Annex A. Global experiences with bioenergy development

Bioenergy solutions, including waste-to-energy applications, make up a diverse landscape of technologies and feedstocks that can be used for heat and power generation, amongst other uses like biofuels for transport. Abundant residues in Colombia, from livestock and agriculture as well as municipal and industrial waste can be used to meet the country's clean energy ambitions, alongside other socioeconomic and environmental goals such as reduced emissions and limiting waste going to landfills. Bioenergy solutions, like the current use of waste residues for energy generation in Colombia's sugarcane and palm industries, can address heavy reliance on fossil fuels and the country's growing dependence on energy imports. Tapping into locally available waste can equally support ambitions to provide clean, reliable and affordable energy, for instance in zones not connected to the national grid. Yet, unlocking opportunities for these solutions will require co-ordinated action to create the enabling environment for bioenergy finance and investment.

The following case studies consider international practice in supporting the development of emerging bioenergy and waste-to-energy markets. In particular, these examples assess the policy considerations and support mechanisms that helped to create an enabling environment for finance and investment in those projects, from both domestic and international sources. Lessons learned from the experiences in Brazil, Chile, India, Turkey and even domestically in Colombia shine light on the different policy measures and good practices that can be applied in Colombia to scale up finance and investment in bioenergy applications.

Brazil: from waste to energy in the cement industry

Cement production is one of the most energy-intensive industries in the world, given the required crushing, grinding and blending of raw materials (mainly limestone and clay) that are burned at high temperatures (around 1 450 degrees Celsius) in a kiln in order to produce clinker, which is afterwards ground with gypsum to produce the final cement product. Fossil fuels, including in particular petroleum coke (petcoke), are consequently a major input into cement manufacturing, and the average amount of tonnes of CO_2 released per tonne of cement produced has continued to increase globally over the last decade (IEA, 2021[1]).

Given the high-heat consumption and energy intensity (e.g. for grinding) of the cement production process, energy-related expenses can account for as much as 30-40% of cement companies' operating costs (IFC, 2017[2]). The global cement industry subsequently started looking as early as the 1970s for substitutes to fossil fuels in order to reduce cash costs and to improve economic competitiveness. Since then, there has also been greater attention paid to the environmental impact of cement production, and finding economically viable alternative fuel solutions, without reducing the quality of cement, has become a central strategy to mitigating the carbon footprint of the sector.

In Brazil, the cement industry has one of the lowest CO_2 intensities in the world, thanks to a number of actions that the sector has taken since the 1990s, including for example energy efficiency measures and clinker substitution. While overall cement production in the country grew by nearly 275% between 1990 and 2014, the sector's emissions intensity dropped by 18% over the period, from 700 to 564 kilogrammes of CO_2 per tonne (SNIC, 2019[3]). This reduction was due in part to the use of alternative fuels, which began to grow in earnest in the early 2000s due to concerns about fluctuations in petcoke prices. By 2014, 14% of energy used for cement manufacturing in the country was through co-processing with alternative fuels, and this share has continued to grow, reaching about 30% in 2020 (ABCP, 2021[4]).

Alternative fuel use for cement production in Brazil

Co-processing in the country's cement sector began in the early 1990s when Votorantim Cimentos, the largest cement producer in Brazil, completed its first demonstration of alternative fuel inputs using industrial waste at one of its plants in Paraná in the south of the country. Since then, alternative fuels such as tyres, agricultural residues (e.g. rice husks and açai pits) and industrial waste have become more common for co-processing across the cement industry. For example, 14 of Votorantim's plants in Brazil co-process waste to substitute part of the petcoke used in kilns with alternative fuels (Cemnet, 2020[5]).

A wide variety of alternative fuels can be used for co-processing in cement plants, ranging from biomass and municipal waste to sludge, tyres and even hazardous industrial waste such as spent solvents and used oil. The type of alternative fuel determines its thermal substitution value and pre-treatment may be necessary with some refuse-derived fuel (RDF) in order to remove unwanted elements, increase the calorific value and/or convert the fuel input into forms compatible with the cement kiln.

Tyres and hazardous industrial waste are the most common alternative fuels used for cement co-processing in Brazil, in part due to their heat values and their availability. Other substitutes such as biomass and agricultural waste are also used, although they have a lower heating value and are used by other industries (e.g. biorefineries). Availability and cost of alternative fuels naturally influence their potential attractiveness for co-processing in cement production, where sufficient quality, density and predictability of RDF supply below petcoke prices has played an important role in justifying investments (e.g. for pre-processing and treatment capacity). Broadly speaking, cement companies in Brazil have typically looked to substitute petcoke with investments that have a payback less than three to five years (ABCP, 2021[4]).

A number of additional factors have influenced the use of alternative fuels in the country's cement sector. For instance, national regulations preventing tyres from going to landfills played a critical role in driving RDF use. Specifically, regulations set in 1999, then updated under National Council for the Environment (Conselho Nacional do Meio Ambiente, CONAMA) Resolution 416 of 2009, required manufacturers and importers to collect and dispose of old tyres for each new one produced. The National Tyre Industry Association (Associação Nacional da Indústria de Pneumáticos) accordingly worked to establish services for collection and final disposal of scrap tyres (da Silva, Chaves S. G. Francisco and Lopes, 2017[6]). This led to the creation of more than 1 500 collection points across the country, which supported development of waste and energy-recovery processes such as tyre granulation and co-processing in cement production.

Environmental sustainability has also played a role in co-processing in the cement sector. Already in 1999, Votorantim joined with the nine other largest cement manufacturers in the world to create the Cement Sustainability Initiative,[1] which set targets to mitigate the sector's environmental impact. In 2019, Brazil's National Union of Cement Industry (Sindicato Nacional da Indústria do Cimento, SNIC) and the Brazilian Portland Cement Association (Associação Brasileira de Cimento Portland, ABCP) launched a *Cement Technology Roadmap* with the Initiative, the International Energy Agency and the International Finance Corporation (SNIC, 2019[3]). This set further ambitions to reduce the specific CO_2 emissions from cement production in the country by another 14% over 2014 levels by 2030, increasing that target to 30% reductions by 2050. To achieve these ambitions, the roadmap noted the role of increasing alternative fuel use in line with the National Policy of Solid Waste (Política Nacional de Resíduos Sólidos, PNRS), setting targets to achieve 35% thermal substitution in cement production by 2030 and 55% by 2050.

PNRS was launched in 2010 by the federal government under Law No. 12.305,[2] which instituted national regulation on the reduction, re-utilisation, recycling, treatment and appropriate disposal of solid waste. Enforcement of this law has been more challenging compared to the tyre industry (which is a smaller pool of actors), but even so, it offers opportunity for further co-processing, given the roughly 79 million tonnes of urban waste generated annually in Brazil (Souza, 2019[7]). In fact, a first demonstration for municipal solid waste (MSW) co-processing was tested for licensing at Votorantim's Salto de Pirapora plant in São Paulo in 2018. Upgrades to the plant, including equipment modernisation and adaptation for co-processing, cost roughly USD 9 million (BRL 47 million) between 2016 and 2019, and the facility received a permanent environmental license to use MSW in 2019 after successful testing with nearly 18 thousand tonnes of RDF, resulting in 5.3% petcoke substitution (Votorantim, 2019[8]). Looking forward, Votorantim plans another USD 32 million (BRL 167 million) in investment for the plant to process up to 65 thousand tonnes of MSW per year. Four additional Votorantim plants are also adding capacity to transform collectively around 130 thousand tonnes of MSW to energy for cement production.

Under the SNIC Roadmap, the cement industry also set a voluntary target to increase use of MSW co-processing from almost nothing in 2019 to nearly 10% of fuel input by 2030, representing about 2.5 million tonnes of RDF for the sector (SNIC, 2019[3]). This initiative is being driven by industry considerations to tap into the large potential for MSW as a cost-effective solution beyond tyres and industrial waste. While the financial margin with respect to MSW cost and energy content is likely smaller than with tyres and hazardous industrial waste, cement manufacturers nevertheless consider that there is longer-term value in meeting sustainability targets and overall capacity to manage fluctuations in petcoke prices.

To achieve these ambitions, ensuring cost-effective supply and processing of MSW for cement co-processing will be critical. As in many other countries, MSW in Brazil is not only an environmental challenge but also often a waste management problem. Around 45% of municipal waste currently goes to landfills with no associated charges, and as much as 41% of MSW is not sent to appropriate sanitary waste sites (Gutberlet, Bramryd and Johansson, 2020[9]). Thus, while urban waste is an RDF opportunity for cement production, cost can still be an issue (as it is cheaper or free to landfill), and there can be little incentive to handle MSW for alternative uses.

Previous RDF experience with tyre co-processing (where roughly half of tyre waste, or 60 million tonnes per year, now goes to the cement industry) is helping in the development of an MSW market for cement production. For example, a pre-treatment facility was built by four companies that associated themselves to ensure sufficient, quality supply of RDF. A new MSW pre-treatment facility, Ecoparque Pernambuco, was also developed in 2019 to supply a LafargeHolcim cement plant located in Caaporã in the northeast of Brazil. ABCP has equally met with cement manufacturers in seven regions, representing roughly half of current co-processing capacity (1.2 million tonnes) in order to try to develop a cluster project for MSW.

The aim of these efforts is to promote co-operation with local governments in order to build a pipeline for MSW use in local cement industries. ABCP and its industry members are working with the Ministry of Environment to this extent in order to create an association with the two main waste groups in Brazil and increase potential synergies. Votorantim Cimentos also launched its own subsidiary, Verdera, in 2019 to provide waste management services across the country. This company is part of an overall transformational strategy for Votorantim, but it also builds upon opportunity to complement the company's main cement production activities and increase capacity for co-processing through waste management.

Policy measures to enable co-processing in cement production

While cement co-processing in Brazil has been largely driven by industry initiative, it has been supported all the same by a policy framework creating the underlying, enabling conditions for RDF use. Importantly, CONAMA Resolution 264/1999[3] defined and approved waste incineration in cement kilns. Further regulation under CONAMA Resolution 316 of 2002[4] addressed thermal treatment of waste incineration with emission limits for dioxins and furans in co-processing.

The 2010 PNRS also provided impetus for co-processing, signalling the government's intent to end irregular landfills and illegal dumping, while also setting a legal hierarchy for waste management. While implementation of the PNRS encountered a number of challenges, including notably enforcement of local and federal waste disposal regulations, the federal government has worked to improve this situation and passed a new Basic Sanitation Framework under Federal Law No. 14.026 of 2020.[5] In addition to a number of important reforms (e.g. on public concession of sanitation and waters services), the law allows municipalities to begin charging a tax for waste management services. It also requires states to define their municipal waste management programmes. Additional measures included plans for an auction of electrical energy from MSW to improve the economic viability of alternative waste management and the government has also provided around USD 20 million in support to municipalities aiming to find solutions for better waste management, including industry co-processing (Government of Brazil, 2021[10]).

Additionally, Resolution 499 of 2020[6] replaced and updated the 1999 co-processing regulation with clearer procedures for licensing of waste burning in rotary kilns. This update pulled from European regulations, notably on emissions parameters and concentration limits of persistent organic pollutants in the composition of waste. It is now being implemented by individual states, which have autonomy to create their own regulations at the same level or better than federal requirements. One such example is in São Paulo, whose regulation for blending stations does not allow certain types of wastes (e.g. wood containing halogenated organic compounds) that are permitted (or are not explicitly excluded) elsewhere. São Paulo likewise has specific regulation on thermal treatment of MSW, noting explicit guidelines on licensing, operational conditions, emissions limits and monitoring criteria. In other instances, states have specific minimum heat values for alternative fuels in co-processing. For example, the state of Minas Gerais in south-eastern Brazil specifically mentions "treated household waste" at a minimum lower heating value of at least 6.3 gigajoules per tonne (Lima Cortez and Goldemberg, 2016[11]).

In some instances, these types of state guidelines can encourage MSW and other RDF co-processing, but the heterogeneity of policies, and specifically state regulations that prohibit or complicate co-processing of certain wastes allowed in other areas, was highlighted in the SNIC Roadmap as an important challenge to further implementation of alternative fuel use in the country's cement industry. Alternative fuels were equally highlighted as one of the three core pillars (alongside energy efficiency and clinker substitution) to decarbonise energy use in the cement sector and the roadmap highlighted recommendations to enable co-processing solutions moving forward. This included the suggestion to establish standardised procedures across the waste management chain in order to document, monitor and track waste. This could build upon current issuance of "thermal destruction certificates" for certain types of waste as regulated by CONAMA Resolution 316 of 2002. The roadmap also recommended expanding existing state regulations for MSW co-processing to set national standards for urban solid waste treatment and energy recovery.

SNIC, ABCP and others are now working with national and regional authorities, including the Ministry of Environment, to carry forward these recommendations and to improve the business case for alternative fuel use in Brazil's cement industry. A technical agreement was signed in 2020, and the first output was an atlas (Atlas de Recuperação Energética) showing the current status of energy recovery, including the potential for the future.

Lessons learned and implications for the Colombian context

Experience with co-processing in Brazil's cement sector highlights that the success of alternative fuel use in industry depends on several important factors. This includes a well-defined regulatory framework for RDF use as well as an effective, reliable management process to ensure economically viable supply of waste. For example, manufacturer mandates for product recovery and disposal were critical to early adoption of cement co-processing with tyres. Policy guidelines and legal definitions on the use of residues in cement kilns also played a vital role in enabling industry investment, whilst measures such as the government's 2020 policy reforms have helped to facilitate licencing and industry participation. More recent efforts to expand co-processing to MSW substantiate this critical juxtaposition of waste management policy with industry regulation. Without levers to establish reliable MSW supply with consistent operational rules for manufacturers, there is low incentive to make long-term investments for alternative fuel use.

Colombia can learn from Brazil's experiences to promote similar opportunities for industry co-processing through waste-to-energy solutions. Co-processing may be recognised as a sustainable alternative under Ministry of Environment and Sustainable Development (Ministerio de Ambiente y Desarrollo Sostenible, MADS) Resolution 909 of 2008, but RDF use outside Colombia's sugar and palm industries remains limited. This is due in part to waste management and supply issues, where low tipping fees and lack of sorting and treatment do not facilitate development of co-processing capacity. Efforts to address these issues, such as the recently announced landfill tax, will help to address these barriers, although the Ministry of Mines and Energy (Ministerio de Minas y Energía, MME) and other relevant authorities should identify where more targeted policy support will enable industry initiative. For instance, the cement company Argos installed co-processing capacity using tyres as RDF at its Cartagena plant, using more than 75 thousand tonnes of waste as alternative fuel in 2018 (Stewardson, 2019[12]). This experience can provide useful insights for development of similar installations at other industry sites, highlighting where policy action can increase the opportunity and business case for co-processing.

One such action can be to encourage an early, clear supply chain of available refuse with good thermal substitution value, for instance by mandating extended producer responsibility requirements for tyre manufacturers, as was done in Brazil. Lessons from Brazil's cement sector and on-going efforts to expand RDF use to MSW stress this need for adequate waste management policy and disposal fees to ensure cost-effective fuel substitutes for petcoke. Industry concerns for environmental impact, consumer image and long-term decarbonisation may be factors that influence co-processing opportunities, but broadly speaking, these considerations still require a clear business case for RDF use (e.g. who will pay for pre-treatment of waste). This is underscored by low uptake of RDF in Colombia's cement sector, which like Brazil has concerns about petcoke price fluctuations but still has not actively pursued waste-to-energy opportunities.

Lessons can also be drawn on the impact of dialogue and co-ordination between industry and government. Brazil has benefited from leadership from SNIC and ABCP, who have supported co-ordination across stakeholders on matters relating to co-processing. Importantly, these associations provide a forum for cement manufacturers to engage with government, highlighting experiences and issues as well as actions to increase use of alternative fuels. These considerations can be pulled into the Colombian context, for instance through dialogues with the Latin American cement association (Federación Interamericana del Cemento) and the Colombia cement association, Procemco.

Brazil's experience highlights that working across such stakeholders (including actors such as landfill managers, recycling companies and municipal authorities) promotes an enabling environment for alternative fuel use in industry. Individual firms may be able to create "pocket" co-processing (i.e. local examples of supply and demand capacity), but achieving high shares of RDF use requires strong co-ordination of the actors and policies that influence the overall waste-to-energy value chain. For example, variations across Brazil's states in guidelines and definitions on what can be used in cement kilns underscores the need for national and subnational policies to be sufficiently harmonised in order to enable cement companies to expand co-processing installations across site locations.

Lastly, insights can be drawn from the development of the SNIC roadmap, which has helped to provide clear targets for thermal substitution in cement production in Brazil over the coming decade and beyond. Development of a similar roadmap in Colombia, for instance with Procemco, can help create consensus and a clear vision of how industry can increase capacity for RDF substitutes. The roadmap development process would likewise facilitate and encourage discussions across government and industry stakeholders on the pathways to reduce industry reliance on fossil fuels while identifying the appropriate policy signals and market conditions to enable long-term investment in alternative fuel use.

Chile: international collaboration for better waste management

In 2015, Chile submitted its Nationally Determined Contribution (NDC)[7] under the Paris Agreement, targeting waste management as a priority sector for the country. Households in Chile generate around 8.1 million tonnes of waste each year, and nearly 60% of that is organic wastes such as fruits, vegetables and garden trimmings (Ministerio del Medio Ambiente, 2020[13]). Only 1% of this waste is recycled, whilst the rest is sent to landfills where it decomposes and releases greenhouse gases (GHGs) such as methane. Overall, Chile's landfills emit more than 4 million metric tonnes of emissions each year, in addition to their wider environmental impact (Arcadis, 2021[14]).

In response, the government embarked on a bilateral co-operation with Environment and Climate Change Canada in 2017 to identify solutions that would accelerate actions to reduce the amount of organic waste going to landfills. The programme, called Reciclo Organicos[8] (organic recycling), aimed to build upon Canada's strong environmental and regulatory expertise in waste management in order to design a sustainable strategy for organic wastes in Chile through four core mandates to support: technology deployment; measurement, reporting and verification (MRV); capital leveraging and co-financing: and community engagement.

One of the major outputs of the programme was the development of a National Organic Waste Strategy (Estrategia Nacional de Residuos Orgánicos, ENRO), which Chile launched in March of 2021 as part of its NDC update. ENRO set an ambitious target to increase municipal waste recovery from 1% to 30% of organic waste by 2030, and to achieve 66% recycling by 2040 (CCAC, 2021[15]). Through recycling and waste management approaches (e.g. composting and biodigestion), the Strategy aims to reduce emissions from organic waste by as much as 70% by 2040.

The Reciclos Organicos programme

Reciclo Organicos was funded under Canada's USD 2.65 billion of climate financing commitment to help countries in their transition to low-carbon, resilient economies (Government of Canada, 2021[16]). The main objectives of the programme was to promote reduction of methane emissions in the waste sector through composting, biodigestion and landfill gas capture.

ImplementaSur, a consulting firm in Chile focused on climate change issues, was engaged to support development of Reciclo Organicos, whose USD 7 million of funding runs from 2017 to 2022. Specifically, the funding supported work with Chile's Ministry of Environment to develop ENRO as well as technical assistance to support municipalities and private sector stakeholders in preparing projects (e.g. supporting site selection, permitting, project engineering and financing). The programme has also co-financed some of these projects, and its support has additionally helped to create a portfolio of waste management initiatives across the country.

One such example is a waste-to-energy (biogas) project owned by biogas company, BioE. The project uses organic waste from a San Pedro vineyard, and BioE installed a pre-treatment facility that can receive different types of waste from farmers and local industry in the region (e.g. salmon farms) to produce electricity and heat cogeneration. The Reciclos Organicos programme supported BioE by providing co-financing for the plant upgrade and with help to pilot blockchain technology for an MRV system. The project is now operational and sells heat to the vineyard, which has a contractual agreement at an agreed price for the heat in exchange for its organic waste. BioE also receives a tipping fee for other wastes received, where the disposal fee charged depends on the type of waste (e.g. lower fees are used for higher energy-content waste). Electricity generated is also sold to grid. In total, the project investment was around USD 5 million for 1 MW of initial generation capacity, which is in the process of being increased to 2 MW.

Another example under the Reciclo Organicos programme is a project under construction undertaken by a landfill in Osorno in the south of Chile. A treatment facility is being built and will be in operation in 2022. This facility will divert organic waste (mainly animal waste from dairy farming and slaughterhouses) from the landfill for use in an anaerobic digester. Development of the project was encouraged in part by calls for circular economy solutions with some of the local companies, who have set goals for zero waste to landfills by 2030. The project will help to capture at least half of the total waste that is currently landfilled, and eventually 100% of that amount could be used for energy production using biodigestion. The producer, Ecoprial, will charge local firms in lieu of tipping fees, where companies were already paying relatively high amounts for treatment of their wastes. Resulting electricity will be sold to the grid, and while there presently is no plan to sell excess heat from the project, this is a future possibility (e.g. to local dairy industries).

Reciclo Organicos also supported Bioenergía Los Pinos[9] in expanding its biogas production and power generation capacity using methane emissions from the Concepción Waste Management Center (Centro de Manejo de Residuos Concepción) in the Biobío region. The project, which is expected to reduce emissions by around 2.3 million tonnes of CO_2-equivalent between 2020 and 2040, added biogas cleaning and conditioning systems to existing facilities as well as four new power generation units that increased the previously installed generation capacity from 2.8 MW to 9 MW. Several phases of expansion represented around USD 15 million in total investment (Parra, 2018[17]), where the Reciclo Organicos provided co-financing on the latest expansion, which had a capital expenditures of USD 6.4 million.

In addition, around 20 municipal projects have received support from the Reciclo Organicos programme since 2017. Three will be fully implemented by 2022 (implementation was extended a year due to the COVID-19 pandemic), and the remaining projects will continue to be developed with support from Chile's Ministry of Environment. Programme support depends on the specific needs of each project and can include, for example, identifying the right site, obtaining permits or developing the detailed engineering for the implementation of composting plants. In this process, the Reciclo Organicos programme works with partners, including local governments, to develop first-of-a-kind demonstrations such as composting programmes for this market.

An enabling policy environment for market development

The Reciclo Organicos programme was designed to deliver reductions in methane emissions in Chile, but not explicitly for clean energy development. At the same time, the programme's ambitions required consideration for policy measures and technology solutions that could divert organic matter from landfills, including, notably, ways to leverage private sector engagement for scaled-up implementation.

Waste-to-energy provides attractive solutions to help achieve Chile's emissions reduction ambitions, in addition to opportunities to scale up clean energy investment in the country. To enable those potential solutions, Reciclo Organicos needed to look at wider policy issues to address market development beyond simply managing waste. For instance, a number of policy instruments have previously supported growth of renewable energy technologies in Chile, but incentives have not necessarily been effective for the waste sector (e.g. compared with solar power generation). In fact, as growing solar and wind capacity additions lowered the average cost of electricity production, the business model for waste-to-energy projects became more challenging.

Part of this challenge was the lack of fixed tipping fees for waste. These were set by the market, which previously lacked signals on long-term policy strategies and obligations for waste management. ENRO consequently helped to address this issue by setting clear targets on reduced landfilling, signalling to firms that they needed to find new ways to handle their waste. Decisions naturally depend on a number of corporate considerations, but a critical element of Chile's waste management framework is now a legal policy alternative to sending waste to landfills. The development of regulation on burning methane from landfills, which previously was not clearly recognised, is another critical policy measure under review.

The Reciclo Organicos programme also helped to establish a consistent reporting framework for waste management. Co-operation between the Canadian and Chilean governments included development of an adapted version of protocols for emission reduction accounting and verification in waste management from Québec for the Chilean context. This will help to ensure that the waste sector is properly managed, and digital tools, such as innovative blockchain technology, have been deployed as part of the programme's MRV strategy. In addition to enabling real-time monitoring and recording of emissions reduction from projects (as well as MRV cost savings), these digital tools will allow Chile to show progress on its NDC – a key element for attracting further climate finance.

Monitoring and enforcement for waste tipping is a challenge, but awareness of environmental issues and social monitoring has been growing in Chile. For example, community complaints led to the closure of a meat processing facility that had badly designed wastewater treatment with overflow into the local environment. The resulting closure cost the facility millions of dollars in lost investment. The Reciclo Organicos programme has subsequently worked to build upon this growing public awareness, organising webinars, trainings and other educational events to build a network of stakeholders around waste management. In fact, the programme has nearly 70 thousand followers on Instagram.

Knowledge and capacity building were also a huge part of Reciclo Organicos. Through the process of engaging stakeholders and building consensus on waste management strategies, the programme brought together actors that traditionally did not work together (e.g. banks and municipal authorities). This helped to address Chile's overall policy environment for waste management. For example, composting, previously regulated by landfill regulation, will have a specific set of rules to evaluate its compliance of environmental and health regulations. Stakeholder dialogues also helped to revise action plans under Chile's initial NDC, which was resubmitted with specific mention of organic waste management and the government's intent to tackle this issue moving forward.

Lessons learned and implications for the Colombian context

Collectively, Reciclo Organicos projects are anticipated to save more than 9.8 million tonnes of GHG emissions to 2040 (CCAC, 2021[15]). To date, projects have already leveraged around USD 21 million in capital, highlighting the influence of programme support in creating the enabling conditions for market development. The scale of these investments most likely would not have happened without the focus on waste management and the demonstration of viable business models through the programme's support will help with replication moving forward.

As Colombia seeks to prolong the lifespan of the country's landfills, lessons can be drawn from the Reciclo Organicos programme. Importantly, Chile's long-standing engagement with partners like Canada on environmental issues (e.g. under the Canada-Chile Agreement on Environmental Co-operation[10]) and the government's clear commitment to waste management under its NDC supported the development of the Reciclo Organicos programme. Chile's strategic focus on reducing organic waste to landfilling helped the country to benefit from targeted development co-operation in support of these objectives. The focus also helped to design a more pointed programme (in lieu of a general technical assistance project) to encourage development and replication of solutions that divert waste from landfills, such as anaerobic digestion. This helped to design specific interventions, such as the support for the BioE installation that provided a clearer business model for project implementation, thereby helping to leverage private capital for project development.

The Reciclo Organicos experience also underscores the strategic role of policy to address lack of tipping fees, or low tipping fees, as in Colombia. Improving this critical price signal provides greater incentive for companies to seek waste management solutions, including development of waste-to-energy facilities such as those supported by the programme. Additional signals, such as a carbon credit (e.g. as described under Article 6 of the Paris Agreement) and tax incentives, can further improve the attractiveness of bioenergy solutions. For example, ImplementaSur estimated that the effect of increasing tipping fees by around USD 6 per tonne in Chile would noticeably affect the development of new waste-to-energy projects. Such considerations can similarly be considered in Colombia as additions to the new landfill disposal tax.

Improved enforcement, including through social reporting channels, also supported the underlying business case for development of waste management solutions in Chile. Rising public awareness of the environmental and climate-related impact of landfills has encouraged discussions on waste management and can do so in Colombia, for instance by taking advantage of MME and MADS social networks to create opportunities to monitor waste disposal and discuss alternatives to disposal, such as waste-to-energy projects.

In terms of capacity development, support for knowledge transfer was another important element of the Reciclo Organicos programme. For example, the Los Pinos project benefited from strong connections with a German company, who helped to support technology deployment and local staff development (e.g. working with foreign staff), which helped to bring down costs. These opportunities could similarly be pursued in Colombia and could build upon existing interactive channels such as ProColombia.

Colombia can equally look to expand upon approaches used in the Reciclo Organicos programme to adapt organic waste management solutions and business models to the Colombian context. For example, the household waste collection system in Colombia already uses a fee through electricity and water bills, resulting in a higher collection rate for municipal waste compared to other Latin American countries. An organic waste strategy could take advantage of this billing system to work with local and regional waste authorities to explore development of innovative, pilot programmes that divert waste streams from landfills. These eventual changes to Colombia's successful waste collection services, however, should be carefully balanced in order to avoid unintended consequences such as increased illegal dumping.

Alternatively, financial support (e.g. through blended finance) could be provided on top of current billing structures to encourage innovation solutions and new business models for organic waste management. The Reciclo Organicos programme highlights the role of leveraging financial support to create viable, bankable solutions for investors. Such blended finance solutions (e.g. to enable a pipeline of bankable waste-to-energy projects using standardised documentation) could help to reduce investor risks and increase familiarity with bioenergy developments in Colombia, particularly as commercial banks are still rather unfamiliar with the overall business model of such projects. Development finance and national funds such as FENOGE can thus support de-risking of early market development through financial instruments such as co-financing.

Lastly, a key benefit of the Reciclo Organicos programme has been capacity building to develop knowledge and provide standardised protocols (e.g. MRV using block chain technology) to evaluate projects. This, in turn, helps projects to attract finance and investment. Colombia can look to develop similar protocols for emission reduction in waste management with improved accounting and verification. This can include working with international partners to pilot block chain technology for real-time monitoring and recording of emissions reduction from projects. At the same time, this would support greater enforcement of targets on reduced landfilling, allowing for more assertive signalling to firms that they need to explore alternative pathways for waste.

Colombia: lessons from cogeneration in the sugar industry

Colombia's sugar crops occupy nearly 197 thousand hectares of plantations, mostly along the Cauca river. Resultant sugar production accounts for 1% of global sugar exports and equally contributes to Colombia being a top global producer of bioethanol through subsequent use of sugarcane bagasse (Asocaña, 2021[18]). The bagasse and other residues from the sugar production process also provide additional co-benefit through electricity and heat cogeneration in the sector. This helps sugarcane producers to reduce their operational costs as well as the need to dispose of waste residues.

Globally, most sugarcane mills have sufficient residues to achieve energy self-sufficiency with remaining capacity for exportable electricity. Existing use of cogeneration in Colombia and elsewhere underscores the financial benefit this waste-to-energy application provides to the sugar industry through revenues from electricity sales, particularly as the sugar industry operates seasonally. These revenues can be supplemented by other financial streams, such as credits from carbon sinks (Zafar, 2020[19]).

Use of sugar cane for cogeneration activities: the experience of Manuelita

Sugarcane cogeneration capacity in Colombia reached 319 MW in 2020, with 134 MW destined for sale as surplus electricity to the gird (Asocaña, 2021[18]). Manuelita, a public limited company (Sociedad Anónima), is one such contributor to these sales and is the third largest producer of sugar in Colombia. It also is the first producer of palm oil and biocombustibles in the country.

Founded in 1864, Manuelita has a long history in sugar production and other agribusinesses, with activities also in Peru, Chile and Brazil. In 2006, the firm began production and commercialisation of bioethanol from sugarcane in Colombia, and three years later expanded this to biodiesel production from palm residues. As these activities developed, Manuelita began using the palm and cane biomass to produce steam and electricity needs at its process plants (Manuelita, 2014[20]).

Manuelita continued to expand its cogeneration capacity using sugarcane bagasse, palm fibre, hulls and rachis, and biogas (biomethane) captured from the liquid waste in the extraction of palm oil. The company began selling surplus electricity to the grid in 2016, notably in support of efforts to mitigate the shortage of energy supply caused by the El Niño phenomenon. In total, Manuelita sold 5 GWh to the grid in 2016, equivalent to the consumption of around 30 thousand Colombian households that year.

Manuelita subsequently expanded its capacity to sell surplus electricity to the grid and by 2018, sales reached over 57 GWh. In order to achieve this, an investment of around USD 18 million (58 billion pesos) was made to install a new turbo-generator at the company's sugar-alcohol mill in Valle del Cauca. The increased sales of surplus power to replace some existing coal-fired power generation, lowering electricity-related carbon emissions by 20 thousand tonnes of CO_2 per year in 2018 (Manuelita, 2018[21]).

Outside Colombia, Manuelita also increased investment in power generation capacity at its palm and sugar production facilities. For instance, the company was awarded a 25-year power purchase agreement in Brazil to sell 150 GWh per year to the grid starting in 2021, equivalent to the consumption of 870 thousand households. Investment in the additional generation capacity was at the Vale Do Paraná alcohol mill in Brazil as a joint venture with French firm, Albioma (Manuelita, 2018[21]). In Peru, Manuelita likewise is considering investment in more efficient boilers to be able to sell as much as 28 to 30 GWh per year to the national grid.

In Colombia, Manuelita intends to increase its cogeneration capacity (currently around as much as fourfold by 2024, notably through boiler efficiency improvements. The company already identified 13 plants where such investments would be attractive, where reaching this capacity addition target will require investment of around USD 80 million (equivalent to around USD 2 million for each MW of installed capacity). The cost of investment typically includes connection to the grid (depending on the location), and there are some fiscal benefits as the capacity additions fall under renewable energy incentives. Otherwise, the investment will be paid from revenue from electricity sales, where Manuelita currently sells surplus electricity to a local energy utility at around USD 0.05 (200 Pesos) per kWh. It also sells surplus electricity on spot market, where the price is variable and can be very high in drought periods.

Overall, the return on investment for the capacity upgrades is high, given that with the same feedstock a more efficient boiler can produce even more electricity. Additionally, Colombia's temperate climate and longer sugar seasons mean that residues for cogeneration are available over a considerable period (around 320 days per year), adding to the business case for such investment. By comparison, Brazil, which accounts for around half of global sugar exports, has yields that are 33% less productive than in Colombia (Asocaña, 2021[18]).

In spite of these attractive conditions, one important question remains as to how these capacity upgrades will be financed. Previously, Manuelita has made such investments through corporate finance, but the cost of this debt and the need for upfront equity limit the breadth of total investment Manuelita would normally undertake from such projects. For example, a similar upgrade investment in Brazil was made through a financial partner under a 20-year build-own-operate-transfer model. Yet, this financial structure has been deemed too risky in the Colombian context, in particular due to risk of La Niña events, whose abundant rains reduce the sugar production season. As such, current options for financing Manuelita's expanded capacity are more challenging in Colombia.

An enabling policy environment for market development

Cogeneration in Colombia has grown considerably since early regulations permitting the sale of surplus electricity to the grid were passed under Energy and Gas Regulation Commission (Comisión de Regulación de Energía y Gas, CREG) Resolutions 085 and 086 in 1996. Successive regulatory reforms on grid access rules and the technical conditions for thermal and electricity cogeneration enabled impressive capacity additions in the sugar and palm industries (see Figure 3.1 and the regulatory section above). In particular, early guidelines provided the initial impetus for agroindustry to sell electricity on the spot market, either directly or through a retail agent, drawing interest in the first surplus generation sales, which reached over 100 GWh in 1999 (CCC, 2016[22]).

Still, uncertainty in spot market prices provided little incentive to undertake capital-intensive investments beyond selling surplus from existing capacity. Subsequent reforms in the 2000s increased the business case for making capex investment, but financing of those additions was still a challenge. In particular, regulations regarding cogeneration capacity additions only allowed investment to be taken by the actor carrying out the cogeneration activity. This effectively limited third-party participation, for instance through an energy service business model (UPME, 2015[23]). Moreover, constraints in access to bilateral contracts and limits in accessing the reliability charge auctions meant that the business case for new investments remained weak.

Further regulation in the late 2000s subsequently helped to reinvigorate industry interest, notably through fiscal incentives and clear guidance on access to long-terms contracts. This included important changes in exemptions for payment of contributions on energy destined for self-consumption. For larger firms like Manuelita that could ensure guaranteed power over 20 MW, bilateral contracts also created a clearer opportunity for revenue streams to justify capital improvements. Yet, bilateral contracts through a retailer to supply unregulated customers can be difficult to orchestrate, whilst bilateral agreements directly with a regulator equally depend on retailer incentive. The latter is not facilitated by accounting rules for renewable portfolio standards when electricity is used for self-generation (see regulatory section above).

That said, measures such as CREG Resolution 153 of 2013 on firm energy from fuels of agricultural origin have provided additional incentive for further development of industry cogeneration capacity, notably by improving foresight on revenue streams through long-term contracting. Law 1715 of 2014 equally provided for a number of fiscal incentives (e.g. the 50% income tax reduction) for cogeneration projects and these helped to further improve the economics of capacity upgrades and improvements. The effect of these incentives is evidenced by growth in installed cogeneration capacity connected to the grid.

Overall, changes in the regulatory environment regarding industry cogeneration over the last two decades have increased the underlying business case for actors like Manuelita to continue to invest in capacity improvements and additions. Still, policy reform has not adequately addressed how these projects are financed, where investment through corporate finance may not be a particularly attractive solution for certain companies and may be limiting the amount of capacity additions a firm can take on simultaneously, as is the case for Manuelita.

Lessons learned and implications for opportunities moving forward

The example of strong growth in sugar and palm industry cogeneration highlight the important role effective policy plays in supporting development and expansion of bioenergy technologies. Lessons from experiences in these industries, notably on clear guidance and incentives for industry actors to engage in capacity additions, can be applied to other potential sources of bioenergy, such as biogas opportunities that remain particularly untapped.

The example of Manuelita's experience also highlights some remaining barriers that can be addressed to improve the pipeline of bioenergy capacity additions moving forward. Even in cases where technical and market conditions have been well demonstrated over the last two decades, limitations in the potential vehicles to make such investment may be limiting the speed of new cogeneration additions. Addressing these issues, for instance through regulatory measures to facilitate bilateral agreements with or through retailers, will further help to demonstrate clear revenue streams for development and use of project financing. Financial support, for example through limited revenue guarantees, can equally help to address barriers to project finance for these types of capex improvements. Additional measures such as reforms addressing third-party engagement in these investments will also increase the pool of potential investors in bioenergy cogeneration.

These reforms will also help to increase investment in other bioenergy technologies, such as anaerobic digestion, which remain limited for a number of reasons (see regulatory section above), not least of which is the typical size of such actors, who may not be in the position to undertake direct financing (i.e. on-balance sheet finance) or have access to corporate finance. Investments in these opportunities will require greater access to various forms of finance, from affordable bank loans to co-investment with potential partners and energy service models such as the build-own-operate-transfer scheme used by Manuelita in Brazil. Some of these firms also have limited technical capacity and experience navigating the licencing, permits and connection to the grid. Thus while the existing regulatory framework provides a solid foundation for cogeneration, further policy measures and support mechanisms (e.g. capacity building or a project preparation facility) will help increase the pipeline of self-generation and distributed generation bioenergy technologies.

Additional support for market development can come through improved energy efficiency finance in Colombia. For example, increased cogeneration in the sugar industry can be achieved through investment in more efficient boilers. The return on investment through these improvements is typically high, as it cuts down on operation costs and increases available electricity for sale to the grid without changing the quantity of feedstock. Development of market-based initiatives such as the European De-risking Energy Efficiency Finance Platform[11] and the Investor Confidence Project[12] can help to build investor confidence in these types of energy efficiency upgrades, providing a clear evidence based on asset performance and the return on investment. Such initiatives in Colombia could be undertaken by FENOGE, possibly in collaboration with international partners, to increase affordable financing to bioenergy and other clean energy projects.

India: foreign investment for paddy straw to biogas in Punjab

Biomass is an important energy source in India, and more than 10 GW of power generation and cogeneration capacity has been installed in the country using bagasse and other biomass sources[13] (MNRE, 2021[24]). India's Ministry of New and Renewable Energy (MNRE) has emphasised the role of bioenergy as part of the country's clean energy targets to 2030 and beyond. Notably, it has highlighted the potential for 230 million metric tonnes of annual agricultural residues (e.g. bagasse, straw, rice and soya husks, coffee waste and cotton stalks) that could be used to produce as much as 28 GW of clean power capacity. An additional 14 GW of bagasse-based cogeneration could also be produced in India's sugar industry.

MNRE has equally supported implementation of biomass capacity development through a number of policy schemes and incentives, such as its national project on biogas development, its New National Biogas and Organic Manure Programme, and its off-grid biogas power generation and thermal energy application programme. These initiatives have supported the development of more than five million small-scale biogas plants (out of an estimated potential for 12.3 million units) as well as the addition of 389 off-grid biogas power projects since 2006. The latter represents nearly 9 MW of off-grid generation capacity (MNRE, 2021[25]). The New National Biogas and Organic Manure Programme also supports refined biogas products such as compressed biogas (CBG), which can be used for other priority sectors like green transport fuels and clean cooking (MNRE, 2021[26]).

The Verbio biogas project

In 2016, Verbio AG, a leading bioenergy manufacturer in Europe, launched the development of new biogas production activities in India. Verbio is a large-scale producer of biodiesel, bioethanol and biomethane, with production plants and bio-refineries globally turning out around 660 thousand tonnes of biodiesel, 260 thousand tonnes of bioethanol and 900 GWh of biomethane in 2020 (Verbio, 2021[27]). The company expanded its activities to India to build upon its experience as an alternative energy supplier in an emerging market that has large, promising bioenergy potential.

Verbio is currently in the process of completing its first biomethane plant in India, which is expected to be operational by the end of 2021. The project, worth around USD 13 million (INR 100 crore) is located in northern India in the Bhutal Kalan village area of the Sangrur District in Punjab. It was approved by the Punjab government in 2018 and is part of a wider agreement for an in-principle approval of nine such future plants in various parts of the state. These are worth as much as USD 120 million (INR 900 crore) in total potential investment (Project Reporter, 2018[28]).

The current plant is being built on a piece of land that Verbio purchased through the normal governmental permitting process. The acquisition and plant development are being financed directly by Verbio through its German headquarters as foreign direct investment. This covers the entire CBG process from raw material supply to biogas generation, transportation and sales. Verbio will purchase paddy straw from local farmers, pre-treat it and turn it into CBG using fermenters built by an Indian company. The CBG will then be transported to filling stations within a 70-100 kilometre distance from the plant for final use in trucks.

Verbio identified India as a new investment market (amongst other countries such as the United States, Canada, Poland and Hungary) given its significant potential for bioenergy development from agricultural, livestock and municipal waste. CBG potential in India is estimated at 32 million metric tonnes of annual output, relative to current production levels of less than 20 thousand metric tonnes (MIIM and EAC, 2020[29]). In addition, agro-production in CBG-relevant sectors (e.g. sugarcane and food grains) has continued to increase since 2015, where Punjab is among high-yield states for biofuel potential.

In this first CBG project, Verbio will convert around 100 thousand tonnes of straw per year to pure biomethane, demonstrating the potential for further capacity growth as well as how bioenergy production can deliver on multiple policy objectives such as reduced fuel imports and job creation in rural areas. Verbio's choice to develop CBG capacity in Punjab was due in part to legislation in India guaranteeing the fuel price at filling stations, while other factors encouraged this first demonstration project. For example, India already has a large fleet of compressed natural gas (CNG) trucks, and density of demand at fuelling stations can reach around 33 tonnes per day for large consumers along key highways. Other CNG vehicles and captive fleets (e.g. taxis) could equally be eventual consumers of CBG, tapping into consistent demand profiles that warrant expanded plant production. There may also be eventual synergies in CBG production, for instance humus (i.e. digestate) from the biomethane production could be burned and used for electricity generation or for heat cogeneration with local industry as secondary markets.

Financing biogas development

While market potential for CBG is promising, this first Punjab biomethane project is not by itself bankable, as it does not yet have guaranteed offtake. Feedstock sourcing, being managed by Verbio, is equally an additional cost to the project, although at the same time, it is necessary to ensure sufficient sourcing of agricultural waste for CBG production. As such, Verbio sees this project as a way to validate the business case for multiplying these types of CBG production units in India, using this first demonstration as a test on the various design elements and potential business model. For instance, the original 2016 plans were looking at bioenergy use for electricity production, but these shifted to CBG production given the low cost of electricity (around USD 0.03-0.04 per kWh) with India's rapidly growing solar and wind markets.

As Verbio looks to expand beyond this initial CBG project, it will need financing to do so. Equity is an option, although this is typically expensive and needs to be combined with debt to lower costs. Achieving expected returns of 10-15% (e.g. compared with other renewable energy developers in India) may equally be challenging for use of equity. In particular, it may be difficult to achieve these rates given current CBG market demand and the need to develop comparable growth in scale (both on the raw material side as well as through procurement/sales) in order to achieve those levels of return on investment. Debt financing could also be used to expand capacity, but interest rates are typically high (e.g. 12%).

India does have available funds for these types of clean energy projects, for instance through MNRE bioenergy support schemes[14] and waste-to-energy financing schemes through the Indian Renewable Energy Development Agency.[15] International finance, for example through KfW, a German state-owned investment and development bank, is also a possible way to expand Verbio's biogas capacity in India. Other support such as de-risking mechanisms (e.g. through a corporate guarantee) would help to address some of these early-market financing challenges.

Policy support can help to address some of these risks, for instance by creating targets or quotas that provide greater offtake assurance. The Government of India is planning legislation to allow some blending in the gas network, and there are also discussions with oil majors, which would help to create sizeable market demand as these companies have around 40 thousand fuelling stations across the country.

Addressing other barriers to expanding biogas production in Punjab and elsewhere in India can facilitate further investment and expansion. For example, recycling humus back to farms will help to maintain source production, and efforts such as capacity building and awareness raising can support this. Farmers have not always seen fertiliser as a good thing, and Verbio has had to work closely with them as part of it sourcing activities, which have an added cost to CBG production. Project development was also relatively long and complicated (it required working with about 50 landowners to acquire land), although Verbio did receive support from the local government, the state minister and the Indian oil minister, which helped in the development of this first project. Notably, Punjab facilitated the Verbio investment through a clear contact point that helped with permitting and approval process, through the Punjab Bureau of Investment Promotion (Invest Punjab),[16] effectively serving as a one-stop shop.

The overall impression from this first CBG project as its development nears completion is that there is considerable room for future growth and investment. Farmers have been happy to be involved, even if they do not receive any money (for now) because it means they do not have to dispose of or burn their waste, the latter having become an important social issue in India due to air pollution from agricultural burning. The government also set targets of 15 million metric tonnes per annum for CBG production by 2025 under its Sustainable Alternative Toward Affordable Transportation scheme[17] announced in late 2018. This will help to drive market demand for CBG as a substitute for CNG with large future growth potential as only around 0.1% of the this target has been achieved to date (MIIM and EAC, 2020[29]). Verbio consequently has plans to build five additional facilities at an estimated investment of around USD 120 million.

Lessons learned and implications for the Colombia context

The Verbio project highlights various market elements and design considerations that influence private sector investment in an emerging clean energy market. Raw material supply, the potential market for the product, local and national legal frameworks (including access to English documentation), and security of investment are all important factors that contribute to investor willingness to step into a new market.

Policy signals such as long-term targets or energy plans, market statistics and energy pricing also help to create an enabling environment for investment. The Verbio project demonstrates how creating these conditions (e.g. in support for accessing/acquiring land for the CBG plant and raw material supply as well as a legal framework and policy environment that signal a market for biogas development) encourage the investor to take on investment risk, even in a nascent bioenergy market. Some of these elements have been addressed and have helped to reduce perceived risks for Verbio, who has taken an investment decision based on future demand potential. By comparison, Verbio found in other countries it considered for potential investment that those essential conditions were still too risky.

As Colombia seeks to increase private investment in biogas, the Verbio case stresses the importance of clear policy signals in supporting developer assessment of risks and returns. Regulations around bioenergy targets and programmes focused on biogas development have helped Verbio to take investment decisions, staking on the government's commitment to executing its biogas strategy. Notably, the Verbio project underscores that future market potential is a key interest in this type of early-stage investment. Such strategic outlooks in Colombia, for instance adding biogas targets for industry and electricity generation, building upon expanded biofuel mandates for transport, would enable similar business ventures.

Other support measures include end-use prices (e.g. for CBG fuel sales) that can increase attractiveness of investment, giving improved investor visibility on potential future returns and encouraging early market development. These price signals also provided an important incentive to develop strategic biogas activities such as work with local farmers in order to capture future needs and opportunities. Colombia could consider similar use of targeted pricing for bioenergy vectors (e.g. biogas) that have notable potential but that currently have limited market use. This would help to drum up investor appetite, whilst equally support deployment of generation capacity that will help improve price competitiveness in the future.

Finally, the case of Verbio illustrates the importance of business facilitation, such as a clear contact point for questions on permitting and approval processes. This can simplify the investment experience for foreign bioenergy developers and investors, who may need support in navigating formal procedures for project development, cutting down related investment costs and time. Support in working with farmers for acquiring raw material input could also help to ensure a clear supply chain, given the fragmented and informal nature of supply in Colombia. This can be done through measures addressing network development, for instance to find potential off-takers like the filling stations and oil companies working with Verbio in India, and will help create a solid business case for future investment.

Turkey: biogas production from livestock manure

Turkey is an important exporter of agricultural products and ranks as one of the 10 largest agricultural producers in the world (FAO, 2021[30]). Accordingly, the share of the agriculture sector in the Turkey economy accounts for 6.4% of GDP value added (OECD, 2021[31]), and large volumes of subsequent residues with high diversity of agricultural waste mean the sector represents considerable opportunity for bioenergy development. In fact, residues from agriculture are estimated to represent as much as 100 TWh of potential energy. Of this, biogas potential could be as high as 23 TWh, or roughly 7% of the country's electricity generation in 2019 (IEA, 2021[32]). Bioenergy capacity would equally address issues such as emissions and soil degradation from agricultural activities. Livestock in particular accounts for over half of the sector's GHG emissions and contributes to other environment issues from livestock waste (FAO, 2016[33]).

The government's Renewable Energy Action Plan (REAP)[18] set out targets in 2014 to achieve 1 GW of energy from biomass by 2023, compared to 224 MW installed by 2013 (FAO, 2016[33]). This target was surpassed before 2020, with over 1.1 GW of capacity installed by the end of 2019 (Gönül et al., 2021[34]). Bioenergy for power generation alone accounted for 3.2 TWh of renewable electricity in 2019 (or 1.1% of total generation), mainly from biogas. This supported achievement of broader renewable energy targets, achieving 44% of the country's electricity generation from clean energy in 2019, exceeding the goals set in the country's Eleventh Development Plan for 2019-2023 (IEA, 2021[32]).

This impressive growth in bioenergy and renewable energy capacity additions over the last decade was supported by a number of supportive policies. Notably, the Renewable Energy Support Mechanism (Yenilenebilir Enerji Kaynakları Destekleme Mekanizması, YEKDEM)[19] under the Ministry of Energy and Natural Resources (MENR), has offered attractive feed-in-tariffs and other financial incentives for renewable energy projects, encouraging investment in solutions like biogas production across the country.

The experience of Energrom Energy in developing biogas capacity

Energrom Energy is a private engineering and investment company focused on renewable energy, including bioenergy production. The firm was established in 2015 as a partnership between Moots Investment (United States) and the owners of international contracting companies operating in Turkey.

Energrom has three biogas power plants that produce clean electricity and biofertiliser. These include the company's Foça plant in İzmir (3 MW capacity), its Balıkesir plant in Balıkesir (3 MW) and the Kuyucak plant in Aydın (2 MW). All three plants were recently completed in order to benefit from the YEKDEM scheme ending in June 2021. Notably, the projects were finalised under the last round of the scheme as it provided a USD-denominated tariff for a period of ten years.

Energrom also has two further projects under preparation, pending public permits. These will fall under the most recent YEKDEM scheme,[20] valid to December 2025, which offers feed-in-tariffs in Turkish lira, as well as a price adjustment mechanism. Renewable energy investments under the scheme can also benefit from other incentives such as exemptions for value-added tax and custom duties for projects over a given investment size, dependent on the region of installation.[21]

An important element in Energrom's previous and on-going biogas projects has been to secure site locations in sufficient proximity to livestock farms in order to have clear access to residue feedstock. This can be a challenge, as the plants sites themselves cannot be on land destined for agricultural activities. The sites also require pre-feasibility studies co-ordinated with municipal authorities. To expedite this process, Energrom has undertaken the feasibility studies itself and purchased site locations before starting the bioenergy project permitting and licensing procedures. The company also secured supply contracts with regional farmers to have sufficient feedstock for the plants' electricity production, as demonstrating this capacity is required to obtain the plant permits. These supply contracts are incentivised, indirectly, by environmental requirements for farms over a certain threshold (e.g. 500 animals for cattle breeders) to dispose of waste through licenced institutions. Additionally, Energrom provides a fee per tonne of waste, which encourages not only obliged farms but equally those below the regulatory threshold to engage in supply contracts. Some of these supply contracts (e.g. for vegetable and other organic wastes) can also require further environmental permits. As such, the preparatory phases of project development can be relatively onerous and Energrom often contracts a third party to identify and co-ordinate these waste suppliers.

Once its sites are operational, Energrom plant electricity is sold to the interconnected grid on a daily basis through a distribution company, for instance under a fixed tariff through the YEDKEM scheme. Sales can also be done outside the scheme by selling directly through a private distribution company at an agreed price. As long as electricity generators are licensed, they have the right to register in the YEDKEM scheme for any year within the 10-year eligibility period. Generators who negotiate directly with a private distribution company can always register for the YEDKEM scheme the following year.

The choice to sell electricity through the YEDKEM scheme or via a private distributor allows firms to choose agreements with a more advantageous return, which is useful in the case of the Energrom installations, especially as foreign capital from Moots Investment constitutes an important share of finance for the plants. Exchange rate fluctuations already are a potential investment risk, including for capex costs for machinery that is commonly supplied from abroad. Bank credits have been used as mezzanine finance, but to date the projects have not benefited from any concessional or dedicated (e.g. green) lending, as this is still uncommon in Turkey. Energrom is consequently looking into green funds or climate financing opportunities to fund future projects.

Additionally, Energrom has registered its operational facilities under an internationally approved carbon standard, VERRA,[22] which provides carbon emissions reduction certification for the sites such as the 3 MW Foça plant.[23] Turkey does not have a carbon emissions trading scheme in place, and the certification allows Energrom to issue tradable emissions reduction credits on the open market for companies to offset their emissions.

An enabling policy environment for bioenergy market development

Renewable energy sources are prioritised in Turkey's energy agenda under the 2014 REAP. Specifically, the plan set a target for renewable energy to make up at least 30 percent of electricity generation by 2023. This ambition was supported by technology specific targets, including 1 GW of bioenergy, 1 GW of geothermal, 2 GW of hydropower, 5 GW of solar and 20 GW of wind energy (FAO, 2016[33]).

In order to deliver on these targets, the YEKDEM scheme has provided attractive feed-in-tariffs with a local content bonus for generation components manufactured in Turkey. The 2015-20 round of the scheme played an instrumental role in encouraging investment across renewable energy technologies, particularly through USD-denominated tariffs (CIFTCI, 2021[35]). The result was a near tripling of renewable electricity generation in the 2010s (IEA, 2021[32]), and by 2021, investment in renewable power reached nearly USD 66 billion (Erkul, 2021[36]). In 2020 alone, renewable energy financing reach USD 3 billion, supporting nearly 5 GW of new capacity additions (Erkul, 2021[37]).

The new YEKDEM scheme, running to 21 December 2025, will continue to provide a domestic production incentive, with the notable change to feed-in-tariffs in Turkish lira. To address the risks of this denomination for investors, the 2021-25 scheme includes a quarterly escalation mechanism, based on the producer price index, consumer price index, and USD and euro purchase rates. Feed-in-tariffs also were decreased to reflect the declining cost of renewable energy. While the effect of these changes remains to be seen, the added exchange and interest rate volatility risks may be challenging for some projects like geothermal and bioenergy solutions, whose costs have not fallen as significantly as other technologies, like solar and wind. One such example is biomethane feed-in-tariffs, which decreased by 44% under the new scheme, from USD 0.13 per kWh to a 0.54 Lira per kWh (roughly USD 0.075 per kWh in January 2021[24]). This drop does not likely reflect any such cost improvements in new bioenergy generation capacity additions and, as a result, the payback period for Energrom biogas projects, which previous was seven years under the USD-denominated tariff, will likely increase under the new YEKDEM scheme.

In addition to feed-in-tariffs and other economic incentives for renewable energy projects, the Government of Turkey has also taken steps in recent years to simplify clean energy project development. For example, an Energy Investments Co-ordination Board was created in 2016 to facilitate the permitting processes for public and private sector investments in energy projects (Ersin, Arseven and Baydar, 2016[38]). Project developers can also bring investment challenges before the board, which is headed by the vice minister of MENR and is comprised of representatives from various government ministries. The board does not serve as a one-stop shop, for now, and projects are not required to go through the board. For example, Energrom did not use the board and instead pulled from permitting, licensing and project design experiences with other companies that previously had invested in biogas.

Still, co-ordination across the relevant authorities and procedures has helped to simplify and accelerate the investment process (IEA, 2021[32]). For example, the board has helped to inform new regulation that supports renewable investments and particularly investments in bioenergy. It also has helped to increase co-ordination across ministries, which is particularly important for biogas production. For example, use of various animal, vegetable and organic wastes in biogas and biofertiliser production, such as the Energrom facilities, means licensing for these projects can fall under the regulatory frameworks of MENR, the Ministry of Environment, the Ministry of Agriculture and other government authorities. Co-ordination of technical studies, impact assessments, permits, licenses and procedural steps to installation is therefore critical to limiting the time and expenses for project preparation and development activities such as those undertaken by Energrom and its consultancy groups. Once developed, generation licences and YEKDEM incentives have to be approved by the Energy Market Regulatory Authority. Subsequent activities for related fertiliser production (and applicable grants[25]) then go through the Ministry of Agriculture. Thus, the co-ordination helps in ensuring this process is as straightforward and in step as possible. Future measures, such as a one-stop shop for all of these procedures, would further facilitate similar biogas plant development.

Lessons learned and implications for the Colombian context

The Energrom Energy biogas projects will together produce as much as 150 GWh of annual electricity output and around 105 thousand tonnes of fertiliser. This will equally eliminate around 414 thousand tonnes of emissions from the clean electricity output and reduced carbon footprint of agricultural waste, supporting achievement of the government's commitment to increase the share of renewable energy, with added benefits such as improved energy security using locally available energy feedstock.

One important element supporting the development of bioenergy projects such as the Energrom biogas plants is the near-term targets set forth in the REAP strategy to 2023. These provided the foundation for subsequent feed-in-tariffs under the YEKDEM scheme, which alongside other incentives such as tax exemptions have encouraged development of bioenergy and renewable energy additions in Turkey. The effect of recent changes from USD to lira-denominated tariffs will be seen in coming years, though the escalation mechanism should help to address some of those currency exchange risks. The potential impact on bioenergy projects from recent price adjustments also is to be seen, although it underscores an important element in the design of these types of schemes: notably, that use of financial support mechanisms should aim to account for market evolutions to apply public funds as effectively as possible.

As Colombia looks to increase the share of renewable energy technologies in the country's energy mix, including tapping into bioenergy potential, it can clarify short- to medium-term signals under UPME planning in order to reflect policy ambitions in more concrete terms. These specific targets can then be used to assess technology-specific incentives or price signals, such as those under the YEKDEM scheme, to encourage investment in less developed markets (e.g. biomethane production). MME may also want to assess the potential role of other support mechanisms to address eventual risks for bioenergy developers and investors, specifically as the multifaceted nature of these projects (as seen in Energrom's experience) already can have several possible risks through the project cycle (e.g. in impact assessments, licencing, land acquisition and supply contracting).

MME could also consider design of financial mechanisms to address risks for foreign investors. The USD-denominated feed-in-tariffs under the last round of the YEKDEM scheme played a critical role in mobilising foreign capital for Turkey's renewable energy market, supporting phenomenal growth in renewable energy technologies, from 2% of generation capacity in 2010 to more than 15% in 2019 (IEA, 2020[39]). While the risk of a USD denomination was borne by the YEKDEM scheme (and the Turkish government), other de-risking instruments, such as support for a currency hedging mechanism, could be considered to address this risk and attract greater FDI for bioenergy projects in Colombia.

Finally, lessons can be extracted from Turkey’s experience with the Energy Investments Co-ordination Board, which is an important step towards simplifying complex permitting and licencing procedures. More recent measures to take this body forward as a one-stop shop will continue to facilitate investment in clean energy development, whilst streamlining processes that can add to the costs and time commitments for project developers. A similar body in Colombia, for instance under MME or the National Planning Department (Departamento Nacional de Planeación), would help to improve institutional co-ordination and address the more complicated nature of bioenergy projects. A one-stop shop, for instance through the ProColombia portal, would likewise facilitate project development and help to attract foreign investment for bioenergy additions, whilst helping to reduce developer time and costs. Additional features could also be added to this portal, for instance targeting bioenergy projects through the platform to facilitate matchmaking between planned and proposed projects with prospective investors.

References

ABCP (2021), *OECD communication with the Brazilian Portland Cement Association (Associação Brasileira de Cimento Portland, ABCP)*. [4]

Arcadis (2021), *Designing a sustainable waste management program in Chile*, Canadian Ministry of Environment and Climate Change and the Chilean Ministry of Climate Change, https://www.arcadis.com/en/projects/north-america/canada/can-chile (accessed on 4 October 2021). [14]

Asocaña (2021), *Annual Report (Informe Annual) 2020-2021*, Colombian Sugarcane Growers Association (Asociación de Cultivadores de Caña de Azúcar, Asocaña), https://www.asocana.org/documentos/1782021-3772D9B2-00FF00,000A000,878787,C3C3C3,FF00FF,2D2D2D,A3C4B5.pdf (accessed on 8 September 2021). [18]

CCAC (2021), *Chile and Canada Partner to Reduce Emissions from the Waste Management Sector*, Climate and Clean Air Coalition (CCAC), https://www.ccacoalition.org/en/news/chile-and-canada-partner-reduce-emissions-waste-management-sector (accessed on 4 October 2021). [15]

CCC (2016), "Cámara de Comercio de Cali", *Cali Chamber of Commerce (Cámara de Comercio de Cali, CCC) Rhythm Cluster (Ritmo Cluster)* 03, https://www.ccc.org.co/inc/uploads/informes-economicos/ritmo-cluster/3.pdf?__cf_chl_captcha_tk__=pmd_InPQWtyNiusgTdfX_gAHa6ciIY8LFy.akEfLyB1rk7w-1632660979-0-gqNtZGzNAyWjcnBszQbl (accessed on 26 September 2021). [22]

Cemnet (2020), *A new destination for waste*, International Cement Review, https://www.cemnet.com/Articles/story/169339/a-new-destination-for-waste.html (accessed on 4 October 2021). [5]

CIFTCI (2021), *Turkey Introduces the New YEKDEM Scheme*, CIFTCI Attorney Partnership, https://www.ciftcilaw.com.tr/content/site-ycap/en/publications/recent-publications/turkey-introduces-the-new-yekdem-scheme/_jcr_content/parsys_article/download/file.res/Client%20Briefing_TURKEY%20INTRODUCES%20THE%20NEW%20YEKDEM%20SCHEME.pdf (accessed on 27 September 2021). [35]

da Silva, R., R. Chaves S. G. Francisco and A. Lopes (2017), "Co-processing of Scrap Tires and Waste from the Re-refining of Used Lube Oil in Cement Kilns", *International Journal of Engineering and Applied Sciences*, Vol. 4/6, https://media.neliti.com/media/publications/257451-co-processing-of-scrap-tires-and-waste-f-c3ca228a.pdf (accessed on 4 October 2021). [6]

Erkul, N. (2021), *Clean power investments in Turkey reach $66B, creating 53% of electricity capacity*, https://www.aa.com.tr/en/energy/renewable/clean-power-investments-in-turkey-reach-66b-creating-53-of-electricity-capacity/33610 (accessed on 5 October 2021). [36]

Erkul, N. (2021), *Turkey's renewable sector to attract $3B fund in 2021*, https://www.aa.com.tr/en/energy/finance/turkeys-renewable-sector-to-attract-3b-fund-in-2021/31845 (accessed on 29 September 2021). [37]

Ersin, B., E. Arseven and C. Baydar (2016), *Energy Investments Tracking And Coordination Board Established In Turkey*, Moroglu Arseven, https://www.mondaq.com/turkey/oil-gas-electricity/475254/energy-investments-tracking-and-coordination-board-established-in-turkey (accessed on 5 October 2021). [38]

FAO (2021), *Turkey at a glance - FAO in Turkey*, Food and Agriculture Organization (FAO) of the United Nations, http://www.fao.org/turkey/fao-in-turkey/turkey-at-a-glance/en/ (accessed on 5 October 2021). [30]

FAO (2016), *BEFS Assessment for Turkey: Sustainable bioenergy options from crop and livestock residues*, Food and Agriculture Organization (FAO) of the United Nations, Rome, https://www.greengrowthknowledge.org/sites/default/files/downloads/resource/FAO_EBRD_Bioenergy%20and%20Food%20Security%20Assessment%20for%20Turkey.pdf (accessed on 27 September 2021). [33]

Gönül, Ö. et al. (2021), "An assessment of wind energy status, incentive mechanisms and market in Turkey", *Engineering Science and Technology, an International Journal*, http://dx.doi.org/10.1016/J.JESTCH.2021.03.016. [34]

Government of Brazil (2021), *R$ 100 million public notice opened for works under the Lixão Zero programme in Minas Gerais (Aberto edital de R$ 100 milhões para obras do programa Lixão Zero em Minas Gerais)*, Government of Brazil, Ministry of Environment (Ministério do Meio Ambiente), https://www.gov.br/mma/pt-br/assuntos/noticias/aberto-edital-de-r-100-milhoes-para-obras-do-programa-lixao-zero-em-minas-gerais (accessed on 4 October 2021). [10]

Government of Canada (2021), *Canada's international climate finance*, Canada's international action, https://www.canada.ca/en/services/environment/weather/climatechange/canada-international-action/climate-finance.html (accessed on 30 September 2021). [16]

Gutberlet, J., T. Bramryd and M. Johansson (2020), "Expansion of the Waste-Based Commodity Frontier: Insights from Sweden and Brazil", *Sustainability*, Vol. 12/7, http://dx.doi.org/10.3390/SU12072628. [9]

IEA (2021), *Tracking Clean Energy Progress: Cement*, International Energy Agency (IEA), https://www.iea.org/reports/cement (accessed on 4 October 2021). [1]

IEA (2021), *Turkey 2021*, IEA, Paris, https://www.iea.org/reports/turkey-2021 (accessed on 27 September 2021). [32]

IEA (2020), *Turkey*, Electricity Information, https://www.iea.org/countries/turkey (accessed on 28 September 2021). [39]

IFC (2017), *Increasing the Use of Alternative Fuels at Cement Plants: International Best Practice*, International Finance Corporation (IFC), Washington, D.C., https://www.ifc.org/wps/wcm/connect/33180042-b8c1-4797-ac82-cd5167689d39/Alternative_Fuels_08+04.pdf?MOD=AJPERES&CVID=lT3Bm3Z (accessed on 4 October 2021). [2]

Lima Cortez, C. and J. Goldemberg (2016), *Cement Technology Roadmap: Alternative Fuels for Cement Sector in Brazil*. [11]

Manuelita (2018), *Manuelita aumenta la generación y venta de energía eléctrica renovable en Colombia | Manuelita*, Manuelita Noticias, https://www.manuelita.com/manuelita-noticias/manuelita-aumenta-la-generacion-y-venta-de-energia-electrica-renovable-en-colombia/ (accessed on 10 September 2021). [21]

Manuelita (2014), *Manuelita completes 150 years producing much more than sugar (Manuelita completa 150 años produciendo mucho más que azúcar)*, https://manuelita.com/manuelita-noticias/manuelita-completa-150-anos-produciendo-mucho-mas-azucar/ (accessed on 4 October 2021). [20]

MIIM and EAC (2020), “India Renewable Energy Opportunities”, *Made in India Mittlestand (MIIM) and EAC International Consulting*, https://www.energyforum.in/fileadmin/user_upload/india/media_elements/misc/20200000_Misc/20200430_LR_MIIM_Webinar/PPT_EAC_India_Renewable_Energy_Opportunities.pdf (accessed on 4 October 2021). [29]

Ministerio del Medio Ambiente (2020), *Programa Reciclo Orgánicos: los principales hitos a dos años de su lanzamiento – MMA*, Noticias, https://mma.gob.cl/programa-reciclo-organicos-los-principales-hitos-a-dos-anos-de-su-lanzamiento/ (accessed on 29 September 2021). [13]

MNRE (2021), *Bioenergy - Current Status*, Government of India, Ministry of New and Renewable Energy (MNRE), https://mnre.gov.in/bio-energy/current-status (accessed on 4 October 2021). [25]

MNRE (2021), *New National Biogas and Organic Manure Programme*, Government of India, Ministry of New and Renewable Energy (MNRE), https://biogas.mnre.gov.in/about-the-programmes (accessed on 4 October 2021). [26]

MNRE (2021), *Physical Progress in 2020-21*, Government of India, Ministry of New and Renewable Energy (MNRE), https://mnre.gov.in/the-ministry/physical-progress (accessed on 4 October 2021). [24]

OECD (2021), *OECD Economic Surveys: Turkey 2021*, OECD Publishing, Paris, https://dx.doi.org/10.1787/2cd09ab1-en. [31]

Parra, N. (2018), *Bio Energía Los Pinos de Penco plant expansion approved: it will pass from 2.8 to 9 megawatts (Aprueban ampliación de planta Bio Energía Los Pinos de Penco: pasará de 2,8 a 9 megawatts)*, Biobiochile, https://www.biobiochile.cl/noticias/nacional/region-del-bio-bio/2018/02/20/aprueban-ampliacion-de-planta-bio-energia-los-pinos-de-penco-pasara-de-28-a-9-megawatts.shtml (accessed on 4 October 2021). [17]

Project Reporter (2018), *Verbio to set up RS 100 Crore Bio-gas Plant in Sangrur*, https://projectreporter.co.in/prnews.aspx?nid=5561 (accessed on 4 October 2021). [28]

SNIC (2019), *Cement Technology Roadmap (Roadmap Tecnológico do Cimento)*, National Cement Industry Union (Sindicato Nacional da Indústria do Cimento), Rio de Janeiro, http://snic.org.br/assets/pdf/roadmap/roadmap-tecnologico-do-cimento-brasil.pdf (accessed on 4 October 2021). [3]

Souza, L. (2019), *Brazil generates 79 million tons of solid waste every year*, Agência Brasil, https://agenciabrasil.ebc.com.br/en/geral/noticia/2019-11/brazil-generates-79-million-tons-solid-waste-every-year (accessed on 4 October 2021). [7]

Stewardson, L. (2019), *Cementos Argos increases waste co-processing capacity in Colombia*, World Cement, https://www.worldcement.com/the-americas/10052019/cementos-argos-increases-waste-co-processing-capacity-in-colombia/ (accessed on 4 October 2021). [12]

UPME (2015), *Integration of non-conventional renewable energy in Colombia (Integración de las energías renovables no convencionales en Colombia)*, Planning Unit of the Ministry of Mines and Energy (Unidad de Planeación Minero Energética, UPME), http://www.upme.gov.co/Estudios/2015/Integracion_Energias_Renovables/INTEGRACION_ENERGIAS_RENOVANLES_WEB.pdf (accessed on 16 September 2021). [23]

Verbio (2021), *VERBIO AG - Company Close-Up*, https://www.verbio.de/en/group/company-close-up/ (accessed on 4 October 2021). [27]

Votorantim (2019), *Urban Waste as a Source of Energy for our Plants*, Votorantim Cimentos, http://www.votorantimcimentos.com/en-US/media-center/news/Pages/Urban-Waste-as-a-Source-of-Energy-for-our-Plants.aspx (accessed on 4 October 2021). [8]

Zafar, S. (2020), *Cogeneration of Bagasse*, BioEnergy Consult, https://www.bioenergyconsult.com/cogeneration-of-bagasse/ (accessed on 4 October 2021). [19]

Notes

[1] For more information, see: https://www.wbcsd.org/Sector-Projects/Cement-Sustainability-Initiative.

[2] For more information, see: http://www.braziliannr.com/brazilian-environmental-legislation/law-no-12305-brazilian-national-policy-solid-waste/.

[3] For more information (in Portuguese), see: https://www.areaseg.com/conama/1999/264-1999.pdf.

[4] For more information (in Portuguese), see: http://www.mp.go.gov.br/portalweb/hp/9/docs/rsulegis_12.pdf.

[5] For more information, see: https://www.in.gov.br/en/web/dou/-/lei-n-14.026-de-15-de-julho-de-2020-267035421.

[6] For more information, see: https://www.in.gov.br/en/web/dou/-/resolucao-conama/mma-n-499-de-6-de-outubro-de-2020-281790575.

[7] For more information (in Spanish): https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Chile%20First/Chile%20INDC%20FINAL.pdf.

[8] For more information, see: https://reciclorganicos.com/en/.

[9] For more information (in Spanish), see: http://seia.sea.gob.cl/expediente/ficha/fichaPrincipal.php?modo=ficha&id_expediente=2132658501.

[10] For more information, see: https://www.canada.ca/en/environment-climate-change/corporate/international-affairs/partnerships-countries-regions/latin-america-caribbean/canada-chile-environmental-agreement/overview.html.

[11] For more information, see: https://www.oecd.org/cefim/cross-cutting-analysis/DEEP.htm.

[12] For more information, see: https://www.oecd.org/cefim/cross-cutting-analysis/ICP.htm.

[13] Note : liquid biofuels like biogasoline and biodiesel are also commonly used in India, for example for road transport, and represented more than 875 thousand tonnes of oil equivalent in final energy consumption in 2018 (IEA, 2020).

[14] For more information, see: https://mnre.gov.in/bio-energy/schemes.

[15] For more information, see: https://www.ireda.in/waste-to-energy.

[16] More information, see: https://investpunjab.gov.in/home.

[17] For more information, see: https://mopng.gov.in/en/pdc/investible-projects/alternate-fuels/sustainable-alternative-towards-affordable-transportation.

[18] The National Renewable Energy Action Plan (NREAP), presented under Directive 2009/28/ EC, establishing strategies to promote the development of renewable energy in Turkey.

[19] Published in the Official Gazette in 2011, the Renewable Energy Support Mechanism (Yenilenebilir Enerji Kaynakları Destekleme Mekanizması, YEKDEM), provides feed-in tariffs for renewable power plants, including wind, solar, biomass, hydro and geothermal. Presidential Decree published on 18 September 2020, extended the implementation period for the YEKDEM scheme, by six months until 30 June 2021 due to delays from the COVID-19 pandemic. More information available: https://www.epdk.gov.tr/Detay/Icerik/3-0-0-122/yenilenebilir-enerji-kaynaklari-destekleme-mekanizmasi-yekdem.

[20] Decree No. 3453 published in the Official Gazette No. 31380 on 30 January 2021, outlining the New Renewable Energy Support Mechanism (YEKDEM). This introduces the new feed-in tariff scheme that will apply to renewable energy power plants that become operational between 1 July 2021 and 21 December 2025. More information available: https://www.epdk.gov.tr/Detay/Icerik/3-0-0-122/yenilenebilir-enerji-kaynaklari-destekleme-mekanizmasi-yekdem.

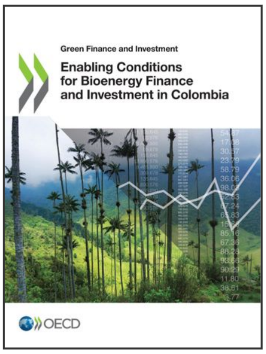
[21] Decision on State Aid in Investments in 2012: hydro, wind, biomass, geothermal and solar all fall under the scope of the general incentive system. Investments must amount to at least TRY 1 million (around USD 172 thousand) in the 1st and 2nd regions, and at least TRY 500 thousand (USD 86 thousand) in the 3rd, 4th, 5th and 6th regions.

[22] VERRA - Verified Carbon Standard. More information at: https://verra.org/.

[23] More information, see: https://registry.verra.org/app/projectDetail/VCS/2347.

[24] Calculated based on the USD-to-TRY exchange rate on 30 January 2021, which was USD/TRY: 7.31.

[25] Declaration No. 2017/22 on the Rural Development Investments Support Program of the Ministry of Food, Agriculture and Livestock.



From:

Enabling Conditions for Bioenergy Finance and Investment in Colombia

Access the complete publication at:

https://doi.org/10.1787/20f760d6-en

Please cite this chapter as:

OECD (2022), "Global experiences with bioenergy development", in *Enabling Conditions for Bioenergy Finance and Investment in Colombia*, OECD Publishing, Paris.

DOI: https://doi.org/10.1787/8fc1fe9c-en