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Electricity security in South America

Are we on the right path?

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Abstract. *Greenhouse gas (GHG) emissions are largely driven by energy production and use, accounting for over one third of global emissions. Therefore, diversifying our energy sources is a critical step towards decarbonization. In Latin America, energy demand is on the rise, and most countries in the region rely heavily on hydropower, with an electricity mix of over 50%. In this article, we'll explore the impact of climate change on current energy systems and examine how transitioning to alternative energy sources can contribute to reducing GHG emissions. We aim to shed light on the importance of energy diversity in promoting a sustainable and secure energy future: how will the future climate affect current energy systems, and how are they transitioning towards alternative sources reduce GHG emissions?*

Keywords. *renewable energies · South America · development · electricity use · climate change*

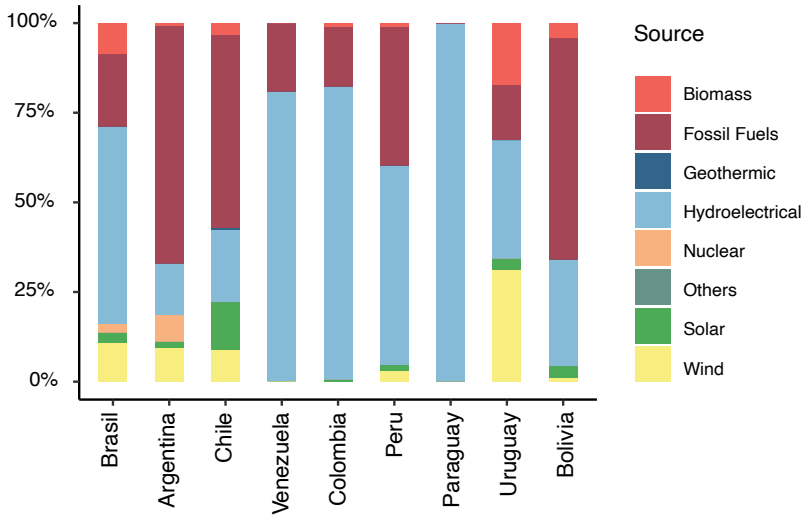
Résumé. *Les émissions de gaz à effet de serre (GES) sont en grande partie dues à la production et à la consommation d'énergie, qui représentent plus d'un tiers des émissions mondiales. Par conséquent, la diversification de nos sources d'énergie est une étape essentielle vers la décarbonisation. En Amérique du Sud, la demande d'énergie est en hausse et la plupart des pays de la région dépendent fortement de l'hydroélectricité, avec un mix électrique de plus de 50 %. Dans cet article, nous souhaitons mettre en lumière l'importance de la diversité énergétique dans la promotion d'un avenir énergétique durable et sûr : comment le climat futur affectera-t-il les systèmes énergétiques actuels, et comment la transition vers des sources alternatives permettra-t-elle de réduire les émissions de GES ?*

Mots-clés. *énergies renouvelables · Amérique du Sud · développement · consommation d'électricité · changement climatique*

Introduction

In 2021, the biggest increase in global CO_2 emissions came from the production of electricity and heat with a 6% increase compared to the 2020. While the adoption of cleaner electricity sources is on the rise on a global scale, the largest contribution comes from hydroelectricity. Hydropower plants generated 4300 TWh of energy, 17% of the global generation.

Central and South America accounts for only 5% of the global electricity demand, with growth rates second only to the Asia-Pacific regions (Washburn & Pablo-Romero, 2019). South America's energy mix is diverse (Figure 1), primarily consisting of fossil fuels and hydropower. The region was once a leader in renewable energy, primarily utilizing hydropower. However, economic factors led to fossil fuels gradually replacing these sources. Future projections estimate that by 2040, the electricity demand will increase by 80% of its current production (Maia et al.,2022). The region's reliance on hydropower and its location in a climate-sensitive region makes it vulnerable to climate change. This means that opportunities and challenges will arise as the region seeks to meet its rising demand for energy while reducing carbon emissions. This article aims to examine the current state-of-art of electricity in South America and its related emissions, the impact of climate change in the current energy systems and the alternatives available and its feasibility at a bio-physical level. Additionally, it explores alternative approaches to energy production and consumption in South America and assesses if these approaches align with the global climate agenda.



1 Distribution of the energy "mix" in each South American country, 2021.
Source: SIELAC, 2022

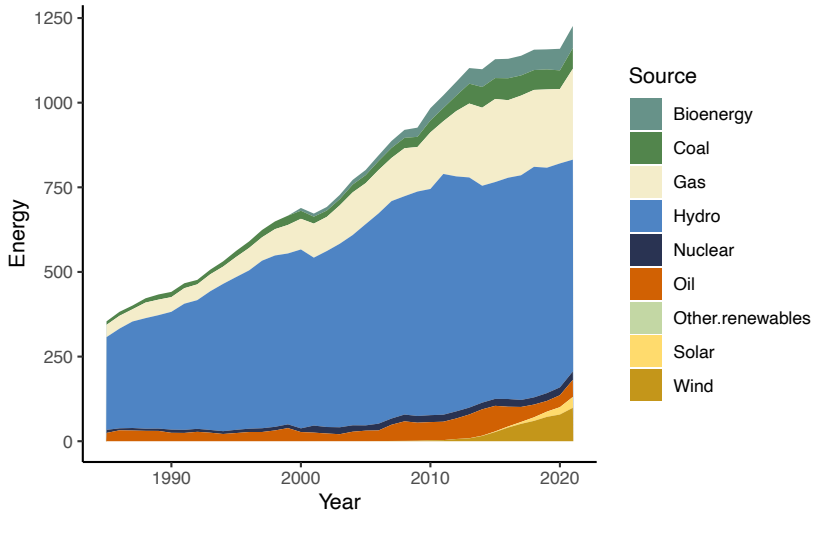
Outlook of Electricity Generation

As Fig. 1 shows, one of the defining characteristics of Latin America's (LA) electricity mix is its heavy reliance on renewable sources, particularly hydropower In 2021, hydropower played an important role in the region's electricity generation, contributing to more than half of the output (58%). In most of the countries, as it´s shown by fig.1, hydropower is the primary source of power, accounting for over 80% of electricity generation in Paraguay, Colombia and Ecuador (SIELAC, 2022).

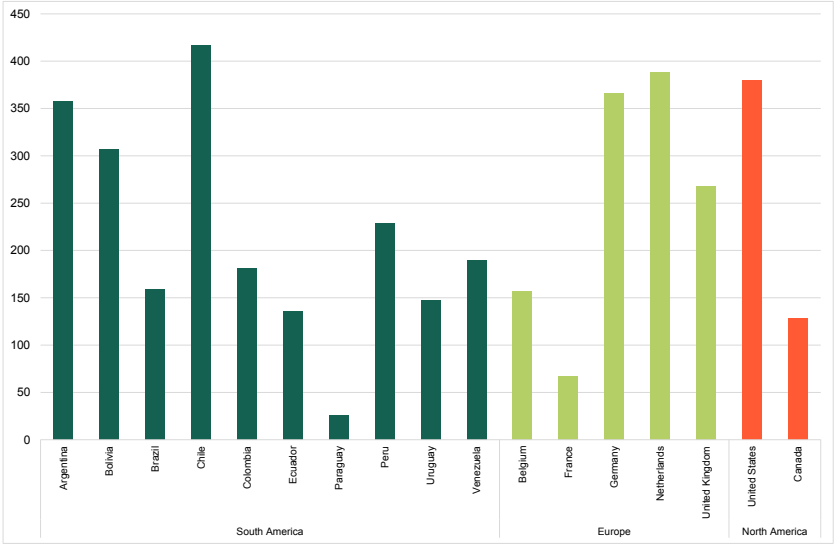
Thermoelectric power, mainly natural gas and coal, is the second most dominant energy source, it accounts for 28% of consumption in 2021. Rising energy demand has led to the inclusion of other energy sources besides hydroelectric, mainly fossil fuels. Consequently, natural gas has become an increasingly important source of electricity generation in LA, given the region's significant reserves (Chavez-Rodriguez et al., 2017).

Notable is the increasing, in the last decade, of solar and wind based energies, with wind energy production multiplying over 300 times and solar energy experiencing a 15-fold increase by 2021.

This growth can be attributed to specific policies and incentives. In the early 2000s, feed-in-tariffs encouraged solar energy adoption in Brazil, Ecuador, and Argentina (Kitzing et al., 2015; Sauma, 2012). Later, policies shifted towards net-metering systems, a scheme that credits small and renewable source owners for the electricity they generate (Jacobs & Sovacool, 2012). For example, if the excess electricity from solar



2 Electricity generation in South America by type of source (1985–2021). Units are in Terawatts hour – TWh.
Source: OWID, 2022



(3) Emissions factor in South America, Europe and North America. These factors consider emissions during the use phase and not during the construction and decommission phases. Source: Dale, 2021

panels of a building can be sold back to the electric grid. These measures have been adopted by Colombia, Argentina, Brazil, and Chile in the last decade, leading to an increase in renewable energy capacity (Coviello & Ruchansky, 2017). Government-led auctions have been a primary mechanism for procuring or auctioning renewable electricity capacity, significantly contributing to the renewable energy landscape in the region (Lucas et al., 2013).

Sectors such as transportation and industry are vital for meeting global climate change goals. However, with increasing energy consumption rates and expected future growth due to economic expansion, the electricity sector is crucial for reducing GHG emissions.

Let's look at the science: How is the vulnerability to climate change going to affect the electricity supply?

Energy security refers to the stable and continuous provision of energy in a region that involves resiliency, reliability and diversified energy supplies (Valentine, 2011). Energy supplies can be threatened by man-made events (economic crises) and natural occurrences (storms or earthquakes). Given the current climate trend, the effects of climate change on the electricity supply from renewables will be investigated.

Climate change can have a wide range of impacts on hydropower generation and operations. Precipitation patterns can influence streamflow, or the amount of water required to generate electricity. Temperature increases can also have affected evapotranspiration, reducing the amount of water available in the basin and leading to underrate total capacity (Hoes et al., 2017).

The case of South America is, in this sense, paradigmatic. This region has the most tropical glaciers that feed several hydropower run-of-river plants (Bradley et al., 2006). Run-of-river plants don't require to store water since they collect water directly from the river, and rely on the river's geography produce electricity. Because dams or reservoirs are scarce in this region, it implies a high reliance on seasonal variability due to limited storage capacity. As a result of rising global temperatures, many glaciers are receding and, in some cases, vanishing.

The findings so far of studies that predict these vulnerabilities in the future are not entirely consistent. Caceres et al. (2021) analyzed 134 hydropower plants in Colombia, Brazil, Ecuador and Peru projecting climate change impacts until the year 2100. The study found increased rainfall patterns in summer and winter, leading to increased capacity: 2.6%-8.4% for Colombia and 6.7-9.3% for Peru. In the case of Brazil, seasonal changes of capacity increase and decrease up to 5% depending on the scenario adopted.

A study examining the impact of climate change on a Colombian basin projected increased extreme events leading to a 35% reduction in total river inflow and up to 32% reduction in electricity production by 2040 (Noreña et al., 2009). In contrast, a project that studied changed in hydropower potential until 2050 in Ecuador (Carvajal et al., 2019) predicted a 14%.increase in electricity generation. Due to this increase, a seven-fold reduction of GHG emissions

is expected compared to a natural gas predominant scenario. Climate Change also affects wind energy, particularly in northern and tropical regions. Colombia and Venezuela are examples of regions where wind velocity is predicted to increase, leading to a wind power capacity of up to 48% of the historical mean.
Research on climate change's impact on South American electricity is limited compared to regions such as East Asia and Europe. For instance, studies indicated that rainfall will be the main factor affecting electricity availability in the region, with positive effects on electricity output. However, studies considering only annual values may overlook seasonal variations, and the ones that did show mixed results. As a consequence, the uncertainty of the impact of climate change can result in a short-sighted approach to future planning and decision-making.
South American countries are creating medium- and long-term energy plans to achieve sustainable growth. Main common themes include ensuring energy accessibility and quality, modernizing infrastructure and embracing digitalization to improve efficiency, and prioritizing environmental goals by reducing emissions, promoting renewables, and planning for future climate impacts. A summary of the policies corresponding to the last theme is shown in Fig. 4.
Long-term goals in most of the plans aim for the dominance of renewables, which in turn will result in fewer carbon emissions. Most of these countries are planning to opt for solar and wind power, due to the fact that these are become cheaper and easier to implement and acquire (Kavlak et al., 2018).

A Global challenge

Determining whether each country is taking the *right* path or taking suitable measures to address climate change is a complex task. Given to its global acceptance, The Paris Agreement (PA) then becomes the main frame of reference to determine the compromise of each country towards future environmental impacts. When implementing global climate policies, holding developing countries to the same emission standards as to industrialized countries, raises questions of fairness. Climate and energy justice involve the fair distribution of the benefits and burdens of energy production and its environmental impacts among communities, societies, and countries (Lyster, 2017).
Countries in South America, as much as other developing countries, desire to achieve the same levels of economic development in the same way industrialized countries now have in levels of prosperity, comfort and wellbeing. Historically, economic growth has been intrinsically linked with resource use and emissions. Industrialized countries used a large amount of energy and resources to achieve their current economic development and prosperity, contributing greatly to the global GHG emissions. Efforts are being made in order to *decouple* economic growth, material use and emissions as societies continue to grow (Haberl et al., 2019). The objective of decoupling is to maintain productivity and GDP growth while using fewer resources than in the past. While there is evidence that in some countries, the rate of resource use is slower than economic growth, an absolute separation is rare and often occurs in periods of economic depression (Shao et al., 2017).

Country	Renewable Energy Goals	Current Progress	Implementation Mechanisms & Policies
Brazil	37 GW additional electricity by 2030, 110 GW wind by 2050	Investing in solar and wind	Reverse auctions, auctioning power plants, increasing small-scale solar PV capacity
Chile	70% renewables by 2050, phase out coal by 2040	20% renewables by 2020, 18% from solar & wind	Power Purchase Agreements (PPAs) through auctions
Argentina	20% renewable electricity by 2025	13% of the total by 2021	Long-term plans to double renewable energy production, natural gas to produce up to 50% of electricity mix
Colombia	50% renewables by 2050, 2,500 MW by 2022	Less than 1,512 MW achieved	Wind and solar auctions, a law requiring 10% clean energy purchase
Bolivia	79% renewable energy by 2030, increase wind, biomass, geothermal	5% in 2020 to 19% by 2030	State-owned electricity company, Central Bank of Bolivia, international funding, regulations to decentralize the system, exemption of equipment from import duties

(4) Future plans and policies for South American countries

Therefore, it is important to acknowledge that developing countries will still need resources, energy, and thus, emissions, to change their socioeconomic conditions.
This issue was raised at the COP26 summit in Glasgow, Chinese delegates proposed (and were rejected) an approach based on attributing *responsibility* for historical emissions contributions (The Guardian, 2021). Developing countries are more concerned with ensuring global mitigation policies rather than adaptation policies specific to individual countries (Onifade, 2021). Industrialized countries have historically opposed responsibility measures due to fears of compensation claims. Moreover, high-income countries' commitment to provide low-income countries $100 billion per year by 2020 for climate-change mitigation and adaptation measures was not fulfilled (Timperley, 2021).

The right (?) path for decarbonization processes in South America

This article provided an overview of the current state of electricity generation in South America. The region has historically relied mainly on hydropower as the dominant source of electricity, but rising energy demand has led to the inclusion of other sources, such as fossil fuels. This *path* has also led to a significant increase in carbon emissions. The transition to cleaner energy is already underway, as evidenced by the individual efforts of each nation of this continent, and it is expected to accelerate, but at a slower pace than in other regions. As South America's energy production continues to grow, it's crucial to address the challenge of meeting rising energy demands sustainably.
Switching to renewable energy sources comes with infrastructure and financial challenges. Future climatic events could endanger the energy systems and the delivery of energy, particularly hydroelectricity. While some studies suggest that increased rainfall patterns may positively impact hydropower production, uncertainties remain about the negative effects of climate change on the region's availability. More research is needed to fully understand these impacts.
The globally accepted PA arises issues of climate and energy justice when considering the fair distribution of benefits and burdens among communities and countries all over the globe. Developing nations are seeking to improve their economies and lower their emissions, but they still need resources (Wang et al., 2019). Holding them to the same emission standards as industrialized countries raises questions of fairness, emphasizing the need for cooperation in combating climate change. ■

Bibliography

Bradley, R. S., Vuille, M., Diaz, H. F. & Vergara, W. (2006). Threats to water supplies in the tropical Andes. *Science*, 312(5781), 1755–1756.

Caceres, A. L., Jaramillo, P., Matthews, H. S., Samaras, C., & Nijssen, B. (2021). Hydropower under climate uncertainty: Characterizing the usable capacity of Brazilian, Colombian and Peruvian power plants under climate scenarios. *Energy for Sustainable Development*, 61, 217–229.

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.

Chávez-Rodríguez, M. F., Dias, L., Simoes, S., Seixas, J., Hawkes, A., Szklo, A., & Lucena, A. F. (2017). Modelling the natural gas dynamics in the Southern Cone of Latin America. *Applied Energy*, 201, 219–239.

Coviello, M. & Ruchansky, B. (2017). Avances en materia de energías sostenibles en América Latina y el Caribe: resultados del Marco de Seguimiento Mundial, informe de 2017.

Dale, S. (2021). *BP statistical review of world energy*. BP Plc: London, UK, 14–16.

Haberl, H., Wiedenhofer, D., Pauliuk, S., Krausmann, F., Müller, D. B., & Fischer-Kowalski, M. (2019). Contributions of sociometabolic research to sustainability science. *Nature Sustainability*, 2(3), 173–184.

Hoes, O. A. C., Meijer, L. J. J., Van Der Ent, R. J., & Van De Giesen, N. C. (2017). Systematic high-resolution assessment of global hydropower potential. *PLOS ONE*, 12(2), e0171844.

Jacobs, D. & Sovacool, B. K. (2012). Feed-In Tariffs and Other Support Mechanisms for Solar PV Promotion. *Comprehensive Renewable Energy*, 1, 73–109.

Kavlak, G., McNerney, J., & Trancik, J. E. (2018). Evaluating the causes of cost reduction in photovoltaic modules. *Energy policy*, 123, 700–710.

Kitzing, L., Wendring, P., Wigan, F., & Förster, S. (2015). Auctions for Renewable Support in Denmark: Instruments and lessons learnt: Report D4. 1-DK, December 2015.

Lucas, H., Ferroukhi, R., & Hawila, D. (2013). *Renewable energy auctions in developing countries*. International Renewable Energy Agency (IRENA).

Lyster, R. (2017). Climate justice, adaptation and the Paris Agreement: a recipe for disasters? *Environmental Politics*, 26(3), 438–458.

Maia, S., Demôro, L. & Foroni, L. (2022). *Climatescope 2022 Power Transition Factbook*. https://global-climatescope.org/

Noreña, J. E. O., García, C. G., Conde, A. C., Magaña, V., Sánchez, G., & Esqueda, T. (2009). Vulnerability of water resources in the face of potential climate change: generation of hydroelectric power in Colombia. *Atmósfera*, 22(3), 229–252.

Onifade, T. T. (2021). Climate Justice Under the Paris Agreement: Framework and Substance. *CCLR*, 233.

OWID. (2022). *Electricity generation*. https://ourworldindata.org/grapher/electricity-generation?tab=chart

Sauma, E. E. (2012). *Políticas de fomento a las energías renovables no convencionales (ERNC) en Chile*. Centro de Políticas Públicas UC.

Shao, Q., Schaffartzik, A., Mayer, A. & Krausmann, F. (2017). The high "price" of dematerialization: A dynamic panel data analysis of material use and economic recession. *Journal of Cleaner Production*, 167, 120–132.

The Guardian. (2021). *China's top Cop26 delegate says it is taking "real action" on climate targets* | Cop26 | The Guardian. https://www.theguardian.com/environment/2021/nov/10/chinas-top-cop26-delegate-says-it-is-taking-real-action-on-climate-targets

Timperley, J. (2021). The broken $100-billion promise of climate finance - and how to fix it. *Nature*, 598(7881), 400–402.

Valentine, S. V. (2011). Emerging symbiosis: Renewable energy and energy security. *Renewable and sustainable energy reviews*, 15(9), 4572–4578.

Wang, Q., Jiang, R. & Zhan, L. (2019). Is decoupling economic growth from fuel consumption possible in developing countries? A comparison of China and India. *Journal of cleaner production*, 229, 806–817.

Washburn, C. & Pablo-Romero, M. (2019). Measures to promote renewable energies for electricity generation in Latin American countries. *Energy Policy*, 128, 212–222.