

CNG FOR COMMERCIAL, LAW ENFORCEMENT AND RECREATIONAL BOATS

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ABSTRACT

CNG has significant environmental and economic advantages as a marine fuel in commercial applications as well as law enforcement and recreational use. This paper covers the current technical and business aspects of the current deployment of CNG marine systems for boat propulsion, on-board power generation, fueling operation and the practical considerations that make it all possible today for the different use of boats. The technology and its benefits are reviewed and measurements from existing CNG hybrid boats currently in operation are analyzed.

NOMENCLATURE

The Blue Gas Marine (BGM) natural gas hybrid fueling systems for on-board marine propulsion and power generation were created as a direct response to solve two significant problems in the boating industry: How to reduce the operating cost of power boats and how to introduce a clean fuel to make a significant reduction in marine pollution. The systems currently commercialized by BGM solve both problems in many boating applications.

BGM evaluated several advanced fuels from a technical, safety, fuel availability, cost and business deployment feasibility such as Hydrogen, Propane, and Natural Gas. In 2011, it was determined that Natural Gas was the most practical of these fuels and the company was born the following year to create and commercialize Natural Gas fueling systems to be used in existing marine stock engines that run on gasoline and subsequently in 2016 BGM expanded the product offering to marine diesel stock engines.

Benefits

Environmental: The environmental benefits from running internal combustion engines on Natural Gas are well known as more than 17 Million vehicles (Add Ref) on the road already run on this fuel every day around the world. The major benefit there is a significant reduction in air pollution from car exhaust, which has caused smog to disappear from some cities and air quality drastically improved, with reduced respiratory diseases in humans and reductions in environmental pollution to nature and the planet.

On boats these benefits are magnified due to unique factors. These are in several major categories: higher energy requirements of boats versus cars, the technical difference between boat engines and automotive engines, direct water and air pollution are both present in boats operating on traditional fuels versus just air pollution in automotive vehicles and finally the gains in efficiency introduced by the BGM hybrid systems that make all these benefits possible.

After deploying a BGM hybrid system to a stock gasoline propulsion engine, air and water pollution is reduced by 70% and when deployed on a diesel propulsion engine, air and water pollution are reduced by 90%. These measurements are an average of the pollutants that are eliminated and reduced in water and air pollution and every pollutant is given an equal weight regardless of how or if they are regulated. This gives us a relative comparison to the environmental value of Natural Gas when used to displace gasoline and diesel. For example, when running a marine diesel engine on 100% natural gas, the following reductions are achieved:

- Reduces Nitrogen Oxides pollution by 90%
- Eliminates 100% of Sulfur Oxides pollution
- Reduces Carbon emissions by 25% (GHG)
- Eliminates engine smoke + odor (Particulate Matter emissions)
- Eliminates carcinogenic exhaust (Benzene)

The overall pollution reduction varies from engine model to engine model and the environmental benefits are listed here only for guidance purposes and order of magnitude and not for quantitative analysis. BGM's experience in the field has determined that the numbers given are found as the mean, in the majority of the cases.

Additional environmental benefits come from not having fuel spills that contaminate water or land, unlike traditional fuels.

It becomes obvious that the environmental benefits from air and water pollution reduction are staggering and this plays well with the environmental sustainability efforts that larger operators already strive to achieve.

The economic benefits that come from deploying a BGM hybrid system are listed below in order of most significant cost impact to least:

- Fuel cost reduction of 50% on average
- Increased fuel efficiency up to 50%
- Reduced maintenance
- Increased engine longevity
- Reduced environmental liability insurance

The environment wins, regardless of the reason used for the adoption of the technology: economic savings, or pollution reduction. Both types of adoption reasoning are interconnected, which is great for the economics of the marine industry and the natural resources we depend on.

Technology

It is important to note that the BGM Hybrid System is not a conversion, it is an add-on system that is installed on top of a stock engine and the engine is never modified. This is important because the original performance of the engine is retained. This is also important for warranty matters on new engines, although it also benefits engines out of warranty, since the add-on can be quickly

removed and the engine sold for use with just the traditional fuel, thus preserving its resale value in areas where Natural Gas filling infrastructure is not yet available.

System Components or Modules:

INSERT DIAGRAM of modules that make up the BGM Hybrid System

Gasoline Hybrid

The BGM system for gasoline provides a boater with three modes of operation: Gasoline-only, CNG-Only, and Advanced Hybrid. The Gasoline mode is the traditional mode of operation; CNG is the Natural Gas mode where only Compressed Natural Gas is used to power the engine(s); Advanced Hybrid is a dual-fuel mode that mixes Natural Gas with Gasoline at a variable rate, but it uses primarily Natural Gas with a small amount of gasoline.

Diesel Hybrid

The BGM system for gasoline provides a boater with two modes of operation: Diesel-only and Advanced Hybrid. The Diesel mode is the traditional mode of operation; Advanced Hybrid is a dual-fuel mode that mixes Natural Gas with Diesel at a variable rate, but it uses primarily Natural Gas with a small amount of Diesel.

Diesel Conversion

BGM also offers a conversion system for Diesel engine models. This technology converts Diesel engines into spark ignited engines that burn 100% natural gas, eliminating the need for Diesel. However, the engine loses its ability to use Diesel as a backup fuel, since the engine internals are modified and will no longer be able to auto-ignite diesel by compression as it does traditionally. This method is primarily used for fixed boat routes where it is guaranteed that the boat has the necessary natural gas refueling infrastructure.

Installation: Retrofits Vs New Boats

BGM routinely retrofits existing boats with commonly available stock engines and also installs the Hybrid System in new boats while they are under construction at the boat manufacturer or shipyard.

Retrofits

On an existing boat, BGM installs the system as an addition to the boat and usually recommends leaving intact the traditional fuel capacity and associated fuel tanks. The reason is that existing boats usually have enough available space to install up to 40% of natural gas, in relation to the capacity of traditional fuel originally onboard. After a retrofit installation the boat has 20 to 50% of natural gas in addition to all the existing fuel capacity that was put there when the boat was originally built. This also averts the extra expense of having to make deck modifications to access and remove traditional fuel tank(s). BGM has learned that this capacity of natural gas is usually sufficient for several days' worth of boat use for the majority of customers.

Even in boats where deck space is at a premium and all the space underdeck is utilized BGM has patented the ability to install vertical natural gas tanks. This is possible since compressed natural gas is a gas, not a liquid therefore there is never any sloshing and vertical CNG tanks save horizontal usable space without affecting the operation of the boat.

In rare circumstances, the customer does not want traditional fuel onboard for safety reasons and prefers the safer natural gas. Another reason is that customer wants to maximize the use of natural gas capacity onboard since gasoline is no longer needed to operate or start the engines once a BGM system is installed and the operator feels comfortable about the availability of natural gas filling infrastructure where the boat is in operation. In this case, BGM disables the helm control feature to run the boat on gasoline since there is none onboard. This feature is present on all out-of-the-box BGM helm controls for all gasoline hybrid systems and can be disabled by customer request at any time.

New Boats

The system for a retrofit installation is identical to the system installed on a new boat. There is however an important difference in natural gas fuel storage capacity between retrofitted boats and new boat installation. On new boats the amount of natural gas capacity is usually increased to maximize the use of this cheaper and cleaner fuel alternative. Therefore the capacity of the traditional fuel (Gasoline or Diesel) is reduced to accommodate for more natural gas onboard. This normally yields a ratio of 60% of natural gas to 40% of traditional fuel.

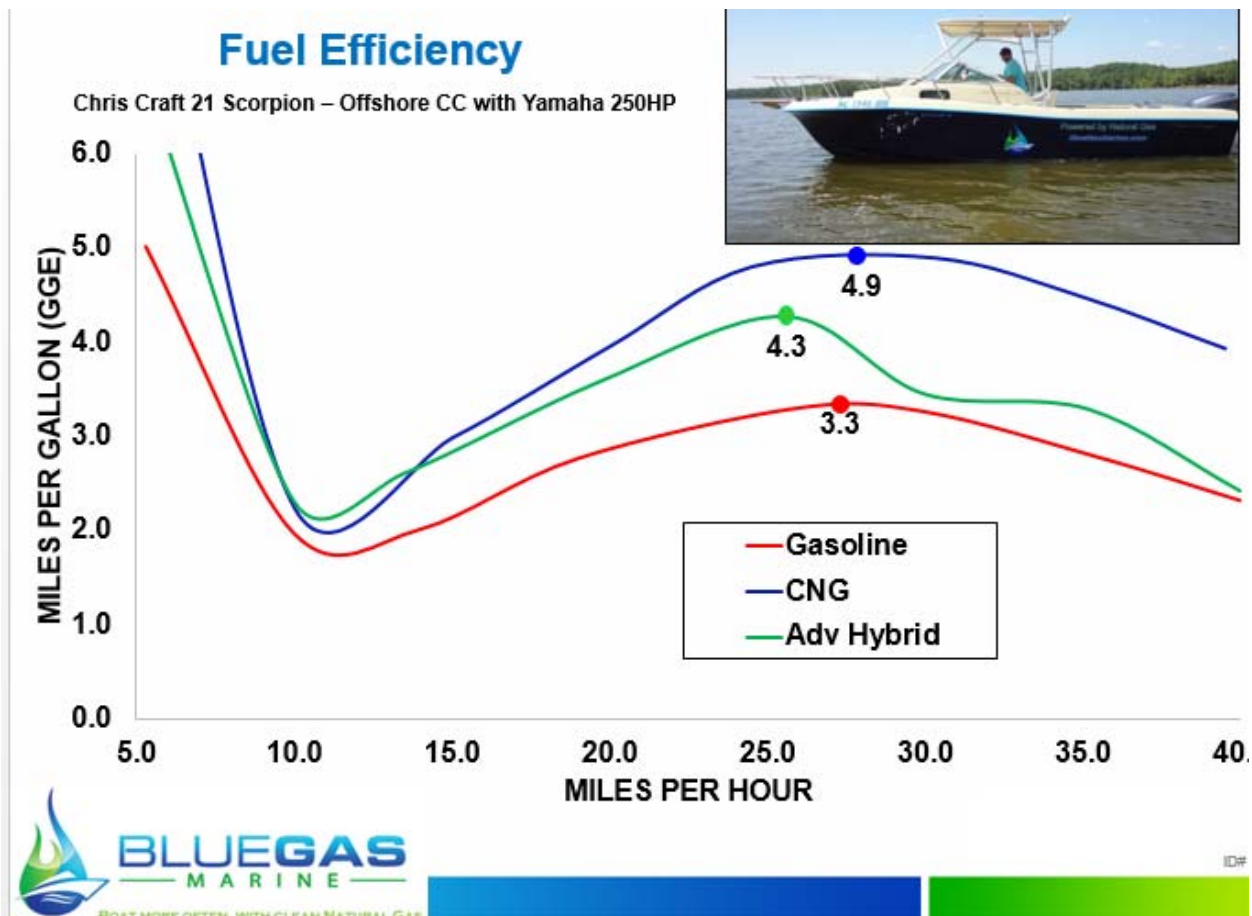
Fuel Efficiency and Consumption

We wanted to show you how the performance and economics of deploying a BGM Hybrid Natural Gas system work, first for a small gasoline boat and then for a larger diesel ship.

It is important to note that the BGM System is not a conversion, it is an add-on system that goes on top of a stock engine and the engine is not modified. This is important because you retain the original performance of the engine. This is also important for warranty matters on new engines, although it also benefits engines out of warranty, since the add-on can be quickly removed and the engine sold for use with just the traditional fuel, thus preserving its resale value.

As such, the BGM system for gasoline provides a boater with three modes of operation: Gasoline-only, CNG-Only, and Advanced Hybrid. The Gasoline mode is the traditional mode of operation; CNG is the Natural Gas mode where only Compressed Natural Gas is used to power the engine; Advanced Hybrid is a dual-fuel mode that mixes Natural Gas with Gasoline at a variable rate, but it is primarily Natural Gas with a small amount of gasoline.

The following chart shows the Fuel Efficiency of a 21-foot long Chris Craft Scorpion 215 offshore fishing boat equipped with a single Yamaha Outboard F250 3.3L engine (250 Horse Power) and the 2nd generation BGM Advanced Hybrid CNG System:

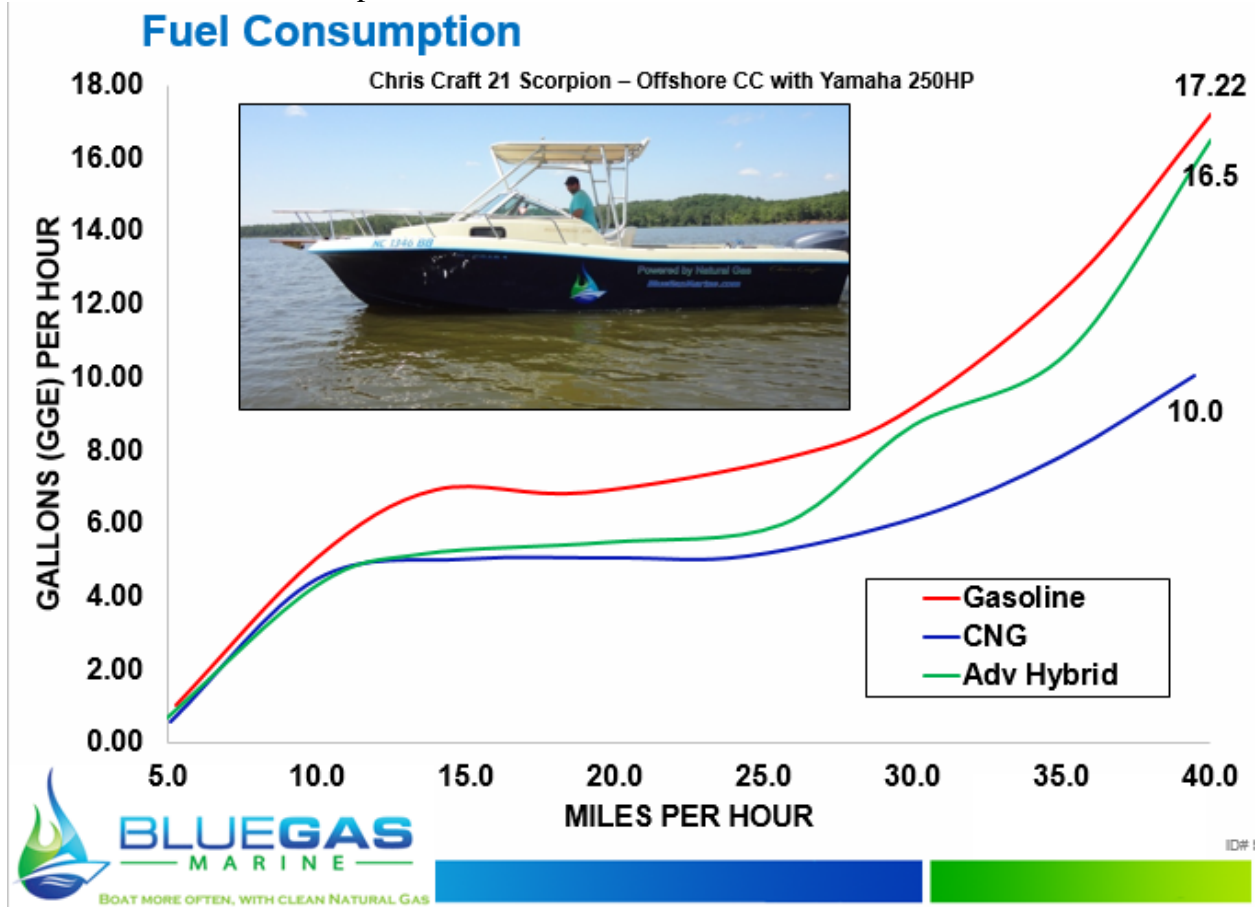


The fuel efficiency is displayed for each one of the modes of operation and the most efficient point highlighted with the display of its maximum efficiency. As expected, all three modes of operation reach maximum efficacy between speed and fuel consumption at a speed of 28 miles per hour. The interesting fact is the gasoline's maximum efficacy is 3.3 miles for every gallon burned, but if the boat is run at the same speed under the CNG mode, the efficiency gets much higher to 4.9 miles for every gallon equivalent of compressed natural gas. This represents an increase of efficiency of 48% which means you are spending a lot less fuel to go at the same speed. The efficiency of the Advanced Hybrid mode is 4.3 miles per gallon, which is better than gasoline but not as good as pure CNG. This is expected since it uses primarily natural gas, but it starts using more gasoline after beyond cruise speeds.

CNG mode gives you maximum efficiency and maximum economy but it is a couple seconds slower to the boat on plane. This is primarily used by ferries, towing, salvage and fishing boats. The Advanced Hybrid gives you good efficiency and the same acceleration as pure gasoline, so it is a compromise between the best of both worlds and it is a favorite of first responders and patrol boats that require quick reaction time but can still take advantage of CNG.

The operator can switch between any of the three modes of operation at any speed and the engines can be started on any mode as well. This is a feature that gives boats great safety on the water, because if there is a problem with the gasoline system, the operator can switch to CNG mode, start the engine and continue to operate (or return home). This is possible because the BGM add-on system is completely independent from the gasoline system and don't share any components with it.

On the next chart you will find the fuel consumption comparison of running the same boat in each one of the three modes of operation.



In summary, the CNG mode is always much more efficient than the other two at any speed, so the boat consumes the least amount of fuel in this mode. For example, at top speed, under gasoline mode this boat is consuming 17.22 gallons per hour, but only 10 gallons when run on CNG mode. If we assume that the boat runs on ethanol-free gasoline, which retails for \$4 in the largest boating markets in the US and fuels up with CNG for \$2 per GGE (gasoline gallon equivalent). This means that at the top speed of 40 miles-per-hour under gasoline-mode the cost to operate this boat is \$69 per hour, but only \$20 per hour under CNG, a fuel cost savings of 72%.

The diesel version of the BGM system is also an add-on, which has two modes of operation: pure-diesel and Advanced Hybrid. The diesel mode is the traditional mode of operation and uses 100% diesel. The Advanced Hybrid is a dual-fuel mode where Natural Gas replaces 50% to 89% of diesel. The operator can change between modes at any time and at any speed. BGM can also turn a diesel engine into a 100% natural gas engine, with permanent modifications, however that engine becomes a spark-ignited engine and therefore loses its ability to use diesel as a back-up mode, but it provides the maximum savings for an operator since it uses no diesel at all. This is popular with larger fleets of vessels that serve fixed routes like ferries.

BGM finds that most diesel vessel operators request to install the add-on system that provides the two-mode operation, since it allows them to keep diesel onboard as a back-up, but enjoy the savings of replacing most of it with natural gas. The following picture (Pic 4) is an example of a 25-ton harbor tug boat operated in the US to bring larger ships into port and take them out to deeper

water, which typically consumes 300,000 gallons of diesel per year with 2,000 combined horse power from two diesel propulsion engines. When the same vessel is operated primarily on the BGM Advanced Hybrid mode, it achieves savings of \$250,000 per year, recouping the investment in the BGM system in less than 2 years. The same vessel when operated in Europe can have savings greater than \$750,000 per year due to diesel being several times more expensive there than in the US, so the payback period in Europe is usually less than 12 months. Natural Gas is always much cheaper than the traditional fuel it replaces because it is so abundant and that is the case in most nations that do not subsidize marine diesel. This is forecasted to remain the case as most nations strive to become self-sufficient from their own natural gas domestic production.

The savings get even better when a fleet purchases a CNG station from BGM, which allows for its vessels to run on 50-cents per GGE and take advantage of the green incentives that exist in the US and many other countries. This is possible because unlike traditional fuels (gasoline and diesel) Natural Gas is very abundant around the world, but petroleum is scarce and expensive to produce.

Boating Applications:

As BGM started deploying the technology on boats and ships, the company started learning about the different ways boats are used and which of those uses makes them better candidates a BGM system and as you will see below, there are significant differences between using a boat on a commercial operation, or law enforcement patrol duty and even more so when a boat is used for recreational purposes. We will analyze below what are the operating profiles of each that makes that application a good candidate for CNG.

Conversely, BGM believes as a general rule that long-range boats and transient boats are not usually good candidates for CNG because they require greater quantities of fuel than there is room for without major modifications and transient boats require CNG stations at most ports or marinas they visit and that infrastructure is still in its infancy and not available everywhere, although there may be exceptions for certain long-range boats and certain transient boats.

The boats that make excellent candidates for CNG deployment are therefore, short range boats that return to the same port every day or often, so we don't have to install huge amounts of CNG onboard because they can fill up often and very fast.

Commercial:

Ferry

INSERT PIC and REFERENCE

The transport of passengers and vehicles between two points several times a day makes these boats great candidates for the use of CNG for several reasons. They are range bound, consume great amounts of diesel fuel due to their frequent daily operation and return to the same port where they depart from several times a day with most trips being less than 50 miles each way. Outfitting these ferries with BGM's Natural Gas Hybrid system and installing a station at one of the ports the ferry uses makes this project very feasible from a technical and economical perspectives. Also, because CNG is replacing up to 70% of the diesel, pollution/emissions could get reduced by 90%.

As an example, the North Carolina ferry system has 24 of these car and passenger ferries and a typical boat consumes 1,000 gallons of diesel per day. These vessels range in length from 150 to 220 feet in length and transport (at maximum capacity) of 40 to 50 cars and 300 passengers each. Some of the ports used with by these ferries are great candidates for a CNG station with available pipeline already in the ground, but other ports are located in barrier islands not currently serviced by gas pipelines, so those locations are not immediately great candidates for a CNG station.

This example shows how the boat usage profile and the pipeline gas availability are interconnected to make a project like this technically feasible and also provide a fast payback for the customer.

Fishing/Chartering

INSERT PIC and REFERENCE

Daily operations of fish harvesting at sea or in the sounds are usually associated with fleets of commercial fishing boats that make good candidates for CNG deployment because they are usually small vessels that return to port daily to offload their catch. These vessels usually have plenty of room for CNG tanks to be installed in and convenient to refuel at the port of departure.

Charter boats used for fishing or to transport passengers onto diving locations are part of the same operating profile group since they display similar behavior.

These boats are often 25 to 50 ft long and use one or two engines. Those smaller than 35 ft usually have a pair of large gasoline outboard engines and for boats greater than this length, they have one or two small diesel engines and a power generator. BGM hybrid systems are compatible with these engines, including the generators. These vessels consume anywhere from 20,000 to 50,000 gallons of traditional fuel per year. In the case of gasoline powered boats the BGM hybrid system has the mode to run the engines at 100% natural gas, or if equipped with diesel engines, the retrofitted boat can replace 50 to 70% of Diesel with natural gas.

Tugs

INSERT PIC and REFERENCE

At major metropolitan areas or main ports, there are usually a great number of tug boats. The tugs that transport commodity barges in rivers and along the seashore on very long distances are not great good candidates for CNG applications. However, those that push those barges on medium distances have a better chance of being candidates for CNG use. The ones that are used for short distances make the best case for a CNG deployment. In addition, major metropolitan areas attract large cargo ships and cruise liners and that also means that there are harbor tugs to bring them from the sea into port and vice-versa. The harbor tugs make up the ideal boats for CNG deployment within the tug category.

These vessels are usually 70 to 120ft with a pair of diesel propulsion engines ranging from 1,500 hp to 3,000 hp each and a twin set of power generators. Each boat consumes 50 to 80 gallons per hour during normal operation and only operate at peak consumption during less than 20% of their operating time.

Law Enforcement: Police, Sheriff, Coast Guard, Rescue

Patrolling the waters of a port or a city every day, has its own unique operational profile. Usually patrol boats range from 25 to 35 ft in length and have a couple of large gasoline outboard engines. These boats are usually used on patrol mode at a slow speed, with the throttle just barely above idle. Then, with a sudden response to an emergency or a critical call, the operator engages the full throttle to operate the boat at top speed or close to it, if the water and wind conditions allow it. This type of daily operation mixing large periods of slow speed intermixed with maximum speed are typical of marine units of the police, sheriff, coast guard (defender-class boats) and water rescue fleets of law enforcement. This is also the same operating profile of rescue and salvage fleets like Seatow and TowBoatsUS, where their engines idle in waterways and inlets waiting for the calls of recreational mariners in distress so they can go rescue them and tow their boat back to land. These

vessels usually spend 20 to 50 gallons of gasoline per day and return to their dock or base in the same day after their shift is complete. The size of these boats usually allows for BGM to install hybrid CNG systems that provide several days of operation between CNG fill-ups and they are the best candidates for CNG deployment on small boats, because it is this group of operators that spends the most fuel throughout the year for boats in this size range. These operators also use their engines at the worst possible efficiency, since outboard engines are the most efficient in fuel consumption at their cruise speed in the midrange of throttle. Natural gas, being much more efficient throughout the entire power curve, provides great efficiency gains. In addition, these boats always return to base at the end of the shift, which makes for a great refueling opportunity to have a CNG station at the base or a marina conveniently located near their base of operations. It was at the request of these operators that BGM developed the advanced hybrid mode or auto-mode and now a standard feature available on all BGM hybrid systems for gasoline boats. This mode uses primarily natural gas mixed with small quantities of gasoline. While on this mode, the BGM hybrid system is operating near maximum economy (mostly natural gas), however when the operator suddenly shifts into wide-open-throttle this mode allows the boat to operate with the same exact hole-shot times (time to plane) and speed as if it was running on gasoline-only mode. This provides the operator with the ability to act quickly and focus on responding to the emergency call without having to manually switch the BGM helm controls from CNG-only to Gasoline-Only mode. The advanced hybrid mode is also a favorite of fishermen that have returned from deep sea and prior to entering the dangerous waters of inlets with unpredictable waves and shallow sandbars, switch the BGM system from CNG-only (maximum economy) into hybrid mode, so in case they need maximum acceleration speed they have it to ride the crest of a wave or prevent the boat from being broadsided by an unpredictable wave pattern. The CNG-only mode can achieve the same speed of gasoline-only mode, but its acceleration is a couple of seconds slower on time-to-plane than running on pure gasoline, hence the advanced hybrid mode providing the best of both worlds: near maximum economy of natural gas operation and the fast acceleration of gasoline for critical moments without any need for manual switching between two fuels.

Recreational: Cruising, Fishing, Water Sports

It is important to note that out of all boats in the US, the number of recreational boats outweigh the number of commercial and law enforcement boats by a ratio of 9 recreational boats for every one that is non-recreational with the typical recreational user getting 12 trips on the water per year, according to the National Marine Manufacturers Association (NMMA).

According to the NMMA, more than 65% of these boats are engaged in recreational fishing, with a smaller percentage devoting time to cruising and site-seeing and an even smaller percentage engaging in water sports like water skiing and wake surfing.

Among recreational boaters, there is a subset that takes to water very frequently and at several times more than 12 trips of the average boater. BGM calls these boaters “professional weekenders” because they use their boats almost with the same frequency as professionals do, but mostly during the weekends. These boats make up the best option for deploying BGM’s hybrid CNG systems within the recreational category because of the great amount of fuel they use relative to the average boater and there is a good payback from an economic perspective.

However, there is also a strong (in numbers) group of average recreational boaters that are attracted to the clean properties of running on natural gas, primarily the fact that on CNG-only mode there is zero exhaust smoke (particulate matter emissions) and no exhaust odor. As you can imagine, a fishing boater is bombarded by noxious gasoline exhaust while trolling at low speeds

and a water skier or surfer has to breath all the smoke and unpleasant odors of gasoline while riding being the boat at the end of a rope. The CNG-only mode eliminates these problems, making recreational boating truly enjoyable and a healthier family past time. For these reasons, some of these boaters become BGM customers even if they don't consume enough fuel during the year to make the BGM system have an attractive economic payback. The payback for these boaters is the ecofriendliness and an enjoyable time on the water. Others like the convenience of being able to fill-up their boats at home with BGM's personal stations.

The recreational boats are primarily gasoline powered and range in size from 16 to 40ft with a few longer ones operating on diesel, primarily operated by cruisers.

The majority of these boats exhibits fleet behavior so when a marina has a station with a CNG station, the recreational boats that normally depart from that location or near that marina become good candidates for CNG systems. However, a marina normally starts with a CNG station to provide fuel to professionals and then proceeds to augment its market by providing fuel to recreational users as well, but the recreational boats would not make that CNG station economically viable by themselves without the existence of the professional fleets that anchor and attract the CNG station with their consistently high volume of fuel consumption.

Economics Drive Technology Adoption

The leading motivation for deploying BGM hybrid systems in the US and the rest of the world is economic. The leading factors are a reduction in operating cost from being able to use natural gas as a fuel that is traditionally much less expensive than petroleum based fuels. The environmental benefits still manifest themselves and are usually used for marketing purposes by the professional operators that deploy CNG systems, but the true motivation is the economics.

Environmental (Government projects)

The leading motivation for deploying BGM hybrid systems by municipal, state and federal governmental entities is a combination of BGM systems being environmentally friendly, but that they also reduce the operational cost. Often, government operational budgets are fixed with a small or no extra budget for adoption of new technology. However, the environmental benefits of the BGM system, make it eligible for emissions reductions grants and favorable tax status. Governments are then able to use grants for the capital expenditure to purchase and install the systems onboard their vessels and subsequently justify the lower operating expenditure with lower cost of operation and maintenance and a significant reduction in water and air emissions.

Fueling Operations

BGM designs and sells CNG fixed-stations for marinas, individual fleets and even small personal stations for recreational users to install at home which start at \$6,000 and can go to \$5 Million for a large station that can fuel dozens of ferries. Each is sized and tailored to the fueling capacities and fueling frequency of the boats that fill-up there.

In the US and several other countries, BGM has partnered with Natural Gas utilities and Natural Gas distributors to make Natural Gas available for boaters on the water, which means that in some locations BGM is able to provide fleet owners with fueling contracts for Natural Gas as an additional optional option that eliminates the need for a fleet to operate a natural gas station. Some boating locations currently do not have natural gas pipelines, so for those locations BGM developed mobile gas stations that are full turn-key filling stations packaged in a trailer that can be pulled by a light duty vehicle. This allows CNG to be transported and dispensed at any location

not currently served by pipelines. Boats equipped with LNG (Liquefied Natural Gas) can also be filled up directly from a tanker truck since LNG is not transported by pipeline.

Public stations

In the US, there are approximately 3,000 public and private CNG stations on the road with the great majority of these being publicly accessible stations, which serve as the refueling infrastructure for approximately 300,000 CNG vehicles. BGM recognized that by making its Natural Gas hybrid systems for boats compatible with on-road CNG filling stations, the marine market would be able to take advantage of this infrastructure and that is the case today.

In the US, all major metropolitan areas have natural gas vehicle fleets and several CNG stations located there are routinely used by BGM customers that normally transport their boats with a trailer and launch the boat at boat ramps. These customers normally operate gasoline-powered boats and the majority are recreational customers, but there are some commercial customers and law-enforcement operators in this group as well.

The filling nozzles that BGM installs in the marine fueling panel are of identical dimensions and built for the same operating pressures as those built for on-road use. The BGM-certified marine service centers that perform the BGM hybrid system installations also place the CNG fueling panel in locations that make it easier for boats to fill up easily while on the road, often the vehicle pulling the boat trailer and the boat can fill-up on the same side. This makes the filling operation more convenient. The only difference between the marine nozzles and the automotive is that the marine versions are made of materials that prevent and delay corrosion from saltwater exposure and humid salt air and they are placed inside protective enclosures that eliminate or greatly reduce the normal saltwater splashing that comes from operating a boat on plane.

Public Stations at Marinas

BGM also recognizes that a good portion of boats are usually not transported on trailers and therefore the only way to fill-up these is to create new CNG fill stations at marinas, which is the place where they normally fill-up with traditional fuels.

This presents both an opportunity and a challenge. The opportunity is that it creates a new revenue stream for marinas to sell a much cleaner fuel at half the price of marine grade gasoline, but with much larger profit margins because it is an American fuel, not usually susceptible to the volatile price fluctuations of traditional fuels whose price is greatly influenced by geo-political dynamics outside the US.

The challenge is that new fueling infrastructure has to be built in order for all boats at those locations to be fueled with CNG. To address this challenge, BGM has partnered with the major natural gas utility providers in several key markets and is opening small and scalable CNG stations that are economically supported by initial adopters that are professional operators of a fleet. The high fuel consumption of these professional fleets make a CNG station economically feasible and then all types of boats can take advantage of it. Because BGM is leading this market development in the US, the company can estimate when it is time to scale up the fueling capabilities of these stations since orders for additional hybrid systems at those locations provide a forecasting window into future CNG consumption.

It is important to start with small stations because the reduced cost makes more stations possible. Once the market is established with a station at a marina, its scalability allows it to grow as the number of boats operating with CNG grows locally.

There are approximately 16,000 marinas in the US, however only less than half of those offer any fuel, so the task of providing a good coverage of CNG availability to the majority of the marine

market is not as daunting of a challenge as offering CNG at all 160,000 on-road fuel stations for vehicles.

In addition, the great majority of boats display fleet behavior regardless of how they are used or if they belong to a fleet or not. Fleet behavior means that they depart port, go about their route and return to the same port usually in the same day, without expecting to fill-up at sea or other ports. Only 1% of boats exhibit transient behavior, going from port to port. Thus, fleet behavior makes boats excellent candidates for the deployment of CNG fueling systems. The fleet behavior is also where the success is in the deployment of CNG systems over the road.

Personal Station: Home and Boat Yard

CNG is quite different than traditional liquid fuels. One of those differences is that it is primarily distributed via pipelines. BGM recognizes that this is a tremendous advantage for a boat operator because the same pipeline that delivers gas for heat and cooking at home or at a commercial location can also be used to fuel a boat.

However, the pressure in that pipeline is usually 5 psi and a CNG tank aboard a boat is full at 3600 psi.

To solve this challenge BGM provides a small personal size station that is rated as an appliance and can fill the CNG tanks of a boat at home or at a boat yard over a number of hours, while the boat is not in use. This is called a timed-fill station and it uses no fuel storage. Instead, it compresses the natural gas from the pipeline into the boat's CNG tanks until these are full, over a period of hours, usually overnight.

This is also the most inexpensive way to fill-up on CNG since the gas at home is not sold as a fuel but at the state-regulated utility price. A common average price equivalence in 2017 is 60-cents per gasoline-gallon-equivalent (GGE).

A few BGM customers request the personal station when they purchase a BGM hybrid system. This is especially popular for recreational customers that keep their boat at the house, on a trailer or on the water at a private dock near their house, which already uses natural gas for heat and cooking. The convenience of never having to wait in line to fill up the boat at a public marina or at a public gas station while trailering it, is what drives this motivation.

Mobile Fuel Station

BGM has found that certain marinas that currently dispense traditional fuels, do not have natural gas pipelines on their property. This is more frequent in states with warmer climates that do not rely on natural gas to create heat during the winter or because the marina does not have a restaurant on site that uses natural gas for cooking (a common practice). Florida is a good example of this, where there may be natural gas on the main street, but not at the marina property.

To solve this challenge, BGM created Mobile Fuel Stations that are trailers equipped with CNG storage tanks, a fuel dispenser mechanism and a meter.

Using these fuel stations, a marina can start providing CNG on the water immediately while the project to build a CNG station and extending the pipeline from the street is executed as the long-term solution.

These mobile stations require only a light duty vehicle like a pick-up truck to tow it to a CNG station and fill-up its capacity and return immediately to the marina. Usually this is a solution used when a location already has a CNG boat in operation but the permanent fixed station is not yet ready.

Alternative uses for these stations are to support the temporary operation of any CNG boat that gets deployed to an area where it normally does not operate and therefore there may not be marine CNG stations. This is sometimes the case with certain law enforcement boats, which get deployed to areas in support of an event or to augment service coverage during a short busy time of the year, like the summer season in many coastal states.

Summary

The CNG hybrid technology is here now and it is being deployed in the US and around the world on a wide range of boats with different engines, boat sizes and operating profiles, but just like any other new technology it has found a sweet-spot with the commercial operators of ferries, fishing vessels, law enforcement and rescue fleets. The large numbers of recreational users that boat above average and those who are attracted by the clean benefits of natural gas are also important customers of new CNG stations that are being built in several marinas in the US and abroad. The refueling infrastructure on land helps the marine market for CNG boats establish itself with the large number of public stations where boats transported on trailers can fill-up, while the build of CNG stations at marinas are ramping up and creating solutions for the largest cost of operating a boat: fuel cost. BGM has created a new category of products in the marine industry and with it an ecosystem where all players benefit: The boaters get half priced fuel and much greater fuel efficiency, the marinas get to sell an American fuel that is more profitable at a lower retail price than the traditional liquid fuels at a higher retail price and has no water spills and messy water contamination or spills, the marine service centers get a new source of revenue from installing and maintaining BGM's CNG hybrid systems and engine maintenance becomes easier and cheaper, the US gets greater energy security by rolling out a domestic fuel and the marine industry assures that geo-political turmoil outside of the US has less chance to affect marine fuel prices and therefore the collapse of its boat and engine sales. The air, rivers, lakes and the ocean also benefit from the cleanliness of emissions that come out of these boats and the significant reduction of pollution. These are the true direct and indirect benefits of the deployment of CNG as a marine fuel. The path forward is clear, CNG is the clean and affordable fuel that can evolve the marine industry into a clean and more affordable plane of existence.

ACKNOWLEDGMENTS

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REFERENCES

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