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Committed emissions and the risk of stranded assets from power plants in Latin America and the Caribbean

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October 2019

Please cite this paper as:

GONZALEZ-MAHECHA E., O. LECUYER, M. HALLACK, M. BAZILIAN and A. VOGT-SCHILB (2019), "A single indicator of strong sustainability for development: Theoretical basis and practical implementation", *AFD Research Papers*, No. 2019-116, October.

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ISSN 2492 - 2846

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Abstract

Latin America and the Caribbean (LAC) has the least carbon-intensive electricity sector of any region in the world, as hydropower remains the largest source of electricity. But are existing plans consistent with the climate change goals laid out in the Paris Agreement? In this paper, we assess committed CO₂ emissions from existing and planned power plants in LAC. Those are the carbon emissions that would result from the operation of fossil-fueled power plants during their typical lifetime. Committed emissions from existing power plants are close to 6.9 Gt of CO₂. Building and operating all power plants that are announced, authorized, being procured, or under construction would result in 6.7 Gt of CO₂ of additional commitments (for a total of 13.6 Gt of CO₂). Committed emissions are above average IPCC assessments of cumulative emissions from power generation in LAC consistent with climate targets. The paper concludes that 10% to 16% of existing fossil-fueled power plants in the region would need to be “stranded” to meet average carbon budgets from IPCC. Our results suggest that international climate change commitments are material even in developing countries with low baseline emissions.

Keywords: Carbon Budget, Climate Change, Power Sector, Stranded Assets

JEL Codes: O13, Q40, N56

Original version: English

Accepted: October 2019

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Abstract

Latin America and the Caribbean (LAC) has the least carbon-intensive electricity sector of any region in the world, as hydropower remains the largest source of electricity. But are existing plans consistent with the climate change goals laid out in the Paris Agreement? In this paper, we assess committed CO_2 emissions from existing and planned power plants in LAC. Those are the carbon emissions that would result from the operation of fossil-fueled power plants during their typical lifetime. Committed emissions from existing power plants are close to 6.9 Gt of CO_2 . Building and operating all power plants that are announced, authorized, being procured, or under construction would result in 6.7 Gt of CO_2 of additional commitments (for a total of 13.6 Gt of CO_2). Committed emissions are above average IPCC assessments of cumulative emissions from power generation in LAC consistent with climate targets. The paper concludes that 10% to 16% of existing fossil-fueled power plants in the region would need to be “stranded” to meet average carbon budgets from IPCC. Our results suggest that international climate change commitments are material even in developing countries with low baseline emissions.

JEL codes: O13, Q40, N56

Keywords

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1 Introduction

Latin America and the Caribbean (LAC) has the least carbon-intensive electricity sector of all principal regions in the world, thanks to the highest share of hydroelectricity in the world (IEA 2018a). But this is changing. Hydropower generation has scaled down its percentage in the power mix from 58% in 2009 to 50% in 2016 (IEA 2018a). Utilization rates have been reduced by droughts, and capacity additions have slowed down due to social and environmental concerns, and increasing capital cost (IRENA 2016, Van Vliet *et al* 2016, Soito and Freitas 2011, Pereira de Lucena *et al* 2011, de Queiroz *et al* 2019).

Natural-gas-based power generation has generally filled the gap, sustained by abundant and competitive supply, turning it into the second source in the power mix (IRENA, 2016; Yépez-García *et al.*, 2018a, 2018b). While unconventional renewable energy is growing rapidly, representing 57% of renewable capacity addition in 2017, it still represents only 6.5% of total capacity (Enerdata 2019). Looking forward, it appears likely that in the absence of changes in public policies and/or market design, natural gas and coal could play an increasingly important role in the electricity mix (Lucena *et al* (Lucena *et al.*, 2016), Calderón *et al* (2016), Di Sbroiavacca *et al* (2016), Clarke *et al* (2016) and Octaviano *et al* (2016) (van der Zwaan *et al* 2016).

While most countries in the region have presented Nationally Determined Contributions (NDC) emphasizing emission reductions in the power sector as part of their contribution to the Paris Agreement, current energy planning appears out of sync with those commitments, and would result in the addition of new fossil fuel power plants in the region (OLADE 2018, Cadena 2019).¹

To keep climate change impacts on development in check, global leaders have agreed to pursue efforts to limit global warming well below 2°C, and as close to 1.5°C as possible (United Nations 2015). Either target requires reaching net zero emissions of CO₂ globally (Fay *et al* 2015, Rogelj *et al* 2015, Sachs *et al* 2016) and in LAC (Paredes 2017, Vergara *et al* 2016). In particular, stabilizing

¹ And even if LAC countries meet their NDCs, it is not guaranteed that they are following the path to meet the expected limits of global warming (Iyer *et al.*, 2015; Rogelj *et al.*, 2016; UNEP, 2017).

climate change requires that all regions switch to carbon-free electricity by 2050 (Audoly *et al* 2018, Davis *et al* 2018, Williams *et al* 2012).²

Long-term climate goals matter for energy infrastructure planning because power plants lifetime may range from 30 to 50 years (Fay *et al.*, 2015; Grubb *et al.*, 2018; Millar *et al.*, 2016; Sachs *et al.*, 2016b). To assess the impact of long-lived infrastructure on climate change, Davis and Socolow (2014) introduced the concept of *committed* carbon emissions in existing infrastructure. Those are the carbon emissions that would result from the operation of existing fossil-fueled power plants and other carbon-intensive equipment during their typical lifetime. The same concept has been applied to *planned* power plants that are announced, authorized, being procured, or under construction (Edenhofer *et al* 2018, Pfeiffer *et al* 2018, Shearer *et al* 2017).

Here, we assess committed emissions from operational and planned power plants in LAC. We use the Power Plan Tracker (PPT) database from Enerdata (2019b), which provides information on power plants classified by fuel type, age, capacity, historical output, and operational status. We compare committed emissions with carbon budgets for the LAC power sector from IPCC (2018). In this paper, we call *carbon budget* the cumulative emissions from the power generation sector extracted from global pathways that keep global warming in the 1.5–2°C range. The IPCC considers pathways generated using a variety of modeling paradigms; different technology assumptions – in particular, exploring the impact of whether carbon dioxide removal can offset emissions from power generation–, discount rates, and interpretations of temperature targets – peak or long-term warming (Huppmann *et al* 2018b, IIASA 2017, Weyant 2017, Rotmans *et al* 2001).

We find that committed emissions from the power sector in LAC amount to 6.9 GtCO₂, or 19 years of current emissions from power generation in the region. This commitment is within the range of LAC power carbon budgets consistent with 1.5°C, which

² The IPCC's special report on global warming of 1.5°C finds that by 2050, the net carbon content of the power sector should fall to close to 0 and renewable supply should represent 70% of the electricity mix (Huppmann *et al.*, 2018a).

we find to be 1.1 to 13.5 GtCO₂. However, it is above 80% of 1.5°C-compliant carbon budgets reported in the IPCC database, and above 50% of 2°C carbon budgets. These findings suggest that to meet the average allowable carbon budget for 2°C (6.2 GtCO₂) or 1.5°C (5.8 GtCO₂), utilities in the region would need to close prematurely 10% to 16% of the existing fossil-fueled capacity, respectively, or reduce the utilization rate of existing plants to the same effect. If all planned power plants are built, we find that committed emissions would rise to 13.6 GtCO₂, which is more than 90% of LAC power carbon budgets reported in any 1.5°C or 2°C scenario

Closing plants early to meet climate targets would result in losses of revenues for the owners of fossil fuel power plants, that is in stranded assets, and potentially in sudden losses of jobs for the workers and communities who depend on those assets, which could make the political economy of climate policies more difficult to manage (Bertram *et al* 2015, Gambhir *et al* 2018, Hallegatte *et al* 2013, ILO 2018, Jenkins 2014, Nemet *et al* 2017, Rozenberg *et al* 2018, Vogt-Schilb and Hallegatte 2017).

This paper is part of a growing literature that quantifies committed emissions in energy infrastructure (Davis *et al* 2010, Pfeiffer *et al* 2018, 2016, Smith *et al* 2019). This literature has focused on global emissions, or on showing that coal power plants under construction globally (Edenhofer *et al* 2018), or even just in India (Shearer *et al* 2017), would make a significant contribution to global emissions. In this paper we focus in LAC, a region that was home to only 5% of CO₂ emissions in 2016 (IEA 2018b). Unlike global commitments from coal, the committed emissions we find in LAC are not a game changer for the global climate change agenda. But international commitments do matter to LAC energy planners. Existing plans would surpass most of LAC's power carbon budget. Adding fossil fuel power plants may increase the risk of stranded assets in LAC. In a region that invests \$21 billion in power generation per year (OECD/IEA 2018), the risk of stranded assets cannot be ignored.

Section 2 presents the methods and data, while Section 3 provides results. Section 4 discusses those results and concludes.

2 Methods and data

We define committed emissions as the emissions that will occur over the remaining lifespan of a fossil-fuel-burning electric generator.³ We focus on generators, defined as devices that generate electrical power for use in an external circuit. A plant consists in one or more generators.

2.1 Carbon emissions per generator from Enerdata and IEA

We compute committed emissions in two basic steps. In the first step, we assess current emissions by generator. We decompose CO₂ emissions F (tCO₂/year), as the product of capacity C (GW), utilization rate E/C where E is electricity output (GWh/year), and carbon intensity of electricity generated F/E (tCO₂/GWh). Each quantity is computed per country i , fuel f , and status s :

$$F_{i,f,s} = C_{i,f,s} \times \left(\frac{E_{i,f}}{C_{i,f}} \right)_s \times \frac{F_{i,f}}{E_{i,f}} \quad (\text{Eq 1})$$

We take existing and planned capacities $C_{i,f,s}$ from the Power Plant Tracker (ENERDATA 2019b). The PPT reports unit status, date of commissioning, fuel type, net capacity, electricity output and localization in January 2019. The database reports 14,816 generators in Latin America and the Caribbean, 34% of which (5,048) are fossil-fuel-based (oil; coal, peat and oil shale; and natural gas). We focus on fossil fuel plants, as the others do not commit CO₂ emissions.

The PPT classifies generators in operational, announced, authorized, bidding process and under construction, stopped, canceled, mothballed, and synchronized statuses. We qualify as *planned* the generators under the announced⁴, authorized⁵,

³ Davis and Socolow (2014) define committed emissions as the emissions that occur over the lifetime of a fossil-fuel-burning (realized emissions plus remaining emissions). Our approach focuses on the remaining emissions.

⁴ Project either announced by a company or planned in a national development plan released by Governments, TSOs, regulators, agencies.

⁵ The power project has received public/statutory consents by the national authorities in charge of delivering authorizations for new power infrastructures.

bidding process and under construction statuses. Operational and synchronized units are included in the *existing* status.

We take electricity output $E_{i,f}$ per country and energy type from Enerdata (2019a) and Enerdata (2019b). These two sources are slightly inconsistent. The total (bottom-up) sum of power generation listed in Power Plant Tracker (ENERDATA 2019b) does not match national statistics of power generation per country and fuel (ENERDATA 2019a). In total, fossil-fuel-based generation reported in PPT for 2016 (450 TWh) represents 67% of total electricity production from national statistics (665 TWh). We solve this issue at the country and fuel level. In most cases, the sum from PPT is lower than the reported national statistic. One reason is that PPT does not report any electricity output for some generators. Another is that for some flex-fuel plants, PPT reports only generation from the main fuel. We fill missing generation data using averages per country and fuel, then scale up production from all plants to match production from national statistics. In very rare cases, production from PPT is slightly larger than production reported in Enerdata (2019a). For those cases, we scale down linearly the electricity output in the PPT database to match the statistics.

We take CO₂ emissions by country and fuel F from Enerdata (2019a). Since the last year full reported for CO₂ emissions is 2016, we compute the carbon intensity of electricity per country and fuel based on electricity output for 2016 reported in Enerdata (ENERDATA 2019b, 2019a). We latter test the sensitivity of our results to the data sources chosen.

2.2 Remaining lifetime of generators

The second step to compute committed emissions is to project the remaining lifetime of each generator. The PPT provides a date of commissioning for most generators. We fill data gaps with the averages at country, technology and unit status level. In addition, there are 23 fossil-fuel-based generators that classify as planned, but for which the reported date of commissioning is in the past. For those, we reset the commissioning date to 2019.

We assume the lifetime of power generators to be 37, 35 and 32 years for coal, natural gas and oil technologies, respectively, following Davis and Socolow (2014). (We later perform a sensitivity analysis on these assumptions.) The PPT reports

251 operating fossil-fuel based generators older than that. For those, we assumed their lifespan is extended by 5 years more.

Table 1 summarizes the assumed lifespan and average carbon intensity of electricity in LAC by technology. Appendix 1 contains detailed assumptions of carbon intensity by country and technology.

Table 1. Lifespan and average carbon intensity of electricity

Fuel	Lifespan (years)	Carbon intensity (g/kWh)
Coal, peat and oil shale	37	930
Natural gas	35	427
Oil	32	640

2.3 Correcting for missing countries

The PPT covers only 18 Latin American countries: Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Dominican Republic, Ecuador, El Salvador, Guatemala, Jamaica, Mexico, Panama, Paraguay, Peru, Trinidad and Tobago, Uruguay, and Venezuela. According to Enerdata (2019a) these countries are responsible for 94% of carbon emissions from electricity generation in LAC. We create a “rest of LAC” aggregate to which we assign the missing emissions per fuel type, with average age taken from the other countries reported in PPT.

2.4 Carbon budgets from IPCC

To assess carbon budgets available for power generation in LAC, we rely on the IAMC 1.5°C database hosted by IIASA (Huppmann *et al* 2018a). This database contains an ensemble of quantitative, model-based climate change mitigation pathways consistent with 1.5°C and 2°C warming supporting the IPCC’s special report on 1.5°C (IPCC 2018, Huppmann *et al* 2018b). Table 2 provides a classification of the pathways reported.

Table 2. Classification of the pathways supporting the Special Report on Global Warming of 1.5°C

Temperature target	Description	Number of scenarios
Below-1.5°C	Pathways limiting peak warming to below 1.5°C during the entire 21 st century with 50-66% likelihood	9

Lower/higher 1.5°C-low overshoot	Pathways limiting median warming to below 1.5°C in 2100 and with a 50–67% probability of temporarily overshooting that level earlier, generally implying less than 0.1°C higher peak warming than below-1.5°C pathways.	44
Lower/higher 1.5°C-high overshoot	Pathways limiting median warming to below 1.5°C in 2100 and with a greater than 67% probability of temporarily overshooting that level earlier, generally implying 0.1–0.4°C higher peak warming than Below-1.5°C pathways	37
Lower-2°C	Pathways limiting peak warming to below 2°C during the entire 21st century with greater than 66% likelihood	74
Higher-2°C	Pathways assessed to keep peak warming to below 2°C during the entire 21st century with 50–66% likelihood	58

We use two variables from the IPCC database: *CO₂ emissions of electricity supply*, and *carbon sequestration in the electricity supply*.⁶ We compute gross CO₂ emissions from the power sector as the sum of net CO₂ emissions from electricity supply and carbon sequestration in the electricity supply sector. To compute budgets, we aggregate emissions between 2019 and 2064 – which is the year when the last planned unit would operate under normal conditions according to our assumptions.

Since the 1.5°C database provides regional model outputs, we select the ensemble of scenarios related to the region R5LAM.

3 Results

3.1 Committed emissions of operating and planned generators

We first consider power generation capacity reported in PPT. The database reports that 4,146 existing generators in early 2019 use coal, peat and oil shale (*coal* for short); natural gas; or oil as their main fuel. This comprises 169 GW of fossil-based capacity. Their average age is 17 years (they have operated since 2002 on average), corresponding to an average remaining lifetime of 18 years (to 2037). Mexico and Argentina lead the natural gas

⁶ Many pathways in the IPCC database rely on carbon dioxide removal, in particular using biomass coupled with carbon capture and storage, at large scale to keep within the carbon dioxide emissions budget. It is not clear whether such technology is socially, politically, environmentally, technologically or economically acceptable or possible (Smith *et al* 2016, Williamson 2016)

capacity with 44 GW and 23 GW, respectively. For coal, Mexico and Chile have most of the capacity with 6 GW and 4.9 GW, respectively. Brazil and Mexico lead oil capacity with 11 GW and 6.7 GW, respectively. Figure 1 displays operational and planned capacity by technology in LAC⁷ (the appendix 2 contains results per country).

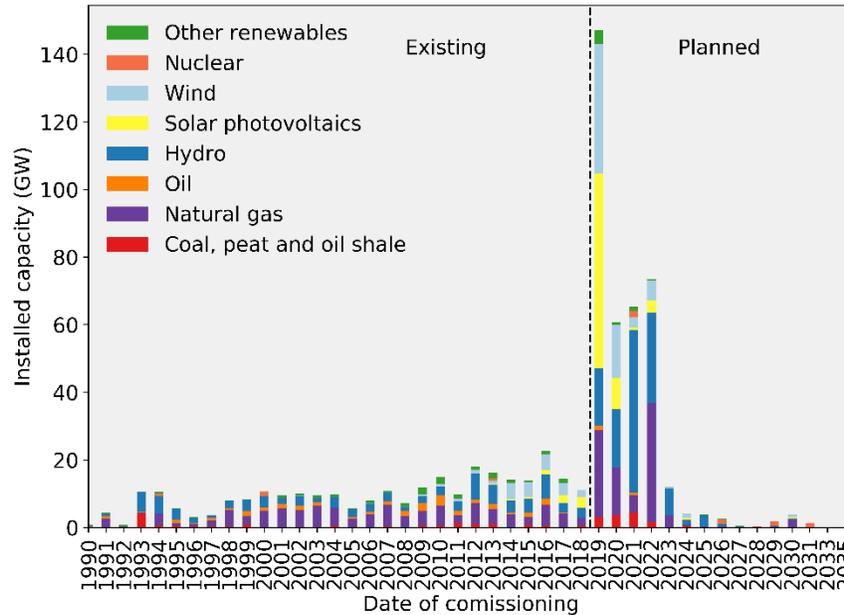


Figure 1. Capacity by date of commissioning. The bars in 2019 and after correspond to planned power plants. We plot data from 1990, however, the database includes units which started to operate before that.

The PPT reports 456 planned fossil-based generators, summing to 102 GW or 61% of current fossil-fueled capacity in the region. Most planned fossil fuel power plants are natural gas plants (87 GW), followed by coal, peat and oil shale (13.5 GW) and oil (2.1 GW). Brazil leads the fossil-based pipeline, with 38 GW of natural gas, 4.8 GW of coal, and 0.9 GW of oil. Mexico and Chile have in their planned pipelines 22 GW and 6.7 GW of natural gas capacity, respectively. Committed emissions from the pipeline are dominated by natural gas (63%), followed by coal (26%).

⁷ The peak in 2019 is influenced by our decisions to “correct” to 2019 the commissioned date of units that appear as “planned” but with a commissioning date in the past in the PPT. Note that this choice does not influence our estimates of cumulative committed emissions, our preferred metric in this paper.

In terms of committed emissions, we find that the continued operation of existing capacity over its remaining lifetime at current utilization rates would result in 6.9 GtCO₂ of emissions through the coming decades. Most committed emissions from operational generators come from natural gas (52%). This contrasts with the global situation, where coal generators are the main contributors of committed emissions (Pfeiffer *et al* 2018).

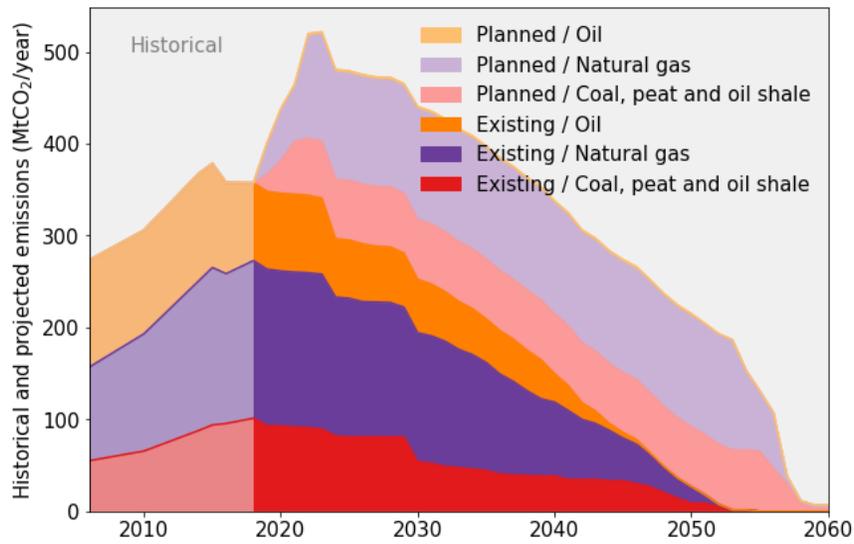


Figure 2. Historical and committed emissions (operational and planned plants). Under normal conditions, the last operational unit would operate until 2054. The last unit in the current planned pipeline would operate until 2064. Dark colors indicate operational status, while the planned pipeline is displayed in light colors.

Figure 2 shows projected emissions through time by fuel and status (appendix 3 shows projections by country). Projected emissions increase at an average annual rate of 13% between 2018 and 2030 as planned power plants are built and start to operate. Meanwhile, projected emissions from the operational plants decrease at an average annual rate of 2.9% as existing plants reach the end of their lifetime and are decommissioned. Additions to the capital stock are higher than retirements over this period. Committed emissions from operational generators decrease to zero by 2054, as the last planned generator will start to operate in 2030. In total, building all planned power plants would add 6.7 GtCO₂ of committed emissions.

The peak in 2022 is a result of the entry into operation of the plants which are in bidding process in Brazil (31 GW). It would

represent an addition of 60 MtCO₂ coming from natural gas. If instead of filling up the missing date of commissioning based on averages at country, technology and unit status level, we used a more realistic distribution of entry dates, this peak would be smoothed over the time, without affecting our estimates of total committed emissions.

Figure 3 provides details of committed emissions from both existing and planned power plants by country. Mexico, Argentina, and Brazil lead committed emissions from operational generators, at 1.8, 1 and 0.9 GtCO₂, respectively. If planned plants are built, Brazil would become the top contributor to committed emissions in the region, with 2.7 GtCO₂, almost tripling committed emissions from its operational generators. Mexico would add 1.2 GtCO₂; Chile would add 0.9 GtCO₂ and become the third largest committer in the region. Brazil, Colombia, and Dominican Republic are the countries where building the planned plants add most emissions relative to committed emissions from operational plants (at 3.1, 2.1 and 1.8 times the operational committed emissions, respectively).

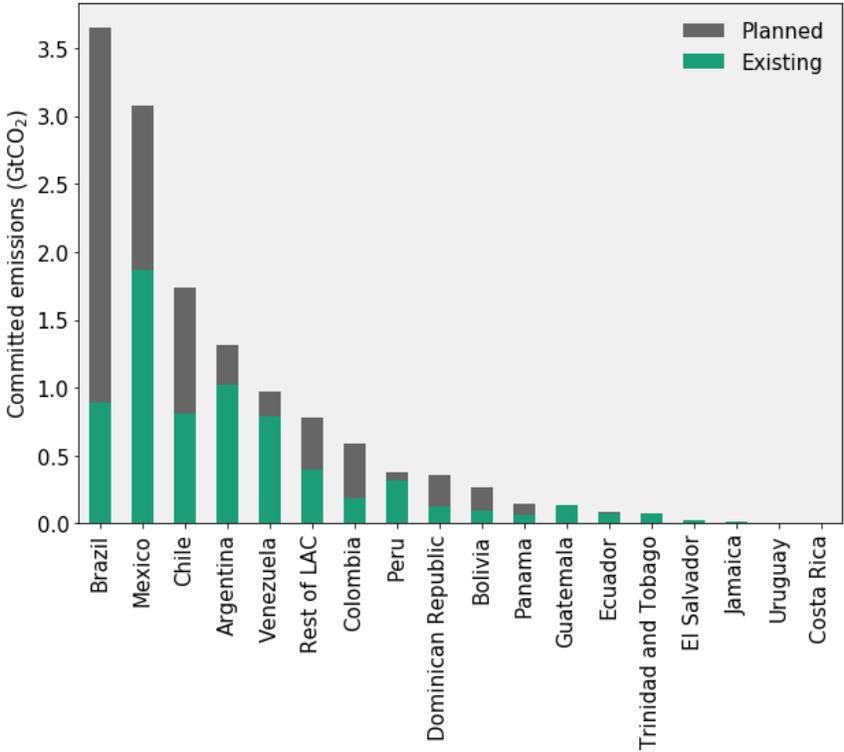
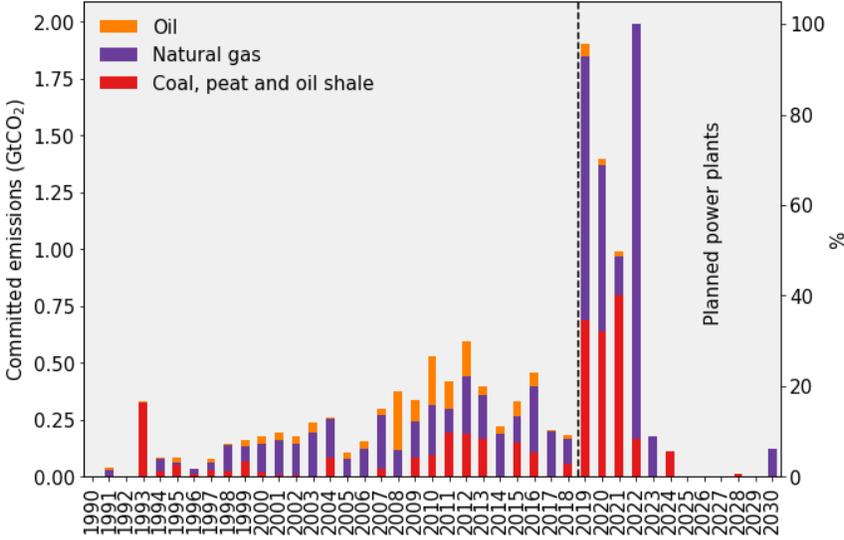
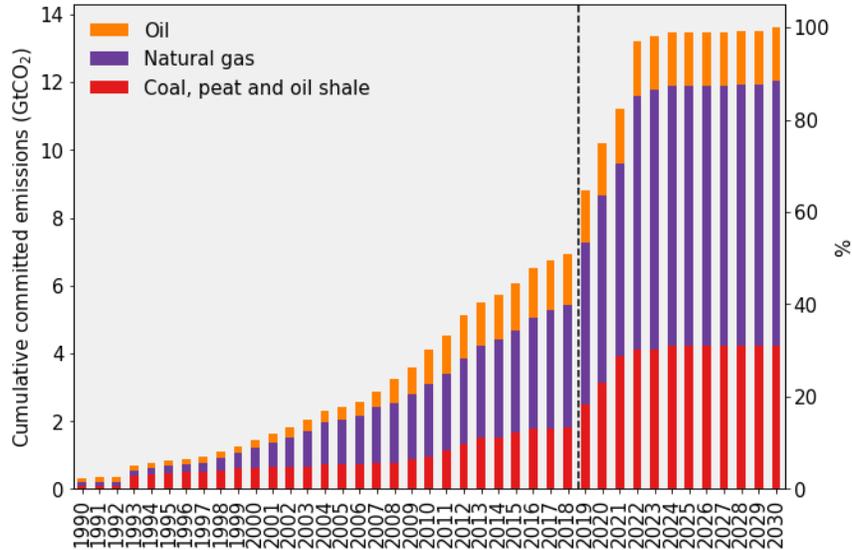


Figure 3. Committed emissions from existing and planned power plants by country

Figure 4 shows the same information by year of commissioning and fuel. Each bar in Figure 4.A corresponds to committed emissions from power plants added at a specific year in the past. Committed emissions added by the generators in operation in the 90s come primarily from coal. In LAC, natural gas started to gain importance in the late 90s and it turned into the main contributor of committed emissions from 2001 onward. Figure 4.B plots the same information in a cumulative fashion. It shows that while committed emissions have roughly grown linearly over the last two decades, building all the power plants that appear as *planned* in the PPT would roughly double committed emissions in only 4 years. (Again, our assessment does not feature a prediction of how much of the units planned in the PPT will be actually built).



(A) Committed emissions



(B) Cumulative committed emissions

Figure 4. Committed emissions by fuel and year of commissioning. Panel A shows remaining committed emissions in 2019 grouped by the date when existing power generators were built. Panel B shows the same information cumulatively.

Committed emissions from plants under construction and bidding status sum 4.3 GtCO₂, while authorized and announced would add 1.4 GtCO₂ and 0.9 GtCO₂, respectively. More than half (62%) of committed emissions from planned power plants come from natural gas generators, which would add 4.1 GtCO₂. The largest chunks would be added by Brazil (1.9 GtCO₂) and Mexico (1.1GtCO₂). This finding is consistent with previous results putting into question the fitness of new gas power plants as a bridge towards intermittent renewable energy in the region (Binsted *et al* 2018). Building all planned power plants in LAC would add as much emissions as what all existing plants would emit over 28 years. Cancellations of planned natural gas power plants would result in a reduction of 31% of total committed emissions. Cancelling all the planned coal generators would represent a reduction of 17% of total committed emissions.

Our finding of 6.7 GtCO₂ is slightly less than, but close to the 6.9 GtCO₂ reported by Pfeiffer *et al.* (2018) for LAC. Pfeiffer *et al.* (2018) merge five databases for generators allocating in the planned pipeline the generators under construction or planned statuses in early 2017. They use emission factor from individual

fuels and historic heat rated from the IEA. Conversely, we use the PPT database comprising the planned pipeline to announced, authorized, bidding process and under construction statuses in early 2019. We calculate emission factors from the country dashboard from ENERDATA (2019).

Figure 5 plots committed emissions against current emissions. For instance, the red dots on the right indicates that Mexico today emits 120 MtCO₂/yr from the power sector. But existing power plants will emit about 1.8 GtCO₂ over their lifetime and adding planned power plants would bring this number to 3 GtCO₂. The Brazilian case is the most contrasting. Today, Brazil emits 42 MtCO₂/yr. However, committed emissions from existing plants will be 0.9 GtCO₂ over their lifespan. This number will scale up to 3.6 GtCO₂ if the planned power plants are fully implemented. In other words, committed emissions from existing and planned generators in Brazil represents 87 years of CO₂ emissions. Map 1 shows that Brazil is the most extreme case according to that metric. On average in the region, committed emissions from existing and planned power plants sum to 34 years of current emissions.

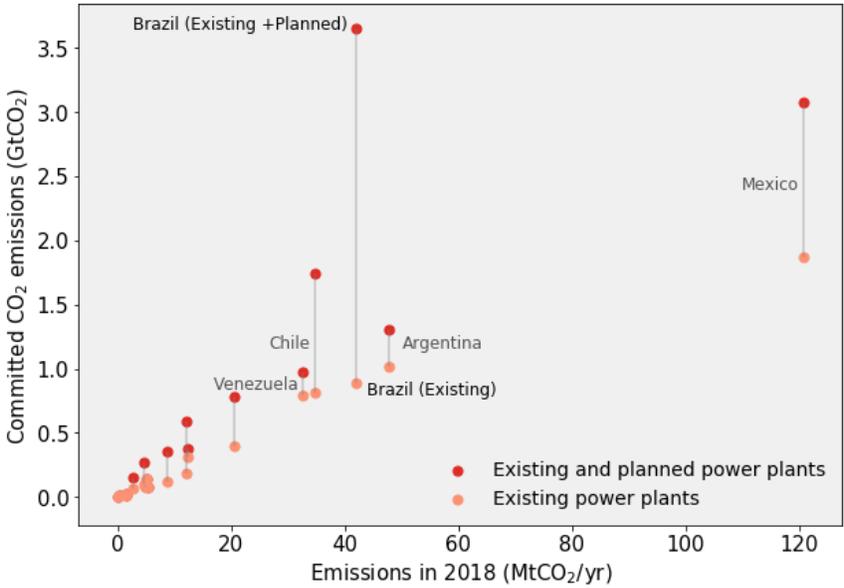
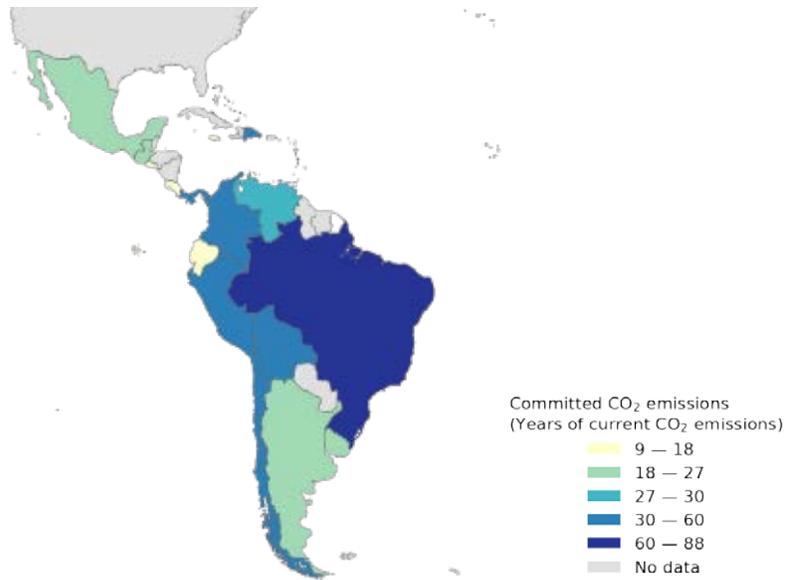


Figure 5. Emissions in 2018 vs total committed emissions. Dark dot indicates committed emissions from existing and planned power plants, while existing power plants are displayed in light colors.



Map 1: Committed emissions from existing and planned power plants per country, expressed as years of current emissions from the power sector.

While committed emissions would grow dramatically if planned power plants are built, the average carbon content of electricity would not change drastically. Table 3 shows the carbon intensity of electricity generation of the top four countries CO₂ emitters in LAC in 2012 (OECD 2015), 2018 (ENERDATA, 2019b) and 2030. We calculated the electricity output from the full set of operational and planned technologies (both renewable and fossil fuel) based on PPT capacities and the ratio between current electricity and capacity (ENERDATA 2019b). If the planned plants are fully implemented in Brazil, the carbon intensity of the electricity would be 134gCO₂/kWh, which is 61% higher than the current intensity.

Table 3. Carbon intensity of electricity generation (gCO₂/kWh)

Country	OCDE (2012)	ENERDATA (2018)	Own projection (2030)
Brazil	55	83	134
Mexico	549	384	265
Chile	444	771	740
Argentina**	NA	353	297

** The report includes 41 OECD countries, Argentina was not reviewed in this report (OECD, 2015).

3.2 Compatibility of the capital stock with remaining carbon budgets

Figure 6 shows carbon budgets for the LAC power sector computed from the pathways gathered in Huppmann *et al* (2018a). In the scenarios compatible with 1.5°C, gross carbon budgets range from 1.1 GtCO₂ to 13.5 GtCO₂, with an average of 5.8 GtCO₂. In the scenarios compatible with 2°C, gross carbon budgets range between 1.7 GtCO₂ to 16 GtCO₂, with a mean of 6.2 GtCO₂.

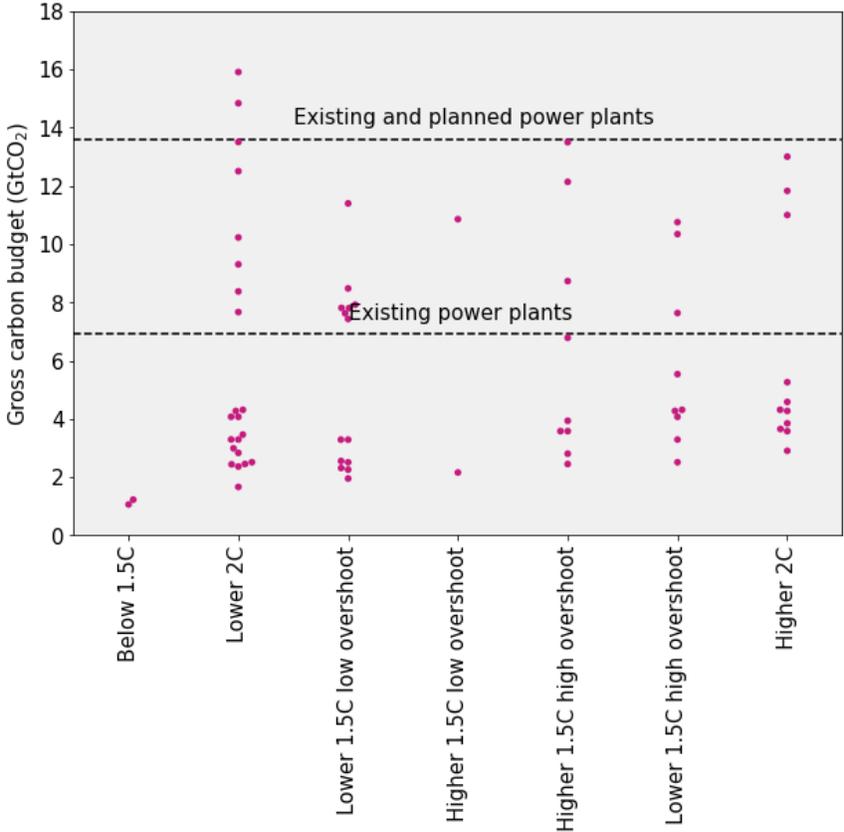


Figure 6. Comparison of committed CO₂ emissions LAC (dashed lines) with carbon-only generation budgets computed from the emission pathways reported in the IPCC 1.5°C report (dots)

Committed emissions from existing generators (6.9 GtCO₂) are thus within the range of LAC power carbon budgets consistent with 1.5°C to 2°C. However, they are above 60% of 1.5°C-compliant carbon budgets reported in the IPCC database, and above 50% of 2°C carbon budgets. If all planned power plants are built, the committed emissions would surpass 90% of the carbon budget scenarios consistent with 1.5°C or 2°C.

The above suggests that, if the climate goals set out in the Paris Agreement are to be achieved, roughly⁸ 52% to 55% of existing and planned fossil-fueled power plants in Latin America will need to be underutilized, retired early, or retrofitted with expensive CCS or efficiency upgrades, or—in other words—stranded.

3.3 Sensitivity of findings

We conduct a sensitivity analysis to assess the extent to which our conclusions depend on our lifespan and emission factor assumptions.

Based on a 37-year lifespan for coal generators, every additional year of lifetime would increase the original emission commitments from coal-based operational units (1.8 GtCO₂) by 0.09 GtCO₂ (+5.12%). For coal-based planned pipeline, every additional year of lifespan would increase committed emissions from 2.41 GtCO₂ to 2.47 GtCO₂ (2.70%). Based on a 35-year lifespan for gas-generators, every additional year of lifetime would increase the original emissions commitments from gas-based operational units (3.60 GtCO₂) by 0.15 GtCO₂ (+4.26%). Committed emissions from the gas-based planned pipeline (4.18 GtCO₂) would increase by 0.12 GtCO₂ (+2.86%).

The lifetimes we used are calibrated from typical historical averages. In the private sector, payback times can be shorter than technical lifetimes. For instance, contractual terms in LAC auctions vary from 15 to 30 years, with most of countries adopting a contract term of 20 years (Mejdalani et al., 2019). If power plants are used only during the typical time required for financial profitability, committed emissions would be lower. To quantify that and provide a lower bound to our estimates of committed emissions, we analyzed the impact of keeping existing and new power plants for only a total of 15 years. Figure 7 compares the results of committed emissions using our baseline technical lifespan assumption and the shorter payback times.

With lifetimes of 15 years, committed emissions from both existing and planned plants would be much smaller (5.3 GtCO₂,

⁸ We simply report the ratio of committed emissions to the average carbon budgets, minus 100%.

40% of our best guess estimate). In fact, they would be below our estimate of committed emissions from just existing power plants used during the typical lifetimes (6.3 GtCO₂), and average carbon budgets from IPCC. However, committed emissions from existing generators (2.8 GtCO₂) would still be above 20% of 1.5-2°C-compliant carbon budgets, and adding planned power plants would surpass 50% of the carbon budgets consistent with 1.5°C or 2°C.

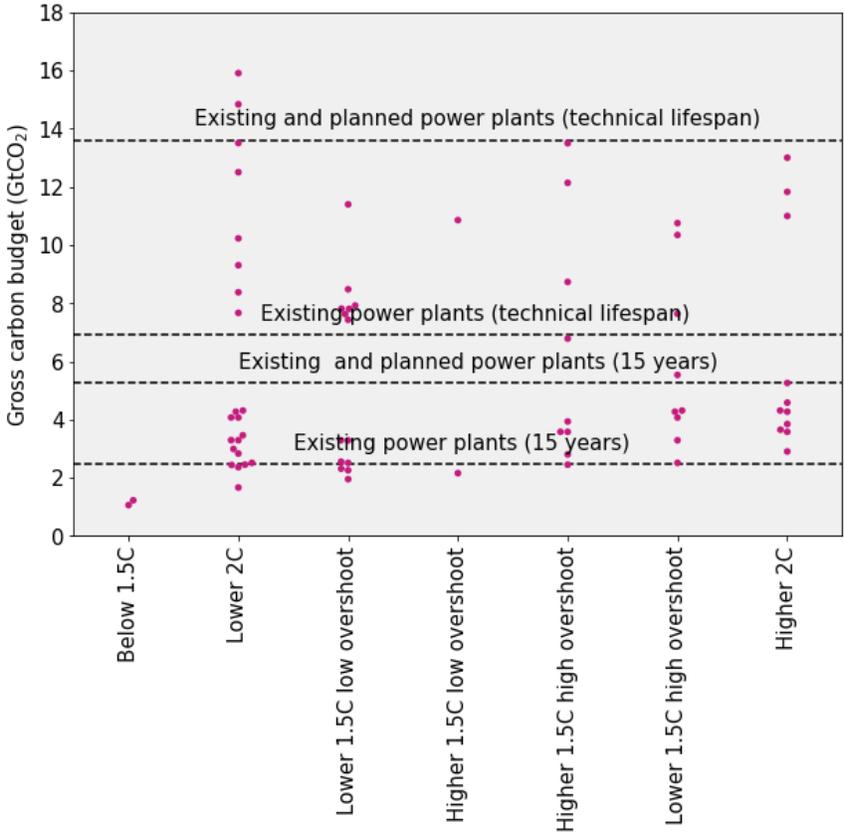


Figure 7. Committed CO₂ emissions from existing and planned power plants in LAC, compared with various estimates of carbon budgets (comparison of long technical lifespan vs lifespans consistent with short payback times)

We also test different data sources. We run a simulation using emission factor calculated with the CO₂ emissions from *Electricity and heat production* from (IEA, 2018b) and *electricity output from electricity power plants* from the energy balances (IEA, 2018a) instead of Enerdata. Using data from the IEA (and back to long technical lifetimes), committed emissions from both operational and planned pipeline jump to 13.6 GtCO₂ to 17.52 GtCO₂ (+29%), reflecting perhaps the inclusion of “heat generation” in the scope

of carbon emissions. Using the IEA as a data source would thus increase our estimate of the amount of asset stranding required to meet the average carbon budget from the IPCC.

4 Discussion and conclusion

Our rough estimates of the risk of stranded assets provide a crude quantification of the possible disruption to plant owners, workers, and communities that may happen during a transition to clean electricity consistent with the Paris Agreement targets. They do not quantify a fraction of power investments that would turn out to be net losses for their owners from a financial perspective (Vermeulen et al., 2018). Lower utilization rates do not necessarily mean lower economic returns, albeit at a cost either for public resources or for consumers. Even at lower utilization rates, the value of power generated by fossil fuel power plants, and the value of the power reserve they may be able to provide are important parts of the equation.

Notwithstanding those limitations, our results illustrate how international climate change commitments matter to energy infrastructure planners even in developing countries with low baseline emissions.

The case of Brazil is the most telling. While the country's power sector currently only emits 42 MtCO₂, existing power plants are on track to emit a total of 890 MtCO₂ during their lifetime. Worse, building the full set of fossil fuel power plants that are announced, authorized, being procured, or under construction in the country would bring committed emissions to 3.6 GtCO₂; or 87 years of current emissions. Planned natural gas power plants would be responsible for the largest chunk of committed emissions from planned plants, adding 2.3 GtCO₂.

While Brazil is an extreme example, these results apply broadly to the region. Today the power sector in LAC only emits 357 MtCO₂, but implementing the totality of fossil-fueled power expansion projects reflected in Enerdata's Power Plant Tracker would commit 6.7GtCO₂, or 46 years of emissions. We find that 10% to 16% of existing fossil-fueled power plants in the region would need to be stranded to meet average carbon budgets from IPCC. Based on average investment costs reported by Soria *et al* (2016) *and* Carvajal *et al* (2019), the total investment cost of these portions would correspond roughly to \$27 billion to \$44 billion.

More than half of those commitments come from new planned power plants. If the planned power plants are fully implemented, the need of stranded assets to meet average carbon budgets from IPCC would range between 52%-55%. The total investment cost then would scale up to \$231 billion to \$244 billion.

Ultimately, assessing the compatibility of any fossil fuel power plant addition with the Paris Agreement goals is necessarily more complex than the simple assessments presented in this paper. The key for governments to do so might be to develop domestic long-term power generation development strategies that start from the goal of achieving net zero carbon power generation by 2050, and work backward to establish sectoral roadmaps towards that goal (Binsted et al., 2018; Fay et al., 2015; Pathak, 2017; Waisman et al., 2019). Countries in the region and internationally have already started using such tools to decide on the expansion plans and the scheduled decommissioning of existing coal power plants, taking into account social, technical and economic impacts of doing so (O’Ryan, 2019; Wacket, 2019).

5 Acknowledgments

The views expressed in this paper are the sole responsibility of the authors. They do not necessarily reflect the views of the Inter-American Development Bank or the countries it represents. This research received funding from IDB project RG-T3193.

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Appendix 1. Carbon intensity of electricity (gCO₂/kWh) in 2018

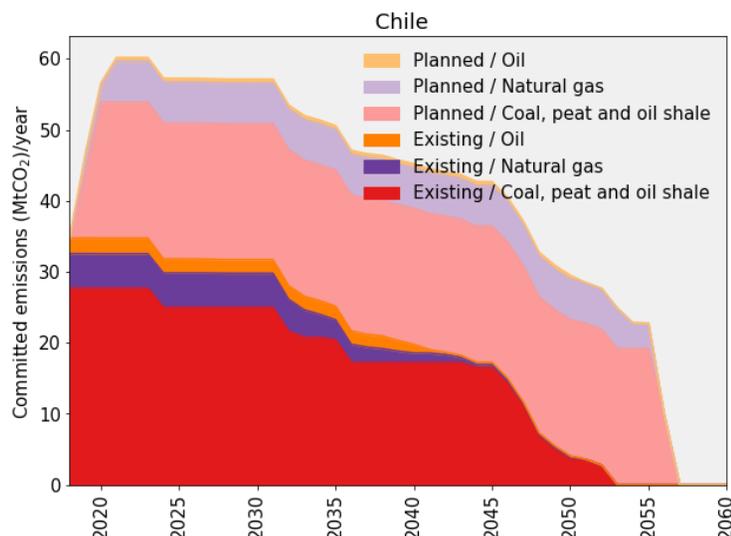
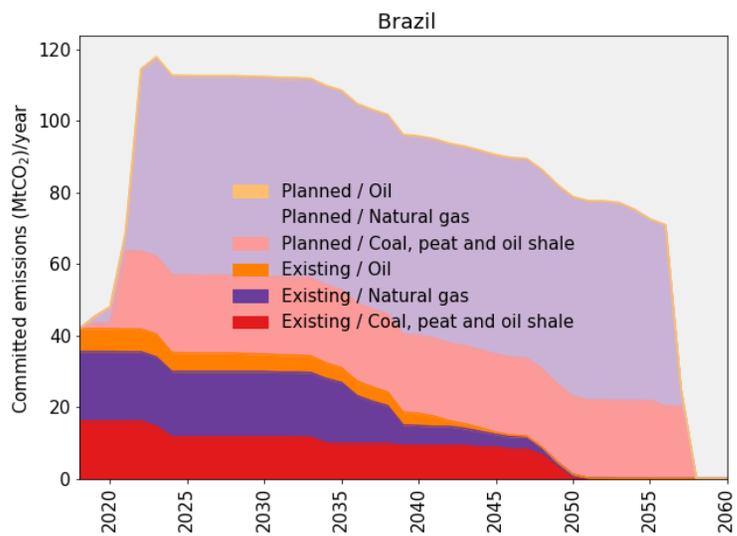
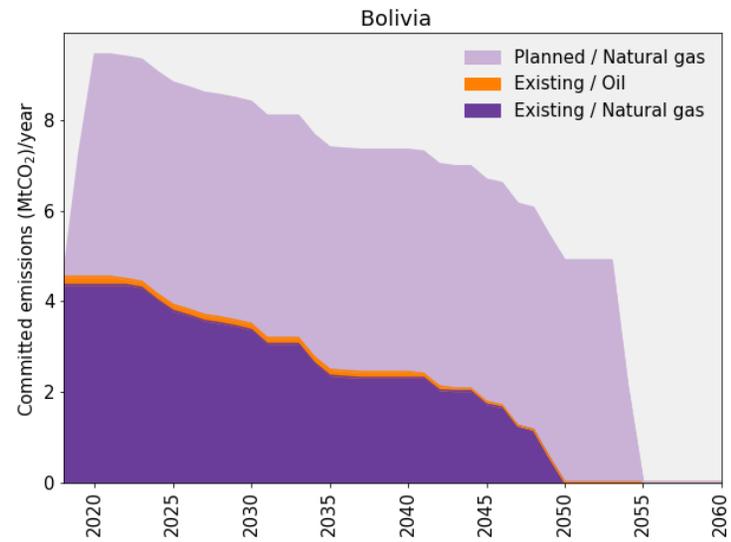
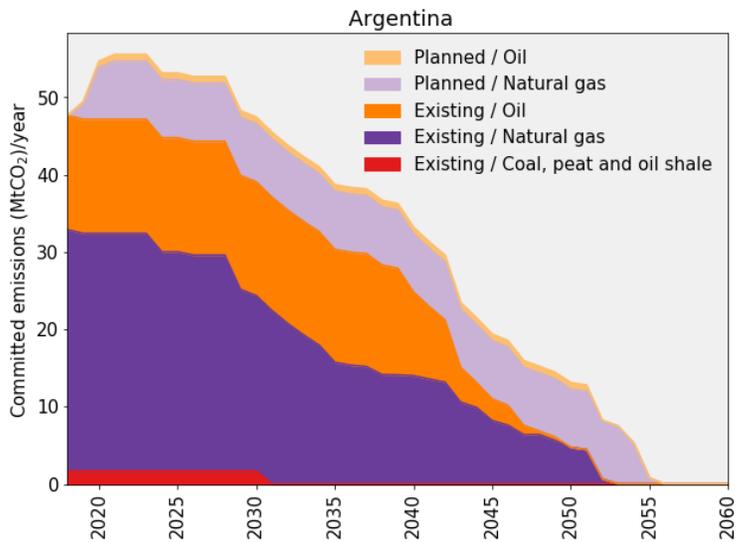
	Coal, peat and oil shale	Natural gas	Oil
Argentina	669	414	705
Bolivia		610	953
Brazil	624	344	421
Chile	916	411	745
Colombia	872	305	469
Costa Rica			679
Dominican Republic	979	472	443
Ecuador		290	515
El Salvador			582
Guatemala	1,115		622
Jamaica			415
Mexico	1,048	327	631
Panama	1,118		636
Peru	1,030	446	695
Trinidad and Tobago		523	
Uruguay			763
Venezuela		563	971
Mean	930	427	640

Appendix 2. Operational and planned installed capacity by country

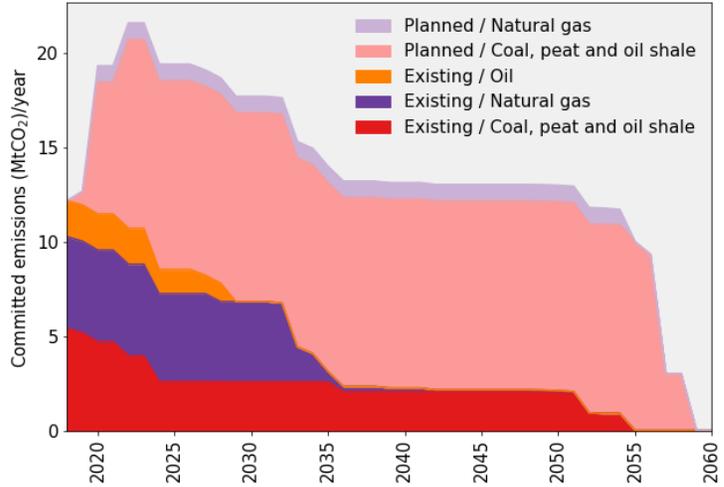
Country	Existing	Planned
Argentina	37.62	20.66
Bolivia	2.54	15.26
Brazil	166.15	145.75
Chile	24.27	41.08
Colombia	17.35	19.80
Costa Rica	3.65	1.28
Dominican Republic	4.43	1.55
Ecuador	8.32	16.52
El Salvador	2.00	1.09
Guatemala	4.30	1.42
Jamaica	1.26	0.71
Mexico	80.85	54.61
Panama	3.72	9.94
Paraguay	8.80	2.06
Peru	13.42	37.11

Trinidad and Tobago	2.39	
Uruguay	4.71	0.65
Venezuela	31.89	8.11

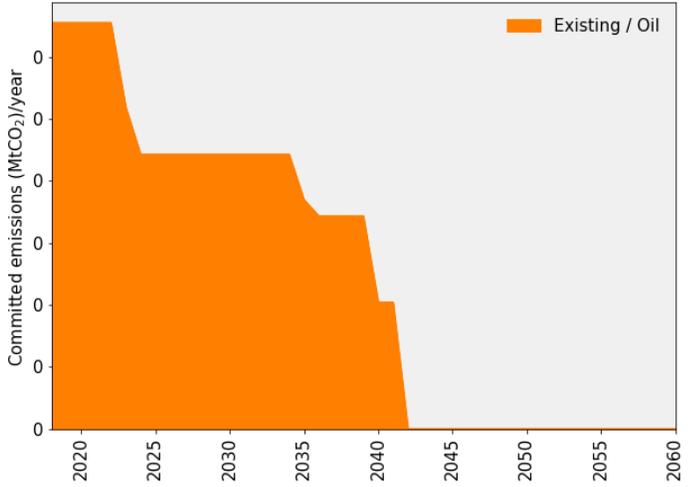
Appendix 3. Projected emissions of the operational plants and planned pipeline



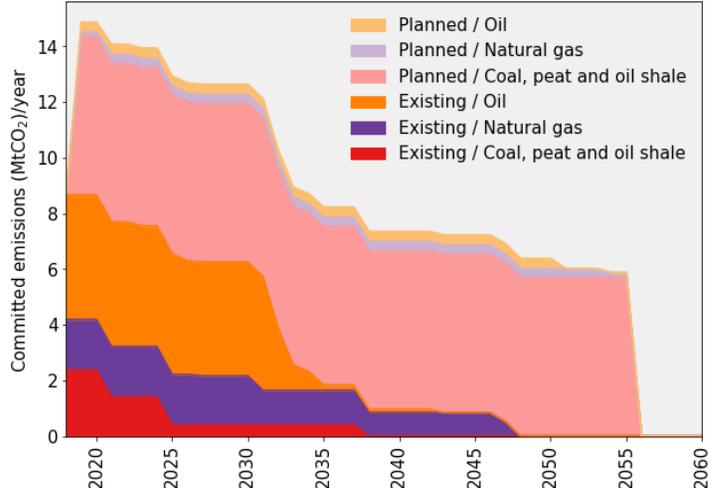
Colombia



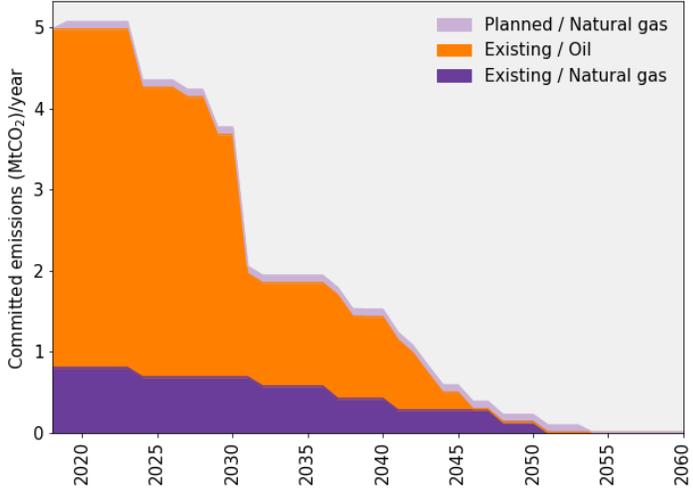
Costa Rica



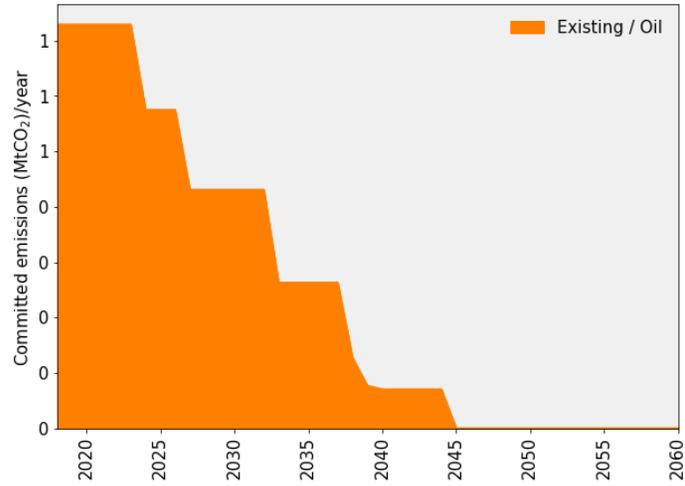
Dominican Republic



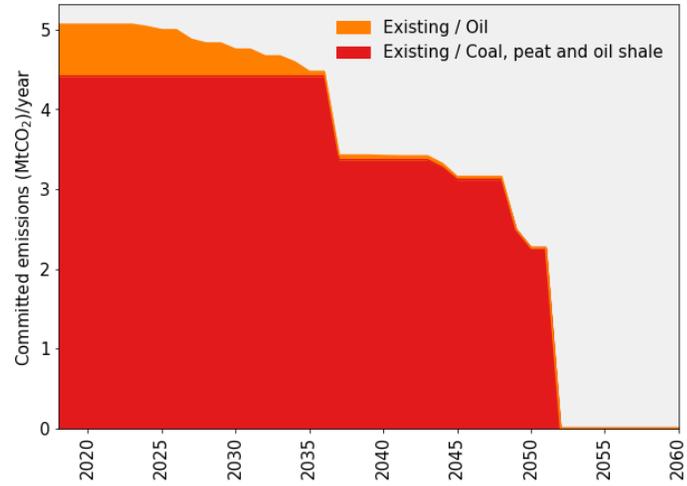
Ecuador



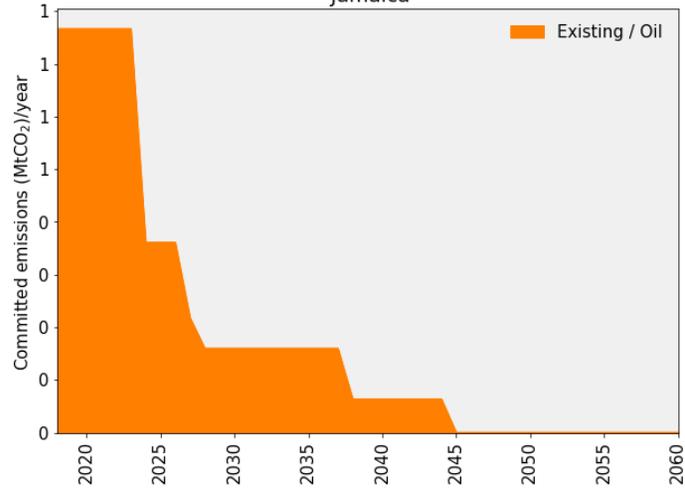
El Salvador



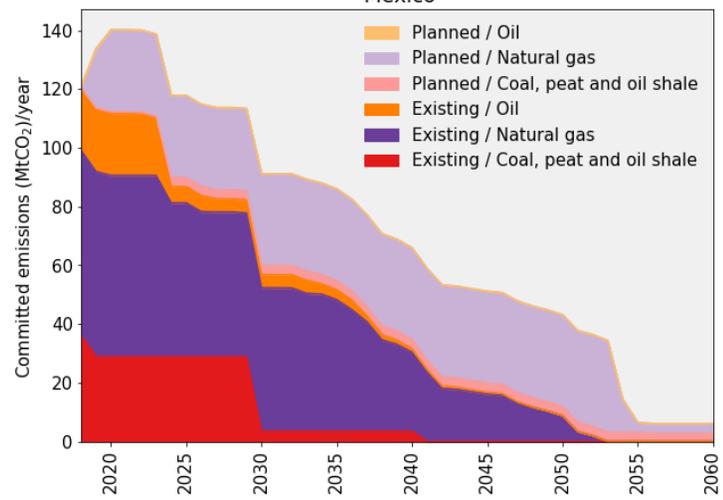
Guatemala

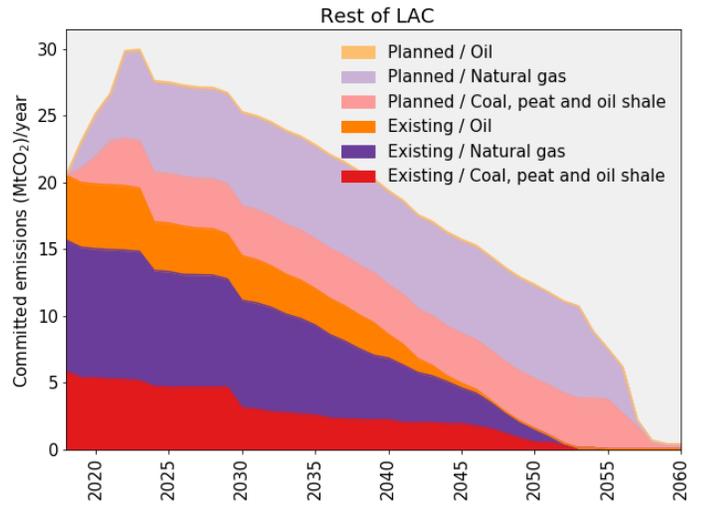
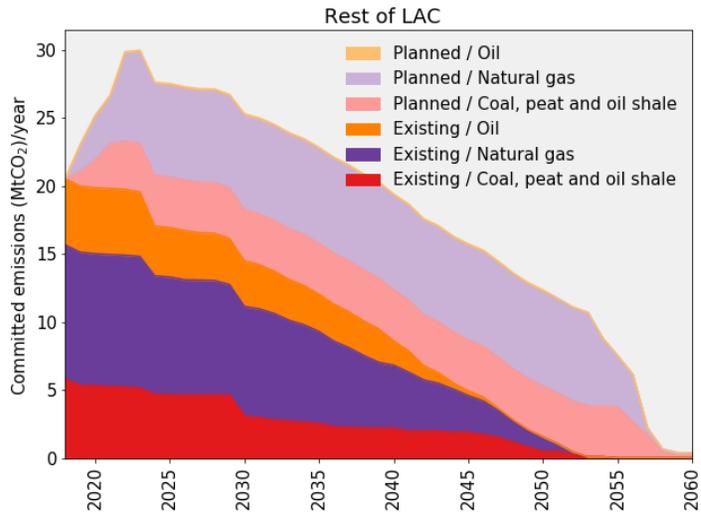
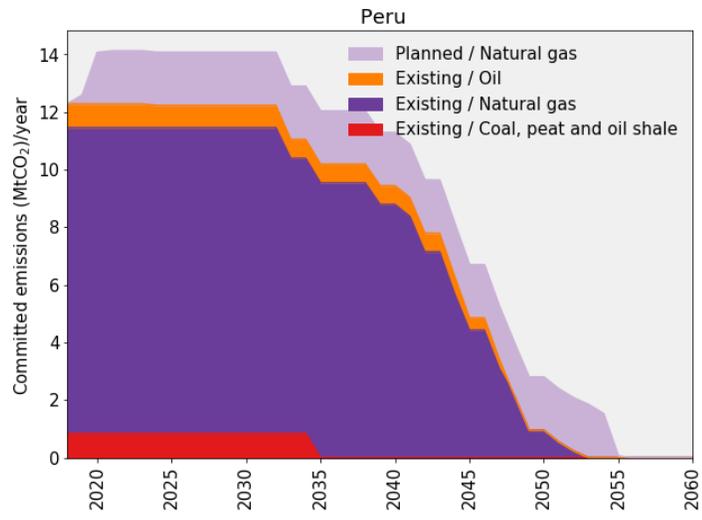
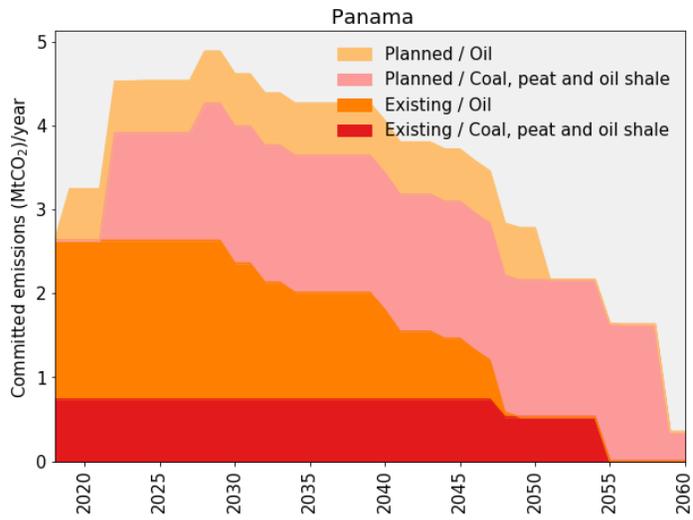


Jamaica

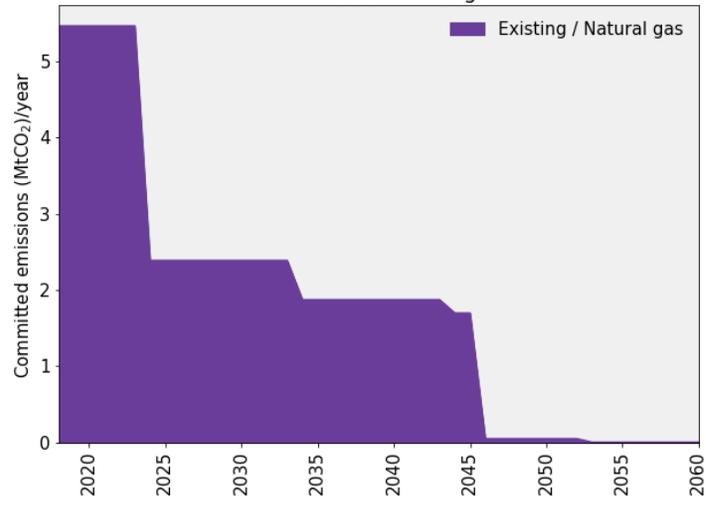


Mexico

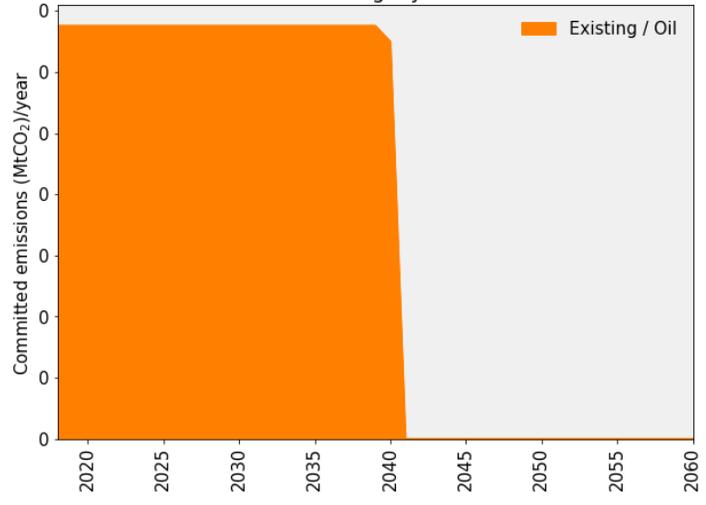




Trinidad and Tobago



Uruguay



Venezuela

