Innovation System for Sustainability in Developing Countries. The Renewable Energy Sector in Bolivia

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Abstract

The paper describes the main ideas surrounding the topic of innovation for sustainability in developing countries. Innovation is a crucial element to foster sustainability as well as an egalitarian development. The work illustrates that sustainable development is possible by exploiting local potential and traditional knowledge in order to achieve at the same time economic growth, social equality and environmental sustainability. In order to prove such an assumption a specific case study is described: The renewable energy sector in Bolivia. The case study analyses several dimensions of the innovation process in developing countries such as technological transfer, diffusion and adaptation, social dimension and development issues. The Bolivian case showed that it is possible to foster sustainability and local entrepreneurship by triggering the endogenous energies embedded in territories and traditional knowledge.

Keywords:

innovation systems; eco-innovation; environmental sustainability; sustainable development; developing countries; renewable energy; photovoltaic systems; PVS; traditional knowledge; local entrepreneurship; Bolivia.

Biographical Statement:

Mario Pansera is a Ph.D. research fellow in Management at University of Exeter. His work is focused on Eco-innovation with a particular interest for emerging and developing countries. A graduate of University Federico II of Naples (MSc, 2005) in Telecommunication engineering, he spent two years in Bolivia working in the field of renewable energy for remote rural areas. Most recently he came back to academia working as project Manager of R&D projects funded by European Commission at Polytechnic University of Madrid. His always existing interest in economics and social development issues has been constantly increasing during the last years, reason for which he decided to earn a Master's Degree in "Economics and Management of Innovation" at the Polytechnic of Madrid in collaboration with Autonomous University of Madrid and Complutense University in 2009.

1 Introduction

During the last thirty years several economists have shifted their attention to a different approach of economic issues characterized by an increment of interdisciplinary analysis. The criticisms moved against the Mainstream Neo-Classic approach to Economics were that it essentially lacks the concepts to deal adequately with nature, justice and time (Faber, 2008). As the Brundtland Report stated more than twenty years ago, economics have to take into account nature (Brundtland, 1987; van Dieren, 1995). Resources scarcity is already incrementing inequality and threat to jeopardise social justice, social stability and even modern lifestyle (Meadows & Randers, 2006). Other approaches, such as Ecological Economics, try to address the flaws of the *Classic concept of Development* advocating for more sustainable economic models. However, it has become clear that sustainability means important long-term changes in technologies, lifestyle, infrastructure and institutions. While ecological economists are convinced that a strong effort is needed to redefine the concept of progress, no efforts have been done to

redefine the idea of innovation (Rennings, 2000). In order to shift from the present linear model of extraction-production-consumption-throw-away to a *closed-loop* system of production, a tremendous technological effort is needed. In other words, green innovations and a green Innovation System are both needed. The paper, thus, aims to contribute to the analysis of the concept of Innovation System for sustainability and its impact on development. Fostering eco-innovation is the key to achieve a sustainable development in the long term. This is valid for modern developed countries as well as for developing countries

The present paper is divided in three parts. The first part aims to illustrate the main ideas surrounding the topic of environmental sustainability. In particular it focuses on the debate existing between the Neo-Classic approach and the holistic vision of the Ecological Economists. In this part the concept of Eco-Innovation System (Eco-IS) is also introduced and further considerations are provided for the case of developing countries. The second part tries to analyse the challenge of sustainability in less developed countries within the Eco-IS framework. Finally the last part describes a particular case study: The renewable energy sector in Bolivia.

2 Innovation Systems for sustainability and institutional change

2.1 Sustainable development: Neo-classical vision Vs Evolutionary theory

Nowadays few people in the academia would deny that modern society is facing an epochal crisis in terms of sustainability. While in the last 50 years the world has witnessed an incredible economic growth providing millions of people with high levels of wellbeing, only few efforts have been invested to find out whether such an amazing development can be sustained forever. For those reasons, many scholars, with very diverse backgrounds, reckon that it is needed to rethink the relationships between human economic activity and nature. We can start by making a clear division between the human economic system and what Raskin (2008) calls the *Human Ecological System* (HES). While the former is the way in which humans beings organize and exchange labour and capital, the latter involves all the relation between humans and the eco-systems that nurture them (Bonaiuti, 2009). This view includes, in addition to the economic dimension, at least three other dimensions: the *biophysical dimension* (the whole of the interactions with the natural environment), the *social dimension* (where economic relations are only a part of the total), and a *cultural dimension* (institutions and values).

During the last 60 years several economists have been trying to analyse the impact of industrial development on the environment using the marked-based approach of neo-classical thinkers. They introduced the concept of *externality*, which is the unpaid cost of pollution that is usually charged on the entire society. One consequence of such an analysis is to adopt policies that force the polluter to pay for their environmental damages or stimulate investments in sustainable technology through fiscal measures. In a nutshell, environmental degradation is a market failure that needs to be addressed through appropriate market policies. As a consequence, the neo-classic approach focuses on the study of the comparison of different market equilibrium states rather than the paths that moves from a certain state to a more sustainable one (Mulder & van Den Bergh, 2001). Consequently, for the neo-classics, *sustainable development* coincides with *sustainable growth* (van Den Bergh, 2007). Neo-classical approach seems to raise more doubts than solutions when we try to apply it to investigate the process of change toward a sustainable society. The main reason of this weakness is that sustainable development requires changes that include not only quantitative but also qualitative aspects of the economic system. In other words, an alternative framework is necessary to study such a process, a different approach that takes into account the systemic nature of the HES (Georgescu-Roegen, 1971). Furthermore the process of eco-system degradation involves not only the productive activity but also affects the interface between economy, ecology and society: the incessant growth of production and consumption implies a greater flow of matter and energy, usually from poorer countries, generating social conflicts in areas where these resources are exploited. This "*environmentalism of the poor*", introduced by Martinez-Alier, is a useful concept to understand the impacts on the social sphere and culture of local populations as well as to comprehend why the prices of many essential resources for the global production system, are linked to the outcomes of these conflicts (Martinez-Alier, 2002).

According to other authors the interaction between economy and environment should be seen as an evolutionary process (Mulder & van Den Bergh, 2001). Ecological Economics, for instance, aims to describe the relationships existing between ecosystems and the economic system. This approach relies on the cohabitation of economics and ecological models (Costanza & Daly, 1987). As a consequence, development itself is considered an evolutionary process with continuous feedback between economy and the environment. Contrary to the belief that the economy is independent from the natural environment, ecological economics states that the economy evolves in conjunction with natural environment. This concept is known as Co-evolution and it is focused on the reactions of both economic and environmental systems to changes like resources scarcity, environmental degradation and regulation (Kallis & Norgaard, 2010; Norgaard, 1984). The notions of irreversibility, uncertainty and non-linearity of ecological-economic systems are crucial in the evolutionary framework and fundamental to understand how the systems are evolving from their initial diversity (Arnold, 2002).

2.2 Eco-Innovation and Innovation Systems for Sustainability

Taking nature into account has important implication for the study of technology and innovation. The nature of innovation process itself is intimately uncertain and non-linear. The knowledge that underlies innovation depends on a multitude of factors such as culture and institutions among many others. Sustainable development, thus, requires radical changes not only in policy but also in the current system of governance (Kemp, Loorbach, & Rotmans, 2007). For this reason, any attempt to find a way to govern the transition to sustainability cannot avoid a systemic analysis. From a methodological perspective, the Innovation System (IS) concept results to be very useful in this regard. The IS idea suggests that innovation originates from a web of relationships between firms, organization and public institutions (Edquist, 2006; Chris Freeman, 1995; Furman, Stern, & Porter, 2002; Lundvall, 2010). So, the output of a sustainable system of innovation is *sustainable technology*. By *Sustainable Technology* we mean all the processes, products, organizational ways and institutions that do not affect critically the present and the future dynamic equilibrium of the HES. Many authors call this kind of innovation environmental innovation, ecological innovation or simply eco- innovation. Many definitions have been provided (Carrillo-Hermosilla, del Rio Gonzalez, & Könnöla, 2009). According to Klemmer (1999), the concept of Eco-innovation can be summarized as following:

> *"Eco-innovations are all measures of relevant actors (firms, politicians, unions, associations, churches, private households) which;*
>
> - *Develop new ideas, behaviour, products and processes, apply or introduce them and*
> - *Which contribute to a reduction of environmental burdens or to ecologically specified sustainability targets."*

2.3 Toward a sustainable innovation system

Perhaps even more interesting is the fact that some authors have attempted to extend the IS framework to include environmental sustainability. For instance in the development of the IS concept, Lundvall (2010) explicitly mentions natural elements that influence the functioning of the system. According to Segura-Bonilla (1999), in the process of rethinking IS, it is not possible to separate human activity from its dependence on functional ecosystems. He considers that:

"a sustainable system of innovation is constituted by human and natural elements and relationships which interact in the production, diffusion and use of new, and economically useful, knowledge".

Figure 1 shows one possible model to describe the interactions between the actors of the IS, the society and the eco-systems. The conceptual framework described above shows that it is possible to reconsider the function of innovation and learning in a system and shape its components in order to achieve concrete sustainable goals. The dynamic of such a process lies in the co-evolution between knowledge infrastructures, production structures, institutions and, of course, the eco-systems without which any economic activity would be impossible. As Kemp et al. (2007) suggests, a crucial role must be played by governance and all

the components of society. In fact, the so-called *civil society*, which is composed by users and citizens' organization, NGOs and think-tank groups, has an increasingly important weight in the decisions making related to environmental issues.

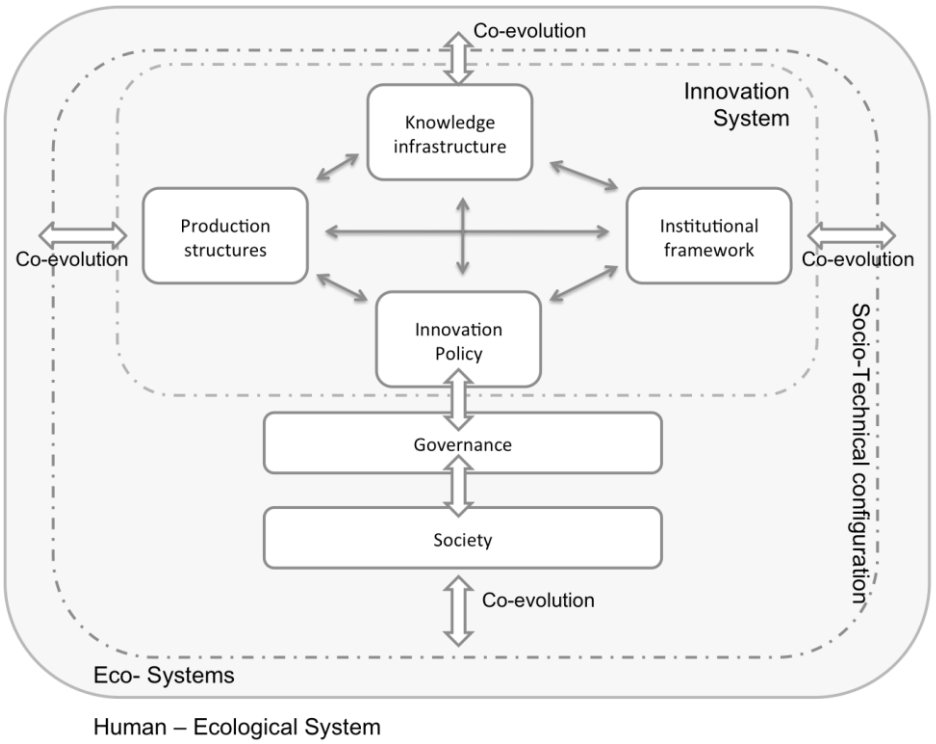

Figure 1: Knowledge flows in an Innovation System for Sustainability. Based on: (Elzen, Geels, Hofman, & Green, 2004; Segura-Bonilla, 1999)

The nature of institutional change appears to be even more complex when we consider that it involves a wider sphere of humans' affairs than the mere economic dimension. Many institutions are strongly related to religious beliefs and territorial evolutions. Rather than improving economic performance, in many traditional societies institutions aim to preserve the *integrity and stability* within them (Jenkins, 2000). This process requires rethinking the institutions of the market, repositioning it "*within time and space, embedding it within local contexts so that it has a more immediate reality to participants*" (Fournier, 2008). Hence, we assume that institutional change for sustainability requires at least the following elements:

- Cultural and Institutional diversity to assure flexibility and adaptability to changing environments;
- Involvement of local actors and their traditional heritage to assure continuity and ethic motivation;
- Involvement of local actors in the process of decision making about environmental issues favouring the territorial aspect;
- Educated citizens rather docile customs. People should be aware of the impact of their actions as technology users on the environment;
- Communication and investment in social capital. Enhance the faith in the *economy of common*.

3 Eco-Innovation System in Developing countries

3.1 Development and Sustainability in Low-Income Countries

Nowadays the concept of development appears to be a monolithic idea that does not give room to any misunderstanding. However this concept in its modern formulation is quite new. In this respect Wallerstein (2004) is enlightening in providing a brilliant description of the origin of the term:

"Development, as the term came to be used after 1945, was based on a familiar explanatory mechanism, a theory of stages. Those who used this concept were assuming that the separate units - national societies - all developed in the same fundamental way but at distinct paces (thus acknowledging how different the states seemed to be at present time)."

In the real world, nations do not seem to follow the linear pattern often illustrated by Western scholars. Economic growth, poverty and environmental degradations all evolve according complex trajectories in the so-called developing world that are far to be linear (Bratt, 2009). Developing countries are very dissimilar to each other and are almost always characterized by development's model that may be very different if compared with industrialised countries. The amazing ascension of the Chinese economy is a good example of development that does not follow the *western paradigm*. In the last five years China became the biggest investor in renewable energy in the world. The Chinese are trying to tackle the growing environmental issues generated by the economic growth by adopting new strategy, like the *Law of Circular Economy* or involving local communities in the decision making process (Zhang, Yuan, Bi, Zhang, & Liu, 2010; Zhijun & Nailing, 2007). Hence we can state that developing countries can enjoy at least three important assets for achieving sustainability:

- Less developed countries can avoid mistakes made by industrialized countries during the early stages of development. *Learning from the mistakes of the others!*

- They can take advantage of clean technology generated so far by more developed countries. Actually, they can acquire mature technology without investing huge amount of money in R&D activities.

- Lastly, most of developing countries' economies are still based on traditional habits of production and consumption. The challenge is to enhance the local capability and exploit and valuate them to preserve the sustainability of traditional habit and, at the same time, improve the efficiency of production.

3.2 Systems of Innovation from the South

Since most of the so-called *less or late developed countries* do not present an articulate infrastructure for innovation, it is crucial to understand how it is possible to use local competences for boosting development processes. Those countries are characterized by *"proto-innovation systems"*. According to Arocena and Sutz (2000), when one uses the concept of Innovation System it is decisive to take into account four essential aspects:

1. Unlike developed countries, in the periphery, IS concept is basically an *ex-ante* concept. In the industrialized countries the study of innovation has been based on empirical analysis that allowed identifying common patterns among different nations and regions. In developing countries it is very difficult to find regular patterns in the economic system at a national level;

2. *"The IS concept carries a normative weight".* That means that there is no *ideal system*. Some measures can be useful in a specific context and may be less effective in other situations.

3. The IS concept is, in its nature, a *relational* model. The good relationships between the actors are often the most important factor of success in the systems. In the case of Latin America, for example, it has been easy to create organizations to boost innovations, but it was hard to make them work.

4. Finally, the IS concept is useful to formulate policies.

Lundvall and Chaminade (2009) focus their attention on the contribution of the IS approach to development economics. The scenario depicted shows that some emerging economies preferred to passively imitate more developed nations, while others invested in learning dynamics. Maybe more important, in this context we have to consider i) the abandonment of the assumption of socio-economic agents always acting rationally, ii) the importance of the interactions between the economy and political institutions and, iii) *"endogenous evolution of preferences in public policy"*. Rather than unique recipes for development, IS approach suggests investing in endogenous capability through a process of interactive learning. This strategy is often called *competence-building* or, in other words, *the processes of learning and renewal of skills necessary to innovate* (Lundvall & Borrás, 1999). Even local administrations can play a crucial role in *dynamizing* the territorial innovation systems even in rural areas (Cummings, 2005). On the other hand communities can take advantage or suffer the consequences of radical innovation (Cozzens & Kaplinsky, 2009; Cozzens, 2008). Actually innovation, in all its form, can increase or decrease inequality. To avoid such a vicious circle it is again necessary to invest in local skills but also provide good working conditions, prevent environmental externalities and involve local energies as much as possible. In Figure 2 a model of IS for developing countries as the intersection of four elements is proposed:

1. Local economic growth: Local initiative is crucial in endogenous development. Local and territorial infrastructures can be compared to the *hardware* of the system while local initiatives and policies represent the *software* (Vazquez-Barquero, 1999).

2. Social inclusion and equality: *Innovation Policy should focus on inclusive innovations and their diffusion* (Altenburg, 2009). Inclusive innovations aim to reduce inequality and provide dignified jobs.

3. Sustainability: Innovation policy has to preserve traditional culture and take advantage of it to achieve environmental sustainability.

4. Competence Building: Innovation Policy has to foster the formal production of knowledge through S&T policy but also valorising local potentiality.

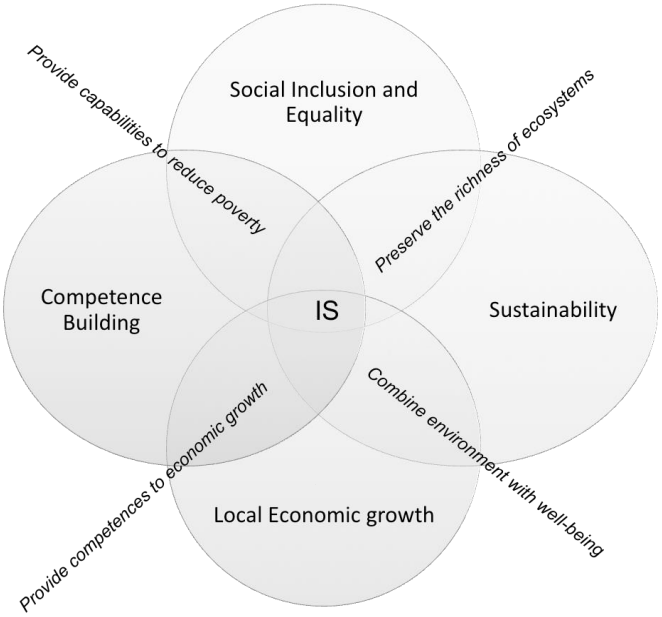

Figure 2 Innovation System approach for developing countries

In the following sections is shown the application of that model to a concrete case: the renewable energy sector in Bolivia.

4 Innovation, Sustainability and Endogenous Forces: Evidence from Bolivia

In order to show the usefulness of the conceptual framework proposed in the previous sections, an exploratory case study is considered. In this specific case, the IS approach is adopted to study the Bolivian renewable energy sector with a particular attention to rural applications. The case study aims to disclose the connections between institutions, traditional knowledge, local firms and the international community that have been established to deliver a set of sustainable solutions for rural electrification programs. The case attempts to describe the dimensions introduced in the Section 2.3. However, for this specific case, some considerations are needed. In Bolivia, indeed, it is hard to find a real innovation policy. All the innovative initiatives are carried out or promoted by foreign actors. In the specific case of Renewable Energy (RE), international cooperation plays a fundamental role in the technology transfer as well as in improving local capabilities. On the other hand, the international action in the last decade in Bolivia has been strictly related to public institutions especially in the formulation of a strategy to spread sustainable use of energy in rural zones. In this context it has been shown that Bolivian society and traditional habits are fundamental for the functioning of the system. The following sections are dedicated to illustrate the main components of the national IS.

4.1 Network of stakeholders

The concept of a network is fundamental in the understanding of the dynamic of IS, especially when one wants to modify the local environment through policy (Schienstock, 2005). The Bolivian IS is mainly based on four kinds of stakeholders:

- *Universities*: Academic institutions produced several experimental spin-offs in the field of photovoltaic cells and solar energy. Some of them turned quickly into SMEs, which currently employ several skilled people.

- *Local Enterprises:* The first enterprises were the result of successful university spin-offs. However, after almost 15 years of activity, the demand of skilled personal is continuously increasing.

- *NGOs:* Local and foreign NGOs have been crucial in building a network of subjects that allowed the diffusion of renewable energy services. Those organizations play as an interface between local communities, micro-enterprises and academics.

- *National and Local institutions:* Even though national government has been directly involved in many projects, it is still missing the necessary legislative framework to foster a national renewable energy market. Furthermore, local municipalities, which have been participating in several projects providing funds and infrastructures, played a special role in the diffusion of renewable technology among the people.

4.2 Innovation Dimensions

According to the World Economic Forum, Bolivia occupies 18th place in the innovation index ranking in Latin America (WEF, 2009). Bolivia does not have a developed industry able to carry out R&D projects, and most of the technology is imported. Even though Bolivia is becoming one of the most important exporters of hydrocarbons in the *Mercosur*, the majority of the rural population has no access to electricity. The use of renewable sources in that context affects the productive system at several different levels. From an innovation perspective we can identify three fundamental dimensions:

Technological dimension

The majority of the innovations introduced in the RE market in Bolivia might be classified as new to the country (OECD, 1992). However the most important contribute to technological innovation seems to be the adaptation of existing technology to local necessities.

Institutional Dimension

The most important advance in the country‘s institution framework has been the introduction of sustainability awareness. For the first time in Bolivia there is a debate about the eco-efficiency and sustainability of development. This fact is certainly due to the involvement of local municipalities, local universities and the final users in the process of diffusion and adaptation of sustainable technology. The post-colonial history of Bolivia has often precluded the civil society from the possibility of designing or perpetuating its own institutions. This represented a strong limitation of freedom but also a constrain to the development of local potential (Becker & Ostrom, 1995; Sen, 1999).

Social Dimension

Indigenous tradition in Bolivia is characterized by a systemic vision of Planet Earth. The ancestral linkage of the indigenous world to the land (*Pachamama*) is crucial to understand how those people interact with the environment. They feel part of an intertwined web, which connects people, animal and natural resources. In recent years the Bolivian government has been promoting the concept of *Buen Vivir* (living well) versus the dogma of *vivir mejor* (living better) of industrialized countries (MRE, 2009).

4.3 Institutional framework, Local firms, and social context

The diffusion of RE technologies in Bolivia has been hampered by several institutional barriers. However in the last two decades the Bolivian state unexpectedly moved towards the implementation of an alternative strategy for rural development. In particular, it is worthy of mention the *Ley de Participación popular* (Law of popular participation) and the *Estrategia de Energía rural* (Rural energy strategy). The law of popular participation, promulgated on 20th of April 1994, recognizes indigenous communities in rural and urban areas of the country, establishes mechanisms of social support and aims to redistribute resources equally among all the inhabitants. This scheme allows adjustment of electrification programs to the characteristics of rural areas and finally integrates rural development, quality of life, environmental management and energy technology in a complementary way. That strategy is based on three pillars: i) *co-financing* that aspires to mix state and private funds, ii) a *broad technological base* that incorporates renewable energy in the rural context, and finally, iii) the *demand management* considered as a process identification as well as satisfaction of energy demands.

Thanks to the adoption of an innovative *off-the-grid* [1]model, Bolivia has been carrying out the largest program of rural electrification in the region. This unexpected achievement was in part due to the implementation of big projects supported by international institutions such as the World Bank and the BID (Inter-American Development Bank) and a strong commitment by the Bolivian government. The program *"Electricidad para Vivir con Dignidad"* (Electricity to live with dignity) was one of the actions taken in that framework(VMEEA, 2008). One of the most important purposes of the program was to increase the extension of electricity networks in order to supply rural populations with no access to electrical infrastructure. However the most interesting and innovative aspect of that program was the strong financial commitment in fostering the use of RE. In fact, the project allowed the implementation of renewable and alternative energy sources such as photovoltaic systems, wind, micro-hydroelectric and the efficient use of biomass. Those systems were supposed to cover the ambitious figure of approximately 180,000 rural households throughout the country. In that sense, Bolivia represents a sort of experiment in massive rural electrification strategy (interview with prof. Eduardo Lorenzo, Polytechnic University of Madrid, Spain, 1st April 2010).

4.4 Local firms and knowledge infrastructure

The interest in RE in Bolivia, especially for PVS, dates back to the 1980s. During the last two decades that interest has been clearly increasing to such an extent that it is currently estimated that in rural areas of Bolivia there are about 20,000 installed PVS. That achievement was possible thanks to two main factors: i) the development of local technological and organizational capability and ii) the international cooperation aid. Virtually all the local subjects, basically micro-firms and NGOs, involved in the RE sector have a similar story. Those subjects were born from the interest of local technicians, academic personnel or people involved in social organizations focused on the problems of rural areas. Osvaldo Peña, for instance, is the owner of a micro-firm that installs and repairs PVS in many rural zones of central part of Bolivia. Since 1990 Pena's company, SIE (Servicios integrales de Energia S.A), has installed about 8000 PVS and participated in several international projects (interview with Osvaldo Peña, Cochabamba, Bolivia, 11th of May 2010). Another emblematic case is the example of *Prosol*. This micro-company was founded by Alvaro Fontanilla, an anthropologist interested in improving the quality of the life of people living in the rural areas. Alvaro approached the PVS technology thanks to the work of German cooperation in Bolivia (GTZ). *Prosol* and GTZ created a workshop to build and repair electrical components for simple PVS. After a few years *Prosol* was able to produce in-series switches and battery regulators as well as to assemble and install basic PVS. According to *Prosol*, the most successful cases in terms of the sustainability of the systems have been those in which it was possible to identify the key persons of the community and convince them that the well-working of PVS was crucial to improve their life (interview with Alvaro Fontanilla, Cochabamba, Bolivia, 14th of May 2010). On the other hand, the problem of the lack of financial resources was partially solved by implementing an innovative *micro-credit* program involving local municipalities. It has been noted that the financial involvement of the families in rural communities increased the awareness and the sustainability of the systems in the long run. In other words, when the people pay according to their incomes they are more disposed to take care of the systems.

Another interesting example is the case of Energética. Since its creation in February 1993, Energética, has attempted to promote greater and more rational use of RE in Bolivia. The idea behind their action is that RE is the key to achieving sustainable development in many sectors of the Bolivian economy in urban zones as well as in rural areas. Their philosophy is well described by their motto: *"Both the poor and the rich must overcome the illusion that more energy is better... the energy and equity have to go hand in hand".* Unlike Prosol, Energética was created by people coming from the Universidad Mayor de San Simón of Cochabamba. For those reasons the organization is focused not only on technological issues but also on sociological aspects related to environmental sustainability and poverty. According to Miguel Fernandez, current director of Energética, the volume of the existing facilities is enough to develop a model of Micro

[1] The term *off-the-grid* (OTG) or *off-grid* refers to the production of domestic or public energy in a self-sufficient manner without reliance on the public electricity infrastructure.

Maintenance Companies that can provide adequate service and access to spare parts. In 2009, according to Energética, 9 micro enterprises have been created. However the NGO expects to create between 30 and 40 independent businesses (interview with Miguel Fernandez, Cochabamba, Bolivia, 10th of May 2010).

Based on the above reasoning it is possible to extrapolate a sort of pattern according to which local proto-entrepreneurial initiatives become active micro enterprises. The Figure 3 shows three levels in the evolution of local micro firms: i) Firstly we witnessed the creation of local initiative promoted by social organization (*Prosol* case), local technicians (*SIE* case) or skilled people coming from the academia (*Energetica* case). In this early stage the activity of those organization is based mostly on local and limited actions; ii) Secondly those subjects achieve a sufficient level of know-how that allows them to have access to international aid programmes. This jump triggers a dynamic of knowledge accumulation that permits an increase in their ability to compete at national level; iii) finally, the original organizations formalize their structures in different ways such as NGOs or small profit companies. In this scenario the roles of Bolivian NGOs seems to be a bridge between international aid programme, local providers, micro companies and the users.

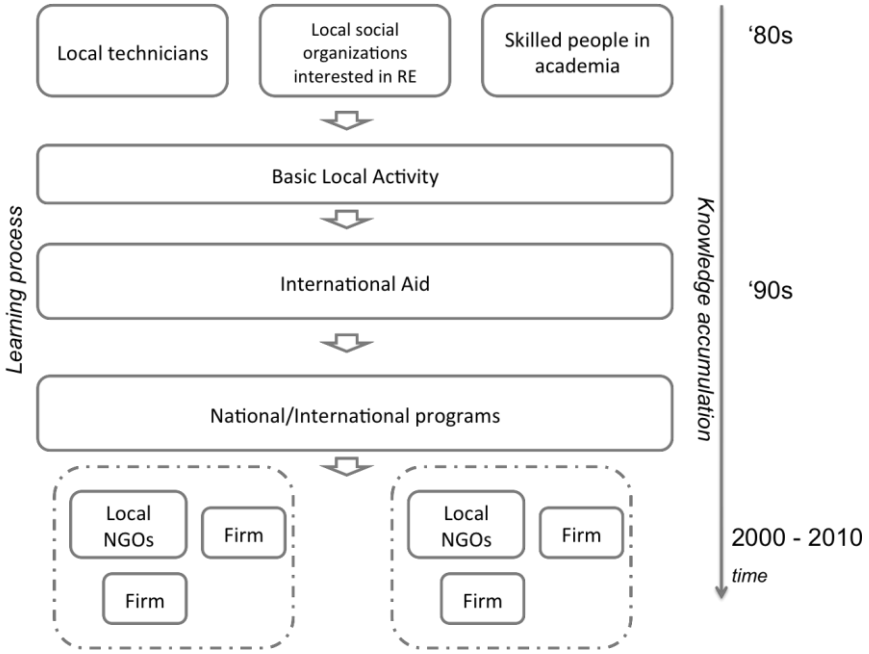

Figure 3: Patterns of micro firms' creation

4.5 Indigenous communities and energy production: the case of Kami

Bolivia, more than other countries in the region, still conserves an almost intact indigenous social life. Although indigenous population always was an overwhelming majority, Quecha, Aymara, Guarani and many other native groups have never had the opportunity to participate in the administration of the republic. However in recent decades there has been a renaissance of indigenous community in Bolivia. According to Ruth Volgger, national director of the Italian NGO Ricerca e Cooperazione for more than 20 years, restoring traditional knowledge is not simply an anthropologic task, rather it is a way to rediscover more efficient techniques of production and management of the land. She claims that in the age of the Incas quality and biodiversity of food in Bolivia were much higher than during the colonial period. That is because indigenous populations developed a very efficient system of terraces over thousands of years in order to take the maximum advantage from the poor soil of the Bolivian plateau (interview with Ruth Volgger, La Paz, Bolivia, 6th of June 2010). Today people like Ruth Volgger are working to restore ancient knowledge in a new way. This new vision is based on the belief that a dialogue between local and traditional knowledge, academy and enterprises, is possible. They call this approach "*dialogo entre saberes"*, dialogue between *knowledges.*

An example of this approach is certainly the case of Kami. Kami is a little Aymara community in the Bolivian Andes between the departments of La Paz and Cochabamba. Kami was a place of peasant farmers before it became a mining centre. However, because of its isolation and the strong fluctuation in mineral's prices, a lot of people were compelled to immigrate to a more populated and prosperous zones. In 2000 the local community of Salesian of Don Bosco started an ambitious project to improve the conditions of the local population. The original idea was to build a micro-hydroelectric plant to provide electricity to the community and, additionally, raise money selling energy to the neighbours to finance social projects such as schools, public infrastructures and education. The project took off when it was decided to use only local workforce. The initiative relied on a loan by the Italian bank Banco San Paolo, achieved thanks to the help of the Italian Salesian community. In the Alps micro-hydroelectric technology has been widely used since the beginning of the 20th Century. Thus, with the support of local electrical companies in Val D'Aosta (Italy), two old turbines of 2 MW were reassembled and sent from the Italian Alps to Kami. The work consisted in the excavation of a 4 km long tunnel for the channelling of the water of the local river. The water was then channelled in two turbines installed in an engine room connected to the electricity network. The tunnel was divided into 14 sections of 500 meters and each piece was assigned to a group of workers selected by the community. The work took more than three years and involved about 200 persons. The work required the development of many different capabilities that led to the creation of at least 20 mini companies specialized in digging, construction and electricity (*learning by doing*). Most of those groups, due to the experience acquired in Kami, were able to export their capability, working in other projects all around the country (interview with Alberto Schiappapietra, GVC delegate in La Paz, Bolivia, 23rd of April 2010). Finally, the energy produced was sold through the connection to the national network.

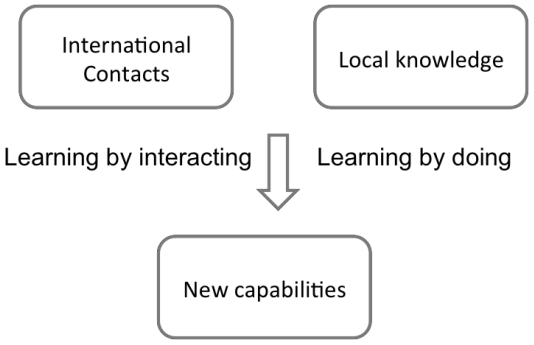

Figure 4: Kami's learning process

What happened in Kami illustrates that a sustainable development is possible by exploiting local potential. In the case of Kami, the learning process has been triggered by the interaction of foreign actors with a long experience in micro-hydroelectric technology that provided the basic technology to start the project. Then, through a process of learning by doing, the community organized itself to adapt the novelty to the local environment. As it has been shown in other areas of Bolivia (Devisscher & Mont, 2008), such a process endowed the territory not only with clean electricity but also with new capabilities that can foster the development of the zone.

5 Discussion

Although the Bolivian case presents several interesting characteristics, we cannot identify a well-developed system of innovation in the RE sector. Rather it is possible to affirm that the sector is in an initial phase that could be named proto-innovation system. Even though there have been many important advances, especially in the PVS technology, Bolivia still miss two important components of an IS that are a strategy for innovation policy and an adequate education system. The case shows that the absorption capacity of the countries depends mostly on local and often isolated subjects. In other words, the systematization of knowledge and its organization in order to achieve coordinated actions to trigger the local development processes is still a missing piece in the puzzle and, probably, the most important one. On the other hand, the case shows an innovative approach in using traditional knowledge in spreading clean technology and in the activation of local potential. In any case, a positive framework emerges from the analysis, which indicates

what might be the future actions necessary to build an effective system of innovation for renewable energy in Bolivia:

- First of all, it is crucial to invest in Bolivian Universities. Lack of infrastructures, ridiculous wages, and inexistent research programmes are insurmountable barriers for innovation in academia It is crucial not only to endow Bolivian Universities with adequate tools but also to foster coordination at national and international level. The case study shows that local firms rely on foreign universities rather than local institutions.

- Secondly, it is fundamental to promote renewable energy in public administration. Bolivia has an enormous potential in terms of sun, wind and micro-hydroelectric energy. It is time to develop specific policies to foster the use and production of clean energy. Those policies should include the possibility of local communities financing their own projects of decentralized energy production and selling the excess energy in the case of over production. Such a process could yield to a very interesting development of traditional communities that can experiment with different regimes of ownerships and management of the plants.

- Finally, it is crucial to promote and sustain local firms in the urban context as well as in rural areas. It has been show that Bolivian micro-firms are able to work in the urban zone as well as in isolated traditional communities. They represent the most active actors in the framework and possess the necessary capability to understand local context.

In order to analyse the main findings of the case study, it is useful to use the model introduced in Figure 2. The model advocates for an IS approach for developing countries pointing out 8 dimensions for the analysis:

- 4 basic dimensions: Local economic growth, Social inclusion and equality, Sustainability and Competence Building;

- and other 4 dimensions derived from the intersection of the previous ones: Provide capabilities to reduce poverty, Preserve the richness of ecosystems, Combine environment with well-being, Provide competences to economic growth.

For the case in hand, we can apply the above model using a radar *chart* that shows the impact of the RE sector on each one of the described dimensions. Let us define for each dimension a qualitative scale of effectiveness using scores from 0 to 4:

0. No specific effects have been found.
1. Slight effects have been found. However it is not possible to quantify them.
2. Slight effects have been found and it is possible to quantify them.
3. Important effects have been found and it is possible to quantify them.
4. Great impact easily verifiable.

Table 1 contains the scores and the description of each dimension:

Table 1: Eco-IS dimensions

Dimension	Score And Description
Inclusion and Equality	3. The case showed clearly that in Bolivia an innovative approach to energy has been adopted. This approach is particularly interesting because it is focused on the social use of energy in rural zones and degraded urban areas. Consequently energy also becomes a tool for social inclusion, which has been proved by the installation of electricity in schools, rural health posts and public infrastructures.

Ecosystem preservation	0. Although in all the projects analysed in the case study there are several vague allusions to the preservation of the local ecosystems, no particular details deserve to be mentioned.
Sustainability	2. The level of sustainability has improved. In several rural areas people replaced the production of energy with biomass with that of PVS or Hydroelectric. However it seems hard to evaluate the impact of the sector on a large scale.
Environmental well-being	2. As it has been shown in the case, the quality of life of several thousands of families has improved due to the use of clean energy. However, there are many other factors that still affect the life of Bolivian people such as scarcity of fresh water, malnutrition, low levels of education and inefficient health infrastructures.
Local Economic growth	3. The renewable energy sector, especially in the case of PVS, has been strongly increasing in the last two decades. The birth of many local firms in the sector led to growth in employment related to the installation and maintenance of electrical infrastructures.
Competitiveness	2. The accumulation of knowledge and capability in the sector is creating, step by step, a group of small enterprises that are already able to compete at national level. However, this entrepreneurial environment is still too dependent on government and international funding.
Capabilities building	4. The process of accumulation of knowledge and capability building has had a great impact on the sector. Nowadays there are several organizations in Bolivia able to design a plan for rural electrification and carry out it efficiently. Furthermore, over time, the local actors were able to create a network of international contact that was crucial for technological transfer.
Poverty reduction	1. Although electrical energy in rural areas considerably improves the potential productivity, it is quite difficult to assess its impact on poverty. A specific study is needed to find out if the massive installation of PVS yielded to an increment of the income of the users.

The results of multidimensional analysis are summarized in the radar chart of Figure 5. As it is possible to note in the graph, the grey area is wider between the dimension *Competence Building* and *Local Economic Growth*. That means that, although a special effort has been dedicated to improve social dimension and environmental impact, a lot of work is still needed to make the system work efficiently in all dimensions. Furthermore, the impact of energy on rural economy is not so clear is. Up until now there has been no study that addressed this point. It would be fascinating to investigate the impact of those programmes on the income of the people in rural areas and try to extrapolate a model for further improvements. Furthermore, it would be interesting to investigate how the sector will be able to deal with the sustainability of the PVS installed in the future. Those are all interesting questions, which are very hard to answer at this level of analysis.

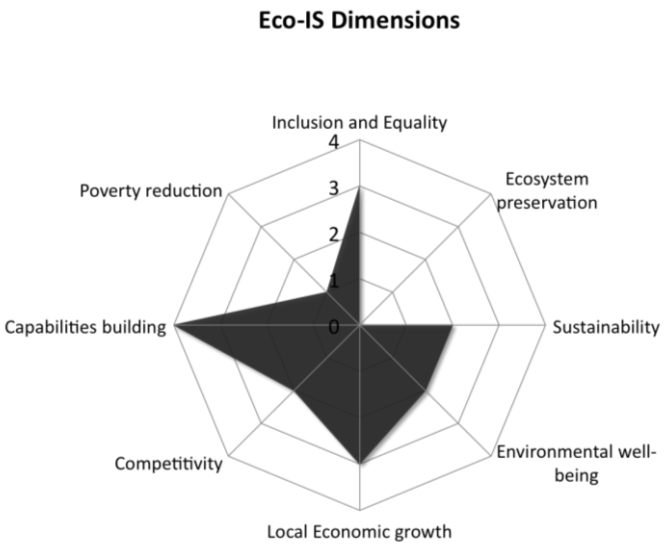

Figure 5: Radar Charts of Eco-IS Dimensions

6 Conclusions

The present article is an attempt to introduce the concept of environmental sustainability in the IS approach drawing on the conceptual framework developed by ecological economists. Moreover the concept of innovation as development tool is also analysed and proposed as an alternative to the classic top-down approaches commonly used by International Aid programs. The main contribution of the model proposed is to highlight the importance of a holistic approach that covers not only the chrematistic dimension of development process, which is economic growth, but also many other dimensions like social equality, community empowerment and environmental sustainability. The evidence from Bolivia seems to confirm the validity of such an assumption. What is more, the case clearly depicts emerging countries as a prolific environment for new paths of innovation and new sustainable practices. The understanding, thus, of the evolution of sustainable innovations in the so-called South of the world is crucial. There is an extensive literature that shows how socio-technological regimes rise in specific conditions that can be hardly reproduced in other contexts (Chris Freeman, 1995). So, first of all, it is needed to identify the initial conditions that originate new and alternative paths of innovation in developing countries. In other words, it is necessary to understand how and why eco-innovation occurs in a great variety of contexts different than the western industrialised countries. In the last decade, indeed, the dynamic of innovation in the West has been largely studied and understood. We know that, once a dominant socio-techno paradigm is well established, only incremental changes tend to take place (Freeman & Soete, 1997). The exiting question for the future research agenda is if emerging countries are able to trigger new frames. If so, many other questions will become germane. How much will they consume? How will they keep warm, cook, move and so on? In this scenario it is relevant to formulate a very stimulating hypothesis: Emerging countries are a fruitful reservoir of innovations and sustainable practices. In order to validate such an assumption, it is not only crucial to provide evidence that eco-innovation is taking place somehow in there, but also to identify the factors that drive and govern this process. It would not be surprising to discover that sustainability and resilience in the developing world still rely on social values and traditional knowledge. Nevertheless, it is intriguing thinking that emerging economies, at least potentially, might trigger a new alternative frame, it becomes extremely important to quantify the extent of such a change. The last decade has seen an increasing connection between emerging countries like China, Latin America and some African countries. China is already exchanging infrastructures for natural resources in Africa and Brazil is playing a similar role with its neighbours. As they share expectations and problems, it would be interesting to understand the process of sustainable practices diffusion between these countries. Even more important might be to find out if those practices can potentially have a disruptive impact on industrialised countries leading to what Seely-Brown calls Innovation blowback (Brown, 2005). As R. Kaplinsky (2011) argues, "*there are many reasons to believe that changes originating in the South will become a major driver of innovation in the 21st century* ".

It is probably too ambitious to think that Emerging Economies will lead a global sustainable transition, but it is improbable that they are going to be simply passive spectators.

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