# Transference of Ecotechnology in Disadvantaged Regions of Mexico, Towards Sustainable Development

**Lorena del Carmen Alvarez-Castañon, Daniel Tagle-Zamora and Maricruz Romero-Ugalde**

**Abstract** The provision of ecological technology has been one of the strategies undertaken by the Government of Guanajuato, Mexico. Their ecotechnology programs include ecological artefacts that contribute to home improvement. The goals of program have been achieved (number of ecotechnology units installed); however, the impact has not been as high as expected due to high social rejection by the beneficiaries. Our hypothesis is that ecotechnology adoption failures are associated with the absence of a process that follows environmental education sustained in a process of transference of ecotechnology (TET) that would facilitate social adoption. The aim of this paper is to analyse the process of TET in two municipalities—*Penjamo* has a high rejection of ecotechnology and *Tierra Blanca* has a low rejection—and to determinate the factors that influence its social adoption. The results show that there are exogenous and endogenous factors that influence the social adoption of ecotechnologies. Hence, TET involves a social process of multilevel negotiation because its implementation depends on technical issues and on intervention strategies—these should consider social, cultural and political aspects. The challenge is to harmonize the vernacular knowledge of the region with the technical knowledge to improve socio-technical capabilities that promote development.

**Keywords** Transference of ecotechnology · Social adoption · Disadvantaged areas

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## 1 Introduction

Over the last few years, the ways technology can, or should, contribute to social inclusion processes and the sustainable development, have been debated (Fressoli et al. 2013). Numerous studies argue that technology transfer (TT) is feasible in different regions where socio-environmental problems emerge (Burgos and Bocco 2016). The challenge is the social adoption of technology, above all in emerging areas, such as Mexico as regional imbalances are frequent in the coexistence of regions with strong social and economic lags, with innovative and dynamic regions (Burgos and Bocco 2016).

The government of the state of Guanajuato in Mexico has implemented the program "Impulse of social development" to improve the welfare of the vulnerable population (SEDESHU 2015). This program is pertinent to the reality of Guanajuato because 9.8% of its population report deficiencies in the quality and spaces of their homes and 14.9% lack of access to basic services in housing (CONEVAL 2010). The fourth aim of this program is to integrate ecotechnology in housing spaces that are not capable of satisfying a basic well-being line (SEDESHU 2015); these green technologies purport to mitigate environmental issues and provide basic services (UNDSD 2000). In the program, the installed ecotechnologies are: solar heaters, photovoltaic panels, rainwater harvesting, ecological stoves, concrete-iron cisterns, bio-digesters and dry baths (SEDESHU 2015).

The goal of the program has been accomplished, if you only measure the number of ecotechnology units installed. However, some indications show that there is resistance from the population in the use of these ecotechnologies, apparently, these could be generating local socio-environmental problems, even greater than the problems before installation. It is assumed that the failure is that the program is limited to the installation of the ecotechnology, without the execution of a technology transfer (TT) process that guarantees the social adoption of these devices. TT is part of a plan of adoption, assimilation, and technological learning (Hamidi and Benabdeljalil 2013; Jasso 1999). The TET is a matrix process based on the environmental education of the actors involved—users, local leaders, installers, among others—to achieve the effective assimilation of the technology, to build capabilities and new local knowledge; this is integrated into a series of transitional stages that favour the efficient use of the ecotechnology (Fressoli et al. 2013).

TET in dissimilar regions implies a participatory model in which the local actors deal with their own interests (Herrera 2006) and the requirements of the program that promotes ecotechnologies. TT is articulated through direct communication in a multidirectional learning process (Hamidi and Benabdeljalil 2013; Heijs et al. 2007). Therefore, the TET process must be designed in line with the heterogeneity of regional conditions where ecotechnology will be installed to reduce social, economic, and technological gaps. The TET will achieve the expected results only if the actors are fully involved in the process (Herrera 2006), and it is designed as a process that motivates the construction of technological capabilities per the characteristics and the profile of the region where it is implemented.

In these regions, it is necessary to reassess the role of all the social actors involved with a participatory approach of the TET process (Herrera 2006). Here, we must go beyond the classic approach of the TT that is limited to installing the ecotechnology and to train for its use (Fressoli et al. 2013). In this paper, we propose that TET process recognize the importance of cultural aspects to increase the odds of success (Lee et al. 2013). The purpose of this study is focused on the social adoption process of ecotechnology in disadvantaged regions of Mexico. We studied the municipalities of *Penjamo* and *Tierra Blanca*, Guanajuato; *Penjamo* reports a high rate of rejection and *Tierra Blanca* a low rate of rejection of the environmental technologies implemented because there is evidence of negative externalities that have been caused by the social rejection of the beneficiaries. According to the previous statement, we formulated the research question: which factors motivate the social adoption of ecotechnologies that help these municipalities have a sustainable development?

The paper is structured in five sections; in the first, we outline the reference framework of the research; in the second, we show the background of municipalities that we have studied and in the third, the methodological strategy is shown. In the fourth section, we present and discuss the results, and we close with the conclusions in the fifth section. Based on the results, we propose that TET should move towards a participatory and holistic process, that disposes spaces where knowledge is shared beyond the investment of government's programs in the ecotechnologies; in addition, the programs should be redesigned to encourage collective learning processes and sociotechnical partnerships between the different actors involved in the implementation and operation of ecotechnology.

## 2 Reference Framework

Technology transfer (TT) implies a transaction between the one who has the technology and the one who will use it (Fressoli et al. 2013), it is a planned displacement of the previously mentioned technology (Herrera 2006), in this case, it will be between the suppliers of the ecotechnology and the Secretary of Social and Human Development of Guanajuato (SEDESHU for Spanish initials) with the people benefited by the program. The classic view of TT considers that the key to success in technological adoption is the transmission of technical knowledge from one individual or organization to another for its application through a certain means of communication (Rogers et al. 2001); i.e., TT is a tacit and explicit knowledge transmission process between different actors involved in the process (Dominguez and Brown 2004).

According to Bozeman (2000), the TT process should consider five strategic dimensions: the actor who transfers, the transfer method, the transferred object, the transfer receiver, and the context or environment in which it takes place. In addition to this, according to Villavicencio (1994), the TT triggers technological learning to take place in four phases: when the technology is acquired, because the supplier

transmits the necessary information for its use; when the technology is put into operation, because the user must be capable to make the technology work; when the technology needs maintenance or it must be repaired; when the user needs to modify, or improve the technology.

Pirela et al. (1991) explain that technological learning switches according to the characteristics of the technological culture of the actors and of the region where this transfer occurs. The authors sustain that TT generates four technological capabilities: the ability to complete their own knowledge as new technologies are incorporated; the capability of technological interdependence to systematize their knowledge and to accumulate a technological memory so the individual does not depend on the knowledge of the person who installs the technology; the prospective capability in which they can avoid negative externalities of technology in the short, medium, and long-term; the capability to adapt the technology change with the characteristics and profile of the region where the transfer takes place.

In this study, TET occurs in vulnerable households. Therefore, we identify the TT strategies per the characteristics of the studied regions. The "learning by doing" strategy is based on solving problems on the fly; it is assumed that the gradual use of technology leads to learning and efficient use of technology (Arrow 1974). The "learning by using" strategy defends that TT progressively accumulates skills and generates knowledge through the experience of using technology, over time it achieves its efficient use (Rosenberg 1979); this strategy is a hybrid, based on the interaction between "learning by doing" and "learning by using" (Lundvall 1988), where TT is generated by a collective process of technological learning (Villavicencio 1994).

The "learning to learn" strategy seeks to build specialized skills, since those involved in the TT process appropriate new knowledge and combine it with their own knowledge, it is possible to make efficient use of technology (Stiglitz 1987); this mix motivates the technology to solve social and environmental issues (Fressoli et al. 2013; Ilgin and Gupta 2009; Truffer and Coenen 2012). Hence, the relevance to integrate vernacular or local knowledge into the TET process as the technological culture is fundamental to achieve a successful process of TT based on the environmental education of the members of the community whose capabilities respond to different social needs.

A region with passive technological culture shows low levels of learning and poor technological memory; the technological culture is reactive when learning and technological memory is held by only a few settlers of the community. Therefore, the TT is vulnerable, fragile, and segmented. In the active technological culture, the community learn to coexist with the technology and TT is achieved with a backwards and forwards integration with the installers of the ecotechnology and within the community when the tacit knowledge is transmitted to the following generations (Lundvall 1988; Pirela et al. 1991; Stiglitz 1987).

Different studies in Mexico report that the institutionalization of "technological packages" in projects vertically designed by the government generate new local problems and the programs do not achieve the underlying objectives (Herrera 2006). Thereby, increasing the participatory processes of the TET is very important

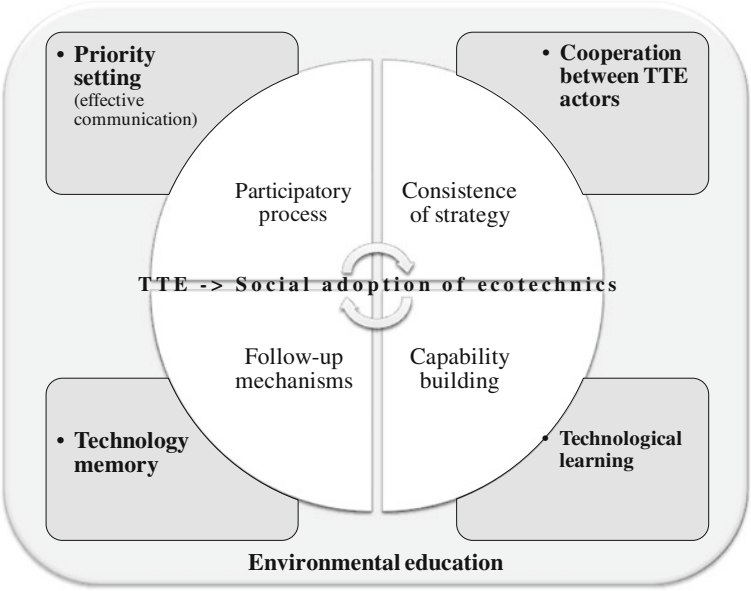


**Fig. 1** TET model for dissimilar regions. *Source* Elaborated by the authors based on reference framework (Bozeman 2000; Dominguez and Brown 2004; Fressoli et al. 2013; Herrera 2006; Heijs et al. 2007; Lee et al. 2013; Lundvall 1988; Massa and Andersen 2000; Pirela et al. 1991; Rogers et al. 2001; Stiglitz 1987; Villavicencio 1994; among others)

to accelerate the construction of technological capabilities, to make technology work, and to promote its use (Massa and Andersen 2000).

Based on the literature review, Fig. 1 shows the theoretical model that explains TET in dissimilar regions such as Guanajuato. In this case, participative interaction is the basis of the TET process to motivate technological learning, which is necessary for the social adoption of these devices. The model may involve the beneficiaries in the installation of the ecotechnology, the installers in the monitoring of the use of technology, and higher education institutions in the design of environmental education programs, among others.

## 3 Background of *Penjamo and Tierra Blanca, Guanajuato, Mexico*

Despite the strong economic growth in the state of Guanajuato in Mexico (SDES 2016), it continues to have heavy debts in terms of social marginalization (CONAPO 2000, 2010). Specifically, *Penjamo* reports a human development index of 0.652 and *Tierra Blanca* of 0.633; however, when it is disaggregated, the index reveals greater vulnerability in the indicators of income and health for both

**Table 1** Social characterization of *Penjamo* and *Tierra Blanca*

| | *Penjamo* | | *Tierra Blanca* | |
|---|---|---|---|---|
| Human development index (income) | 0.6168 | | 0.5914 | |
| Human development index (health) | 0.5351 | | 0.5339 | |
| Human development index (education) | 0.8381 | | 0.8026 | |
| Total of private dwellings | 35,786 | | 3,861 | |
| Private dwelling houses that have water from the public network | 31,970 | 89% | 3,214 | 83% |
| Private dwelling houses with drainage | 29,494 | 82% | 1,096 | 28% |
| Private dwelling houses with toilet or sanitary facilities | 29,937 | 83% | 2,350 | 60% |
| Private dwelling houses with electric power | 34,881 | 97% | 3,424 | 88% |
| Private dwelling houses with refrigerators | 29,249 | 81% | 1,789 | 46% |
| Private dwelling houses with washing machines | 21,297 | 59% | 692 | 17% |

*Source* Prepared by the authors based on INEGI (2010) and UNDP (2014)

municipalities (UNDP 2014). In terms of the quality of housing there are important lags, neither of the two municipalities fully guarantee basic services of potable water, sewerage, and electricity to its populations. In addition, the problem of the lack of sanitary facilities and refrigerators in homes are strong (INEGI 2010), and it is aggravated the sanitation problems imposed by these absences (Table 1).

The municipality of *Penjamo* is integrated by 782 localities; its main economic activity is in the primary sector; 67.5% of the population is in poverty and 19.7% reaches levels of extreme poverty (INEGI 2010); the most worrying indicators of social deprivation are to health services, access to food, and basic housing services (CONEVAL 2010). *Tierra Blanca* is concentrated in 99 locations; its main economic activity is temporary agriculture; 70.7% of its population is in poverty and 28.1% in extreme poverty (INEGI 2010); the most worrying indicators of social deprivation are to basic housing services and income levels—the population with incomes below the welfare line is 38.2%—(CONEVAL 2010).

## 4 Methodology

The research described herein is explanatory and transversal. We used a qualitative methodological strategy through the ethnographic method to approach the object of study. We are interested in bringing out into open social trends, focusing on meaning and trying to understand social behaviour around ecotechnology. This research is a part of the project "*Transformación sociocultural, uso y aplicación de ecotecnias para el mejoramiento de la vivienda de las familias vulnerables de los municipios de Penjamo, Comonfort, Apaseo el alto, Tierra Blanca y San Felipe del estado de Guanajuato*" that it was funded by SEDESHU. As part of the

methodological process, quantitative data was collected on the ecotechnologies installed in each municipality, which enriches the thick description of the interactions between the different actors (Clifford 2003) involved in the TET.

The purpose of this research is to study the TET in two municipalities—*Penjamo* has a high rejection of ecotechnology and *Tierra Blanca* has a low rejection—and to find the factors that facilitate social adoption of the technology in disadvantage areas of Guanajuato, Mexico. Insomuch as, this focusing is to analyse the conditions to help the TET and the social adoption of ecotechnologies for to achieve sustainable development of this regions, so the qualitative approach through the thick description allowed us to consider the subjective configurations of the social (Clifford 2003) was supported by the four tools of data collection, which facilitated and enriched the interpretation of the studied phenomenon.

During the project, these four implements were: semi-structured interview; non-structured interview; ethnographic letter; focus group in each municipality. The Table 2 shows the mechanisms of data collection and the interviewed; in parenthesis is indicated the number of people interviewed in each tool. For example, the focus groups were conducted and semi-structured interviews were applied to those responsible for the social development management of the municipalities; some beneficiaries and suppliers were also interviewed. Participant observation was another instrument of data collection that contributed to the meaning of the phenomena that occurs in *Penjamo* and *Tierra Blanca* for the reasons explained above.

The main limitation of this paper is the coverage of the study, since only two municipalities were studied. Although the qualitative strategy limits the generalization of results, the profile of the selected cases allows to assume that these are disadvantaged municipalities that could advance to sustainable development.

**Table 2** Mechanisms of data collection in the project

| | |
|---|---|
| Semi-structured interview | Director of social development in each municipality (1) |
| | Promoters of ecotecnias in each municipality (average = 8 in each municipality) |
| | Beneficiaries and candidates of the ecotechnology programs of SEDESHU (average = 40 in each municipality) |
| | Civil associations that promote ecotechnologies (3) |
| Non-structured interview | Research centres related to ecotechnology: UNAM. UAQ and UAM |
| | Officials of various instances of state government (5) |
| Ethnographic letter | Beneficiaries of the ecotechnology program, about their experience and perception on risks, barriers and benefits of eco-technology (average = 40 in each municipality) |
| Focus group in each municipality | Director of social development (1) |
| | Promoters of ecotecnias (8) |
| | Beneficiaries and candidates of the ecotechnology programs of SEDESHU (average = 55) |

*Source* Prepared by the authors

This is important to confirm the findings of the investigation and to be able to identify additional categories in relation to the TET given this profile, i.e., due to the explanatory nature of the research, although it is not possible to infer about other municipalities, the results allow to generate a concrete an idea of how the transfer processes of ecotechnologies are executed and which are the factors that influence the social adoption of technology.

## 5 Results and Analyses

The use of ecotechnologies in the municipalities of Guanajuato can be traced from three decades ago; however, a strong ignorance about its use is also detected (Tagle 2016). From 2013 to 2015, the government program has installed more than 2,700 ecotechnology units—39.5% of these are solar water heaters; 36.0% bathrooms; 10.5% ecological stoves; 7.0% photovoltaic panels, and 7.0% dry toilets; with a budget of approximately four million dollars (SEDESHU 2015).

The process of installation in both municipalities was homogeneous. The general sequence is: the municipal government detects that there are resources in the program; the potential beneficiaries are identified and are selected according to the degree of marginalization of their locality; fieldwork is carried out to collect information on the houses that will be benefited, likewise, any necessary adjustments to the housing for ecotechnology installation are noted; the installation program of ecotechnology is defined between promoters and suppliers; installation is performed; the installed eco-technology is presented to the beneficiaries; the suppliers teach the beneficiaries to use and to maintain the technology; the beneficiaries sign an agreement of installation; photographic evidence is collected to demonstrate the installation.

Based on the fieldwork, the main exogenous factors that were identified as hurdles that impede the social appropriation of technology are:

1. The lack of diagnoses pertinent to the reality of the municipalities, without these diagnoses ecotechnologies are installed in houses that do not need them;
2. The weak or null participation of the beneficiaries during the process impedes the dialogue between vernacular and technical knowledge;
3. The absence of an effective and efficient communication process between the installer and the beneficiary, to avoid the generation of an environment of conflict and the lack of cooperation in the community;
4. The total absence of environmental education during the process of TET to guarantee the social adoption of the beneficiaries and socio-environmental contextualization of the community;
5. The scarce articulation and communication with the different governmental institutions involved in the installation of ecotechnologies;

6. The neglect of the gender perspective in the TET process, without preconceived preferences is assumed relevant since the main contact and recipients of the technologies are women.

In both municipalities, the beneficiaries do not know the word ecotechnology. These beneficiaries demand information and training for its use and its maintenance. About the main endogenous factors, aside from the evident economic insolvency and the undervaluation of the supports of the program, we identified:

1. The low level of education of the beneficiaries;
2. The disinterest and passivity of the community for the environment;
3. The disinterest of the domestic units regarding the use and management of the ecotechnologies;
4. The lack of commitment and of appraisement of their ecotechnologies.

In *Penjamo*, the most used ecotechnology is the solar heater. The septic system is the ecotechnology with the worst problems; there was a widespread carelessness and abandonment of the septic systems installed by the government program; the users changed the purpose and they used them as cellars or refuse disposal. The main cause was the unfeasibility of use by the type of soil of the communities of the basin; however, where its installation was feasible, success cases were identified in the use of this technology. Therefore, it was evidenced that the lack of knowledge increases the rejection level of ecotechnology.

In *Tierra Blanca*, we found that there are many houses with ecotechnologies and in some cases, more than one ecotechnology per dwelling. For example, concrete-iron cisterns are used to water the backyard orchard. The communities show a high interest in ecotechnologies. However, they expressed the lack of information, training, and monitoring provided by the government program. Although they recognize the benefits from the ecotechnologies, in some cases, they also abandoned them. In the case of the septic system, there is a strong uncertainty about the bio-filter. However, many beneficiaries modified it to function as a septic tank or to connect it to the drainage network; these changes affect the environmental function but not the social function of ecotechnology.

When comparing the social adoption of ecotechnologies in the studied municipalities, the results obtained allow us to assume that the TET in the framework of the program "Impulse of development" must be redesigned based on a participatory process. A TET process where the beneficiary of the ecotechnology temporarily share part of their daily space for the incorporation of technology is required. If the beneficiary of the environmental technology is involved in the process, then the mixture of knowledge would facilitate the social adoption of these devices (Fig. 2).

In Fig. 2, we show the participatory TET model. In this process, the beneficiary is the cornerstone and the agent of change, who achieves the continuous use of ecotechnology and guarantees the permanence and functionality of the installed technology. According to Herrera (2006), families promote the use of technology, beyond the promoter or the social program that finances them. During the TET process, capability building is achieved through environmental education,

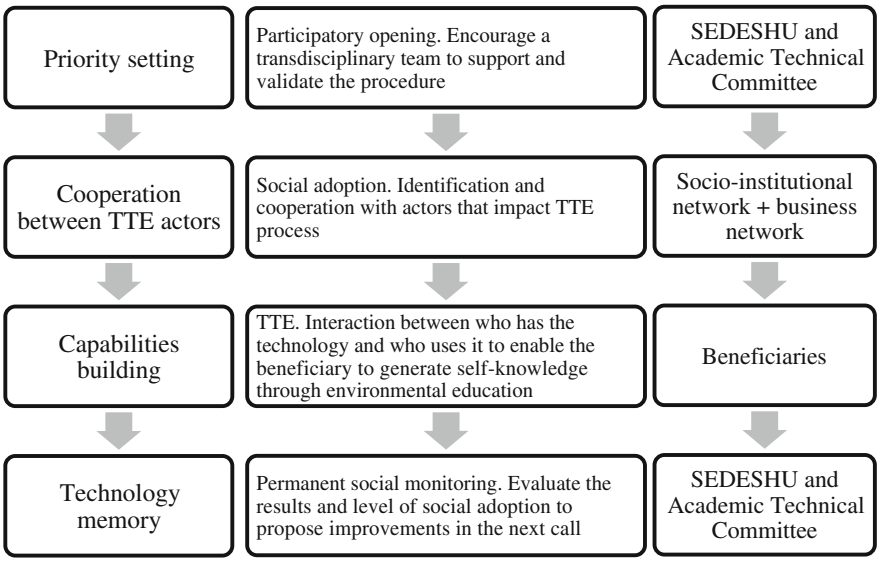


**Fig. 2** Flowchart based on four participatory processes. *Source* Elaborated by the authors based on fieldwork

through both "formal" training given by the installer of ecotechnology and "non-formal" for the transmission of knowledge between the very inhabitants of the community and external actors, for example, educational institutions or NGOs, among others. According to Pieck (2011), environmental education outside the structures and the formal education system facilitate the adoption of technologies.

In this regard, there are innumerable proposals to train rural communities to build productive capabilities in their regions, which have been frequently implemented by Mexican social policy (Herrera 2006). However, the participative process of TET with environmental education must be multidirectional among groups or individuals so that it strengthens both knowledge and technical skills. Consequently, facilitating the social adoption of technology increase the probability of sustainable development in the municipalities. Training in rural regions is complex because of the nature of their social, economic, and environmental conditions (FAO 2012). In the case of vulnerable regions, the FAO (2012) considers three dimensions that condition or allow for training: the accumulation of knowledge and skills required to achieve the development of these regions; the formative process that would allow for capability building; the social context where the community develops.

The TET process must achieve the appropriate mix of objective environmental education strategies to foster capability building in communities. According to Herrera (2006), TET is a holistic, continuous and participatory process, it should be designed from the concrete reality of the communities where it is sought to stimulate the generation of knowledge and the construction of capabilities; it is through

the systematization of experiences between the teacher and the student that it is possible to walk towards the achievement of actions that allows the initiation of a transformation of their reality (Pieck 2011). A participatory TET would hope to build capabilities to achieve social adoption of the environmental objects.

This is a counterproposal to traditional training processes in rural environments or rural schools; models that have been based on authoritarianism, vertical design, and have no link with reality (Mata 2013; Mata et al. 2007; Pieck 2011; Rendon et al. 2015). According to Pieck (2011), environmental education should promote technological learning on an integral, analytical, participatory and self-managing basis of their capabilities. In praxis, if we hope to achieve capability building in the region, then the TET should consider instruments such as: the transfer and mix of technical and vernacular knowledge; the preparation of technical manuals to explain the ecotechnology, thus, SEDESHU could follow the program at low cost; the technical assistance of technology providers for a considerable time after the installation of the technology; among others.

## 6 Conclusions

1. The main result was to identify that the factors of success and resistance are endogenous and exogenous to the beneficiaries; the mix of these factors weakens or strengthens the social appropriation of the ecotechnology.
2. In the case of *Penjamo*, a participatory society is identified, which could be the basis for generating positive synergies in the TET process; if and only if the TET is based on diagnoses pertinent to the reality of this municipality.
3. In the case of *Tierra Blanca*, there is a diversity of perceptions about ecotechnologies, although community members have "spread the word" that ecotechnologies bring economic benefits, thus, there is expectation about them. However, the most important problem is the abandonment of technology for lack of environmental education.
4. The results showed that TET involves a social process of multilevel negotiation because the functioning of ecotechnologies depends not only on technical issues of technology transfer, but also their intervention strategies. Intervention strategies should consider social, cultural, and political aspects of the region where the transfers take place.
5. The challenge is to harmonize the vernacular knowledge of the region and technical knowledge to improve socio-technical capabilities that promote their development; thus, the participative learning and the spaces of negotiation of knowledge between the TET actors would allow the empowerment of the users of the technology (Fressoli et al. 2013) in the TET process.
6. The TET must move towards a participatory process where the users of technology are considered active players in transfer processes.

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