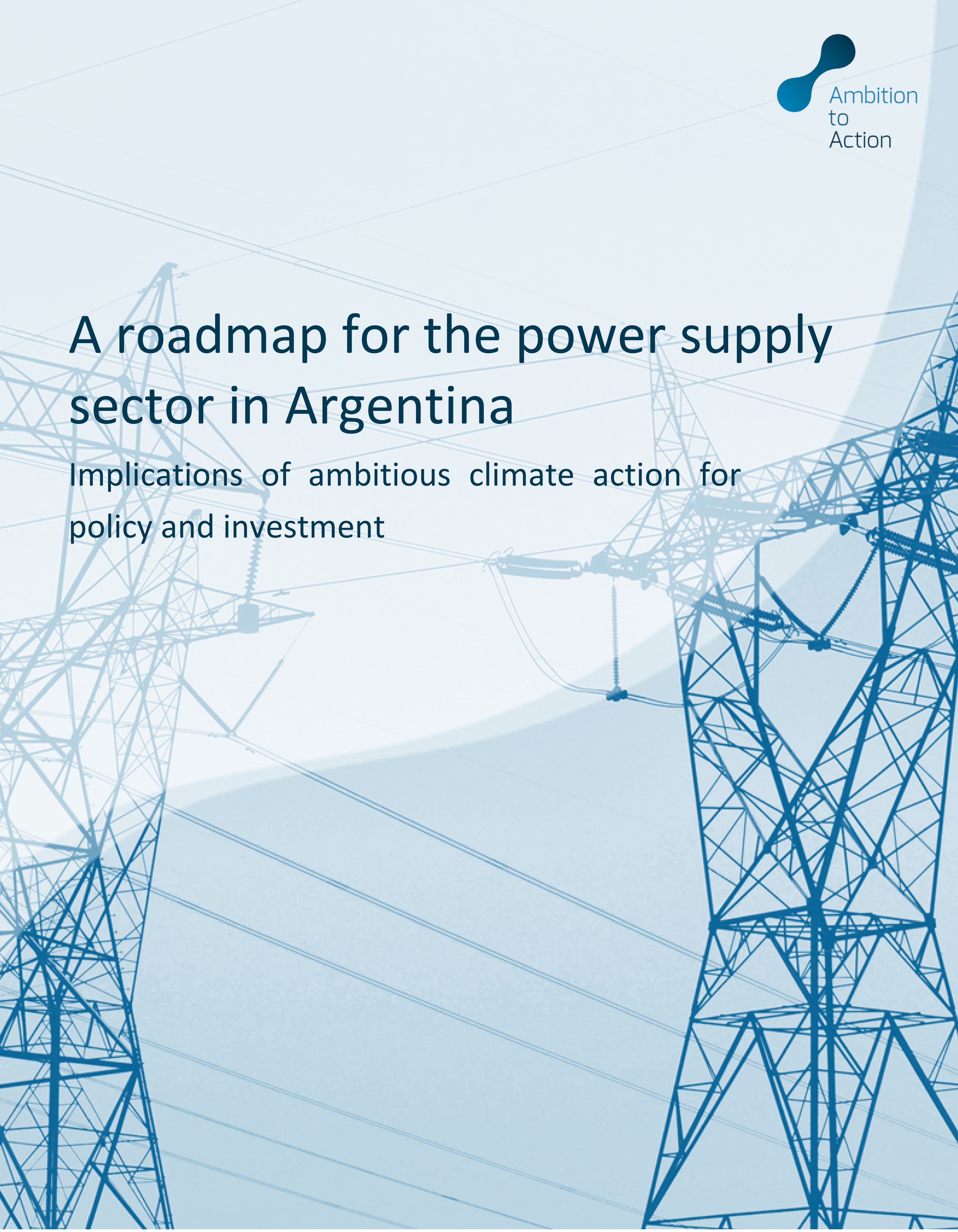
A roadmap for the power supply sector in Argentina

Implications of ambitious climate action for policy and investment



Ambition to Action

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A roadmap for the power supply sector in Argentina

Implications of ambitious climate action for policy and investment

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Introduction

This report draws together the key strands of analysis and results from capacity support activities undertaken as part of the “Ambition to Action” (A2A) project in Argentina between March 2017 and October 2019. Overall, the A2A project supported NDC processes in partner countries with a view to accelerate implementation of current NDCs and inform the setting of more ambitious NDC targets for upcoming NDC cycles. The underlying rationale of the project was to support policy makers to better understand the broader implications of higher ambition in key NDC sectors by comparing alternative sector pathways in terms of their socio-economic impacts and technical implications. The analysis involved the development of assessment tools to allow for the quantification of impacts or so-called co-benefits and was undertaken in close consultation with local experts.

Reflecting the importance of the sector for the Argentinean NDC, the project activities focussed on the energy sector, in particular the electricity supply sector. The energy sector accounts for the majority of emissions of the country and hence plays a key role for the efforts to decarbonise the economy long-term. Formally, the project was anchored at the national Environment Secretariat (*Secretaría de Ambiente y Desarrollo Sustentable de la Nación*) as NDC focal point. However, given the sector focus, the project engaged deeply with energy sector stakeholders, both on the government and non-government side. In particular, the project engaged with the Energy Secretariat (*Secretaría de Energía de la Nación*), including the departments for energy planning, renewables and energy efficiency and the NDC focal point for the energy sector. Outside of government the project worked with CAMMESA, the partly state-owned company responsible for the operation of the electricity grids, as well as the *Plataforma Escenarios Energéticos 2040*, an initiative which brings together key public, private and civil society stakeholders in the energy sector to develop and debate different trajectories for the sector into the future.

The objective of this report is to integrate the insights gained throughout the project to inform policy planning in the energy sector targeting policy makers and other interested stakeholders. More specifically, the insights aim to feed into the discussions around more ambitious climate targets for successive NDCs and the long-term strategy to be presented to the international community under the Paris Agreement. As such the report will discuss the following:

- The electricity supply sector in the context of the Paris Agreement;
- An overview of Argentina’s electricity sector, including current sector scenarios;
- What it means for the electricity sector to move towards Paris compatibility;
- Socio-economic impacts of different sector scenarios; and
- Achieving power system transformation and associated technical challenges.

In the last chapter, the report draws a number of conclusions and provides recommendations for upcoming policy planning processes.

1. The electricity supply sector in the context of the Paris Agreement

The Paris Agreement aims to limit global warming to “well below 2°C aiming for 1.5°C”, an ambitious goal all governments have committed to. The findings of the IPCC Special Report on Global Warming of 1.5°C (IPCC SR 1.5) illustrate the climate impacts and risks associated with exceeding 1.5°C and clearly underscore that greater ambition is urgently needed to achieve this limit. In order to limit the global temperature increase to 1.5°C, global CO_2 emissions need to decrease, on average, by about 45% from 2010 levels by 2030. By around 2050, global emissions need to reach ‘net zero’ (IPCC, 2018). The results of the IPCC SR 1.5 create a sense of urgency and momentum for all countries to raise their ambition, strengthen their NDCs and effectively accelerate decarbonisation efforts. It also becomes clear that current national pledges under the Paris Agreement are by far not enough to stay on track towards this goal (UNEP, 2019a).

Together with recent years of global GHG emissions growth, this increases the sense of urgency, shifting the main focus from “Who reduces how much emissions?” to “How fast can we reduce emissions in each sector and country” (Roeser, 2018). In this new environment, the former question has gained a new meaning and can be rephrased as “Who pays for what?” in the light of common but differentiated responsibilities. All countries need to push the envelope on all ends, with significant changes in all sectors. To achieve this, all parts of society must become engaged.

The IPCC SR 1.5 highlights the need and urgency for all sectors to decarbonise. However, the speed and depth may vary as for some sectors it is less feasible to achieve zero emission by 2050 than for others. In contrast to the agriculture, industry and aviation sectors, for example, where full decarbonisation is technically challenging, the energy supply sector (especially the electricity supply sector) can count on many proven mitigation options and market-ready technologies. This, and the role of the electricity supply sector for decarbonisation of key demand sectors (i.e. electrification of transport and buildings services) make a fast transformation of this sector paramount.

For this to happen, the use of renewable energy, including sustainable biomass if coupled with negative emissions technology, needs to be significantly scaled up along with an effective reduction of unabated fossil fuels to enable a fully decarbonised electricity sector by the 2040s (Joeri Rogelj, Luderer, Pietzcker, Schaeffer, et al., 2015). On the demand side, efforts need to be increased to reduce energy consumption as well as to shift away from fossil fuels towards electricity in transport and buildings. The transformation of the sector requires significant investments in infrastructure to accompany the systemic shift. Investments into low-carbon technologies need to increase, while those into fossil fuels must decline; in particular investments into coal need to cease by 2030 in all regions to ensure a complete global coal phase-out by 2050 (Climate Analytics, 2016).

Argentina’s commitment to the Paris Agreement

Argentina was one of the first 25 countries to ratify the Paris Agreement and the first country to submit a revised NDC in 2016. The revised NDC includes an unconditional and a conditional absolute emission target for 2030. The unconditional target aims to limit GHG emissions to 483 MtCO2e per year by 2030, while the conditional target goes down to 369 MtCO2e per year (both including LULUCF), conditional on the provision of international finance and support (Government of Argentina, 2016).

When comparing these numbers to historical emissions, the unconditional target would lead to an emission increase of 35% above 2010 levels and 80% above 1990 levels, excluding LULUCF. The conditional target would still lead to a 3% increase above 2010 levels and 38% above 1990 levels, excluding LULUCF. The Climate Action Tracker rates the country's NDC as "Highly Insufficient", resulting in 4°C global warming if all countries would take similar efforts according to the principle of common but differentiated responsibilities (Climate Action Tracker, 2019a)

The increase in ambition of the revised NDC target is small compared to that of the previous (I)NDC (around 1%). Beyond the minimal increase in mitigation ambition, the process-level changes were however important. The absolute mitigation target is more reliable than the previous one, which was based on a relative reduction compared to a BAU scenario. In addition, the methodology for calculating historical emissions was adapted to the IPCC 2006 guidelines, which caused a decrease in the baseline scenario and relative emission reductions due to the change in Global Warming Potential (GWP) values. The government also revised some of the mitigation actions included in the NDC: the revised NDC includes, for example, energy sector emissions from co-generation (Ministry of Environment of Argentina, 2016).

The NDC process in Argentina is coordinated and led by the National Cabinet for Climate Change (*Gabinete Nacional de Cambio Climático* – GNCC), which was created in 2015. The GNCC is a cross-ministerial body tasked with developing national and sectoral initiatives to reduce GHG emissions as well as formulating commitments in line with international agreements, such as the development of the NDCs. The GNCC operates under the helm of the Chief of the Cabinet of Ministers, and over half of the country's ministries and secretariats are involved. Each ministry or secretariat has identified a focal point to coordinate NDC related tasks.

Figure 1: Decision making process in the GNCC (based on MAyDS, 2016)

The role of the energy sector for Argentina's NDC

The energy sector – including supply and demand sectors such as transport and buildings – is the most relevant sector for Argentina's NDC (responsible for 53% of national emissions), followed by the land-use sector (responsible for 39% of emissions) (Government of Argentina, 2017).

Since the NDC submission in 2016, several sector action plans have been elaborated under the lead of the GNCC in order to support NDC implementation. In the energy sector, the National Action Plan for Energy and Climate Change, coordinated by the Sub-secretariat for Energy Saving and Efficiency within the Energy Secretariat, includes estimations on the impact of the NDC in the energy sector in Argentina. While providing emission reduction figures (77 MtCO2eq by 2030 as an unconditional target, and 101 MtCO2eq conditional on international finance and support), the document does not clearly state what these emission reductions are relative to (e.g. against a baseline or a base year, in a target year or cumulated over a target period) and therefore do not provide insights into the magnitude of expected emissions reductions from the sector. It however states that the energy sector is the sector with the highest mitigation potential in Argentina's NDC (MINEM, 2017b).

The plan proposes a set of mitigation measures, including the energy supply side as much as the demand side, and will be implemented along four axes: 1) energy efficiency, 2) renewable energy, 3) fuels, and 4) large scale generation[1]. The main contribution is envisaged to come from the supply side. Here, the share of non-conventional renewable energy sources in the power sector should increase from 8% in 2018 to 20% by 2025 unconditionally and to 25% by 2030 conditionally. In addition, the plan mentions targets of 56.000 user-generators in 2030 (conditional), 2.503 MW (unconditional) plus 465 MW of new hydro plants by 2030 (conditional), additional nuclear capacity in the order of 1895 MW (unconditional) plus 1300 MW (conditional) as well as other measures to promote bio fuels and island systems (MINEM, 2017b).

[1] The National Action Plan for Energy and Climate Change emphasises that the distribution of measures is purely meant for internal planning and does not translate into sectoral targets.

2. Argentina's electricity sector

Given the relevance of the electricity sector for the decarbonisation of the global energy sector (see section 2) and the importance of supply side measures in the electricity sector for the implementation of Argentina's NDC, this project took a closer look at the development of this sector in Argentina.

The Argentinean power system is characterised by its hydro-thermal configuration, where 63.8% of the generation in 2018 came from fossil fuels, mainly natural gas (90%), followed by 29.1% from hydro and 4.7% nuclear. The remaining 2.4% corresponded to other renewables, mainly wind and solar (CAMMESA, 2019a). With a total installed capacity of 38.5 GW by 2018, thermal and hydro power plants represent 92% of the total installed capacity in Argentina, making up for the 64% and 28%, respectively. The installed capacity split is illustrated in Figure 2 (CAMMESA, 2019a).

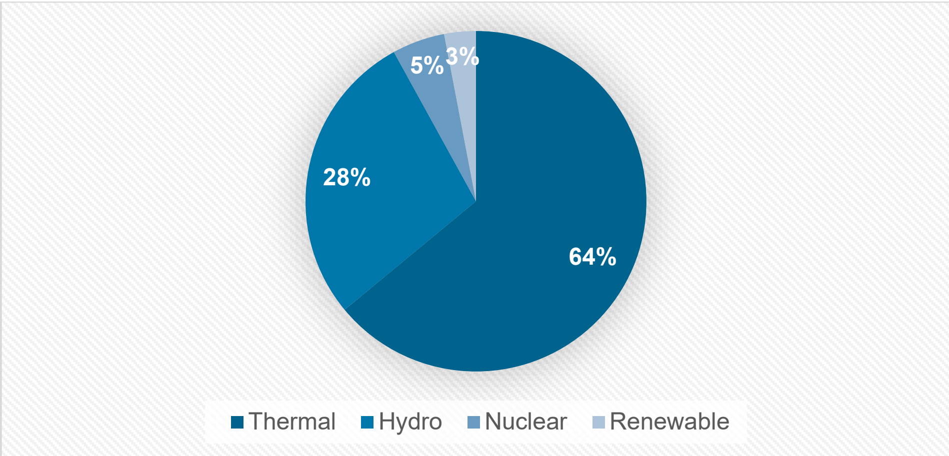


Figure 2: Installed capacity in Argentina in 2018 (CAMMESA, 2019a)

Figure 3 shows the evolution of the generation mix since 2000, illustrating the noticeable participation of hydro power, as well as the significant load growth that has been met mainly with increasing fossil fuel-based power generation. The total electricity demand has grown in line with the country's development after its economic crisis in 2002. The growth of total population, the increase in electricity consumption per capita and the achievement of 100% electricity access also explain the significant growth of total electricity demand. By 2030, the Energy Secretariat expects a further increase of more than 42% compared to 2019 levels for the 'Trend Scenario' and to about 26% for the 'Efficient Scenario' (Sectretaria de Energía, 2019).

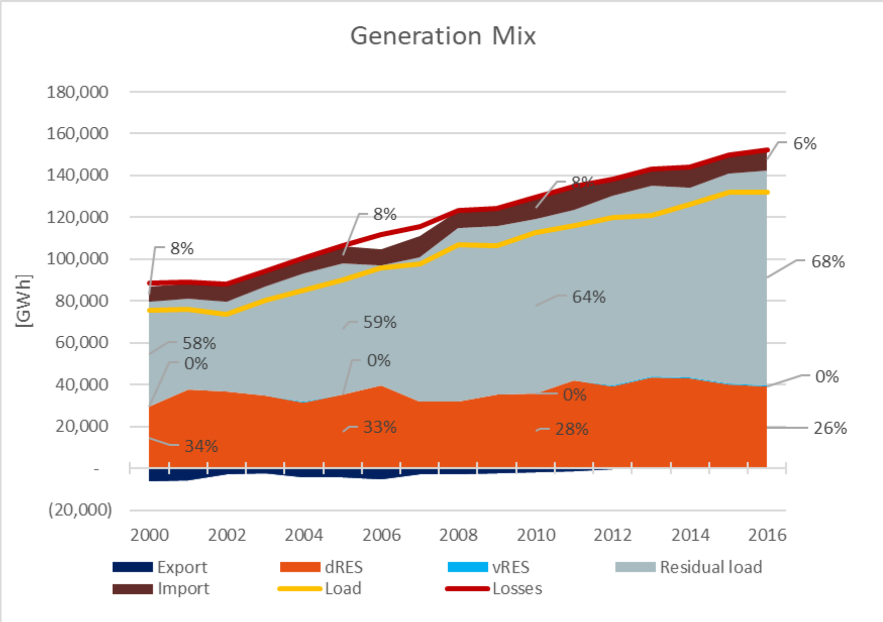


Figure 3: Evolution of electricity generation mix in Argentina (2000-2016). Source: (IEA, 2018)

By 2018, renewable energy (RE) supply has been exclusively hydro. Favourable hydro resources allowed for the installation of significant hydro capacity, totalling 10.8 GW in 2018. Since 2000, this capacity has been relatively constant. However, due to (the?) growing load, the share of hydro in generation decreased from 34% in 2000 to about 26% in 2016. On the other hand, the participation of wind and solar (grouped as variable renewable energy sources – vRES) was negligible up until 2018, when total installed capacity increased to 1.4 GW and contributed to 2.4% of total generation. The successful completion of four renewable auctions (RenovAr) will likely further add 4.7 GW of renewable capacity, which is expected to be installed in the next two years.

The substantial participation of hydro power in the generation mix has led to emission intensities below the global average, although they are higher than other countries in the region where the share of hydro is even larger (e.g. Brazil). While the fluctuation in the emissions intensity responds to the annual availability of hydro resources (except for the dip in 2002, which was a consequence of a national economic crisis), the increasing participation of gas in the generation mix has led to a steady increase in CO_2 emissions per kWh of electricity generated (Figure 4).

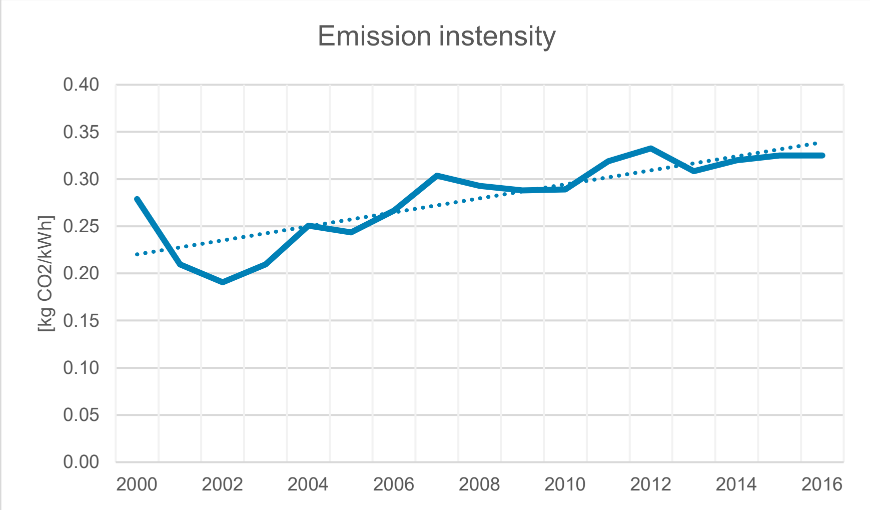


Figure 4: Emission intensity in the electricity sector in Argentina (2000-2016). Source: (IEA, 2018)

More than one third of the country's population lives in the Greater Buenos Aires area and less than half of the population lives in rural areas and small cities. The population density outside the larger cities is extremely low, with about 7 inhabitants per km^2.

From the demand side, electricity consumption in the industry represented close to 40% of total electricity demand in 2018, making it the highest electricity consuming sector in Argentina, followed by the residential sector (34.5%) and the service sector (25%). The transport sector remains minor (0.4%) and currently comprises only rail transport (Government of Argentina, 2018).

2.1 Legislative framework

Already back in 2006, Argentina adopted a target to reach 8% of electricity generation from renewable sources (Law 26.190). Given little progress towards its implementation in the ensuing years, the law was superseded in 2015 by the Renewable Energy Law (Law 27.191) which reiterates the original target of 8% from renewables (including hydro smaller than 50 MW) in electricity consumption by the end of 2017 and mandates a 20% share by the end of 2025 (Government of Argentina, 2015).

The auctioning scheme RenovAr has been put in place to support the renewable energy target. As of October 2019, four auctioning rounds have been completed (RenovAr 1, 1.5, 2 and 3), leading to contracting of a total of 4.7 GW of renewable energy capacity (Morais, 2019). In April 2019, the government announced a fifth round (RenovAr 4), under which it expects to contract around 1 GW of new renewable capacity. In contrast to the last round (RenovAr 3), which focused on small-scale renewables with a capacity of up to 10 MW per installation, RenovAr 4 will again be directed to (towards?) larger scale wind and solar power projects (similar to RenovAr 1, 1.5 and 2) and will, in addition, include grid infrastructure projects (Bellini, 2019a). As of 2019, 2.6 GW of renewables (incl. wind, solar, small hydro, bioenergy) are installed in Argentina (CAMMESA, 2019b).

The current limitations in the grid put the fulfilment of the renewable targets by 2025 at risk. Concerns about grid limitations have been raised before RenovAr 3, potentially causing a delay in grid connection of contracted capacities and making additional auction rounds more difficult to realise. The national grid operator CAMMESA has recognised this issue and is working on the extension of the electricity grid (CAMMESA, 2018). In order to address the problem and contrary to previous auction rounds, the government therefore plans to include grid infrastructure projects in RenovAr 4 to support the further expansion of renewable capacity in the country.

Despite progress on renewable energy through RenovAr, the renewable target set for 2017 has not been reached, with renewable-based power generation representing 2% in that year. Argentina's energy plan is still heavily centred around the development of oil and natural gas production; especially the continued support for natural gas indicates that fossil fuel resources will retain strong participation in the electricity supply sector also in the future (Climate Action Tracker, 2019b).

2.2 National projections

2.2.1 MINEM scenarios

The former Ministry of Energy and Mining (MINEM) which was changed to the Energy Secretariat during the course of the project, developed two main scenarios for the electricity sector for the years 2025 and 2030 (published in December 2016 and 2017 respectively), in line with Law 27.191: a reference scenario ("*escenario tendencial*"), and a scenario with additional energy efficiency measures ("*escenario eficiente*"). The main difference between the scenarios is, as the names imply, that under the "efficient scenario" the electricity demand is lower than under the "reference scenario", due to a higher level of energy efficiency measures.

Under the reference scenario, 34 GW of new capacity need to be added by 2030, whereas under the efficient scenario, the additional capacity can be reduced with the help of energy efficiency measures to 26 GW to allow the country to reach a renewable share of 20% in the electricity sector by 2030 (excluding large hydro) (see Figure 5 and Figure 6). By 2025, the MINEM scenarios foresee an additional 24 GW of capacity under the reference scenario and 17 GW under the efficient scenario (MINEM, 2017a).

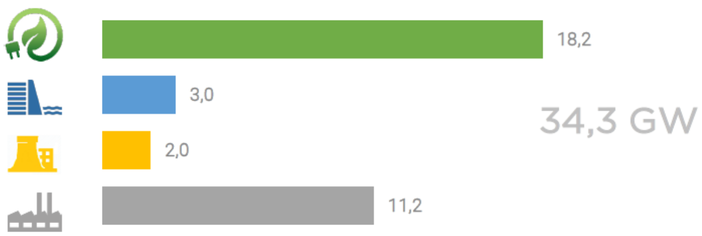


Figure 5: Projected newly installed electricity generation capacity by technology in 2030 – Reference scenario (*escenario tendencial*)

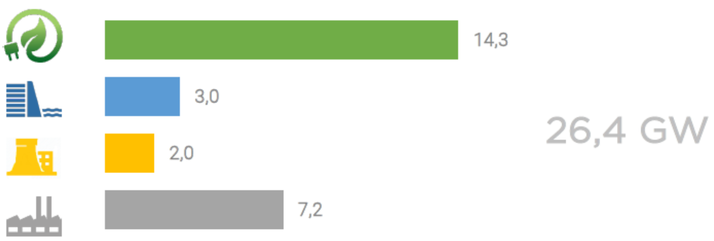


Figure 6: Projected newly installed electricity generation capacity by technology in 2030 – Efficient scenario (*escenario eficiente*)

Source: (MINEM, 2017a).

Due to the different levels of demand side energy efficiency measures the expected total electricity generation differs between the two scenarios: it is 20% higher in the "reference scenario" (~214 TWh) than in the "efficient scenario" (~180 TWh) in 2030 (MINEM, 2017a).

An updated version of the 2030 scenarios has been released in November 2019 by the Energy Secretariat, shortly before the end of the project, but was not considered in this report.

2.2.2 Plataforma scenarios

Additional national scenarios for the energy sector were developed by the "*Plataforma Escenarios Energéticos 2040*", a non-governmental initiative under which different modelling groups develop and discuss alternative energy sector pathways for Argentina up to the year 2040 (Beljansky, Katz, Alberio, & Barbarán, 2018).

In its third round, the Plataforma process reopened the dialogue about the direction of the Argentinian energy sector transition. While the Plataforma exercise does not aim to accurately predict or project the future of the energy sector, it seeks to identify key elements that may affect the way in which this sector is evolving over the coming decades.

For this purpose, a total of eleven *'escenaristas'*, representing different energy-related institutions and interests, elaborated nine scenarios for the evolution of the energy sector up to 2040, applying a consistent methodological framework. An agreed set of indicators was used to quantitatively and qualitatively evaluate each scenario in its environmental, social and economic dimensions (Beljansky et al., 2018).

The Plataforma base-case scenario (highlighted in orange in Figure 7) follows the projections from the MINEM scenarios up to 2030.

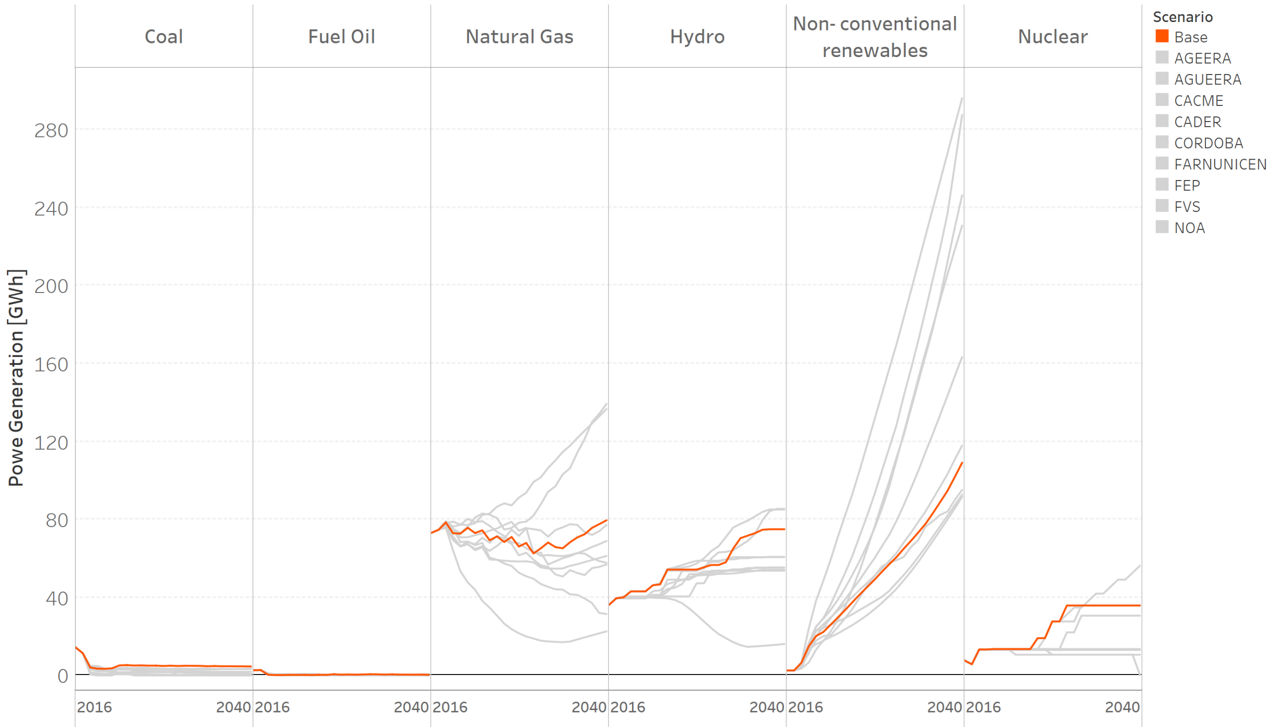


Figure 7: Power generation from *Plataforma Escenarios* 2040 with base-case scenario highlighted in orange

The Plataforma scenarios also provide indicators from a climate change perspective. These include total emissions from power generation, emissions intensity of primary energy, and emissions intensity of the power sector (Beljansky et al., 2018). While the scenarios were not developed with the aim to achieve compatibility with the long-term goals of the Paris agreement, these indicators allow a comparison of these scenarios with what is needed to achieve these goals.

3. Moving towards Paris compatibility of the electricity sector

While the implications of the long term Paris temperature goals at the global level have been analysed and discussed at length (Climate Action Tracker, 2016; Joeri Rogelj, Luderer, Pietzcker, Kriegler, et al., 2015; UNEP, 2019b), the concrete implications for a sector in a given country, in this case the Argentinian electricity sector, are less well understood. To derive relevant results, national modelling exercises have to translate the globally required emission reductions into the national context. National circumstances such as the availability of technologies, reduction potential, institutional setups, etc. must be considered when determining priority sectors and measures for national climate action. As highlighted in Section 3.2, to date a series of national modelling exercises exist in Argentina that take some or most of these national characteristics into account.

While these scenarios are highly useful to advance the discourse around the NDC and energy sector policy in the country, they have two significant drawbacks: first, they only cover a **limited timeframe** until 2040 (Plataforma) or 2030 (MINEM). As the IPCC SR 1.5 has shown, Paris compatibility has to be viewed in a timeframe until 2050 and beyond. Second, they are **not linked to the temperature goal** of the Paris Agreement, nor were they developed with the aim to achieve the highest level of ambition (see Section 2).

Several different methods exist to better reflect this. Back-casting methods, which start from the end point, provide a direct way to link sector developments to the long-term goals of the Paris Agreement. A desired end-goal is entered into a given model, such as an emission level or temperature limit, and the model calculates an optimised path towards this goal. Most optimisation processes thereby use cost optimisation as the main optimisation paradigm (e.g. Integrated Assessment Models (IAMs)), with some, like the IEA ETP scenario, also taking account of other considerations such as the availability of policies. These models are however of limited use when it comes to supporting nationally driven discourses around the sectoral transformations, as they are relatively non-transparent and do not supply enough country and sector specific resolution. An alternative approach would be to develop pathways that maximise possible emission reductions using bottom up models with better country- and sector-specific resolution.

The fact that the current national scenarios do not take account of these factors leaves policy makers with a dilemma: while they have well proven modelling work they can and have relied on, they cannot be sure that the pathways modelled will be in line with what is needed according to climate policy goals and hence provide the right signals for implementing important policies. This becomes especially critical when considering investment choices today that might be appropriate under the existing scenarios but would lead to a lock-in or stranded assets under a Paris-compatible scenario. Similarly, important sectoral transformations that would need to be initiated today under a Paris-compatible scenario might get delayed or ignored, potentially leading to higher costs later on. The development of Paris-compatible scenarios is therefore essential for countries not only to understand their long-term trajectory but also to guide immediate actions.

3.1 Modelling approaches for Argentina

In the absence of nationally-driven and Paris-compatible scenarios at the country level for Argentina, we compare the existing national energy sector scenarios with Paris-compatible scenarios that can be downscaled from the regional to the national level (IEA, 2017; Jacobson et al., 2017; Teske et al., 2019). A set of pathways was derived using three different approaches:

1) **Climate Action Tracker Scaling Up Paris Agreement compatible scenarios (CAT SUPA compatible scenario 1 and 2)** A number of global modelling (Jacobson et al., 2017; Teske et al., 2019) efforts have provided relatively detailed perspectives on developments needed at the sectoral level. Under the CAT, these were used as an input to develop Paris-compatible sectoral scenarios using a simplified book-keeping model, the PROSPECTS tool[2].

2) **IEA ETP non-OECD downscaled (IEA non-OECD trend)** – The IEA provides a number of modelling scenarios around Paris compatibility, including scenarios of their World Energy Outlook and Energy Technology Perspectives (ETP) editions. The ETP 2017 includes the "Beyond 2 degree" scenario, which provides sufficient detail to translate the regional scenarios to Argentina. Again, using the PROSPECTs tool, we derive a Paris-compatible scenario for Argentina. This scenario plays an important role here as the IEA has a high reputation among country experts.

3) **Zero CO_2 emissions by 2050 in electricity sectors (Zero by 2050 trend) –** The zero CO_2 emission scenarios presented here use the IPCC SR 1.5°C (IPCC, 2018) based assumption that the power sector needs to be CO_2 emission free by 2050.

While not the result of national modelling exercises, these scenarios provide a useful point of reference for discussion amongst national stakeholders: When comparing the underlying assumptions made in these scenarios in comparison to existing national scenarios, important conclusions on where more or different interventions may be needed can be drawn.

3.2 Results: pathways and decarbonisation indicators

We compare the above mentioned Paris-compatible scenarios with the national scenarios put forward by the Energy Secretariat (here referred to as 'MINEM scenarios'), as well as the scenario range derived from the "*Plataforma Escenarios Energéticos Argentina 2040*" (here referred to as 'Plataforma') (see Section 3.2). In addition to the national scenarios, we added a range of scenarios developed under the Climate Action Tracker that provides an indication of where the sector is currently heading.

[2] PROSPECTS is a user-friendly, open-source, excel-based bookkeeping tool and simplified energy system model that can be used to create transparent, bottom-up historical and future energy and greenhouse gas emissions pathways. PROSPECTS was developed by NewClimate Institute and the Climate Action Tracker based on the logic of ClimateWorks Foundation's CTI models.

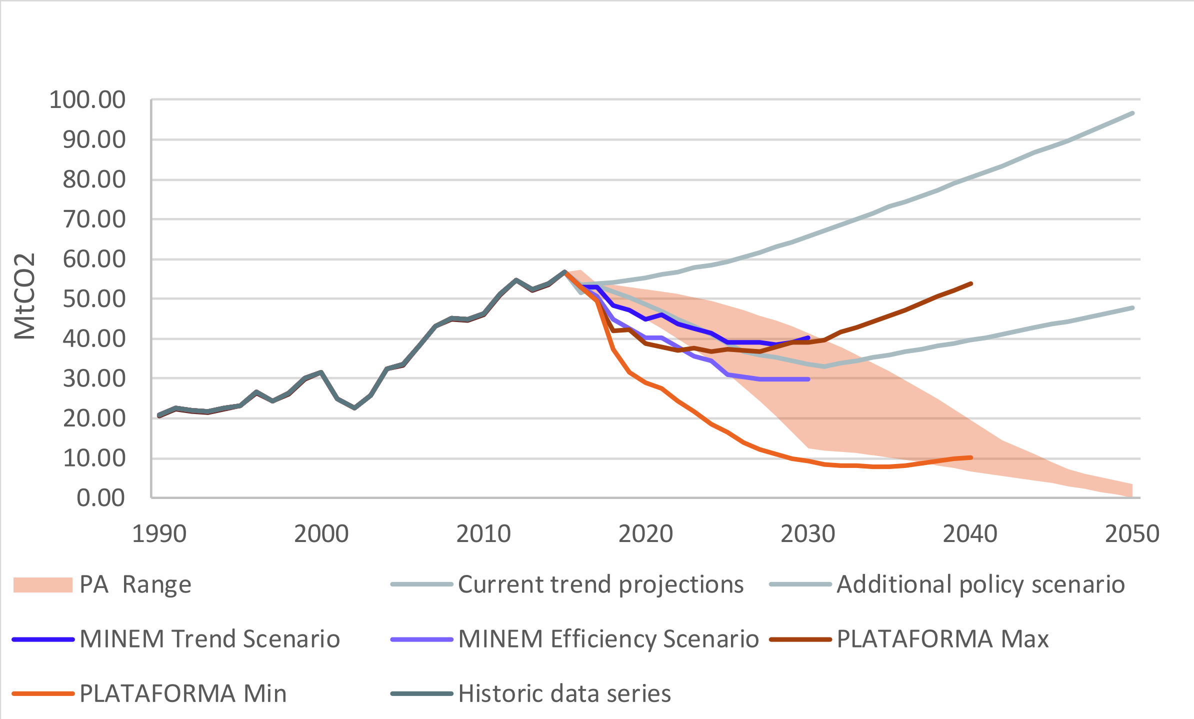
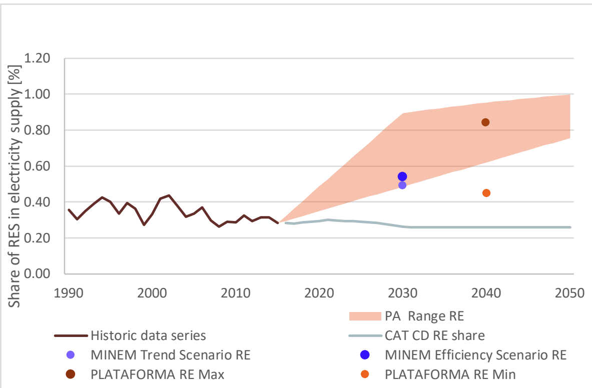


Figure 8: CO_2 Emission projections in the power sector - Comparison of Paris-compatible scenarios with current trend and additional policy scenarios

A comparison of CO_2 emission in the power sector between the scenarios highlights that the majority of national scenarios is well aligned with, or even lower than, the Paris-compatible scenarios until about 2030, for some even until 2040. All scenarios thereby show a steep decrease in emissions in the initial years, that in many cases even goes deeper than under Paris-compatible scenarios. Beyond 2030 the rate at which emissions decline decreases under almost all national scenarios, while the contrary is the case under the Paris-compatible scenarios. This suggests optimistic assumptions on low carbon technology uptake in the early years in all national scenarios, supported by actual developments in recent years, but also highlights the lack of back-casting or Paris compatibility check in these scenarios. The scenarios seem to assume that renewables will become part of a diversified energy mix in the power sector alongside fossil fuel-based technologies, a paradigm that has long been upheld by power sector experts. Under Paris-compatible scenarios however the emissions, and therefore also the emissions intensity of the power generation sources, will have to reach zero by 2050 (see Figure 9 right side). This changes the paradigm as zero-carbon technologies will have to become the dominating source of energy.



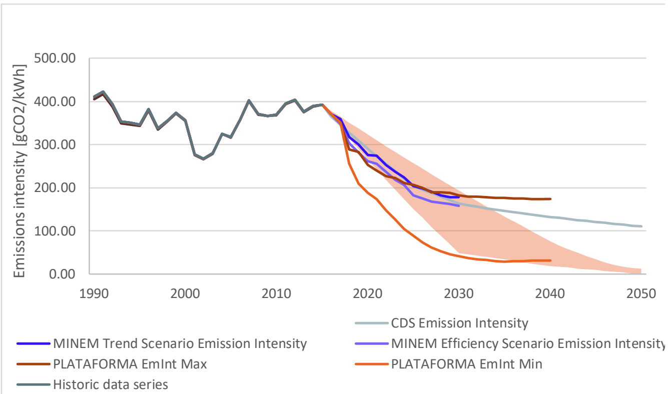


Figure 9: Decarbonization indicators in the electricity sector; **left panel:** share of RES technologies in electricity supply; **right panel:** average emission intensity in the electricity sector

As all Paris-compatible scenarios show, renewable energy sources (RES) will play the leading role among all low carbon technologies. Until 2050 the Paris-compatible scenarios analysed here indicate that the share of RES will need to grow to between 70% and 100%. Those scenarios at the lower end of this range rely on technologies that have not reached market maturity to date (CCS) and/or are associated with large social and environmental risks (nuclear and to some degree CCS). In comparison, the MINEM scenarios are at the lower end of the Paris-compatible range for RES in 2030. Among the Plataforma scenarios, the share of RES diverges significantly: While some scenarios end up with shares in the upper half of the Paris-compatible range, others are well below such range. The picture is similar for emission intensities, suggesting that the latter scenarios also do not take account of other low carbon technologies in lieu of RES, but instead rely on more carbon intensive technologies such as gas, also towards 2040.

In this context, another important fact requires mentioning: In the recent years, two technologies have emerged as winners among low carbon technologies: wind and solar (Agora Energiewende, 2013). Since 2016, globally more investments went into those two technologies than any other power generation technology (IEA, 2019a). The IEA WEO predicts that between 2020 and 2030, the installed capacity of PV will surpass that of any other technology (IEA, 2019b). Wind and solar are however unique in their characteristics and introduce variability from the supply side into the system (hence they are referred from here on as vRES). This requires an all-encompassing transformation of the power system, with implications described further in section 6 of this report. The largest challenge is that integrating these two technologies requires more flexibility in the system. Such system flexibility can be provided for instance by other power plants, energy storage or a more interconnected grid. How large the vRES share will be makes a significant difference as to what challenges will be faced, what flexibility options will be needed and how far the transition will have to go. A system with a low share of vRES might be able to operate almost as today's system, one with large shares will need to change significantly.

While the national scenario exercises have opened the horizon towards considering a Paris-compatible future of the sector, they have also fostered a discourse which still considers all technologies as viable and as equal alternatives in the mid- and long-term (in terms of power generation, not in terms of system integration). Constraining the discourse with Paris compatibility requirements in the context of current technology development would also limit the technology options. Natural gas for instance, will remain an option for the integration of variable renewables in the short- and mid-term, but will also need to be phased out in the long-term, if not combined with CCS and/or switched to renewable based synthetic fuels. CCS imposes additional cost on the technology which in turn changes its relative competitiveness in comparison to other low carbon options. Hence new investments into gas infrastructure in the near-term need to consider the long-term need to decarbonize the entire power sector, meaning that plants built today might not be feasible anymore if they cannot operate in the future.

For Argentina a few important lessons can be drawn from this:

- Existing renewable capacity, especially hydro power, is important as it has favourable characteristics to enable the integration of vRES. It is not significantly variable and can be used to follow load. This is especially relevant in the mid- to long-term, when fossil-based alternatives that also provide this flexibility need to be phased out.
- Investment in power generation to cover the growing electricity demand in Argentina in the last decade has focused on natural gas. Since Argentina has difficulties attracting (foreign) investment, these new plants have been rather small. This is advantageous to the integration of vRES in the short-

to mid-term as these types of plants have historically been used as peak shaving plants and could in turn be used to provide flexibility for vRES.

- Considering Paris compatibility also means that no new investments in gas power plants should be made and that the existing plants need to be phased out or transferred to renewable-based synthetic fuels in the long term. Notably, Plataforma scenarios with increasing natural gas generation would hence be incompatible in this context (see Figure 7).

Considering Paris compatibility will not only shift the discourse on power generation options but also on important other infrastructure decisions. This affects especially the transmission system infrastructure but, similarly important, investments in natural gas infrastructure as well (see Box 1). Exploiting and integrating vRES will require a grid expansion that differs from what is needed for the integration of fossil fuel power plants. Renewable energy potentials for large scale renewable energy deployment are often in remote locations that require designated transmission lines to load centres, such as the greater metropolitan area of Buenos Aires. These are not in the same geographical locations as fossil fuel power plants. Additionally, distributed renewable energy generation will pose new challenges as current power plants are rarely connected to the distribution grid but rather at the transmission level. All in short, mid- and long-term power system planning will have to be reconsidered and investments shifted to enable a transition to large shares of vRES sources.

Box 1: Implications of intensive gas infrastructure development

The guiding objective in the Argentinean energy plans is the large-scale exploitation of recently discovered shale gas reserves to supply domestic demand and become one of the largest LNG exporters. These plans have significant implications for Argentina's position on climate change.

Current energy plans assume a significant increase in domestic demand of natural gas. The recently updated 2030 Energy Scenarios, developed by the Energy Secretariat (Sectretaria de Energía, 2019), assume a growth in the end-use demand of natural gas by 39% between 2030 and 2018, which could increase to 74% above 2018 levels in a scenario with significant investments in gas-intensive industries and gasification of the transport sector due to the increased availability of natural gas supply.

Guided by these assumptions, the national scenarios show a significant development of the natural gas industry, with the objective to double gas and oil production in five years and export half of the production, aiming to turn Argentina into the fifth largest LNG exporter by 2026. The aggressive development of the gas industry requires significant capital investments for the exploration, production, transportation (pipelines and rail lines) and exports (liquefaction plants) of natural gas. Total capital investments are estimated at US$ 87-93 billion between 2019-2030 (of which around US$11-13 billion correspond to investments in transport and export liquefaction infrastructure (Sectretaria de Energía, 2019)). The investment needs could further increase if the scenarios considered the need to expand the installation of gas-fired power plants and grid expansions due to the increased supply of natural gas. Argentina is currently investing in gas infrastructure and has opened concessions to private investors.

However, the underlying assumption to develop natural gas is that there will be a continued increase of domestic and global demand for fossil fuels. This notion is not compatible with the Paris Agreement. The IPCC report on 1.5°C suggests that gas consumption in the electricity sector should decrease to 8% in 2050 at a global level, and that all remaining gas plants would need to be equipped with carbon capture and storage (J. Rogelj et al., 2018).

The cost-benefit analyses that support these plans should consider the risks associated with importing countries aligning their economy with the Paris Agreement temperature goal, which could shift global demand and export markets to renewable-based energy systems. Argentina's current exports plans, and hence economy, would face significant risks under such developments, including stranded gas infrastructure assets.

In a 1.5°C and 2°C world, there might be a need for gas but mainly as a transition technology and to provide adequacy and flexibility to the power sector. The IEA's *Beyond 2°C Scenario* considers the use of natural gas in power plants, but only marginally - around 4% of electricity generation in 2060 would be natural gas-based (IEA, 2017). In IEA's *Sustainable Development Scenario*, which exceeds the Paris temperature limit, global natural gas demand will grow by 6% from today's levels and plateau at around 22% of the total primary energy demand in 2040 (IEA, 2019b). In Greenpeace's *Advanced [R]evolution Scenario*, natural gas is not used for energy purposes and the dispatchable conventional gas power plants will be converted to operate on hydrogen or synthetic fuel by 2050 (Teske, Sawyer, & Schäfer, 2015).

Argentina, with more than half of its current power generation coming from natural gas, already has sufficient gas infrastructure to enable the transition to a Paris-compatible economy. Any further investments to expand the gas industry other than the conversion of the gas infrastructure to be suitable for hydrogen and/or synthetic gas based on renewable power will lead to stranded assets in a 1.5/2°C compatible world.

Alternatively, the role for natural gas in the power sector would have to rely on carbon capture and storage (CCS). This technology is increasingly unlikely to be able to compete with renewable energy due to large capacity factors needed to make CCS cost efficient, no observed cost improvements and limited co-benefits.

The full decarbonisation of the Argentinian energy sector by mid-century in accordance with a 1.5°C compatible trajectory requires continued efforts to accelerate the deployment of renewable capacity and moving away from supporting the expansion of fossil fuels. The deployment of renewables beyond 2030 could be hampered by the strong support for natural gas and the intended exploitation of the shale gas reserves that would increase the demand for natural gas, including for electricity generation.

4. Analysing socioeconomic impacts of electricity sector pathways

All future electricity sector pathways will require large investments in the coming years. To better understand the implications of different sector pathways on the Argentinian economy, NewClimate Institute developed and applied – in collaboration with key stakeholders – the Economic Impact Model for Electricity Supply (EIM-ES).[3] This spreadsheet-based model estimates the domestic employment and wider economic impacts of investments in new electricity generation capacity within a country to provide a comparative assessment of impacts under different future scenario pathways for the development of the electricity sector. The analysis provides critical insights to planners and policy makers into how different technology choices may determine investments and employment opportunities across different sectors of the economy in Argentina over time.

Growth in energy demand and the transition to low carbon technologies require large investments in capital, land and labour. The scale of the investment and the beneficiaries of these financial flows depend on a wide range of factors such as the choice of technology, location, rate of deployment, and capacity of local supply chains, among many others.

It is important that policy makers carefully consider the wider socio-economic and environmental impacts of their approach to tackling climate change, which can lead to a wide range of so-called "co-benefits" through improved air and water quality; more secure, accessible and sustainable energy supplies; and opportunities for economic growth and job creation in new sectors.

Investments present an opportunity for economic growth and typically directly impact employment levels. However, where these investments are made, and the structure and capacity of the economy into which they are channelled, can have important implications for the extent to which the investments support economic activity and employment within a given country.

As with any transition, there will likely be those that stand to gain more and those that are potentially disadvantaged by the change. An analysis of the likely magnitude and distribution of future impacts can help policy makers to prepare the skills and capacities required to support the transition, to ensure that those losing out as a result of the change are appropriately compensated and to best facilitate a just transition that works for all.

4.1 Analysis of employment impacts

In 2018, the A2A project team worked with the *Plataforma Escenarios Energéticos 2040* to estimate employment impacts in the electricity supply sector and its associated supply chains from the ten scenarios developed by stakeholders to the initiative (Plataforma Escenarios Energéticos, 2018). We worked with the modelling experts within the "Plataforma" technical committee to develop a soft link between their scenarios modelled using the LEAP software[4] and the EIM-ES. This link aligned all of the relevant scenario information including both inputs and outputs of the LEAP modelling, such as electricity generation and capacity by technology and year, investment costs and the share of fuels sourced domestically. One of the objectives of

[3] https://newclimate.org/2018/11/30/eim-es-economic-impact-model-for-electricity-supply/

[4] https://www.energycommunity.org/default.asp?action=home

the collaboration was to set up the link to facilitate the analysis of employment impacts for scenarios developed by the stakeholders to the Plataforma not just in 2018, but also continuing in future years.

In parallel, NewClimate Institute also analysed employment impacts using the EIM-ES for a set of eight future scenarios for the electricity sector in the CAT Scaling Up Climate Action series, covering a current development scenario, a scenario based on 'MINEM Energy Scenarios', two Paris-compatible scenarios, two "best in class" scenarios and two national scenarios selected to provide a range from amongst those developed under the Plataforma (Climate Action Tracker, 2019c).

Input data to the EIM-ES for Argentina was derived from a variety of sources, including the OECD (Input Output tables); Observatorio de Empleo y Dinámica Empresarial (annual labour costs by economic sector); Plataforma modelling assumptions (electricity scenarios, costs and local share assumptions for fuels); the former Ministry of Energy and Mining (MINEM) (renewable costs and local share estimates); and survey responses from industry experts developing projects in Argentina.

4.2 Analysis of industrial development impacts

In addition to employment impacts, the EIM-ES estimates investments in Argentina over time as well as their "value added" to the economy (a proxy for gross domestic product) for a given scenario. The model breaks-down these estimates by economic sector - e.g. construction, manufacturing, professional services, etc. - and by electricity supply technology - e.g. combined cycle gas turbines, wind, solar PV, etc. One of the key determinants of spending in Argentina are the assumptions on the local content share of each investment, i.e. how much of the total cost is spent on domestic activities in Argentina, rather than on imported goods and services. The model splits investments into the component parts of individual technologies. For example, investments in wind electricity generation are broken down into parts such as the turbine, the blades, the tower, as well as civil works and construction at the site, and project management; all of which can have a different local content share assumption attached to them. We derived estimates of the local share of investments from technology and sector experts represented in the Plataforma, a survey of project developers, as well as detailed information shared by MINEM on the expected local share of investments for renewable projects bidding into the RenovAr auctions.

An important element of our industrial development analysis considers the *potential* for domestic investment and economic growth in Argentina under different future pathways for the development of the electricity sector. Through surveys with national experts, as well as a literature review of both regional and global electricity generation supply chain information, we derived estimates of the feasible potential for increasing the local content share of investments over the medium-term (5-10 year time horizon), focusing in particular on electricity capacity and generation from wind and solar PV installations. Both these technologies are at a relatively early developmental stage in Argentina. Figure 10 below sets out the four key indicators that we asked survey respondents to consider when assessing the potential future local content share for each component part. Our analysis examines both the range of economic impacts from investments in the electricity supply sector across different future pathways as well as the potential scope for increasing impacts if enabling policies are put in place to raise the local share of investments over time.

1) Competitive advantage:
Relative economic attractiveness of local production compared to importing components/services, considering factors such as material costs, wages, labour expertise, economies of scale, subsidies and tariffs.

2) Regulatory environment:
Non-economic barriers or incentives affecting the attractiveness of local production such as local content requirements, planning regulations, available infrastructure, industrial policy plans (e.g. national energy plans).

3) Trend:
Current and future plans for development of local supply chains such as new production facilities opening up in the country or global manufacturers shifting their production hubs to the country.

4) Global and regional context:
State of supply chain(s) on a global and regional scale such as major production hubs in a specific region/country to supply global and/or regional demand.

Figure 10: Indicators provided to survey respondents to inform their assessment of the potential local content share for each component part over the medium term.

The scope of our industrial development analysis does not consider electricity price effects from policies that mandate minimum local content shares. For example, there is a risk that increasing local content shares drives up the cost of certain input components relative to their globally traded values, at least in the short-term. This can have the effect of raising electricity prices and harming industrial competitiveness, particularly for electricity intensive producers exposed to international competition. We also do not consider detailed sub-national regional implications of different scenarios. Both elements would be interesting areas to explore further in the future, along with a more detailed consideration of additional technology options.

4.3 Results of the impact analysis

4.3.1 Employment

The headline results of our employment analysis are shown in Figure 11 for the ten scenarios analysed as part of the Plataforma initiative. These show employment impacts expressed as full time jobs lasting one year in duration, or “job years”, over the period 2017 to 2040 both in terms of direct employment (e.g. preparation of site, construction, manufacturing of key component parts, fuel production; shown by the blue bars) as well as total employment which also includes indirect and induced impacts (e.g. supply of inputs to key component parts, manufacturing and supply of equipment used in construction as well as wider economic impacts derived from the spending of those employed either directly or indirectly in the electricity supply sectors; shown by the grey bars). Ten “job years” could reflect the employment of one individual full-time for ten years, e.g. supporting the operation of the plant, or it could reflect the employment of five individuals full-time for a duration of two years, e.g. in construction of a new plant.

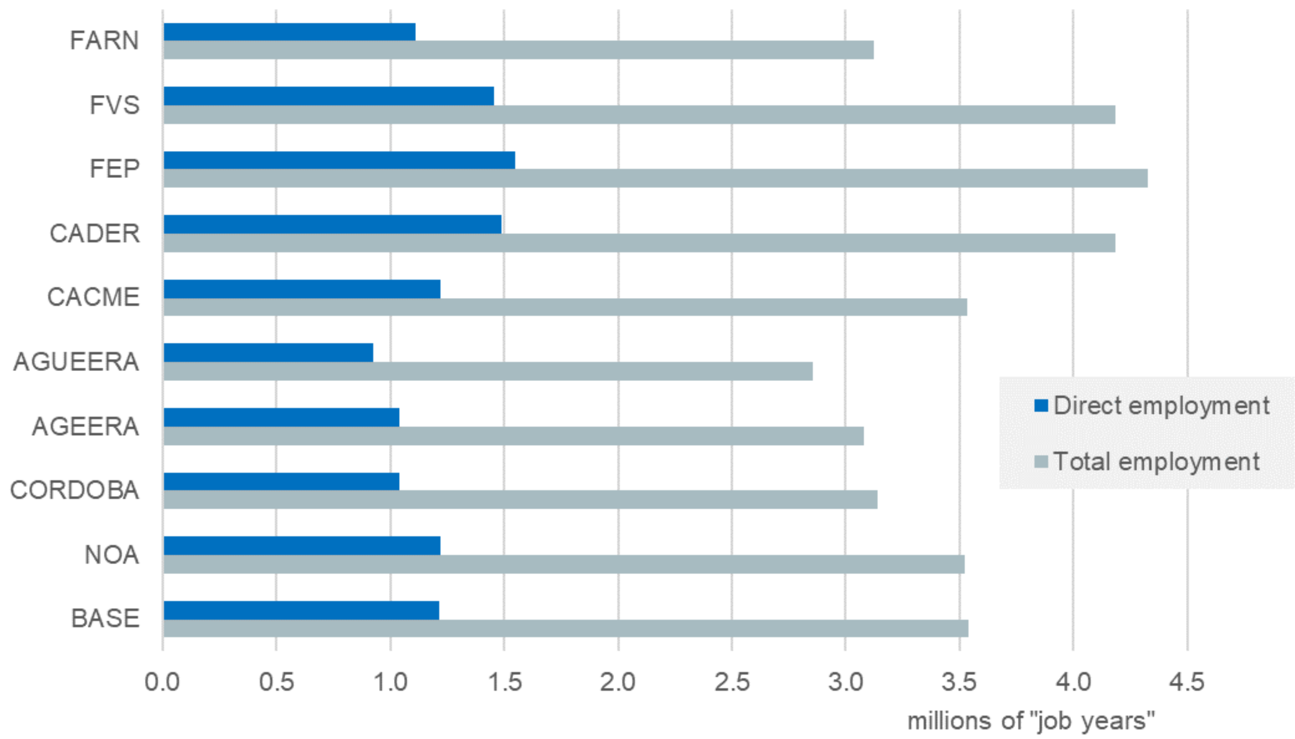


Figure 11 Direct and total (direct, indirect and induced) employment impacts for different electricity supply scenarios developed by stakeholders to the *Plataforma Escenarios Energéticos 2040*, estimated using NewClimate's EIM-ES. See the report for detailed descriptions of the different scenarios (Plataforma Escenarios Energéticos, 2018).

The highest employment impacts are in the FEP, CADER and FVS scenarios, all of which deploy relatively high levels of new renewable capacity. Employment impacts are lowest in the AGUEERA, AGEERA and CORDOBA scenarios, although these scenarios are also lower cost and have some of the lowest levels of overall electricity supply across the ten different pathways. When comparing the employment impacts per unit of investment and per unit of electricity generation, the differences between scenarios are less pronounced.

For policy makers to undertake a holistic evaluation of the merits of future pathways, they need to consider a number of factors alongside employment impacts, including cost, risks and the overall balance of the technology mix. According to our analysis, employment impacts for fossil fuel-based generation, such as natural gas-fired power plants, are relatively similar to employment impacts for renewable options, such as wind and solar PV, when compared per unit of investment or unit of electricity generation. Critically, however, Argentina has signed up to the Paris Agreement and will need to fully decarbonise the electricity supply sector in the medium term. Creating new jobs today in conventional and unconventional natural gas-based electricity generation (including in the fuel supply chain) means that at some point these workers will need to re-train, and possibly relocate, to continue working in other sectors once natural gas is phased out of the energy mix both in Argentina as well as other countries which may provide short-term export market opportunities for Argentina's natural gas reserves. Re-training and relocating parts of the labour force can be extremely costly for the government, both in terms of offering support to workers and, in some cases, welfare payments, as well as in terms of reduced tax revenues. Phasing out domestic industries can also lead to social challenges, which are likely most pronounced where the phase-out is rapid and poorly planned. In contrast, creating new jobs today in renewable electricity generation technologies presents much less of a risk in terms of the skills and experience of these workers longer being needed at some point in the coming decades.

4.3.2 Industrial development

Interviews with industry experts, complemented by our literature review, identified the potential to increase the local content share in Argentina for a selection of component parts that make up the total required investment in wind and solar PV generation.

4.3.2.1 Wind

For wind power the components with greatest potential to increase the local content share include raising the average spending in Argentina on nacelles from just over 10% of the total investment today to close to 50% in the medium-term, doubling the local content share of blades from 10% to 20%, increasing the local content share of the electrical 'balance of plant' from approximately 50% to close to 90%, as well as increasing the share of domestic spending on finance, plant operation and maintenance. Figure 12 shows the estimates of the local content share for key component parts for wind in Argentina today ('base case') in grey and the higher potential local content share estimates over the medium-term in orange bars.

It is important to note that the potential local content shares are based on expert judgement of how the industrial supply chain for wind energy could feasibly develop in Argentina over the next 5-10 years. This allows us to analyse the impact of realising this potential on the economy in the event that supporting policies, a suitably attractive investment climate and a sufficiently resourced labour market, along with other enabling factors, are put in place. The potential local content shares neither represent a forecast, nor a prediction for the future.

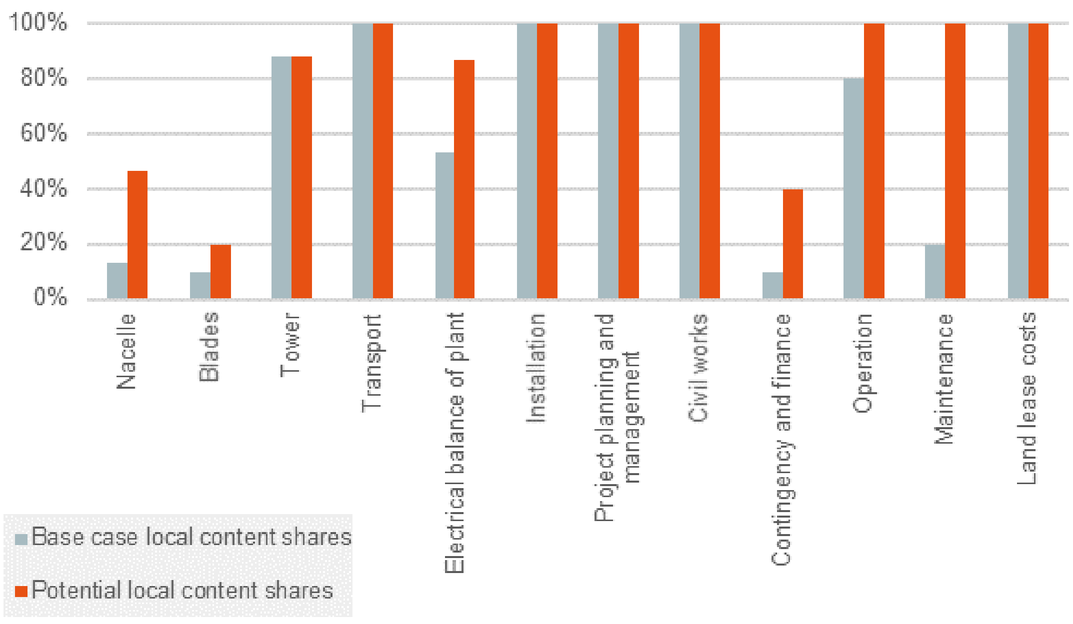


Figure 12 Base case (current) and potential medium-term local content shares for key component parts of investments in wind energy in Argentina

Higher local content shares for wind electricity generation component parts can materially increase both the domestic investment in Argentina as well as the value added to the economy of the expected investments in building new capacity as well as the operation and maintenance of new and existing plants. Our analysis estimates the economic impacts of five future pathways for the electricity sector, first with current estimates of the local content share of investments for all technologies and then again with estimates of the (higher) potential local content share for wind generation over the medium-term, keeping all other inputs the same. The five scenarios we analyse are those developed as part of the CAT Scaling Up work series (Climate Action Tracker, 2019c). They include a current development scenario (CDS); a scenario of planned policies based on 'MINEM Energy Scenarios' (MINEM); a Paris Agreement-compatible scenario (Paris); and two national scenarios, which match those developed by the Political Ecology Forum (FEP) and the Argentinian Association of Large Electricity Consumers (AGUEERA) under the Plataforma initiative.

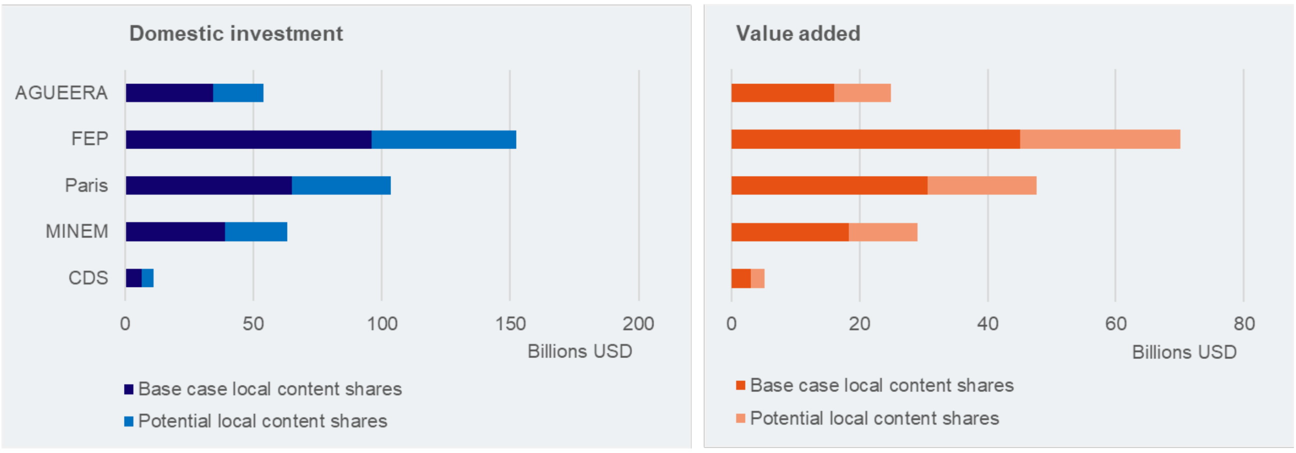


Figure 13 Range of investment and value-added impacts in Argentina under different scenarios with current and potential local content shares for spending on wind generation over the period to 2050. Values shown include direct, indirect and induced impacts.

In Figure 13, we show the total domestic investment as well as the value added from spending directed towards the wind sector under the five different scenarios. The darker shaded parts of the bars show the values based on current local content shares for investments in the wind sector and the lighter shaded parts show the additional investment and value added under the higher potential local content shares for wind shown above in Figure 12.

Domestic investment on new wind capacity and the operation of both existing and new plants is highest in the FEP scenario. Based on current local content shares for all component parts, aggregated investment over the first half of the century is approximately 96 billion USD. Increasing the local content share of investments in the wind sector to potential levels would raise aggregated investment over the period to approximately 150 billion USD, or 1.6 times the level if local content shares remain unchanged. Domestic value added, as well as employment levels, would rise by a similar order of magnitude. Under the Paris-compatible scenario, the domestic investment from spending on the wind sector could rise from approximately 65 billion USD to just over 100 billion USD over the period if local content shares were increased to their potential level, with economic value added increasing from approximately 30 billion USD to almost 50 billion USD.

The analysis therefore signals a possible opportunity to materially raise investment levels in Argentina through putting in place favourable conditions to boost local content shares for wind generation to their potential levels. The opportunities are most pronounced in future scenarios with a higher uptake of wind in the energy mix. As noted above, however, any policy decisions to focus on developing the sector domestically should factor in wider considerations related to the likely impact on the costs of building and operating electricity generation installations and ultimately electricity prices. This analysis provides an initial, high-level assessment of the potential opportunity for enhancing domestic investment. The appraisal of policies in this area would certainly benefit from a more detailed and comprehensive analytical exploration of Argentina's competitive position in regional and global markets for different component parts.

4.3.2.2 Solar

We also carried out similar analysis for the solar PV sector in Argentina where the market experts we surveyed identified potential to increase the local content share, particularly amongst investments in grid connections and the balance of system costs, as well as in the maintenance of the plants. The Paris-compatible scenario includes extensive roll-out of new solar PV in Argentina and is the scenario with the highest domestic investment across the five that we analysed. Total direct, indirect and induced domestic investment from spending on the solar PV sector in the Paris-compatible scenario is approximately 45 billion USD under current local content share assumptions over the period to 2050. This rises to approximately 76 billion USD, or 1.7 times as high, under higher potential local content share assumptions. Economic value added in Argentina over the same time horizon from these investments in the solar PV sector is approximately 21 billion USD, assuming local content shares continue at their current level, and rises to an estimated 36 billion USD under higher potential local content shares for the sector.

5. Achieving power system transformation

Argentina has a large potential to increase the participation of renewables in its electricity generation mix and drive the decarbonisation of the economy. The transition to a cleaner and more efficient power system, based on the substantial deployment of non-conventional renewable sources (e.g. wind and solar), challenges the traditional way to plan and operate the system. A deep understanding of the power system transformation and the challenges that it entails are key to identify actions and design policies that guide the transition in the sector.

The A2A project team developed an assessment framework that aims to support policy makers and planners in the energy sector to get a deeper understanding of the power sector transformation required (De Vivero, Burges, Kurdziel, & Hagemann, 2019).[5] The framework intends to identify common challenges that arise in different countries that have embarked on the power system transformation and that are struggling to integrate variable renewable energy sources (vRES) into the grid. It furthermore assesses potential solutions to these challenges and encourages peer learning.

The approach builds on the idea that countries will likely face similar challenges in each phase of the power system transformation, and that differences between countries can be described by a set of characteristics. Countries with similar characteristics will likely face similar challenges in each phase and will likely be able to apply similar solutions. To facilitate peer learning on this basis, the assessment contains eight case studies of countries with representative local conditions and that are at different phases of the transformation process, including Argentina.

5.1 The power system transformation framework

The main challenge of the energy transitions is that vRES have specific characteristics (when compared to conventional energy sources) that lead to specific technical challenges as countries start to integrate vRES into existing power grids. In the framework presented here, these challenges and potential solutions are structured around six phases of the integration process. They are shaped by country-specific geographical and socio-economic characteristics which may determine the starting point, speed and scale of the power system transformation (see Figure 14).

[5] The full report can be downloaded at: https://newclimate.org/2019/10/02/transition-towards-a-decarbonised-electricity-sector/.

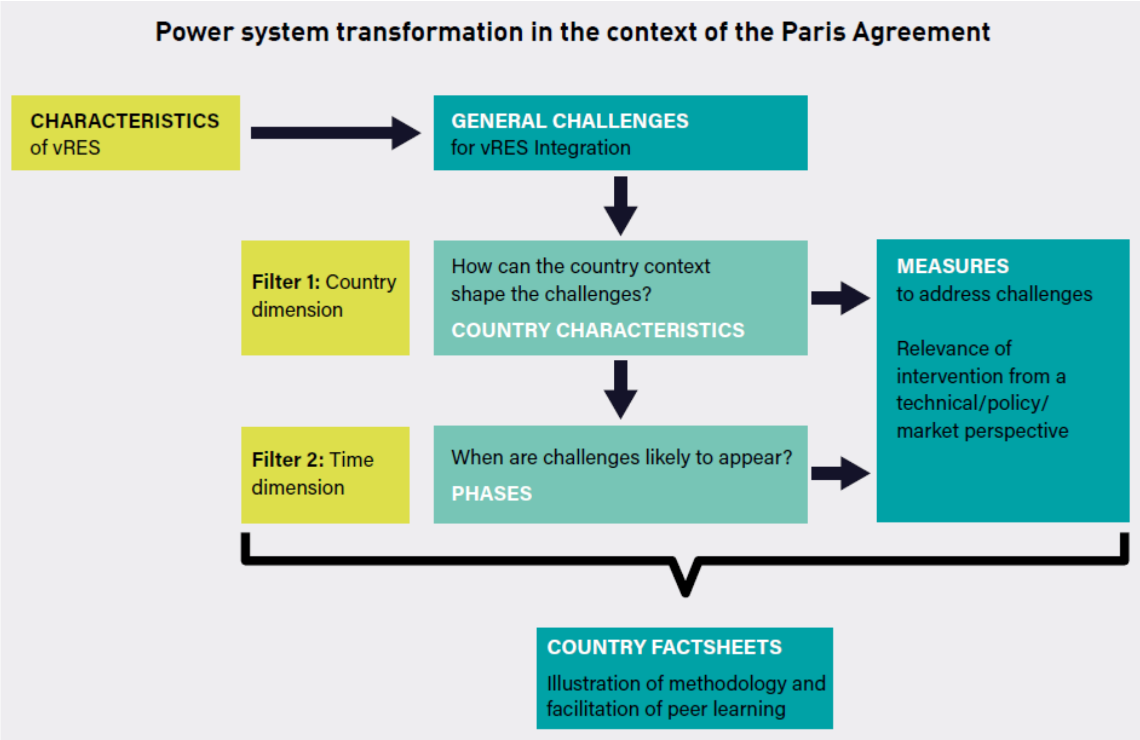


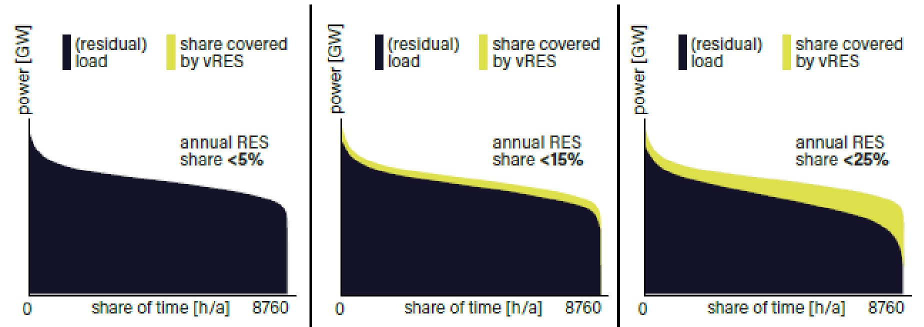
Figure 14: Overview of components of the assessment framework

VRES characteristics

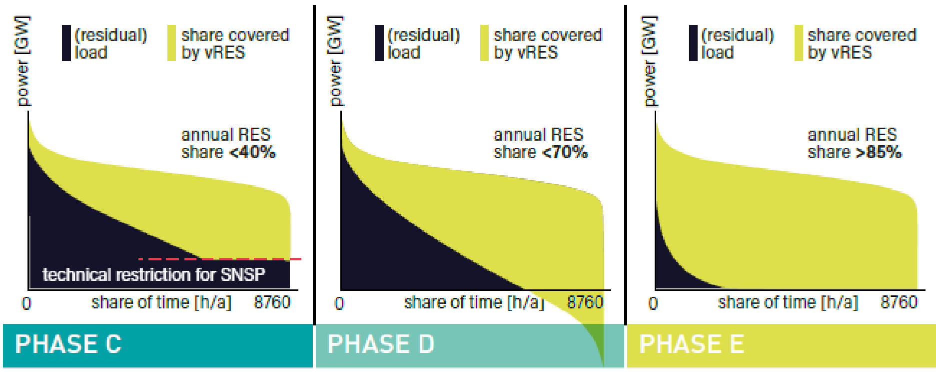
The increasing vRES penetration in a power system gives rise to specific challenges in power system planning and operation that must be tackled adequately during the power system transformation process. Many of these challenges can be attributed to specific characteristics of vRES, such as the fluctuating nature of wind and solar resources, their limited forecasting accuracy or the fact that large vRES capacity is often installed in remote locations.

Phases

The power system transformation process can be structured around different phases that mark the steps of increasing shares of vRES in the generation mix and the specific configuration of the power system along the transformation process. Six phases of power system transformation can be distinguished, with separate implications for power system planning and operation (see Figure 15).



	PHASE 0	PHASE A	PHASE B
Phase description	Negligible amounts of vRES and no systemic effects	First systemic effects of vRES can be observed	Temporarily substantial shares of load are covered by vRES
Impact on the Load Duration Curve (LDC)	Negligible changes.	vRES starts to contribute to load (area in light blue), residual load starts to decrease (area in dark blue).	vRES share in load becomes significant at certain times (right side of the graph), while remaining low in others (left side).
Impact on system configu-ration and operation	Negligible challenges.	Standard concepts of power operation are still sufficient. Power system planning needs to anticipate the upcoming transition.	Due to the fluctuating character of vRES, the share in load coverage at particular time differs. At this point, changes in hourly generation become more extreme.



PHASE C	PHASE D	PHASE E
System operation with temporarily high SNSP limits; system can reach technology restrictions	High load coverage by vRES over many hours	High shares of vRES in load coverage (80+% scenarios)
vRES share increases and becomes significant more often (right side drop increases); SNSP restriction limits maximum instantaneous vRES share (horizontal line).	Periods with zero or negative residual load increase (green area below the x-axis).	Load shifting through storage and/or sector coupling allows reaching greater levels of vRES shares while minimising uneconomic RE curtailment and negative residual load.
SNSP restrictions imply curtailment of vRES whenever its instantaneous generation share exceeds the SNSP limit (horizontal line). As long as the SNSP restriction is not resolved, increasing vRES capacity leads to increased curtailment, not to increased vRES shares.	The system is not able to absorb the excess of power generated, leading to negative residual load. This may occasionally happen in phase C. However, in phase D the occurrences and associated volumes of electricity are significantly higher. Curtailment is no longer economically viable.	The transformation process approaches the target system: an economically viable, technically reliable and secure, and sustainable power system operating at carbon levels close to zero. vRES generation must be combined with seasonal storage, extended interconnections, sector coupling and/or RE-based energy chemical carriers (e.g. synthetic gas).

Figure 15: 6 Phases of power system transformation and their influence on the Load Duration Curve (LDC)

Country characteristics

Individual country characteristics can furthermore shape the way in which the challenges related to increased shares of vRES in a power system influence the further integration of vRES. Certain characteristics may be favourable for the integration of vRES, while others may be only moderately favourable or unfavourable for the integration of vRES.

A set of five relevant characteristics may have an effect on power systems and the transformation process in the long run:

- Availability and potential of dispatchable renewable energy sources
- Patterns of renewable resources in time (seasonal ratio of solar)
- Trend of load growth
- Density and distribution of population
- Interconnection to directly neighbouring countries

These country characteristics may accentuate or alleviate the respective challenges faced at a given share of vRES in the system. For instance, low availability of dRES may increase load balancing and reserve challenges, while the presence of interconnectors may ease this challenge.

Measures

The power sector transformation process must be accompanied and stimulated by country-specific policy frameworks and implemented through targeted measures. At early stages of the power sector transformation process, supportive policies are required to create an enabling environment for the development and uptake of vRES in a country. The challenge lies primarily in stimulating investments, for example through the design of supportive renewable energy financing or de-risking mechanisms. A different set of policies is needed to guide the implementation of the necessary measures to support the technical integration of vRES into the existing grid. While various enabling policies have proven successful in supporting the development and uptake of vRES, there is less clarity on universally applicable policy frameworks to accompany the successful integration of vRES. Yet, as indicated above, many of the mostly technical challenges encountered during the integration process are, influenced by country specific characteristics, comparable across countries, and can be addressed by similar measures. A set of exemplary measures to address the challenges encountered in the different phases are highlighted in our main report on power system transformation (De Vivero et al., 2019). These measures do not provide a one-size-fits-all recipe for vRES integration. Rather, the applicability and effectiveness of the measures must be assessed on an individual country and system basis.

5.2 Power system transformation in Argentina

Country characteristics play a decisive role in the shape and speed of the transformation process of the power system in each country. An understanding of the characteristics of the Argentinean power system, as highlighted in Section 3, is the starting point for identifying potential barriers and opportunities in moving towards a decarbonized power sector.

The substantial participation of hydro resources lessens the need to rely entirely on variable renewable resources (vRES) to decarbonise the power sector. Moreover, the availability of existing hydro power generation, which is dispatchable, provides the system with valuable flexibility needed to integrate higher shares of vRES, especially in the first and middle phases of the power system transformation process.

The low population density outside the largest cities and concentration of the demand around populous urban centres result in a grid that is meshed and concentrated in the greater Buenos Aires area and weakly developed in the southern and western parts of the country, where wind and solar resource potentials respectively are more favourable. In addition, the long distances to the existing hydroelectric capacities is another factor leading to a sparse transmission network. Large-scale deployment of the remote solar and wind resources will inevitably trigger network reinforcements.

Argentina and Uruguay together form a synchronous electrical island. Power exchanges with Paraguay and Chile are marginal and the interconnection to Brazil are based on non-synchronous, HVDC technology. These current conditions of the grid limit the potential of the grid to balance the system with neighbours, especially when the penetration of renewables is substantial in later stages of the transition process.

5.2.1 Status and challenges of power system transformation

The relatively small penetration of vRES in the Argentinean power system currently does not significantly affect the day to day operation of the system. However, given the observed and foreseen rapid increase in vRES, Argentina is rapidly moving from phase A to phase B in the power sector transformation process (see Figure 15 for an overview of the phases).

Forecasting tools are necessary and currently being introduced in system operations by CAMMESA[6]. Such tools are already implemented in other systems around the world, supporting a smooth and reliable integration of vRES, including in Spain, Demark and Germany. Argentina can learn from their experiences and implement forecasting tools adjusted to the country's conditions. In the coming years, CAMMESA will support operators to replace **automatic generation control (AGC)** coordinating the real time output of dispatchable plants with the current, manual dispatch. This is a precondition for maintaining efficient and reliable system operations with increasing shares of vRES starting from phase B.

Furthermore, Argentina's hydro resources facilitate the integration of vRES into the system by providing flexibility in the generation of electricity. Hydropower generation can support the system to cope with vRES variability. At the same time, electricity generation through wind and solar resources can contribute to keep hydro reservoirs at higher levels, so that these can be used in circumstances when vRES are not available.

The growth in electricity demand can open room for installing additional renewable installed capacity without affecting the normal operation of the system (except for the size of the grid, which needs to increase accordingly). However, this also means that additional installed renewable capacity does not necessarily lead to increasing shares of vRES, unless its growth rate is greater than the demand growth. Similarly, if the latter is not the case, total emissions in the sector will likely increase with growing demand. While a constant growth in demand, as it is the case in Argentina, facilitates the installation of vRES capacity, it also requires a

[6]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.

larger effort to expand renewables. In any case, a load growth inevitably leads to a **need to expand the grid**, which is currently Argentina's main challenge in the transition from phase A to phase B.

The limitations in the grid to transfer electricity to major load centres are already restricting the further deployment of vRES. Renewable projects are facing major delays due to financial difficulties and grid-related limitations. The auctions of large-scale renewable projects (RenovAr), which are the main mechanism to guide the development of vRES in Argentina, are suspended until grid limitations are resolved (Bellato, 2018; Bellini, 2019b).

Substantial **grid infrastructure and transmission investments as well as grid management upgrades** are key to guide the transformation towards a predominantly renewables-based electricity supply sector. **Coordinated long-term planning of generation and transmission** allows for a better understanding of improvements needed in grid infrastructure, as well the resulting investment and technical assistance needs to guide the transition towards a decarbonised energy system. Argentina aims to expand the transmission grid by means of centrally organised tenders under a Public-Private Partnership (PPP) scheme to build high voltage transmission lines linking supply and demand centres.

5.2.2 Potential measures to support the transformation

A wide set of measures for vRES integration already exists in various country contexts, which can be adjusted to Argentina's conditions and characteristics to accompany the transformation into a renewable-based power system. Measures to integrate the initial shares of vRES require relatively low effort and are already available. In the Argentinean case, relevant measures to implement in the near future include forecasting tools and automatic generation control (AGC).

Although Argentina needs to overcome its major challenge of grid limitations to advance the integration of vRES, policy makers should start thinking ahead of the potential challenges that may emerge in more advanced phases of the transformation process. Such forward-looking planning includes adjustments in control and monitoring operations during the earlier stages of the process, defining the role of gas in the transition process, introducing market design concepts and enhanced system infrastructure flexibility, as well as planning the advanced stages in areas such as storage and sector coupling.

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. 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 not only mitigates stability risks but also contributes to the integration of vRES by providing flexibility to the system. 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 today.

As Argentina gets closer to phase C, hydropower will become more relevant as an already available resource that may contribute to overcoming system non-synchronous penetration (SNSP) limitations. At this stage in the transformation process, regional integration with neighbouring countries will also be beneficial to cope with stronger fluctuations and overcome SNSP limitations.

In more advanced stages beyond phase C, the role of current gas-fired power plants should be revised. The constant growth in demand makes continued operation of gas-fired power plants necessary in the short- and medium-term. However, no new gas power plants are needed, and future load growth should be met with renewable sources to achieve a low carbon transition and minimise the risk of stranded assets. In advanced phases, already existing small and medium size gas power plants could adapt their operating mode and play a role as peaking units. Multiple systems around the world have encouraged the adaptation of fossil-fuel based power plants to more flexible operation modes in order to facilitate the integration of vRES, including in Germany and California. In a renewable-based system, peaking units are more valuable to provide reliability and adequacy to the system to meet peak load during few hours a year than for the generation of electricity only.

In the final phases of the power system transformation process, Argentina must develop strategies to integrate vast amounts of vRES in an efficient and economic manner. The electrification of end-use sectors such as transport and industry can contribute to absorbing the surplus of vRES. Furthermore, Argentina counts with attractive conditions to develop hydrogen or synthetic fuel industries based on renewable power. The wind speeds in the south of the country are one of the best in the world and their relative uniformity throughout the year could provide electrolyser capacities that ensure high utilisation rates, offering significant flexibility to the system. To avoid stranded investments and to achieve higher utilisation rates, Argentina could convert gas infrastructure, including the remaining conventional gas plants, to operate on hydrogen. Teske et al. (2015) assume in their Paris-compatible scenarios that Argentina will generate 30% of its electricity from dispatchable plants based on hydrogen or synthetic fuel by 2050. These conditions have the potential to make Argentina a world leader in hydrogen production based on renewable power generation, supplying local energy demands and the export markets.

As a country moves forward with the integration of vRES, flexibility becomes a key enabler. Policies need to evolve and system operation must be modified pro-actively, enabling the system to adapt to the changes initiated by the transformation and guiding the integration of vRES. Adjustments in the market design can also encourage and value flexibility, which in turn can facilitate the integration of vRES. For instance, Argentina could take advantage of its zonal/nodal pricing scheme by adjusting it: under the current market design, locational prices are fixed for long periods of time according to predefined factors. Flexibility could be enhanced by adjusting the locational pricing scheme to respond to the needs and actual operation of the system (e.g. variations in the power flows as result of increased penetration of vRES in specific nodes, grid congestions and vRES availability in different regions). This could also prevent the concentration of projects in the same region and encourage installation of vRES plants where it is beneficial for the system.

6. Conclusions

In recent years Argentina has significantly advanced the institutionalisation of climate policy in national planning processes. The inter-ministerial committee on climate change and the climate focal points at line ministry level have been steering and coordinating NDC implementation and NDC review at the sector and national levels. Processes to develop long term strategies (LTS) – as mandated in the Paris Agreement – have been initiated in the energy and agriculture sectors, the key sectors for Argentina from a climate change perspective. It will now be important to build on these achievements to further institutionalise NDC and LTS planning processes in order to enable the full implementation of the current policies and targets as well as to research, debate and eventually drive a process for a step-wise increase in the level of ambition in line with the goals of the Paris Agreement.

Important modelling exercises have been conducted in recent years so as to develop a clearer view on how the energy sector may evolve. In 2019, a dialogue process in the energy sector concluded in a 2050 vision for the sector (“*Hacia una Visión Compartida de la Transición Energética Argentina al 2050*”) which provides an excellent basis to deepen the exercise by adding a quantitative perspective. Any such exercise would benefit from and can build on the experiences gained under the *Plataforma Escenarios Energeticos* initiative, which brought together key sector stakeholders to develop quantified 2040 scenarios for the energy sector. In this context, it will be important to also introduce scenarios that aim for the alignment with the Paris temperature goal to enable a discussion on what this means for the sector and the economy in the long-term. Expanding and deepening the dialogue on the challenge of long-term decarbonisation can provide the necessary basis to introduce and implement future-proof policies supported by a broad stakeholder base. Equally, such exercise and knowledge are critical to inform investment decisions, in particular those on long-life infrastructure to reduce carbon lock-in and stranded asset risks.

From a climate policy perspective, it is important to frame the recurring NDC target setting in the context of the long-term decarbonisation goal. Linking short- and medium-term NDC targets with the long-term perspective ensures that the incremental bottom up NDC process does not lose sight of the ambitious end goal. Although full decarbonisation is a daunting challenge for any country, understanding what it would mean to achieve the transformation in terms of resources, investments and structural change is fundamental to inform decision making. It also increases chances of attracting international support and investment, in particular as investors – both public and private – are increasingly seeking to align their portfolios with the Paris Agreement goals. Policy makers need to gain a better understanding of how much of the transformation effort can be achieved through domestic budgets and finance, considering also wider economic benefits, and where additional international finance, technology transfer and capacity building may be needed.

Important benefits can be realised in the transition of the economy. The analysis of employment and industrial development impacts in the power sector undertaken as part of this project highlight the potentials in this regard. For example, the power sector transformation presents opportunities for Argentina to seize regional (and global) technology leadership in the development and commercialisation of renewables-based hydrogen and synthetic fuels. The renewable energy sector will require new skills and provide higher quality, future-proof jobs compared to the fossil fuel sector. In contrast, communities which currently rely on fossil-based industries may need to be compensated and accompanied by policy interventions to ensure a socially just transition. Here again, it is critical to gain a deeper understanding of the wider socio-economic impacts of different pathways in order to enable policy interventions which maximise benefits and soften potential negative implications.

In the energy supply sector, in particular the power sector, the new Renewable Energy Law and the implementation of the *RenovAR* auction scheme have been important steps to increase the participation of renewable energy sources in the current system. The further integration of variable renewables (vRES) at increasing scale is important to drive the decarbonisation of the energy supply sector, which in turn is fundamental to decarbonise key demand sectors, in particular transport and buildings. A deep understanding of the challenges arising in the power system transformation process is important for the design of efficient and effective system operation tools and adequate policies to integrate higher shares of vRES. In the Argentinean case, grid limitations are the prominent short-term challenge to increase the participation of renewables in the system. However, other conditions, such as the availability of hydro resources and the existence of technology and practices already implemented in other systems should allow Argentina to integrate smaller shares of vRES with relatively little effort.

The integration of higher shares of vRES in later phases (e.g. more than 30%) present more challenging obstacles. These include, for instance, the institutional challenges to drive sector coupling, the risks associated with technologies that are not yet mature and the resistance to deeper structural changes in the policy framework and market design. However, this shall not hinder the progress in the earlier phases, and actions should focus on the identification of challenges and long-term planning to mitigate their risk. Deeper analysis of transformation needs and response strategies can support policy makers to timely plan the power system transformation, anticipate the main challenges of vRES integration and identify appropriate measures and policies for their solution.

Lastly, it will be important for Argentina to consider the long-term implications of the Paris Agreement goals for the gas sector which is currently an important pillar of the national energy system and economy. Investments into new gas infrastructure, including the further exploration of new gas resources of *Vaca Muerta*, bear significant financial and economic risks which need to be understood well. Implementation of stringent climate policies at global scale will eventually limit the demand for natural gas, turning current investments into potential stranded assets. The opportunity costs for the exploration of new fossil resources and the development of the associated infrastructure are significant. Public funds may be better oriented towards climate proof investments and opportunities.

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