Mexico's Renewable Natural Gas Potential

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1. Introduction

Biomethane is a biofuel derived from the upgrading of biogas (2018 CCST Report, June 2018), and similarly to natural gas, it is predominantly composed of methane gas (CH_4). Biogas, in turn, is the gas produced through the biological conversion of biomass because of its decomposition or fermentation (Chamber of Deputies of the Congress of the Union, 2008). The term **biofuel** (also referred to as bioenergy fuel) refers to fuels produced directly or indirectly from biomass and is categorized based on its origin into three sources: wood fuels; agrofuels; and municipal waste-derived byproducts (Center for Studies on Sustainable Rural Development and Food Sovereignty, 2007).

The use of biomass for energy purposes is known as **bioenergy**, which is classified into **traditional** and **modern** (International Renewable Energy Agency, IRENA, 2022). Traditional bioenergy includes the use of wood (firewood), animal waste (mainly excreta), and charcoal for combustion. Modern bioenergy involves the energetic use of primarily residual biomass to obtain different types of biofuels—gaseous, liquid, or solid. Examples of these include biogas and biomethane (gaseous); methanol and ethanol (liquid); and wood pellets or pellets made from other organic compounds (solid).

Depending on the type of biomass used, biofuels are also classified into first, second, or third generation. **First-generation biofuels** are produced from food crops intended for human consumption. **Second-generation biofuels** come primarily from non-food agricultural crops. **Third-generation biofuels** do not rely on agricultural inputs and thus do not impact the food chain. In this category, biofuels are obtained through molecular biology techniques applied to non-food plant inputs with fast growth or high energy density, such as algae and microalgae (Clemente Reyes, Ingeniería ambiental; factor clave de la bioenergía y la sustentabilidad, 2022, págs. 4-8).[1]

The most common and cost-effective method for utilizing various types of residual biomass to produce biogas is **anaerobic digestion**. In this process, organic matter generates several gases that can be upgraded to obtain **biomethane**. (Intergovernmental Panel on Climate Change, IPCC, 2012).

Biomethane, also known as **Renewable Natural Gas (RNG)**, is virtually indistinguishable from fossil natural gas and can be transported and used in the same way (International Energy Agency, IEA, 2020). Most of the biomethane currently produced worldwide is distributed through local natural gas (NG) pipeline systems and is

[1] The biomass derived from Municipal Solid Waste (MSW) and sludge from Wastewater Treatment Plants (WWTPs) does not originate from crops and therefore is not classified as conventional first- or second-generation biofuel. It is considered part of advanced biofuels or extended second-generation biofuels, as it utilizes organic waste without affecting food production or requiring additional use of agricultural land.

primarily used for thermal purposes or to generate electricity as a fuel in engines, boilers, or natural gas turbines. It can also be compressed or converted into various liquid fuels using different processes. In all these cases, biomethane is an alternative for emission reduction (Intergovernmental Panel on Climate Change, IPCC, 2012). When compressed, biomethane can be used locally as fuel for vehicle fleets or, in the form of RNG, blended and injected into NG transportation pipelines (International Council on Clean Transportation, ICCT, 2023).

The International Energy Agency (IEA) conducted a comprehensive study on the production of biogas and biomethane, analyzing 19 different types of biomasses across 25 global regions using its World Energy Model (International Energy Agency, IEA, 2020). The study identified two main methods for biomethane production: biogas upgrading and biomass gasification. At the current state of technology, biogas upgrading is the most cost-effective and efficient method for obtaining biomethane, while biomass gasification remains a niche opportunity for large-scale industrial production. From an environmental perspective, biomethane is seen as a promising fuel to mitigate the climate impact associated with natural gas use (Von Walda, Stanion, Rajagopal, & R., 2019).

2. Energy Characteristics of Biogas, Biomethane, and Natural Gas

Natural gas typically has a Higher Heating Value (HHV) between 37.259 MJ/m³ and 42.848 MJ/m³ (International Council on Clean Transportation, ICCT, 2023). Raw biogas usually presents a lower heating value compared to natural gas due to:

i. A lower volumetric fraction of methane (CH_4) than NG;

ii. A higher volumetric fraction of non-combustible compounds (mainly CO_2 and, in the Mexican context, N_2) than NG;

iii. iii. The absence of longer-chain alkane hydrocarbons such as ethane (C_2H_6), propane (C_3H_8), butane (C_4H_{10}), and pentane (C_5H_{12}), which, depending on NG composition, contribute to its HHV.

The exact composition of biogas depends on the feedstock used and the production method (International Energy Agency, IEA, 2020). The most common production methods, based on biological processes, include the use of anaerobic digesters that process residual biomass from agricultural and livestock production, the organic fraction of municipal solid waste, and activated sludge from wastewater treatment plants (WWTPs).

In the case of residual biomass with high lignocellulosic content, biogas and biomethane production is typically achieved through thermal processes such as biomass gasification (International Energy Agency, IEA, 2020).

As an example, when focusing on the production of biomethane from raw biogas[2] with a typical composition of 40–65% CH_4 by volume, and considering that the remainder of the mixture consists of non-combustible compounds such as CO_2 and other impurities, the resulting heating value ranges from 14.904 MJ/m³ to 24.218 MJ/m³ (International Council on Clean Transportation, ICCT, 2023). By upgrading or "methanizing" the biogas to reach at least 95% CH_4 by volume, the heating value increases to a range of 35.396 MJ/m³ to 37.632 MJ/m³. When comparing these values to a typical natural gas HHV of 37.781 MJ/m³, it becomes clear that biomethane falls within a range that is virtually indistinguishable from natural gas and can be used as an energy source for electricity generation or heat in thermal processes (International Energy Agency, IEA, 2020).

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[2] Raw biogas refers to the gas obtained directly from anaerobic digestion without the removal of any impurities such as H_2O, H_2S, or N_2.

While heating value is an important indicator for blending natural gas with biomethane, it is not the only factor to consider in gas interchangeability (Ortíz, 2014). Today, the Wobbe Index (WI) is a simple parameter used in engineering to analyze the interchangeability of gaseous fuels like natural gas and biomethane, as it relates the higher heating value of a gas to its relative density. In practice, most industrial or domestic equipment operating on natural gas tolerates Wobbe Index fluctuations of up to 5% (Ortíz, 2014). The WI represents the ratio between the energy content and the characteristic density of a gaseous fuel. Therefore, similar Wobbe Index values help determine whether biomethane and natural gas are interchangeable or can substitute for one another without compromising their energy characteristics or combustion performance (International Council on Clean Transportation, ICCT, 2023).

3. Processes and Technologies to Produce Biogas and Biomethane.

According to the national regulatory framework, biogas and biomethane are classified as biofuels that constitute clean and renewable forms of energy (Cámara de Diputados del H. Congrso de la Unión. , 2015) (Cámara de Diputados del H. Congreso de la Unión, 2008) (Cámara de Diputados del H. Congreso de la Unión, 2024) (Cámara de Diputados del H. Congreso de la Unión, 2023).

According to the national regulatory framework, biogas and biomethane are classified as biofuels that constitute clean and renewable forms of energy (Secretaría de Energía, SENER, 2024) and for the production of biogas and biomethane from several biomass sources, such as the organic fraction of municipal solid waste (OFMSW), agricultural waste, livestock (manure) waste, sludge from wastewater treatment plants (WWTPs), and dendroenergetic (forestry) residues (Secretaría de Medio Ambiente y Recursos Naturales, SEMARNAT, 2020) (International Energy Agency, IEA, 2020).

In parametric terms, bioenergy is closely dependent on factors such as the type, composition, and moisture content of the usable biomass, as well as the volume and frequency of its generation (Clemente Reyes, La Bioenergía. Un gigante olvidado que puede convertirse en un poderoso aliado para México, 2022). **Table 1** presents a summary of mature technologies available on the market for the bioenergetic utilization of various types of waste and their applicability, depending on the biomass moisture content and the type of emissions typically expected (Clemente Reyes, Bioenergía y sustentabilidad en parques industriales y PTARs, 2024). Additionally, **Figure 1** illustrates common technological schemes for the energy recovery of waste (Clemente Reyes, Bioenergía, valorización de los residuos, 2023)

Table 1. Mature Technologies for Energy Recovery from Waste.

Technologies:						
Concept	**Composting**	**Anaerobic Digestion**	**Combustion**	**Gasification**	**Pyrolysis**	**Hydrothermal Carbonization**
Residual Biomass	Suitable	Suitable	Suitable	Suitable	Suitable	Suitable
Inorganic Waste	Not suitable	Not suitable	Suitable	Suitable	Suitable	Suitable
Moisture Content	50-80%	50-80%	≤ 50%	≤ 30%	≤ 30%	50-90%
Main Products	Compost	Biogas, Biomethane, Bio-H_2, Digestate	Heat, Ashes	Syngas, H_2, Biochar	Syngas, H_2, Biochar	Hydrocarbon, Liquid Fertilizers
Type of Emissions	CO_2, CH_4	CO_2	CO_2, CO, CH_4, VOCs, PAHs	CO_2	CO_2	CO_2

Source: Own elaboration by the AMBB with data from G2E, Green to Energy.

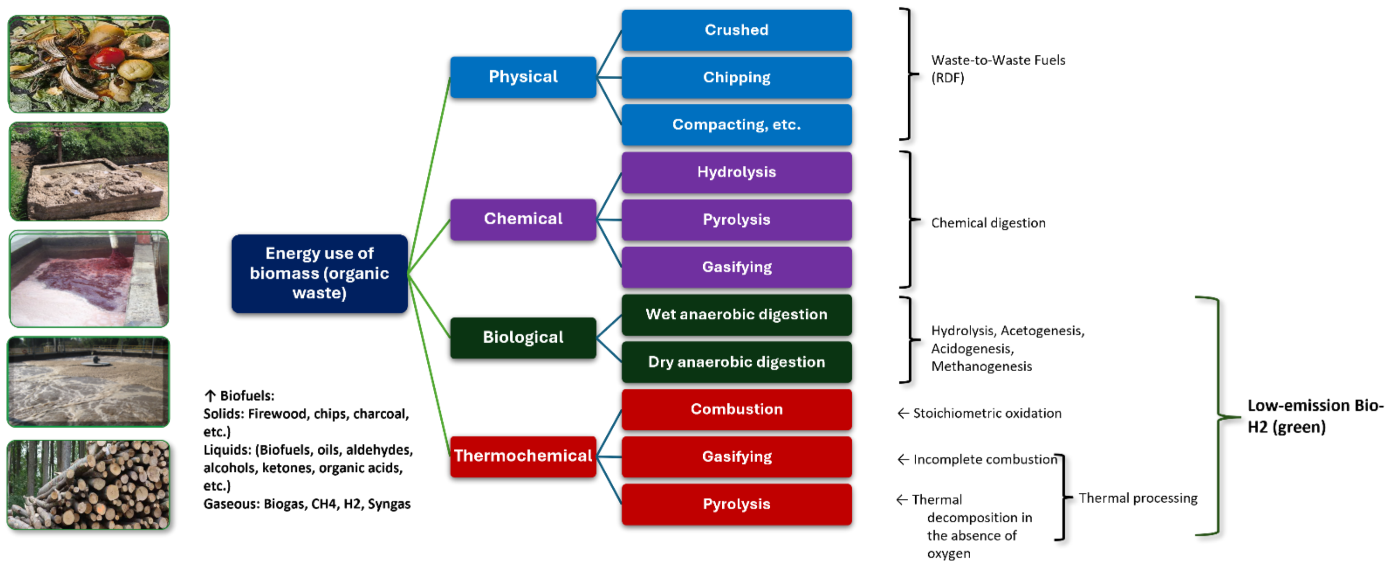

Figure 1. Common Processes Available in the Bioenergy Industry.
Source: Own elaboration by the AMBB with information from: *"Renewable Energies. An Engineering Perspective." Omar Guillén Solís. Trillas. 2012.*

Table 2 presents an excerpt from the Agreement issued by SENER, which approves and publishes the update of the Transition Strategy to Promote the Use of Cleaner Technologies and Fuels (Secretaría de Energía, SENER, 2024). This excerpt refers mainly to the technologies used in bioenergy processes related to the generation of biogas and biomethane.

Technologies or Systemic approaches	Degree of maturity	Development Trend	Cost of technology		Level of technology use	
	Global	Global	Local	Global	Local	Global
Efficient and wood-saving stoves	High	Speedy	Low	Low	Middle	Middle
Biomass Drying and Roasting	High	Speedy	Middle	Middle	Low	High
Biodigesters for the use of biogas	High	Speedy	Middle	Middle	Low	High
Solid biofuels: Pellets	High	Speedy	Middle	Middle	Null	High
Gasification to produce hydrogen	Low	Moderate	High	High	Null	Low
First and second-generation biofuels	High	Speedy	Middle	Low	Low	Middle
Advanced biofuels	High	Speedy	High	High	Null	Middle

Table 2. Main efficient technologies for the use of bioenergy.
Source: SENER, DOF 23/01/2024

It is important to note that methane gas obtained from municipal solid waste (MSW) in sanitary landfills is known as landfill gas. In the Mexican regulatory context, this is also considered biogas by extension (Centro de Estudios para el Desarrollo Rural Sustentable y la Soberanía Alimentaria, 2007). Biogas derived from landfills or sources such as wastewater treatment plants (WWTPs) and sewage systems (also known as sewer gas) differs from biogas obtained from agricultural or dendroenergetic sources, as it contains volatile organic silicon compounds known as siloxanes, which originate from human consumer products like cosmetics.

When biomethane contaminated with siloxanes is combusted, amorphous silicon-based nanoparticles are produced, which can form deposits in pipelines and equipment. These deposits may damage internal surfaces of combustion systems such as burners or engines (2018 CCST Report, junio de 2018). For this reason, the processes, equipment, norms, and standards for the use of biomethane contaminated with siloxanes are designed to limit their presence and require the removal of these compounds before utilizing the biomethane.

Siloxane-free biomethane is typically derived from anaerobic digestion processes in biodigesters, such as those processing agricultural waste.

Most of the biomethane produced worldwide currently comes from biogas upgrading processes, which transform raw biogas into high-quality biomethane (International Energy Agency, IEA, 2020). These processes focus on the purification of biogas, removing impurities such as carbon dioxide (CO_2), hydrogen sulfide (H_2S), and moisture, to obtain biomethane with characteristics similar to natural gas. This enables its direct injection into natural gas distribution networks or its use in industrial and transportation applications, as shown in **Figure 2**, which identifies strategic areas of utilization based on local or sector-specific contexts.

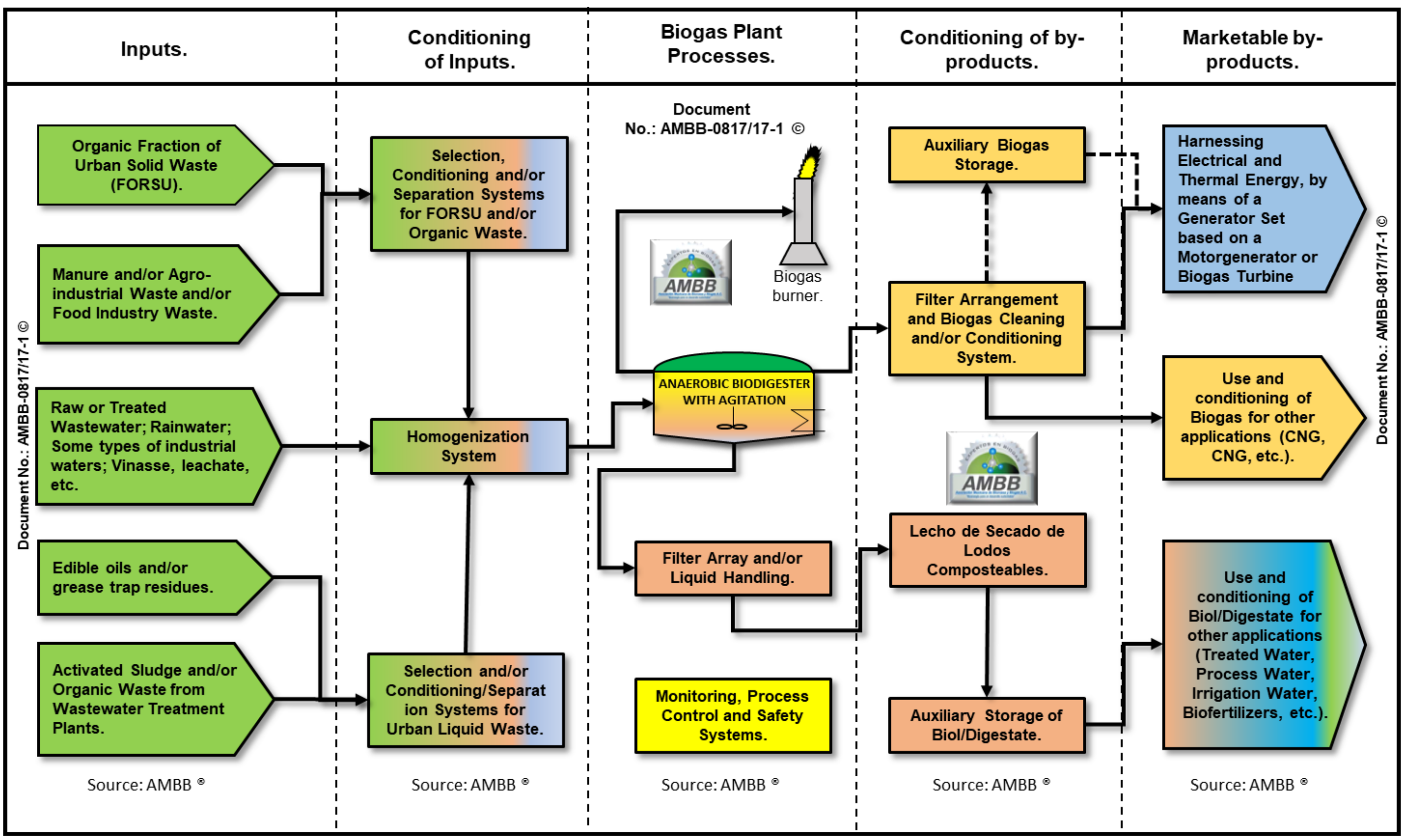

Figure 2. General Block Diagram of a Typical Biogas Plant to Produce Electricity, Biofuels, and Biofertilizers.
Source: Own elaboration by the AMBB

Among the most commonly used **biogas upgrading technologies** are:

1. **Pressure Swing Adsorption (PSA)**: This method relies on the use of adsorbent materials that, through high- and low-pressure cycles, retain and release specific gases. CO_2 and other contaminants are removed, resulting in high purity biomethane.

2. **Absorption**: There are several variants of this technology, which may or may not involve water circulation. In the water absorption process, biogas is passed through pressurized water columns where CO_2 dissolves in the liquid, effectively separating it from methane. This method is simple and widely used. Other technologies use chemical solutions or physical processes without water to remove contaminants from the biogas (United Nations Framework Convention on Climate Change, 2012).

Both technologies are key to achieving natural gas quality, which facilitates the use of biomethane as a direct and renewable substitute for fossil gas in various energy applications. However, it should be noted that some biogas production processes involving specific types of biomasses inject small amounts of air into biodigesters to control or reduce the formation of H_2S (hydrogen sulfide). Although, as previously mentioned, biomethane is chemically identical to methane found in natural gas, it is advisable—without affecting the calorific value of biomethane or natural gas—to allow a degree of flexibility in the criteria and limits imposed for inert compounds such as O_2 (oxygen) and N_2 (nitrogen). This is to avoid unnecessarily increasing the cost of upgrading processes for biomethane production (Saavedra, 2023) as it would affect its levelized cost and commercial competitiveness. **Figure 3** illustrates the stages to be considered in the biomethane production process for its injection into conventional or virtual natural gas grids for distribution to end users.

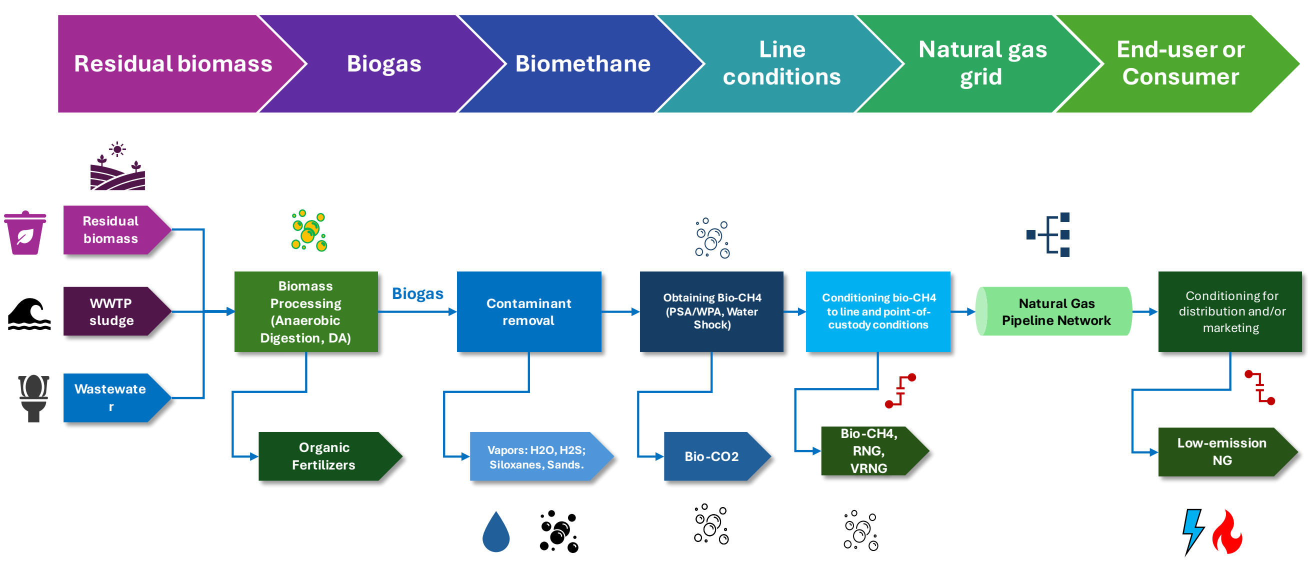

Figure 3. Stages to consider in the production of biomethane and its utilization and injection into natural gas networks.
Source: Own elaboration by the AMBB.

4. Injection of Biomethane into Natural Gas Networks

The percentage of biomethane allowed for injection into natural gas distribution networks varies depending on each country's regulations and the composition of local natural gas. Biomethane must meet specific quality standards to be compatible with existing natural gas. The situation in various countries is detailed below:

4.1 International Reference Context

Europe

1. **Germany**: There is no maximum injection limit for biomethane. As long as it meets technical specifications (methane content, calorific value, etc.), it can be injected in any proportion.
2. **France**: Like Germany, biomethane can be injected without a maximum limit as long as it complies with technical standards. France aims to reach 10% biomethane in its gas grid by 2030.
3. **United Kingdom**: Biomethane can be injected without a specific volume limit but must comply with UK gas standards, including calorific value, sulfur levels, and other compounds.
4. **Italy**: Injection of biomethane is allowed in any proportion, provided it meets established natural gas quality standards.
5. **Denmark**: About 25% of the gas circulating in the Danish network comes from biomethane. No specific percentage limit exists as long as technical requirements are met.
6. **Spain**: The regulatory framework permits biomethane injection as long as it meets quality standards. There are financial incentives to encourage this technology.

North America

1. **United States**: Regulations vary by state. In California, Oregon, and Texas, there is no maximum injection limit if biomethane complies with quality standards, including limits on CO_2, hydrogen sulfide, and other contaminants.
2. **Canada**: Provinces such as Quebec and British Columbia allow biomethane injection without set volume limits, provided it meets natural gas standards.

Asia

1. **China**: Still in early stages, but quality standards similar to those in Europe are being developed. Currently, injection is allowed if biomethane meets adequate purity and energy content requirements.
2. **India**: Pilot projects do not have a fixed limit, but biomethane must meet the standards established by local energy authorities.

Latin America

1. **Brazil**: There is no set maximum percentage for biomethane injection as long as it meets Brazilian natural gas quality standards (methane content, calorific value, etc.).
2. **Argentina**: Similar to Brazil, no maximum limit has been set, but biomethane must comply with natural gas technical quality standards

4.2 Common Quality Standards for Natural Gas

The Mexican Official Standard **NOM-001-SECRE-2010** establishes the specifications for natural gas quality. Key parameters include:

1. **Chemical Composition**:
   - Methane (CH_4): Minimum 85% by volume
   - Ethane (C_2H_6): Maximum 10% by volume
   - Propane (C_3H_8): Maximum 3% by volume
   - Butane (C_4H_{10}): Maximum 2% by volume
   - Other hydrocarbons: Maximum 2% by volume (combined total of heavier hydrocarbons)
2. **Wobbe Index**:
   - Must range from 47.5 to 52.5 MJ/m^3
3. **Relative Density**:
   - Between 0.6 and 0.9 (compared to air)
4. **Higher Heating Value (HHV)**:
   - Between 38 and 42 MJ/m^3
5. **Lower Heating Value (LHV)**:
   - Between 33 and 37 MJ/m^3
6. **Contaminants**:
   - Carbon Dioxide (CO_2): Max 2% by volume
   - Oxygen (O_2): Max 0.1% by volume
   - Hydrogen Sulfide (H_2S): Max 5 ppm
   - Moisture: Max 7 $grams/m^3$
7. **Solid and Liquid Contaminants**:
   - The gas must be free of solids, liquids, and other contaminants that could affect gas quality or damage equipment.
8. **Temperature**:
   - Delivery temperature must be between 0°C and 40°C

4.3 National Context for the Utilization of Biomethane or Renewable Natural Gas

Based on the international context outlined in section 4.1, most countries using biomethane do not impose volumetric injection limits. The prevailing criterion is that any volume of biomethane may be injected into natural gas networks provided all undesirable or contaminating components are removed in accordance with applicable regulations, ensuring energy equivalence and system integrity. Thus, developing a regulation for biomethane injection into Mexico's natural gas distribution network requires balancing several technical, economic, environmental, and quality-related factors. These include: the quality and composition of renewable natural gas, maintaining its calorific value, setting strict limits on methane (CH_4) concentration, and defining maximum levels for contaminants such as CO_2, N_2, O_2, and other inert or harmful gases.

5. Potential for Industrial Use of Biomethane

According to data from SENER, in 2022 the national demand for fossil natural gas in Mexico reached 8,341 million cubic feet per day, of which 2,517 came from domestic production and 5,824 were covered through imports of dry and sweet gas. Notably, over 60% of electricity generated in Mexico that year relied on natural gas, and 78% of that gas was imported—mainly from the United States.

As shown in **Figure 4**, national industrial consumption is expected to grow from approximately 1,377 million cubic feet per day in 2025 to at least 1,950 million cubic feet per day in 2050, representing a 42% increase in fossil natural gas demand.

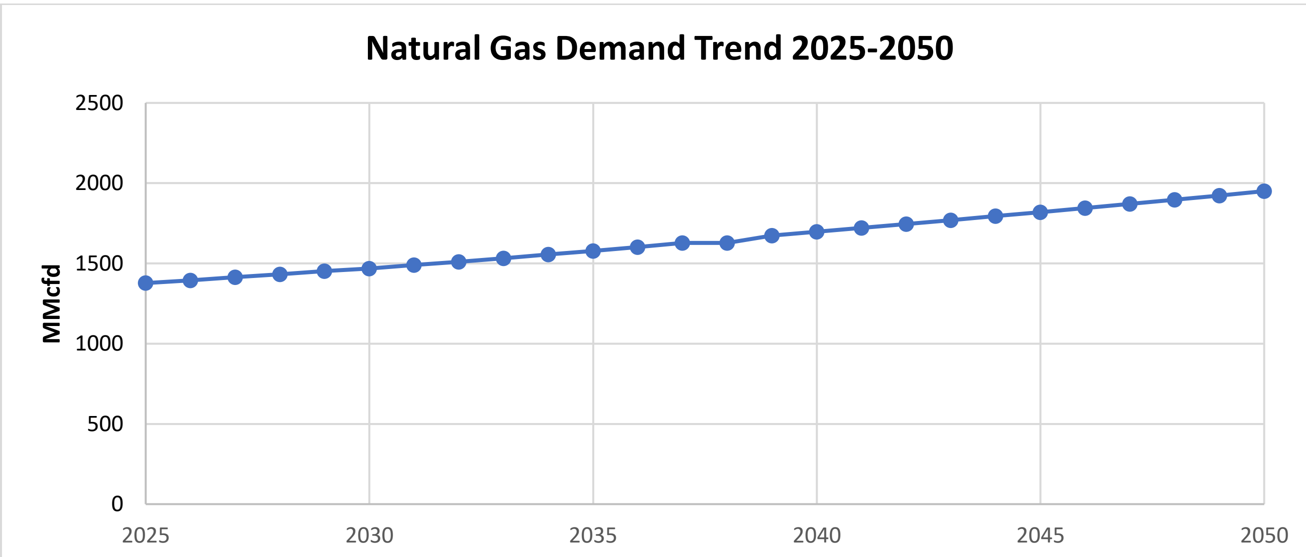

Figure 4. Natural Gas Consumption Trend in Mexico's Industrial Sector.
Source: Own elaboration by the AMBB.

Meanwhile, as illustrated in **Figure 5**, if proper strategies in the waste sector were already implemented by 2025, biomethane from organic waste could cover 5% of total fossil natural gas consumption. Moreover, if residual biomass streams in the country were adequately restructured and a sustainable industry developed around them, up to 60% of industrial natural gas demand could be met with biomethane. This is achievable not only due to the biofuel legislation enacted in 2025, but also through a fundamental shift in national strategy regarding integrated waste management, promoting a culture that goes beyond composting and recycling.

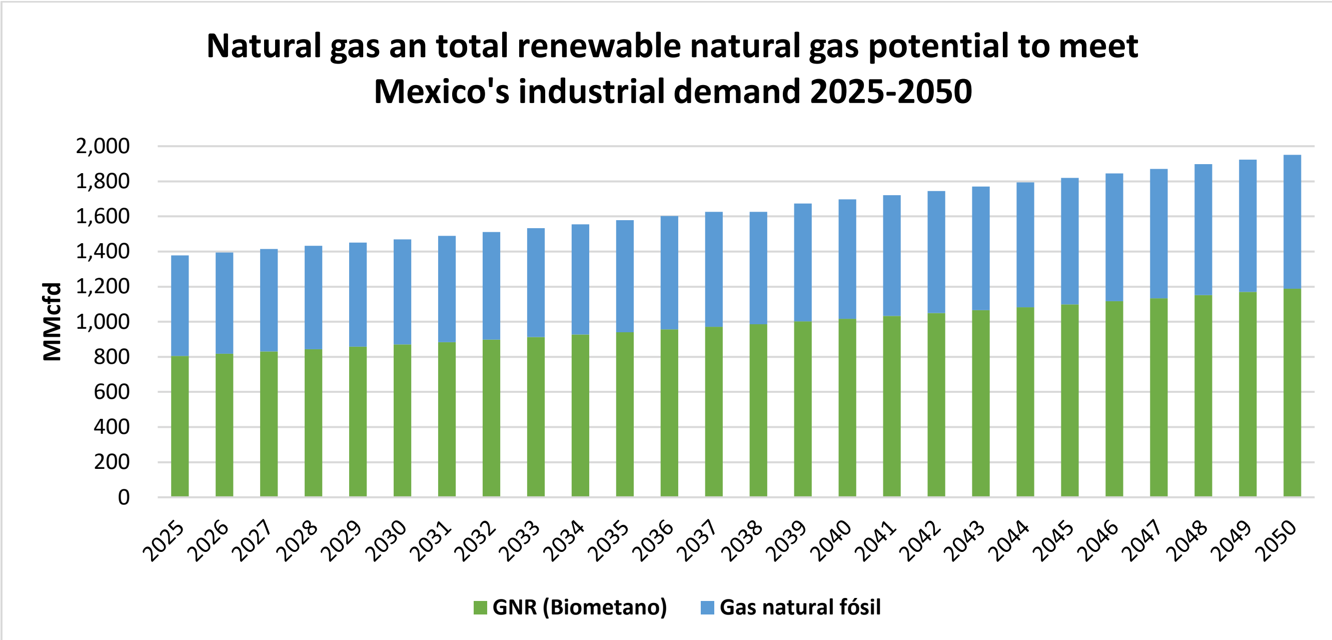

Figure 5. Potential Consumption of Renewable Natural Gas in Mexico's Industrial Sector.
Source: Own elaboration by the AMBB.

The statistical projection by federal entity and by type of residual biomass for the year 2050 is shown in **Figure 6**, with estimated potentials per federal entity and a national total of 643,695 tons per day (t/d).

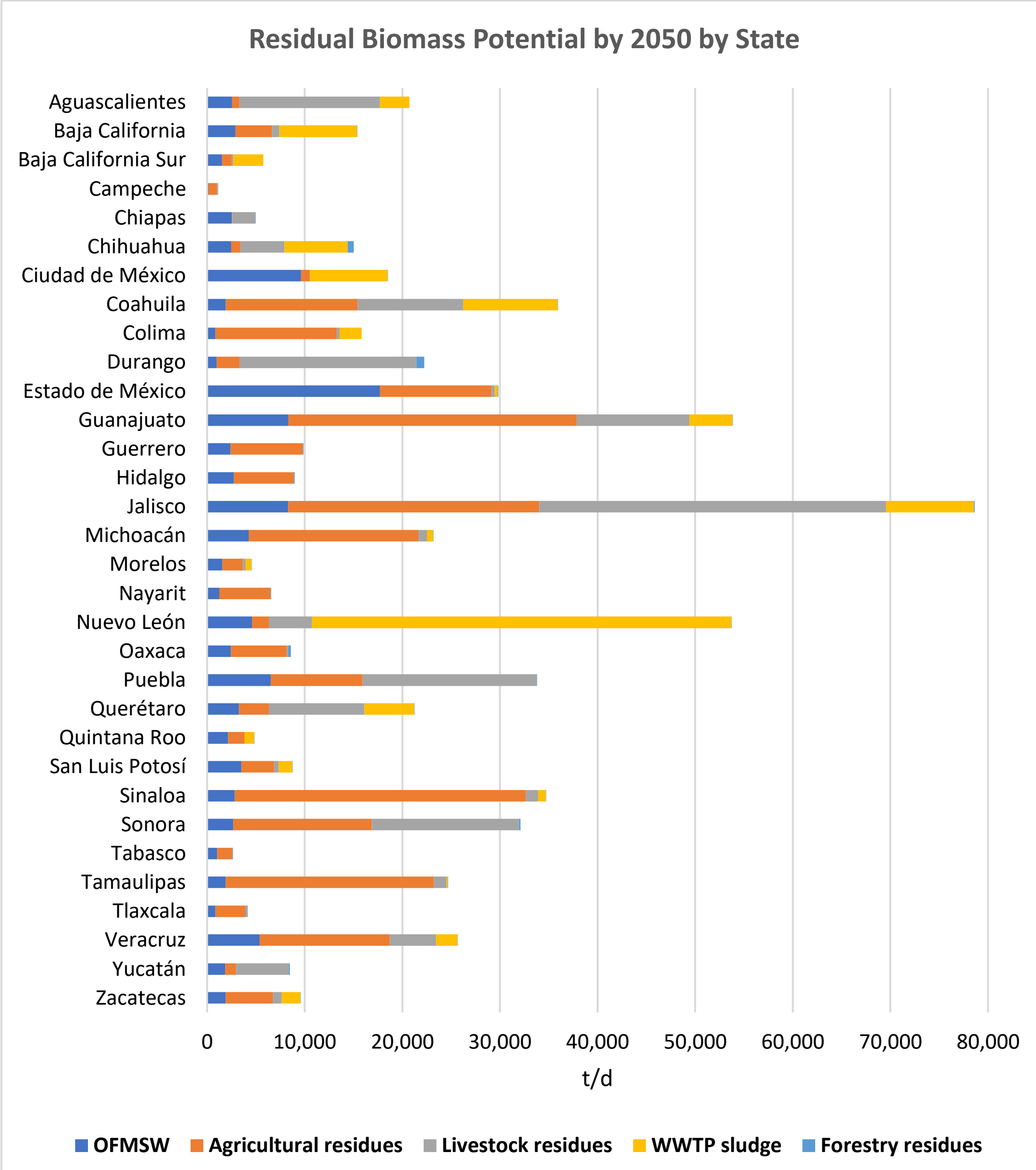

Figure 6. Estimated Biomass Generation by Type of Waste in the States by 2050.
Source: *Own elaboration using the BIO-ACT-2 tool and information from INEGI, CONAPO (2020), and GCMA.*

Assuming that all the different types of residual biomass presented in **Figure 6** could be used for biogas production and its subsequent upgrading to biomethane, the potential per federal entity is shown in **Figure 7**. By utilizing the total amount of residual biomass produced daily in the country, the total biogas generation potential would amount to 53.6 million normal cubic meters per day (MMNm^3/d) or 1,827.5 million standard cubic feet per day (MMscfd), and in the case of biomethane, it would be 34.8 MMNm^3/d (1,187.8 MMscfd).

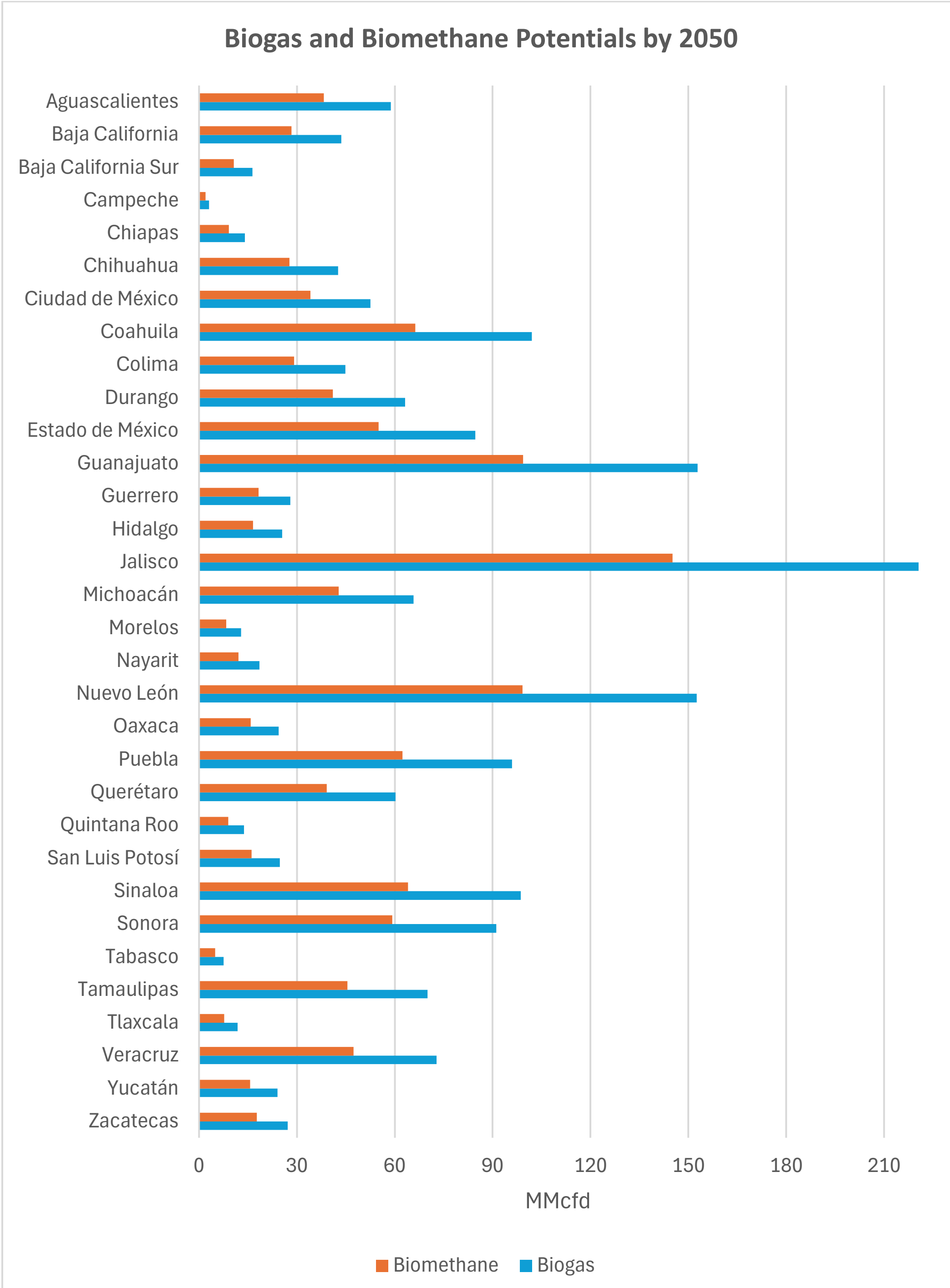

Figure 7. Estimated Biogas and Biomethane Generation through Full Utilization of Residual Biomass by State. Source: Own elaboration using the BIO-ACT-2 tool and information from INEGI, CONAPO (2020), and GCMA.

Figure 8 presents the achievable potential for biomethane production by the year 2050, categorized by type of residual biomass. According to this analysis, agricultural biomass accounts for 39.7%, followed by livestock waste at 23.8%, wastewater treatment plants (WWTPs) at 21.5%, the organic fraction of municipal solid waste (OFMSW) at 14.6%, and the remainder corresponds to forestry residues.

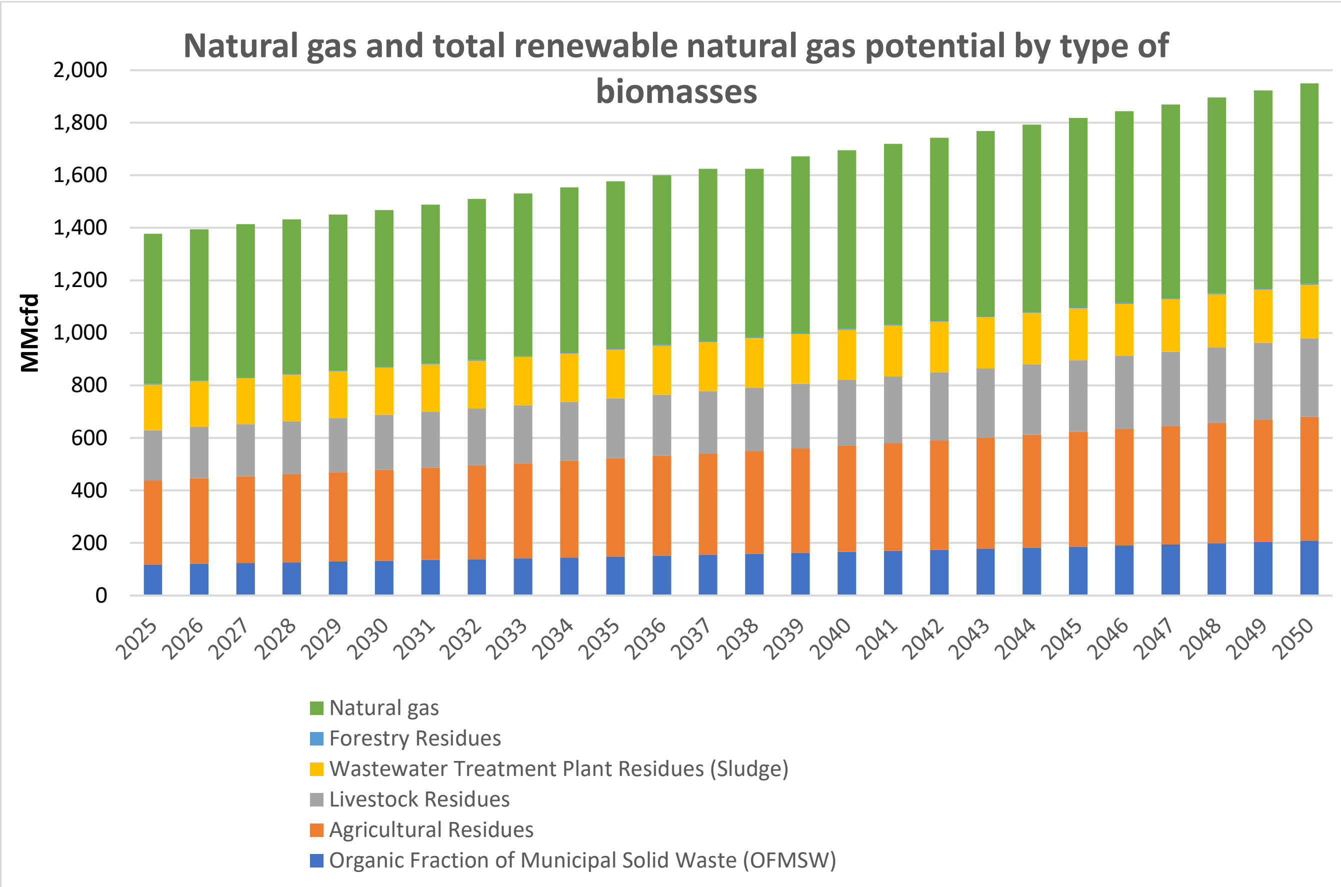

Figure 8. National Demand of Fossil Natural Gas in the Industrial Sector and Interchangeability with Biomethane by Type of Residual Biomass. Source: Own elaboration using the BIO-ACT-2 tool and information from INEGI, CONAPO (2020), and GCMA

6. Compatibility with Decarbonization Policies

The regulatory framework must align with emission reduction goals, the energy transition, and sustainable development objectives:

- **Decarbonization goals**: Regulations should establish clear targets for increasing biomethane injection with natural gas quality to fulfill carbon reduction commitments and boost the share of renewable energy in the national energy system, in step with Mexico's trade partners.

- **Priority for biomethane over other gases**: If synthetic or other types of gases are used, biomethane should be given priority, as it is a renewable gas and can significantly reduce greenhouse gas (GHG) emissions.

6.1 Integration with Existing Infrastructure

It is important to ensure that biomethane injection does not require major infrastructure modifications:

- **Technical compatibility**: Confirm that processing, distribution, and storage systems can handle the biomethane–natural gas blend without significant technical issues.

- **Integration costs**: Assess the costs associated with integrating biomethane into industrial operations and gas networks, and design mechanisms to fairly distribute these costs among biomethane producers, gas distributors, and consumers.

6.2 Management of Variable Injection Volumes

Biomethane can come from various sources with fluctuating production levels. Regulation should allow for managing these variable volumes:

- **Injection flexibility:** Establish mechanisms that allow biomethane with natural gas quality to be injected during periods of high production and stored when demand is low.

- **Balancing agreements**: Encourage agreements between biomethane producers and gas distributors to efficiently manage injection volumes based on supply and demand.

6.3 International Cooperation and Regulatory Harmonization

To enable cross-border trade of biomethane with the same quality and interchangeability as natural gas and to support regional infrastructure development:

- **Harmonization with European or international regulations**: Align national regulations with international guidelines, such as those of the European Union, the United States, and Canada, which set uniform criteria for the utilization, transport, and distribution of renewable gases and energy carriers like bio-H_2.
- **Network interconnection**: Facilitate interconnection of distribution networks to allow for the import and export of biomethane between countries

7. Conclusions

In the harmonization of secondary regulations within the energy sector, and specifically regarding biofuels such as biomethane, the use and injection of renewable natural gas into pre-existing gas distribution networks must balance operational flexibility with technical rigor, ensuring the safety of personnel, facilities, processes, users, and society. It is crucial to establish science-based, clear standards to define the composition, quality, and interchangeability of biomethane, as well as injection pressure and monitoring mechanisms to guarantee compatibility with existing systems and ensure the safe and reliable operation of the national natural gas system.

To preserve the energy properties of natural gas, biomethane used in industrial facilities or injected into gas pipelines must meet the quality and safety standards already established in Mexico. This includes the removal of contaminants according to Mexican standards and limiting the variation in the interchangeability index (IW) to less than 5%. Furthermore, the methane (CH_4) content in renewable natural gas must exceed 95%, regardless of the percentage injected, to ensure that the IW of the biomethane–natural gas mix does not vary by more than 5%, always prioritizing the quality and energy properties of natural gas.

The national strategy to harness biomethane's potential may consider distributed generation schemes and local uses, delivering operational and environmental benefits. Regarding its integration into natural gas networks, a phased approach is suggested based on biomethane quality and, depending on volumes, technologies, and locally available safety measures at injection points, starting with low-level injections (up to 35%). Periodic reviews should then be carried out to increase these limits as described in this study, aiming to meet at least 60% of the national industrial demand for fossil natural gas with renewable natural gas or biomethane, in alignment with the country's energy policies and its capacity to utilize its full residual biomass potential.

At the same time, Mexico should adopt incentives such as renewable origin certificates and preferential tariffs, following international best practices, such as those in the European Union, to encourage large-scale investment and use of biomethane. These incentives would support the country's decarbonization goals, as reflected in its Nationally Determined Contribution (NDC).

A well-designed and coordinated regulatory framework will not only facilitate the inclusion of biomethane in Mexico's energy matrix, but also significantly contribute to emission reductions and progress toward a more sustainable energy system, in alignment with the Sustainable Development Goals and the principles of the circular economy.

Implementing the use of residual biomass in Mexico for the production of biomethane and its utilization and injection into the country's natural gas networks is a climate change mitigation measure that aligns with Mexico's Nationally Determined Contribution and its international commitments under the Paris Agreement.

Acronyms and Technical Terms

CH_4	Methane Gas
C_2H_6	Ethane Gas
C_3H_8	Propane Gas
C_4H_{10}	Butane Gas
C_5H_{12}	Pentane Gas
CONAFOR	National Forestry Commission in Spanish
CONAPO	National Population Council in Spanish
GCMA	Agribusiness Market Consulting Group
GHG	Greenhouse Gases
NG	Natural Gas
RNG	Renewable Natural Gas
H_2	Hydrogen (molecular)
H_2S	Hydrogen Sulfide or Sulfhydric Acid
HHV	High Heating Value
HV	Heating Value
IEA	International Energy Agency
ICCT	International Council on Clean Transportation
INEGI	National Institute of Statistics and Geography in Spanish
IPCC	Intergovernmental Panel on Climate Change
IRENA	International Renewable Energy Agency
IW	Wobbe Index
LHV	Low Heating Value
MJ/m^3	Megajoules per cubic meter
$MMNm^3$	Million Normal Cubic Meters

MMcfd	Million Cubic Feet per Day
NDC	Nationally Determined Contribution
GDP	Gross Domestic Product
HV	Calorific Value
LHV	Lower Calorific Value
HHV	Higher Calorific Value
WWTP	Wastewater Treatment Plant
SEMARNAT	Ministry of Environment and Natural Resources in Spanish
SENER	Ministry of Energy in Spanish
tCO_2e	Tons of CO_2 Equivalent
tCO_2e/d	Tons of CO_2 Equivalent per Day

8. References

2018 CCST Report. (June, 2018). *Biomethane in California Common Carrier Pipelines.* 1100 11th Street, Sacramento, CA 95814, USA,: California Council of Science and Technology.

Cámara de Diputados del H. Congreso de la Unión. (2008). *Ley de Promoción y Desarrollo de los Bioenergéticos.* Ciudad de México: Secretaría General. Secretaría de Servicios Parlametarios. Diario Oficial de de Federación (DOF).

Cámara de Diputados del H. Congreso de la Unión. (2023). *Ley General para la Prevención y Gestión Integral de los Residuos.* Ciudad de México: Secretaría General. Secretaría de Servicios Parlamentarios.

Cámara de Diputados del H. Congreso de la Unión. (2024). *Ley de la Industria Eléctrica.* Ciudad de México: Secretaría General. Secretaría de Servicios Parlamentarios.

Cámara de Diputados del H. Congreso de la Unión. (2015). *Ley de Transición Energética.* Ciudad de México: Secretaría General. Secretaría de Servicios Parlamentarios.

Centro de Estudios para el Desarrollo Rural Sustentable y la Soberanía Alimentaria. (2007). *Glosario de Bioenergéticos .* Ciudad de México: H. Cámara de Diputados, LX Legislatura.

Clemente Reyes, A. (2022). Ingeniería ambiental; factor clave de la bioenergía y la sustentabilidad. (pp. 4-8). Ciudad de México: Asociación Mexicana de Biomasa y Biogás, A.C. (AMBB).

Clemente Reyes, A. (2022). La Bioenergía. Un gigante olvidado que puede convertirse en un poderoso aliado para México. *Revista del Colegio de Ingenieros Mecánicos y Electricistas*, 27-35.

Clemente Reyes, A. (2023). Bioenergía, valorización de los residuos. *2° Seminario de Energías Renovables Internacional* (pp. 1-52). CC Dos Bocas CFE, Veracruz, Ver.: Comisión Federal de Electricidad (CFE). Centro de Desarrollo y Capacitación en Energías Renovables (CDCER).

Clemente Reyes, A. (2024). Bioenergía y sustentabilidad en parques industriales y PTARs. *XXXIII Seminario de Pensamiento Sistémico y Análisis de Sistemas* (pp. 1-60). Ciudad de México. Ciudad Universitaria: Facultad de Ingeniería, UNAM. Academia Mexicana de la Ciencia de Sistemas.

Clemente Reyes, A., Martín Del Campo Márquez, C., Nelson, P. F., & Duran Moreno, A. (2023). A comparative assessment of open flame flares and enclosed ground flares for cleaner and safer hydrocarbon production in Mexico. *Cleaner Engineering and Technology*. doi:https://doi.org/10.1016/j.clet.2023.100671

Intergovernmental Panel on Climate Change, IPCC. (2012). *Special Report on Renewable Energy Sources and Climate Change Mitigation. Summary for Policymakers.* Potsdam. Germany: A Report of Working Group III of the IPCC. Potsdam Institute for Climate Impact Research (PIK).

International Council on Clean Transportation, ICCT. (2023). *2030 California Renewable Natural Gas Outlook: RESOURCE ASSESSMENT Resource Assessment, Market Opportunities, and Environmental Performance.* Washington D.C. 20005, USA: ICCT White Paper.

International Energy Agency, IEA. (2020). *Outlook for biogas and biomethane. Prospects for organic growth. World Outlook Energy Report.* Design in France by IEA: International Energy Agency, IEA.

International Renewable Energy Agency, IRENA. (2022). *Energy-Transition*. Retrieved from Bioenergy-and-biofuels: https://www.irena.org/Energy-Transition/Technology/Bioenergy-and-biofuels

International Renewable Energy Agency, IRENA. (2022). *IRENA Energy Transition/Technology*. Retrieved from Bioenergy & biofuels: https://www.irena.org/Energy-Transition/Technology/Bioenergy-and-biofuels

Ortíz, J. M. (2014). Fundamentos de la intercambiabilidad del gas natural. *Met & Flu*(9), 6-15. Retrieved from chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://www.cdtdegas.com/images/Descargas/Nuestra_revista/MetFlu9/Revista%20MET&FLU%209.pdf

Saavedra, A. (2023). *Conferencia: "Mesa Redonda, análisis, discusión y conclusión sobre el hidrógeno" Ponencia: SysAdvance North America, Co.* Ciudad de México, Junio 2023: 3er. Congreso Internacional y 5to. Congreso Nacional de Ingeniería Eléctrica y Energías Renovables 2023. Colegio de Ingenieros Mecánicos y Electricistas, A.C. (CIME).

Secretaría de Energía, SENER. (2024). *ACUERDO por el que se aprueba y publica la actualización de la Estrategia de Transición para Promover el Uso de Tecnologías y Combustibles más Limpios.* Ciudad de México: Diario Oficial de la Federación.

Secretaría de Energía, SENER. (2024, 01 23). ACUERDO por el que se aprueba y publica la actualización de la Estrategia de Transición para Promover el Uso de Tecnologías y Combustibles más Limpios. *Diario Oficial de la Federación, DOF*.

Secretaría de Energía, SENER. (2024, 03). *Sistema de Información Energética. SENER*. Retrieved from https://sie.energia.gob.mx/inicio/#/

Secretaría de Medio Ambiente y Recursos Naturales, SEMARNAT. (2020). *Diagnóstico Básico para la Gestión Integral de los Residuos, DBGIR.* Ciudad de México: Secretaría de Medio Ambiente y Recursos Naturales, SEMARNAT.

United Nations Environment Programme (UNEP) and Climate & Clean Air Coalition (CCAC). (2017). *Progress and Opportunities for Reducing Short-Lived Climate Pollutants across Latin America and the Caribbean .* Luisa T. Molina (Molina Center for Energy and the Environment, USA).

United Nations Framework Convention on Climate Change. (2012). *Biogenic methane injection to a natural gas distribution grid.* UNFCCC/CCNUCC. CDM Executive Board.

Von Walda, G., Stanionb, A. J., Rajagopalb, D., & R., B. A. (2019). Biomethane addition to California transmission pipelines: Regional simulation of the impact of regulations. *Applied Energy, 250*, 292-301. doi:https://doi.org/10.1016/j.apenergy.2019.05.031