Decreasing costs of renewables - Implications for Argentina's climate targets

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Table of Contents

1 Introduction

In the run-up to the Conference of the Parties in Paris in 2015 (COP21), countries defined their mitigation commitments as part of their Nationally Determined Contributions (NDC). A few countries have revised their NDCs since the adoption of the Paris Agreement (e.g. Argentina, Chile and Norway). However, on aggregate, NDCs are not yet sufficient to limit global warming to well below 2°C, aiming at 1.5°C, as agreed in Paris. According to recent analysis, the aggregated ambition of existing NDCs would lead to global warming of about 3°C (Climate Action Tracker, 2019a).

The Paris Agreement foresees regular revisions of the NDCs following a periodic global stocktake, with the objective to take stock of the implementation and increase ambition of pledges over time. These NDC revisions should be informed by up to date information on national circumstances, including the development of costs for key mitigation technologies.

Recent analyses developed by Fraunhofer ISI and NewClimate Institute show that faster and steeper than expected cost reductions for certain key mitigation technologies over the past five years can lead to an increased technology uptake and to a higher level of ambition, if the initially intended investment sum is maintained (Wachsmuth and Anatolitis, 2018; Fekete and Nascimento, 2019). The present work builds on the previously developed methodology to estimate the potential impact of investment cost reductions for renewable energy technologies (solar photovoltaics (PV) and onshore wind) on Argentina's climate targets.

Argentina submitted a revised NDC in 2016 based on an updated methodology for the GHG inventory and a more comprehensive set of mitigation measures in key sectors (Ministry of Environment of Argentina, 2016). The current NDC presents unconditional and conditional absolute emissions targets of 483 $MtCO_2e$ and 369 $MtCO_2e$ in 2030, respectively, including the forestry sector (Government of Argentina, 2016). Argentina also developed sector action plans for six key mitigation sectors: Energy, Transport, Forestry, Industry, Agriculture and Land-use, and Infrastructure and Territory. These sector action plans present strategies to implement the country's NDC.

We argue that a faster and steeper than expected investment cost reduction for key mitigation technologies included in these plans should not lead to savings, i.e. the implementation of the same sector action plan at a reduced cost, but ideally be used as a stepping-stone towards increased ambition. Against this backdrop, our analysis quantifies the potential impact of these investment cost reductions for renewable energy technologies on Argentina's climate targets.

Section 2 of this analysis presents an overview of the methodological approach. Section 3 outlines the starting point for the research, including Argentina's NDC targets and respective sector measures related to the renewable energy technologies explored (solar PV and onshore wind). In Section 4, we present recent developments of investment costs for these technologies. Section 5 summarises the data and estimates the potential impact of cost progressions on additional renewable energy uptake and sectoral emissions. The last section summarises the conclusions of the analysis.

2 Methodology

The central argument underlying this analysis is that the costs for key mitigation technologies have decreased faster and steeper than expected since countries developed their NDCs in 2015. These cost developments should not lead to savings, e.g. through the implementation of sector action plans to achieve the NDC targets at lower costs but would ideally be used as a stepping-stone towards increased ambition. We use a simplified methodology that has been developed under a previous project to investigate the relevance of technology cost progressions for raising ambition in the energy sector and in Argentina's NDC (Wachsmuth and Anatolitis, 2018).

The methodology involves two basic steps. In a first step, we evaluate and compare pre- and post-NDC investment cost projections for renewable energy technologies to calculate the ratio between the original and most recent cost projections. In a second step, we estimate the potential additional uptake of these technologies by multiplying the original capacity additions with the ratio calculated in the first step. This simplified approach assumes a linear relationship between investment costs and further capacity additions, meaning that if the costs half, double the capacity can be installed.

This calculation assumes that unused funds for investments in renewable energy technologies, due to lower-than-expected costs, are reinvested in the same area. An estimative of the new capacity additions based on cost progressions can be used to calculate specific emissions reductions, and the potential increase ambition, if the additional uptake displaces fossil fuel technologies. In this analysis, we assume that lower-than-expected costs would lead to additional renewable energy uptake in comparison to what is currently outlined in Argentina's energy sector plan (MINEM, 2017b). The potential to scale up mitigation measures included in the energy sector plan serves as a basis to calculate the potential to raise the level of ambition in Argentina's NDC. It is important to highlight that a realisation of the full estimated emissions reduction potential depends on a translation of the new capacity additions into renewable electricity generation, which may be limited by system constraints (Wachsmuth and Anatolitis, 2018).

While previous analyses use the levelized cost of electricity (LCOE) to approach cost estimates for renewable energy technologies, we base our calculations mainly on investment costs. This is due to better data availability as well as the fact that investment costs can be considered the main driver of reductions observed in LCOEs. Investment costs are understood as the capital expenditure for the acquisition of a new renewable energy technology unit.

3 Argentina's climate and renewable energy commitments

In this section, we present an overview of Argentina's NDC and identify the expectations for deployment of renewable energy under the mitigation targets. This information provides the basis for scaling up the relevant technologies using cost progressions observed from pre-NDC cost projections to post-NDC cost projections. We argue that the expected technology uptake in the periods 2021-2025 and 2026-2030 could be increased without additional investments[1] if cost progressions were considered.

NDC overview

Argentina's revised NDC, presented in November 2016, includes two absolute emissions targets for 2030, as presented in Figure 1 (Government of Argentina, 2016). The projections consider emissions of all major emitting sectors, including land use, land-use change, and forestry (LULUCF). The targets are split into an unconditional and a conditional component:

- **Unconditional target**: limits emissions to 483 MtCO_2e in 2030 (including LULUCF). This unconditional target is equivalent to 14% above 2010 levels and 80% above 1990 levels.

- **Conditional target:** is dependent on international support and limits emissions to 369 MtCO_2e in 2030 (including LULUCF). This is equivalent to a 13% reduction below 2010 levels and 37% increase above 1990 levels.

In this analysis, we assume that any further uptake of renewable energy would take Argentina beyond its conditional target. Argentina's business-as-usual (BAU) scenario projects that economy-wide emissions could reach 592 MtCO_2e in 2030. Thus, in order to reach the conditional NDC target of 369 MtCO_2e in 2030, Argentina needs to reduce emissions by 223 MtCO_2e by that year (Figure 1).

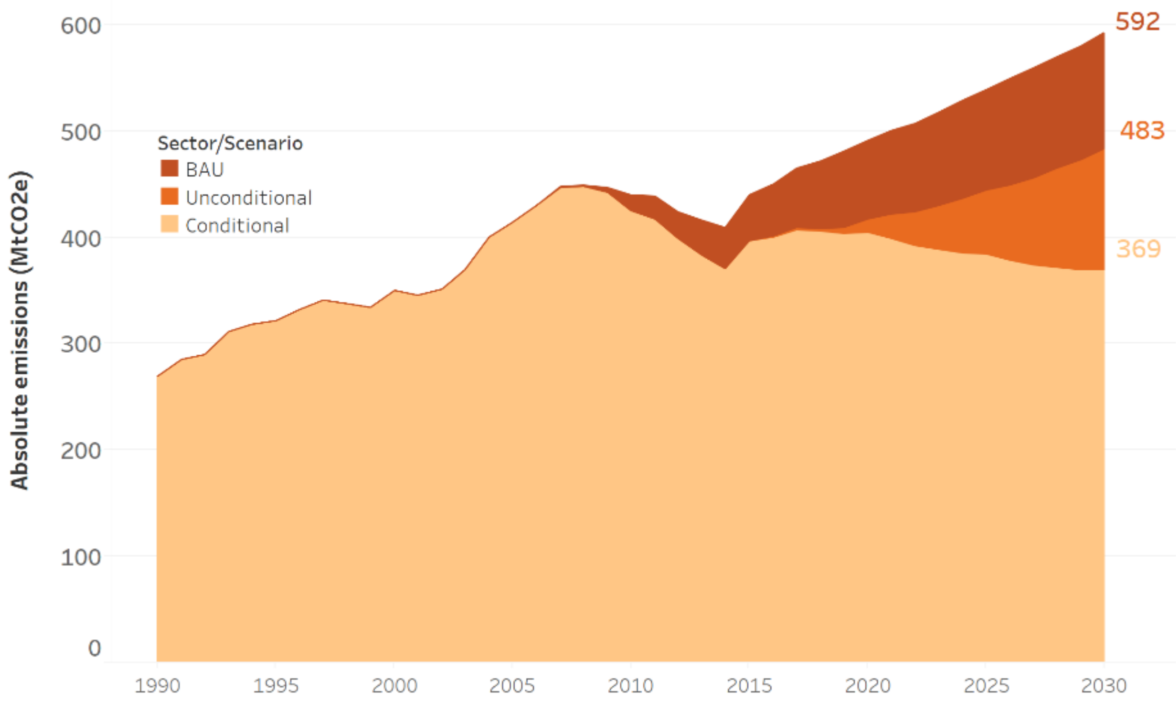

Figure 1 Argentina's GHG emissions projections according to the NDC.

Source: (Government of Argentina, 2016)

[1] This refers exclusively to renewable energy installation costs and excludes any integration or other system costs.

Argentina's revised NDC has a higher level of ambition when compared to the original Intended Nationally Determined Contribution (INDC) submitted in 2015, since the target in the latter was formulated as a reduction below BAU and led to higher overall emissions levels. Argentina updated the methodology for calculating the historical data which it used to determine the target levels of the revised NDC and included further mitigation measures in key sectors (Ministry of Environment of Argentina, 2016).

Argentina also developed sector action plans for six key mitigation sectors: Energy, Transport, Forestry, Industry, Agriculture and Land-use, and Infrastructure and Territory. These sector action plans present strategies to implement the country's NDC. The sector action plan relevant for this analysis is the National Action Plan on Energy and Climate Change (referred to as 'energy sector plan' throughout the study) which was published in 2017 (MINEM, 2017b). It includes specific measures for the sector to contribute to reaching the overall absolute emissions reduction target presented in the NDC.

The energy sector plan includes three measures associated with non-conventional renewable power generation – defined by the Argentinian government as including solar, wind, and hydro smaller than 50 MW (Table 1). The plan presents both a conditional and an unconditional measure associated with the generation of renewable power using sources connected to the grid. It also includes a conditional and an unconditional measure related to small-scale off-grid renewable power generation.

Table 1 Summary of emissions reduction potential in 2030 from measures in the 2017 energy sector plan related to renewable power generation.

Source	Measures[2]	Unconditional (MtCO2e)	Conditional (MtCO2e)
The National Action Plan on Energy and Climate Change	Grid connected electricity generation using non-conventional renewable technologies (3.1.1)	17.55	+4.61
	Decentralised electricity generation using non-conventional renewable technologies (3.1.2)	-	+0.88
	Stand-alone electricity generation using non-conventional renewable technologies (3.1.6)	0.05	-

Source: (MINEM, 2017b)

Based on its conditional NDC commitment to keep emissions below 369 $MtCO_2e$ in 2030, Argentina needs to reduce emissions below BAU by 223 $MtCO_2e$. According to the energy sector plan, the energy sector is expected to reduce emissions by 103 $MtCO_2e$ in 2030 (46% of the required emissions reductions) through different measures (MINEM, 2017b). Power generation from renewable energy technology alone corresponds to a reduction below BAU of 23 $MtCO_2e$, which is equivalent to 10% of the economy-wide emissions reductions expected in 2030 (MINEM, 2017b).

Energy scenarios and projected renewables development in Argentina

The Argentinian government established its renewable energy targets with the adoption of the Renewable Energy Law (Law 27.191) at the end of 2015. The law aims to increase the share of non-conventional renewables in total power generation to 20% by 2025 (Government of Argentina, 2015). According to the energy sector plan, an additional commitment would bring the renewable share in power generation to 25% in 2030 (MINEM, 2017b).

In late 2017, the then Ministry of Energy and Mining (MINEM) conducted a modelling exercise to develop energy scenarios up to 2030 (MINEM, 2017a). In 2019, these scenarios were updated by the Energy Secretariat. The latest estimations project an electricity demand growth of between 21% and 64% in comparison to 2018, reaching 161-218 TWh per year in 2030. The lower range of the projected electricity consumption is the result of an energy efficient scenario which assumes a reduced electricity

[2] The numbers within brackets refer to the section in the energy sector plan where the measures are presented in detail.

demand growth of 1.6% per year. The upper range is based on a scenario with higher electrification of demand sectors, leading to an average growth in electricity demand of 4.2% per year. The scenarios also estimate that 12 to 18 GW of non-conventional renewable energy capacity needs to be installed by 2030 to fulfil the projected demand and the renewable targets (Secretaria de Energía, 2019).

A parallel exercise conducted by independent organisations in Argentina that together form the initiative "Plataforma Escenarios Energéticos Argentina" (Argentina Platform for Energy Scenarios) investigated various alternative scenarios for the power sector. The *Plataforma Escenarios 2040* report presents a set of ten scenarios (see Figure 2) based on different assumptions about the development of the power system. The analysis also quantifies wider socio-economic impacts of and evaluates similarities as well as discrepancies between these scenarios (Beljansky *et al.*, 2018).

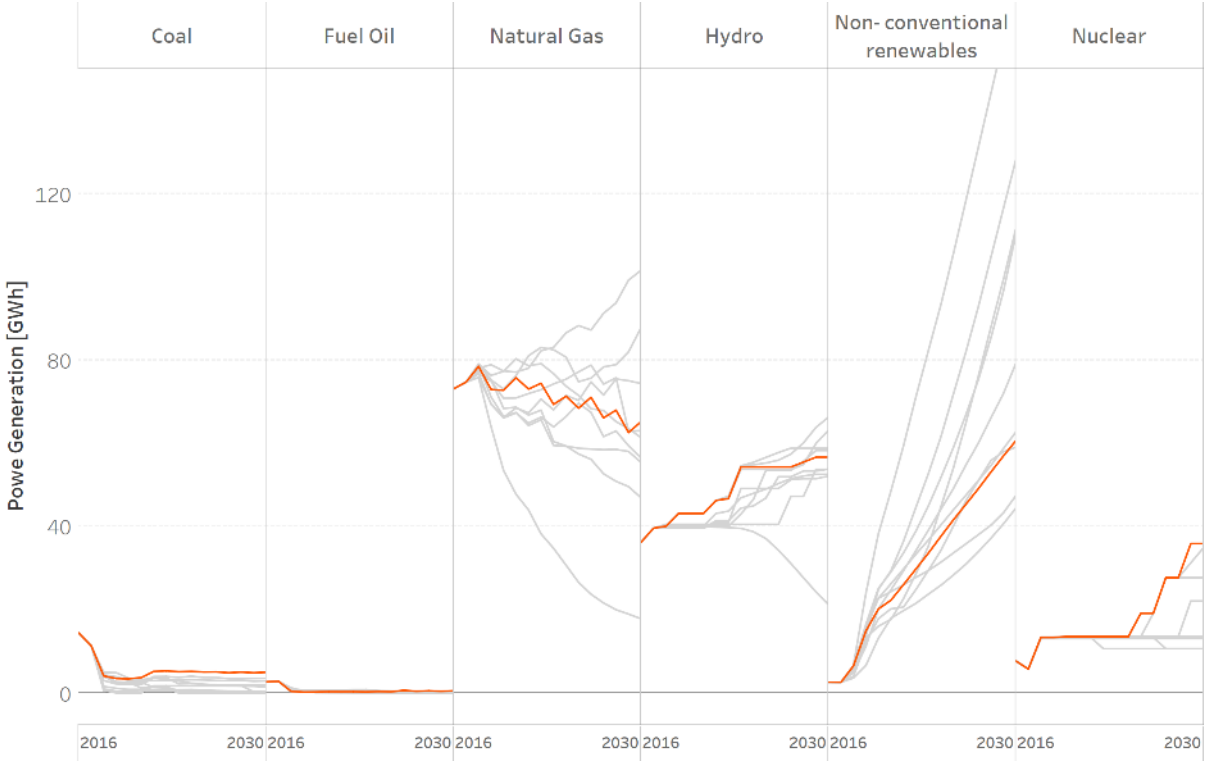

Figure 2 Power generation from *Plataforma Escenarios 2040*; base case scenario highlighted in orange.

Source: (Beljansky et al., 2018)

Since detailed data on projected installed capacities for the distinct renewable power generation technologies is not publicly available from the official energy scenarios developed in 2017 and updated in 2019, we use the base case scenario from the *Plataforma Escenarios 2040* as a reference for new capacity additions in our calculations. The electricity demand in this scenario falls within the range of the latest update of the official energy scenarios, and meets the non-conventional renewable energy share of 20% prescribed in Law 27.191 by 2025 as well as the share of 25% from the conditional commitment in the energy sector plan by 2030. It also provides detailed information on the capacity additions per technology up to 2030 (Beljansky *et al.*, 2018).

4 Technology cost trends in Argentina between 2015 and 2020

The following section outlines the cost and price developments for renewable energy technologies observed in Argentina since 2015, presenting trends in projected investment costs as well as recent auction results for solar PV and wind.

Onshore wind and solar PV investment costs are falling faster than anticipated in 2015

At a global level, constant technology development and accelerated uptake of renewable energy technologies lead to a decrease in investment costs. However, technology costs are also influenced by local factors, e.g. the local content share of a technology or import taxes.

This analysis looks at country-specific investment cost projections in Argentina (Figure 3). The most recent cost projections for solar PV and onshore wind are retrieved from the government's 2030 energy scenarios from 2017[3] and from the *Plataforma Escenarios 2040* analysis published in 2018 (MINEM, 2017a; Beljansky *et al.*, 2018). The pre-NDC cost curves are based on the investment costs assumed in the *Plataforma Escenarios 2035* analysis, published in 2015 (Fernández, 2015).

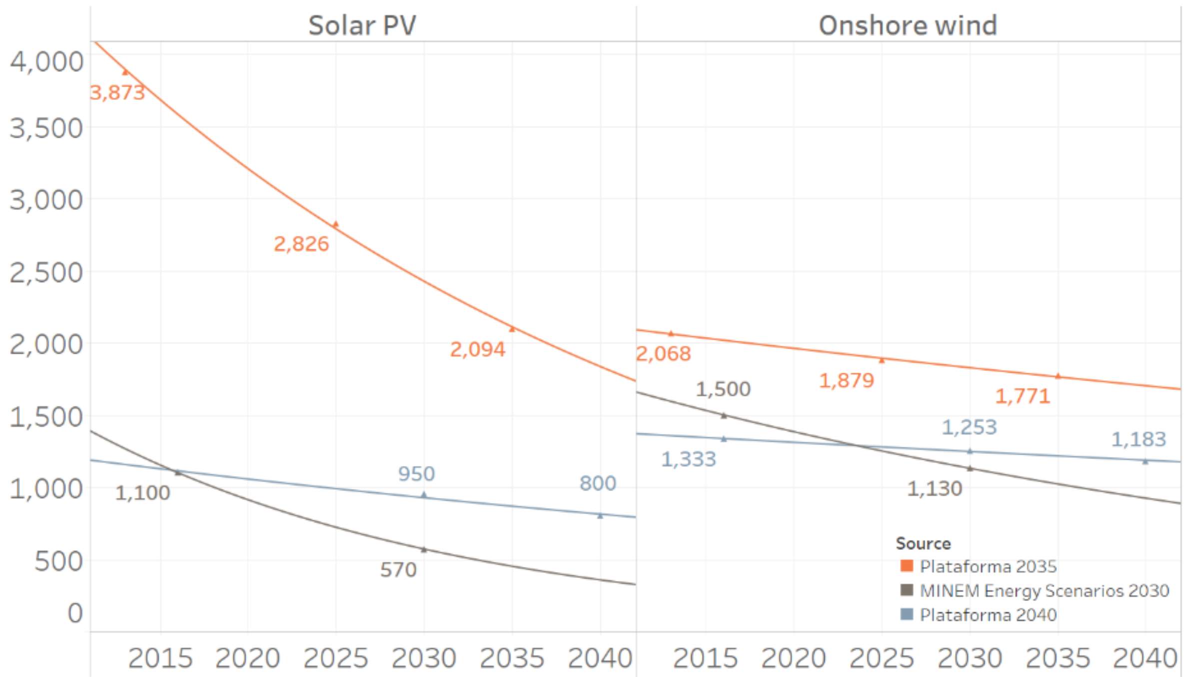

Figure 3 Investment costs projections for onshore wind and solar PV. The orange cost curve represents pre-NDC cost expectations and the others (gray and blue) post-NDC cost expectations.

Source: (Fernández, 2015; MINEM, 2017a; Beljansky *et al.*, 2018)

The results in Figure 3 show that the projected costs for renewable energy technologies in Argentina before the formulation of the NDC were higher than the cost projections used in more recent modelling exercises. In some cases new estimates are less than half of the originally estimated costs. The reduction observed in investment costs is the main driver of reductions in the LCOEs of these technologies. We consider the ratio between pre- and post-NDC investment costs in our analysis as a potential driver for the additional uptake of renewable energy technologies in Argentina.

[3] The most recent energy scenarios from the Energy Secretariat do not present investment cost curves up to 2030.

Despite falling costs, renewable auctions are put on hold due to grid limitations

Auction prices can be analysed as the market expectation of a technology's future LCOE. They help to understand recent national trends as they account for the specific market conditions. Auction prices are influenced by investment cost reductions but can also be very strategic. Potential investors bid considering future cost projections to accommodate the delay between the auction and the start of operation. It is also common for investors to bid low prices to get a foothold in early markets or, in other cases, for them to be conservative to accommodate uncertainties (Couture, Jacobs and Appleman, 2018).

In 2016, the Argentinian government launched the RenovAr programme, a renewable energy auction, as a first step towards the achievement of Law 27.191 (MINEM, 2017b). As of October 2019, the programme awarded 185 renewable energy projects that resulted in a total of 4.7 GW contracted. The average cost per megawatt hour has fallen significantly for solar PV and wind power between Round 1 and Round 2 but increased again in Round 3 (see Figure 4).

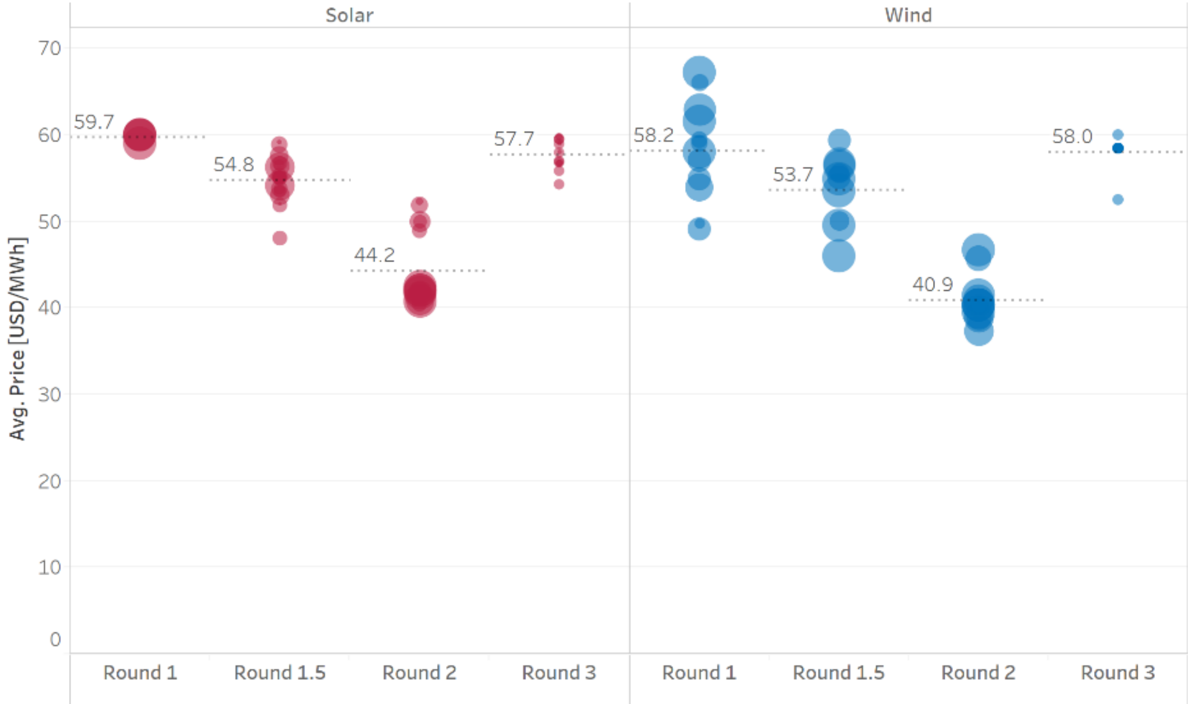

Figure 4 Average prices per MWh for wind and solar power generation contracted under the RenovAr programme. Each bubble represents a distinct project, the bubbles' size reflects the installed capacity.

Source: (MINEM, 2019a)

This increase can be explained mainly by two factors: the reduced project size and a rise in uncertainty. Round 3 resulted in 38 contracted projects adding up to 259 MW. The average installed capacity per project for wind and solar PV projects dropped from 62 MW in Round 2 to 10 MW in the last round, which tends to increase costs. Round 3 targeted small-scale projects primarily due to limitations in the grid infrastructure. Furthermore, market actors might have bid lower costs under the initial expectation that the market would develop differently and have integrated additional risks in their pricing strategy. The auctions of large-scale renewable projects have been put on hold until grid limitations are resolved (Bellato, 2018; Bellini, 2019).

Renewable electricity is competitive in Argentina but not realised to its full potential

The recent steep investment cost reductions, observed for some renewable energy technologies, brings the cost of electricity generated by renewables into the range of fossil-fired technologies in many countries (IRENA, 2019). A similar trend is observed in Argentina, as depicted in a comparison of the LCOEs of the different technologies.

Solar PV and wind technologies are already competitive in Argentina (Figure 5). Considering the development of the investment cost curves presented in the previous section, LCOEs could drop even further. However, this analysis does not fully account for system costs, it nonetheless indicates that these renewable energy technologies could guide the expansion of the system provided that the main barriers to this expansion are addressed in time (see discussion in Annex II).

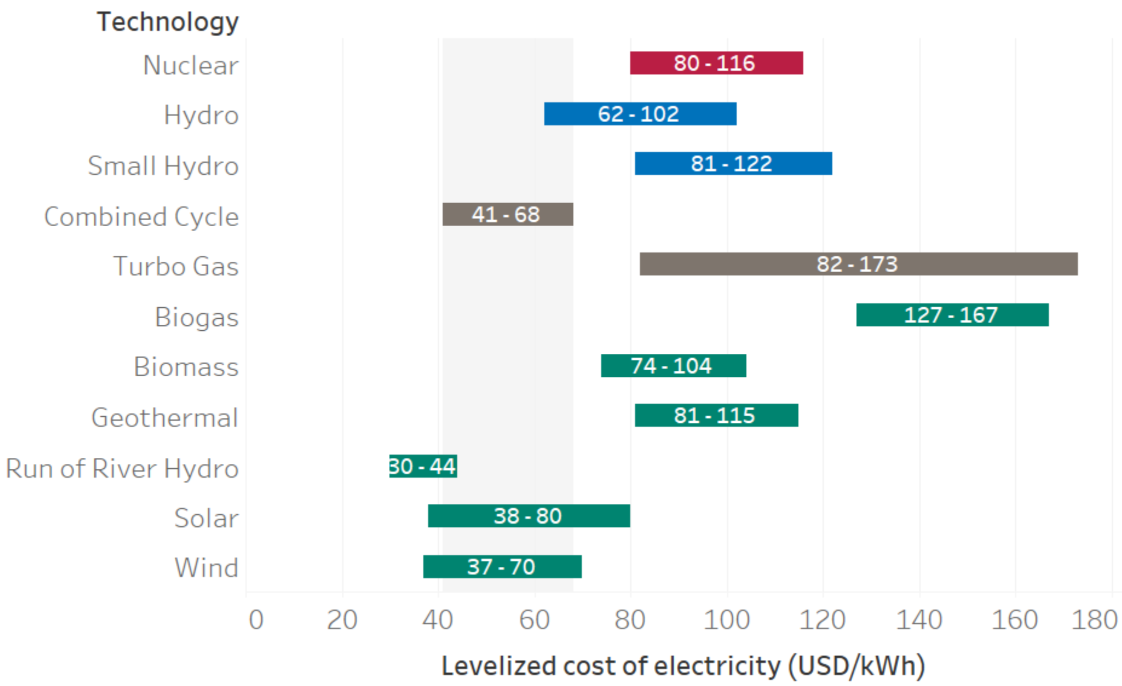

Figure 5 Levelized cost of electricity per technology. The colours match Argentina's definition of non-conventional renewables (green), fossil fuels (grey), hydro (blue) and nuclear (red). The ranges include broader costs such as those covering the transportation of natural gas for fossil fuel technologies or grid expansion, included in the range of solar PV and wind.

Source: (Secretaria de Energía, 2019)

5 The relevance of cost progressions for renewable energy expansion and emissions

According to the government's official energy scenarios, the energy sector plan and the renewable energy targets, renewables are expected to reach a share of 20% of power generation by 2025 – in line with Law 27.191. This suggests that, even though the energy sector plan was developed after the NDC and its targets could reflect more recent investment cost developments for renewable energy technologies, the target remains the same as specified in the law issued pre-NDC.

To assess the potential impact of the investment cost progression of renewable energy technologies on the specific measures included in the energy sector plan, we first identify the expected uptake of renewable energy technologies up to 2030 as reflected in the base case scenario of the *Plataforma Escenarios 2040* analysis. This scenario is aligned with the target of 20% renewable share by 2025 and with the conditional commitment of 25% by 2030 as per the energy sector plan (Beljansky *et al.*, 2018). Table 2 presents an overview of the expected capacity additions considered in this analysis. We split the following ten years into two five-year intervals (2021-2025 and 2026-2030).

Table 2 Summary of approximate onshore wind and solar PV power capacity additions compatible with the targets presented in the energy sector plan.

Capacity additions	2021-2025	2026-2030
Onshore wind capacity [MW]	2,400	2,400
Solar PV capacity [MW]	2,010	2,080

Source: (Beljansky et al., 2018)

We then compare pre-NDC investment cost curves to the most recent investment cost curves (as identified in Figure 3 in the previous section) in order to evaluate the cost progression between 2015 and 2018 and the corresponding potential to upscale renewable energy, i.e. solar PV and onshore wind power generation in Argentina. These cost curves are used to create ranges of cost reductions between 2021-2025 and 2026-2030 for the different technologies.

The most ambitious cost reduction is defined as the difference between the highest pre-NDC cost curve and the lowest post-NDC cost curve. It shows the largest possible reduction from pre-NDC to post-NDC costs, indicating higher savings. Similarly, the difference between the lowest pre-NDC and highest post-NDC cost curve defines the least ambitious cost reduction, i.e. the smallest possible reduction from pre-NDC to post-NDC costs, implying lower savings.

Table 3 Percentage cost reductions for solar PV and wind onshore comparing pre- and post-NDC investment cost curves.

Technology	Cost reduction	2021-2025	2026-2030
Solar PV	Most ambitious	-73%	-76%
Solar PV	Least ambitious	-66%	-63%
Wind onshore	Most ambitious	-33%	-36%
Wind onshore	Least ambitious	-32%	-32%

Source: (Fernández, 2015; MINEM, 2017a; Beljansky *et al.*, 2018)

The percentage cost reductions shown in Table 3 present savings due to reduced investment costs. In this analysis we assume that if these savings were fully reinvested in the same technology, this could lead to an additional uptake of solar PV and wind technology, respectively.

In the simplified methodology applied in this analysis the relationship between cost reductions and capacity additions of renewable energy technology is linear, meaning that if costs half, the added capacity doubles. This additional technology uptake may cause reductions in GHG emissions if displacing emitting alternatives such as fossil fuel plants. Note that this assumption is simplified and does not account for other important aspects such as competitiveness of renewable energy technologies, nor does it reflect how electricity generation expansion is planned in reality.[4] However, it estimates the potential impact these cost reductions may have on the future uptake of renewable energy technologies.

New renewable energy additions

We use the investment cost reduction ranges shown in Table 3 to scale the capacity from solar PV and onshore wind between 2020 and 2030, assuming the initially intended investment sum is kept constant. Figure 6 displays capacity additions in the least and most ambitious scenarios in comparison to the original capacities planned in five-year intervals. The capacity additions refer to the total installed capacity within that period. In order to obtain the total installed capacity over the next ten years, capacity additions from both periods must be added.

Figure 6 shows that while original capacity additions for solar PV would reach 4,090 MW in 2030, technology uptake along the least ambitious scenario could scale this to 11,446 MW in 2030 and along the most ambitious scenario to 15,997 MW in 2030. For onshore wind, original capacity additions expect to reach 4,800 MW in 2030, while additional technology uptake along the least ambitious scenario could reach 7,062 MW and along the most ambitious scenario 7,343 MW in 2030, respectively.

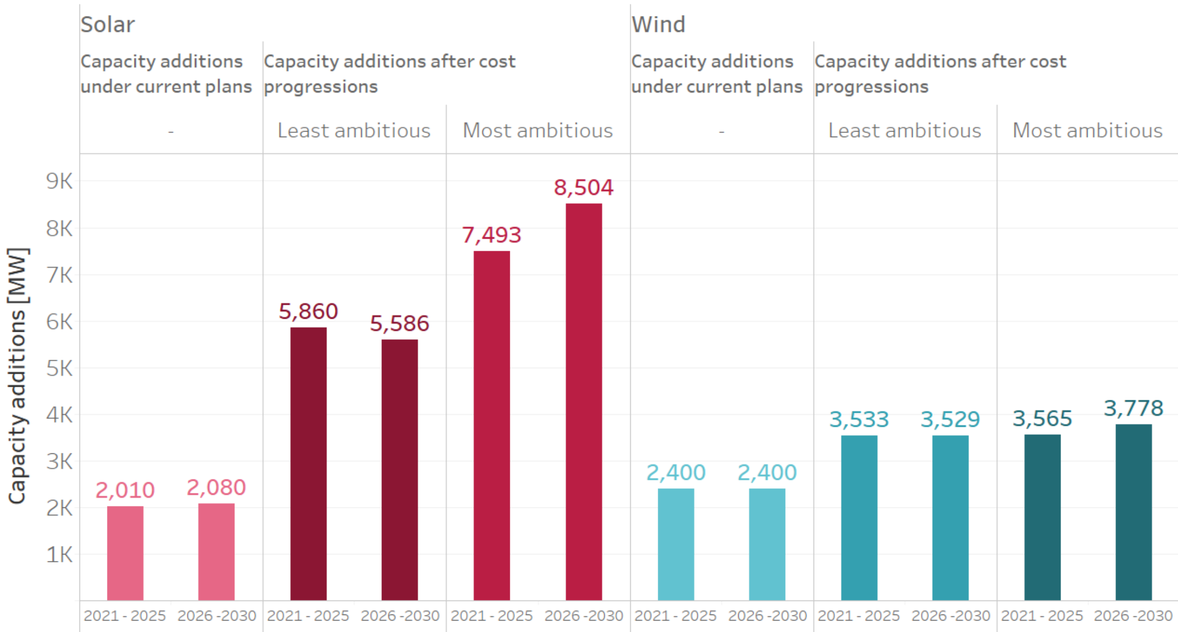

Figure 6 Capacity additions within the specified timeframes for solar PV and onshore wind before and after cost progression considerations.

Source: (Beljansky et al., 2018) combined with analysis results

The translation of new capacity additions into increased renewable power generation depends on multiple barriers the detailed analysis of which falls outside the realm of this study. However, assuming those barriers were addressed in time, the additional renewable capacities could result in increased shares of renewable power generation.

[4] It must be considered that renewable energy technologies, in particular solar PV and onshore wind, are already competitive in Argentina. It can be expected that these technologies would drive the expansion of the system regardless of additional investment sums made available, provided other system constraints were overcome.

In 2016, non-conventional renewables represented 2% of total power generation in Argentina. According to the *Plataforma Escenarios 2040* base case scenario, the share of non-conventional renewables would reach 21% in 2025 and 26% in 2030. We calculate the potential increase in the share of renewables in power generation after the cost progression considering the additional capacity expansion potential shown in Figure 6 and average capacity factors. The capacity factor presents the ratio between the effective power generated in comparison to the maximum possible power generated by a plant over a period of time. In this analysis, we use the average capacity factors of the *Plataforma Escenarios 2040* base case scenario: 27% for solar PV and 42% for onshore wind. These percentages are equivalent to full load hours of 2,365 and 3,679 per year for solar PV and onshore wind, respectively (Beljansky *et al.*, 2018).

Under these assumptions, the share of non-conventional renewables in total power generation could reach 28-30% in 2025 and 38-43% in 2030, following the least and most ambitious scenario, respectively. Thus, cost progression considerations could potentially increase the share of renewable energy in total power generation by up to 17 percentage points compared to the base case scenario in 2030 (Figure 7).

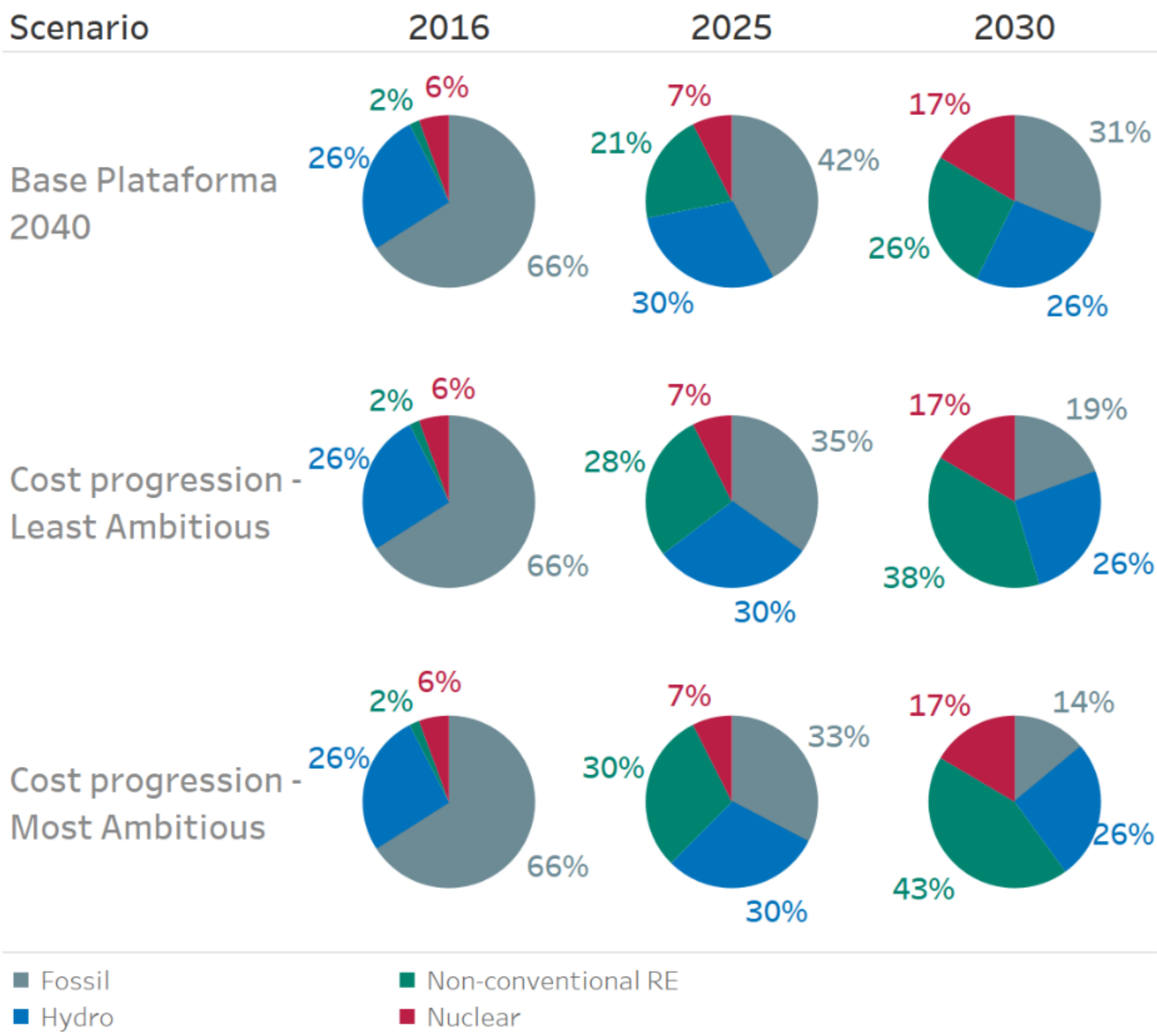

Figure 7 Evolution of power generation shares in Argentina under the base case scenario and least and most ambitious cost progression scenarios.

Source: (MINEM, 2017a) combined with analysis results

Impact on sector emissions

The additional renewable capacity is assumed to displace gas-fired power generation in Argentina. This assumption is based on the fact that natural gas is the only fossil fuel still projected to play a significant role in power generation in 2030, with a share of 29% (Beljansky *et al.*, 2018). It therefore represents the highest emissions impact if displaced by further renewable energy uptake. Taking an emissions factor of 0.49 $kgCO_2/kWh$ for natural gas as a basis[5], the additional renewable capacity uptake would result in emissions reductions in the range of 12.7-18.5 $MtCO_2$ by 2030, considering the scenarios with the least and most ambitious cost reductions, respectively. The emissions reduction is calculated by multiplying the total additional generation from non-conventional renewables (based on the capacity additions in Figure 6 and the full load hours for each technology) with the emissions factor of natural gas.

Finally, the emissions avoided from the displaced gas-fired capacity are added to the emissions reductions foreseen under the energy sector plan to calculate the potential impact of cost progressions. Non-conventional renewable energy measures presented in the energy sector plan lead to emissions reductions of 23.1 $MtCO_2$ in 2030. Adding to those the calculated avoided emissions (12.7-18.5 $MtCO_2$ by 2030) would result in emissions reductions in the range of 35.7 and 41.6 $MtCO_2$ in 2030. These avoided emissions can also be added to the total expected emissions reductions in the energy sector plan as well as in the NDC to illustrate the potential to increase ambition (Table 4).

Table 4 Emissions reductions in the year 2030 by measure and scenario. Emissions reductions include both unconditional and conditional measures.

Measure (unconditional + conditional)	Scenario	Current plans ($MtCO_2e$)	Cost progression ($MtCO_2e$)	Percentage Increase
Emissions reductions from renewable energy				
Renewable energy measures in the 2017 energy sector plan (measures 3.1.1, 3.1.2 and 3.1.6)	Least/ most ambitious	23.1	35.7 - 41.6	+55 - 80%
All measures in the 2017 energy sector plan	Least/ most ambitious	103.2	115.8 - 121.6	+12 - 18%
Emissions reductions from all NDC measures				
Economy-wide measures (difference between BAU and conditional scenarios)	Least/ most ambitious	223.0	235.7 - 241.5	+6 - 8%

Figures in this table might differ slightly from the ones in Table 1 due to rounding. Current plans include measures presented in the 2017 energy sector plan.

Source: (MINEM, 2017a) combined with analysis results

To assess the potential impact of emissions reductions on total NDC emissions, we consider that any further emissions reductions will take Argentina beyond its current conditional commitments. Emissions reductions from the energy sector measures presented in Table 4 range between 35.7 and 41.6 $MtCO_2e$ in 2030. In 2030, the emissions reduction potential in the energy sector would increase from 103 $MtCO_2e$ to 116-122 $MtCO_2e$. This is equivalent to an increase of economy-wide emissions reductions between 6% and 8%. The economy-wide emissions reductions are subtracted from the BAU scenario, which is expected to reach 592 $MtCO_2e$ in 2030, leading to an absolute emissions level between 351 and 356 $MtCO_2e$ in comparison to the conditional emissions target of 369 $MtCO_2e$ in 2030.

[5] The gas emissions factor has been estimated based on Argentina's grid emissions factor (MINEM, 2019b).

6 Conclusions

This analysis makes use of a simplified methodology to show that Argentina could increase the level of ambition of its conditional NDC target by considering the evolution of technology investment costs for solar PV and onshore wind since 2015. We assume that savings due to faster and steeper than expected technology investment cost reductions would be reinvested in the same area, which could lead to additional renewable technology uptake. As a result, the overall NDC target of limiting emissions to 369 MtCO_2e in 2030 could be further reduced to 351-356 MtCO_2e in the same year. This improvement is equivalent to a 6% to 8% increase in emissions reductions in comparison to reductions expected under the conditional NDC target.

The additional emissions reductions would come from an expected increase in the share of renewable energy in Argentina's power generation. The current targets set out in Law 27.191 and the energy sector plan are expected to bring Argentina's renewable electricity share to 20% in 2025 and potentially to 25% in 2030. The consideration of cost progressions outlined in this analysis would render an update of the target to 28%-30% in 2025 and 38%-43% in 2030 possible. This would put Argentina's power sector well within the range of what is considered to be aligned with the Paris Agreement (see Annex II).

Our findings illustrate how technology cost progressions could impact a country's future NDC ambition. A comprehensive revision of the NDC, however, always needs to consider country-specific barriers as well as a holistic evaluation of the broader political and economic landscape that shapes the capacity of a country to act. Our analysis provides a first estimate of the impact that technology cost progressions could have on Argentina's energy sector emissions and ultimately on NDC ambition. This strongly suggests considering the larger-than-expected decrease in costs of key mitigation technologies when revising Argentina's climate targets.

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Annex I – Impact of cost progression on electric vehicle uptake in Argentina

Solar PV and wind power generation are not the only mitigation technologies which have seen a significant drop in investment costs, batteries are also cheaper than was anticipated in the run up to the Paris Agreement (Wachsmuth and Anatolitis, 2018). Battery cost reductions result in lower-than expected costs for electric vehicles. Thus, the same method applied in the analysis for renewables could be used to investigate the potential impact of cost progressions on the further uptake of electric vehicles.

No official government targets for EVs existed pre-NDC and it remains to be seen whether the increasing attractiveness of electric mobility will lead to more explicit consideration of EVs in future updates of the Argentinian governments' climate commitments. The National Action Plan on Transport and Climate Change (MINEM, 2017b), developed after the NDC, includes specific measures to reach the overall absolute emissions reduction target presented in the NDC for the transport sector. The plan includes two unconditional measures to promote the use of low-emissions light-duty vehicles and alternative fuel buses.

Projected uptake of electric vehicles (EVs) in Argentina's energy plans

MINEM's 2030 energy scenarios as well as its update expect the sale of EVs in total vehicle sale to rise from the current 0% to 3% by 2025 and to 12% by 2030. These sales figures would lead to an increase in the share of EVs in the car fleet to 0.3% in 2025 and to 1.5% in 2030 (MINEM, 2017a). There is nonetheless no national policy supporting this uptake in Argentina, unlike in many other countries (IEA, 2019). Electricity vehicles rely on niche policies and market developments as the ones seen in the City of Buenos Aires. The city has launched a Clean Mobility Plan that involves several pilot projects using electric taxis and buses for public transportation (Ministry of Transport Argentina, 2018). The mobility plan aims for 30% of electric buses and 35% of electric taxis by 2035 in the Buenos Aires metropolitan area (Ministry of Transport of Argentina, 2017).

MINEM projects that 61,000 vehicles will be electric in Argentina by 2025 and 310,000 by 2030 (MINEM, 2017a). If we assume that the current share of EVs is zero, we can consider that approximately 60,000 new EVs would reach the streets between 2021 and 2025 and 250,000 more between 2026 and 2030. No country specific data for Argentina is available, we thus use global data reported for battery technology (IRENA, 2017; Wachsmuth and Anatolitis, 2018). We assume that cost reductions in battery technology could lead to further uptake of electric vehicles. The increase in costs observed in the least ambitious scenario is understood to be a result of short-term steep increase in demand.

Table 5 Percentage cost reductions for batteries comparing pre- and post-NDC cost curves.

Technology	Cost reduction	2021-2025	2026-2030
Batteries	Most ambitious	-32%	-52%
Batteries	Least ambitious	+14%	-19%

Source: (Wachsmuth and Anatolitis, 2018)

Scaling the number of electric vehicles considering the cost reduction ranges presented in Table 5 leads to a total of approximately 90,000 EVs by 2025 and between 300,000 and 520,000 EVs by 2030, in comparison to 27,000 and 200,000 EVs without the consideration of the cost progressions. The results for 2025 are based exclusively on the most ambitious cost progression curve as the results for the least ambitious scenario does not lead to further uptake of technologies.

Data on the current share of vehicles per fuel source is not available. Nonetheless, the transport sector plan presents gasoline and diesel as the two biggest sources of automobile emissions in 2014 (Ministry of Transport of Argentina, 2017). We assume that all EVs would replace cars running on gasoline or diesel to create a range of emissions reductions considering the emissions factor from each fuel, 196 gCO_2/vkm and 484 gCO_2/vkm respectively (ONDaT, 2013). Our estimates indicate that based on the two emissions factors, additional emissions reductions in the transport sector could lie between 0.07-0.17 $MtCO_2e$ in 2025 and 1.37-3.49 $MtCO_2e$ in 2030, taking only the most ambitious cost reduction scenarios for batteries as a basis, since the least ambitious reduction would not lead to additional EV uptake in comparison to the reference case.[6] Argentina's BAU scenario projects that economy-wide emissions could reach 592 $MtCO_2e$ in 2030. Therefore, Argentina needs to reduce emissions below BAU by 223 $MtCO_2e$ in order to reach the conditional NDC target of 369 $MtCO_2e$ in 2030. The additional emissions reduction in 2030 would lead to an improvement of 1-2% of the total expected emissions reductions in 2030.

[6] The current estimation does not consider the impact of increased electricity consumption from EVs. Therefore, emissions savings would be slightly reduced.

Annex II – Broader considerations of renewable uptake in Argentina

The present analysis provides a first estimation of the impact that falling investment costs for renewable energy technologies might have on Argentina's energy sector and NDC targets. It assumes that investment cost reductions for certain key mitigation technologies could lead to increased technology uptake and thus to a higher level of NDC ambition provided reduced costs are not taken as savings but are reinvested in the same technologies.

Consideration of technology cost progressions may support Paris compatibility in energy sector

While the methodology underlying the calculations in this analysis and respective assumptions are simplified and may not fully reflect reality, this analysis illustrates the relevance and potential of technology cost progressions to achieve further emissions reductions in key sectors and support development pathways that are compatible with the Paris Agreement's goals. Figure 8 shows a range of renewable electricity generation shares that would be aligned with a Paris compatible development of the energy sector (Climate Action Tracker, 2019b). The results of our analysis, i.e. the renewable electricity share that could be reached through cost progressions in Argentina (green stars in Figure 8), clearly fall within this range. The larger-than-expected cost progressions for key mitigation technologies in Argentina's energy sector can be considered to ease the transformation necessary to become aligned with what is needed for power sector decarbonisation.

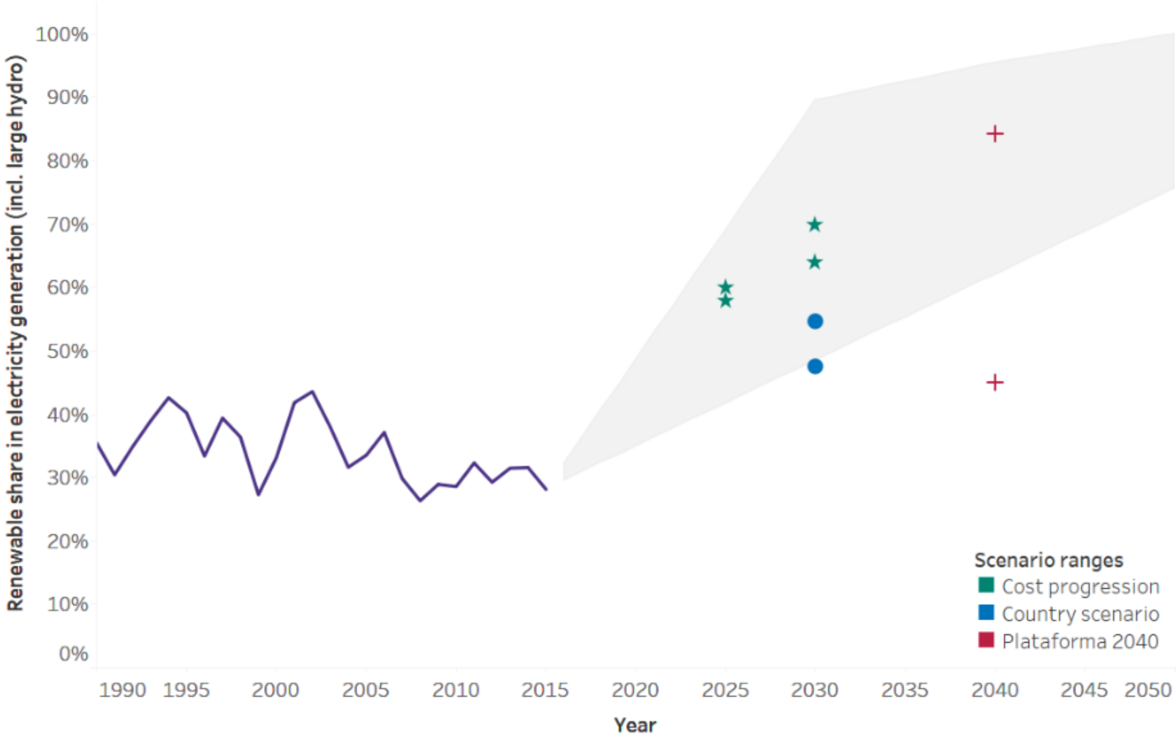

Figure 8 Renewable electricity generation shares compared to a Paris compatible range. The marks correspond to the minimum and maximum values of renewable shares in the respective analyses. See Box A for more information on the scenarios.

Source: Own illustration based on (Climate Action Tracker, 2019c)

To reach the goals of the Paris Agreement, countries must explore pathways leading to net-zero emissions, which requires decarbonising individual economic sectors. Therefore, a discussion of the cost progressions of key technologies that can help achieve decarbonisation, i.e. solar PV and onshore wind, is valuable when considering a revision of sector targets as well as of the NDC target in light of the Paris Agreement. It also shows the importance to address any potential barriers to the unfolding of this additional potential in a near future.

Box A: Defining the different scenarios

The *Plataforma 2040* range is based on the resulting renewable shares of all ten scenarios developed under the Plataforma initiative (Beljansky *et al.*, 2018). The *Country scenario* range is based on the four scenarios included in the latest official energy scenarios up to 2030(Secretaria de Energía, 2019). In the absence of nationally-driven and Paris compatible scenarios for Argentina, we compare existing national energy scenarios with global Paris compatible scenarios (IEA, 2017; Jacobson *et al.*, 2017; Teske *et al.*, 2019). These global Paris compatible scenarios are downscaled to Argentina following the approach defined by Hagemann *et al.* to create the shadowed range in Figure 8 (Hagemann *et al.*, 2020).

A successful power sector transformation and integration of high shares of non-conventional renewables in Argentina requires timely solution of challenges

The penetration of increasing shares of non-conventional and mainly variable renewables in a power system, referred to as "power sector transformation process", gives rise to specific challenges in power system planning and operation that must be tackled adequately. Many of these challenges can be attributed to specific characteristics of non-conventional, variable renewable energy sources, such as the fluctuating nature of wind and solar resources, their limited forecasting accuracy or the fact that large variable renewable capacity is often installed in remote locations (De Vivero *et al.*, 2019).

In Argentina, the substantial participation of dispatchable renewable hydro resources supports the expansion of variable renewable energy sources (vRES) to decarbonise the power sector as it provides the system with valuable flexibility needed to integrate higher shares of non-conventional, variable renewables.

Large-scale deployment of remote solar and wind resources will inevitably trigger network reinforcements. Substantial grid infrastructure and transmission investments as well as grid management upgrades are key to guide the transformation towards a predominantly renewables-based power system. A coordinated approach to long-term planning of generation and transmission allows for a better understanding of improvements required in grid infrastructure, as well the resulting investment and technical assistance needs. As a first step into this direction, Argentina currently plans to expand the transmission grid by means of centrally organised tenders under a Public-Private Partnership scheme, in order to build high voltage transmission lines linking supply and demand centres (Hagemann *et al.*, 2020).

Forecasting tools are necessary and currently being introduced in system operations by CAMMESA[7]. Such tools are already implemented in other systems around the world where they support a smooth and reliable integration of vRES, including in Spain, Demark and Germany. This is an opportunity for Argentina to learn from other countries' experiences and implement forecasting tools adjusted to its own conditions (Hagemann *et al.*, 2020).

Although Argentina needs to overcome the major challenge of grid limitations to advance the integration of vRES, policymakers should start thinking ahead of other potential challenges that may emerge in the

[7]CAMMESA (Compañia Administradora del Mercado Mayorista Eléctrico) is the administrator of the wholesale electricity market in Argentina. Its main functions include the real-time operation of the electricity system, the dispatch of generation and the administration of the commercial transactions in the electricity market.

near future. Such forward-looking planning includes adjustments in control and monitoring operations, defining the role of gas in the transition process, introducing market design concepts and enhanced system infrastructure flexibility, as well as developing a strategy for areas such as storage and sector coupling (De Vivero *et al.*, 2019).

While the development of large-scale renewables is halted by grid constraints, small-scale renewable generation is gaining presence in low-voltage levels of the network (MINEM, 2019a). The sudden and non-harmonised installation of generation sources at the distribution level (i.e., distributed generation) could threaten the stability and reliability of the grid. However, a smart and controlled integration of distributed resources could mitigate these risks. Although Argentina is only starting to develop distributed generation at scale, planning processes and operations that enhance their monitoring and controllability can already be initiated (De Vivero *et al.*, 2019).

While this section does not aim to exhaust the concerns related with an increasing penetration of non-conventional renewables in Argentina's power grid, it outlines why investment cost reductions alone will not result in a decarbonisation of the power sector. The analysis of cost progressions of key mitigation technologies and their potential impact must be complemented with an analysis of the associated opportunities and challenges of the power sector transformation and identify solutions to overcome the latter, in order to successfully harvest the benefits of such potential.

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