Inter-American Development Bank

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

Climate Change Division

Esperanza González-Mahecha
Oskar Lecuyer
Michelle Hallack
Morgan Bazilian
Adrien Vogt-Schilb

DISCUSSION PAPER Nº IDB-DP-00708

September 2019

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

Esperanza González-Mahecha
Oskar Lecuyer
Michelle Hallack
Morgan Bazilian
Adrien Vogt-Schilb

Inter-American Development Bank
Agence Française de Développement
Colorado School of Mines

September 2019

Inter-American Development Bank

Inter-American Development Bank
1300 New York Ave NW
Washington, D.C. 20577

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

Esperanza González-Mahecha[1], Oskar Lecuyer[2], Michelle Hallack[1], Morgan Bazilian[3], Adrien Vogt-Schilb[1]

[1] Inter-American Development Bank, Washington DC, United States of America (rosago@iadb.org, michellecar@iadb.org, avogtschilb@iadb.org)
[2] Agence Française de Développement, Paris, France (lecuyero@afd.fr)
[3] Colorado School of Mines, Golden, Colorado, USA (mbazilian@mines.edu)

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.

Keywords

Carbon Budget, Climate Change, Power Sector, Stranded Assets

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 CO_2 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 climate

---

[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).

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 $GtCO_2$, 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 we find to be 1.1 to 13.5 $GtCO_2$. 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

---

[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).

average allowable carbon budget for 2°C (6.2 $GtCO_2$) or 1.5°C (5.8 $GtCO_2$), 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 significative contribution to global emissions. In this paper we focus in LAC, a region that was home to only 5% of CO_2 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 CO_2 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:

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

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 CO_2 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 announced[4], authorized[5], 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

---

[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.

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 PTT 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 CO_2 emissions by country and fuel *F* from Enerdata (2019a). Since the last year full reported for CO_2 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 21st 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	37

	than Below-1.5°C pathways	
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: *CO_2 emissions of electricity supply*, and *carbon sequestration in the electricity supply*.[6] We compute gross CO_2 emissions from the power sector as the sum of net CO_2 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 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 LAC[7] (the appendix 2 contains results per country).

---

[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)

[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

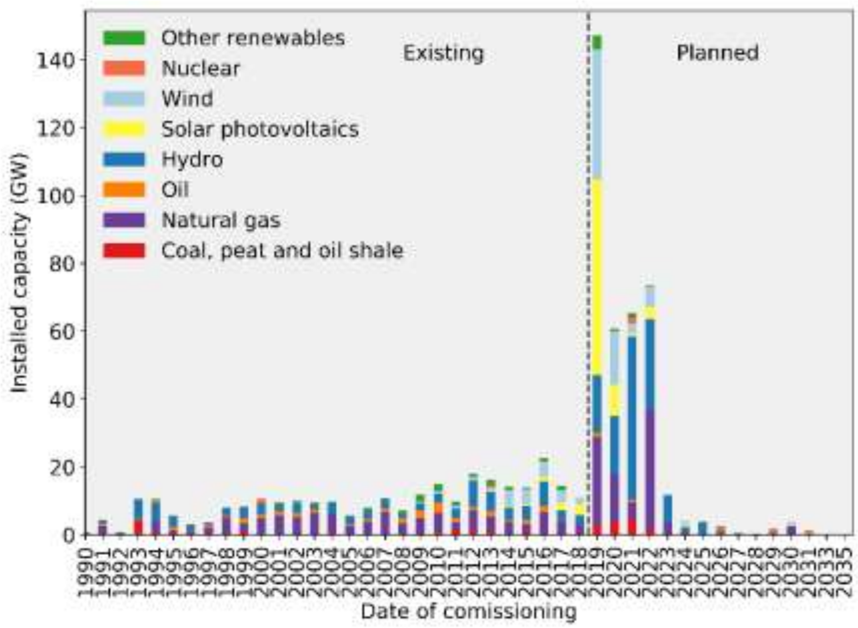


Figure 1. Capacity by date of commissioning. The bars in 2019 and after correspond to planned power plants. We plot data from 1990, however, the database includes units which started to operate before that.

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%).

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 $GtCO_2$ 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).

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.

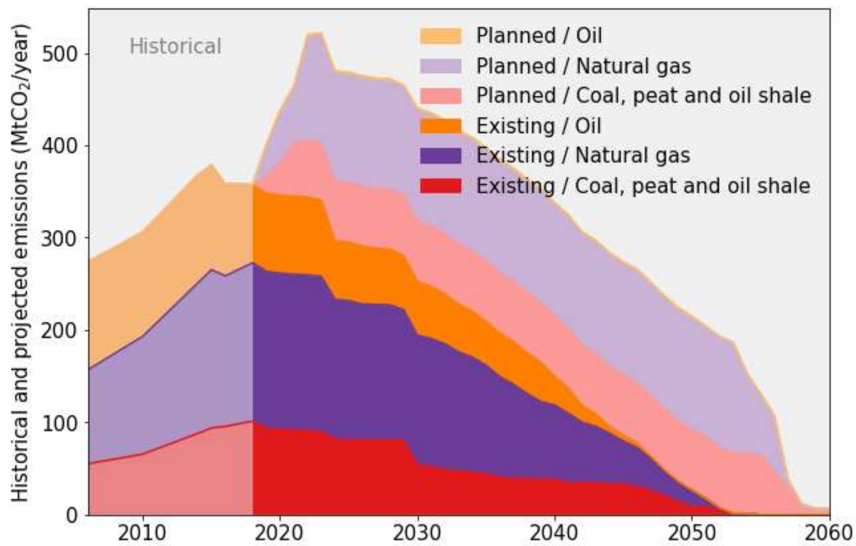


Figure 2. Historical and committed emissions (operational and planned plants). Under normal conditions, the last operational unit would operate until 2054. The last unit in the current planned pipeline would operate until 2064. Dark colors indicate operational status, while the planned pipeline is displayed 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 $GtCO_2$ 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 $MtCO_2$ 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 $GtCO_2$, respectively. If planned plants are built, Brazil would become the top contributor to committed emissions in the region, with 2.7 $GtCO_2$, almost tripling committed emissions from its operational generators. Mexico would add 1.2 $GtCO_2$; Chile would add 0.9 $GtCO_2$ 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).

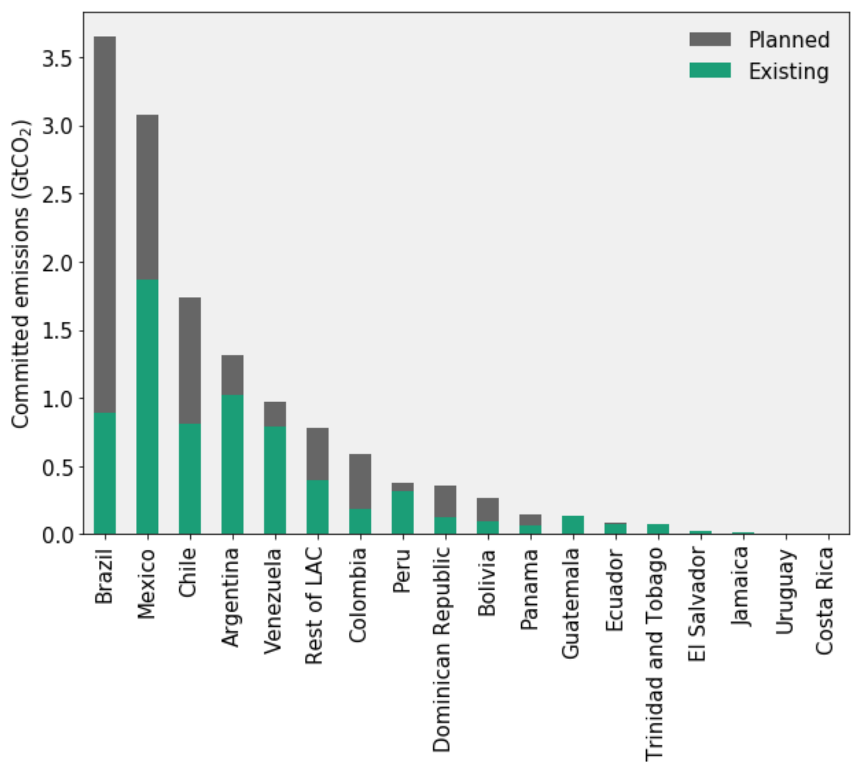
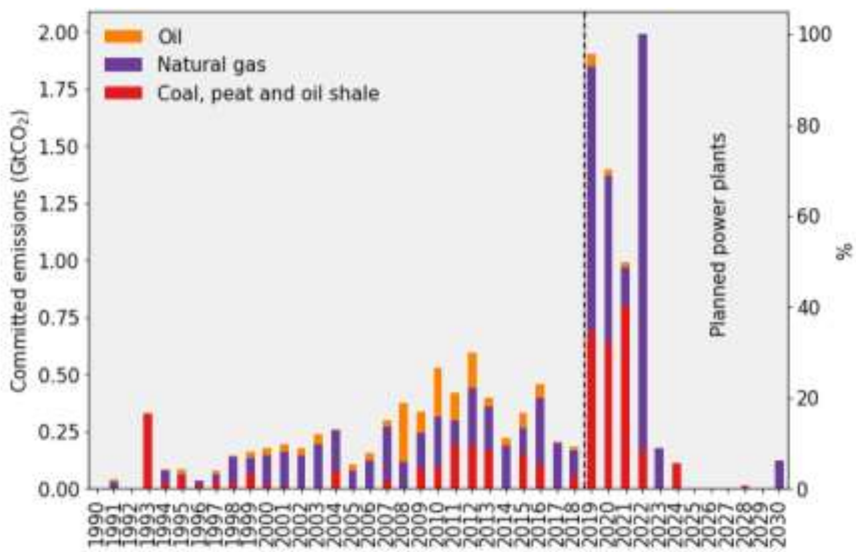


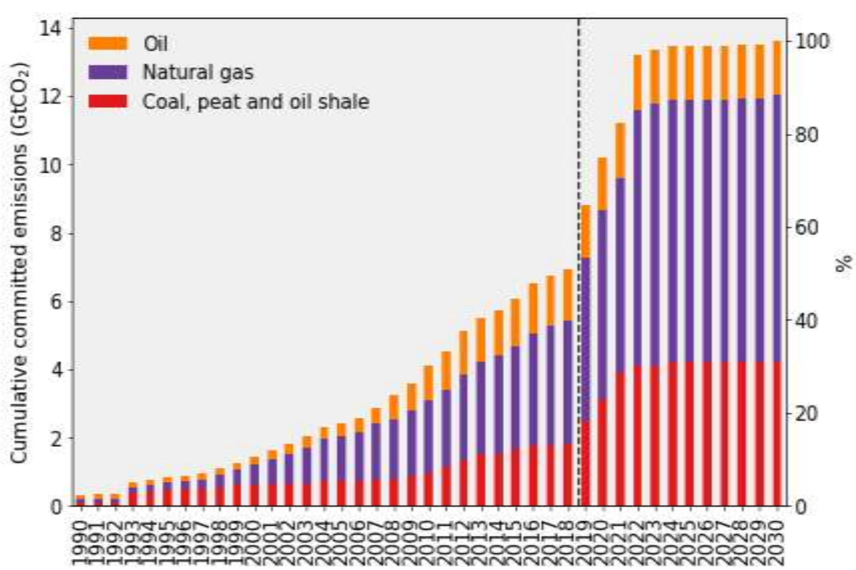
Figure 3. Committed emissions from existing and planned power plants by country

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 where built. Panel B shows the same information cumulatively.

Committed emissions from plants under construction and bidding status sum 4.3 $GtCO_2$, while authorized and announced would add 1.4 $GtCO_2$ and 0.9 $GtCO_2$, 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 $GtCO_2$) and Mexico (1.1$GtCO_2$). 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. Cancelations 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 $GtCO_2$ is slightly less than, but close to the 6.9 $GtCO_2$ 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 $MtCO_2$/yr from the power sector. But existing power plants will emit about 1.8 $GtCO_2$ over their lifetime and adding planned power plants would bring this number to 3 $GtCO_2$. The Brazilian case is the most contrasting. Today, Brazil emits 42 $MtCO_2$/yr. However, committed emissions from existing plants will be 0.9 $GtCO_2$ over their lifespan. This number will scale up to 3.6 $GtCO_2$ if the planned power plants are fully implemented. In other words, committed emissions from existing and planned generators in Brazil represents 87 years of CO_2 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.

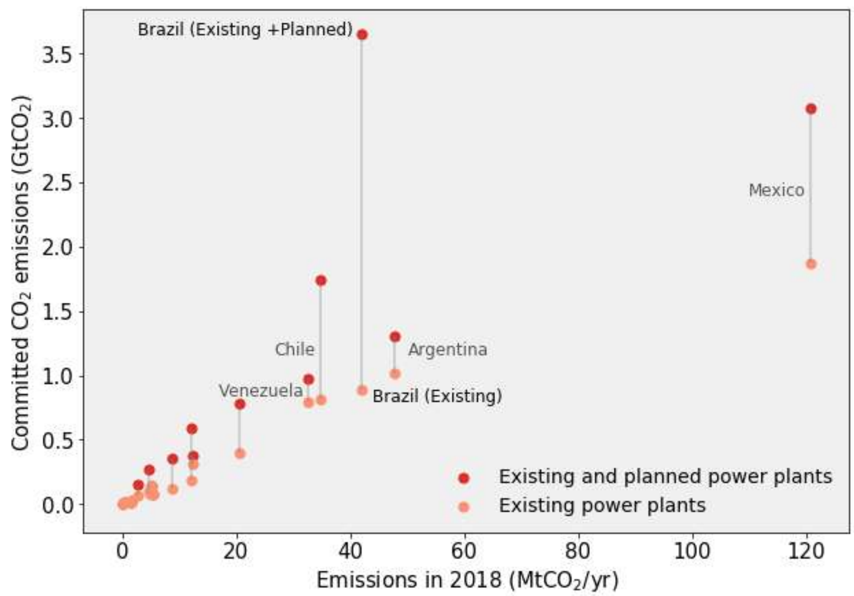
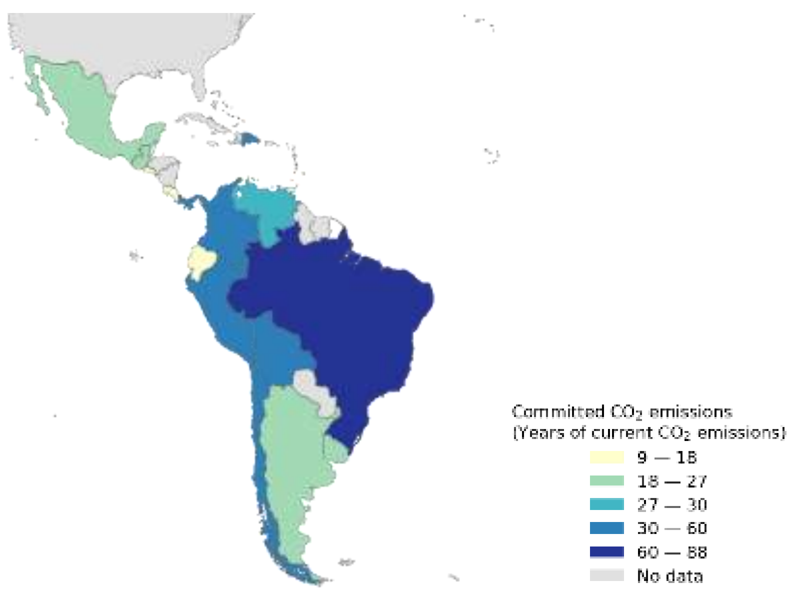


Figure 5. Emissions in 2018 vs total committed emissions. Dark dot indicates committed emissions from existing and planned power plants, while existing power plants are displayed in light colors.



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 CO_2 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 134gCO_2/kWh, which is 61% higher than the current intensity.

Table 3. Carbon intensity of electricity generation (gCO_2/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 GtCO_2 to 13.5 GtCO_2, with an average of 5.8 GtCO_2. In the scenarios compatible with 2°C, gross carbon budgets range between 1.7 GtCO_2 to 16 GtCO_2, with a mean of 6.2 GtCO_2.

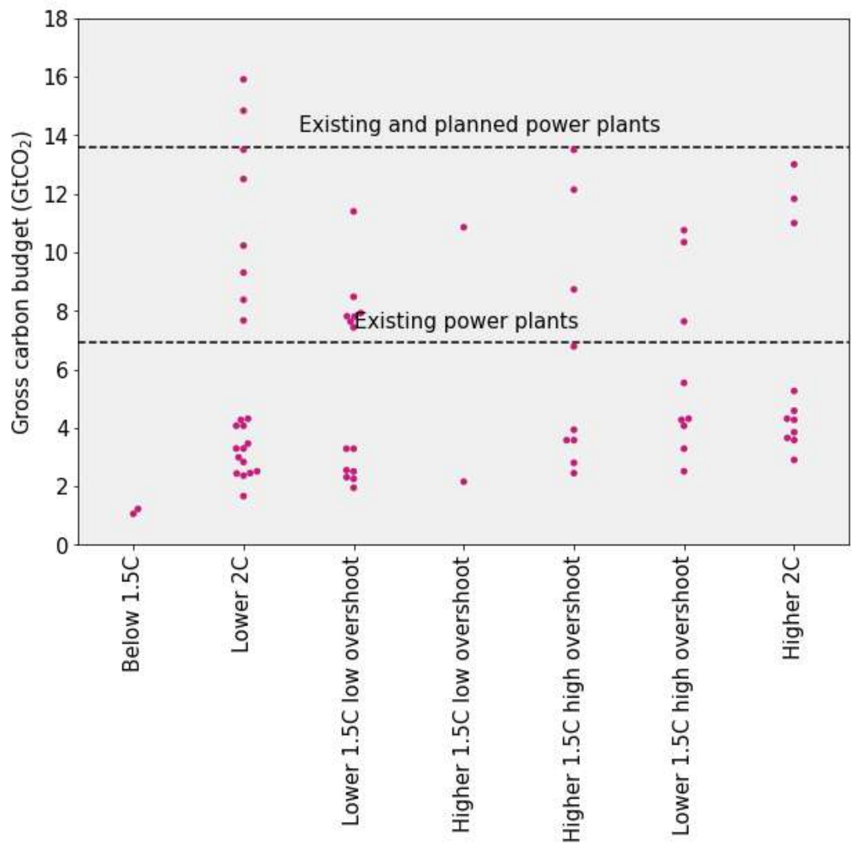


Figure 6. Comparison of committed CO_2 emissions LAC (dashed lines) with carbon-only generation budgets computed from the emission pathways reported in the IPCC 1.5°C report (dots)

Committed emissions from existing generators (6.9 $GtCO_2$) 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, roughly[8] 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.

---

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

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 $GtCO_2$) by 0.09 $GtCO_2$ (+5.12%). For coal-based planned pipeline, every additional year of lifespan would increase committed emissions from 2.41 $GtCO_2$ to 2.47 $GtCO_2$ (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 $GtCO_2$) by 0.15 $GtCO_2$ (+4.26%). Committed emissions from the gas-based planned pipeline (4.18 $GtCO_2$) would increase by 0.12 $GtCO_2$ (+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 $GtCO_{2,}$ 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 $GtCO_2$), and average carbon budgets from IPCC. However, committed emissions from existing generators (2.8 $GtCO_2$) 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.

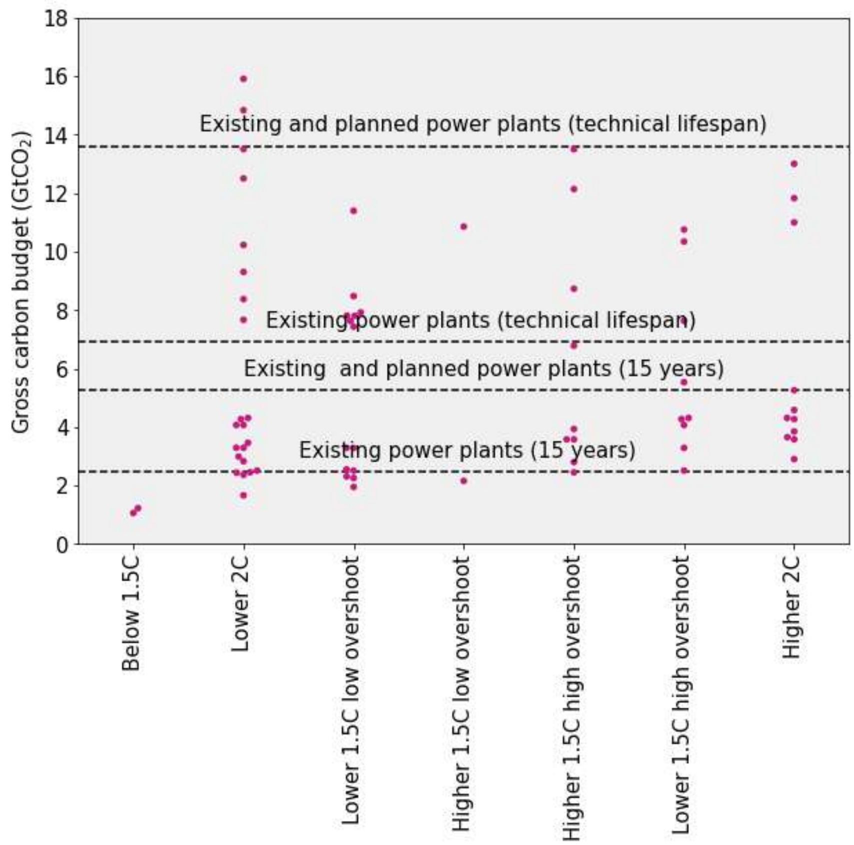


Figure 7. Committed CO_2 emissions from existing and planned power plants in LAC, compared with various estimates of carbon budgets (comparison of long technical lifespan vs lifespans consistent with short payback times)

We also test different data sources. We run a simulation using emission factor calculated with the CO_2 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 $GtCO_2$ to 17.52 $GtCO_2$ (+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 $MtCO_2$, existing power plants are on track to emit a total of 890 $MtCO_2$ 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 $GtCO_2$; 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 $GtCO_2$.

While Brazil is an extreme example, these results apply broadly to the region. Today the power sector in LAC only emits 357 $MtCO_2$, but implementing the totality of fossil-fueled power expansion projects reflected in Enerdata's Power Plant Tracker would commit 6.7$GtCO_2$, 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.

6 References

Audoly, R., Vogt-Schilb, A., Guivarch, C., Pfeiffer, A., 2018. Pathways toward zero-carbon electricity required for climate stabilization. Applied Energy 225, 884–901. https://doi.org/10.1016/j.apenergy.2018.05.026

Bertram, C., Luderer, G., Pietzcker, R.C., Schmid, E., Kriegler, E., Edenhofer, O., 2015. Complementing carbon prices with technology policies to keep climate targets within reach. Nature Climate Change 5, 235–239. https://doi.org/10.1038/nclimate2514

Binsted, M., Iyer, G., Edmonds, J., McJeon, H., Miralles-Wilhelm, F., Vogt-Schilb, A., 2018. Implications of the Paris Agreement for Stranded Assets in Latin America and the Caribbean.

Cadena, A., 2019. Alignment between expansion plans and Intended Nationally Determined Contributions in LAC. Work in progress.

Calderón, S., Alvarez, A.C., Loboguerrero, A.M., Arango, S., Calvin, K., Kober, T., Daenzer, K., Fisher-Vanden, K., 2016. Achieving CO2reductions in Colombia: Effects of carbon taxes and abatement targets. Energy Economics 56, 575–586. https://doi.org/10.1016/j.eneco.2015.05.010

Carvajal, P.E., Li, F.G.N., Soria, R., Cronin, J., Anandarajah, G., Mulugetta, Y., 2019. Large hydropower, decarbonisation and climate change uncertainty: Modelling power sector pathways for Ecuador. Energy Strategy Reviews 23, 86–99. https://doi.org/10.1016/j.esr.2018.12.008

Clarke, L., McFarland, J., Octaviano, C., van Ruijven, B., Beach, R., Daenzer, K., Herreras Martínez, S., Lucena, A.F.P., Kitous, A., Labriet, M., Loboguerrero Rodriguez, A.M., Mundra, A., van der Zwaan, B., 2016. Long-term abatement potential and current policy trajectories in Latin American countries. Energy Economics 56, 513–525. https://doi.org/10.1016/j.eneco.2016.01.011

Coulomb, R., Lecuyer, O., Vogt-Schilb, A., 2018. Optimal transition from coal to gas and renewable power under capacity constraints and adjustment costs. Environmental & Resource Economics.

Davis, S.J., Caldeira, K., Matthews, H.D., 2010. Future CO2 Emissions and Climate Change from Existing Energy Infrastructure. Science 329, 1330–1333. https://doi.org/10.1126/science.1188566

Davis, S.J., Lewis, N.S., Shaner, M., Aggarwal, S., Arent, D., Azevedo, I.L., Benson, S.M., Bradley, T., Brouwer, J., Chiang, Y.-M., Clack, C.T.M., Cohen, A., Doig, S., Edmonds, J., Fennell, P., Field, C.B., Hannegan, B., Hodge, B.-M., Hoffert, M.I., Ingersoll, E., Jaramillo, P., Lackner, K.S., Mach, K.J., Mastrandrea, M., Ogden, J., Peterson, P.F., Sanchez, D.L., Sperling, D., Stagner, J., Trancik, J.E., Yang, C.-J., Caldeira, K., 2018. Net-zero emissions energy systems. Science 360, eaas9793. https://doi.org/10.1126/science.aas9793

Davis, S.J., Socolow, R.H., 2014. Commitment accounting of CO<inf>2</inf> emissions. Environmental Research Letters 9. https://doi.org/10.1088/1748-9326/9/8/084018

de Queiroz, A.R., Faria, V.A.D., Lima, L.M.M., Lima, J.W.M., 2019. Hydropower revenues under the threat of climate change in Brazil. Renewable Energy 873–882. https://doi.org/10.1016/j.renene.2018.10.050

Di Sbroiavacca, N., Nadal, G., Lallana, F., Falzon, J., Calvin, K., 2016. Emissions reduction scenarios in the Argentinean Energy Sector. Energy Economics 56, 552–563. https://doi.org/10.1016/j.eneco.2015.03.021

Edenhofer, O., Steckel, J.C., Jakob, M., Bertram, C., 2018. Reports of coal's terminal decline may be exaggerated. Environ. Res. Lett. 13, 024019. https://doi.org/10.1088/1748-9326/aaa3a2

ENERDATA, 2019a. Power Plan Tracker.

ENERDATA, 2019b. Country Dashboard.

Fay, M., Hallegatte, S., Vogt-Schilb, A., Rozenberg, J., Narloch, U., Kerr, T., 2015. Decarbonizing Development: Three Steps to a Zero-Carbon Future. World Bank Publications, Washington DC, USA.

Gambhir, A., Green, F., Pearson, P.J.G., 2018. Towards a just and equitable low-carbon energy transition (Grantham Institute Briefing paper No 26). Imperial College London.

Grubb, M., Mercure, J., Salas, P., Lange, R., Sognnaes, I., 2018. Systems Innovation, Inertia and Pliability: A mathematical exploration with implications for climate change abatement (Working Paper). University of Cambridge.

Hallegatte, S., Fay, M., Vogt-Schilb, A., 2013. Green Industrial Policies: When and How. World Bank Policy Research Working Paper.

Huppmann, D., Kriegler, E., Krey, V., Riahi, K., Rogelj, J., Rose, S.K., Weyant, J., Bauer, N., Bertram, C., Bosetti, V., Calvin, K., Doelman, J., Drouet, L., Emmerling, J., Frank, S., Fujim, S., Zhang, R., 2018a. IAMC 1.5°C Scenario Explorer hosted by IIASA. https://doi.org/10.22022/SR15/08-2018.15429

Huppmann, D., Rogelj, J., Kriegler, E., Krey, V., Riahi, K., 2018b. A new scenario resource for integrated 1.5 °C research. Nature Climate Change 1–4. https://doi.org/10.1038/s41558-018-0317-4

IEA, 2018a. Extended world energy balances. https://doi.org/10.1787/4bcaaac5-en

IEA, 2018b. IEA CO2 Emissions from Fuel Combustion Statistics (database). https://doi.org/10.1787/data-00430-en

IIASA, 2017. Evaluating Process-Based Integrated Assessment Models of Climate Change Mitigation.

ILO, 2018. World Employment and Social Outlook 2018: Greening with jobs. Intenrational Labor Organization.

IPCC, 2018. Global warming of 1.5°C An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, .

IRENA, 2016. Renewable Energy Market Analysis: Latin America, Irena. http://www.irena.org/DocumentDownloads/Publications/IRENA_Market_GCC_2016.pdf

Iyer, G.C., Edmonds, J.A., Fawcett, A.A., Hultman, N.E., Alsalam, J., Asrar, G.R., Calvin, K.V., Clarke, L.E., Creason, J., Jeong, M., Kyle, P., McFarland, J., Anupriya Mundra, Patel,

P., Shi, W., McJeon, H.C., 2015. The contribution of Paris to limit global warming to 2 °C. Environ. Res. Lett. 10, 125002. https://doi.org/10.1088/1748-9326/10/12/125002

Jenkins, J.D., 2014. Political economy constraints on carbon pricing policies: What are the implications for economic efficiency, environmental efficacy, and climate policy design? Energy Policy 69, 467–477. https://doi.org/10.1016/j.enpol.2014.02.003

Lucena, A.F.P., Clarke, L., Schaeffer, R., Szklo, A., Rochedo, P.R.R., Nogueira, L.P.P., Daenzer, K., Gurgel, A., Kitous, A., Kober, T., 2016. Climate policy scenarios in Brazil : A multi-model comparison for energy. Energy Economics 56, 564–574. https://doi.org/10.1016/j.eneco.2015.02.005

Mejdalani, A., Soto, D.L., Antonio, K., Hallack, M., 2019. Promoting Renewable Generation in Latin America and The Caribbean: experiences and lessons from utility and distributed scale policies. Work in progress.

Millar, R., Allen, M., Rogelj, J., Friedlingstein, P., 2016. The cumulative carbon budget and its implications. Oxford Review of Economic Policy 32, 323–342. https://doi.org/10.1093/oxrep/grw009

Nemet, G.F., Jakob, M., Steckel, J.C., Edenhofer, O., 2017. Addressing policy credibility problems for low-carbon investment. Global Environmental Change 42, 47–57. https://doi.org/10.1016/j.gloenvcha.2016.12.004

Octaviano, C., Paltsev, S., Gurgel, A.C., 2016. Climate change policy in Brazil and Mexico: Results from the MIT EPPA model. Energy Economics 56, 600–614. https://doi.org/10.1016/j.eneco.2015.04.007

OECD, 2015. Climate Change Mitigation: Policies and progress, Climate Change Mitigation. Paris. https://doi.org/10.1787/9789264238787-en

OECD/IEA, 2018. World Energy Investment. https://doi.org/10.1787/9789264301351-en

OLADE, 2018. Política Energética y NDCs En América Latina y El Caribe. Organización Latinoamericana de Energía.

O'Ryan, F., 2019. Mesa de descarbonización concluye con positivo balance de la industria. La Tercera.

Paredes, J.R., 2017. La Red del Futuro: Desarrollo de una red eléctrica limpia y sostenible para América Latina. https://doi.org/10.18235/0000937

Pathak, S., 2017. Why Develop 2050 Pathways? 2050 Pathways Platform.

Pereira de Lucena, A.F., Schaeffer, R., Fleming, F.P., Boulahya, M.S., Harrison, M., Szklo, A.S., Pupo Nogueira, L.P., Moreira Cesar Borba, B.S., Troccoli, A., 2011. Energy sector vulnerability to climate change: A review. Energy 38, 1–12. https://doi.org/10.1016/j.energy.2011.11.056

Pfeiffer, A., Hepburn, C., Vogt-Schilb, A., Caldecott, B., 2018. Committed emissions from existing and planned power plants and asset stranding required to meet the Paris Agreement. Environmental Research Letters 13. https://doi.org/10.1088/1748-9326/aabc5f

Pfeiffer, A., Millar, R., Hepburn, C., Beinhocker, E., 2016. The '2°C capital stock' for electricity generation: Committed cumulative carbon emissions from the electricity generation sector and the transition to a green economy. Applied Energy 179, 1395–1408. https://doi.org/10.1016/j.apenergy.2016.02.093

Rogelj, J., den Elzen, M., Höhne, N., Fransen, T., Fekete, H., Winkler, H., Schaeffer, R., Sha, F., Riahi, K., Meinshausen, M., 2016. Paris Agreement climate proposals need a boost to keep warming well below 2 °C. Nature 534, 631–639. https://doi.org/10.1038/nature18307

Rogelj, J., Schaeffer, M., Meinshausen, M., Knutti, R., Alcamo, J., Riahi, K., Hare, W., 2015. Zero emission targets as long-term global goals for climate protection. Environmental Research Letters 10, 105007. https://doi.org/10.1088/1748-9326/10/10/105007

Rotmans, J., van Asselt, M., Asselt, M.B.A. Van, 2001. Uncertainty in integrated assessment modelling : A labyrinthic path. Integrated Assessment 2, 43–55.

Rozenberg, J., Vogt-Schilb, A., Hallegatte, S., 2018. Instrument

choice and stranded assets in the transition to clean capital. Journal of Environmental Economics and Management. https://doi.org/10.1016/j.jeem.2018.10.005

Sachs, J.D., Schmidt-Traub, G., Williams, J., 2016a. Pathways to zero emissions. Nature Geoscience 9, 799–801. https://doi.org/10.1038/ngeo2826

Sachs, J.D., Schmidt-Traub, G., Williams, J., 2016b. Pathways to zero emissions. Nature Geoscience 9, 799–801. https://doi.org/10.1038/ngeo2826

Shearer, C., Fofrich, R., Davis, S.J., 2017. Future CO2 emissions and electricity generation from proposed coal-fired power plants in India. Earth's Future 5, 2017EF000542. https://doi.org/10.1002/2017EF000542

Smith, C.J., Forster, P.M., Allen, M., Fuglestvedt, J., Millar, R.J., Rogelj, J., Zickfeld, K., 2019. Current fossil fuel infrastructure does not yet commit us to 1.5 °C warming. Nature Communications 10, 101. https://doi.org/10.1038/s41467-018-07999-w

Smith, P., Davis, S.J., Creutzig, F., Fuss, S., Minx, J., Gabrielle, B., Kato, E., Jackson, R.B., Cowie, A., Kriegler, E., van Vuuren, D.P., Rogelj, J., Ciais, P., Milne, J., Canadell, J.G., McCollum, D., Peters, G., Andrew, R., Krey, V., Shrestha, G., Friedlingstein, P., Gasser, T., Grübler, A., Heidug, W.K., Jonas, M., Jones, C.D., Kraxner, F., Littleton, E., Lowe, J., Moreira, J.R., Nakicenovic, N., Obersteiner, M., Patwardhan, A., Rogner, M., Rubin, E., Sharifi, A., Torvanger, A., Yamagata, Y., Edmonds, J., Yongsung, C., 2016. Biophysical and economic limits to negative CO2 emissions. Nature Climate Change 6, 42–50. https://doi.org/10.1038/nclimate2870

Soito, J.L.D.S., Freitas, M.A.V., 2011. Amazon and the expansion of hydropower in Brazil: Vulnerability, impacts and possibilities for adaptation to global climate change. Renewable and Sustainable Energy Reviews 15, 3165–3177. https://doi.org/10.1016/j.rser.2011.04.006

Soria, R., Lucena, A.F.P., Tomaschek, J., Fichter, T., Haasz, T., Szklo, A., Schaeffer, R., Rochedo, P., Fahl, U., Kern, J., 2016. Modelling concentrated solar power (CSP) in the Brazilian energy system: A soft-linked model coupling

approach. Energy 116, 265–280. https://doi.org/10.1016/j.energy.2016.09.080

UNEP, 2017. The Emissions Gap Report 2017: A UN Environment Synthesis Report. United Nations Environment Programme.

United Nations, 2015. Paris Agreement. United Nations Treaty Collection, New York, USA.

van der Zwaan, B., Kober, T., Calderon, S., Clarke, L., Daenzer, K., Kitous, A., Labriet, M., Lucena, A.F.P., Octaviano, C., Di Sbroiavacca, N., 2016. Energy technology roll-out for climate change mitigation: A multi-model study for Latin America. Energy Economics 56, 526–542. https://doi.org/10.1016/j.eneco.2015.11.019

Van Vliet, M.T.H., Wiberg, D., Leduc, S., Riahi, K., 2016. Power-generation system vulnerability and adaptation to changes in climate and water resources. Nature Climate Change 6, 375–380. https://doi.org/10.1038/nclimate2903

Vergara, W., Fenhann, J.V., Schletz, M.C., 2016. Carbono Cero América Latina-Una vía para la descarbonización neta de la economía regional para mediados de este siglo: Documento de visión.

Vermeulen, R., Schets, E., Lohuis, M., Kölbl, B., Jansen, D.-J., Heeringa, W., 2018. An energy transition risk stress test for the financial system of the Netherlands, Occasionl studies 16-7. De Nederlandsche Bank.

Vogt-Schilb, A., Hallegatte, S., 2017. Climate policies and nationally determined contributions: reconciling the needed ambition with the political economy. Wiley Interdisciplinary Reviews: Energy and Environment 6, 1–23. https://doi.org/10.1002/wene.256

Wacket, M., 2019. Germany to phase out coal by 2038 in move away from fossil fuels. Reuters.

Waisman, H., Bataille, C., Winkler, H., Jotzo, F., Shukla, P., Colombier, M., Buira, D., Criqui, P., Fischedick, M., Kainuma, M., Rovere, E.L., Pye, S., Safonov, G., Siagian, U., Teng, F., Virdis, M.-R., Williams, J., Young, S., Anandarajah, G., Boer, R., Cho, Y., Denis-Ryan, A., Dhar, S., Gaeta, M., Gesteira, C., Haley, B., Hourcade, J.-C., Liu,

Q., Lugovoy, O., Masui, T., Mathy, S., Oshiro, K., Parrado, R., Pathak, M., Potashnikov, V., Samadi, S., Sawyer, D., Spencer, T., Tovilla, J., Trollip, H., 2019. A pathway design framework for national low greenhouse gas emission development strategies. Nature Climate Change 9, 261. https://doi.org/10.1038/s41558-019-0442-8

Weyant, J., 2017. Some Contributions of Integrated Assessment Models of Global Climate Change. Review of Environmental Economics and Policy 11, 115–137. https://doi.org/10.1093/reep/rew018

Williams, J.H., DeBenedictis, A., Ghanadan, R., Mahone, A., Moore, J., Morrow, W.R., Price, S., Torn, M.S., 2012. The Technology Path to Deep Greenhouse Gas Emissions Cuts by 2050: The Pivotal Role of Electricity. Science 335, 53–59. https://doi.org/10.1126/science.1208365

Williamson, P., 2016. Scrutinize CO2 removal methods. Nature 530, 153–155.

Yépez-García, R.A., Hallack, M., Ji, Y., López Soto, D., 2018a. The Energy Path of Latin America and the Caribbean. Inter-American Development Bank.

Yépez-García, R.A., Ji, Y., Hallack, M., López Soto, D., 2018b. The energy path of Latin America and the Caribbean. Washington D.C.

Appendix 1. Carbon intensity of electricity (gCO_2/kWh) in 2018

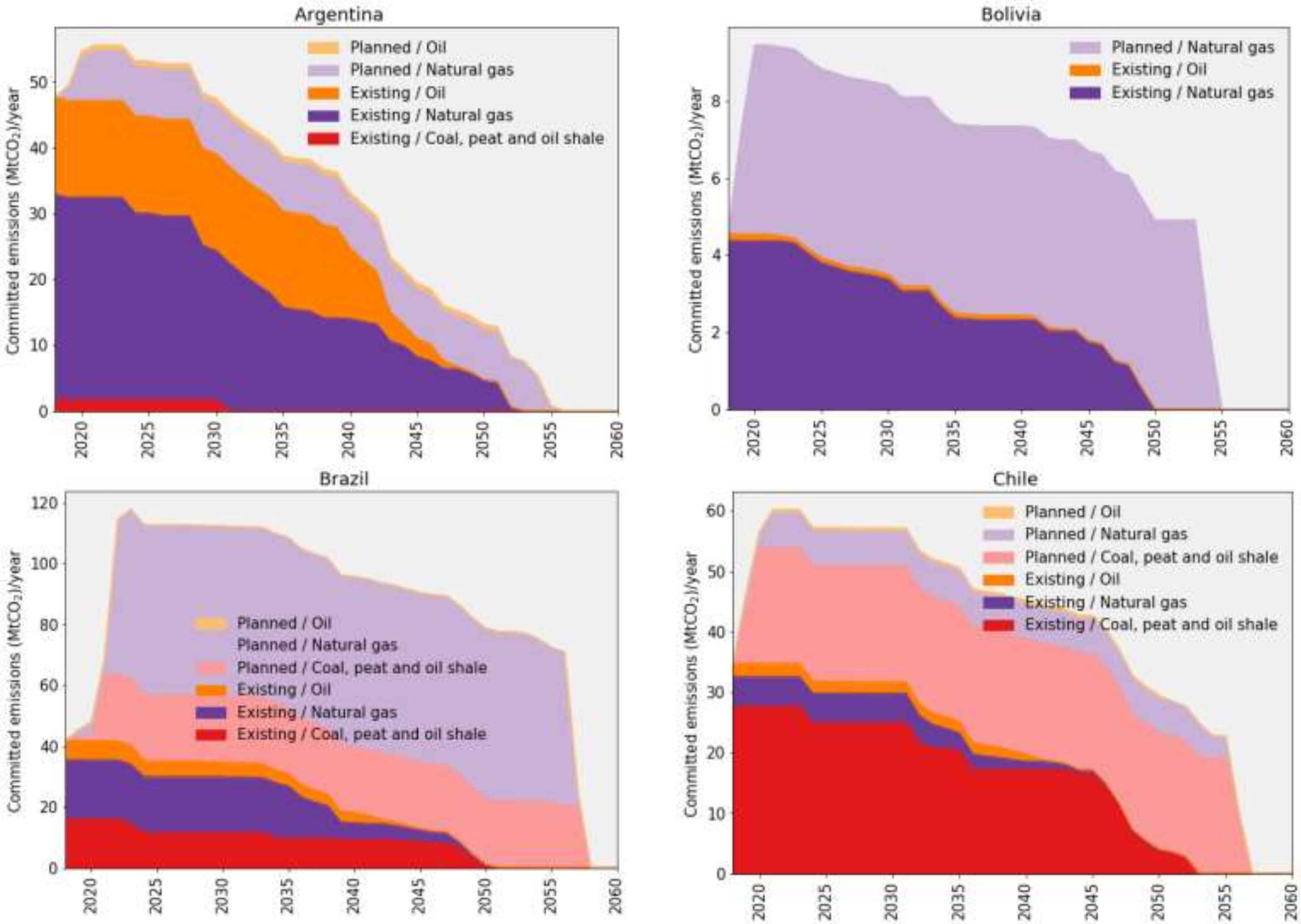
	Coal, peat and oil shale	Natural gas	Oil
Argentina	669	414	705
Bolivia		610	953
Brazil	624	344	421
Chile	916	411	745
Colombia	872	305	469
Costa Rica			679
Dominican Republic	979	472	443
Ecuador		290	515
El Salvador			582
Guatemala	1,115		622
Jamaica			415
Mexico	1,048	327	631
Panama	1,118		636
Peru	1,030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

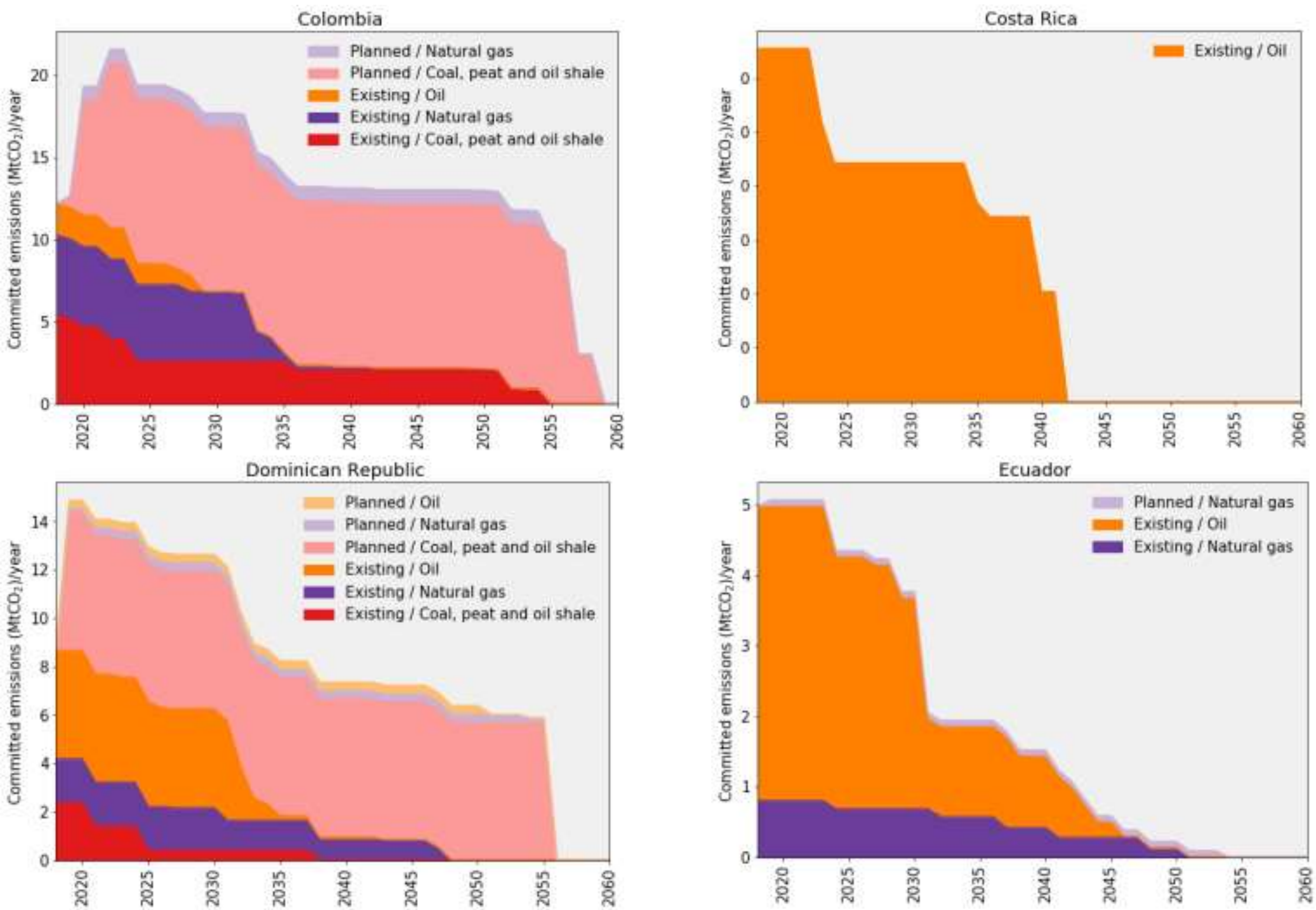
Appendix 2. Operational and planned installed capacity by country

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

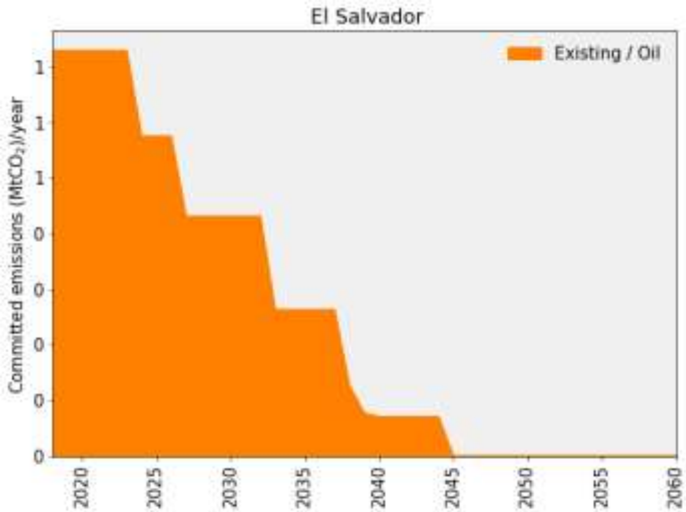
Trinidad and Tobago	2.39	
Uruguay	4.71	0.65
Venezuela	31.89	8.11

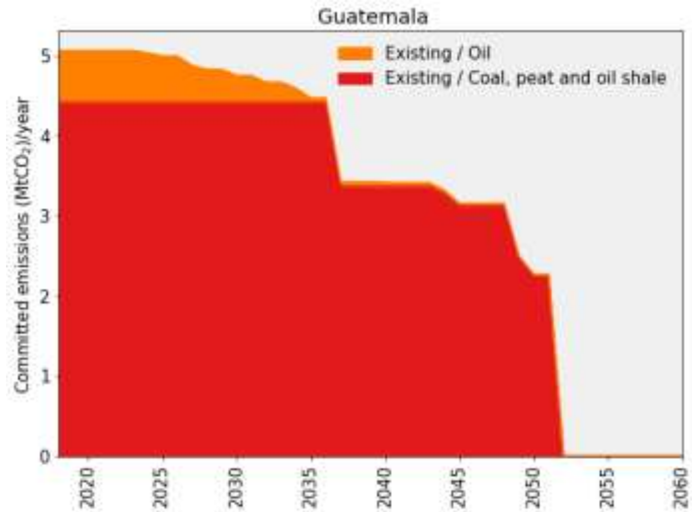
Appendix 3. Projected emissions of the operational plants and planned pipeline

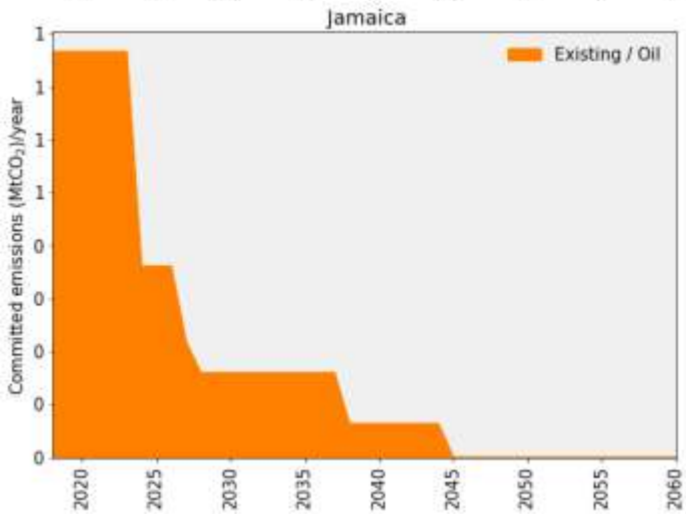


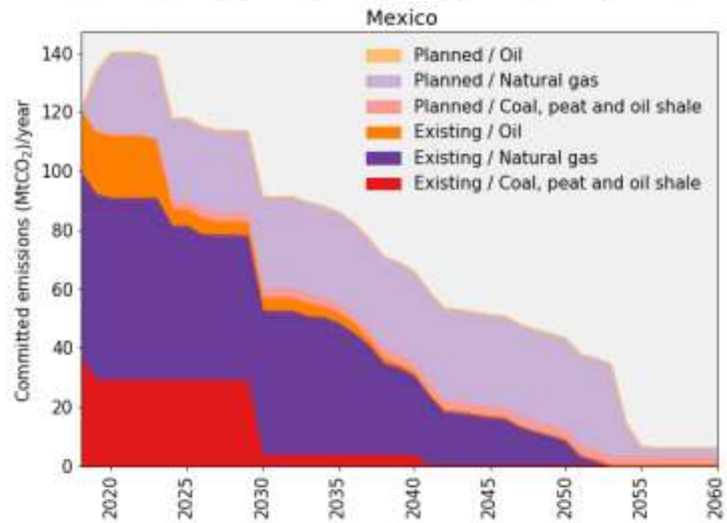


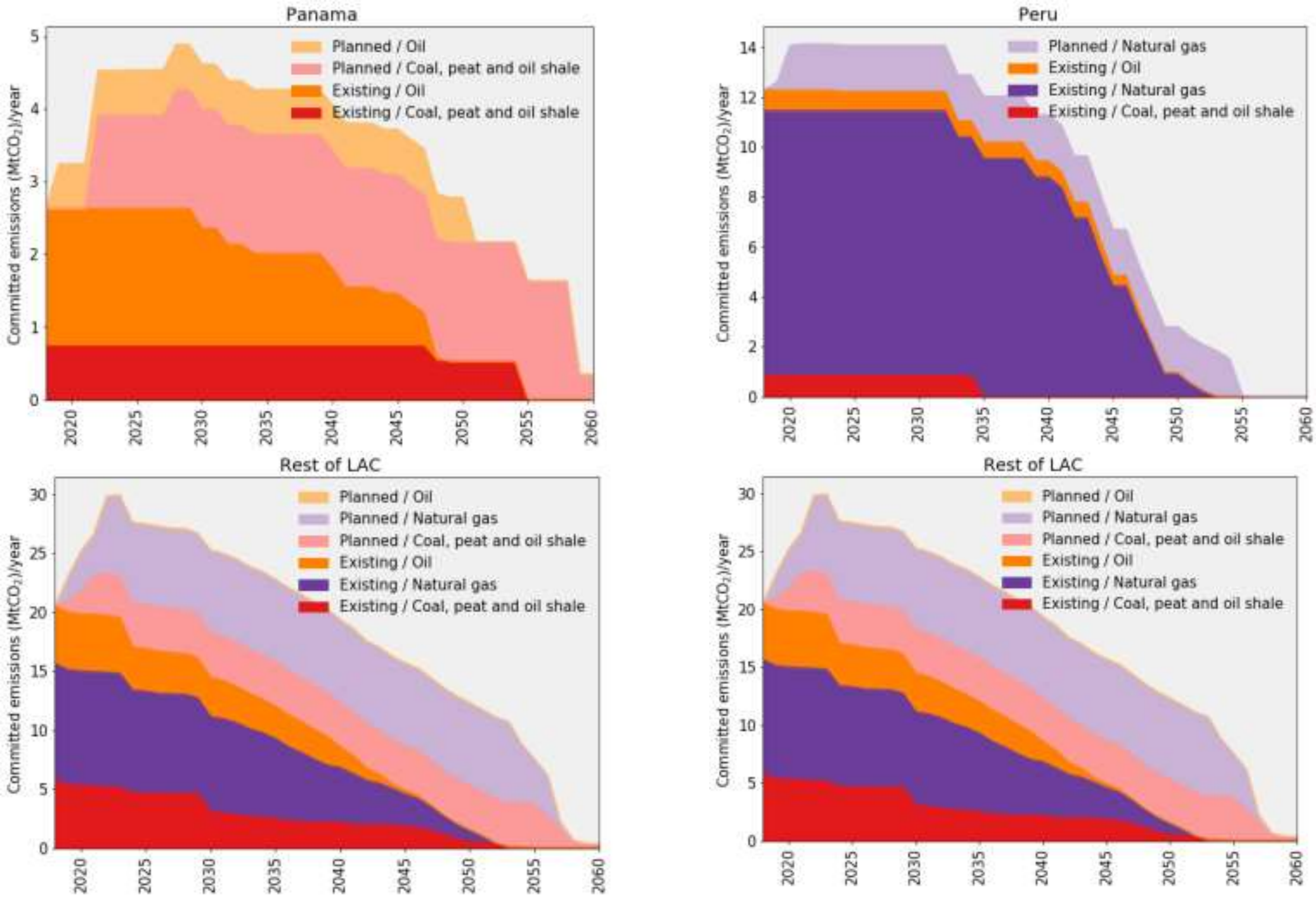
Colombia
Planned / Natural gas
Planned / Coal, peat and oil shale
Existing / Oil
Existing / Natural gas
Existing / Coal, peat and oil shale
Committed emissions ($MtCO_2$)/year
Costa Rica
Existing / Oil
Committed emissions ($MtCO_2$)/year
Dominican Republic
Planned / Oil
Planned / Natural gas
Planned / Coal, peat and oil shale
Existing / Oil
Existing / Natural gas
Existing / Coal, peat and oil shale
Committed emissions ($MtCO_2$)/year
Ecuador
Planned / Natural gas
Existing / Oil
Existing / Natural gas
Committed emissions ($MtCO_2$)/year
2020
2025
2030
2035
2040
2045
2050
2055
2060


El Salvador
Existing / Oil
Committed emissions ($MtCO_2$)/year
2020 2025 2030 2035 2040 2045 2050 2055 2060

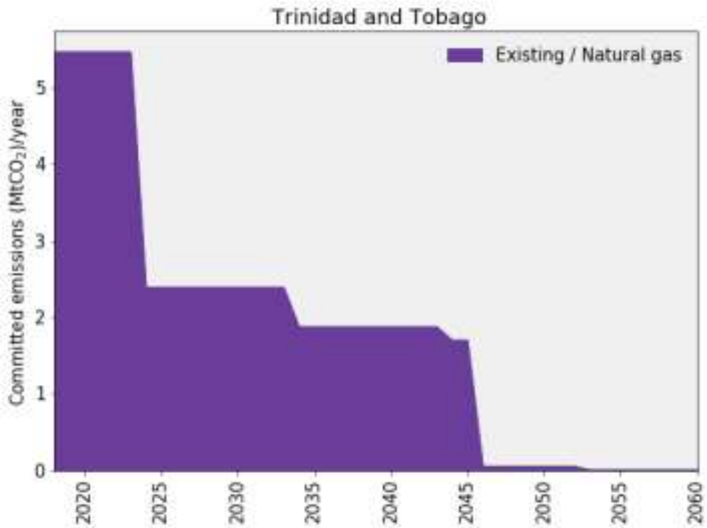

Guatemala
Existing / Oil
Existing / Coal, peat and oil shale
Committed emissions ($MtCO_2$)/year
2020 2025 2030 2035 2040 2045 2050 2055 2060

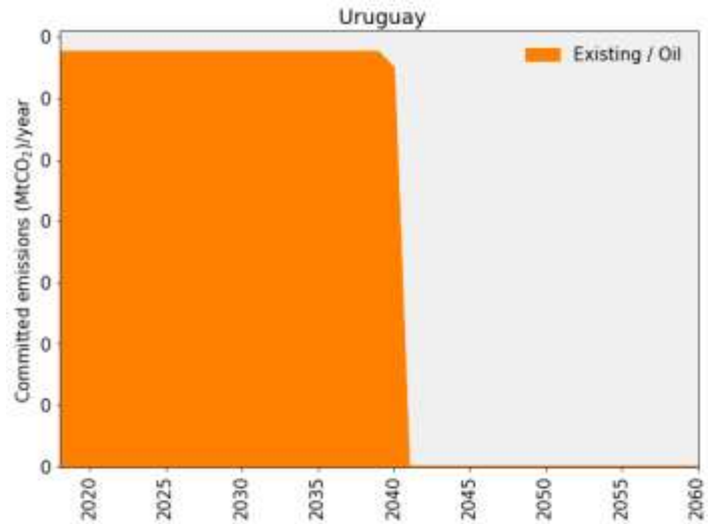

Jamaica
Existing / Oil
Committed emissions ($MtCO_2$)/year
2020 2025 2030 2035 2040 2045 2050 2055 2060

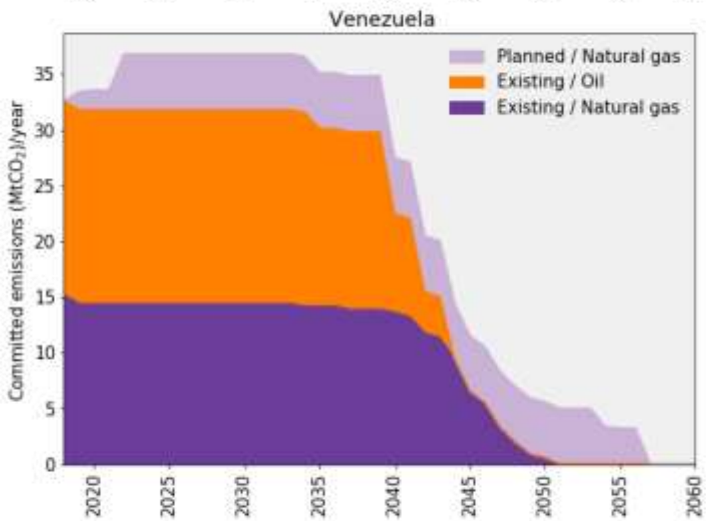

Mexico
Planned / Oil
Planned / Natural gas
Planned / Coal, peat and oil shale
Existing / Oil
Existing / Natural gas
Existing / Coal, peat and oil shale
Committed emissions ($MtCO_2$)/year
2020 2025 2030 2035 2040 2045 2050 2055 2060



Panama
Planned / Oil
Planned / Coal, peat and oil shale
Existing / Oil
Existing / Coal, peat and oil shale
Committed emissions (MtCO$_2$)/year
Peru
Planned / Natural gas
Existing / Oil
Existing / Natural gas
Existing / Coal, peat and oil shale
Committed emissions (MtCO$_2$)/year
Rest of LAC
Planned / Oil
Planned / Natural gas
Planned / Coal, peat and oil shale
Existing / Oil
Existing / Natural gas
Existing / Coal, peat and oil shale
Committed emissions (MtCO$_2$)/year
Rest of LAC
Planned / Oil
Planned / Natural gas
Planned / Coal, peat and oil shale
Existing / Oil
Existing / Natural gas
Existing / Coal, peat and oil shale
Committed emissions (MtCO$_2$)/year
2020 2025 2030 2035 2040 2045 2050 2055 2060


Trinidad and Tobago
Existing / Natural gas
Committed emissions (MtCO$_2$)/year
0
1
2
3
4
5
2020
2025
2030
2035
2040
2045
2050
2055
2060


Uruguay
Existing / Oil
Committed emissions (MtCO$_2$)/year
0
2020
2025
2030
2035
2040
2045
2050
2055
2060


Venezuela
Planned / Natural gas
Existing / Oil
Existing / Natural gas
Committed emissions (MtCO$_2$)/year
0
5
10
15
20
25
30
35
2020
2025
2030
2035
2040
2045
2050
2055
2060