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An economic and carbon analysis of biomethane production from food waste to be used as a transport fuel in Mexico

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ABSTRACT

Biomethane produced from food waste is a potential fuel for urban buses in Mexico to reduce greenhouse gas (GHG) emissions in transport. Biomethane from food waste can potentially produce 42.32 PJ per year, equivalent to 6.5% of the energy content of diesel used in transport in 2015. By replacing diesel with biomethane from food waste, a reduction of 17.91 $MtCO_2e$ can be effected, 6.06% of the 2050 GHG emissions target. The economic feasibility of a biomethane plant for a Mexican city was investigated using two scenarios: co-digestion of food waste and sewage sludge (scenario 1); and co-digestion of food waste and pig slurry (scenario 2), both scenarios utilising anaerobic high density polyurethane digesters. Economic performance based on net present value (NPV) gave a positive outcome for scenario 1 with 33% of the revenue coming from gate fees. The levelised cost of energy (LCOE) for biomethane was $US 11.32/GJ ($US 40c/m^3 CH_4). Scenario 2 has a negative NPV; to break even (LCOE) biomethane has to be sold at $US 14.38/GJ ($US 51 c/m^3 CH_4). Biomethane from scenario 2 can be economically viable if a subsidy of $US 1.38/GJ is applied, equivalent to 5% of the cost of diesel.

1. Introduction

1.1. Greenhouse gas emissions in Mexico

By 2050 Mexico is committed to reduce its greenhouse gas (GHG) emissions by 50% (287.92 Mt CO_2e) with respect to the emissions produced in the year 2000 (SEMARNAT, 2013a). To achieve this, a National Strategy for Climate Change (ENCC) was published in 2013 (SEMARNAT, 2013a). This strategy establishes a road map for new national policies and courses of action involving government departments and the private sector in compliance with the General Law for Climate Change (LGCC) (DOF, 2012; SEMARNAT, 2013a). The ENCC is primarily focused on the creation of economic instruments that promote the production and use of renewable electricity, sustainable development, energy efficiency and waste management (SEMARNAT, 2013a). Within the LGCC framework, large electricity consumers are obliged to purchase energy from renewable sources (clean energy certificates) equivalent to 5% of their annual electricity consumption (DOF, 2012). In 2016 the first auction of clean energy certificates (CECs) was carried out, reaching an average price of $US 45.4/MWh (KPMG, 2016). According to the National Inventory of GHG, in 2013, 665.30 Mt CO_2eq was produced in Mexico (SEMARNAT, 2015). The major contributor was the transport sector with a 26.17% share (174.15 Mt CO_2eq) followed by electricity generation with 19.02% (126.6 Mt CO_2eq) (Fig. 1).

1.2. Renewable energy in transport

Energy in transport accounted for 2361.75 PJ in 2015 equating to 44.7% of the total energy consumption in the country (SENER, 2015). The three most consumed fuels were petrol (1498.58 PJ), diesel (652.2 PJ), and liquefied petroleum gas (53.09 PJ). Natural gas consumption in this sector was only 0.83 PJ, clearly indicating the lack of natural gas vehicles (NGVs) and gas fuelling stations. As of

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Nomenclature

AD	Anaerobic digestion
BMP	Biomethane Potential Test
BOC	Biofuel Obligation Certificate
CAPEX	Capital Expenditure
CDM	Clean Development Mechanism
CEC	Clean Energy Certificate
CNG	Compressed Natural Gas
DGE	Diesel Gallon Equivalent
DS	Dry Solids
FW	Food Waste
GGE	Gallons of Gasoline Equivalent
HDPE	High Density Polyurethane
HWPS	High Pressure Water Scrubbing
LCOE	Levelised Cost of Energy
NGV	Natural Gas Vehicle
NPV	Net Present Value
OPEX	Operational Expenditure
OFMSW	Organic Fraction of Municipal Solid Waste
SMY	Specific Methane Yield
VS	Volatile solids
WWTP	Waste Water Treatment Plant

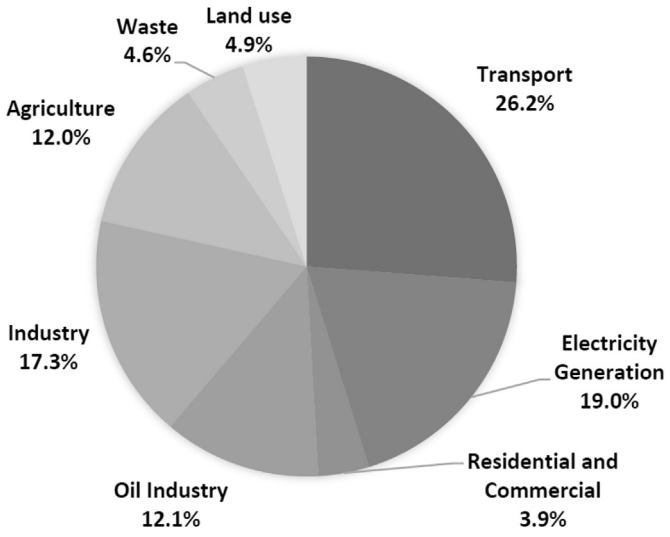

Fig. 1. GHG emissions per sector in 2013 in Mexico (SEMARNAT, 2015).

2015, the NGV fleet was estimated at 3100 vehicles (SENER, 2016a). The use of renewable fuels (biodiesel and bioethanol) remains incipient. According to SENER (National Secretariat of Energy) the advances of biofuels in Mexico are focused on the design and implementation of new policies that encourage their production and use as described in the Law for the Promotion and Introduction of Bioenergy (DOF, 2008; SENER, 2016b). The introduction of ethanol within the energy matrix is set to commence in 2017 with a test trial that proposes to introduce a 5.8% ethanol mix in petrol (SENER/CONUEE, 2016). The production of biodiesel is estimated to be 4182 m^3/year and is undertaken in demonstration scale plants using mostly used oil as raw material (SENER, 2016b). The production of biogas reached 1.87 PJ in 2015, however, the majority of this gas was used to produce electricity (SENER, 2015). To date, no firm targets have been set for the production and use of biofuels, except ethanol blending.

1.3. Biomethane as a transport fuel

Biogas that has been upgraded (through the removal of CO_2) and cleaned from contaminants is termed biomethane. Biomethane can be obtained using biogas purification systems such as membranes, bio-filters and water scrubbers amongst other technologies. This gaseous biofuel can be used as a substitute for natural gas in NGVs. The use of natural gas as a transport fuel is growing worldwide. As of 2015 there were over 18 million vehicles running on natural gas (Khan et al., 2015). Countries such as Iran, Pakistan, China, Argentina and Brazil have developed a strong market for NGVs. In Europe natural gas is replacing traditional fuels (diesel and petrol) in buses and refuse collection trucks (Bord Gais, 2010). Sweden uses natural gas predominantly in transport, with 195 NGV refuelling stations (64 with biomethane) and ca. 60 biogas upgrading plants. The NGV fleet in Sweden is estimated at 44,000 vehicles (Fevre, 2014). In the city of Linkoping, biomethane has been used in all the urban city buses since 2002, sourced from an anaerobic digestion plant that treats a combination of household waste, animal manure, abattoir waste and industrial organic waste (IEA, 2005). In Mexico, the number of NGVs may be set to increase as SEMARNAT invests in projects to encourage the use of fuels with low carbon footprint. An emphasis is placed on natural gas as it is considered “the cleanest and securest fuel in the country” (SEMARNAT, 2017).

1.4. Anaerobic digestion in Mexico: state of the art

Anaerobic digestion (AD) has been used in Mexico to treat municipal and industrial wastewater and sewage sludge since the 1980s. In the majority of these plants, the biogas produced is not recovered due to its low production and associated high costs (Monroy et al., 1998). Interest in AD has grown significantly in the last 15 years especially in the agricultural sector to treat pig, dairy and cattle slurry. This is a result of the Kyoto Protocol's clean development mechanism (CDM), which allowed farmers to sell carbon credits (Lokey, 2009). The biogas plants are typically high-density polyurethane (HDPE) covered lagoons with no mechanical agitation. Slurry is pumped from the farms to the digesters without any pre-treatment. As of 2012, there were 966 biodigesters treating animal slurries in Mexico (Weber et al., 2012). AD of the organic fraction of municipal solid waste (OFMSW) and food waste (FW) has been less employed. In 2015, the first OFMSW digestion facility was employed in the city of Merida. This plant mechanically separates the inorganic fraction of the municipal solid waste from the organic fraction. The biogas generated powers an internal combustion engine to produce electricity, which is sold to a third party using the national electric grid. The technology employed for this plant is similar to the aforementioned agricultural digesters in Mexico, consisting of a HDPE anaerobic pond with a cover on top to collect the biogas generated. Given the novelty of this system in the region, little information regarding design and operation is available.

To date, there are no biogas plants that aim to produce biomethane as a transport fuel in Mexico; most of the efforts undertaken in this area are solely based on the sale of carbon credits. Furthermore, very few studies have been conducted that analyse