Economics of Greenhouse Gas Limitations

REGIONAL STUDIES

Andean Region Study

Instituto de Economía Energética (IDEE/FB)

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UNEP Collaborating Centre on Energy and Environment
Risø National Laboratory
P.O. Box 49
DK 4000 Roskilde
Denmark
Phone: +45 46 32 22 88
Fax: +45 46 32 19 99

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Executive Summary

1 Purpose and scope of the study

New opportunities for climate change mitigation arising from a higher energy integration among Andean Pact nations were analysed within the framework of the UNEP / GEF Project. Apart from the search for regional mitigation actions, the study was mainly aimed at detecting methodological problems which arise when passing from a strictly national view to the co-ordination of regional actions to deal with climate change.

In accordance with the available resources and data, and in view of the mainly methodological nature of the project, it was decided to analyse the opportunities to delve into the energy integration of the Region as regards electricity and natural gas industries and their eventual impact on the emission of greenhouse gases.

It is necessary to point out that all opinions and conclusions drawn from the present work only express the view of its authors and in no case do they represent the view of the respective governments.

2 The Andean Region

The Andean Region comprises Bolivia, Colombia, Ecuador, Peru and Venezuela, covering a surface close to 3.125 million square miles. The Andean population (104 million inhabitants) registered in 1996 an average income of $ 1,700 per inhabitant, in 1990 US dollars.

For some countries in the Region (Venezuela, Ecuador and Bolivia), the exportation of their hydrocarbon resources represents a significant source of income to the economy and acquires relevance in the financing of federal budgets. Venezuela and Ecuador export oil, while Bolivia exports natural gas.

In terms of meeting domestic energy requirements, all Andean nations have a significant supply of energy resources, specially hydroelectricity and different types of hydrocarbons.

As regards oil and oil products, Bolivia and Peru were importers in 1995, while Colombia, Ecuador and Venezuela exported from 57% to 89% of their production. The hydrocarbon reserves of Bolivia and Peru are mainly of natural gas. The domestic natural gas market has yet to be developed in Peru, while in Bolivia natural gas contributes with 25% of the net domestic energy supply, and it also exports 54% of its natural gas production to Argentina and will do soon to Brazil. The largest producer of natural gas in the Andean Region is Venezuela, where natural gas contributed with 54% of the net domestic energy supply in 1995. The natural gas market is at a stage of full development in Colombia, where the main hydrocarbon is mineral coal, which is mainly exported.

Hydroelectricity has a prevailing share in the supply of electricity within the Andean Region (72% of electricity generation in 1995), even when there are asymmetries as we move further inside the Region. Natural gas is the main burned fossil fuel in power stations (63% of the total fuel burned).

Final energy consumption in 1995 reached 34 GJ / inhabitant, highly influenced by the high energy consumption of Venezuela. These values include biomass products used for energy purposes (16% of the total amount). A gradual substitution of biomass was registered during the last decades - particularly in Ecuador and Colombia -, increasing the growth rate in the consumption of hydrocarbons and electricity. It was precisely the substitution of biomass that which allowed cutting down the share of the Household and Commercial Sector in final energy consumption by more than 10% during the last 25 years. It is worth mentioning that over 30% of final energy consumption within the Andean Region is registered at the industrial sector, slightly below the transport share.

The significance of the oil industry in some Andean Nations - specially Venezuela - is the reason why the energy sector's own consumption registers a similar volume to the burning of fossil fuels in all power stations of the Region, representing some 12% of the net domestic energy supply.

The energy intensity of the Andean economy (gross supply of primary sources per GDP unit) has been kept relatively constant during the last 25 years, ranging around 31 GJ per million 1980 US dollars.

3 The course of CO_2 emission within the Andean Region

Non-biogenic emission of the Andean Region's energy system reached in 1995 220,000 Gg of CO_2, representing 2.2 tons of CO_2 per inhabitant per year and less that 1.3 kg of CO_2 per 1980 US dollar generated by the Andean economy. Even when there are dissimilarities among the Andean nations with respect to their emission indicators, the Region's contribution to global warming was and still is quite scarce.

Even when total non-biogenic CO_2 emission within the Region shows a rising trend during the last 25 years - equivalent to an average 3.2 % annual rate - specific emission indicators (per capita emission and emission intensity of the economy) register a much more moderate trend, with average annual rates not exceeding 0.8%.

It is worth pointing out that such a moderate rise in emission took place within a context of strong expansion in the consumption of non-biogenic energy sources through biomass substitution in final consumption, which in some countries could not be extrapolated in the future due to the depth of the historical substitution process.

Several factors contributed to restrain the rise in emission, generally actions and policies related to energy supply. In the first place, the oil-exporting Andean nations made a great effort to cut down the flaring of natural gas associated to crude-oil production, additionally increasing the energy efficiency of the energy system. At present, fugitive emission originated in the flaring of natural gas represents less than 1% of the total emission of the energy sector, against an 8% in 1970.

At the same time, the higher use of natural gas led to a substitution in the consumption of oil products, mainly within the electricity sector, with clear benefits in terms of lower CO_2 emission, due to that source's lower carbon content.

Nonetheless, the highest impact on the evolution of emission within power stations of the Andean Region was undoubtedly given by the exploitation of hydroelectricity, which increased by 20% its share in total electricity generation during the last 25 years.

The total volume of emitted CO_2 per every Gwh generated in the Region did not reach 250 tons in 1995, that is, 46% less than the unit emission of power stations in 1970.

4 Current energy strategies within the Andean nations

Energy industries within the Andean nations are of a significance which falls beyond the mere interest in guaranteeing the domestic supply of energy in the long run, in view of the influence of hydrocarbon exports on State financing.

In this context, the Andean nations have decided to expand the exploitation of their energy resources and delve into the surveying of their territories for the purpose of guaranteeing the sustainability of this policy in the long run. This promotion is being carried out in a context of deep restructuring of energy industries, aimed at attracting private investors and cutting down the State share. This general approach may be appreciated in all Andean nations, and coincides with a prevailing trend in Latin America, although the degree of progress of the reforms is not homogeneous as we move further inside the Region.

Bolivia, Peru and Colombia have progressed in the process of privatisation of facilities and in the establishment of competitive markets, mainly in the electricity industry, where reforms were implemented at a higher speed. In turn, reforms in Ecuador and Venezuela are at their implementation and debate stages, respectively.

The opening levels of the energy markets, as well as the ownership and regulation system, vary in the different Andean nations, especially as regards the oil and natural gas industry. There is higher homogeneity in the restructuring of the electricity industry - at least in those nations which have already implemented it -, and the trend is towards the vertical and horizontal disintegration of the industry, with a view to promoting the establishment of a competitive wholesale electricity market with scarce State influence.

Within such context, the energy policies in force in the Andean nations tend to develop the domestic natural gas market through the construction of transportation and distribution facilities, with the sole exception of Ecuador, whose measured natural gas reserves are insignificant.

Under the new regulation and the current conditions of the international unit market for electricity generation, there is no doubt that electricity generation may swiftly contribute to the expansion of the domestic natural gas market in those nations in which the resource is available. Official policies promote in the medium term hydrocarbon substitution within the manufacturing industry and, in the long term, the use of compressed natural gas in transport, which would have a beneficial impact on CO_2 emission.

The official prospective studies for the electricity sector already incorporate this expectation of a more intensive use of natural gas within power stations, the consumption of which would rise by 94% until the year 2010, even when hydroelectricity generation will still representing 65% of total electricity generation within the Andean Region.

This evolution would presuppose a slight increase in CO_2 emission per generated Gwh (of some 15% with respect to estimated values for 1996), although it would remain within reduced margins for international standards.

5 Energy integration and its environmental effects

The promotion of economic and energy integration in Latin America in general and in the Andean Region in particular registers a long tradition expressed through agreements from government to government and through the establishment of regional integration bodies (OLADE, CIER, ARPEL, etc.). These actions led in the past to the construction of two-nation hydroelectricity stations, electricity interconnections, oil supply agreements and natural gas exports.

As from the energy systems restructuring, we notice a rising interest in the part of private energy companies in developing regional energy markets in their search for new business opportunities, favoured by the presence of the same company groups on both sides of the national borders.

The highest impact of this situation was registered in the natural gas industry of South America's South Cone, where private oil companies from Argentina and Bolivia have been quite active in the signing of agreements for the construction of international gas pipelines with Brazil, Chile and Uruguay. Bolivia seems to move towards higher energy integration with non-Andean neighbouring nations (MERCOSUR), favoured by topographic conditions, the attraction of the potential natural gas market and a higher energy complementary condition with these nations rather than with those from the Andean Region.

Private natural gas industry agents compete against electricity generators to attract foreign markets for their products, the coexistence of initiatives for gas pipelines and electricity interconnections to supply the same market being more and more frequent.

Within this general trend of the Latin American energy agents, integration projects towards the inside of the Andean Region still depend on official initiatives, and there is no record of private agreements to develop this type of projects.

It must be admitted that the energy systems of the Andean nations are competitive rather than complementary. Leaving aside the production and transportation of oil products - the integration of which will surely bring benefit to the parties but whose impact on the emission of GHG is harder to measure - the Andean nations anticipate a more intensive exploitation of their own natural gas reserves, with the sole exception of Ecuador, where known reserves are not enough to promote the substitution of oil products.

The existence of own natural gas reserves - usually closer to domestic markets - does not mean that no natural gas exportation projects have been discussed among the Andean nations. In fact, there are already official agreements for the construction of a gas pipeline between Venezuela and Colombia, which would make the supply of Colombia's Gas Massification Program more reliable. Nevertheless, certain problems have come up at the time of agreeing on a sound natural gas supply volume, since Venezuela would export associated natural gas the production of which depends on the exploitation rate of the oil fields.

The impact of the construction of this gas pipeline on the Colombian system's GHG emission would not be quite significant in as much as Colombian plans already presuppose a swift penetration of natural gas to replace oil products and electricity for cooking purposes within the Household sector.

At some moment, it was also proposed to export Bolivian natural gas to Peru's southern region (Ilo) to supply power stations and meet the heat consumption of the industrial mining complexes. However, this idea did not prosper and, on the contrary, private generators began the construction of thermal stations burning Colombian mineral coal. Although from an energy viewpoint this project represents an example of co-operation between both Andean nations, its impact in terms of CO_2 emission is unfavourable.

An alternative which was not much analysed in the past but which result indeed in emission reduction is the supply of natural gas to Ecuador from Colombia, with the possible backing of Venezuelan natural gas should the planned gas pipeline between both nations become a reality. Burning natural gas in the Ecuadorian power stations would allow cutting down CO_2 emission by some 1,200 Gg per year (calculated on the basis of the expected thermal generation for the year 2010), both through the substitution of oil products as well as due to a higher efficiency in combined cycles with respect to the steam turbines foreseen in power plans. The impact would be even higher should natural gas penetrate the final uses of energy, specially within transport - as compressed natural gas -, even when its effect would not be as swift due to its lower penetration speed.

Electricity integration in the Andean Region is currently restricted to the interconnections related to the supply of border areas, except for the cases of Colombia and Venezuela, where there are three lines with a joint transport capacity of 380 MW, representing 5% and 7% of current peak load of both systems.

At present, the Regional Electricity Integration Commission (CIER, in its Spanish abbreviation) is holding studies to analyse the prospects of a higher integration of the South American systems and the challenges for the establishment of a subcontinental electricity market. It is possible that the results of this study will show the possibility of delving into electricity interchange among the Andean nations with clear advantages as regards the reliability of the electricity supply.

Nevertheless, it must be said that the Andean systems have quite similar characteristics, which reduce complementation possibilities. In particular, and as regards the possibilities of thermal generation substitution, the hydrological rates of the Andean nations are similar and the systems have their own thermal compensation.

The international electricity trade favoured by cost differences within the Andean nations would still prove convenient, but its impact on emission reduction would be scarce.

The projects on the shared use of the hydraulic resource by Andean nations - surveyed as the present study was being carried out - are of scarce magnitude and high cost, and their individual contribution to mitigation would not exceed 400 Gg of CO_2 per year.

This type of projects is precisely that which requires a special promotion on the part of the governments and regional integration bodies if the purpose is to have private agents from the energy industries developing such projects. In particular, the detection of the sites and the holding of basic studies are not easily dealt with by private investors, and will require official promotion.

Even in those cases in which the interest of the companies may promote energy interchange between the nations, certain adjustments will be required as regards regulation in order to prevent asymmetries in the markets and in the way to take possession of the benefits resulting from the higher integration. The consideration of the impacts of energy integration projects on global warming proves even more complex every time the projects have to do with private commercial agreements. This type of benefits is not clearly perceived by the investors unless there are economic compensation mechanisms and the Andean nations are still far from the co-ordination of strategies and actions to deal with the climate change issue.

6 Conclusions

One of the key objectives of the UNEP / GEF "Economics of GHG Limitations" Project was to test through case studies the applicability of the IPCC methodology to the particular case of the developing nations, both from a purely national viewpoint as well as from a regional perspective.

Abstracting the difficulties posed by this method when applied to mitigation studies of national scope, its use in the detection and selection of regional mitigation options seems highly complex, particularly in Regions where regional decision processes are not clearly institutionalised.

The IPCC methodology presupposes the definition of unique decision criteria to evaluate and order the different mitigation options, making national projects compete with regional ones. The "automation" of the decision through the construction of the mitigation incremental cost curve presupposes the comparability of the different options and excludes the negotiation process present in every integration project.

Notwithstanding the fact that these comments apply to every regional study, they become much more relevant when member nations are not obliged to take mitigation actions in the medium run, as is the case of the Andean Region.

The Andean nations have yet to determine a national strategy to deal with the climate change issue, which would exceed the restriction on the consumption of fossil fuels within their territories. As hydrocarbon exporting nations, the impact of international climate change mitigation agreements on them is twofold: on the one hand, on account of the higher costs represented by the restriction on their own GHG emission without affecting their economic development; and on the other, due to the influence of restrictions on the burning of fuels within central markets over the volume and prices of their exports. Within this context, the adoption and co-ordination of strategies among member nations proves complex, and is incipient at the present stage.

On the basis of these considerations, and in view of the scarce resources available for the present research work, it was decided to carry out a first exploratory analysis of the regional mitigation options which would result from higher energy integration within the electricity and natural gas industries.

Although possibilities of setting up electricity and natural gas markets are real, their impacts on GHG emission from the energy system would not prove substantially higher than those which the nations could achieve through the use of their own energy resources, in view that the Andean systems are competitive rather than complementary.

More in-depth studies and detail information will be required - unavailable for the present study - to be able to properly evaluate all benefits associated with higher energy integration. Nevertheless, the supply of natural gas to Ecuador seems to be the alternative with the highest impact on GHG emission.

If we were to analyse the supply and final consumption of energy jointly, we would most certainly detect additional mitigation options resulting from higher co-operation and co-ordination in the energy field.

Climate Change Mitigation

1 The international context and the developing world

Although developing world nations are not immediately bound to carry out actions with a view to mitigating the emission of greenhouse effect gases (GHG), an increase in GHG concentration in the atmosphere and its potential consequences on climate change deserve the attention of the entire nations of the globe. Considering the magnitude of the potential effects of climate change, the application of policies based on the precaution principle is recommended. GHG inventories and vulnerability and adaptability studies are to be found within this context.

To concern as regards vulnerability to an increase in ocean levels, we now add the impact of the change in the precipitation system on the development of economic activities and on the sustainability of populations from different regions. This aspect proves to be particularly critical in the developing world, since the degree of vulnerability to these phenomena depends on the capacity of the social groups to absorb, dampen or mitigate the effects of these changes, something which is associated with the possibility of having proper technology, infrastructure and means.

Due to the gravity of the issue, time is running out to determine effective actions to mitigate climate change. The current process in search of consensus within international fora calls for the active participation of the developing world to guarantee that equitable decisions are adopted, considering both future impact as well as historical contribution to the generation of the problem.

1.1 Mitigation impact

In general, when we speak about the impact of actions to mitigate climate change in the developing world, we think of the consequences which the implementation of a mitigation policy within their territories would have on their economic and social development. Setting aside methodological difficulties to properly evaluate the incremental costs of mitigation actions within their own borders, the interesting issue here is to point out the importance of analysing the impact that a more and more restrictive international context with respect to GHG emission would have on the possibilities of economic progress for developing nations.

As these measures affect more drastically the consumption patters in force within the industrialised world, this could also affect the international market of certain products, which prove vital to finance the development of the developing world. To this respect, it should be borne in mind that most of the fossil energy traded at the international market comes from developing countries and is destined to the industrialised world. Even when environmentally necessary, a drastic cut in the consumption of these products would have a significant economic effect in the developing countries which produce energy, which, on account of their own characteristics, would have difficulty in restructuring their economies in a short period.

A similar situation could take place in the market of other energy-intensive products, specially basic goods such as steel and other metals. In this case, the industrialised nations could resort to importation as an effective means to assign the responsibility of

GHG emission to the exporting countries. After the second oil crisis at the end of the 1970s, a similar method was used to bring down the energy intensity of the industrialised world, displacing energy-intensive industries towards developing countries with a guaranteed low-cost energy supply.

Ever since globalisation began to show the need to carry out adjustments in the industrialised economies, the idea that international trade should have some type of regulation against any sign of disloyal competition in the markets began gaining strength. Apart from the agreements reached within the World Trade Organisation (WTO), some voices called for the consideration of social and environmental aspects in such regulations.

The international context has forced nearly all developing countries to carry out structural adjustments in their economies, which notably affected the capacity of their internal markets to sustain growth of economic activity within their borders. Under the present circumstances, their economic growth depends and will depend on their capacity to position themselves within the markets of the developed nations. Hence, the conditions to be imposed by the industrialised nations to open their markets to international trade are of vital significance for the development of the developing countries.

In particular, environmental regulations could force the developing world to assume the cost of climate change mitigation just to guarantee their insertion to the international markets and contribute to overcome the deep social crisis brought by the economic adjustment plans.

These considerations on the impacts on development are not aimed at debating on the unsuitability of mitigating climate change, which, in accordance with every analysis, should be implemented in the short run. Nevertheless, it seems important to bear these aspects in mind at the time of agreeing on actions to take and on cost distribution.

1.2 Risks and opportunities for climate change mitigation

Even when the weather is affected by the concentration of GHG in the atmosphere, the industrialised nations insist on concentrating the analysis on the future evolution of annual emission and its distribution in the different regions of the globe. However, the irreversibility of past emission should not restrict the debate to the future responsibilities of the different countries in increasing their current levels of GHG concentration.

In fact, the proposed theoretical and conceptual approaches are based on models and criteria which prove incapable of considering the contribution to the generation of the problem. Instead, they are oriented to the search of more attractive mitigation opportunities from a cost viewpoint. Since the methods recommended to appraise mitigation options are strongly influenced by income distribution, the final result may lead to the paradox of giving priority to the implementation of mitigation actions in the regions which register less relative responsibility in the emergence of the problem.

However, and considering the planetary characteristic of the weather, it is important to reach the voluntary action of all nations to bring down future GHG emission and prevent the developing world from future taking of development paths which have already proven their lack of environmental sustainability. An effective restriction would demand, however, deep change both in consumption patterns in force as well as in production ways. Even if the re-conversion effort were to be mainly carried out in the industrialised world, the developing countries would face the cost of maintaining a low standard of living for a significant part of their population on account of difficulties to guarantee an adequate growth rate for their economies.

To additionally assume the commitment to implement actions to bring down GHG emission within their borders would translate for the developing world into an increase of these social and economic costs, which would hardly be evenly distributed among all social and economic agents. In the present context of social fracture and trans-nationalisation of their economies, the governments of the developing countries face the exhaustion of their capacity to guarantee social equity when distributing mitigation costs.

Hence, the evaluation of actual climate change mitigation costs should be strongly related to considerations on equity. Although it could be deemed that this type of problem has to do with the domestic policy of the developing nations and is subject to the ethical and political appraisal made by each government in particular, it is important that the equity issue be included in debates, methodological guides and training courses aimed at establishing a consistent approach to the studies on mitigation within the developing world.

At the same time, the international negotiation process on climate change mitigation should progress towards an equitable distribution of mitigation costs within the international community. From this perspective, the analysis of the present situation and of the expected future evolution of GHG net emission for the different countries proves insufficient. It is necessary to determine the historical responsibility for having reached current GHG concentration levels in the atmosphere and for the levels to be reached in the next 100 years.

Serious debate is required for this purpose on the extension of the historical period to analyse, the way to allocate the CO_2 sinks shared by the international community and the establishment of criteria for the allocation of emission between exporters and importers in the international trade of GHG-emission-intensive goods. To the examples previously given for this type of tradable goods, we could add the deforestation in certain developing countries promoted by wood exports. Such accounting should be carried out on the basis of responsibilities on the levels of GHG concentration, allocating “assets” and “liabilities” to each country correlated with the allocation and contribution of funds for climate change mitigation.

In the specific case of Latin American nations, their historical contribution to climate change mitigation through hydroelectric development is internationally renowned. What is less mentioned is the economic and social cost these nations had to face for their “environmental” contribution to the international community after having to complete these works through their own resources and short-term high-interest-rate loans from international private banks, which led to a rise in their external debts. It may be stated that such harmful effects were fuelled by a certain inefficiency in the handling of the funds, but we cannot deny the international benefit of this capital allocation policy adopted by Latin American countries to the detriment of immediate consumption and the economic welfare of their peoples.

It is to be expected that the contribution of the different regions of the globe to GHG concentration in the atmosphere will continue showing significant asymmetries, maintaining a higher responsibility of the industrialised world. Recent studies[1] show that the contribution of Annex 1 countries to global warming in the year 2096 would be some 30% higher than that of the rest of the world, even assuming that their emission dropped some 40% for the year 2016 and that the emission of the rest of the world rose some 300% for the same year.

Although the Convention on Climate Change introduces the issue of equity in its Section 3, the international negotiation process has been marked by the defence of the economic interests of each participant, and its results do not cease to show the power relations within the international community. However, never before has the interdependence of all nations been so clear as to provide solutions to a problem which due to its nature equally affects all inhabitants of this planet. Hence, we face a unique opportunity to transcend domestic interests and co-operate in the search for effective and viable actions to mitigate climate change.

2 Opportunities for a regional approach

In this international context, it seems appropriate to transcend national borders in the analysis of the actions and consequences of climate change mitigation measures and evaluate the opportunities posed by a higher regional integration. In the same way, the analysis of integration projects could include the dimension of the climate change, with a view to specifying its contribution to the mitigation of GHG emission for the region as a whole, as well as for each member nation.

The detection of these opportunities may strengthen co-operation and integration ties within the region, although in certain cases it will require additional negotiation efforts to determine criteria to allocate regional environmental benefits among member states, allowing compensations to the region's hinterland. In fact, the United Nations Frame Convention on Climate Change admits regional representation at the Conference of the Parties, on condition that it replaces the national representations of member nations.

Although the diversity of particular interests and situations of the countries could pose difficulties to the achievement of joint representations of these characteristics, stronger regional interaction would certainly facilitate the interchange of experiences and the co-ordination of criteria and strategies to face negotiations at international fora.

In the special case of Andean Subregion countries, the fossil fuel producer / exporter nature these nations share could facilitate the search for a common regional strategy to deal with the climate change issue.

3 Methodological challenges

The preparation of two regional mitigation studies within the context of the GEF/UNEP Project, "Economics of GHG limitation" presupposes the analysis of the applicability of available methods to carry out mitigation studies within a regional scope. In accordance with the analysis made, transcending national borders to comprise a regional scope requires significant methodological adjustments with respect to the following:

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[1] Pinguelli L, Kahn Ribeiro S.: "Present, past and future contributions to global warming". COPPE/UFRJ, 1996

- Redefinition of the goals and scope of the study
- Methods to evaluate regional mitigation alternatives
- Ways to set up the Scenarios
- Consideration of the implementation issue

We sum up below the methodological adjustments which we deem necessary for each one of the aspects previously mentioned.

3.1 Goals and scope for a regional study

The available methods to carry out domestic mitigation studies are aimed at facilitating the incorporation of the environmental dimension in the domestic process of government policy and strategy decision-making. Thus, they suggest the use of different instruments to decide among conflictive goals in order to establish a priority order among the mitigation options analysed. This means to represent the utility function (or preference structure) of the political decision-maker.

One of the most promoted methods to carry out this task - which assumes the reduction of multiple objectives to the addition of scalar elements in a common measuring unit - is the use of shadow prices for those input and production factors which could be affected by the implementation of the mitigation options. Costs thus calculated would represent the inverse of the social welfare associated with each mitigation option analysed. Thus, the ordering of the options in accordance with their rising incremental costs would automatically represent the priority allocated to the different mitigation alternatives by the political decision-makers in representation of the society as a whole.

Notwithstanding the assumed objectivity of shadow prices, there is no doubt from a theoretical point of view on their high dependence on the subjective appraisal of the decision-maker. Since it does not result from a process of global optimisation of the economic system, they represent the “trade-off between objectives” or relevant aspect for decision-making from the special viewpoint of the political decision-maker.

Apart from the objections and difficulties for the application of this approach in defining domestic policies, it seems highly inadequate within the regional scope. In fact, regional decision-making results from a negotiation process, which is more or less strenuous depending on the levels of regional understanding and integration, which may never be “automated” through the construction of a joint utility function which may allow to conclude the order of priorities for the options analysed. It is important to point out that this negotiation among national representatives may not be eluded, even in those regions in which integration process has reached high institutionalisation levels, as is the case of the European Union.

On the other hand, the ordering of mitigation options presupposes that they are fully comparable in terms of wills and political decision-makers involved. Comparison between regional options may be strongly affected every time the regional options involve different countries.

In our opinion, and in accordance with these considerations, there is no doubt that the scope of a regional study should be exploratory in order to identify joint mitigation options and contribute with judgement elements for the further negotiation process on their regional and domestic impacts, as well as on the eventual obstacles which could oppose to their implementation.

3.2 Evaluation of regional alternatives

Regional mitigation options should be submitted together with an analysis of their impacts - as wide as possible -, both as regards type of impact as well as the geographical area in which they would take place.

As regards type of impact, the following should be included:

- Environmental effects
- Direct impact on the economic sector which would apply the mitigation actions
- Direct costs of undertaking the actions analysed
- Some macroeconomic considerations, as far as possible

It would be convenient to include - apart from the quantification of GHG emission saving - some considerations on other local environmental impacts of the options analysed.

Since, as a general rule, there are no development plans applicable to a region as a whole, the type of impact to analyse will depend on the scope of the regional study in particular, as well as on the prior identification of explicit policies within member nations. Nonetheless, we must acknowledge the difficulty in going further with a detailed study on the macroeconomic impacts of the regional mitigation options.

With respect to the geographical area of the impacts, it is important to note that certain regional mitigation options could produce quite asymmetric effects among member nations, even when they show a clearly positive balance for the region as a whole. In these cases, it is essential to identify these asymmetries in order to facilitate the adoption of compensating mechanisms among the parties during the negotiation process.

Hence, a regional mitigation study may hardly go beyond the construction of impact matrixes - one per each member, apart from the regional matrix - , which allow to compare the different effects of the regional options analysed. Any appraisal of these impacts in terms of their desirability will depend on the subjective evaluation of domestic political decision-makers and on their willingness to facilitate agreements with the other parties involved.

3.3 Setting up the scenarios

Even when is not our aim to build a regional mitigation incremental cost curve, we shall need regional Scenarios to go further in the quantification of the impacts of regional options, as far as available information allows it.

The specification levels of the scenarios will thus depend on the extent of the specific regional study. However, they should allow to anticipate the effect on essential variables with and without the option analysed, both for the region as a whole as well as for each member nation.

The regional Baseline Scenario should be the addition of the provisions of member nations to the sectors where regional mitigation options may be considered. These provisions may include or not domestic climate change mitigation options, depending on the commitments undertaken by the parties.

In the event that the mitigation potential of a regional option would be limited or restricted by a domestic action, the degree of existing competitiveness between both options as for sensitivity should be analysed. Nevertheless, from a strictly regional viewpoint, it does not seem advisable to ignore domestic decisions, which could have different degrees of implementation.

As far as regional studies aim at promoting the search of consensus on the most effective strategy and methods within the region to mitigate climate change, these should be understood as a process with an initial exploratory stage which may delved into according to the interest shown by the parties. It is clear that the characteristics of these studies and of the analysis scenarios will vary as we move further into this regional decision process.

A similar situation may take place with respect to the order of inclusion in the Mitigation Scenario of the different regional options identified. Contrary to the case of domestic studies, a regional mitigation scenario is not associated with a certain GHG emission saving objective nor does it represent an established mitigation action program.

Although difficulties to determine the order of priority among mitigation options when setting up a scenario are not the exclusive territory of regional studies, uncertainties may be much higher than in domestic studies, specially if we consider that the viability of the different options may depend on a further negotiation process.

Hence, its seems best to carry out at a first instance an analysis of the direct impacts of each regional option and, whenever it may correspond, determine the crossed impact among the mitigation options as for sensitivity, without assigning priority to any of them.

3.4 The implementation issues

In the case of regional studies, the viability of the regional options could be affected by legal and / or regulatory asymmetries among member nations, and this could represent an additional obstacle to their implementation. The importance of legal and regulatory aspects will depend on the sector for which mitigation options were detected. Such issues could be especially significant for energy industries within the present context of regulatory change that the nations are carrying out with unequal rate and views on the most appropriate methods to guarantee the normal supply of energy requirements within their territories.

An issue which should deserve special attention in regional studies is the treatment of the eventual asymmetries in GHG emission savings within member states resulting from regional mitigation actions. From this viewpoint, more strength should be given to the purpose of regional studies to contribute with elements of judgement for further negotiations among the parties.

For this purpose, it will be necessary not only to quantify GHG savings for the region as a whole, but also to clearly indicate the impact of the regional mitigation option analysed on the emission of each of the countries involved, considering both direct and indirect emission.

4 Scope of the Andean Region Study

The specific situation of the Andean Region, comprising Bolivia, Colombia, Ecuador, Peru and Venezuela, was analysed within this general perspective, and without losing sight of the main purpose of this project, that is, to test the applicability of the methodology in question.

The energy sector was chosen among all sectors in which regional co-operation could be expected in the search for regional climate change mitigation options, both on account of its higher information availability as well as for the existence of institutions in the region which have long promoted energy integration actions.

Within the energy supply industries, special attention was given to the electricity industry and to the possibilities of setting up a sub-regional Natural Gas market. This election does not mean in any way that there is a lack of attractive mitigation options in other socio-economic sectors. However, their study would require the application of human and economic funds quite above those available for the preparation of the present study.

Diagnosis for the Andean Region

1 Socio-economic characterisation

The Andean Subregion comprises Venezuela, Colombia, Ecuador, Peru and Bolivia, and is located at the northern and centre-western portion of South America. In all, it covers a surface of a little over 2.9 million square miles of territory framed by the Andean mountain range. This attribute provides the region with an ample weather variety, notwithstanding the fact that it is entirely located within a tropical area. The region is also rich in minerals.

In accordance with information from the Regional Electricity Integration Commission (CIER, in its Spanish abbreviation), the total population of the Region reached 104 million inhabitants by 1996, with a 73% urbanisation degree. Hence, the Region's mean population density is just over 22 inhabitants per square kilometre.

Nonetheless, the Region is not homogeneous neither in its urbanisation level nor in its territorial occupation density. The countries registering a higher urbanisation rate are Venezuela (81%), Colombia (75%) and Peru (72%). In the other end, we have Bolivia (54%) and Ecuador (61%).

These two countries with higher rural population proportion are precisely those with higher population rate, 2.4% and 2.1%, respectively. In Colombia and Peru, the population growth rate has dropped throughout the period to level around a yearly 1.7%. Only Venezuela, with a yearly 2.2%, does not follow the rule which goes that the higher the urbanisation level the lower the population growth.

The Andean Region as a whole also shows a deceleration in its population growth, which currently around a yearly 1.9%.

According to publications from the Latin American Economic Commission (CEPAL, in its Spanish abbreviation), the Region's Gross Domestic Product (GDP) reached in 1996 178,000 million 1990 US dollars. Thus, per capita GDP reached US$ 1700 per inhabitant.

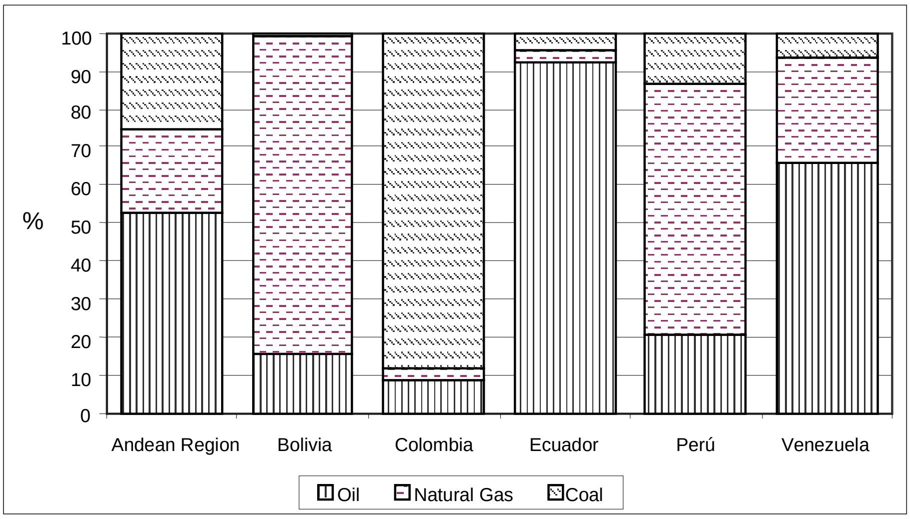
In the Region's hinterland, the scattering of the per capita product is significant. While Bolivia barely reaches 50% of the regional mean income, Venezuela exceeds it by almost 50%. Only Peru and Venezuela register a per capita product higher than the regional mean figure. Colombia and Ecuador register a very similar per capita GDP, of some 75% of the region's figure.

2 Energy within the Andean Region

Andean Region countries have abundant energy resources, specially hydroelectricity and different types of hydrocarbons. The region shares with the rest of Latin America a large hydroelectric potential, which is scarcely used notwithstanding the almost excluding significance of hydroelectricity in practically all member nations.

Nevertheless, hydrocarbons are without a doubt the most significant resources in the region, given their relevance in the financing of national budgets. According to data from the OLADE's Energy-Economic Information System, proven hydrocarbon reserves reached nearly 920000 Petajoules in 1996, with the distribution shown in Figure 1.

Figure 1 Proven hydrocarbon reserves within the Andean Region - 1996

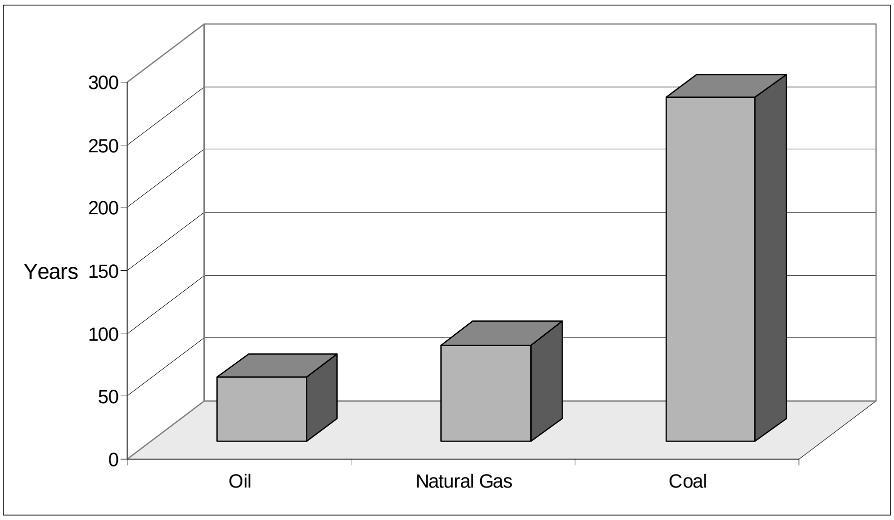


As may be appreciated, the relative significance of each type of hydrocarbon differs from nation to nation. Thus, while natural gas is the main hydrocarbon in Bolivia and Peru, the reserves of Ecuador and Venezuela are mainly of oil. Finally, mineral coal is the most important resource in Colombia.

Although hydrocarbon reserves are significant in practically all the nations of the Region, the situation in the Andean Region is highly influenced by Venezuela's supply of resources. This country contributes with a little over 90% of the region's oil and natural gas reserves. On the contrary, the Region's mineral coal concentrates mainly in Colombia (81%).

The significance attributed to hydrocarbons in the region may be appreciated in Figure 2, which shows the temporal horizon of the production of each type of hydrocarbon should the production registered in 1995 be maintained.

Figure 2 Hydrocarbon reserves / production ratio within the Andean Region - 1995



However, strong asymmetries are registered in the Region's hinterland. In the case of oil, the highest temporal horizon is shown by Venezuela and Ecuador (64 and 24 years, respectively), since the rest of the countries registered in 1995 a reserve / production ratio which ranged from 8 to 14 years. With the exception of Bolivia and Peru, which were net oil and petroleum-product importers in 1995, the remaining three countries exported between 57 and 89% of the production of crude oil and petroleum products.

In the field of natural gas, foreign trade in the Region is still limited, and only Bolivia regularly exports natural gas to Argentina, such exports representing in 1995 54% of its production. The domestic market for natural gas is also little developed throughout the member nations, with the exception of Venezuela, where it represents 54% of the net energy supply. Nonetheless, as will be later shown, all countries from the region are striving to develop their natural gas market.

Hence, the reserves / production ratio does not exactly show the magnitude of the resources available in each country when production is little developed. Such is the case of Peru, whose temporal horizon is almost 19 times that of Colombia, although they have practically the same volume of natural gas reserves.

In turn, the high temporal horizon registered by coal production within the Andean Region has to do both with the magnitude of reserves as well as with the relatively low current production (less than 10% of the oil production). Nonetheless, current production volumes depend on foreign markets (to which 78% was allotted), since mineral coal only supplied 3% of the region's energy requirements in 1995.

3 The development of the Andean energy system

Unless otherwise stated, information from the Energy-Economic Information System (SIEE, in its Spanish abbreviation) from the Latin American Energy Organisation (OLADE) will be used for the analyses submitted in this item for each one of the member nations of the Andean Region.

3.1 Final energy consumption

Final energy consumption within the Andean Region rose steadily during the last 25 years at an average yearly rate close to 4%, until reaching 3400 Petajoules in 1995. It is worth pointing out that this swift expansion in energy consumption coincided with a biomass-substitution process, as may be appreciated in Figure 3. Thus, the rise in energy service measured in terms of the energy actually used by consumers was even higher in this period.

Indeed, biomass, which at the beginning of the 1970s represented 27% of the Region's final consumption, decreased its share to less than 16% in favour of the expansion of natural gas and electricity consumption, which practically doubled their share. Biomass substitution was especially significant in Ecuador (from 53% to 19%), Colombia (from 35% to 25%) and Peru (from 40% to 35%). On the contrary, Bolivia shows an irregular trend throughout the period, with a 4% rise between end years (25% to 29%). Venezuela, in turn, practically registers no biomass consumption throughout the period under evaluation.

Aside from the process of substitution among sources in final consumption, the growth rate shows distinct differences among the member nations, Peru and Venezuela representing the extreme cases, with average rates of 1.5% and 5.3%, respectively. The strong expansion registered in consumption in Venezuela has allowed it to increase its share in regional consumption from 30% in 1970 to 42% in 1995, to the detriment of Peru's share, which fell from 26% to 14% in 1995.

Figure 3 Evolution of final energy consumption within the Andean Region

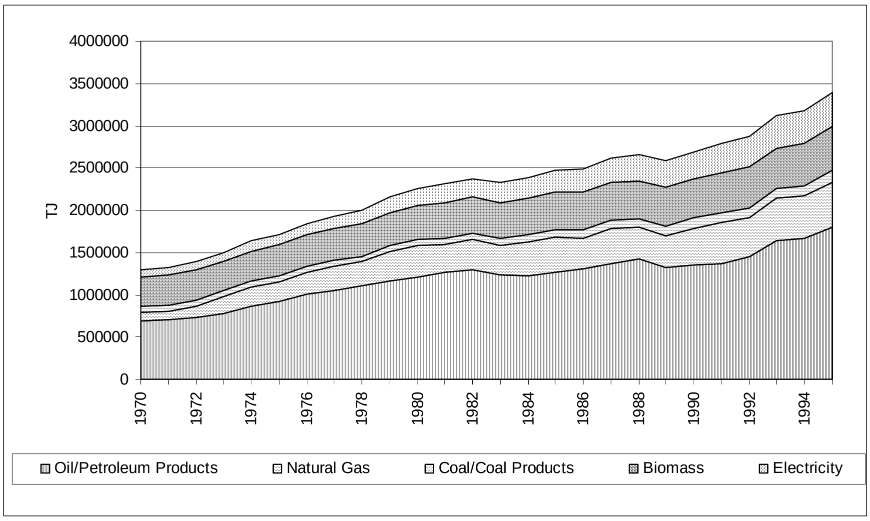
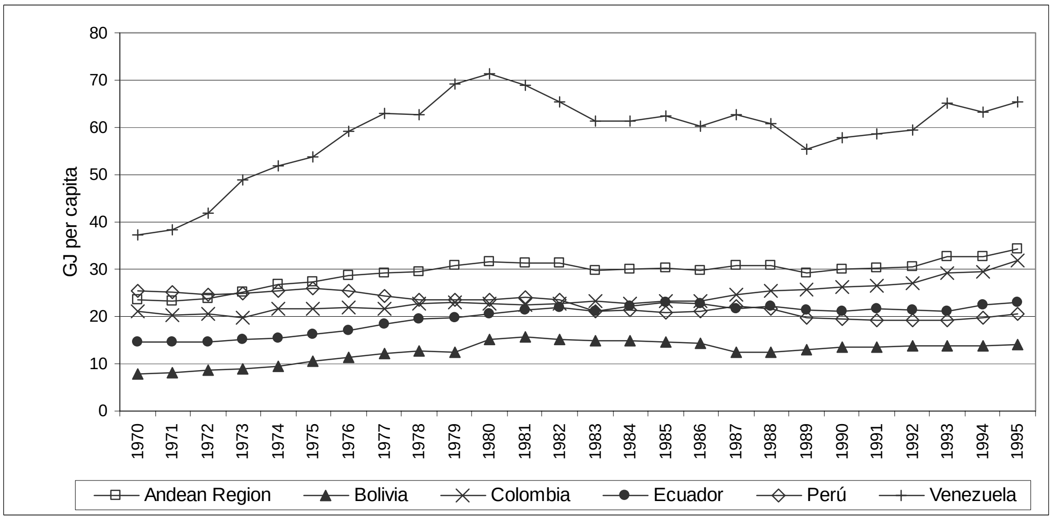


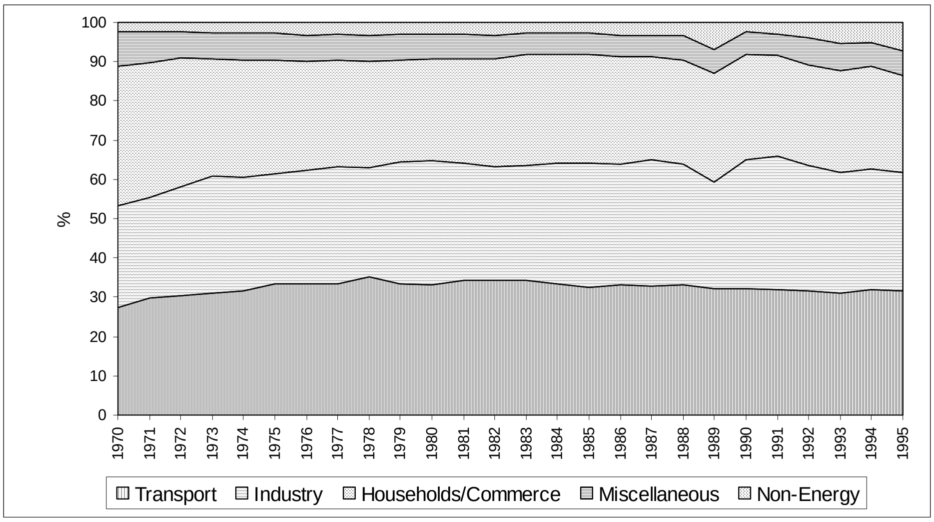
Figure 4 shows, by way of an indicator of the significance of these differences, the evolution of final per capita consumption for the Region and its member nations. As may be appreciated, Venezuela doubled regional averages in 1995, notwithstanding the fact that the strong expansion registered in the 1970s came to a halt. The other nations of the region show a more homogeneous situation among them, notwithstanding certain differences.

Figure 4 Final per capita energy consumption within the Andean Region



Throughout the period, industry and transport were the most dynamic sectors, representing as a whole in 1995 62% of the Region's final consumption. As Figure 5 shows, the main changes in the sectoral final consumption structure were registered during the 1970s.

Figure 5   Sectoral structure of final energy consumption within the Andean Region



In such decade, industry and transport gained a 6% share each, to the detriment of the household and services sector, whose share fell from 35% to 26%. Since 1980, the share of these three consumption sectors shows certain stability, only disturbed by fluctuations on account of consumption for non-energy purposes. Nonetheless, such fluctuations seem more associated with difficulties to identify the energy volumes aimed at non-energy purposes than with actual variations.

The sectoral structure of final consumption is not homogeneous in the Region's hinterland. The significance of industrial consumption ranges from 40% for Venezuela to 15% for Peru and Ecuador, with intermediate values for Bolivia (22%) and Colombia (29%). It is worth mentioning that mining consumption in Peru is classified under Miscellaneous, representing 13% of total consumption.

Less fluctuations are noticed in the influence of energy consumption for transport, which ranges from 27% (Peru) to 40% (Ecuador). In the case of Ecuador, biomass substitution within the household and commerce sectors favoured the fall in the share of consumption in this sector (from 55% in 1970 to 34% in 1995), offset by transport (from 25 to 40%). Only Venezuela shows a relatively significant drop in transport throughout the period (from 41 to 33%).

Household and commerce consumption still maintain a high influence in almost all Andean nations, from 43 to 29%, with the exception of Venezuela, where they only represent 15% of final energy consumption.

3.2 The electricity sector

Electricity consumption rose steadily throughout the period at a yearly 6.2% rate, until reaching 116 TWh in 1995, as Figure 6 shows. 50% of the electricity consumption is concentrated in Venezuela, which gained 7% in its share of the Region's total amount.

The highest growth rate was registered in Ecuador (yearly 8.9%), which practically allowed it to double its share since 1970, reaching in 1995 6% of regional consumption. Peru registered the lowest growth rate (yearly 3.7%), especially during the 1980s, falling from 20% in 1970 to 11% in 1995. Colombia, in turn, shows an evolution quite similar to that of the Region as a whole.

Figure 6 Evolution of electricity consumption within the Andean Region

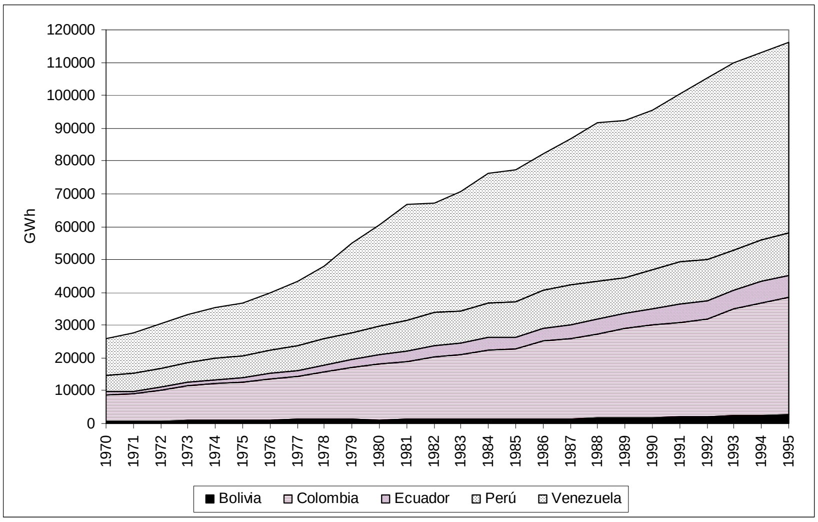
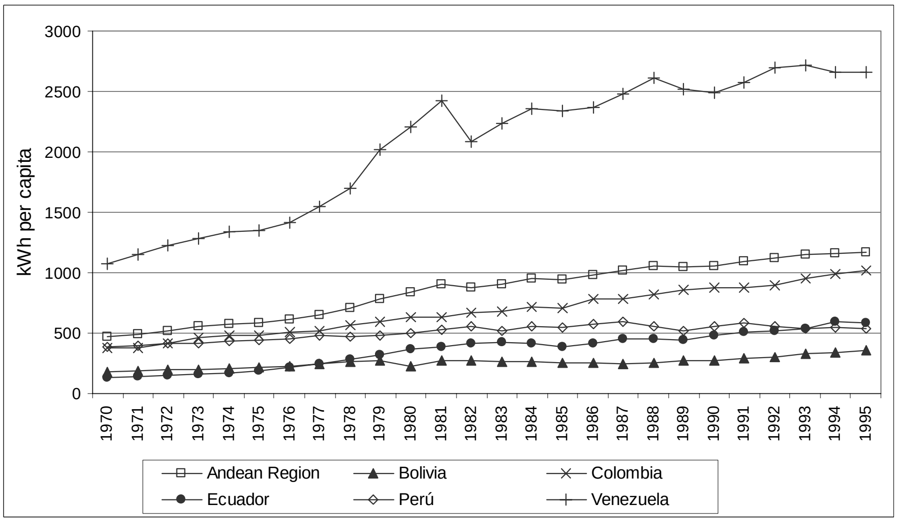


Figure 7 shows the significance of this evolution in terms of per capita electricity consumption for the Region as a whole and its member nations. Once again, we appreciate the influence of Venezuela over the regional averages, with a blasting growth as from the middle of the 1970s and until the early years of the 1980s, equivalent to a yearly 10.7%.

Figure 7 Per capita electricity consumption within the Andean Region

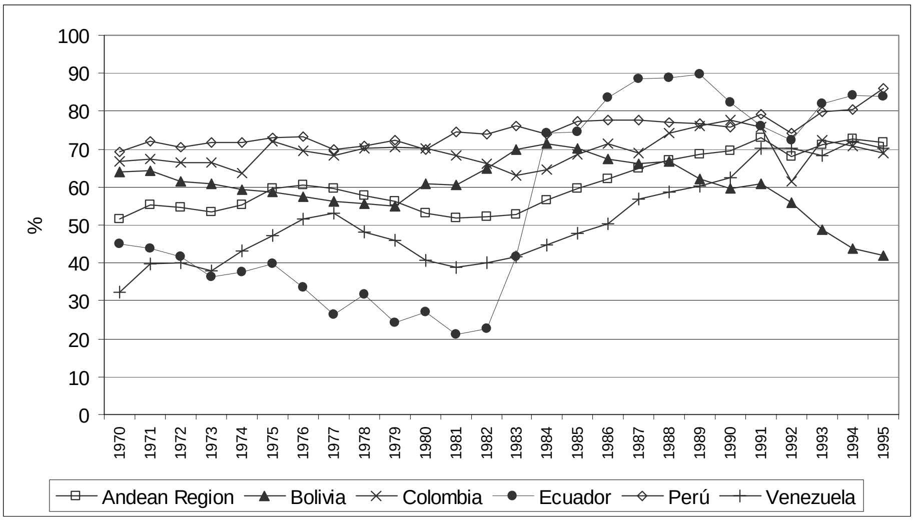


The rise in electricity consumption throughout this period was associated with the expansion of the coverage of the service and an increase in the share of household and service consumption, which grew from 48% to 53% of total electricity consumption in the Region. This phenomenon was registered with more or less intensity throughout the member nations. The current influence of household and commerce consumption ranges from a maximum of 67% (Ecuador) and a minimum of 38% (Peru). It is worth mentioning that the significance of electricity consumption in mining activities in Peru is what causes the fall of the share of the household and commerce sectors in electricity demand.

From the point of view of the efforts to expand the electricity supply throughout this period, a rise in network losses - from 11% in 1970 to 21% in 1995 - added to the fast growth in final consumption. With the exception of Bolivia, which shows an opposite trend, all the countries from the Region experienced the same problem, which intensified as from the early years of the 1980s.

An ample part of the expansion in electricity supply was based on the use of the hydro resource, as Figure 8 shows. Indeed, the share of hydroelectricity in electricity generation within the Andean Region rose from 51% in 1970 to 72% in 1995.

Figure 8 Hydroelectric contribution to electricity generation within the Andean Region



The high hydro share at the beginning of the period was sustained by Peru, Colombia and Bolivia, where hydro contributed with some two thirds of generation at national level. Ecuador and Venezuela, in turn, even when hydroelectricity is important, had a not so determining contribution.

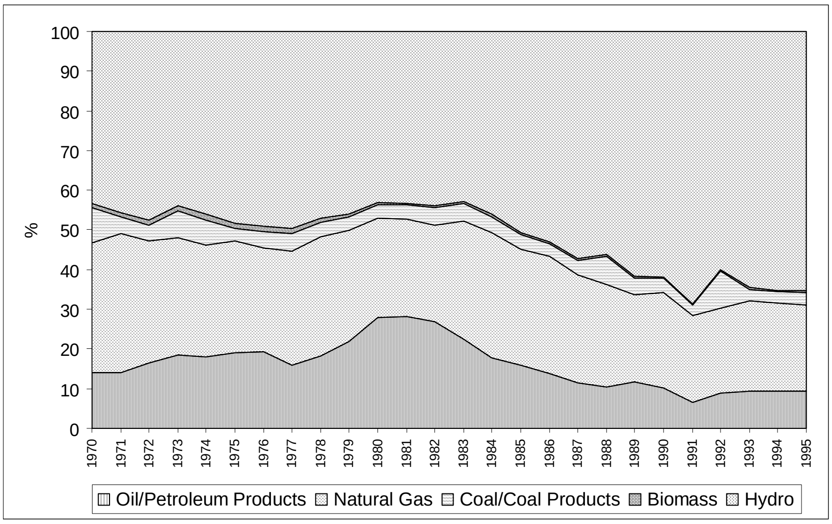
Notwithstanding natural fluctuations due to prevailing hydrological conditions at each moment, it may be stated that hydroelectric contribution has consolidated in Peru and Colombia throughout this period. Ecuador and Venezuela have substantially altered their generation structure, with a hydroelectric contribution respectively reaching 84% and 70% of total generation. Bolivia is the only member nation in which hydroelectricity has lost significance in these past years.

The alteration of the generation structure was shown in the type of input used in power stations, as Figure 9 shows. A 36% yield was adopted in this figure for hydroelectric plants, which is higher than the average yield of the Region's thermal stations throughout the period.

As may be appreciated, fossil fuels burnt in power stations in 1995 represented 34% of the total input, natural gas registering 63% of the total amount of this type of fuel. Only at the beginning of the 1980s, and due to the influence of the Venezuelan system, petroleum products represented 29% of the total input in power plants.

In general terms, and with the exception of Bolivia, the Andean nations reduced their contribution of hydrocarbons in the total input to power stations in favour of a higher use of their hydroelectric resources.

Figure 9 Input structure in power stations within the Andean Region



In those countries in which the natural gas industry is more developed (Venezuela, Bolivia and Colombia), natural gas is the most burnt hydrocarbon in power stations. In the case of Bolivia and Colombia, the use of natural gas within power plants materialised during the analysed period, currently reaching 85% and 52% respectively of the total hydrocarbons burnt within power stations. Contrary to this, the natural gas share in Venezuela as for fuel burnt within power stations dropped from 87% in 1970 to 75% in 1995. Such evolution does not necessarily represent an intention to replace natural gas, but could be associated with the need to maintain certain levels of thermal generation in areas where there is no natural gas available, within a context of strong substitution of thermal generation with hydroelectricity.

The burning of mineral coal within power stations is almost solely concentrated in Colombia, the Region's largest coal producer. Nevertheless, the trend in this period is that of a falling share, notwithstanding the natural fluctuations resulting from the contingency of the hydro resource.

3.3 Gross energy supply

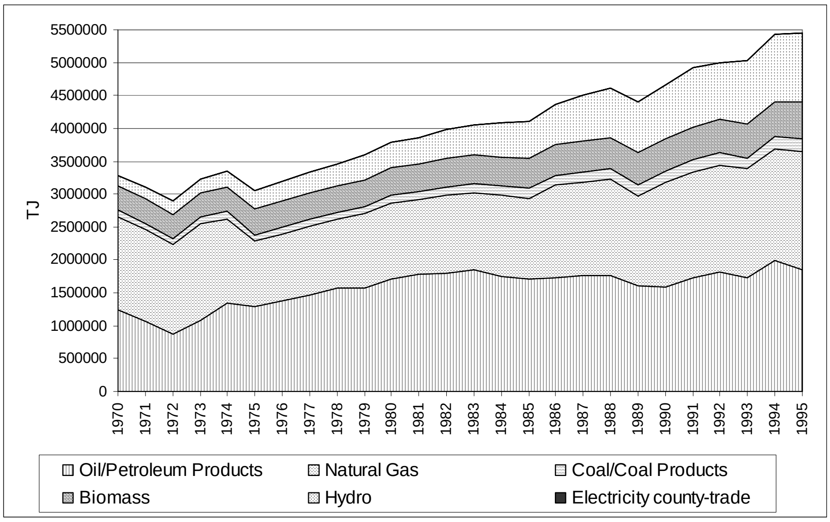
As may be appreciated in Figure 10, domestic gross energy supply within the Andean Region showed an upward trend throughout the period, with an average yearly rate of 2%, until reaching 5440 Petajoules in 1995.

This rise took place together with a change in the composition by energy supply sources, where the higher penetration of hydro energy stands out (from 5% to 19%), to the detriment of the natural gas share (from 43% to 33%) and, to a lesser degree, of oil (from 38% to 34%).

However, this joint result was not uniform in all member nations. With respect to hydro energy, the comments made when analysing the evolution of the electricity sector also apply here. It is sufficient to state that the contribution of hydro energy is of some 20% in all countries, with the exception of Bolivia.

Contrary to this, the liquid hydrocarbon share in gross supply shows well-differentiated situations. Only Colombia and Venezuela have managed to reduce their dependence on oil by-products during this period, from 40% and 35% in 1970 to 38% and 24% in 1995, respectively.

Figure 10   Gross energy supply evolution within the Andean Region



On the contrary, Ecuador's dependence on petroleum products rose until reaching 60% in 1995, due to a lack of natural gas and biomass substitution. Nevertheless, the 20% rise in the oil share was checked by a rising use of the nation's hydroelectric resources. The growth in the hydro share in Peru could scarcely offset biomass substitution, leading to an increase in oil dependence.

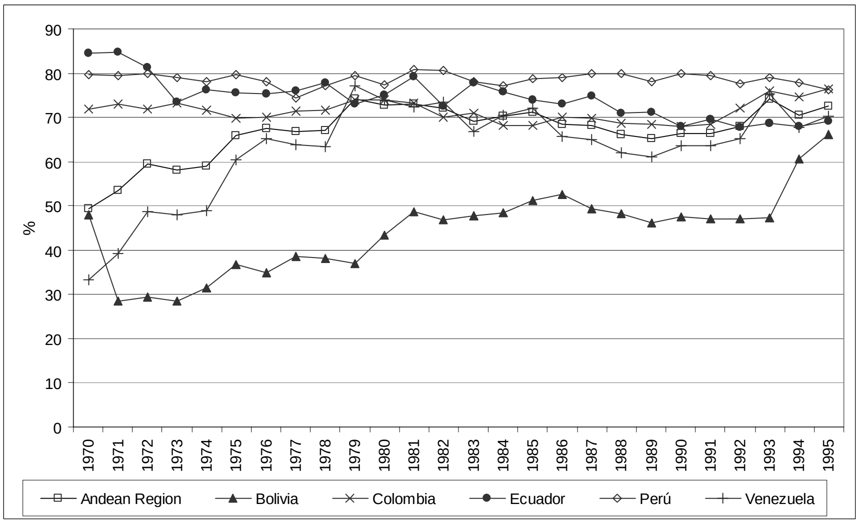
The natural gas share in gross energy supply registers a drop throughout the period, both within the Andean Region (from 43% to 33%) as well as in all member nations, with the sole exception of Colombia, where it remained around 11%. It is important to observe that these figures correspond to gross energy supply, that is, they include distribution, transport and transformation losses, as well as the energy produced and not used. Most of the unused energy in the Region throughout the period corresponds to natural gas associated to the production of crude oil.

The changes in the true role of natural gas in the supply of energy to the Andean Region are shown by the evolution of its share in net supply (gross supply minus unused energy), which rose from 21% to 31% in the end years. The most remarkable changes were registered in Bolivia and Venezuela, the two largest natural gas producers in the Region. When eliminating unused energy, a seemingly falling trend in the natural gas share in supply is reverted in both countries, registering a significant increase in the relative importance of this source. Indeed, natural gas - which only represented 4% of the Bolivian net supply in 1970 - rose to 25% in 1995. Although less significant, the rise in the natural gas share in Venezuela's net supply was also substantial (from 37% to 54%).

The reason for this difference lies in the control of unused energy, which represented 28% of the regional gross supply in 1970 and fell to only 4% in 1995. At the beginning of the period, over 40% of the energy supplied by Bolivia and Venezuela was not used. Venezuela managed to cut down this percentage to only 5% in 1995, while in Bolivia unused energy still represents 12% of the gross supply.

It is evident that this effort to improve the use of produced energy has resulted in an improvement in energy supply efficiency, measured in terms of the percentage of gross supply assigned to final consumption or the energy industries' own consumption, as shown in Figure 11.

Figure 11 Energy supply efficiency within the Andean Region



As may be appreciated, the highest rise in regional energy efficiency was reached during the 1970s, from 50% to 70%, a value that has remained relatively stable since then. It is important to observe that, throughout the period, certain factors have promoted higher efficiency, while others worked in the opposite direction. The first include the reduction of flared gas in oilfields and the improvement in the performance of power stations on account of a higher share of hydroelectricity. The main adverse factor was the sustained increase in electricity distribution and transport losses.

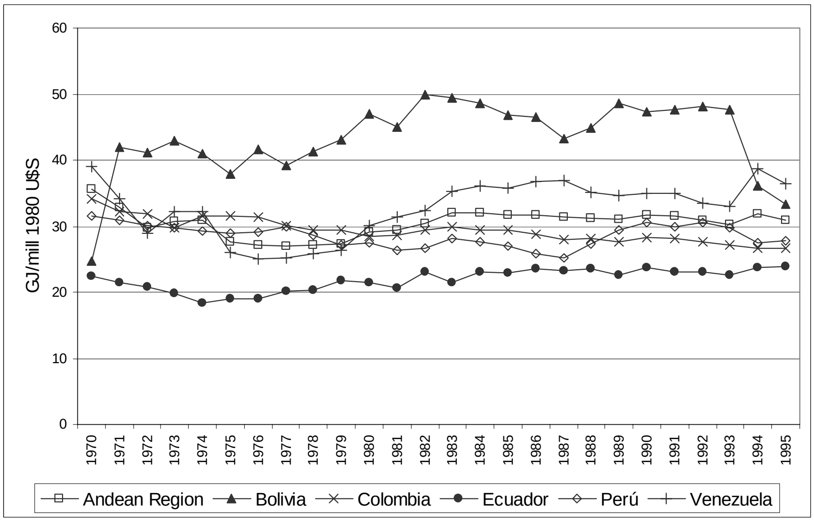
Although Bolivia and Venezuela managed similar achievements as for the increase in energy efficiency, it must be pointed out that improvements in Bolivia were slower, and only in recent years did the rise prove to be substantial, from 47% to 66%. Ecuador, in turn, is the only country in the Region to show deterioration in energy supply efficiency, originating both in higher losses within electricity networks as well as in a rise in natural gas flared in oil fields.

The highest efficiency reached in energy supply allowed maintaining a relatively stable per capita gross energy supply in the Region (somewhat near 55 GJ/inhabit.), notwithstanding a strong hike in energy consumption. The strife to check unused energy carried out by Venezuela at the beginning of the 1970s allowed it to bring down in a few years some 40% of the per capita gross supply, from 193 GJ/inhabit. in 1970 to 120 GJ/inhabit. in 1975. Since then, per capita gross supply has remained close to such value.

There is more irregularity registered in the energy intensity trend in the Andean economies, measured in terms of the gross energy supply per every GDP dollar, as Figure 12 shows. The GDP series of the Andean nations included in SIEE's socio-economic module, expressed in 1980 US dollars, was used to calculate the indicators shown in the above-mentioned figure.

Contrary to per capita consumption, this indicator proves to be quite sensitive to changes in the economy structure, as well as to fluctuations at economic activity levels which affected all Andean nations during this period. In general terms, it is verified that the periods of economic expansion coincide with a drop in energy intensity, while recessions lead to a rise in intensity due to the inertness of household consumption.

Figure 12 Energy intensity within the Andean Region



At the beginning of the 1970s, two factors joined to reduce energy intensity by 20%, namely: economic expansion and an improvement in energy supply efficiency. The economic standstill during the 1980s, which specially affected Venezuela and Bolivia, reverts this falling trend in energy intensity, although not regaining the values registered in the 1970s.

4 GHG emission within the Andean energy system

Although the development of the energy system of the Andean nations has surely led to a significant number of local environmental impacts, we shall focus here solely on the analysis of greenhouse effect gases (GHG). Of all thermoactive gases emitted by the supply and consumption of energy, CO_2 is undoubtedly the most significant and the only one whose volume solely depends on the type of fuel and is independent of the special characteristics of the each burnt fuel.

Hence, and within a long-term historical perspective, it was opted to analyse solely the evolution of CO_2 emission as an indicator of past trends in the contribution of the Andean nations to the global warming phenomenon.

The calculation of CO_2 emission was carried out as from data on energy consumption and supply provided by SIEE, and the corresponding emission was registered using emission factors from the emission inventories of the countries analysed. This procedure was chosen after comparing the emission calculated in the SIEE environmental module with the respective GHG emission inventories of the Andean nations. Differences in emission factors, as well as in the calculation methodology, showed the need to calculate once again historical CO_2 emission in a way which was consistent with the GHG Emission Inventory reports from the Andean nations.

4.1 Total CO_2 emission

As may be appreciated in Figure 13, total CO_2 emission rose between 1970 and 1995 at an yearly average rate of 2.9%, until reaching 276000 Gg in 1995. However, the rate has not been uniform throughout the period. During the economic expansion registered in the 1970s, emission rose swiftly at a yearly average rate of 4.8%. The recession which took place in the 1980s checked emission, which only rose at an yearly average rate of 0.7%. Emission regained its growing pace during the first five years of the 1990s, at an average yearly rate of 3.5%.

Figure 13 Total CO_2 emission from the energy system within the Andean Region

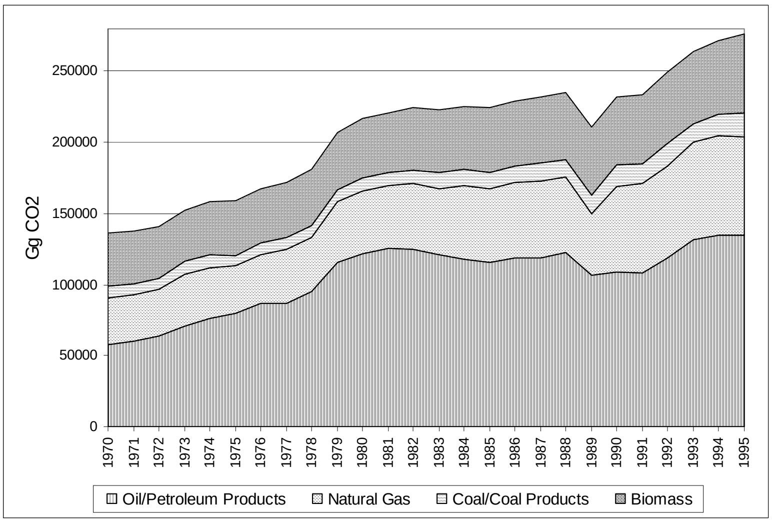


Figure 13 also included the emission originated in the burning of biomass so as to provide a more thorough idea of the true growth rate of total emission, for the process to substitute biomass with fossil fuels to meet the Region's energy requirements during this period led to a swifter rise in non-biogenic emission (an yearly 3.2%). Evidence of this is given by the reduction of biomass share in total emission, from 27% in 1970 to a current 20%.

Ecuador, which registered the highest biomass substitution in all Andean nations (from 53% to 19% of total consumption), clearly shows the impact over the growth rate of non-biogenic emission. During the 1970s, non-biogenic emission rose at an average yearly rate of 11.5%, against less than a yearly 5% in total emission. As from 1980, we notice higher coincidence between both rates due to the suspension of the biomass substitution process.

Specifically as regards non-biogenic emission, the oil and petroleum products share substantially grew during the 1970s (from 59% to 70%), not only due to a rise in the use of petroleum products but also on account of a reduction in natural gas fugitive emission originating in natural gas flaring in oil fields.

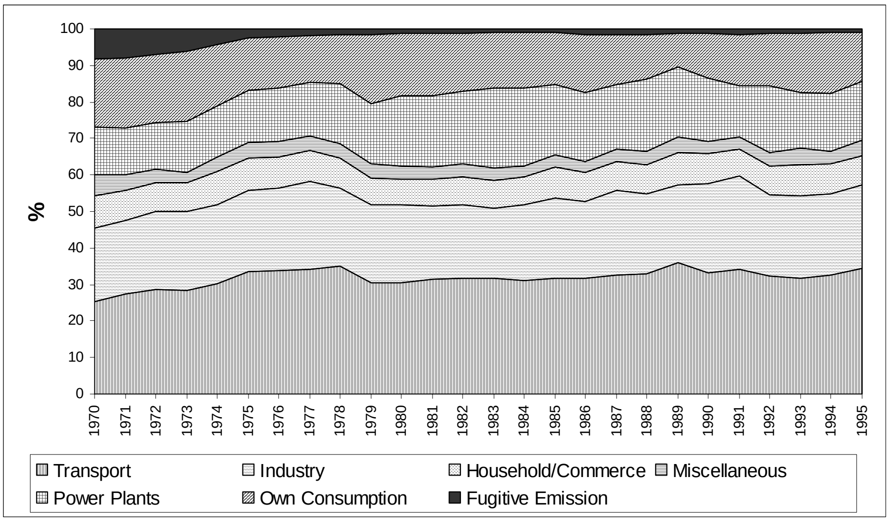
Indeed, the control of the volumes of flared natural gas, which as we have seen represented a rise in energy efficiency, allowed to bring down fugitive emission by 75%. As from then, a more intensive use of natural gas increased its share to 32% of total non-biogenic emission, thus decreasing the contribution of oil products to 61%.

Emission from coal burning is not significant to the Region as a whole (less than 10% of total non-biogenic emission). Most of this emission originated in Colombia, where coal continues to contribute with 25% of total emission, even when the relative significance of this source has fallen during the analysed period.

Together with the energy production and consumption volumes in each country, the space distribution of non-biogenic emission was also highly concentrated in Venezuela and Colombia, which in all contributed with some 80% of regional emission. In general terms, the period registered a rise in the Ecuadorian and Bolivian share on account of the loss of relative significance of Peruvian emission in the Region.

As concerns emission sources, Figure 14 shows the changes registered over the last 25 years in the sectoral structure of non-biogenic emission within the Region.

Figure 14 Sectoral structure of non-biogenic CO_2 emission within the Andean Region



The transport sector represents the most important source of emission, contributing since the middle of the 1970s with close to one third of total non-biogenic emission. Industry, in turn, contributes with a little over 20%, although its share registered fluctuations which went side by side with the changes in industrial activity levels.

The rest of the final energy consumption sectors (Household, Commerce, Public, Mining, Fisheries, Agriculture and Construction) have a scarce share in non-biogenic emission, and registered a strongly falling trend throughout the period. In 1995, their overall contribution was about half that of industry, and of only 35% of that corresponding to transport. Nonetheless, should we consider the total emission of these sectors, including that resulting from the burning of biomass, their emission would exceed industrial emission.

Among the activities linked to the supply of energy, we must point out the significance of emission from the own consumption of the energy industries, mainly the oil industry. This emission has a relative significance similar to that of power stations, although both registered fluctuations throughout the period. It is evident that this fact admits two causes. In the first place, the activity level of the oil industry is associated to exportation rather than to supplying the domestic market. In the second place, more than 50% of electricity generation within the Region throughout the period came from hydroelectric plants, currently reaching 72%.

The relative significance of emission from energy supply varies from one country to another depending on its characteristics. For example, the emission associated to the burning of fuel for the production of hydrocarbons (own consumption) is specially significant in Venezuela, where it represented 21% of total non-biogenic emission in 1995 and, to a lesser extent, in Bolivia (13%). However, the historical trend in this type of emission is opposed in both countries. While in Venezuela the emission of the oil industry reduced its share by one half throughout the period, in Bolivia its relative importance is currently two and a half time higher.

In the same way, differences are registered among the nations with respect to the role played by emission from hydroelectric plants. To this respect, Ecuador stands out, where hydroelectric stations reduced their share to less than 10% since the middle of the 1980s, when the hydroelectric share in the supply of electricity rose four times. In the rest of the countries, on the contrary, the importance of power stations in total non-biogenic emission rose throughout the period, notwithstanding the higher share of hydro supply. The highest growth is observed in Bolivia, which, as we have seen, is the only country in the Region registering a systematic fall of hydro contribution since the middle of the 1980s.

Fluctuations in the relative importance of activities related to energy supply in total emission are logically offset by final consumption sectors. The transport sector is in all countries the strongest source of emission, with rising significance throughout the period. The highest contribution is reached in Ecuador, where it represented 50% of total emission in 1995. Only in Venezuela the contribution of the sector is lower than 29%, fluctuating around 40% in the remaining countries.

Differences in the production structures of the Andean nations are clearly shown in the relative importance of industry emission. Regional average values are highly influenced by the situation of Colombia and Venezuela, where industrial emission represented 29 and 24%, respectively, of the total emission registered in 1995. It barely exceeds 10% of total non-biogenic emission in the rest of the countries, with a general downfall trend. It must be noted that the significance of the mining activity in Peru, which is included in the Miscellaneous sector, places emission from this sector in second place, after transport. Non-biogenic emission from this sector reached in 1995 a volume similar to that registered in 1970, having recovered in the last years from a nearly 40% fall between 1970 and 1989.

Emission from the Household and Commerce sectors is in turn significant only in Ecuador and Peru, with a 16 and 15% share, respectively. The rising trend in emission from this sector in Ecuador led it to gain second place as source of emission from the industrial sector. Contrary to this, household and commerce emission in Venezuela fluctuated around 6% of total emission.

4.2 CO_2 emission indicators

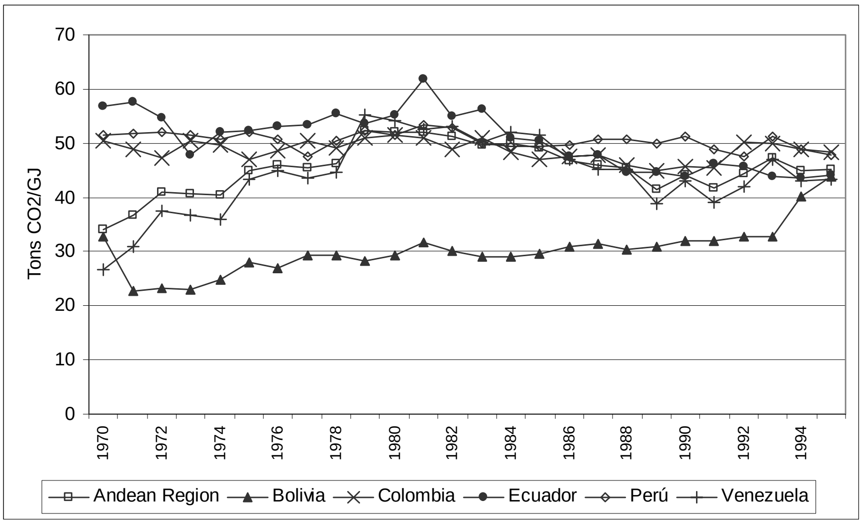
The following emission indicators were calculated with a view to placing this total emission evolution in perspective:

- specific CO_2 emission, measured as the amount of emitted CO_2 by the energy unit used
- Unit CO_2 emission from power stations, measured as the amount emitted per generated GWh
- per capita CO_2 emission
- CO_2 emission intensity, measured as emission volume by GDP unit

5 Specific CO_2 emission

On account of how it is calculated, specific emission proves to be a good indicator of the influence of the process of substitution among sources on average emission. However, it is incapable of registering the improvements which result from higher energy efficiency. For the purposes of the calculation shown in Figure 15, total specific emission was calculated relating total non-biogenic emission (including both that resulting from the burning of fossil fuels as well as fugitive emission) with the gross domestic energy supply.

Figure 15 Total specific non-biogenic CO_2 emission within the Andean Region



Total specific emission within the Andean Region shows two opposed trends during this period. It rose some 50% during the 1970s, only to drop some 14% between 1980 and 1995. The initial behaviour of the series shows the impact of fugitive-emission reduction and of the rise in the share of the other hydrocarbons in energy supply. As from 1980, the fall in specific emission seems mainly related to a higher penetration of electricity and natural gas in final consumption, as well as to the higher contribution of hydroelectricity.

Only Venezuela shows a behaviour quite similar to that of the Region as a whole, since the significance of its energy system is vital for the mean regional values. In the case of Ecuador, the evolution of specific emission was mainly determined by the behaviour of the electricity sector against scarce changes in the final consumption structure. Until 1982, a rise in emission from power stations was registered, only reverted as from 1983 through higher hydro contribution.

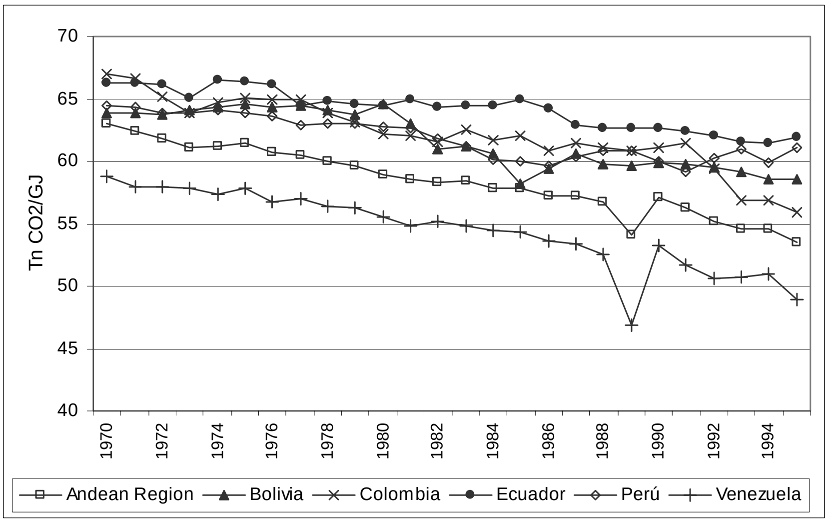
The specific emission of Peru and Colombia, in turn, show certain stability throughout the period, although we note a downward trend as a result of a higher penetration of electricity in final consumption and a growing hydro share in electricity generation.

The emission pattern in Bolivia, with a clearly different trend from the other Andean nations, poses certain doubts as to the reliability of the starting data, particularly that referred to the efficiency of thermal stations at the beginning of the period (over 60%).

Aside from historical trends, note should be made of the similarity of the specific emission of all countries in 1995, which fluctuated around 45 Tons of CO_2 / GJ.

With a view to better appreciating the effects of the substitution among sources on emission, Figure 16 presents the evolution of specific emission in final energy consumption.

Figure 16 Specific non-biogenic CO_2 emission from final consumption within the Andean Region



As may be appreciated, the specific emission from end-use sectors within the Andean Region decreased systematically throughout the period, being 15% lower in 1995 than the values registered in 1970. Such behaviour is clearly influenced by the trend registered in Venezuela, and shows higher electricity and natural gas share in final energy consumption, as well as higher use of energy for non-energy purposes. It was precisely this increase in the use of energy for non-energy purposes the factor which brought about the valley in specific emission registered in Venezuela in 1989, although that same year showed a contraction in energy consumption, specially within the industrial and transport sectors. The base information available to carry out the present study did not allow us to elucidate the origins of this specific modification in the destination of consumed energy, which could well correspond to lack of homogeneity of the series in the detection of use for non-energy purposes

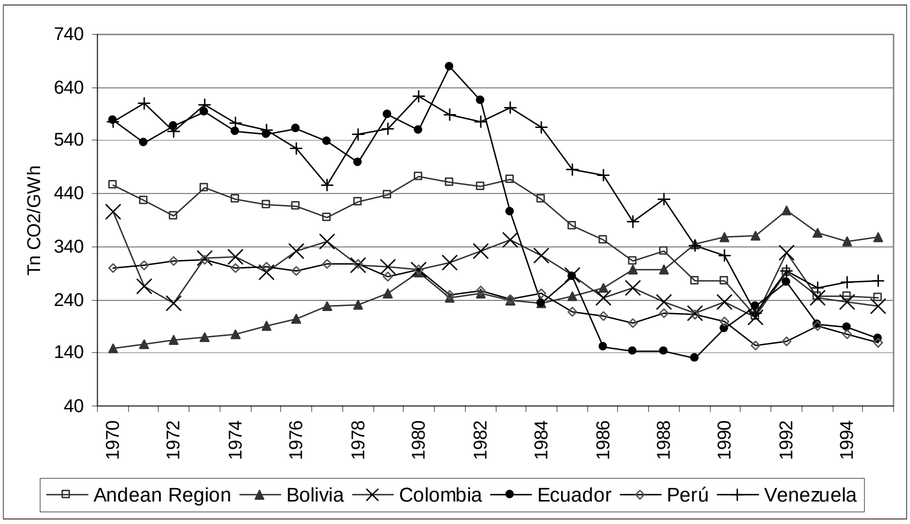
It should be pointed out that the specific emission of Venezuela was systematically below that of the rest of the Andean countries, on account of a higher penetration of natural gas in the supply of domestic energy consumption. There is a similar trend registered in the other nations, which shows the impact on emission of a higher electricity penetration in final consumption.

6 Unit emission from power stations

To calculate unit emission from power stations, total emission originated in the stations, including biogenic emission, was related to the electricity produced. In this case, it was not possible to consider only non-biogenic emission because the available information did not allow to identify the generation reached as from biomass, particularly used by self-production stations. Nevertheless, biogenic emission from power stations was below 3% of total emission in the Region throughout the period, and shows a falling significance, representing less than 1% in 1995. However, biogenic emission from power stations in Bolivia and Peru represented 18% and 23%, respectively, of station emission in 1970. Although its relative importance was reduced throughout the period, it still contributed with 10% and 6% of station emission in 1995.

Figure 17 shows the evolution of unit emission from power stations within the Andean Region, as well as that in each of the member nations, between 1970 and 1995.

Figure 17 Unit CO_2 emission in power stations within the Andean Region



The first element to point out is the scattering in unit emission until the beginning of the 1980s, with a 1 to 4 relation in 1970 between the lowest emission (Bolivia) and the highest one (Venezuela and Ecuador). Even if we eliminate the value of Bolivia, which - as previously stated - poses doubts on the reliability of the information from SEI, there would be still be a scattering of 90%.

To explain this event, as well as the behaviour of unit emission, 3 factors which influence this indicator were analysed, namely: the hydroelectricity share, the efficiency of thermal stations and the type of fuel burnt in thermal stations.

The higher initial emission in Venezuela and Ecuador was mainly due to a lower hydro share, 32% and 45%, respectively, against over 65% in the rest of the Andean nations. The rise in unit emission at the end of the 1970s coincided with lower hydro contribution and, in the special case of Venezuela, with a higher proportion of petroleum products among the fossil fuels burnt in power stations. The sustained fall of unit emission since the beginning of the 1980s was a direct consequence of the incorporation of new hydro supply. As a result of this process, unit emission fell some 67% in Ecuador and some 53% in Venezuela.

Unit emission in stations in Colombia shows throughout the period the fluctuations which are to be expected in a system with high share of hydroelectric stations with low regulation capacity. Nonetheless, a falling trend is registered since the middle of the 1980s on account of a more intensive use of natural gas, to the detriment of coal.

Peru, together with Ecuador, registers at present the lowest unit emission within the Andean Region. The systematic decrease observed in unit emission since 1980 (of around 40%) admits 3 causes, namely: an increase in the share of hydroelectricity (of some 70% to some 86% of total generation); a slight improvement in the thermal efficiency of thermoelectric stations (from 27% to 35%) and the lower relative importance of generation through biomass (from 7 to 4%).

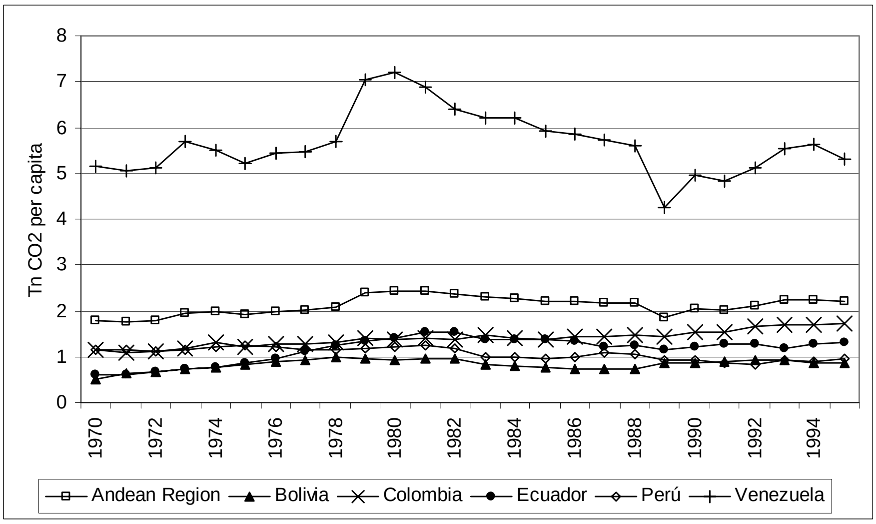
On account of lack of reliability from the information on input in Bolivian power stations for the first years of the period, we will only consider what was registered as from 1983, when the thermal efficiency of the stations begins to reach reasonable values. The rise in unit emission registered as from 1987 was mainly caused by a loss in the share of hydroelectricity supply, which only contributed with 42% of total generation in 1995. The rise in unit emission would have certainly been higher had part of the petroleum products not been substituted with natural gas.

The evolution of unit emission in power stations within the Region results from this change process in the electricity systems of the member nations. Considering the weight which the Venezuelan system has in regional averages, these follow the trends outlined for Venezuela, with an average unit emission reduction of some 47% between 1984 and 1995.

7 Per capita emission

As Figure 18 shows, the average non-biogenic emission of CO_2 per inhabitant has experienced a quite stable behaviour in the last 25 years, with a rise lower than a yearly 1%.

Figure 18 Per capita non-biogenic CO_2 emission within the Andean Region



In terms of per capita emission, the contribution made by the Andean Region to global warming was and still is very scarce. Indeed, its 2 Tons of CO_2 per inhabitant per year does not represent even 20% of the average per capita emission of the industrialised nations members of the Organisation for Economic Co-operation and Development (OECD). Even Venezuela, with a per capita emission over twice the averages of the Andean Region, registers emission 50% lower than that of OECD nations.

Given the accrued nature of the effect of thermoactive gases on weather, the historical responsibility of the Andean nations as regards GHG concentration in the atmosphere would be even lower, at least with respect to their energy systems.

Quite on the contrary, the efforts made to base their supply structure in cleaner sources from an environmental viewpoint, such as hydroelectricity and natural gas, should translate into a credit with respect to the emission of thermoactive gases. It is precisely this “asset” in terms of their contribution to GHG concentration in the atmosphere which could be used by the nations to offset an eventual future rise in emission as the economic activity and the satisfaction of the energy needs of their population grow within their territories.

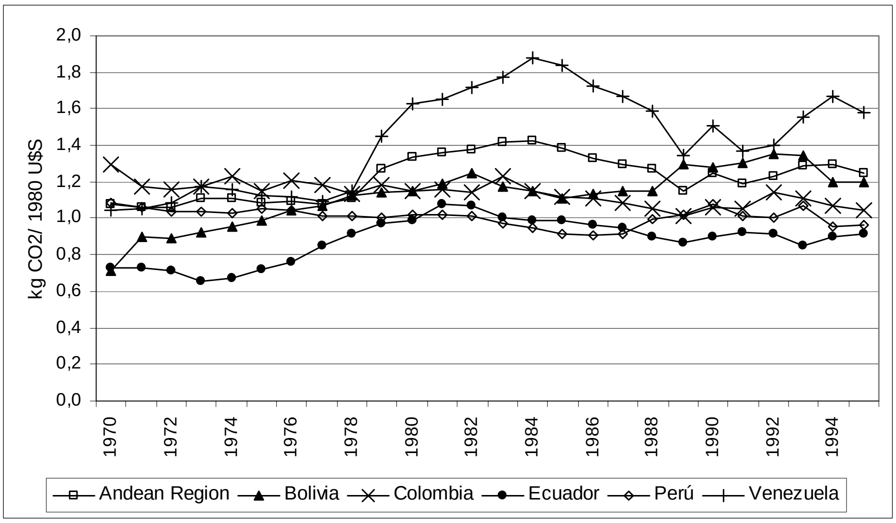
It should be noted that the values given in Figure 18 solely correspond to non-biogenic emission and, thus, their evolution was affected by the substitution of biomass in energy consumption. This process was more intense throughout this period in Ecuador and Colombia, leading to an increase in per capita emission higher than the regional mean value (yearly 3.1 and 1.4%, respectively, against a regional 0.8%). Nevertheless, this trend in per capita emission will hardly be extrapolated in the future, considering the current biomass share.

The evolution of per capita emission in Venezuela, in turn, deserves special analysis. The strong rise in energy consumption, especially electricity, led to a 40% increase in per capita emission during the 1970s, only partially dampened by a rise in the energy efficiency of supply. Since 1980, structural changes in electricity generation and a higher use of natural gas allowed to bring down per capita emission until reaching in 1995 similar values to those registered in 1970.

8 The intensity of non-biogenic emission by the Andean economy

The emission intensity shown in Figure 19 was calculated relating the total non-biogenic emission of the energy system with the corresponding Gross Domestic Product (GDP) values consigned in the SIEE's socio-economic module, expressed in constant 1980 US dollars.

Figure 19 Non-biogenic CO_2 emission intensity within the Andean Region



The average regional value shows the fluctuations experienced by the Andean economies. During the economic expansion of the 1970s, emission intensity remained stable around 1.1 kg of CO_2 per US dollar of GDP. With the economic recession registered during the first half of the 1980s, emission intensity rose 30% on account of the higher weight of transport consumption and higher emission from power stations. This rise in hydro share allowed to reduce the emission intensity of the Andean economy as from 1984, its value being only 16% higher in 1995 than the value registered in 1970.

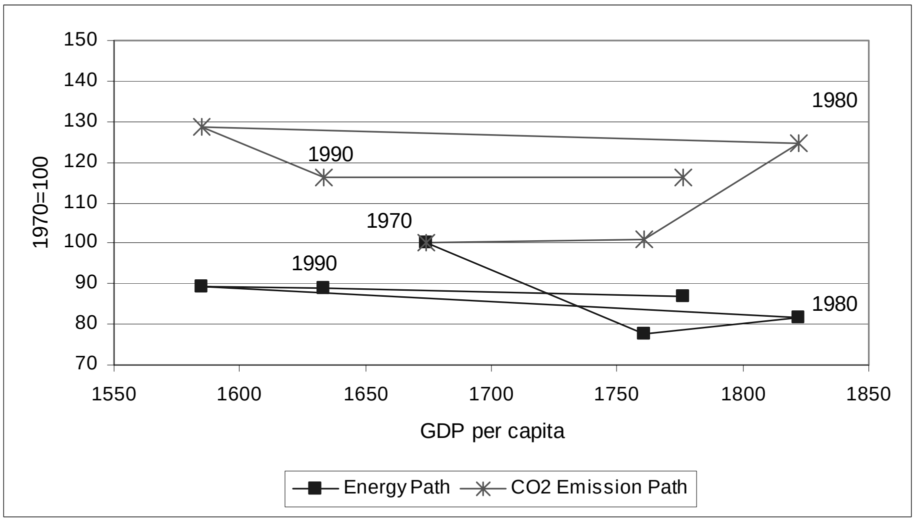
This indicator also shows a certain scattering among the values of the member nations, with minimum values for Ecuador and maximum ones for Venezuela. The rise in emission intensity within the Ecuadorian economy at the beginning of the period was associated to biomass substitution and with the development of the oil industry. A slightly downward trend is observed since 1982 due to the lower emission registered in power stations, which is currently 27% lower than the regional mean value.

Peru and Colombia, which today register an emission intensity lower than the regional mean value (23% and 16%, respectively) are the only Andean nations which show a downward trend throughout the period, following a drop in the energy intensity of their economies.

8.1 Energy and CO_2 emission paths

The trend followed by energy intensity (gross energy supplied per GDP unit) in accordance with per capita GDP variations marks the energy path of a country and allows to graphically relate the evolution in energy consumption and economic activity. At the same time, the CO_2 emission path represents the emission intensity trend (total non-biogenic emission per GDP unit) in accordance with the changes registered in per capita GDP. Figure 20 shows the energy and emission paths for the Andean Region between 1970 and 1995.

Figure 20 Energy and CO_2 emission paths within the Andean Region



As maybe appreciated, the trends of both energy and emission paths during the 1970s were opposed. Indeed, while energy intensity dropped some 20%, emission intensity rose some 25% within a context of economic growth which allowed to increase per capita income by 9%.

This behaviour of the regional mean values results from a series of phenomena with opposite effects. The paths corresponding to Colombia and Peru show a clear downward trend throughout this period, more significant as regards energy intensity than in the case of emission.

These achievements seem to have been offset by a rise in the specific emission of Ecuador and Venezuela. In the case of Ecuador, on account of the substitution of biomass with fossil fuels; and in that of Venezuela, because the reduction in the volume of natural gas flared in fields increased the share of petroleum products in the gross energy supply.

The economic recession registered at the beginning of the 1980s, which represented losses of 13% in regional average per capita income, brought about - as usually in this cases - a slight rise in energy intensity (9%) which was practically not shown in emission intensity on account of the use of less-emitting sources.

The recovery in economic growth since 1985 (12% rise in per capita GDP until 1995) did not substantially alter the energy intensity of the Andean economy. However, emission intensity dropped some 10% until 1990, to remain stable since then. Changes in the structure of electricity generation and the higher penetration of natural gas were the causes for a stable emission intensity since 1990, notwithstanding the economic expansion registered.

It should be mentioned that Colombia is the only Andean nation in which both the energy path as well as the emission one show a constant downward trend, with a fall close to 20% in both cases.

Prospect for the Andean Region in the field of energy

1 Introduction

In view of the scope of the present study, this Chapter sums up the forecasts which the nations themselves make on the expected evolution of their energy systems and on the way environmental aspects are contemplated in the determination of energy policies.

For the making of the present analysis, the representatives of the Andean nations were requested to send available energy plans, GHG emission inventories, and Climate Change Mitigation Studies. We further list the documents received as a result of this request, as well as any other documentation used for the analyses of the Andean Region carried out in the present Study, namely:

1.1 Bolivia

- Greenhouse effect gas emission by the energy-industrial sector in Bolivia. Freddy Tejada Miranda, Engineer, Ministry of Sustainable Development and the Environment, Bolivian Natural Resources Secretariat, Bolivian Climate Change Program
- Inventory of greenhouse gas emission of anthropogenic origin, Ministry of Sustainable Development and the Environment, Bolivian Natural Resources Secretariat, Undersecretariat of the Environment, Bolivian Climate Change Program, US Country Studies Management Team, 1996
- Preliminary evaluation of greenhouse gas emission mitigation options, Javier Hanna Figueroa, Engineer, Ministry of Sustainable Development and the Environment, Bolivian Natural Resources Secretariat, Undersecretariat of the Environment, Bolivian Climate Change Program
- Preliminary evaluation of greenhouse gas emission mitigation options, Ministry of Sustainable Development and the Environment, Bolivian Natural Resources Secretariat, Undersecretariat of the Environment, Bolivian Climate Change Program, US Country Studies Management Team, 1996
- Ecosystem vulnerability and adaptation to a possible climate change and analysis of greenhouse gas mitigation, Ministry of Sustainable Development and the Environment, Bolivian Natural Resources Secretariat, Undersecretariat of the Environment, Bolivian Climate Change Program, 1997.
- Institutional proposals, Juan Carlos Guzmán Salinas, Ministry of Economic Development, Bolivian Energy Secretariat, ESMAP - World Bank
- Bolivian Interconnected System, Energy expansion plan, 1996 - 2005 period, Update April, 1996.

1.2 Colombia

- Preliminary inventory of greenhouse gases: sources, sinks and reservoirs, Fabio González B, Ismael Concha P, Jorge I. Vallejo M, Humberto Rodríguez M.

Magazine from the Colombian Academy of Exact, Physical and Natural Science, Vol. XXI, No. 79, March 1997

- Preliminary inventory of greenhouse gases: sources, sinks and reservoirs - Final Report, Colombian Academy of Exact, Physical and Natural Science, July 1996
- Joint implementation to mitigate climate change in Colombia: the direction to follow, Juan Manuel Soto de la Cruz, Environmental Advisor, Ministry of Mines and Energy, January 1997
- Outline of a national mitigation plan proposal for Colombia, Colombian Academy of Exact, Physical and Natural Science
- Reference expansion plan, Generation - Transmission 1996 - 2010, Reviewed in 1996, Ministry of Mines and Energy, Mining - Energy Planning Unit

1.3 Ecuador

- Ecuadorian inventory of greenhouse gas emission - Draft Final Report - 1990, Ministry of Energy and Mines, Environmental Protection Undersecretariat, Alternative Energy Office, Ecuadorian Institute of Hydrology and Meteorology, May 1997
- Study on Ecuadorian energy policies, Executive Summary, Environmental Consulting Committee, June 1995
- Study on energy policy guidelines in Ecuador, Environmental Consulting Committee, Office of the President of the Republic, Ministry of Energy and Mines, October 1995
- Electric Sector Law, Official Register, year 1, No. 43, 10 October 1996
- Regulations for the transitory operation of INECEL, Official Register, year 1, No. 82, 4 December 1996
- Ecuadorian electricity system - Electrification Plan 1996 - 2010, Regional Electricity Integration Commission, Ecuadorian Federal Committee, July 1997

1.4 Peru

- Peruvian Study on climate change, Executive Summary, University of Engineering of Peru, October 1996
- Energy policy in Peru: the environmental dimension - Energy efficiency and the environment, Luis J. Geng, CONAM
- Reference electricity plan (to October 1996), Ministry of Energy and Mines, Technical Energy Office

1.5 Venezuela

- Preliminary National Greenhouse Gas Inventory, Venezuela, UNEP Project GF/4102-92-40. Draft, January 1995.
- Series of energy balances for the 1970 - 1995 period
- Evaluation of generation supply - 1996 - 2005 period - Update, OPSIS Planning Committee
- Estimate on fuel consumption within the Venezuelan Electricity System 1996 - 2006, EDELCA Electricity System Planning Division
- Venezuelan Electricity system - Energy and Power Forecasts - 1996 - 2020 period, Update

It must be noted that the Andean Region nations, as well as those of the rest of Latin America, are undergoing a process of restructuring of their energy industries, the depth and rate of which varies according to each nation. These reforms - aimed at attracting the participation of private capital and promoting more competition in the development of activities related to energy supply - clearly influence the characteristics of energy planning.

Regardless of the progress degree reached in the restructuring of energy industries, all countries continue carrying out prospective studies on the development of their electricity systems. Nevertheless, the nature of these studies -in terms of the certainty on future works - changes substantially as the evolution of the system lies more strongly on private initiative.

Integral planning or prospective studies on the energy sector prove to be less frequent, although it is fair to admit that - even under the exclusive State management of energy industries -, integral energy planning was not a common practice in all countries.

In accordance with these considerations, the following Sections provide the data gathered on energy and environmental strategies within the Andean Region nations, and a more in-depth analysis is carried out on prospects for the electricity supply, the only sector for which sufficiently detailed information was available.

2 The energy strategy of the Andean Nations

This notion will comprise both energy policy goals as well as energy supply regulatory and institutional arrangement set up by the Andean nations to meet their objectives.

On account of its significance on the expected evolution of energy supply, it has been deemed convenient to make at a first instance a summary of the reforms carried out as regards regulation and institutional arrangement within the energy industries of the Andean Region. Given the dynamic characteristic of the restructuring process, it is necessary to note that the information provided here corresponds to the degree of progress reached by the middle of 1997. Secondly, we provide the objectives of the energy policy of member nations, special attention being given to the role assigned to natural gas in their future energy matrix.

2.1 Energy industry restructuring within the Andean Region

In view of the scope of the present study, we shall solely refer here to the reforms carried out in the natural gas and electricity industries, even when the said reforms comprise the energy industries as a whole. Nonetheless, comments made on the upstream of the gas industry may also be extended to crude oil exploration and production.

Even when there are differences among the nations with respect to the scope of the reform and the degree of its implementation, it can be stated that an opening of energy activities to private capitals is taking place, with the elimination of the State monopoly in force until the beginning of the 1990s. Such de-monopolisation comes naturally hand in hand with the establishment of energy markets whose regulation degree depends on each country and on the corresponding product and / or process type.

2.1.1 The restructuring of the natural gas industry

To sum up the characteristics of the gas industry within the Andean countries, we shall follow the categories defined in the study on "Natural Gas in the energy policy of Latin America and the Caribbean" carried out within the OLADE / CEPAL / GTZ project on "Energy and sustainable development in Latin America and the Caribbean".

This categorisation considers three essential elements, namely: property structure, institutional organisation of energy activities, and the type of energy markets and their price-setting methods.

With respect to the property system, the following three categories were detected in the Region:

- *State property without opening or with limited opening*: resources and assets are the property of the State, even when their activities may be complemented by private companies. Limited opening in the case of upstream corresponds to the obligation of delivering the entire production generated by private companies to State companies in the field. Contrary to this, the downstream refers to third party access to the networks. This category includes the entire natural gas industry in Venezuela (limited opening in the upstream and without opening in the downstream), as well as the upstream of the natural gas industry in Colombia. It must be noted that the natural gas industry in Colombia is at the moment in full development, and that the general opinion - even of private investors - is that the role of the State will remain significant until markets are consolidated and the necessary physical infrastructure is developed.
- *Mixed property with total opening*: Companies are of private capitals or State and private companies coexist, the latter having access to the use of State installations and able to import the product. In the upstream, the opening refers to the free availability of production, while the downstream refers to the free access of third parties to the network. The entire natural gas industry in Bolivia and natural gas transportation in Colombia falls within this category.
- *Essentially private property with full opening*: The companies' capital is mostly private after the privatisation process of State companies, and private companies freely determine the destination of production. Hydrocarbon production regulation in Peru falls within this category. Although the development of the natural gas industry in Peru is still insignificant, the contract signed in 1994 with Maple Gas Corporation for the development of the Aguaytía field falls within this category.

In the case of Ecuador, natural gas production corresponds to natural gas associated to oil, and is only used to obtain condensates. The mainly State-owned system falls within the control of PETROECUADOR. However, the government is aiming at eliminating State monopoly over the natural gas industry, as well as on the other energy activities, incorporating the participation of private capitals. Anyhow, no substantial progress has been reached yet in the implementation of such changes.

As for institutional organisation, in general terms, the different stages of the natural gas chain are independent (vertical disintegration). Exploration and production linked to the oil industry, while transportation and distribution services are independent activities. Nevertheless, it must be noted that vertical disintegration is mostly virtual in the case of systems mostly owned by the State, with a view to specifying the operational results of the management of each process.

Although in all these cases the countries proclaim the State property of hydrocarbon resources, such property not always translates into comprehensive control over field exploitation strategy and over the destination of local production. In general, it may be stated that the systems aimed at attracting private investors to natural gas exploration and production mainly grant concessions which guarantee to the private investor the free availability of the product and of the foreign currency obtained in the trading of the corresponding production. This is the case of Bolivia and Peru. In Venezuela and Colombia, on the contrary, the entire private production must be sold to the corresponding State company.

The association of the opening to private investment to the vertical disintegration of the industry presupposes the intention to set a wholesale market for natural gas. Effective competition within such market will depend on the degree of supply decentralisation (horizontal disintegration). In the case of Peru, for example, there are restrictions in its hydrocarbon law for the horizontal reintegration of upstream activities, even when vertical reintegration is not banned.

The exploitation of transportation and distribution networks is regulated by its quasi-monopolic nature. In the systems aimed at establishing competitive wholesale markets for natural gas, third parties are enabled to access the network to guarantee the proper operation of the contracts between consumers and producers. Such is the current case of Bolivia and Peru. Colombia is planning to move further towards this plan in the future, but at the moment its networks are closed, even when there may be several transmitters and distributing companies. As previously pointed out, the aim is to grant more certainty to investors on the future prospects for their businesses during the first stages of network and market development. The Venezuelan system is also closed, under the exclusive jurisdiction of different State companies.

These types of organisation certainly carry influence over price-setting mechanisms within the wholesale natural gas market. Here, we may distinguish two categories, namely: free prices co-ordinated by market mechanisms or prices centrally fixed according to some economic rationale. In general, wholesale natural gas prices within the Andean nations are fixed centrally, although Colombia is aiming at a gradual opening of the market as such market consolidates.

The retail natural gas market - in the local distributor captive segment - is centrally regulated, even when not all nations have independent regulating bodies.

2.1.2 Electricity industry restructuring

In the case of the electricity industry, there is more homogeneity in the basic reform principles, even when there are still significant differences on the implementation degree as well as on organisational matters, which gives the new structure a distinctive national feature.

The promotion of private initiative and a competitive environment is mainly centred at electricity generation level, which, together with the opening of the electricity transmission and distribution networks, gives origin to the establishment of a wholesale market in which generators, traders and large consumers meet.

All plans aim at the necessary co-ordination in the operation of generation stations by means of the establishment of specific bodies to deal with the system’s load dispatching. In general, these are independent institutions, except for the case of

Colombia, where load dispatching is associated to the handling of the high-voltage transmission network.

All countries aim towards the vertical disintegration of the electricity industry as a favourable element for the establishment of a wholesale market, as well as for its clear operation. Nevertheless, the vertical integration of the different processes under the same business unit is tolerated, except for the case of Bolivia where it is expressly banned within the interconnected system and is only admitted within isolated systems.

Regulatory bodies have been set in all nations to control the performance of electricity companies, even where the State still owns the installations, in an evident attempt to guarantee that the State assume in a clear way its role of regulator of public service rendering.

Although this type of reforms is usually known as “liberalisation” or deregulation of the electricity industry, the operation of the electricity markets is far from lacking specific regulations, particularly as regards operation and reward settlements for operations registered within the wholesale market and for transmission services rendered.

In general, there are at least two operating modes within the wholesale market, namely: through the signing of supply contracts and eventual supplies (spot market or electricity pool). In certain cases, as those of Bolivia and Peru, the regulating bodies set top limits to eventual transactions between supply and demand. In Colombia, instead, prices within the electricity market are set in accordance with the system’s marginal prices.

It is important to point out that both in Ecuador and Venezuela the new system has not been fully implemented yet, and previous comments solely reflect the spirit of the law which regulates the rendering of the electricity service, detail regulations on operational aspects having not been developed yet.

Bolivia, Colombia and Peru, on the contrary, have already implemented the new regulatory system.

There are also significant differences among the Andean nations as regards the methods chosen to attract private capitals to electricity activities, as well as on the actual private share reached so far.

Bolivia and Ecuador have chosen methods for the capitalisation of public companies. In the case of Bolivia, private investors are allowed to subscribe capital increases for up to 50% of the capital of State companies. In Ecuador, a trust manages the shares of the State company and, with prior authorisation, could sell up to 39% of the shares.

The other Andean nations have opted to cut up and privatise State companies. This process is in full development in Colombia and Peru, where some privatisations have already taken place. In Venezuela, however, there is still debate on the passing of a law which would allow to implement these changes in the property and institutional organisation of the electricity system.

2.2 Energy policies within the Andean Nations

As already seen in Chapter II, energy resources within the Andean nations are of higher significance than the mere supply of domestic energy requirements, since hydrocarbon exports represent a substantial part of public income. Venezuela, Ecuador and Bolivia stand out in this respect, although the latter does so only on account of its natural gas exports. It is thus not unusual that both Venezuela and Ecuador register a slower progress towards the opening of the hydrocarbon industry to private capitals.

Although coal exports are also significant, the remaining hydrocarbons are analysed paying special attention to meeting the supply of domestic energy demand in the long run, through a rational and balanced use of domestic energy resources. The Peruvian oil industry, in turn, had experienced a deep crisis prior to the reform on account of the financial suffocation posed by low domestic price levels for the State oil company's petroleum products. Aside from the operational problems which this situation caused to the oil company, proven oil reserves had fell substantially. Hence, the reform was also aimed at promoting an active private participation in oil exploration with a view to reverting the situation.

For one reason or another, the search for new hydrocarbon reserves and the expansion of the temporal horizon for their production represents a significant issue for the energy policy objectives of the Andean nations.

As regards the supply of domestic energy demand, all nations propose to assign a more important role to natural gas, which, in terms of final consumption supply, is only significant in Venezuela and, to a lesser degree, in Colombia. Only in the case of Ecuador, whose proven natural gas reserves are not as significant as those of other member nations, prospects on the future use of natural gas are much more modest. Nevertheless, local authorities promote a higher use of the fields recently discovered in the Guayaquil area, as well as the intensification of surveys in search of natural gas fields.

Logically, the markets towards which natural gas supply is aimed depend on the necessary efforts to develop the networks which may be required to supply them. In those countries with networks still requiring development, priority is given to the use of natural gas in power stations, although in all cases the medium-term goal is to substitute the use of liquid hydrocarbons within the industrial sector. Such is the case of Peru and Ecuador.

Both in Colombia and Bolivia, with current networks of limited extension, the next goal is to meet household heat consumption and promote the use of compressed natural gas (CNG) in urban transport. Natural gas would mainly replace liquefied petroleum gas (LPG) within the Bolivian household sector, while Colombia aims at replacing electricity for cooking.

With respect to transport, it must be stated that Colombia's northern region, at present supplied with natural gas, already has a program for the use of compressed natural gas in urban buses which has proved successful. The aim is to repeat the experience in the new urban centres where natural gas distribution networks are to be laid.

Venezuela, in turn, registers a significant share of natural gas in the supply of energy requirements, especially within the industrial and petrochemical sectors. Aside from the network expansion, there is concern in this case to improve the efficiency of the natural gas supply, cutting down losses within the transportation and distribution systems.

Concern to improve energy efficiency both in the supply as well as in the end-use sectors is a general objective within the Andean Region. As regards supply, mention has already been made on the high level of losses registered by the electricity systems.

It is probable that private network operators will quickly confront the problem if the regulations include the adequate incentives. The results to be yielded by the energy conservation programs in final use within the new organisational system for the electricity industry are less evident. In principle, distributors and traders operating within a competitive environment are only inclined to promote those actions which yield true competitive advantage (through cost reduction, and / or product differentiation) or else guarantee the growth of their market share. It is too early to draw conclusions on the future evolution of energy efficiency in final use, and the challenge lies in finding proper promotional mechanisms.

As regards policies for the electricity sector, we shall only state that there is evident concern to increase the coverage of the service in rural areas, especially in those countries with a large rural population, as is the case of Bolivia. We shall leave our comments on the policies on the type of energy resource promoted for electricity generation to Section 4 of the present Chapter, which deals with the expected evolution in electricity consumption and supply until the year 2010.

3 The environmental strategy of the Andean Nations

All Andean nations register a growing concern on the environmental impacts caused by the supply and consumption of energy, and on methods to guarantee an adequate protection of the environment. Logically, the highest concern lies on the local impacts produced by the production and burning of hydrocarbons, as well as on the construction of hydroelectric plants. Hence, priority in the establishment of domestic policies is given to the co-ordination of development strategies with the preservation of the local environment.

Although all member nations take active part within international fora in the debate on how to address global environmental problems such as climate change, it is evident that local impacts have high priority in as much as their emission of thermoactive gases still remains very low.

However, the governments carried out their inventory studies on greenhouse gas emission, which were available for the present study - either in a preliminary or a final version - and some of them are carrying out studies on climate change mitigation.

Only a preliminary version of the mitigation study carried out by Bolivia was available for the development of the present project. Mitigation studies carried out by Ecuador and Peru were developed parallel to the regional study, within the framework of the UNEP / GEF “Economics of GHG limitations” project in the first case and under DANIDA co-operation in the latter. Colombia, in turn, was negotiating the financing of its mitigation study, although there was no information available on the mitigation options which would be most interesting to the country. In the case of Venezuela, no mitigation study was available, although certain studies have been carried out within the framework of the US Country Studies program.

It is necessary to point out that, regardless of the progress of the studies carried out by each country on the possibility of implementing mitigation measures within their own territories, these do not represent in any case official policies, but are merely exploratory analyses which do not compromise the official position of the respective nations. This lack of definition - which on the other side is also registered in many industrialised nations - is absolutely consistent with the character of non-Annex 1 nations shared by the member nations of the Andean Region.

From a methodological viewpoint, and for the purposes of the present regional study, the lack of domestic mitigation policies already implemented leads to determining the Regional Baseline Scenario as the addition of domestic Baseline Scenarios. The analysis of eventual regional mitigation options would allow in this case to contribute with new options to the nations' domestic decision process on climate change mitigation.

As an example, the type of mitigation options considered by the Bolivian study will be briefly outlined. The study mainly concentrates on the possibilities given by final consumption to reduce thermoactive gas emission. Two types of measures are proposed to this effect, namely: increases in energy efficiency in final use and promotion of the switching from liquid fuels to natural gas within all consumption sectors.

With respect to efficiency, it is assumed that some 15% of household and commerce users will have in the year 2010 lighting devices 4.5 times more efficient than those currently used. At the same time, more efficient refrigerators would register a 10% penetration in homes for the year 2010, while the intensity of the use of electricity within the commerce sector could fall some 11% in the same year. In the case of the mining industry, it has been assumed that energy intensity for heat generation could drop some 7% in the year 2010, and some 12% in the case of electricity use, through the improvement of maintenance systems and processes, as well as through a domestic rearrangement of activities within industrial plants.

As for substitution among sources, it has been assumed that 5% of urban homes and 4% of rural homes would have solar heaters to meet their hot water requirements. To this respect, it is worth noting that the use of solar heaters in rural areas would bring down the use of firewood stoves for water heating. This fact, together with the expected increase in firewood-stoves' efficiency, would allow reducing biomass consumption by 7% in the year 2010.

With respect to the use of natural gas, its penetration in domestic use and urban transport as compressed natural gas has been increased. Natural gas replaces LPG for cooking and electric heaters for water heating. Compressed Natural Gas has already been introduced in Bolivia in the last years, and the Mitigation Scenario presupposes increasing its penetration both in automobiles as well as in light duty trucks.

As for energy supply, higher efforts should concentrate on reducing fugitive natural gas emission through the recovery of condensates and the further re-injection of dry gas which is currently flared.

With these measures, the study anticipates a reduction of some 9% in gross energy consumption in the year 2010, which would represent savings of some 14% in CO_2 emission and still higher reductions for the other thermoactive gases.

4 Prospects on the evolution of the electricity sector within the Andean Region

An analysis was made on the expected evolution of the public electricity service in the Andean Region to the year 2010, on the basis of the reference plans for the electricity sector in each Andean nation. Considering the significance of electricity consumption within the mining sector, supplied to a large extent by self-production plants, the reference plan of the Peruvian electricity sector includes total demand and supply without distinguishing between public sector and self-production. For this reason, values calculated for the Andean Region as a whole also incorporate Peruvian electricity self-production.

In general, reference plans include the consideration of different electricity demand growth scenarios. In these cases, and for the purposes of the present study, medium growth alternatives were chosen.

According to these prospects, electricity requirements are expected to grow to the year 2010 at an average yearly rate close to 4.5%. This rate results from well-differentiated prospects for the Andean nations. Electricity demand in Bolivia, Colombia and Ecuador would rise at an average yearly rate ranging from 5.8 and 7%, depending on the country. Instead, the expansion in electricity consumption would be much lower in Peru and Venezuela, with expected average yearly rates of 4.4 and 3.1%, respectively.

With a view to meeting this rise in demand, it could be necessary to install some 27700 MW in power stations within the Andean Region until the year 2010. Most of this additional capacity would be installed in Colombia (39%) and Venezuela (37%), followed by Peru (12%), Ecuador (8%) and Bolivia (4%).

As regards the type of plants to install, we still note a strong share in the new hydroelectric stations, which would contribute with 44% of the power added to the Andean systems, with a total capacity of 12300 MW. Nonetheless, the installation in the region of 8200 MW is expected in gas turbine or combined-cycle gas turbine plants, which are practically non-existent to date, and would contribute with 30% of the total capacity added in this period. It is evident that this equipment will replace in the future the role traditionally given to steam turbine plants in meeting the base demand, even when the incorporation to the service of nearly 1500 MW in steam turbine plants (9% of the total added) is also expected, concentrating mainly in Colombia and Ecuador.

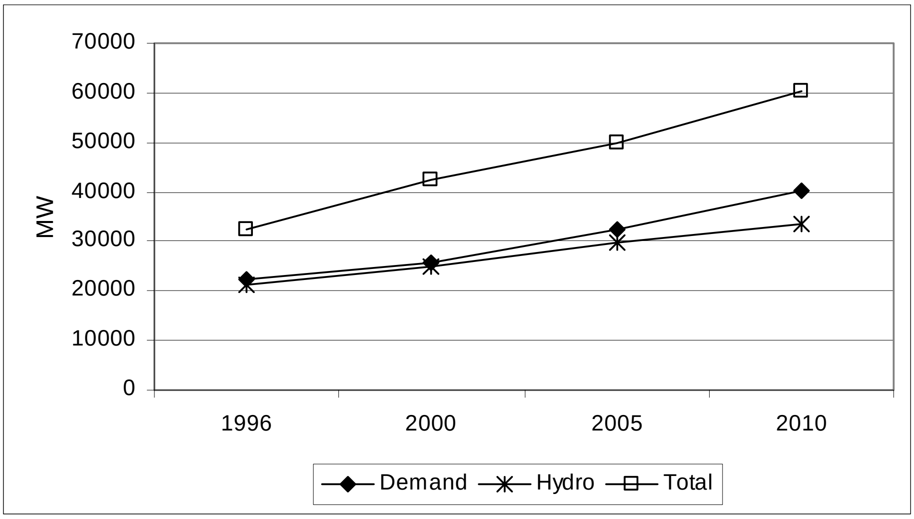
It is important to point out that the incorporation of new hydroelectric stations within the Andean Region would be mainly sustained through the electricity supply strategy planned in Venezuela (with 71% of the total power added in that country) and Ecuador (59%). Even when some of the incorporated works are currently under construction, it is likely that these public company prospects may experience alterations were these nations to go further into the processes towards a higher participation of private capitals in electricity supply.

Figure 21 presents the expected evolution for demand and supply in accordance with these prospects.

This figure also shows the expected evolution of installed power in hydroelectric plants. As may be appreciated, hydroelectric power installed in 1996 covered 94% of the peak load demand. This fact reflects the situation of the two largest electricity systems within the Andean Region, those of Colombia and Venezuela. In both, although particularly in the Colombian one, the high percentage of hydroelectric generation makes it necessary to have thermal generation backup to face draught periods. This event explains the high reserve values which would be maintained throughout the analysed period, exceeding 40% of the peak load demand.

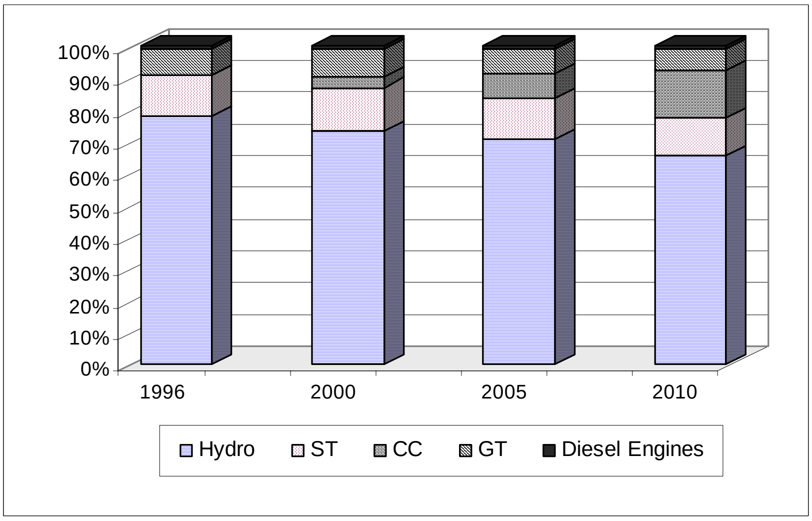
Still predominant, power installed in hydroelectric stations in the year 2010 would represent some 83% of the peak load, reducing its current contribution by nearly 10% as a result of the diversification of generation technologies expected to take place within the Andean Region in the coming years.

Figure 21   Electricity demand and supply within the Andean Region



These changes in generating plants would be reflected in the structure of electricity generation, as Figure 22 shows. With respect to the values presented, it must be noted that while 1996 data corresponds to the actual generation registered, prospects for future years were carried out in accordance with the hydroelectric contribution of the mean hydrological year.

Figure 22   Electricity generation structure within the Andean Region



Two are the elements which must be pointed out on the expected operation of the Andean power stations. In the first place, the gradual reduction of hydroelectric contribution, which would drop from a current 78% to 65% in the horizon year. Secondly, the rise of combined cycles as second technology in importance for electricity supply, contributing with 15% of total generation in the year 2010.

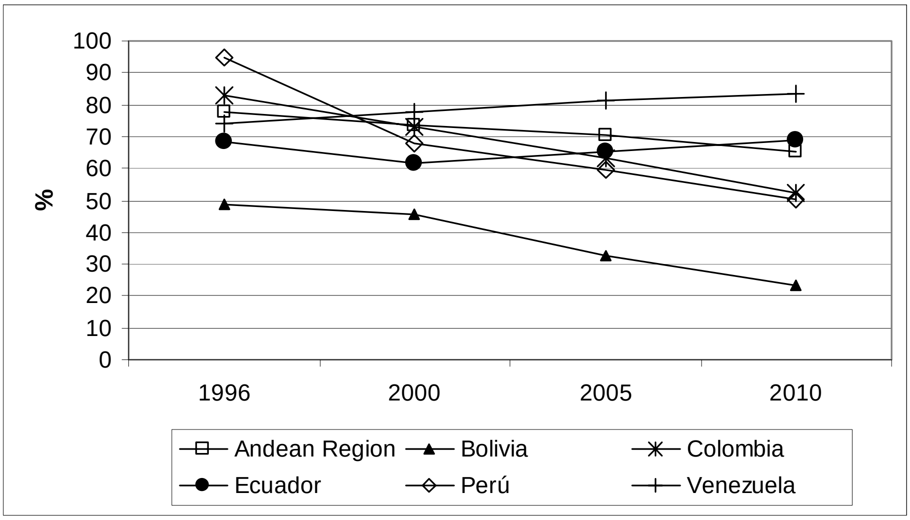
The current share of both open-cycle gas-turbine as well as steam-turbine stations would remain practically unaltered throughout the period. From this fact, we could conclude that future combined cycles appear as a more competitive alternative than hydroelectric plants within the new context established by the restructuring of the electricity industry within the Andean Region.

It is evident that the competitiveness of combined cycles strongly depends on the availability of natural gas to be burned in plants at a low price, even when progress in this technology may have allowed to simultaneously cut down investment costs and specific consumption in this type of stations.

From this viewpoint, policies to promote the development of the natural gas industry in Bolivia, Colombia and Peru will significantly facilitate the installation of combined cycles in those nations. Although such contribution will prove significant to reach the established regional averages, it is necessary to note that Venezuela also plans to install combined cycles as a complement to hydroelectric stations.

With a view to showing with more clarity the different prospects for hydroelectricity within the Andean Region, Figure 23 presents the expected evolution of hydroelectric share in total generation for each member nation and for the Region as a whole.

Figure 23 Hydroelectric share in total generation

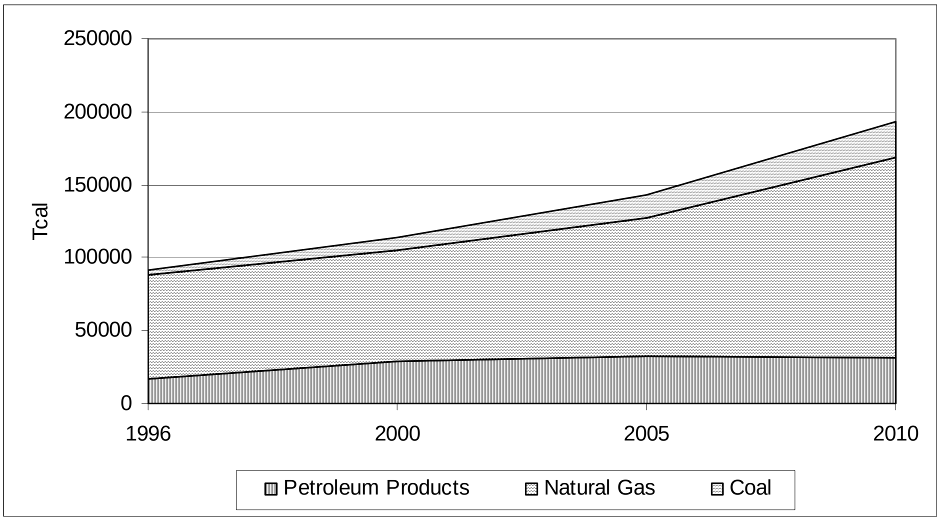


As previously mentioned, these prospects are clearly linked to domestic policies on the use of energy resources and to the expected behaviours of private investors within the more and more competitive environment for electricity generation. The high availability of natural gas in Venezuela and its low price could undermine in the future the predominant role which official plans attribute to hydroelectric stations as progress is reached towards the reform of the electricity industry in the terms established in a bill currently under debate.

An estimate was carried out - as from the expected operation of the generating plants - on the evolution of fuel consumption in power stations per type of fuel, the results of which are given in Figure 24.

The volume of fuel burned in power stations would double until the year 2010, representing an average annual rate of 5.5% against an annual 8% for the expected generation in thermal stations. This difference in growth rates gives evidence of the prospects to improve the thermal efficiency of the stations. In fact, the average efficiency of thermal stations would rise in the horizon year from a current 29% to 41%, on account of the incorporation of high yield combined cycles, which would contribute with 43% of thermal generation within the Region.

Figure 24   Fuel consumption in power stations within the Andean Region



With respect to the share of the different fuels, natural gas will continue having a predominant role, with some 71% of total calories burnt in power stations. Nevertheless, these values represent an almost 6% loss of share with respect to the situation registered in 1996.

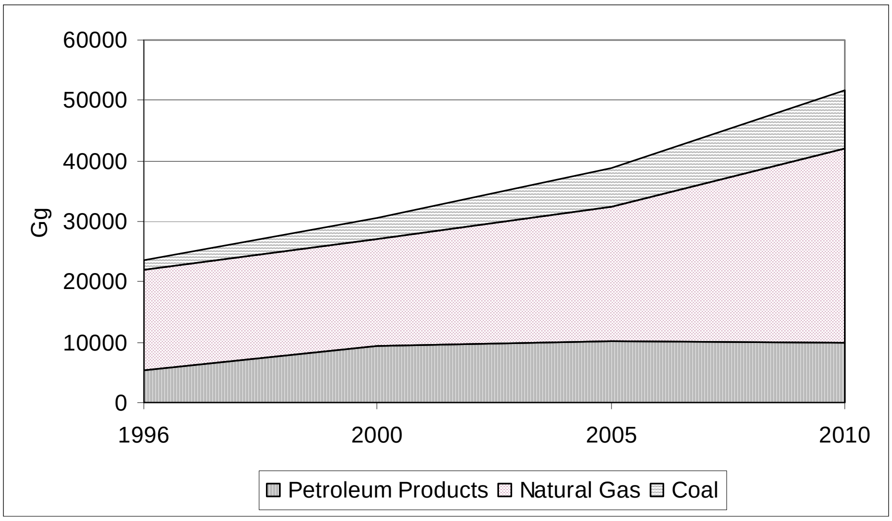
As may be appreciated in Figure 24, petroleum products are not to be accounted for the lower use of natural gas but coal, which increases its share from a current 4% to 13% in the year 2010. To this respect, it must be noted that this situation shows the prospects carried out for the Colombian system, the only nation of the Region where power stations burn this fuel.

As shown in Chapter II, coal is the most abundant hydrocarbon in Colombia, currently representing 20% of the calories burnt within Colombian thermal stations. The electricity plan is aimed at diversifying the energy sources used by the electricity sector, considering the availability of resources in the country. Hence, it is expected to slightly increase the coal share until reaching 24% of the fuels input within power stations in the year 2010. This slight percentage variation would nonetheless bring about a large increase in coal consumption due to the great expansion which thermal generation would register to the detriment of hydroelectricity. The plan aims at cutting down the share of hydroelectricity in total generation in the horizon year from a current 83% to 52%. It must be noted that such reduction is not solely linked to the expectations on the behaviour of private investors as regards the expansion in generation capacity, but gives evidence of the intention to achieve a more balanced supply which may prevent in the future electricity shortages in dry years. In recent years, the Colombian system has faced severe restrictions in electricity supply on account of low hydro contribution and the scarce regulation capacity of Colombian hydroelectric stations.

The evolution of CO_2 emission from Andean stations to the year 2010 - shown in Figure 25 - was estimated as from the estimates on fuel consumption in power plants. The figure also presents the contribution of each type of fuel.

CO_2 emission would rise some 120% during the period analysed, which is equivalent to an average annual rate of 5.8%. This growth rate slightly exceeds the increase in fuel consumption (yearly 5.5%) on account of more coal burning within power stations.

Figure 25 CO_2 emission in power stations within the Andean Region



In fact, coal contribution to total emission from Andean power stations would rise from a 7% registered in 1996 to a 19% for the horizon year, to the detriment both of the share of natural gas as well as of that of petroleum products.

However, the expected growth rate in emission from Andean stations is well differentiated within the member nations, highly influenced by plans on prevailing technologies to expand the system and the type of fuel to use.

The highest rise would be registered in Peruvian stations (an average yearly 20% throughout the period) fueled by a strong expansion in thermal generation, estimated in more than a yearly 24%. Thus, it may be stated that the rise in emission will be dampened by the plan to burn natural gas in Peruvian power stations, as well as by the higher thermal efficiency of the new stations.

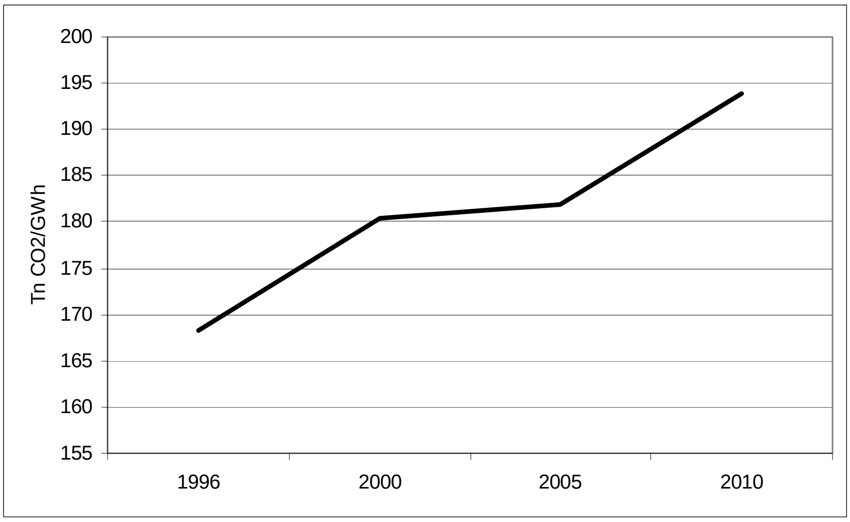
Emission from Colombian power stations would also have in the future a higher growth rate than the regional mean, equivalent to an average 12.7% per year. The higher emission would be fueled in this case by the rise in conventional thermal generation (yearly 14.5%) as well as by the burning of coal.

Nevertheless, it must be pointed out that in both countries the current share of thermal stations in total generation is quite low, which explains such a swift rise in thermal generation and maintains total emission from the electricity sector at acceptable levels with respect to international standards.

A totally different situation would be registered in Venezuelan stations should the expectations of the electricity plan be met. Favoured by the expected low rise in electricity demand and a high hydro contribution, total emission from the electricity sector would drop at a rate over a yearly 3% throughout the period.

Specific emission was measured as emitted CO_2 per generated kWh with a view to placing in perspective the significance of the expected evolution of total emission from Andean power stations. Results are presented in Figure 26.

Figure 26 Specific CO_2 emission in power stations within the Andean Region



As the figure shows, it is expected that unit emission from the Andean stations rise some 15% over the next years, even when they would remain in low levels with respect to international standards, with only 194 Tons of CO_2 per generated GWh. Variations in this indicator clearly show the expected modifications in the generation structure per type of technology within each Andean nation, as well as the changes in the thermal efficiency of power stations and in the type of fuel burnt.

To this respect, we must point out the evolution expected in Ecuador, where the rise in thermal efficiency would allow to bring down specific emission from power stations by almost 20%. Specific emission in Venezuela would drop almost 60% with respect to current values, and this nation would be the only one in the group with specific emission lower than the regional average in the horizon year, with only 78 Tons of CO_2 per generated GWh.

Specific emission within the remaining member nations is expected to rise throughout the period, from 9% in the case of Bolivia to 479% in the case of Peru. Notwithstanding the spectacular growth in specific emission within Peruvian plants, resulting values for the horizon year remain at levels quite similar to those of Ecuador (250 Tons of CO_2 per generated GWh). Such behaviour is due to the very low levels of specific emission being currently registered in Peru, of only 44 Tons CO_2 per generated GWh.

Energy Integration within Latin America

1 Introduction

The search for regional climate change mitigation options is aimed in this project solely towards the analysis of energy integration opportunities within the Andean Region which may yield positive environmental impact from the point of view of GHG emission saving. In view of the scope given to the present project, we shall restrict ourselves to the analysis of integration prospects within the electricity and natural gas industries.

Latin American nations have shown an early will to promote higher economic and energy integration, setting instruments and institutions for the co-ordination of domestic strategies and the interchange of information. Specifically within the energy field, the Latin American Energy Organisation (OLADE) was established in 1973 so that governments had an adequate forum in which to debate the Region's energy problems.

At the same time, bodies were set up for energy companies to get together, in a clear attempt to favour regional integration. Hence, in the electricity area, the Regional Electricity Integration Commission (CIER) groups the electricity companies of ten South American nations, and has been working for the last 35 years to favour integration and technical co-ordination in the operation of the electricity systems. A similar organisation groups Latin American oil companies (the Latin American Oil Corporate Reciprocal Association - ARPEL), also including private companies after the oil reform.

Integration processes, both in the energy and economic fields, have gained new strength in the last years by means of sub-regional agreements which not always coincide with the geographical distribution originally determined for the establishment of integration blocs within Latin America.

Such dynamic integration action is specially noticed within the energy field, and seems to be fueled by the regulatory and institutional reforms implemented by the Latin American nations. Private energy companies show a commercial strategy distinguished by the search for business opportunities which far exceeds domestic borders, and aims mainly at detecting new markets where to place their products.

This commercial strategy is favoured by two essential elements. In the first place, the trans-nationalisation of the energy companies operating in the subcontinent, comprising an intricate network of economic interests on both sides of the borders. Energy agents now view Latin America and the world as their natural operating environment rather than just limiting themselves to their respective domestic territories. Although this event is favoured in the energy field by the participation of trans-national companies, it must be pointed out that such behaviour is also registered in Latin American companies, which are quite active in the privatisation processes taking place in the region.

In the second place, governments seem more prone to favour these business actions and provide assistance to the establishment of regional energy markets through agreements on common rules for the treatment of these initiatives within the different countries. This in no way means that regulations with respect to the foreign trade of energy products are wholly homogeneous in the different Latin American countries, since aspects such as local supply reliability and the strategic nature of energy resources are evaluated in different ways by the respective governments. However, and on the basis of the analysis of specific projects, progress is being reached on the regulation of the new regional energy market.

In this new context, energy integration initiatives spring mainly from companies and are fueled by the closeness of attractive markets for the trade of products and thus giving economic value to the energy resources exploited by these companies. Hence, integration projects may be posed with more ease among nations granting similar facilities to private agents through the regulation of their activities rather than through the geographic limits established through prior economic integration agreements.

In accordance with these considerations, it was deemed convenient to sum up current trends towards a higher integration of natural gas and electricity industries within South America as a frame for the analysis of energy integration prospects towards the Andean Region’s hinterland.

2 Recent trends within the natural gas industry

The natural gas industry is perhaps the best exponent of this trend towards the establishment of regional markets. The highest number of initiatives to date is put in evidence in South America’s South Cone region. The privatisation of natural gas reserves in Argentina and Bolivia, which are now run by private oil companies, led to the search for new markets where to place the natural gas of the region. The expansion of the domestic markets (electricity generation and use of compressed natural gas in transport, apart from promotion of the expansion of industrial and household consumption) was complemented with the assessment of export opportunities.

It must be stated that two nations stand out in South America for the degree of development reached in natural gas infrastructure and market development within their borders, namely Venezuela and Argentina. In 1995, trunk gas pipelines in both nations had reached a length of 6,000 miles in Argentina and 3,300 miles in Venezuela.

The development of this infrastructure was based on the availability and use of their domestic natural gas resources. However, Argentina complemented its own resources with the importation of Bolivian natural gas as from 1972, in a volume around 6 million m^3 per day. The original agreement covered a period of 20 years, and was re-negotiated upon expiration on the basis of terms quite different from the original ones, both as regards prices as well as volumes involved. This way, attempts were made to adapt natural gas imports to the new competitive energy - industry environment within Argentina.

The fact that several oil companies exploit natural gas and oil fields both in Bolivia and Argentina has facilitated the signing of agreements on the operation of the gas pipeline linking both countries. Although the flow of natural gas remains towards Argentina, the possibility of the flow being inverted in the future towards a joint supply of foreign markets is not ruled out.

Although the Brazilian market seems to be the most important focus of attention for export projects on account of the eventual volumes involved, the materialisation of export projects has begun in other markets which, even though they may be smaller, have the advantage of being closer to the fields.

Figure 27 shows the gas pipeline networks existing in South America, as well as the gas pipelines which would be used to materialise natural gas exports, and gas pipelines under construction. As may be appreciated, there are two international gas pipelines in full operation apart from the Argentine - Bolivian one, both connecting Argentina and Chile.

The first of these gas pipelines to start operations was the Magellan gas pipe in Tierra del Fuego, south of the continent, at the end of 1996. It connects the towns of San Sebastián (Tierra del Fuego – Argentina) and Posesión (Magallanes – Chile), with a total distance of 68 miles and a capacity of 2 million m^3 per day. The natural gas carried through this network is used to feed a methanol plant.

The second gas pipeline (Gas Andes) joins the Argentine gas pipeline network in Mendoza with Santiago, Chile, and began operating in 1997. It is expected to transport an initial flow of 5 millions m^3 per day, and could reach 8 million in the next years, carrying gas from the Neuquén basin in Argentina. Although the distribution network to supply natural gas to the household and commerce sectors and promote the use of compressed natural gas is currently under construction, at a first stage the gas will be used by the industrial sector and for electricity generation. If prospects on the installation of new gas stations are met, these could take up nearly 45% of the natural gas imports.

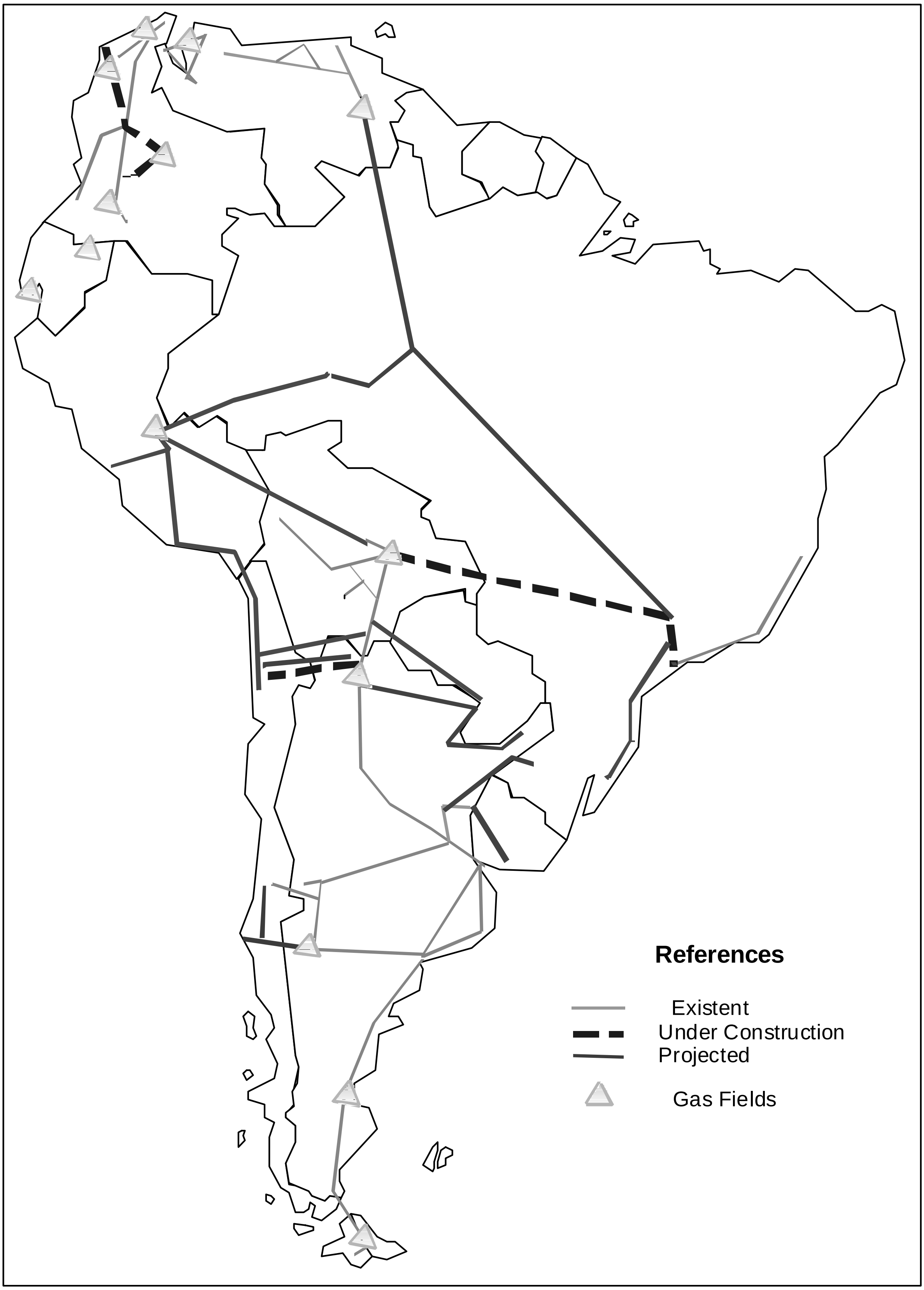
Two international gas pipelines are currently under construction, one between Argentina and Chile and the other between Bolivia and Brazil. The Atacama gas pipeline linking Campo Durán (north of Argentina) with Mejillones (north of Chile) runs for over 562 miles, with a 20” diameter through which up to 8.5 million m^3/day may be carried.

The gas pipeline from Bolivia to Brazil - with a maximum expected capacity of 30 million m^3 per day - aims at a first stage at supplying natural gas to the Sao Paolo industrial region, although it is planned to expand to Porto Alegre. Even when the initial supply of the Brazilian market would be carried out with Bolivian natural gas, there are projects to complement it deviating natural gas from the Camisea field in Peru, and, eventually from the Argentine northern region, inverting the flow of the Argentine - Bolivian gas pipeline.

Three new South American markets attract the interest of natural gas suppliers in the region. The main one as for volume is the industrial zone at the Brazilian south-eastern region, where power stations fed with natural gas could also be installed as long as the abundance of the supply allows it. With a view to guaranteeing supply, some analysts have proposed the construction of an independent gas pipeline from Camisea, and even carrying natural gas from the Venezuelan gas pipelines, that nation having South America’s largest natural gas reserves.

A second market is represented by the mining region in northern Chile, which seems interesting on account of its potential both for final use and electricity generation. With respect to this, it is worth mentioning that these gas pipelines also compete against electricity interconnection projects with the Argentine northern region, as outlined in the following Section.

Figure 27   South American gas pipeline network



The degree of interest posed by this market may be determined by the number of alternative gas pipelines proposed to supply the area. As shown in Figure 27, there are three alternative projects apart from the gas pipeline currently under construction. One of them is a second gas pipeline from the gas fields in northern Argentina to Tocopilla, Chile, with a capacity of 3 million m^3 per day. Another project proposes supplying the area with Bolivian gas, while a third one aims at supplying the area from Camisea, Peru.

The third attractive market is Chile's central region, where there is a project to supply natural gas from Neuquén (Argentina) to Concepción and Santiago (Chile) through a 12-16" gas pipeline with a carrying capacity of 2.5 million m^3 per day. Private natural gas producers in Argentina, in association with Chilean companies promoted this project, as the existing gas pipeline.

As Figure 27 shows, there are also projects to export Argentine gas to the Brazilian southern region (to feed a Brazilian power station) and Uruguay, for a volume close to 2.5 million m^3 per day each. Both projects could materialise in the near future.

The possibility of supplying the Paraguayan capital with Bolivian natural gas is in turn promoted by the Paraguayan government, although large distances with respect to potential gas consumption make the project less attractive to gas producers.

As may be appreciated, most of the gas pipelines projected or under construction correspond to South America's southern region. As for the Andean nations, Bolivian and Peruvian export projects are mainly aimed towards non-Andean markets. The negotiation for the construction of a Venezuelan - Colombian gas pipeline seems to be delay as from the discovery of natural gas reserves in Colombia. The same took place with the idea of supplying Ilo, south of Peru, with Bolivian natural gas, on account of the interest in promoting the use of Peru's own natural gas from Camisea.

3 Electricity interconnections

In the field of electricity, Latin American countries have a long tradition in the road towards the integration of their systems. The integration movement puts into evidence three types of causes for the promotion of electricity interchange.

In the first place, the proximity of urban centres in the border area pose wide possibilities, these centres many times offering higher possibilities of mutual aid in electricity supply than the rest of the respective domestic system. The following minor interconnections (voltage lower than 132 kV) fall within this category, listed from north to south:

- *Colombia - Venezuela*: 13.8 kV line between Arauca (Colombia) and Guasdalito (Venezuela).
- *Peru - Bolivia*: 22.9 kV line between Desaguadero (Bolivia) and Zepita (Peru)
22.9 kV line between Casani (Bolivia) and Yunguyo (Peru)
- *Bolivia – Brazil*: 34.5 kV line between San Matías (Bolivia) and Corixa (Brazil)
13.8 kV line between Puerto Suárez (Bolivia) and Corumbá (Brazil)
- *Bolivia – Argentina*: 33 kV line between Pocitos (Argentina) and Yacuiba (Bolivia)

- *Brazil – Paraguay*: 68 kV line between Ponta Borá (Brazil) and Juan Caballero (Paraguay)
- *Argentina – Paraguay*: 66 kV line between Posadas (Argentina) and Encarnación (Paraguay)
- *Argentina – Uruguay*: 30 kV line between Concordia (Argentina) and Salto (Uruguay)
- *Brazil - Uruguay*: 13.8 kV line between Chui (Brazil) and Chuy (Uruguay) Supply to Cerrillada (Uruguay), 13.8 kV line

The second fuelling element for the connection of the electricity systems through extra high voltage interconnections was the use of shared hydroelectric resources, by means of the construction of two-nation stations. Three stations of this type operate to date, all of them located on the Del Plata Basin, as shown in Figure 28. The following stations fall within this category:

- *Brazil – Paraguay*: Itaipú Station, 12600 MW installed, connected to the Brazilian system with 750 kV lines as in direct current
- *Argentina – Paraguay:* Yacyretá Station, 3100 MW installed, connected to the Argentine system in 500 kV
- *Argentina – Uruguay:* Salto Grande Station, 1890 MW installed, connected in 500 kV.

Moreover, a large number of interconnections have been built among the different nations to make use of the supply availability in one nation to meet the demands of another. Such interconnections, diagrammatically marked in Figure 28, are the following:

Venezuela – Colombia:

- Cuestecita (Colombia) – Cuatricentenario (Venezuela): 230 kV, 150 MW carrying capacity
- San Mateo (Colombia) – Corozo (Venezuela): 230 kV, 150 MW carrying capacity
- Zulia (Colombia) – La Fría (Venezuela): 115 kV, 80 MW carrying capacity

Colombia – Ecuador:

- Ipiales (Colombia) – Tulcán (Ecuador): 115 kV, 30 MW carrying capacity

Brazil – Paraguay:

- HS Acaray (Paraguay) – Foz de Iguazú (Brazil): 132 kV, 70 MW carrying capacity

Argentina – Paraguay:

- HS Acaray (Paraguay) – Posadas (Argentina): 132 kV, 30 MW carrying capacity
- Clorinda (Argentina) – Guarambaré (Paraguay): 132 kV, 80 MW carrying capacity

Argentina – Brazil:

- Paso de los Libres (Argentina) – Uruguayana (Brazil): 132 kV, 50 MW carrying capacity

Argentina – Uruguay:

- Paysandú (Uruguay) – Concepción (Argentina): 132 kV, 100 MW carrying capacity, currently out of service due to the existence of a 500 kV interconnection.

Figure 28 also shows 3 interconnections currently under construction, namely:

- 230 kV line between Guri in Venezuela and Boa Vista in Brazil, with a carrying capacity of 60 MW, 400 kV line planned between these two points to increase carrying capacity to 200 MW;
- 500 kV line between Salta, in Argentina and Antofagasta, in Chile, which is being built by a private company to export electricity from its Argentine-based plant to the Chilean northern system.
- 132 kV line is under construction between Rivera in Uruguay and Livramento in Brazil, with a transmission capacity of 70 MW.

With respect to planned interconnections, some of the lines marked in Figure 28 correspond to studies carried out long ago by State-owned companies. In other cases, they correspond to initiatives taken by private agents, as in the case of the Argentine - Brazilian interconnection which could soon materialise. This line would result from an international bidding process called by a Brazilian company for a firm supply of 1000 MW. The work was awarded to a consortium of Argentine companies, which contracted the sale of generation surpluses in Argentina.

CIER is currently evaluating the economic and technical feasibility of promoting interconnections in South America within a series of corridors, which would allow the establishment of a regional electricity market. The analysis comprises the ten largest countries in South America, while the temporal horizon extends until the year 2010. The aim is to analyse complementation possibilities in the generation from the different systems, paying special attention to the hydrological complementation possibilities of the different basins.

Besides this study, we must say that trends in the natural gas industry towards the establishment of a regional market prove in general competitive with respect to electricity interconnections. Such competition was clearly observed when the Chilean companies operating the northern system put in evidence their corporate strategy to supply this system.

Figure 28 Extra high voltage electricity interconnections

Making use of the facilities given by the development of activities in Argentina, one of the companies decided to install a 600 MW station within Argentine territory and build a 500 kV line to export the production of that station to Chile. The immediate response of its competitors in Chile was to promote the construction of a gas pipeline, currently under construction as the high voltage line is. As long as natural gas is availability, the competitiveness of imported electricity seems unlikely.

Although this is but just one example, natural gas availability could in a general way work against electricity inter-country trade in the region, considered as permanent supply. One of the biggest advantages of interconnections in South America arises from the differences in hydrological contribution in a single period and, hence, in the use of non-firm hydro energy. Nevertheless, the availability of natural gas will certainly cause a higher expansion in thermal generation and will cut down hydroelectric surpluses.

As long as private agents are the ones promoting the works, it would seem that, from a corporate viewpoint, the laying of gas pipelines offers higher business opportunities than electricity interconnections, especially for electricity generators. However, distributors and / or consumers could appear who could show interest in importing electricity, as long as there are long term persisting comparative advantages for the export system.

Institutional and regulatory reforms are still quite recent to draw accurate conclusions on the future behaviour of the regional natural gas and electricity markets.

Energy Integration Opportunities within the Andean Region

1 Introduction

As seen in Chapter IV, opportunities to reach higher energy integration in some nations of the Andean Region seem to be more attractive for the bordering nations which are not part of the Andean Pact, al least in the view of private agents. Such is the case of Bolivia and, to a lesser extent, Peru. Nevertheless, the analysis of this type of options and of their impacts on GHG emission goes beyond the scope of the present study.

Since the only information available on the future evolution of the energy systems within the Andean Region are reference plans for the electricity sector, a search was started for integration projects with impact on the electricity supply of the Region. For this purpose, use was made of a document on “Andean Energy Integration Projects” prepared by consultants from the five Andean nations for the Andean Development Corporation.

Hence, consideration was paid both to electricity interconnection projects and the ideas mentioned in the study for the Andean Development Corporation to export natural gas to meet the needs of the power stations of the importing nations. Nonetheless, there have been significant changes in domestic planning for the electricity sector since the time when the consultants carried out their evaluation. At present, we notice higher interest in programs for the development of the natural gas industry on the basis of the nations’ own resources, which would limit the impact of the integration process on GHG emission.

The list of projects identified as from this analysis is outlined in the following Section, which also includes some comments on the current situation and the feasibility of the said projects. Finally, Section 3 of the present chapter analyses the energy impact of the projects considered and provides some estimates on their effects on the volume of GHG emission within the Andean Region.

2 Identification of integration options

It is appropriate to point out that in the case of the study for the Andean Development Corporation, a consultant from each Andean nation was appointed to evaluate the integration projects of his/her country with the rest of the Andean nations. Such working methodology allows to cross-examine the view of both parties on each integration project. Although the opinions gathered only represent the view of the consultant and not of the respective governments and / or companies, the priorities assigned by each consultant and, even more, the lack of mention to certain projects could indicate the relevance attributed to each project in the respective countries.

With a view to providing a clearer picture, integration projects are grouped per pair of nations involved. The opinion and the priority assigned to each project by the consultants of each country are also specified.

2.1 Bolivia – Peru

Integration projects between both nations may be classified according to their area of influence in projects aimed at the electricity supply of the border area, on the one hand, and of a more systemic scope, on the other. The border area between Bolivia and Peru presents well-differentiated physical and demographic attributes as we move further from south to north.

Most of the population and, thus, the electricity demand on both sides of the border, concentrates at the proximity of Lake Titicaca (Altiplano). From a point of view of resources, we can only point out an abundant insolation, for water resources are scarce.

The central area, corresponding to the mountain range and the foot of the mountains, is the highest, with accessible and relatively abundant hydroelectric resources. However, there is scarce electricity demand, except for the development of certain mining projects.

The northern border corresponds to the Amazon rain forest, with abundant hydroelectric resources although scarcely evaluated. The area has practically no inhabitants, although in the opinion of the Bolivian consultant (Jorge O'Connor D'Arlach, engineer) it has high economic potential.

Hydroelectric undertakings detected in the border area between both nations are included as integration projects on account that they require prior agreement for the use of watercourses of international nature. Nevertheless, the works are aimed at supplying domestic markets.

Two hydroelectric projects fall within this category within Bolivian territory, namely: one over the Charazani River, La Paz district; the other over the Tahuamanu River, in the Pando district. For the supply of the border area on Peruvian territory, the Peruvian consultant (Juan Incháustegui Vargas, engineer) analyses the use of international waters of the Maure River in the Tacna special project, which affects Chile apart from Peru and Bolivia. Production from the stations within this project would be used to supply the Peruvian demand at the border area, although carrying works would run through part of Chilean territory.

To make use of the *Charazani River*, the Bolivian State-owned electricity company analysed three projects of possible hydroelectric stations with powers of 25 MW, 40 MW and 50 MW, respectively. In the opinion of the Bolivian consultant, the most attractive option from an economic viewpoint is that corresponding to an installed capacity of 25 MW, with a production capacity of 147 GWh per year and a guaranteed power of 5 MW. Although the project analyses two alternatives for the connection of the *Charazani* station to the Bolivian electricity network, the variable deemed most convenient is a 50 mile 115 kV line towards the Guanay substation.

According to estimates from the preliminary study, total investment would reach 52.5 million US dollars, 10 million of which would correspond to the cost of the associated transmission system. As for the energy generated, the estimates give a cost of US$ 41 / MWh, using a 12% discount rate. These works are not included in the reference plan for the expansion of the Bolivian electricity system, nor are they commented as an option by the Peruvian consultant who took part in the study for the Andean Development Corporation.

The works over the *Tahuamanu River* in the northern area of the Peruvian - Bolivian border are also considered only by the Bolivian consultant. Although the ENDE

Bolivian company analysed in 1992 alternative sites for the dam, the preliminary feasibility study corresponds to a station with 2.4 MW installed and an annual generation capacity between 13 and 14 GWh. The incorporation of the stations to the Bolivian system would be carried out through a 21-mile line to the city of Cobija.

According to estimates carried out, the cost of the hydroelectric works without including the purchase of the land nor cost escalation during construction works would reach 11.2 million US dollars. Some 600,000 US dollars should be added to these costs corresponding to the associated transmission system. From this data, the consultant estimates that generation costs could range between US$ 90 to 100 per MWh.

The *Tacna special project* in the Peruvian district of the same name, in the southern border area with Bolivia and Chile, consists in the construction of 5 cascade hydroelectric stations, with a total installed capacity of 80 MW to make use of a terrain fall of 8856 feet. Studies are currently at a pre-feasibility stage, and give an estimated total investment close to 182 million US dollars. Unfortunately, the study does not specify the energy that could be generated by the stations, due to which it is impossible to estimate the mean cost per generated kWh.

The works would also allow irrigation regulation in the Tacna valley, and would contribute to the supply of drinking water in the area. There is no information on which part of the investment costs anticipated could be diverted to these other water uses.

The remaining energy integration projects between Bolivia and Peru have to do with different ways to promote the use of Bolivian natural gas to supply electricity to the Peruvian southern region. The two most significant variants analysed are the exportation of electricity generated by a station which would be specially installed on Bolivian ground for exportation purposes, and the construction of a gas pipeline from Bolivia to southern Peru (Ilo).

With respect to the *exportation of electricity*, the two alternatives are either to install the station close to the border (Desaguadero) or at the proximity of the natural gas fields of Carrasco, distant 481 miles from the city of Desaguadero. In the first case, it is necessary to extend the natural gas transportation capacity from Carrasco to Desaguadero with works that depend on the power to install at the station.

Both variants additionally differ by the fact that the location of the station in Desaguadero poses restrictions on the type of technology to use. Since Desaguadero is located 12,464 feet above sea level, gas turbines would register a 35% efficiency loss. Hence, nominal power would have to be 50% higher than that committed to exportation if gas turbines were to be installed. The installation of steam turbine units would only prove feasible should a minimum base demand guarantee the operation of the station within reasonable standards.

The Desaguadero installation project proposes a station generating with a 60-cycle frequency, even when the Bolivian system uses 50 cycles, with a view to avoiding the costs of a converter station in the electricity interconnection in question.

The variant to install the station close to the natural gas fields poses the need to advance the conversion of the Bolivian transmission system to 230 kV and build the converter station to 60 cycles. The installed power here would be only 10% higher than that committed to exportation, so as to cover transmission losses.

Whatever the location of the station, export variants between 50 and 200 MW were considered, subject both to the availability of Bolivian natural gas as well as to the demand from the Peruvian southern system.

The necessary investment for the exportation of 50 MW does not differ much according to the location of the station, and would represent some 50 million US dollars, without considering the eventual extensions of the Peruvian transmission system to absorb the imported power.

As an alternative to the exportation of electricity, consideration was also paid to a plan to build a *gas pipeline* from the Carrasco Bolivian field to the port of Ilo, in the Moquegua district, Peru. The gas pipeline would run along nearly 750 miles, and would allow carrying 140 million cubic feet per day without intermediate compressor stations, assuming a 20-inch diameter. The investment involved in the works was estimated in 560 million US dollars.

The natural gas export goal would be more ambitious than the sale of electricity, and the gas pipeline would also aim at supplying the mining area in southern Peru, particularly the mining - industrial complex of the Southern Peru Copper Corporation (SOUTHERN). According to estimates made in 1988, Southern's heat consumption represented some 60% of the total liquid hydrocarbon consumption of the Peruvian southern system, and was five times higher than the consumption of the State-owned utility in the southern region.

Although this project could compete against a gas pipeline laid from the Peruvian Camisea field, the reference electricity plan does not anticipate the availability of natural gas in the area, while the local electricity demand would be supplied on the basis of thermal stations burning petroleum products.

A preliminary agreement has been recently reached to install a power station in the region running with Colombian coal which is neither included in the reference electricity plan for Peru.

2.2 Peru – Ecuador

A commission was established in 1988 with representatives from the electricity companies which supply southern Ecuador and the Tumbes system in Peru to analyse the possibilities of a border interconnection. It must be explained that the Tumbes electricity system, close to the border with Ecuador, remains isolated from the Peruvian interconnected electricity system. Although no agreement has yet been formalised, different variants were analysed towards the interconnection of the border systems.

In the medium term, a *69 kV line could be laid between Machala (Ecuador) and Tumbes (Peru*) which would allow exports of some 20 MW. The investments associated to the construction of the 54-mile line were estimated in 6 million US dollars, and would allow supplying the Tumbes area.

The construction of a *220 kV line between Machala (Ecuador) and Piura (Peru)* have been considered for the longer term. With a total length of 156 miles, this line would allow the flow of 100 MW, although its cost would reach 70 million US dollars. Nevertheless, the advantages of this interconnection could be dampened by the recent interconnection of Piura with Chiclayo, at least as regards GHG emission saving.

Both nations have jointly analysed the possibilities of a multiple exploitation of the *Puyango - Tumbes* border rivers, something which has been recently incorporated to the negotiations to solve border differences as a sign of the common will to increase integration levels.

The project - which exceeds by far the electricity purpose - proposes the entire use of these border waterways through the establishment of artificial reservoirs which may allow to promote the agricultural development of 173,000 acres from the surrounding area, control floods, strengthen the supply of drinking water and encourage the establishment of fish farms. As regards the electricity field, it includes 2 stations, one in each country, with a joint installed capacity of 150 MW, which would contribute to the supply of the Peruvian northern system and would strengthen the Ecuadorian system's stability with the incorporation of generation on line ends.

According to estimates made in the feasibility study, total investment would reach 1920 million US dollars, to be paid by both nations in direct proportion to the future use made of the water. The higher use would take place in Ecuador, at an approximate cost of 1200 million US dollars, while Peruvian investment would reach 740 million US dollars. These costs are expressed in 1990 US dollars and do not include the specific costs of the irrigation purpose. Regrettably, there is not enough information to estimate which part of the investment should be appropriate for electricity generation.

2.3 Ecuador – Colombia

Both nations have worked since 1978 in studies towards the integration of their electricity systems. As a result of these efforts, a 115 kV line is now operational between Ipiales (Colombia) and Tulcán (Ecuador). These same negotiations anticipated a last interconnection stage through a *400 kV line between Quito (Ecuador) and Pasto (Colombia)*, with a transmission capacity between 150 and 300 MW. Such interconnection was devised mainly to make both the Ecuadorian electricity supply and the Colombian southern system more reliable. The Ecuadorian electricity supply highly depends on the Paute hydroelectric station. Although it may be important from this viewpoint, it is difficult to estimate its impact on GHG emission as from available information.

With a view to electricity generation, there is an agreement reached between both nations in 1982 to analyse the possibilities of using a high-enthalpy aquifer at the border area for energy purposes (*Chiles (Colombia) and Cerro Negro – Tufiño (Ecuador) Geothermal Program*).

Geo-scientific pre-feasibility studies were carried out during 1987 within an area of 1125 square miles on both sides of the border. The results of these research activities indicated the possible existence of a thermal aquifer at a depth of 4900 / 6500 feet, and three drillings were recommended to be carried out, which remain pending due to lack of financing. However, INECEL carried out in 1990 a first estimation of the aquifer's potential, established in 138 MW, which has to be confirmed in further studies.

The first studies pose the possibility of installing a geothermal station with 5 MW installed capacity and an 85% utilisation factor. The cost of the station was estimated in 12 million US dollars, although a similar sum would have to be disbursed to complete prior evaluation studies of the geothermal resource.

A project that was given little evaluation is the possibility of building a gas pipeline to Ecuador, possibly from the fields in southern Colombia. The report from the Colombian consultant in the study for the Andean Development Corporation (Hans Collin Morales, engineer) only mentions the switching from petroleum products to domestic natural gas from the Guayaquil Gulf area, as a way to release fuel oil and diesel oil to be traded with the rest of the Andean nations. According to this estimate, 17300 Tons of fuel oil would be released per year, as well as 10000 of diesel oil, assuming a domestic natural gas consumption of 20 million cubic feet per day.

However, and from the point of view of their impact on GHG emission, the construction of a gas pipeline from Colombia to complement and strengthen the probable use of Ecuadorian natural gas could prove to be highly interesting.

2.4 Colombia – Venezuela

The Colombian and Venezuelan electricity systems experienced their first interconnection in 1964. There are currently 3 major interconnections with a total transmission capacity of 380 MW. Although the future construction of a 400 kV interconnection between both countries is not ruled out, it is estimated that such line would not have a significant impact on the GHG emission from the Colombian system, unless it is accepted that part of the Colombian demand be permanently supplied with Venezuelan hydroelectric generation. For the purposes of this study, and in view of the context in which the Colombian system operates, such alternative was not considered.

In the very long run, there would be a possibility of developing joint hydroelectric undertakings on the Orinoco River basin. Regrettably, there was no information available on possible sites, power which could be installed or energy generation estimates.

In 1992, the presidents of both nations agreed to promote the construction of a gas pipeline to export Venezuelan natural gas to Colombia, with a maximum flow of 200 million cubic feet per day. Technical studies carried out identified two possible routes for the gas pipeline, one joining Ule (Venezuela) with Maicao in northern Colombia, with a total length of 144 miles, and another from Ule to Tibú, in north-eastern Colombia, with a total length of 291 miles.

Although the new Colombian natural gas fields of Cusiana had already been discovered by that time, it was deemed convenient to strengthen the natural gas supply with imports from Venezuela. During the first technical meeting of the parties, at the end of 1992, certain problems were detected to formalise the initial offer made by Venezuela to sell 60 million cubic feet per day during the first twelve years. Since the exportation would be of natural gas associated to oil, its availability would be subject to oil exploitation needs. On account of this, and considering updated estimates on oil production in the international gas pipeline's feed area, the Venezuelan experts concluded that the amounts initially offered would not be readily available.

Nevertheless, and for the purposes of the present regional study, the gas pipeline with Venezuela would only serve to make the supply to the master Plan on natural gas massification in Colombia more reliable. The international gas pipeline would scarcely alter the forecasts for the Colombian electricity supply, as it is already expected to use natural gas.

3 Possible impact of regional energy integration

Below, we analyse in brief the possible consequences of the implementation of the energy integration projects on the Andean systems. According to the information available when the present study was drafted, the analysis is almost solely limited to the electricity sectors. As regards the expected impact of the integration projects strictly in the energy field, the following comments have a qualitative scope, due to the impossibility to anticipate in a detailed way modifications in the operation of the systems. Nonetheless, a gross estimation has been attempted of the impact of certain integration projects on GHG emission from the Andean electricity system.

3.1 Energy impact

It is most likely that the Andean nations will continue their trend to strengthen energy integration ties with a view to increasing the reliability of the energy supply. Such actions will not be restricted now to initiatives from the respective governments but will also be promoted in some cases by the new private energy companies.

The interest shown by the Regional Electricity Integration Commission (CIER) - which groups State-owned and private electricity companies - to search for the possibilities of a large scale South American electricity market represents a good sign in this direction.

The results of this study by CIER will prove significant to analyse both true possibilities for hydroelectric generation complementation within the South American basins as well as the opportunities for electricity inter-country flow and their impact on domestic electricity prices.

With the information available at the moment the present study on the Andean Region was drafted, and without having the results of the CIER study, it is difficult to specify in a quantitative way the impact of having stronger interconnections among the Andean electricity systems. Hence, we will only present here a qualitative analysis on the type of impact expected for this type of integration project.

The actual verification of a significant hydrological complementary nature among the basins - both at yearly as well as seasonal levels - would have a direct effect on firm electricity which may be generated by the Region’s hydroelectric stations as a whole. The firm electricity from all these hydroelectric stations would exceed the sum of the firm electricity of the stations considered individually.

It is significant to remember here that hydrological risk obliges the Andean nations to maintain high installed backup thermal power to face draught periods, the more so when the hydro share is higher. As an example, it may be stated that the firm electricity from the Ecuadorian hydroelectric stations is 25% lower that that estimated for mean hydrological conditions, while Venezuela loses 18% of mean hydro generation in dry years.

The Colombian system has experienced severe restrictions in electricity supply during draught periods due to a lack of capacity to regulate water inflows in its hydroelectric stations, which could be partly offset through electricity imports from Venezuela.

Considered in terms of fuel consumption and, thus, GHG emission from the electricity sector, the rise in firm hydro generation within the Andean nations would have positive impact by allowing to cut down generation from fossil-fueled stations. Should firm hydroelectric energy be increased, the mean energy which could be generated by the hydroelectric plants would also be higher, the latter used in electricity plans to estimate the future operation of plants, as seen in Chapter II of the present report.

It is true that the Andean countries plan to bring down hydroelectric share in future electricity supply, but the latter will remain sufficiently high for the benefit brought by the mentioned interconnections to be significant.

From a strict energy viewpoint, we have to mention the contribution which would be made by these interconnections to the reliability of the electricity supply in the event of forced outages in the generating units, even when these have no direct correlation with expected GHG emission.

Notwithstanding the potential reduction of hydrologic risks brought by the said interconnections, their actual contribution to the promotion of the hydroelectric option in the future expansion of the generating capacity of the Andean countries is less certain. Some conclusions in this sense could only be drawn as from the analysis of the impact of regional electricity trade on the wholesale electricity prices in each country.

An essential element for this analysis - which could rise from the CIER study - is the effect of electricity interchange on the volatility of wholesale prices, which appears as characteristic of the electricity markets after the reform with the presence of high hydro share. As these interconnections increase the volatility of prices or substantially reduce their mean level, private investors would be more reluctant to invest in new hydroelectric stations.

Anyhow, the future expansion of the hydro supply within the Andean countries will strongly depend on the availability and price of natural gas. Aside from the benefits which the availability of natural gas would have in substituting liquid fuels within end-use sectors, the possibility of burning natural gas in power stations would strengthen the trend to substitute hydroelectric options.

This event is already reflected in the reference plans of Bolivia, Colombia and Peru for the electricity sector, where generation on the basis of the burning of fossil fuels is expected to expand. The recent evolution of the Argentine system and the works undertaken by Chile as from the importation of natural gas confirm the general trend of private investors to opt for the use of natural gas rather than building new hydroelectric stations.

3.2 Impact on GHG emission

Due to the impossibility of building a complete Mitigation Scenario for the Andean Region on account of lack of detailed information, estimations were made on the emission saving which some of the energy integration projects outlined in Section 2 of the present Chapter would represent.

For this calculation, it was considered that the hydroelectric stations detected as a regional option would be built in all cases, since they represent non-GHG emitting generation technology. Hence, we incorporate the Charazani and Tahuamanu stations in Bolivia as well as the Puyango - Tumbes plant in the border area between Peru and Ecuador. It was understood that the interconnection line between Machala (Ecuador) and Tumbes (Peru) competes against the stations of the Puyango – Tumbes project, and hydroelectric stations were chosen due to their higher impact on GHG emission.

Moreover, a 200 MW Bolivian export to southern Peru was considered, with an estimated utilisation of 5000 annual hours. Although the potential impact of a gas pipe to the port of Ilo could be even higher, we lacked sufficient information to estimate the consumption of petroleum products that could replace the imported natural gas.

The project which would have the highest impact on GHG emission within the Andean Region would be the construction of a gas pipe from southern Colombia to Ecuador to complement the exploitation of the Ecuadorian natural gas fields in the Guayaquil Gulf area, not considered in the base estimates for the Ecuadorian electricity system.

On the basis of a hypothesis on the type of station and fuel which would replace these projects, we estimated the volume of GHG emission which could be avoided within the Andean electricity sector, as shown in the following table.

Table 1 Avoided GHG emission within the Andean electricity system

Project	**Effect on Power System**	**Effect over Fuel Cons.**	**Avoided Emission** (Gg CO_2)
Charazani Hydro Plant	Replacement of 147 thermal GWh	Saving of 411.6 Tcal of natural gas	96.68
Tahuamanu Hydro Plant	Replacement of 14 thermal GWh	Saving of 39.2 Tcal of natural gas	9.21
Puyango-Tumbes Hydro Plant	Replacement of 525 thermal GWh	Saving of 1260 Tcal of natural gas	406.20
Electricity Export from Bolivia to Peru	Replacement of 1000 thermal GWh	Additional consumption of 2420 Tcal of gas in Bolivia and saving of 2500 Tcal in Peru	237.54
Gas pipeline to Ecuador	Replacement of 70% of thermal generation	Saving of 1155Tcal by CC burning rather than ST Substitution of 9800 Tcal of petroleum products with gas	1134.55
	Replacement of 80% of thermal generation	Saving of 1155Tcal by CC burning rather than ST Substitution of 11300 Tcal of petroleum products with gas	1257.87

In the case of the new Bolivian hydroelectric stations, it has been assumed that, on account of their geographic location, they will replace low yield gas turbine generation. The emission avoided in these stations as a whole represents some 3.5% of the expected emission from Bolivian power stations for the year 2010.

The exportation of electricity from Bolivia to southern Peru would represent to Bolivia an emission increase of some 570 Gg of CO_2 per year, nearly 19% with respect to forecasts for the year 2010. In turn, the importation of electricity would allow cutting down emission from the Peruvian southern system by 806 Gg of CO_2, representing 11% of the total emission from the Peruvian power stations for that year.

Calculations on the consumption of fuel associated to this exportation assume that the thermal efficiency of the Bolivian station will be higher than that of Peruvian stations, for it is a new station. Nevertheless, transportation losses bring down the magnitude of fuel savings. Hence, most of the prevented emission results from the different carbon content of the fuels used on one side of the border and the other.

This project represents a clear example in which the balance for the whole results in GHG emission saving, even when there is an imbalance in the impact on the parties. In such cases, the parties should agree on the way to allocate emission savings to each nation.

The emission avoided by the Puyango – Tumbes project should also be distributed between Ecuador and Peru. One possibility is to distribute the saving in the same proportion as hydroelectric production. Unfortunately, available information does not show how the production from the stations would be distributed. Since the project establishes the construction of 2 independent stations, one in each country, this issue should be agreed upon by now.

Should a gas pipe to Ecuador be laid, it has been assumed that the 300 MW steam turbine estimated by the reference plan would be replaced with combined cycle gas turbines. This change would allow fuel consumption reduction, as shown Table 1. Thus, natural gas would have two effects which combine to reduce CO_2 emission within Ecuadorian power stations even further.

The extent in which the stations will be able to replace liquid fuels with natural gas will naturally depend on the available volumes of natural gas (own and imported) and on the priority that the authorities assign to its use. For the sole purpose of presenting an order of magnitude of the avoided emission, Table 1 included two hypotheses, which are nonetheless quite ambitious, namely the replacement of 70 or 80% of liquid fuels. Depending on the hypothesis chosen, 23 or 25% of the expected emission in Ecuadorian power stations for the year 2010 could be avoided.

Both hypotheses assume a supply to power stations ranging from 3 to 4 million m^3 of natural gas per day. If we deduct from this total figure the supply with own gas resources, we would reach the natural gas import needs for just the power stations. Unless natural gas reserves prove to be significant, the feasibility of gas imports from Colombia would gain strength should the Venezuela - Colombia gas pipeline be built.

Besides the impact which these projects could have on emission by local power stations, the series of analysed energy integration projects would allow reducing total emission from Andean power stations by less than 4%.

Obstacles to Energy Integration

1 Introduction

Although the present work is not aimed at providing a detailed study on the obstacles which could be encountered in the implementation of energy integration projects, this study cannot be completed without making some comments on the issue, in view of the reforms undertaken by the governments of all Andean nations.

The following Sections include some brief comments on the obstacles which could result from differences in the regulation of energy activities in the different countries, as well as on the role which existing regional integration bodies could have in promoting such integration.

2 Regulation aspects

The promotion of regional energy integration projects comprises different stages posing specific problems, namely: opportunities search, facilities for the establishment of domestic markets, and the impact of regional markets on the operation of domestic systems.

Even when private agents seem quite active in promoting projects towards a higher integration of Latin American energy markets, its is important to point out that their action is limited to the search for interesting business opportunities from a corporate viewpoint. This means that there is usually a business profit aim expectation over a systemic view of the needs and conveniences of all agents.

Hence, it seems that corporate initiative should be complemented with surveys in order to co-operate in the search for new integration opportunities. This would mean continuing and delving into tasks which until now were carried out by State-owned energy companies and regional integration bodies.

With reference to the facilities granted by the nations to set up regional markets, it is interesting to note in the first place the aspects linked to the availability of energy resources to the agents involved. Recent experience in Latin America seems to indicate that most of the export initiatives came from those countries in which agents have free availability of the resources they exploit.

As long as non-renewable energy resources are committed, it is important that official policies clearly establish the volume of reserves available for foreign trade, especially if private agents are to have a predominant role in the setting of regional markets.

The main element to consider in the regulation of the regional energy market is undoubtedly the impact that these interchanges have on the normal operation of the energy systems, particularly on costs and domestic prices.

Especially within the market of products which are distributed through physical networks, such as electricity and natural gas, the use of existing transport installations and the allocation of their costs could lead to conflict between local consumers and exporters. At times, the appearance of export projects may bring the need to extend domestic transport systems in the medium run. Should that be the case, it would be important that regulation guarantee an equitable share of the extension costs.

The case of Argentine natural gas exports will be mentioned only as an example of the type of situations which may be brought about by exports. The trunk gas pipeline network is designed to supply most of the domestic demand from the northern and Neuquén basins, both located close to borders and distant from consumption centres. The intensive exploitation of these basins with a view to natural gas exportation could require the beginning of production of the natural gas fields located in Argentina's southernmost region, for which the natural gas network needs to be extended. Regulation establishes that those using them pay gas pipelines. Since the export gas would not use these new gas pipelines, their cost should be borne by local consumers, which would be probably paying more than the foreign consumers for the same Argentine natural gas. A similar situation may be given in the case of electricity transmission, depending on the network configuration and the export destinations.

For the importation of natural gas by Ecuador, the Colombian gas pipeline network could be required to channel Venezuelan natural gas towards Ecuador if an intensive substitution of petroleum products is to be implemented. Colombian regulation should consider this option and the costs to add to the natural gas in transit to Ecuador.

The other essential element within the regional electricity market is who obtains the profit from electricity interchange, and through which mechanisms. Prior to the reforms, two-nation interconnection agreements contemplated an equitable share between the nations of savings in the operational costs of the systems. When market forces foster interchange initiatives, the main system to gather profit is the price charged or paid for electricity, unless regulation sets special appropriation mechanisms.

The mere existence of interchange between two markets generates a trend towards the balancing of their domestic prices, since it is precisely a price difference what leads to trade. Should regulation establish markets which are wholly open to international transactions, interconnection benefits will be unevenly shared by the agents from the exporting nation.

As a matter of fact, an export would have the same effect on prices as a hike in domestic demand, with pressure towards a rise. Thus, consumers from the exporting nation would be negatively affected by having to pay higher prices for the same product, while producers would earn an extra profit equivalent to the product of the price rise by the total demand of the exporting nation. In the importing country, on the contrary, prices would tend to fall, favouring consumers and harming suppliers.

Clearly, the magnitude of the impacts on one and the other will depend on the significance of the export flows. Nonetheless, in those markets in which prices are set in accordance with marginal costs, the impact of inter-country trade will be substantially higher and could cause price fluctuations.

The importance of the inter-country trade impact on prices exceeds the benefit appropriation issue. Price instability increases corporate risk perception in investors. Even when the risk may not fully discourage the participation of private investors, it leads them to demand higher profitability from the chosen works.

Precisely, this characteristic could work against the development of certain regional mitigation options, especially hydroelectric plants which seem to have excessively high costs. In those cases in which private agents do not show interest in the works, it will be necessary to find adequate incentives to promote such works.

To this respect, special consideration should be paid to cost overrun to offset and the way to finance it. As long as the works respond to the aim to cut down GHG emission, it would be important to prevent local consumers from having to pay such cost overrun for their energy supply while contributing to mitigate a serious problem on which they have limited responsibility.

Most of the incentive mechanisms used at international level to lead to changes in the behaviour of economic and social agents with respect to energy consumption translate into a rise in energy prices, either through taxes or through product differentiation (“green markets”).

Hence, the challenge lies in devising promotion ways which may observe equity principles in cost and benefit distribution without discouraging initiatives from energy agents.

3 Regional integration organisations

Different regional organisations have long been established to promote economic and energy integration within the Region. To this respect, we must point out the work carried out at Latin American level by OLADE and CIER, and that of the Andean Development Corporation for the specific case of the Andean Region.

As long as we do not rely solely on private initiative to spot opportunities to move further into the energy integration of the Region, there is a series of issues which would require extra efforts to improve the already excellent work carried out so far by these organisations.

One of the key elements to promote higher energy integration within the Region will be information transparency as regards integration opportunities. Within the new context set by the reforms of the energy industries of the Andean nations, private agents and investors usually have a very partial view in the analysis of the issue, and are generally not willing to invest on basic studies.

Surveys on shared hydroelectric potential and studies on operational aspects of the integrated markets will certainly prove not attractive to certain agents. Thus, additional efforts will be needed to complement private initiative with these studies.

To this respect, it is auspicious that the study on the establishment of a South American electricity market be dealt upon in a joint way by CIER and the Andean Development Corporation. The results of this work will prove highly useful in the promotion of electricity inter-country trade opportunities, as well as in the identification of relevant regulatory aspects for the integration to yield the expected results.

Basis studies, especially when we include surveys on the resource (hydro, geothermal or whichever it maybe), tend to be costly, and a large amount of efforts and financial resources will be required to guarantee their continuity.

The dissemination of the results of these studies represents yet another relevant issue. If investors are expected to take integration initiatives, a catalogue of already identified projects should be available, with detailed information on their characteristics and costs and easily accessible to all interested parties.

Moreover, these organisations may carry out comparative studies with other regions of the world on the promotion methods used, as a way to co-operate with the respective governments in dealing with integration promotion under conditions wholly different from historical ones.

Within this new context, effort co-ordination between OLADE, CIER and the Andean Development Corporation will represent a key element to move further towards regional energy integration and assist governments in this direction.