Chapter 4
Renewable Energy in Argentina

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Abstract Since 2010, Argentina has had a revival of interest in the use of renewable energy sources (RES). In particular, with the GEN-REN plan, an impulse was given to the wind and solar energy systems in farm-type installations and biomass (ethanol or biodiesel) used in transport and agroindustries.

The number of bidders exceeded expectations, but the economic conditions of energy price in the wholesale electricity market brought about for a few of them to be installed.

In 2016, after the new administration took office, there was a call for the RENOVAR plan; 1000 MW were tendered but more than 6000 MW were offered. Market conditions were much better, and by September 2017, all selected projects will be implemented.

During 2010 to 2016, legal conditions for low voltage users were approved, which permit them to be energy generators, and these laws allow today the opening of a large market of wind and solar energy systems for domestic installations. In particular, several universities and institutes of renewable energy sources are researching on the use of wind turbines in tall buildings to supply the energy for common uses (elevators, water pumps, hallway lighting). It is also possible to adapt new building projects to the use of mini-hydro turbines by the accumulation of gray water.

In Neuquén Province, northwest Patagonia, a delegation of the National Institute of Industrial Technology is in Cutral Có City. That institution has a test bench for small wind turbines to certify its operation. In the Faculty of Engineering of the National University of Comahue is the Center for Study and Analysis of Applications of Renewable Energy Sources composed of three consolidated research groups. They are developing and testing different wind turbines of their own projects or local entrepreneurs. Also they developed and tested micro- and mini-hydro turbines in the Laboratory of Mini Hydro Power Plants. They made a project of energy efficiency on a building of about 10 floors, where it can obtain 20–25% more wind

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speed than an average one and better radiation without obstacles. Also, using wind, solar (on terraces), and mini-hydro (on gray water pipes) energies, it can supply between 30 and 40% of energy for common services of a building especially in the hours of maximum demand, during the day and night. This kind of projects would allow to reduce the demand in the low voltage grid and to distribute generation in urban places. It represents for the users of the building a monthly RE equipment amortization fee during a few years.

4.1 Introduction

4.1.1 Beginning of the Use of the Renewable Energy Sources in Argentina

During 1984 Argentina implemented the first national institutions related to renewable energy sources. These were the Regional Centers for the Development of Renewable Energy Sources (RES) (Table 4.1):

The interest on RES of private companies in Argentina began a few years earlier. In 1977–1978 the San Miguel Institute, a part of the University of Salvador, joined some experts to work on photovoltaic cells and train in solar energy. Then some of them were absorbed by the National Commission of Space Research, dependent of the Argentine Air Force at that time. Then, during 1985, Neuquén began to work on geothermal energy prospecting in Caviahue-Copahue, and during 1988, it developed a rural electrification plan for dispersed inhabitants without access to the services, by means of PV systems. In addition, the province of Chubut, since the beginning of 1990, has been developing its rural electrification plan for dispersed inhabitants by means of installation of wind turbines and photovoltaic panels.

Table 4.1 Regional Centers for the Development of Renewable Energy Sources in Argentina 1984

Centers	Location	Characteristics
Regional Wind Energy Center (RWEC)	Rawson, Chubut http://organismos.chubut.gov.ar/cree	It continues working and developing the wind map of the Argentine Republic. It is also an international consultant for the study of the wind resource and installation of wind farms
Regional Geothermal Energy Center (RGEC)	Neuquén, Provincial Development Council	The first geothermal development in South America is in "Las Mellizas" lagoons (Caviahue-Copahue) where a power plant of 670 kW is installed. It is attended by the provincial energy company
Regional Micro Hydraulic Center (RMHC)	Obera, Misiones	Absorbed by other institutions, the National University of Misiones continues in developing micro-hydro turbines Banki and Pelton
Regional Solar Energy Center (RSEC)	Salta INENCO	Represented by the research Institute of non-Conventional Energy of the National University of Salta that develops solar thermal equipment

Since 1995, a national electrification plan for the dispersed rural population has been projected, evaluating how many inhabitants there were in that condition (4,000,000 inhabitants). Private companies were created, particularly in the Northwest of Argentina, which installed and maintained photovoltaic systems, with a subsidized rate of 50% on electricity tariff, but in 2001 the companies began to be deficient. Rural electrification throughout the country was continued in 2004 by means of the World Bank funds, which financed the Renewable Energy for Rural Markets Project (PERMER) [1].

In the case of wind farms, since the early 1990s, Argentina has been installing wind equipment in Patagonia. The first state wind farms had the problem that they were not properly maintained, resulting in a short service life (Table 4.2).

The national biofuels industry began during the 1980s. The government by means of the National Company of Fuels (YPF) promoted the consumption of "alconafta" in cars from 1984 to 1991 using bioethanol from sugarcane. Then, during the 1990s, the production of "alconafta" was suspended because it was not profitable.

In the mid-1990s, as a result of the opening to the international market, a new impetus was given to wind energy where several cooperatives and municipalities began to install wind turbines of European origin (Neg-Micon, Enercon, Bonus, etc.). These installations are made by cooperatives and municipal services connected at medium voltage to the Argentine Interconnection System (SADI). Most of these facilities are still in service today and have been the private pioneers in wind energy in the country (see Table 4.3).

Table 4.2 First wind farms in Argentina

Year	Wind farm	Turbines, type, total power	N°	Power	Situation
1995	Pico Truncado, Santa Cruz	VENTIS 20-100, 100 kW	10	1 MW	Disassembled
1990	Río Mayo, Chubut	Aeroman, 30 kW	4	120 kW	Disassembled

Table 4.3 Wind farms from 1994 to 2002 of cooperatives and municipalities

Location	Province	Service since	N° turb.	P. turb. (kW)	Total (kW)	Cumul. (kW)
C. Rivadavia	Chubut	July 1, 1994	2	250 – Micon	500	500
Cutral Có	Neuquén	Oct. 1, 1994	1	400 – Micon	400	900
Punta Alta	B. Aires	Feb. 1, 1995	1	400 – Micon	400	1300
Tandil	B. Aires	May 1, 1995	2	400 – Micon	800	2100
Rada Tilly	Chubut	Mar. 1, 1996	1	400 – Micon	400	2500
C. Rivadavia	Chubut	Sep. 1, 1997	8	750 – Vestas	6000	8500
Mr. Buratovich	B. Aires	Oct. 1, 1997	2	600 – Bonus	1200	9700
Darregueira	B. Aires	Oct. 1, 1997	1	750 – Vestas	750	10,450
Punta Alta	B. Aires	Dec. 1, 1998	3	600 – Bonus	1800	12,250
Claromeco	B. Aires	Jan. 1, 1999	1	750 – Vestas	750	13,000
P. Truncado	Santa Cruz	Nov. 1, 2000	2	600 – Enercon	1200	14,200
C. Rivadavia	Chubut	Jul. 1, 2001	16	660 – Gamesa	10,560	24,760
Gral. Acha	La pampa	Mar.1, 2002	2	900 – Vestas	1800	26,560

4.1.2 Training in FER

During the 1990s, the lack of specialized workforce, mainly in maintenance of renewable energy devices, was critical. From 1977 to 1990, courses were given on solar energy from the Solar Research Group of the University of Salvador with the support of the Argentine Air Force. This research group had been formed to develop photovoltaic cells but this project did not prosper. Eventually wind energy courses were given, and the Argentine Navy manufactured a wind turbine of 16 kW whose project was directed by Dr. Bastianon [2].

Since 1998, a postgraduate training in renewable energy has been developed in Argentina. The first institution to do it was INENCO at the University with Workshop methodology. Then this course was given in different places (Buenos Aires, Comodoro Rivadavia), expanding training possibilities.

But the reality on workforce market was that there were no technicians for large-scale RES device installations except for Big Hydro installations.

The author of this work returned to his country in 2000 after his postgraduate in renewable energy at the University of Reading and realized that there is no skilled workforce for installation, operation, and maintenance for RES equipment. That is why in 2003 he created the "Technicature" of Renewable Energy and Environment (REE) in the National Technological University [3], located in Plaza Huincul, which allowed to have the first 55 technicians in REE of the country in 2005. From this event other institutions and provincial education councils have been created, "Technicatures" in renewable and nonrenewable sources. Today practically most of the provinces with renewable resources have courses to be RE technicians.

From 2008, there were more postgraduate trainings offered in national universities such as the National University of Rosario, National Technological University (Buenos Aires), and National University of Comahue. The first two institutions developed a Master's Degree in Renewable Energy and the third a Specialization in Wind Energy. The National University of Rosario has been dedicated especially to the application of solar and wind energy sources in buildings and industrial installations.

In the case of the National University of Southern Patagonia, Santa Cruz, the Academic Unit Caleta Olivia dictates a degree course in Electromechanical Engineering with Renewable Energy Orientation, including the vector hydrogen as a vector of energy accumulation.

Also in Pico Truncado, Santa Cruz, is the first Hydrogen Generation Station by Wind Energy in South America (Fig. 4.1) which offered international courses of H generation [4], security, supply facilities, etc. Argentina has been a pioneer in Hydrogen (Santa Cruz) and Geothermal (Neuquén) technology applications in South America.

4.1.3 Legal Framework for Promotion and Regulation of RES

From the mid-1990s onwards, awareness about caring for the environment began in Argentina. It is initiated in primary and secondary education and then in state universities, also highlighting the advantages of renewable energy sources (RES).

Fig. 4.1 Pico Truncado plant of H [4]

Already in 1984, Argentina stopped using coal and oil to generate electricity in the country. Argentina begun to use only natural gas for electricity generation. Argentina, in the late 1990s, commissioned IPCC experts to study the influence of terrestrial overheating in the country for the next 100 years. It is the only country in America to deal with this type of study. These actions permit Argentina to begin to have a legal framework, which is summarized in the following table (Table 4.4):

4.2 The Great Takeoff of RES in Argentina

Law 26,190/2006 [9] of RES promotion allowed to initiate the national private wind industry that was impulsed by import protections and permitted to design and to produce wind turbines in the country by two companies: Pescarmona Industries (IMPSA) and the consortium NRG (Fig. 4.2). The first one developed a wind turbine of 2.5 MW with multipolar generator with Nd-Fe-Bo permanent magnets, without multiplier and pitch-controlled rotor. The second is a consortium of oil service companies that bought a 1.5 MW turbine design, built a prototype, tested it, and had it certified by international standards. In addition, NRG developed strongly the production of spare parts for wind turbines for international market.

From 1998 to 2014, Argentina suffered a lack of investments in exploration and exploitation of hydrocarbons and dry years for Big Hydro Energy plants. This situation produced an imbalance between energy demand and availability. So, Argentina had to import gas and oil. In 2010 the Argentinean government promoted GEN-REN plan [12] of 1000 MW for Wind, Solar, Biofuels and Mini−/Micro-Hydro implementation. Fifty-one projects with 1436.5 MW offered in this plan. During the middle of 2010, 895 MW were awarded, where 84% were wind energy (17 wind farms shared in Chubut, Santa Cruz, and Buenos Aires), 12% were thermal energy using biofuels (Buenos Aires, Corrientes, and Santa Fe), 1% were Mini-Hydro (Jujuy, Catamarca, Mendoza), and 2% of PV (San Juan).

Table 4.4 Laws related to RES

Law/year	Topic	Characteristics	Restrictions
25,019/1998 [5] (cooperatives impulse)	Wind and solar energy promotion	Tax advantages for investments in solar and wind energy. Creation of promotion funds for RE investments	Only for energy companies of distribution or generation plants
26,093/2006[a] [6] (biofuels impulse)	Biofuels promotion for production and use	Biodiesel promotion by means of soya oil. Twenty percent of national production should be used by distribution oil companies	Instability of local and external markets of biofuels
26,334/2008[a] [7] (ethanol impulse)	Bioethanol promotion	Ethanol legal framework obtained. Eight percent should be used in the local market	Instability of the local market
26,123/2006[b] [8]	H promotion to development, use, and applications as energy	National fund of H promotion and tax advantages for H industries. Five percent should be included in the pipeline	No regulation approved
27,191/2015–16 Review of 26,790	National promotion for RES use and applications	Argentina opens to international RE market. It permits a minimum 30% of national purchasing	National market is stable

[a]Legal framework was established with Laws 26,093/2006 [6] and 26,334/2008 [7]. Biofuels had the major production impulse with regulating its production and use: 5% of bioethanol should be included in gasoline and 7% of biodiesel in gas oil. This regulation guaranteed at the beginning the use of 20% of the local production of biodiesel in oil refinery companies. Biodiesel surplus is exported to Europe and other countries where Argentina is the largest producer of soybean derivatives in the world, including oil

[b]Argentina was a pioneer in Ibero-America in the development of technology, use, and an application of H as energy vector, but it has not been possible to develop its use because the H Law was not regulated

Fig. 4.2 Wind turbines manufactured in Argentina (Pescarmona Industries S.A., Mendoza [10];. NRG Patagonia S.A., Comodoro Rivadavia, Santa Cruz [11])

But in that time, the tariff conditions of Wholesale Electricity Market (MEM) did not give a capital return to amortize installation and operation. That is why few projects were implemented; for example, of about 754 MW wind farms, only 130 MW (20%) was installed. The restrictions on generation required special provisions for cogeneration, for example, specific events of large electric charges (such as spectacles, football matches, etc.) have to use autonomous generators because of the lack of energy and low reliability of the electric distribution in the low voltage system.

In spite of this, there is notable approval of provincial policies, for example, of San Juan province (2008), which promoted the installation of solar farms (2% of GEN-REN's) and a solar panel factory (2012) to produce wafers for PV cells (2014) (Table 4.5).

New tariff conditions were created for new power plant installations by "Energy Plus" plan because of the successive energy crises since 2004. Some thermal power plants (combined cycle) and wind farms (see Table 4.6) were built after GEN-REN 2010.

Figure 4.3 (left) shows wind farms that were in production in 2013. It can be seen that most of them are in Patagonia and south of Buenos Aires province. The Veladero (Barrick Gold mine) (7 in Fig. 4.3) in San Juan has the highest wind installation in the world (3000 m), 2.5/1.6 MW.

Table 4.5 Wind farms offered at GEN-REN 2010 (755 MW were offered, 130 MW were installed) [12, 13]

Wind farm	Company	MW	It began installation on
Malaspina I	IMPSA	50	
Puerto Madryn Oeste	Energías Sustentables S.A.	20	
Malaspina II	IMPSA	30	
Puerto Madryn II	Emgasud Renovables S.A.	50	
Puerto Madryn I	Emgasud Renovables S.A.	50	
Rawson I	Emgasud Renovables S.A.	50	OK – September 2011
Rawson II	Emgasud Renovables S.A.	30	OK – January 2012
Puerto Madryn Sur	Patagonia wind energy S. A.	50	
Puerto Madryn Norte	International new energies S.A.	50	
Koluel Kaike I	IMPSA	50	
Koluel Kaike II	IMPSA	25	
Loma Blanca I	ISOLUX S.A.	50	OK – July 2013
Loma Blanca II	ISOLUX S.A.	50	
Loma Blanca III	ISOLUX S.A.	50	
Loma Blanca IV	ISOLUX S.A.	50	
Loma Blanca I Básica	Sogesic S. A.	49,5	
Loma Blanca II Básica	Sogesic S. A	49,5	

Table 4.6 Wind farms by "Energy Plus" plan

Wind farm	Company	MW	It began operation on
Arauco – La Rioja	IMPSA	50.4	2011–2013
Diadema – Chubut	Compañía Argentina de Petróleo S. A.	6.3	2011

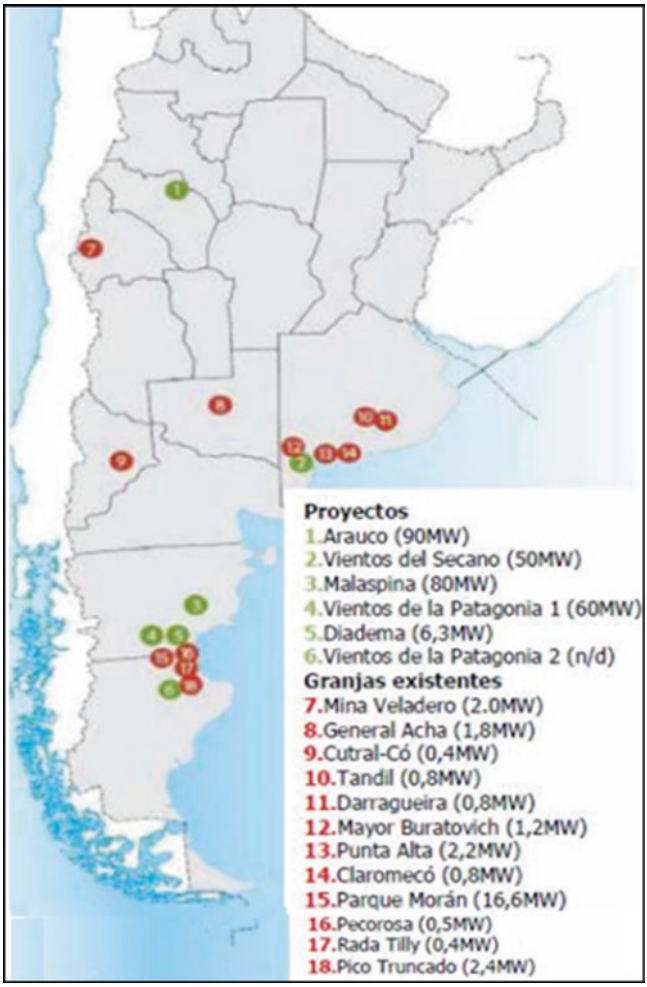

Fig. 4.3 GEN-REN 2010 plan (green) [13]

Facilities 8–18 correspond to cooperatives; these did not exceed 3 MW per wind farm, except Antonio Morán Park in Comodoro Rivadavia, Chubut, of 16.6 MW (15 in Fig. 4.3). Since 2001, several cooperatives entered into financial crisis and did not perform the corresponding maintenance, and some machines are out of service today (15 in Fig. 4.3).

Changes in the electricity tariff of Wholesale Energy Market during 2016 and the application of Law 27,191 (Law 26,190 review) permitted RENOVAR plan [14, 15] was implemented by the present government (Fig. 4.4). This plan will permit to have 8% of RE into the grid in 2018 and 20% in 2025. The first stage of RENOVAR-1 required 1000 MW of RE installations. It had 123 offers with a total of 6343 MW. The government accepted 103 offers (5209 MW) for wind farms (3468 MW), solar

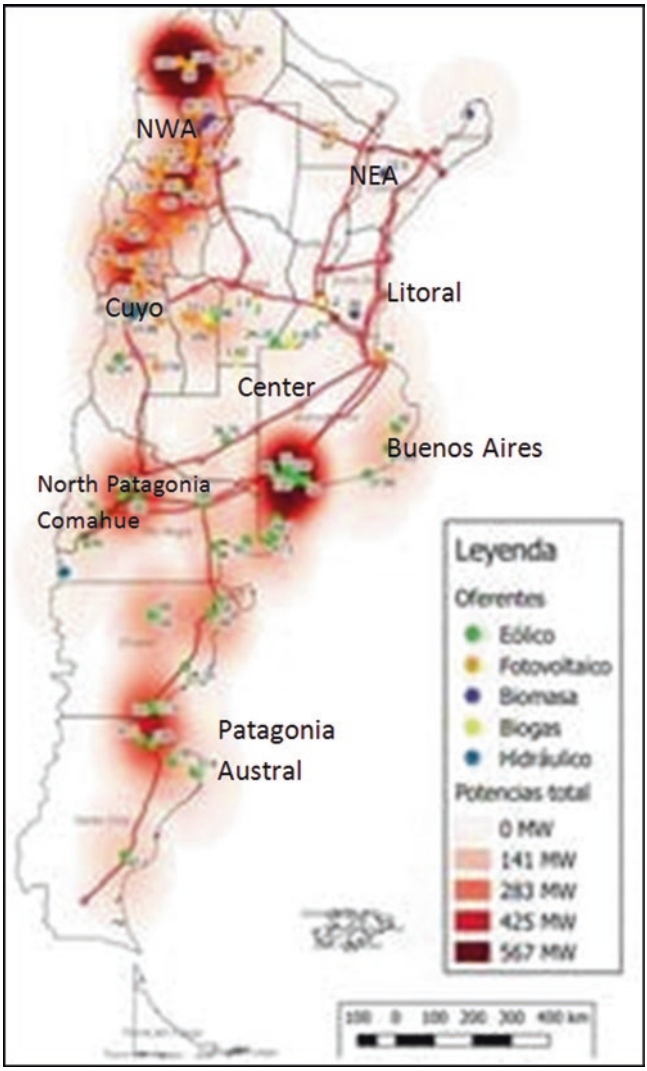

Fig. 4.4 500 kV national grid and location of RENOVAR-1 projects [15]

farms (2811 MW), Biofuels and Biogas plants (11 MW), and Mini-Hydro plants (5 MW). Eighteen offers were not accepted for 598 MW Wind, 506 MW Solar, and 30 MW Biomass. It may be that in the future, the RE proposal will be increased more than 1000 MW (RENOVAR 2, during 2017–2018).

RENOVAR-1 plan gave a real and great impulse to RES in Argentina, and it allowed to continue projects of GEN-REN 2010 which were standstill. In the case of Patagonia because of the transmission limit on a 500 kV network, the power to be installed is limited to 600 MW in Comahue and 400 MW in Southern Patagonia.

Table 4.7 Offered prices in RENOVAR-1 and reference ones for the government (blue) [15]

Tecnología	PRECIO USD/MWh		
	OFERTADO		MÁXIMO DE ADJUDICACIÓN
	Mínimo	Promedio*	
EÓLICA	49,1	69,5	82
SOLAR	59,0	76,2	90
BIOMASA	110,0	114,6	110
BIOGÁS	118,0	177,8	160
PAH	111,1	114,5	105

Average Wholesale Energy Market prices offered in RENOVAR-1 for Wind and Solar farms (Table 4.7) were lower than the government reference ones. During 2017, 59 RE projects of RENOVAR-1 will be finishing its installation. RENOVAR-2 will be during the second half of 2017.

4.2.1 RES Pending Development in Argentina

In Argentina, as described, energy facilities have been developed by means of wind energy (since 1990), solar energy (since 1985), mini- and micro-hydro power (since 1960), and biomass energy (since 1984). In the case of geothermal energy, during 1985, Neuquén province began studies of geothermal energy prospection at "Las Mellizas," Caviahue-Copahue Geothermal Park, and install in 1990 the first geothermal power station of South America (670 kW). It works until 1997 when it began to be out of service because of steam well decay. Today three provinces are making geothermal energy prospection: Neuquén on the volcano Domuyo (North Comahue), and Salta and Jujuy in North West of Argentina.

During 2010 ocean energy sources (tidal and wave) began to be studied in Argentina by several National Universities (UNPA, UTN, etc.). Technology has been developed (marine and fluvial hydrokinetic turbines, oscillating column systems, and nodding tubes) according to available data, but no prototypes have been installed in situ until now. At present, efforts are being made to unify a database on wave and tidal characteristics and ocean currents not only on the coast but also on the high seas. This data will be able to have details of the oceanic resources to have microscale maps and to be able to design appropriate prototypes.

4.3 Domestic Energy Generation Situation

Since the 1980s, several provinces of Patagonia began rural electrification using PV panels and wind turbines in Neuquén (Fig. 4.5) and Chubut. Then, during the 1990s, a rural electrification plan was put in practice, which allowed isolated rural

Fig. 4.5 Rural electrification plan in Neuquén (Mina La Continental, left; Currumil Quillen, School. N°65, right) [16]

Fig. 4.6 INTI testing plant in Cutral Có, Neuquén [17]

electricity users served by a rural electrical equipment company with a subsidized rate in most of the rest of the Argentine provinces.

In 2004, the PERMER National Plan [1] financed all the provincial rural electrification plans by means of PV panels. During 2014 and 2015, laws which promoted domestic electric power generation by RE were developed in provincial governments, where Neuquén, Santa Fe, Córdoba, and San Juan were the pioneers. In addition, since 2008, the University of Córdoba developed a laboratory for matching PV panels and the National Institute of Industrial Technology (INTI) installed a test bench in Cutral Có, Neuquén to verify characteristics of low-power wind turbines. This test bench is relevant to test wind turbines in isolated sites in the provincial rural electrification plans (Chubut, Neuquén, etc.) and in remote communication stations, particularly in hard winds of Patagonia. Figure 4.6 shows a Cutral Có wind turbine testing plant, which is able to certify turbines up to 10 kW.

Since 2010, architecture and civil engineering companies began to apply RE systems in buildings. The opening of the international market during 2016 permitted domestic solar and wind applications to be integrated in houses and buildings up to 20 floors, which are located in cities in the most critical areas of electrical demand. Figure 4.7 shows technology which can be applied for domestic and rural use.

Fig. 4.7 RE devices developed and/or available in Argentina for domestic and rural applications Wind turbines developed in UNCo (right); solar thermal and PV technology (center); micro-hydro (left)

4.4 Conclusions and Recommendations

It can be seen that the development of the applications of RES devices in Argentina has been very dependent on the economic situation and sometimes the country's politics. But in spite of this, the last 40 years has had a great growth, especially in the last decade, generating a legal and tariff framework that allows RE applications in constant evolution with greater installed power reaching 2500 MW in 2018 (10% of total demand, 25,000 MW).

Argentina has been a pioneer in South America in the use of different renewable energy products and devices: domestic photovoltaics (1980), geothermal (1985), private wind farms (1990), biomass (1983 ethanol, 1995 soybean biodiesel), and micro-hydro (1940). In the last three decades and with more emphasis in the last 5 years, wind farms, thermal power plants using biomass, and PV farms have been included in the Argentine System of Electrical Interconnection (SADI), giving the bases in the next future to export Energy to Chile (Hydrocarbons dependent) and Brazil (Big Hydro dependent).

Development Centers and Universities give the possibility to obtain the necessary Human Resources in the next future to designing, construction, installation, operation, and maintenance of RE systems.

RE converters developed and tested in Argentine Institutions (micro-hydro and wind turbines), and solar thermal and PV (Fig. 4.7) applied on projects of energy efficiency on buildings of about 10 floors, permit supply between 30 and 40% of energy for common services of a building, especially in peak demand hours, during the day and night. These developments will allow to reduce the demand in the low voltage grid and to distribute generation in urban distribution networks.

In Argentina, the development of RE technologies and exchange of experiences had been possible thanks to research and development between European and Argentine Universities and Institutes, taking experience by means of European RE equipment installed in Argentina.

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