2. Nuclear energy and energy efficiency in Argentina

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Nuclear energy has a long history in Argentina, backed by sustained government intervention and support that has made it a dynamic sector of the economy. Argentina is now at the centre of nuclear innovation, as one of the leading countries in the development of small modular reactors (SMRs).

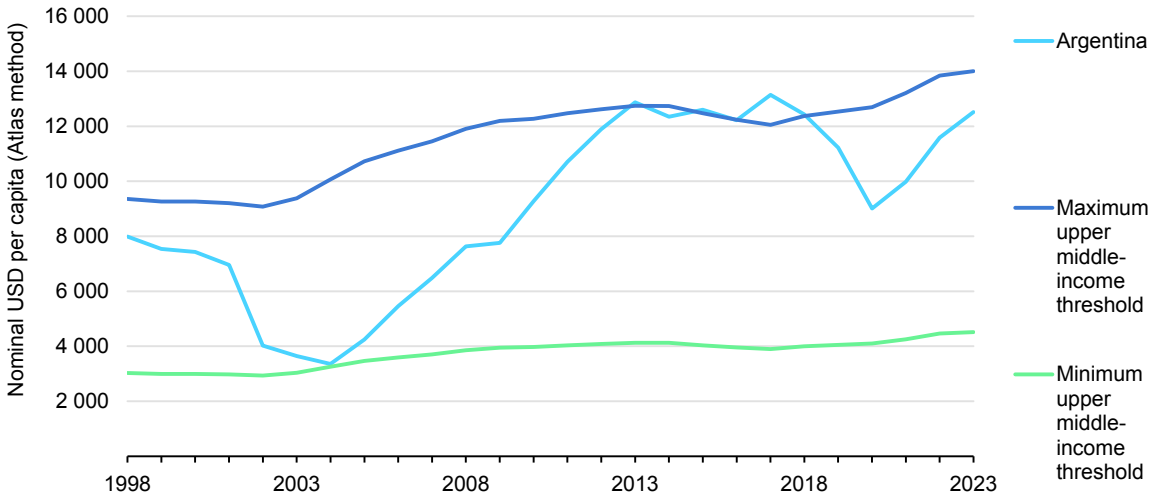
In contrast, energy efficiency only became a policy target in 1999. Since then, there have been several measures aimed at different sectors, but these have largely been "stop-go" policies, strongly dependent on the economic cycle. Beyond the nuclear industry, there has been limited sustained focus on clean energy technological innovation, the creation of specialised institutions or human resources. While public sector bodies in the oil and gas sector have well-developed research capabilities, the technical know-how does not overlap strongly with nuclear, buildings energy efficiency or mass-manufactured clean energy products. However, it could nonetheless be a platform for innovation in adjacent areas such as hydrogen or carbon capture if they became a domestic priority.

Policies in the two spheres, nuclear energy and energy efficiency, have followed very different paths, not least in terms of their duration, and comparing them can help deepen understanding of how energy policy is formulated and how it affects innovation. However, both policy approaches share the aim of developing domestic industry and increasing the share of national components in the value chain of the goods and services involved in the energy sector.

Country context

Argentina, Latin America's second-largest country by size, has undergone significant political shifts over the past century, vacillating between periods of economic growth and economic contraction. It has fluctuated between income classifications and, while it has been considered an upper middle-income country for most of this century, it has met the high-income definition at times and also come very close to being a lower middle-income country (Figure 2.1). Despite these fluctuations, it remains a member of the G20 group of advanced economies. Inflation has also risen steeply since 2021. In 2023 annual inflation was 254%, with monthly inflation recorded at more than 25%.

Figure 2.1 Gross national income per capita, and thresholds for income level classification, Argentina, 1998-2023



Sources: IEA analysis based on World Bank (2024) GNI per capita, Atlas method (current US$) - Argentina and World Bank Country and Lending Groups.

The Argentinian economy is characterised by significant external indebtedness, which in 2020 reached more than 60% of gross national income, and the country has defaulted on its international sovereign debt several times in the past two decades. In 2022, ahead of a general election in October 2023, the government secured a deal with the International Monetary Fund to restructure its debt of more than USD 44 billion.

In addition, its trade balance with the rest of the world has shown a sustained deficit over the years, with the exception of the period between 2002 and 2009. In the most severe years, the current account deficit within the balance of payments has reached 5% of the country's GDP. In 2022 Argentina's current account deficit stood at USD 4.3 billion. Argentina is ranked 26th globally for industrial production, and 45th in per-capita terms. The industrial sector (including construction) accounts for 24% of GDP.[1]

Argentina is currently classed as an upper middle-income country by the World Bank. Although the UNDP ranks the country as having "Very High Human Development", Argentina has serious problems at the macroeconomic level due to high productivity volatility, cycles of significant expansion and contraction, an international position as a supplier of products with low added value, high inflation rates, exchange rate volatility, institutional instability and problems with corruption,

[1] Estimated based on data from the World Bank World Development Indicators according to constant manufacturing value added at 2010 prices, averaged over 2010-2022.

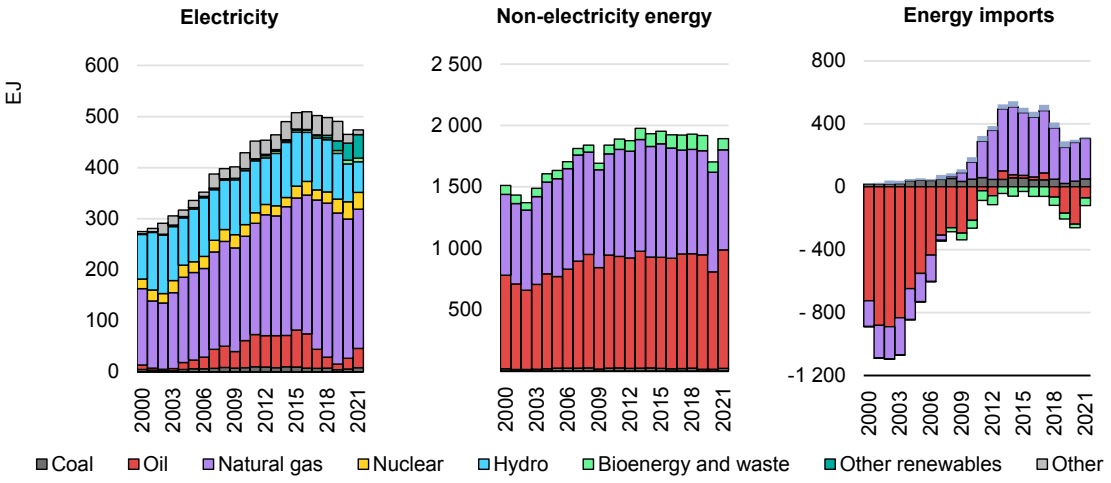
among other issues. Evidence points to significant inequality of income distribution and the worsening of already high rates of poverty after the Covid-19 pandemic.

Faced with this fragile economic outlook, the government that took office on 10 December 2023 is implementing a policy and stabilisation plan that encompasses a range of monetary, exchange rate, productivity and fiscal measures.

Energy sector context

Argentina's energy consumption increased steadily between 1970 and 2016, but has since slightly decreased. The energy mix is highly dependent on fossil fuels, especially natural gas and oil, and also relies on nuclear power and hydropower, albeit to a far lesser extent. The promotion of solar and wind energy began in the 1990s, with the results only becoming visible in the energy supply data from 2010. They currently represent only a small share of primary supply. In 2021, 24% of electricity generation was from renewables, of which half was large hydropower. Energy intensity remained relatively stable over the same period.

Figure 2.2 Energy sources for electricity and other uses, and level of imports, Argentina, 2000-2021



Notes: Electricity and non-electricity energy are shown on a final consumption basis. Imports are shown net of exports. "Other" refers to imported or exported electricity.
Source: IEA (2024), World Energy Balances.

In 2022 Argentina ranked 33rd in the world for total CO_2 emissions, producing 184 Mt CO_2. However, in terms of total GHG emissions, Argentina ranked 27th with 383 Mt CO_2-eq, reflecting the significant impact of the agricultural and livestock sectors, which contribute 37% of the country's GHG emissions, well above the global average of 12%. In terms of per-capita CO_2 emissions from fossil fuels and industry, Argentina ranked 92nd in the world with 4.3 t CO_2 per capita.

Argentina ratified the Paris Agreement in 2016 and numerous policies have been initiated to support the transition to a cleaner and more flexible energy system in recent years, and to increase the transparency of information on the energy sector. In its latest NDC, submitted in 2021, Argentina committed to emit no more than 359 Mt CO_2-eq in the year 2030.

Notable policy initiatives include the Energy Scenarios 2030 initiative, which is led by the Undersecretary of Energy Planning. This began in 2016 with the aim of setting a long-term vision for energy policy. More recently, the Guidelines for an Energy Transition Plan to 2030 have shaped Argentina's vision for energy policy. When the Energy Transition Plan 2030 (which was based on the guidelines) was approved in 2023, it set targets to:

- Not exceed net emissions of 349 Mt CO_2-eq in 2030.
- Reduce energy demand by 8%.
- Reach more than 50% renewable energy as a proportion of electricity generation.
- Achieve EV penetration of 2% of the vehicle fleet.
- Reach 1 GW of distributed renewable power capacity.
- Increase the high-voltage electrical transmission network by 5 000 km.

The plan also includes qualitative goals such as local development of the clean energy technology value chain and job creation, a reduction in energy poverty, and promotion of a just energy transition. Energy efficiency, clean energy and the development of national technological capacity account for three of the nine strategic lines included in the plan.

Innovation context

Argentina has a dynamic scientific sector, predominantly based in public institutions, and the number of full-time researchers has tripled in the past decade. Articles in scientific and technical publications in Argentina increased by 40% between 2008 and 2018.

According to the World Intellectual Property Organization, Argentina ranked 73rd in the Global Innovation Index Globalin 2023, and 6th at regional level. It ranked 18th among the 34 economies in the upper middle-income group – a relatively low result given its level of development. However, it performs above the regional average on human capital and research, infrastructure, business sophistication, and knowledge and technology products. Various indexes note that Argentina has a strong skills base, market size and ability to innovate, although poor macroeconomic stability and the functioning of markets and institutions negatively impact its overall competitiveness.

In 2019 investment in R&D in Argentina was Argentine Pesos (ARS) 96 664 million (equivalent to USD 1.6 billion as of 31 December 2019), of

which 39.1% was accounted for by public science organisations, 22.3% by public universities, 36.1% by private companies, and the remaining 2.5% by private universities and non-profit entities. Total investment represented 0.46% of GDP in the same year (0.28% public investment and 0.18% private investment). In 2021 the Law on Financing National Science, Technology and Innovation proposes to gradually increase public investment in R&D to 1% of GDP by 2032.

Since 2003 science and technology policy at the national level has focused on priorities for economic development, such as renewable energy, the rational use of energy and technological advances in oil and gas. The Green Productive Plan, launched in 2021, aims to develop domestic business in the green economy, and the Productive Argentina Plan 2030, launched in 2022, sets out to develop the green economy for a just environmental transition. Although national government generally defines the direction of innovation policies, priorities are also determined at the provincial level.

The National Agency for the Promotion of Research, Technological Development and Innovation (Agencia I+D+i) is a decentralised body reporting to the Ministry of Science, Technology and Innovation, and has a key role in determining the direction of innovation through its funding calls. In addition, Y-TEC, a research company created by the National Scientific and Technical Research Council (CONICET) and the majority state-owned YPF oil and gas company, focuses on technology development in the oil and gas and chemicals sectors and plays a key role in directing investment in energy innovation. In recent years, Y-TEC has launched initiatives in the areas of carbon capture, utilisation and storage (CCUS), hydrogen and lithium-ion batteries

The case of innovation in nuclear energy technology in Argentina

Innovation in nuclear energy technology has a long history in Argentina, dating back to the formation in 1950 of the National Atomic Energy Commission (CNEA), created to promote R&D related to the peaceful use of nuclear energy. In addition, the Balseiro Institute, founded as the Instituto de Física de Bariloche in 1955, has been a locus for physics and nuclear energy research in Argentina ever since.

Building technological and innovation capacity in the nuclear sector has received sustained policy support and been regarded as an engine of economic development. With the exception of a short period in the 1990s, Argentina has had a remarkable degree of continuity in nuclear energy policy in spite of volatility in the economic and political landscape.

The nuclear sector is one of Argentina's most sophisticated technological clusters, making it a leader within the Latin American region and the wider world. This has

served different purposes, including the development of research reactors, large nuclear power plants, satellites, radars, the first prototype of the SMR, irradiation plants for industrial uses, uranium dioxide conversion, and nuclear medicine centres, among others.

One of the main aims of development in the nuclear sector has been to diversify the energy mix to support decarbonisation and improve energy security.

Historical milestones in nuclear energy innovation

Between the 1950s and 1970s a nuclear ecosystem began to take shape at CNEA scientific and technological facilities located across Argentina. CNEA started South America's first operational experimental reactor, the RA-1 Enrico Fermi, in 1958, built mainly using local technologies. The RA-1 pioneered the production of radioisotopes for medical and industrial use in Argentina, and is still used today for scientific purposes, including the testing of nuclear reactor materials and the development of medical therapies.

In 1968 construction began on what was to become Latin America's first nuclear power plant, Atucha I (Lima, Province of Buenos Aires, 362 MW), which was inaugurated in 1974. This was followed by Embalse (Córdoba, 648 MW) in 1983, and finally Atucha II (Lima, Province of Buenos Aires, 745 MW) in 2014. Construction of Atucha II began in 1980, but was halted between 1994 and 2006, when it was restarted as a result of renewed presidential support for nuclear development. All three nuclear power plants are pressurised heavy water reactors (PHWRs) operated by Nucleoeléctrica Argentina (NA-SA), which is majority owned by the Ministry of Economy and the CNEA. The reactors were built using technology imported from Germany (Siemens) for Atucha, and from Canada (CANDU) for Embalse. Local industry was behind most of the civil engineering, some of the assembly work and a small share of supplies; NA-SA prioritised using Argentine suppliers whenever possible and imported technology only when necessary. To facilitate this, it certified national companies to international standards, which also enabled them to bid for international tenders afterwards. The contract with the Canadian company, CANDU Energy, included technology transfer to the Argentine company IMPSA.

A key objective of nuclear innovation policy in the early years was to become self-sufficient by developing all the necessary technologies for the industrial production of key inputs in the nuclear fuel development cycle, including enriched uranium. This became a particularly pressing objective following the entry into force of the Nuclear Non-Proliferation Treaty in the 1970s.[2] Argentina's uranium enrichment plant was constructed by the public company INVAP for the CNEA and became

[2] Argentina signed the treaty in the 1990s.

operational in 1983, using gaseous diffusion technology, but was stopped in the late 1990s. In 2015 Argentina reactivated the plant, two decades after production was initially halted, but production ceased again in 2018. The plant has not been used for commercial or export purposes since.

In the 1970s Argentina began to evaluate the possibility of constructing an industrial plant to produce heavy water to supply PHWRs. The CNEA was authorised to start construction of a such a plant in 1979, and work began with the expectation of completion in 1983. However, the need to reduce the fiscal deficit in the 1980s put a halt to the project, which required a total investment of USD 1 billion. The plant was later commissioned in 1994 by ENSI (Empresa Neuiquina de Servicios de Ingeniería). This allowed Argentina to meet domestic demand for heavy water, which was also exported to Australia, Canada, France, Germany, Korea, Norway, Switzerland and the United States. In 2006, when Argentinian nuclear development again became a policy priority, the plant underwent improvement after years of budget restrictions. However, it has been idle since 2017 due to financial difficulties, and in 2021 Argentina imported heavy water. Most of the plant's workers have now left. Pre-commissioning or restarting the plant would be costly but would reduce import needs and open up export potential, including for heavy water needs in medical applications. Alternatives under consideration include converting the plant to produce ammonia-based fertilisers, including the possibility of using low-emissions hydrogen in the future.

Public participation in nuclear energy innovation

One of the distinctive characteristics of technological development and innovation in the Argentinian nuclear sector is the central role of the state in financing and promotion. This has led to the creation of a large number of public institutions, organisations and public–private partnerships within the sector. One key player is INVAP, a public company created in 1976 to commercialise knowledge developed in CNEA research centres. INVAP is owned by the province of Rio Negro and aims to be self-financing, but a large part of its activity is driven by requests from the CNEA. INVAP has established itself as a major exporter of nuclear research reactors, including multipurpose and medical research reactors, and has exported them to Algeria, Australia, Egypt and Peru. In January 2018 INVAP won an international tender worth USD 400 million to manufacture a research reactor for the Netherlands – the first time this type of technology had been exported to an EU member state. Large nuclear power plants are managed by NA-SA, which is state-owned. Research and development continues to be led by the CNEA, and since 1994 regulation has been overseen by the Nuclear Regulatory Authority.

Argentina has built significant research and innovation capacity in the nuclear sector, most prominently through the Balseiro Institute, a public institution, which

specialises in training scientists and technologists in the peaceful use of nuclear science. Student scholarships, funding and training opportunities have also helped to build a skilled workforce.

In 2022 a financing opportunity for companies active in the nuclear sector was added to the existing National Programme for the Development of Suppliers (PRODEPRO), which aimed to develop domestic supply in strategic sectors. Projects could receive grants of up to ARS 100 million (approximately USD 274 000), up to a limit of 75% of all financing.

A new era for nuclear innovation targets exports

The launch of the Argentina Nuclear Reactivation Plan in 2006 marked the start of a renewed push for nuclear innovation. The plan was behind the completion of the Atucha II nuclear power plant, and the extension of the Embalse plant's lifespan. The latter project, which began in 2015 and was completed in 2019, directly employed more than 3 000 people and fostered the development of highly qualified national suppliers of goods and services. The plant's useful lifetime was extended by 30 years.

Looking to the future, the plan also included a proposal to build the first prototype of an SMR, called CAREM, designed to produce 32 MW, or 9% of the capacity of the Atucha I plant. When construction began in 2014, led by the CNEA, the CAREM pressurised water reactor (PWR) was the first SMR project in the world to move from design to construction, demonstrating the strength of technological innovation in the Argentinian nuclear sector. In addition, unlike Argentina's existing nuclear power plants, CAREM would be entirely designed and developed domestically, using low-enrichment uranium as fuel, and light water as coolant and moderator, in a first for the country. As of 2024 the research prototype is expected to start operating between 2028 and 2030. The advances made to date are a result of a process of constant technological innovation in the national industry, from the development of the pressure vessel, classified and non-classified components, fuel, heat exchangers and overhead cranes and engineering work. It is expected that around 70% of inputs, components and related services will be provided by Argentine companies certified under the international quality standards supervised by the CNEA.

The Productive Argentina Plan 2030 sets out the aim of exporting the SMR technology at a scale of up to 100-120 MW for the international market. In addition, the CNEA is already working on a commercial design that, using the same technology, will integrate four 120 MW reactors in a medium-sized plant with a total capacity of 480 MW. This commercial model of CAREM is expected to cost USD 1.5 billion and to require two years for construction. The CNEA estimates that the commercial module will be able to produce energy at USD 80 or

USD 90 per MWh. This type of reactor could potentially bring grid-connected electricity to regions and places that are traditionally off-grid, as well as boosting the reliability of the power grid, especially for energy intensive sectors.

Despite having had government support since 2003, the CAREM project has faced interruptions in funding. This has resulted in uncertainty about completion, overall cost, the participation of the national industry and, above all, the probability that the CAREM prototype can be reproduced on a commercial scale. CAREM has two major challenges. One is technological, and relates to completing the prototype and demonstrating that the technology is scalable to a commercial model of four reactors. The other is to make the medium-sized 480 MW plant commercially viable by producing 1 MWh at a competitive cost. More than 80 SMR designs are under development by several companies worldwide, but only two are operational: one in the Russian Federation (hereafter "Russia") Russia (70 MW) and another in China (210 MW). While some reactors are under construction in Russia and China, most SMR technologies worldwide remain in the design phase, with around 22 GW planned as of Q1 2024, led by the United States with nearly 4 GW. In July 2024 Rolls Royce SMR advanced to stage 3 of the three-step Generic Design Assessment for its 470 MW SMR design in the United Kingdom. There SMR field includes prominent incumbents such as NuScale's light water SMR (United States, 77 MW per module), GE-Hitachi's BWRX-300 (United States/Japan, 300 MW), Nuward (France), Holtec International (United States, 300 MW) and Westinghouse AP300 SMR (United States, 300 MW), as well as numerous start-ups pursuing innovative designs. Both established players and emerging companies would be in direct competition with CAREM.

The Argentina Nuclear Reactivation Plan also set out to investigate the feasibility of a fourth nuclear power plant in order to expand the share of nuclear generation in the energy supply. Argentina has since begun negotiations to purchase a large 1 150 MW Hualong-type PWR plant from China, which would be called Atucha III. In 2014 the governments of Argentina and China signed a framework agreement to co-operate on economic initiatives, including the aforementioned nuclear power plant, but negotiations stalled, and in 2018 were cancelled by Argentina due to fiscal constraints. More recently, in 2022 Argentina signed a co-operation agreement in which China agreed to finance 85% of the project, representing an investment of USD 8 billion. However, this has not yet been implemented, with Argentina negotiating for China to finance a larger share of the project and to grant a licence to produce nuclear fuel domestically, ensuring subsequent knowledge transfer.

Technological leadership and international co-operation as a driver of development

Argentina's nuclear sector has become a paradigmatic example of the results of public policy focused on the accumulation of technological and innovative capacity. This has been underpinned by a Latin American perspective on science, technology and development that, since the late 1960s, has emphasised the need for states to strengthen scientific and technological infrastructure through active funding and infrastructure policies. This approach sought to align scientific and technological efforts with the interests and developmental objectives of the countries of the region, by advocating the co-ordination of three fundamental elements: government, industry, and scientific and technological infrastructure.

The success of this approach can be seen in the favourable environment created for the formation of a nuclear industrial complex in Argentina, and the establishment of scientific and technological institutions and specialised capacity to train experts in the field. Over the years, this has fostered an ecosystem of companies and institutions capable of producing components and final products with international nuclear certification, positioning Argentina as a leader in the nuclear sector both in Latin America and globally. Despite the macroeconomic challenges faced by Argentina and the implementation of fiscal adjustment measures since the mid-1980s, which led to cutbacks and interruptions in the nuclear industry, the country's strong skills base, the maintenance of a degree of autonomy and continuity of nuclear institutions and a forward-looking approach, both domestically and outwards, have enabled the nuclear industry to continue to progress.

In the 1970s Argentina and Brazil competed for regional leadership in nuclear technology, but in the 1980s their relationship began to shift towards co-operation. In 1985 the creation of the Argentine-Brazilian Permanent Committee on Nuclear Policy (CPPN) marked a turning point in bilateral nuclear relations. This co-operation deepened in 1991 with the creation of the Brazilian-Argentine Agency for Accounting and Control of Nuclear Materials (ABACC), the world's only bilateral and supranational safeguard organisation dedicated to the mutual verification of the peaceful use of nuclear materials. Taking their partnership further, the Binational Commission on Nuclear Energy (COBEN) was created in 2008 to promote bilateral co-operation on the development of multipurpose reactors. The evolution from competition to co-operation between Argentina and Brazil underscores a comprehensive integration in policy (CPPN), control (ABACC) and innovation (COBEN), characterised by sustained political dialogue, technical exchanges and mutual inspections of nuclear facilities, which together have transformed their nuclear relationship into a unique model of bilateral co-operation, including in innovation, with a combined weight that the two countries may not have achieved on their own.

The case of energy efficiency policies in Argentina

Energy efficiency in Argentina has gained support at a political level only relatively recently. Until the late 1990s energy policy largely centred on exploiting and exporting fossil resources. The first signs of a broader vision for energy policy appeared in 1999 with Resolution 319, which promoted appliance efficiency standards and labelling. Later, the Rational Use of Electric Energy Programme (PUREE), launched in 2004, and the National Programme for the Rational and Efficient Use of Energy (PRONUREE) launched in 2007, further contributed to shaping a national vision for energy efficiency in Argentina.

However, the economic crisis of the early 2000s had knock-on effects for energy supply, and when PRONUREE was launched, energy efficiency was thought of as just one of many measures to alleviate the energy crisis, and the programme faced implementation problems. Consequently, energy efficiency slipped off the agenda when the crisis was over.

Only in 2015 did energy efficiency begin to appear as a central axis of long-term public policies. The period of greatest transparency was between 2015 and 2018, at which time the Undersecretary of Energy Saving and Efficiency existed and periodically published reports on its activity.

Implementation

PRONUREE constitutes the general framework for the promotion of energy efficiency in Argentina. In the case of the residential sector, the main lines of action proposed by the programme in the short term were: promotion of an energy efficiency labelling regime and the implementation of minimum standards for the sale of equipment; education, awareness and information campaigns; and the replacement of incandescent light bulbs. As a result of the latter, 18 million low-energy light bulbs were distributed and 23 million incandescent light bulbs collected.

Different objectives were established for the medium and long term, including the decision to work with the Ministry of Science, Technology and Productive Innovation to promote development and technological innovation in materials and methods of construction for new housing. Improving construction materials has therefore become a primary policy target for innovation on energy efficiency in the medium and longer term. In general terms, the promotion of energy efficiency policies in the building sector is relatively recent. Appliance design has not been a major focus of energy efficiency policy, as appliances are typically imported or dependent on imported parts. Despite this, there have been equipment

replacement programmes such as the Programme to Promote the Production and Marketing of Energy Efficient Household Electrical Appliances (RENOVATE).

Different instruments have been used to promote energy efficiency policies, such as demand pull, knowledge management and resource push. However, energy efficiency policies have often been isolated actions that have not served to accelerate the overall effective improvement of energy efficiency.

Appliances, standards and labelling

Resolution 319, which was passed in 1999, only came into force (at least partially) in 2007 through a provision to establish the characteristics and minimum standards of energy efficiency for lighting. This delay in implementation was due to the lack of recognised testing laboratories capable of carrying out the required certification. Since 2007 the National Directorate of Internal Trade has validated different points of the resolution.

Within the framework of PRONUREE, in May 2010 the Argentine Institute of Standardization and Certification (IRAM) developed the IRAM Standard 11 900 “Heating energy efficiency label for buildings”. This establishes a methodology for calculating the level of energy efficiency of the building envelope that can be heated, with information presented on a label.

Based on the interest in improving the thermal envelope of buildings, the National Housing Labelling Programme was launched in October 2016. This has the objective of introducing energy efficiency labels to provide information on the energy performance of a dwelling, to support consumers looking to buy or sell their homes or undertake renovations. This programme is currently under development, with pilots in a few provinces.

Financial incentives

In the case of residential buildings, between 2004 and 2016 PUREE offered bonuses for those who reduced their electricity consumption. However, the programme was unsuccessful in creating incentives to save energy because electricity rates remained frozen from the start of the programme until 2007, and because it did not have an appropriate advertising campaign. In 2016 this initiative was replaced by a stimulus plan (Plan Estímulo), which aimed to incentivise energy saving.

Some fiscal incentives and soft loans provided by the government to industry are designed to improve the level of energy efficiency of industry in terms of its energy use. This means that they are usually not designed to promote improvements in materials or energy efficiency inputs. In many instances, industries belonging to the construction sector are not eligible for funding. One such example is the

Argentine Energy Efficiency Fund (FAEE), which was in force between 2014 and 2017 with the aim of enabling credit for technology improvements at manufacturers and processors of industrial products, service providers, agricultural and agro-industrial undertakings, and in the commercial, mining and tourism industries. However, some loans are available to the construction sector, such as a financing line from the Ministry of Productive Development for strategic investments aimed at medium-sized and large companies that want to acquire fixed assets, build or improve facilities to develop new products and create new production lines.

Looking ahead, industries in the construction sector will need access to financing in order to innovate and design new products that in the long term will help to optimise the country's energy consumption. This issue is due to be addressed by the current Green Productive Development Plan, which includes the consideration of measures to improve the energy efficiency of equipment and building sector materials, and deploy more smart devices.

Another recent initiative with the strong participation of government in public financing is the Competitiveness Support Programme for Micro, Small and Medium-sized Enterprises (PAC Empresas). The government grants a non-reimbursable contribution to cover a maximum of 70% of the project and up to ARS 3 million for business development projects that incorporate improvements in digital transformation, sustainable development, quality, design and innovation or export development. The sectors eligible comprise agriculture, manufacturing industry, trade, construction and services, but companies in the construction sector are assigned lower scores in the selection process. A specific area of innovation promoted by the programme is related to design, products and processes.

Support from international development banks has also encompassed energy efficiency initiatives. For instance, the Energy Efficiency Project funded by the Global Environment Facility (GEF) was approved in 2009, consisting of a donation of USD 15 million through the World Bank. In the context of a growing market for energy efficiency services and equipment, this project aimed to increase efficiency in the use of energy, and to contribute to the reduction of GHG emissions through the application of alternative energy sources. Some of the actions were aimed at replacing incandescent lighting with compact fluorescent lighting in the residential sector, as well as standardisation and labelling.

Participation in national and international initiatives to promote knowledge sharing

Argentina participates in several international alliances relevant to energy efficiency. It has been an associate member of the International Energy Agency since 2022 and participates in the Clean Energy Ministerial (CEM). It is also a

member of the Renewable Energy and Energy Efficiency Partnership (REEEP), International Partnership for Energy Efficiency Cooperation (IPEEC), and Three Percent Club for Energy Efficiency.

At the national level, the Portal of Energy Efficiency in Argentina network exists to link interested parties and spread information about events; any interested party can register.

Within the building sector, the innovation platform Transform and Innovate the Building Industry (TIIC), created by the Argentine Chamber of Construction, provides a forum for entrepreneurs and startups to present projects and ideas that can provide innovative solutions to problems in the construction industry. TIIC brings together companies in the construction industry with startups, universities and scientific centres, governments and venture capital funds. Its current call includes the area of sustainable construction. Some of the goals of the call are to achieve greater sustainability in conventional materials and to promote the development of new materials and techniques.

Argentina is also working with the European Union on several initiatives to promote knowledge-sharing. The project Mitigation of greenhouse gases and adaptation to the impacts of climate change in Latin America, funded by the EUROCLIMA+ programme, aims to strengthen policy and practice on energy efficiency through the transfer of knowledge between Argentina and Chile. The National Energy Efficiency Plan (PlaneeAR), which was first published in 2021, began in 2018 through co-operation between the European Union and the Secretary of Energy of Argentina. The plan includes guidelines for promoting energy efficiency actions in the industrial, transport and residential sectors, in line with emissions reduction targets for 2030/2040.

Assessment and learning, and next steps

Energy efficiency is a central pillar of Argentina's energy policy, although progress towards policy objectives is less easy to identify. Nevertheless, there has been an improvement in the enabling conditions for energy efficiency in recent years.

Massive public awareness campaigns have been carried out in the past decade, and awareness is growing, but public support remains weak. Energy efficiency is beginning to gain prominence in the private sector, and the Secretary of Energy now publishes a list of energy efficiency consultants. Nevertheless, the market is only just emerging. There are no energy service companies (ESCOs) in Argentina, due to the presence of high subsidies that delay the payback date of investments and the lack of a clear norm for ESCOs, including their accreditation.

However, within the framework of the Argentina 2030 Productive Plan, policy instruments are now being designed to promote the production of goods and services linked to energy efficiency.

Energy efficiency policies have, to date, incorporated more regulatory instruments than economic and voluntary measures, largely due to economic and financial barriers. In turn, there are institutional barriers and boundary conditions that hinder the development of energy efficiency measures.

For example, implementing energy efficiency policies for buildings requires co-ordinated effort from national and subnational governments. While federal policies can provide a comprehensive framework and set broad standards, subnational governments play a critical role in ensuring compliance. Challenges include ensuring regulatory consistency among regions, allocating adequate resources, adapting policies to diverse local contexts, and a lack of co-ordination among all stakeholders involved. For example, measures aimed at improving the thermal envelope of buildings, both existing and new, have made very little progress in Argentina, mainly due to the lack of centralised regulation that would provide municipalities with the enforcement capabilities to implement this type of policy. The norms of thermal conditioning of buildings fall into the jurisdiction of local government. In addition, policies launched through presidential decrees (as was the case with the PRONUREE), rather than legislative decision-making bodies, can be particularly affected by a lack of co-ordination between local decision-making bodies and the ministries, secretariat and programmes of the national government.

In contrast, more progress has been seen with regard to appliances used in the residential sector, which have shown a substantial improvement in energy efficiency indicators. In this case, centralised co-ordination was based on the gradual but sustained incorporation of minimum energy performance standards (MEPS), combined with an increase in consumers' real wages in the first half of the 2010s, which led to a relatively rapid replacement of appliances.

There is still a lot to be done regarding construction materials. To date, there have been no significant initiatives to improve the energy efficiency performance of construction materials, though this could change in the medium term as a result of policies currently being designed.

In contrast to the case of promoting nuclear energy innovation, the enabling conditions for energy efficiency are notably different: Argentina has no specialised institutions, has made no great advances in human resource training and has no overall legal framework for policies. Instead, there is a presidential decree that functions as a general framework for the promotion of energy efficiency. In addition, there is only one declared national industry development objective: the development of innovative materials for buildings in the PRONUREE programme.

Another difference relates to interest groups and the national policy agenda. In the case of the long-established nuclear sector, there has been some learning about the need to have continuity in policy to promote the national industry and develop the market. The development of energy efficiency policy is not yet at an advanced stage, but there is a possibility that it will be strengthened in the coming years given that it is part of the objectives of the Productive Argentina 2030 industrial development plan. The primary mission of this plan relates to the development of a green economy for a just environmental transition. Interventions on appliances and smart devices are prioritised, while interventions to improve innovation in materials are considered secondary actions.

Finally, regarding monitoring and evaluation, there is a clear political desire to develop better indicators and data. Alongside the interactive platform for Argentina's GHG inventory is a tool to monitor the different strategic lines of the Energy Transition Plan. However, this platform currently only has results for renewable energy policies. No data are available in the case of energy efficiency or other strategic lines.

Findings

Argentina's ongoing commitment to fostering innovation in the nuclear sector has yielded positive outcomes, showcasing the effectiveness of a public policy approach that prioritises the accumulation of technological and innovative capabilities. This strategy, which has its roots in a Latin American perspective on science, technology and development since the 1960s, emphasises the need for states to actively strengthen their scientific and technological infrastructure as a means of promoting development. Argentina's continued political support for nuclear innovation over seven decades, coupled with its strong skills base, has created a favourable environment for the emergence of a robust nuclear industry. Specialised research institutions, companies and training programmes have positioned Argentina as a regional and global leader in the nuclear sector. The evolution of Argentina's nuclear relationship with Brazil, from competition to co-operation, highlights the potential of South-South international co-operation to enhance technological leadership and achieve a combined impact greater than either country could achieve independently.

Argentina's nuclear innovation demonstrates the value of a long-term vision supported by dedicated institutions. The CNEA and INVAP have been instrumental in maintaining Argentina's leadership position, enabling the country to develop and export advanced technologies, including research reactors and medical applications. However, Argentina's nuclear leadership faces significant challenges in a volatile macroeconomic environment, particularly as the global market for emerging technologies such as SMRs is becoming increasingly competitive. With over 80 SMR designs currently in development worldwide and

intense competition from major economies with greater domestic demand and financial resources, the success of Argentina's nuclear industry will depend on its ability to leverage its technological strengths and secure stable funding for projects such as CAREM. The country could be at risk of losing its position in nuclear innovation if economic difficulties persist. In this context, it is crucial to allocate resources effectively to priority areas, particularly in a highly regulated sector such as nuclear, where the state plays a significant role in R&D and innovation. Argentina's longstanding prioritisation of nuclear energy has been a significant factor in its success in innovation. The country should identify specific nuclear-related technology components in which it can maintain a competitive edge. This approach recognises that innovation success extends beyond reactor exports to encompass niche technologies with the potential for spillover into sectors such as medical applications.

In comparison, energy efficiency policy in Argentina has followed a more fragmented path, characterised by a lack of continuity, institutional support and strategic alignment with broader economic and environmental goals. In contrast to the nuclear sector, energy efficiency lacks the dedicated institutions, long-term financing mechanisms and regulatory frameworks that are essential for sustained progress. The implementation of recent initiatives to improve energy efficiency has been hindered by regulatory gaps, inconsistent implementation and limited engagement with the private sector. Argentina's experience with appliance efficiency standards demonstrates the challenges faced in this area. The lack of significant local innovation has been due to the country's relatively small manufacturing base and, at the outset of the promotion of energy efficiency, by the lack of infrastructure to support compliance, such as testing laboratories.

Economic and institutional barriers also hamper the implementation of energy efficiency measures, particularly in the building sector, where a lack of co-ordinated national and sub-national efforts has restricted progress. While there is a clear need for investment in building materials, the lack of adequate financial and regulatory support has slowed the adoption of energy-efficient practices. Energy efficiency innovation in Argentina would benefit from enhanced inter-jurisdictional collaboration and economic instruments aligned with policy objectives.

Monitoring and evaluation are key to ensuring progress in both sectors. Argentina's nuclear sector benefits from well-established monitoring and data collection mechanisms, which have contributed to its sustained success. However, there is currently no comparable monitoring system in place for energy efficiency policies, which limits the ability to assess policy effectiveness and hinders the refinement of initiatives. Improved data transparency and accountability in the energy efficiency sector would significantly enhance Argentina's capacity to achieve its energy transition goals.

Argentina's contrasting experiences in nuclear energy and energy efficiency demonstrate the importance of strategic long-term planning, prioritisation, institutional support and international co-operation in fostering technological innovation. To maintain Argentina's leadership in nuclear innovation and advance its energy efficiency agenda, it is essential to address macroeconomic instability, promote private sector participation and maintain political stability regarding clean energy priorities with institutionalisation of certain long-term goals that achieve broader societal consensus.