends in the adoption of plastic pipe in the gas industry—thereby directing the analysis to a "diffusion curve" approach. One can construct a scenario that may have existed without benefit of the GRI plastic pipe R&D results, and compare it to the scenario that has developed and exists today. Benefits, in the form of consumer savings from the selection of plastic rather than higher cost steel, can be measured as the net present value (NPV) of the cumulative cost savings differences between the two scenarios.

An econometric model of the residential gas market was developed with state-level data from the American Gas Association to measure this benefit. Two alternative scenarios were constructed—one that assumed a 5% increase in plastic pipe share of new installations due to GRI research results and a second that assumed a 10% share increase. This range of 5-10% is considered conservative given the relatively small impact compared to the current 85% PE pipe market share. Given these assumptions, the model shows price differences averaging $0.02/MMBtu to $0.04/MMBtu on a national basis for the two scenarios. Over the period 1982 through 1995, these price depressions result in an NPV of consumer savings of $1.4 to $3.1 billion (in 1989 dollars) for the 5% and 10% scenarios under a 5% discount rate.

Proper Venting of Mid-efficiency Furnace Systems

The conventional atmospheric furnace has a strong history of providing reliable, low-cost space heating to residential consumers. These long-life furnaces generally have an annual fuel utilization efficiency (AFUE) of 60-75%. The vent systems used for conventional atmospheric furnaces are typically composed of single-wall galvanized connectors and either a masonry chimney or double-wall (Type B) vent.

In response to rising energy costs in the 1970's and advances in technology, furnace manufacturers developed new, mid-efficiency furnaces that have AFUEs of 78-83%. Over 2.5 million mid-efficiency furnaces have been installed in the U.S. since 1980. The mid-efficiency furnace achieves a higher AFUE through a combination of decreased flue gas temperature and dilution air flow, and the use of fan-assisted combustion. These factors that have led to increased efficiency have also introduced a potential new problem to the furnace and vent manufacturing and service industries—possible vent and furnace corrosion. This corrosion can be the result of excess condensation caused by traditional vent sizing practices applied to mid-efficiency furnaces.

GRI and the gas industry recognized that research was needed to improve the durability of these furnace systems to conform with the high standards of the consumer and the gas industry. As a result of the GRI venting program, new vent sizing tables for Type B vents were established for mid-efficiency as well as conventional furnaces. The tables were developed by GRI, the American Gas Association Laboratories (AGAL), and Battelle Memorial Institute–Columbus and have been adopted by the Gas Appliance Manufacturers Association (GAMA). The venting tables help manufacturers to specify venting system designs that ensure proper vent sizing practices. The tables now appear in mid-efficiency furnace installation instructions for equipment shipped after September 1, 1990. The tables are being reviewed by the American National Standards Institute (ANSI) for inclusion in the 1992 National Fuel Gas Code.

Benefits analysis methodology. A cost-benefit analysis approach was used to assess the economic impacts of the venting research. The focus of the cost-benefit analysis is on the quantitative derivation of benefits, including direct benefits to the gas customer and the gas industry from the application of venting research, and indirect benefits (or costs) from potential loss of gas market share. Distinct benefits are expected to accrue to several parties directly associated with the selling or installation of mid-efficiency furnaces. They include:

- Existing mid-efficiency furnace owners.
- New mid-efficiency furnace owners.
- Gas furnace manufacturers.
- Furnace installers.
- Natural gas production and distribution companies.

To establish the net benefits of the venting research, an evaluation of the present value of the annual costs and benefits of mid-efficiency furnaces sold each year from 1980 to 1995 were calculated. The costs and benefits were calculated for three scenarios: GRI research results available in 1991; industry research results (without GRI assistance) available in 1996; and no venting research. Through interviews with representatives of the gas industry and allowing for time considerations associated with the adoption process for new vent sizing tables into the National Fuel Gas Code it was determined that, without GRI assistance, the most probable scenario for comparable venting research would entail a lag of at least five years if individual furnace manufacturers attempted the research and transferred the results industry-wide.

The information produced from the venting research is projected to provide a net savings of $670 million to the gas industry and consumers between 1991 and 1995. The savings are attributed to an increase in the durability of mid-efficiency furnace system components brought about by the virtual elimination of corrosion-related problems caused by traditional venting practices applied to these furnaces. The estimate of $670 million represents the benefits of GRI research compared to five-year delayed industry research results.

The results assume a high level of compliance to the new venting tables by furnace installers. Discussions with industry representatives have indicated that the dissemination and application of the information has been extensive.

Types of Benefits

Several categories of benefits can be realized through information products. The three case studies identified the following types of benefits:

Increased speed of diffusion. In all three case studies, increases in the speed of diffusion of new products or techniques were experienced. In the venting case study, due to the difficult nature of the problem, a furnace manufacturer or any one organization would not have the facilities or the broad level of expertise to develop the information products as quickly. Also, the codes and standards that incorporate the venting research findings are updated every four years. All industry representatives interviewed conceded that the GRI research information could not have been duplicated and approved on an industry-wide basis until at least 1996.

Reduction of risk. Benefits from reductions in risk were cited in the CAM and plastic pipe R&D case studies. Because of uncertainties in the 1970's regarding the performance and safety of plastic pipe, natural gas local distribution companies restricted the number of miles of plastic pipe installed on their systems. A primary objective of GRI's research was to produce information products that would assure the safety and performance of plastic pipe. Distribution companies obtained the information through such information transfer mechanisms as publications, seminars, and informal contacts between colleagues. Based on this information, local distribution companies gained confidence that they could safely install plastic pipe in more areas of their service territory, increasing the share of plastic pipe installed.

Coordinated R&D expenditures. CAM is a good example of the benefits of coordinating R&D expenditures. By having a focused, defined research group that has direct input from GRI and a large number of stakeholders in the advanced materials industry, duplication of research expenditures is minimized. CAM is able to synthesize research and ideas from industry which helps to increase the speed of research information produced and technology transfer of the research information produced at the Center.

Regulatory and consumer perceptions. To the extent that R&D can generate information that assists in the regulatory oversight process, such information can provide benefits associated with avoiding regulatory requirements that might otherwise have been imposed. For example, if the venting research information was not created or disseminated to industry in a reasonable amount of time and incidences of furnace system corrosion occurred, regulatory bodies may impose penalties or enact regulations which may create additional costs or delays to the furnace industry and ultimately to consumers. Also, if consumers realize or perceive problems with a particular product, they may spread the perception through an entire product line, not just the product in question.

Reduced operating costs. The benefits analysis of information produced from plastic pipe R&D showed that a greater market share of plastic pipe was installed because economics and increased confidence in the safety and performance of plastic pipe. Distribution companies favor plastic pipe over traditional steel pipe because of the cost advantage and the corrosion resistance of plastic pipe. The increase in plastic installed and lower system operating costs had two effects: it lowers the average real price of gas and/or increases the number of customers that can be served, which again can reduce the average costs of the utility (which has substantial fixed costs). The price is reduced because not only is the cost of the capital stock required by the distribution system reduced, the dollar value of the required rate of return on the rate base is also lowered. Also, if there are customers that cannot be served because of prohibitive hook-up costs, the increase in the use of plastic means that, at the margin, more customers can be added to the service area.

Expanded markets. Information R&D can affect not only the growth of demand in a particular market, it can also increase the number of markets for which a particular technology or process can be applied. CAM's benefits include expansion of markets. Much of the research on advanced materials is focused on developing new durable materials whose applications can penetrate or create new markets. Advanced ceramic radiant tubes, for example, have opened up new opportunities for gas use in many industrial applications.

Information Flow—Identifying Situations Where Information Products Can Yield Large Benefits

The flow of information from GRI to users and, conversely, from users to GRI, give new insights into problem solving and the decision processes of organizations. The channels and flows of information are critical in defining linkages where information may be getting "bottled up" or, perhaps more importantly, linkages where information has impacted decisions.

Two network diagrams illustrate information flows of the venting research case study. In Figure 1, if the consumer notices a corrosion problem with the furnace, the consumer will contact the installer of the furnace, usually a local contractor or the local utility. The local utility or contractor will attempt to correct the problem and then look for reimbursement of failed parts under warranty from the furnace manufacturer. The furnace manufacturer, in this case, is typically skeptical. The manufacturer does not believe that the problem lies with the furnace because the corrosion probably is caused by condensation in the vent system dripping into the furnace due to the use of improper vent sizing techniques. The manufacturer believes that he has a high quality product and that the installer did not properly install the furnace, and the installer, not the manufacturer, should be held responsible. The contractor or local utility counters by saying that the furnace manufacturer did not provide proper installation instructions to alleviate the problem and thus they should not be liable. With both parties unable to find a solution, the utility seeks assistance from one of its trade organizations, the American Gas Association (AGA), and the furnace manufacturer seeks assistance from GAMA. Notice in Figure 1 that the flow of information follows a circular pattern with no immediate linkages to a solution.

In Figure 2, the creation and dissemination of information is apparently much more complex than the information flow associated with the initial problem. GRI wanted to have input from all possible parties involved, thus creating an integrated industry approach to problem solving. GRI selected two research laboratories to provide support, AGAL and Battelle Memorial Institute–Columbus. GRI also received guidance from a technical advisory group consisting of furnace and vent manufacturers, utilities, trade associations, and codes and standards representatives.

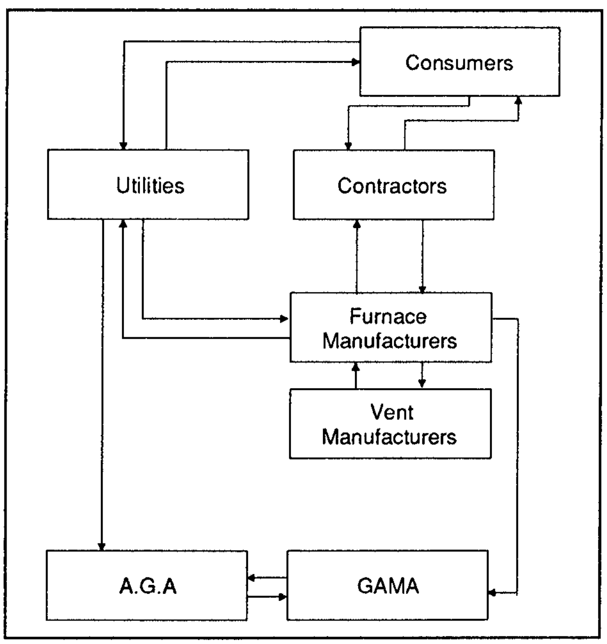

Figure 1. Information Flow before Dissemination

After information products were produced, dissemination took two distinct directions. ANSI used the venting research information to begin the process of incorporating the results into industry-wide codes and standards for furnace manufacturers and installers. The GRI information helped ANSI establish mandatory guidelines for proper vent sizing for mid-efficiency (and other categories) furnaces. GAMA used the information to help customize installation instructions for manufacturer-specific furnaces. Beginning in September 1990, all mid-efficiency furnaces manufactured had these new installation instructions packaged with the units.

Information flow also followed a different path. As soon as the research information was verified, GRI entered into a large and detailed dissemination process to industry to ensure the research information was available and understood by all parties associated with furnace and vent system manufacturing and installation. GRI distributed the information to utilities, furnace and vent manufacturers, contractors, and the media through publications, workshops, software products, and informal contacts. These information recipients, in many cases, passed the information to secondary sources—other utilities and contractors. Utilities and contractors are now better able to understand and correct potential furnace system corrosion problems that consumers may incur. The research information has virtually eliminated future corrosion problems due to improper vent sizing.

Figure 2 is structurally much different than Figure 1. In Figure 2, a smooth downward flow of information is seen. Research information was able to provide a solution and abolish the circular effect of Figure 1.

A clear lesson was learned by this exercise: large benefits may result from information products that are able to open new linkages that were otherwise closed. Research organizations such as GRI, can realize large consumer and industry benefits by identifying information programs that can establish new linkages or repair damaged linkages to the players involved in the issue.

Evaluation Transfer: "Layers of Rigor" Approach

Evaluation of benefits in an analytical manner is only a small first step in the information benefits analysis framework. Effective communication of the benefits to diverse audiences is crucial to the success of elevating the importance of information-based research in the minds of R&D and organization management and in influencing the planning process, as well as ensuring that

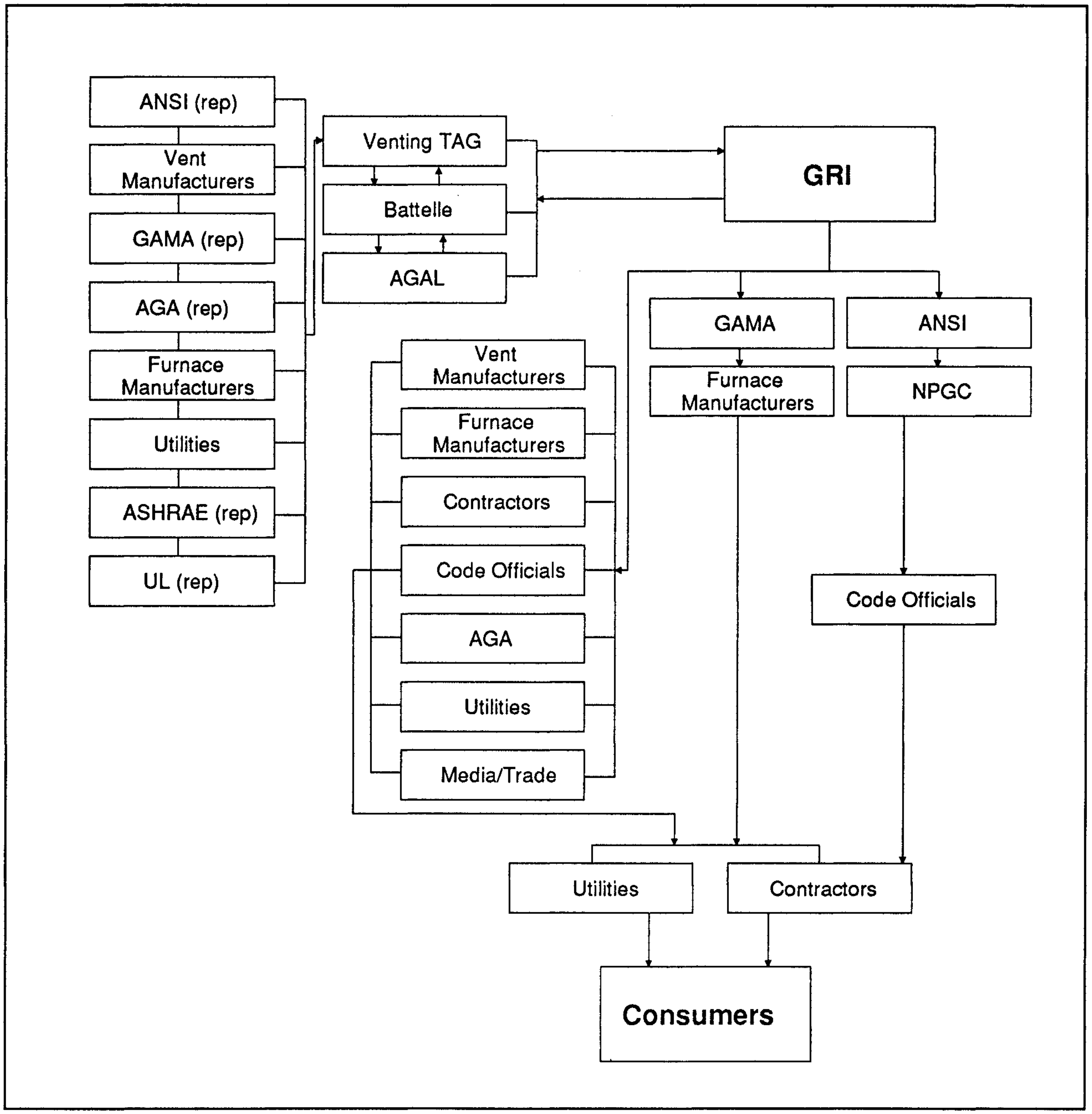

Figure 2. Information Flow after Dissemination

benefits of the R&D do, in fact, exist and in enhancing technology and evaluation transfer. A rigorously correct analysis that proves convincing to trained analysts may not be understandable to management audiences whom may not have formal analytical training or the time to invest in following the line of thought of a detailed analysis.

We have found it useful to approach the presentation of results in an iterative fashion, beginning with simple heuristic approaches consistent with the more rigorous results. More rigorous analytical approaches are held in reserve to establish the credibility with technical audiences.

Presentations and analysis text are designed to technically overlay so that audiences are able to digest key points and assumptions relevant to decisions without being overloaded with information. The first layer of the approach is a double-sided one-page "benefits profile" which presents a story-like interpretation of the information product and the benefits assessment. One or two key results are used. Discussions on methodology are very simple or left out completely. The first layer is basically an introduction to benefits analysis for management, policy makers, and other parties who may have an interest only in the final result and not in the methodology. This layer serves as an enticement for audiences to proceed to the next level of detail without alienating them with technical language.

The second layer is similar to an executive summary. A two- to five-page summary of the history, methodology, and results are presented. Again, this layer is fairly simplistic in content and format. Engineering, economic, and technical jargon is discouraged. Three to five slides/overheads are also provided in this packet which highlights the main points of the information program and benefits analysis. The slides/overheads give project managers and senior management the ability to present evaluation results without having to dig out or interpret the key results from a lengthy report. This technique helps to ensure that the expertise of the evaluator is transferred to presenters and end-users of the information.

The third layer is the information benefits analysis report. An executive summary combined with the comprehensive analysis of all methodologies and results, and corresponding appendices, are part of this layer. The methodological rigor and validation of the benefits analysis is the strength of the report. Conservative and detailed assumptions of the analysis methodologies must be meticulously presented for internal and external defensibility. The third layer is primarily used as the foundation and support for the first two layers. Economists, technical staff, and parties interested in the "guts" of the analysis will find this layer of the most value.

Lessons Learned and Useful Evaluation Heuristics

Although each of the three case studies was very different in terms of scope and information produced, several common observations surfaced as a result of the studies. These observations appear to be applicable to most information products and corresponding benefits analyses.

- Information benefits can be quantified. A conservative philosophy must be adopted to remain consistent with the overall goal of believability.
- Information benefit quantifications can be defensible. Analysis assumptions and methodologies and their validation by qualified "experts" (not methodological experts but experts familiar with the use of the information product) inside and outside the organization is crucial to general acceptance of the results.
- Identifying information benefits can elevate the importance of a program. By quantifying benefits, the value of information can be evaluated on the same level as tangible items.
- Simplified summary comparisons for economics-related analyses are useful for readers less familiar (or less interested) in the more methodological or indirect approaches.
- Methodologies and results should be as transparent as possible.
- Only a few key numbers and assumptions should be initially presented. Many numbers in an analysis tend to dilute or take away from the main points.
- An integrated or cross-cutting involvement of stakeholders approach to information product generation and problem solving is critical to finding solutions and maximizing the value of information.
- A layers of rigor approach to information benefits reporting can broaden audiences, increase levels of understanding, and establish multi-discipline dialogues by selectively increasing levels of palatable information.

Conclusion

Through the course of these analyses, the importance and magnitude of the benefits of information confirmed the need to quantify information products to gain an accurate assessment of the value of the total R&D program. Skepticism and creditability issues were greatly diffused by a layers of rigor approach backed by a conservative, detailed report. Heuristic design of evaluation methodologies and results will enable information programs to be understood and assist in the design of future information and research programs.