Chapter 11
Promoting Renewable Electricity Generation in Developing Countries: Findings from Comparative Analyses in South America

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Abstract Access to electrical energy has a key role with regards to socio-economic development and poverty alleviation in particular. Local generation and use of renewable energy offer significant potential for local economic development as well as different environmental benefits. However, in many regions, the lack of electrification is a major impediment to economic development. Even though most of the South American countries have specific and defined strategies as well as plans to improve renewable energy generation, actual implementation is threatened by a wide range of legislative, financial, political and technological problems. This paper presents the key findings of a study carried out as part of the Renewable Electricity Generation in South America (REGSA) project, which comprises comparative analyses of the legislative and institutional frameworks as well as the technical and socio-economic potential of electrical power generation by means of renewable energy in South America and in particular Bolivia, Brazil and Chile. In addition, the paper analyses the results of a mapping of best-practice renewable electricity generation projects in South America and the EU. Finally, it will conclude with some suggestions for fostering renewable electricity generation in developing countries.

Keywords Developing countries · Latin America · Renewable energy · Electricity generation

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Short Introduction

This paper presents the key findings of a study carried out as part of the Renewable Electricity Generation in South America (REGSA) project, which comprises comparative analyses of the legislative and institutional frameworks as well as the technical and socio-economic potential of electrical power generation by means of renewable energy in South America and in particular Bolivia, Brazil and Chile, analyzing the results of a mapping of best-practice renewable electricity generation projects in South America and the EU.

The REGSA Project

A well-established energy infrastructure that reliably supplies the population with electricity is an indispensable element in the process of socio-economic advancement in developing countries. Many South American countries, however, suffer a considerable lack of energy infrastructure. In addition to their different environmental benefits, renewable energy (RE) offers meaningful potential for improvement of energy supply and security in South America as well as poverty alleviation. Particularly rural and difficult-to-access regions can benefit from the implementation of RE with regard to the independent nature of RE generation.

The Renewable Electricity Generation in South America (REGSA) project is a technology and knowledge transfer project funded by the European Union. The project's overall objective is to promote renewable electricity generation in South America and contribute to increasing RE utilisation in Bolivia, Brazil and Chile.

In order to achieve good and sustainable results through technology and knowledge transfer in the field of RE between the REGSA partners, it is first essential to investigate the current situation and to explore existing structures. Within the framework of the work package 2 (WP2) of REGSA a survey was conducted with the objective of a comparative analysis of political and institutional frameworks for RE development and the status quo analysis of RE generation in South America.

Related Literature

Studies that analysed the situation of RE policy making and the use of REs in South America have been conducted at different times in the past. Subsequently some examples of international studies that are thematically similar to the one presented in this paper are given. In 1999 the GTZ published the first edition of the TERNA country survey conducted on behalf of the German Federal Ministry for Economic Cooperation and Development. Since then, three updated editions have

been published—in 2002, 2004 and 2009. In the revised versions new country surveys were added and previous ones were updated. The survey sampled developing and emerging countries in Latin America, Africa, the Middle East and Asia. The survey aims to provide information that helps interested players to access new RE markets. It puts together detailed information about the framework and policy conditions in the surveyed countries as well as about the current RE situation (Posorski and Werner 2009).

In 2004 the GTZ published a paper in cooperation with the United Nations Economic Commission for Latin America and the Caribbean (ECLAC), focusing on the current status of RE in Latin America and the Caribbean with regard to policy making and baseline conditions. After presenting a background review of past efforts to promote REs in the region, it divides the area into six subregions comprising several neighbouring countries. The subregions are analysed with regard to the current state of renewable in the region. Moreover obstacles and opportunities for the penetration of REs and RE policy making are described. The paper points out the importance of the sustainability of RE production. This remark relates to the fact that the intensive use of hydroelectric power and power from biomass in some countries is practised without considering the negative environmental and social effects it generates. Finally, the need for improved cooperation between important governmental, non-governmental and private organisations and institutions is expressed (GTZ and ECLAC 2004).

The global energy network institute published a paper on the RE potential in Latin America in 2009. It aims to give an overview of the RE potential in every Latin American country and thus contribute to RE development in general, the reduction of greenhouse gases and their consequences. Every country was analysed individually for its solar power, wind power, hydro power, geothermal power and biomass potential. The paper provides a multitude of maps illustrating the potential distribution of these RE sources in the different countries. One of the main outcomes was that the big share that REs have in energy generation in Latin America is somewhat misleading because it almost entirely comprises hydro energy and biofuels. For a number of reasons the authors doubt the adequacy of the large-scale use of these RE sources. At the same time they see big potential for the expansion of the other ones (Meisen and Krumpel 2009).

In 2011 the MIT Center for Energy and Environmental Policy Research published a paper on support schemes for REs in South America. Initially it describes the South American perspective on REs from the security-of-supply point of view as well as from the economic point of view. It then reviews the RE support schemes that have been, are and could be developed in South America and names the most important support schemes, laws and stakeholders in each of the ten surveyed countries. It identifies long-term energy auctions as the main instrument for RE promotion in South America and leaves the question open if the increasing efforts to implement REs into the energy mix will be successful (Batlle and Barroso 2011).

In 2011 the UNEP's Technology Needs Assessment project presented the first edition of a new series called Technology Transfer Perspectives. This first edition investigates the possibilities for diffusing REs on the basis of a number of case studies of enabling frameworks in developing countries. Sample regions include South America. The report objective is to "provide insights for governments on how to reform their policies and institutions so as to provide clear and stable incentives that promote diffusion of climate-friendly technologies". The report is divided into two parts: enabling frameworks addressing specific technologies and enabling frameworks addressing multiple technologies. One major finding is that there is no "one" solution for the successful transfer and diffusion of technology. This obstacle is addressed by specifying appropriate policies and actions individually for each surveyed country (Haselip et al. 2011).

Within the framework of the work package 2 (WP2) of the REGSA project, this new survey was conducted with the objective of a comparative analysis of political and institutional frameworks for RE development and the status quo analysis of RE generation in South America.

South American Energy Markets

Figure 11.1 shows a map of South America.

The majority of all the countries that were researched for this survey display a similar energy market model. Table 11.1 shows the market designs and methods of electricity pricing by country.

The by far dominating energy market model is that of a pool marked with bidding competitions. In this case electricity generators obtain capacity rights in competitive auctions held by public utilities. These markets are wholesale-operated, meaning that the wholesale price (the marginal cost) is set by the generators hourly (Lennard 2003). This market model is presented by Argentina, Bolivia, Brazil, Chile, Ecuador, Peru and Uruguay. In the Colombian energy market, on the other hand, electricity is not sold at the hourly marginal cost but at the hourly power exchange price. Retailers act as intermediaries who buy and sell electricity at spot markets where energy is being traded and the power exchange price is set hourly. Consumers buy electrical energy from those retailers and can choose the cheapest one (Posorski and Werner 2009).

Chile, Colombia, Ecuador and Peru present capacity payments, i.e. additional costs for energy purchase during peak periods, as an indication for greater energy demand and therefore an incentive for the creation of new capacity (Lennard 2003; Oren 2000).

Paraguay and Venezuela are the only two countries surveyed that have kept the integrated model of a public monopoly.

Fig. 11.1 Map of South America (http://www.world-atlas.us)

Renewable Energy Support Schemes in South America

In the first decade of the 21st century the vast majority of South American countries have come to realise that renewable energies (RE) are an inevitable part of their future energy supply (Batlle and Barroso 2011; Haselip et al. 2011). Initiatives to promote RE generation emerged in a variety of forms on national and local levels. Fiscal and tax incentives, soft loans and RE funds are moderate ways to support the implantation of REs and can be found in many countries. However, a number of countries have also introduced more impelling measures. Energy contract auctions, tenders, renewable portfolio standards and capacity payments

Table 11.1 Market designs, methods of electricity pricing and existence of capacity payments in the surveyed countries

	Argentina	Bolivia	Brazil	Chile	Colombia	Ecuador	Paraguay	Peru	Uruguay	Venezuela
Market model	Pool financial BC	Pool financial BC	Pool financial BC	Pool financial BC	Pool(PX) financial BC	Pool financial BC	Monopoly	Pool financial BC	Pool financial BC	Monopoly
Wholesale market operation spot price	Marginal cost hourly	Marginal cost hourly	Marginal cost hourly	Marginal cost hourly	Power exchange price hourly	Marginal cost hourly		Marginal cost hourly	Marginal cost hourly	
Capacity payment				Yes	Yes	Yes		Yes		

have become an important and in some countries *the* major instrument for RE market stimulation (Batlle and Barroso 2011; Haselip et al. 2011).

Subsequently, the main steps in the implementation of RE in each country surveyed are described.

In **Argentina** in 2007 the secretary of energy passed the 26 190 law, which aims to increase the percentage of renewable energy sources in power supply to at least 8 % by 2016. To reach that target the Ministry of Federal Planning, Public Investments and Services (Ministerio de Planificación Federal, Inversión Pública y Servicios) initiated a programme for the generation of RE (RENGEN) in 2010 (Posorski and Werner 2009; IEA 2010). The system operator CAMMESA (Compañía Administradora del Mercado Mayorista Eléctrico S.A.) and the public service corporation ENARSA play an important role in this plan, as they hold energy contract auctions and guarantee energy purchase (Batlle and Barroso 2011).

In 2007 **Bolivia** passed a national development plan (Plan Nacional de Desarrollo) in which the government commits itself to the complete electrification of Bolivia by 2025. To achieve that goal, the governmental programme, Electricity for Living with Dignity (Electricidad Para Vivir con Dignidad), among other efforts was initiated and coordinated by the Vice Ministry of Electricity and Alternative Energies. This programme also promotes the use of REs. For example, the biggest project within the programme, the Decentralized Infrastructure for Rural Transformation (Infraestructura descentralizada para la transformación rural—IDTR), has a budget of $15 million that exclusively promotes the implementation of solar home systems for rural electrification (Rutschman 2010).

In 2002 **Brazil** introduced a feed-in programme for wind and biomass energy called the PROINFA (Programa de Incentivo às Fontes Alternativas de Energia Elétrica) programme (Batlle and Barroso 2011). Prior to that the Brazilian government enacted the 10438 law, which was responsible for the start of PROINFA (IEA 2002), however was not specific to RE development. It was connected to energy purchasing contracts with the state-owned company Eletrobras but was criticised for a lack of efficiency. In 2007 a second initiative to foster REs was launched by implementing a reduction of cost for transmission and distribution tariffs beneficial to the consumer and subsidised by the government (Batlle and Barroso 2011). Today the energy contract auctions have become the major instrument for general market expansion and RE market stimulation in Brazil. Pre-investment appraisal subsidies and tax incentives are also present in Brazil.

The production of electricity through hydroelectric power plants covers the majority of Brazil's electricity demand and is treated preferentially compared to the other RE resources. Therefore it must be viewed separately from them.

In 2008 **Chile** passed the 20.257 law, which aims to increase the RE share in energy production to 5 % by 2010 and 10 % by 2024 (Wright and Adlerstein-Gonzalez 2009). Generators that do not fulfil this obligation by the prescribed time will be fined US$28/MWh and US$42/MWh after a three-year violation period. With not enough RE projects in sight it has become questionable if the renewable portfolio standard will be successful. Energy providers have asked for alternative solutions such as a feed-in tariff (Batlle and Barroso 2011).

In 1995 **Colombia** created a national development plan for alternative energies (Plan de Desarrollo Nacional de las Energías Alternativas), which makes suggestions for strengthening RE sources. However, this proved to be nothing more than lip service, as no action was taken in the years to follow (Projekt-Consult GmbH and Loy 2007). In 2001 the Colombian government created a framework for the promotion of renewable energies with the passing of the 697 law. This law was designed for developing the Program of Rational and Efficient Use of Energy and Other Forms of Non-Conventional Energy, PROURE (Programa De Uso Racional y Eficiente de Energía y Fuentes no Convencionales). Since then the promotion of RE has emerged in the form of tax incentives. PROURE is supervised and led by the Ministry of Mines and Energy (Projekt-Consult GmbH and Loy D. 2007). In 2010 the 180919 resolution was issued and follows an action plan to further develop PROURE from 2010 to 2015 (Mojica 2011).

In 2000 **Ecuador** introduced a feed-in tariff for photovoltaic energy generation. However, the Ecuadorian government has never fulfilled its duty of payment, which it imposed upon itself. Minor efforts to promote PV technology were made in 2003 and 2006 by setting up a few hundred isolated systems. The rural electrification project for Amazonian homes (Perva) presently aims to electrify 15,000 households with PV systems until 2013 (Batlle and Barroso 2011). In 2011 the administrative institution, CONELEC (Consejo Nacional de Electricidad), passed the regulation, CONELEC 004/11, which introduces a feed-in tariff for the next fifteen years regarding energy generation from wind, sunlight, water, biomass and geothermal sources (Gipe 2011). However, due to the recent regulation passed by president Correa that enables the state to fully regain control of the countries electric system, private investments are expected to be held back significantly (Batlle and Barroso 2011).

In **Paraguay** 99 % of the generation capacity is hydroelectric. No incentives for the development of other REs exist and no initiatives are presented (Batlle and Barroso 2011).

In 2005 **Peru** passed the law of promotion and use of non-conventional energy recourses in rural, isolated and frontier zones of the country, law no. 28546 (Peru 2005). A regulation with force of law was passed in 2008 proclaiming the fostering of REs a matter of national interest and exigency. This regulation, called the 1002 decree, promotes wind, solar, geothermal, hydroelectric and biomass power generation. Hydroelectric power is only considered an RE source if it comes from power plants of 20 MW installed capacity or less. It furthermore specifies that the Ministry of Energy and Mines must define a target percentage of the share of RE in the national electricity consumption every five years. For the first five-year period this percentage was set to 5 % (SNMPE 2011). To achieve these goals the country has now introduced energy contract auctions in order to stimulate RE investment.

In 2005 **Uruguay's** Ministry of Energy and Mines and the national energy supplier UTE (Administración Nacional de Usinas y Trasmisiones Eléctricas) took their first step in integrating REs into their energy mix by enacting the 389/005 decree. It allowed UTE to call for tenders for RE generation projects. But the

limitations were too many and thus only one small wind power project was realised. In 2006 the 77/006 decree was issued where limitations had been reduced but not sufficiently (UNFCCC—CDM—Executive Board 2006). In this manner the policy process continued increasing project sizes, lately attracting wind power projects of up to 150 MW (Batlle and Barroso 2011). In 2009 the 18.585 law was passed, which promotes solar thermal energy. It requires hotels, hospitals, public buildings and new buildings to generate 20 % of the energy needed to heat water with solar/thermal power (Epp 2010).

In **Venezuela** no initiatives for the development of other REs exist and no incentives are presented. In 2009 the Organic Law of the Electric System and Service (Ley Orgánica del Sistema y Servicio Eléctrico) came into effect. In article 21 the government raises the prospect of a development plan for the national electric power system that will include the use and development of renewable energies. However, a development plan incorporating these targets has yet to be created (Batlle and Barroso 2011; Venezuela 2010).

The Tables 11.2, 11.3 and 11.4 give a summarised overview of the institutional and legal frameworks in the different countries.

Renewable Energy Generation in South America

The data that is the basis for this comparative analysis dates back to 2009 (Argentina, Colombia, Peru and Bolivia) and 2010 (Brazil, Ecuador, Uruguay, Chile and Germany).

Figure 11.2 shows the share that each of the renewable energy sources—water, wind, sunlight and biomass—have in the entire range of energy generation technologies of the different countries.

The most obvious fact displayed in Fig. 11.2 is that hydroelectric power is the dominating RE in South America. Argentina, Bolivia and Chile generate approx. one-third of their entire energy from water power, Brazil and Colombia about three quarters and Uruguay almost covers its whole energy demand with water power. Ecuador and Peru are somewhere in the middle. Furthermore, Fig. 11.2 shows that all other RE sources only play an insignificant role in the energy production of these countries. In Brazil the production of biofuels from biomass is quite important for the transportation sector and in Chile and Ecuador this also amounts to about one percent of the country's energy generation. Energy production from wind accounts for approx. half a percent in Brazil and Chile and 0.7 % in Uruguay. Solar power generation is practically non-existent in the surveyed countries. It has no or less than a 0.1 % share in the different countries' energy production.

For a more detailed analysis it is necessary to put these percentages into perspective of the amount of energy that the single countries produce. In Brazil for example, which is the country with the biggest energy demand of the surveyed

Table 11.2 Overview of the institutional frameworks in Argentina, Bolivia, Brazil, Chile and Colombia

	Argentina	Bolivia	Brazil	Chile	Colombia
Policies	Secretaría de Energía (SENER)	Vice Ministry of Electricity and Alternative Energies (Ministry of Hydrocarbons and Energy)	Ministério de Minas e Energia (MME)	Ministerio de Energía	Ministerio de Minas y Energía
Regulator	Ente Nacional Regulador de la Electricidad (ENRE)	Electricity Supervision and the Social Control Authority (AE)	ANEEL	Comisión Nacional de Energía (CNE)	Comisión de Regulación de Energía y Gas (CREG)
Supervisor	ENRE	Electricity Supervision and the Social Control Authority (AE)	ANEEL	Superintendencia de Electricidad y Combustibles (SEC)	La Superintendencia de Servicios Públicos Domiciliarios (SSPD)
System operator	CAMMESA	National Committee for Charge Dispatch (CNDC)	Operador Nacional del Sistema Eléctrico (ONS)	Centro de Despacho Económico de Carga (CDEC)	XM filial de ISA S.A
Planning	Ministerio de Planificación Federal, Inversión Pública y Servicios	Vice Ministry of Energy Development (Ministry of Hydrocarbons and Energy)	Empresa de Investigación Energética (EPE)	Comisión Nacional de Energía (CNE)	Unidad de Planeación Minero Energética (UPME)
Environmental authority	Secretaría de Ambiente y Desarrollo Sustentable (SEMARNAT)	Ministry of the Environment and Water	Ministério do Meio Ambiente	Ministerio del Medio Ambiente y CONAMA	Ministerio del Ambiente, Vivienda y Desarrollo Territorial
RE promotion	Dirección Nacional de Promoción (DNPROM)			Centro de Energías Renovables (CER)	
Conflict solving	ENRE			Panel de Expertos	Superintendencia de Servicios Públicos Residenciales

Table 11.3 Overview of the institutional frameworks in Ecuador, Paraguay, Peru, Uruguay and Venezuela

	Ecuador	Paraguay	Peru	Uruguay	Venezuela
Policies	Federal Ministry of Policies/ Ministerio de Electricidad y Energía Renovable (MEyER)	Viceministerio de Minas y Energía	Dirección General de Electricidad	Ministerio de Industria, Energía y Minería	Ministerio del Poder Popular para la Energía Eléctrica (MPPEE)
Regulator	CONELEC	ANDE	Dirección General de Electricidad	Unidad Reguladora de Servicios de Energía y Agua (URSEA)	MPPEE
Supervisor	CONELEC	ANDE y Contraloría General de la República	Organismo Supervisor de la Inversión en Energía (OSINERG)		MPPEE
System operator	CENACE	ANDE	Comité de Operación Económica del Sistema Interconectado Nacional (COES)	Administración del Mercado Eléctrico (ADME)	MPPEE
Planning	CONELEC	ANDE y Secretaría Técnica de Planificación	Ministerio de Energía y Minas	Dirección Nacional de Energía y Tecnología Nuclear (DNETN)	MPPEE
Environmental Authority	Ministerio del Ambiente	Consejo Nacional del Ambiente (CONAM) y la Secretaría del Ambiente (SEAM)	Consejo Nacional del Ambiente	Dirección Nacional de Medio Ambiente (DINAMA)	MPPEE y Ministerio del Ambiente
RE promotion	MEyER	ANDE	Fondo Nacional del Ambiente (FONAM)	DNETN	Dirección General de Energía Alternativa
Conflict solving					

Table 11.4 Overview of the legal frameworks in the different countries

	Argentina	Bolivia	Brazil	Chile	Colombia	Ecuador	Paraguay	Peru	Uruguay	Venezuela
General law	Law 24.065	Electricity law 1604	Law 10 848	General Law of Electric Service (DCL4)	Laws 142 and 143	Law of the Electricity Sector Regime (LRSE, ROS 43)	Law 167/93	Law of electric concessions	National Electricity Law (Law no. 14.694)	Organic Law of Electric System and Service
Renewable law	Law 26 190		Law 10438	Law 20.257	Law 697 and resolution 180919	CONELEC - 004/11		Law no 28546 and decree 1002	Law 18.585 and decree 77/06	

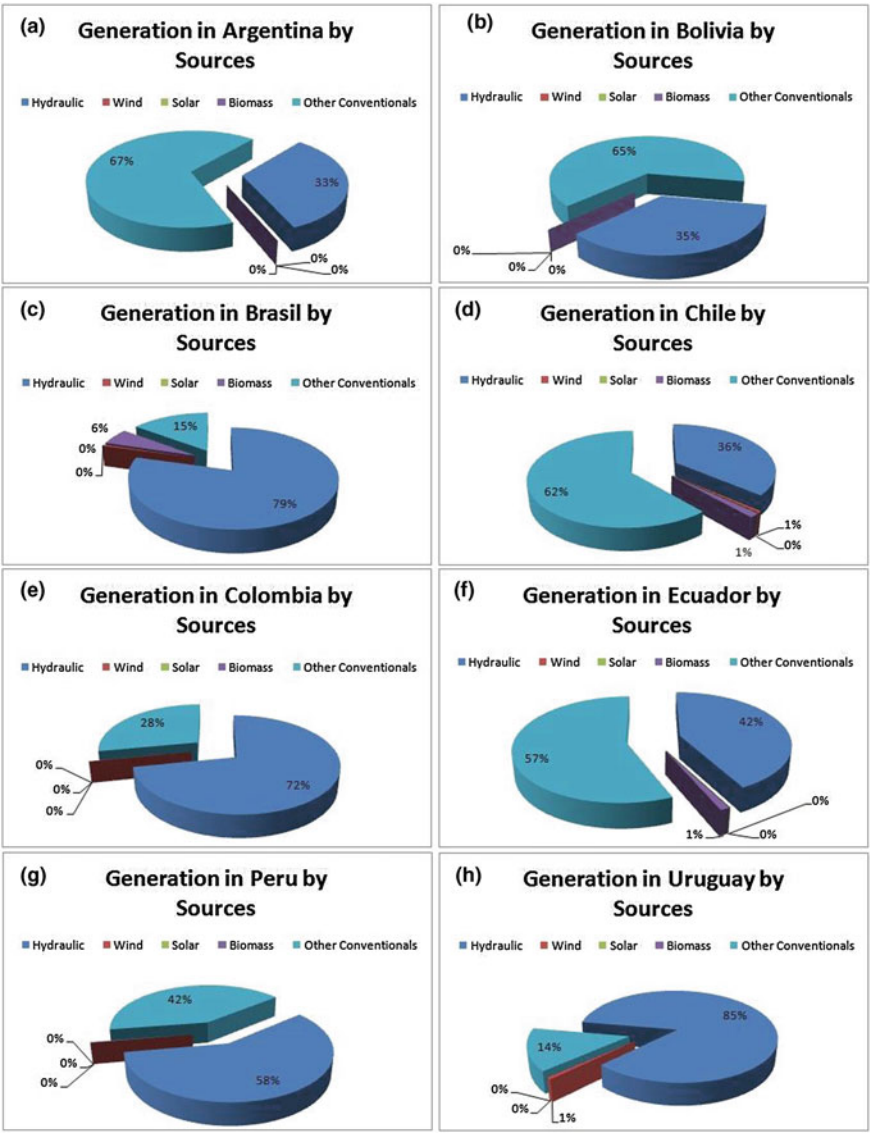

Fig. 11.2 Distribution of the energy generation among the different energy sources in the countries surveyed

countries, the 0.43 % that wind energy contributes to the energy production represents 927 MW installed capacity and the 6 % that is the energy production from biomass equals 7.8 GW installed capacity.

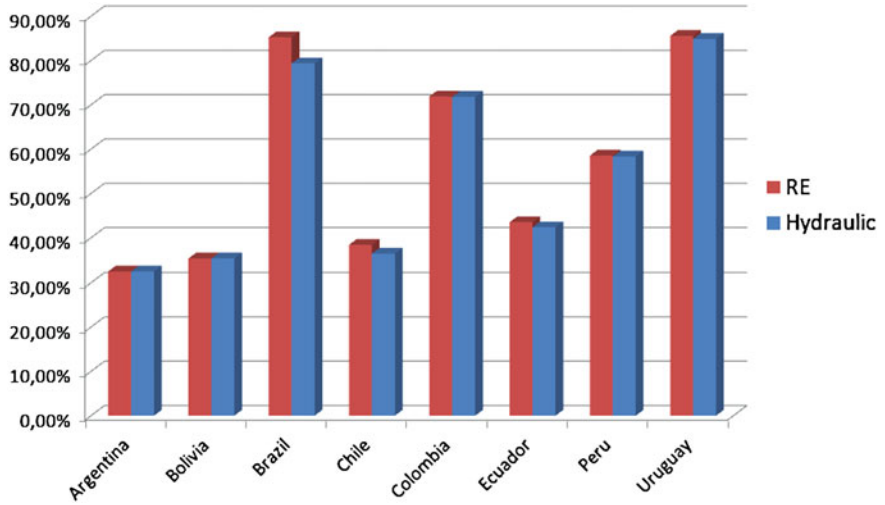

Fig. 11.3 Share of RE and hydroelectric power in the entire range of energy production technologies of the different countries

The Controversy of Hydroelectric Power

On average RE contributes 54 % to the energy supply of the surveyed countries. That is quite an impressive number especially compared with ratios of OECD countries, which do not even come close to that figure. However, this impression can be very misleading. As we have seen above REs are dramatically underrepresented with the exception of hydroelectric energy. Figure 11.3 illustrates the dominating position that hydroelectric power generation takes among the REs in the countries surveyed.

Whether or not hydroelectric power can be called sustainable and in some cases even renewable is somewhat questionable and therefore problematic. This applies particularly to large-scale hydroelectric plants, which of course make up the biggest share of installed hydroelectric capacity (Meisen and Krumpel 2009).

There are two main reasons for this controversy. Firstly, many South American countries have become dependent on hydroelectric energy production. That makes them very vulnerable to dry periods and the ensuing fall of water levels. Secondly, large hydroelectric projects have been the cause for large environmental and social problems. The damming up of big rivers and the consequent flooding of vast areas has led to the loss of valuable natural reserves and was the reason for the relocation of indigenous peoples from their traditional territory (UNFCCC—CDM—Executive Board 2006).

Even though it is arguable to what extent these criticisms are applicable, it becomes clear that some perceive large-scale hydroelectric generation as not the most adequate solution.

Conclusion

The survey showed the existence of similarities and differences among South American countries regarding RE development. Particularly in the comparison of preferences for the different RE technologies, similarities become apparent. The fact that all RE sources besides hydroelectric only play an insignificant role in the energy production is certainly partly due to the level of complexity that is inherent to the different RE technologies. But it may well be suspected that a lack of appropriate RE incentives is also a reason.

Furthermore, the analysis shows that there are initiatives for the development and the promotion of RE in South America. However, despite the big RE potential, large-scale implementation of RE generation has yet to be realised.

All in all the survey conducted in the WP 2 shows that most of the countries surveyed perceive RE to be an inevitable part of their future energy supply. It is thus crucial that existing efforts are duly supported by means of appropriate knowledge and technology transfer.

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