

Green Economy: Dubai's Paradigm Shift in Using Methane Gas as Renewable Energy

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Abstract

This case study is intended to expand the horizon of Methane Gas threats to environment, which are produced from treatment of Sewage Waste at Jebel Ali Sewage Treatment Plant in the Emirate of Dubai, United Arab Emirates. The paper then, under the basis of UAE's Green Economy, will assess the opportunity of using Methane Gas as a renewable energy, and in comparison with literature.

Furthermore, the case study provides concept of Methane Gas as Compressed Natural Gas (CNG) to be used in vehicles as an alternative fuel instead of fossil fuels. This paper is also an addition to another two research papers that author has carried out, related to emission of gases from Sewage Treatment Plants; one related to H₂S, and the other paper related to Carbon Capture, Storage and Utilization.

Keywords: *Methane Gas, CNG, Renewable Energy, Green Economy, STP Gases*

Foreword

The result of this case study is intended to expand the horizon of importance of reusability of Methane Gas that are generated from treatment of Sewage Wastewater in Sewage Treatment Plants (STP's), which is classified as Green House Gases (GHG), and consideration of implementation of Clean Development Mechanism (CDM) project by concerned authorities in the Emirate of Dubai to produce Compressed Natural Gas (CNG) as an alternative renewable fuel for vehicles.

Introduction

"The EU wants to see alternative fuels accounting for 20 per cent of vehicle fuel by 2020, half of which could be natural gas" (Crosse, 2008)."

The term *Natural Gas* also refers to naturally occurring fossil fuel gases that are primarily composed of methane, with some ethane, propane, butane and other heavier hydrocarbons, which are removed in production. Therefore, commercial *natural gas* is basically methane. Natural gas replacements may require changes to fueling infrastructure and maintenance facilities. CNG are currently used to power yard tractors, forklifts and loaders"¹.

¹http://www.designmatrix.com/pl/ecopl/natural_gas_vehicles.html

"CNG is made by compressing natural gas, which is mainly composed of methane. It is stored and distributed in hard containers at a pressure of 2,900 to 3,600 psi. CNG is a non-toxic, clean burning fuel and reduces carbon emissions, compared with gasoline. According to the US Environmental Protection Agency, using CNG can result in 30 to 40% less greenhouse gas emissions" (Smith, 2011).

The Importance of the issue

Blass (2006) cites that the Kyoto Protocol adopted in December 1997 by United Nations Framework Convention on Climate Change (UNFCCC) is significant because it sets limits and standards of emission GHG's. "CH₄ (Methane) represents approximately 14 % of the total GHG emissions worldwide. CH₄, with a global warming potential 23 times higher than that of CO₂ and an atmospheric concentration increasing at 0.2–1 %year⁻¹, is mainly emitted from organic waste treatment activities such as landfilling, composting, and wastewater treatment" (López, Quijano, Souza, Estrada, Lebrero& Muñoz, 2013).

"As warming agents, methane molecules are about 30 times stronger than Carbon Dioxide" (Easterbrook, 2001).

"Natural gas is a combustible mixture of hydrocarbon gases. While natural gas is formed primarily of methane, it can also include ethane, propane, butane, and pentane." (Park & Tak, 2012). "The major component of natural gas is methane that has the lowest molecular weight (only 16) and simplest structure (one carbon atom and four hydrogen atoms in a molecule) as compared to diesel and gasoline" (Khillare, Agarwal&Shridhar, 2008).

There are varieties of sources of Methane Gas emissions from manmade activities. Municipal Landfills and STP's are some sources of such. In the recent years, gases from STP's have begun to have significant concerns on Dubai's ambient air quality and Public Health. These gases have potential pollution problems as well as negative health impacts.

UAE's Green Economy

The concept of green economy focuses primarily on the intersection between environment and economy. This recalls the 1992 Rio Conference: the United Nations Conference on Environment and Development².

"We launched today UAE Green Development Strategy to build green economy in UAE" (Sheikh Mohammed Bin Rashed Al Maktoum, 2012). In his January 2012 announcement, Sheikh Mohammed adds, "UAE Green Development Strategy aims to build an economy that preserves the environment, and an environment that supports economic growth. We seek an economy that will provide opportunities for our citizens, preserve our resources, and enhance our global competitiveness".

²<http://www.uncsd2012.org/index.php?menu=62>

UAE's Green Economy strategy includes six tracks:

1. The first track aims to promote renewable energy, clean fuels, and energy efficiency usage.
2. The second track is designed to encourage investments in green economy and green technologies and to create job opportunities for citizens.
3. The third track is about the green city and it includes urban planning, sustainable transportation, and clean air initiatives.
4. The fourth track aims to deal with climate change through reducing carbon emissions, encouraging organic agriculture, and preserving biodiversity.
5. The fifth track aims to rationalize the use of our water and energy resources, encourage recycling, and raise environmental awareness.
6. The sixth track includes the green technology and will focus on carbon capturing and storage technologies plus generating energy from waste.

Organization's Background

Dubai Municipality is currently operating two main STP's, serving the city, one located in Al Warsan and the other STP in Jebel Ali. For the purpose of this case study, the Jebel Ali Sewage Treatment Plant (JASTP) will be focused on.

JASTP³ is designed to treat 300,000 m³/d with a process peak flow of 480,000 m³/d. The plant is located along the Jebel Ali Lahbab road, southeast of the Jebel Ali Free Zone. Sewage is collected and pumped through sewer network to the plant, 70 km from the city center. In addition, tankered wastes (Trade and Domestic) are also discharged to the plant.

Main Figures for JASTP

- Cost: AED 1.550 Billion
- Capacity: 300,000 m³/day
- Total Land Area: 680 hectares
- Constructed Area: 43 hectares

Important Dates

- Contract Commencement Date: 15 April 2007
- Contract Completion Date: 13 April 2010
- Received Tankered Sewage: August 2009
- Received Main Inflow from Network: 17 October 2010

Treatment Stages:

- Preliminary Mechanical Stage
- Primary Settling Stage

³ Source of Organization's Background data: Dubai Municipality - JASTP

- Biological Treatment Stage
- Polishing, Disinfection and Reuse
- Sludge Treatment Process
 - Gravity Belt Thickeners & Rotary Thickeners
 - Digesters
 - Sludge Dewatering and Thermal Drying
- Odor Control Units
- Laboratory

Scope of Case Study

This case study expands the opportunity in production of CNG from Methane Gas as renewable energy. The case study is preliminary based on first track of UAE's Green Economy, which aims to promote renewable energy, clean fuels, and energy efficiency usage. Considering the huge existing - and moreover potential - methane gas resources from STP gas at JASTP, there is an economic (and strategic) sense and opportunity to replace gasoline and diesel in vehicles with CNG. A variation of such vehicles is the bi-fuel vehicle, which can switch between gasoline and CNG.

Economic Benefits

"The cost of the fuel will be crucial, especially in emerging markets, where CNG can sell for as little as €3/kg compared to between €6 and € 10/kg for gasoline. Use of CNG could also help to improve city air quality" (Crosse, 2008).

Natural gas vehicles usually run on compressed natural gas (CNG). According to the U.S. Dept. of Energy (DOE) in October 2006, the national average for gasoline was \$2.22/gal, and the average price for CNG was \$1.77/GGE (gasoline gallon equivalents) (80% of gasoline). By July 2007 gasoline had risen to \$3.03/gal while CNG was \$2.10/GGE (69% of gasoline). A look at CNG price websites in October 2008 show prices in southern California ranging from \$1.75 to \$3.00 per GGE⁴.

Environmental Benefits

"Air pollution is a major threat to public health due to the effects of its environmental degradation, causing 2 million premature deaths worldwide per year. Air pollution also causes respiratory infections, heart disease, and lung cancer" (Park & Tak, 2012).

"Heavy vehicles in particular, such as public buses and garbage trucks, emit a large amount of air pollutants. In an effort to confront the problems related to vehicle exhaust gas, existing diesel vehicles have been replaced with CNG vehicles in many countries" (Park & Tak, 2012). "

In particular, vehicle exhaust gas is considered as the main culprit in the fight against urban air pollution" (Park & Tak, 2012).

⁴ Source: http://www.designmatrix.com/pl/ecopl/natural_gas_vehicles.html

“Unburned carbon atoms are more likely to occur, and the composition of the unburned and partially oxidized hydrocarbons in the diesel exhaust are much more complex and extend over a larger range of molecular size than those for Natural Gas and, consequently increase the PM emissions” (Khillare, Agarwal&Shridhar, 2008). “Environmental policy can be justified on the grounds that its benefits easily diffuse throughout society and directly impact the health of its citizens” (Park & Tak, 2012). “Consisting principally of methane, CNG is high in hydrogen and so has a high energy content while being low in carbon” (Crosse, 2008).

Natural gas vehicles (NGV) have many environmental benefits over gasoline and diesel, including⁵:

- Vehicles produce 60% of carbon monoxide (CO) pollution in the U.S. according to the EPA. NGVs reduce carbon monoxide (CO) exhaust emissions by 70%, over gasoline vehicles.
- Vehicles produce 33% of hydrocarbon and nitrogen oxide emissions in the US according to the EPA. NGVs reduce volatile organic compounds (VOCs) by 89% and nitrogen oxides (NOx) by 87%, which combine to make ozone and smog, over gasoline vehicles.
- About 82% of man-made greenhouse gases are carbon dioxide (CO₂), but the methane molecule contains about half of the carbon than that of gasoline or diesel. In fact, of all fossil fuels, natural gas produces the least CO₂ per unit of energy. Consequently, although methane is a greenhouse gas too, NGVs produce 20% to 30% less greenhouse gases than gasoline vehicles and 15% to 23% less than diesel vehicles. In addition, NGVs have sealed tanks and fuel systems that reduce evaporation. Using bio-methane from sources that would otherwise release it into the atmosphere would also reduce this greenhouse gas source.
- NVGs help eliminate groundwater contamination from leaking gasoline and diesel fuels.

Vehicles

Natural gas has a variety of fuel applications on and off the highways. Its versatility can power classic hot rods and off-road vehicles such as lawnmowers, forklifts, freight mounts and street sweepers. Since some of these specialty vehicles require time in idle with the motor running, natural gas proves to be a cleaner and more cost-effective alternative to gasoline- and diesel-powered engines. These benefits also make it more attractive to city leaders and manufacturers when considering fleet applications

Today, there are two types of CNG fuel systems available:

- Dedicated vehicles or conversions that run solely on CNG and normally have a fuel capacity equal to or larger than the original gasoline or diesel tank.
- Bi-fuel vehicles that have the ability to run on either CNG or gasoline/diesel. These bi-fuel vehicles typically retain their original gasoline/diesel tank and are retrofitted with an additional, smaller-capacity CNG tank.

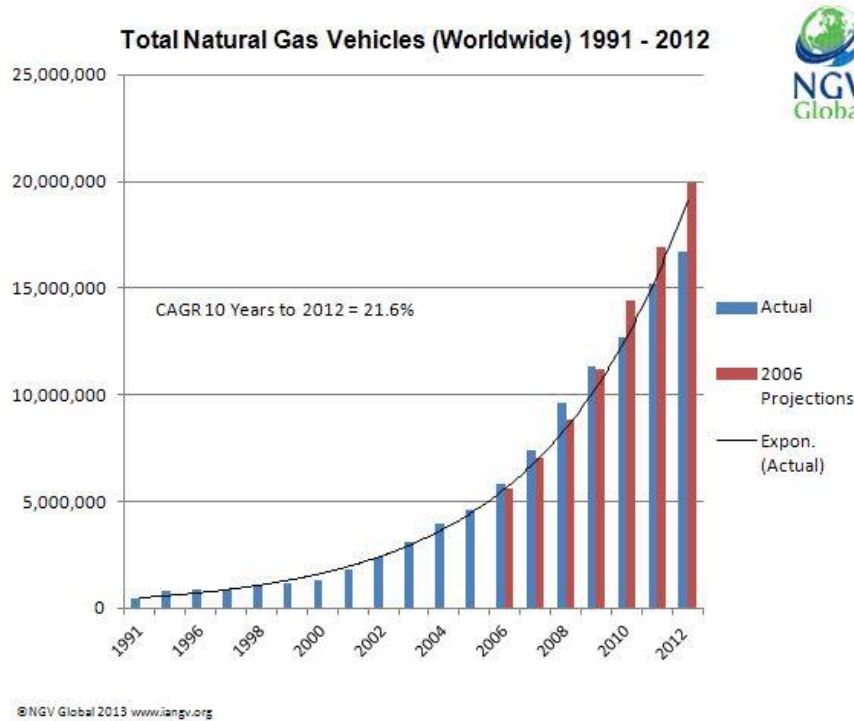
Currently, about 12-15% of public transit buses in the U.S. run on natural gas (either CNG or LNG – liquefied natural gas). That number is growing, with nearly one in five buses on order today slated to run

⁵ Source: http://www.designmatrix.com/pl/ecopl/natural_gas_vehicles.html

on natural gas. States with the highest consumption of natural gas for transportation are California, New York, Texas, Georgia, Massachusetts and D.C.⁶

Graph 1 details us an exponential growth of NGV usability from 1991 to the year 2012.

Graph 1: Total Natural Gas Vehicles⁷



The scope of this case study is to use Methane Gas from JASTP to produce Compressed Natural Gas (CNG) as an alternative renewable fuel for vehicles. More specifically, the case study expands the discussion of capturing Methane Gas, which is classified as Green House Gas (GHG) from Dubai's Sewage Treatment Plant (STP).

Digesters' Gas

The thickened sludge is pumped to the anaerobic digesters after preheating at the heat exchangers. Anaerobic Digestion of the sludge takes place in the digesters producing stabilized sludge and biogas as products. Biogas produced a digesters are partially used as fuel for the dryers in Thermal Dryers.

Current Gas Production at JASTP is measured on an average of 30,000 m³/day⁸. Table 1, which is a result of laboratory analysis obtained from JASTP reveals that at on an average, at least 66% of daily gas

⁶ Source: <http://www.cngnow.com/vehicles/Pages/information.aspx>

⁷ Source: http://www.iangv.org/wp-content/uploads/2013/02/NGV_Growth_Chart_2012.jpg

⁸ Source: Dubai Municipality – Jebel Ali Sewage Treatment Plant

production at JASTP is Methane Gas. This is equivalent to a daily average of 19800 m³/day of Methane Gas.

Table 1: STP Digester Gas Analysis⁹:

Sample Date:	13/08/2012	
Nitrogen	0.60	%
Carbon Dioxide	31.23	%
H ₂ S	2.06	%
Methane	66.11	%
TOTAL	100%	%
AvgMolWt	25.04	Gram/mol
SP. Gravity	0.8644	
Gross BTU/Cu Ft	681.72	BTU/Cu Ft
Sulfur	19,388	PPM

CNG equivalent to a gallon of gasoline¹⁰

- 1.25 Therm = 1 Gallon equivalent of gasoline.
- A Therm is a unit of heat energy equal to 100,000 British thermal units (BTU). It is approximately the energy equivalent of burning 100 cubic feet (often referred to a 1 Ccf) of natural gas.

Table 2: Natural Gas vs. Gasoline Vehicles¹¹

Natural Gas Vehicle (8 GGE tank)	\$1.31 x 8 = \$10.48 per tank	28 mpg	224 Miles	\$.0468
Gasoline Vehicle (8 gallon tank)	\$1.70 x 8 = \$13.60 per tank	28 mpg	224 Miles	\$.0607

NGV tanks are sized in "gallons of gasoline equivalent" (GGE). NGVs get the same mileage per GGE as gasoline powered vehicles get per gallon of gasoline (i.e., a Honda Civic GX with an 8 GGE tank will get the same gas mileage and distance as a gasoline powered Honda with an 8 gallon gasoline fuel tank.) This table is based on compressed natural gas selling for \$1.31 per GGE and gasoline selling for \$1.70 per gallon. Fuel prices fluctuate regularly and should be taken into account when making purchasing decisions.

SWOT Analysis

⁹ Source: Dubai Municipality – Jebel Ali Sewage Treatment Plant

¹⁰ Source: <http://www.sceg.com/en/residential-services/why-choose-natural-gas/natural-gas-vehicles/>

¹¹ Source: <http://www.sceg.com/en/residential-services/why-choose-natural-gas/natural-gas-vehicles/>

Following extracts of SWOT analysis further expands the importance of horizon of usability of Methane Gas as CNG.

Strengths

- “In contrast bio-fuel CNG engines are a mature, cost effective technology and do not suffer from limited range” (Volkswagen backs CNG to cut CO₂, 2013).
- Minimizing the emitting of gas burning into ambient air.
- Reduction of operation cost, by using CNG instead of fossil fuel.

Weaknesses

“Although available in abundance and an ideal fuel for internal combustion engines in more than one respect, compressed natural gas (CNG) is still relatively little used to power vehicles. The problem has been infrastructure rather than vehicle technology” (Crosse, 2008).

“Other problems will be harder to solve - such as the lack of CNG filling stations in Europe” (Volkswagen backs CNG to cut CO₂, 2013).

Following could also be listed as weaknesses and challenges for the transformation from fossil fuels to CNG:

- Extra Costs related to modifications of vehicles such as cylinders used, filling, Vehicle Kits, storage within vehicles
- CNG Vehicle Installation
- CNG Re-fuelling Stations
- CNG Trailers used in mother-daughter refueling systems
- CNG Vehicle workshops and parking facilities.

Opportunities

- Carbon footprint reduction
- Possibility of earning Carbon Credit

Threats

In U.S., natural gas or CNG vehicle fuel systems must also meet U.S. Federal Motor Vehicle Safety Standards 303 and 304 or any other internationally acknowledged legislations and/or standards (i.e. ISO 19078 for Gas Cylinder requalification inspection standards). Cylinders must be designed not to rupture when fully fueled over six times a day, 365 days a year, far beyond what they will see in service.

Cylinders must even withstand a bonfire test and penetration by a 30-caliber bullet without No matter what the fuel, fueling stations, indoor parking structures and repair garages must be built to ensure high levels of safety. Requirements for facilities handling natural gas and natural gas vehicles may differ from those for gasoline or diesel vehicles. For example, leaking diesel and gasoline form puddles on the

floor. Natural gas normally rises toward the ceiling and disperses. Therefore the danger of fire would be greatest near the floor for liquid fuels and near the ceiling for natural gas.

"Storage of the gas is crucial. Engineers are seeking lighter alternatives to steel. Magna Steyr is developing a module that can be installed into a vehicle as a complete unit" (Crosse, 2008).

Safety

"The stringent safety standards for compressed gas storage also make development difficult" (Crosse, 2008). "CNG has a fairly high octane number, which means it can withstand the pressure of the engine cylinder better than other fuels. It also has a high burning point, so the danger of explosion is quite low even if it leaks into the air. In addition, the caloric value per kilogram of CNG is 55 mega joules (MJ), which is relatively high compared to other fuels" (Park & Tak, 2012).

Conclusion

"An estimated 110bn cm of gas is flared every year, pumping around 200m t/y of carbon dioxide and 1.5m t/y of methane into the atmosphere" (Thomas, 2003). Air emissions have no physical boundaries or borders. They cross from a city to another, and from one country to the next. Therefore, any air pollution eventually affects the whole world. "Think globally and act locally, and do it in a way that cuts costs." (Ball, 2005).

Dubai, inline with Green Economy and Sustainable Development, has all the reasons in serious consideration of Methane Gas capture from its STP's and production of CNG as renewable energy. This will effectively contribute to reduction of emitting Methane as GHG into ambient air, which is a contributor of global warming. Additionally, producing CNG provides a cleaner alternative renewable energy for vehicles, in which in turn produces and emits less pollutants into ambient air quality.

It's furthermore suggested to have a clear environmental policy for proper and sustainable implementation of such CDM projects.

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