



2016 North American
Gas Storage Systems for Natural Gas Vehicles
New Product Innovation Award

F R O S T & S U L L I V A N

BEST
2016 PRACTICES
AWARD

NORTH AMERICAN GAS STORAGE
SYSTEMS FOR NATURAL GAS VEHICLES
NEW PRODUCT INNOVATION AWARD

2016
BEST PRACTICES
AWARDS

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Background and Company Performance

Industry Challenges

Environmental sustainability is one of the key trends leading to significant technological changes in the North American Energy and Transportation sector. The varying fuel prices and the imperative need to reduce CO₂ emissions are driving the need to develop new

alternative powertrain concept such as natural gas (NG) alternatives. With the recent shale gas revolution in the United States, the market for natural gas vehicles (NGVs) is gaining considerable momentum as an alternative to petroleum.



Type IV Conformable Tank 8" X 32" X 48"
Capacity = 5.5 GGE - Available January 2017 (projected)

gasoline equivalent. For instance, the NGV Honda Civic (Civic GX) costs \$5,000 more than its gasoline counterpart in North American market. Additionally, all NGV vehicles with CNG as the only power resource fail to compete with the petroleum equivalent in terms of mileage. Honda's natural gas Civic is able to cover a distance of only 220 miles on one tank, whereas a typical gasoline-powered Civic can travel approximately 350 miles on one tank. This shows that conventional CNG is not a suitable alternative for fueling motor vehicles, compelling market participants in the industry to seek out lower cost NG storage solutions with larger storage capacity.

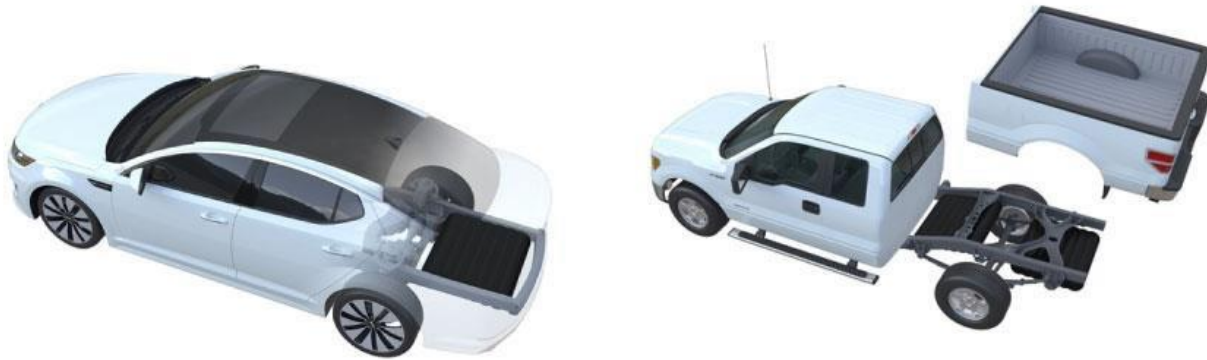
In most of today's available NGVs, fuel is stored on board vehicles as compressed natural gas (CNG). As the name sure cylinder at a pressure around 3,600 NG system a bit more expensive than its

New Product Attributes and Customer Impact

Match to Needs

Recognizing the above-mentioned concerns of sustainability, reliability, and cost-effectiveness, Adsorbed Natural Gas Products, Inc. (ANGP) recently commercialized the first-ever on-board, low-pressure adsorbed natural gas (ANG) storage system for fueling light duty vehicles (LDVs) including all kinds of passenger cars and sport utility vehicles (SUVs). The system stores large quantities of NG at a far lower pressure (at <1,000 psi) compared to the 3,600 psi typically used in CNG cylinders. Consequently, this makes the system a reliable and cost-effective alternative to petroleum distillates.

ANGP's system offers significant economic benefits over other commercialized NG-based alternatives available in the market. The lower pressure of this ANG system distinguishes it from competing solutions by permitting fuel dispensers to use smaller, less expensive compressors that consume far less energy. This, along with its thin tank walls, makes the entire system highly cost-effective and convenient for the customer.



Design

ANGP's first generation (GEN I) ANG system is based on seamless aluminum cylinders. To design and develop this GEN I ANG system, ANGP collaborated with notable companies like Ingevity Corporation, Worthington Industries, and Aspen Compressor. It took four years of dedicated effort by ANGP and its manufacturing partners to successfully develop this commercially viable ANG fuel system. The basis of the system is comprised of Ingevity Corporation's Nuchar[®] Fuelsorb[™] activated carbon monoliths, a highly porous and adsorbent material. This material can densely store NG molecules at 900 psi or lower. Ingevity Corporation worked closely with Worthington Industries to develop the seamless aluminum closure of ANGP's ANG cylinder. Additionally, ANGP worked closely with Aspen Compressor to develop the first NGV fuel pump, which is the embodiment of ANGP's patent pending Fuel Extraction and Pressurization System (FEPS[™]) for low pressure NG storage.

ANGP has recently installed its first ANG system on a 2014 Ford F-150 pick-up truck. To gain better prominence in the market, ANGP holds an exclusive license with the United Technologies Research Center (UTRC)—the innovation engine of United Technologies Corporation—for its innovative Type IV conformable tank design. ANGP will use this in its second generation (GEN II) storage system. Replacing the aluminum cylinder in GEN I with a short-strand carbon fiber composite conformable tank enables ANGP to register a 40% reduction in tank weight and 20% greater storing capacity per unit of vehicle displacement. The estimated capacity of ANGP's GEN II Type IV conformable tank (dimensions: 8"x32"x48") is 5.5 gasoline gallon equivalent (GGE). ANGP has already displayed a full-scale mock-up of its GEN II conformable tank, which is scheduled for an early 2017 release. It will provide optimal space utilization for a broad expanse of the LDV market, including passenger cars and SUVs.

Quality

Because automotive applications rely on “working storage capacity” as a true measure of usable fuel capacity for a NGV, Ingevity developed high-quality activated carbon monoliths with an industry leading high working storage capacity. Most of adsorbent materials, other activated carbons and metal organic frameworks, available to date rely on total storage capacity, which results in thermal properties that make the gas release process difficult while reducing the practical working storage capacity. With superior thermal physics, Ingevity monoliths cause significantly reduced heat generation when filling and significantly reduced heat loss on release when compared to other available adsorbent types. The superior thermal physics of Ingevity monoliths allows ANGP to utilize a simple, patent-pending mechanical extraction process—the Fuel Extraction and Pressurization System (FEPS). All these efforts helped ANGP meet the challenges of producing the industry’s first fully ANSI NGV2-certified low-pressure ANG storage system for motor vehicles.

Positioning & Customer Experience

With superior economic and environmental benefits, such as a cost-effective storage tank design and a reduced carbon footprint, ANGP’s low-pressure ANG system has immense potential to disrupt a century of petroleum distillate dominance in fueling motor vehicles. ANGP’s product can also compete effectively with current alternatives of high-pressure CNG and liquefied natural gas (LNG) with its excellent off-board low compression economics and on-board vehicle conformity benefits. This innovative system also enables customers to utilize flexible fueling infrastructure, including public access, private depot, and home fueling for a safe, reliable and hassle-free driving experience. Post-commercialization, ANGP will closely work with its customers to configure storage systems for optimal space utilization while maximizing the aesthetic appeal of the vehicle. This combination of unrivaled performance, better pricing, and conformity to quality standards has made ANGP quite unique in the market.

Price/Performance Value

The superior operational and maintenance economics of a low compression ANG system effectively offers consumers continuous cost savings in the range of \$0.20 to \$0.30 per GGE. Due to the elimination of retail infrastructure cost and maintenance, private fueling can add up to another \$0.50 per GGE in cost savings. Hence, low pressure NGVs fueled by the ANG system is able to enjoy as high as \$0.80 per GGE savings over the CNG available from competing companies. It is estimated that an ANG fueling infrastructure is expected to cost 50% less than what is required for CNG systems to fuel motor vehicles. Also, at a time when a home refueling appliance for CNG systems from competitors, costs more than

\$4,000, ANGP’s low-pressure ANG system is estimated to be less than \$2,000, indicating the best value for money. With a higher storage capacity than the competitor’s CNG-based system for the same displacement on a vehicle, ANGP’s low-pressure system also offers the benefit of greater range.

Conclusion

ANGP's low-pressure ANG tank for fueling motor vehicles is an optimized blend of sustainability, cost-effectiveness, and optimized performance. This enables a more rapid adoption of NGVs, which are privately fueled by fleets and individuals. The ANG system focuses on the automobile industry and is targeted towards fleet owners, original equipment manufacturers (OEMs), infrastructure providers for refueling, and retrofitters that convert existing petroleum-based vehicles, enabling them to run both bi-fuel and dedicated NG. Because of its strong overall performance, ANGP is recognized with Frost & Sullivan's 2016 New Product Innovation Award.

Significance of New Product Innovation

Ultimately, growth in any organization depends upon continually introducing new products to the market, and successfully commercializing those products. For these dual goals to occur, a company must be best-in-class in three key areas: understanding demand, nurturing the brand, and differentiating from the competition.



Understanding New Product Innovation

Innovation is about finding a productive outlet for creativity—for consistently translating ideas into high quality products that have a profound impact on the customer.

Key Benchmarking Criteria

For the New Product Innovation Award, Frost & Sullivan analysts independently evaluated two key factors— New Product Attributes and Customer Impact—according to the criteria identified below.

New Product Attributes

Criterion 1: Match to Needs

Requirement: Customer needs directly influence and inspire the product's design and positioning

Criterion 2: Reliability

Requirement: The product consistently meets or exceeds customer expectations for consistent performance during its entire life cycle

Criterion 3: Quality

Requirement: Product offers best-in-class quality, with a full complement of features and functionality

Criterion 4: Positioning

Requirement: The product serves a unique, unmet need that competitors cannot easily replicate

Criterion 5: Design

Requirement: The product features an innovative design, enhancing both visual appeal and ease of use

Customer Impact

Criterion 1: Price/Performance Value

Requirement: Products or services offer the best value for the price, compared to similar offerings in the market

Criterion 2: Customer Purchase Experience

Requirement: Customers feel like they are buying the most optimal solution that addresses both their unique needs and their unique constraints

Criterion 3: Customer Ownership Experience

Requirement: Customers are proud to own the company's product or service, and have a positive experience throughout the life of the product or service

Criterion 4: Customer Service Experience

Requirement: Customer service is accessible, fast, stress-free, and of high quality

Criterion 5: Brand Equity

Requirement: Customers have a positive view of the brand and exhibit high brand loyalty

The Intersection between 360-Degree Research and Best Practices Awards

Research Methodology

Frost & Sullivan’s 360-degree research methodology represents the analytical rigor of our research process. It offers a 360-degree-view of industry challenges, trends, and issues by integrating all 7 of Frost & Sullivan’s research methodologies. Too often, companies make important growth decisions based on a narrow understanding of their environment, leading to errors of both omission and commission. Successful growth strategies are founded on a thorough understanding of market, technical, economic, financial, customer, best practices, and demographic analyses. The integration of these research disciplines into the 360-degree research methodology provides an evaluation platform for benchmarking industry players and for identifying those performing at best-in-class levels.

360-DEGREE RESEARCH: SEEING ORDER IN THE CHAOS



Best Practices Recognition: 10 Steps to Researching, Identifying, and Recognizing Best Practices

Frost & Sullivan Awards follow a 10-step process to evaluate award candidates and assess their fit with select best practice criteria. The reputation and integrity of the Awards are based on close adherence to this process.

STEP	OBJECTIVE	KEY ACTIVITIES	OUTPUT
1 Monitor, target, and screen	Identify award recipient candidates from around the globe	<ul style="list-style-type: none"> • Conduct in-depth industry research • Identify emerging sectors • Scan multiple geographies 	Pipeline of candidates who potentially meet all best-practice criteria
2 Perform 360-degree research	Perform comprehensive, 360-degree research on all candidates in the pipeline	<ul style="list-style-type: none"> • Interview thought leaders and industry practitioners • Assess candidates' fit with best-practice criteria • Rank all candidates 	Matrix positioning all candidates' performance relative to one another
3 Invite thought leadership in best practices	Perform in-depth examination of all candidates	<ul style="list-style-type: none"> • Confirm best-practice criteria • Examine eligibility of all candidates • Identify any information gaps 	Detailed profiles of all ranked candidates
4 Initiate research director review	Conduct an unbiased evaluation of all candidate profiles	<ul style="list-style-type: none"> • Brainstorm ranking options • Invite multiple perspectives on candidates' performance • Update candidate profiles 	Final prioritization of all eligible candidates and companion best-practice positioning paper
5 Assemble panel of industry experts	Present findings to an expert panel of industry thought leaders	<ul style="list-style-type: none"> • Share findings • Strengthen cases for candidate eligibility • Prioritize candidates 	Refined list of prioritized award candidates
6 Conduct global industry review	Build consensus on award candidates' eligibility	<ul style="list-style-type: none"> • Hold global team meeting to review all candidates • Pressure-test fit with criteria • Confirm inclusion of all eligible candidates 	Final list of eligible award candidates, representing success stories worldwide
7 Perform quality check	Develop official award consideration materials	<ul style="list-style-type: none"> • Perform final performance benchmarking activities • Write nominations • Perform quality review 	High-quality, accurate, and creative presentation of nominees' successes
8 Reconnect with panel of industry experts	Finalize the selection of the best-practice award recipient	<ul style="list-style-type: none"> • Review analysis with panel • Build consensus • Select winner 	Decision on which company performs best against all best-practice criteria
9 Communicate recognition	Inform award recipient of award recognition	<ul style="list-style-type: none"> • Present award to the CEO • Inspire the organization for continued success • Celebrate the recipient's performance 	Announcement of award and plan for how recipient can use the award to enhance the brand
10 Take strategic action	Upon licensing, company may share award news with stakeholders and customers	<ul style="list-style-type: none"> • Coordinate media outreach • Design a marketing plan • Assess award's role in future strategic planning 	Widespread awareness of recipient's award status among investors, media personnel, and employees

About Frost & Sullivan

Frost & Sullivan, the Growth Partnership Company, enables clients to accelerate growth and achieve best in class positions in growth, innovation and leadership. The company's Growth Partnership Service provides the CEO and the CEO's Growth Team with disciplined research and best practice models to drive the generation, evaluation and implementation of powerful growth strategies. Frost & Sullivan leverages over 50 years of experience in partnering with Global 1000 companies, emerging businesses and the investment community from 45 offices on six continents. To join our Growth Partnership, please visit <http://www.frost.com>.