MECHANISMS AND NETWORKS TO TRANSFER TECHNOLOGIES RELATED TO CLIMATE CHANGE IN LATIN AMERICA AND THE CARIBBEAN

"Consultancy for survey and development of Sustainable Behaviour Standards of buildings in the Galapagos Islands"

EXECUTIVE SUMMARY

December 2018

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Background

The "Consultancy for survey and development of sustainable behaviour standards of buildings in Galapagos Islands" was born as part of the strategy proposed for the Galapagos Islands under the National Energy Efficiency Plan (PLANEE, for its Spanish acronym) 2016 – 2035 and the "zero fossil fuel for Galapagos" initiative. In 2007, the former Ministry of Electricity and Renewable Energy of Ecuador (current Ministry of Non-Renewable Energy and Natural Resources) requested the technical cooperation of the Bariloche Foundation under the framework of the "Mechanisms and networks to transfer technology related to climate change in Latin America and the Caribbean (RG-72384)" project implementation, developed by the InterAmerican Development Bank (BID, for its Spanish acronym) and approved for funding by the Global Environment Fund (GEF). The project aims to promote the development and transfer of rational environmental technologies which contribute to reducing greenhouse gas emissions and the vulnerability to climate change in sectors such as energy, transport, agriculture and forestry and where the Bariloche Foundation acts as the Project Executing Agency for activities related to the energy sector. Under this framework the role allocated to the consultancy was to carry out survey studies enabling: "*generating the necessary inputs to set the sustainable behaviour standards of buildings in the Galapagos Islands, Ecuador, in the residential, commercial and public services sectors which may be applicable along the coastal area of Ecuador through the survey and analysis of the information available*", as defined in the reference terms; and contribute in this way to reduce accumulated fossil energy consumption in the Galapagos Islands, as foreseen in the PLANEE for the Galapagos axis. The successful tenderer of the works was Tecnalia Foundation who started and completed consultancy activities in September 2017 and October 2018, respectively.

Although obviously the Galapagos Islands attract particular attention from scientists worldwide, the issues related to the Islands building stock have not yet been studied in depth. This consultancy work has contributed to quantify the extent of the problem and the impact from the possible strategies. Moreover it has also contributed from the governance point of view, with the definition of a road map, and launching a process to establish a multilevel governance which may carry it through.

Methodology

Two parallel routes providing continuous feedback have been used to define the standards: An **approach based on data and information analysis**, which has included a comprehensive background review, an extensive and oriented data survey, and simulations of representative buildings, where the issues and impact from the proposals has been quantified; and an **approach based on joint creation and monitoring,** including three visits to the region, where partial results from the different project phases have been socialised by key agents and collecting their feedback.

The first approach was divided into four methodological phases:

1. **Data Survey:** The first phase revolved around defining the criteria, aims and resulting framework of indicators guiding decision-making throughout the project. This enabled setting-up the information requirements needed and defining the data survey strategy to be implemented. The data survey was carried out in two visits to the region. The first visit took

place in November 2017 (V1) with the aim of achieving a massive data survey which will enable the definition of the prevailing building types in the islands, and therefore the characterisation of the building stock in the islands. The architectural and constructive data of 911 buildings (345 in Santa Cruz, 313 in San Cristóbal and 253 in Isabela) was gathered and 407 surveys were carried out (142 in Santa Cruz, 134 in San Cristóbal and 131 in Isabela). The 22 resulting types were validated at the workshops which took place during the visit V2 (February 2008). Representative buildings were selected from each type and studied in further detail in the second visit to the region. The data was structured in a Geographical Information System (GIS) which has been made available to all stakeholders.

2. **Baseline definition:** With the ultimate aim of characterising the energy efficiency parameters of representative buildings in terms of energy demand and consumption, 22 energy models were developed: one for each of type resulting from the data survey. These energy models facilitated the identification and quantification of the different types of end use energy both in the current scenario as well as in other scenarios resulting from the implementation of improvement measures oriented to increase the energy performance of these buildings. Thanks to energy modelling and database analysis work, the baseline was defined and the improvement opportunities for the building types were identified, as well as their related specific issues. In order to validate and calibrate the models, the results of these analyses were compared with the actual consumption values obtained from invoices. This analysis was complemented by a comprehensive bibliographical study and a comparison of existing policies.
3. **Impact and future scenarios:** For the design future scenarios, future energy consumption trends were studied, using growth trends (population and tourism), future weather change projections caused by climate change and potential energy use changes due to equipment obsolescence, among other variables. On the other hand, the different scenarios for possible degrees of standard implementation were designed. Sets of measures were defined by assessing the capacity of the measures as a whole to reduce the building energy demand, as well as energy consumption and CO_2 emission, as well as improving comfort for building users.
4. **Sustainability solutions:** In the final phase, the sustainability solutions established have been defined in detail indicating their suitability and impact for each type. An assessment of visual impact from the solutions on the different types was carried out based on the following criteria: energy saving, reduced CO_2 emissions, improved comfort, visual impact and implementation cost. Furthermore, the following aspects were defined for each solution: i) types of buildings where the measure can be implemented; whether a measure can be used in new buildings and/or refurbishments; and the set of strategy measures where this is included; ii) characteristics, functionality and improvement aims to be achieved; iii) sketch and diagrams showing concepts and results derived from its implementation; iv) materials and/or elements needed to be used for its implementation; v) advantages and disadvantages of its implementation; vii) sustainability issues related to its implementation; viii) any

constraint which may exist and has to be taken into account for extrapolation to the coastal area of Ecuador.

The participative approach was structured in one-to-one interviews and workshops carried out in the three islands and at different stages of the project, using the visits to the region. The inputs obtained from these workshops have enabled the different perspectives provided by local agents to be present throughout the entire project. And in particular, these inputs have contributed to: i) validating and completing the types of buildings described; ii) assessing and prioritising the different criteria; iii) identifying the acceptability of solutions; iv) defining the content of standards; and v) establishing the road map for further standard implementation.

Main concerns related to building in the Galapagos Islands

Based on *in-situ* data collection, there are many concerns related to the building stock which prevent users from achieving the optimal comfort conditions inside the buildings. The main problem faced by users inside the buildings are high temperatures due to radiation affecting the building envelope. This causes comfort reduction and in the case of the hotel and educational centres, increased energy consumption due to the use of air conditioning devices to fight high temperatures. The simulations carried out reinforced this idea, with two main scenarios: buildings not fitted with air conditioning systems and buildings fitted with air conditioning systems. In the first scenario, indoor temperature evolves in direct relation to outdoor temperature, and indoor conditions are out of the comfort conditions for a high number of hours. This situation is translated into a high percentage of unsatisfied people. In the second scenario, despite the existence of air conditioning systems, and ratifying the conclusions based on the data surveys, simulations have demonstrated that the number of hours where comfort conditions are not met and the percentage of unsatisfied people although significant, are not as high as in the first scenario. This is mainly due to the construction characteristics of buildings, which are summarised in the following table.

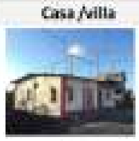
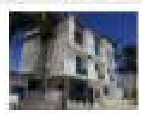
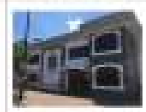
		Casa /Villa	Departamentos	Hoteles	Colegios	Oficinas
						
Estructura	N.º pisos	1	2	2	1	2
	Estructura	Hormigón	Hormigón	Hormigón	Hormigón	Hormigón
Envolvente	Fachadas	Bloque hormigón sin aislamiento acabado blanco cal	Bloque hormigón sin aislamiento acabado blanco cal	Bloque hormigón sin aislamiento acabado blanco cal	Bloque hormigón sin aislamiento acabado blanco cal	Bloque hormigón sin aislamiento
	Cubierta	Inclinada Chapa	Plana Hormigón	Plana Hormigón	Inclinada Chapa	Plana Fibrocemento
	Carpinterías	Aluminio sin RPT Practicables Vidrio simple 25-50% huecos	Aluminio sin RPT Practicables Vidrio simple 25-50% huecos	Aluminio sin RPT Practicables Vidrio simple 25-50% huecos	Aluminio sin RPT Practicables Vidrio simple 25-50% huecos	Aluminio sin RPT Practicables Vidrio simple 25-50% huecos
	Sombreamiento	Aleros + Mosquitera	Aleros + Mosquitera	Aleros + Mosquitera	Aleros	Aleros
Instalaciones	Ventilación	Natural cruzada	Natural cruzada	Natural cruzada	Natural cruzada	Natural cruzada
	Climatización	No	No	Split AA individual	Split AA individual	Split AA individual
	Energía principal	Electricidad	Electricidad	Electricidad	Electricidad	Electricidad
	Iluminación	Bajo consumo	Bajo consumo	Bajo consumo	Bajo consumo	Bajo consumo
	Fuentes renovables	No	No	No	No	No

Table 1: Summary of construction characteristics for the types defined

As well as mass data collection, the study of energy models in the 22 representative buildings selected led to the identification of the main weaknesses of each construction type:

- **Opaque enclosure types:** The envelope of residential, hotel or public buildings consists of concrete blocks with white or light coloured lime finishes. This type of envelope poses two significant disadvantages from the building energy behaviour viewpoint in warm climates such as the Galapagos Islands weather: on the one hand, as its thermal resistance is low, heat is easily transferred through the envelop into the building during the day; and on the other hand, its high thermal inertia makes the enclosures capable of storing heat during the day through solar radiation and that heat is transferred inside the building during the night. In both day and night scenarios, the buildings in the Galapagos Islands show high heat gains through enclosures. This problem is aggravated in buildings where enclosures are not fitted with mortar finishes, and concrete blocks are directly exposed to solar radiation, which leads to an increased amount of solar radiation being absorbed by the block which in turn increases thermal transmittance inside the building . This issue has been observed in most residential buildings which are only fitted with one mortar coating on the main façade, while the other façades are fitted with exposed concrete blocks. This type of façade with very low thermal resistance and high thermal inertia, provokes heat gains through the façade both day and night. **Approximately 16% of total heat gains are through façades**
- **Types of openings:** In most cases, heat gains are directly caused by solar radiation entering the building through glass envelopes. Most windows of the islands buildings are made of a metallic framework with single glazing and without the suitable shading elements. This facilitates the direct impact from radiation on windows and further transmittance inside the buildings. This type of window is a very significant source of gains, and even more so when the envelope has a medium-high ratio of glass / opaque surfaces (50% glass surface). **Approximately 26% of total heat gains are through the windows**
- **Roof types:** The Island buildings are not fitted with roof spaces or ventilated roofs, i.e. the roof components are in direct contact with a living area. As a result, all the heat impacting on the roof due to solar radiation is directly transferred inside the building, making indoor temperature rise, reducing comfort and increasing air conditioning demand. This heat transfer inside the buildings through the roof is more common on roofs comprising metallic sheets or fibre cement corrugated sheets, due to the higher transmittance and low reflectance capacity of these materials and to the lower thickness of this solutions. Due to the location of the islands, buildings are very exposed to solar radiation, and the highest heat gains inside the buildings take place through the roofs. **Approximately 46% of the total heat gains are through the roofs**
- **End use energy:** In the residential sector, only a few homes are fitted with air conditioning systems and existing equipment use result in high energy consumption. This is due to two factors: the high demand of air conditioning systems for buildings in this sector, which is translated into electricity consumption when the home is equipped with air conditioning devices on the one hand; and to the low energy efficiency of the devices on the other. In the commercial sector, the main electricity consumption is used to supply air conditioning, which

concentrates from 40% of the final energy consumption in Santa Cruz to 72% of the total energy consumption in San Cristobal. The low electricity consumption in home lighting, is possibly due to the hours of use (in any case less than 6 hours/day) and to the change of lighting appliances promoted in the Islands in recent years, as 100% of the buildings have low energy appliances. In the commercial sector, due to its activity and hours of use, the end consumption percentage used to satisfying lighting demands is higher than in the residential sector. Light fittings change programs can clearly illustrate that standardisation, implementation incentives and clear impact have been crucial to achieve an effective massive change. **Indoor loads (lighting, domestic appliances and occupation), in particular in hotels and educational centres represent the remaining 14% of total heat gains**.

Although passive strategies, vital for sustainable comfort, are present in existing buildings, they are badly designed and quite inefficient (inefficient natural ventilation or poorly designed shading elements).

A determining factor which facilitates or forbids the use of a specific material or the application of a constructive solution in vulnerable and protected environments such as the Galapagos Islands' environment, are the landscape and the environment where the buildings are located. This issue was analysed in 22 representative buildings selected and three degrees of landscape constraints were identified: High, moderate and low. 80% of the building stock is rated as Low, which means low or no landscape value and therefore measures or actions with high visual impacts could be implemented as they would not have an impact on the landscape value of the environment. Nevertheless, all sustainability measures related to the building envelop which have been proposed in each strategy defined, were designed taking the sustainability of Galapagos environment into account. Therefore, we can state that the application of the sustainability measures and standards defined will not provoke any visual impact on landscape; on the contrary, many of the existing building in the island will benefit and be visually improved thanks to these measures, as their appearance will be more consistent and according to the unique environment of Galapagos.

Finally, there is also significant room for improvement regarding water management and consumption savings. Primarily this is due to the fact that the installation of meters to quantify water consumption has not yet been implemented in rural municipalities; and in addition, the actual water consumption is not yet being invoiced, which may encourage an irresponsible use of water by the building users. The information gathered has revealed that measures to improve water consumption savings have started to be implemented, including water aerators for taps and the use of saving water tanks. These devices have been installed to a greater extent in the hotel sector as opposed to the residential or education building sectors. However, the survey data shows that there is still plenty of room for improvement, as the implementation of these devices in all sectors represents less than 50% of the building stock, and below 25% in the residential sector. Thus, we could conclude that the installation of these water saving systems will result in a considerable reduction of water consumption in the islands. Such savings could be very high if implementation is focused on the hotel sector buildings, as this sector produces higher water consumption per square meter built. Major water saving could be also obtained through the application of these systems to residential buildings, which in spite of registering lower consumption per square meter than hotels, they represent the most widespread constructive type in the island.

Sustainability strategies

The typology study has enabled the classification of the building stock into five basic types based on the set of characteristics which define them: i) villa/house type homes; ii) residential apartment type building; ii) hotels; iv) educational centres; and v) public office buildings The sustainability strategies defined for each sector analysed addresses the energy, social, environmental and financial challenges faced by buildings in Galapagos. These challenges identified since the start of the project focused on the following issues: i) reduced consumption of non-renewable energy; ii) improved comfort and public acceptance; iii) reduced environmental impact from buildings; and iv) reduced financial Impact from the solutions. To define the intervention strategies in the buildings, four following main matters have been taken into account: i) the characteristics of buildings in the islands; ii) weather, landscape, environmental and geographical constraints (including the difficulty added by insularity and environmental protection policies regarding provisioning of materials and equipment); iii) the conclusions of socialisation workshops held throughout this project and iv) the constructive and formal characteristics of each building type, as well as their energy conditions.

The solutions were grouped into sets of measures or intervention standards for each type of building defined. In order to meet different energy and comfort improvement aims, various socio-economic and investment capacity circumstances, or the existence of any subsidies or grants offered by public administration among others, three action levels have been defined for each type: **Basic intervention, Medium Intervention and High Intervention.** The following core of measures includes refurbishment and new built interventions, and the right hand side column features the measures suitability for each case. The sustainability standards for each building type will be defined later in this document.

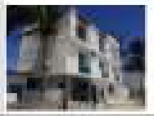
			Edificios residenciales		Edificios terciarios			Rehabilitación	Obra Nueva
			Casa /villa	Departamentos	Hoteles	Colegios	Oficinas		
									
Estrategia de intervención BÁSICA									
Minimizar ganancias de calor	Cubierta	Acabado en colores claros con alto índice de reflectancia solar.	X	X	X	X	X	X	X
	Fachadas	Acabado en colores claros con alto índice de reflectancia solar.	X	X	X	X	X	X	X
	Ventanas	Reducir superficie ventanas en fachadas Este y Oeste.	X	X	X	X	X		X
	Sombreamiento	Generar sombra en aberturas de fachada con vegetación propia del lugar	X		X	X		X	X
		Voladizos ligeros en aperturas de fachada.	X	X	X	X	X	X	X
Maximizar enfriamiento por las noches	Ventilación	Potenciar ventilación cruzada a través de ventanas en las fachadas opuestas, mediante eliminación de obstáculos que puedan disminuir la velocidad del viento.	X	X					X
		Grandes superficies de ventanas (madera o aluminio) + vidrio simple + mosquiteras	X	X	X	X	X	X	X
Medidas activas	Aguas	Utilización de artefactos de bajo consumo de agua.	X	X	X	X	X	X	X
		Uso de vegetación que necesita poco regadío.	X	X	X	X		X	X
Estrategia de intervención MEDIA									
Minimizar ganancias de calor	Cubierta	Aislar cubierta + Acabado en colores claros con alto índice de reflectancia solar.	X	X	X	X	X	X	X
	Fachadas	Aislar fachadas Este y Oeste + Acabado en colores claros con alto índice de reflectancia solar.	X	X	X	X	X	X	X
	Ventanas	Reducir superficie ventanas en fachadas Este y Oeste	X	X	X	X	X		X
		Aplicación de laminas de control solar en vidrios.	X	X	X	X	X	X	X
	Sombreamiento	Generar sombra en aberturas de fachada con vegetación propia del lugar	X		X	X		X	X
		Voladizos ligeros en aperturas de fachada.	X	X	X	X	X	X	X
Maximizar enfriamiento por las noches	Ventilación	Potenciar ventilación cruzada a través de ventanas en las fachadas opuestas, mediante eliminación de obstáculos que puedan disminuir la velocidad del viento.	X	X					X
		Grandes superficies de ventanas (madera o aluminio) + vidrio simple + mosquiteras	X	X	X	X	X	X	X
		Bajo cubierta ventilado.	X	X		X	X	X	X
Medidas activas	Equipos	Instalar ventiladores de techo en habitaciones de larga permanencia.	X	X	X	X	X	X	X
		Usar refrigeradoras y electrodomésticos energéticamente eficientes (mínimo Energy Star).	X	X	X		X	X	X
		Uso de cocinas de inducción en vez de coicnas de gas	X	X	X			X	X
	Iluminación	Uso de sistema de iluminación energéticamente eficientes. (LED)	X	X	X	X	X	X	X
	Aguas	Recogida de aguas pluviales (sistema recogida + depósito en propia finca).	X	X	X	X	X	X	X
		Tratamiento de aguas grises (Foso séptico o biodigestor)	X	X	X	X	X	X	X
		Utilización de artefactos de bajo consumo de agua.	X	X	X	X	X	X	X
		Uso de vegetación que necesita poco regadío.	X	X	X	X		X	X
Estrategia de intervención SUPERIOR									
Minimizar ganancias de calor	Cubierta	Aislar cubierta + Acabado en colores claros con alto índice de reflectancia solar	X	X	X	X	X	X	X
		Aislar cubierta + Cubierta vegetal			X		X	X	X
	Fachadas	Aislar fachadas Este y Oeste + Acabado en colores claros con alto índice de reflectancia solar / o fachada vegetal.	X	X	X	X	X	X	X
	Ventanas	Reducir superficie ventanas en fachadas Este y Oeste	X	X	X	X	X		X
		Sustitución ventanas de alto rendimiento.	X	X	X	X	X	X	X
	Sombreamiento	Generar sombra en aberturas con vegetación propia del lugar	X		X	X		X	X
		Voladizos ligeros en aperturas de fachada	X	X	X	X	X	X	X
		Creación de porche o veranda en sombra a modo de espacio ventilado.	X	X	X	X	X	X	X
Maximizar enfriamiento por las noches	Ventilación	Potenciar ventilación cruzada a través de ventanas en las fachadas opuestas, mediante eliminación de obstáculos que puedan disminuir la velocidad del viento.	X	X					X
		Grandes superficies de ventanas (madera o aluminio) + vidrio simple + mosquiteras	X	X	X	X	X	X	X
		Utilización de particiones interiores operables (correderos) para regulación manual del flujo de aire.	X	X	X	X	X	X	X
		Bajo cubierta ventilado.	X	X		X	X	X	X
Medidas activas	Equipos	Instalar ventiladores de techo en habitaciones de larga permanencia.	X	X	X	X	X	X	X
		Usar refrigeradoras y electrodomésticos energéticamente eficientes (mínimo Energy Star).	X	X	X		X	X	X
		Uso de cocinas de inducción en vez de coicnas de gas	X	X	X		X	X	X
		Usar sistemas de aire acondicionado de alta eficiencia energética.			X	X	X	X	X
		Colectores solares para ACS.	X	X	X	X	X	X	X
		Placas FV para electricidad.	X	X	X	X	X	X	X
	Iluminación	Uso de sistema de iluminación energéticamente eficientes. (LED)	X	X	X	X	X	X	X
	Aguas	Recogida de aguas pluviales (sistema recogida + depósito en propia finca).	X	X	X	X	X	X	X
		Tratamiento de aguas grises (Foso séptico o biodigestor)	X	X	X	X	X	X	X
		Utilización de artefactos de bajo consumo de agua.	X	X	X	X	X	X	X
		Uso de vegetación que necesita poco regadío.	X	X	X	X	X	X	X

Table 2: Core of energy efficiency intervention and action strategies for the building types defined.

House / Villa




Description

- Residential type single-storey individual home.
- Sloping roof mainly consisting of metallic sheets and to a lesser extent in fibre cement which provides low insulation.
- Low ratio of windows and opaque surfaces in façades.
- Electricity consumption to cover the demands of lighting and domestic appliances.
- The production of Domestic Hot Water (DHW) is different in each case as a major percentage of buildings do not have equipment dedicated to produce DHW.
- Lack of air conditioning devices, and therefore zero consumption in this section.
- Building suitable for family use.

Representing approximately 50% of the building stock of the islands

Inefficiency issues and main causes

- Roofs with high heat transfer.
- Façades with very low thermal resistance and very high thermal inertia.
- Windows without suitable shading elements.

Overall sustainability standard for house/villas in Galapagos

The type of buildings known as house/villa in the Galapagos Islands have a medium energy demand for air conditioning equal to 57.32kWh/m^2 per year. Taking into account the major impact from the **roof** in this type of buildings, the first measure to be implemented will be **reducing heat gains through the roof.** Thanks to this measure up to 69% of the cooling demand could be reduced. This can be achieved through roof insulation and solar radiation protection measures through a ventilated roof, using thermal insulation or implementing light colour finishes with high solar heat reflectance. The second measure to be implemented involves improving vertical enclosures. An improved **insulation of façades** both on glass surface through solar control sheets and/or cantilevers, as well as on opaque surfaces via insulation, including light-colour finishes with high solar heat reflectance, may represent a cooling demand reduction of 28%. If **shading** in openings using local vegetation is added to the above, demand from these buildings will be significantly reduced, while comfort for residents will rise with affordable implementation costs for the intervention. Finally, replacing light fittings, swapping current bulbs with LED types, will achieve a reduction of up to 50% of lighting-related electricity consumption (in the case of incandescent bulbs savings could reach 90%) as well as reducing internal heat gains.

Roof insulation + shading via carpentry + façade insulation + change of lighting equipment

Apartments

…

Description

- Residential type 2-3 storey building housing several homes
- Flat concrete roof providing better insulation than roofing sheets.
- A medium-high ratio of window / opaque surfaces of façades
- Electricity consumption to cover the demands of lighting and domestic appliances.
- Lack of air conditioning devices, and therefore zero consumption in this section.
- Building suitable for family use.
- The ground floor is often used for commercial purposes.

Representing approximately 40% of the building stock of the islands

Inefficiency issues and main causes

- Roofs with high thermal transmittance as they have no insulation
- Façades with very low thermal resistance and very high thermal inertia.
- Large glass surfaces and without suitable shading elements

Overall sustainability standard for buildings Apartments in Galapagos

The type of buildings known as Apartment Buildings in the Galapagos Islands, have a medium energy demand for air conditioning equal to 70.11kWh/m^2 per year. Unlike house/villa buildings, the incidence of roofs on apartments is more reduced while the façade plays a more important role. Therefore, the first measure to be implemented will be the improvement of vertical enclosures. Measures related to an improved **insulation of façades** both on the glass surface through solar control sheets and/or cantilevers, and on opaque parts through **insulation**, including light-colour finishes with high solar heat reflectance, could achieve a cooling demand reduction of 28%. The second measure to be implemented will be the **roof insulation and/or protection** using the thermal insulation, a ventilated roof or the application of light-coloured finishes with high solar reflectance index to minimise thermal gains. This will achieve a significant reduction in air conditioning demand for these buildings, as well as increasing comfort for residents with affordable costs for the intervention. Finally, the replacement of light fittings with LED types will achieve a reduction of up to 50% of lighting-related electricity consumption (in the case of incandescent bulbs the savings could reach 90%), as well as reducing internal heat gains.

Roof insulation + shading via carpentry + roof insulation + change of light fittings

Hotels

Description

- 2-3 storey hotel buildings
- Flat concrete roof providing better insulation than roofing sheets.
- A medium-high ratio of window / opaque surfaces of façades
- Electricity consumption to cover the demands for air conditioning, lighting and domestic appliances.
- Main electricity consumption from air conditioning devices.
- Building suitable for tourism.
- Two types of hotel buildings can be differentiated: one with larger built areas and therefore higher net energy consumption; and hotels with smaller areas and therefore lower global energy invoice.

There are over 300 buildings in the tourism sector with very high energy consumption

Inefficiency issues and main causes

- Roofs with high thermal transmittance as they have no insulation
- Façades with very low thermal resistance and very high thermal inertia.
- Large glass surfaces and without suitable shading elements
- Low-efficiency air conditioning devices

Overall sustainability standard for hotel buildings in Galapagos

The type of hotel building in the Galapagos Islands has a Medium energy demand related to air conditioning of 33.11 kWh/m^2 per year, as usage hours in these buildings are more reduced. As in the case of apartment buildings, the roof surface is not significant in relation to the total envelope of the building and therefore its impact is lower. However, the façade plays a more relevant role in these buildings. Therefore, the first measure to be implemented will be the improvement of vertical enclosures. Measures related to an improved **insulation of façades** both on the glass surface through solar control sheets and/or cantilevers, and on opaque surfaces through **insulation**, including light-colour finishes with high solar heat reflectance, could achieve a cooling demand reduction of 30%. The second measure to be implemented is the **roof insulation and/or protection** to minimise heat gains. Given the high lighting consumption, the replacement of light fittings with LED types is recommended, and this will achieve a reduction of up to 50% of lighting-related electricity consumption (in the case of incandescent bulbs the savings could reach 90%), as well as reducing internal heat gains. This will result in a major reduction in air conditioning demand from these buildings and increased tourist comfort. Finally, due to high consumption of air conditioning devices, replacing them with high efficiency devices is recommended.

Façade insulation + shading via carpentry + roof insulation + change of light fittings + change of air-con devices

Schools




Description

- One or two storey school buildings
- Sloping roof mainly consisting of metallic sheets and to a lesser extent in fibre cement which provides low insulation.
- Low ratio of windows and opaque surfaces in façades.
- Electricity consumption to cover the demands of lighting.
- A large number of these buildings have air conditioning systems.
- Building suitable for educational use.

There are approximately 30 school buildings in the Islands building stock

Inefficiency issues and main causes

- Roofs with high heat transfer.
- Façades with very low thermal resistance and very high thermal inertia.
- Windows without suitable shading elements.

Overall sustainability standard for School Buildings in Galapagos

This type of building is used for educational purposes and has Medium energy demand for air conditioning equal to 41.44kWh/m^2 per year. Taking into account the major impact from the **roof** on this type of buildings, the first measure to be implemented will be **reducing heat gains through the roof.** Thanks to these measures, up to 50% of the cooling demand could be reduced. This can be achieved through roof insulation and solar radiation protection measures through a ventilated roof, using thermal insulation or implementing light colour finishes with high solar heat reflectance. The second measure to be implemented involves improving vertical enclosures. An improved **insulation of façades** both on glass surfaces through solar control sheets and/or cantilevers or vegetation for shading, as well as on opaque surfaces, including light-colour finishes with high solar heat reflectance, may represent a cooling demand reduction of 40%. As a result of the above, demand from this type of buildings will be significantly reduced, increasing comfort for students and reducing air conditioning consumption, when buildings are fitted with air conditioning devices.

Roof insulation + shading via carpentry + façade insulation

Offices

Description

- 2 storey high office building
- Flat concrete roof providing better insulation than roofing sheets.
- A medium-high ratio of window / opaque surfaces of façades
- Electricity consumption to cover the demands for air conditioning, lighting and domestic appliances.
- Main electricity consumption from air conditioning devices.
- The building is for office use and therefore air conditioning devices are used for many hours a day.

Although this is the least representative type of building stock, these buildings have a very high energy consumption

Inefficiency issues and main causes

- Roofs with high thermal transmittance as they have no insulation
- Façades with very low thermal resistance and very high thermal inertia.
- Large glass surfaces and without suitable shading elements
- Inefficient air conditioning devices and extended use hours

Overall sustainability standard for Office Buildings in Galapagos

The Office Building type of buildings in the Galapagos Islands, has a medium energy demand for air conditioning equal to 137.3kWh/m^2 per year. As other types with more than one storey where the roof surface is not significant in relation to the total building envelope, and also being fitted with a flat concrete roof, the roof impact is lower while the role played by the façade is more important. Therefore, the first measure to be implemented will be the improvement of vertical enclosures. Measures related to an improved **insulation of façades** both on the glass surface through solar control sheets and/or cantilevers, and on opaque surfaces through **insulation**, including light-colour finishes with high solar heat reflectance, could achieve a cooling demand reduction of 47%. The second measure to be implemented is the **roof insulation and/or protection** to minimise heat gains. Given the high lighting consumption, the replacement of light fittings with LED types is recommended, and this will achieve a reduction of up to 48% of electricity consumption as well as reducing internal heat gains. This will result in a major reduction of the air conditioning demand from these buildings, increased comfort for employees and reduced the energy consumption of these devices. Finally, due to high consumption of air conditioning devices, replacing them with high efficiency devices is recommended.

Façade insulation + shading via carpentry + roof insulation + change of light fittings + change of air-con devices

Impact from strategies and future scenarios

The information gathered during the data survey enabled the development of different virtual models for representative buildings, to assess their behaviour in relation to energy uses, comfort and expected water consumption, calculating the baseline for level 1 indicators (building level). On the other hand, the mass data survey conducted in the first phase facilitated the extrapolation of results at municipality and island level establishing the level 2 baseline (municipality level). These models were also used to estimate the impact from intervention strategies. For the design and estimate of future scenarios, growth trends (population and tourism), future weather change projections caused by climate change and potential energy use changes due to equipment obsolescence have been taken into account, among other variables. The possible future scenarios of strategy implementation in the Islands buildings were also estimated. Then, future scenarios were simulated enabling standard definition including alternatives aimed at meeting the sustainability targets set by the PLANEE for the Galapagos, i.e. the reduction of accumulated fossil energy consumption in the Galapagos Islands by 0.36 Mbep. On the basis of the results defined in the baseline analysis regarding air conditioning and Domestic Hot Water (DHW) energy demand, average season outputs and end energy to CO_2 emissions equivalent ratios, the possible demand and emission scenarios of Galapagos future buildings were obtained, according to the different implementation levels of measures in the islands building stock. It was confirmed that energy savings and reduced CO_2 emissions were achieved at all levels, facilitating therefore for the aims set forth by PLANEE in the Galapagos Axis to be met. The impact to be achieved by the implementation of energy measures on other indicators such as water consumption and comfort improvement was also analysed.

Once the impact from the implementation of standards and sets of measures as a whole was determined, a multi-criteria analysis of the each solution application and specific result was conducted. The aim of this analysis of each solution was to facilitate access to measures for the stakeholders and promoting their application, as well as identifying the measures yielding greater energy, social and environmental benefits at a lower cost.

Confirming the assumption made at the start of the project, these measures are mainly passive and many of them are easy to implement. The measures improve one of the main weaknesses identified in Galapagos buildings: low thermal and construction quality of buildings envelopes. In residential buildings, the **light-colour finishing with high reflectance index** of the envelope, and in particular of the roof, as well as improving the aesthetic issue and urban quality derived from the high number of residential buildings with no finishing materials which leave concrete exposed, would improve their energy behaviour (with a demand reduction of up to 41% and comfort improvement of 47%) at low cost.

Demand reduction	**35%**
Residential	41%
Hotels	14%
Public	40%
Total consumption reduction	**18%**
Residential	19%
Hotels	7%
Public	20%
Improved comfort	**36%**
Residential	47%
Hotels	9%
Public	33%
Reduced CO_2 emissions	**5.6 kg/m2 per year**
Visual impact	**1**
Price	**≈ 28 $/m^2**

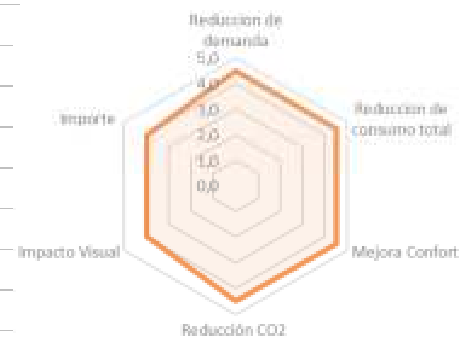


Table 3: Impact from light colour finishes with high reflectance index on residential buildings

The **thermal insulation** of the façade and roof is a logical step when improving the envelope of any building. However, as the following figure shows, in Galapagos this is particularly beneficial for public buildings due to their higher air conditioning demand. Although the most accessible and currently commercialised solution in the Islands is Expanded Polystyrene (EPS) insulation, finding other more sustainable insulation solutions from the lifecycle analysis point of view is also recommended.

Demand reduction	**33%**
Residential	28%
Hotels	16%
Public	47%
Total consumption reduction	**24%**
Residential	28%
Hotels	8%
Public	27%
Improved comfort	**14%**
Residential	19%
Hotels	8%
Public	5%
Reduced CO_2 emissions	**2.18 kg/m^2 per year**
Visual impact	**1**
Price	**≈ 28 $/m^2**

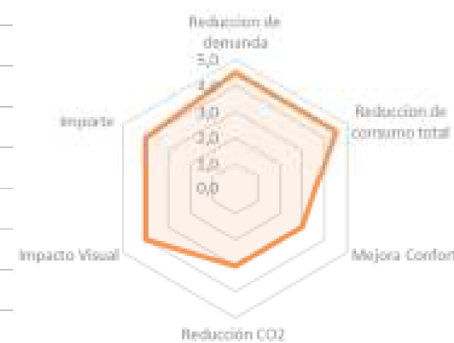


Table 4: Impact from thermal insulation on the envelop

Another slightly more costly solution compared with the previous ones but achieving better results in all types of buildings, is the installation of **ventilated roofs.**

Demand reduction	**69%**
Residential	73%
Hotels	29%
Public	77%
Total consumption reduction	**30%**
Residential	35%
Hotels	12%
Public	29%
Improved comfort	**67%**
Residential	88%
Hotels	10%
Public	70%
Reduced CO_2 emissions	**9.96 kg/m^2 per year**
Visual Impact	**1**
Price	**≈ 67 $/m^2**

Table 5: Impact from ventilated roof

As part of the strategy to minimise solar gains through glass envelopes, **sun control sheets** and **shading through vegetation** are the highest impact solutions for all types. The first option is the most cost-effective when it comes down to reducing demand and improving comfort; while the second option entails all the combined social, environmental and visual benefits provided by natural solutions.

Demand reduction	**27%**
Residential	24%
Hotels	29%
Public	11%
Total consumption reduction	**11%**
Residential	8%
Hotels	14%
Public	7%
Improved comfort	**25%**
Residential	25%
Hotels	26%
Public	25%
Reduced CO_2 emissions	**1,9 kg/m2 per year**
Visual Impact	**0**
Price	**≈ 22,5 $/m2**

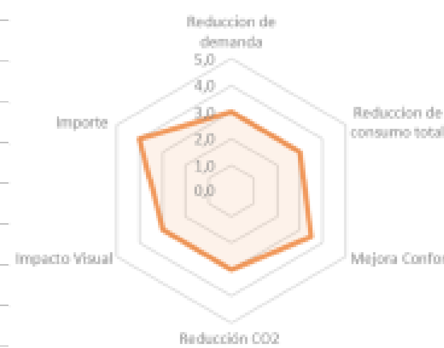


Table 6: Impact from solar control sheets

Demand reduction	**12%**
Residential	12%
Hotels	11%
Public	9%
Total consumption reduction	**9%**
Residential	6%
Hotels	13%
Public	3%
Improved comfort	**13%**
Residential	13%
Hotels	9%
Public	23%
Reduced CO_2 emissions	**1,64 kg/m2 per year**
Visual Impact	**2**
Price	**≈ 58 $/ud**

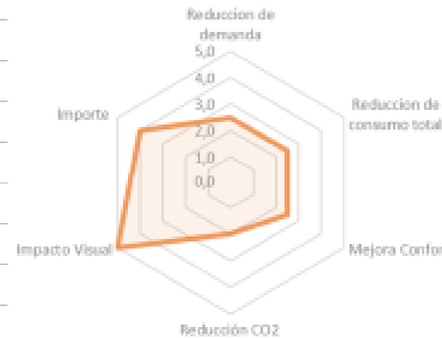


Table 7: Impact from shading through vegetation

In this context and according to global trends involving nature-based sustainable solutions, **vegetation façades** are also proposed**.** In Galapagos this solution is very well suited for the hotel sector as it is highly effective for this type of buildings in particular. Hotels could balance its higher costs, with the visual improvement and prestige derived from adopting state-of the art solutions.

Demand reduction	**26%**
Residential	24%
Hotels	29%
Public	15%
Total consumption reduction	**13%**
Residential	11%
Hotels	14%
Public	8%
Improved comfort	**22%**
Residential	22%
Hotels	19%
Public	25%
Reduced CO_2 emissions	**3.2 kg/m^2 per year**
Visual impact	**2**
Price	**≈ 110 $/m^2**

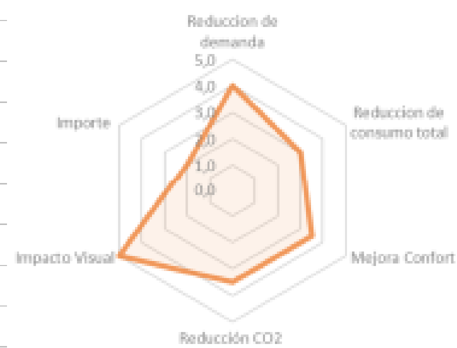


Table 8: Impact from vegetation façades

In hotels, due to their high consumption, the air conditioning systems recommended are high energy efficient systems so that consumption can be reduced by 25% which will make a major impact on the total consumption of the island.

Total consumption reduction	**36%**
Residential	26%
Hotels	25%
Public	48%
Reduced CO_2 emissions	**7.5 kg/m^2 per year**
Visual impact	**-2**
Price	**≈ 1920 $/u,**

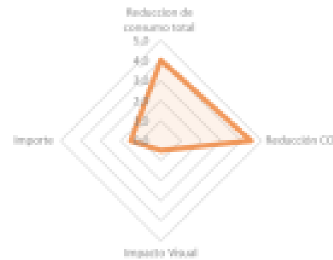


Table 9: Impact from high-efficiency air conditioning systems

Other solutions easy to implement and with significant impact are **energy efficient lighting systems (LED)** capable of significantly reducing electricity consumption by up to **54% on average** and **low water consumption appliances which will achieve a water consumption reduction of up to 40%.**

As the future scenario analysis demonstrated, the ad-hoc application of these measures will not be sufficient to contribute to meet the sustainability targets defined in PLANEE for the Galapagos axis. However, due to its multicriteria impact, easy implementation and universality, these solutions could be the basis of incremental policies to support and encourage sustainable construction in the islands supported by a economy of scale.

Workshop outputs and roadmap

The workshops carried out helped to identify that the existing barriers were not isolated but systemic and were present throughout the entire value chain: i) starting by the lack of specific regulations for Galapagos sustainability and the lack of knowledge among the population regarding existing regulations; ii) lack of skilled and qualified labour (both professionals as well as trades); iii) difficulty to find sustainable materials and solutions as logistics are not in place; iv) high cost of materials due to a lack of economy of scale and estate policy on investments; and finally v) lack of audit. Regarding the sectors, there is a general lack of awareness regarding sustainability and a major cultural hurdle preventing the adoption of materials other than concrete in the residential sector. In the hotel sector, the main hurdle is the lack of incentives due to subsidised energy costs. The highest priority criteria identified were comfort and economic drivers, although the visual component was found to play a particularly important role in hotels.

Regarding acceptability of solutions, the need for the solutions proposed to be practical, easy to implement, accessible and generating clear benefits was highlighted. In this regard, the light fitting change programme was considered a good practice. The standardisation of construction elements would facilitate implementation, economy of scale and could enable the development of a plan of sustainable solutions for gradual implementation. Local materials would need to be standardised and the study of technical handling of timber-yielding trees and local stones is required to optimise their sustainable use and to ensure their compatibility with outsourced materials from abroad. This work carried out with the relevant stakeholders resulted in the following proposals:

- **Systemic change:** The whole system needs to be changed for the entire chain to work: regulation, implementation, training and audit.
- **Local economy boost through sustainable construction:** The work of craftsmen and local producers may activate the local economy and economic production in a sustainable way.
- **Encouraging the participation of the private sector** and public-private agreements including tax incentives and transport subsidies to reduce the price of sustainable equipment and solutions.
- **Generation of evidence:** Study the sustainability of materials and their influence on energy behaviour to generate specific evidence and recommendations for Galapagos through pilot projects.
- **Standardisation** to facilitate the optimal management of materials and achieve easier and more accessible implementation of solutions.
- **Demand reduction:** Increased focus should be placed on demand, and not only on generation (micro-solution, at building level). Support and regulate decentralised generation.
- **Comfort improvement:** Create and define minimum comfort standards.
- **Public Policies:** Public policies must be adapted to the local circumstances and culture of Galapagos. A road map for the long term including aims, targets and a monitoring and verification plan is needed to put forward a multi-level governance and define the local-national legislation needed to implement an incremental strategy for the economy of scale. The energy saving policy for the islands must be consistent with a more general planning scheme, and include a financing fund to implement standards and initiatives highlighting the value of the differential factor, highlighting the value of education and awareness in tourists.
- **Education and awareness:** The human factor needs to be taken into account in energy management. Raising awareness and educating the population on random energy use to achieve comfort. A change of mentality is needed and it can only take place through a communication strategy specifically aimed at the population (visual media, radio, etc.) and education at schools. A major step along this path could be the socialisation of standards and awareness based on implementation, demonstrating the benefits of the different materials and solutions and justifying the return of additional costs. The public sector needs to lead by example.
- **Regulation:** An electrical equipment regulation is required as well as an audit of the new sustainable buildings.
- **Standards:** should envisage passive low-cost solutions and sector solutions putting particular stress on the hotel sector, due to its higher consumption and possible interest in and capacity to innovate.
- **Propositions for the future:** to develop a branding strategy for hotels highlighting the value of the differential factor of the Islands, encouraging tourists who are more responsible from the energy point of view. The possibility of implementing a standardised social housing

system through sustainable prefabricated homes. Fostering solutions based on nature due to their combined benefits, low cost and effectiveness.

Finally, the study concluded that the viability of standards was associated with the capacity of fostering skill training and solving the current constraints in terms of transport and lack of suppliers. Moving from the theoretical to the implementation phase was considered the next logical step: for learning by doing, to demonstrate viability, raise awareness and compare the results of the study with actual monitoring data.

Figure 1: February Workshops

One of the project results was the definition of a roadmap which will enable the work done to continue. This roadmap was agreed at the event held on 13 September in Santa Cruz.

Figure 2: Road map design event

Conclusions and recommendations for standards application

This consultancy study compared the policies implemented at national level in Ecuador and in the Galapagos Islands, and analysed the regulatory and institutional documentation in place in Ecuador. This analysis found that the regulatory and institutional framework in Ecuador is suitable to facilitate the development and application of energy efficiency improvement plans, such as the development of Sustainable Behaviour Standards for buildings in the Galapagos Islands. Furthermore, the specific regulatory standards which can be supported and nurtured by this project have been identified:

- This project is to support compliance with PLANEE. In addition, the aims of PLANEE will be reinforced and progress on the way towards achieving the goals described in the plan will be enabled.
- The project will define and/or extend the characteristics defined in the NEC Standard regarding the materials to be used to achieve the aims specified in the standard. Moreover, the project will provide guidelines and specific indications regarding construction design for greater comfort for the islands.
- This project can feed the "Practical guide for efficient use of electricity in Ecuador", defining new energy efficiency actions included in the standards.

This consultancy study has laid down the methodological foundation and information tools to be used to quantify the impact from specific policies and to continue working on the transformation of the Galapagos Islands towards a more sustainable model. Nevertheless, moving from the theoretical model to the implementation and experimentation phase under actual conditions is necessary to verify the existing constrains and limitations, quantify impacts and create transformation processes involving multiple stakeholders in relation to real case scenarios. Another outcome of this consultancy work was the start of the multi-level governance process which has led to the definition of a roadmap shared by all the key stakeholders. Only a systemic change addressing all the issues as a whole can achieve a sustainable future for construction in the Galapagos. This systemic change shall put forward not only technical but also logistics, financial, legal, economic, educational and awareness solutions to promote, preserve and reinforce the environmental and territorial sustainability of the Islands, boosting socio-economic activity in the region, as well as protecting the unique environment of the Galapagos.