The Challenge of Sustainable Tourist Infrastructure in the Araucania Andina, Chile

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Special interest tourists demand high-quality accommodation that respects its local environment and resources, and enhances existing cultures whilst meeting their expectations in terms of comfort and service. With its mix of volcanoes, monkey puzzle tree forests, indigenous Mapuche culture, ski resorts and a high concentration of National Parks, the micro-region of Araucania Andina in Chile's 9th Region has become increasingly attractive as special interest tourist destination. As this demand increases the infrastructure of the region must adapt and evolve. Accommodation must provide comfort both during the cold wet winters which coincide with the main influx of international tourists and the short hot summers of the local peak holiday season. At the same time priority must be given to minimizing energy consumption due to both national and international energy shortages, and in some cases the lack of connection to the national grid due to isolated locations. This paper presents a review of the current tourism accommodation available in the micro-region, with post occupancy evaluation of selected establishments. Initial results show that most accommodation is inefficient in its energy use and provides poor hygro-thermal comfort. However innovation and some exemplary projects do exist. The findings of this paper form the benchmark for the design of a sustainable construction system, using local resources for thermal insulation, and the transfer of technology and best practice in energy generation, waste disposal, and heating systems for the tourism infrastructure in the micro-region of Araucania Andina.

Keywords: Special Interest Tourism, Sustainable Tourism, Hygro-thermal comfort, Post Occupancy Evaluation.

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ABSTRACT: Special interest tourists demand high-quality accommodation that respects its local environment and resources, enhances existing cultures, whilst meeting their expectations in terms of comfort and service. With its mix of volcanoes, monkey puzzle tree forests, indigenous Mapuche culture, ski resorts and a high concentration of National Parks, the micro-region of Araucania Andina in Chile's 9th Region has become increasingly attractive as a destination for this type of tourist. As this demand increases the infrastructure of the region must adapt and evolve. Accommodation must provide comfort both during the cold wet winters which coincide with the main influx of international tourists and the short hot summers of the local peak holiday season. At the same time minimizing energy consumption is a priority in the face of national and international energy shortages and in some cases lack of connection to the national grid due to isolated locations. This paper presents a review of the current tourism accommodation available in the micro-region, including post occupancy evaluation of selected cabins, hostels, lodges and Bed and Breakfast establishments with in situ measurements of summer and winter dry bulb temperature and relative humidity. Initial results show that most accommodation is inefficient in its energy use and provides poor hygro-thermal comfort. However innovation and some exemplary projects do exist. The findings of this paper form the benchmark for the design of a sustainable construction system, using local resources for thermal insulation, and the transfer of technology and best practice in energy generation, waste disposal, sewage water plants and heating systems for the tourism infrastructure in the micro-region of Araucania Andina.
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INTRODUCTION

Special Interest Tourism (SIT) refers to tourism focused around specific activities or interests. These may be, among others, trekking, bird watching, ecotourism, geo-tourism, scientific tourism, cultural or nature based actives and other outdoor pursuits [1]. The term is used to differentiate from "mass tourism", in which relaxation and leisure are given precedence over specific interest in the place and its particular attributes and qualities. Given the Special Interest Tourists' specific interest in their destination and its natural and cultural attributes, these tourists are often well informed, conscientious, responsible, and concerned over their environmental and cultural impact.

According to official statistics 3,554,297 tourists visited Chile in 2012 [2]. In 2011 of those tourists visiting on holiday 78.6% had chosen Chile for its natural beauty and landscapes, 36% observed wildlife during their stay, 30.6% visited National Parks and 15.4% took part in mountain activities [3]. At a national level, domestic SIT is increasing as a result of the growing disposable income of the Chilean population, the increased access to further education and rising environmental awareness. As a result of this growing market SIT has been identified as one of the 5 main "clusters" of the National Board for Innovation for Competitiveness which aims to double the Gross National Income between 2008 and 2020. This shows that together with Food Production, Mining, Fish Farming and General Services, SIT has an important role to play within the development of Chile's economy. The three main areas highlighted by the cluster as "destination-products" for SIT are Arica-Parinacota in the far North of Chile; Patagonia, covering in general the far south; and the Araucanía Andina.

THE MICRO REGION OF ARAUCANÍA ANDINA

The micro region of Araucanía Andina is located in the 9th Region of Chile, the Región de la Araucanía. It lies between the latitudes of 38° 12' and 39° 6' south, and extends eastwards from the city of Temuco up to the border with Argentina. The micro region consists of the Malleco, Cautín, Alto Bío Bío and Allipén valleys and the mountain ranges that divide them. Within its limits lie 5 nationally protected conservation areas; Parque Nacional Tolhuaca, Parque Nacional Conguillío, Reserva Nacional Malalcahuello, Reserva Nacional Alto Bío Bío and Reserva Nacional China Muerta. These parks protect a rich biodiversity of forests of monkey puzzle tree (*araucaria araucana*) mixed with other deciduous and evergreen broadleaf trees, the importance of which was recognised by UNESCO with the formation of the Araucania Biosphere, which also includes the micro-region of Araucania Lacustre that lies directly to the south. The region is dominated by the volcanoes of Tolhuaca, Lonquimay, Sierra Nevada, Llaima and Sollipulli, two of which have erupted recently and which together with the lakes, forests, thermal spas and the indigenous Mapuche culture that survives in the region, create a unique destination that has become a draw for walkers, mountaineers, nature lovers, geologists, seismologists and those interested in eco and ethno-tourism. The availability of both downhill and cross-country skiing coinciding with the Northern Hemisphere's summer and peak holiday season, means that the region has an almost year-round influx of tourists.

INFRASTRUCTURE FOR S.I.T.

The profile of a Special Interest Tourist is typically that of a highly educated professional, with disposable income and free time. In addition many visitors to the region are European, North American or Chileans from the capital. Whilst many do not seek luxury accommodation and may even actively choose rustic or more basic lodgings, in general their expectations in terms of environmental comfort are high. Much of their time is spent outdoors and so on their return to "solid" accommodation (as opposed to camping) they are not prepared to put up with the cold nor overheating. Unpleasant odours from humidity and poor ventilation are not welcomed either, nor is poor acoustic separation between rooms. At the same time their environmental conscience implies that environmental comfort should be provided with the minimum use of natural resources and non-renewable energy. It is therefore important that the tourist infrastructure responds adequately to its surroundings and climate to minimize its impacts at the same time as providing the levels of comfort expected in the most efficient way.

CLIMATIC CONDITIONS

The Chilean Standard NCh1079 of.2008 [4] defines two climatic zones within the micro region of Araucania Andina (fig.1). Up to an altitude of approximately 600m above sea level the region forms part of the "South Interior" climatic zone which it defines as "Wet and cold with frequent frosts; short summers of 4-5 months with moderate insolation; numerous lakes and rivers with microclimates; robust vegetation; humid air and ground; winds southerly and calm." [4] Above 600m the climate is classified as Andean "Zone with dry atmosphere and large diurnal thermal oscillations; blizzards and snow in winter; high altitude vegetation; large component of UV in the solar radiation. Given its large range of latitudes, this zone presents very particular characteristics along its length, being in general of extreme conditions." [4] The Andean zone also has the footnote that it "Consists of various subzones that have not been studied in detail due to its low population density." [4] According to the classification of Köppen [5] the region is divided into 3 climatic zones, these being; towards the west and in the bottom of the valleys Cfb a temperate climate with no dry season, short hot summers and wet cold winters; on the higher slopes Cfcs a cold wet temperate climate; and on the high peaks ETH cold tundra due to altitude. The Bioclimatic Atlas of Chile [6] goes further to subdivide the region into 4 climatic zones however in those areas where permanent tourism infrastructure is located it can be concluded that in winter there is an average minimum temperature of around 0°C, dropping to a minimum minimum of around -10°C and an average maximum 8-10°C during winter days. In summer average temperatures range between 5°C and 25°C with extremes of 0°C and 37°C being recorded [7]. Chilean Thermal Building Regulations only apply to new build residential dwellings and do not cover holiday accommodation [8].

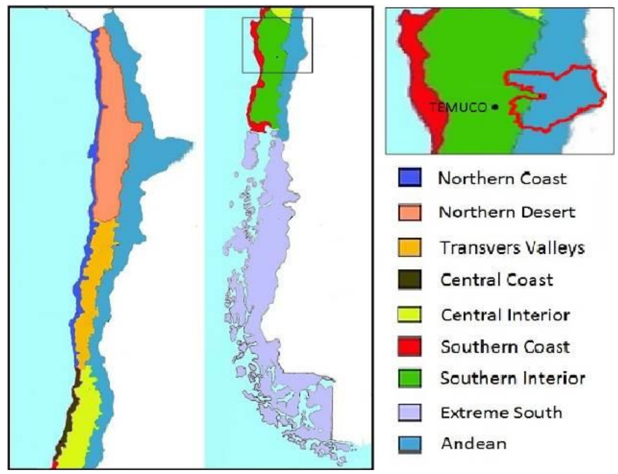


Figure 1: Climatic zones of Chile as defined by NCh1079.

POST OCCUPANCY EVALUATION OF EXISTING TOURIST INFRASTRUCTURE IN THE ARAUCANIA ANDINA

As part of the research project "Sustainable and Energy Efficient Construction System for Special Interest Tourist Infrastructure in the Araucanía Andina," post occupancy evaluation of existing available accommodation in the study area was undertaken in order to define a benchmark. Six tourist establishments (fig. 2) were selected to provide a representation of different typologies located in or near the four main poles of existing development, Curacautín, Malalcalhuello, Lonquimay and Melipeuco.

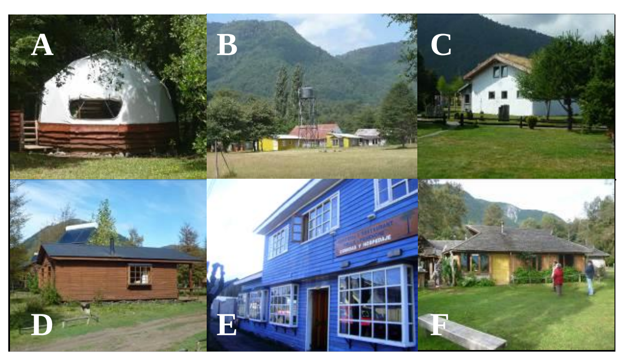


Figure 2: Establishments A-F

Establishment A, four geodesic domes with an aluminium structure covered by PVC fabric, offering what the owner describes as "comfortable camping," 12km east of the town of Curacautín in the valley of the River Cautín. The private bathroom and outdoor kitchen are located next to each dome in timber constructions. Two of the domes are raised on timber decks "in the trees," the other two are at ground level. The domes are un-insulated but have gas fires with balanced flues. Two of the domes were evaluated one raised and one at ground level; in addition to the timber cabin reception/ café.

Establishment B, a traditional tourist complex 5km further east along the international road to Argentina, it consists of a main single storey timber building with reception, restaurant, bar and guest rooms, an outdoor swimming pool and 5 timber cabins. The cabins are timber framed, clad with vertical boarding, un-insulated and have single glazed timber framed windows. Heating is provided by wood burning stoves. Two cabins were evaluated numbers 15 and 17.

Establishment C, a project started by a Swiss owner over twelve years ago, 28km east of Curacautín, 3km west of the village of Malalcahuello. The main lodge building is a restored timber, two storey building that was originally built by a Swiss settler in the 19th Century. During the restoration the building was insulated with expanded polystyrene with a tyvec vapour barrier. Additional accommodation is provided in a new build timber building also insulted with expanded polystyrene, and a bungalow built with lightweight concrete blocks (Hebel). The current owners of the complex live on-site in a two storey straw bale house with a grass roof. Measurements were taken in the new-build timber building, the lightweight concrete block bungalow and the straw bale house.

Establishment D, five cabins and a 3-bedroom hostel, developed over the past 10 years, 1.5km west of Malalcahuello. The timber cabins have 5cm of expanded polystyrene insulation and are heated by one wood burning stove in the living room and electric wall heaters in the bedrooms. Hot water is provided by evacuated tube solar collectors in summer and a gas boiler in winter. The two systems are not interconnected. One cabin "Los Notros" was evaluated.

Establishment E is located in the town of Lonquimay at the end of the alto Bio Bio valley and is separated from the rest of the Araucanía Andina by the Las Raices mountain range, connected either via a 1650m high pass or a 4.5km long tunnel. Founded and run by the local indigenous Pewenche community as a boarding house for when they have to visit the town, the hostel also provides accommodation for tourists visiting the region. The hostel serves local food and also functions as the point of contact for tourists wishing to visit the indigenous conservation territory of Quinquén. The hostel is a two storey un-insulated timber building, heated by two wood burning stoves, one in the ground floor dining room and one on the first floor landing.

Establishment F, a bed and breakfast located a few kilometres outside the village of Melipeuco in the valley of River Allipén. It is run by a Pewenche couple who spent 20 years in France living in exile due to the military dictatorship. On their return to Chile they built the B&B drawing on important aspects of their indigenous architecture whilst integrating features to provide improved comfort for their guests. The main structure is of locally forested timber, finished in timber, stone and colihue, a local bamboo. The walls are insulated with expanded polystyrene and the windows are double glazed in timber frames. The roof is clad with coigüe (*Nothofagus dombeyi*) shingles but however is not insulated. Heating is provided by a wood burning stove situated centrally in the living room. One guest room, the communal living and the owners' second floor private accommodation were evaluated.

Establishment G, eight fibreglass domes located on the slopes of the Sollipulli volcano, 23km East of Melipeuco. The domes are modelled on Mongolian yurts and insulated with glass fibre insulation. Private bathrooms are located within the domes. Previously the accommodation was in un-insulated geodesic domes similar to those at Establishment A, however these have now been replaced by the fibreglass yurts to improve thermal comfort and reduce heating demand. Heating is provided by a centralized heating system with radiators and a wood burning boiler. Electricity is provided by a small scale hydroelectric generator which is currently being replaced by a larger installation. The owner hopes the new generator will provide sufficient electricity to replace the wood burning boiler which is viewed by some European tourists as unsustainable polluting and burning native forest. One site visit was made and the owner was interviewed, however post occupancy evaluation of this establishment was not undertaken due to its remote location and difficulties of year round access.

In addition to the post occupancy evaluation of these six establishments, the park wardens from the two National Parks and two of the Reserves were interviewed. As these protected areas do not offer any accommodation other than camping, post occupancy evaluation was not undertaken.

METHODOLOGY

In April 2012 (autumn), August 2012 (winter) and January 2013 (summer) interviews were undertaken with the owners and staff of the selected establishments and the National Parks. At the same time insitu measurements of internal and external dry bulb air temperature and relative humidity were taken with a thermo-hygrometer Kestrel 3000. Radiant surface temperatures of internal surfaces (walls, floor and ceiling) were measured with a RadioShack IR Thermometer and thermo-graphic photos were taken with a Testo 875-201 thermal imager externally with the heating on inside. The daylight factor was calculated with measurements with a digital photometer LX1010B. Concentrations of carbon dioxide were recorded with a Testo 535 CO2 meter checking for problems with air quality and poor ventilation. Background noise levels were measured internally and externally with a Cirrus sound level meter. In addition to the specific insitu measurements iButton Hygrocron data loggers were installed 1.7m above floor level to record the dry bulb air temperature and relative humidity at half-hourly intervals. Due to the limited number of data loggers, measurements were recorded in establishments A-C from the 13th April 2012 until the 7th July 2012. The sensors were then relocated to establishments D-F and measurements recorded from 18th August 2012 until the 11th of November. The sensors were then once again relocated in A-C on the 19th of January 2013 and measurements are on-going. The dry bulb temperature and relative humidity readings were then plotted on psychrometric charts according to Givoni [8].

RESULTS

INTERVIEWS WITH PARK WARDENS

Tolhuaca National Park: Due to the parks remote location, accessed by a single track dirt road, one of the biggest challenges faced by the park wardens is the winter snows that often leave them isolated for three months of the year. Fortunately they are self-sufficient in terms of energy, with heating demand being met by locally collected firewood and a Pelton hydroelectric generator providing their electricity. The energy generated currently exceeds the park wardens' needs and they are hoping to implement a limited supply to the camping sites. The water supply comes from local streams and sterilization that complies with the requirements of the Ministry of Health was implemented in 2011. Only one of the park wardens' cabins has thermal insulation.

Malalcahuello National Reserve: Being located on the international road on the outskirts of the village of Malalcahuello, the park wardens of this reserve do not suffer the same problems of being cut off by winter snows. The electrical supply is connected to the national grid. The timber cabins built 35 years ago are only partially insulated with expanded polystyrene and are heated by wood burning stoves. The resulting unstable temperatures are one of the park wardens' main complains, especially those who live alone. As they spend long periods outside or in the reception area, each time they return to the cabin they often have to relight the stoves which then take time to raise the air temperature.

Conguillio National Park: Given the parks altitude of 1300m the park closes during the winter from May until December when the area around the information centre receives up to 2m of snow and temperature drop to a minimum of -20°C. Electricity is provided by small scale hydro and heating is provided by wood burning stoves.

POST OCCUPANCY EVALUATION OF EXISTING TOURIST INFRASTRUCTURE

Establishment A: The dry bulb temperature measurements clearly show the lack of thermal insulation. Figure 3 shows two days, 20th and 21st May 2012 during which dome 1 was occupied but dome 2 was not. The elevated temperatures of the occupied dome are the result of the gas fire. The temperature of the unoccupied dome closely follows the outdoor temperature. The owners confirmed that the gas bills were one of their largest outgoings.

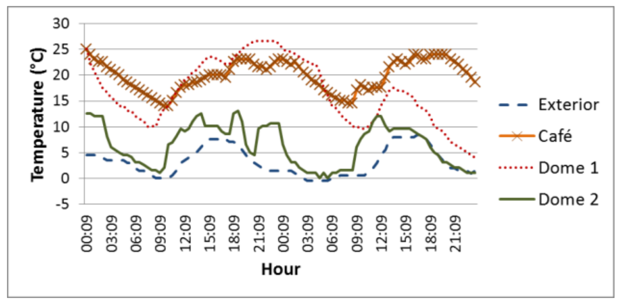
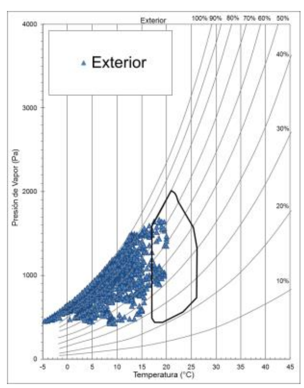


Figure 3: Dry bulb air temperature, Establishment A as measured 20th-21st May 2012.

Figures 4&5 show that the relative humidity in the domes is constantly high and is at times higher than the outdoor levels. The readings for Dome 2 rarely fall within the hygrothermal comfort zone.



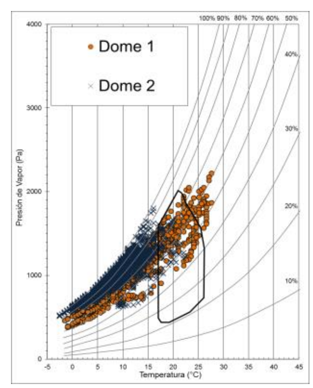


Figure 4: Psychrometric chart of outdoor air temperature and relative humidity.

Figure 5: Psychrometric chart of indoor air temperature and relative humidity domes 1 and 2

Measurements of radiant surface temperatures showed temperatures equal to internal air temperature except for in the case of the roof which recorded 1°C above internal air temperature. Acceptable day-light factors were recorded. Background noise levels were identical inside and outside showing that the domes provide no acoustic separation.

Establishment B: The dry bulb temperature readings show that without heating, both cabins closely follow the outdoor air temperatures. With heating the temperatures often rise beyond the upper thermal comfort limits with temperatures up to 37°C. Once the stoves burn out in the night the temperatures quickly drop but in general remain 3°C above outdoor temperatures. Thermal imaging showed high thermal losses through the un-insulated timber walls.

Establishment C: The dry bulb temperatures show that when occupied the accommodation is within the thermal comfort zone. When the accommodation is not occupied, background heating, provided by the oil fired central boiler, maintains the internal temperature around 15°C to avoid pipes freezing. Figure 6 shows a day when the lightweight concrete (hebel) bungalow is vacated and the temperature drops over the day to 14°C.

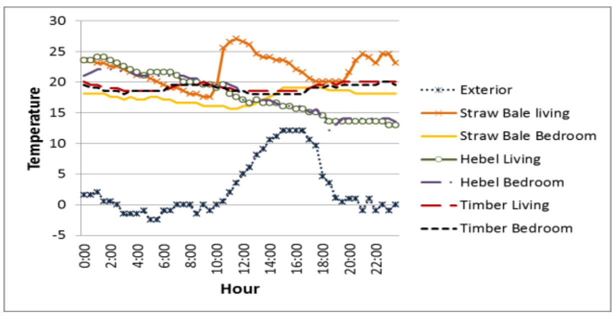


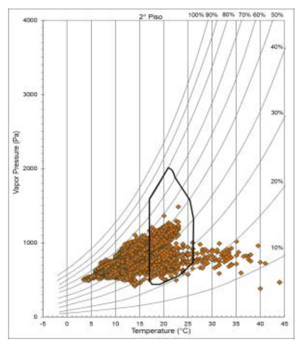
Figure 6: Dry bulb air temperature, Establishment C as measured 21st May 2012.

Over the 2 ½ months of winter measurements the straw bale dwelling showed the most stable temperatures. This is in part due to its constant occupation, it being the home of the owners, but also the high levels of insulation provided by the straw bales help to reduce heat losses. Thermal imaging of the exterior of the walls showed no thermal bridging in the wall surface; it did however identify heat loss through the aluminium window frames that are not thermally broken as this technology is not currently available in Chile. The owners commented that they have received guests in winter, relocating from other establishments where they had experienced the cold.

High levels of relative humidity were recorded in both the timber and lightweight concrete block (hebel) cabins. Olfactory evidence suggests a lack of background ventilation although CO_2 readings were not high, due to minimal occupancy.

Establishment D: On the coldest day recorded during the 3 months of measurements, the external temperature dropped to minus 7°C. Due to the fact the building envelope is insulated with 5cm of expanded polystyrene, internal temperatures remain 7°C higher than the external temperature, however this temperature is still 0°C. The cabin was unoccupied on the day in question but it relates to a specific problem noted by the owner, that the pipes and boiler diaphragms freeze in the winter. As the boilers are simple boilers without a balanced flue, by law they must be located externally. The pipes are un-insulated and so freeze and burst. It would be recommendable to bury water pipes 750mm below ground, insulated all external pipe-runs and located boilers inside with a balanced flue.

Establishment E: Figures 7&8 show the dry bulb temperatures and relative humidity plotted on psychrometric chart according to Givonni. Figure 7 shows measurements recorded between August and November 2013 which demonstrate that a large percentage of the time the readings fall below the comfort zone. However some readings show overheating due to the wood-burning stove, with temperatures reaching 44°C. The summer readings (fig.8) also show overheating up to 33°C due to the glazed skylight over the stairwell.



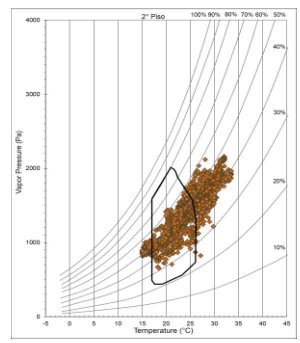


Figure 7: Psychrometric chart of indoor air temperature and relative humidity of second floor landing of Establishment E August-November 2012 (winter).
Figure 8: January 2013 (summer)

Daylight factors in the dining room ranged between 2% and 15% and no problems with air quality were detected.

Establishment F: In general both dry bulb temperature and relative humidity readings during winter months fall within the comfort zone in this establishment heated by only one wood burning stove. This clearly illustrates the advantages of insulating the walls and double glazing the windows. The main problem identified by both the measurements and the owners is the overheating of the second floor during summer. This could be reduced by insulating the roof and the introduction of a ventilated roof space. Exploring the use of the endemic bamboo colihue as an insulating internal finish could be interesting to explore, especially as some ceilings are already treated in this way (fig.9). Research by the authors, presented in the paper "Natural fibre insulation in rural southern Chile," at this congress, shows that colihue has a coefficient of thermal conductivity of 0.161W/mK.

Figure 9: Colihue an endemic bamboo as internal finish. Establishment F

There follows a summary of the main findings of the post occupancy evaluation of the 6 tourist establishments.

Table 1: Summary of establishments evaluated. (x) Problems encountered, (+) positive readings of (Temp.)- Thermal insulation, (Vent.)- Ventilation, (Ilum.)- Natural daylighting, Inov.- Innovation

Establishment	Temp.	Vent.	Ilum.	Innov.
A	x	+	+	+
B	x	x	x	x
C	+	x	+	+
D	x	+	+	+
E	x	+	+	x
F	+	+	+	+

CONCLUSION

The most common problem encountered in the Araucanía Andina is the lack of sufficient thermal insulation leading to high heating demands and poor hygrothermal comfort. Four of the 6 establishments evaluated lack sufficient insulation and a fifth would benefit from additional insulation in its roof. Measurements of summer dry bulb temperatures also show problems of overheating due to lack of solar protection and lack of thermal mass. Due to the lack of insulation, heating becomes one of the major outgoings for the owners in order to maintain the temperatures within comfort levels expected by the tourists. Even in the case of the most well insulated establishment, Establishment C, heating is provided by an oil fired boiler which is far from a sustainable solution. The owner is however interested in exploring ground sourced heating solutions.

The majority of the establishments studied, except the oldest and most traditional (B) have good natural day lighting. Few problems with presence of high levels of CO_2 were detected (continuous air quality monitoring was not undertaken) but high relative humidity levels were identified, especially in winter months when tourists are unlikely to open windows. Thus, ventilation with heat recovery is needed.

The biggest challenge is therefore to improve the thermal insulation of the existing and new tourist accommodation to meet the needs and expectations of the Special Interest Tourists. For this reason the authors are currently working on the development of a sustainable construction system with locally sourced natural fibre insulation. With this construction system, coupled with best practice in energy generation, waste disposal, sewage water plants, heating systems and mechanical ventilation, that draws on the cultural identity of the region and stimulates the local economy, it is hoped to be possible to meet the challenge of providing sustainable tourist infrastructure in the Araucanía Andina.

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