Clean Energy and Water: an Assessment of Services for Adaptation to Climate Change

Final Assessment Report

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List of Acronyms and Abbreviations

AIC	Inter-jurisdictional Basin Authority (Limay, Neuquén and Río Negro rivers)
BOS	Balance of PV system
CAZALAC	Water Centre for Arid and Semi-Arid Zones in LA&C
CC	Climate Change
CD	Capacity Development
CIIFEN	International Centre for Research into the El Niño Phenomenon
CNA	National Agriculture Census
COHIFE	Federal Hydrological Council
EAP	Rural productive unit
EE	Electricity
ENOHSA	National Institute of Hydraulic Works
ENSO	El Niño Southern Oscillation
ETP	Potential evapotranspiration rate
Ha	Hectare
IADB	Inter American Development Bank
IADIZA	Argentine Institute for Arid Zones Research
IANIGLA	Argentine Institute of Snow, Glaciology and Environmental Sciences
IARH	Argentine Institute of Hydro Resources
IICA	Inter American Institute for Cooperation on Agriculture
INA	National Water Institute
INDEC	National Institute of Statistics and Census
INTI	National Industrial Technology Institute
INTA	National Agriculture and Livestock Technology Institute
IPCC	Intergovernmental Panel on Climate Change
IRAM	Argentine Metrology and Standards Institute
LA&C	Latin America and the Caribbean
O&M	Operation and Maintenance
PAN	National Action Program for Fighting Against Desertification
PHI	International Hydrologic Program for LA&C
pp	rainfall rate
PROSAP	Provincial Agricultural Services Program
PSA	Social Agricultural and Livestock Program
PV	Photovoltaic
RE	Renewable Energy
RETs	Renewable Energy Technologies
RIOD	International Desertification Network
SAyDS	Environment and Sustainable Development Secretariat
SMN	National Meteorological Service
SSRH	Hydro resources Under Secretariat
T&D	Electricity transmission and distribution
WEC	Wind Energy Converter
Wp	Watt peak

1. Executive Summary

Arid, semiarid, and sub-humid regions constitute 75% of the total area of Argentina, the country with the largest extension of dry regions in LA&C. These regions are inhabited by close to a quarter of the country population and produce around 50% of total agricultural and livestock products, mainly in irrigated valleys. Within Argentina, Catamarca, La Rioja, San Juan, Mendoza, Neuquén and Río Negro provinces have large extensions of dry areas and will be affected by climatic variability phenomena through a reduction in snow precipitation in the High Andes, mainly due to El Niño Southern Oscillation. Climate Change will also have its effects through increased evapotranspiration and water requirements. Though most of the population inhabits urban areas, there is still a significant number of rural inhabitants living on subsistence economies based on cattle breeding activities and small scale agriculture. Water resources are already scarce and severely limit the production alternatives and health of the poor rural population, constituting a huge barrier for improving income levels. Climatic scenarios indicate that this trend will probably worsen in coming years, transforming sporadic drought events in permanent ones.

The water services regulatory framework seems to be unprepared to cope with the trend in water availability. Effectively, in spite of water scarcity, water efficient technologies are not fully supported and disseminated, salinization and erosion have reached significant levels, and integrated management of water resources is burdened by the provincial nature of water resource management. A multitude of provincial stakeholders have competence in water issues, making difficult the adoption and implementation of measures at regional level. Poor rural inhabitants are in a still more difficult situation to cope with the changes that are required to sustain their livelihoods. This population is often relegated to the poorest areas, with lower access to groundwater resources and water infrastructure investment. In spite of their potential importance for the rural population, knowledge on underground water resources is still limited, and their exploitation requires significant investment, which generally lies beyond the economic capacity of rural communities.

Thus, the vulnerability of arid and semi-arid regions to climatic variability depends on the complex interaction of natural and anthropogenic factors that reinforce each other, the latter playing a very important role. Due to this reason, the adaptation to this issue requires the coordinated adoption of a set of actions in very different areas, including those aimed at guaranteeing the access to water resources. In the same context, renewable energies could play a role in the mitigation of this problem under some specific circumstances, but they do not guarantee a successful outcome on their own. Given the anthropogenic component of these phenomena, the measures that could be adopted to improve the management of water and soil resources are of equal or higher relevance than those aimed at guaranteeing adequate access to water resources.

Some of the dry regions analyzed depend almost exclusively from underground water resources to satisfy current water requirements (Barros, 1997). More than 95% of water resources in La Rioja Province are underground resources. Thus, the potential influence of climate change over access to underground water resources becomes the key issue for these

regions. Additionally, underground water supply schemes seem to be better adapted to cope with increased water stress situations, even more if they are linked to high volume storage facilities.

However, both renewable and non-renewable water supply systems could be affected by a decreased availability of underground water due to salinization, pollution or water level depression, linked or not to climate change. These effects are becoming more common and indicate the need to exploit deeper aquifers. Under these situations both types of energy systems face increased costs and technical challenges to solve water availability problems. Also, reliability and energy security problems are not exclusive of conventional energy systems. Effectively, renewable systems could also be affected by these problems and require significant planning and support schemes to prevent most of them and ensure long term sustainability, as indicated by case studies (Michacheo and Catamarca) and Parodi, 1999.

Under some situations, renewable energy systems seem to offer a cheaper and more reliable alternative to conventional systems when pumping water from underwater sources in isolated locations. However, renewable energy systems could also show limitations to cope with some situations posed by climatic variability when pumping head and/or water volume requirements are large or highly seasonal (e.g. for crop irrigation). For example, photovoltaic pumping systems are not available for high head wells for flow rates above 4m3/day. In particular, under high water demand levels the depression of water level in wells could lead to diesel becoming a more cost effective option than PV pumping (EmCom, 2006). Thus, medium to large productive activities usually depend on conventional technology options (grid, diesel).

In summary, an adequate adaptation strategy to climate change induced water stress should go beyond the specific technology used to pump water and include measures such as: diversify water supply sources, increase water storage facilities, and implement efficient and rational water use. This in turn requires adequate planning that takes into account the potential climatic scenarios when designing/modifying water supply schemes. Finally, there are also significant differences among renewable energy systems in terms of cost, O&M requirements, power available, social acceptance, that should be considered when selecting a technology. In broad terms it could be said that the preferred order among renewable options in the analyzed area would be: hydro, wind, solar. However, resources availability is the key factor to make the final selection between these three resources, and usually leads to excluding hydro from the list in dry areas.

Some conclusions from the diagnosis:

- The dry regions under study seem to be particularly sensible to the increased climatic variability that would occur in the coming decades. These changes will probably aggravate the existing water stress problem, transforming sporadic critic situations into a common condition.
- In the Cuyo valleys region, the ENSO phenomenon seems to be the key aspect that restrains both surface and underground water availability through the reduction of snowfalls in the high Andes. It is still not clear in which way Climate Change could affect ENSO, but it is probable that it will contribute to the worsening of arid conditions through the increase in evapotranspiration.

- Climatic variability and the potential effects of Climate Change over it is only one of the many issues that lead to water availability problems in arid and semi-arid regions, others being related to water infrastructure, water management and use.
- Though the region has suffered extreme hydrological events, it has not yet implemented rational and efficient water use measures in a complete, integrated and systematic way. In particular, small rural productive units still use traditional irrigation methods (mainly gravitational). The adaptation of these regions to the growing water stress will require significant investments in new infrastructure and financing capacity. These are generally beyond the possibilities of individuals and should be supported by the State. The investment required also goes beyond the implementation of renewable energy water pumping systems, comprising also storage and distribution infrastructure as well as technologies that allow more efficient water use and can protect adequately both the soil and its natural cover.
- It is unlikely that the conditions for the adequate implementation of an adaptation strategy could be created without an active State long-term intervention and support, and based on the strengthening of productive activities adapted to each region. In this sense, the redesign of productive activities and the commercialization of higher market value products that are better adapted to dry conditions than traditional products, and the manufacture of high added value ones may constitute and interesting strategy to cope with the reduction in productivity associated with decreased water availability.
- Young people migration phenomenon is already present in some of these regions due to harsh conditions, isolation and low quality of life compared to urban areas. Energy has a key role to improve living conditions and reduce isolation perception (recreational and social uses of energy). Where adequate water resources are available, the adoption of other measures to reduce vulnerability and migration risk is also highly recommended (e.g. small forestation projects for firewood, fodder and windbreak in areas where biomass is usually scarce; solar water heating).
- Regulatory framework and water policies in some provinces seem to be inadequate for dealing with increased water stress situations in the coming decades. Particularly, the implementation of rational water use practices and efficient technologies is not fully enforced and supported by adequate incentives. This may be due to lack of human resources and of adequate budget for implementation, but also to fragmentation and deficiencies in the integrated management of water resources between several institutions and sectors.
- A couple of well developed water management schemes are found in the Negro, Neuquén and Limay River basin and in Mendoza water resources' authorities. Both are interesting organizational regulatory examples for shared resources management, based on the participation of irrigation users. Nevertheless, some doubts remain related to the broad community access to these participative schemes, remarkably small agriculture productive units located far from the main river basins.
- The water stress situation aggravates in marginally productive areas surrounding the so called "Oasis. The population with less economic resources and which is not comprised by long term development policies is usually displaced towards these areas, creating high vulnerability conditions, while large agricultural producers have a privileged access to the best productive areas in the oasis As a consequence, small producers face an unfair distribution of water infrastructure investment which limits access to adequate water resources for irrigated agriculture.

- An adequate management of pumping systems, boreholes, and pumping schedule could play a significant role in preventing a lowering in water table level and the salinization of boreholes. This in turn could enhance the opportunities of dissemination of PV pumping
- Information available is still scarce and fragmented. The sole identification of the current status of rural communities in relation to water availability and uses poses a challenge since the main information sources are outdated and limited in extent. More information is available on water and energy resources at provincial level, but with important gaps in monitoring infrastructure still exist.
- At least three other conditions are fundamental for an adequate implementation of adaptation strategies: an advanced degree of community organization and commitment; capacity development for the implementation and use of the new technologies; and support of productive activities consistent with the water resource available (land use planning).
- The complexity of the problem situation requires for the intervention of many knowledge areas and their corresponding institutions. However, deficiencies in inter-institutional coordination can lead to the overlapping of sporadic initiatives and population lack of commitment, and to projects lacking key components and prone to failure.
- The long term productive sustainability of these regions depends on the adoption of an adaptation strategy that incorporates all these elements in a coherent way.

In relation to the use of renewable energy resources and technologies:

- Many small rural producers in these dry areas have historically settled in places where there existed surface aquifers or shallow underground water resources that are disappearing due to climatic variability. In these cases renewable energies could offer a suitable pumping option for some uses (e.g. Savonius locally made windmills, PV, or small WEC).
- In other dry areas where the lack of surface aquifers prevents productive activities, exploiting underground water resources is a key component of development. In those places where water volume and depth are suitable, renewable energies could play a significant role.
- Isolated RE could also have a key role to improve energization levels in rural areas, increasing life quality conditions, making possible small productive activities, and reducing rural-urban migration (e.g. PV and small WEC for productive and recreation uses, SWH, solar driers, thermoelectric generators with biomass, windmills for mechanical energy, etc.).
- There exists some small scale and fragmented experience accumulated since the 80´s in the use of renewable energy systems for improving the access to water resources in these areas. Results have been variable, but in general they have led to an improvement in access, though problems have manifested in the adoption and long term implementation of the new technologies.
- RE pumping projects tend to have a high investment cost (particularly PV), which requires the participation of a financing institution or a donor in the project. These specific project requirements are usually beyond the administration activities and knowledge of local authorities.

- The implementation of water supply initiatives based on renewable energies still rely on the dissemination and technical support provided by research centers working in each region (Universities, INTI, INTA, etc.). No widespread knowledge is available on these options among local planners. Renewable options tend to be adopted when conventional options are excluded, mainly due to cost or fuel supply issues.
- Isolated renewable energy based pumping systems seem to require more technical support (long term) and capacity development of the local community than diesel systems.
- Conventional systems tend to have a better local support infrastructure, and more knowledge is locally available on this technology than on renewable energy systems. Accordingly, maintenance time may be longer for renewable energies (spare parts supply, human resources availability), which constitutes a serious problem when dealing with water supply
- When feasible, the extension of the power grid should be the first option to assess given its advantages in terms of energization of productive activities, and water pumping and distribution. In this context, grid connected renewable energies could help support weak networks, reduce electricity costs and specific emissions, and increase the reliability and power available. This requires a high renewable resource potential in an area close to the transmission grid that is not saturated.
- Renewable energy alternatives could also be a first step towards electrification, followed by interconnection to the grid. This is a relevant role as it involves a first improvement in life quality, which can be reinforced later on. However, it could also postpone interconnection plans.
- For highly isolated communities, the availability of renewable energy resources close to the users usually restricts the range of pumping options. In some arid and semiarid areas, solar is sometimes the only renewable resource available with adequate distribution along the year.
- For isolated applications, under specific circumstances conventional pumping systems could offer certain advantages over solar pumping (e.g. suitable for high hydraulic loads and variable water demand, well-known technology). In these situations it could be advisable to combine both systems into a hybrid system. This has the added advantage of not depending on a single pumping technology or on a single borehole.
- Isolated PV pumping could offer a technical solution for very small rural productive units with no previous pumping system or replacing manual systems, or for human water supply in communities with even water demand along the year. In this sense, PV pumping could constitute an intermediate step between precarious low volume water supply systems and hybrid or diesel pumping systems more suitable for medium to large scale productive units.
- Any water supply system requires plans to ensure provision during maintenance periods, particularly during water stress and/or high demand periods. This may require the installation of hybrid systems, the availability of large storage capacity, and the perforation of at least two productive boreholes per community.

Based on this diagnosis and on case studies, a summary of barriers to the use of renewable energies for water supply in dry areas can be presented:

a.	**General framework**		
1.	Lack of inter-institutional and sectorial coordination. Integrated planning		
2.	Institutional weakness, Inadequate control, investment, and/or implementation of water services and works		
3.	Inadequate regulatory framework (e.g. to cope with climatic variability)		
4.	Lack of adequate information		
5.	Exclusion of rural poor population from development model		
b.	**More or less independent of pumping technology (including REs, diesel and EE)**		
1.	Low payment capacity. Subsistence economies		
2.	Low Community organization level / resources. User conflicts		
3.	Restricted access to underground water resources / Water level depression (partly associated to inadequate management of pumping infrastructure and climatic variability)		
4.	Restricted availability of water resources. Increased erosion.		
5.	Unsustainable water use / Increased water requirements (partly due to increased evapotranspiration)		
6.	Salinization of water resources (associated to inadequate management of pumping infrastructure)		
7.	Requirements for investment in associated infrastructure (e.g. trickle irrigation, water storage and distribution, and technologies allowing more efficient water use).		
8.	Limited knowledge on community characteristics, resources and water requirements		
More specific to Renewable Energy options			
c.	**Isolated systems (e.g. standalone PV Catamarca)**	**d.**	**Large scale - Grid connected (e.g. Arauco wind farm)**
1.	Technical limitations in water volume and/or head restricts their use under some conditions and for productive activities, particularly for irrigation	1.	Large scale projects associated with good power availability and low costs may reach unsustainable water use levels if not properly designed
2.	High investment cost (pumping system and storage)	2.	High investment cost
3.	Weak O&M infrastructure / long term technical support. Risk of extended down-time periods	3.	Limited extent of EE T&D infrastructure.
4.	Renewable energy resources need to be available close to the users.	4.	Good quality renewable energy resources should be available close to the transmission grid. Resource quality requirement is higher than for small scale projects.
5.	Knowledge and perception about the performance and suitability of the technology is limited among local planners.		

Strategic outlines are proposed to cope with each of these barriers. Among the most relevant strategic outlines and instruments are those aimed at improving the knowledge on underground water resources, improving the coordination among institutions, assigning adequate funds and human resources to the development of water supply infrastructure for rural inhabitants and small producers, supporting the rational and efficient use of water resources, promoting productive activities consistent with water resources available and high value products, promoting land use planning, updating/modifying regulatory frameworks, supporting capacity development at all levels, improving information available on requirements and resources, promoting R&D&D on technology options, assigning investment in more equitable way, improving pumping systems´ reliability and technical support network.

Considering that subsistence economies that characterize rural poor population constitutes one of the main barriers to their development, and that productivity will be affected by drier conditions, a main objective of an adaptation strategy involves achieving an increase in income through a redefinition of productive activities. In a first stage this can be done by adding value to existing animal and plant products, while in a second stage it could involve the production of higher market value products better adapted to drier growing conditions. In both cases a significant support is needed in terms of R&D, capacity development and market access.

Given the intrinsic complexity of water issues in Argentina, and in particular those affecting rural population, a strategy is needed to provide viability to the implementation of strategic outlines. This strategy is based on three main pillars:

- Create political will and an enabling framework to deal with the required changes
- Secure the required funds and resources for implementation
- Guarantee the coordination and commitment of participating institutions in the design, implementation and long term follow-up stages of a national strategy with regional components

The participation of society providing public support, building a technical proposal, and in the follow-up of this process is desirable.

The strategy to cope with increased water stress due to climatic variability outlined in this work could be **extrapolated** to other regions of LA, but not without significant restrictions.

Similar problem situations due to climatic variability and social vulnerability exist in:

- Inner Northeast Brazil
- Perú´s Highlands
- Bolivia Altiplano, Northern Chile and Argentina (Puna)
- Chaco (Paraguay)
- Northern México

These regions present both similarities and important differences with Argentina´s case studies. Among the latter we can mention social and cultural traits and water regulatory and institutional frameworks.

The methodological steps followed in this work allow the eventual replication of the proposed guidelines and actions to similar problem situations. Once the relevant elements are identified (section 2.3 and particularly table 2.24), possible alternatives regarding the role of energy for water supply in the context of increased climate variability could be evaluated (strategic outlines contained in tables 3.1 to 3.4).

Summarizing, isolated renewable energy systems have a role to play to improve access to underground water resources, particularly when those resources are not too deep and for uses that do not require large volumes or have a large seasonal variation. Interconnected renewable energies could also play a significant role, with the added advantage of the power levels

involved. However, RE for water supply should be considered as one set of technical options in the framework of a complex development problem and a wider strategy that involves many components covering regulatory, institutional, social, economic and technical issues. All these issues must be tackled in a coherent way with the active long term support and participation of the National and Provincial State.

Finally, the main areas of research that link renewable energies and water issues in the framework of an increasing water stress due to climatic variability are listed below, specific ideas are included as footnotes, when relevant. High and medium priority levels for research and investment were assigned following diverse criteria like population benefited, uncertainty level, providing an answer to a growing problem, the impact on key productive activities, and the development of capacities, among others.

High priority research subjects:

1. Assessment of hydrological balance of semi-arid regions. Assessment of evapotranspiration adapted to local conditions and taking into account wind effect (ETP models were developed for bio geophysical areas which are quite different from those under study in the present project).
2. Improve underground water resources knowledge (availability, quality, deficiencies, yields, recharge processes, etc.) Integrate dispersed and fragmented geological, geophysical and hydrological information[1].
3. Improve the degree of snow precipitation predictions over the high Andes.
4. Prediction of the regional impact of ENSO on temperature and precipitation.
5. Improve knowledge on water requirements and use practices. Role of social and cultural factors in the evaluation and "buy-in" of an energy technology for water services.
6. Water Resources administration, how to secure access for all and allocation among competitive uses of water? Role for long term State intervention and support within the adaptation strategy by strengthening of productive activities at the regional level.
7. Harmonization between the up to now disjoint water and energy policies. Research on ways to implement - in an efficient way - regulatory frameworks and rules. Particularly identification of existing or potential conflicts between water and energy ruling (policies and regulation).
8. Perform a survey of boreholes status in semi-desert region (water quality, dynamic head, sustainable yield).
9. Land use planning and water management schemes based on climatic scenarios. Productive structure adaptation[2].

[1] Observed and projected groundwater and river water overdraft. The assessment of underground water's age and origins is considered highly desirable. There is particular interest (and some research already done) in regards to mining activities, some national universities – La Plata and Buenos Aires - and River Basin authorities will probably be interested.

[2] The emphasis here is at the community/regional level, but the Research Topic of identifying the water energy footprint of productive activity is also suitable. However, the approach to this footprint assessment should not imply the creation of commercial barriers to the developing world products in general. A possible strategy for avoiding this, consist in analyzing current situation and from there onwards research how to improve such a footprint. Some work is already been carried on by FLACSO/San Andrés University, both in Argentina.

10. Research on vegetable and animal varieties suitable for semi-arid regions. Productive reconversion. High value products.
11. Development of cost effective PV pumping options for high hydraulic loads and higher depths. Technology gap between 120 and 200m.
12. Development of cheaper and lighter drilling and underground water resources survey equipment for deep resources[3].
13. Potential for the energization of productive and residential requirements with isolated RE systems (e.g. clothes and leather washing and tanning using wind energy, thermoelectric generators coupled with biomass stoves, low cost food refrigeration using solar energy).
14. Water and energy rational use and efficient technologies and strategies adapted for these regions. Cheaper large capacity water storage options[4].

Medium priority research subjects:

15. Survey of climatic and hydrologic measurement stations, and assessment of infrastructure and upgrading needs
16. Assessment of potential for the development of alternative productive activities (e.g. ecotourism, hydrotherapy, water commercialization with high fluorine levels).
17. Development of regional and sub-regional models that could allow a better estimation of climatic trends and hydrology at local level (current models run at global scale). An example of a regional model under development is the MCR-CIMA.
18. Research on the links between ENSO and Climate change phenomenon.
19. Aquiculture development using high salinity water resources. Species identification.
20. Development of GIS adapted for monitoring hydrological conditions.

[3] A concrete action with the participation of municipalities and producer's cooperatives is the assessment of an implementation strategy for improving water access. More specifically, both capacity building and equipment acquisition/purchase is required for excavating wells (or deepening existing ones) in order to find more water for those producers whose *aguadas* (natural rain water reservoir) are getting dry. Renewable energy for pumping will be required along this transition from *aguadas* to excavate wells. This action requires previous identification of the relevant stakeholders.

[4] Regarding basin level water management and National level energy policy, there is an interesting work done by the AIC, developing a forestation strategy for flood control. Such a strategy can be useful to some other regionally relevant river basins (Comallo Valley with a poor native community in its headwaters). http://www.aic.gov.ar/aic/publicaciones/CUENCA_NQN.pdf

2. Description of problem situations and diagnosis

This section is based on the assessment of case studies and regional climatic scenarios. It includes a description of the general framework and makes focus on the use of renewable energy technologies (RETs) for water supply.

The main case studies analyzed in the present document are:

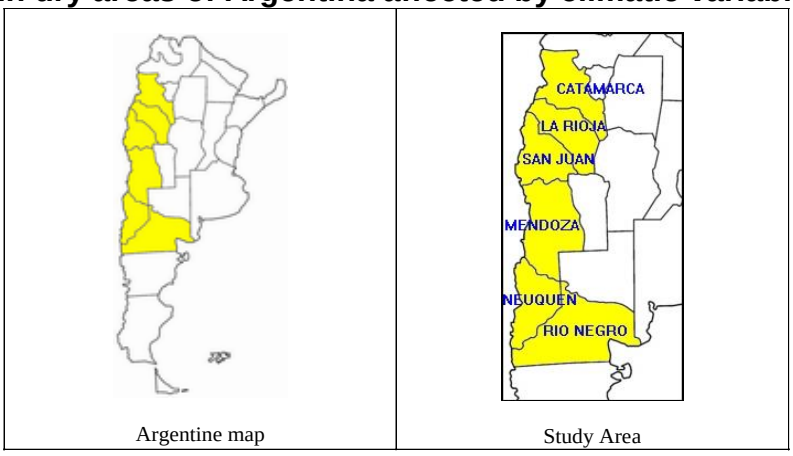
- Photovoltaic pumping from deep wells in Catamarca
- Small wind turbine pumping for isolated producers in Comahue - Neuquén
- Grid connected high-power wind turbines for irrigation in La Rioja

In this last case, the large wind power capacity allows irrigation to take place in a previously weak grid area located close to the end of the national electricity system. Some climatic scenarios are presented and discussed for the Comahue as a macro-region. As work structure, the three case studies are developed, but instead of putting the main focus on the technology, the analysis is based on the characteristics of the communities suitable for implementation, based on actual examples and some hypothesis. Key issues are the level of community organization and existing infrastructure, productive activities and required expertise, and their links to technology.

Constraints and difficulties found during the assessment

The relevant region under study was redefined in order to take advantage of the best available quantitative data. Thus, the provinces analyzed (employing quantitative indicators whenever possible) are Catamarca, La Rioja, San Juan, Mendoza and Neuquén, accounting for 19% or the Argentine territory, and covering a large fraction of the arid, semiarid and sub-humid regions of the country, which comprise 75% of the country (Figure 2.13). Whenever possible, Río Negro province is also taken into account in the diagnosis.

Figure 2.1 Main dry areas of Argentina affected by climatic variability



Source: own elaboration

Among the main constraints faced during the assessment are worth mentioning:

- Scarcity of specific data.
- Very little documented experience in the region for identifying typical costs, implementation efforts, and barriers in general.
- The profile of analyzed projects reveals a strong relevance of local and provincial support and involvement. This means – remarkably for the implementation stage - that each case is unique and makes it difficult to elaborate generalized conclusions.

The main strategy for solving the mentioned data issues was to propose from the very beginning a flexible descriptive and analytical methodology, that allows finding a solution – in terms of strategic guidelines and actions - for the complex, complete and detailed problem situation that is faced.

This general strategy was complemented by an assessment of relevant technologies (solutions at its most specific level) following a "niche" concept, by which the specific advantages and features of the renewable option is linked with the requirements, available resources, local situation, etc. Finally, some indicators are used to judge the feasibility of the options.

Other issues were a challenge to the assessment, like the several institutions from many fields that were involved in water issues, e.g. agriculture and livestock, water and sanitation, energy planning, renewable industries and enterprises, social development entities, rural development agencies, among others. Allocating more time than initially estimated and relying on interdisciplinary work and consultation allowed overcoming this barrier.

When the contents of the work were planned, the objective was to strengthen the analysis with geo-referred mapping. Some undergoing activities like the Wisdom Project for Argentina,[5] where FAO, the INTA, the Agriculture Ministry and other public entities are working together, made us think that it would be possible to present the different dimensions of the problem situation with this versatile tool. Among them: main electricity grid map, with T&D detail; rural settlements and poverty areas; irrigated agriculture zones; and renewable energy resources data. However, very little detailed information and data bases under GIS format were obtained. Useful information is not easily available in Argentina, mainly due to cultural traits, the strategic value of some information, and a perception of other stakeholders as potential competitors. Nevertheless, when writing this final version, some interesting and promissory GIS information was available at the official Energy Secretariat website[6]. This sort of tool might feed future work with more specific information in form of multi-layers maps.

[5] http://www.fao.org/docrep/011/i0900s/i0900s00.htm

[6] http://sig.se.gob.ar/visor/visorsig.php?layers=e9727e811f4fefc87367b8a310c2f6a1,dba1d3a66c795c64fe7bee1152dbb976,fd4ffe16e75056504157dd35fa8e67d7,7c15f1e0fb59202eb80f60483a8c60e2

2.1 Socioeconomic context

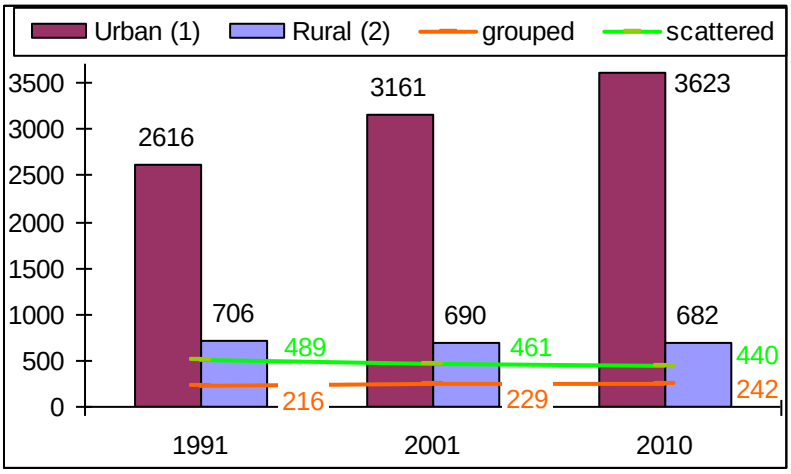
Population characterization

The rural population in this area includes a large fraction of "criollo"[7] settlers with indigenous origin (mainly Mapuches), and descendants from the first migration movements towards this region that took place at the beginning of the XX century.

According to the national census of year 2001[8], the rural population in Argentina (including both grouped and dispersed inhabitants) represents 11% of total population. Preliminary results from the agricultural census carried out on year 2008 indicate a reduction of the number of agricultural and livestock exploitations and an increase in their average area in relation to year 2002. This seems to point towards a larger concentration in land tenure and a migration phenomenon towards urban areas.

The characterization of relevant rural population and its evolution can be detailed using two full data periods – 1991 and 2001. For the 2010 Census, only aggregated data is available, thus an extrapolation of the 1991-2001 period variation was performed for the four relevant categories[9].

Figure 2.2 Urban-Rural Population in Catamarca, La Rioja, San Juan, Mendoza, Río Negro and Neuquén (thousands inhabitants)



Source: own elaboration from INDEC data
Note (1): Urban population is defined as inhabitants living in villages of 2000 people or more

[7] Descendants from European migrants born in America
[8] 2001 National Census, http://www.indec.gov.ar/webcenso/provincias_2/provincias.asp . Data from the last national population census carried out on 2010 were not available when the report was being written.

[9] Specifically, the 1991/2001 accumulated annual increase rates for rural (and rural scattered) population variation by province was replicated for 2001/2010. Then Urban population (and rural grouped) was defined as difference

Note (2): Rural population is classified as grouped in villages of less than 2000 inhabitants or scattered along the rural areas.

As an aggregate region, the reduction of the rural fraction is evident, even in absolute terms; while the figure of rural scattered inhabitants tend to decrease and rural grouped tend to increase. If the analysis is performed on a province basis, some differences arise. In La Rioja and Catamarca, scattered population clearly overtook grouped inhabitants, the opposite happens in the rest of the analyzed provinces (reflecting only 1991-2001 data, as 2010 detail is not available yet).

Migration and settlement patterns

Most of the population migrates towards more densely populated rural areas or larger cities. Migration patterns, mainly involving women and kids, are motorized by the lack of adequate opportunities for the young population in the rural area (e.g. primary and secondary education). Men remain in the fields and visit their families in towns and cities or receive them during holidays. The final outcome of this process is fields inhabited by grown-up couples without kids, since the young population that experience urban life rarely returns to the rural area.

Unfortunately data on these issues is scarce. As an illustration, the male fraction of Mendoza province, the most relevant jurisdiction in terms of rural inhabitants, reached 47.9% among urban inhabitants, while the respective share for the scattered rural inhabitants increases up to 52.1%, always by year 2001.

Cultural and social organization traits

Rural families are generally grouped into what is called “parajes”, which are rural areas without defined boundaries and close to primary schools. Rural inhabitants are devoted mostly to cattle raising activities (mainly sheep and goats), and grouped into producers’ cooperatives in order to obtain better conditions for the sale of their production and for buying food and other materials. It is also common to find in each “paraje” a provincial government representative and a sanitary outpost with communication links with regional hospitals via a high frequency radio network.

Land tenure

Land tenure is supported in many cases by title deeds, though precarious land rights are more frequent since rural settlers use to occupy land that belongs to the State. The appropriation of land by neighbors, usually in an illegal way, is facilitated by two facts: the lack of a clear provincial government policy towards those who may inherit property rights when the original settlers die; and the lack of interest by the descendants.

There also exist areas of degraded land and lower economic value that are occupied by indigenous communities. A community is characterized by many families, each one

maintaining a piece of land assigned by historical tenure rights, but with no right to sell the land.

A first legal classification of land tenure status distinguishes between rural productive units with and without defined boundaries. In 1988, those with undefined boundaries were estimated as a 27% of the total at national level. These lands present problems from the point of view of land tenure since land boundaries are not specified in land titles.

A second relevant classification of land tenure status is as follows[10]:

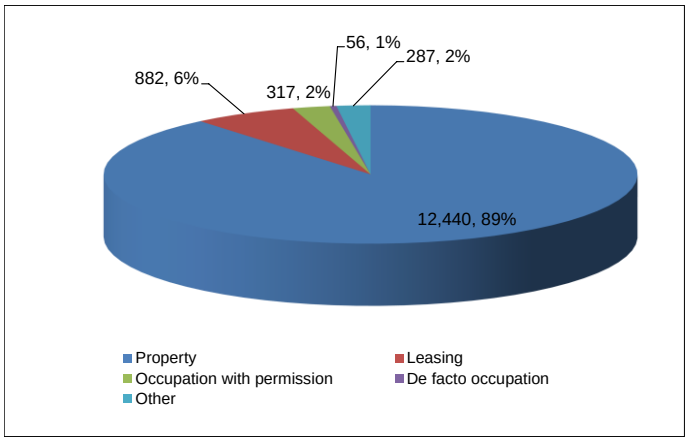
- Standard property rights. Personal or familiar property, or under death duty legal process. This situation implies the existence of a valid title deed or a situation where complete possession is exerted, even when the owner does not possess the final legal instruments. This category includes: personal property, familiar property, undivided state
- Under agricultural lease contracts. Oral or written contract that provides rights of use over land. The retribution could be a fraction of the production and if it lasts more than three years it is called "Aparcería". If it lasts for less than two years it is called "Accidental" contract.
- Occupation. Precarious land use with no title deed or contract. This can be "de facto" or with the owner´s permission. The occupation of fiscal land is the most common example of this category.
- Community land. Derives from a colonial land tenure status, where a fraction of the territory was granted to the subjects of the Spain kingdom. These lands are not covered by proper regulation. Transaction operations involving these lands are performed between persons that have documents with diverse legal validity ("Derechosos"). Within these lands there are also de facto occupation situations and also with permission.
- Other. Categories not specified elsewhere.

In the region under study (Catamarca, La Rioja, San Juan, Mendoza and Neuquén provinces) [11], land tenure status is as shown in figures 2.3 and 2.4.

[10] (González, 2000)

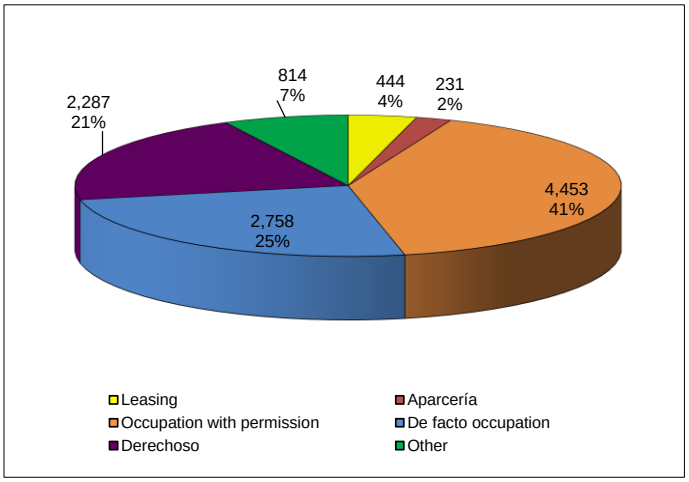
[11] Rio Negro province is included when convenient, as it belongs to the studied river basin, but some large scale features of the agriculture exploitation along valleys cannot be compared and integrated to the rural areas under analysis.

Figure 2.3 Rural productive units with defined boundaries by land tenure category in Catamarca, La Rioja, San Juan, Mendoza and Neuquén (Thousand Hectares and %)



Source: own elaboration based on (CNA, 2002)

Figure 2.4 Rural productive units without defined boundaries by land tenure category in Catamarca, La Rioja, San Juan, Mendoza and Neuquén (Number and % of EAP)

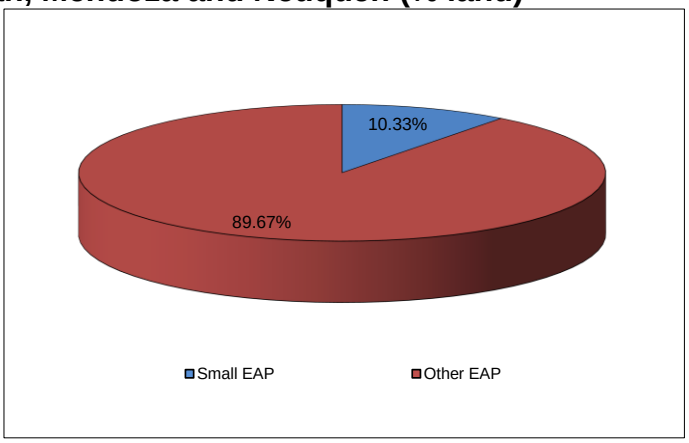


Source: own elaboration based on (CNA, 2002)

Within this complex land tenure framework, there exist many problematic situations. The main ones are those relate to: occupation of fiscal land, occupation of private land, community lands, precarious land tenure, indigenous communities lands, lands under death duty process and other special cases such as poor producers in protected natural areas.

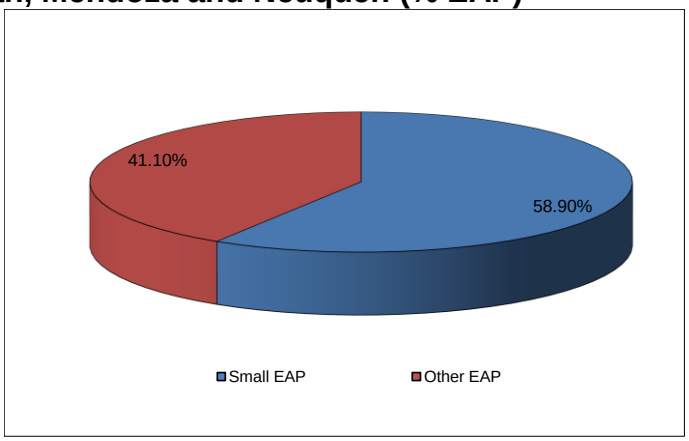
It is also relevant to note that there exists a land concentration process in the whole country that is exemplified in the following figures. These figures show quantity and area of rural productive units for the region under study, distinguishing between small units and the rest of the units.

Figure 2.5 Land occupied by rural productive units by unit size in Catamarca, La Rioja, San Juan, Mendoza and Neuquén (% land)



Source: own elaboration based on (CNA, 2002)

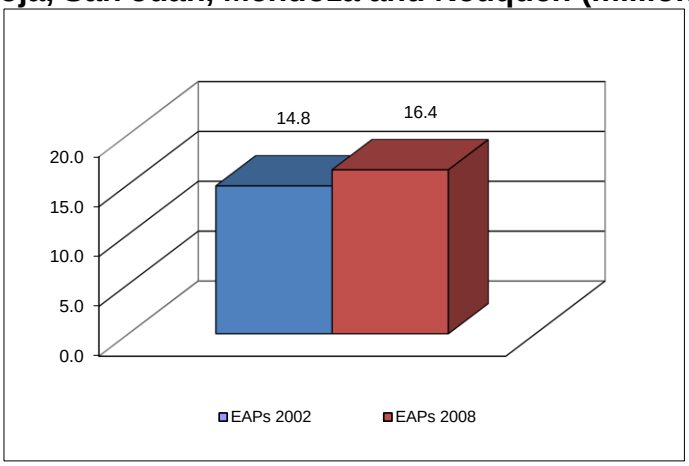
Figure 2.6 Relative number of rural productive units by unit size in Catamarca, La Rioja, San Juan, Mendoza and Neuquén (% EAP)



Source: own elaboration based on (CNA, 2002)

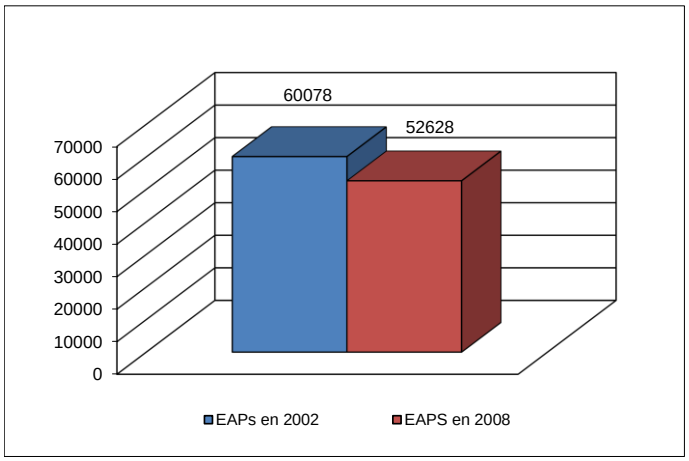
This increasing concentration process exemplified through agricultural census data from 2002 to 2008, not only shows a reduction in the quantity of rural productive units, but also the expansion of the area under production. In many cases this last phenomenon is carried out by advancing the agricultural frontier towards native forest areas.

Figure 2.7 Evolution of the area occupied by rural productive units in Catamarca, La Rioja, San Juan, Mendoza and Neuquén (million Hectares)



Source: own elaboration based on (CNA, 2002) and (CNA, 2008)

Figure 2.8 Evolution of the number of rural productive units in Catamarca, La Rioja, San Juan, Mendoza and Neuquén



Source: own elaboration based on (CNA, 2002) and (CNA, 2008)

These figures show a trend towards increased average size of rural productive units due to a concentration phenomenon in land tenure.

Poverty and indigence levels. Income levels

Only scattered data is available on rural poverty and indigence levels in Argentina. In Neuquén province it is possible to identify a relevant target group of 4,900 households. This figure is composed by scattered rural inhabitants, willing to accept electricity services using renewable technologies (or other means). This was identified by a PV electricity supply feasibility study, done under the PERMER Project by 2006[12]. Therefore, from the survey

[12] Energy Secretariat, Permer Project, Electricity supply of rural scattered population by renewable energy Feasibility Study, Neuquén Province. 2006

developed in the framework of that project it is possible to present some features of the relevant and representative population:

The average household is composed by 4.6 people, 97% of interviewed live all year in the rural area. The maintenance of houses is good in 61% of the cases. 85% of interviewed has finished primary school studies - only 9% has finished secondary school.

The average distance to the main / access road is around 29Km (in coincidence with average distance to the electricity grid) and to the closer town is 40Km (extreme values being 1 and 115 Km).

The main economic activity is extensive livestock raising, mainly sheep and goat. Frequently - 96% of surveyed families – not only the head of the household works in this activity, but also his/her partner, sons or other family members. (Energy Secretariat, 2006).

The average monthly income was $402 (134 USD) and can be decomposed into a fixed sum of $161 and a temporary or season related sum of $394. While the temporary income is featured by higher uncertainty levels, originated in animals sales during 2 or 3 months or "changas" meaning sporadic and informal day jobs. Remarkably 73% of the interviewed receive the most extended social plan of Argentina: "plan jefes/as de hogar" ($150).

The energy consumption profile of these households can be characterized by a typical liquefied gas lamp for lighting and a battery radio for communications. 63% of the interviewed had one of these lamps and 98% a radio. The $73 average expenditure in these services implies 18% of their income. Regarding productive uses, 96% of surveyed households are interested in having electricity also for productive uses like workshops and poultry breeding.

A similar but smaller study was conducted in San Juan province (Energy Secretariat, 2006); some figures illustrate the differences and similarities with the Neuquén study. Remarkably, while the number of rural scattered households lacking EE in the later reaches 63.5% (study´s figures divided by national census data of 2001), in San Juan it would only be around 3%[13]. Interestingly, the San Juan survey inquired for the expectations to have access to electricity for productive uses and for water supply (pumping). In this case the survey was aimed at the identification of both existing requirements (in order to replace current sources by electricity from PV) as well as additional energy services of interest by interviewed.

It is concluded that the basic energy requirements – lighting and communications – demanded by all the users, involve only a 31% of total foreseen electricity consumption. On the other hand, food conservation (fridge and freezer) is only required by 30% of this population group, but it takes more than a half of total foreseen electricity. Water pumping, required by 43% of the people, only takes 16% of needed electricity.

Monthly expenditure in energy - from surveys - reached $68, if compared with $300 of estimated income results in 23% of it spent only in energy. The use of liquefied gas or

[13] From a similar but older study of the Mendoza province, scattered households without electricity would reach 6613, a 10% of the total rural scattered inhabitants (Energy Secretariat, 1999).

kerosene fueled fridges, by 28% of surveyed households is an outstanding driver of this high share.

The household profile is completed with a few more details: all household heads are permanently in the rural area, earning subsistence levels of income, the main occupation is "*puestero*" shepherd (72%) averaging just 300$ of monthly income. Only 8% of interviewed had finished primary school studies. Most of the people employs animals or long distance buses for traveling to town, 17% has a car or truck but in bad functioning conditions. Scattered pattern of settlement prevails: 57%.

The survey indicates four main productive activities, handcrafts, commercial shops, workshops (mechanical, ironworks, and tire shops) and others (lighting for productive uses, fans, grain mills, etc.). The possibility of water supply for cattle and human consumption, including vegetable gardens irrigation provided by water pumping from 100-120m water wells, was addressed separately. These productive uses would require a total 4830 kWh/month of electricity, it is estimated that this amount of energy - excluding deep water pumping - can be provided by 805 solar panels of 75 Wp (64.4 kW of electricity capacity).

The study remarks that the problem of good quality water provision affects 90% of targeted population. Pumping systems for households' uses (plus some eventual surplus for cattle) only solves this problem partially. Typical wells are superficial (20-25m) in desert areas, or are built for pushing water from nearby dams (rain water) to the houses mainly in the Serrano areas.

Further considerations from this survey regarding water pumping is given below, it is remarked that 70 out of 156 interviewers where interested in a deep water pumping devise, consisting of PV panels of flexible energy input, allowing the pumping of 1m3 per hour at 100m depth. The electricity capacity of such equipment will be 570W, and could be fed by a battery of six panes of 100Wp each.

Existing and potential productive activities[14]

The dry regions of Argentina[15] are important from the point of view of production. These areas concentrated 9 million people in 2001 and produce around 50% of agricultural production and 47% of livestock production. Most of the production takes place in the so called irrigation oasis (1.5 million hectares, less than 1% of total dry areas). Non-irrigated areas focus on livestock raising activities based on natural pastures and concentrating 100% of goats and camelids, 80% of ovines, and 40% of bovines of Argentina. The combination of unsustainable livestock raising practices and a fragile environment increases the risk of desertification in these areas. 60 million hectares are affected by desertification and soil degradation processes, with an increasing trend around 650,000 Has per year. 40% of irrigated areas present desertification problems due to erosion and salinization. Other activities that have affected negatively soil conditions and water resources are forest overexploitation and mining activities. In the last 75 years the extension of natural forest has decreased by 66% (Perez Pardo, 2003).

[14] Based on (Paoli, 2003) (Perez Pardo, 2003)
[15] These regions cover a much larger area than assessed in the present document

As mentioned above, existing productive activities basically differentiate between the regions of irrigated valleys and dry agriculture areas (“secanos”).

Irrigated valleys: corresponds to the valleys situated close to the large rivers of the region, upon which a system of dams and channels has been built in order to distribute water. The main productive activities are fruit production, vegetable production, wine production and other crops. Due to scale and lack of organization issues, small producers are in a difficult situation since products prices are inadequate. The existence of multinational enterprises, both at production and stocking stages, aggravates this situation since they tend to fix reference prices even at levels that are below small enterprises production costs. There also exist producers that do not have access to water supply channels and irrigate directly from rivers or boreholes using electric pumps. However, in spite of water being available, electricity costs usually prevent an adequate irrigation of crops.

Dry agriculture areas: in practical terms this region comprises the west mount and the Patagonian steppe. The main activity is extensive livestock raising, mainly sheep and goat. Cattle raising activities are also present but to a lesser extent and restricted to the best fields. In those rural productive units where there are areas with good soil quality and abundant/shallow underground water (called “mallín”), some producers have forage crops (mainly lucerne) for self-consumption and also for surplus commercialization. These activities are usually complemented with vegetable gardens for self-consumption. The production of these gardens is marginal and due to climatic reasons they work from spring to autumn. This could be another area where renewable energies, specifically solar energy, could play a role through the implementation of greenhouses. It is also common to find cases where crops are abandoned by mid-summer due to lack of water for irrigation.

Productive diversification is not an easy task, due mainly to cultural reasons (e.g. many generations working on the same productive activity with good profit levels). There exist a significant potential for adding value to traditional products. The possibility of wool and hair washing, wool spinning and weaving could allow increasing income with a lower animal stock. This could form part of an adaptation strategy where renewable energies could play an important role (motive power, lightning).

Biomass production is another activity with high potential. Even when there are not large land areas with adequate water availability for forestry activities, there exist many boggy areas where firewood plantations could be carried out. The biggest obstacle is the lack of irrigation infrastructure and fences that protect the young plants from animal grazing (electrified fences using PV power could play a role here).

Figure 2.9 Example of a family-scale forestation experience in semi-arid conditions of Río Negro Province

Small fenced area (50m x150 m) in dry land conditions irrigated by spring water (see geographical location in Michacheo satellite map)

14 year old trees in the Patagonian steppe, irrigated using ad-hoc drip irrigation using spring water

Source: Google Earth and own pictures

In the Cuyo oasis region the Spanish colonization introduced activities such as livestock raising, agriculture and industry, leading to important changes in the local environment. All these productive activities are highly dependent on snowfall in the high Andes, which are increasingly affected by climatic variability phenomena. The main agro-industrial activities are related to wine production, olive industry, selected fruit production, vegetables, among others. Irrigation is a key aspect for agriculture in these areas since dry climate crops are not feasible in this region due to the existing water deficit.

Table 2.1 Existing and potential rural productive activities in the region under study

	Michacheo - Neuquén	Catamarca	Arauco - La Rioja
Existing	• Low scale vegetable growing in greenhouses and open field • Sheep/rabbit raising	• Subsistence sheep and goat raising • Subsistence agriculture	• Olive cultivation
Potential	• Mid-scale vegetable growing. • Specialty crops requiring low irrigation levels • Windbreaks/forestation • Adding value to products	• Camelids • Specialty crops requiring low irrigation levels • Low scale agriculture • Adding value to products	• New specialty crops requiring low irrigation levels • Windbreaks/forestation • Adding value to products

Source: own elaboration

Figure 2.10 Vegetable production in the Michacheo valley, Neuquén

Production area and greenhouses

Satellite image of Michacheo region near Zapala city

Source: Technical Extension Unit, INTI Neuquén and Google Earth

The transformation of productive processes towards an increased size in rural productive units and the mechanization of activities have reduced the demand of seasonal human labor that was a traditional complement of rural livelihoods. As a consequence, rural population migrated to peri-urban areas or intensified the time devoted to its own productive activities.

2.2 Energy, hydrologic and climatic framework

This section discusses energy uses or services, requirements[16], technologies, and resources availability (energy, water, soil, human labor, capacities, etc.), including future trends.

Historical climatic and hydrological data and trend. Regional scenarios. Potential impacts on productive activities, health and rural livelihoods in general.

There exist two climatic phenomena that could affect water availability in the arid and semi-arid areas under study, climatic variability associated to the ENSO phenomenon (El Niño-Southern Oscillation) and the increase in evaporation rates brought about by Climate Change. Climate Change could affect the intensity and frequency of ENSO, but this has not been proved so far (Barros, 1997). The relative impact and interaction between these two phenomena depends on the studied region. In this sense, two main areas can be distinguished: Andes piedmont oasis and Patagonian oasis.

[16] Requirements make reference to what is potentially needed to satisfy current and future needs in an adequate way.

Andes piedmont oasis (La Rioja, San Juan, Mendoza)[17]

All the region under study has a reduced fresh water supply by rainfall within the region (100mm/year in Catamarca, La Rioja and San Juan, to 300mm/year in southwest Mendoza), and gets most of its surface and underground water resources from the fusion of snow located in the high Andes range, mostly during the winter. In this sense, it can be said that water availability depends from factors that are external to the region under study. In some extreme cases, such as in La Rioja province, water supply depends in 95% from underground water resources.

It is expected that for the oasis area situated between 29ºS and 36ºS the ENSO phenomenon will be the key driver on water availability, modifying significantly snowfalls in the Andes range. In this case, Climate Change phenomenon will aggravate the water deficit due to an increase in temperatures and ambient dryness levels. This would lead to an increase in evapotranspiration rates that in the oasis and surrounding areas could be between 135mm and 165mm higher in summer months towards year 2050. Additionally, climate change would increase the altitude of the snow line, affecting the process of spring/summer fusion and consequently altering the availability of water along the year.

Several studies[18] pointed out that climatic and hydrological trends in all the areas located close to the Andean region, up to the parallel 40ºS (mainly in Comahue and Cuyo Regions), will suffer hydrological stress in the near future and also in the long term (2040 or 2100, depending on the study). Those trends will be similar to the behavior observed in the recent past, in which water flows of the main rivers of Comahue and Cuyo have been decreasing from the 40's. As most of the economic activities developed in the area depends strongly on water resources (agriculture, wine making, livestock, tourism), water will be the greatest limiting factor, conditioning the development of the Region.

Patagonian oasis [19]

The climatic scenarios show a progressive warming situated close to 2ºC in 2080 and without seasonal differences. Water balance would get worse. In particular, in the Andes area and north Patagonia is where the most significant changes are observed (Scenario A2). It is expected that this situation reduces biomass growth rate and increases erosion problems in pasture areas due to an increase in fires. The removal of the biomass cover favors the deep percolation of rainfall. The flow-rates of the main hydrological basins of north Patagonia would reduce by 40% towards 2080, mainly during summer (Scenario A2[20]).

[17] Based on (Barros, 1997)

[18] (Argentine Government, 2007) Second National Communication to the Parties of the UNFCCC; (Girardin, L.O., 2010e) Estudio Regional de la Economía del Cambio Climático en Sudamérica (ERECC-SA) - ECLAC-CEPAL; among others.

[19] Based on (Fundación Torcuato Di Tella, 2006)

[20] Summary for policy makers, Emissions Scenarios, Special report from IPCC Working Group III, available atn http://www.ipcc.ch/pdf/special-reports/spm/sres-sp.pdf .

Towards year 2080 equal or worse dryness conditions are foreseen during the summer in the Patagonian oasis. In some cases the condition changes from arid to hyper-arid. On the other hand improvements are expected in some cases during the winter season (measured in terms of dryness index = pp / ETP, rainfall / potential evapotranspiration).

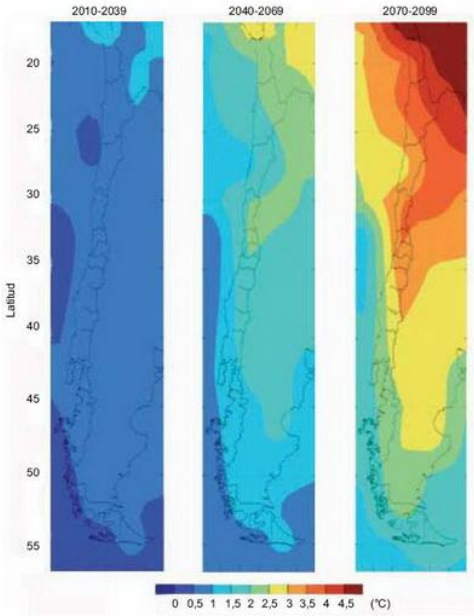
High present and future water deficit situations are recorded for all uses, for all Patagonian oasis and all the crops typically produced there. In many cases an excess of rainfall is also recorded in winter. However, taking advantage of this surplus during the summer season would require important works in water storage and distribution infrastructure that are technically feasible but are beyond the possibilities of the individuals and communities. These works could mitigate in part the annual deficit.

Towards year 2020 no significant changes are expected in dryness conditions or in irrigation requirements in the Patagonian oasis. Towards year 2080, an increase in irrigation between 5% and 13% would be required in most Patagonian oasis to maintain current productivity. The exceptions are those located towards the northeast, thanks to the increase in summer rainfall (Colorado Inferior and Valle Inferior of Río Negro).

Glacier retreat in northwest Patagonia will not sensibly affect main rivers´ flow rates. The reduction in water volumes in river will be insignificant compared to that derived from the reduction in rainfall level.

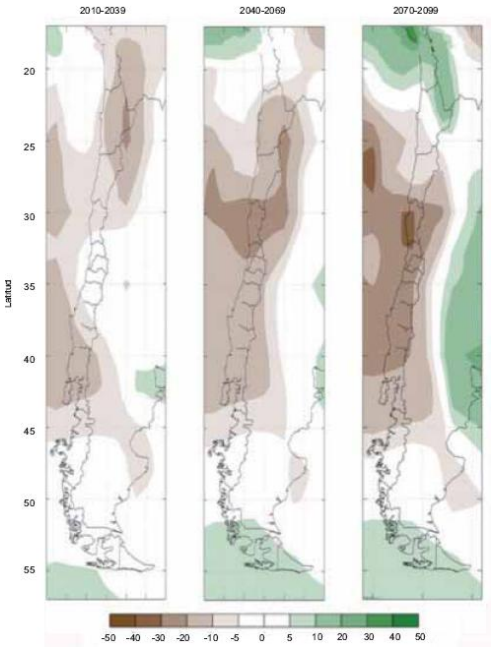
The changes produced in dry areas of Patagonia have occurred so far due to human intervention, and those derived from climate are small in relation to them. It is foreseen that the latter will increase in magnitude, worsening the effects of anthropogenic intervention if some non-sustainable practices are maintained (e.g. sheep mono production, meaning a single intensive productive exploitation or “mono culture”).

Figure 2.11 Temperature projections scenario A2 (ºC)



Source: (CEPAL, 2010)

Figure 2.12 Precipitation variation projections scenario A2 (%)



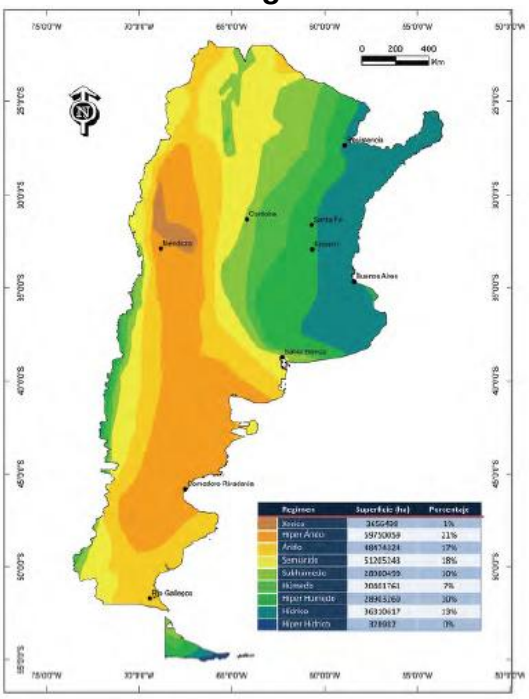
Source: (CEPAL, 2010)

Availability of renewable and non renewable resources. Potential impacts.

Both the core area under assessment (Comahue) as well as Cuyo (at the north of Comahue, along the Andes mountains) have not only renewable resources (solar, wind, geothermal, hydro energy) but also big amounts of fossil fuel resources (mainly natural gas, but oil as well). Nevertheless, most of the livestock activity and some of the agriculture are limited to small scale and subsistence level, and they suffer not only water restriction but, in many cases, shortages in electricity supply (lack of access or access to isolated networks based on diesel generator sets with high operating costs and supply security issues).

As previously mentioned, the oases located in the Cuyo region depend almost exclusively on snowfall in the high Andes as a source of water, both surface and underground. The contribution of rainfall within the region is very low since they vary between 100mm/year in the north (La Rioja) up to 300mm/year in the south (Mendoza). This does not exclude that rainfall could have a relevant role as irrigation complement in very specific geographic areas. There also exist differences within the region in relation to the contribution of snow fusion to the water resources available, being much lower towards the north (La Rioja) due to the lower altitude of the Andes range at that latitude.

Figure 2.13 Map of arid conditions of Argentina



Source: (Verbist, 2010)

In the particular case of the Michacheo valley water is available through the public distribution service. However, cost and volumes are inadequate for irrigation of vegetable plantations since it increases the cost of products to non-competitive levels. Similar situations can be found in rural communities of the semi-arid regions of Río Negro, Mendoza, San Juan, La Rioja and Catamarca where water is also scarce and costly.

Table 2.2 Characteristics of underground water resources in the region under study

Location	Water table depth	Quality	Other
Michacheo	<20m	Adequate	Under risk of pollution
La Rioja city area	2-150m	Adequate. Some resources present arsenic	Increasing salinity problems reduces soil quality for agricultural uses.
Catamarca	2-32m	Salinity problems in some wells	Water table depth increases in some locations
Mendoza north basin[21]	0-80m 190-230m >260m	Not adequate for human or agricultural use Salinity problems in some areas Salinity problems in some areas	High salinity[22], chemical and biological pollution Under risk of pollution

Source: own elaboration based on (Sirolesi, 2009)

[21] (Sirolesi, 2009)
[22] Maximum allowed salinity level is 900 mS/cm

Water uses and requirements.

Current water uses are described, mainly in relation to productive activities. Minimum fresh water requirements are assessed for maintaining an adequate quality of life and income.

Agricultural and livestock activities in a large fraction of this dry region count with adequate climatic and soil conditions, but are severely restricted by the low availability of water resources, reducing the areas under agricultural production, lowering productivity, and limiting the range of species that are grown. This situation is particularly serious where there are no adequate surface water resources, and where there is low or null availability of low cost energy for water pumping and irrigation. Surface water resources are not distributed homogenously. Even when average indicators on water availability are adequate for some provinces such as Mendoza and Neuquén, these figures do not reflect regional water stress situations (Figure 2.14).

The region presents records of extreme dry seasons and reduced snow levels originated in climatic anomalies that have led to the sporadic adoption of adaptation measures. Since climate change could transform these extreme situations into custom conditions for this region, sporadic measures should be replaced by permanent and integrated ones to face this possibility in the coming decades.

In arid and semiarid regions of Argentina, agricultural use of water represents more than 90% of total water use (Miranda, 2009).

Average annual water requirements for crop irrigation in the Patagonian oasis are close to 7000 m3/hectare (assuming a water deficit of 700mm/year). This is equivalent to the specific water demand per hectare of urban areas with a density of 6000 inhabitants/km2. This figure stresses the relevance of water requirements for agriculture in relation to those for residential uses and other productive activities. Irrigation water requirements in other dry areas are also high, even for vegetable species adapted to these conditions (e.g. olive). Water requirements for animal husbandry are much lower than for irrigation and explain why this is the main productive activity in the dry region outside the irrigated valleys.

Table 2.3 Reference water requirement levels by type of use

Use	Annual consumption	Specific consumption (m3/Ha.year)
Urban residential	90-150 m3/ person	>7,200 (6000 inhabitants/km2)
Rural residential	25 m3 / person	
Agriculture		
Patagonian Oasis	7,000 m3 / Ha (700mm/year deficit)	7,000
Catamarca	11,000 m3 / Ha (lucerne)[23]	11,000
	10,000 m3 / Ha (olive)[24]	10,000
San Juan	20,000 m3 / Ha (average Jachal basin)[25]	20,000
Livestock		
Goat	2 – 4 m3 / head[26]	
Sheep	2 – 4 m3 / head	2–40 (depending on pasture productivity)[27]

[23] (D´Attellis, 2005)
[24] (Searles, 2011)
[25] (Miranda, 2010)
[26] (Nickisch, 2007)

Bovine Equine Porcine	19 – 30 m3 / head 15 – 25 m3 / head 2 – 6 m3 / head	

Source: own elaboration

It is possible to implement some measures to achieve a better use of the available water resources. For example, the reduction of evapotranspiration by means of the control of wind effects on the crops could be an important measure in most of Patagonia. The measures aimed at the protection of biomass soil cover and erosion prevention are also particularly relevant.

However, in spite of the important restrictions to water availability in the regions under study, techniques for the rational and efficient use of water have not been adopted in a systematic way. This has led to the depopulation of areas that used to host an important population and activity (e.g. Guanacache ponds system (Mendoza), close to the source of the Desaguadero river) (Barros, 1997).

Some of the problems related to the use of underground water resources in this region are linked to the overexploitation of boreholes when recharge times are not respected. This is an issue where PV pumping systems have certain advantages over diesel pumping since they tend to protect weak boreholes. The other problem is the salinization of boreholes and soil due to a wrong management of extraction volumes and schedules, and of agricultural practices. Finally, it can be mentioned the pollution of underground aquifers due incorrect borehole close down and surface contamination. Some issues that may contribute to the salinization process are irrigation practices (both with traditional and advanced technologies), the lack of maintenance of drainage system network, inadequate leveling of land, and water overuse. One third of the 1.6 million hectares under irrigation in Argentina has salinization and/or drainage problems (Sirolesi, 2009).

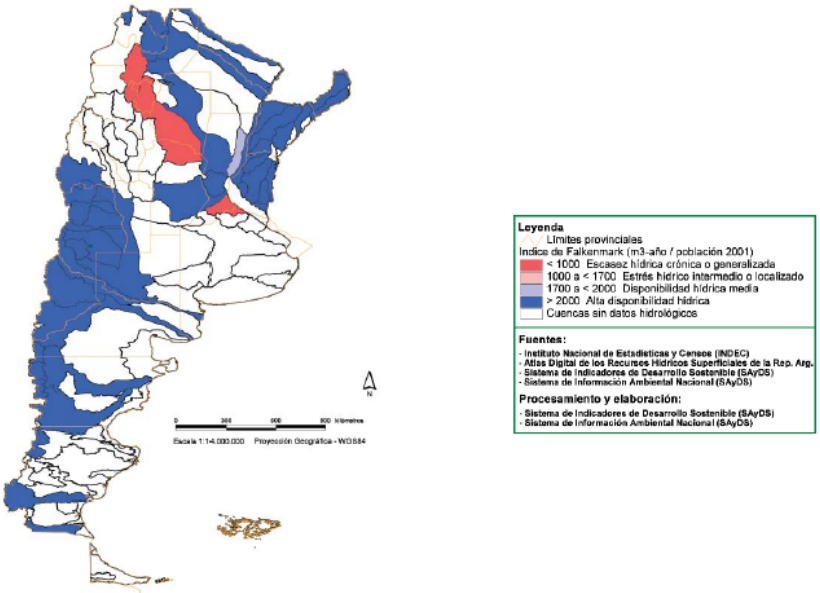
Table 2.4 Water availability in Argentina and in the region under study

Location	Water resources available (m3/person.year)[28]
Argentina	21,000[29]
La Rioja	1,125[30]
Catamarca	2,974
San Juan	1,635
Mendoza	4,100
Mendoza river basin[31]	1,154 (2020)

Source: own elaboration

[27] (Siffredi, 1998)
[28] Critic stress level is 1,000m3/person.year, threshold level is 1,700m3/person.year (UN Cuyo, 2004)
[29] (IPEC, 2007)
[30] (Gimenez, 2011)
[31] (Sirolesi, 2009)

Figure 2.14 Surface water availability by basin (m3/person.year)



Source: (SAyDS, 2006)

Table 2.5 Water uses in La Rioja city area (year 1998)[32]

Water use	Volume (Hm3/year)[33]	Volume (%)	Source
Drinking water	17-27	38%-60%	74% underground
Irrigation	14-24	31%-53%	100% underground
Industry	2.7	6%	
Other uses	1.6	3%-4%	
Total	45-46	100%	

Source: own elaboration

Table 2.6 Olive irrigation in La Rioja city area (1998)[34]

Parameter	
Olive productive area	10,470 Has
Underground water demand	14.4Hm3/year (1998) to 28Hm3/year (2000)
Water well average yield	150m3/h
Water well irrigation coverage	70 Hectares
Number of water wells	150

Source: own elaboration

In the La Rioja city area water available is higher by a 50% than 1998 water extraction level (46Hm3/year). This corresponds to the water that currently evaporates in the Antigua salar (20Hm3/year). It is interesting to note that extraction increased from 2.4Hm3/year in 1974 to

[32] (Martinez, 2002)
[33] 1 Hm3 = 1million m3
[34] (Martínez, 2002)

46Hm3/year in 1998. Water table depth only increased by 0.5m in 17 years due to increased extraction. However, salinity levels duplicated and temperature also increased. This reduces the quality of the soil for agricultural uses.

Water use methods differ widely among the different regions under study and generally respond to the degree of economic resources and organizational capacity available. Agricultural producers in Arauco region generally use advanced irrigation procedures (trickle or sprinklers) that have higher distribution and application efficiency. They also produce vegetable species adapted to water availability and climate conditions (e.g. olive). These agricultural producers develop the infrastructure required to extract the water from underground aquifers and distribute it in the fields and also operate and maintain the systems. In contrast, subsistence farmers and shepherds still use traditional irrigation and cattle raising methods which tend to be incompatible with changing environmental conditions. Thus, we can see that under adequate conditions, it is possible to reach a balance between water resources available and productive activities that lead to economic prosperity and avoids further degradation of the environment. However, even under these circumstances, salinization problems sometimes are still present.

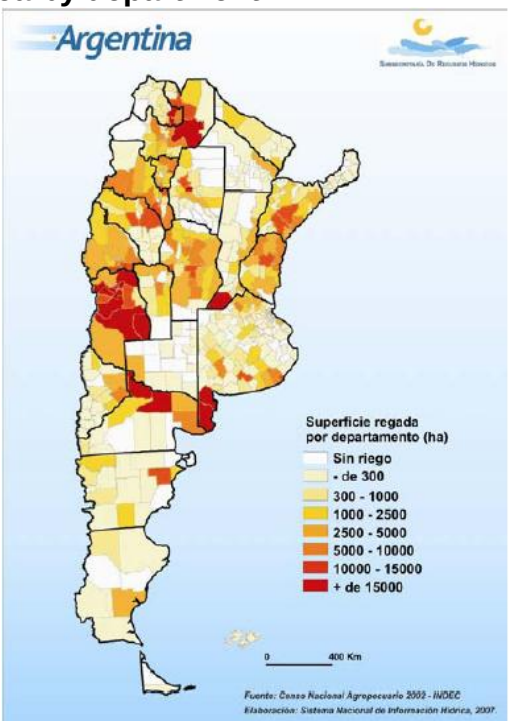
Table 2.7 Irrigated area by province and irrigation method

Province	Irrigated area (Hectares)	Localised irrigation		Gravitational irrigation		Sprinkler irrigation	
		(Hectares)	(%)	(Hectares)	(%)	(Hectares)	(%)
Catamarca	61,676	18,695	30%	23972.3	39%	19008.1	31%
La Rioja	41,813	25,095	60%	15211.9	36%	1505.9	4%
San Juan	79,515	21,265	27%	57239.6	72%	1010.9	1%
Mendoza	267,887	21,621	8%	244916.5	91%	1349.1	1%
Neuquén	15,354	1,572	10%	13700.1	89%	82	1%
Total	466,244	88,248	19%	355,040	76%	22,956	5%

Source: own elaboration based on (CNA, 2002)[35]

[35] Localized irrigation comprises trickle, micro-sprinklers and other efficient methods.

Figure 2.15 Irrigated area by department



Source: (SSRH, 2007)

We can see in Table 2.8 that localized irrigation is highly disseminated in La Rioja province thanks to a supporting legal framework that promoted certain high value agricultural products such as olive and wine grapes that aim at the export market (e.g. National Law 22021). Low value products, particularly those cultivated by small and subsistence farmers do not justify the investment in advanced irrigation methods (Table 2.9).

Table 2.8 La Rioja province irrigation by species and method (% of hectares)

Species	Localised irrigation	Sprinkler irrigation	Gravitational irrigation
	(% of hectares)		
Cereals	0%	0%	100%
Other industrial	70%	30%	0%
Pulses	0%	0%	100%
Fodder	0%	4%	96%
Vegetables	6%	0%	94%
Lemon	24%	0%	76%
Other citric	27%	0%	73%
Grape	39%	0%	61%
Other fruit	74%	1%	25%
Other	71%	0%	29%
Total	60%	4%	36%

Source: own elaboration based on (CNA, 2002)

The incentives are aimed at medium to large producers and do not cover small and subsistence ones. Effectively, from the analysis of the irrigation methods by agricultural exploitation size we can observe that the modern irrigation technologies have been implemented mostly in medium to large agricultural units and that traditional methods are dominant in small units (Table 2.9).

Table 2.9 % of irrigated area by irrigation method and rural productive unit size (Catamarca, La Rioja, San Juan, Mendoza and Neuquén provinces)

Agricultural exploitation size (ha)	Gravitational	Sprinklers	Localised		
			Trickle	Microsprinklers	Other
Up to 5	99.4%	0.2%	0.3%	0.0%	0.0%
5,1 - 10	99.3%	0.1%	0.6%	0.1%	0.0%
10,1 - 25	98.2%	0.2%	1.4%	0.2%	0.0%
25,1 - 50	94.5%	0.4%	4.2%	0.9%	0.1%
50,1 - 100	88.3%	0.5%	10.1%	1.1%	0.0%
100,1 - 200	76.0%	0.3%	20.7%	3.0%	0.0%
200,1 - 500	54.0%	3.5%	38.8%	3.2%	0.5%
500,1 - 1.000	47.2%	5.7%	45.1%	2.0%	0.0%
1.000,1 - 2.500	33.1%	17.5%	43.7%	5.6%	0.0%
2.500,1 - 5.000	12.2%	53.2%	34.6%	0.0%	0.0%
5.000,1 - 10.000	37.5%	16.6%	43.5%	2.3%	0.0%
More than 10,000	39.4%	57.6%	3.0%	0.0%	0.0%
Total	76.1%	4.9%	17.2%	1.6%	0.1%

Source: own elaboration based on (CNA, 2002)

As for the water source, we can see in Table 2.10 that for the smaller rural productive units surface water supply is still more widespread than underground supply. However, a significant fraction of small size rural productive units have underwater supply systems, and consequently depend on pumping. More than 80% of the rural productive units that use channels for water supply are smaller than 25 hectares. Also, within surface supply, channels are much more common than direct water supply. For medium and large size rural productive units, surface supply is still prevalent but underground supply has a higher significance than for smaller rural units.

Around 12,000 rural productive units use underground water for water supply in this region by means of almost 15,800 working wells. This represents around 19% of rural productive units in Catamarca, La Rioja, San Juan, Mendoza and Neuquén provinces (51,000). The water is extracted using electricity in most of these wells (73%, 11491 wells), followed by diesel oil and gasoline (16%, 2496 wells), naturally flowing (7%, 1053 wells), and other energy sources (4%, 685 wells). In principle, decentralized renewable energy systems could be used to pump water out of those wells corresponding to the fuel and other categories. Additionally, grid connected renewable energy systems could provide power for those powered by electricity.

Table 2.10 Water source and distribution system by rural productive unit size (number of rural productive units) (Catamarca, La Rioja, San Juan, Mendoza and Neuquén provinces)

Agricultural exploitation size (Hectares)	Surface			Underground
	Channel	Direct supply		
		No pumping	Pumping	
Up to 5	18,527	260	130	3,208
5.1 - 10	7,267	118	44	2,214
10.1 - 25	6,611	84	56	2,904
25.1 - 50	2,739	49	35	1,671
50.1 - 100	1,412	30	29	961
100.1 - 200	723	29	16	541
200.1 - 500	444	50	28	339
500.1 - 1,000	190	34	12	104
1,000.1 - 2,500	120	35	9	64
2,500.1 - 5,000	55	21	2	25
5,000.1 - 10,000	55	11	4	27
More than 10,000	50	27	5	34
Total	**38,193**	**748**	**370**	**12,092**

Source: own elaboration based on (CNA, 2002)

Table 2.11 Number of wells and rural productive units using underground water by rural productive unit size (Catamarca, La Rioja, San Juan, Mendoza)

Rural productive unit size (Hectares)		Fuel	Electricity	Flowing	Other	Total	Wells (%)	Total EAP in each size category
Total	**EAP**	**2,072**	**8,446**	**868**	**485**	11,871		
	Cantidad	**2,496**	**11,491**	**1,053**	**685**	15,725		
% working wells by energy source used for extraction		16%	73%	7%	4%	100%		
Total without defined boundaries	EAP	9	20	5	22	56		
	Quantity	9	20	5	23	57		
Total with defined boundaries	EAP	2,063	8,426	863	463	11,815		48,802
	Quantity	2,487	11,471	1,048	662	15,668	100%	
Up to 5	EAP	415	1,533	397	99	2,444		21,598
	Quantity	418	1,560	420	110	2,508	16%	
5,1 - 10	EAP	395	1,353	146	49	1,943		8,311
	Quantity	432	1,423	176	57	2,088	13%	
10,1 - 25	EAP	535	2,260	143	101	3,039		7,892
	Quantity	581	2,486	173	115	3,355	21%	
25,1 - 50	EAP	281	1,450	79	56	1,866		3,769
	Quantity	353	1,839	109	68	2,369	15%	
50,1 - 100	EAP	174	876	54	59	1,163		2,199
	Quantity	242	1,378	93	94	1,807	12%	
100,1 - 200	EAP	108	483	25	36	652		1,437
	Quantity	153	1,071	36	62	1,322	8%	
200,1 - 500	EAP	73	294	14	26	407		1,275
	Quantity	110	849	32	47	1,038	7%	
500,1 - 1.000	EAP	23	95	3	7	128		728
	Quantity	40	401	5	22	468	3%	
1.000,1 - 2.500	EAP	26	50	1	13	90		643
	Quantity	74	301	3	47	425	3%	
2.500,1 - 5.000	EAP	12	9	1	6	28		429
	Quantity	34	30	1	16	81	1%	
5.000,1 - 10.000	EAP	9	12	0	5	26		183
	Quantity	28	62	0	16	106	1%	
More than 10.000	EAP	12	11	0	6	29		338
	Quantity	22	71	0	8	101	1%	

Source: own elaboration based on (CNA, 2002)

50% of the wells (7,951) are located in rural productive units of less than 25 hectares. Most of these wells use electricity to extract water (69%, 5469 wells), 18% use fuels (1431 wells), 10% are free flowing wells (769 wells), and 4% use other energy sources (282 wells). Thus, the number of wells in rural productive units of less than 25 hectares that use fuels for water pumping represent 9% of total wells, and those corresponding to other energy sources represent 2% of total wells.

It is also relevant to assess specific improvement measures related with water supply and storage in rural productive units. Table 2.12 presents this type of data for the region under study. Overall, only a fraction of total EAP has some storage infrastructure, windmill or water well. It can be seen that for small rural productive unit sizes the occurrence of independent supply and storage infrastructure is very low in relation to the total number of productive units. For example, only 4% of productive units of less than 25 hectares have some kind of water reservoir, a key issue from the point of view of adaptation to climate variability. Also, only 4% have windmills or fuel engines for water extraction. In contrast, the occurrence of this type of infrastructure is much higher for large rural productive units.

Table 2.12 Water supply and storage infrastructure by rural productive unit size (Catamarca, La Rioja, San Juan, Mendoza, and Neuquén provinces).

Rural productive unit size (Hectares)		Windmills	Water wells for consumption (with engine)	Australian tanks	Dams and dikes	Other artificial water bodies	Total EAP in each size category
Total	EAP	852	3,185	1,980	5,149	1,923	
	Quantity	1,461	3,857	3,341	7,367	3,049	
Total without defined boundaries	EAP	185	595	285	1,211	926	
	Quantity	197	671	311	1,594	1,096	
Total with defined boundaries	EAP	667	2,590	1,695	3,938	997	51,000
	Quantity	1,264	3,186	3,030	5,773	1,953	
Up to 5	EAP	7	573	113	174	117	22,242
	Quantity	7	593	138	198	157	
5,1 - 10	EAP	6	385	70	201	70	8,737
	Quantity	6	406	71	242	91	
10,1 - 25	EAP	9	396	206	477	81	8,293
	Quantity	9	442	220	499	103	
25,1 - 50	EAP	10	233	195	532	56	3,889
	Quantity	10	281	202	578	90	
50,1 - 100	EAP	8	116	150	499	76	2,278
	Quantity	8	155	167	608	88	
100,1 - 200	EAP	19	119	108	444	70	1,492
	Quantity	19	143	136	633	90	
200,1 - 500	EAP	23	133	129	537	93	1,405
	Quantity	25	169	663	781	133	
500,1 - 1.000	EAP	58	130	95	353	95	844
	Quantity	58	155	117	523	157	
1.000,1 - 2.500	EAP	152	164	191	310	148	735
	Quantity	177	203	232	540	288	
2.500,1 - 5.000	EAP	135	113	152	170	77	471
	Quantity	188	162	235	343	138	
5.000,1 - 10.000	EAP	136	116	156	126	59	201
	Quantity	307	177	338	331	198	
More than 10.000	EAP	104	112	130	115	55	413
	Quantity	450	300	511	497	420	

Source: own elaboration based on (CNA, 2002)

In summary, larger rural productive units seem to be much better adapted to climate variability, both in terms of water supply and storage, and also in terms of water use methods. Since land cost in this region probably is highly influenced by water access and soil quality, one would also expect that larger productive units aimed at the production of high value crops also occupy better lands.

Institutional, legal, regulatory and economic issues in relation to water and energy management and supply. Access to resources.

In general terms, the institutional framework of water management and supply in Argentina, not only at the national level but also at the regional one, is characterized by a high degree of fragmentation. There is a lack of coordination, interchange of information and communication breakdowns among the different institutions with water supply and management related responsibilities. This situation generates overlaps of functions and in some cases the dilution or ambiguities on the responsible party. The sector's privatization process that took place by the beginning of the 90´s, has incorporated a set of new actors to this framework, increasing the complexity of the institutional network. However, the deregulation process did not create a water market, as happened in other countries. Privatization processes affected La Rioja, Catamarca and Mendoza provinces and provided control of water resources mainly to foreign enterprises (Aspiazu, 2008). However, both in Catamarca and Mendoza the enterprises have shown signs of transferring the business to local enterprises or even provincial governments. San Juan, Río Negro, and Neuquén have provincial water management enterprises.

According to the National Constitution, each province has management rights over its natural resources, including water. Accordingly, each province has its own regulatory framework and set of institutions in charge of water resource management and implementation. However, since hydro resources can be shared among provinces and neighboring countries, there exists a federal institution (COHIFE) responsible for coordinating national water policies and also several basin authorities. Some provinces delegated the provision of water services into municipalities. Regarding the costs, in general terms, tariff frameworks for different water uses are not integrated and, in most cases, rates only cover operating costs and maintenance of water systems.

In principle, access to water resources is considered a public right in Argentina. Many provinces consider a high priority the supply of water for productive activities and an annual fee is set for the concession of water use rights in these cases. A set of conditions are imposed to provide water use rights. As an example, in the case of irrigation in Neuquén province the concession is given if the area is suitable for irrigation agriculture, water bodies have enough supply capacity, the producer has land property rights, and regulatory issues are respected (Ministerio de Producción y Turismo, 2008). Whenever a rural producer has not adequate water resources nearby, infrastructure works are needed in order to improve access (e.g. dams and channels). In practice, large producers are the main beneficiaries of infrastructure works aiming at guaranteeing irrigation for productive activities as can be observed in Mendoza and La Rioja (León, 2005). In Mendoza, irrigation investment did not correspond with poverty alleviation objectives, nor even with rural development ones. It is also common to observe in

Río Negro province situations where isolated rural inhabitants depend on the good will of water service providers and local government to gain access to water resources.

In most cases water service is provided by municipalities, cooperatives, or neighbors associations, but at a high cost and with significant restrictions, making unfeasible many productive activities. Thus, the choice between diverse infrastructure investment options selectively benefits large producers and acts as a barrier for the development of small producers. This is also linked to the different access that small and large producers have to the best agricultural areas in each province. The problem is compounded by the investment that the producer has to make in order to take advantage of the access granted to nearby water resources.

As a result of increased productive activities, population and water stress, conflicts between users´ categories are beginning to appear in some of these areas (e.g. La Rioja). This leads to the need to further assess present and future water resources availability and implement an adequate planning of productive activities and priorities through a legal and regulatory framework. This will help protect water availability for productive activities of the more vulnerable sectors of society vis a vis the demand for extractive and highly concentrated activities such as mining. This is particularly relevant since large mining projects are increasing along the Andes range, and many of them are located in the upper basins, close to glaciers and important fresh water resources. These projects could affect other users located downstream, both through competition in the use of water resources and through pollution (e.g. most of the large projects are aimed at the extraction of gold and other high value metals). The National Glacier protection law was recently passed to prevent damage to the most important fresh water resources. However, some provinces are still reluctant to implement it.

Institutional Description of Water Resources management and Renewable Energy development

By 2003 an agreement between most of the provinces and the Federal Government on hydro policy was signed. It constitutes an initial common platform for aligning norms and institutions. It departs from a shared vision on water issues, taking into account the socioeconomic profile, resources, costs and benefits, that makes possible the implementation and evaluation of a hydro policy[36].

There exists no national water law today, current legislation is composed of Civil, Commerce, Mining and Penal Codes and federal laws like the Energy, Navigation, Transport, Ports, Environment and Natural Resources, that includes resolutions concerning water resources directly or indirectly. The Nation has also ratified international treaties involving water resources on: shared waters, nuclear vessels navigation in territorial waters, credits for drinking water and sanitation supply infrastructure and multiple purpose infrastructure construction, among others.

[36] Next paragraphs rely strongly on (Pochat, 2005).

In December 2002, Law 25688 concerning a Scheme for the Environmental Management of Water was enacted, but its ruling is still pending. It establishes the creation of River Basins Committees. What is pending is the effective sanction of a more comprehensive national law establishing basic principles of hydro policy, common and valid among all provinces, pointing to the compatibility of potentially conflictive interests.

(Pochat, 2005) considers that a conceptual and institutional dispersion exists among the several competence levels linked to the river basins management. A common arrangement and management policy is missing, framed by laws, norms and endowed with a specific budget.

If the provinces' Constitutions are addressed, only the ones of Catamarca, Santiago del Estero and Rio Negro established their own competence for ruling the water use of their inter-provincial rivers (basins with common hydro resources) by treaties with neighbor provinces. Other provinces do not have specific laws on issues directly affecting them, as irrigation system promotion, users' organization, water rights, tariffs including adequate payment, aquifers management, etc.

Pioneer water codes were sanctioned in Córdoba and Santiago del Estero during the seventies, La Pampa, La Rioja, San Juan and San Luis followed them. Hydro policy principles were included and modern law criteria ruled the new institutions, under an interdisciplinary approach, enacting for example the cost of the water which had been largely ignored or resisted. Nevertheless few provincial laws refer explicitly the water management of river basins[37].

Institutionally, the lack of coordination, communication and exchange of information between institutions triggers overlapping of functions and dilutes responsibilities. It also generates conflicts, both between competitive uses – irrigation and hydroelectricity generation – and between jurisdictions. Main causes of conflict are linked with water flow quotas, management of water flow volumes surplus from floods, and inter provincial water courses pollution.

The country does not possess an agreed mechanism for solving these controversies. From year 2003 the main water resources management authority at the federal level is the Water Resources Sub Secretariat, within the Ministry of Federal Planning, Public Investment and Services. In turn, the Agriculture, Livestock, Fishing and Food Secretariat, from a different Ministry, has an oversight role on the execution of programs for restoring irrigation areas and flooded areas recover or salinized. Within the former Ministry, the Energy Secretariat develops basic schemes for hydroelectricity projects, coordinating with other areas the compatibilities and prioritized uses.

Water management at the provincial level has different features depending on the main local interests and conflicts arising from water demand and supply. Typical examples are in the arid region irrigation management, and in the more humid region the harmful effects of climate events like floods. It is possible to make a clear distinction between sanitary entities committed to drinking water and sanitation services supply, and hydro entities, in charge of projects construction, hydrological measures, protection against floods, etc.

[37] Law Nº 12.257 (Buenos Aires); Law Nº 9830 /1986 and Ruling Decree Nº 4960, (Santa Fe); specific legislation of Córdoba and Law Nº 5178 of Chubut. (Pochat, 2005).

In the irrigation field, a large diversity appears as well. Typically, dry region provinces have agencies specifically committed to the water issue, while in humid areas, irrigation is managed from natural resources or agriculture related entities.

Thus, from the privatization onwards, the institutional framework has increased both in size and complexity. Private operators (drinking water supply and sanitary services, hydroelectric plants operation, irrigation and waterways navigation maintenance) have been incorporated as well as regulatory entities. In particular, rural producers' participation in operation and maintenance of irrigation systems has increased.

Due to the lack of impact evaluation of policies on water and associated services, most of the privatizations have been unsustainable (Pochat, 2005), at least under their original scheme. Several concession contract holders have left the country, other are suing Argentina in international courts, as original contracts designs and regulatory models moved away from national economy evolution.

Among the several models adopted by the argentine provinces for the management of their water resources, Mendoza and the AIC (Rio Negro, Neuquén and Limay Rivers Basin Inter-jurisdictional Authority) stand out. A brief description of these two interesting examples of river basin authorities is included below.

River flow modification, first by reservoir filling and then by the regulation of the water flow, produced major changes in the river flow in the lower areas of the basin. Thus by a treaty signed in 1985, the provinces involved – Río Negro, Neuquén and Buenos Aires – and the Federal Government initiated the institutional organization of the river basin, giving birth to the AIC River Basin Authority. The sole existence of this legal entity allowed the allocation of the authority role for water management, environment and civil protection. This AIC responsibility was embodied in the concession contracts. Moreover, an income obtained from the hydro energy sales, was secured in order to finance both the required works and projects in the downstream of the dams and the AIC itself.

The operative structure of the AIC includes qualified human resources that allow the provision of useful services to the society. Besides, the entity does not depend exclusively on political decisions and having secured its budget and performing a high interaction with the community it has an outstanding strength relative to other river basin authorities.

In Mendoza the body for water administration DGI (Mendoza General Irrigation Department), mentioned in the provincial constitution, is in charge of hydro resources management, the agency delegates the role in the communities of organized users, who are responsible of water administration at the secondary and tertiary level. This has stimulated the development of a user participation culture in the resource management. Tariffs for water rights are also charged, which allows not only the effective administration of the resource, but also to know its existence and uses, and perform a proper low cost conflict administration.[38]

[38] In turn, the Buenos Aires province in its recently promulgated Water Code, creates an autonomous entity – subject to public law - of multidisciplinary nature, in charge of planning, registry, rights constitution and protection, police function among other missions attributed by current legislation: the Water Authority.

The DGI is a public decentralized entity in charge of the administration of hydro resources at the province level, ruling and monitoring its use. It has institutional and budgetary autonomy, as well as jurisdiction roles that make it the water court for solving conflicts among users. Its main objective is the regulation, preservation and distribution of water, in order to take advantage of possible uses, by a direct control on existing concessions and promoting the ones that become necessary. First, it develops the necessary studies and later promotes the respective concession law, interacting with the provincial parliament.

As indicated above, both the province water Law Nº 6.405 of 1996 and the province Constitution enacts a lower scale institution consisting in Water Channels Inspectors. These public mandatory associations – not voluntary and out of the state bodies – are composed of the water right holders that employ a single channel for irrigation. They are autonomous and authorized to collect and invest their own funds, they are independent from the DGI, which in turn has a legal control on them. The Water Channel Inspector is simply one of the users openly elected by the concurrent users, and is in charge for a four years period of the internal smaller network of channels.

More recently, voluntary groups of Water Channel Inspector Associations are appearing, sharing interests and objectives in order to improve the resource management for the common benefit. Currently 160 Inspectors and 16 Associations exist. User participation and decision making in regards to channels operation and works, jointly with the shared water administration - between the state body and users – improves the interaction with stakeholders. This Organism possesses the most advanced development stage in the country (Pochat, 2005).

Nevertheless our previous concern on the scope of beneficiaries remains. As small productive entities without access to the infrastructure for water distribution do not have access to this organization.

In some provinces, there still exist legal and regulatory voids in water resources management, particularly concerning underground resources and supply in rural areas.

Table 2.13 Management schemes and regulatory institutional framework

			Management Scheme	
			Private	Public
Regulatory institutional framework	Autonomous institutions	Multi-sectorial	Catamarca La Rioja	
		Sectorial	Mendoza	
	Auto-regulated	Regulation by public property		Neuquén San Juan Río Negro

Source: adapted from (Aspiazu, 2008)

Regarding the energy dimension it is also possible to describe the regulatory situation, as the provinces again are responsible for rural electrification. The status varies highly among them, and the most important program for rural electrification employing renewable resources is the

PERMER. A brief description of the program can be found in (Alazraki, 2006)[39] and at the Program's website[40].

The project is under execution by the national Energy Secretariat, it is aimed mostly at low-income families living in isolated areas. Depending on provinces acceptance and economical characteristics 87,000 users might benefit from this program, as well as around 2,000 isolated rural schools, health services centers, police stations, and public buildings.

Electricity supply includes basic lighting and social communication needs. The objectives are improving rural life quality, positively impacting on education, productive activities and overall social development. If economic activity of the private sector is encouraged, local jobs can be created following renewable energy equipment demand.

In order to be part of the PERMER scheme, the province must sign an agreement with the National Government and must also be capable of giving concession rights for electricity provision on its rural disperse market. As a local contribution, provinces should basically allocate own funding coming from electricity market, mentioned FEDEI. To complete the institutional picture, the provincial electricity regulatory entities are in charge of the oversight of the concession contract observance.

Energy supply, uses and requirements.

Current energy uses are described, mainly in relation to productive activities (e.g. pumping, distribution, irrigation). Minimum energy requirements are assessed for maintaining an adequate quality of life and income.

Most of the rural productive units in the region under study are connected to some kind of electricity grid (73%, 37070) (Table 2.14). According to the National Agricultural Census (year 2002), a significant fraction (>23%, 11738) is not connected to the grid and does not have an alternative energy supply. Around 3% of the rural productive units count with photovoltaic power generation and less than 1% have a generator set. Finally, hydro, wind and other generation systems are marginally present (0.5%). Thus, the universe of rural productive units where renewable energy systems could have some relevance for energy supply is around 14,000 (28% of total).

Table 2.14 Energy supply in rural productive units by energy source (Catamarca, La Rioja, San Juan, Mendoza and Neuquén provinces).

	Rural electricity grid	Descentralised generation					Total EAP
		Generator set	Hydro	Wind	Solar	Other	
EAP	37,070	389	28	33	1,569	173	51,000
EAP (% of total EAP)	73%	0.8%	0.1%	0.1%	3.1%	0.3%	

Source: own elaboration based on (CNA, 2002)

[39] Alazraki, R and Haselip, J. Assessing the uptake of small-scale photovoltaic electricity production in Argentina: the PERMER project, Journal of Cleaner Production 15, 131-142, 2006.
[40] See home page of the program http://energia.mecon.gov.ar/permer/permer.html , and description in English http://energia.mecon.gov.ar/permer/abstract.html

In relation to electricity requirements, an estimation is made based on a community of 40 households whose main productive activity is cattle raising (Table 2.15). Power is considered both for residential and productive uses (fodder production, processing of products, storage, etc.). Total power required during the productive season is around 30kW or 0.75kW per household. This power level is much higher than the power usually considered in PV power pumping projects for isolated communities. As an example, we can mention Balde de Leyes project with close to 0.1kW/household, and Catamarca with a range of 0.05-0.17kW/household. Thus, these projects alleviate one of the most important needs of rural isolated population (water supply) but are still far from contributing to a sustainable development initiative that promotes an increase in households´ income through the energization of productive activities. Currently, the most common electricity supply option for isolated communities is based on diesel generator sets.

Table 2.15 Community electricity requirements for residential and productive uses in a dry area (40 households)

Use	Temporal distribution	Main Impact	Power (kW)	Hours (hs/year)	Energy (kWh/year)
Drinking water supply (pumping)	Daily, flexible, any moment of the day	Life quality	2	2920	5,840
Products processing	Seasonal, any moment of the day	Income	9	150	1,350
Agricultural (5 Ha fodder) and cattle water (pumping)	Highly seasonal, any moment of the day	Income	10	1440	14,400
Irrigation	Highly seasonal, any moment of the day	Income	10	450	4,500
Various tools	Daily, any moment of the day	Income	20	365	7,300
Food conservation	Daily, all day long	Quality of life and income	8	2555	20,440
Other domestic appliances	Daily, continuous except during the night	Life quality	12	730	8,760
Lighting	Daily, night hours	Life quality	9	1460	13,140
Communications	Daily, continuous	Life quality	0.1	4380	438
Total			30 (simultaneous in summer)		76,168

Source: own estimation based on (Bravo, 2004)

Other quantitatively important household energy requirements are those corresponding to thermal uses (cooking, water heating and heating). Renewable energies can cover a variable fraction of these uses, depending on the energy resource and the investment. Solar water heaters could cover a significant fraction of households´ requirements with a standard 2m2 collector (>50%). Solar cooking is also highly feasible in this region and could cover at least one meal per day. Heating requirements could be covered by a combination of adequate housing design, passive solar, and biomass. The introduction of these technologies presents cultural and infrastructure challenges. In all cases, biomass energy will still have a significant role to play in poor rural isolated areas. Thus, specific measures are needed to guarantee biomass supply, in particular in dry areas, such as multipurpose forestry projects for food, fodder, energy and windbreak.

Technologies available for water and energy exploitation, and adequate for the situations under assessment

Technologies will be assessed taking into account a multi-criteria methodology that evaluates their feasibility of implementation in a given context and their contribution to sustainable livelihoods[41]. As an indicator of the first issue the following aspects will be taken into account:

- Affordability (cost of the technology relative to user income)
- Efficiency (cost of the services provided)
- Risk of obsolescence (temporal sustainability of the technology and associated services)
- Flexibility (ability to satisfy both current and enhanced uses)
- Technological capability (compatibility with the services network that supports the technology)

In relation to the contribution to sustainable rural livelihoods, the following indicators will be taken into account:

- Suitability and urgency (ability to provide critical services)
- Effectiveness and efficacy (in relation to society objectives)
- Resilience (technology effects on human/community resilience)
- Diversification (contribution of the technology towards a wider range of options)
- Environmental protection (impacts associated to the implementation of a technology in a given context)

Concerning the specific technologies used for water supply in rural areas, they will be separated into those for isolated small scale and those more adequate for rural communities.

The following technological options are used in the rural area and could be assessed in the study:

- Wind and solar electric pumping coupled with modern pumps and an inverter (Catamarca[42] and Neuquén[43] case studies). The implementation of these options generally counts with a strong institutional support and adequate human and economic resources.
- Multi-blade traditional wind pumps. Not very disseminated due to high costs and the requirement of skilled labor for installation and maintenance. This situation is compounded by the large range of commercial brands and quality available, a barrier for consumer choice and spare parts supply. Installed capacity is generally the outcome of individual initiatives.
- Electric pumps coupled to a generator set (usually made in China). It is a technology commonly used thanks to its low investment cost and its large distribution network. Usually commercialized, designed, installed and used without proper training, resulting in a short lifetime.

[41] For a complete description of these indicators refer to (Villavicencio, 2003)

[42] (Rodriguez, 2000)

[43] http://www.inti.gov.ar/e-renova/erEO/er01.php Both places, as well as Arauco Wind Farm in La Rioja Province are identified by satellite images in the annexes of this report.

- Siphon (uses level differences to suck water from a source into a storage area). It is still an underexploited practice but largely disseminated.
- Manual pumps (rope or piston pumps). Its use is not very common. In the case of piston pumps due to their cost, maintenance complexity, and problems with low temperature operation. Rope pumps have many benefits over extracting water manually from a well using a bucket, but they are not much disseminated due to lack of awareness.
- Hydraulic ram. Not very common to find but could be used in several locations.

The assessment of these technological issues will be made following a "niche" concept or criteria, which roughly means trying to match the specific advantages and features of the renewable option with the required needs, the available resources, the local situation, etc. Described indicators are used to judge the feasibility of the options[44].

Water extraction

Table 2.16 Technologies used for water extraction/supply

Technology	Advantages	Limitations	Niches
Electric pump connected to regional /national grid	• Reliability. • Level of power available allows many uses • Flexible to adapt to fluctuating water demand along the year	• Cost of electricity distribution/access. • Limited reach. Not feasible for dispersed inhabitants in isolated rural. • Could lead to borehole overexploitation	• All uses and hydraulic loads within distribution grid range. • In particular, medium to high scale productive activities • Irregular water demand (e.g. irrigation)
Electric pump / diesel or gasoline generator set	• Ease of operation and maintenance. • Available local knowledge, experience and support infrastructure • Low investment cost • Available for wide range of hydraulic loads • Flexible to adapt to fluctuating water demand along the year • Easy to transport to another borehole	• Potentially unreliable due to maintenance and fuel availability (major service every 500hr to 1,000hr) • Low system useful lifetime (8,000hr to 35,000hr) • Operation & maintenance cost (fuel, spare parts) • More expensive than PV for isolated areas • Could lead to borehole contamination and overexploitation • Not efficient at partial load operation	• All uses and medium to high hydraulic loads in isolated areas. • In particular, medium to high scale productive activities • Adequate access to maintenance services, spare parts and fuel supply. • Irregular water demand (e.g. irrigation)

[44] For further detail of niches assessment for renewable energies see (Nadal, 2006). The concept of niche is applied there to select technologies which are also important from the point of view of their impact on the poor population, their stage of technological development and their economic feasibility. In particular the study focuses on the assessment and policy formulation for Argentina of solar water heaters (SWH) and wind energy converters (WEC).

Photovoltaic pump	• Cheaper than diesel for isolated areas • Solar resource is widely available in semi-desert areas • Solar resource availability matches with seasonal water requirements • Quiet operation • Suitable for weak boreholes and resource protection • More adequate to highly isolated regions where fuel supply is uncertain • Adequate for replacing manual pumps (hand pumps, treadle pumps, etc.)	• Maximum head is between 100m and 230m depending on technology. • Hydraulic load is between 300m4/day and 4000m4/day. • Low water volumes at medium to high depths • High Investment cost • Specialized O&M requirements and weak local support/service infrastructure available • Power range 300W to 6kW • Requires specific design and installation procedure to operate properly • The pump is generally the component of the system with lower reliability • Not available for high hydraulic loads • Not adequate for fluctuating water demand situations (e.g. seasonal irrigation) • Requires backup water storage capacity • Costly to replace (theft) • Underutilizes boreholes with safe medium to high yields (>2m3/hour) • Low match with daily water demand (morning and afternoon peaks)	• Residential, services and small scale productive activities in isolated areas • Very small scale irrigation • Medium to low hydraulic loads and depths. • Homogeneous water demand along the year. • Storage capacity available.
Wind turbine (electric)	• Cheaper than diesel for isolated areas • Minimum wind speed required is relatively low	• Requires backup water storage capacity • Wind resource availability and variability • Investment cost • In variable frequency systems with the pump directly connected to the generator the pump does not work at the optimum level and disconnects when the frequency is not adequate	• Residential, services and small scale productive activities in isolated areas • Storage capacity available
Wind mill (mechanical)	• Cheaper than diesel for isolated areas • Minimum wind speed required is relatively low • Relatively easy to maintain	• Requires backup water storage capacity • Wind resource availability and variability • Investment cost	• Cattle watering in isolated areas where storage is available
Siphon	• Low cost • No energy consumption • Rugged • Easy O&M	• Requires groundwater body to operate • Requires adequate topography	•

Hydraulic ram	• Low cost • No energy consumption • Easy O&M	• Requires flowing water to operate • Requires adequate topography	•
Manual pumps	• Low cost • Rugged • Easy O&M	• Limited pumping volume and depth (hydraulic load < 250m4/day) • Requires human/animal labor to operate	•
Hybrid Wind/diesel or PV/diesel	• Flexible to adapt to fluctuating water demand along the year • More reliable than specific technology options • Available for wide range of hydraulic loads and depths •	• Very high investment cost • Increased complexity and maintenance requirements	• All uses and whole range of hydraulic loads in isolated areas. • Adequate access to maintenance services, spare parts and fuel supply. • Irregular water demand (e.g. irrigation at all scales)

Source: own elaboration

According to an assessment performed for Namibia, PV pumps tend to be cheaper than diesel pumps for a wide range of hydraulic loads (EmCom, 2006). However, PV pumping is not available for heads above 120m, except for very low water requirements (<4m3/day), neither is it available for lower heads at a flow rate above 35m3/day. Furthermore, PV pumps may not be cost effective for fluctuating water demand situations (e.g. seasonal irrigation schemes). Thus, diesel pumping is the technology choice in these cases. Unit water costs increase with increasing head and are higher for low volume demand, in particular if diesel pumping is used. Since PV pumping system components are imported in Argentina, one would expect qualitatively similar results for this country. This represents a limitation for the penetration of PV pumping for productive uses where requirements are higher than 4m3/day (equivalent to the watering demand of 80cows, or 0.2Ha to 0.6Ha of crops in a semi-desert area), and in particular for irrigation of medium to large areas. Maintenance interval varies between 1 and 5 years depending on specific PV pump technology.

A feasibility assessment study for PV pumping was performed in San Juan province (Secretaría de Energía, 2006). This technology was proposed due to the limitations of the present pumping system, which only partially covers residential water needs and sometimes produces a surplus for cattle. This system is based on not very deep water wells (20-25m) located in semi-desert areas, or in rainwater supply from a barrage in the Sierra area. Both options produce water unsuitable for human and cattle consumption due to high salinity and/or organic pollution levels. In all cases rainfall is scarce and drought season is long.

According to this study, preliminary data indicate the existence of underground water resources at 100 to 120m depth and of higher quality. A system was analyzed consisting of PV panels pumping 1m3 per hour at 100m depth, for cattle and human consumption, including vegetable gardens irrigation. The nominal power of such equipment will be 570W, and could be fed by a set of six PV panels of 100Wp each.

The cost of the equipment was estimated in 16,100 USD, including drilling costs. It was also estimated that for small scale cattle raising activity – typical of the area – such equipment could satisfy the needs of three to five *puesteros* (shepherds) located nearby, giving also the chance of developing small or community vegetable gardens.

Almost half of the interviewees were interested in this service, so the projected population is 190 potential users, implying a million dollars investment. As the equipment will be of communitarian use it is recommended to develop a pilot project, that besides detailing the technical and economic aspects, proposes social solutions for the efficient and sustainable water resource management.

A second study is available in the same province, San Juan[45] the Balde de Leyes Remote Village Electrification case. In September 1994 Solar Home Systems were installed, followed by the installation of a PV driven water pump, with batteries. The village was composed by 65 people whose main activity was livestock raising (300 cows, horses and some goats). The main community need was replacing the diesel pumping system, followed by electrical lightning. This was due to repeated pump break down and the subsequent need of bringing water for the cattle from far away. Human resources were not available at community level to carry out system maintenance. According to (Parodi, 2003), in order to solve this problem it was proposed to drill a new borehole and install - as a back-up system - a new pump, operated by the already existing diesel motor. At the old well a new PV-pump was to be installed. This pump should be able, to pump an average of 15 m³/d of water in winter and 30 m³ in summer from a depth of 29 m. This water will fill a main storage tank with a capacity of 30 m³ or two open basins with 30 m³ and 50 m³. A distribution system would connect the 13 houses to the main storage, while the open basins should provide water for the animals and for a community field nearby.

The PV pumping system used a Grundfos submergible pump, driven by a three phase inverter with variable voltage and connected to a PV generator of 1,7 kWp rated power. The system was provided by Solartec Company from Argentina and installed jointly by the Dirección de Recursos Energéticos (the energy unit of the province government) and the inhabitants of the village. The evaluation of the project indicated no problems with the inverter. However, the submergible pump failed after 4 years of operation and the entire motor-pump unit had to be replaced.

From the technical point of view Wind/diesel and PV/diesel hybrid systems combine many of the advantages of these technologies and overcome many of the limitations of renewable energy systems. Thus, they offer an adequate solution to isolated rural productive units and communities. However, the increased investment costs and maintenance complexity usually make this option unfeasible.

[45] Parodi, Orlando and others, Balde de Leyes: The Electrification of a Remote Village in Argentina, Fraunhofer Institute for Solar Energy Systems ISE, 2003. http://artsarchive.tripod.com/03sene/argentina_Solar.pdf

Storage

Table 2.17 Technologies used for water storage

Technology	Advantages	Disadvantages
Open barrages	Lower cost by volume	Higher pollution risk. High evaporation. Requires lining to reduce losses
Underground pits	Low-Medium cost. Widespread for low volume and shallow water resources	Rare to find with large volume capacity. Infiltration losses. Labor intensive for construction.
Uncovered Australian tanks	Fast installation	High evaporation losses and cost
Covered tanks	Fast installation. Lower risk of water pollution. Low evaporative losses	Higher cost by volume

Source: own elaboration

Storage is a key component of an adaptation strategy to increased water stress due to climate variability. Reference storage capacity can be calculated based on community water requirements (three days storage) and cattle watering (five days storage). Storage in tanks is costly but usually less expensive than investing in larger PV pumping capacity.

Open basins and reservoirs should be utilized only for providing drinking water for animals and irrigation.

Irrigation

Table 2.18 Technologies used for irrigation

Technology	Advantages	Disadvantages
Drip	• Low pressure and water flow requirements. High efficiency • Adequate for areas with inadequate topographic conditions for gravity irrigation. • Adequate for areas which do not have irrigation rights (access to public water distribution infrastructure) • Compatible with fertirrigation and weed control techniques	• Incorrect management methods could lead to salinization. • Uniformity problems with some technologies and irrigation schemes. • High energy consumption under incorrect application/design schemes (1.6 to 4.6 HP/Ha).(Fontela, 2005) • Cost • O&M requirements • Blocking of drip emitters by sediments
Sprinkler	• Mid-high water pressure and flow. • Adequate for areas with inadequate topographic conditions for gravity irrigation.	• Medium losses • Medium to high energy consumption • Cost • O&M requirements

	• Adequate for areas which do not have irrigation rights (access to public water distribution infrastructure)	
Trench	• High water flow requirements. • Lower cost. • Lower energy consumption	• Low efficiency. Large evaporation and infiltration losses. • Depends on gravity and thus is restricted to areas with adequate planialtimetry. • Access depends on water use rights

Source: own elaboration

Drip irrigation cost in Mendoza province is between 1,400USD/Ha and 2,500USD/Ha depending on the type of crop (Fontela, 2005). The main drawback in semi-desert conditions is the risk of salinization of the root area when using water with significant salinity levels. The investment cost is usually justified when producing high value crops, in particular for the export market.

The most adequate technologies for the areas under study are advanced localized irrigation methods such as drip irrigation. However, these technologies also present drawbacks when designed or applied incorrectly.

Purification

Table 2.19 Technologies used for water purification

Technology	Advantages	Disadvantages
Chemical	Reliable	Requires chemical input. Cost. Dose application
Solar	Low cost	Efficiency. Volume treated

Source: own elaboration

Niches

Table 2.20 Main niches assessed in the present study

Technology	Population	Type of use	Associated Case Study
1. Small scale wind pumping WEC[46] (isolated)	Isolated users	Productive with some restrictions, Services, Residential (low power)	Michacheo - Neuquén
2. Small scale PV pumping (isolated)	Rural communities	Residential, Services, productive with significant restrictions (hydraulic load and depth limits). Small variations in demand	Rural isolated - Catamarca
3. Large scale wind power (grid connected)	Rural areas close to the distribution grid	All power levels and uses	Arauco – La Rioja

Source: own elaboration

Table 2.21 Assessment of indicators for Niche 1

Niche	Small scale wind pumping for isolated rural households (based on Michacheo Case Study) R, (P), S
REPRESENTATIVENESS	
Replicability	Medium to high (moderately windy areas with shallow to medium water level depth)
Population benefited	Low
Complexity	Medium. Low and medium voltage electricity uses and water volumes.
SUSTAINABILITY/ VIABILITY/ SUITABILITY	
Affordability	Medium to low
Effectiveness	Medium
Risk of obsolescence	Low to medium. Coupling with the pump needs improvement
Flexibility	Medium to high. It requires a certain management of the demand to accommodate a higher requirement. Furthermore, another generator or storage facility must be installed if water demand increases
Technological capability	High potential but far from application place. Weak O&M
Suitability and urgency	Medium to high
Resilience	Medium to High, if combined with adequate water storage and productive activities
Environmental protection	Low negative impact. Noise, electromagnetic interference.
Social acceptance	High
CD requirements	High. Minimum maintenance and adequate design, installation, and use.
Income generation	Medium. It allows limited productive activities

Source: own elaboration

R: residential uses; S: services; P: productive uses; () means that could be used with restrictions

[46] Wind energy converters

Figure 2.16 A 4.5kW wind energy converter installed in the Michacheo Valley for water pumping

Source: Technical Extension Unit, INTI Neuquén

Table 2.22 Assessment of indicators for Niche 2

Niche	Small scale photovoltaic pumping for rural communities (based on Catamarca Case Study) R, S, (P)
REPRESENTATIVENESS	
Replicability	High (high insolation rural areas in semi-desert regions, low to medium underground water levels)
Population benefited	Low
Complexity	Medium to low. Allows meeting multiple medium and low voltage electricity and water requirements.
SUSTAINABILITY/ VIABILITY/ SUITABILITY	
Affordability	Very Low
Effectiveness	Medium. Limited by the high cost and low voltage of the systems. In turn, in certain places it represents the only option to provide electricity for pumping water in limited amounts.
Risk of obsolescence	Medium. The efficiency of the systems is still quite low. Much research is being carried out on this. Also the coupling with the pump and the hydraulic load range of the pumps need improvement.
Flexibility	Low to medium. The modules yield low power and water volumes and may only supply electricity/water to limited applications. The technology is modular, except for some BOS components. Expansions are restricted by cost considerations and the need of new boreholes. They may be transferred without much effort, if required.
Technological capability	Still deficient and costly O&M infrastructure for the supplier and the consumer.
Suitability and urgency	Very high for certain uses and places lacking other reliable options for electricity generation and water pumping. The most critical uses are related to residential uses and community services.
Resilience	Medium to low. The procurement, O&M of the system may capture the scarce economic resources of the community without enhancing productive activities and income generation
Environmental protection	Medium to low negative impact. Mainly related to the operation of the batteries and the manufacture of the photovoltaic cells.

Social acceptance	Medium. Some rejection associated to its limited power and water volume, which prevents meeting a raising or fluctuating demand, and is worsened by troubles due to misuse and lack of adequate maintenance.
CD requirements	Medium to high. Adequate design, installation and use, knowledge on limitations, minimum maintenance
Income generation	In general, brought forward here for social purposes, although water pumping, communications, and lighting uses also have repercussions on production activities and, thus, on income generation. Nevertheless, the high cost per power unit results in the installation of low-power systems with limitations for production applications.

Source: own elaboration
R: residential uses; S: services; P: productive uses; () means that could be used with restrictions

Table 2.23 Assessment of indicators for Niche 3

Niche	**Large scale wind power generation for grid interconnection R, S, P (based on Arauco Case Study)**
REPRESENTATIVENESS	
Replicability	Medium (good wind resource available near transmission grid)
Population benefited	High (provides electricity to the national grid, for all uses and power levels)
Complexity	High. Needs complement with non-variable generators.
SUSTAINABILITY/ VIABILITY/ SUITABILITY	
Affordability	Medium (incentives available at national level). Beyond certain power levels may increase energy cost and backup requirements.
Effectiveness	High
Risk of obsolescence	Medium to Low (technology advances towards higher level power units)
Flexibility	High. Can easily accommodate increasing and fluctuating demand
Technological capability	Medium to high (national capacity available)
Suitability and urgency	Very high. Allows medium and large scale productive activities.
Resilience	High
Environmental protection	Medium to low negative impact (noise, electromagnetic interference, visual nuisance)
Social acceptance	High (some conflicts near urban areas)
CD requirements	High (design, installation, O&M). T&D infrastructure
Income generation	Medium to high (allows many productive activities without significant power constraints)

Source: own elaboration
R: residential uses; S: services; P: productive uses; () means that could be used with restrictions

2.3 Identification of problems and priority setting

This section presents a characterization of the current situation and its possible trend in the framework of climatic scenarios. The diagnosis allows identifying and setting a priority level to the different problems, pinpointing those where energy could significantly contribute to its resolution. The diagnosis also allows a classification of problems into the following dimensions:

- Economic-Financial
- Sociocultural
- Technological
- Institutional
- Regulatory/Legal
- Environmental
- Crosscutting

In turn, each problem actually constitutes a component of what can be called a problem situation. Several of these components can be identified and are relevant for the diagnosis:

- Dimension (Economic, environmental, etc.)
- Causes
- Problem definition
- Manifestation of the problem
- Stakeholders involved

Key problems for selected Case Studies

Table 2.24 Identification of problems for Case Studies

Problem	Michacheo	Catamarca	Arauco
Low precipitation rates, semi-desert conditions	•	•	•
Scarce availability of groundwater and water storage capacity	•	•	•
Pollution, sedimentation and evaporation in groundwater reservoirs		•	
Increased climatic stress (higher temperatures, lower precipitation rates, high evaporation)	•	•	•
Increased cloudiness, lower generation		•	
Regions prone to soil erosion	•	•	•
High cost of conventional energy/water (O&M costs)	•	•	•
Conventional Energy access issues (e.g. fuel supply, equipment failure, low reliability/power, restricted water supply)	•	•	•
Underground water access and quality issues (increase in water level depth, salinity)	?	•	
Limited knowledge on local hydrologic cycle/balance and in particular of the dynamic of underground water resources	•	•	•
Limited monitoring and information availability	•	•	•
Use of unsustainable water use methods	?	•	
Unsustainable productive activities		•	
Conflicts between uses			•
High investment cost of renewable energy systems	•	•	•
High cost of water irrigation/storage/distribution infrastructure	•	•	•
Technical limitations of renewable energy systems	?	•	
Low income / subsistence economies	•	•	
High requirement of human resources for adaptation, implementation and long term operation of renewable systems.	•	•	•
Technology transfer barriers due to cultural traits of target population and institutional/organizational issues	•	•	
Low number of rural inhabitants, exclusion from development model and policy agenda	•	•	
Rural-urban migration of young people	•	•	
Precarious land tenure rights		•	
Poor soil quality, scarce forage production aggravated by over-exploitation		•	
Community disbelief due to negative experiences		•	
Inadequate Community organizational/management levels		•	
Poor institutional coordination for technological transfer. Bureaucracy		•	
Lack of adequate financing	•	•	

Source: own elaboration

Table 2.25 Problem situations related with RETs. Niche 1 – Case study Michacheo

Elements of the problem Field or dimension	Problem definition	Problem manifestation	Causes	Involved stakeholders	Objective
Socioeconomic	Pump system investment cost is not affordable by farmers	Households restrict water use for productive activities to subsistence levels	System is aimed at high income sectors (e.g. oil industry). Manufacturing processes are underdeveloped. Small production level. Adequate financing schemes and incentives are not available. Too low income.	Energy Secretariat, Economy Ministry, Congress	WEC systems are affordable for farmers
Technical	Small wind turbines from different brands have uneven quality and performance. Installation procedures are variable. Post sales services are limited and critical for long term sustainability (guarantee, insurance, maintenance infrastructure, technical support)	Inadequate materials, installation/use results in early malfunction and creation of negative reputation. Installations require long-term technical support.	Systems are not always of adequate quality and adapted for intended use (reducing maintenance requirements and increasing reliability). Users and installers not always have appropriate capacitation	IRAM, INTI, CREE, manufacturers, R&D institutions	Good quality equipment and installation procedures are available at reasonable cost and can be clearly identified. Post sales service is adequate.
Political-Institutional	WEC systems are not well known among planners, developers	Conventional systems are preferred for grid interconnection. Diesel or gasoline generating sets are preferred for isolated applications	No dissemination campaign. Uncertainty, negative reputation and higher perceived complexity and cost than conventional systems. Perception of lack of maturity. Quality standards are not enforced. Lack of experience	Developers, planners, developers, installers, IRAM, INTI, CREE, manufacturers, R&D institutions	WEC are well known to all relevant stakeholders and considered as a feasible option to complement conventional systems in grids and for isolated applications.
Political-Institutional	Small WEC are not promoted and have low priority	Only very specific WEC niches linked to mid and high income population (small WEC) and pilot projects (large WEC) are developed.	WEC are not well known. Playing rules are not stable (economy, policy). Lack of maturity perception	Energy Secretariat, Economy Ministry, Congress	WEC systems are promoted by means of adequate incentives to ensure long term growth

Strictly energetic	For small communities WEC may not cover 100% of water pumping requirements.	Water storage system is needed with resulting impact on investment.	Wind resource is variable along the year	Installers, developers, planners	Advanced WEC/Diesel systems are designed as a tradeoff between conventional fuel savings and system cost

Source: own elaboration

Table 2.26 Problem situations related with RETs. Niche 2 – Case study Catamarca

Elements of the problem **Field or dimension**	**Problem definition**	**Problem manifestation**	**Causes**	**Involved stakeholders**	**Objective**
Socioeconomic	Subsistence economies prevent investing in PV water pumping and associated infrastructure	Water supply systems are precarious, mostly depend on groundwater sources and public investment decisions	Rural low income population is not included in the development model. No specific policies are implemented.	Agricultural development units (PSA), INTI, National water institutions (SSRH, ENHOSA)	Rural inhabitants can afford investment in required technologies
Technical	PV water pumping system presents limitations. PV pumping does not adapt to fluctuating demand (e.g. irrigation)	PV pumping does not cover all water requirements	Incorrect match between supply option and requirements. Inadequate system management and storage capacity.	Provincial planning institutions; local government; service provider	Supply scheme is adequate for expected water requirements along the year
Political-Institutional	Lack of long term planning. Technology driven projects.	Limited system life time. Extended maintenance periods	Lack of proper O&M infrastructure, availability of spare parts, and technical support due to population dispersion and low payment capacity. Lack of capacity development.	Provincial planning institutions; local government; service provider	Systems perform adequately in the long term

Source: own elaboration

Table 2.27 Problem situations related with RETs. Niche 3 – Case study Arauco

Elements of the problem / Field or dimension	Problem definition	Problem manifestation	Causes	Involved stakeholders	Objective
Economic	Projects require public financing and incentives, which are limited	Projects take long time to mature and secure funds	Lack of performance records and of experience in providing finance. Project investment and guarantees required are high.	Planning Ministry, Manufacturers, Provincial government	Adequate financing is available and project implementation is streamlined
Technical	Lack of long term experience with this technology in Argentina.	Increased maintenance requirements and reduced generation in relation to expected.	Lack of adaptation of technology/farm management to local conditions. Lack of long term assessment of wind resources.	Manufacturers, operator, provincial government	Systems perform as expected in the long -term
Strictly energetic	Sites for implementation must comply with several restrictions (high wind resource + adequate transmission infrastructure + access + property + others)	High potential sites are limited and not evenly distributed among provinces	Wind resources distribution is uneven and T&D infrastructure has a limited extent and presents weak areas.	Energy Secretariat; Planning Ministry; provincial governments	All good potential wind sites are exploited and supply energy to the interconnected grid

Source: own elaboration

The identification of problems for each case studies constitutes the necessary input to identify barriers to the use of RE for water pumping in a more general framework and applicable to other situations with similar characteristics (see Section 2.4 for a general description of barriers).

2.4 Diagnosis Summary

This section summarizes the main findings of case studies assessment and the issue of water access in arid and semiarid areas in the framework of the climate change and climate variability phenomena. An assessment of the potential role of renewable energies and the main barriers is carried out.

The vulnerability of arid and semi-arid regions to climatic variability depends on the complex interaction of natural and anthropogenic factors that reinforce each other, the latter playing a very important role. Due to this reason, the adaptation to this issue requires the coordinated adoption of a set of actions in very different areas, including those aimed at guaranteeing the access to water resources. In the same context, renewable energies could play a role in the mitigation of this problem under some specific circumstances, but they do not guarantee a successful outcome on their own. Given the anthropogenic component of these phenomena, the measures that could be adopted to improve the management of water and soil resources are of equal or higher relevance than those aimed at guaranteeing adequate access to water resources.

Some of the dry regions analyzed depend almost exclusively from underground water resources to satisfy current water requirements (Barros, 1997). More than 95% of water resources in La Rioja Province are underground resources. Thus, the potential influence of climate change over access to underground water resources becomes the key issue for these regions. Additionally, underground water supply schemes seem to be better adapted to cope with increased water stress situations, even more if they are linked to high volume storage facilities.

However, both renewable and non-renewable water supply systems could be affected by a decreased availability of underground water due to salinization, pollution or water level depression, linked or not to climate change. These effects are becoming more common and indicate the need to exploit deeper aquifers. Under these situations both types of systems face increased costs and technical challenges to solve water availability problems. Also, reliability and energy security problems are not exclusive of non-conventional energy systems. Effectively, renewable systems could also be affected by these problems and require significant planning and support schemes to prevent most of them and ensure long term sustainability, as indicated by case studies (Michacheo and Catamarca, and (Parodi, 1999)).

Under some situations, renewable energy systems seem to offer a cheaper and more reliable alternative to conventional systems when pumping water from underwater sources in isolated locations. However, renewable energy systems could also show limitations to cope with some situations posed by climatic variability when pumping head and/or water volume requirements are large or highly seasonal (e.g. for crop irrigation). For example, photovoltaic pumping systems are not available for high head wells for flow rates above 4m3/day. In particular, under high water demand levels the depression of water level in wells could lead to diesel becoming a more cost effective option than PV pumping (EmCom, 2006). Thus, medium to large productive activities usually depend on other technology options (grid, diesel).

In summary, an adequate adaptation strategy to climate change induced water stress should go beyond the specific technology used to pump water and include measures such as: diversify water supply sources, increase water storage facilities, implementation of efficient and rational water use. This in turn requires adequate planning that takes into account the potential climatic scenarios when designing/modifying water supply schemes. Finally, there are also significant differences among renewable energy systems in terms of cost, O&M requirements, power available, social acceptance, that should be considered when selecting a technology. In broad terms it could be said that the preferred order within renewable options would be: hydro, wind, solar. However, resources availability is the key factor to make the final selection between these three resources, and usually leads to exclude hydro from the list in dry areas.

Some conclusions from the diagnosis:

- The dry regions under study seem to be particularly sensible to the increased climatic variability that would occur in the coming decades. These changes will probably aggravate the existing water stress problem, converting sporadic critic situations into a common condition.
- In the Cuyo valleys region, the ENSO phenomenon seems to be the key aspect that restrains both surface and underground water availability through the reduction of snowfalls in the high Andes. It is still not clear in which way Climate Change could affect ENSO, but it is probable that it will contribute to the worsening of arid conditions through the increase in evapotranspiration.
- Climatic variability and the potential effects of Climate Change over it is only one of the many issues that lead to water availability problems in arid and semi-arid regions, others being related to water infrastructure, water management and use.
- Though the region has suffered extreme hydrological events, it has not yet implemented rational and efficient water use measures in a complete, integrated and systematic way. In particular, small rural productive units still use traditional irrigation methods (mainly gravitational based).
- Where adequate water resources are available, the adoption of other measures to reduce vulnerability and migration risk is also highly recommended (e.g. small forestation projects for firewood, fodder and windbreak in areas where biomass is usually scarce, solar water heating).
- Young people migration phenomenon is already present in some of these regions due to harsh conditions, isolation and low quality of life compared to urban areas. Energy has a key role to improve living conditions and reduce isolation perception (recreational and social uses of energy).
- The reduction of rural productivity due to climatic variability will have to be compensated by a redesign of productive activities and the commercialization of higher market value products in order to sustain or even increase income.
- The adaptation of these regions to the growing water stress will require significant investments in new infrastructure and financing capacity. These are generally beyond the possibilities of individuals and should be supported by the State. The investment required also goes beyond the implementation of renewable energy water pumping systems, comprising also storage and distribution infrastructure as well as technologies that allow more efficient water use and can protect adequately both the soil and its natural cover.

- Regulatory framework and water policies in some provinces seem to be inadequate for dealing with increased water stress situations in the coming decades. Particularly, the implementation of rational water use practices and efficient technologies is not fully enforced and supported by adequate incentives. This may be due to lack of human resources and of adequate budget for implementation, but also to fragmentation and deficiencies in the integrated management of water resources between several institutions and sectors.
- At least three other conditions are fundamental for an adequate implementation of adaptation strategies: an advanced degree of community organization and commitment; capacity development for the implementation and use of the new technologies; and support of productive activities consistent with the water resource available (land use planning).
- It is unlikely that the conditions for the adequate implementation of an adaptation strategy could be created without an active State long-term intervention and support, and based on the strengthening of productive activities adapted to each region. In this sense, the promotion of high value products that are better adapted to dry conditions than traditional products and the manufacture of high added value ones may constitute and interesting strategy to cope with decreased water availability.
- The water stress situation aggravates in marginally productive areas surrounding the so called "Oasis". The population with less economic resources and which is not comprised by long term development policies is usually displaced towards these areas, creating high vulnerability conditions.
- An adequate management of pumping systems, boreholes, and pumping schedule could play a significant role in preventing a lowering in water table level and the salinization of boreholes. This in turn could enhance the opportunities of dissemination of PV pumping
- Information available is still scarce and fragmented. The sole identification of the current status of rural communities in relation to water availability and uses poses a challenge since the main information sources are outdated and limited in extent. More information is available on water and energy resources at provincial level, but with important gaps in monitoring infrastructure still exist.
- Small producers face an unfair distribution of water infrastructure investment which limits access to adequate water resources for irrigation agriculture. This is partly due to privileged access of large agricultural producers to the best productive areas in the oasis.
- The complexity of the problem situation requires for the intervention of many knowledge areas and their corresponding institutions. However, deficiencies in inter-institutional coordination can lead to the overlapping of sporadic initiatives and population lack of commitment, and to projects lacking key components and prone to failure.
- The long term productive sustainability of these regions depends on the adoption of an adaptation strategy that incorporates all these elements in a coherent way.

In relation to the use of renewable energy resources and technologies:

- Many small rural producers in these dry areas have historically settled in places where there existed surface aquifers or shallow underground water resources that are

disappearing due to climatic variability. In these cases renewable energies could offer a suitable pumping option for some uses (e.g. Savonius locally made windmills, PV, or small WEC).

- In other dry areas where the lack of surface aquifers prevents productive activities, exploiting underground water resources is a key component of development. In those places where water volume and depth are suitable, renewable energies could play a significant role.
- Isolated RE could also have a key role to improve energization levels in rural areas, increasing life quality conditions, making possible small productive activities, and reducing rural-urban migration (e.g. PV and small WEC for productive and recreation uses, SWH, solar driers, thermoelectric generators with biomass, windmills for mechanical energy, etc.).
- There exists some small scale and fragmented experience accumulated since the 80´s in the use of renewable energy systems for improving the access to water resources in these areas. Results have been variable, but in general they have led to an improvement in access, though problems have manifested in the adoption and long term implementation of the new technologies.
- RE pumping projects tend to have a high investment cost (particularly PV), which requires the participation of a financing institution or a donor in the project. These specific project requirements are usually beyond the administration activities and knowledge of local authorities.
- The implementation of water supply initiatives based on renewable energies still rely on the dissemination and technical support provided by research centers working in each region (Universities, INTI, INTA, etc.). No widespread knowledge is available on these options among local planners. Renewable options tend to be adopted when conventional options are excluded, mainly due to cost or fuel supply issues.
- Isolated renewable energy based pumping systems seem to require more technical support (long term) and capacity development of the local community than diesel systems.
- Conventional systems tend to have a better local support infrastructure, and more knowledge is locally available on this technology than on renewable energy systems. Accordingly, maintenance time may be longer for renewable energies (spare parts supply, human resources availability), which constitutes a serious problem when dealing with water supply
- When feasible, the extension of the power grid should be the first option to assess given its advantages in terms of energization of productive activities, and water pumping and distribution. In this context, grid connected renewable energies could help support weak networks, reduce electricity costs and specific emissions, and increase the reliability and power available. This requires a high renewable resource potential in an area close to the transmission grid that is not saturated.
- For highly isolated communities, the availability of renewable energy resources close to the users usually restricts the range of pumping options. In some arid and semiarid areas, solar is sometimes the only renewable resource available with adequate distribution along the year.
- For isolated applications, under specific circumstances conventional pumping systems could offer certain advantages over solar pumping (e.g. suitable for high hydraulic loads and variable water demand, familiar technology). In these situations it could be

advisable to combine both systems into a hybrid system. This has the added advantage of not depending on a single pumping technology or on a single borehole.

- Isolated PV pumping could offer a technical solution for very small rural productive units with no previous pumping system or replacing manual systems, or for human water supply in communities with even water demand along the year. In this sense, PV pumping could constitute an intermediate step between precarious low volume water supply systems and hybrid or diesel pumping systems more suitable for medium to large scale productive units.
- Any water supply system requires plans to ensure provision during maintenance periods, particularly during water stress and/or high demand periods. This may require the installation of hybrid systems, the availability of large storage capacity, and the perforation of at least two productive boreholes per community.

Table 2.28 Summary of barriers to the use of renewable energies for water supply in arid and semi-arid areas – Components of the problem situation

e. General framework	
6. Lack of inter-institutional and sectorial coordination. Integrated planning	
7. Institutional weakness, Inadequate control, investment, and/or implementation of water services and works	
8. Inadequate regulatory framework (e.g. to cope with climatic variability)	
9. Lack of adequate information	
10. Exclusion of rural poor population from development model	
f. More or less independent of pumping technology (including REs, diesel and EE)	
9. Low payment capacity. Subsistence economies	
10. Low Community organization level / resources. User conflicts	
11. Restricted access to underground water resources / Water level depression (partly associated to inadequate management of pumping infrastructure and climatic variability)	
12. Restricted availability of water resources. Increased erosion.	
13. Unsustainable water use / Increased water requirements (partly due to increased evapotranspiration)	
14. Salinization of water resources (associated to inadequate management of pumping infrastructure)	
15. Requirements for investment in associated infrastructure (e.g. trickle irrigation)	
16. Limited knowledge on community characteristics, resources and water requirements	
More specific to Renewable Energy options	
g. Isolated systems (e.g. standalone PV Catamarca)	**h. Large scale - Grid connected (e.g. Arauco wind farm)**
6. Technical limitations in water volume and/or head restricts their use under some conditions and for productive activities, particularly for irrigation	5. Large scale projects associated with good power availability and low costs may reach unsustainable water use levels if not properly designed
7. High investment cost (pumping system and storage)	6. High investment cost
8. Weak O&M infrastructure / long term technical support. Risk of extended down-time periods	7. Limited extent of EE T&D infrastructure.
9. Renewable energy resources need to be available close to the users.	8. Good quality renewable energy resources should be available close to the transmission grid. Resource quality requirement is higher than for small scale projects.
10. Knowledge and perception about the performance and suitability of the technology is limited among	

local planners.	

Source: own elaboration based on Case Studies

3. General description of an adaptation strategy to climate change

3.1 Objectives, Strategic Outlines and Instruments

The objectives that should guide an adaptation strategy are defined based on the identification of the main problem situations. These objectives indicate what needs to be achieved through the implementation of policies. Thus, their definition requires an identification of the desired and feasible situation. Those objectives where energy could play a significant role are identified.

Strategic outlines are defined for each objective and indicate how to put them into practice in the context of framework conditions. Those strategic outlines where renewable energies could play an important role are identified.

An assessment of the role of renewable energies is performed in the framework of the adaptation strategy (barriers, advantages and limitations of their contribution to this strategy). The assessment will try to evaluate to what extent the renewable energies can provide a tool for building resilience and adaptation capacity through the provision of sufficient energy for pumping water, supply to productive activities, processing and preservation of agricultural products, among other issues. Diverse situations are analyzed: small and large-scale, isolated areas as well as grid connected areas with energy security problems.

Case studies provide illustration of specific situations where renewable energies implementation allowed objectives fulfillment. It is important to identify and remark as far as possible, those particular elements that allowed the success of the experience. Meaning financial, political, local population capacity or expertise aspects, that took place at the case studies.

From the assessment of barriers we can see that climate variability may affect water resources through three main mechanisms:

a) Reduced water availability
b) Reduced water access (e.g. water table level depression)
c) Increased water requirements (e.g. due to increased evapotranspiration)

These mechanisms affect in different ways each water supply technology. In this sense, some renewable energy technologies seem to be less adapted to cope with changes related with b) and c) (e.g. PV). On the other hand, all water supply technologies, but in particular RE ones, benefit from the implementation of rational water use measures and water storage facilities.

We can also note that successful agricultural/livestock production experiences in the semiarid regions have combined high market value products coming from species adapted to dry conditions, adequate power supply, knowledge, technology and organization. Thus, the above mentioned mechanisms (a), b), c)) also affect rural populations in different ways, depending

on whether a given rural community can adapt to increased water stress situations. This in turn depends on a set of rural population traits among which we can stress the following:

d) Degree of socioeconomic development
e) Organizational/capacitation level
f) Potential access to energy resources

Community resilience to climatic variability strongly depends on these characteristics. This also indicates the need to develop d) and e) as a necessary condition for the successful and long term implementation of water/energy systems in isolated regions as the basis for a sustainable productive structure. It also indicates the need for long term support and a large assignation of human and economic resources for the most deprived communities that goes beyond the specific water issue and covers more general capacitation, technology and infrastructure issues. In summary, tackling water supply in these communities involves a coherent and integrated development strategy involving a strong State support and policy decision, and where producers´ associations and cooperatives could play a key role.

Table 3.1 General Strategic Outlines

Problem: Lack of inter-institutional and sectorial coordination
Objective: Projects are successful and effective in the achievement of development objectives
Strategic outlines • Develop national/provincial strategy for dealing with the problem situation • Conceive projects in the framework of coordinated programs and plans • Coordinate the participation of all relevant institutions
Instruments / Actions • Perform diagnosis with participative methodology • Provide visibility to the problem situation • Convene stakeholders for discussing and elaborating strategies • Constitute inter-institutional links and work areas • Promote information sharing among institutions and with the general public • Assign human resources and funds • Develop plans and projects, assign priorities • Implement and monitor projects • Review strategies and iterate • Promote land use planning and integrated resource management • Strengthen application authorities
Stakeholders • Policy makers • Planners at all levels • INTA • INTI • Universities and other academic institutions

- NGOs
- Professional associations
- RE associations
- Public water institutions and other water/energy services providers
- PAN
- RIOD
- ENOHSA
- SAyDS
- SSRH
- COHIFE

Problem: Institutional weakness, inadequate control, investment, and/or implementation of water services

Objective: Institutions carry out their tasks in adequate way

Strategic outlines

- Support capacity development in public institutions
- Ensure the availability of adequate resources for task implementation

Instruments / Actions

- Provide capacitation opportunities
- Provide incentives for further capacitation of technical and policy levels
- Promote restoring of information sources and sharing of information among institutions
- Support the incorporation of technical human resources, particularly at key positions
- Design and implement long term action plans
- Provide adequate funds for implementation and control tasks
- Assign priorities in the use of the fiduciary fund for water infrastructure
- Review water services concessions
- Promote coordination between institutions
- Financing management

Stakeholders

- Planners at all levels
- Regulatory bodies
- Policy makers
- Water/Energy Public institutions
- Universities and other academic institutions
- ENOHSA
- SSRHN
- COHIFE

Problem: Inadequate regulatory framework (e.g. to cope with climatic variability)

Objective: The regulatory framework supports adequately an adaptation strategy

Strategic outlines

- Update/modify water/energy regulatory framework in the context of the problem situation

Instruments / Actions

- Perform diagnosis and identify main modifications required
- Modify institutional framework, coordinate institutions
- Assign specific funds for infrastructure and incentives for most deprived population
- Disseminate problem situation among policy makers
- Technical departments perform a review of the regulatory framework and propose main modifications to competent regulatory body and legal representatives
- Lobby for updated regulatory framework with users´ support
- Assign responsible institutions for implementation
- Assign corresponding funds and human resources
- Implement and control

Stakeholders

- Policy makers
- Planners at all levels
- Regulatory bodies (energy and water)
- Service providers
- Technical departments
- PAN
- RIOD
- ENOHSA
- Universities and other academic institutions
- SAyDS
- SMN

Problem: Exclusion of rural poor population from development model

Objective: Deprived rural sectors achieve adequate development levels

Strategic outlines

- Design and implement long term development strategy for this sector
- Assign funds and human resources in a more equitable way

Instruments / Actions

- Assess infrastructure and capacity requirements
- Assign irrigation and water infrastructure funds in equitable way
- Support capacity development
- Implement adequate rural energization programs for productive, residential and service sectors. This will increase rural life quality conditions and reduce isolation perception and young people migration

Stakeholders

- Policy makers

- Planners at all levels
- Regulatory bodies (energy and water)
- PSA
- PROSAP
- Agriculture Ministry
- Planning Ministry

Table 3.2 Strategic Outlines relevant for isolated RE systems

Problem: Technical limitations in water volume and/or head restricts their use under some conditions and for productive activities, particularly for irrigation

Objective: Provide a suitable technical solution for every volume/head pumping conditions

Strategic outlines

- Foster R&D&D on advanced renewable energy pumps for high hydraulic load situations
- Develop low cost large volume storage options
- Promote productive activities compatible with supply volume (livestock, low scale irrigation, plant varieties for dry conditions and high value products)
- Promote efficient water use technologies

Instruments / Actions

- Include development/improvement of RE pumping technology into national R&D&D areas and assign funds and human resources
- Improve access to funds, machinery and expertise available for the construction of barrages, dams and other water storage infrastructure
- Disseminate plant and animal varieties adapted to dry conditions, particularly those with high market value
- Provide subsidies and adequate financing for investment in efficient technologies (e.g. trickle irrigation)

Stakeholders

- Universities and other academic institutions
- SeCyT / CONICET
- Agricultural and livestock Ministry
- INTA
- INTI

Problem: High investment cost (pumping system and storage)

Objective: Improve access to technology

Strategic outlines

- R&D&D to reduce technology costs (e.g. materials and processes)
- Support the development of local industrial capacity to reduce technology imports of costly

components
- Enlarge market volume to reduce technology costs.
- Provide adequate financing and funds for selected projects
- Develop low cost large volume storage options
- Support productive activities and integration to markets

Instruments / Actions

- Include development/improvement of RE system components and production methods into national R&D&D areas and assign funds and human resources
- Promote links between R&D&D capacity and related industries for knowledge transfer concerning RE
- Provide tax incentives and financing to the industrial development of RE components
- Identify selected communities where RE pumping option is feasible. Elaborate national plan in order to coordinate the association of all projects and reduce fixed transaction costs (project bundling)
- Promote projects at national scale for RE water supply for public services (rural schools, health outposts, park rangers, etc.)
- Involve National Development Banks in project financing
- Improve access to funds, machinery and expertise available for the construction of barrages, dams and other water storage infrastructure
- Provide capacity development for obtaining better conditions for the commercialization of products, the local creation of added value, and the access to markets.
- Support the creation of producers associations and cooperatives in order to take advantage of economies of scale, reach minimum commercialization levels, and be able to negotiate better prices

Stakeholders

- Universities and other academic institutions
- SeCyT / CONICET
- Agricultural and livestock Ministry
- Energy Secretariat / Infrastructure Ministry
- INTA
- INTI

Problem: Weak O&M infrastructure / long term technical support. Risk of extended down-time periods

Objective: Ensure long term operation and low maintenance time

Strategic outlines

- Improve post sale and technical support services (geographical coverage)
- Improve system failure diagnosis (component, expected lifetime range) and use it to anticipate spare parts requirements.
- Increase system reliability (adequate design, use and technology)

Instruments / Actions

- Develop standards and certification schemes for technologies and services. Associate incentives to the certification of production methods, products and services. Promote a clear identification and disseminate certified products
- Develop a regional spare parts storage facility

- Contemplate long term technical support alternatives from the project design stage involving local resources and public technical institutions
- Involve local community in projects. Develop local resources to tackle minimum maintenance requirements, perform preliminary diagnosis and ensure an adequate operation/use
- Implement adequate communication mechanisms to report failures and request support/spare parts
- Develop local capacities (e.g. blacksmiths, craftsmen)

Stakeholders

- System components´ manufacturers, importers and distributors
- National Metrology and Standards Institute
- Universities and other academic institutions
- RE associations
- INTI
- Local government representatives
- Producers associations

Problem: Renewable energy resources need to be available close to the users.

Objective: Improve the knowledge on RE resources at local level

Strategic outlines

- Implement monitoring of renewable energy resources at local level.
- Develop a geographical database for the integrated assessment of population settlements and resources (GIS).
- Identify suitable technical options for energy supply in each community.

Instruments / Actions

- Expand coverage of RE resources measurement stations, integrate into meteorological stations.
- Collect and associate geographical data to population distribution and traits, and for resource mapping, including water resources
- Classify rural population settlements according to resources availability and assign priority level
- Perform detailed in situ assessment for selected communities and develop RE project for water/energy supply

Stakeholders

- Universities and other academic institutions
- RE associations
- National Meteorological Service
- Local government representatives
- National and provincial statistics departments
- National Water Institute
- Energy Secretariat

Problem: Knowledge and perception about the performance and suitability of the technology is limited among local planners
Objective: Improve the knowledge on RE options
Strategic outlines • Implement pilot and demonstration projects in key locations • Disseminate technologies advantages and disadvantages
Instruments / Actions • Select key locations to carry out demonstration projects. Communities should comply with minimum requirements such as project commitment and participate in capacity development and system management • Organize capacitation and dissemination events through professional associations and education institutions. Target planners, policy makers, public technical departments
Stakeholders • INTI • INTA • Universities and other academic institutions • Local government representatives • Planners at national and provincial level • Professional associations

Table 3.3 Strategic Outlines relevant for grid connected – large scale RE systems

Problem: large scale projects associated with good power availability and low costs may reach unsustainable water use levels if not properly designed
Objective: Use water resources in a sustainable way
Strategic outlines • Promote productive activities compatible with supply volume (e.g. large scale irrigation of plant varieties suitable for dry conditions and high market value) • Combine with efficient water use technologies
Instruments / Actions • Develop / disseminate plant and animal varieties suitable for dry conditions and with high market value. Provide capacitation and incentives for their adoption • Implement incentives and regulation for the use of efficient water use technologies (subsidies, loans) • Provide capacitation on the use, design and implementation of efficient technologies
Stakeholders

- INTA
- Universities and other academic institutions
- Planners at provincial level
- Professional associations

Problem: High investment cost

Objective: Expand technology implementation

Strategic outlines

- Reduce production costs
- Implement national incentives for power generation with RE (e.g. GENREN)
- Facilitate access to adequate financing

Instruments / Actions

- Support local manufacturing of components (wind turbine blades, towers, etc.) and develop market volume
- Assess generation costs and set appropriate incentives for future GENREN calls
- Solve funding gaps in GENREN program and issues related to project guarantees. Involve Development Banks and other local funds (Federal Investment Council, CFI)
- Support applications to CDM and other international funds available

Stakeholders

- Planning Ministry
- Energy Secretariat
- CAMMESA
- Environment Secretariat
- IMPSA
- INVAP
- NRG
- IADB
- Banco del Sur
- CAF
- GEF

Problem: limited extent of EE T&D infrastructure prevents the electrification of isolated communities

Objective: expand the access to the interconnected EE grid

Strategic outlines

- Collect geo referenced information on rural communities, access to energy infrastructure, national EE grid.
- Perform feasibility studies for interconnection of selected communities
- Assess T&D infrastructure status and upgrading requirements

Instruments / Actions

- Identify most feasible communities for interconnection.
- Elaborate long term plan for expansion/upgrade of T&D infrastructure in order to reach isolated inhabitants. Assign priority level.
- Assign funds and human resources

Stakeholders

- Planning Ministry
- Energy Secretariat
- CAMMESA
- National and provincial statistics departments
- T&D enterprises
- ENRE and provincial regulatory bodies

Problem: requires renewable energy resources available close to the transmission grid. Resource quality requirement is higher than for small scale projects.

Objective: Integrate renewable energy capacity into interconnected grid

Strategic outlines

- Assess renewable energy potentials and feasibility of interconnection for selected resources
- Assess impact on service quality and T&D infrastructure upgrading requirements
- Elaborate T&D expansion plans taking into account RE resources and settlements

Instruments / Actions

- Complete measurement infrastructure and activities
- Perform at least one year local measurement at high potential sites
- Carry out simulations to evaluate potential for RE integration into the national grid and identify key upgrading requirements and bottlenecks
- Identify weak grid / high RE potential sites
- Assess impact on reserve margin requirement and energy cost
- Assess RE generations costs and provide adequate incentives for projects

Stakeholders

- Energy Secretariat
- Planning Ministry
- CAMMESA
- T&D enterprises
- Power generators
- Universities and other academic institutions
- ENRE and provincial regulatory bodies
- RE associations
- RE manufacturers and distributors

Table 3.4 Strategic Outlines more or less independent of pumping technology

Problem: Low payment capacity. Subsistence economies

Objective: Increase income in a sustainable way

Strategic outlines

- Include target population into the development policy
- Develop progressive strategy for enhancing productive capacity
- Support the development of productive activities compatible with natural resources available
- Support the reconversion of productive activities non-compatible with natural resources available
- Support relocalization of productive activities incompatible with resources available
- Improve conditions for market access and price setting

Instruments / Actions

- Develop and disseminate productive opportunities adapted to dry conditions and that have higher market value than traditional ones and use water less intensively
- Promote the elaboration of higher added value products
- Provide capacity development (technical, management, financial issues)
- Provide tax exemptions and incentives
- Support product diversification and storage for decreasing vulnerability
- Promote producers associations and cooperatives

Stakeholders

- Producers
- Producers´ associations
- Social Development Ministry
- Production Ministry
- INTA
- INTI
- PSA
- PROSAP
- Planners

Problem: Low Community organization level / resources. User conflicts

Objective: Ensure long term operation of pumping system

Strategic outlines

- Strengthen community organization level
- Increase system reliability (adequate design, use, maintenance and technology)
- Coordinate actions

Instruments / Actions

- Ensure local commitment to the project and involve community in project design
- Develop local resources to tackle minimum maintenance requirements, perform preliminary diagnosis and operate/use adequately
- Improve post sale and technical support services (geographical coverage, extended guarantee).
- Improve system failure diagnosis (component, expected lifetime range), and use it to anticipate spare parts requirements.
- Develop a regional spare parts storage facility
- Develop standards and certification schemes for technologies and services
- Contemplate long term technical support alternatives from the project design stage
- Implement adequate communication mechanisms to report failures and request support/spare parts
- Use participatory approaches for project development

Stakeholders

- Local population
- Local government representatives
- INTA
- INTI
- PSA
- Technology providers and manufacturers
- Universities and other academic institutions
- Service providers

Problem: Unsustainable water use / Increased water requirements

Objective: Make a rational and efficient use of water resources available

Strategic outlines

- Support the implementation of efficient water distribution and use technologies
- Perform research on trend in evapotranspiration levels and effects on productive plant varieties
- Support productive activities compatible with trend in water resources
- Help relocalization/reconversion of productive activities with intensive water use levels

Instruments / Actions

- Review/update regulatory framework to include rational water use issues
- Implement incentives for the adoption of rational water use practices and efficient technologies
- Develop/disseminate alternative plant/animal varieties adapted for dry conditions and high market value products
- Promote water reuse
- Promote land use planning
- Determine carrying capacity of soil resources
- Penalize inefficient water use
- Set priority water uses

Stakeholders

- Universities and other academic institutions
- INTA

- Planners
- Policy makers
- Water institutes
- Rural producers
- SSRH

Problem: Salinization/pollution of water well

Objective: Ensure adequate quality in water supply

Strategic outlines

- Support capacity development on water resource management and irrigation methods
- Improve knowledge on water resources quality.
- Prevent pollution of soil / borehole
- Prevent undesired flows between aquifers
- Implement water purification systems

Instruments / Actions

- Support research and monitoring of underground water resources
- Disseminate and enforce good practice methodology for borehole perforation, conditioning, materials and closure
- Improve knowledge on exploitation potential for each location
- Enforce regulations on effluent treatment and solid waste disposal
- Develop contingency plans for preventing/managing pollution events
- Disseminate/develop the use of pilot scale purification systems for the control of arsenic, fluorine and other endemic pollutants
- Provide clean-up and assessment funds
- Support land use planning

Stakeholders

- National / provincial Water Institutes
- INTA
- INTI
- Universities and other academic institutions
- Local governments
- SSRH
- SAyDS
- INA

Problem: Requirements for investment in associated infrastructure (e.g. efficient water use and storage)

Objective: Increase income. Improve access to efficient technologies

Strategic outlines

- Support the development of productive activities compatible with natural resources available
- Provide adequate financing and funding for infrastructure (long term)
- Support capacity development in water management and use methods

Instruments / Actions

- Develop and disseminate productive opportunities adapted to dry conditions and that have higher market value than traditional ones and use water less intensively
- Promote the elaboration of higher added value products
- Provide capacity development (technical, management, financial issues)
- Provide tax exemptions and incentives
- Support product diversification and storage for decreasing vulnerability
- Promote producers associations and cooperatives
- Provide funds for water infrastructure upgrade

Stakeholders

- Planners
- National/provincial government
- Planning Ministry
- Agriculture and Production Ministries
- Producers
- PAN
- RIOD
- SSRH
- PSA
- PROSAP

Problem: Limited knowledge on community characteristics, resources and water requirements

Objective: Improve coverage of water requirements

Strategic outlines

- Improve public information available on energy/water issues (supply and use)
- Develop geographical database on population, water and energy resources (GIS)
- Perform feasibility assessments for the implementation of RE water supply systems in selected communities.
- Improve measurement network coverage for meteorological and renewable energy resources at local level. Integrate into existing network.
- Perform assessment of underground water resources at local level.
- Coordinate resources

Instruments / Actions

- Review and incorporate questions related to water/energy supply and use in all national population and agriculture censuses
- Perform specific surveys in rural communities, particularly isolated ones. Assess water and energy consumption, requirements, supply, and efficiencies by use
- Collect available information from different sources (both public and private) and integrate into database.

- Perform census of measurement stations and their status.
- Elaborate and implement a modernization plan in order to upgrade/repair/expand water/energy resource measurement network
- Implement a network for hydro-meteorological and environmental monitoring to allow the emission of early alerts and inform about the persistence of adverse or beneficial conditions
- Install rain/snow meters
- Provide public access to available information
- Implement methodology to ensure geographical data compatibility at national level
- Collect and associate geographical data to surveys, censuses and monitoring activities
- Integrate information through public statistics institutes
- Provide funds and perform hydrogeological studies on underground water resources
- Improve Nation/Provinces coordination and strengthen basin authorities
- Determine carrying capacity of soil resources

Stakeholders

- National and provincial statistics institutes
- Energy secretariat
- National and provincial water institutes
- SMN
- SSRHN
- COHIFE
- PHI
- INTA

Problem: Restricted access to underground water resources / water level depression

Objective: Improve access to underground water resources

Strategic outlines

- Improve knowledge on dynamics of underground water resources
- Facilitate technology for tapping underground water resources
- Support capacity development on water resource management
- Help develop water storage infrastructure
- Prevent resource salinization

Instruments / Actions

- R&D&D on low cost methods for underground water resource assessment
- Develop and facilitate accessible/lighter and cheaper technology for deep well perforation
- Support research and monitoring of underground water resources. Improve knowledge on exploitation potential and effects of climate variability on water table level
- Provide adequate funds and human resources

Stakeholders

- National and provincial water institutes
- SMN
- Universities and other academic institutions
- INTI

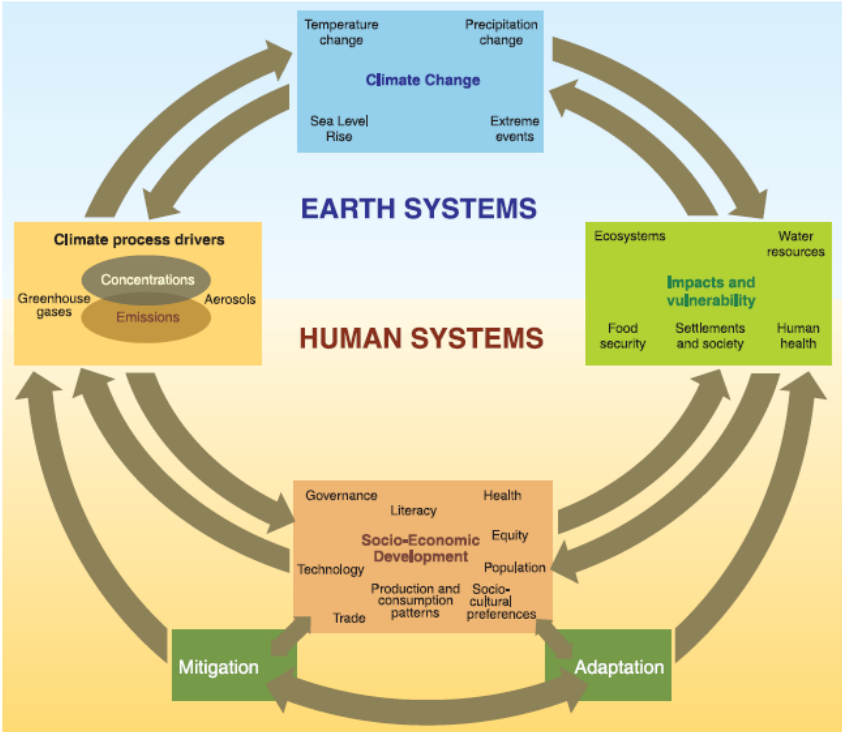
Problem: Restricted availability of water resources. Increased erosion
Objective: Use available water resources in a sustainable way
Strategic outlines • Improve knowledge on water resources • Promote efficient water use • Promote productive activities compatible with available water resources • Support relocalization of productive activities • Improve collection and storage of available water resources
Instruments / Actions • Recover information sources and measurement network • Modify/upgrade regulatory framework • Provide incentives and capacity development for the dissemination of rational water use practices and efficient technologies • Develop and disseminate plant and animal varieties less intensive in water use than tradition ones and with high market value products • Promote water reuse • Promote land use planning
Stakeholders • National and provincial water institutes • National meteorological institute • SSRH • SMN • INTA • PAN • SAyDS

Source: own elaboration

3.2 Synergy between adaptation and mitigation

The potential complementarities between mitigation and adaptation actions are analyzed here. The potential impact of a joint strategy relative to an adaptation only strategy is also assessed

Figure 3.1 Schematic framework representing anthropogenic drivers, impacts and responses to climate change, and their linkages.



Source: (IPCC, 2007)

Figure 3.1 shows a schematic framework representing anthropogenic drivers, impacts and responses to climate change as well as their linkages. Some time ago (for instance at the time of the Third Assessment Report in 2001)[47] the information was mainly available to describe the linkages clockwise, to derive climatic changes and impacts from socio-economic information and emissions.[48] Now, it is possible to assess the linkages also counterclockwise, due to increased understanding of them. So, it is possible to evaluate potential development path-ways and global emissions constraints that would reduce the risk of future impacts that society may wish to avoid (IPCC, 2007).

As it could be observed in Figure 3.1 there are many ways in which different factors interact in the decision making process.

[47] (IPCC, 2001). Third Assessment Report. Summary for Policy Makers.

[48] How changes in temperature, precipitations, sea level and extreme events regarding to climate change affects ecosystems, food security, settlements and society, human health or water resource (Impacts and Vulnerability) and how Impacts and Vulnerability influences Socio-Economic Development and hence how the Socio-Economic Development determines Climate Process Drivers (mainly Emissions and Concentrations of GHG and Aerosols).

Although climate change is a global-scope phenomenon, the geographical distribution of the potential effects it is not enough foreseeable to plan previously the appropriate policies and measures to overcome them, not only for physical reasons but also because the repercussions will be distributed in a very heterogeneous way socially and geographically (as not all the inhabitants of the Earth are equally prepared to face the potential future changes).

The presence of such uncertainties and heterogeneity among the different actors involved will influence the decision making process. Decisions should be taken in spite of the scarce level of knowledge on the future consequences to be faced. However, the magnitude of the potential effects justifies certain type of intervention to avoid them through the mitigation of their potential effects. Faced to situations in which uncertainties related to future functioning of a system prevail, the application of preventive policies on the basis of the precautionary principle is recommended (Girardin, 2008b).

As resources that will be dedicated to certain policies and measures will not be available for allocating them for alternative uses, the decision between allocating resources for adaptation or mitigation to climate change is one of the most relevant for Developing Countries, from the economic point of view. Every concrete policy or measure that would be adopted will mean certain type of sacrifice in terms of resources allocated to one option instead of another one. Resources destined to be applied in certain measures (mitigation) will not be available to be applied in others (adaptation). For this reason, it is suggested the implementation of the so-called “no-regret measures”. This type of measures, in this context, means that they could cover not only adaptation objectives but also mitigation ones (Girardin, 2007).

Attempts to adapt and mitigate climate impacts share common objectives with efforts to promote sustainable development, such as: access to knowledge and resources, equity in the distribution of resources and citizen participation mechanisms, risk distribution and decision making skills to tackle situations of uncertainty (Agrifor Consult, 2009).

Both adaptation and mitigation can help to reduce climate change risks. However their effects vary with time and space. Mitigation offers benefits which will generally be possible to see in the longer-term, because of the delay times in the climate and biophysical systems. The benefits of adaptation, however, have an effect closer in time (in some cases immediately), especially when they target the vulnerability to current climate conditions and variability. Because of these differences between adaptation and mitigation climate policies should not stick to a choice between adapting to climate change or mitigate it. To address key vulnerabilities to climate change is necessary to adapt because even the most stringent mitigation efforts cannot prevent the advance of climate change in the coming decades.

Creating synergies between adaptation and mitigation can increase cost-effectiveness of actions and make them more attractive for financing, mainly considering that the majority of international funds that are available are focused to develop mainly mitigation efforts more than adaptation ones.

The relationship between climate change and energy constitutes a very big issue in the identification of synergies between adaptation and mitigation, not only related to the mitigation side (the opportunities coming from energy sector for abating GHG emissions) but also in regards to the adaptation side (in two ways: (a) reducing the vulnerability of the own

energy sector to changing conditions of the climate, and (b) contributing to prepare society in a better way to cope with climate change in other sectors), and promoting, at the same time, sustainable development path-ways.

The two main opportunities for synergies between adaptation and mitigation in energy sector are related to energy efficiency and renewable energies. Climate change policy-oriented actions in these sectors are often economically beneficial, improve security of supply and reduce emissions of local pollutants.

Nevertheless, in this particular case, rural population covered in this study presents important unmet energy requirements, some of them corresponding to water pumping. Thus, a successful development strategy implies an increase in energy and power demand, and thus of emissions. However, given the low fraction of rural poor population in dry areas compared to total population (<10%), the absolute power and energy requirements are very low compared to national consumption levels. An adaptation strategy will probably increase energy demand with very little impact on national GHG emissions, even when the requirements were met using fossil fuels. Likewise, a strategy based on the dissemination of dispersed RE systems would have a negligible impact on GHG emissions savings at national level.

On the other hand, the energization of rural areas based on the extension of the T&D grid and on the interconnection of RE power would have a significant positive effect on GHG emissions in relation to a fossil fuel scenario, mainly thanks to the demand of urban areas and the productive sector. As an example, Arauco wind farm (25MW) saves around 7,000tons of CO2/year and provides energy both for olive irrigation and urban areas.

3.3 Financing options

Assessing the feasibility of implementation of the defined strategic outlines requires, among other issues, finding mechanisms that could finance putting them into practice. This is valid for both the strategic outlines as well as for the associated instruments and actions that are described in the previous section.

A first conceptual consideration related to the business profile of renewable energy projects, specifically for improving the management and use of water resources should be expressed. A far more solid economic profile, would be obtained if positive externalities of developing renewable energy and securing drinking water availability for basic productive uses (mainly agriculture and livestock raising, and household consumption) are accounted for. As long as the evaluation of possible alternatives is discussed under pure financial terms – meaning market prices – the attractiveness of projects and objectives will hardly overpass a cost-benefit analysis, for example considering 15% discount rate. This discussion could be framed within the “public benefits” concept. Furthermore, from a State policy point of view it is possible to give increased weight for projects outcomes including – besides renewables deployment and drinking water provision – employment generation, rural productive activity empowerment, basic needs fulfillment, among others.

In the same direction the analysis must admit the scientific uncertainty and the difficulties for identifying the cause effect relationship for quantifying adaptation resources. Similarly, the total costs estimation, the impacts on non market values like ecosystem services' provision, the distribution of costs among private and public agents, triggers many challenges to private oriented costs-benefit analysis and risks determination. These become issues of core relevance when financial institutions' assistance is required. In the adaptation context, it is easier to identify current costs than future and diffuse possible benefits, as well as current cost externalization to other sector and future generations. Early adaptation should be the precautionary approach to be adopted in order to better allocate the costs along time (Samaniego, 2009).

This section discusses the opportunities for obtaining local and international financing for implementing an adaptation strategy that includes renewable energy technologies. Several mechanisms could be explored: from CDM and other carbon market tools, World Bank, Corporación Andina de Fomento, Interamerican Development Bank, GEF, to bilateral and multilateral agreements and the remarkable leading role of Development National banks, as the Brazilian BNDES. Argentina does not have a strong funding entity equivalent to the BNDES, although some institutions like the BICE[49], described below, can perform this key function, if endowed with enough resources. This would constitute an ideal funding source for water resources infrastructure, as core issue in national development.

In turn, international cooperation funding is channeled or driven by several Public institutions in the Water, Agriculture or Energy areas. Some relevant available alternatives are presented below. Remarkably, a large share of the administrated funds comes from international cooperation.

Similarly, some funds are available along the six programs of ENHOSA, national water works entity. The resources come mainly from international cooperative funding, and are aimed at the improvement and guaranteeing of current drinking water and sanitary services in all the country, including urban and rural settlements[50].

The PROSAP (Provincial agricultural services program, Agriculture and Livestock Ministry) in turn, constitutes a very interesting source of funding. It is the main public investment tool of this important Ministry and hence of the Argentine Agriculture policy. Analyzing the 148 projects already funded by PROSAP in the three stages (executed, under execution and under formulation) 61 of them are related with water resources administration and management; including irrigation and channels works, drainage piping, smaller irrigation works, pressurized irrigation pipelines, etc. All the provinces under analysis are included in the beneficiaries. Further 33 projects are related with basic infrastructure, meaning rural electrification and roads construction. Analyzing the period 2007 – 2008, 467 million USD from BIRF and BID were allocated, giving an approximate funding capacity of 40 million USD by year, without considering the local component or contribution.

The PSA (Social agricultural and livestock program) is another financial scheme managed by the Agriculture and Livestock Ministry, and offers financial and technical assistance to small

[49] It is posible to mention another three institutions: the Provincia de Buenos Aires Bank (Bapro); Banco de la Nación Argentina and Fondo de Capital Social - Foncap S.A.
[50] http://www.enohsa.gov.ar/

producers, and promotes producers associations. However, funds and program outreach are limited (León, 2005), and are mainly assigned to the improvement of management capacities. The definition of the beneficiaries of this program is interesting and could constitute a good platform for providing assistance on water resources needs.

Renewable electricity funding for the rural area is channeled mainly by the PERMER project – described above in the institutional issues of the diagnostic – and the FEDEI (national fund for the development of Electricity in the provinces) allocated by the CFEE Federal Council of Electric Energy. Both schemes – that are also linked – provide long term credits at low rates and are administrated by the provinces[51]. The CFEE allocated credits for almost 5 million USD in year 2009.

The PERMER Project is funded by the World Bank (US$ 30 million loan), the Global Environmental Facility (GEF, US$ 10 million Grant), and the Provincial Governments, (around US$ 40 million equivalent local contribution). Regarding the last component, resources come mainly from the FEDEI (specific preexisting federal fund aimed at developing the argentine electricity sector excluding the Buenos Aires metropolitan area) and Education Ministry funding for rural schools electrification. Additionally the concessionaire - of the rural electricity service provision - recovers investment through the monthly payments for the service - around $ 10 per month – indicated as a substantial reduction if compared to the $ 20 of current rural homes expenditure for satisfying lighting and social communication needs[52].

Large renewable energy projects also face financial limitations, mainly in the initial capital investment. Multinationals might solve this barrier employing their own funds, but local groups, specifically encouraged by current GENREN program, suffer from the difficulties in access to funding in the local financial market. This novel Renewables' program was developed for the diversification of the electricity generation matrix and is based in long term guarantied power purchase contracts, totaling 1000 MW within its first and successful call for tenders. It includes a preference price for the electricity generated and introduced in the national system[53]. The scheme administration is performed by the State Company ENARSA.

Within the GENREN program a specific credit line was launched in 2010 by the BICE (Investment and Foreign Trade Bank) in order to provide financial help to the potential investors in renewable sources of energy. In close coordination with ENARSA and the Federal Planning Ministry, with support of the CAF and other international development banks, a total amount of 100 million USD is available, with 10 years of payment deadline[54].

The table below summarizes these alternatives, providing a brief view of possible funding resources.

[51] http://www.cfee.gov.ar/pres_sintesis.php?screen_check=done&Width=1024
[52] http://energia.mecon.gov.ar/permer/financiamiento.html
[53] http://energia3.mecon.gov.ar/contenidos/verpagina.php?idpagina=3065
[54] A 19 million credit for two photovoltaic projects developing in the San Juan province and further 20 million for financing three hydro projects in Catamarca and Jujuy, were approved in 2010. http://www.bice.com.ar/SP/novedades/gacetilla_det.asp?id=42

Table 3.5 Sources of funds

National Funds

Water

- ENHOSA Federal Planning, Public Investment and Services Ministry, the three more relevant funding schemes are:
    - Water + Work Program (Agua más Trabajo,). Subsidies for expansion of drinking water infrastructure, in urban areas through cooperative work.
    - Water works program in areas under sanitary risk (Programa de obras de Saneamiento en Áreas con Riesgo Sanitario, PROARSA,) Expansion and improvement of drinking water services. Includes storage tanks and pumps.
    - Loans for small water works (PROMES, ENHOSA). Includes building and enlarging drinking water facilities and also the elaboration of studies towards this end.

Energy

- PERMER (Rural electrification program. Basic electricity services, mainly based on RE. Subsidy for investment, partial charge to users, concessionaire involvement)
- CFEE Federal Council of Electric Energy. Soft long term loans mainly for transmission, but also for rural electrification
- GENREN (Program for RE interconnection to national grid in large scale, preferential energy prices, long term guaranteed purchase)
- BICE - ENARSA (Investment and Foreign Trade Bank) credit line for the GENREN renewable electricity generation promotion program.

Productive activities

- PROSAP (Provincial agricultural services program, Agriculture Ministry)
- Agricultural and Livestock Social program (PSA, Agriculture Ministry). Financing of management capacities for small productive projects.

Environment

- PAN (desertification action plan) (Environment and Sustainable Development Ministry)

Multilateral Funds

- IADB, CAF, Banco del Sur
- CDM funds

Source: adapted from (SSRH, 2007)

Regarding environmental funds available for fight against desertification and climate change, currently Argentina has just 11 renewable energy project registered at the UNFFFC for the CDM (of a total 24 registered). In particular, the projects related to water in arid regions, seems to be very small to afford the transaction costs involved in the mechanism.

Nevertheless, the possibilities of bundling several smaller projects might help in overcoming this barrier of scale. On the other hand bigger projects like Arauco wind farm can improve their financial merits using the CDM, considering it could save around 7,000tons of CO2/year.

In summary, provincial funds are available for water infrastructure. As mentioned above, in some cases funds are not evenly distributed among rural inhabitants. Those with large productive units and those located close to ground water resources tend to have a better access to adequate infrastructure and resources (large producers, as in Mendoza Tunuyán valley and La Rioja main agricultural valleys). On the other extreme, those with small productive units located far from irrigated valleys where water infrastructure investment is concentrated, depend on the access to underground water resources, which is expensive. Specific funds are needed to tackle the water requirements of this population and provide access to underground water resources in adequate quantity.

Regarding renewable energy developments at small scale in connection with water resources, funding is scarce and mainly managed by the provinces.

4. Application of the adaptation strategy to concrete situations

4.1 Feasibility of implementation

As stated in the methodology, this applies to both strategic outlines and to instruments and actions as well, all aimed at the use of renewable energies. This requires the assessment of the potential reaction of stakeholders and the conflicts between them.

Actions listed in section 3.1 cover a wide range of areas and affect diverse stakeholders´ interests in many ways. A strategy for the successful implementation of the policy outlines proposed cannot ignore this fact and should develop specific mechanisms aimed at providing political feasibility to the proposal, even when it negatively affects some interests in exchange of the improvement of life conditions of a significant number of rural inhabitants. Among the key components of this strategy are those presented in Table 4.1. Each of these stages also present particular challenges.

Table 4.1 Components that provide political feasibility to the proposed strategy

Feasibility Component • Create political will and the enabling framework to deal with the required changes **Challenges** • Achieve enough priority level in political agenda, displacing other issues and negatively affecting some interests **Strategy** • Initiate/organize public discussion events • Create lobby and communicate population requests to competent institutions. • Request information to policy makers and planners through associations, NGOs, technical bodies, etc. • Perform and present technical assessment involving diagnosis and concrete proposals.
Feasibility Component • Secure the required funds and resources for implementation **Challenges** • Compete with other fund requirements, usually in the framework of scarce funds **Strategy** • Estimate funds required • Perform research on potential sources of funds • Present technical proposal for securing funds • Include in the assessment non-monetary values and public benefits

• Develop and bundle a set of projects in order to have a larger scale of beneficiaries and increase the attractiveness for finding funds.
Feasibility Component • Guarantee the coordination and commitment of participating institutions in the design, implementation and long term follow-up stages of a national strategy with regional components **Challenges** • Assign scarce human resources, sometimes in detriment of other tasks **Strategy** • Support capacity development • Support the incorporation of human resources • Clearly identify tasks, responsible persons, and schedule of activities • Request periodic information on status and achievements through associations, NGOs, technical bodies, etc. • Create inter-institutional links and discussion areas • Create and implement information sharing mechanisms

Source: own elaboration

As mentioned above, one of the main issues affecting the feasibility of implementation of the proposed strategic outlines is the diversity of institutions with competence in water issues, the provincial character of water resources management, and the lack of coordination of an integrated national policy on the issue, with particular emphasis on underground water resources exploitation. Thus, a clarification is needed in relation to the responsibilities of each entity, and in some cases a change in regulatory framework may be required to ensure water supply for productive activities to rural inhabitants. The leading role of the National State through national public institutions is very important for the achievement of this integration and coordination.

The modification of regulatory and institutional frameworks may constitute issues where a significant opposition could be expected from the involved institutions and enterprises, both private and public. These modifications may affect important interests and could modify the relative power, responsibilities, and the way in which funds and resources are allocated among the different actors. Since most of these changes have to be approved by the provincial legislative chambers, building public support to the initiative is highly relevant. Changes are usually designed by regulatory authorities and technical departments. At this point, the participation in building and reviewing the technical proposal by independent stakeholders and technical departments is a key aspect. Two examples of this participation are provided by the Mendoza Province institutional framework (Mendoza General Irrigation Department and Water Channel Inspectors Associations) and the AIC Inter-jurisdictional Basin Authority of the Limay, Neuquén and Río Negro rivers.

Even when adequate regulatory and institutional frameworks are in place, the lack of adequate funds and human resources may lead in practice to the lack of implementation of policies.

Thus, technical proposals should be accompanied by instruments aimed at securing the funds and human resources required for policy implementation and control. Funds may provide from existing or new sources. Concerning the use of existing sources, opposition may be expected from current users of those funds.

Finally, since several institutions are usually involved in policy implementation, capacity development, coordination and commitment are key elements that must be developed within each institution. A coordinated strategy should include a clear identification of tasks, responsibilities, and a schedule of activities. Furthermore, the creation of links between institutions is needed and requires fluid information exchange, stable conditions and specific discussion areas. Opposition may be expected from individuals within institutions that have a record of dispute over resources and responsibilities, or that have conflicting visions and interests. Institutions that have their human resources already committed to other tasks should incorporate human resources to cope with the additional activities in adequate way.

4.2 Extrapolation of strategies

The possibility of extrapolating the main findings to other regions of Latin America is assessed here, jointly with the potential limitations of this approach. Niches are identified where renewable energy technologies could play an important role within an adaptation strategy.

LA&C regions with similar climatic variability problems to those studied in previous sections can be identified through the analysis of ENSO geographical coverage and effects. ENSO phenomenon also produces[55]:

- Dry conditions during El Niño years in the north of Brazil (December to February)
- Dry conditions during La Niña years in north of Chile and in Perú (June to August)
- Dry and warm conditions during El Niño years in the north of South America and the Eastern part of Central America.(June to August)
- Dry and cool conditions during La Niña years in the coast of Ecuador and Colombia (December to February)

The first two cases correspond to dry regions that share some similarities with the regions under research in the present document (See Figure 4.1 and Figure 4.2). In particular, northeast Brazil is one of the regions that is highly vulnerable to climatic variability (subjected to both Climate Change and ENSO phenomena).

Other dry regions of LA&C will probably be affected by climate change with increased drought events and desertification processes, and also share some similarities with the case studies presented in this document:

- Bolivia´s Altiplano/North of Chile and Argentina (Puna)
- Chaco (Paraguay)
- Northern México

[55] http://www.ncdc.noaa.gov

There exist important differences among these regions, for example, there are coastal areas in northeast Brazil dry region where sea level rise could produce the introduction of saline wedges in the underground aquifers located near the coast. This phenomenon does not exist in the cases under study for Argentina and could significantly affect the role that renewable energies could play, indicating that solar desalinization will also have a key role to play (reverse osmosis). This phenomenon could also manifest in many island states of the Caribbean, worsening the already present salinization problems due to resource overexploitation.

Northeast Brazil is a dry region with precipitation levels between 500mm and 900mm per year, and potential evaporation exceeding 2000mm/year. The ENSO phenomenon has already created severe drought events in this area (Wilby, 2008). Brazil´s northeast is one of the most densely populated dry areas of the world. It concentrates around 28% of the total population of Brazil and presents high poverty and social vulnerability levels. According to climate models, agricultural yield impact of climate change for Brazil is one of the highest for all regions, with production reductions between 17% and 53% (Watson, 1997). In particular, northeast Brazil agriculture will be severely affected, triggering a migration effect towards other parts of the country (Barbieri, 2010). As in Argentina dry regions, investment in water projects seems to exclude small agricultural producers and favor large water consumers (e.g. urban areas). Underground water resources are beginning to be used in large scale, though salinization is a problem and its exploitation expensive. Like in Argentina, knowledge on underground water resources is still limited (Clevelario, 2005). Rational and efficient water distribution and use still needs to be strengthened, as in Argentina. Another important difference is that in Brazil management of water resources seems to be better integrated under Federal Agencies and plans (Costa, 2006). Finally, other main difference between northeast Brazil and Argentina case studies refers to hydrologic cycle. In Argentina snowfalls play a large role concerning the recharge of aquifers and also act as a buffer, distributing water supply more evenly along the year.

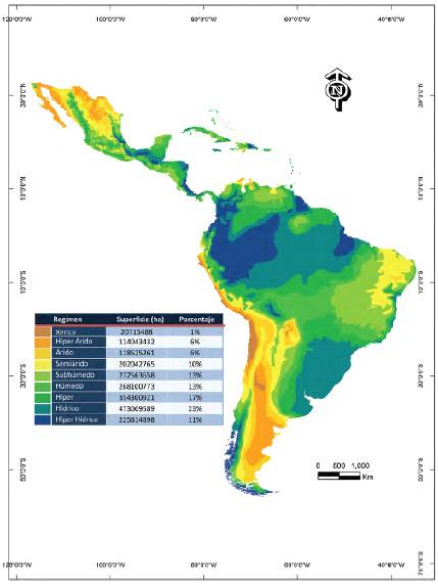
Table 4.2 Comparison of Argentine case studies, Brazil´s Inner Northeast and Perú´s Highlands

Similarities	**Differences**
Primary rural productive activities (agriculture, cattle raising) Subsistence economies High social vulnerability and risk of migration Dry conditions and negative climatic trends associated to ENSO Water scarcity Lack of information on water requirements and resources Limited knowledge and exploitation of underground resources High desertification risk Salinization risk Limited rational and efficient water use Uneven assignment of investment and limited funds Experience in the use of RE pumping technologies High cost of underground water supply	Population density Evapotranspiration rate Temperature Altitude Soil quality Vegetal and animal productive species Cultural and social traits Precipitation levels Regulatory framework Institutional framework and coordination Hydrological cycle Dynamics of underground water resources Water level depth (site specific)

Source: own elaboration

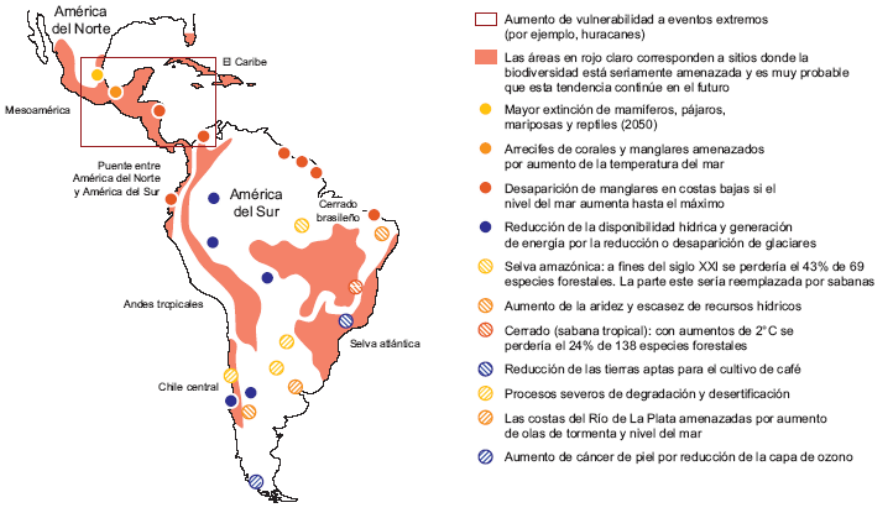
The situation in Perú´s highlands is somewhat different from that of Argentina and Brazil. The highlands have seasonal rainfall patters but are affected by severe droughts, particularly in the south. More than 70% of agriculture in the highlands does not rely on irrigation and corresponds to traditional agriculture practices, making it more vulnerable to climate variability. Highlands are widely affected by erosion processes and by ENSO phenomenon, resulting in the loss of cultivated land. The hydrological cycle in this region also involves snowfall in the High Andes and will probably be affected by glacier retreat. Rural poverty and indigence levels are higher in Perú than in Argentina. 90% of rural poor people live in the arid highlands, practice subsistence agriculture and is highly vulnerable to climatic variability (World Bank, 2009). It is this population which presents more similarities with that covered by Argentina case studies. However, they have a long history of adapting to climatic variability. Two strategic outlines proposed to cope with droughts associated to ENSO phenomenon in the Highlands of Perú are the improvement of irrigation infrastructure and the exploitation of underground water resources. Towards this aim many boreholes were recovered for water supply, and 10,000 manual pumps were installed in communities of Altiplano, Tacna and Moquehua. This indicates the existence of relatively shallow underground water resources, a marked difference with some dry regions of Argentina. In this context, renewable energies are a feasible alternative for improving water supply. Due to its historic and present vulnerability to climatic variability, Perú seems to have a more developed strategy to cope with the changes ahead and is already implementing actions towards this aim (CAF, 2000). Some of these actions rely on the replication of traditional practices, such as the Waru Waru technique for irrigation and drainage (Agrifor Consult, 2009). A similar example, called “qotañas”, exists in Bolivia´s Altiplano.

Figure 4.1 Arid zones map of Latin America and the Caribbean



Source: (Verbist, 2010)

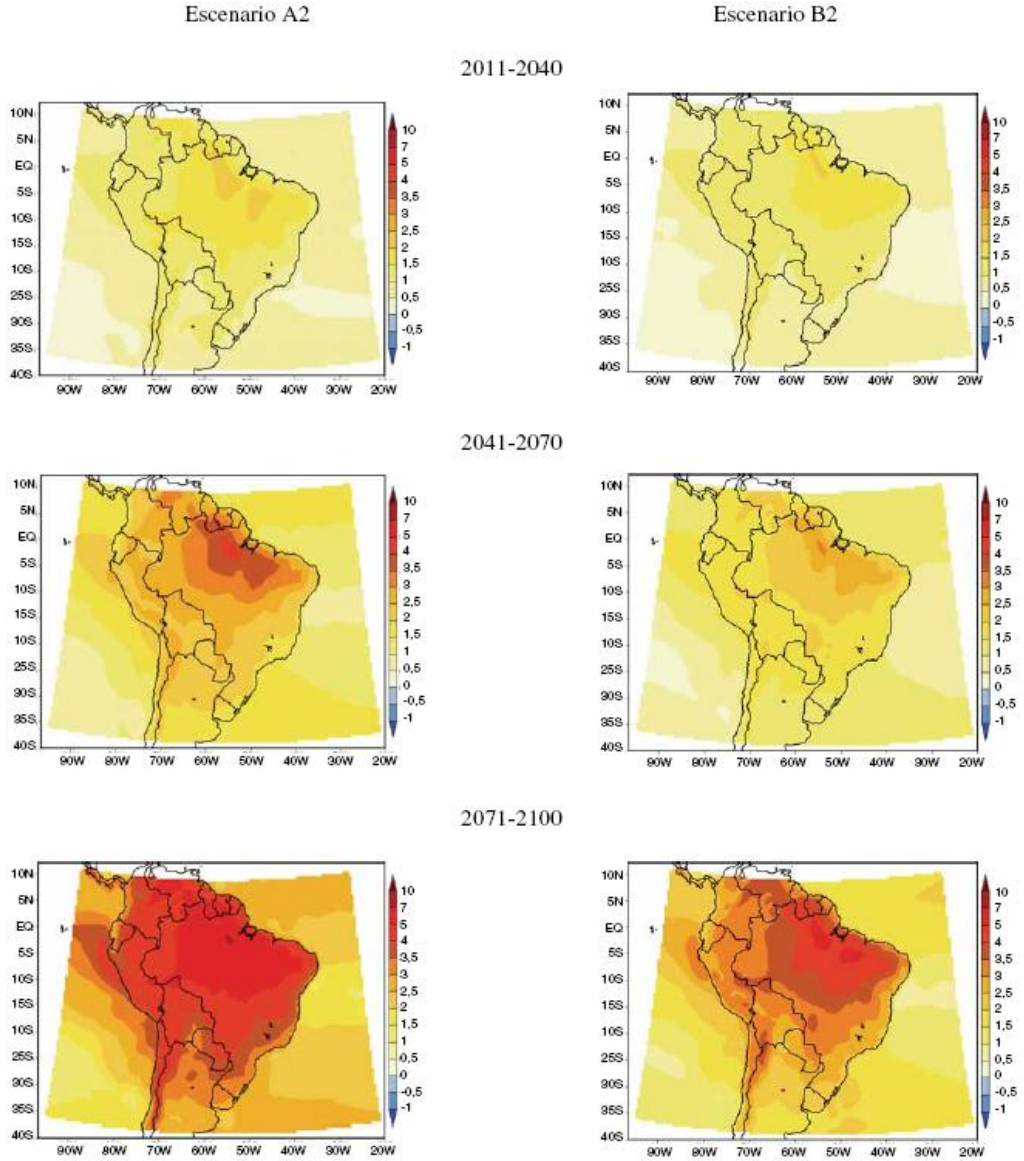
Figure 4.2 Vulnerability to climate change in Latin America and the Caribbean



Source: (CEPAL, 2010)

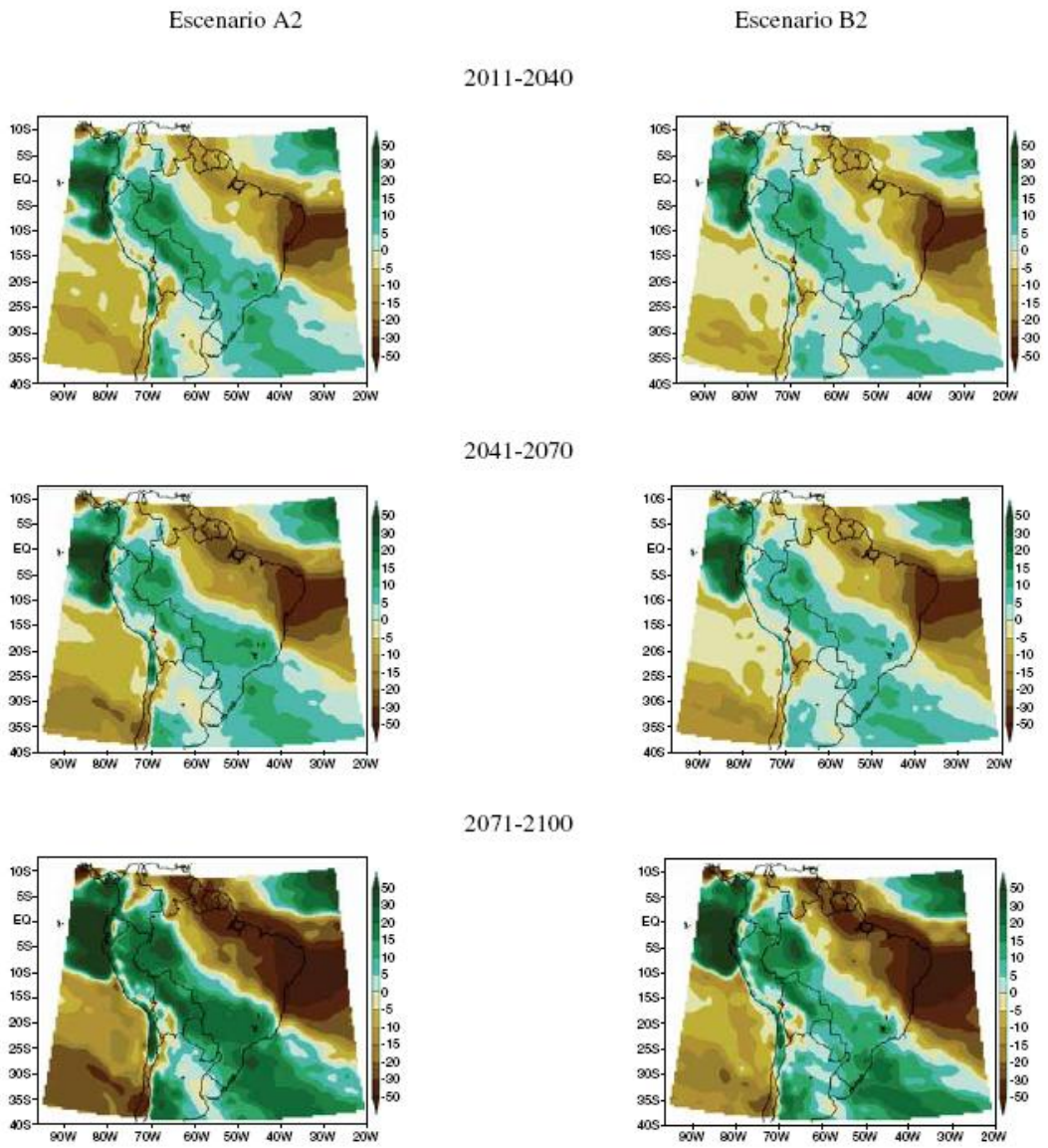
Concerning the extrapolation of the strategic outlines and instruments described in section 3.1, those associated to the issues/barriers classified as “Similarities” in Table 4.2 could be broadly applied in the case of northeast inner Brazil and Perú´s highlands. However, caution has to prevail when trying to apply more detailed components of the strategy to other countries (e.g. instruments and actions) since framework conditions may be substantially different (e.g. social and cultural traits, regulatory framework). Renewable energies could play a relevant role in all the regions identified above, in particular in those where relatively shallow underground water resources are available (e.g. some areas of Perú´s highlands), or where large renewable energy resources could be used to support electricity grids (e.g. Northeast Brazil).

Figure 4.3 Temperature projections (ºC)



Source: (CEPAL, 2010)

Figure 4.4 Precipitation projections (%)



Source: (CEPAL, 2010)

5. Issues where support to research and investment is needed

This section summarizes the main areas of research that link renewable energies and water issues in the framework of an increasing water stress due to climatic variability. Main issues are identified and classified based on their relative importance (only medium and high priority issues are listed). Some of the criteria that have been used to assign priority levels for research and investment are[56]: population benefited, uncertainty level, providing an answer to a growing problem, the impact on key productive activities, the development of capacities.

Table 5.1 Summary of research and investment needs

Research Subject	Priority Level
1. Assessment of hydrological balance of semi-arid regions. Assessment of evapotranspiration adapted to local conditions and taking into account wind effect (ETP models were developed for bio geophysical areas which are quite different from those under study in the present project).	High
2. Improve underground water resources knowledge (availability, quality, deficiencies, yields, recharge processes, etc.) Integrate dispersed and fragmented geological, geophysical and hydrological information.[57]	High
3. Improve the degree of snow precipitation predictions over the high Andes	High
4. Prediction of the regional impact of ENSO on temperature and precipitation.	High
5. Improve knowledge on water requirements and use practices. Role of social and cultural factors in the evaluation and "buy-in" of an energy technology for water services.	High
6. Water Resources administration, how to secure access for all and allocation among competitive uses of water? Role for long term State intervention and support within the adaptation strategy by strengthening of productive activities at the regional level.	High
7. Harmonization between the up to now disjoint water and energy policies. Research on ways to implement - in an efficient way - regulatory frameworks and rules. Particularly identification of existing or potential conflicts between water and energy ruling (policies and regulation).	High
8. Perform a survey of boreholes status in semi-desert region (water quality, dynamic head, sustainable yield)	High
9. Land use planning and water management schemes based on climatic scenarios. Productive structure adaptation[58].	High
10. Research on vegetable and animal varieties suitable for semi-arid regions. Productive reconversion. High value products	High

[56] This might require setting up similar or at least compatible criteria for the four studies under the Clean Energy and Water Assessment of Services for Local Adaptation to Climate Change

[57] Observed and projected groundwater and river water overdraft. The assessment of underground water's age and origins is considered highly desirable. There is particular interest (and some research already done) in regards to mining activities, some national universities – La Plata and Buenos Aires - and River Basin authorities will probably be interested.

[58] The emphasis here is at the community/regional level, but the Research Topic of identifying the water energy footprint of productive activity is also suitable. However, the approach to this footprint assessment should not imply the creation of commercial barriers to the developing world products in general. A possible strategy for avoiding this, consist in analyzing current situation and from there onwards research how to improve such a footprint. Some work is already been carried on by FLACSO/San Andrés University, both in Argentina.

11. Development of cost effective PV pumping options for high hydraulic loads and higher depths. Technology gap between 120 and 200m.	High
12. Development of cheaper and lighter drilling and underground water resources survey equipment for deep resources. [59]	High
13. Potential for the energization of productive and residential requirements with isolated RE systems (e.g. clothes and leather washing and tanning using wind energy, thermoelectric generators coupled with biomass stoves, low cost food refrigeration using solar energy)	High
14. Water and energy rational use and efficient technologies adapted for these regions. Cheaper large capacity water storage options. [60]	High
15. Survey of climatic and hydrologic measurement stations, and assessment of infrastructure and upgrading needs	Medium
16. Assessment of potential for the development of alternative productive activities (e.g. ecotourism, hydrotherapy, water commercialization with high fluorine levels).	Medium
17. Development of regional and sub-regional models that could allow a better estimation of climatic trends and hydrology at local level (current models run at global scale). An example of a regional model under development is the MCR-CIMA	Medium
18. Research on the links between ENSO and Climate change phenomenon	Medium
19. Aquiculture development using high salinity water resources. Species identification.	Medium
20. Development of GIS adapted for monitoring hydrological conditions	Medium

Source: own elaboration

[59] A concrete action with the participation of municipalities and producer's cooperatives is the assessment of an implementation strategy for improving water access. More specifically, both capacity building and equipment acquisition/purchase is required for excavating wells (or deepening existing ones) in order to find more water for those producers whose *aguadas* (natural rain water reservoir) are getting dry. Renewable energy for pumping will be required along this transition from *aguadas* to excavate wells. This action requires previous identification of the relevant stakeholders.

[60] Regarding basin level water management and National level energy policy, there is an interesting work done by the AIC, developing a forestation strategy for flood control. Such a strategy can be useful to some other regionally relevant river basins (Comallo Valley with a poor native community in its headwaters). http://www.aic.gov.ar/aic/publicaciones/CUENCA_NQN.pdf

6. Conclusions and recommendations

Summary of main findings and recommendations:

- RE are part of a set of technical options that could be used within a broad strategy designed to cope with a very complex development problem affecting rural poor inhabitants of LA&C, not only in dry areas. This problem situation involves regulatory, institutional, cultural, social, economic, and technical issues that require the coordination, and active and long term intervention of the State.
- Isolated RETs can have a role within a strategy to cope with increased climatic variability in dry regions of Argentina, particularly for not too deep water resources, residential and small scale productive requirements. However, there are some cost, technical and implementation limitations that may restrict their use in some situations and may require considering conventional solutions (e.g. large irrigation projects with highly seasonal water demand).
- RETs interconnected projects can provide adequate power and energy for large scale water supply for productive activities and for urban areas, among other requirements.
- Within a comprehensive strategy to tackle this underdevelopment problem situation some components arise as relevant:

    - Detailed information is needed on the hydrological cycle, and in particular on the dynamics of underground water resources in dry areas
    - The improvement in rural life quality conditions requires a comprehensive energization and infrastructure program for residential, productive and service sectors
    - R&D&D for the development of cheaper and more adequate options is needed in various areas (RE pumping in difficult conditions, deep borehole drilling in isolated areas, large storage tanks, products´ preservation, lower power appliances and tools, animal and vegetal species adapted to drier conditions).
    - Public funds and human resources should be assigned more evenly and in a coordinated way, with particular focus on rural poor population
    - Rational and efficient water use and distribution should be implemented at all levels
    - A reconversion of productive activities and products is needed in order to produce more income with less water, and generating less negative impacts on soil.
    - A particular strategy is needed to prevent further desertification and salinization processes.
    - Capacity development plays a key role at all levels and for diverse issues (RE technology dissemination, increased system lifetime and reliability, efficient water use, water borehole management).
    - Regulatory and institutional frameworks need adaptation to cope with this problem situation.

Considering that subsistence economies that characterize rural poor population constitutes one of the main barriers to their development and that productivity will be affected by drier conditions, a main objective of an adaptation strategy involves achieving an increase in

income through a redefinition of productive activities. In a first stage this can be done by adding value to existing animal and plant products, while in a second stage it could involve the production of higher market value products better adapted to drier growing conditions. In both cases a significant support is needed in terms of R&D, capacity development and market access.

Given the intrinsic complexity of water issues in Argentina, an in particular those affecting rural population, a strategy is needed to provide viability to the implementation of strategic outlines. This strategy is based on three main pillars:

- Create political will and an enabling framework to deal with the required changes
- Secure the required funds and resources for implementation
- Guarantee the coordination and commitment of participating institutions in the design, implementation and long term follow-up stages of a national strategy with regional components

The participation of society providing public support, building a technical proposal, and in the follow-up of this process is desirable.

In relation to the extrapolation of strategic outlines, some regions of LA&C present similarities in characteristics and problem situations with the case studies in Argentina: worsening of dry conditions due to climatic variability, subsistence rural economies, social vulnerability, salinization, inefficient water use, and limited knowledge on underground water resources. Thus, the respective policies could be broadly applied. However, important differences also exist, for example in relation to regulatory and institutional frameworks and also to social and cultural traits. Consequently, caution should prevail when extrapolating strategies to other situations.

Similar problem situations due to climatic variability and social vulnerability exist in:

- Inner Northeast Brazil
- Perú´s Highlands
- Bolivia Altiplano, Northern Chile and Argentina (Puna)
- Chaco (Paraguay)
- Northern México

These regions present both similarities and important differences with Argentina´s case studies. Among the latter we can mention social and cultural traits and water regulatory and institutional frameworks.

The descriptive analytic discussion performed in this work allows the identification of the necessary steps to be followed for the development of feasible alternatives regarding the role of energy for water issues in the framework of increased climate variability. An analysis can be proposed for a potential case replication. Then, if the proposed guidelines and actions as responses to similar or equivalent problem situations are present, it will be possible to consider the extrapolation of a specific renewable technological alternative for water supply, storage or distribution.

In summary, RE for water supply should be considered as one set of technical options in the framework of a complex development problem and a wider strategy that involves many components covering regulatory, institutional, social, economic and technical issues. All these issues must be tackled in a coherent way with the active long term support and participation of the National and Provincial State.

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8. Annexes

8.1 Research Centers assisting to the International Workshop

Five Institutions were contacted in order to:

- Identify research lines and activities in the field of water & energy, in connection with climate change and adaptation and
- Ask about their interest in attending to the 23, 24, 25 September workshop.
- Interact in order to identify useful inputs, coming from parallel research and related with FB's main report.

These Institutions or Centers will participate in the International Workshop "Clean Energy and Water: an Assessment of Services for Local Adaptation to Climate Change". After interacting with IDRC and FB in order to define the specific subjects and themes to be presented, the centers expressed their commitment to join the Workshop, basically enriching the event with their research experience. The preliminary title of each Institution presentation is presented in the table below.

Center	Country / Headquarters	Contacted person	Institutional data	Preliminary Presentation's Title
PIRNA –IGEO- / UBA *Research Program on Natural Resources and Environment*	Argentina Buenos Aires City Universidad de Buenos Aires Geography Institute, School of Philosophy and Literature	Ana Murgida animurgida@gmail.com	Puán 480 3er.piso (1406) Buenos Aires City Telephone 54-11-432- 0218/ 0334 http://www.pirna.com.ar/	Climate, water management and adaptation in the Chaco Salteño region of Argentina.
IVIG/COPPE/UFRJ. *International Virtual Institute of Global Change*	Brazil COPPE, Federal University of Rio de Janeiro	Maria Silvia Muylaert, msmuylaert@ivig.coppe.ufrj.br	Rua Pedro Calmon, S/Nº Cidade Universitária - Ilha do Fundão Rio de Janeiro - RJ - CEP: 21945-970 Telephone: 55-21-2562-021 http://www.ivig.coppe.ufrj.br/pbr/sobre_ivig.html	A Study of the Vulnerability of Rio de Janeiro State water resources to climate change - an indicator to evaluate the future hydro energy potential
CEPAL LA&C Region. Natural Resources and Infrastructure Division.	Chile Santiago de Chile ECLAC,	Andrei Jouravlev, andrei.jouravlev@cepal.org,	Av. Dag Hammarskjöld 3477, Vitacura, Santiago de Chile Telephone: (56-2) 471-2000 - 210-2000 – 2085051 http://www.cepal.org/cgi-bin/getprod.asp?xml=/drni/noticias/paginas/8/12088/P12088.xml&xsl=/drni/tpl/p18f.xsl&base=/drni/tpl/top-bottom.xsl	Decentralization and provision of water services: a public policy perspective from Latin America.
Centro de Cambio Global UC *Global Research Center*	Chile Pontificia Universidad Católica de Chile	Dr. Sebastian Vicuña, Executive Director, svicuna@uc.cl	Vicuña Mackenna 4860. Santiago, Chile Telephone 54-11-432- 0218/ 0334 http://cambioglobal.uc.cl/	Water, energy, agriculture and climate change nexus in one of the most important hydroelectric basins in Chile.
Fundación EcoAndina	Argentina Jujuy Province	Silvia Rojo, President ecoandinapuna@yahoo.com.ar; ecopuna@yahoo.com.ar María Virginia Bauso [Participant] virginia@formasverdes.com	Enrique Romero N°43. Villa Jardín de Reyes, San Salvador de Jujuy. Casilla de Correo: 10 Telephone: +54 0388-4922275 www.ecoandina.org	Solar Towns in the Andes, Argentina

8.2 Climatic data

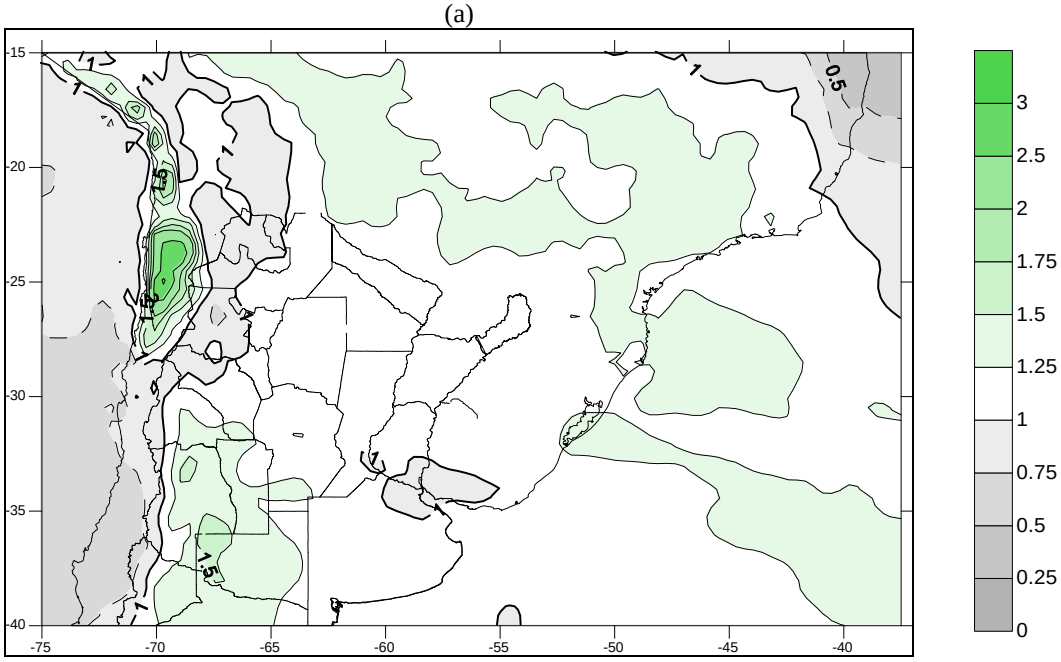
The main sources for climatic and hydrologic data were the studies carried out in the context of the Argentinean Second National Communication on Climate Change (SCN) and in the Argentinean Chapter of the Regional Study on Climate Change Economics in South America (ERECC-SA), developed by ECLAC-CEPAL.

In this study, was utilized the climatic data supplied by the CPTEC-INPE (Brazil) that results from de use of PRECIS climatic model (by the Hadley Center - UK) for the period 1960-1990 (as representation de current climate) and 2070-2100 (as estimation of the climate in the future). For the period 1990-2070 climatic data was obtained through and interpolation elaborated by the CPTEC-INPE that included mainly mean values, but not the inter-annual variations. Those variations were estimated by local sectorial teams dedicated to elaborate the studies related to water flows.

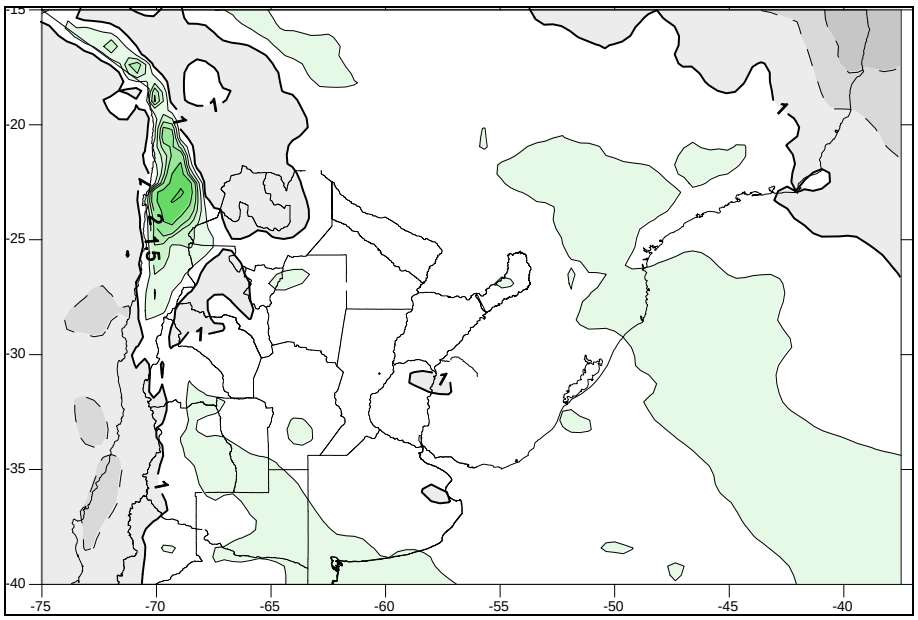
The results obtained are showed in Figures 10.1.1 (a) and (b) and (c), for precipitation and in Figures 10.1.2 (a), (b) and (c), for temperature, as follows:

Figure 10.1 (a) and (b). Scenarios of Changes in mean annual precipitation (Ratio for 1960-1990 period) corresponding to 2090-2099 period. (a) corresponds to Scenario A2 and (b) to B2.

(a)



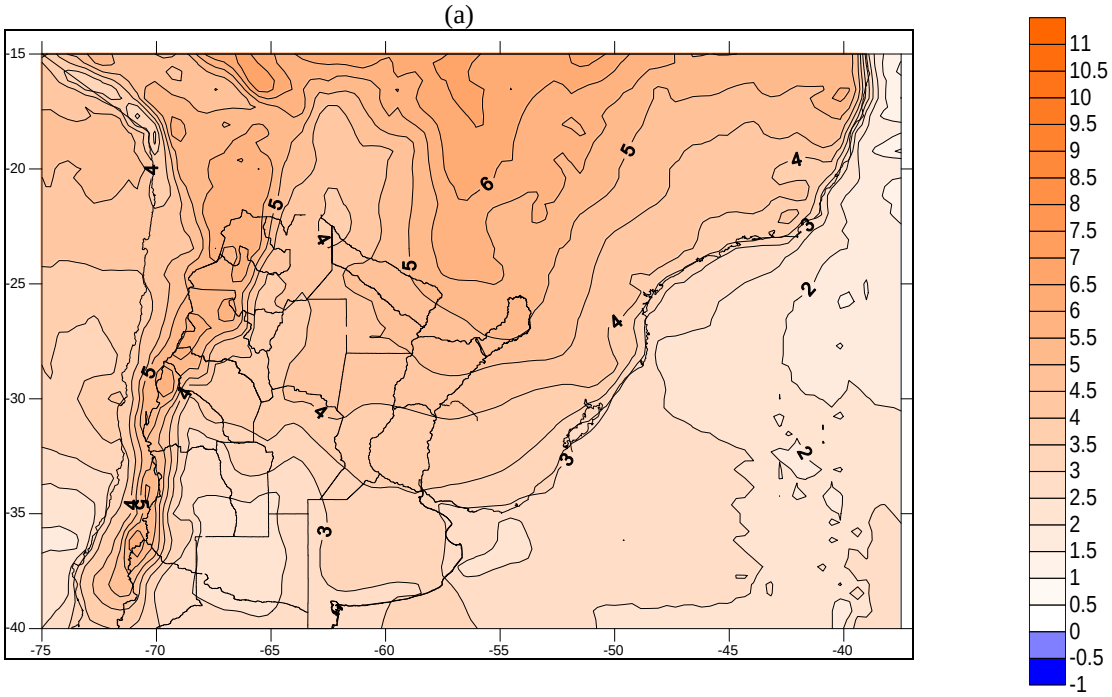
(b)



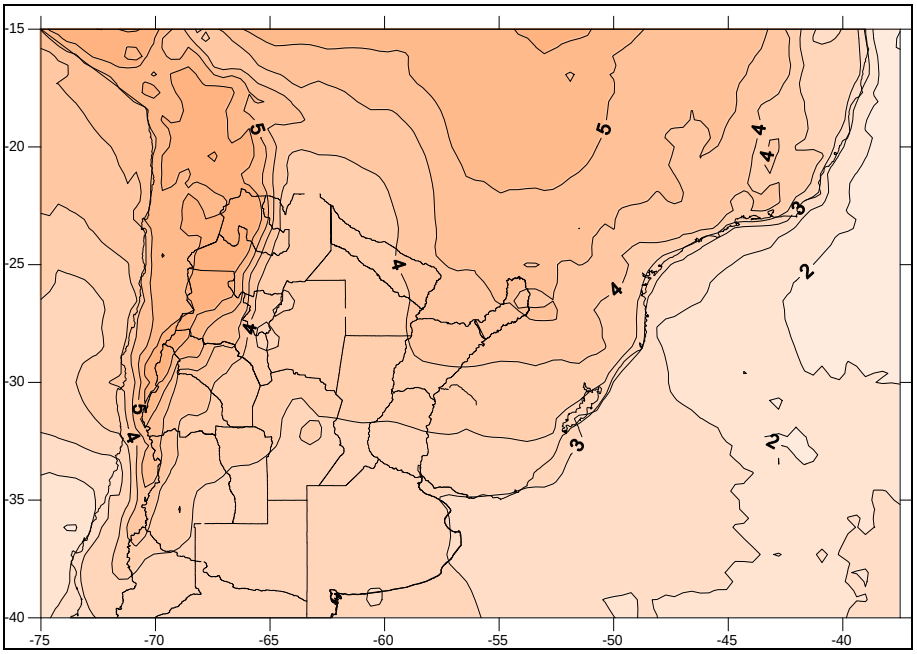
Source: ERECC-SA based on climatic scenarios from PRECIS model supplied by INPE (Girardin 2010d)

Figure 10.2 (a); (b) and (c). Scenarios of Changing in Temperature (in ° C) for 2090-2099 period compared to 1960-1990 period. Maximum Temperature (a) and Minimum (b) annual mean for Scenario A2 and Maximum Temperature (c) annual mean in Scenario B2.

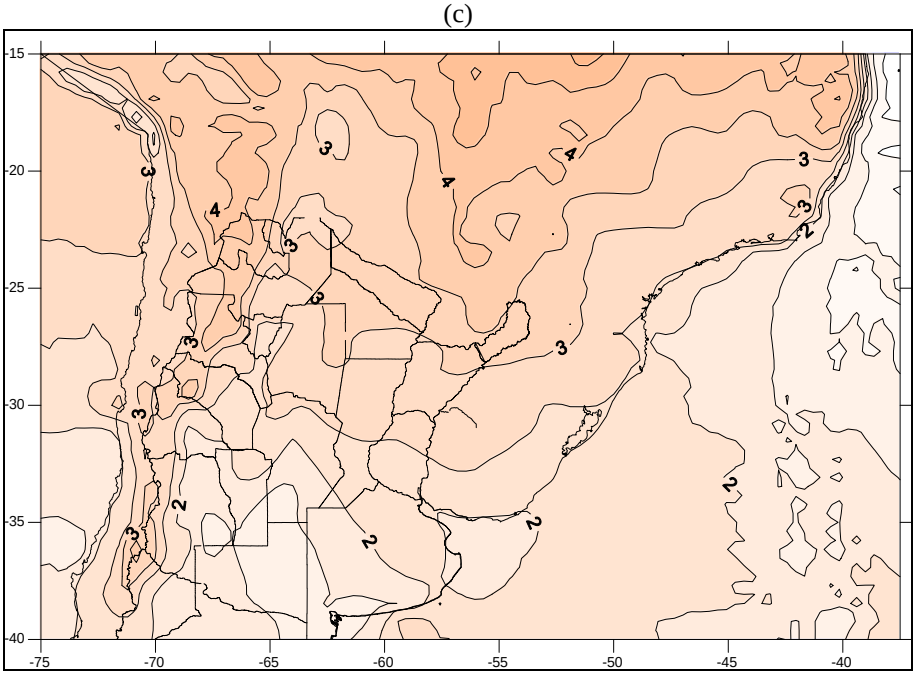
(a)



(b)



(c)



Source: ERECC-SA based on climatic scenarios from PRECIS model supplied by INPE (Girardin 2010d)

8.3 Hydrologic data

Regarding the Comahue Region, the study developed with the most updated data was the one carried out for ERECC-SA study, related to Limay River and Neuquén River the two most important of the Region.

Departing from available hydrologic and meteorological data a statistical model, was developed that allows estimating annual mean water flows.[61] Hence, in this study the results of different climate scenarios are used to characterize changes in precipitation patterns and a precipitation-flow regression model, to estimate the effects of those variations on the annual mean water flows.[62]

Total precipitations in the area and the annual mean observed water flows were used to calibrate a regression model for being utilized with the rainfall predictions of the future climate scenarios (IPCC SRES A2 and B2) in order to estimate the differences in the water flows under current and future climate conditions. Monthly precipitations were estimated on the basis of the climate scenarios obtained by the PRECIS model.

The basins under analysis are those corresponding to Neuquén and Limay rivers. The total area under consideration is about 57.243 km^2. Figure 10.3 shows the hydrographical network and the two control points taken in the study.

The feeding regime of both basins is based on rainfall and snow. The maximum of precipitation is concentrated on winter. The annual hydrograph of both rivers shows two maximums: one caused by rainfall in June-August and other by fusion in October-December.

61 Although it is considered better to use a *Variable Infiltration Capacity* (VIC) model, the lack of detailed hydrological and meteorological information did not allow utilizing this type of models. The VIC model, estimates runoff in monthly and annual scale, using a daily or hourly step in climate forcing and considering various forms of sub-surface runoff.

62 Taking into account those limitations in the available hydrologic and meteorological data, the results of this analysis must be taken as a first approach to the estimation of future changing scenarios regarding to the runoff of both basins (Limay and Neuquén).

62 Taking into account those limitations in the available hydrologic and meteorological data, the results of this analysis must be taken as a first approach to the estimation of future changing scenarios regarding to the runoff of both basins (Limay and Neuquén).

Figure 10.3 Limay and Neuquén Rivers Basins. Location of the PRECIS model data.

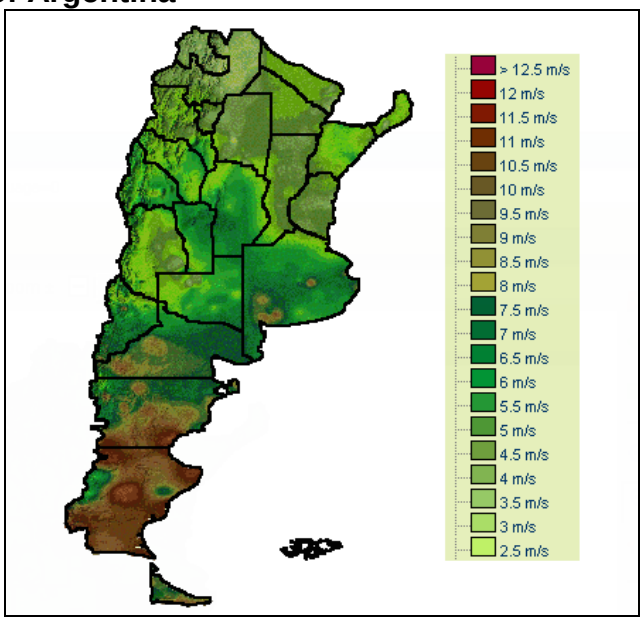
Source: Source: ERECC-SA (Girardin 2010d)

8.4 Renewable resources

- Wind resource

Although it has very local characteristics, wind is an abundant resource in this region, as shown by vegetation growing patterns. Nevertheless, the analyzed case studies places are not located in the most attractive wind potentials of the country.

Figure 10.5 Wind map of Argentina

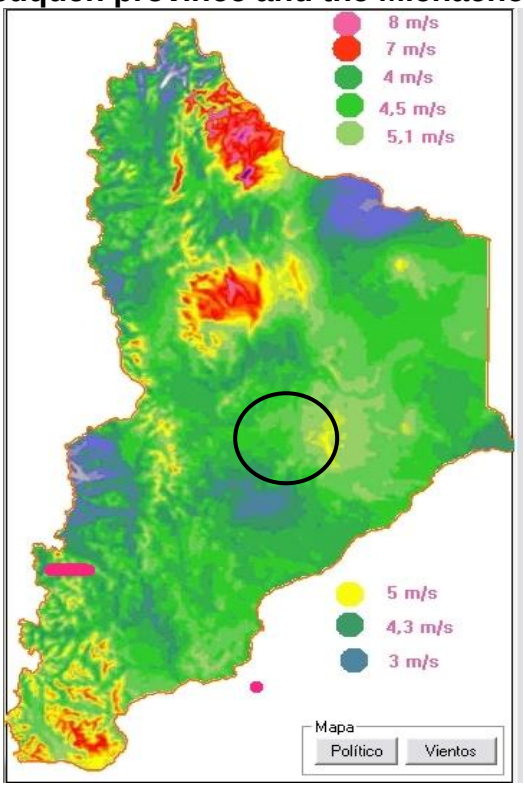


Source: http://www.sigeolico.com.ar/

For the particular case of Neuquén province the following wind map is available in the website of the Provincial Energy Authority, EPEN[63].

[63] http://www.epen.gov.ar/institucional/mapaeolico.php

Figure 10.6 Wind map of Neuquén province and the Michacheo region



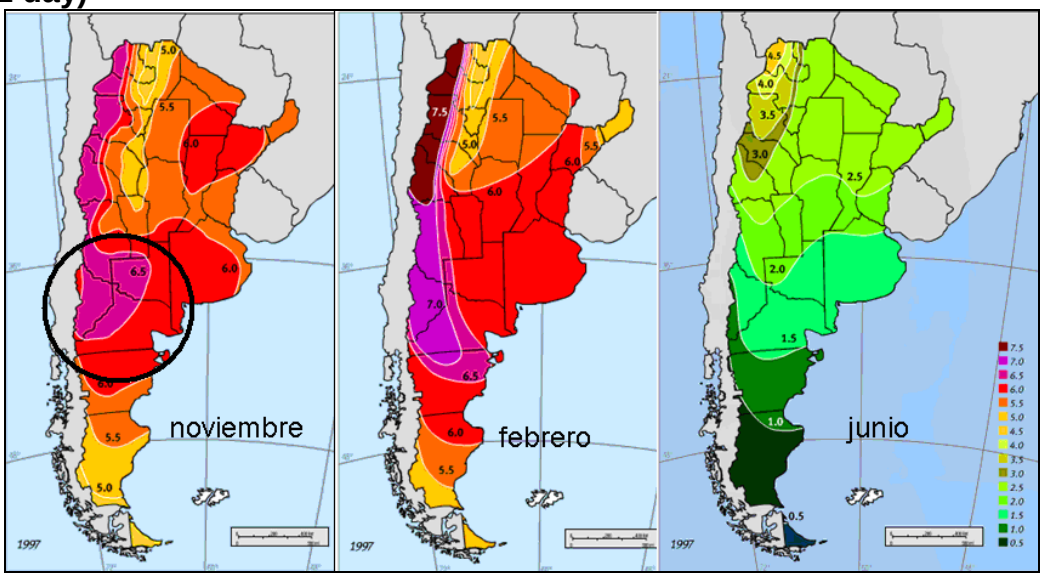
Source: (EPEN, 2011)

- Solar resource

Solar resource data, both solar global irradiation and actual heliophany, were extracted from the Solar Energy Atlas of Argentina[64]. In the following figure solar irradiation levels (in kWh/m2.day) for November, February and June are shown. The area within the circle corresponds to the Comahue region.

[64] Atlas de Energía Solar de la Republica Argentina, disponible en http://www.gersol.unlu.edu.ar/pagina3.htm (Gallegos, 2007)

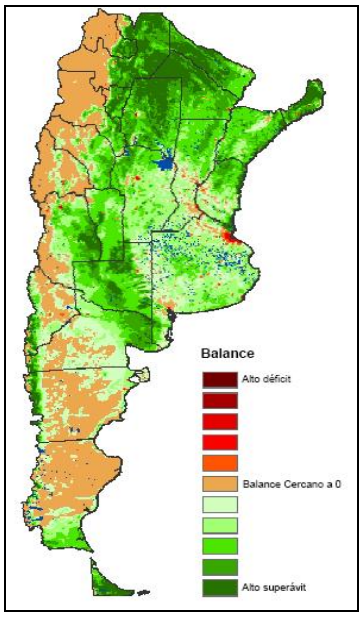
Figure 10.7 Solar radiation maps of Argentina and the Comahue region (kWh/m2 day)



Source: (Gallegos, 2007)

- Biomass resource

Figure 10.8 Biomass balance for Argentina in relation to average biomass productivity of each biome.

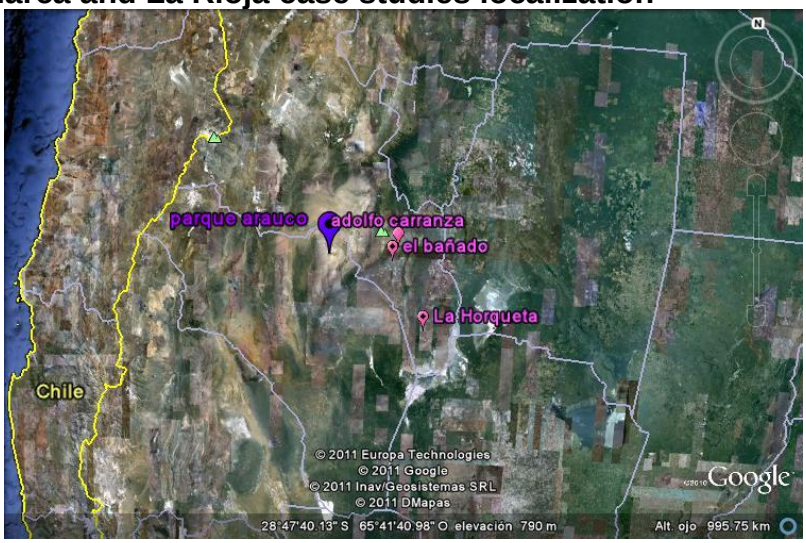


Source: (WISDOM, 2009)

8.5 Case Study locations

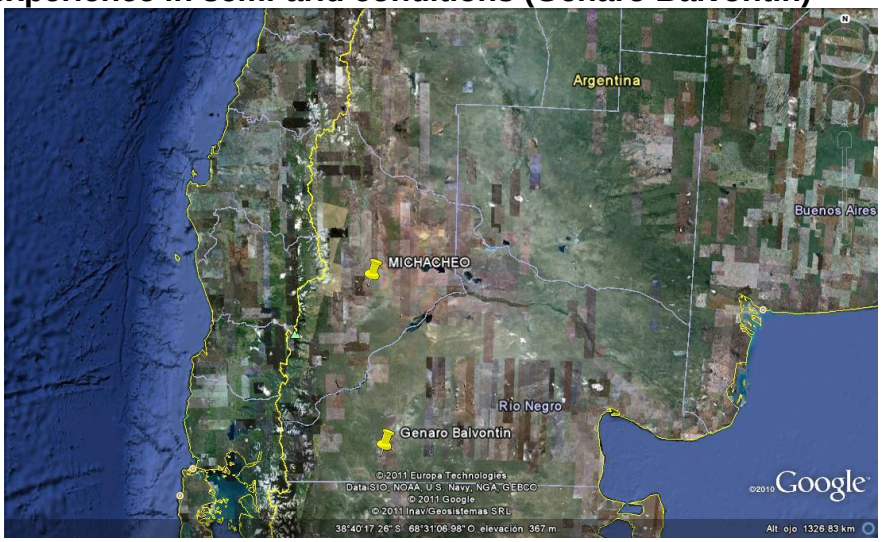
As roughly indicated using the Argentina map above, the precise sites of the case studies are identified. The wind farm Arauco is placed in the border of La Rioja and Catamarca provinces. The three more important populations of the photovoltaic pumping from deep wells in Catamarca are placed nearby, as indicated in pink color.

Figure 10.9 Catamarca and La Rioja case studies localization



Source: Google Earth

Figure 10.10 Michacheo case study localization, Comahue region and small scale forestation experience in semi-arid conditions (Genaro Balvontín)



Source: Google Earth

Finally Michacheo is situated in the Neuquén province to the south of Zapala city, and belongs to the core case study of Comahue region.