3 Regulatory measures to improve the case for sustainable bioenergy

Policy reforms and market incentives played a critical role in enabling early growth of bioenergy cogeneration in the sugar and palm industries in Colombia. Over the last decade, the country's regulatory framework for renewable energy has provided further clarity on the operational rules and remuneration for clean energy additions, such as bioenergy self-generation. Improving the transparency on grid-access rules and connection costs, whilst aligning incentives to encourage retailers to procure distributed energy generation, can further increase opportunities for bioenergy development. Strengthening the regulatory framework on waste management, for instance, to address low landfill and waste collection fees, will also improve incentives for bioenergy projects. Additional regulatory signals could include use of emissions trading and carbon pricing mechanisms to drive demand for clean energy sources like biogas for industry use.

Highlights

- Market incentives and policy measures over the last two decades encouraged early growth in bioenergy capacity additions like cogeneration in Colombia's sugar and palm industries. Lessons from these developments, including important regulatory reforms that supported the business case for industry investment, can be applied to encourage bioenergy opportunities in other industries, such as dairy production and hog farming.
- Legal measures like the Renewable Energy Law of 2014 have played a critical role in establishing the operational rules and remuneration for renewable energy projects, but there remain barriers for bioenergy projects. The regulatory framework can do more to provide transparent criteria on grid-access rules and connection costs, including clear guidance on negotiations for back-up supply charges, whose cost calculations are not readily understood.
- Current renewable portfolio standards do not give credit to retailers for renewable energy production used on-site by regulated consumers, nor for renewable electricity sold to unregulated customers, which represent about half of Colombia's electricity demand. Addressing these restrictions would provide greater inventive for retailers to secure potential clean energy agreements, including through bioenergy capacity additions.
- Colombia can learn from international experiences with renewable energy certificates and other policy tools that have encouraged sourcing of renewable energy. This can include use of financial incentives and support for bioenergy projects, alongside obligations for industry and/or large energy consumers to increase their share of clean energy consumption.
- Landfill and waste collection fees are typically low in Colombia, and waste management companies and landfill operators have little incentive to sort and recover waste as fees apply to the amount of waste collected or disposed of. Firm targets and/or mandatory retrieval of certain wastes, paired with progressive increases in the overall value of fees and landfill taxes, will encourage greater sorting and treatment of waste, including for waste-to-energy applications.

Colombia's energy policy environment has continued to transform since the 1990s, when severe energy insufficiency and power outages driven by an el Niño event led to the energy crisis of 1992. This resulted in critical reforms such as the passage of Law 142 of 1994 (and modification under Law 689 of 2001) that established a number of core public services, regulatory commissions, market competition rules and standards (Table 3.1). Concerns over the reliability of electricity supply also led to the development of a wholesale electricity market (Mercado de Energía Mayorista). Since then, policy reforms have continued to promote development of a reliable and affordable energy system, including the passage of regulations aimed at renewable energy, such as Law 697 of 2001,[1] which targeted the "rational and efficient use of energy and the use of other non-conventional energy sources".

These actions, complemented by measures such as tax reform for renewable energy projects, have helped to foster clean energy growth over the last two decades, including early bioenergy developments in the sugar and palm industries. Strengthening this regulatory framework, for example through targeted policy to realise ambitions in the forthcoming bioeconomy Nationally Appropriation Mitigation Action, will further facilitate development of bioenergy solutions, ensuring that regulations address any remaining policy gaps and market barriers to these opportunities. This includes ensuring the regulatory environment clearly addresses the role of waste management and related market incentives for its recovery for energy production. Colombia already has a strong policy regime for waste collection and disposal, and this, too, can be expounded to realise bioenergy opportunities whilst achieving the country's circular economy and bioeconomy ambitions.

Table 3.1. Highlights of electricity market regulations since the 1992 energy crisis

Law 142 of 1994 (later modified by Law 689 of 2001) established the regime of domestic public services, fixing rules and principles of economic competition
Law 143 of 1994 established the regime for generation, interconnection, transmission, distribution and marketing of electricity
CREG Resolution 055 of 1994 regulated activities of electricity generation in the National Interconnected System
CREG Resolution 024 and 025 of 1995 regulated the commercial aspects of the wholesale energy market and establishing the network code as part of the operating regulations in the National Interconnected System
CREG Resolution 020 of 1996 established rules to promote free competition in the wholesale electricity market
GREG Resolution 034 of 2001 issued rules on the operation of the wholesale electricity market
CREG Resolution 071 of 2006 issued the remuneration methodology for the reliability charge
CREG Resolution 091 of 2007 established the general methodologies to remunerate the activities of generation, distribution, and retail of electric energy in Non-Interconnected Zones
CREG Resolution 051 of 2009 modified the price scheme, ideal dispatch and rule determining the price of the wholesale market exchange
CREG Resolution 156 of 2011 established regulation on the retail of public electricity service

Early bioenergy cogeneration stresses the importance of a clear regulatory framework

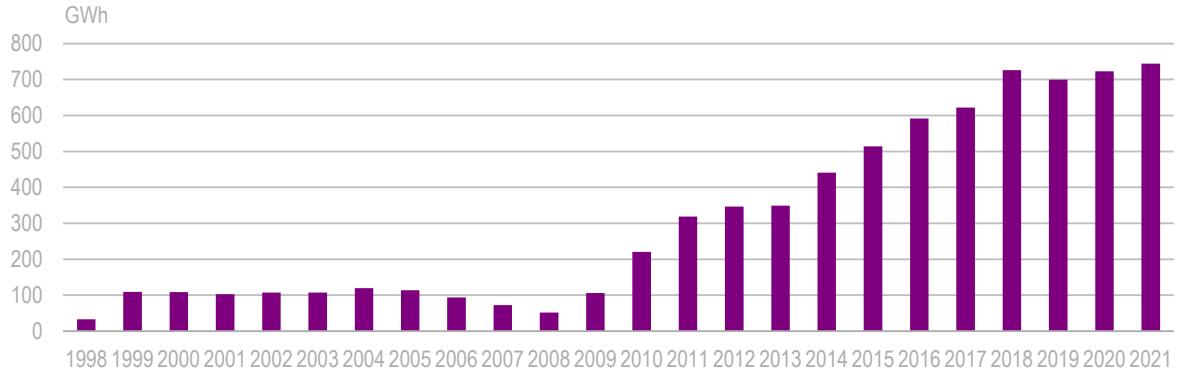
Bioenergy cogeneration in Colombia's sugar and palm industries started in the late 1990s, when early adoptions began making use of abundant sugarcane bagasse and palm oil residues to provide combined heat and power in those industries. The legal framework allowing for this cogeneration was defined notably under Energy and Gas Regulation Commission (Comisión de Regulación de Energía y Gas, CREG) Resolutions 85 and 86 of 1996[2] and subsequent CREG Resolution 107 of 1998.[3] These determined the regulatory norms for cogeneration and set the legal conditions for co-production of thermal and electric energy as an integral part of an industry process (CCC, 2016[1]). The regulations also set forward the rules for access to the grid for these projects.

Law 788 of 2002[4] later established a tax exemption over 15 years for income generated from the sale of electricity from wind, agricultural waste and bioenergy sources. Eligible projects, including in theory cogeneration, qualified for the incentive as long as they obtained emissions trading certificates, in accordance with the terms of the Kyoto Protocol, and reinvested at least 50% of the revenues from the sale of those permits in social projects situated within the area served by the utility. In principle, these should have encouraged some further bioenergy development but, in practice, the number of such projects remained limited, where electricity sales from cogeneration essentially remained constant through the 2000s.

Law 1215 of 2008[5] and ensuing CREG Resolution 5 of 2010[6] marked a clear turning point in this lack of progress by legally differentiating cogeneration from other forms of energy production. Specifically, these regulations provided technical requirements and incentives for cogeneration, including exemptions for

payment of contributions on energy destined for self-consumption. Law 1215 also opened the door to bilateral contracts (either with the retailer or with unregulated commercial customers) for co-generators that ensure guaranteed power over 20 MW. This re-invigorated industry appetite for combined heat and electricity production, resulting in a sizeable jump of new cogeneration capacity and resultant electricity sales to the grid after 2009 (Figure 3.1). Additional policy measures such as tax incentives provided under the 2010 Programme for the Rational and Efficient Use of Energy and other non-conventional renewable energy (PROURE)[7] and the landmark 2014 Renewable Energy Law further encouraged use of cogeneration with bioenergy and other renewable energy sources. By 2020, cogeneration capacity supplied to the grid, still mostly from the sugar and palm industries, reached 723 GWh of electricity, with a further 989 GWh of energy that were self-consumed by industry itself (Asocaña, 2021[2]).

Figure 3.1. Evolution of electricity sales from grid connected cogeneration, 1998-2021



Note: GWh = Gigawatt hour. 2021 data is from January to September.
Source: adapted from (CCC, 2016[1]), (Asocaña, 2021[2]) and (XM, 2021[3]).

StatLink https://stat.link/whqv8l

Other reforms provided additional incentives to develop bioenergy cogeneration capacity in industry. For example, regulatory changes in the late 2000s enabled cogeneration plants to sell surplus electricity to the wholesale market, but they did not allow these plants to participate in reliability charge auctions for firm power. To address this limitation and improve the business case for eventual cogeneration opportunities, CREG Resolution 153 of 2013[8] enabled co-generators using bioenergy to obtain supply contracts for "fuel of agricultural origin" (Combustible de Origen Agrícola), receiving a reliability charge so long as they obtained guarantees through a technical report on the availability of fuel over the contracted period. This proved particularly effective for the sugar and palm cogeneration (e.g. in centrally dispatched sugar mills) that were able to meet the fuel requirements given their strong supply of feedstock (Asocaña, 2014[4]).

These regulatory reforms and market incentives have encouraged considerable growth in bioenergy co-generation over the last decade by creating the legal framework for those operations and importantly by supporting the clear business case for industry investment in cogeneration capacity. In fact, the Colombian Sugarcane Growers Association (Asociación de Cultivadores de Caña de Azúcar, Asocaña) consistently highlights the value of cogeneration in its annual association reports. It also works with the industry to bring forward regulatory weaknesses that may impede future capacity additions. For example, challenges such as penalties for reactive power[9] havehighlighted a potentially disruptive cost, even if new investments in the sugarcane industry are still proceeding. Other challenges include costs related to grid connections (e.g. possible need for investment in substations) and difficulties accessing finance (e.g. to upgrade to more efficient boilers) for some actors (see Chapter 4).

Lessons from the cogeneration market, particularly around creating a clear legal and business environment for generator participation, can be applied to the development of prospective bioenergy opportunities in other industries such as dairy production and hog farming, where the attractiveness of bioenergy solutions may be less obvious or where the regulatory environment may make the business case for recovery of waste in energy production challenging (e.g. in procuring waste streams).

Clarifying the regulatory environment for bioenergy will support greater project development

The Renewable Energy Law of 2014 was a major milestone for clean energy projects in Colombia, setting the framework for their use and adopting regulations for their integration in the market. A number of decrees and resolutions have successively strengthened this regulatory framework for renewable energy, including its use in electricity generation (Table 3.2).

For example, Planning Unit of the Ministry of Mines and Energy (Unidad de Planeación Minero Energética, UPME) Resolution 45 of 2016 created the context for net metering and allowed self-generators and distributed electricity generation to connect to the grid. CREG Resolutions 15 and 30 of 2018[10] then established the operational rules and remuneration for those projects, and MME Decree 570,[11] including subsequent MME Resolutions No. 40791 and No. 40795 of 2018, established the design for 15-year power purchase agreement (PPAs), with additional guidance on renewable energy auctions. Most recently, Law 2099 of 2021[12] set forth provisions to modernise legislation for the energy transition and to stimulate the development of non-conventional renewable energy (NCRE), including new definitions for green hydrogen (from renewable energy sources) and blue hydrogen (using carbon capture and storage) as NCRE.

These reforms have supported a growing share of renewables in Colombia's energy mix, including from recent solar and wind additions. The evolving regulatory framework has also supported development of bioenergy technologies, even if there remain some barriers to enable greater development of those solutions. For example, the Renewable Energy Law (Law 1715 of 2014) prioritised the use of local renewable energy resources, thereby indirectly promoting nearby agricultural, industrial and municipal waste for recovery in energy production. The Law also legally defined these potential energy sources from organic materials ("biomasa") and from energy recovered from solid waste as bioenergy.

Definitions and regulatory norms for bioenergy were also elaborated in policies such as CREG Resolution 240 of 2016,[13] which created the regulatory conditions for development of biogas and biomethane capacity. Importantly, these measures reinforced bioenergy as eligible for NCRE incentives, such as those under Presidential Decree 2143 of 2015,[14] which provided a 50% income tax reduction over a five-year period with rules on accelerated depreciation. The Decree also provided value-added tax and import duty exemptions on purchase of goods and services for the production and use of energy from NCRE. Decree 829 of 2020[15] by the Ministry of Finance and Public Credit (Ministerio de Hacienda y Crédito Público) then streamlined the process for evaluating project eligibility in order to reduce administrative procedures for securing such fiscal incentives. Specifically, the decree made UPME the sole responsible entity for the process, effectively halving approval time from three months to 45 days (Sanchez Molina, 2020[5]).

Access to such incentives has been particularly important for bioenergy development, where these technologies would likely struggle to be financially viable without such fiscal incentives, especially for early adopters (Alzate-Arias et al., 2018[6]). Specifically, regulation governing application and remuneration of bioenergy capacity is critical to project development. This is evidenced by growth in electricity sold to the grid from bioenergy cogeneration in the sugarcane and palm oil industries, where a clear, legal revenue stream helped to justify investments in expanded capacity and improved generation efficiency to maximise recovery of waste residues (RVO, 2021[7]).

Table 3.2. Highlights of legal measures targeting renewable energy development

Congressional **Law 788 of 2002** regulated the sale of electricity from wind energy, biomass and agricultural waste, exempting these from income tax for 15 years under certain conditions.
MME Resolution No. 18-0919 of 2010 adopted the 2010-15 Action Plan to develop PROURE, including defining the objectives, sub-programmes and provisions adopted in that regard. The validity of the plan was extended until June 2016, when the 2016-20 Plan was adopted.
Law 1715 of 2014 (the Renewable Energy Law) that regulated the integration of NCRE in the national energy system, with measures for 50% income tax reduction, a value-added tax exemption, import duty exemption and accelerated depreciation rules (under Decree 2143/2015). The Law also created a fund for non-conventional energy and efficient energy management (Fondo de Energías No Convencionales y Gestión Eficiente de la Energía, FENOGE) and increased the electricity tariff by 0.01 USD/kWh to subsidise the fund.
UPME Resolution 281 of 2015 defined the maximum power limit of small-scale self-generation and included VAT exemptions on machinery, equipment and labour costs for non-hydro renewable energy projects. Import tariffs were exempted on machinery, equipment and materials, alongside rules for a boosted depreciation rate up to 20% per year. The Resolution also expanded the income tax deduction for non-hydro renewables, from five to 15 years, and thus the rate to 150%.
UPME Resolution 45 of 2016 set to ease the process of grid-connections for power plants and established net-metering regulations for generation up to 100 kilowatt (peak) to sell surplus electricity.
MME Decree 570 of 2018 established the blueprints for long-term PPAs through renewable energy auctions. MME Resolutions 40791 and 40795 of 2018 then provided operational guidance for the auctions.
CREG Resolution 30 of 2018 set the operational and commercial rules for the integration of self-generation and distributed generation (below 100 kilowatts, between 100 kilowatts and 1 MW, and between 1 and 5 MW) and **CREG Resolution 15 of 2018** set the methodology for the remuneration and back-up supply of electricity in the national grid.
MME Resolution 49715 of 2019 mandated distributors to procure at least 10% of energy sold to regulated customers from solar, biomass, micro-hydro, wind or tidal power.
Congressional **Law 1955 of 2019** modified Law 1715 to increase the benefits of income tax reduction for NCRE generators from five to 15 years. It also added codes for custom tariff reductions on the import of solar panels and other items related to renewable energy generation.
Ministry of Finance and Public Credit Decree 829 of 2020 regulated granting of tax-related incentives for NCRE generation. It also stated that UPME shall be the only authority in charge of evaluating these benefits and their application.
Law 2036 of 2020 authorised the national government to finance support, using contributions from the General Budget of the Nation and the General System of Royalties, for the participation of territorial entities in the generation, distribution, retail and self-generation projects for small-scale and distributed generation with NCRE.
Law 2099 of 2021 modified the regulatory framework for NCRE and legally established green and blue hydrogen as NCRE. Tax exemptions were extended to power storage, smart metering systems and power management, as well as for investments relating to green and blue hydrogen. The law also established provisions on the energy transition, revitalisation of the energy market and economic recovery.

For other bioenergy applications, the business model can be less certain, although Law 2036 of 2020,[16] which recently authorised territorial entities to participate in NCRE development by making use of national funds, should help, as it included specific references to bioenergy and waste-to-energy projects. Still, there remain other critical barriers to widespread bioenergy project development. For example, uncertainty around current regulation for the sale of biogas (e.g. for self-generators connecting to the grid) only serves to compound lack of capacity and experience with such technologies in Colombia. The processes for obtaining licences, incentives and permits for biogas projects can also be complicated and lengthy, and delays in connection of new biogas projects to the grid have been highlighted as an issue (Duarte, Loaiza and Majano, 2021[8]). Part of this is due to the discretionary nature of connection rules, where the regulatory framework can do more to provide transparent criteria for accepted requests. Technical standards and regulations can also be poorly understood by relevant actors, especially in the agricultural sector where there is large untapped potential for biogas development but which has little to no experience in the management and commercialisation of power generation.

Connection rules and procedures can do more to facilitate bioenergy capacity

Addressing these barriers, for instance through clearer guidance on grid-access regulation, will help to encourage new additions in distributed and self-generation bioenergy technologies. UPME could also expand its connection assessment to take into account the potential role of biogas projects in demand response, for example looking at how these projects could partake in the Voluntary Disconnectable Demand Programme (El Programa de Demanda Desconectable Voluntaria). This programme provides the opportunity for self-generation to respond during peak demand periods or when electricity prices are high, either by reducing demand or by making additional power generation available to the electricity system.

The regulatory environment can likewise do more to target policy for bioenergy connections. For example, the legal framework for distributed generation and self-generators to sell surplus electricity to the grid was established under UPME Resolutions 281 of 2015[17] and 45 of 2016.[18] Yet, only small amount of solar (0.6 MW) and biogas (2.2 MW) self-generation capacity was approved for connection as of 2018. The latter was a biogas installation in Cundinamarca supported by grants from the German investment bank, kFW, to use wastewater from the local dairy food industry for cogeneration.

Part of this limited pipeline of additions was due to competition with fossil fuel generation, which also benefited for connection and as of 2018 made up more than 85% of grid-connected distributed and self- generation (UPME, 2021[9]). Subsequent guidance on operational and commercial rules for net metering (passed under CREG Resolutions 15 and 30 of 2018[19]) aimed to enable greater NCRE connection, although this had a more visible impact on solar connections, which reached 34 MW of capacity approved for connection to the grid by 2021. By contrast, approved bioenergy capacity only increased to around 2.9 MW by mid-2021, and the new additions (a 0.2 MW bagasse project and a 0.4 MW agricultural waste project) are still pending connection. Three additional bioenergy projects using agricultural residue are under review, but they would only add around 1.6 MW of new capacity.

This low interest in new connections is partially due to requirements for back-up power supply contracts for systems above 100 kilowatts (under CREG Resolution 15 of 2018), which in addition to reactive energy payments (for any generators that do not have automatic voltage control), have been highlighted as an important cost consideration for distributed energy projects, including bioenergy (Morganstein et al., 2021[10]). Additionally, negotiations on back-up supply charges can be challenging to navigate, and their cost calculations are complicated and not readily understood. This can limit interest in developing bioenergy solutions, and in some instances it has likely encouraged certain players to install smaller, on-site solar systems, even if larger installations or use of bioenergy technologies would offset a greater share of their energy consumption. UPME's record of requests for connection to the grid also highlights a clear challenge for bioenergy additions, where over 2.7 MW of said projects were rejected for connection since

2018, including five industrial projects using agricultural residues and two proposed livestock projects (UPME, 2021[9]).

Renewable portfolio targets can work with bioenergy projects, rather than against them

Recent regulatory reforms have since aimed to strengthen the opportunity for renewable energy projects, but again, these have not necessarily addressed opportunities for bioenergy connections. For example, MME Resolution 49715 of 2019[20] mandated that at least 10% of electricity sold to regulated customers by retailers be sourced from NCRE (excluding all hydro) through long-term contracts of ten years or more. Monitoring of these requirements will commence in 2023, where the recent renewable energy auctions helped retailers to begin securing their requirements through the new solar and wind capacity additions. The mandates also helped to enable the successful auctions, as retailers were looking to secure certain amounts of renewable energy capacity.

Yet, the specific rules for the renewable portfolio requirements do not readily encourage or facilitate retailers in securing bioenergy capacity (amongst other potential renewable opportunities). Specifically, the 10% mandate does not give credit to retailers for any renewable energy production used on-site by their regulated[21] consumers (e.g. rooftop solar or on-site biogas). Moreover, the quota rules do not allow retailer credits for renewable electricity sold to unregulated customers, which represent about half of electricity demand (Morganstein et al., 2021[10]). Without such credits, the requirements provide little incentive for retailers to pursue or facilitate potential clean energy agreements (e.g. via off-site PPAs) with unregulated commercial and industrial users, whose interest in procuring clean electricity, for instance through renewable energy certificate (REC) purchases, continues to grow (CEIA, 2019[11]). The portfolio standard rules also do not incentivise seeking agreements with potential self-generators or co-generators who could use their production capacity (e.g. from biogas co-processing) to sell surplus electricity (e.g. through bundled or unbundles RECs).

Colombia already has a few such REC initiatives, for example under the International Renewable Energy Certification standard, although it does not have an official REC system or regulations regarding the issuance of RECs. In late 2020, the grid and wholesale electricity market operator, XM, launched a REC registry and tracking system (“EcoGox”), which should help to provide improved transparency and accountability for this market to grow (Morganstein et al., 2021[10]). Still, formal guidance and/or measures to link RECs to the regulatory framework (e.g. tying RECs to carbon reduction credits under Decree 926 of 2017[22] and the expected development of an emissions trading scheme (IETA, 2021[12]) would support wider market participation. This includes improved linkages to the portfolio requirements under Resolution 49715, whereby retailers would be more motivated to engage consumers in clean electricity development and REC exchanges if these counted towards renewable portfolio targets. Improved incentive for retailers to work actively with consumers to procure clean electricity would also support the business case to develop bioenergy projects (with added economic benefit from RECs trading).

Colombia can also learn from international experience with RECs and other models for corporate sourcing of renewables (e.g. PPAs through power wheeling arrangements). This includes possible targeting of bioenergy development through these agreements or through an explicit REC framework. For example, the Renewables Obligation Certificates scheme in the United Kingdom awarded more certificates per MWh produced for offshore wind projects, given their more complex nature (e.g. structural design, capex and maintenance costs) compared to other renewable energy sources. Specifically, the number of certificates awarded varied according to the technology, where offshore wind generation received twice as many certificates per MWh than other renewable energy technologies between 2012 and 2014 and 1.5 times as many certificates in 2014 and 2015 (Riley and Zarnowiecki, 2012[13]).

MME and CREG can similarly consider ways to co-ordinate policy and regulatory frameworks to create a “carrot and stick” approach that has helped to encourage corporate sourcing of renewables in other countries. For example, Australia developed a renewable energy target scheme with financial incentives

(e.g. solar subsidies) alongside industry obligations for renewable energy consumption. This helped to bring spot prices down for renewable electricity generation (via certificates) and led to development of 3.5 GW of new renewable generation capacity in 2020, supported notably by corporate PPAs (Kay, 2020[14]). Such incentives could be combined in the Colombian content to encourage further development of bioenergy projects. For instance, tax incentives and/or other financial support (e.g. concessional finance or direct subsidies) could be used to encourage bioenergy development alongside industry obligations to increase its share of renewable energy consumption.

Stronger waste management regulation will encourage greater energy recovery

Colombia stands out amongst its regional peers for having a broad regulatory framework on waste management as well as for having a waste management sector that is primarily operated by private entities. The regulatory statute under Presidential Decree 1076 of 2015[23] incorporates measures to prevent mismanagement of waste and hazardous refuse, aiming notably to protect the environment and human health. It complements the previous Decree 838 of 2005[24] and later Resolution 1890 of 2011[25] which prohibited uncontrolled burning, dumping and temporary trenching of waste. Decree 2820 of 2010[26] similarly prohibited release of waste into bodies of water, and additional regulations such as Decree 2981 of 2013[27] and Decree 596 of 2016[28] provide for overall public sanitation services.

The result is that around 83% of municipal solid waste (MSW) is collected and disposed of in official landfills (RVO, 2021[7]). Disposal regulations also allow for cost recovery through collection tariffs, providing sufficient financial sustainability for these services. Specifically, Law 142 of 1994 and regulations such as Resolution 720 of 2015[29] and Resolution 853 of 2018[30] provided a basis for the provision of municipal services through competing companies with tariffs that are cross-subsidised across the socio-economic strata (Calderón Márquez and Rutkowski, 2020[15]). This allows 99% of municipalities to have waste collection services.

At the same time, close to 50% of landfill sites in Colombia will reach capacity over the next decade, and constraints on new disposal sites, due to public opinion and evolving regulation, mean there is a growing need for sustainable waste management practices. In recent years, the government has sought to prioritise waste-to-energy, recycling and composting through its 2016 policy on integrated management of solid waste policy (Política Nacional Para La Gestión Integral de Residuos Sólidos[31]) and the 2019 Circular Economy Strategy. Both aim to increase the rate of recycling and waste utilisation across the country, from 8.7% in 2020 to 17.9% in 2030 (RVO, 2021[7]).

The cost of waste disposal directly influences appetite for bioenergy solutions

The incentive for sorting and recovery of waste, despite a strong policy framework and policy ambitions, remains low. Landfill and waste collection fees are set by the Commission for the Regulation of Drinking Water and Basic Sanitation and apply to the amount of waste collected or disposed of. Waste management and landfill operators consequently have little incentive to reduce waste as this would impact their revenue streams, especially as most operations are privately owned.

In addition, landfill and waste collection fees are typically low. On average, waste disposal in landfills has a fee of around USD 9.5 per tonne, compared to higher rates such as those used at Bogotá's Doña Juana site, which has fees around USD 16 per tonne (RVO, 2021[7]). By comparison, average disposal costs in the European Union, where waste-to-energy applications are more common, are about USD 60 per tonne (CEWEP, 2020[16]). In European countries with high shares (i.e. >50%) of waste-to-energy treatment (e.g. Denmark, Finland and Sweden), gate fees and landfill taxes are more than USD 120 per tonne (IEA, 2020[17]).

To direct waste streams from landfills towards recycling and energy recovery, Colombia should continue to review waste fees and related market incentives. The Ministry of Housing, City and Territory already introduced a landfill tax in 2020, initially set at around USD 2 per tonne (RVO, 2021[7]). Progressively increasing the value of the tax will provide improved price signals that will encourage greater sorting and treatment of waste, as the current tax is only a marginal increase above current average disposal fees. This would also help to drive new business models around the sorting, recycling, and recovery of waste (e.g. in industry co-processing), where sorting and treatment are an essential step for waste-to-energy projects, as large quantities of organic and non-flammable materials in waste can lead to insufficiently high temperatures for energy production. They can also contribute to toxic emissions during incineration, which have led to public resistance and protests from public health concerns over waste-to-energy projects in countries such as Thailand (Weatherby, 2019[18]).

Given organic residues account for about 60% of MSW in Colombia (Government of Colombia, 2019[19]), sorting and treatment of MSW will play a critical role in enabling effective and efficient waste-to-energy solutions. This includes applications for energy-intensive industries such as cement production, which requires sorted and treated waste of known composition to be suitable for the combustion process and clinker sintering (Jovovic, 2017[20]). Treatment of other forms of refuse like hazardous industrial waste is equally important for these to be used as feedstock, although again, price signals under current regulations for hazardous waste do not sufficiently encourage treatment for recovery in energy production.

The regulatory framework for hazardous waste management in Colombia follows the international Basel Convention with rules and information on the quantities of hazardous waste generated (Ordoñez-Ordoñez, Echeverry-Lopera and Colorado-Lopera, 2019[21]). Notably, Decree 4741 of 2005[32] regulated the prevention and management of hazardous waste, and Ministry of Environment and Sustainable Development (Ministerio de Ambiente y Desarrollo Sostenible, MADS) Resolution 1362 of 2007[33] established the requirements and procedures for generators of hazardous waste to be listed in the Ministry's registry. A number of additional regulations,[34] for instance on equipment and refuse that contain or are contaminated with polychlorinated biphenyls, set requirements for the comprehensive environmental management of hazardous waste and Colombia stands out amongst regional peers for overall industry compliance.

Compliance with existing regulatory requirements may be high, but there nonetheless is little incentive to invest in waste-to-energy solutions, given the comparatively low costs of hazardous waste treatment and disposal, even when in specialised, secure landfills (RVO, 2021[7]). In fact, of the nearly 670 thousand tonnes of hazardous waste generated in 2019, nearly half went to final disposal in secure landfills (IDEAM, 2020[22]). Another 40% was treated (e.g. through pre-remediation and physical-chemical processes), and only 13% was actually recovered for other uses, for instance in energy production. Moreover, recovery of hazardous wastes with typically high calorific values (e.g. from the petroleum oil and chemical industries) was less than 2%, underscoring the lack of regulatory and financial impetus for energy recovery applications.

Firm disposal rules and higher fees will improve the business case for waste recovery

MADS policy on extended producer responsibility has helped to improve motivation with some producers to recover and treat certain hazardous wastes such as electrical and electronic equipment and batteries, although participation is voluntary (RVO, 2021[7]). The National Business Association of Colombia (Asociación Nacional de Empresarios de Colombia) has equally led some programmes to encourage recovery of post-consumer materials, although this has not necessarily led to any significant changes in industrial waste management.

Strengthening these initiatives, for instance through firm targets or mandatory retrieval of certain wastes, can help to increase overall treatment and recovery, as has been the case in other countries. For example, some extended producer responsibility policies have end-of-life requirements (e.g. through eco-fees or

mandatory deposit-refund schemes) to encourage waste retrieval, treatment and recovery.[35] Europe, the United States, Japan, Korea and Brazil, for instance, have end-of-life tyre regulations in place to ensure their proper management, treatment and re-use (e.g. in energy and material recovery) in lieu of landfilling (WBCSD, 2019[23]).[36] This has encouraged development of opportunities for waste-to-energy applications, where by example, 94% of all end-of-life tyres in Europe were collected and treated in 2019, with 40% used for energy recovery (ETRMA, 2021[24]).

Increasing the scope and stringency of the regulatory framework for waste management and recovery in Colombia will encourage similar development of potential waste-to-energy solutions. This will equally help to build the business case for expansion of industry experiences with such investments. For example, the cement company, Argos, developed co-processing capacity at two of its cement plants in Rioclaro and Cartagena, using more than 75 thousand tonnes of waste as an alternative fuel in 2018 (Stewardson, 2019[25]). MADS regulations already legally recognised this co-processing as a sustainable alternative under Resolution 909 of 2008[37] (later modified by Resolution 802 of 2014[38]), but there are no requirements or incentives to seek out such use of refuse-derived fuels. More stringent policies for waste disposal, recycling and recovery (e.g. for tyre manufactures or hazardous industrial waste) would consequently encourage a clearer supply chain and better business model for further alternative fuel applications in cement manufacturing (see Annex A on refuse-derived fuel use for cement manufacturing in Brazil).

Improved price regimes for waste collection services and landfill tipping fees can also support development of recovery and waste-to-energy capacity. This can be through direct pricing, building upon the recently announced landfill tax, or through use of differentiated fee scales for certain types of waste (e.g. high gate fees for hazardous wastes to urge greater treatment and recovery). Additional regulatory signals, such as development of a mandatory emissions trading scheme or carbon pricing that encompasses fossil fuel use in industry, would also provide incentive for waste recovery and re-use, so long as measures are complimented by clear regulation on future landfill disposal (i.e. avoiding a “chicken and egg” situation in which demand for waste is not matched by needs for alternatives to disposal).

The value of these potential price signals is already evident in waste-to-energy applications such as the Bogotá Doña Juana landfill, which is registered as a project under the United Nations Clean Development Mechanism to manage fugitive methane emission. Between 2009 and 2016, the project had already earned 4.6 million emissions reduction certificates from its use of methane to produce power for electricity supply to around four thousand households (Cruz, 2021[26]). The credits, which generate around USD 780 thousand per year in revenue for the project and the city, illustrate the opportunity for similar applications (e.g. the landfill biogas project that will be developed in Medellín) to benefit from carbon trading and/or global climate funds through such emissions reduction credits (Contreras et al., 2020[27]).

Lastly, the government can work with related industry associations to identify opportunities and additional regulatory barriers to waste-to-energy development. For example, the Latin American Cement Association (La Federación Interamericana del Cemento) has actively explored co-processing through its working groups since 2010, and these discussions have helped to inform regulatory frameworks in support of redirecting waste streams towards energy recovery within industry.[39] These types of dialogues can strengthen the regulatory link between waste and industry in Colombia, thereby helping to support development of a policy environment and market signals that enable practical and effective waste-to-energy solutions.

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