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Pacific Northwest
National Laboratory
Operated by Battelle for the
U.S. Department of Energy



# Final Report on National NGV Infrastructure

George M. Sverdrup[a]
John G. DeSteese
Norman D. Malcosky[a]

December 1998

Prepared for the U.S. Department of Energy
under Contract DE-AC06-76RLO 1830

(a) Battelle Columbus Operations, Columbus, Ohio.

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# National NGV Infrastructure

## SUMMARY

This report summarizes work funded jointly by the U.S. Department of Energy (DOE) and by the Gas Research Institute (GRI) to (1) identify barriers to establishing sustainable natural gas vehicle (NGV) infrastructure and (2) develop planning information that can help to promote a NGV infrastructure with self-sustaining critical mass. The need for this work is driven by the realization that demand for NGVs has not yet developed to a level that provides sufficient incentives for investment by the commercial sector in all necessary elements of a supportive infrastructure.

The two major objectives of this project were: (1) to identify and prioritize the technical barriers that may be impeding growth of a national NGV infrastructure and (2) to develop input that can assist industry in overcoming these barriers. The approach used in this project incorporated and built upon the accumulated insights of the NGV industry. The project was conducted in three basic phases: (1) review of the current situation, (2) prioritization of technical infrastructure barriers, and (3) development of plans to overcome key barriers.

An extensive and diverse list of barriers was obtained from direct meetings and telephone conferences with sixteen industry NGV leaders and seven Clean Cities/Clean Corridors coordinators. This information is fully documented in the appendix. A distillation of insights gained in the interview process suggests that persistent barriers to developing an NGV market and supporting infrastructure can be grouped into four major categories:

1. Fuel station economics
2. Value of NGVs from the owner/operator perspective
3. Cooperation necessary for critical mass
4. Commitment by investors.

A principal conclusion is that an efficient and effective approach for overcoming technical barriers to developing an NGV infrastructure can be provided by building upon and consolidating the relevant efforts of the NGV industry and government. The major recommendation of this project is the establishment of an ad hoc NGV Infrastructure Working Group (NGV-IWG) to address the most critical technical barriers to NGV infrastructure development. This recommendation has been considered and approved by both the DOE and GRI and is the basis of continued collaboration in this area.

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# 1. INTRODUCTION

The use of compressed natural gas (CNG) and liquefied natural gas (LNG) as motor fuel is encouraged by national energy and environmental policies to reduce both the nation's reliance on foreign sources of petroleum fuels and vehicular emissions that harm the public health and environment. Vehicle manufacturers, equipment suppliers, natural gas utilities, and other energy providers view natural gas vehicles (NGVs) as a market opportunity. These national needs and commercial opportunities have led both government and industry to introduce NGVs into service and to create an infrastructure to support them.

Despite the combined efforts of the natural gas industry and government during the last few years, the number of NGVs has been growing at a rate of only about 1 percent per year when compared to a 1994 industry projection of 11 percent per year. While some fleet conversions from petroleum represent modest success, NGVs have not penetrated the market to the degree predicted by either the NGV industry or government forecasts.* Among the reasons for the slower-than-anticipated market penetration is a lack of a sustainable infrastructure for NGVs.

As one of many measures to address this situation, the U.S. Department of Energy (DOE), Office of Technology Utilization within the Office of Transportation Technologies (OTT) funded an effort to (1) identify barriers to establishing a sustainable NGV infrastructure, and (2) develop planning information that can help to promote an NGV infrastructure with self-sustaining critical mass. After the project was started by the DOE, the Gas Research Institute (GRI) agreed to co-fund and expand this effort. This report is an account of work performed for the DOE and GRI by the Pacific Northwest National Laboratory (PNNL) and Battelle's Columbus Operations. Battelle operates PNNL for the DOE. This work builds upon the NGV Industry Strategy developed in 1995.

This report is organized in six sections and contains three appendices. The objectives of the project, along with the general approach that was taken to conduct the project, are summarized in Section 2. Section 3 contains a list of barriers to establishing a sustainable infrastructure for NGVs. These barriers, comprising both technical and non-technical barriers, were identified by leaders of the NGV industry. Appendix A contains summaries of the interviews with these leaders. Based upon discussions with industry leaders, GRI, the Natural Gas Vehicle Coalition (NGVC), and the DOE, a recommended approach to overcome technical barriers was developed. It is discussed in Section 4. In Section 5, general technical goals and plans are presented to address the highest priority technical barriers. Finally, Section 6 summarizes the experience of selected areas of the United States that have been working to establish infrastructure for alternative motor fuels. These are DOE-designated Clean Cities and Clean Corridors. Appendices B and C contain a tabular summary of recommended technical goals and strategies related to customers' perceived value of NGVs and a vision of a mature alternative fuel infrastructure, respectively.

* Natural gas fuels, "the numbers don't lie," 2/98, p. 17

## 2. PROJECT OBJECTIVES & APPROACH

The goal of this effort was to provide the NGV industry and the DOE with new information that can be used to support the development of a viable, national NGV infrastructure with growth potential.

The two major objectives of this project were: (1) to identify and prioritize technical barriers that may be impeding growth of a national NGV infrastructure and (2) to develop input that can assist industry in overcoming these barriers. An additional preliminary objective of the part of this project funded by the U.S. DOE was to define a vision of a mature but generic alternative fuel infrastructure that could act as a reference model to guide the definition of the infrastructure required specifically for NGVs.

The approach that we (PNNL and Battelle Columbus) used for this project built upon previous and current efforts by the NGV industry concerning infrastructure. There were three phases to the project: (1) review of the current situation, (2) prioritization of technical infrastructure barriers, and (3) development of a general approach and goals to overcome key technical barriers.

In 1995, the NGV Industry Strategy was published, and the stakeholders intended to develop action plans and to implement them as a means to carry out the strategy. This project built upon the Industry Strategy by interviewing key leaders of the NGV industry to learn from them: (1) current barriers to NGV infrastructure two years after the issuance of the Strategy and (2) issues related to implementing the Strategy. Information from these interviews was combined with information from (1) the U.S. DOE's R&D Plan for NGVs (to be published in 1998) and (2) the Gas Industry RD&D Initiative (January 1998).

In the second phase of the project, the barriers that had been identified were grouped into technical and non-technical categories, consistent with the 1995 NGV Industry Strategy. Then the technical barriers were prioritized.

In the final phase of the project, recommended technical goals and general plans to overcome key barriers were developed. Our emphasis was on near-term goals and an approach that could be implemented in 1998 and 1999 to leverage current industry efforts at overcoming barriers.

As the project progressed, the concept of establishing and operating an industry working group to address infrastructure barriers was advanced by both the DOE and GRI. This general approach was judged to offer the most potential for galvanizing industry to address barriers in a sustained manner. Consequently, project resources planned for defining technical goals more specifically were instead reprogrammed to support developing the working group concept and securing consensus for it. The final products of the project then became: (1) a list of prioritized technical barriers, (2) general technical goals to overcome them, and (3) government-industry agreement on the formation of an ad hoc working group to address NGV infrastructure barriers.

# 3. IDENTIFIED BARRIERS

An extensive and diverse list of barriers was obtained from direct meetings and telephone conferences with fifteen industry NGV leaders and seven Clean Cities/Clean Corridors (CC/CC) coordinators. The interview process did not discriminate or attempt to gather only barriers that may require technical industry goals. Consequently, the list of barriers contained items that were both clearly in need of a technical solution (goal) and other barriers that could require non-technical solutions (goals). To facilitate prioritizing technical goals, the barriers identified by industry leaders were divided into "technical" and "non-technical" barriers. The list of goals that has been developed is not all-inclusive; technical goals may yet be discovered that address one or more of the barriers that we have identified as non-technical.

All the major barriers that are listed in this section of the report were mentioned in more than a single interview during the interview process. We believe that several of the barriers lend themselves to technical solutions. A discussion of some technical goals to overcome these barriers is the subject of Section 5 of this report.

Although this project's primary focus was on technical barriers, we believe that readers can benefit from knowing the non-technical barriers that were identified by industry leaders. The need to foster similar goal setting action within industry marketing or sales groups and within government regulatory agencies has prompted us to include for review this list of non-technical barriers in Section 3.

## 3.1 Barriers (alphabetical)

We identified ten major barriers during the project. Interviews with the industry NGV leaders and CC/CC coordinators (which were Battelle's principal information resources), are summarized in Appendix A and Section 6, respectively. All interview information is presented, but the specific source of the information is not indicated. This was done so that authorship of the details presented does not bias the reader or suggest local problems or issues that may have prejudiced the discussions. Although other suggestions of barriers were noted in Appendix A, the barriers listed alphabetically below have widespread industry acceptance as problems. In each case, the industry believes that improvement is necessary and possible.

- Commitment by investors
- Cooperation necessary for critical mass
- Fuel station economics
- Government intervention and incentives to "level-the-playing-field"
- Identification of retailers for NGV fuel sales
- Industry will
- NGV strategy (too broad and shallow)
- OEM commitment
- Quality of NGV products
- Value of NGVs (compared to gasoline/diesel vehicles).

## 3.2 Top Priority Barriers (prioritized with underlying obstacles)

A distillation of the information gained in the interview process suggests that barriers to the development of an NGV market and supporting infrastructure can be grouped into four major categories:

1. Fuel station economics
2. Value of NGVs
3. Cooperation necessary for critical mass
4. Commitment by investors.

The barriers listed above are prioritized with fuel station economics listed as the most important technical barrier to be addressed. Each major barrier consists of one or more "underlying obstacles" that often have intricate interactions and feedback to other obstacles within the specific grouping and to non-technical barriers identified.

Descriptions of each barrier and supporting obstacles are detailed below.

1. Fuel Station Economics

Major obstacles for this barrier include immature metering/fuel transfer technology, station utilization issues, and lack of equipment standardization as elaborated below. Nationwide, the current development of CNG fueling infrastructure relies principally on compressor based systems. The state of current compressor technology was not identified by a majority of the industry leaders that we interviewed as a critical near-term obstacle affecting CNG fuel station economics. The industry is developing new compressor technologies, and they may offer the promise of improving fuel station economics out beyond five years. Although a number of programs have been focused on compressor station issues (such as standardization of specifications, selection of prime mover, fuel quality, and lubricated versus non-lubricated operation), the near-term economics is principally affected by CNG fuel station utilization.

Prioritized obstacles:

A. Custom Fuel Station Design – For CNG fuel stations, "good engineering" often dictates a match between desired fueling station capacity to meet both the anticipated market demands and the local attributes of the natural gas supply (which may have a high supply pressure). Often this match can only be achieved by the design of a custom compressor station. The benefits promoted are that the custom station could have improved operating efficiencies and higher utilization (operating time). However, the additional cost of a custom station design often outweighs the costs associated in utilizing a larger station or one designed for different gas supply conditions. LNG fuel station design also is generally customized for the situation. As more LNG stations are required, opportunities to use standardized modules may increase.

   Eliminating this barrier will reduce station costs allowing more CNG and LNG fueling stations to be built with available capital resources.

B. Low Utilization of Capital Equipment – The fixed capital costs of a natural gas fueling station must be assigned to each unit of CNG or LNG that is sold at the station. To have reasonably assigned costs (i.e., attractive price to customers and sufficient return on investment to station owners), the amount of fuel passing through the station on a daily basis must be maximized. A recent estimate by Southern California Gas Company suggests that CNG stations must operate more than 60 percent of the time (e.g., over a 24-hour period) to produce reasonably priced CNG.

Eliminating the low utilization barrier will result in better distribution of capital resources for infrastructure development.

C. Fuel Metering and Dispenser Cost – The cost of the current "point-of-delivery" dispenser system burdens the economics of the entire fueling station. Both the dispenser system itself and the metering equipment necessary to measure and display the fuel purchase are expensive. A two-hose CNG dispenser is currently priced in excess of $30,000. Competitive gasoline dispensers are less than 1/3 of this cost. Dispensing at LNG fuel stations is also problematic with limited metering technologies available for use and metering accuracy of the fuel sale in question.

2. Value of NGVs

The value redeemed by the NGV customer is one of the most fundamental barriers to be addressed. NGVs must offer value competitive with gasoline- and diesel-powered vehicles as a prerequisite for user interest in and acceptance of natural gas as a motor fuel. With the possible exception of certain fleet operators, the present low cost of gasoline and diesel fuels and their adequate delivery infrastructure reduce the attractiveness of NGVs as perceived by most potential users. The high cost and less than satisfactory performance of conversion equipment is another major impediment. The limited choice of vehicles and options also contributes to negative perceptions of NGV value.

Prioritized obstacles:

A. Low vehicle driving-range – The typical driving range offered by many NGVs places an additional burden on the development of an infrastructure for natural gas as a transportation fuel. Vehicle owners expect to have useable ranges that are equal to those provided by current liquid petroleum fuels. Although certain fleet owners may be able to conduct operations with reduced vehicle ranges (often only 50 percent of current fuels), many owners face higher operating expenses. These expenses are due to employee time lost to more frequent fueling and possibly higher capital costs if more vehicles need to be purchased to cover driving requirements.

B. Higher cost for NGVs – Economics are of crucial importance to fleet operators competing in the transportation marketplace. NGVs have historically had a higher initial cost when compared to the traditionally fueled vehicles – principally because of higher costs for fuel storage tanks and the high per unit cost of producing NGVs in limited

quantities. This cost difference has decreased in recent years, but still remains a major obstacle to fleet owners considering the use of alternative fuels.

C. Overall NGV economics "clouded" by the combined issues of capital costs, equipment life, and compressor maintenance issues – With the possible exception of certain marketing areas where CNG is available alongside traditional fuels, it is difficult to compare operating advantages of natural gas fuels. A comparison of natural gas with traditional liquid fuels is further complicated when vehicle retirement value or maintenance differences are considered.

Fleet managers and operators with the responsibility of calculating "life cycle" costs for their vehicles are frequently confused by the need to own and operate a CNG or LNG fueling station. Such a station must include depreciation of capital equipment, maintenance expenses, operating labor, pre-treatment and post-treatment gas handling facilities, and a host of other costs. Expecting the traditional transportation industry to understand the economic impact of these complicating issues can be a major barrier to acceptance of NGVs.

D. Warranty differences on OEM vehicles –This barrier is based on prior owner/operator experience with NGVs that have shown poor operating reliability and higher maintenance costs when compared with gasoline- or diesel-powered vehicles. This past negative experience has accumulated from both OEM and conversion NGVs and must be recognized and addressed because it has resulted in less desirable warranties for NGVs in some instances. Improved NGV products will result in greater acceptance of this technology by regulators and governments, reduced customer resistance to purchasing NGVs, and OEM warranties that are comparable with traditionally fueled vehicles.

E. "Credit Programs" for AFVs are poorly described and understood - This government barrier is principally focused on non-technical issues and specifically at clean air/ alternative fuel vehicle credits. However, programs with tax incentives for development of fueling infrastructure are also available. Not having all available credits from both federal and local sources clearly described to potential vehicle customers is a barrier that must be overcome.

3. Cooperation Necessary for Critical Mass – (a non-technical barrier)

According to the majority of the people we interviewed, the present under-developed status of the NGV infrastructure reflects the general lack of persistence or "will" of the industry to achieve the necessary critical mass. Many influences interact in this arena, including the significant investments already sunk that have been unsuccessful as a result of poor marketing strategy and other constraints. A lack of reliable and enduring government incentives has also contributed, as elaborated below.

Prioritized obstacles:

A. Fragmented NGV groups, Clean City, and Clean Corridors programs - These organizations and programs are necessary to foster interest and gather collective support for utilizing natural gas fuels. Group efforts on technical issues can resolve problems that are often insurmountable to smaller stakeholders. Cooperative support is also helpful since in many areas fueling infrastructure does not exist or is available to only a selected number of vehicles. Often support and incentives offered by federal agencies, state, and local governments drive the development of fueling infrastructure and purchase of NGVs. Lack of these incentives or indecision about the continued availability of key incentives causes the entire process to become ineffectual.

B. Short term interest in NGVs that is shown by LDCs. – Recent regulatory changes affecting the natural gas industry have caused many local distribution companies (LDC) to review their commitments to NGVs. Often these regulatory changes alter the focus of the LDC management teams. When coupled with stockholder pressure for rapid payback, long term capital investment in NGV infrastructure or vehicles is not an attractive investment. The changing priorities of the LDCs affect the industry's ability to maintain the momentum necessary to achieve continued growth in the NGV market.

4. Commitment by Investors – (a non-technical barrier)

A large capital investment (billions of dollars nationwide) is necessary to establish an NGV infrastructure. The government does not appear to have the resources or motivation to treat this as a priority. Industry resources could be applied if an adequate rate of return were probable. The ability and inclination of stakeholders, investment groups, major oil companies, and/or natural gas utilities to fill this gap constitute a major barrier to expansion of NGV infrastructure.

Prioritized obstacles:

A. Uncertainty concerning differential value - Capital investment in new transportation technologies is driven by the expectation of monetary returns. If the benefits or rewards cannot be clearly demonstrated to the satisfaction of investors, their resources will be directed to other more profitable opportunities. Continued development of NGV infrastructure will require demonstration of a clear financial benefit to potential investors.

B. Stakeholder support - After initial stakeholders have committed to NGVs, it is important that these stakeholders continue to support their programs. Often the LDC or fuel supplier provides this support. Elimination of financial or technical support or elimination of operating retail fuel stations is often viewed as abandoning their program. Within the transportation industry, negative information spreads rapidly and results in other interested fleets reevaluating their potential interest in NGVs.

# 4. Recommended Approach to Overcome Technical Barriers

An efficient, effective approach is needed by the NGV industry for overcoming technical barriers to NGV infrastructure development. Such an approach will require: (1) practical knowledge of NGVs and CNG and LNG operations, (2) cooperation among diverse stakeholders, (3) funding, (4) acceptance of plans by the NGV industry and (5) long-term commitment to overcoming barriers.

Many resources are available within the industry, but in many cases they are not being marshalled in an efficient, effective, and sustained manner.

Building upon and consolidating existing efforts within the NGV industry and government can be both an efficient and effective approach for overcoming technical barriers to building NGV infrastructure. This approach will place technical efforts within the context of other business and government policy initiatives that may have impacts on NGVs. We recommend the formation and operation of an ad hoc NGV Infrastructure Working Group (NGV-IWG) to address technical barriers to infrastructure.

In the remainder of this section, the ad hoc NGV-IWG concept is summarized in five parts: mission, background, organization, activities, and plans for 1998.

## 4.1 Mission

The mission of the NGV-IWG is to overcome barriers to establishing a sustainable infrastructure for NGVs. The Working Group will establish and pursue strategies in a priority order to achieve specific goals consistent with this overall mission.

## 4.2 Background

While natural gas vehicles are penetrating the marketplace at a modest pace, barriers continue to exist that prevent the establishment of a sustainable natural gas fueling infrastructure. A number of these barriers have been identified in the NGV Industry Strategy of 1995, the Funding 2000-2004 Recommendation prepared by the Gas Industry RD&D Initiative, and DOE's research and development (R&D) plan for NGVs, which will published in 1998.

This effort conducted by Battelle for GRI and the DOE builds upon the NGV Industry Strategy of 1995 and considers recent changes in circumstances affecting the expansion of an NGV infrastructure. It provides a prioritized outline of the technical barriers that need to be addressed before sustainable NGV infrastructure expansion can occur. Barriers to infrastructure can be classified as business, government, and technology related.

A number of NGV industry committees and stakeholder groups have been working on infrastructure issues. These include the Technology Committee of the Natural Gas Vehicle Coalition (NGVC), GRI's Project Advisory Group (PAG), the DOE and its national laboratories, and individual industry stakeholders. Many of the members of these groups actively participated in the development of the NGV Industry Strategy in 1995. And in 1997, these industry players

participated in DOE's workshop to develop an R&D plan for NGVs. All parties recognize that (1) industry and government can come together to overcome the barriers to infrastructure development and (2) industry must ultimately provide a sustainable infrastructure for NGV fueling. An ad hoc NGV-IWG will leverage the past discussions between industry and the DOE and provide an ongoing industry resource for: (1) recommending R&D projects to GRI and DOE, (2) securing industry resources for conducting these projects, and (3) applying the results of these projects, as individual companies, to commercialize new technology. Both GRI and the DOE support the concept of establishing an ad hoc NGV-IWG.

## 4.3 Organization

The organization of the NGV-IWG is shown in Figure 4.1. The DOE will provide funding to GRI, which GRI will match, for administration and operation of the ad hoc group. (Funding for specific R&D tasks will be handled on a case-by-case basis.) The NGV-IWG will be composed of individuals from industry who have demonstrated a commitment to working on the ad hoc group and providing in-kind resources to ensure its success. National laboratories will be active as associate members of the ad hoc group and will meet with the group and participate in the group's deliberations and planning activities. The ad hoc group will form task forces to deal with specific technical barriers. The task forces will have Chairs who will be industry participants in the ad hoc group. The ad hoc group will be facilitated by a director who will call and organize meetings, summarize meetings, and report on progress of the group to interested stakeholders.

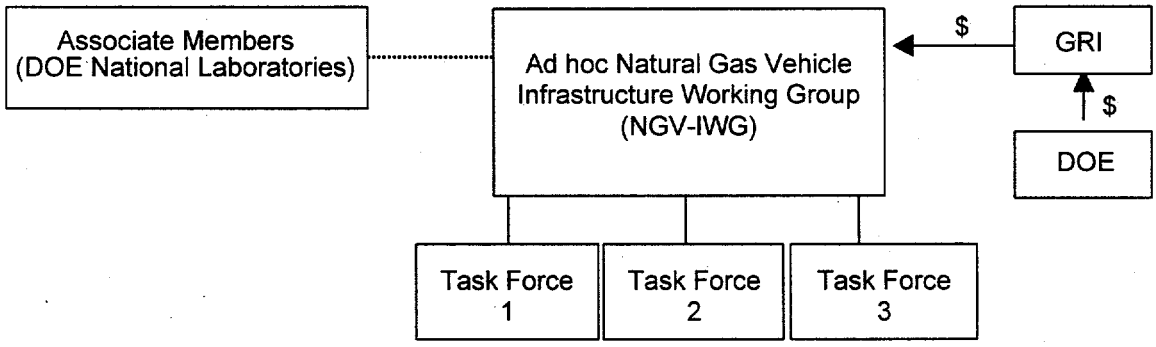



Figure 4.1. NGV-IWG Organization

The ad hoc group will have an Executive Committee composed of five members of the NGV-IWG to include but not be necessarily limited to the director and task force chairs. The Executive Committee will oversee the operations of the NGV-IWG and recommend operating principles to the industry and associate members. The Executive Committee will oversee the acceptance of organizations and individuals into membership on the NGV-IWG.

## 4.4 Activities

Planned activities of the NGV-IWG include the following:

1. Establish a business basis for NGV infrastructure that will examine required rates of return on investment in infrastructure.

2. Establish the NGV Infrastructure Technology Agenda for the industry, prioritize technical barriers and issues, and develop plans to address them.

3. Recommend to GRI and the DOE specific projects to be undertaken and goals for the projects based upon task force recommendations.

4. Secure industry resources to be offered as matching contributions to GRI and the DOE funding for projects.

5. Coordinate work on technical barriers with the NGV industry actions on business and government issues.

6. Promote dissemination of information on infrastructure technology by (a) providing quarterly communication with stakeholders, and (b) holding annual technology workshops.

The NGV-IWG will be an industry resource for securing funding and in-kind services to deal with barriers to establishing a sustainable infrastructure and for reviewing ongoing projects. The NGV-IWG will provide recommendations that the DOE may consider as it implements its R&D plans for NGVs.

The NGV-IWG will establish task forces to deal with specific infrastructure barriers and projects. Each task force will recommend specific objectives and strategies for overcoming a specific infrastructure barrier. The task force will identify possible industry resources that can be brought to bear. The task force will provide its recommendations to the NGV-IWG which will review the recommendations and make its own recommendation to GRI and the DOE for their consideration.

## 4.5 Plans for 1998

The NGV-IWG will be established in 1998 and will (a) define the business basis for decisions on technology goals; (b) establish a Technology Agenda; (c) prioritize technical barriers and (d) form task forces to work on recommendations to overcome each barrier. Certain barriers may be handled by industry itself as work begins to develop the necessary technology. Other barriers may require programs with funding from GRI, the DOE and possibly other agencies and institutions. In these cases, the task forces will recommend possible R&D projects for consideration first by GRI and DOE. These recommendations will be consistent with the industry's strategy and DOE's R&D program for NGVs.

# 5. Recommended Technical Industry Goals

A limited evaluation of major barriers identified in Section 3 was conducted to determine how they could be addressed by new or existing gas industry goals. Some of the goals, listed in Table 5.1 below, were an outgrowth of conversations held during this effort with the NGV industry leaders. Other goals were based on Battelle's experience and involvement in the alternative fuels and the transportation marketplace.

In order to optimize use of the resources available for this project, we concentrated effort on barriers and goals for fueling infrastructure. Work related to vehicle systems was minimal because the NGV OEMs have extensive development and manufacturing efforts. Because fuel storage containers for CNG and LNG have been and are still being refined and produced by a limited number of small- to medium-sized companies, we briefly addressed goals and barriers for this aspect of what we have termed "Value of NGVs."

The technical goals listed in Table 1 were further explored to suggest industry actions that could be undertaken to address the general technical goals. As appropriate, an expanded description of possible goals and their complementing technical actions follows the table. The NGV-IWG is currently being empowered to review this report's suggestions, develop and expand additional actions, and finally prioritize industry actions.

Table 5-1. Recommended Technical Industry Goals

| Barrier Addressed | Industry Technical Goal | |
|---|---|---|
| 5.1 Fuel station economics | Optimal, modular station size | (C,L)* |
| | Standardized compressors | (C) |
| | Improved metering/dispensing strategies | (C,L) |
| | Improved pumping strategies | (L) |
| | Greater fueling station utilization | (C) |
| 5.2 Value of NGVs | Increased vehicle operating range per fueling | (C) |
| | Decreased costs for NGVs | (C,L) |

*C = CNG, L = LNG

To place these goals in perspective, we have summarized in Tables 5-2 and 5-3 recommendations from this project, the Gas Industry RD&D Initiative (1998) and the DOE R&D plan, and the 1995 NGV Industry Strategy. Appendix B summarizes goals related to customers' perceived value.

Table 5-2. Technical Goals and Strategies Recommended to Overcome Infrastructure Barriers Related to CNG Fuel Station Economics

| GRI/DOE Project | Gas Industry RD&D Initiative | | DOE Program Plan for NGV Research | NGV Industry Strategy |
|---|---|---|---|---|
| | 2002 | 2007 | | |
| ▪ Optimize station size with 2-3 sizes | ▪ Develop small scale, <30 scfm, skid-mounted, fueling stations<br>▪ Develop and deploy standardized CNG fueling station<br><$750/scfm <$500/scfm | | ▪ By 2004, fuel station cost to be <2.5 times petroleum system infrastructure cost | ▪ Develop fuel station equipment supporting staged-entry<br>▪ Develop standardized fueling station designs |
| ▪ Standardize compressors with modular volumetric sizes | ▪ Develop advanced concepts, e.g., linear-free piston compressors<br><$500/scfm <$300/scfm | | ▪ Develop small-scale, high-efficiency, lower cost compressors | |
| ▪ Reduce cost of dispensers | ▪ Develop less expensive, 2-hose dispensers<br><$15,000 <$11,000 | | ▪ Improve fuel dispensers | |
| ▪ Develop non-contact metering strategies | ▪ Reduce cost of metering up to 70 percent with volumetric metering | | ▪ Develop advanced sensors | |
| | ▪ Develop reference guide and lower cost dryers | | ▪ Develop advanced dryers | |
| | ▪ Develop controls to assure complete fills with fast filling | | | |
| ▪ Increase utilization of fuel stations by matching station to nearby customer requirement | | | | |

Table 5-3. Technical Goals and Strategies Recommended to Overcome Infrastructure Barriers Related to LNG Fuel Station Economics

| GRI/DOE Project | Gas Industry RD&D Initiative | | DOE Program Plan for NGV Research | NGV Industry Strategy |
|---|---|---|---|---|
| | 2002 | 2007 | | |
| ▪ Optimize station size | ▪ Reduce overall fuel station costs:<br>▪ By 25% | By 50% | | ▪ Develop fuel station equipment supporting staged-entry<br>▪ Develop standardized fueling station designs<br>▪ Small-scale fueling station technology |
| ▪ Develop new, competitive dispensers | | | ▪ Develop LNG station nozzles | |
| ▪ Develop more accurate, less costly metering. | ▪ Develop lower-cost metering | | | ▪ Develop improved metering |
| ▪ Develop improved pumps to minimize startup time and losses | ▪ Develop cost-effective, more reliable, pumps | | | ▪ Develop improved transfer |
| | ▪ Develop models to better manage tank venting | | | ▪ Eliminate venting |
| | ▪ Accelerate development and deployment of LNG fueling station technology | | ▪ Develop LNG corridors | |

## 5.1 Fuel Station Economics

Five gas industry technical goals have been identified that address the barrier defined previously as "fuel station economics." Each of these five suggested industry goals is described in expanded discussion below. A number of "recommended action(s)" are also included in the discussion.

Optimal, Modular Station Size:

Reducing fueling station options to two or three optimized, standard capacity designs or modules would reduce station design customization and, thereby, result in lower manufacturing and installation costs for developing fueling infrastructure. Selection of the optimal modular sizes (e.g., throughput, compression, storage, gas conditioning equipment) for both CNG and LNG stations could be determined by the NGV-IWG. Selection of sizes must be guided by projections that consider anticipated short and long-term growth in the NGV market.

Fueling station reliability can often be achieved by redundant systems, and this is another reason to produce modular equipment systems. Modular type construction details might also be investigated during the station design. For CNG, consideration should also be given to emerging dry-lubricated compressor technology and its economic impact on the overall fueling operation.

We suggest that the NGV-IWG conduct a survey of currently installed CNG and LNG fueling stations in North America. The survey should be structured to discover a consistent set of facts about presently used NGV fueling infrastructure. The data obtained should include: marketing facts about the local fleet(s) that use the facility, station characteristics (such as capacity, pressures, gas treatment, speed, dispensing/measurement information), equipment supplier, site operator, maintenance information, installation date, annual throughput, current operator, and critical infrastructure data.

This information should be statistically reviewed and formulated into a matrix that can be used to facilitate selection of two or three most common station specifications. The station sizes selected should complement the most important, anticipated growth areas in the NGV infrastructure. Current industry insight into the future NGV market includes the need for an optimized larger station typically used by fleet operators and a smaller station for retail/commercial dispensing.

Standardized Compressors:

Reducing the number of compressor choices that a NGV fueling station operator must consider is an important goal. The compressors made available by the manufacturers should responsibly service a good fraction of the intended markets. Achieving this objective will lower station costs and reduce the need for custom design of CNG fuel stations.

The ideal "standard compressor" would be able to operate on the majority of natural gas supply lines in the country and provide adequate compression services for the intended NGV market. Typical cost targets for compressor manufacturers should be formulated that reflect "economies of scale" that would be realized if the present wide variety of compressor options were reduced to a few standard units.

A suggested action to achieve this goal is to utilize the survey information from the "optimal, modular station size" effort described earlier. Results from that survey would enable investigators and compressor manufacturers to evaluate their product lines (with statistical significance) and select a standard set of compressors for the NGV markets.

This effort by the NGV-IWG could result in selection(s) of standard "modular sizes" of CNG fueling stations that satisfy a large fraction of key markets. A documented Canadian *bench-mark*[1] is a "retail-market" compressor station that is targeted at $180,000 for a 125 scfm capacity station. The current GRI cost target of $800 per scfm translates into $100,000 for a 125 scfm station. Another economic restraint is that the station should show a "net profit" when operated at a utilization factor of 50 percent (some analyses suggest 35-45 percent utilization).

[1] Gas Technology Canada, Program Objective, NGV 200-8.42 (9/16/97).

Improved Metering/Dispensing Strategies:

Current high-pressure metering techniques are expensive and inaccurate. Although they are frequently used for cash sales to NGV customers, the total sales can often not be reconciled on a monthly basis with the master gas meter that supplies the fueling station. Because the cost of NGV dispenser/measuring systems burdens the economics of the entire fueling station, a significant change in metering/dispensing technology is warranted.

Both LNG and CNG dispenser systems need to be addressed to determine suitable, new competitive systems. Cost targets need to be established that are based on and comparable to existing gasoline or diesel dispenser costs.

Both the dispenser itself and the metering equipment necessary to measure and display the fuel purchase are expensive. A two-hose CNG dispenser is currently priced in excess of $30,000. Competitive gasoline dispensers are less than 1/3 this cost. Metering at LNG dispensers is even more problematic with limited metering technologies available for use, each with questionable metering accuracy for fuel sales.

A suggested action directed toward this goal is to evaluate metering strategies that are not based on direct-contact metering (i.e. turbines, coriolis, orifice, displacement meters). Such a system may instead utilize temperature and pressure sensors, pressure-volume-temperature (PVT) relationships, and knowledge of the vehicle fuel tank system to determine fuel delivery (w/computer assistance).

Improved Pumping Strategies:

A recommended goal is to develop improved LNG pumping strategies that will minimize startup time and minimize fuel venting and losses during fuel transfers. LNG dispensing stations are often burdened by substantial unaccounted losses from their fuel inventory. These losses have major impact on site economics and can turn profitable ventures into unprofitable ones. These fuel losses can occur for several reasons.

First, vehicle tank heating can result in high pressures that require tank venting in order to transfer fuel into the vehicle. Often this fuel is recovered by recompression or sold into a low-pressure distribution system. Second, low utilization of the LNG can result in pressure buildup in the main LNG storage tank. If excessive pressures are obtained, venting or fuel transfer will be required into a low-pressure distribution system to avoid overpressurization of the main tank.

A third type of loss, and probably the most common, results when it is necessary to "cool down" the dispenser piping, pumps and equipment between vehicle fuelings. This type of loss is small when vehicles are fueled successively but can increase dramatically when vehicles arrive at infrequent intervals for fueling.

Greater Fueling Station Utilization:

The final industry goal that addresses the "Fuel Station Economics Barrier" focuses on the issue of low utilization of the facility. This barrier results in uneconomic operation of the facility and wastes valuable capital resources that could be utilized in other endeavors or to build other parts of the NGV infrastructure.

Under-utilization of a natural gas fueling station can result for a number of reasons. One reason is the obvious oversizing of a facility to meet projected demands that never materialize. A second reason for under-utilization is improper siting of a station relative to the fleet or market it is intended to serve. This can result when the principal fleet changes locations or when NGV adoption does not occur as anticipated.

For CNG, a suggested action for the NGV-IWG to consider is the development and demonstration of an area hub/satellite fuel station system to maximize running hours of compressor stations. This technique is used extensively in Italy to provide CNG fuel to a large population of light-duty vehicles. A program that demonstrates the area hub/satellite fuel station concept should be considered. Off-the-shelf equipment is available including DOT tube trailers to supply the satellites by a drop-off technique, possibly combined with hydraulic transfer of CNG to the vehicles being fueled (a process similar to the "Trenfuel" trailer). This approach has been tried in some locations, but these activities were judged not to be sustainable under the prevailing circumstances. Nevertheless, the concept may warrant reexamination.

## 5.2 Value of NGVs

Two gas industry technical goals have been identified that address the barrier described as "Value of NGVs." This barrier is principally focused on the vehicle owner's perception of vehicle value when natural gas is compared to traditional highway fuels. Issues that detract from a positive comparison will result in lower acceptance of NGVs and must be addressed by industry goals.

An unacceptable vehicle driving range is a major obstacle to the increased use of NGVs. The problem is associated principally with CNG vehicles, because LNG can be stored nearly as efficiently as traditional petroleum fuel on vehicles.

A technical goal to overcome this obstacle has been an NGV industry objective for a number of years. Traditional CNG fuel storage systems exhibit limitations that include limited capacity, heavy and bulky fuel containers, and high fuel container costs. Difficulties associated with creating an improved fuel container include weight/cost tradeoffs that must be considered and approvals by organizations responsible for codes and standards (e.g., ANSI/IAS NGV2, and FMVSS304). Often "high-technology" solutions are too expensive to be viable and traditional steel fuel container solutions are too heavy, thereby limiting vehicle driving range.

In the near term, efforts by GRI and the DOE to improve the weight, cost, safety and durability of conventional metallic and composite CNG fuel tanks should continue to be encouraged. For the longer term, continued investigation of novel fuel storage methods for natural gas may yield important advances. These programs would include investigations of fuel storage techniques

using gas hydrates (clatherates), adsorption on solid materials, and absorption and dissolution in a number of solvents. Performance criteria should be developed to allow comparison of achieved storage efficiencies to those of traditional fuels and LNG.

A second, recommended, longer-term action is the continued development of conformable CNG fuel tanks to increase vehicle range.

A third action item that would lead to increased range would be to initiate a program to alter the basic vehicle design to accommodate more fuel containers. A 200-mile + range is necessary to show value to most fleet applications. Light-duty automobiles, SUVs, and light duty trucks are possible candidates for such design changes because they have restricted space for fuel storage.

# 6. CLEAN CORRIDORS/CLEAN CITIES INFORMATION

Experiences of the U.S. DOE Clean Corridors and Clean Cities (CC/CC) programs were considered by the DOE to be a valuable resource of information that could help guide this project. To include these groups in the task of identifying barriers, a list of key contacts with the CC/CC program was obtained.

Phone conferences were then held in 1997 with principal representatives of major Clean Corridors and Clean Cities programs. The discussions were focused on identifying barriers encountered during planning and deployment of alternative fuels systems. Experience with stakeholder meetings and related CC/CC activities was a means to uncover a variety of barriers and obstacles to their programs.

The following CC/CC representatives were contacted during the information-gathering portion of the effort and are acknowledged for their contributions to the project.

| | | |
|---|---|---|
| Deborah Killian | Susan Summers | Paul Smock |
| Tim Gerlach | Dan Deaton | |
| James Ferguson | Jan Rickey | |

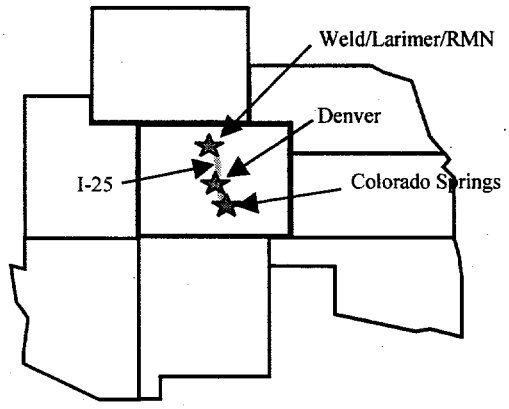
## 6.1 Common Barriers Identified

- Lack of state incentives that focus on alternative fuels
- Decal-based state taxing systems penalizing low-mileage vehicles
- Oil companies that defeat alternative fuel legislation by lobbying
- Federal inaction on EPACT legislation
- Time window for alternative fuels is closing
- Lack of large population centers along corridor
- Industry unclear about CC/CC program
- More dollar resources needed to get the message to the public (competing with major oil)
- Inappropriate location of fueling stations to corridors
- Infrastructure improperly sized – resulting in shutdown of uneconomic stations
- Availability of OEM vehicles in desired configurations for fleet operators
- Dollar resources to set up "package deals" for infrastructure development
- Lack of ongoing state initiatives to encourage CC/CC development
- Lack of incentives that are attractive to the "end users"
- Underutilized fueling stations that are eventually shut down
- Mixed signals from the OEM suppliers concerning vehicle availability year to year
- Lack of sensitivity to "end user" critical needs
- Committed "base load" vehicles needed to assure sustainable economics.

## 6.2 Summaries of Communications

Summaries of conversations with CC/CC representatives are provided in this section of the report. Information contained in these summaries was transmitted to the DOE and GRI as it became available. This information was current as of the summer of 1997.

### Colorado Front Range




**Summary:**

The Colorado Front Range project consists of activities near the cities of Denver, Colorado Springs, Fort Collins, and the counties of Weld/Larimer/and RMNP (Rocky Mountain National Park). Interstate I-25 connects these regions of the state.

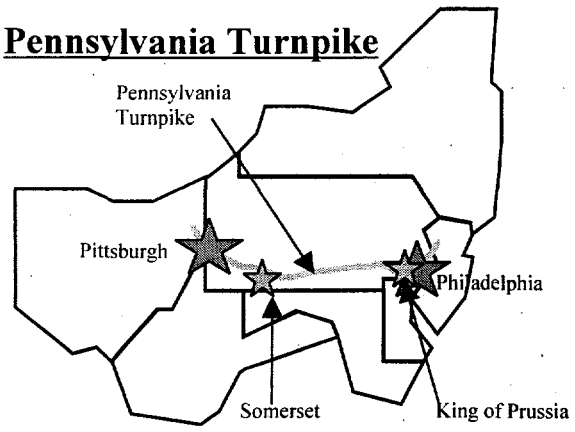
An ambitious corridor program has been proposed that will need additional resources to fulfill its goals. The program will include a full-time manager, staff assistants, a newsletter, a fuel station map (listing credit cards accepted and fuels available), and alternative fuel signage along the interstate. LPG, CNG, ethanol, and methanol are the fuels available at selected outlets.

The corridor is currently working on an outreach program to recruit additional industry support for the corridor and the clean cities.

Barriers to the Clean City/Clean Corridor (CC/CC) initiative include:

- Extension of an on-going state initiative to encourage CC/CC by offering a 60 percent differential dollar rebate for OEM vehicles was vetoed in 1997 by the governor. A revised bill, Colorado House Bill 1169, was introduced and passed in 1998. This new legislation offers tax credits on vehicles ranging from 50 to 85 percent depending upon the emission level of the vehicle. The new legislation also offers a 50 percent tax credit on installation of AFV fueling stations up to $400,000. The tax credit is increased another 12.5 percent if the station is publicly acessible around the clock.

## Pennsylvania Turnpike




**Summary:**

The Pennsylvania Clean Cities/Clean Corridor (CC/CC) (Turnpike) project consists of activities near the cities of Philadelphia and Pittsburgh and along the PA (I-70/76) turnpike.

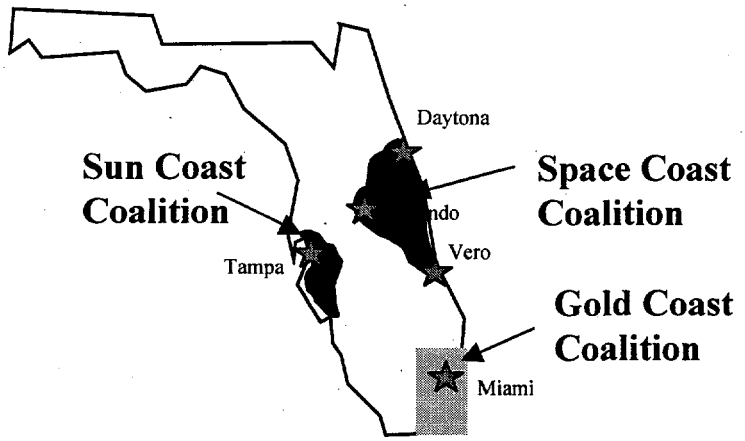
Several stations that were planned for the corridor were either not built, or have been shut down. Grants awarded for construction of LPG and CNG fueling stations at South Somerset and King of Prussia Plazas were not built because lack of a sustainable local fleet to "base load" the station.

A major CNG station at the Philadelphia airport will be constructed to serve airport (tarmac) vehicles, city vehicles, and airport shuttle vehicles. The Congestion Mitigation and Air Quality (CMAQ) program and Commonwealth are jointly funding this program.

Barriers to the CC/CC initiative include:

- Lack of incentives (usually economic) that are attractive to the "end users." This has resulted in inadequate AFV sales and a number of filling stations that are underutilized.
- Underutilized fueling stations are not economic and are eventually shut down or not even built as proposed in grant applications.
- Mixed signals from the OEM equipment suppliers. In/Out/Back-In the alternative fuel market shows vehicle users a serious lack of commitment and interest to the technology.
- A sensitivity to the "end user" critical needs is also important in acquiring and retaining customer confidence. "Shutdown of a school bus fleet because of a vehicle performance problem does not help customer (i.e., end user) relationships."
- "Build it and they will come" strategy simply does not work with CNG, LPG, or any other alternative fuel infrastructure development. A committed "base load" fleet must be assured to make the station economics sustainable.

## Florida Clean Cities




**Summary:**

The Florida Clean Cities/Clean Corridor Program consists of several coalitions (areas within the state) that are obtaining CC/CC status. The area around Miami referred to as the Gold Coast Coalition is already recognized as a CC. This CC has 33 percent of the state's population and 9 percent of the land area. A new CNG fueling station has recently been dedicated at the Miami airport. The CC/CC is trying to make the fueling station available to other potential CNG users in the area Coalition.

Another area that will soon be designated a Clean City is the Sun Coast Coalition, which includes the Tampa Bay area south to Bradenton and east to Lakeland. This coalition has submitted its plan to the DOE and is waiting for CC designation.

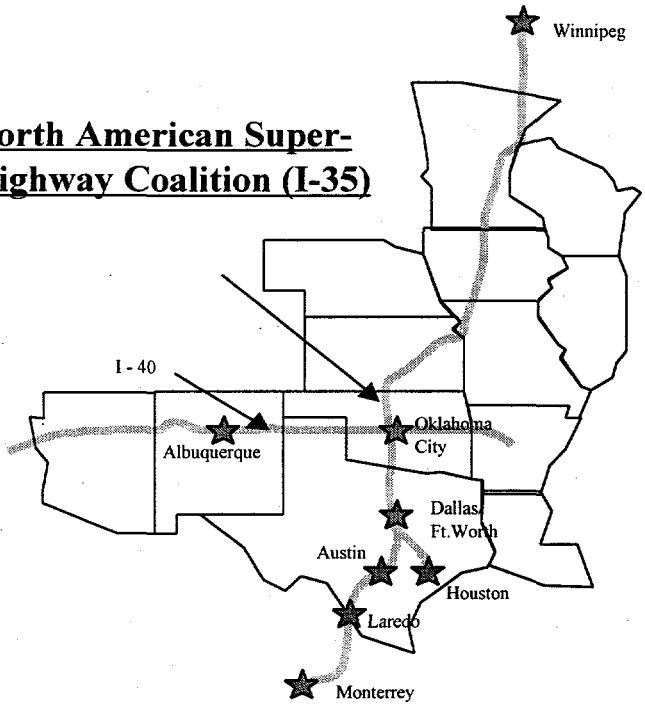
The third area seeking CC designation is the Space Coast Coalition. A kickoff meeting is planned for March 1997 to initiate activities. The coalition encompasses a triangular area bounded by Daytona Beach on the north, Vero Beach on the south, and Kissimmee on the west. This area also hopes to extend further west and eventually include the Orlando area in its coalition.

The CC/CC program in Florida has been encouraging alternative fuels with a grant program that is nearly completed. This year the final grant will end, and they are looking forward to a new initiative referred to as the "Revolving Loan" program. This program will offer low interest loans with a five-year payback period. The program will make $2.5 million available for alternative fuels activities, which to date have been focused on CNG, LPG, and electric. An education program focused on the targeted fleets will begin in 1997. Funding for this activity will be from the Oil Rebate Program (petroleum overcharge funds).

Barriers to the CC/CC initiative include:

- The lack of state initiatives within Florida that focus on alternative fuels.
- The decal system for private fleet operators – this method of taxing alternative fuels is a nuisance to the fleet operators and is especially unfair those that drive limited miles each year. High-mileage vehicles could benefit from such a taxation method, but few do because generally alternative fuel vehicles have limited range and lower annual VMT.
- State legislation that would have placed a surcharge on current fuels – raising monies for alternative fuel programs, was defeated in committee. This defeat was directly attributed to actions of the oil companies.

## North American Super-Highway Coalition (I-35)




**Summary:**

This Clean Cities/Clean Corridor project consists of a number of cities along the southern portion of the I-35 interstate corridor. Houston and Galveston, TX, cities near the corridor, also are being actively recruited to join the CC/CC project. The corridor is referred to as the "North American Super-Highway Coalition." Highway (I-35) is a major interstate on which materials are moved from Monterey, Mexico across the U.S. to Winnipeg Canada. It has also been referred to as the "NAFTA highway." The northern portion of the corridor would include major cities up to the Canadian border.

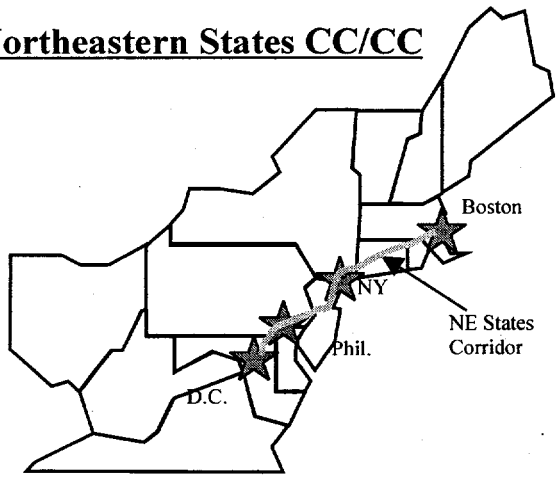
An E-W corridor comprising I-40 that joins Oklahoma City/Albuquerque with California is also a potentially active highway for alternative fuels. Jack B. Kelly Trucking has initiated LNG operations in the New Mexico area. Texas has a major trucking interest and several postal fleets ready to announce alternative fuel initiatives. Alternative fuels of principal interest are LNG and LPG. Lone Star Gas has shown a major interest in LNG.

Strategic plans are being initiated in many clean cities to identify high-mileage vehicles, allow fueling stations to be available to the public, and focus on airports' (such as Dallas/Ft Worth) use of AFVs.

Barriers to the CC/CC initiative include:

- The location of infrastructure at inappropriate sites to promote use of alternative fuels along interstate highways.
- Infrastructure not sized correctly for the available vehicles that would use it. This results in uneconomic fueling stations and the eventual shut-down of alternative fuel stations.
- Availability of the "right kind" of vehicles to sell to the fleet operators. Preference is now for OEM equipment instead of conversions or bi-fuel vehicles.
- Lack of dollars for initial capital outlay necessary for infrastructure development.
- Lack of financial consultants to set up "package deals," find dollars, and document and demonstrate economic advantages.

## Northeastern States CC/CC




**Summary:**

The Northeastern States Clean Cities/Clean Corridor project is comprised of a number of clean cities (coalitions) that have CC/CC status. The areas and highways near the I-95 from Washington DC to Boston, MA, make up the corridor.

The principal alternative fuel (AF) of choice in the CC/CC project is compressed natural gas (CNG). This is principally because of the relatively high interest shown by the many gas utilities that serve in the NE States areas. Although all alternative fuels are welcome, the need to enlist more LPG and electric vehicle participation was noted. Setting up LPG, CNG, and electric charging stations along the I-95 corridor is desired by the CC/CC.

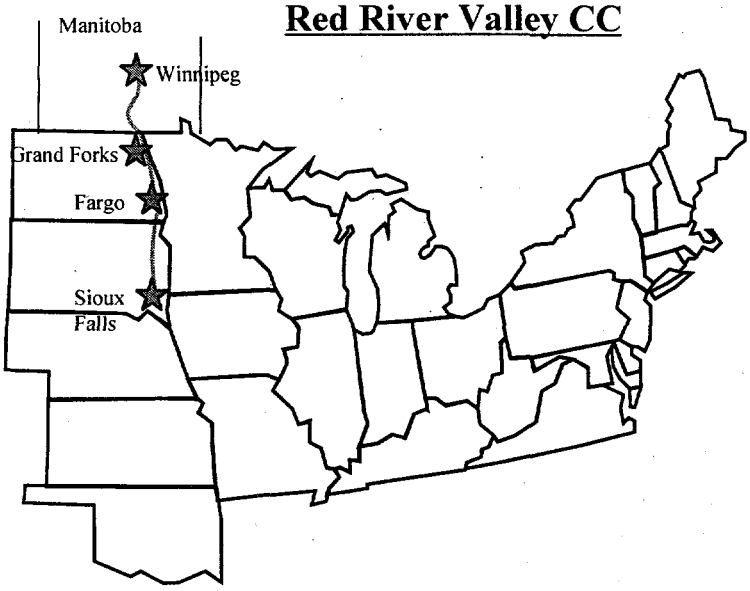
Urgency to get alternative fuel vehicles (AFVs) operational within the next 2–3 years was stressed. The availability of OEM vehicles is the best-it-has-ever-been, and therefore investment in infrastructure to support these vehicles is critical.

A new solicitation is anticipated from the DOE to support the corridor projects. This will help in the effort, but state AF programs are also badly needed.

Barriers to the CC/CC initiative include:

- No Federal rulings on the Energy Policy Act concerning private fleet requirements. This lack of rulings has left the AF market without the incentives needed to stimulate investments in placing infrastructure.
- The time window for CNG and other AFs to reach "critical mass" and become self-supporting is slowly closing. This is caused by changes within the energy industry and gas utilities that place short-term profitability ahead of new market development.

## Red River Valley CC




**Summary:**

The Red River Valley – Clean Cities/Clean Corridor is headed by the Energy and Environmental Research Center (EERC) within the University of North Dakota-Grand Forks. This agency at one time had federal status, but has now been transferred to the State and now is within the University. Staff at the Center is approximately 250.

The CC/CC program in Red River had its introductory "kickoff" in February 1996 and has been gathering local support since then. The clean corridor includes I-29 within the US from South Dakota north to Canada, and C75 from the border to Winnipeg, Manitoba. Official CC designation by the DOE is anticipated in August 1998.

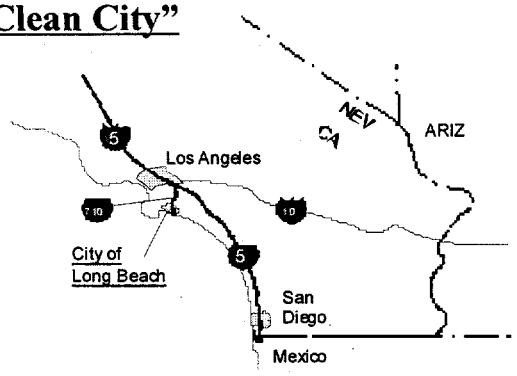
Efforts to date include presentation of the CC/CC concept to the public and fleet operators and education of possible industry partners in alternative fuels. Only positive responses have been noted within the fleets. The need for alternatives to gasoline and diesel are not challenged.

Current alternative fuels that are being nurtured include ethanol, CNG, and LPG. Twenty-one active industry sponsors include Kraus Industries (manufacturer of CNG dispensing equipment), Central Energy Services, Superior Propane, Suburban Propane, Grand Forks Air Force Base (GFAFB), and 17 Wing Command (Canadian air force base). GFAFB is initiating a CNG program while 17 Wing is initiating a LPG and CNG program.

Barriers to the CC/CC initiative include:

- The air along the corridor is "too clean"– i.e., the air quality "driver" for action is not as important as it is in some other CC/CC locations.
- Industry and fleets in general are unclear as to what the CC/CC program is about – (this is perceived as a big city problem.)
- No large population centers are along the corridor.
- Need more funding – this is essential because the CC/CC concept is competing with major oil companies to "get the message" to the public. The oil interests spend a lot of money in advertising their position and products.

## Long Beach "Clean City"




**Summary:**

The Clean Cities Coordinator for Long Beach is an active member in the Interstate Clean Transportation Corridor (ICTC). Perceptions of barriers to infrastructures were discussed and the following points were made:

1. With Respect to Infrastructure Barriers for NGVs

   a. The lack of conveniently situated fueling stations is a barrier to further sales and use of NGVs. The high cost of building and siting fueling stations for compressed natural gas (CNG) is a contributing factor to the scarcity of stations. Access to capital for developing a network of CNG stations was dealt a blow when the California Public Utilities Commission rejected utilities' request for rate-based NGV programs with fueling infrastructure as one component.

   It is difficult for other commercial organizations to justify the capital expense of establishing a network of CNG stations when so few NGVs are available for sale and in use. The projected demand for CNG does not justify the investment in CNG fueling infrastructure for these private-sector organizations.

   b. Users of NGVs do not have a convenient means to locate and purchase CNG. The location of CNG stations is not widely known. Because charge cards are not generally accepted across CNG stations operated by different entities, consumers cannot purchase CNG as conveniently as they can gasoline. Much work on this remains to be done.

   c. The price premium of natural gas vehicles is a major barrier to increased sales.

   d. The NGV industry needs a champion who will effectively present the benefits and costs of NGVs in terms of externalities in order that public policy can be made taking all major benefits and costs into account.

2. With respect to the ICTC

All of the barriers cited above for NGVs apply to the ICTC.

   a. The concept of establishing infrastructure in regions where there is already NGV activity is supportable. As these regions expand, they may support trucking along the ICTC. This approach contrasts to the original plan for the ICTC to promote establishing natural gas fueling infrastructure along the interstate corridor at predetermined distances to support trucking along the interstate system.

3. With respect to Clean Cities

a. Long Beach, along with its municipal gas utility, already had a successful program for NGVs before the municipality became a Clean City. The commitment to succeed was already in place at city management and operating levels. Long Beach funds the Clean City program because the city plays a strong central role in the Clean City. The Clean City coalition has had to have only two meetings to keep the Clean City Program functioning.

b. Benefits to Long Beach, as a result of its status of being a DOE Clean City, have included its ability to attract DOE funding to enhance local NGV programs and the opportunity to host the national Clean Cities Conference.

# Appendix A

## Interviews with NGV Leaders

# APPENDIX A. INTERVIEWS WITH NGV LEADERS

This appendix contains the detailed information concerning NGVs and NGV infrastructure that was obtained from the key NGV industry leaders listed below. The twelve interviews presented in the following discussion do not identify the individuals that contributed specific information. The information is offered only as a backup resource to this work. We acknowledge the contributions of following key individuals who participated in the interview process:

| | | |
|---|---|---|
| Burnett, Herb | - | Southern California Gas Company |
| Cavanagh, Christopher | - | Brooklyn Union Gas Company |
| Clarke, Jeff | - | Natural Gas Vehicle Coalition |
| Dallinger, Curt | - | Natural Fuels Corporation |
| Eaves, Michael | - | Southern California Gas Company |
| Franklin, Cecily | - | Consolidated Natural Gas |
| Garrett, Nancy | - | Shell Oil Products |
| Horne, Doug | - | Atlanta Gas Light |
| Jackson, Mike | - | Acurex Environmental |
| Minerick, Thomas J. | - | Minnegasco |
| Moore, James R. | - | Lone Star Gas Company |
| Stokes, Brian T. | - | Pacific Gas & Electric |
| Thomason, Annalloyd | - | Thomason Associates |
| Turner, Sean | - | Natural Gas Vehicle Coalition |
| Wilding, Bruce | - | Idaho National Engineering & Environmental Laboratory |
| Zilberfarb, Gregory D. | - | Natural Gas Vehicle Coalition |

## Interview 1 -

Strategy

The original intent of the project (NGV Industry Strategic Plan) was to develop a plan with specific actions for building a sustainable NGV presence in the U.S. In the end the general strategy became the product, and detailed action plans were not produced. The process itself was an impediment to developing an action plan. The composition of the Working Group varied from meeting to meeting with different people representing their companies. The new people had to be brought up to speed each time. The group structure was unwieldy for making decisions.

At the first meeting, in the spring, gas utilities, A.G.A., GRI, American Automobile Manufacturers Association (AAMA), and Engine Manufacturers Association (EMA) were present. The AAMA and EMA were concerned that the natural gas industry was pushing mandates. They declined to participate further in the meetings.

The team developed a list of strategies and test-marketed them. By this time most of the funding had been spent in working with the Industry Working Group. Later a review meeting was held with the Executive Committee of the NGVC in which some members were not ready to deal with

the specific issues in the strategy. The Executive Committee was used to dealing at a higher level.

Planmetrics had the task of formatting the document. All through the process, the issue of the "mystery investor" loomed, and this was not helpful to the Industry Working Group. The completed strategy document was used by the gas industry to help sell the NGV program internally. It may not have been of much help because it was so general.

Strategy & Implementation

Not much has happened in the industry to implement the strategy. There has been a lack of marketing. One of the critical success factors that has not been met is industry commitment to the strategy.

The issues that were identified when the strategy was being developed were very diverse. For fueling infrastructure, the issues included the following:

1. For light-duty vehicles, the "chicken & egg" situation concerning availability of fuel and the number of vehicles needing fuel
2. Public versus private onsite fueling
3. National strategy versus regional strategies versus local strategies
4. Appropriate site location
5. Hardware capabilities
6. Cost reduction for fueling facilities.

Critical Success Factors Continue to Include:

1. Commitment of the industry – central leadership is missing
2. Investment
3. Emission credits – benefits for NGV emissions that are below ULEV standards
4. Product improvement

Lessons Learned

1. Group meetings to form a consensus are a very difficult approach to developing a strategic plan
2. Developing the Industry Strategy was the right thing to do
3. More attention needed to be given on what the industry would do with the strategy
4. An action plan is needed that is easily usable by the variety of people in the industry helping them to make better decisions
5. The action plan needs to be specific, tightly written, and usable.

Interview 2 -

NGV Situation

The California Public Utilities Commission (PUC) has directed that no work be done on LNG using rate payer money, and NGV business has been reduced dramatically as California utilities have been ordered to sell their public access California stations by 2001. Sixteen customer CNG compressor stations were constructed in 1996.

NGVs remain a remarkable sales opportunity. Gaining 10 percent of California's transportation market would double gas sales.

Infrastructure Barriers

The cost of NGVs and infrastructure is a barrier. Even if operating costs for NGVs are less than for gasoline vehicles, organizations typically have constraints on capital budgets, and they may not be able to afford the additional capital expense. A minimum fuel price differential of 50 cents/gallon is needed to offset the additional capital cost of an average fleet. The price of oil would have to rise dramatically for this NGV advantage to occur.

There is a lack of commitment to retailing CNG as a motor fuel. Oil companies advertise that they are in the energy business and, therefore, might be expected to be interested in selling natural gas at retail fuel stations as another form of energy. Most oil companies have natural gas reserves that they tap, but they do not seem interested in marketing natural gas. The low cost of natural gas makes selling it at fuel stations a low margin business. To overcome this, the price of CNG was raised to 90 cents/equivalent gallon.

Oil companies were asked to consider using natural gas as a solution to excessive emissions when engines are cold started or for acceleration cycles. Natural gas could be offered as a new product line with "green" appeal. However, no interest was shown. The oil industry is, in fact, trying to dispose of its natural gas supplies which are a byproduct of the petroleum exploration and refining processes.

The utility industry does not have a consensus on who is to be the retailer for natural gas as a motor fuel. As the natural gas utility industry restructures, the local distribution companies (LDCs) will be "pipe" companies with no retail services. They may not even handle the billing themselves. Unregulated energy services will be providing these services in the future. The types of services many of these unregulated service companies will consider will have large return on investments (ROIs), e.g., greater than 20 percent and revenue streams in excess of $25 million within 3-5 years.

There is a lack of commitment to commercialize NGVs on the part of the original equipment manufacturers (OEMs). The OEMs claim that they only make a return on the initial sale of the NGV whereas the utilities make a return over the life of the vehicle by selling fuel. To date, the OEMs generally have worked only on incremental adaptations of gasoline systems for NGVs.

Honda has been working on issues that may create major market demand, such as improving fuel economy.

No one has done a good enough job of selling the whole NGV concept. All of the above add up to a massive lack of industry-will to develop NGV products and supplies. Baby companies are struggling to carry the development and inventory costs and the cost of ensuring quality in gas cylinders that are low volume items.

Technology voids continue to be a barrier. For LNG, fuel metering, fuel transfer, and fuel storage need development. NGV products that are not very good have been marketed. Experience with an OEM distributor repowering a truck was less than satisfying. The correct transmission and rear axle were not used in this repowering job. It took months of trial and error to achieve acceptable driving performance.

New technology and innovation could reduce the cost differential of NGV construction. For example, integration of the CNG tank structure with that of the vehicle could produce weight, payload and cost savings. OEM initiative would be required for such an undertaking. Ford's recent decision to produce up to 500,000 Flexible Fuel Vehicles annually is a good example of what's wrong with OEM's alternative fuel vehicle (AFV) programs.

NGV Industry Strategy

The industry should be concentrating on heavy-duty vehicles. LNG is more suited to heavy-duty vehicles than is CNG. However, many natural gas utilities are committed to CNG, not LNG. LNG is a barrier because it is seen as a market threat by some of the LDCs. Gas utilities need to see themselves as energy companies and sell LNG, but generally they don't. Often pipeline companies have the gas supply, and could transport natural gas to a liquefaction plant. Also, major transmission lines in the northeast are underutilized.

To be successful, NGV infrastructure needs an infusion of $20-40 billion. There is no credible source of an investment of this magnitude, from either government or industry, or a combination of both. It will certainly not be the utilities. This lack of investment is a fundamental weakness in the strategy.

The public transit sector is a sales target that can be managed, and many marketing people favor this segment. The industry does not have any monetary incentive to invest in this area but FTA, ISTEA funds (via local AQMDs) have seeded installation of 16 new CNG stations in northern California this year.

The NGV Coalition, in concert with GRI and large third-party investors, needs to create a demand for NGVs. The industry should concentrate on medium and heavy-duty vehicles, and passage of Boston's NGV funding bill. The LNG fuel tax is the primary barrier to LNG and LCNG market development. This needs to be corrected as soon as possible.

To date, the NGV strategy has been too broad and shallow. The NGV industry has not bought into the plan. Implementation of scenario analysis as the strategic plan was developed, but this approach was not used.

Diesel fuel may provide a model for developing infrastructure. Even though diesel is very similar to gasoline, it took ten years for diesel to gain a niche. Diesel was hurt by poor technology. Simply installing a diesel head on a gasoline engine block didn't work. We're experiencing similar problems with natural gas.

Scenarios

Alternative scenarios are described that may be effective in establishing an NGV infrastructure.

Government Intervention Scenario. Government intervention is needed to provide incentives and to level the playing field with other energy sources. Funding is needed to overcome startup costs and achieve a critical mass of infrastructure and vehicles. When the General Services Administration (GSA) decides that it wants to go with a solicitation for alternative fuel vehicles, vehicles need to be available for sale. (Nevertheless, the industry should focus on medium and heavy-duty vehicles.) The excise tax on LNG needs to be lowered to provide parity with CNG and federal money needs to be used to build up the federal fleet of alternative fuel vehicles.

The concept of alternative fuel corridors that expand to build the infrastructure should be supported.

One means to spur infrastructure would be to unleash military and national lab resources in a program similar in commitment to the 1960's space program. Capital is a problem for industry. Funding is needed to crystallize technology development. The Partnership for a New Generation of Vehicles (PNGV) is a baby version of the space program. NGV infrastructure implementation could be a step towards the national goal of establishing a hydrogen economy.

Oil Price Scenario. Under this scenario the price of oil is increased. This could include internalizing such externalities as air quality health costs, global warming, the Gulf war, and follow-on maintenance costs.

Industrial Gas Scenario. In the western region, Jack B. Kelly is promoting liquefaction, but other regions of the country don't have this leadership. The fuel will be sold by weight in California. Better metering, fuel transfer equipment, and containers are needed. Also, a controlled fuel composition for LNG that withstands weathering is needed.

Conversion of LNG to CNG may be more economical than compression of natural gas to form CNG. There will be issues about siting the equipment and indemnification.

Interview 3 -

Barriers to NGV Infrastructure

The number one barrier is the inertia of drivers and fleet operators being satisfied with present vehicles and fuel systems. Many would switch to either compressed natural gas (CNG) or liquefied natural gas (LNG) if significant cost savings were possible or if the availability of present fuels became threatened. Shortages inspire people to take desperate actions but something has to go badly wrong with the present system before people react.

The general population needs to realize some significant net benefit from switching to NGVs that is not available today. For example, while the fuel may be cheaper than gasoline, NGVs are more expensive than gasoline-powered counterparts. The potential market is depressed by current NGVs having performance problems (e.g., Ford Contour), being recalled or having production suspended by OEMs (e.g., Chrysler, Honda, and GM). Another factor is the present small choice of NGV vehicles (two pickups, one van, two sedans). Even fuel cost and tax advantages are tentative with the tax benefit on its way to being lost. (In 1993, a fuel cost differential of 65 cents/gallon was estimated as being necessary to drive about a 50 percent conversion of vehicles of which 30 percent might be voluntary.)

Other issues are the generally shorter driving range, availability of fueling stations and perceived safety (numerous accidents reported with vehicles and at fueling stations). The bottom line is, for the market to develop, NGVs must offer everything that gasoline and diesel vehicles offer now plus one big benefit.

Experience with alternative fuel marketing shows that two major lessons have been learned:

- Legislation cannot be counted on to create a market
- One cannot market something that doesn't work as well as the established system.

The history of NGVs, to date, is the premature marketing of a product that has not been ready. Too many technical shortcomings need to be addressed. Examples are gas composition, the incomplete tank fill problem, slower fills, resale value, and cylinder design. The approach used by the NGV industry has been local in-situ fixes rather than system wide.

The Industry Strategy

The Industry Strategy, developed with utility input, advanced the strategy in 1994 of focusing first on customers (i.e. fleet operators) who use a large amount of fuel. However, the process used to develop the strategy had problems. Members of the working group experienced a level of frustration because they felt the contractor drew conclusions before adequate discussion had been allowed.

Also the strategy has not been implemented. However, without factors that motivate people to switch to NGVs, the goals of the strategy are difficult, if not impossible, to achieve.

A trade association cannot tell industry how to create a market. Even parent companies often have little control over their subsidiaries. The interviewee thinks the best organizations to sell natural gas (as NGV fuel) are the utilities, but they have now grown tired of trying. The local distributors have the most to gain. The pipelines probably would not find enough potential volume.

As the utilities are losing stamina and belief in the potential of the market, representatives of state and local governments are replacing utilities as the major participants at many conferences. This loss of interest on the part of the utilities is based on realization that it currently doesn't make sense to invest heavily in NGV market development and, in any case, should a market develop, the utilities will be there to supply natural gas for it.

Investment still makes sense in developing NGV markets in localities with special problems or enabling circumstances such as in areas with already poor air quality or with codes and standards in place. The use of LNG is potentially favorable when it can be set up near to sources of supply.

Also, in terms of a strategy, the industry needs to tackle potential problems before they occur. The past has seen the industry addressing problems during and after their occurrence. Examples are issues of gas composition, oil carryover from compressors, rupture of cylinders, and incomplete fills of gas cylinders.

Role of the DOE

In answering the question, "If the DOE had a few million dollars to invest in the problem, where should it be spent?," the respondent answered that vehicle performance and availability are critical issues. OEMs should be involved in market development. They claim they are reactive to demand but really aren't. More OEMs need to be involved in offering products that encourage demand.

## Interview 4 -

Several issues concerning fueling stations and the NGV industry are mentioned:

- User integration is needed. Customers must use more natural gas, and this can be achieved if they understand the benefits to their operations and are provided with a complete package of service.
- The critical mass of NGVs, fueling stations and throughput of natural gas sales needs to be better understood on a regional basis. For example, Southern California Gas Company stations had about 40,000-sfcm capacity, and 25 percent utilization was needed.
- Each customer or company needs a goal for throughput.
- Alliances should be encouraged to nurture support for infrastructure.
- A process is needed to share information on safety. Maybe a Website could be used.
- An industry spokesperson is needed.
- More petroleum companies and cardlock operators should be recruited to sell natural gas retail. Innovative approaches are needed.

- Siting fueling stations is an issue. Where vehicle maintenance bays are shut down, this may be a place to install a NGV compressor skid. Innovative concepts for siting at existing gasoline stations are needed to reduce costs.

## Interview 5 -

In the specific metropolitan area, the CNG fueling infrastructure business has grown to some 30 public/private-fueling stations. There are a couple of gaps to fill, but in general, the fueling infrastructure for CNG is about done.

A successful CNG fueling infrastructure business should be, for the most part, non-regulated. Two factors account for this. First, Public Utility Commissions (PUCs) have restricted the ability of gas utilities to use rate-based financing for NGV infrastructure. Second, the CNG fueling business does not lend itself to operating in a regulatory environment. The business must be sufficiently nimble to adjust to the market, including relocating stations and adjusting prices of fuel.

### Status of the NGV Industry

Compressed Natural Gas. The time to "break even" has been longer than many gas companies across the country, anticipated. The industry is "on the bubble" in terms of whether or not utilities and other participating companies can realize the required return on investment soon enough.

Liquefied Natural Gas. Many LDC were early supporters of LNG for the heavy-duty vehicle market – some continue to be. LNG is basically a by-pass issue for some gas companies.

### Barriers to Infrastructure

The biggest barrier is economics. The incremental price of NGVs versus gasoline or diesel models has stifled the market. A result has been that only a few private fleets with large fuel use have converted to CNG, whereas significant numbers of public fleets (i.e. municipalities) utilizing CMAQ funding to offset most of the incremental vehicle costs are switching to CNG. This proves that incentives designed to reduce the incremental cost of NGVs are successful. The industry must get CNG sales volume up and vehicle sales up and the price of NGVs down.

The NGV industry needs to consolidate. Regional or possibly even national, organizations could achieve economies of scale that individual companies cannot achieve.

In terms of technology barriers, converted vehicles are perceived as being increasingly unacceptable to fleet owners. OEM NGVs are needed. This is being accomplished, resulting in improved range and vehicle performance.

An additional barrier is the lack of OEM vehicle model offerings. The OEMs are addressing this barrier, but prices for NGVs must come down.

Another barrier has been governmental policy and regulation. Insufficient support for the fledgling NGV industry has been provided by the federal and state governments. In Texas, the petroleum industry succeeded in having reformulated gasoline listed as an alternative fuel, which has hurt the market penetration of CNG. The OEMs did not, in the past, support some of the positions of the Natural Gas Vehicle Coalition (NGVC) (e.g., mandates for alternative fuel vehicles), but the OEMs and NGVC are now working more closely together.

Retailing Natural Gas

In response to the question, "Who should be selling natural gas as a motor fuel?," the following comments were offered: It makes sense for local distribution companies (LDCs) or their affiliates to sell CNG. They understand the characteristics of the fuel and the gas distribution business. While almost anybody could broker LNG, the competitive advantage will rest with those having access to LNG supplies and transportation, and with those possessing knowledge of the heavy-duty vehicle industry and having the financial and manpower resources to develop this market.

NGV Industry Strategy

The Industry Strategy is supported in two major areas. First, public access stations should be more of a priority than strictly private fueling stations. High volume fuel users should be pursued. Second, whereas the Industry Strategy implies that only the medium/heavy-duty vehicle market offers the promise of sufficiently high volume in the near-term, some industry experts believe that the light-duty vehicle market segment could also provide high volume sales of CNG.

## Interview 6 -

NGV Business

In general, oil companies may engage in direct investments in stations for gasoline or they may use jobbers. Sixty-two billion gallons of fuel (gasoline plus diesel) are used annually by commercial fleets, but less than one percent of these sales are made through proprietary credit cards at retail stations. Fuel is sold by the following means:

- Customers have on-site fuel storage and dispensing amounting to about 26 percent of the annual sales.
- Customers buy fuel at card-lock installations.
- Customers buy fuel at retail stations and truck stops.
- Customers use a commercial fleet card.
- Customers buy fuel via commercial mobile refueling.

An unknown factor is how many non-fleet commercial customers exist.

A new strategy has been tried for increasing sales of CNG. This is to have a team go out and identify potential customers and sell them on CNG. The ideal team would include the fuel retailer, the gas utility, and the vehicle OEM who would join together in marketing. Most participants however, are not ready to increase their expenses in marketing given the poor return thus far. They are looking for other sources of funding for the effort. For example, the DOE/GRI Clean Cities opportunities and, in California, AB2766 funding.

Barriers to Infrastructure

The number one barrier is the lack of sales of CNG. Additional CNG stations will not be built until the sales increase at its current CNG stations. Oil companies have had offers from people to pay for all the equipment and guarantee a sales load with all of the profit margin going to the oil company. However, even with zero investment the oil companies can generate more income by using the property for another means. Consequently it will be a hard sell to convince oil companies to use the land for retail CNG.

The Gas Research Institute (GRI) and others consider the cost of CNG stations to be a barrier to infrastructure, but this is uncertain. Adding diesel to a gasoline station costs about $100,000, and a CNG station may cost $250,000. The margin on sale of fuel itself is better for CNG so the cost of infrastructure is not such a barrier if there is sufficient throughput of CNG sales per station. For example, the maximum monthly sales volume capability at one CNG station is 25,000 gallons, which is a profitable rate of use. This contrasts with a gasoline station that sells about 120,000 gallons of gasoline per month. Recently the year-to-date sales volume of CNG for 17 stations over five months of business has been 42,000 gallons (for all 17 stations). These stations have ranged from selling 62 to 1,714 gallons of CNG in a month and are not profitable at such low rates.

Even in southern California, where there are relatively more CNG vehicles, and there is the incentive for customers to change to CNG from diesel, people are not using much CNG.

A second barrier is that organizations are retailing CNG as a fuel with little experience in selling motor fuel. Some partners have been marketing CNG as a motor fuel, but some of them (i.e., some gas utilities) do not do a good job. They do not have the expertise. Not enough people (utilities or vehicle OEMs) are identifying potential customers and selling them on the idea of CNG. A lack of vehicles for sale exacerbates the problem.

Nevertheless, the activity of selling CNG as a logical extension of the fuel business for many oil companies. Customers want the retail fuel industry to carry fuel products. Oil companies that are large producers of natural gas will stick to what it produces. For example, many oil companies do not plan on installing charging stations for electric vehicles or selling M-85 (methanol) - because it does not directly manufacture the fuels.

Now many petroleum companies have separated the natural gas business from the gasoline business within the company. There has been a resulting loss of synergy.

Tariffs imposed by gas transmission companies to deliver the fuel make it uneconomic for many petroleum companies to sell its own natural gas. For example, a retailer must guarantee it will receive a certain quantity of fuel, but it may only sell one-third of it. Now companies are optioning to buy natural gas by short-term contract wherever it is the cheapest.

The Industry Strategy

Little growth is seen in the market segments selected by the NGV Industry Strategy, i.e., the medium-duty and heavy-duty vehicles market segments. In fact, no segment seems to be growing. The industry needs a collective strategy requiring many different factions working together (i.e., oil companies, gas utility companies, OEMs) coordinated by someone who knows how to market.

LNG is not thought of as practical for public fueling and that it is currently uneconomic as a source of CNG.

Overall, the situation for alternative fuels in 1997 compared to 1995 is a relaxation of mandates and improved emissions from gasoline vehicles.

## Interview 7 -

The person's company's NGV program is one of market development, and it has been designed to address market issues. Activities have included promoting the use of NGVs with local fleets and promoting incentives for NGVs. They started with trade organizations in the state. They also worked to influence state legislation. They are now reassessing the viability of the NGV market in the light of the market's presently stalled development and the new competitive nature of the natural gas industry.

When asked the question, "Who should be selling natural gas at retail locations"?, the person replied that, to date, customers have not provided sufficient utilization of compressed natural gas (CNG) fueling stations to provide break-even economics for owners of the stations. Amoco and Super America have had stations in the area, the city has one, and gas utility has fueling stations. The person thought the oil companies would be best at retailing CNG, if a market ever develops. Currently, only those organizations with a vested interest constitute the customer base, i.e., utilities with their own NGV fleets.

Barriers to Infrastructure

The principal barrier is the price of infrastructure and vehicles. The cost of compressor stations is a barrier, and GRI and the industry are working on several aspects of this issue. When an economic analysis is made, even with reduced costs for infrastructure, customers will not purchase NGVs and fuel unless the difference in price of CNG and gasoline or diesel is greater than it is now. Incentive packages are needed to promote NGV use.

Standardization of equipment would help, but utilization of fueling stations is the main driver. For example, a major commercial airline had a 340-vehicle NGV project set to go that would

have provided 45 percent return on investment, but they decided not to undertake the project. A $100,000 grant from GRI for innovative design of a fueling station was a part of the package. This airline may look at other areas of the country where there is more pressure to implement NGVs (such as Denver and California). Also, they are now looking at diesel technology.

A second barrier is the accumulating uncertainty concerning most aspects of NGV infrastructure development, including the lack of government incentives or mandates. Environmental policy makers have backed off on regulations. Fleets mandated under EPACT to purchase alternative fuel vehicles are not meeting their goals and are waiting for incentives. The Barton bill is now causing uncertainty in the marketplace and the publicity of Chrysler's pullout on NGVs is also a strong negative factor. Uncertainties coming from many directions, including the anticipated development potential of the diesel engine, are causing latent NGV users to wait and see how these issues develop and, in the meantime, let someone else be the pioneer.

Battelle asked the interviewee if he thought marketing has been a barrier to infrastructure development. The interviewee indicated that, in the past, market research identified the potential number of vehicles conversions but not the number of real NGV customers. Market research has not been based, in his experience, on questionnaires administered to the public. However, in targeting high-use opportunities, the full range of promotional media has been employed (e.g., literature, seminars, open houses) and reached most of the best potential customers. The previously noted disincentives caused interest to fizzle. Awareness of the technology is not an issue.

## Interview 8 -

A total of 13 fueling stations have been built to seed the market. Now, their organization will only build a station that has an anchor customer guaranteed. They will also build a station under contract for another organization, and they are interested in joint ventures with oil companies. However, they do plan to be in the business of selling natural gas from retail fuel stations. An unregulated type of organization can be more dynamic and respond better to the marketplace in retail fuel sales.

### Barriers to NGV Infrastructure

1. Economics driven by relative fuel costs are the overriding barrier to NGV infrastructure. The current low cost of gasoline and diesel fuels does not provide sufficient incentive to people to use NGVs. The cost differential does not provide sufficient margin for retailers to cover the cost of fueling infrastructure. Gasoline and diesel fuel are currently about 50 cents/gallon cheaper than anticipated when NGV strategy was first developed. The NGV industry had expected the price of gasoline and diesel to be over $1.50 per gallon by now. If the difference in price of natural gas versus gasoline or diesel continues to widen, the NGV industry can keep going, but if it doesn't it will not be economical to expand. A basic problem is trying to achieve a return on large capital investment with sale of a small margin commodity.

A major target market is diesel fleets. The present cost of diesel fuel exacerbates the economic problem. For example, a transit fleet can buy jet fuel for $0.69/gallon untaxed.

The economic situation is regionally dependent. For example, potential customers at the end of the pipelines are typically in the non-attainment areas where air quality is an incentive to use NGVs. However, the price of natural gas is higher at the end of the pipeline than in the middle. In the middle of the country, where natural gas prices are more favorable, the air quality driver for conversion to NGVs is not as strong as in the northeast, for example.

2. A second economic issue is the failure of the industry to reduce prices as quantity of hardware and operating experience have increased. For example, that this is the situation regarding compressor stations and NGV cylinders even though much manufacturing experience has been gained. Each station design seems to be unique. The industry needs to be able to deliver a 30 scfm station at less than $1,000 per scfm (about 25 percent of the cost of current designs). High costs center on three parts: (a) compression, (b) gas storage, and (c) labor.

   Low volume sales cannot support relatively high cost of station equipment maintenance. Areas for improvement include, for example, effort to decrease maintenance requirements and frequency for compressors, and regenerating gas dryers. Station economics are also affected by the local cost of electric power used to operate compressors.

3. A major barrier includes having too many different fuel station design applications. A mistake analogous to that made by the nuclear power industry being made by the NGV industry also in failing to introduce widespread design standardization. For example, NGV stations are designed like utility plants, not a commercial product. Design standardization is needed for fuel stations and that it could reduce their cost from about $4,000/scfm to $1,000-$2,000/scfm.

4. Funding remains an issue. Funding from the Congestion Mitigation and Air Quality (CMAQ) improvement program along with funding from the Federal Transit Administration (FTA) have been important.

5. The organizations most suited to selling motor fuel are not currently selling CNG. Petroleum companies are best suited to sell CNG as a motor fuel.

6. The economics of building facilities can also be a barrier. Requirements for and cost of flammable gas detection and ventilation inside buildings vary considerably between jurisdictions and among consultants. Local officials want to be convinced that the building will be safe. Sometimes consultants or fleets specify costly upgrades to building systems. This strategy affects the cost per square foot. For example, gas detection costs can range from $2/ft$^2$ to $10/ft$^2$. Application criteria are needed for consistent, safe, cost effective installations. FTA guidelines are good.

7. Vehicles – engine efficiency needs to be improved. High costs center on three parts: (a) gas storage cylinders, (b) under-hood equipment, and (3) labor. The configuration and cost of the gas storage cylinders are disincentives. A major barrier to acceptance is the current practice of adding a CNG cylinder to a vehicle originally designed for gasoline. OEMs need to offer vehicles designed specifically for natural gas with conformable storage, for example, that retains the normal trunk space and other amenities of gasoline vehicles.

1995 NGV Industry Strategy

The strategy made sense in 1995. Its implementation should be segmented. The first segment needs to be focussed on subsidized fleets, such as transit agencies. Then taxi fleets could be targeted. It takes a lot of resources for school buses and medium-duty trucks. It is hard to make an economic case for them.

LNG

There are local restrictions on LNG use such as the moratorium on LNG storage in effect since a major release incident in the 1960s. On a national basis, however, LNG could become a good alternative fuel, especially if the tax is reduced or eliminated.

Role for DOE

Perhaps the NGV industry isn't doing enough on standardization. The DOE might be able to encourage and support efforts towards standardization.

## Interview 9 -

Summary of Meeting

The meeting was held to learn how the Industry NGV Strategy was developed. A chronological summary was developed. A request-for-proposals was issued just before Christmas 1993. The winning contractor proposed to show the industry the state of technology and build a consensus for a strategy. They quantified various aspects of the status of the NGV market for industry.

Stakeholders in the process included natural gas utilities, GRI, A.G.A., NGVC, and equipment suppliers. The first Working Group meeting was held at GRI on April 13, 1994. The climate of the times is exemplified by T. Boone Pickens' call for 20 million light-duty NGVs. The industry was not standardized at the time of strategy development. Over the course of the project the industry developed a set of issues and ended up coming to the same conclusion summarized at the first Working Group meeting.

A crude economic model was developed to quantify the investment needed in infrastructure. The question of who would pay for a large portion (about $9-15 billion) of the estimated bill was always before the group. Options ranged from rate-basing to $NO_x$ emission credits. A key question was how the industry could break out of the box on economics.

The working group looked at timing of various strategy options.

The learning curve for NGVs and volume effects (doubling volume produces a 10 percent price reduction) on economics were modeled. The model considered segments of vehicle applications. The strategy was designed to help the industry shift its focus from light-duty vehicles to vehicle segments with the best economics. At the time, the Natural Gas Council was against mandates while the NGVC was promoting implementation of existing mandates.

Since August 1995, the development of low emission diesel engines has been competing with NGVs. There is a window of opportunity for NGVs, but it is growing smaller. Also, diversification of energy sources for the country versus cost of alternative fuel infrastructure continues to be problematic.

## Interview 10 -

### NGV Program

A business model for NGVs was developed and made available to GRI. About 9-10 companies have been trained to use it. It is an economic model that segments the market. In applying the model within its customer service region, it was determined that only about five of the 33 segments even approached economic viability. The modelers are currently working on incorporating externalities into the model. When an organization uses the model to identify attractive market segments, the next step is to create action plans to penetrate the market sector with NGVs.

Why the market projections have not been met in the customer service areas is currently being studied. This could lead to identifying barriers.

### NGV Industry Strategy

The "mystery investor" was always in the background of the deliberations. It was never clear who the investor would be. The required investment (identified in the Strategy) is far beyond what natural gas utilities will invest. In general, utilities will not be investing amounts close to what the Strategy identifies as needed. The weakest link in the strategy/action is identifying the investor: "If the market penetration estimates are rolled up for different market sectors, what infrastructure will be required, and where will the investment dollars come from?"

It may be wise to aggregate groups to order NGVs.

Current strategy is to market individual fleets with their own fueling stations. Some of the fleets may allow public access. Other gas utilities may be marketing this way as well. The fleet-by-fleet approach is in contrast to the Industry Strategy call for emphasis on public stations with open access.

New approaches, not envisioned by the Strategy, may be necessary. For example, a combination of a natural gas engine coupled to both a compressor for fuel and an electric generator will not

have to wait five years for an economic payback as NGV demand at the station builds. Maybe this type of a system could attract the oil industry to sell CNG alongside gasoline and diesel fuel. Also, the natural gas industry just does not have the land and locations like the petroleum industry has for retail sales. The NGV industry should try to get the petroleum industry involved. The NGV industry needs to recognize that a huge adjustment in marketing natural gas as a fuel may be needed: the petroleum industry may need to market CNG as a motor fuel if NGVs are to penetrate the market.

The vehicle OEMs are becoming less enchanted with the viability of the NGV market.

Barriers to Infrastructure

People are playing the numbers game and not coming to grips with the magnitude of the task. Fueling infrastructure for NGVs is very limited in capacity. For example, stations are being put in with only 200-300 cfm capacity, and this is only 1,000 to 2,000 equivalent gallons per day. Gasoline stations pump much more gasoline each day to be economically viable.

Fueling time windows for public fueling are a barrier. Will people be satisfied if they have to queue up and then fill up at a rate that causes them to take several minutes to obtain a full fill? Fuel delivery capacity is a problem. Providing fill rates comparable to gasoline with a daily station throughput on the order of a gasoline station will really drive up the cost of the CNG station.

Looking at the medium-duty and heavy-duty market segments is a problem because they have different fueling requirements than automobiles that may need 5-6 gallons per fill. The infrastructure that the industry has may not be suitable for the medium-duty and heavy-duty market sectors because the stations do not have the capacity to fill vehicle after vehicle at a high rate.

Locations of stations are a barrier to growth.

Hardware innovation is needed. Fueling station equipment is functional but it needs added reliability, durability, and throughput capacity. The system needs to be simplified. A process for recommending design of stations was initiated several years ago. The best conceptual design and practice is needed. There is too much variability in stations now. There is little commonality of parts between stations. Customers build stations "from the ground up" – modular systems are needed.

Industry Evaluation

An ad hoc gathering of industry people to examine where the industry is in 1997 and where it is going is suggested as a next step. Both strategy and implementation could be addressed.

Interview 11 -

NGV Industry Strategy

With regards to the 1995 Industry Strategy, a comment was made that the underpinning of the strategy was the size of various market segments. Industry people didn't buy in to the numbers that were used; they were hypotheses, not good data. Therefore in evaluating how to overcome barriers to NGV infrastructure, starting from the 1995 strategy will be hard. Yet the insight gained that the industry should not focus on the light-duty vehicle market because there is not sufficient sales potential for fuel was a good and valid finding. The Strategy didn't look at customers; it needs a customer focus.

In 1995 the industry was relying on regulations (EPACT & Clean Air Act Amendments) to promote its sales. Now natural gas is being sold on the strength of the NGV products.

State of the NGV Market

A number of factors affect the market for NGVs:

1. More fueling stations are needed. An effective approach is if a large fleet installs its own fueling station and allows public access.
2. Fleets don't want to change their practices. All aspects of NGVs must be user friendly.
3. Multiple fuels (e.g., natural gas and gasoline or diesel) create a "hassle" for fleets.
4. An incentive that fleet owners might use to promote use of natural gas is to reimburse employees for fuel for a bi-fuel vehicle only when natural gas is used.
5. The high cost of fuel stations (e.g., dispensers that cost three times those for gasoline) is a barrier. Also, the imprecision of fuel monitoring is an issue when retailers are concerned about losing 0.1 cents per gallon.
6. NGV fuel stations don't have a common design. They look different. Lack of communality has led to high costs per station.
7. Fleets for whom it makes economic sense will switch to natural gas. Super Shuttle is an example.
8. The natural gas utility industry is not positioned well to sell natural gas as a motor fuel. The industry didn't follow through on the 1995 Strategy. The utilities are not retailers; petroleum companies are. The utilities are used to serving all customers who want service and to answering incoming calls, not making calls out at customers' locations. The utilities are short of funding for the effort. The gas utility industry remains a utility/mandate driven industry. Economics only accounts for a small percentage as a driver of decisions.
9. The industry needs to understand what fuel services a typical fleet expects to be provided with.
10. The turnover of fleet vehicles (2-3 years) is hard on the NGV industry because the fleet may not yet have paid back the incremental price of the vehicle through fuel cost savings and because there is a poor market for used CNG vehicles.

Technical Barriers

1. Cost of metering is high. GRI has sponsored development of meters, but companies are not ready to go to market.
2. Cost of compressing gas is high. The cost to compress 100 cfm is particularly high when only 25 cfm are needed. Modules are needed. A common design for station with modules of capacity 2 to 25 cfm is needed.
3. Poor temperature compensation routines are being used. When driving, fuel is being drawn from the cylinders and there is constant cooling. The temperature in the cylinders may be several degrees cooler than ambient temperature.

## Interview 12 -

NGVs were considered to be a mass market, but the fueling technology was designed for fleet NGVs that are satisfied with slow fill rates. The public needs a fast fill capability comparable to that available with gasoline and diesel vehicles. All fast fill technology was designed to be used primarily to top off a tank of fuel.

Conversion is the principal method to obtain NGVs. The interviewee's company has concentrated on vehicles that make the most economic sense and even have some dedicated CNG vehicles.

The most successful NGV program has been transit buses with more than 118 CNG transit buses in service in the region. Forklifts have also been a successful target. Fuelmaker hardware has been used successfully. Fill rates have been in the range of 10-20 scfm. The taxi fleet has about 70 CNG Ford Crown Victorias. The US Postal Service and Coke Cola have also had NGV programs.

Through rulings by the Public Utilities Commission, CNG fueling stations have been established that only charge for the cost of compression and maintenance.

CNG fuel stations with public access are the principal marketing thrust. However, fleets generally want CNG fuel stations on their sites. Slow fill stations are best at these locations. The public stations are generally used by municipal fleets. Every station has a fast fill capability, but to obtain a complete fill, the design calls for using a slow fill rate.

Clean Cities

The Clean Cities program has been helpful to the NGV market, and good experience has been generated with the mass transit and taxi fleets in the city.

Barriers to NGV Infrastructure

In discussing specific barriers, the following issues were identified :

1. The cost of compression equipment is a key barrier. Attempts to mitigate this have been attempted by ganging together a series of small compressors to optimize the size of the compressor station. Stations are based on skid-packaged systems of common design. They have also used 3,000 psi gas storage rather than 3,600 psi.
2. The technology for compression that is commonly used is old technology based on high-pressure air technology from the World War II era. Now some R&D studies on new compressor technologies are underway.
3. The cost of one-of-a-kind fueling station designs for each site is also a barrier. Everyone believes it necessary to do their own engineering, whereas common standards would reduce cost. The gas industry used to perform a complete engineering analysis for each fueling station. Now, some skid-mounted stations have a common design, and this helps to reduce costs. There is also a need for better and cheaper metering equipment.
4. A third barrier is the diversity of organizations and opinions in the NGV industry. It was suggested that the different organizations may need to get together to tackle barriers to infrastructure. For example, an industry-accepted set of Recommended Best Practices for designing fuel stations is needed.
5. The low volume and size diversity of vehicle market segments is a barrier to cost reduction. The vehicle OEMs' marketing and pricing strategy also appears to be a barrier. If the OEMs are seriously interested, they should invest more in the engine technology, vehicle design, etc.
6. Location of fueling stations is a barrier. When asked who should be selling CNG retail as a motor fuel, it was believed that it is a natural for the oil companies, but the utilization of stations has been poor and not providing the required payback. Generally the locations of fueling stations have not been optimal for fleets. Transportable, skid-mounted stations can be used to test locations. If sales do not develop sufficiently, the equipment can be moved to a new location.

<u>DOE Research & Development on NGVs & NGV Infrastructure</u>

Research and development was suggested in the following areas. These areas are sufficiently large that the DOE could usefully become involved to complement work by GRI and others:

- Innovative designs for compressors
- Recommended practices for designing compressor stations
- Improved metering equipment.

Work in these areas would respond to needs identified by the NGVC that were sent to the DOE earlier this year.

# Appendix B

## Recommended Goals and Actions – Customers' Perceived Value

# APPENDIX B. RECOMMENDED GOALS AND ACTIONS – CUSTOMERS' PERCEIVED VALUE

This appendix contains a summary of recommended goals related to customers' perception of value. Four sources of information are compared:

- This GRI/DOE project
- Gas Industry RD&D Initiative (January 1998)
- DOE Program Plan for NGV Research (1998)
- NGV Industry Strategy (May 1995).

Table B-1. Technical Goals and Strategies Recommended to Overcome Infrastructure Barriers Related to Customers' Perceived Value of NGVs

| GRI/DOE Project | Gas Industry RD&D Initiative | | DOE Program Plan for NGV Research | NGV Industry Strategy |
|---|---|---|---|---|
| | 2002 | 2007 | | |
| ▪ Develop novel methods of storing natural gas in fuel containers<br>▪ On board fuel storage design/integration<br>▪ Alter the basic design of vehicles to accommodate more CNG storage containers | ▪ Using advanced materials, decrease the cost of CNG storage<br><$0.40/scf ($50/gge) | <$42/gge[a] | ▪ Develop lower cost, lighter weight tanks<br>▪ Develop improved adsorption techniques for storage<br>▪ Integrate vehicle structure and fuel storage<br>▪ Develop "smart" tanks for CNG that report safety condition of tanks<br>▪ Lower capital costs of NGVs<br>▪ Develop conformable tanks | ▪ Develop on-board CNG & LNG containers optimized for cost, weight, and range<br>▪ Redesign vehicles to accommodate more fuel<br>▪ Develop improved LNG on-board fuel pump |
| | ▪ Using advanced cryogenic materials and processes, reduce the cost of LNG storage<br>▪ <$62/gge | <$42/gge | | |
| | ▪ Ensure fuel fill of CNG containers by communicating temperature and pressure<br>▪ Develop improved sensors for CNG & LNG fuel pressure, temperature, level and flow<br>▪ Develop less costly, non-intrusive, real-time cylinder inspection methods<br>▪ Develop less costly pressure relief devices (PRDs)<br>$25/PRD | $5/PRD | | |

(a) gallons of gasoline equivalent.

# Appendix C

## Vision of Mature Infrastructure

# APPENDIX C. VISION OF MATURE INFRASTRUCTURE

As indicated previously in Section 2, an objective of this project (funded by U.S. DOE) was to define a vision of a mature but generic alternative fuel infrastructure that could act as a reference model to guide the development of the infrastructure required specifically for NGVs. The vision includes the basic attributes and elements considered necessary to create a competent and sustainable infrastructure that would enable the competitive entry of one or more alternative fuels into the national marketplace. While not fully descriptive of an infrastructure for all possible alternative fuels (e.g., infrastructures supporting electric and hybrid electric vehicles are not considered specifically), the elements of this generic vision are described below.

## Fuel Production, Transport, Storage and Delivery

The primary requirements of a fuel delivery infrastructure are: 1) a secure and dependable fuel supply; 2) consistent fuel quality; 3) diversity of wholesale vendors and 4) price competition.

### Fuel Supply

The first element encompasses the establishment of all necessary links in the chain from fuel production to retail supply. From a supply security perspective, a domestic production capability including separation and refinement is essential even if a portion of the unrefined feed stock is from foreign sources. Storage infrastructure is most often required at separation/production facilities and at wholesale and retail nodes of the delivery system. One or more modes of transportation infrastructure are needed between the production and wholesale storage, and wholesale and retail storage nodes. The design of production facilities, storage and transportation containers, and transfer equipment may need to include fuel specific features depending on fuel type.

### Fuel Quality

The marketing of an alternative fuel will require the development and implementation of new fuel-specific quality standards. The SAE Standard J1616 has been established for CNG vehicle fuel. Associated test and certification capabilities exercised by industry and required by federal, state and local levels of government (see also Fuel Specifications and Standards, below) will also be necessary. Fuel quality control contributes to its acceptance in and safe delivery to the marketplace, and it protects the end-user from fraud, possible hazard and equipment damage. Fuel quality accountability is also relevant in handling procedures, release prevention and clean-up, and environmental hazard control. The required quality control infrastructure would have much in common with and may be partially covered by existing measures for currently used motor fuels.

Diversity of Wholesale Vendors and Price Competition

Upon introduction, an alternative fuel will spontaneously compete with existing fuels. Later in the process, after the new fuel develops a market share, market forces will encourage vendor diversity and price competition within the fuel type. Free market forces should enable this desirable outcome. Barriers would be legislation, permitting, taxes, subsidies and other constraints on trade that could upset normal market supply/demand and price elasticity equilibria. These considerations also apply at the retail level. However, building market share of an alternative fuel to a self-sustaining level may require temporary incentives to offset the institutional advantages of established fuels. Such issues are considered below in 0Fuel Marketing, and 0Policies, Regulation and Incentives.

## Fuel Marketing

Issues addressed by a fuel marketing infrastructure include 1) diversity of retailers; 2) fuel pricing: 3) retailing strategies; 4) advertising and 5) public acceptance.

Retailer Diversity

A mature fuel market will be supported by a network of franchised retailers. Retailers are distributed geographically so that consumers are offered convenient locations to fuel vehicles. The retail infrastructure for a new fuel type will need time to develop. During this period, potential users face the prospect of running out of fuel before they can find a source of supply, a major barrier to consumer acceptance. A minimum critical number and distribution of retail outlets must be in place before a new fuel market can be self-sustaining. Eventually, as the market develops, a diversity of retailers in conjunction with diversity of wholesalers will promote price competition and the offering of other services to attract customers.

Fuel Pricing

Providing that the entire delivery infrastructure maintains fuel availability to match demand, fuel price per unit energy content or other value delivered will eventually be competitive with other motor fuels, as driven by market forces. Retailing strategies that maintain equilibrium between supply and demand will minimize fluctuations in price otherwise caused by scarcity or over-supply.

Retailing Strategies

The principal companies that are expected to offer alternative fuels are (1) well-established members of the motor fuel industry or (2) organizations associated with an alternative fuel industry (e.g., natural gas utilities or new organizations emerging from the natural gas and electric utility industries). These organizations would develop their own retail marketing strategies. However, it is likely that some or all of these companies will lobby for special concessions from government and permitting agencies at all levels to promote market entry, especially if the product is considered to provide social value or promote government policy.

Advertising

As a sub-set of retailing strategies, the companies expected to enter the alternative fuel market will need to develop effective advertising programs. Agencies of government would assist early market penetration by disseminating educational materials, generic supportive information and fuel-switch endorsements, because alternative fuels are desirable from national energy and environmental policy perspectives.

Public Acceptance

A mature fuel delivery infrastructure will include the promotional means for increasing public awareness and acceptance of the fuel. Potentially important barriers to overcome are public attitudes that a given fuel's availability, price and performance characteristics discourage the acquisition of vehicles designed for this fuel. Promoting vehicles that can operate on more than one type of fuel can encourage consumer acceptance of alternative fuels.

## Fuel Specifications and Standards

In a mature market, a given fuel type may be offered in a range of grades that are targeted to different market segments. Specifications and validated test procedures would be established to assure that the fuel meets quality and consistency standards that consumers can rely on.

Fuel Grade Specification

A mature infrastructure would allow a purchaser of bulk fuel quantities (e.g., a fleet operator or a retailer) to specify a grade of fuel to suit particular market segments. This, in turn, would provide consumers with options to suit specific application requirements and tastes. The purchaser of bulk fuel will also have resources to verify that the proper grade of fuel was supplied. Such resources should also be available to consumer protection agencies.

Test Procedures

Consumers would be assured that fuel grade specifications are backed by verifiable test procedures. Accepted test procedures are established for fuels in current use. Such tests would need to be adapted or developed for alternative fuels entering the market. Test procedures would be needed to ensure that alternative fuels are safe to use and compatible with all equipment that they contact throughout production, delivery and use. Testing procedures are also necessary to verify that the fuel meets grade and quality specifications. The present testing infrastructure available to industry and regulatory agencies would need to be capable of handling new fuel types.

## Fuel Dispensing

A mature fuel dispensing infrastructure will include 1) adequate fuel measurement and transfer equipment; 2) facilities at the consumer interface; 3) standardized design and installation of

fueling stations; 4) a diversity and density of fueling stations matched to consumer needs; and 5) the ability to refuel vehicles that have run out of fuel away from a dispensing station.

Fuel Measurement and Transfer Equipment

Certified equipment is available commercially to measure and record the dispensed quantity of existing fuels. Standardized equipment and procedures also exist for the transfer of these fuels at the production, storage, wholesale and retail nodes of the system. The corresponding equipment will be needed for alternative fuels at all transfer points in the delivery chain. Some alternative fuels will also require specific safety procedures and personnel training based on the relative hazard potential at all handling interfaces in the delivery system.

Consumer Interface Facilities

Retail dispensing of fuel into vehicles must be safe and convenient for public acceptance. Ideally, dispensing equipment will be available that is safe and convenient to use in the self-service mode. However, the nature and potential risks of dispensing a new fuel in this manner must be evaluated. Depending on a given fuel's properties (e.g., propane in today's market), self-service may not be permitted from a risk and liability perspective. New or modified dispensing facilities including hardware and personnel trained in fuel handling will be needed as part of the infrastructure for alternative fuels.

Standardized Fueling Station Design

The infrastructure for an alternative fuel would need to contain a sufficient number, diversity, and appropriate density of fueling stations. This would be enabled by the development of a relatively small number of standard, possibly modular fueling station designs. A mature infrastructure would develop standard design and commonality requirements during its growth mode as a basis for building this part of the necessary infrastructure cost-effectively.

Fueling Station Availability

A mature infrastructure will have a diversity and density of retail fueling stations that meets consumer needs and expectations, whether real or perceived. A public perception that a fuel is difficult to find is a critical barrier to the purchase and use of vehicles that operate on this fuel.

Roadside Service

Roadside or point-of-disability service will be necessary to assist the inevitable problem of vehicle operators needing fuel at a location remote from a regular fuel dispensing station. During the evolution phase of the alternative fuel market, this situation could be handled by dispatch of tow trucks. The rescued vehicle would be brought back to a service station where fuel is available. In a mature market, a higher quality of roadside service will be needed. The infrastructure to provide this support will include service vehicles, fuel containers and dispensing hardware and operators trained and qualified in providing roadside service. Fuel-flexible

vehicles could ameliorate this problem, but such vehicles are generally not capable of providing the performance, fuel economy, and emissions of vehicles that use a single type of fuel.

## Vehicle Production

A mature market will demand the production of vehicles by original equipment manufacturers (OEMs) with full warranty and service support. A smaller niche market may be supplied by after-market conversions of conventional vehicles. In addition, vehicle production and conversion should be backed by test procedures to ensure safety and performance certification. Vehicles designed for alternative fuels would have adequate driving range, and acceptable reliability and durability.

### OEM Production versus After Market Modification

OEMs will be required to observe safety design standards, performance requirements (e.g., collision survival, emissions) and other requirements established by government. The niche market suppliers, as a class, may be less able or inclined to conform to these requirements. A mature infrastructure would include consumer protection standards and protocols for certifying the quality and performance of after-market conversion equipment and related products.

### Safety Test Procedures

Standards and test procedures need to be established for alternative fueled and implemented to ensure safety of vehicles as a whole and their individual components.

### Certification

Vehicle certification standards and procedures will be needed for both OEM and after market vehicles. However, an evolving certification infrastructure is not seen as a barrier to the production and marketing of price-competitive, alternative fuel vehicles.

### Adequate Driving Range

A key attribute of alternative fueled vehicles is having a driving range generally competitive with that of an equivalently sized, gasoline powered vehicle. While this should not be a legislated issue, the failure of manufacturers to provide this capability would be a barrier to public acceptance.

### Vehicle Reliability and Durability

To gain a significant market share, a diversity of vehicle models using alternative fuels will need to demonstrate reliability and durability comparable to gasoline-powered vehicles. It will be in each OEM's best interests to invest sufficient engineering, testing and validation to assure this outcome. Failure to do so would reduce market share and offer advantages to the competition.

## Vehicle Marketing

A mature marketing infrastructure for alternative fuel vehicles would offer the consumer 1) competitive pricing; 2) assurance that reputable dealers exist to sell and service the product and 3) an ability to finance sales. Marketing would employ advertising that is a credible basis for consumer acceptance and be geared to creating profitability without perpetual subsidy.

### Competitive Pricing

Alternative fuel vehicles will need to be priced competitively with conventional vehicles including the value of any sales or tax incentives offered by manufacturers and by governments at various levels.

### Reputable Dealers

A mature infrastructure will include a network of reputable dealers to sell and service alternative fuel vehicles.

### Financing Sales

The institutional attitude of the loan industry relating to alternative fuel vehicles is a potential barrier to ownership. In a mature infrastructure, banks, savings and loan institutions and credit unions would be convinced that alternative fuel vehicles are viable and present no unusual risks of failure or depreciation during the loan period that would excessively reduce the collateral value of the vehicle. Such a negative perception could reduce or restrict the availability of financing for vehicle purchases and, thereby, discriminate against alternative fuel use, in general.

### Advertising

Advertising is an established and effective marketing tool for selling vehicles and will become an essential part of the infrastructure as products become available for sale.

### Public Acceptance

Public acceptance of alternative fuel vehicles will depend on the aggregate credibility of available information on vehicle performance, reliability, durability and cost-effectiveness. Provision of this information in an understandable and believable form will be an essential function of the marketing infrastructure.

### Manufacturer Profitability

Vehicle manufacturers and suppliers should be able to make a profit on the sale of price-competitive alternative fuel vehicles and related equipment without perpetual government subsidy. The government may decide that it is in the national interest to promote the use of alternative fuels and may, therefore, offer start-up incentives. However, the mature market must be sustainable without such advantages.

## Vehicle Service and Repair

A critical element of any alternative fuel infrastructure will be the availability of reputable vehicle service and repair facilities.

### Service and Repair Availability

The market for vehicles using alternative fuels will require the backing of a responsive service and repair infrastructure. Much of this capability will be installed by OEMs in the service departments of their dealerships. Dealerships will need to acquire equipment and tools and to facilitate the training of staff for the new fuel systems. As this part of the infrastructure builds, competitive forces will develop similar capabilities in the after market sector. However, the availability of after-market options may be delayed until a certain critical number of vehicles is in operation.

### Parts Supply

The availability of replacement parts is essential component of the service and repair infrastructure and can be expected to be developed by both OEMs and after market competitors.

### Ability to Remove and Dispose of Fuel

Use of an alternative fuel will require the deployment of capabilities to remove fuel from vehicles both in the shop and under various conditions (especially after accidents) while vehicles are in use. Hardware and protocols will be needed to handle and dispose of fuel in these circumstances.

### Reputable Repair Facilities

As for conventional fuels, the public will demand the availability of reputable repair facilities for vehicles using alternative fuels. The competition expected in the service and repair market should provide choices as soon as the number of vehicles exceeds some minimum critical size.

## Vehicle Resale

Essential elements of an alternative fuel infrastructure are the availability of effective after-market sales and disposal channels and the resolution of product liability issues.

### After-Market Sales and Disposal

Consumer interest in alternative fuel vehicles will depend in part on the development of used vehicle sales and disposal market including trade-in options and sales to dealers or private individuals. Initial sales may be discouraged without the prospect of an easy disposal option. An important issue will be how well a vehicle using an alternative fuel maintains its value with age. Eventually, this issue will be decided by the market, with good reliability and durability experience in the introductory years being a critical factor.

Product Liability Issues

With adequate development, engineering and testing, vehicles using alternative fuels should be similar to gasoline- or diesel-powered vehicles when considered from a product liability perspective. Liability is based on harm caused by negligence. Assuming due prudence in design, engineering, manufacturing and testing on the part of the OEMs, class-level liability based on fuel type should be no more an issue than with gasoline or diesel. The existing financial and legal resources of the industry appear sufficient to manage product liability claims regardless of fuel type. Nevertheless, a public perception that a given alternative fuel is intrinsically less safe than conventional fuels would tend to attach potential liability to fuel type. It is unlikely that a reseller would be exposed to liability based on fuel type. However, if such liability were involved, an individual or after-market dealer would likely have fewer resources to defend against such claims.

## Vehicle Warranty

Vehicle warranty issues can be divided into two classes as they pertain to OEM and after-market conversion vehicles.

OEM Vehicles

To address a possible barrier to public acceptance, OEMs would offer a warranty for new alternative fuel vehicles equivalent in value to that offered for gasoline or diesel powered vehicles.

After-Market Conversion Vehicles

Conversion systems and after-market modifications to vehicles should have warranties backed by reputable and sustainable businesses. It is expected that the private insurance industry would also enter this market and offer policies that supplement available warrantee coverage. These elements of infrastructure are necessary to avoid warranty concerns of purchasing a previously owned or converted vehicle.

## Safety Assurance, Procedures and Equipment

A mature infrastructure that provides for the safe production, delivery and use of an alternative fuel may differ from that of currently established fuels (e.g., gasoline and diesel) depending on the relative hazards involved. The following discussion considers safety issues at the principal nodes of the system.

Bulk Fuel Storage

Essentially all potential alternative motor fuels (other than the exact composition of possible blends) are commodities with current industrial uses. In general, the necessary safety protocols and equipment are already developed and implemented at all facilities that handle these commodities. The primary function of safety standards, procedures and equipment is to assure

safe storage and prevent accidental release during transfer operations. Also included are measures to control and minimize the potential impact of any releases that may occur. The existing portfolio of fuel specific safety measures and technology would need to be applied at any new facilities constructed to provide bulk storage of alternative fuels.

Fuel Transfer and Handling

As above with bulk storage, existing safety protocols and technology are adequate to provide release prevention and control at the bulk transfer locations in the commodity delivery chain. These measures will be necessary at newly constructed transfer nodes specifically designed to handle alternative motor fuels. Extra precautions including fuel release detectors connected to alarms and automatic fire control systems may be necessary at retail fuel dispensing stations. Personnel at such facilities will need training and certification in handling the more hazardous fuels. At stations dispensing various fuels, dispensing equipment will need to be clearly labeled and fitted with unique attachments to prevent filling vehicles with an incompatible fuel or other unallowable fuel mixing.

In-vehicle Fuel Storage

The above-mentioned general safety measures will need to be applied to in-vehicle storage of alternative fuels. Vehicles will need fuel specific fittings that allow the transfer of compatible fuels only and prevent undesirable fuel mixing in the vehicle's fuel container. In addition, depending upon the potential hazards, various safety interlocks and tamper protection devices may be needed to prevent the owner or other parties gaining access to the vehicle fuel container. New vehicle specific release prevention, indication and warning devices (e.g., flammable gas detectors) and automatic release control devices (e.g., special or controlled vents) may be necessary depending on fuel characteristics. Safety training for vehicle owners/operators is also advisable.

Vehicle Operation and Storage

Many of the above measures to assure safety of in-vehicle fuel storage will be needed during vehicle operation and storage. Depending on the fuel, additional safety devices will be necessary in the vehicle to protect occupants, the vehicle, and other people and property in the vicinity of a collision or mishap that threatens breech of fuel containment. Onboard devices that provide flammable gas detection, heat and pressure sensors and controlled venting equipment all connected to visible/audible alarms may be necessary with some alternative fuels. Owners may also need to install such sensors and alarms in garages and closed storage spaces for their vehicles.

Maintenance and Repair Facilities

Fuel specific safety protocols and equipment will be necessary in maintenance and repair facilities together with safe means for removing and disposing of fuel, and fueling vehicles. Fuel release detectors connected to alarms and automatic fire control systems may be appropriate for facilities servicing the more volatile fuels.

User Restrictions, Information and Instruction

While in most states the general public may handle gasoline and diesel fuel in self-service stations, untrained individuals are currently not allowed to dispense propane at retail outlets. Similar restrictions will be necessary for some types of alternative fuel that will probably require handling by specially trained and certified personnel. Fuel specific precautions and handling information will be needed.

Some future fuels may require that the owner/operator receive formal instruction and sign an acknowledgment or waiver before taking possession of the vehicle. Vehicles using alternative fuels will need to be identified and carry information concerning the type(s) of fuel they contain or may use.

## Emergency Response

As emergency response to accidents that release materials into the environment need to be commodity specific, the established use of alternative fuels would require the development of an appropriate emergency response infrastructure.

Awareness of Emergency Response Authorities

As indicated above, alternative motor fuels with near term potential for significant market penetration are existing commodities with other current industrial uses. Potentially hazardous materials transported commercially are classified according to potential hazard. A uniform commodity code number is displayed on transportation containers to assist emergency response personnel in recognizing and handling releases in an optimal manner. It is unlikely that the public would wish to display this emergency response information as prominently as in current commercial practice. Nevertheless, vehicles using alternative fuels may need to be identified and carry information concerning the type(s) of fuel they contain or may use. This will be an aid to emergency response and proper fueling at service stations.

Availability of Trained Personnel and Proper Equipment

Present emergency response equipment, training and other resources appear adequate to handle emergency situations involving future alternative fuel vehicles. As indicated above, easily accessible information on the vehicle indicating the type of fuel carried would be required to guide onsite actions of emergency response personnel.

## Insurance

The availability of insurance for alternative fuel vehicles and facilities would be essential in a mature infrastructure.

Vehicle Insurance

It is possible that the insurance industry will consider alternative fuel vehicles as a special class. This may impact the price and availability of coverage. With competition in the insurance industry, it is unlikely that these issues will become major barriers to alternative fuel use. However, restricted availability of insurance and significantly higher policy costs could combine as disincentives to some individuals who might otherwise purchase alternative fuel vehicles. Government/industry cooperation in developing probabilistic risk information on alternative fuel use could help the insurance industry gain an objective risk perspective.

Facility Insurance

The insurance industry already covers facilities that handle vehicle fuels (commodities). Future alternative fuels are essentially identical to commodities in current use. The availability of insurance for bulk storage and transportation is already based on recognized risks and accident histories. The insurance industry can be expected to specify the type and quantity of fire and hazard protection equipment such facilities would be required to install to be eligible for insurance coverage. The elements of infrastructure for this scenario already exist and/or have precedents.

## Policies, Regulation and Incentives

With the established acceptance and market dominance of gasoline and diesel fuels, an infrastructure for alternative fuels will need to include advantageous policies, regulations and incentives to establish a critical mass.

Tax and Regulatory Policy

Government at all levels can impose or reduce taxes or issue regulations to advance policies or promote trends seen to be in the public interest. Tax policy at one level of government can aid or frustrate the purpose of taxing actions carried out at another level. The infrastructure for advancing the use of alternative fuels will benefit from coordinated tax and regulatory treatment at the Federal, state and local government levels.

Incentives

Ideally, alternative fuels should enter the competitive marketplace without unusual tax treatment or government incentives other than those offered by manufacturers to promote their products. However, government is already developing and implementing both voluntary and involuntary incentives (e.g., in southern California). Overview and coordination of directives and incentives will be needed to prevent distortion of free-market selection of the most viable vehicles and fuel options.

## Consumer Awareness and Acceptance

Fundamental to the future success of alternative fuels entering the marketplace are consumer awareness of the advantages and acceptance that the essential elements of infrastructure exist to justify and protect the investment. Both government and industry have a vested interest in disseminating information that improves public awareness and acceptance of alternative fuel options. Government, in particular will need to exercise its prerogative in providing factual and readily understandable information that can educate the public in making informed market-place choices.

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