npj | climate action

Article

https://doi.org/10.1038/s44168-024-00134-0

Techno-productive experiences for climate action in Argentina: Insights from renewable energy projects

Eliana Celeste Canafoglia

The main purpose of this research is to analyze techno-productive experiences within the framework of renewable energy projects based on the use and exploitation of solar energy in a region defined by favorable bioclimatic conditions. Following a primarily qualitative method, the research has been based on four case studies of working groups and their experiences. Stakeholders from diverse origin and background, interested in developing their technologies (processes, inputs, components, equipment) for the use of solar energy have managed to enhance the links among such developments, the productive sector and the communities in the territorial area where they carry out their activities. As a possible path of sociotechnical transition, these specific processes materialize energy transition with the progressive change of production and consumption patterns in favor of climate action.

Forms of production, their pace and their intensity, reveal interaction and relationships at stake between the involved parties in the pursuit of socio-economic objectives. Climate change (CC) has proposed an agenda of collaborative work including stakeholders, institutions, organizations of diverse origin and scope, with significant local specificities. In 2015, the United Nations General Assembly formulated the 2030 Agenda for Sustainable Development, where 17 goals (SDGs) were defined as the horizon to be followed. These include: taking urgent action to combat CC and its impacts (SDG 13) and ensuring access to affordable, reliable, sustainable and modern energy for all (SDG 7).

One of the core issues to be achieved is to transform the still prevalent fossil fuel energy sources to ones that reduce greenhouse emissions (based on the agreements adopted at the forum of the United Nations Framework Convention on Climate Change). This means incorporating renewable energy sources (RE) in the forms of production while reducing the consumption (and production) of fossil fuels. In Argentina, Law No. 27,191 (2015) defines wind, solar thermal, solar photovoltaic, geothermal, tidal, wave, ocean current, hydro, biomass, landfill gas, sewage treatment plant gas, biogas and biofuels as renewable, non-fossil energy sources suitable for sustainable use in the short, medium and long term. As a socio-technical transition (STT)[1], these transformations involve the integration of alternative forms of production, materials and sources into the practices of a range of stakeholders.

Thus, the much-quoted energy transition (ET) is driven by an urgent need to mitigate or eliminate the effects of carbon emissions and address the problem of CC[2,3]. While reliable energy supply, fair access or affordability in economic and technical terms, and sustainable production and consumption dynamics remain a concern[4–6]. That is, a better and reduced use also implies transforming the way in which the goal of economic growth is sustained[7,8].

Looking specifically at energy sources and the environment, we went over research findings on processes dealing with technological linkage and social transformation from a multidisciplinary[9–11] and productive[12,13] perspective. Interactions through which global SDGs are met make these transformations viable also as localization processes[14–16]. The links between public policies, the scientific-technological, productive and social spheres generate spaces of transformation for the production and preservation of the environment.

Then we wondered, what are the possibilities for the development and integration of productive and technological adjustments towards ET in specific territories? The starting point of incorporating RE generation systems should not be a matter of making replacements to end up producing in the same way, but to transform the forms of production and consumption. In this respect, what are the conditions to implement local climate actions (CA) and the possible ways to achieve them?

The purpose of this work is to analyze a setting of techno-productive experiences in RE projects based on the use and exploitation of solar sources (photovoltaic and thermal) in regions defined by favorable bioclimatic conditions. In this setting, we will put an emphasis on distinguishing the relationship between stakeholders committed to the technical-operational development of scientific knowledge and its integration into socio-productive structures (producers, companies, community) within the framework of the UN Sustainable Development 2030 Agenda and the commitments undertaken by Argentina, in particular with respect of SDGs 7 and 13.

Institute of Human, Social and Environmental Sciences (INCIHUSA) CONICET, Mendoza, Argentina.
e-mail: ecanafoglia@mendoza-conicet.gob.ar

The possibilities arising in this context are conditioned by multiple relationships in line with the locations and the changing historical socio-economic realities of each country and their regions. The economic sociology approach, contemplates techno-productive experiences by identifying the involved stakeholders, their practices and their relationships as key elements to strengthen the introduction of technical changes in the forms of production (and consumption) immersed in capitalist social relations. This has been referred above, in other words, as to a socio-technical transition. The way in which economic and productive stakeholders participate, even at local and national government levels, define the composition and dynamics (configuration) of RE integration processes as CA. In this study we identify crucial aspects in the way stakeholders interact that specify the type of local CA and its facilitators[17].

In other words, the extent of these transformations encompasses decision making and state policies, the nature of involved businesses, companies and large industries that are part of the transition and have the potential to change business landscape, markets and base industries[18]. In this sense, at a local level (temporally located space) of actions, various concerned groups, including economic stakeholders, the people living in the territory in question and sustainability experts (scientists, technologists) converge and play an important role in the political-technical system of said transition.

An energy transition as a process of transformation involving energy sources, inputs, equipment and applied technologies, is part of a larger transition at a societal level: it becomes a socio-technical transition. As such it comprises a set of processes leading to a fundamental change in socio-technical systems (e.g.,[19,20].). These are historical changes and in the current times are driven by an urgent need to lead to a sustainable transition. The way in which energy production complexes operate also implies understanding them as a sector of economic activity: they are part of the features of the social structures of accumulation[21,22]. These features, as well as the configuration of economic, social and political relations, will account for the possibilities of implementing, not without disputes, actions that will lead to reduce the production and consumption of fossil fuels as a primary source of energy supply.

The actions performed by various stakeholders, their interaction, culture and practices, innovations and their implementation, institutional arrangements and subsequent regulations will progressively introduce changes[23]. Processes such as energy diversification (i.e., the introduction of alternative sources in coexistence with dominant fossil fuels) and distributed generation (DG) (i.e., generation for self-consumption and redistribution of any unused surplus) are closely linked to those of ET. Such a development, understood as building and applying components, equipment or devices in a process of socio-technical change and adjustment[24], involves the collaborative work of multiple stakeholders, even when they may be not aware of it.

The configuration of socio-productive relations also include subjectivities and practices of the stakeholders[25], as spatio-temporally situated (conditioned) responses they can lead strategies with different degrees of autonomy towards the resolution of needs. Economic sociology[26,27] contributes to the definition of who are those who carry out the transition, who participate and appropriate the result, use and value generated. Thus, it facilitates the definition of alternative directions, features and depth to achieve transitions in each location with its own geographical characteristics. These relationships are embodied and give specificity to the transition process.

Methods

Definition and rationale for case studies

The analysis of socio-productive configurations implies working on different levels of analysis. Based on the proposed objective, the methodological strategy has been mainly qualitative: it comprises four case studies developed by four working groups (Table 1) and certain techno-productive experiences they carried out (Table 3), under regulations in force in Argentina and associated international agreements (Table 2). This strategy facilitates the understanding of the processes under study, considering that these are complex experiences, where different layers of action (political, economic, technical and social) converge.

Based on the study of production networks for the energy transition in Argentina[28], the work being carried out by these groups with different backgrounds and institutional affiliations (Table 1) in the central-west region of the country stood out. As the main line of action in relation to SDGs 7 and 13, these working groups are focused on the fundamental aspects of the current transition[29]: the expansion of RE, promotion of energy efficiency (EE) and, to a lesser extent, electrification. They have a proven track record in: (a) the study of materials and bioclimatic conditions by geographic region; and (b) the development of techniques, equipment and construction systems for the generation and use of energy from renewable sources.

Building techniques and data analysis encompass various sources:

a. In relation to the case study, the tracking and gathering of relevant data, articles and public reports referred to each group and found in the repositories of each institution, were complemented by conducting open interviews with key referents. Once techno-productive experiences related to the topic of study had been identified, the documents owned by the working groups were collected. These documents contain the specific systematization of relevant processes and products.
b. The identification and compilation of resolutions, decrees, statutory regulations and action plans related to the incorporation of NDCs, the adherence to SDGs and the RE transition strategy outlined by the Argentine State (Table 2). The sources of information were taken from the digital repository of Argentine legislation (infoleg), and ministerial reports.

The starting dimensions of the analysis in order to characterize each study case were the institution where each group belonged, and the work record (objective, processes and products) (Table 1). Next, we delved into the interaction of stakeholders involved in each project experience, a cross-linkage with public policy guidelines and the technical and financial resources that contributed to its development (as summarized in Table 3). At the same time, the acknowledgement of applicable regulations in the country as well as the stance with respect to international agreements on CA completed in a coordinated manner the scheme of governance (Fig.1) and provided a framework for some of the possibility conditions of the techno-productive experiences under study.

Results

Sociopolitical background for climatic action in Argentina

The institutional framework for RE projects in Argentina is part of the national energy and climate policy. As a subscribing country of Paris Agreements and the UN 2030 Agenda, Argentina has deployed a number of institutions at different level and scope. The energy policy has been aligned to the nationally determined contributions to address CC[30]. The NDCs are the commitments assumed by the countries that are part of the United Nations Framework Convention on CC (UNFCCC, 1992) and that must be carried out to intensify their actions against CC, either to reduce Greenhouse Gas emissions (mitigation actions) or to adapt to the impacts caused by that phenomenon (adaptation actions).

Among the actions carried out in that process, we found legislative advances that account for regulations related to the incorporation of RE as power generation systems and the information about CA, their registration and monitoring in order to achieve concrete local goals (Table 2). Sustainability as a matter contained in binding regulations can be traced from the National Constitution of Argentina (Article 41, 1994) to more recent laws on the subject.

Sustainable transition has been implemented at different government levels, in an interdependent manner through national agencies around the country, in coincidence with what other authors call the creation of multilevel climate governance[31]. This was accomplished not without difficulties on the coordination strategies[32]. Although explicit reference to SDGs may vary, the coordination of actions in specific local projects is institutionally anchored at national level. At this level, two ministries have worked together on the achievement of affordable and clean energy goal (SDG 7) and climate action (SDG 13): the Environment and Sustainable Development Ministry,

Table 1 | Key features of working groups

Working group	Institution	Objective	Products / services	Equipment and resources	Created in
Energy Institute	National University of Cuyo (UNCuyo)	Create a university space for training, study, implementation of associative projects and actions related to the use of RE and the responsible use of energy.	Training Audits Development of energy efficiency projects and construction of equipment (biodigesters, fruit drying system). Three Programs: Biofuels, Energy and Construction, Hydroelectric Mini-generation. Biogas project	Experimental workshop on solar thermal and photovoltaic energy, biomass and water	2005
CLIOPE Group Energy, Environment and Sustainable Development	National Technological University (UTN), Regional School Mendoza	Promote sustainable development through research and promotion of RE, life cycle thinking and use of associated tools such as eco-labeling, eco-design, Life Cycle Management (LCM), water footprint (WF), carbon footprint (CF), Social Life Cycle Assessment (S-LCA), Economic Life Cycle Assessment (E-LCA).	Solar Energy and Biomass Energy Atlas Impact assessment: carbon footprint, water footprint Thermo-economic analysis, simulation and modeling of complex systems. Energy and exergetic evaluation of systems. Rational use of energy Economic evaluation of environmental and energy projects	Meteorological observatory Specialized software (SIMAPRO) Flowmeters Pyranometers Thermographic camera	2008
Institute of Environment, Habitat and Energy	National Council for Scientific and Technical Research (CONICET)	Provide scientific and technological knowledge in the fields of habitat, environment and energies Contribute to technological design and development by integrating the expectations and behavior of users and producers of habitat in sunny climates. Propose energy and environmental indicators of the habitat on which the decisions of people and institutions can be based.	Environmental rehabilitation of the building envelope, study of natural air conditioning systems. Revaluation of ancestral earth construction techniques. Research, development, construction and transfer of devices that take advantage of solar resources. Development of hybrid solar cooking systems	Meteorological station (radiation, temperature, humidity, wind speed and direction sensors) Thermographic imaging and digitizing equipment Solar power meter Data loggers Specialized software Experimental workshop (building and tools)	1976 as Laboratory of Human Environment and Housing within an executing unit (EU) 2015 as an EU under the name of INAHE
Technological Observatory of the Renewable Energy Program	National Institute of Industrial Technology (INTI)	Contribute to the development of the industry through the generation and transfer of technology, the certification of processes, products and people, and the assurance of the quality of goods and services produced in the country.	Solar Thermal Census Certification of solar thermal equipment installers Solar thermal equipment manufacturing protocol Audits Collaboration in the creation of the Argentine Chamber of Manufacturers of Solar Thermal Energy Equipment	Laboratory for the evaluation and testing of solar thermal systems IRAM and ISO standards Low temperature solar thermal and PV solar pilot plants.	Resolution 90/**2016** INTI Board of Directors, Creation of the 'Center for Research and Development in Renewable Energies'

Personal research. Various sources (refer to Methodological aspects).

through the Secretariat for Climate Change, Sustainable Development and Innovation, which is responsible for the Technical Administrative Coordination within the scheme of governance (Fig.1) and the Ministry of Economy through the Secretariat of Energy[33].

As for regulatory matters, the Secretariat of Energy has issued a number of provisions and regulations specifically connected with the ET[13,34,35] (Table 2). These policies cover different aspects of the energy matrix, and due to their broad scope are presented in different lines of action: (a) energy efficiency (EE), (b) low-emission energy generation, (c) the new role of consumers in the provision of renewable energy (distributed generation) (d) system resilience, (e) gasification, (f) sustainable mobility and hydrogen.[36].

In line with de-carbonization goals, other legislations have been enacted to favor the incorporation of RE in recent times: Law 26,190 of 2006, later amended in 2015 (Law 27,191) and Law 27,424 of 2017 on distributed generation focused on integrating sources to the electric power generation in accordance with the *Guidelines for an Energy Transition Plan to 2030*[37]. In fact, from 2011 to 2021 renewable power increased by 908% (from 496 to 5002 MW) in Argentina[38]. These guidelines gather background information from previous joint work on climate and energy issues, as updated, in favor of the reduction of greenhouse gas emissions[36]. In terms of regulatory provisions, we mention those that are currently applicable (Table 2). However, the new administration of the Republic of Argentina (that took office on December 10, 2023) has questioned the principles previously agreed upon (See Necessity and Urgency Decree (DNU) 70/2023 Official Bulletin dated December 20, 2023, or the failed bill submitted to Congress on December 27, 2023 and Argentina's President remarks at Davos Forum on January 17, 2024).

Still, interdependence between different levels of governance is materialized by the actions of various stakeholders, who carry out the local

Table 2 | List of statutory regulations and action plans related to the incorporation of NDCs, SDGs and the renewable energy transition strategy outlined by the Argentine State

Type of regulation	Year	Description and objective
National Constitution of Argentina	1994	First Part. Chapter II. Section 41. All inhabitants are entitled to the right to a healthy and balanced environment fit for human development in order that productive activities shall meet present needs without endangering those of future generations; and shall have the duty to preserve it.
Law 25.019	1998	National Wind and Solar Energy Scheme
RE Program	1999	Renewable Energy Project in Rural Markets (PERMER)
Law 25.438	2001	Adoption of the Kyoto Protocol (UNFCCC)
Law 26.190	2006	National Incentive Scheme for the Use of Renewable Energy Sources for Electricity Production
Law 27.191	2015	Creation of the "Renewable Energy Development Fund" (FODER) and compliance targets for power generation from renewable sources
Law 27.270	2016	Ratification of Paris Agreement (2015)
First NDC	2015 2017	Emission reduction target for 2030 Revision following the Paris Agreement
RE Program	2016	Implementation of RenovAr Program for power supply from renewable sources in the Wholesale Electricity Market
Law 27.424	2017	Regime for the promotion of the RE Distributed Generation integrated into the National Electricity Grid
Law 27.520	2019	Minimum Budget for Adaptation to and Mitigation of CC. Creation of a National Cabinet on CC (GNCC) and a Federal Environmental Council
Law 27.566	2020	Approval and ratification of Escazú Agreement: regional agreement on access to information, public participation and access to justice in environmental matters in Latin America and the Caribbean
Second NDC	2020	Emissions reduction in 2 pp and sustainable development commitment
Law 27.592	2020	Comprehensive Environmental Education for all public officials *(Yolanda Law)*
National Plan for Adaptation to and Mitigation of CC – Target Year 2030 (PNAyMCC)	2020	Multilevel joint development of a plan under the action of the National Cabinet on CC (GNCC)
Energy Transition Plan to 2030	2021	Guidelines for de-carbonization goals (Secretariat of Energy Res.1036)

Personal research. InfoLeg digital legislative repository and ministerial reports.

transformation in favor of the climate. Whether or not such actions refer to the SDGs, their nature is present in the projects developed, among which we find working groups under autarchic organisms (Table 1), e.g., national universities (UTN, UNCuyo) and science and technical entities (INTI, CONICET)[39–41]. The institutions where these groups belong are key elements for achieving their objectives, products and services provided by them as techno-productive experiences carried out in changing contexts.

The incorporation of technology with better energy performance in residential, commercial and industrial equipment, the use of labeling policies and minimum EE standards in electric and gas appliances are the main lines of action in the projects developed by the groups and are in coincidence with the current guidelines set out in the above-mentioned *ET Plan to 2030*. Key steps in fostering RE integration include Law 25,019 (1998) and the implementation of the Renewable Energy in Rural Markets Project (PERMER in Spanish). This project is one of the main instruments aimed at harnessing power generation from renewable sources to supply the needs of rural territories isolated from the electricity grid[35,42]. This type of programs encompass both climate action and a response oriented to regions distant from the national interconnected power grid.

There are also other instruments related to promoting technological innovation in socioeconomic sectors considered as "Strategic Socio-Productive Cores" (NSPE, in Spanish), the use of solar energy being one of them. The National Agency for Scientific and Technological Promotion (MINCyT), through Argentina Sectorial Fund (FONARSEC, in Spanish), promotes one of the lines of coordination between scientific-technical resources and financing through a Sectorial Technological Innovation Fund. In fact, the National Cabinet on climate change in Argentina (GNCC in Spanish) aims *"to coordinate the design of public policies agreed upon among involved government areas of the National Public Administration, the Federal Environmental Council and other stakeholders of civil society* (Fig. 1).

Through the development and implementation of the *National Adaptation and Mitigation Plan* (PNAyMCC, in Spanish)[43] and the mandatory recommendations of the External Advisory Council (CAE, in Spanish), the GNCC seeks to achieve a meeting point between socio-economic development and a healthy environment[30]. The council consists of researchers, trade unions, communities and indigenous people, representatives of environmental organizations, universities, academic and business entities, public and private research centers, and representatives of political parties (Law 27,520/2019, Section 2).

Techno productive experiences and the incorporation of renewable energy

Techno-productive experiences help to define how socio-technical transition for the incorporation and dissemination of RE is materialized (Fig. 2). As a particular interrelation between public policies, productive and social needs and the scientific-technical working groups, each of these experiences shows specific ways to produce socioeconomic transformations.

Development and socio-technical adaptation processes are based on knowledge construction, its application and appropriation by the productive and community sectors where such processes take place (Table 3). The work developed in these sectors is part of the line of actions contained in the energy transition (ET) plan, which is then merged with the NDCs and the National Adaptation and Mitigation Plan (PNAyMCC) (Table 2).

The Energy Institute (IDE), under the National University of Cuyo, was created with the intention of contributing to the application of knowledge for the use of RE resources in developments that involved low or minimum levels of pollution (43.IDE 2005)[44]. In this respect, one of the techno-productive experiences developed on a local situated level consisted of a system of solar fruit dryers utilized in local agribusinesses (Fig. 3). This experience was also extended to monitoring efficiency, and improving the performance of the system by fine-tuning and testing materials.

The process behind this experience reflects the history of other science and technology organizations within the national scope, whose actions are

Table 3 | Techno-productive experiences - Highlights

Techno-productive developments	PNAyMCC and energy transition for 2030 action line (SDGs 7 and 13)	Stakeholders involved	Type of stakeholders	Governance Level committed	Knowledge and technical resources from	Funding sources or economic resources	Forms of cooperation
Fruit dryers	Socio-productive strategic centres Energy production for regional economies	IDE INTA Primary producers (agribusiness)	Public and private, Institute of technological development, productive sector	Local and national	Multidisciplinary institutes national university, producers know-how, INTA	National university, Science and Technology project funding and local producers	Public-private cooperation, productive sector
Solar radiation and biomass Atlas Study and design of housing prototypes	Sources of information and technological capabilities Energy supply response in social housing	CLIOPE UTN Various national research institutes Province housing institutes	Public, local government, community	Local, national, international	Research teams	National research council (CONICET), national university, European international organization	Public national and international cooperation
Natural air conditioning systems and EE Revaluation of ancestral earth construction techniques Study and design of housing prototypes	Fair access and affordability Energy supply response in social housing	INAHE Municipalities Social organizations	Public, local government, community	Local and national	Research teams, communities (community practices)	National Research Council (CONICET), Science and Technology projects	Local public cooperation - communities
Solar thermal collector and EE in social housing	Industrial development environmental care and reduction of gas emissions	INTI CAFEEST MHyDS, UTN regional school Provincial Housing Institute Domestic manufacturers	Public, private productive sector, community	National and local	INTI technological observatory, domestic manufacturers	National, provincial programs, companies, home buyers	Public-private cooperation, productive sector

Personal research based on documents and interviews (Refer to Methodological aspects).

locally based and encouraged. The National Institute of Agricultural Technology (INTA, in Spanish), working together with fruit and vegetable cooperatives, collaborated to provide generation of energy for local production, by replacing large gas-fired ovens with solar energy and biomass.

The way these projects are funded is through the universities involved in the projects. The concerned areas contribute to track and release information about lines of credit (e.g., FONARSEC or the National Agency for Scientific and Technological Promotion). This generally require building public and private partnerships, bringing together stakeholders such as the university -through IDE- and producers, manufacturers or entrepreneurs.

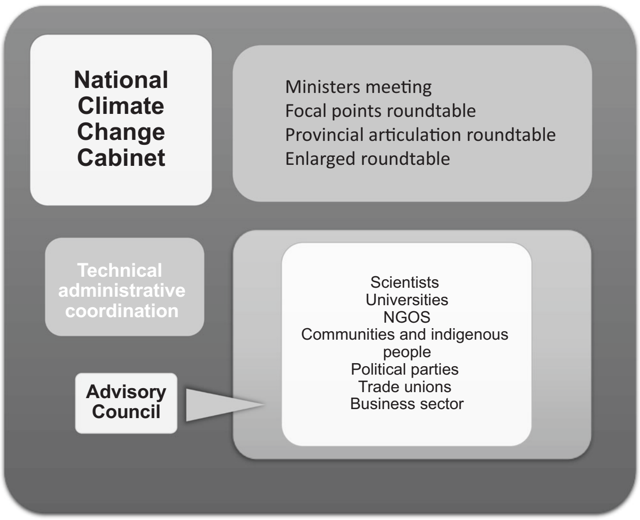

Fig. 1 | Climate governance scheme (Law 27.520/2019).

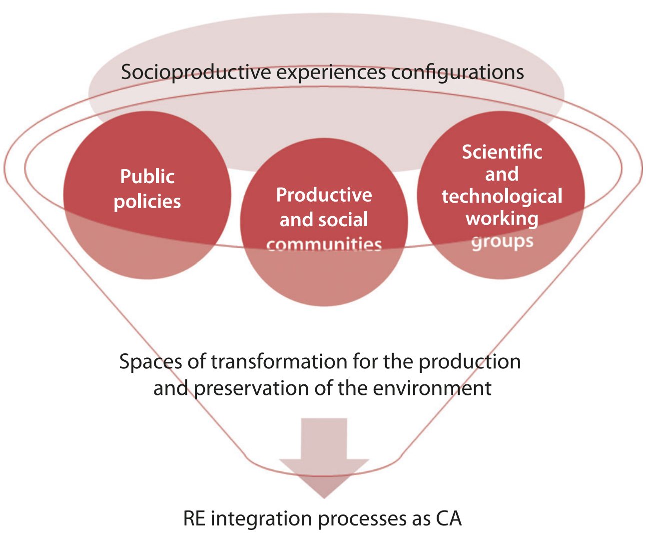

Fig. 2 | Socio-productive configurations for Climate Action (author).

Strategically complementary to IDE's techno-productive experience, the activities and products developed by CLIOPE study group[45] inure in the consolidation of both generation and consumption of solar energy sources. CLIOPE group created a Solar Energy and Biomass Atlas of the Province of Mendoza (Fig. 4), a tool that is open to the public, and is intended to identify and assess the region's potential for the use of energy sources, while also provide political-administrative, physical-natural, infrastructure and service information[46] about the territory where the project is carried out.

The atlas allows users to interactively visualize geographic information on surface solar irradiance, availability of biomass of different origins and bioenergy potential[47]. This work was funded by a research project of the Ministry of Science, Technology and Innovation (MINCyT, in Spanish) at a national level. The School of Agricultural Sciences of the National University of Cuyo, trainers working at the National Technical University (UTN)- Mendoza Regional School-, INTA and private consultants are among the recognized users of this tool.

The activity of the CLIOPE Group integrates scientific research, higher education and the transfer of know-how and services in connection with the analysis, assessment, as well as energy and environmental optimization of systems and products. The development and implementation of technologies that take advantage of RE sources is one of its main lines of action[45]. They built devices such as distillers, ovens, collectors and solar dryers to be installed in rural settlements (in line with the PERMER program,[42]). They also helped to improve techniques and materials associated with said devices (e.g., absorbent pigments for solar heaters) including the training of specialists in these topics, working together with other national organizations, such as INTA, INTI, and local municipalities. Moreover, the CLIOPE group works in coordination with other international networks.

However, even when above mentioned experiences (fruit dryers, Atlas) were geographically close one from the other, there has been no specific communication between the institutions and stakeholders involved. Thus, the need for an enhanced coordination of projects between scientific-technical teams that work on issues under sustainability criteria within the same region, calls for a specific work space oriented to a locally encouraged sustainable transition.

The principles of sustainable development also provided INAHE Institute with a theoretical framework for scientific research applied to different aspects of the habitat. This institute based its group work on the design, construction and energy assessment of a prototype experimental solar house. The house -that was inaugurated in 1980 - was built including improved traditional technology, a result of a project with the Organization of American States and is today known by the name "Enrico Tedeschi"[48]. At present, one of the outstanding research lines of the Institute is renewable energy applied to architecture, construction and equipment, sustainable social housing[49] and bioclimatic urban design[50]. It has also systematized the procedures for manufacturing ovens, solar stoves, solar distillation and sustainable construction with *quincha (wattle and daub)* and earth walls (e.g.,[51]). The application of these procedures in different contexts, will eventually become techniques to be appropriated by the productive sector, for construction and daily use[52].

Fig. 3 | Solar fruit dryer from IDE, National University of Cuyo[63].

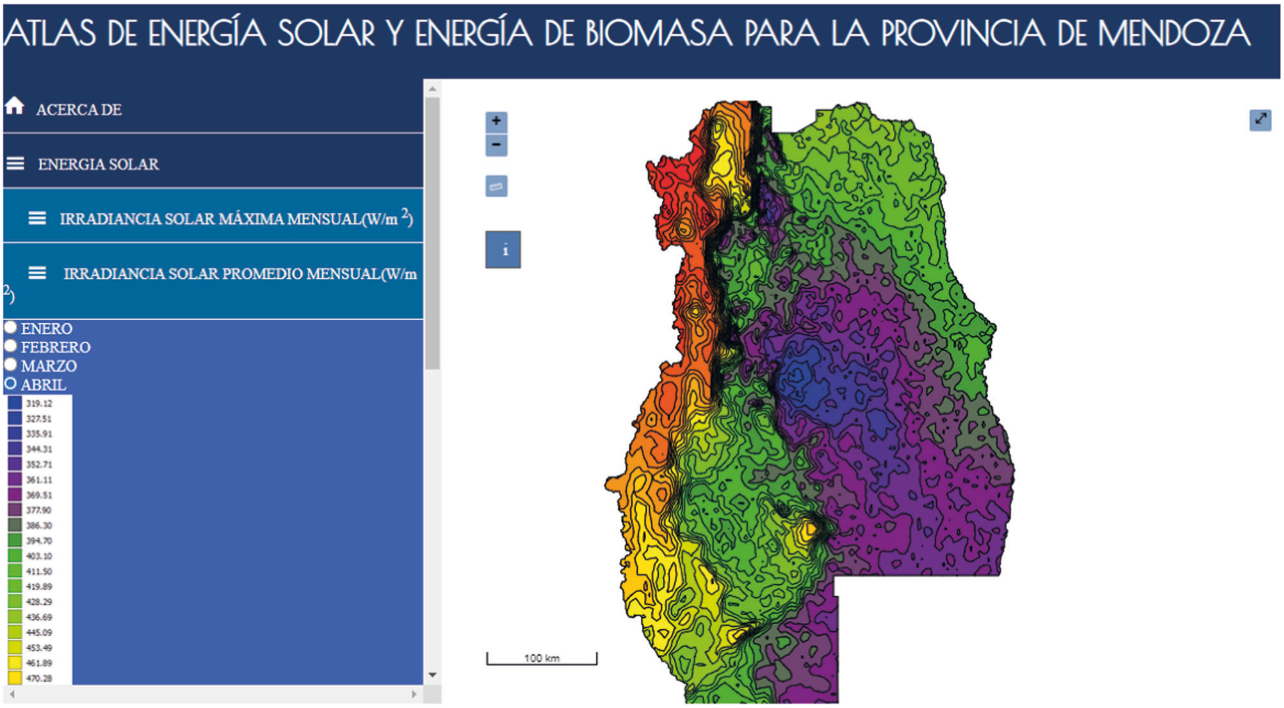

Fig. 4 | Solar Energy and Biomass Atlas of the Province of Mendoza from CLIOPE site: http://www.frm.utn.edu.ar/cliope/atlasdeenergiasrenovables/[46,47].

Fig. 5 | Front page from *Proposals for the implementation of renewable energy in social housing* made by the National Secretariat of Environment and Sustainable Development[54].

The awareness of the importance of incorporating urban bioclimatology concepts in terms of energy saving and optimization of consumption and use is noteworthy along the techno-productive experiences projects. Energy saving is passive and can be put into practice without implying specific devices, but rather adapting and taking advantage of available resources[50,53]. This development is possible thanks to the developed knowledge and applied on materials, shapes, sizes that can be adapted, adjusted and improved as required in productive sectors and communities that make use of them. INAHE puts an emphasis on the systematic incorporation of knowledge in a way that is meaningful in favorable climate terms.

Both INAHE and CLIOPE group researchers, participated in the GEF AR-G1002 project, which resulted in significant advances in construction based on bioclimatology principles, energy efficiency (EE) and the incorporation of renewable energy generation equipment (Fig. 5)[54]. The nationwide project *"Eficiencia Energética y Energía Renovable en la Vivienda Social Argentina"* (Energy efficiency and renewable energy in Argentina Social Housing), funded by the Global Environmental Facility (GEF), was conceived with the purpose of improving EE in social housing and, thus, contributing to the reduction of greenhouse gas emissions and achieve a better quality of life for the inhabitants[53]. The project covered 6 bioclimatic regions in 8 provinces, where 4 housing prototypes were developed by the relevant local government housing agencies. These prototypes incorporate concepts such as thermal insulation in walls and roof, improved windows, new materials, new designs and active solar technologies, specifically photovoltaic solar panels and solar collectors. Life cycle comparison reviews were carried out on the designs prepared for each province, totaling 32 housing prototypes analyzed. Global Warming Potential (GWP) was assessed using IPCC 2013 method and the Cumulative Energy Consumption (CAE) was based on the lower heating value[55].

As a result of this experience, a "*Manual del desempeño ambiental de los materiales y tecnologías utilizadas en la construcción de las viviendas sociales*" (Handbook on the environmental performance of materials and technologies used in building social housing) and a "*Manual de implementación de la metodología de Análisis de Ciclo de Vida en la construcción*" (Handbook on the implementation of Life Cycle Analysis methodology in construction), published by the National Secretariat of Environment and Sustainable Development, are available[56,57]. These books were financially supported by the Inter-American Development Bank, through which it was possible to hire the Regional Center for Science and Technology Research (CONICET Mendoza), a foundation formed by members of the Science and Technology Council in Argentina.

Production of technical and operational knowledge is based on a connection with various stakeholders, a vocation for building and finding suitable technologies for the intended use in production processes and self-consumption of energy. The object of INTI working group (Table 1) is to optimize nationally manufactured equipment and standardize components, materials and manufacturing processes in order to take part in public bidding procedures for social housing building. The mission of the technological development and innovation in power generation area is to promote and coordinate projects without distinction of source and technology, but paying special attention to the national incorporation of RE[58,59].

Specialized professionals work on this area to provide answers in technical and regulatory aspects to national manufacturers, importers, distributors and installers of equipment. Particularly, for solar thermal matters, INTI offers laboratory services for the assessment and testing of solar thermal systems under IRAM and ISO standards, in connection with both energy aspects as well as with equipment performance, resistance and durability aspects. Moreover, INTI work team conducts a National Thermal Census every two years[60]. The survey provides key information about production capacity, products and geographical locations and calls for coordination among manufacturers of solar thermal equipment in both productive and commercial sectors. In fact, INTI specialized work team has participated in the process of forming the Argentine Chamber of Manufacturers of Solar Thermal Energy Equipment (CAFEEST, in Spanish), a very important milestone for the development and professionalization of the production and value chain of this sector. In the same line, a system of technical certifications for installers -individuals responsible for installing equipment- has been developed, with the purpose of professionalizing the activities carried out by the trade.

In terms of aggregated actions and their inter-institutional implications, the techno-productive experience led by INTI has materialized in the elaboration of a protocol and the bidding specifications for housing programs. These are based on previous work including several aggregate phases: 1- Technical support to drive manufacturing, 2- Survey of manufacturers in the national territory (solar thermal catalog and registry of suppliers and goods of national origin for the EE sector, ReProER), 3- Periodic follow-up of manufacturing and improvement of equipment, 4- Support credit lines for the improvement of products (such as FONARSEC), 5- Preparing technical regulations to be controlled by the Secretariat of Commerce (Res. 753/2020)[61].

In this experience, INTI team members have worked with the Solar Thermal Industry Development Program, under the agreement between the Ministry of Productive Development and the Ministry of Territorial Development and Habitat (MDTyH, in Spanish). Also, officers from province government housing agencies were responsible for conducting the bodding processes for the construction of social housing. For instance, within the framework of *Casa Propia* Program, INTI's Energy and Mobility Operational Sub-management - that contributes with test laboratories and accompaniment in the process of improved production- provided support to: manufacturers of CAFEEST, projects from companies that received funds through PRODEPRO (National Supplier Development Program), bringing also other tools to improve and increase production. Moreover, the Ministry of Science, Technology and Innovation (MINCyT) and InnovaT Foundation, created a group, including researchers from various universities and centers in order to provide support to the Program.

Discussion

The experiences described above highlight present actions performed in particular territories, that are related to the goals and commitments undertaken by Argentina in relation to the 2030 Agenda (SDGs 7 and 13, NDCs). The use of RE sources and EE has been regulated in this country since the late 1990s and began to integrate into the productive sector with the implementation of household appliances labels[62] and the development of RE policy programs[13,34,35]. The translation into concrete guidelines to cooperate in the incorporation of other forms of production, materials and sources friendly to the climate and the environment has gained notoriety in national action plans since 2015 (PNAyMCC and Plan TE) (Table 2).

The actions of the working groups from and within the institutions where they belong (Table 1), have materialized climate and energy policies. National public universities and national scientific and technological centers, made the configuration of these experiences possible on the basis of team work interaction with other stakeholders and levels of government. The fact that they are autonomous organizations[39] has helped to overcome public policies differences in terms of priority goals and budget allocation budgets[13,34,35]. Particularly with respect to the history of applied knowledge production in each research line, the strengthening of the groups in practices and learning linked to RE projects has been decisive[9–11,24,28].

In relation to RE projects, incorporating scientific work is achieved with the transformation of practices of the stakeholders interested in energy generation (or intermediate processes). The interactions involved in these projects result in increasing the creation and deployment of knowledge[1,11,24] and contributes to find niches of opportunity (as spaces of transformation) within the domestic energy complex (Fig. 2). As energy diversification processes, techno-productive experience configurations have contributed to reveal that: (a) technical construction of EE is important but not enough; (b) energy production for regional economies is the key for a sustainable energy transition; and (c) the industrial development of equipment and the use of equipment manufactured at local level should be encouraged in the territory.

The expansion of RE and the promotion of EE are bound to the transformation of energy consumption practices. Regulations are then required to establish guidelines for the manufacture and labeling of artifacts used in the processes[62], to monitor compliance with said regulations and to bring orientation for the expansion of energy consumption practices to other production structures and service providers (design, adecuate place for equipment installation, further advice). Prior history of changes originated in the work of INAHE, IDE, CLIOPE and INTI is rooted in operational resolutions and compliance audits. Thus, change is feasible from production to consumption[20,23]. Educational training about the ways to facilitate the efficient use of energy, the optimization of processes and the utilization of appropriate materials complete the strategy (Table 1).

The scope of RE projects is conditioned by the coordinated actions of stakeholders[18]. Project implementation is encouraged by local governments[15,16,32] and supported by national and international policies on the matter (Fig. 1; Fig. 2). This pathway becomes necessary in order to deal with the prevailing interests in certain industries, such as the manufacture of household appliances or the construction industry, where conflicts may arise with sustainability criteria.

The implementation of recommendations and adjustments suggested for fruit dryers, solar collectors and housing prototypes is focused on energy performance, taking into account climate features of the geographic regions where projects are developed and solar orientation in building designs. It also contributes to the operational and economic performance of local production. Within the context of ET in our countries[63], paying attention to regional features, including access to available energy, economic and material resources, involves addressing the issue of fair access or affordability when making technological changes[4–6].

The solar dryer project depicts how the interests of local producers and the actions towards sustainable ET can be brought together[10,12]. However, it is also worth considering that, when projects are implemented, tensions may arise between producers and technicians. New materials, sizes and processes demand attention on optimizing the use of solar heat, thus causing new maintenance and operation tasks. With the support of IDE and INTA technicians and the collaboration of producers, such difficulties have been solved. When procedures required in the production process (e.g., raw material is placed to dry, dryer is solar oriented, rotation, removal and storage times are established, etc.) are smoothed, technology then is adapted and incorporated without further ado. Subsequently, the identification and introduction of improvements in mechanisms, materials and processes are implemented by other producers, types of production and geographical locations[64].

Similarly, improvements in equipment, and protocols required by all equipment suppliers, whether national or imported, have resulted from the collaborative work of INTI and solar collector manufacturers; however this has led to competition in the supply of equipment within the domestic market. In relation to local producers, the above mentioned experiences have helped to overcome certain difficult aspects of the supply chain, such as the market concentration of inputs and components coming mainly from China and the implementation of technology and its diffusion, especially when restricted by intellectual property rights, (e.g., patents), at international level[65]. In this sense, these experiences have also created the possibility of expanding the suppliers network for locally manufactured equipment. At this point, testing manufacture standards, monitoring and enforcing compliance places the State in a supervisory role[61] and promoter from its integration into social housing policies.

These experiences provide for alternatives within capitalist social relations of production[21,22], offering clues about creating potential spaces of transformation, where locally anchored stakeholders, inputs and products result from the interaction of public policy, science and technology organizations, companies and the community of users of equipment and services[18,20]. In the face of economic and political instability in our countries[66], techno-productive experiences offered as alternatives (*other ways of doing*), challenge the discontinuity of concrete RE programs while also encouraging the transformation of ongoing practices and the production of applicable scientific-technical knowledge (Fig. 2). Techno-productive experiences enable transformation spaces as a gradation between corporate transition and socio-ecological transition[2,5–7]. In order to move beyond the techno-productive experiences, an effort will be necessary to coordinate the interests of the stakeholders involved in manufacture, construction and intermediation aspects of commercial relations.

In other words, the possibility of coordinating these responses to climate change imply producing structural transformations. This change in the social relations of production involves acknowledging crucial aspects of interaction, incorporating processes, sources and materials friendly to our environment as transformations in process that are becoming part of our daily life. This is possible as a social process in the long term, as a socio-technical transition[1,20]. The collaborative state action at local and national levels of government, the presence of autonomous agencies, the infrastructure available to make climate action feasible, the regulations that promote climate action through energy policy (NDCs and ET guidelines) and strengthened relations between and with economic, productive and technical actors are the key to give continuity to the transformations intended in favor of the climate.

The cases studied outline localization processes of sustainable development goals in relation to the incorporation of RE in housing construction and the production of affordable energy devices, all of which result in climate action and encourage local industry and professional employment. The political-technical system that accompanies these processes is decisive, in terms of the positioning and the actions of the State, the governmental policies oriented to climate actions and the energy transition towards decarbonization. In line with the political-technical system, a scientific-technical system, both public and private, which supports research and development actions, favors collaborative, multidimensional and interrelated construction to be disclosed and implemented in the social and productive structures of a specific territory. These linkages are crucial when dealing with structural conditions that limit climate action, specifically in economic and financial terms required by renewable energy projects. The focus on techno-productive experiences has enabled to discern the significance, possibilities and limitations in the deployment of the above-mentioned processes that coexist with the dynamics of worldwide production of supplies, materials and equipment.

Locally promoted techno-productive experiences in the process of energy transition show the possibilities and ways of change in practices and subjectivities of the stakeholders involved, facing in that same process structural and conditioning factors of the ongoing transformation. The incorporation of renewable energy generation systems, their dissemination and their rooting in the territory, as well as in production and consumption practices, contributes to several fronts: making an action in favor of the climate, taking advantage of existing bioclimatic conditions, obtaining an economic benefit associated with their use (e.g., reduced generation costs and creation of businesses), being less dependent from the energy system (distributed generation) and achieving autonomy. These changes imply new relationships between stakeholders in each territory and the presence of stakeholders engaged in decarbonization objectives. The fundamental focus now lies on changing the axis to result in further transformations: this is when the forms of production, their pace and intensity in response to socioeconomic objectives come into dispute.

Localization processes of actions in favor of climate consist of exercising the coordination of multiple actions by various stakeholders at different scales that combined transform what is fragmented. The purpose is to create complementary actions leveraged as actions for the climate. Such actions will be able to circumvent the difficulties or impositions of the market, and may, for instance, become social housing policies. Likewise, through the interaction of energy-climate, industrial and social policies, it will be possible to make it a requirement to install or facilitate the installation of equipment that is supplied by renewable energy sources. Such equipment and know-how can be manufactured by national producers, i.e., from the same region, with the possibility of making any specific socio-technical adjustments known to them, as required.

The production, generation and use of energy is then associated with the disclosure and release of appropriable technologies that can be incorporated. As a socio-technical transition, energy transition is possible with the diversification of energy generation sources and the integration of different technologies in the sustainable use of supplies, materials and equipment, the application of these in building construction and production processes. Coexistence of different sources, as well as distributed generation, will reduce the demand on national energy systems by localizing generation and adapting it to the uses required in each territory. Processes in this direction are conditioned by the possibilities of producing and acquiring, purchasing, financing supplies, materials, equipment and operating knowledge to implement, adapt and strengthen the infrastructure that makes possible the material achievement of the energy transition.

Through the actions of working groups engaged in socio-technical adaptation and in response to situated needs, the socio-technical transition which enables energy transition, is possible. In this way, SDGs 7 and 13 towards sustainable development in favor of climate make sense. The diverse institutional backgrounds of the stakeholders involved in renewable energy generation and use projects have common features and prove that action is achieved through complementary efforts. Long-lasting alliances where different governmental levels coexist, allow such complementary to be extended over time and result in sustained actions in favor of the climate.

Reporting summary

Further information on research design is available in the Nature Research Reporting Summary linked to this article.

Data availability

All data generated or analysed during this study are included in this published article. Data sources are included in the main text and references. Interview notes and other raw material, as processing data, will be available in the Institutional Repository of research data of the National Council for Scientific and Technical Research - CONICET Digital.

Received: 30 September 2023; Accepted: 14 May 2024;
Published online: 01 July 2024

References

1. Geels, F. W. Technological transitions as evolutionary configuration processes: a multi-level perspective and a case-study. *Res. Policy* **31**, 1257–1274 (2002).
2. Cubillos, A., Estenssoro, F. (Comps.). Energía y medio ambiente. Una ecuación difícil para América Latina: los desafíos del crecimiento y desarrollo en el contexto del cambio climático. https://biblioteca-repositorio.clacso.edu.ar/handle/CLACSO/8630 (IDEA-USACH, 2011).
3. Gielen, D. et al. The role of renewable energy in the global energy transformation. *Energy Strategy Rev.* **24**, 38–50 (2019).
4. Singh, H. V., Bocca, R., Gomez, P., Dahlke, S. & Bazilian, M. The energy transitions index: an analytic framework for understanding the

evolving global energy system. *Energy Strategy Rev.* **26**, 100382 (2019).
5. Transnational Institute (TNI) (2020). Transición Justa: Encuentros entre movimientos sociales en pos de la transformación social y ambiental. https://www.tni.org/es/publicaci%C3%B3n/transicion-justa (TNI, Milieudefensie, 2020).
6. Heinberg, R. A realistic 'energy transition' is to get better at using less of it, *Resilience*, 17 de febrero de 2023; https://www.resilience.org/stories/2023-02-17/a-realistic-energy-transition-is-to-get-better-at-using-less-of-it/ (2023).
7. Reichmann, J. Sobre transiciones energéticas y transiciones ecológicas. *Viento Sur* https://vientosur.info/sobre-transiciones-energeticas-y-transiciones-ecologicas/#_ftn20 (2023).
8. Godfried, D., Arroyo, J. I. Elefantes en la transición energética, *CEPE Di Tella*, https://www.utdt.edu/ver_novedad.php?id_novedad=5152&id_item_menu=25201 (2022).
9. Belmonte, S., et al. (coords). Experiencias de energías renovables en Argentina: una mirada desde el territorio. (EUNSa, 2017).
10. Garrido, S., Juarez, P. Políticas de energías renovables y dinámicas de desarrollo inclusivo (Argentina, 2001- 2012) in Thomas, H., Albornoz, B., Picabea, F. (org.) Política tecnológica y tecnología política. FLACSO Ecuador- Universidad Nacional de Quilmes. 241 - 278 (2015)
11. Lottersberger, J., Garrido–Noguera, C. (Coords.) Alcances y desafíos de la vinculación tecnológica para la transformación social. https://redue-alcue.org/website/vttransfsocial.php REDUE–ALCUE, UDUAL (2021).
12. O'Connor, E., Battaglino, M. Energía para el desarrollo productivo y social de Argentina. (Fundación Agropecuaria para el Desarrollo de Argentina, 2011).
13. Guzowski, C., Ibáñez Martín, M., Zabaloy, M. F. (coord.). Energía, innovación y ambiente para una transición energética sustentable: retos y perspectivas. (Ediuns, 2020).
14. Medina, T. O. Localization of the Sustainable Development Goals in border areas and cross-border South-South cooperation in Latin America. *Aldea Mundo* **24**, 27–38, https://www.redalyc.org/articulo.oa?id=54364072008 (2019)..
15. Stuhldreher, A. M. Avanços e desafios do desenvolvimento sustentável no Uruguai y suas implicações territoriais: Um olhar a localização dos ODS em Tacuarembó. *Redes (St. Cruz Online)* **25**, 1652–1675 (2020).
16. Sippel, M., Jenssen, T. What About Local Climate Governance? A Review of Promise and Problems. *SSRN*, 1-51 (2009)
17. Tosun, J. Addressing climate change through climate action. *Climate Action* **1**, 1 (2022).
18. Chilvers, J., Bellamy, R., Pallett, H. & Hargreaves, T. A systemic approach to mapping participation with energy transitions. *Nat. Energy* **6**, 250–259 (2021).
19. Geels, F., Sovacool, B., Schwanen, T. & Sorrell, S. The socio-technical dynamics of low-carbon transitions. *Joule* **1**, 463–479 (2017).
20. Grin, J., Rotmans, J., Schot, J. Transitions to sustainable development: new directions in the study of long term transformative change. (Routledge New York, 2010).
21. Schorr M., Wainer A., Kitay I., Canafoglia E., Perez Riposio R. Debates en torno a los modelos de acumulación en la Argentina. Perspectivas desde la Sociología Económica. *Unidad Sociológica*, 10. http://unidadsociologica.com.ar/UnidadSociologica10.pdf (2017).
22. Saiz Bonzano, S. Estado y lucha de clases: ¿instrumento, sujeto o territorio? Una aproximación a la articulación de lo económico y lo político desde la categoría Régimen Social de Acumulación. In Morón S. et al. Procesos de acumulación y conflicto social en la Argentina contemporánea (Universitas, 2013).
23. Hirt, L., Schell, G., Sahakian, M. & Trutnevyte, E. A review of linking models and socio-technical transitions theories for energy and climate solutions. *Environ. Innov. Soc. Trans.* **35**, 162–179 (2020).
24. Belmonte, S., Garrido, S., Escalante, K., Barros, M. & Mitchell, J. Reflexiones y propuestas para mejorar procesos de adecuación socio-técnica y políticas públicas de energías renovables. Talleres participativos ASADES 2012-2013. *Avances en Energías Renovables y Medio Ambiente* **18**, 01–12.08 (2014).
25. De la Garza, E. La metodología configuracionista para la investigación social. (UAM, 2018).
26. Castellani, A. Estado, empresas y empresarios. La construcción de ámbitos privilegiados de acumulación entre 1966 y 1989. (Prometeo, 2009).
27. Schorr, M. Cambios en la estructura y funcionamiento de la industria argentina entre 1976 y 2004. Un análisis socio-histórico y de economía política de la evolución de las distintas clases sociales y fracciones de clase durante un período de profundos cambios estructurales. Tesis de doctorado (FLACSO, 2005).
28. Canafoglia, E. Solar energy and social-productive configurations: regional features of the energy diversification process in Argentina. In *Energy Transition and Sustainable Development in Latin America*. - Edit Lazaro, L. L. B., Serrani, E. Springer (2023).
29. IRENA. A New World: The Geopolitics of the Energy Transformation. http://geopoliticsofrenewables.org/Report (2019).
30. MAyDS. Segunda Contribución Determinada a Nivel Nacional de la República Argentina. Ministerio de Ambiente y Desarrollo Sostenible, República Argentina. https://www.argentina.gob.ar/sites/default/files/segunda_contribucion_nacional_final_ok.pdf (2020).
31. Adriázola, P., Dellas, E., Tänzler, D. Multi-Level Climate Governance Supporting Local Action: Instruments Enhancing Climate Change Mitigation and Adaptation at the Local Level. (Bonn: GIZ, 2018).
32. Dalla Torre, M. & Coronel, D. Políticas públicas y cambio climático: Aportes al problema de la coordinación multinivel a partir de un análisis de políticas municipales. *Rev. Estado, Gobierno y Gestión Pública.* **34**, 89–121 (2020).
33. Consejo Nacional de Coordinación de Políticas Sociales. Informe de País. Argentina 2023 Agenda 2030. https://www.argentina.gob.ar/sites/default/files/informe_pais_baja.pdf (2023).
34. Moragues, J. Cambios institucionales e implementación de políticas en energías renovables en las últimas cuatro décadas en Argentina.Ciencia e Investigación 70, 32–37, https://aargentinapciencias.org/wp-content/uploads/2020/05/3-Moragues-cei70-1-4.pdf (2020).
35. Bertinat, P., Chemes, J. Políticas públicas en el sector de energías renovables (2003 - 2018). (EJES, 2018)
36. Secretariat of Energy (SE). Resolution 517/2023. ANNEX: National Energy Transition Plan to 2030 (PTE 2030), National Directorate of Scenarios and Evaluation of Energy Projects, Assistant Secretary of Energy Planning (SSPE). https://servicios.infoleg.gob.ar/infolegInternet/anexos/385000-389999/386321/res517.pdf (2023).
37. Secretariat of Energy (SE). Resolution 1036/2021. ANNEX I: Guidelines for a 2030 Energy Transition Plan http://servicios.infoleg.gob.ar/infolegInternet/anexos/355000-359999/356100/res1036.pdf (2021).
38. CAMMESA. Mercado eléctrico mayorista. Informe Anual 2022 https://cammesaweb.cammesa.com/informe-anual/ (2023).
39. Molina, M. S. La autonomía institucional y académica de las universidades nacionales. Evolución conceptual en la legislación y jurisprudencia argentina. *Rev.Iberoamericana de Educación Superior*, 66-89. https://www.redalyc.org/articulo.oa?id=299130713005 (2014).
40. Decret-Law 17138/1957 National Institute of Industrial Technology, http://servicios.infoleg.gob.ar/infolegInternet/anexos/60000-64999/61016/norma.htm
41. Decret-Law 1291/1958 National Research Council for Scientific and Technical Research http://servicios.infoleg.gob.ar/infolegInternet/anexos/20000-24999/22660/norma.htm
42. Secretariat of Energy (SE). Moving towards the energy transition, https://www.argentina.gob.ar/economia/energia/permer/en-camino-la-transicion-energetica (2023).
43. MAyDS. Plan Nacional de Adaptación y Mitigación al Cambio Climático. Ministerio de Ambiente y Desarrollo Sostenible de la

República Argentina. https://www.argentina.gob.ar/sites/default/files/pnaymcc_2022_-_vf_resol.pdf (2022).
44. IDE. Ordinance 53/2005 Institute of Energy, National University of Cuyo. https://imd.uncuyo.edu.ar/upload/reglamento-interno-ide.pdf (2005).
45. UTN. Resolution CSU 1586/08 CLIOPE Regional Mendoza School, UTN https://sites.google.com/view/cliopeorg/inicio (2008).
46. Piastrellini R., Rodríguez P. D.; Henderson G., Arena A. P. Atlas de energía solar y de biomasa: Una herramienta para la valoración de fuentes renovables de energía en la provincia de Mendoza. (EdUTecNe, 2021).
47. UTN Regional Mendoza School. Solar Resource Map. Generalities and Implementation of the WRF Model. http://www.frm.utn.edu.ar/cliope/atlasdeenergiasrenovables/solar.html (2017).
48. Alvite, S. Sol y desierto en la arquitectura de Enrico Tedeschi. *AUS [Arquitectura / Urbanismo / Sustentabilidad]* **30**, 68–75 (2021).
49. Mitchell, J. A. La energía solar y los talleres participativos de Vivienda Social. https://www.mendoza.conicet.gov.ar/inahe/wp-content/uploads/sites/10/2022/04/LA-ENERG_A-SOLAR-VIVIENDA-SOCIAL.pdf.
50. Ganem Karlen, C., Barea Paci, G. J. A Methodology for Assessing the Impact of Climate Change on Building Energy Consumption. In: Palme, M., Salvati, A. (eds) Urban Microclimate Modelling for Comfort and Energy Studies. Springer, Cham. 363-381 (2021).
51. Cuitiño Rosales, M. G. et al. Análisis comparativo de aspectos térmicos y resistencias mecánicas de los materiales y los elementos de la construcción con tierra. *Rev. de Arquitectura* **22**, 138–151 (2020).
52. INAHE. Servicios. Línea de investigación Arquitectura sustentable y equipamiento solar. https://www.mendoza.conicet.gov.ar/inahe/lineas-de-investigacion/arquitectura-sustentable-y-equipamiento-solar/servicios/ (2023).
53. Arena, P. et al. Life cycle assessment of the incorporation of active and passive solar technologies in social interest housing in Argentina: photovoltaic power generation, water heating and bioclimatic design. 298-301 https://ri.conicet.gov.ar/handle/11336/174138 (2021).
54. SAyDS. Propuestas de implementación de Energías Renovables en viviendas sociales para la generación de energía eléctrica distribuida y solar térmica https://www.argentina.gob.ar/ambiente/desarrollo-sostenible/vivienda/estudio (2020).
55. IPCC. Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T. F. et al. (eds.)]. Cambridge University Press (2013).
56. SAyDS. Handbook on the environmental performance of materials and technologies used in building social housing https://www.argentina.gob.ar/sites/default/files/manual_del_desempeno_ambiental_de_los_materiales_y_tecnologias_utilizadas_en_la_construccion_de_viviendas_sociales.pdf (2018).
57. SAyDS. Handbook on the implementation of Life Cycle Analysis methodology in construction https://www.argentina.gob.ar/sites/default/files/manual_de_implementacion_de_la_metodologia_de_analisis_de_ciclo_de_vida.pdf (2018).
58. INTI. Resolution 90/2016 Renewable Energy Centre, National Institute of Industrial Technology https://www.argentina.gob.ar/normativa/nacional/resoluci%C3%B3n-90-2016-271299/texto (2016).
59. Queipo G., Pasetti G. Energía solar térmica: oportunidades para la industria argentina. INTI https://www.inti.gob.ar/assets/uploads/files/economia-industrial/01-2023/Energia_solar_termica_Final.pdf (2022).
60. Sabre, M. et al. Censo Nacional Solar Térmico 2020: período 2019. INTI (2021).
61. Secretariat of Commerce (SC). Resolution 753/2020 Technical procedure Solar Thermal Equipment. Ministry of National Productive Development. https://www.argentina.gob.ar/normativa/nacional/resoluci%C3%B3n-753-2020-345966/actualizacion (2021).
62. Iglesias D., C. El uso y la regulación de las etiquetas de eficiencia energética en el derecho latinoamericano y argentino. Su uso como instrumento para la mitigación del cambio climático a nivel local. http://www.saij.gob.ar/ (2021).
63. Benites Lazaro, L., Serrani, E. Energy Transitions in Latin America. The Tough Route to Sustainable Development. Springer Nature, Sustainable Development Goals Series (2023).
64. IDE. Artículos e Informes. Energía. Institutos Multidisciplinarios. Universidad Nacional de Cuyo. https://imd.uncuyo.edu.ar/articulos-e-informes43 (2023).
65. IEA. Securing Clean Energy Technology Supply Chains, IEA, Paris https://www.iea.org/reports/securing-clean-energy-technology-supply-chains (2022).
66. Steinberg, P. F. Welcome to the Jungle: Policy Theory and Political Instability (P. F. Steinberg, S. D. Van Deveer, Eds.; pp. 255–312). (The MIT Press, 2012)

Acknowledgements

This work is part of the research I am conducting on the subject *Diversificación energética y entramados productivos: desafíos en la integración de energías de fuentes renovables en la región de Cuyo (Argentina) - Energy diversification and productive structures: challenges of integrating renewable energy sources in Cuyo region (Argentina)* - Biannual Research Project for new researchers (PIBAA 0590) - CONICET, 2022-2023. Anahí Palacios contributed with the translation from Spanish.

Author contributions

The author conceived the paper and outlined the first draft and revisions. Special collection editors comments contributed to specify case study selection and importance.

Competing interests

The author declare no competing interests.

Additional information

Supplementary information The online version contains supplementary material available at https://doi.org/10.1038/s44168-024-00134-0.

Correspondence and requests for materials should be addressed to Eliana Celeste Canafoglia.