Technical Annex:

Evaluation of social housing building types in Mexico.

Study of energy efficiency, additional costs and CO2 mitigation as a basis for the preparation of the “Supported NAMA for Sustainable Housing in Mexico - Mitigation Actions and Financing Packages” presented at COP17 in Durban.

Passive House Institute

Passive House Institute
Dr. Wolfgang Feist

Rheinstraße 44/46
64283 Darmstadt, Germany

Tel. +49 (0) 6151/826 99-0 /-55
Fax. +49 (0) 6151/826 99-11
mail@passiv.de

www.passivehouse.com

12. October 2012

1. Introduction

The document "Supported NAMA for Sustainable Housing in Mexico – Mitigation Actions and Financing Packages" was prepared in the frame of the Mexican-German NAMA Programme which is implemented by GIZ (German International Cooperation Agency) on behalf of the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU). The NAMA was developed closely between Mexican and German partners such as SEMARNAT, CONAVI, Infonavit, Fovissste, SHF and GIZ and was presented by the Mexican and German governments at the Durban Climate Change Conference 2011 (see [CONAVI, SEMARNAT 2011]). The Passive House Institute (PHI) was part of the international team of consultants for this NAMA (Nationally Appropriated Mitigation Action). The overall goal of the NAMA is to raise donor funding for upscaling Mexican efforts in energy efficient housing by showing energy efficient building concepts that are cost effective, proven to successfully reduce CO_2 emissions and, at the same time, are adapted to the particular Mexican climate and conditions.

PHI's specific task, described in the present document, included analysis and energy balance calculations with help of the Passive House Planning Package (PHPP). The objects of analysis were three characteristic social housing building types (Aislada, Adosada, and Vertical) in four different locations representing four different climate zones of Mexico. Four different energy efficiency cases were produced through the calculation of the effects of different building parameters, such as the improvement of the building envelope and the use of efficient appliances. These building cases range from a baseline case (business as usual, very low efficiency) to the internationally recognised Passive House Standard (sustainable, high comfort, cost-effective). Due to the climate change mitigation nature of NAMAs, a crucial component of the results was portraying the primary energy demand and CO_2 emissions of the different building cases. Furthermore, an analysis of the additional capital costs and total costs over the entire life cycle was conducted.

The results show the Passive House Standard to be the most economical alternative for CO_2 emission reduction in all cases analysed, despite the need for further optimisation of the building and urban design of the original projects. Moreover, the two additional energy efficiency standards between the baseline case and the Passive House case (Ecocasa 1 and Ecocasa 2, see figure 8) demonstrate the feasibility of energy efficiency improvements in Mexico and pave the way for a transition to higher efficiency standards such as Passive House.

2. Background. The Passive House Standard and PHPP

As buildings have a very long life span and renovation cycles last from 15 to 50 years, the energy efficiency standards applied at the construction or renovation stage must be very ambitious to meet climate protection goals. The Passive House concept offers a solution that deals with this trade-off between energy efficiency and cost effectiveness. A Passive House stands for enhanced living comfort with an annual space heating demand of less than 15 kWh/(m²a), an annual space cooling demand of less than 15 kWh/(m²a) (which may be higher according to specific climatic conditions) and a primary energy demand including domestic hot water and household electricity below 120 kWh/(m²a). Due to the increased levels of energy efficiency, a separate heating or cooling system becomes unnecessary.

The Passive House Standard aims at using synergies, regionally adapted and optimised for all climates and building traditions and is the only standard that addresses the overall energy demand of buildings, including hot water, appliances, lighting, and IT/electronics. The Passive House concept is best applied directly from the planning stage of a new build or renovation project onward. Incorporation of Passive House principles early in the planning and the resulting optimisation of the project typically make it so that additional costs spent in Passive House quality components are only marginally higher than conventional construction costs. Building a Passive House is thus a cost effective approach towards considerable energy savings and climate protection.

The Passive House Planning Package (PHPP) is an integrated tool for energy balance calculations including all energy flows within the system boundary. The programme is based in large part on European and international norms (e.g. EN 832 and ISO 13790) and is a design tool for buildings with very low energy demand (such as Passive Houses). This calculation tool has been evaluated with detailed simulations and with measured and monitored results of hundreds of buildings. Thousands of consultants and designers have many years of experience with the use of this tool in designing low energy Passive House buildings. A version of PHPP specifically adapted to a climate region requires climate data sets for this particular region. Such climate data must be specifically adapted to the planning of extremely energy efficient buildings.

3. Energy balance with PHPP for the Mexican NAMA

PHI's contribution to the NAMA included an energy balance calculation with PHPP for three building types in four different locations in Mexico. The building types and locations, chosen together with officials of the Mexican federal government, represented the diversity of the Mexican climate and the reality of the current social housing market in Mexico. The next two sections describe the building types as well as the locations of study followed by a description of the energy balancing process and results.

3.1. Building types

The three building types analysed are based on a study realised by Campos (see [Campos 2011]) on behalf of and supported by GIZ/GOPA. These building types represent some of the most popular social housing building designs in the current Mexican market [CONAVI, SEMARNAT 2011].

It should be noted that all calculations are based on the original building designs presented below, including orientation and materials used. The tables in annex I offer a thorough account of the original projects and its parameters ("Baseline case" columns), including construction materials and house appliances.

a) Isolated housing unit (Aislada)

The Aislada building type (isolated housing unit) has a gross floor area of 44 m^2 lying inside its thermal envelope with a treated floor area of 38.4 m^2. The sample house was based on a real social housing project for Mexico and was provided by GOPA/GIZ based on [Campos 2011]. Figure 1 presents the floor plan of the building and a 3D model. As for the orientation and surroundings of the analysed housing unit, a typical location was chosen within the project's settlement; the orientation can be also appreciated on figure 1. The project's building system is described in table 1.

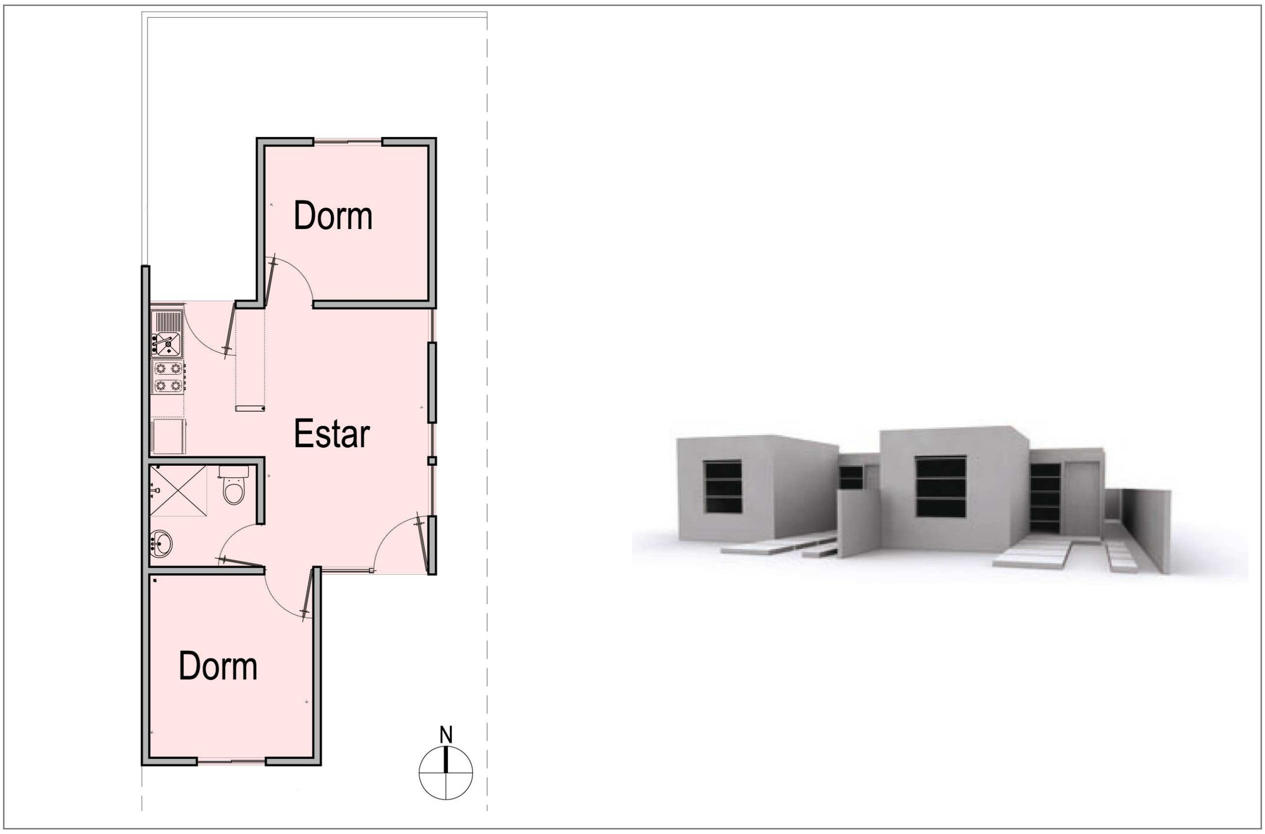

Figure 1: Aislada building type. Floor plan and 3D model, no scale (Source: [Campos 2012])

Table 1: Building system for Aislada building type (Source: information provided by GOPA/GIZ)

External wall build-up	10cm thick, concrete masonry units. Exterior:"Crestuco" plaster, interior: cement plaster (cal arena). Colour painting
Roof build-up	Reinforced concrete slab, 12cm thick, 2% slope, "Plasticool" layer colour white as water proofing
Build-up of floor slab	Reinforced concrete slab, 10cm thick
Glazing	Clear single glazing, 3mm thick and white aluminium 1 ½" frame

b) Adosada

The Adosada building type (row housing unit) has a gross floor area 90 m² inside its thermal envelope, which includes two apartments. The treated floor area is 81.04 m². The sample house was based on [Campos 2011]. The floor plan and 3D model of the project can be found on figure 2 including also the chosen orientation. The building system of the project is described in table 2.

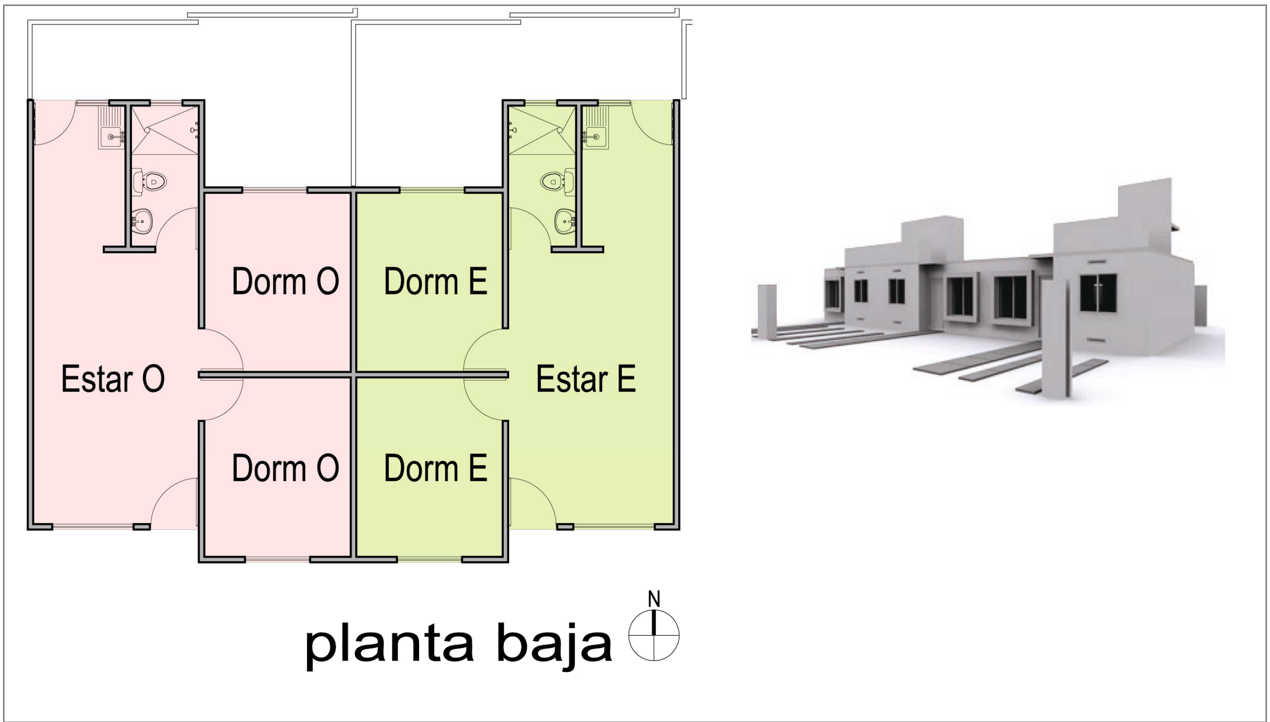

Figure 2: Adosada building type. Floor plan and 3D model, no scale (Source: [Campos 2011])

Table 2: Building system for Adosada building type (Source: information provided by GOPA/GIZ)

External wall build-up	Reinforced concrete, 8cm thick. Interior: cement plaster and plaster finish Exterior: cement plaster, colour paint
Roof build-up	Reinforced concrete slab, 12cm thick, 2% slope, “Plasticool” layer colour white
Build-up of floor slab	Foundation slab, reinforced concrete 10 cm thick. Polished cement finish.
Glazing	Clear single glazing, 3mm thick and white aluminium 1 ½” frame

c) Vertical

The Vertical building type (vertical housing unit) consists of two identical and symmetrical six storey buildings joined by a staircase. Each building has a gross floor area of 93 m^2 per storey within the thermal envelope, which includes two apartments. The treated floor area per storey is 79.4 m^2. In order to simplify the analysis, only one of the two symmetrical buildings was analysed. The sample house was based on [Campos 2011]. Figure 3 presents the floor plan and a 3D model of the building. A typical location was chosen within the settlement of the project. The orientation of the analysed housing unit is also indicated in figure 3 and the building system is described in table 3.

Figure 3: Vertical building type floor plan and 3D model, no scale (Source: [Campos 2011])

Table 3: Building system for Vertical building type (Source: information provided by GOPA/GIZ)

External wall build-up	Masonry concrete blocks with colour (light concrete) 12x20x38, 12cm, mortar. Colour paint
Roof build-up	Reinforced concrete slab, 12cm thick, 2% slope, “Plasticool” layer colour white
Build-up of floor slab	Reinforced concrete floor slab 10cm thick. Polished cement finish.
Glazing	Clear single glazing, 3mm thick and white aluminium 1 ½” frame

3.2. Locations

With the aim of covering the most representative Mexican climates, four different locations were chosen based on information and recommendations by CONAVI and Infonavit (see: [CONAVI 2008] and [Infonavit 2011b]), as shown on figure 4.

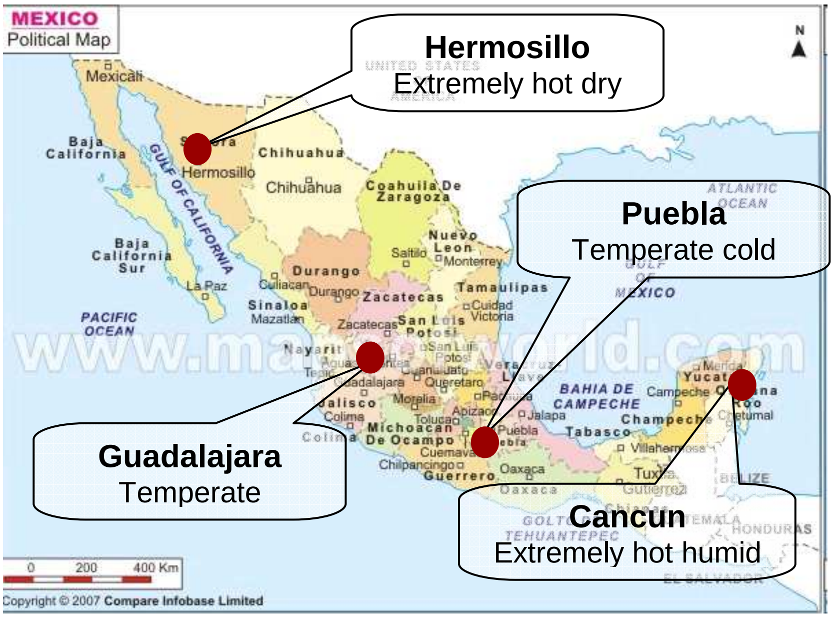

Figure 4: Map of Mexico showing the four locations and corresponding climate zones (Source: Compare Infobase Limited with adaptation by PHI)

3.3. Energy balancing process

The determination of the energy balances of the housing units followed the steps described below.

a) Data collection in Mexico

Data necessary for energy balances with PHPP was collected in Mexico. This includes data about construction systems, building traditions, materials as well as equipment available on the local market and energy production. Where no information was provided or found, the Passive House Institute used standard values. The parameters of all analysed cases can be found in annex I.

b) Generation of climate data

The PHPP requires two types of climate data: a set of monthly temperatures and radiation data in order to calculate projected heating/cooling demand and sets of heating/cooling load data to calculate heating and/or cooling load. The information must be representative of typical local weather conditions over the entire year.

Various climate data sources were accessed to generate monthly data in the PHPP format for the four selected locations in Mexico. They included the software Meteonorm, NASA satellite data and figures from the Mexican National Meteorological Service (Servicio Meterológico Nacional). The final monthly data sets were selected based on careful comparison and analysis. The heating and cooling load information was generated with dynamic simulations based on satellite data of the respective region.

c) Determination of baseline building cases

Conventional building systems and traditions were considered for the baseline building cases, which were based on the original projects. As can be observed in tables 1 through 3, all baseline projects have reinforced concrete floor and roof slabs with walls that are either made of reinforced concrete slabs or concrete masonry units. All windows have single glazing and aluminium, non-insulated frames. For the baseline cases, the energy efficiency of all electrical appliances was based on information of current appliances used in social housing in Mexico and ranged from average to low (see annex I for further details). Table 4 presents some further specifications that apply for all three baseline cases.

Table 4: Baseline case specifications

Type of lighting	Compact fluorescent light 20W
Electrical appliances	Domestic appliances that are common for the current Mexican social housing market: refrigerator (2.68 kWh/d), TV (0.19 kWh/d), A/C (2.5 COP), ventilator (100 W), washing machine (0.32 kWh/d), microwave oven (0.17 kWh/d) (Information about domestic appliances based on: [Infonavit 2011a],[Infonavit 2011b][Luz y fuerza n.d.][SENER 2011]).
Heat generator for water	Tankless LP Gas water heater (e.g. CINSA CDP 06)
Cooking	LP Gas stove
Number of m² per person	20 m² per person (considering 30 year lifecycle)
Internal heat gains	5.3 W/m² (calculated with PHPP)
Airtightness	5 h-1
Temperature limit summer	25°C (28°C low comfort baseline)
Temperature limit winter10	20°C (18°C low comfort baseline)
Primary energy factors	Electricity mix: 2.7 kWhPrim/kWhFinal LP Gas: 1.1 kWhPrim/kWhFinal (Sources: [Enerdata et al. 2011] and PHPP)
CO_2 factors	Electricity mix: 0.59 kg/kWhFinal LP Gas: 0.27 kg/kWhFinal (Sources: [Enerdata et al. 2011] and PHPP)

As per table 4, the electrical appliances that were chosen are based on information about the current average appliances used for social housing of Infonavit. It has been observed that electrical appliances have a great impact on the energy balance of houses not only due to their electricity demand but also due to the fact that they are internal heat loads, which also raises the space cooling demand. For this reason, the energy efficiency cases (EcoCasa 1, EcoCasa 2 and Passive House), which will be described in the following subsections and in annex I, presented an improvement of the appliances which also reduced the internal heat loads. As for the air conditioning unit, the assumption was that an average split unit (COP 2.5) is used every time that the indoor temperatures rises above the comfort temperature defined (see section 4). In reality not all of the houses have such an average split unit but actually some houses may have very old and inefficient units, some may have newer A/C units and some may not have anything to cool actively. This assumption keeps the energy demand calculations and thus the CO_2 calculation on the safe side. As for the temperature limits for summer and winter and the occupation (number of m² per person), please refer to the detailed description in section 4.

Another important feature of the baseline case that should be noted is that the recent Mexican building norm NOM 020, which since August 2011 establishes the minimal energy standard for housing projects in the entire country, was not taken into account. This was agreed with CONAVI prior to the calculations under the understanding that projects to be built in the immediate future, which were registered before the validity of the norm, do not take the norm into account yet. For this reason, the first years of implementation of the NAMA, buildings that do not consider the NOM 020 will be in fact built, but this is part of the transition period. As of August 2011 all projects that apply for building permits should consider NOM 020. In brief, any future consideration of a baseline building in Mexico should consider this norm due to its compulsory nature (see [NOM 020]).

d) Examination of baseline building cases

The next step was setting up an energy balance of the baseline cases for the three building types in the four different locations in Mexico, calculating the energy demand with PHPP.

e) Optimisation of building parameters

In order to achieve the Passive House Standard through fulfilment of the Passive House certification criteria for residential buildings[1], an optimisation of the building elements was calculated. This optimisation included the use of higher levels of insulation and high quality windows (insulated frames with either double or triple glazing, depending on the climate) and highly efficient electrical appliances. Some other measures included the use of removable shading, achievement of an airtight thermal envelope and inclusion of ventilation systems (either highly efficient heat recovery or only extraction depending on the location). All of the

[1] The most recent Passive House Standard certification criteria both for cool moderate climates and for warmer climates can be downloaded from the Passive House Institute's website: *www.passivehouse.com.*

measures were applied without changing the building design. Section 5 and annex I of this study contain further details on these measures.

f) Development of two intermediate cases between baseline and Passive House

The first intermediate housing concept was named EcoCasa 1 on suggestion from CONAVI and it gathered all the energy efficiency measures of the current Hipoteca Verde scheme. The Hipoteca Verde (Green Mortgage) credit programme is provided by Infonavit (Institute of the National Housing Fund for workers) and offers supplemental loans to cover the incremental costs of green technologies and appliances in new homes of social housing projects. These measures, used for the EcoCasa 1 are: around 2.5 cm insulation in the roof and on the wall of the building with highest exposure to solar radiation, reflective paint, use of a tankless LPG gas boiler, solar water heating and an efficient A/C system (this last one depending on the climate). In addition, efficient appliances in the current local market were considered, which are already more efficient than the ones for the baseline (see table 4). Further detail about the efficiency of the appliances, and the rest of the parameters for EcoCasa 1 can be found in annex I. In the case of the Adosada and Vertical building types, the original reinforced concrete roof slab was exchanged for a beam and block system (EPS blocks, reinforced concrete beams), commonly used in many Hipoteca Verde projects. This system was also used in the following energy efficiency cases for the Adosada and Vertical building types.

The second intermediate case, EcoCasa 2, represents a further optimisation towards the Passive House Standard through low level of insulation of all walls, the roof and floor slab (depending on location), improved windows and highly efficient appliances which are not yet common in the Mexican market. Further details about the parameters for EcoCasa 2 can be found in annex I. Figure 5 portrays the four energy efficient cases developed for this NAMA.

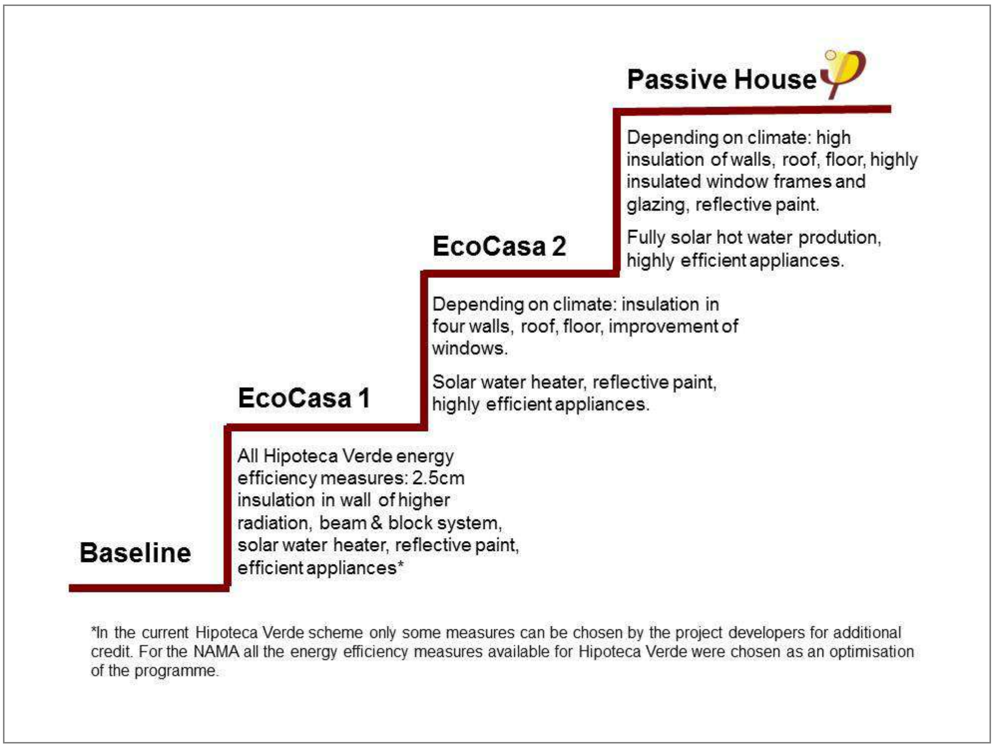

Figure 5: Energy efficiency cases for the Mexican NAMA (Source: PHI)

g) Determination of additional capital costs of investment

The additional capital costs of investment and total costs over the entire life-time of the different energy efficiency cases were calculated under both the current market situation and a future cost scenario.

4. Boundary conditions

For the performed energy balances within this study, some boundary conditions that guided all calculations were defined.

As a first boundary condition, a temperature range had to be chosen. This range of temperature is important because in the calculations it is assumed that when the temperatures inside the house exceed the upper limit, then the house is actively cooled, which has an impact on the energy demand of the building. On the other hand, when the temperatures in the house are below the threshold value, then it is assumed that the users will actively heat the house, also having an impact on the energy demand.

For the NAMA a comfort temperature range of 20°C to 25°C was set. This range of temperatures is based on the ISO7730 norm and establishes the ideal range for human comfort. Alternatively, upon request of the Mexican partners, the baseline cases used a larger temperature range of 18°C to 28°C. This reflects the fact that optimum comfort is often not achieved in houses with poor energetic standards for technical or economic reasons.

Experience shows, however, that as soon as the occupants are able to raise the indoor comfort through the use of active cooling and/or heating, they do, aiming for the optimal comfort range of 20-25°C and thereby increasing their energy use for heating and/or cooling. Nevertheless, the calculation of the baseline for CO_2 emissions reductions had to be made conservatively to portray more realistic emissions reductions for the NAMA. For this reason, a temperature range of 18°C-28°C, identified in the following figures as “Low Comfort Baseline”, was chosen for the baseline buildings.

Figure 6a and 6b show the difference in CO_2 emissions reductions for the different efficiency cases for the Vertical building type in the extreme climates of Hermosillo and Cancun.

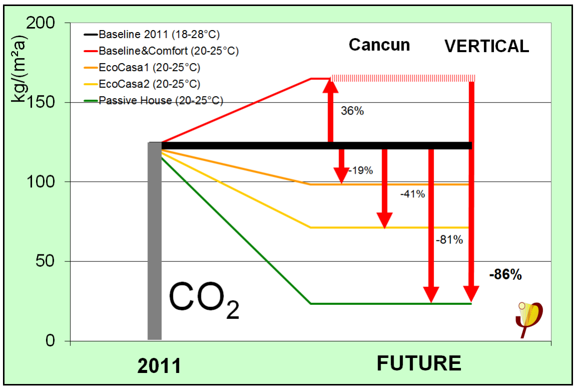

Figure 6a: CO_2 emission reduction estimation for Vertical building type in Hermosillo. Low comfort and comfort baseline cases differentiated.

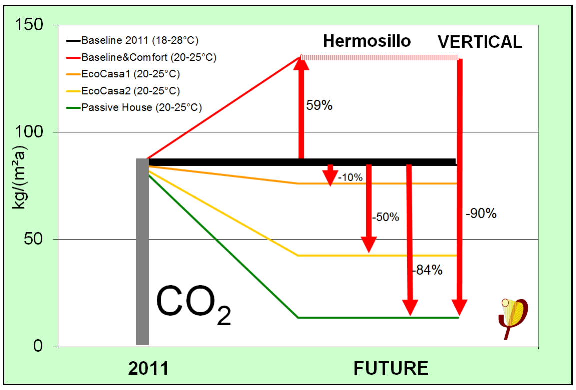

Figure 6b: CO_2 emission reduction estimation for Vertical building type in Cancun. Low comfort and comfort baseline cases differentiated.

In the three diagrams, the thick black line represents the low comfort baseline. Below the baseline, the CO_2 emissions reductions for the different energy efficiency cases are portrayed, using the 20-25°C comfort range. The upper dotted line represents the level of CO_2 emissions that the baseline would produce within the comfort range of 20-25°C. Figures 7a through 8b show the same diagram for the Adosada and Aislada building type.

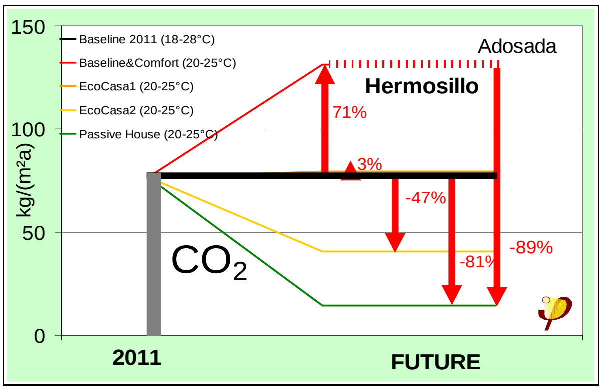

Figure 7a: CO_2 emission reduction estimation for Adosada building type in Hermosillo. Low comfort and comfort baseline cases differentiated.

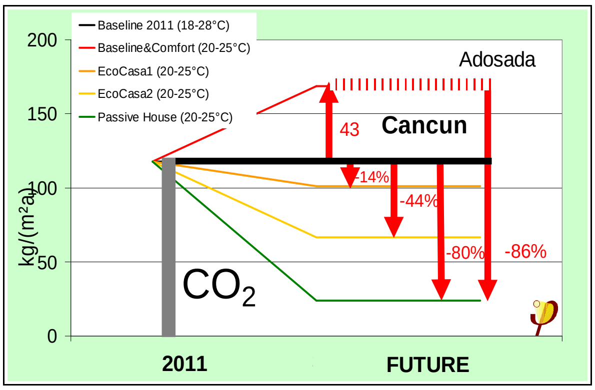

Figure 7b: CO_2 emission reduction estimation for Adosada building type in Cancun. Low comfort and comfort baseline cases differentiated.

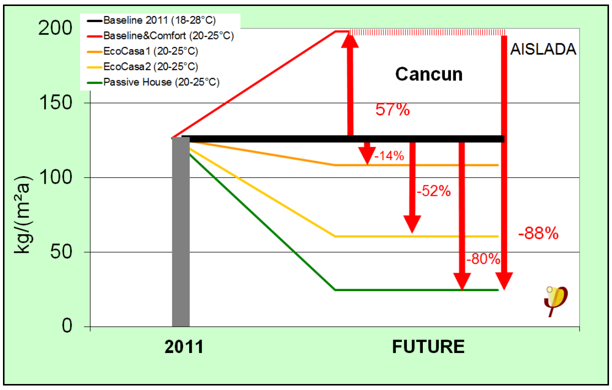

Figure 8a: CO_2 emission reduction estimation for Aislada building type in Hermosillo. Low comfort and comfort baseline cases differentiated.

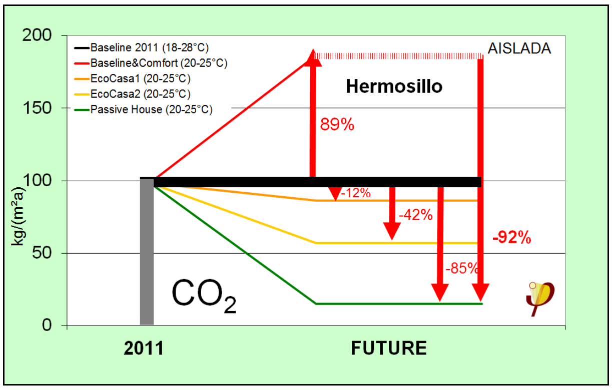

Figure 8b: CO_2 emission reduction estimation for Aislada building type in Cancun. Low comfort and comfort baseline cases differentiated.

Another important boundary condition was that, although all building types are planned for occupancy by four inhabitants, the occupancy was set to two persons per building. This was defined under the conservative assumption that two persons would be the average occupancy over a 30 year lifecycle of the housing unit (period under observation).

The costs were calculated through a price estimation of the additional measures from the EcoCasa 1 to Passive House, using the baseline case as the starting point. A first estimation called “current investment costs” or "current capital costs" reflects the prices that would have to be paid if the building standards were to be realised now. This includes that Passive House components such as efficient windows and ventilation units with heat recovery are not available on the Mexican market and are thus very expensive. Experience in the Central European market shows, however, that the introduction of energy efficient building standards challenges manufacturers to produce more efficient, higher performance products. A further estimation, called “future investment costs”, draws on the assumption that once energy efficient building is a common practice in Mexico through the NAMA, the costs of Passive House components will be significantly lower due to local production of building components under a standard competitive market situation. Table 5 summarises the boundary conditions that were taken into account for the costs calculations.

Table 5: Boundary conditions for the cost calculations (source: PHI)

Real interest rate	2.00%	p.a.
Lifecycle	30	years
Gas price*	0.075	US$/kWh
Gas price increase	2.1%	p.a.
Electricity price	0.083	US$/kWh
Electricity price increase	4.0%	p.a.
Electricity price subsidy	0.14	US$/kWh
Subsidy increase	6.0%	p.a.

*Though the costs of LP gas in Mexico are subsidised, for the NAMA no subsidy was considered. This conservative assumption was done in order to calculate costs on the safe side since, on one hand, natural gas costs (used in some projects) are not subsidised and on the other hand, that the gas consumption is not as high in comparison with the electricity consumption.

5. Overview of measures and results

For a clearer portrayal of the energy balance results, this section provides an overview of the measures applied to the analysed building types in the different locations. To simplify the presentation of the results, only the Vertical and Adosada building case will be described in detail through graphs and tables (for a thorough description of all three building types and their energy efficiency cases see annex I).

5.1. Extremely hot dry (Hermosillo)

For the extremely hot and dry climate of Hermosillo in the north east of Mexico, the measures applied in order to optimise the energy efficiency of the buildings include the insulation of the exterior walls (10 to 30 cm depending on the building type). Additionally, the roofs were also highly insulated (approximately 30 cm) as well as the floor slabs (around 10 cm). The windows were likewise improved, as it was shown that triple glazing with sun protection plays a key role in reducing the cooling demand in this extremely hot and dry climate. Some other measures that proved to be of high relevance for reducing the energy demand and achieving the Passive House Standard are: energy recovery ventilation, separate recirculation cooling, exterior moveable shading, improvement of thermal mass and the application of cool colours or highly reflective paint on the walls and roof. Figures 9a through 9c summarize the specific cooling and heating demands as well as the dehumidification and primary energy demands for all the analysed building types. It can be observed in figure 9b that for the specific case of the Adosada building type, the primary energy demand of the low comfort baseline (18°C to 28°C) is slightly lower as the EcoCasa 1 (with comfort of 20°C to 25°C). However, this was not the case for the Aislada and Vertical building types.

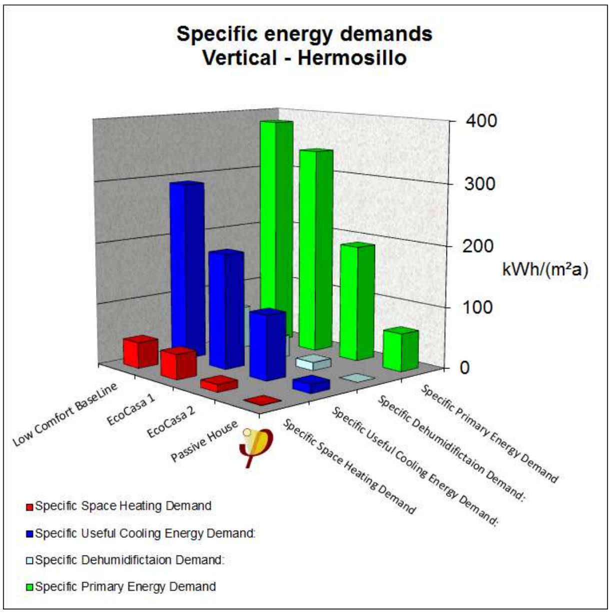

Figure 9a: Specific energy demands for Vertical building type in Hermosillo

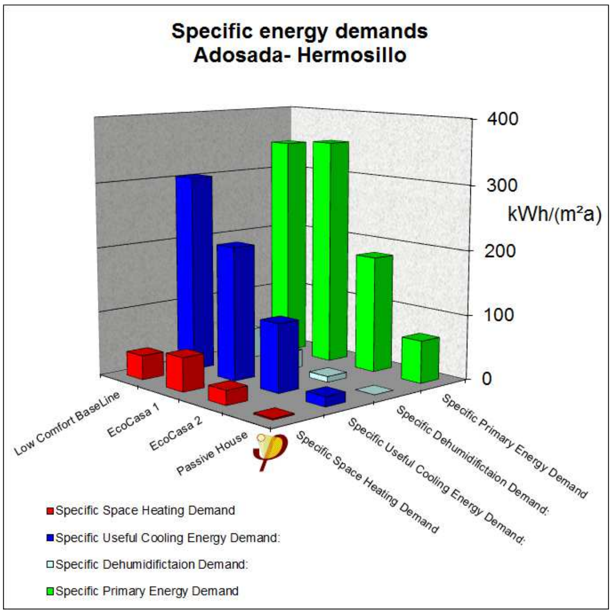

Figure 9b: Specific energy demands for Adosada building type in Hermosillo

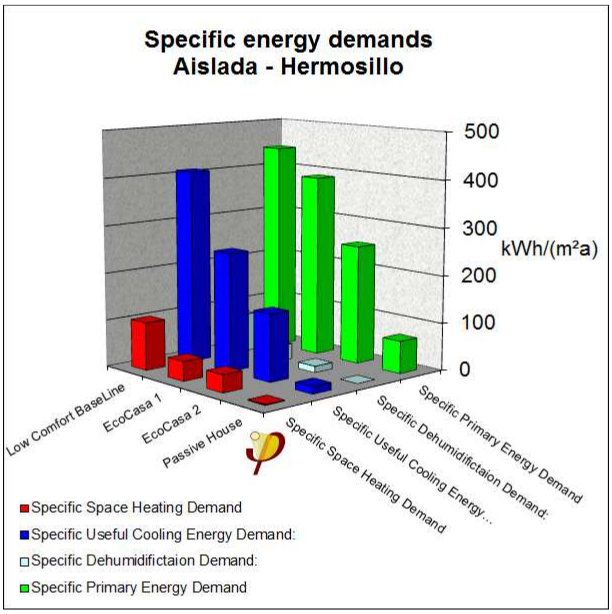

Figure 9c: Specific energy demands for Aislada building type in Hermosillo

As can be appreciated in figures 9, the energy demands sink dramatically from the low comfort baseline to the Passive House Standard. Moreover, figures 10a, 11a and 12a present the energy and capital costs of the different efficiency cases, from low comfort baseline to Passive House. Figures 10b, 11b and 12b present the future investment cost scenario.

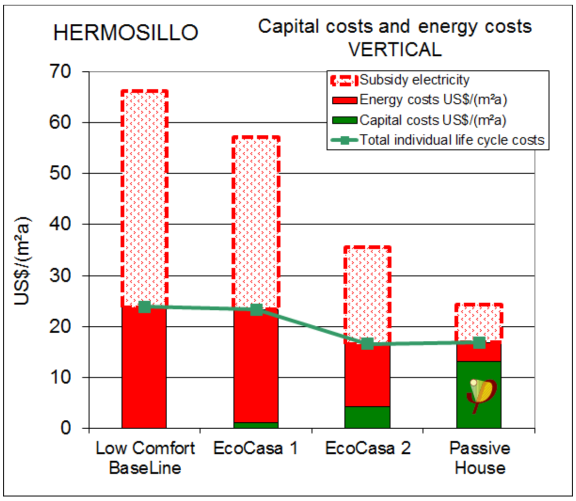

Figure 10a: Current capital and energy costs of Vertical building type compared, from low comfort baseline to Passive House in Hermosillo

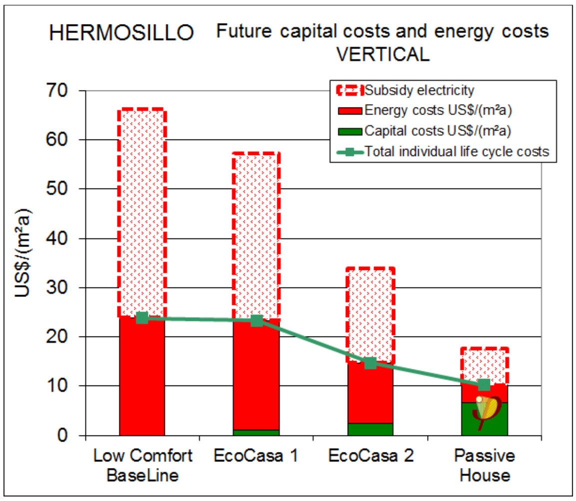

Figure 10b: Future capital and energy costs of Vertical building type compared, from low comfort baseline to Passive House in Hermosillo

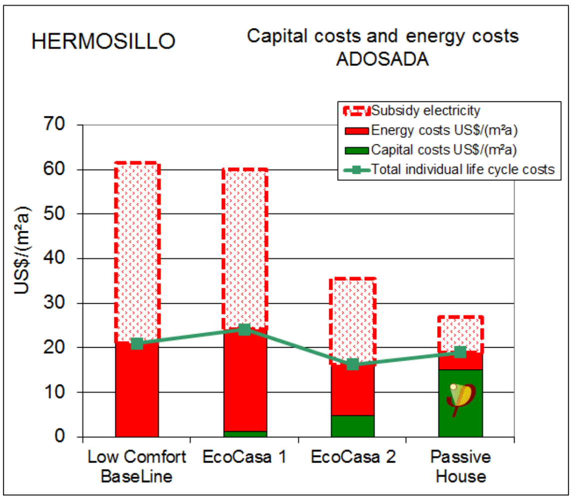

Figure 11a: Current capital costs and energy costs of Adosada building type compared, from low comfort baseline to Passive House in Hermosillo

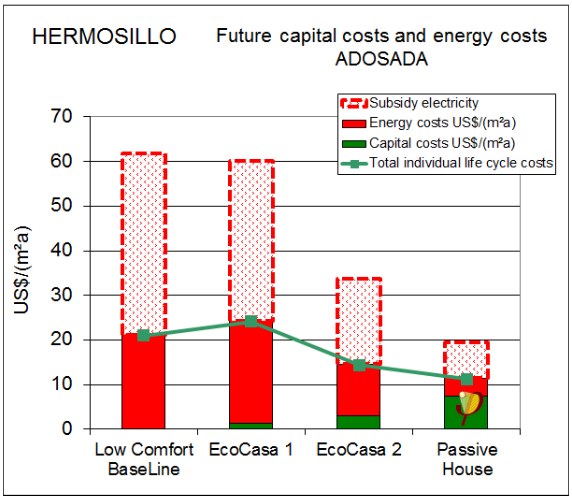

Figure 11b: Future capital costs and energy costs of Adosada building type compared, from low comfort baseline to Passive House in Hermosillo

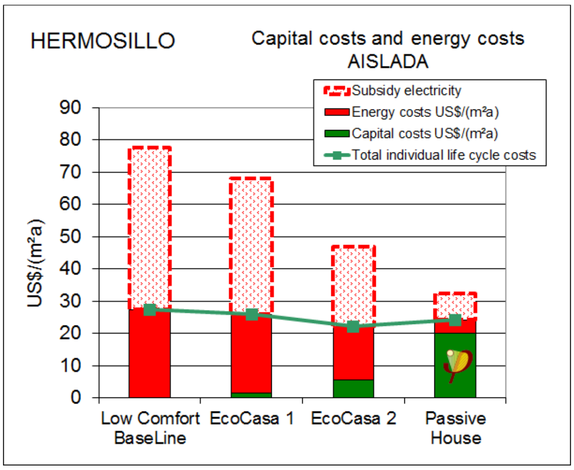

Figure 12a: Current capital costs and energy costs of Aislada building type compared, from low comfort baseline to Passive House in Hermosillo

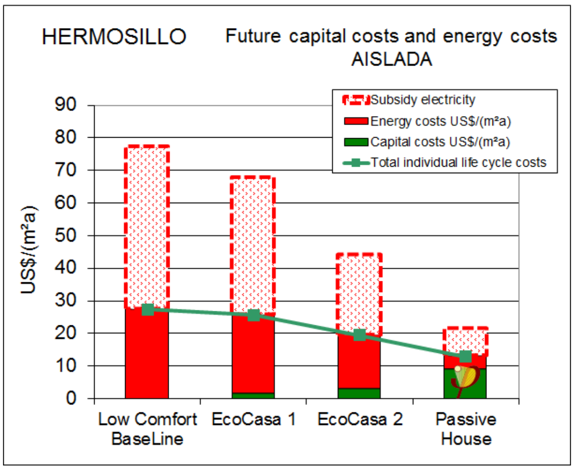

Figure 12b: Future capital costs and energy costs of Aislada building type compared, from low comfort baseline to Passive House in Hermosillo

As can be learnt from the cost comparison graphs in figures 10a and 10b, even assuming current costs for energy efficient components and not taking energy subsidies into account, the Passive House Standard is an economically feasible solution. Nonetheless, while it is the economic optimum for the vertical building even at the present time (current prices), it is clearly shown that the single family houses (figures 11a and 12a) are at disadvantage with respect to energy efficiency. However, once energy efficient components with competitive prices are available on the Mexican market, the scenario ‘future costs’ applies and it can be seen that the Passive House Standard is the most economic option (figures 11b and 12b). In terms of total costs, including the subsidy share in energy supply costs, it is evident that the Passive House Standard is the economic optimum in all cases.

5.2. Temperate (Guadalajara)

The temperate climate of Guadalajara, located in the centre-west of the country, is a perfect example of a so called 'Happy Climate', meaning that the Passive House Standard can be achieved with relatively little effort. The measures taken for this location include the insulation of all the exterior walls (around 5 cm depending on the building type). The roof and the floor slab do not need high levels of insulation, although it was noticed that especially in the roof, insulation does bring further energy savings. The windows were also enhanced, but for these temperate climates, double low-e glazing proved to be sufficient. A pure extract air system instead of energy recovery ventilation, combined with natural ventilation at night and the improvement of thermal mass are of high relevance to minimize the energy demand and for achieving the Passive House Standard here. The different energy efficiency values for each of the cases can be seen in figures 13a through 13c.

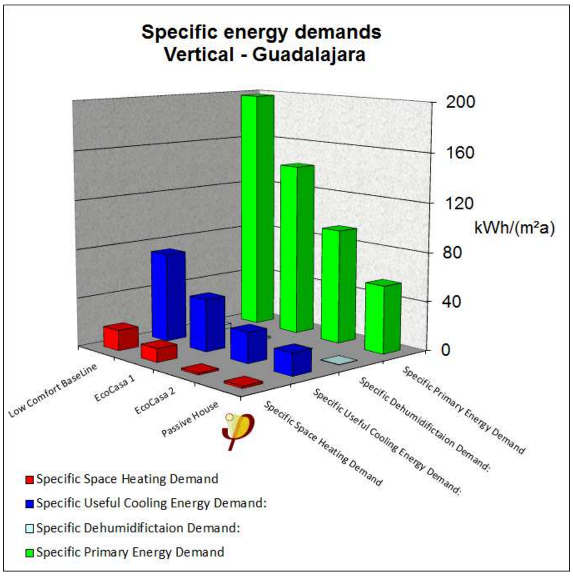

Figure 13a: Specific energy demands for Vertical building type in Guadalajara

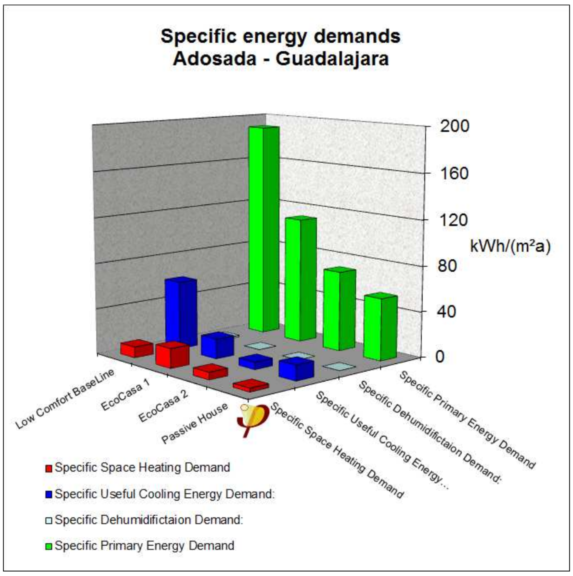

Figure 13b: Specific energy demands for Adosada building type in Guadalajara

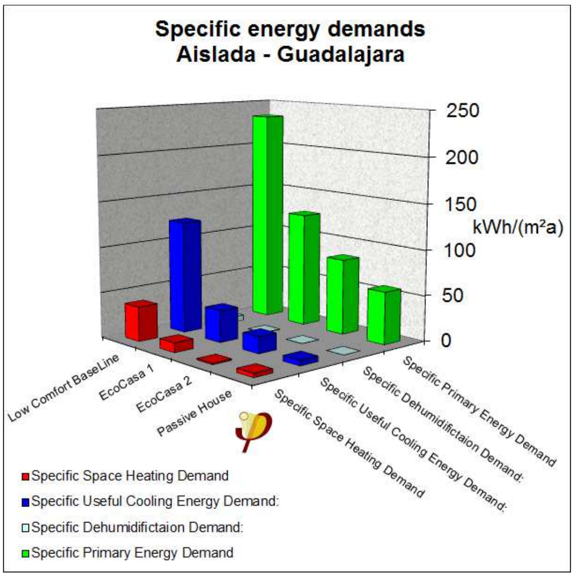

Figure 13c: Specific energy demands for Aislada building type in Guadalajara

In the climate of Guadalajara, dehumidification is not necessary at all, as can be observed in figure 13a through 13c. Furthermore, in figure 14a through 16b, on the far right of the diagrams, an additional bar can be observed under the designation "Passive House Plus". Due to the special situation of the climate of Guadalajara (where the Passive House Standard is relatively easy to achieve), a further optimisation of the building was made. In this case, additional insulation and a further improvement of the windows were applied in order to reach zero energy demand for cooling and heating. Though the Passive House Plus case would not be part of the financing programme of the NAMA, it is an interesting example of the potential that some fortunate climatic regions of Mexico have: reaching outstanding energy efficiency levels is not only possible but also cost effective (as can be observed in the graphs). Another example of a "happy climate" where the Passive House Plus concept is applicable is Mexico City. Due to the size and importance of Mexico's capital city the benefits of this standard are manifold.

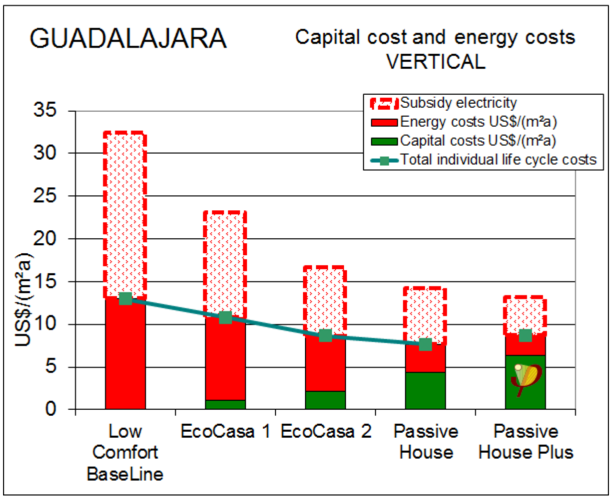

Figure 14a: Current capital costs and energy costs of Vertical building type compared, from low comfort baseline to Passive House in Guadalajara

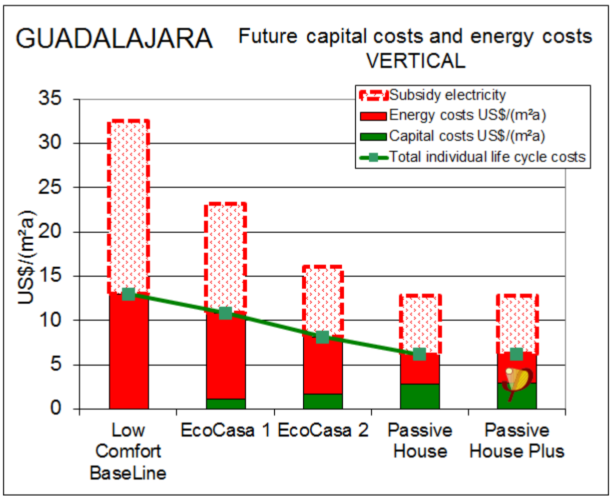

Figure 14b: Future capital costs and energy costs of Vertical building type compared, from low comfort baseline to Passive House in Guadalajara

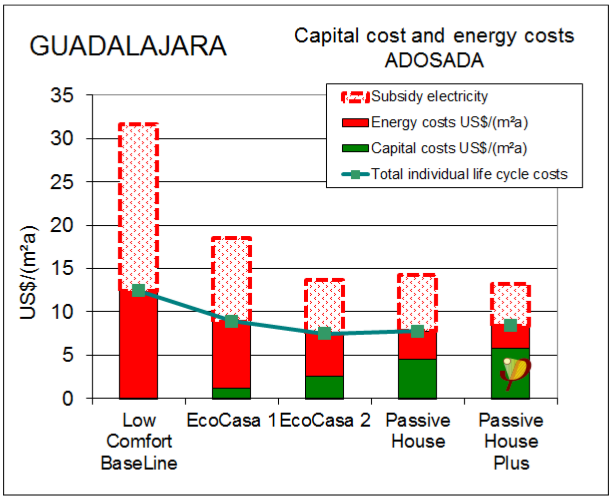

Figure 15a: Current capital costs and energy costs of Adosada building type compared, from low comfort baseline to Passive House in Guadalajara

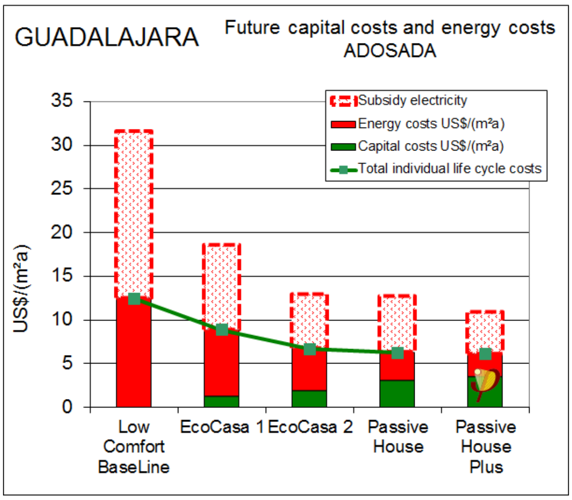

Figure 15b: Future capital costs and energy costs of Adosada building type compared, from low comfort baseline to Passive House in Guadalajara

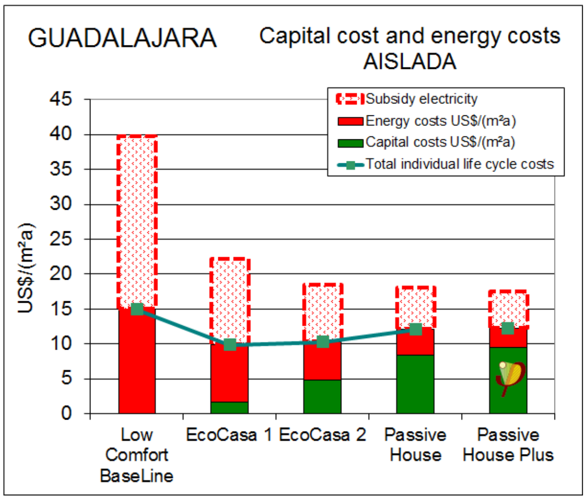

Figure 16a: Current capital costs and energy costs of Aislada building type compared, from low comfort baseline to Passive House in Guadalajara

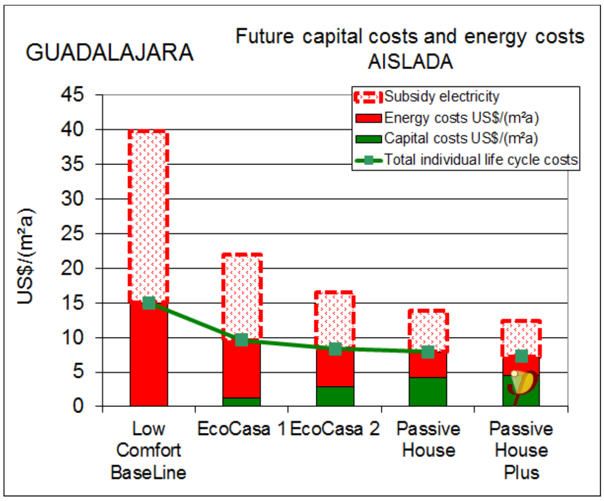

Figure 16b: Future capital costs and energy costs of Aislada building type compared, from low comfort baseline to Passive House in Guadalajara

As can be appreciated in figures 14b, 15b and 16b, the Passive House is the economic optimum for the vertical building type as well as for the single family buildings with respect to the "future costs" scenario. The Passive House Plus case, although having higher capital costs than the Passive House case, is the most economical option when taking subsidies into account (figures 14a, 15a and 16a).

5.3. Temperate cold (Puebla)

For Puebla, located in central Mexico with a slightly cooler climate than Guadalajara, the main energy efficiency measures include 5 cm of insulation in walls and 2.5 cm in the floor slab and roof as well as double glazed windows. A pure extract air system with additional natural ventilation ensures the quality of the indoor air in the building. Figures 17a through 17c portray the energetic advantage of the Passive House Standard in comparison to the other energy efficiency cases.

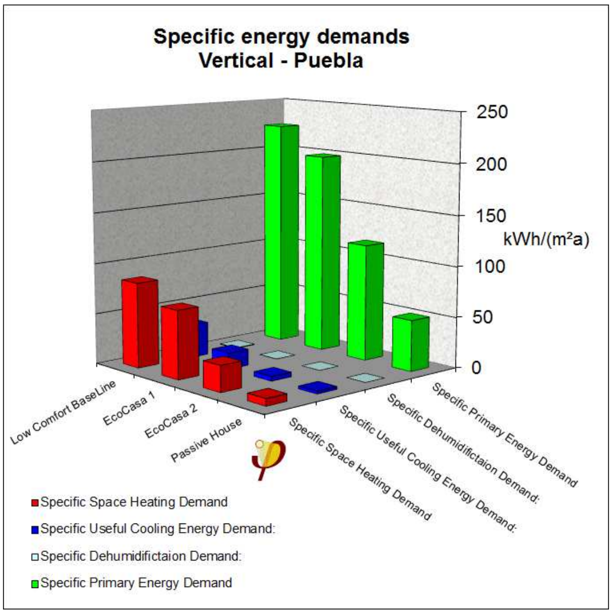

Figure 17a: Specific energy demands for Vertical building type in Puebla

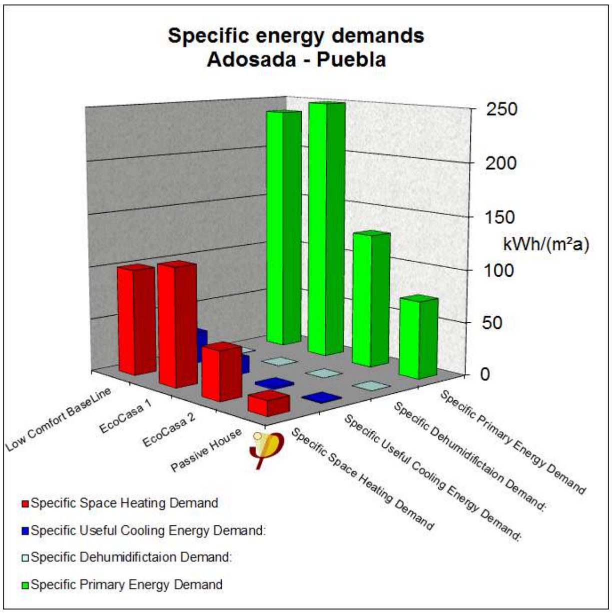

Figure 17b: Specific energy demands for Adosada building type in Puebla

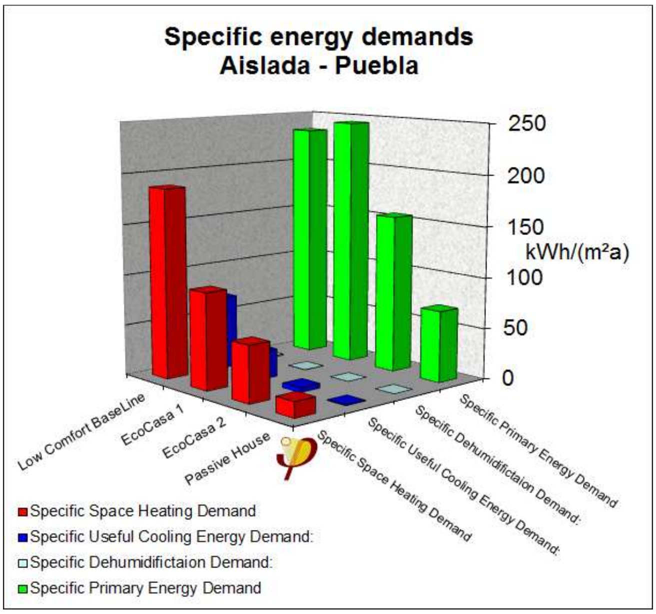

Figure 17c: Specific energy demands for Aislada building type in Puebla

The slightly higher primary energy and space heating demand of the EcoCasa 1 above the low comfort baseline for the Adosada and the Aislada building types (figure 17b and 17c) is explained due to the difference in temperature boundary conditions. Had the baseline within the comfort range of 20-25°C been used instead, the primary energy and space heating demands would have been significantly higher than the EcoCasa 1 cases.

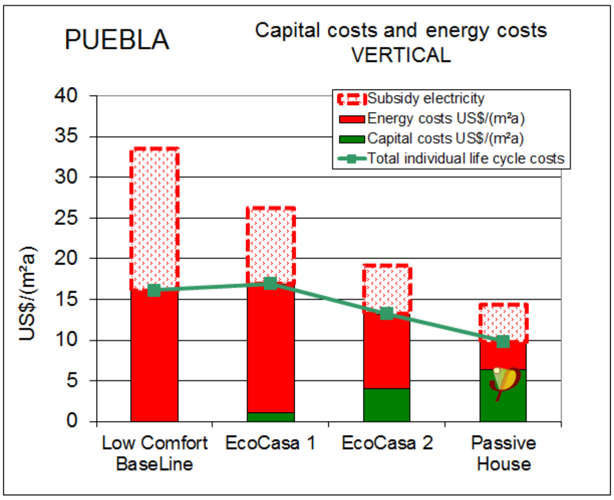

Figure 18a: Current capital costs and energy costs of Vertical building type compared, from low comfort baseline to Passive House in Puebla

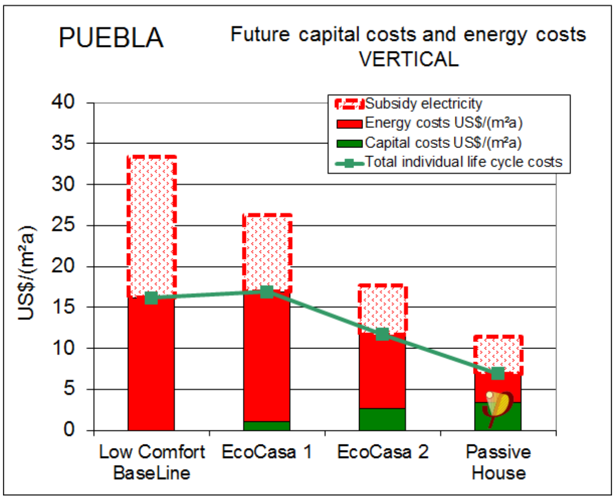

Figure 18b: Future capital costs and energy costs of Vertical building type compared, from low comfort baseline to Passive House in Puebla

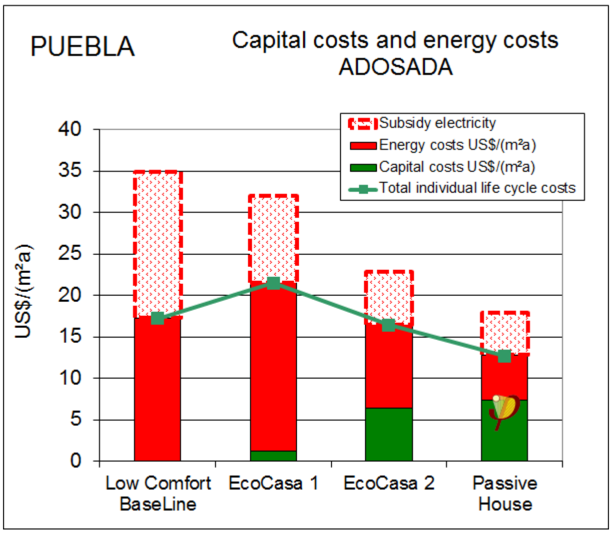

Figure 19a: Current capital costs and energy costs of Adosada building type compared, from low comfort baseline to Passive House in Puebla

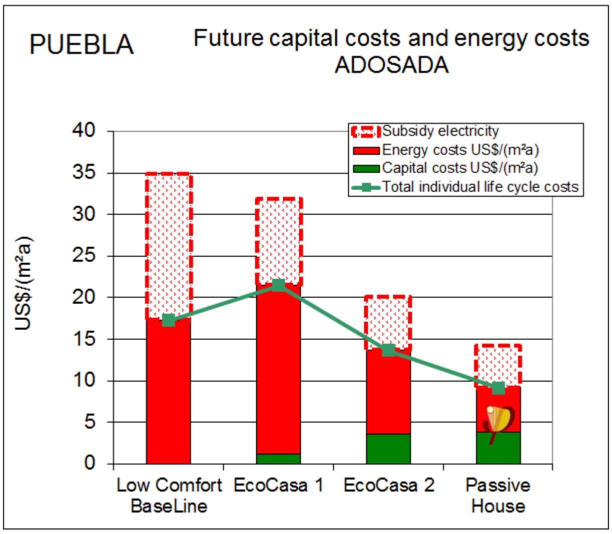

Figure 19b: Future capital costs and energy costs of Adosada building type compared, from low comfort baseline to Passive House in Puebla

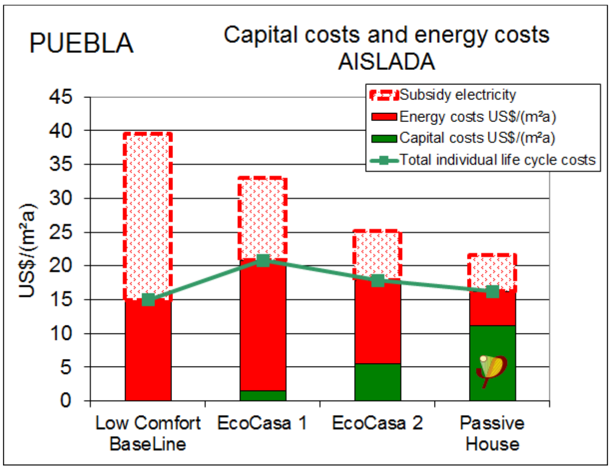

Figure 20a: Current capital costs and energy costs of Aislada building type compared, from low comfort baseline to Passive House in Puebla

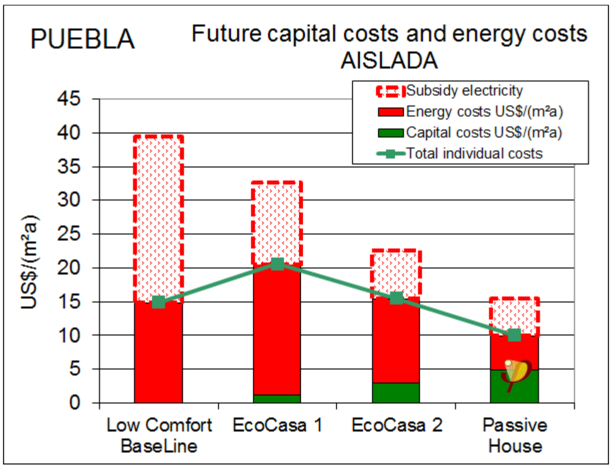

Figure 20b: Future capital costs and energy costs of Aislada building type compared, from low comfort baseline to Passive House in Puebla

The economical superiority of the Passive House case and the economical improvements of the EcoCasa 1 and EcoCasa 2 are also clearly shown in figures 18a through 20b, either for current or for future prices.

5.4. Extremely hot and humid (Cancun)

For the extremely hot and humid climate of Cancun, in southeast Mexico on the Caribbean coast, the measures applied in order to optimise the energy efficiency of the buildings must take humidity into account. As with the rest of the buildings in the other locations, insulation of the opaque building elements was the first step with a minimum of 7.5 cm on all walls and floor, depending on the building type, and around 10 cm on the roof, to achieve Passive House. Triple glazed windows with sun protection were use. Some additional measures to achieve the Passive House Standard included energy recovery ventilation with humidity control, separate recirculation cooling with additional dehumidification, exterior moveable shading, improvement of thermal mass and the application of cool colours on the walls and roof.

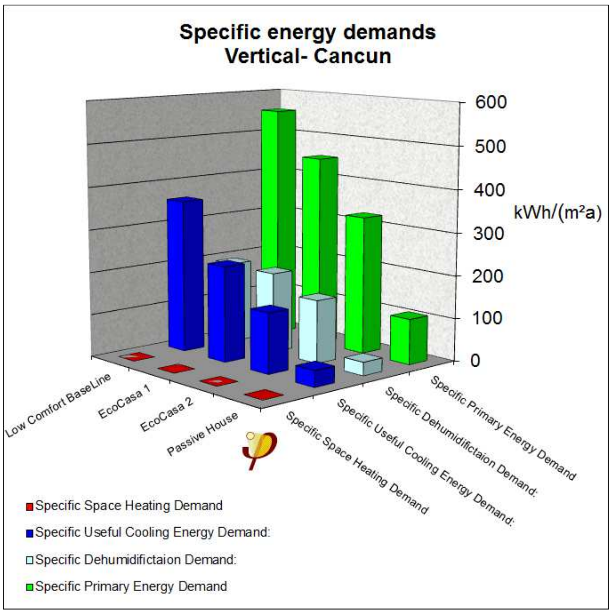

Figure 21a: Specific energy demands for Vertical building type in Cancun

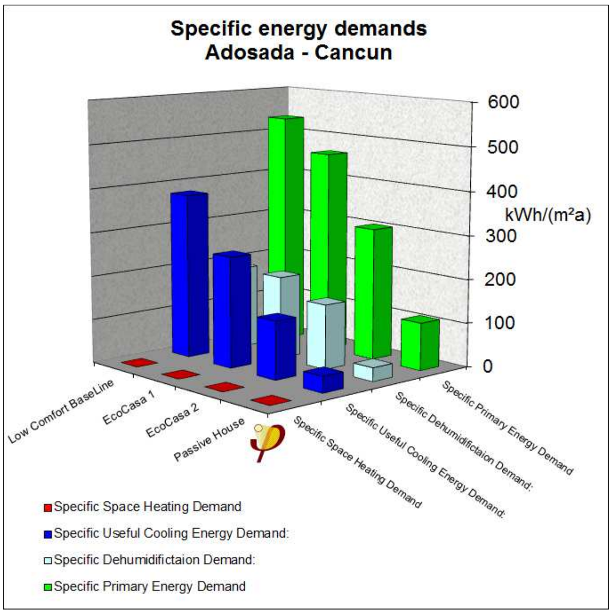

Figure 21b: Specific energy demands for Adosada building type in Cancun

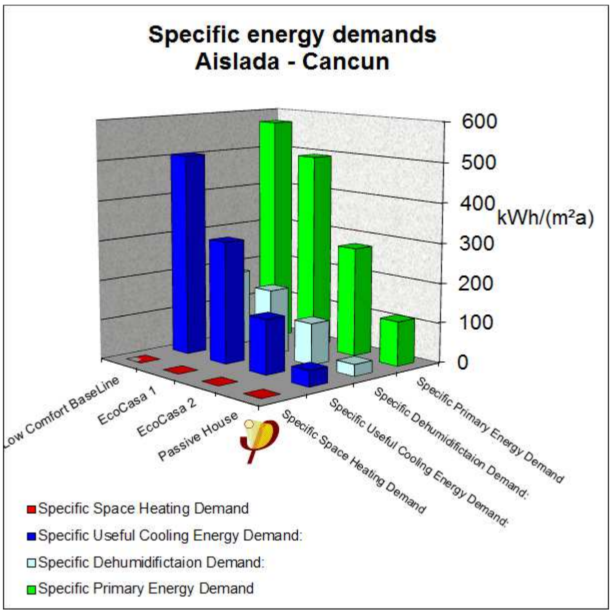

Figure 21c: Specific energy demands for Aislada building type in Cancun

Figures 21a through 21c present the results in terms of the energy efficiency of the different building cases, from baseline to Passive House, for all the analysed building types. It is to be noted that in this tropical climate, the average annual temperatures are so high that in order to keep the maximum indoor temperature of 25°C, it is necessary to cool actively, which has a direct influence on the cooling energy demand of the building. The Passive House Certification criteria state that a building must either not exceed the maximum of 15 kWh/(m²a) cooling energy demand or that the building have a cooling load of 10 W/m² or less. Additionally, recent studies by the Passive House Institute state that, even in the latter case, the cooling and dehumidification energy demand should be limited to a climate dependent value in order to remain economic (see [Schnieders et al. 2012]). This can be observed in the Cancun Passive House case.

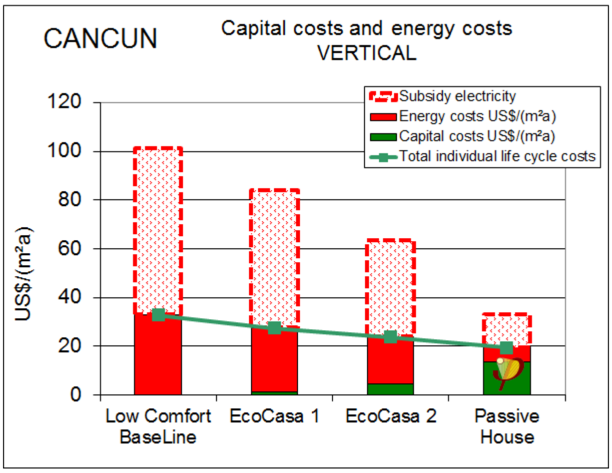

Figure 22a: Current capital costs and energy costs of Vertical building type compared, from low comfort baseline to Passive House in Cancun

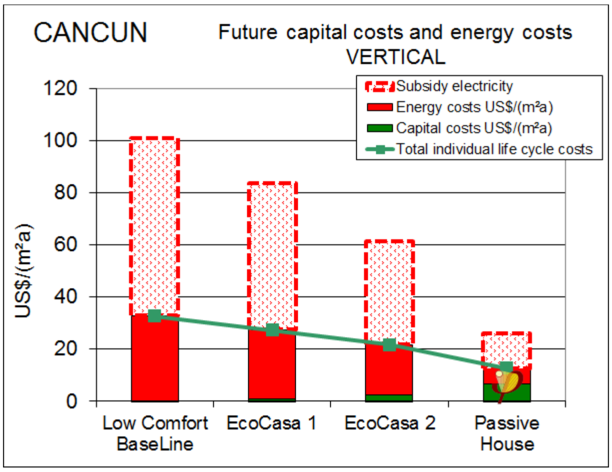

Figure 22b: Future capital costs and energy costs of Vertical building type compared, from low comfort baseline to Passive House in Cancun

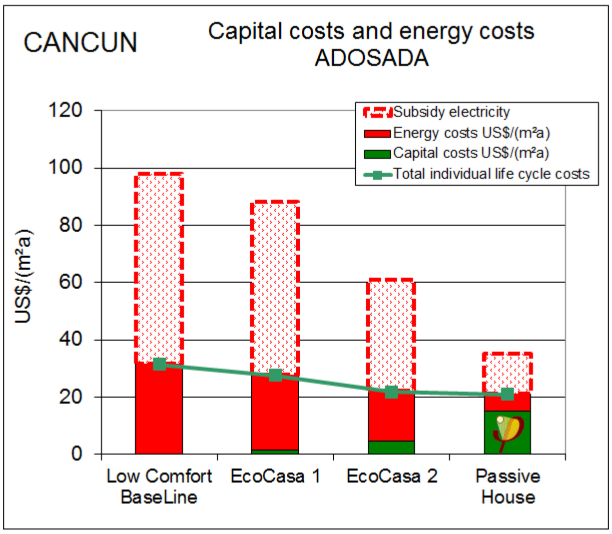

Figure 23a: Current capital costs and energy costs of Adosada building type compared, from low comfort baseline to Passive House in Cancun

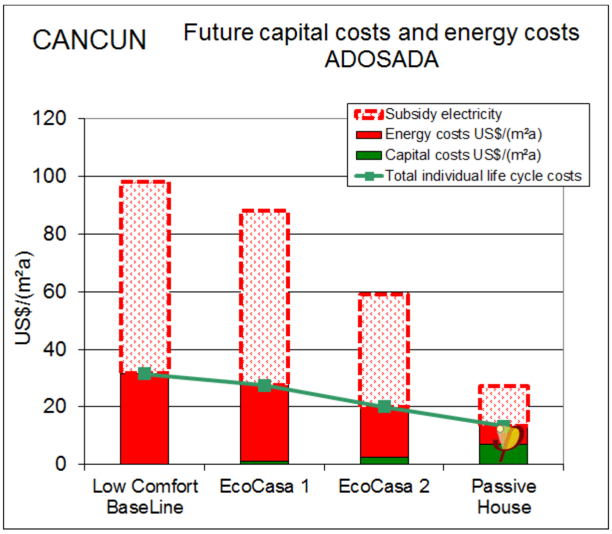

Figure 23b: Future capital costs and energy costs of Adosada building type compared, from low comfort baseline to Passive House in Cancun

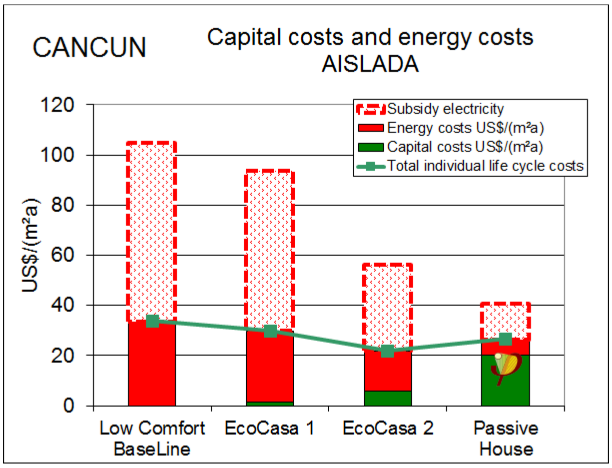

Figure 24a: Current capital costs and energy costs of Aislada building type compared, from low comfort baseline to Passive House in Cancun

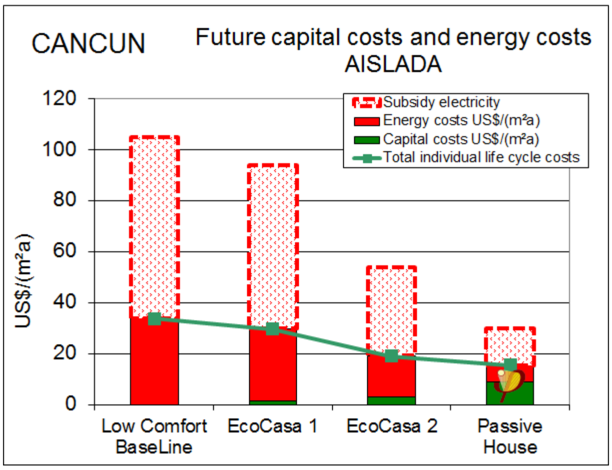

Figure 24b: Future capital costs and energy costs of Aislada building type compared, from low comfort baseline to Passive House in Cancun

Figures 22a through 24b show the analysis of current and future costs for the different energy efficiency cases based on a lifespan of 30 years. As has been observed in the other locations, especially the warmer ones, the Passive House case is already the most cost-effective solution over a 30 year lifespan taking current market prices into account. An increase in the capital costs, meaning increased upfront investment in energy efficiency measures, allows for a dramatic reduction in the energy costs. Besides making the building less dependent on energy price fluctuations, Passive House proves to be the best concept also in terms of overall life-cycle costs.

5.5. Summary: Energy efficiency, CO_2 reduction and lifecycle costs for all building types and climates

The goal of the Mexican Sustainable Housing NAMA is to promote cost effective energy-efficient building concepts across the residential housing sector, with a particular focus on low-income housing, applied through the 'whole house approach', which envisages setting and monitoring values for total primary energy demand from a building, instead of focusing on the performance of individual energy-efficient technologies or solutions. The final goal is thus the reduction of CO_2 emissions coming from new residential buildings. Figures 25a through 25c illustrate the different energy efficiency levels and their corresponding specific emissions for the analysed building types in the four different climate zones of this study.

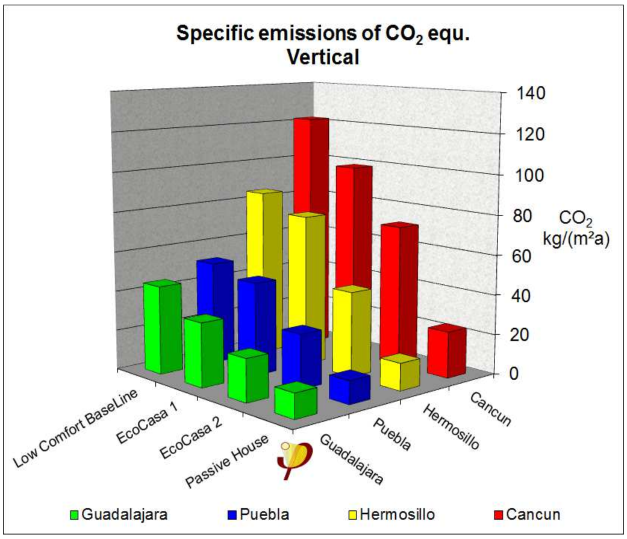

Figure 25a: specific CO_2 emissions for the different efficiency levels of the NAMA in the different locations, Vertical building type

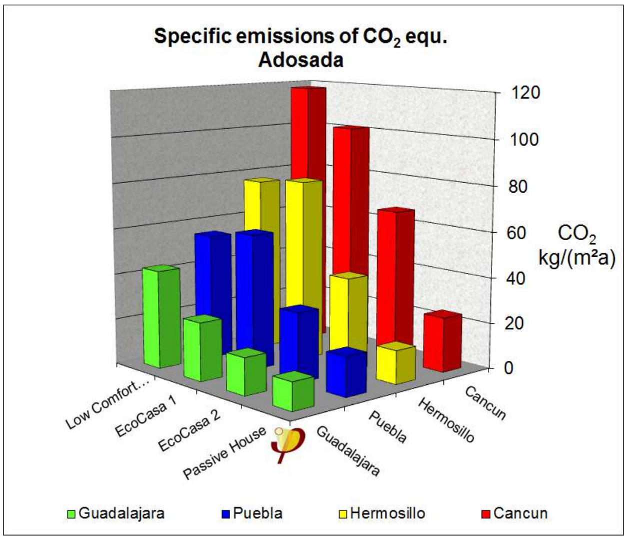

Figure 25b: specific CO_2 emissions for the different efficiency levels of the NAMA in the different locations, Adosada building type

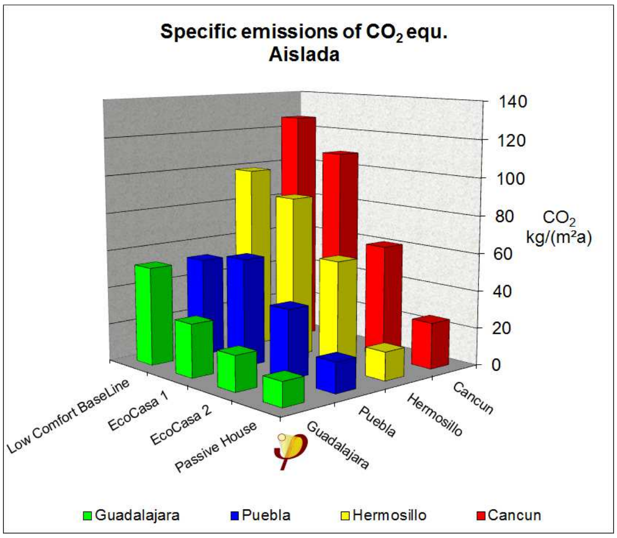

Figure 25c: specific CO_2 emissions for the different efficiency levels of the NAMA in the different locations, Aislada building type

The following graphs provide a comparison of the economic aspects of the NAMA. Figures 26a through 26c compare the additional investment costs, both for the current and future cost scenarios, for all energy efficiency levels of the analysed buildings. As can be seen, the additional investment costs for the Passive House case are always remarkably higher, especially in the warmer locations. However, the estimated savings in energy costs (figures 27a through 27c) and lifecycle costs (figures 28a through 28c) demonstrate that high energy efficiency in a housing project brings even more savings in the long run, making Passive House the best investment from the economic point of view as well. For the EcoCasa 1 and EcoCasa 2 cases it can also be ascertained that higher investment costs in energy efficiency measures are translated in lower lifecycle and energy costs.

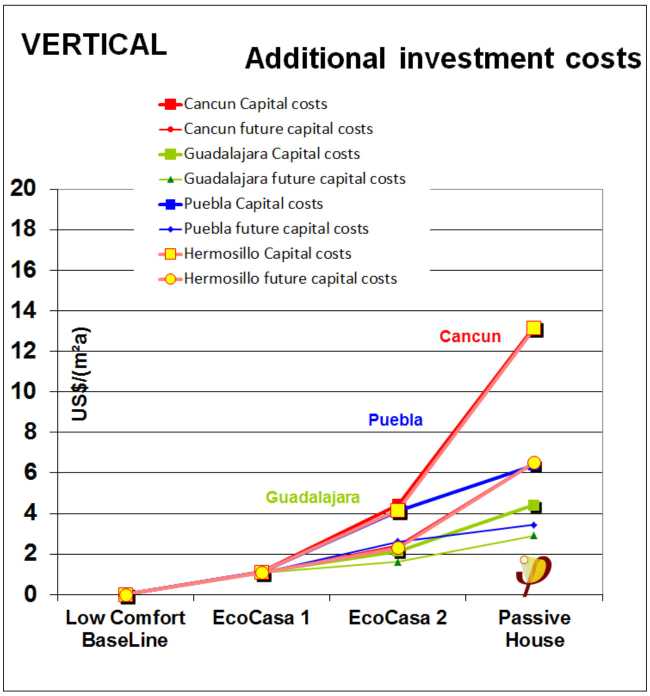

Figure 26a: Estimated additional investment costs, both current and future scenario, for all energy efficiency levels, for the Vertical building type

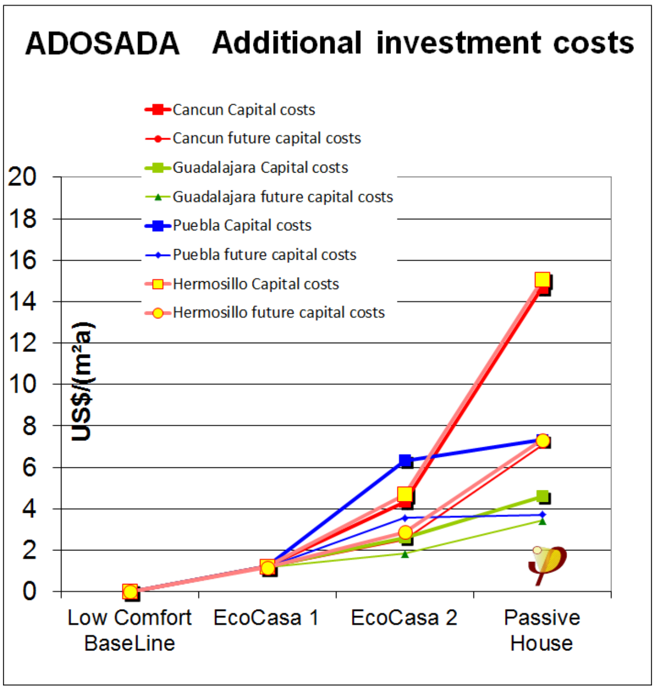

Figure 26b: Estimated additional investment costs, both current and future scenario, for all energy efficiency levels, for the Adosada building type

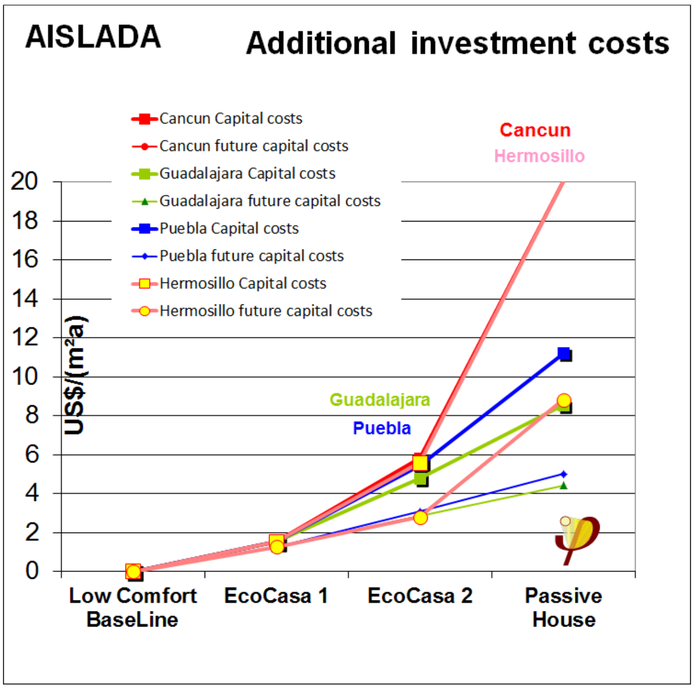

Figure 26c: Estimated additional investment costs, both current and future scenario, for all energy efficiency levels, for the Aislada building type

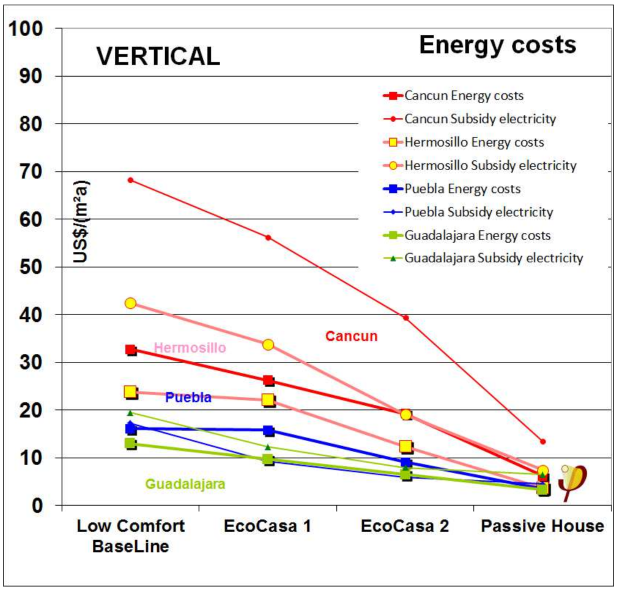

Figure 27a: Estimated energy costs for all the energy efficiency levels for the Vertical building type

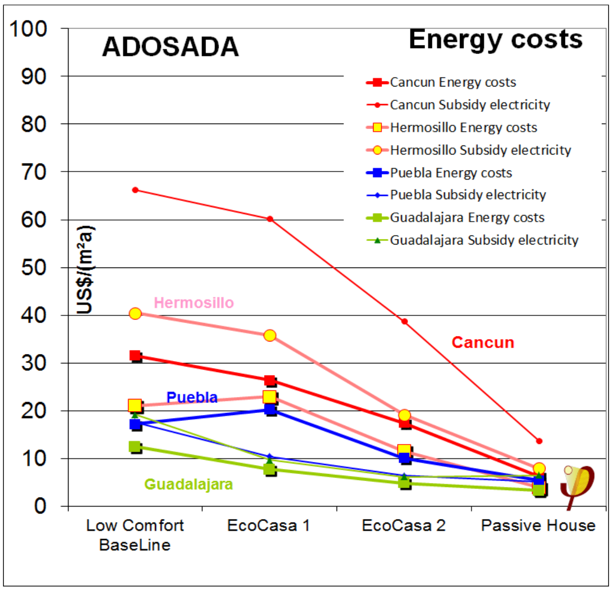

Figure 27b: Estimated energy costs for all the energy efficiency levels for the Adosada building type

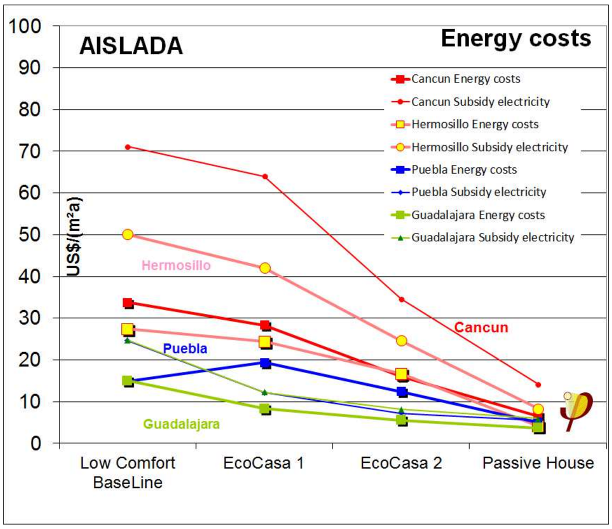

Figure 27c: Estimated energy costs for all the energy efficiency levels for the Aislada building type

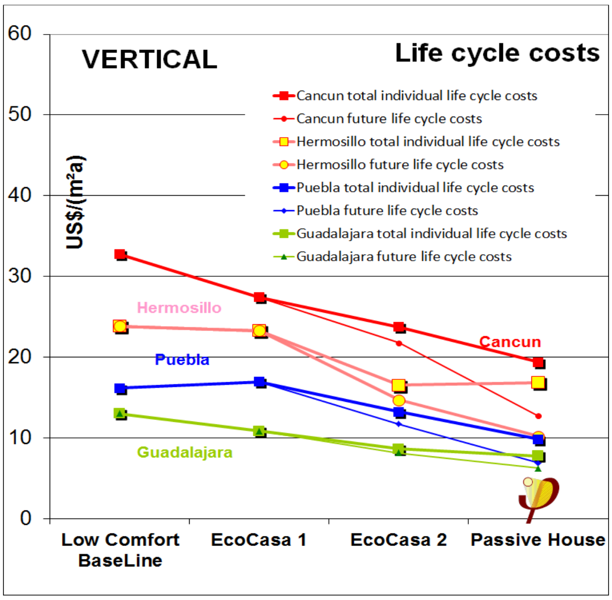

Figure 28a: Estimated lifecycle costs for all the energy efficiency levels for the Vertical building type

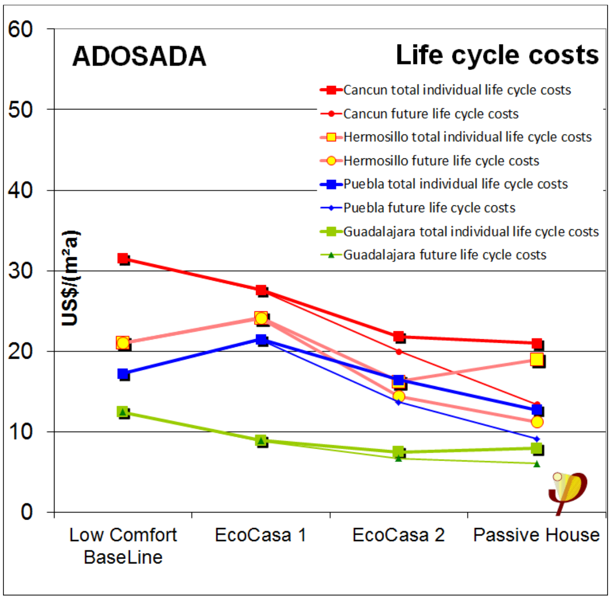

Figure 28b: Estimated lifecycle costs for all the energy efficiency levels for Adosada building type

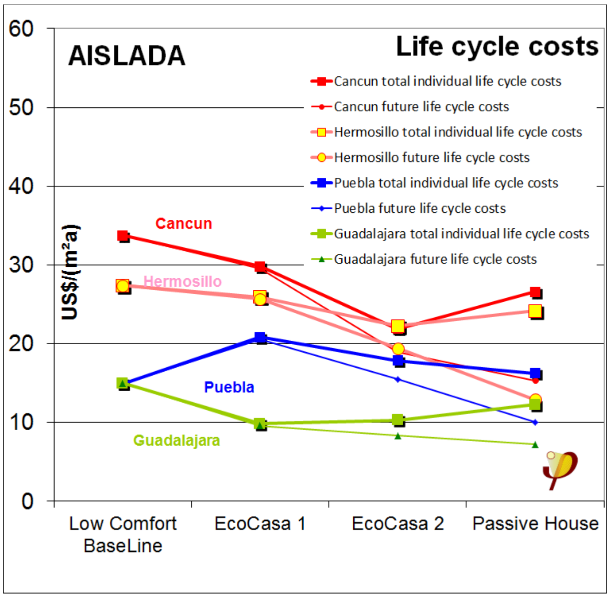

Figure 28c: Estimated lifecycle costs for all the energy efficiency levels for the Aislada building type

5.6 CO_2 abatement costs

Table 6 shows the CO_2 savings for all building types per unit.

Table 6: **Annual CO_2 savings overview**

Aislada	Hermosillo	Cancun	Guadalajara	Puebla
savings per unit	*t/a*	*t/a*	*t/a*	*t/a*
Low Comfort Baseline	**0.0**	**0.0**	**0.0**	**0.0**
EcoCasa 1	**0.5**	**0.7**	**0.9**	**-0.2**
EcoCasa 2	**1.6**	**2.5**	**1.3**	**0.6**
Passive House	**3.2**	**3,9**	**1.5**	**1.4**
Adosada	**Hermosillo**	**Cancun**	**Guadalajara**	**Puebla**
savings per unit	*t/a*	*t/a*	*t/a*	*t/a*
Low Comfort Baseline	**0.0**	**0.0**	**0.0**	**0.0**
EcoCasa 1	**-0.1**	**0.7**	**0.7**	**-0.2**
EcoCasa 2	**1.5**	**2.1**	**1.1**	**1.0**
Passive House	**2.5**	**3.8**	**1.3**	**1.5**
Vertical	**Hermosillo**	**Cancun**	**Guadalajara**	**Puebla**
savings per unit	*t/a*	*t/a*	*t/a*	*t/a*
Low Comfort Baseline	**0.0**	**0.0**	**0.0**	**0.0**
EcoCasa 1	**0.4**	**0.9**	**0.5**	**0.2**
EcoCasa 2	**1.7**	**2.1**	**0.9**	**1.0**
Passive House	**2.9**	**4.0**	**1.3**	**1.6**

Summary for Passive Houses:

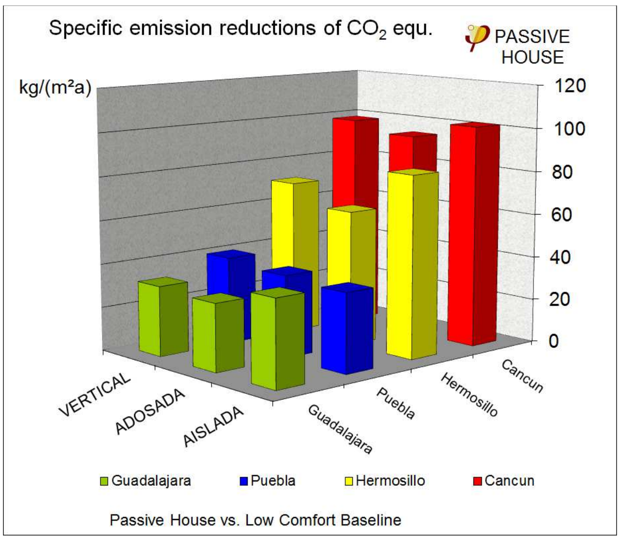

Figure 29a:Passive House in different climate zones: Savings of CO_2 emissions vs. Low Comfort Baseline

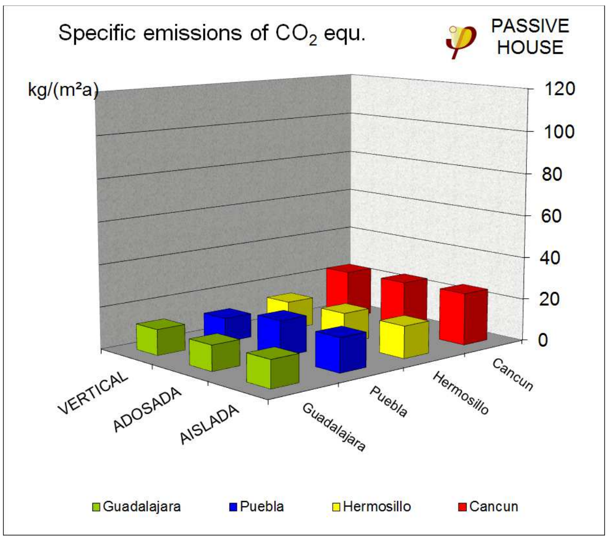

Figure 29b:Passive House in different climate zones: Specific CO_2 emissions

From these data, CO_2 abatement costs were calculated for individual buildings. As shown before, the lifecycle costs normally are lower than in the baseline in all cases. Therefore, the abatement costs are negative. Figures 30a through 31b show examples for 2 climates, with current investment costs and future investment costs after the implementation of the different energy efficiency cases into the Mexican market. The calculation is based on the individual costs, without consideration of energy subsidies.

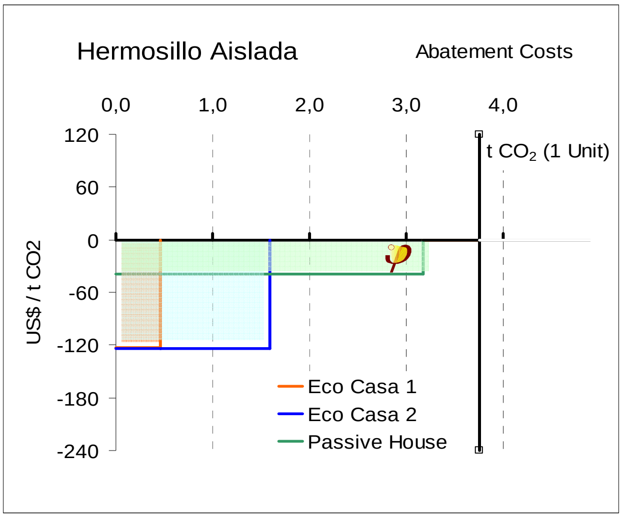

Figure 30a CO_2 abatement costs (only individual costs) in Hermosillo, vs. Low Comfort Baseline.

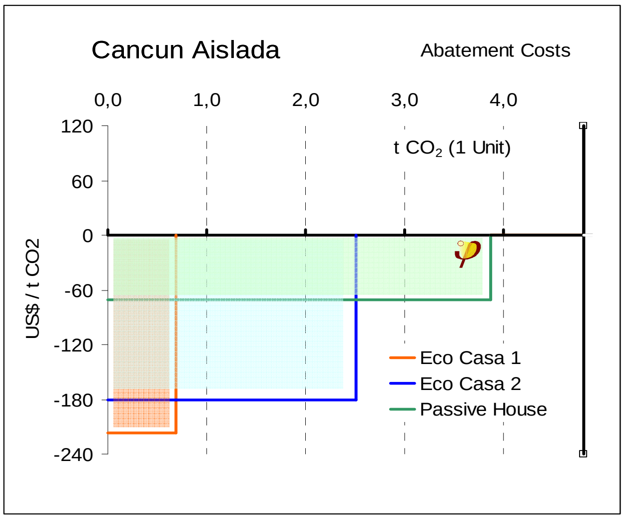

Figure 30b: CO_2 abatement costs (only individual costs) in Cancun, vs. Low Comfort Baseline

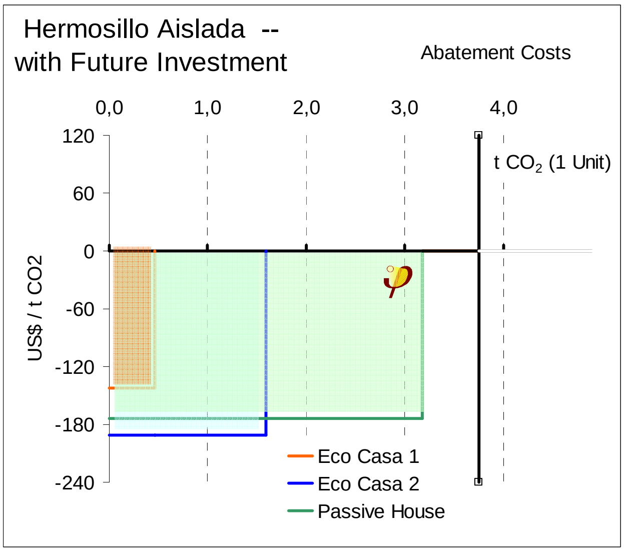

Figure 31a : Future CO_2 abatement costs in Hermosillo, vs. Low Comfort Baseline

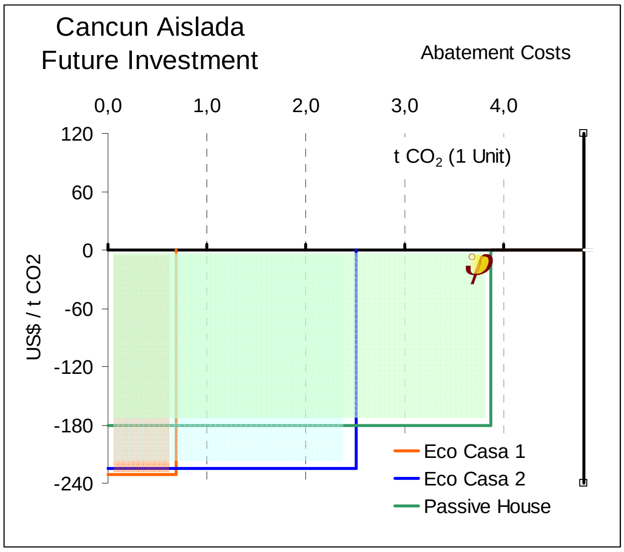

Figure 31b: Future CO_2 abatement costs in Cancun, vs. Low Comfort Baseline

In figures 30a through 31b, only the individual perspective is shown: especially, the energy subsidies are not taken into account.

Abatement costs: Public perspective

From the state's view, grants pay back as a consequence of saved energy subsidies. The assumptions for the following figures (32a and 32b) are: Boundary conditions as before, with a 10 years calculation period. It is assumed that 50% of the additional investment costs (actual prices) are given as a grant by the state. The revenue of the state is the subsidy saved. The additional return caused by the effects on the job market, saved social expenses and additional income taxes were not considered since data were not available.

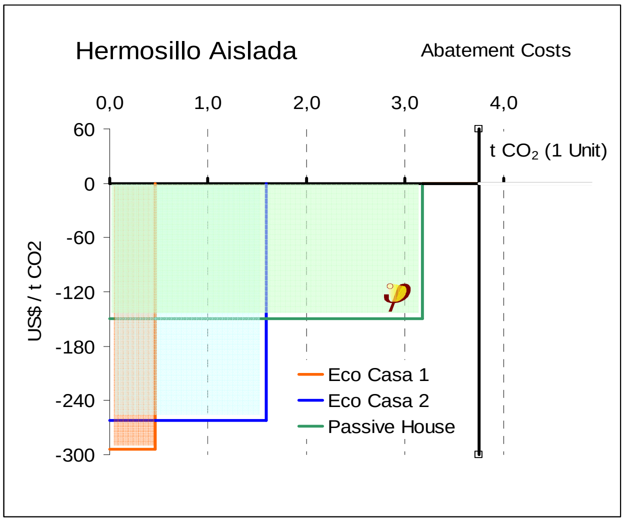

Figure 32a CO_2 abatement costs (public perspective) in Hermosillo, vs. Low Comfort Baseline.

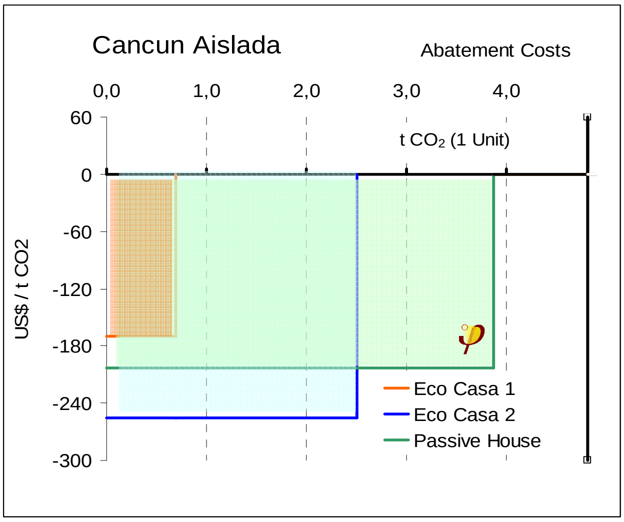

Figure 32b: CO_2 abatement costs (public perspective) in Cancun, vs. Low Comfort Baseline

In general, the abatement costs for the implementation scenario of the Vertical building type is more favourable than the other two building types, with the Aislada type being the least favourable one.

6. Additional architectural and urban considerations

The objective of the energetic optimisation of housing projects in Mexico not only requires an analysis of the energetic balance of typical building types but also a further analysis of urban and architectural design considerations. A holistic approach in which the energy efficiency of buildings is combined with urban planning considerations leads to a win-win situation in terms of cost reductions and CO_2 savings. The following architectural and urban aspects are highly recommended in order to further optimise the outcomes of the NAMA.

6.1. Optimisation of building types

For the NAMA, low-income housing (approximately 40 m² per unit) were analysed, "Aislada" (single, isolated housing unit), "Adosada" (row housing unit), together with "Vertical", a multi-storey housing unit consisting of six floors each with two 40 m² apartments. The results show that improving the energy efficiency of single family units such as the current Aislada and

Adosada designs requires very high levels of insulation (30 cm plus in extremely hot climates like Hermosillo and Cancun) to compensate for excessive solar gains and losses through the windows and the significantly less compact design.

Compact building design is a key measure that can be expressed in the area to volume (A/V) ratio: the A/V ratio of the current Aislada and Adosada buildings is 0.9-1.2, while the Vertical buildings are approximately three times more compact with an A/V-ratio of 0.3. This explains why the Vertical building unit achieves the same high energy performance with remarkably less insulation than the Aislada and Adosada building types.

It can thus be concluded that a compact building design proves to be a very significant factor in terms of a building's energetic performance and should be optimised first before applying energy-efficiency measures such as insulation. If a favourable A/V ratio is combined with an optimised orientation and window size, financial and energetic benefits can be achieved more easily. In addition, less insulation also means energy savings in terms of the production of the materials and their installation. Further design of building types such as L-shaped housing units as well as two and four storey buildings for the Mexican market should be analysed with an eye to taking advantage of the energy efficiency optimisation potentials.

6.2. Urban planning considerations

The following two points represent urban development and architectural design considerations that have a direct impact on the energy efficiency of a building.

a) Emissions reductions and high quality of life in compact settlements

Vertical housing units not only prove to be more efficient in terms of the performance of the building itself, but also allow urban settlements to remain closer to the city centre, thus avoiding urban sprawl. This derives from the assumption that a multi-storey, compact building uses less land to provide housing for more families, while a settlement with isolated or row housing units uses more land. Urban sprawl has many negative impacts such as the loss and/or degradation of green areas as well as increased GHG emissions due to the amplified transportation needs of inhabitants.

In addition, the efficiency of infrastructure such as postal service, ambulance, police, waste management and connections to water, electricity, energy supplies and roads is increased as infrastructure can be provided more easily and quickly at reduced costs for the government. This has a direct impact on the improvement of the quality of life for inhabitants and means reduces the need for individual transport. These effects consequently reduce CO_2 emissions, as the access and use of alternative transportation like walking and the use of bicycles, becomes feasible.

b) Reducing soil sealing by compact settlements

If asphalt roads have to be built to provide access to every single house in a development and no green roofs are installed, rain has fewer possibilities to seep into the ground. This, in turn, can negatively impact the water table and increase water damage/flooding risk. Compact settlements circumvent these problems while allowing more opportunities for the development of green areas. Such areas can contribute to carbon sequestration and can also enhance quality of life by providing recreational opportunities. Moreover, both the reduction of land loss and/or degradation and the diminished water pumping needs directly translate into energy savings.

There are also clear benefits for settlements located in areas subject to flooding, where isolated and row houses are at greater risk. In addition, compact urban planning reduces the heat island effect, which also has impacts on energy performance as it increases a buildings' cooling demand.

6.3. Normative considerations

The appropriate normative and urban planning measures to be applied in Mexico must be further investigated in order to determine the feasibility of compactness of urban settlements. Likewise, further research is required on the relationships between building compactness, housing density, potential shading, building types and the energy efficiency of buildings.

The validity of this study refers to typical building designs for Infonavit settlements. However, the reality of the Mexican building sector is broader and includes informal construction, which bypasses urban and building regulations. The energy savings achieved through the concept presented in the NAMA only address one share of the housing sector in Mexico. It is advisable that further research be carried out parallel to the NAMA to develop plans to influence the energy efficiency of informal buildings.

7. Conclusions

The evaluation carried out for the NAMA document has provided various energy efficient scenarios that can support the realisation of efficient social housing projects in the short, medium and long-term in Mexico. Adapted to local climate conditions and building practices, the results presented in this study show that it is possible to achieve different efficiency standards including the Passive House Standard with the help of PHPP as the calculation tool in a variety of Mexican climates.

Nonetheless, all building types in this study were taken just as they were in the original projects without any change to their design other than the application of energy measures (insulation, airtightness, improved U-values of windows and doors, addition of a ventilation system, etc.). This was done in order to simplify the comparison of the different energy efficiency levels. An optimised urban design as well as building design adapted to climatic conditions would be highly recommended to accompany the implementation of the NAMA. No changes to the orientation or size of the windows were made and no additional shading via roof overhangs or canopies was introduced. This resulted in high levels of insulation to compensate for the current building designs. The optimisation of building designs will result in cost-reductions while also simplifying the measures needed to achieve higher efficiency standards.

It should also be noted that for the economic analysis of this study, only individual energy costs were taken into account; in spite of the low level of energy prices as a consequence of high subsidies. The Passive House is the cost optimal standard with respect to lifecycle costs. From a macroeconomic point of view, Passive House reduces the costs for energy subsidies as well. Passive House incentives would easily be paid back though subsidies saved

Another important finding of the cost analysis is that the CO_2 abatement costs are almost always negative. This means that the additional costs of investment for improving the baseline building to reach the different energy efficiency cases (EcoCasa 1, EcoCasa 2, Passive House) is lower than the cost of the CO_2 emissions themselves, this holds in spite of the assumption of a high tolerance of uncomfortable conditions in the baseline case. In fact, the Passive House case presents the highest CO_2 emission reductions with negative abatement costs. This was of particular relevance for the goals of the NAMA, which are directly related to CO_2 emissions reductions.

As for the direct measures listed in the NAMA, in a first stage it is expected that the construction of Passive House beacon projects would help to analyse best-practice application of energy efficiency in building, the intermediate cases EcoCasa 1 and EcoCasa 2 can be implemented to set minimum energy targets, improve the CO_2 balance and pave the way for the market introduction of highly efficient components and the Passive House Standard

8. Bibliography

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Annex I. Detailed result tables

VERTICAL

Multistory building. 6 floors, 2 appartments per floor. 489,96 TFA		EXTREME HOT DRY				TEMPERATE					TEMPERATE COLD					EXTREME HOT HUMID			
Climate data	-	Vertical Baseline Hermosillo	Vertical EcoCasa 1 Hermosillo	Vertical EcoCasa 2 Hermosillo	Vertical Passive House Hermosillo	Vertical Baseline Guadalajara	Vertical EcoCasa 1 Guadalajara	Vertical EcoCasa 2 Guadalajara	Vertical Passive House Guadalajara	Vertical Passive House Plus Guadalajara	Vertical Baseline Puebla	Vertical EcoCasa 1 Puebla	Vertical EcoCasa 2 Puebla	Vertical Passive House Puebla	Vertical Passive House Plus Puebla	Vertical Baseline Cancun	Vertical EcoCasa 1 Cancun	Vertical EcoCasa 2 Cancun	Vertical Passive House Cancun
Specific Space Heating Demand	kWh/(m²a)	43	41	12	1	17	11	2	2	0	84	67	26	7	1	0	0	0	0
Specific Useful Cooling Energy Demand:	kWh/(m²a)	291	188	105	15	73	43	25	18	4	33	16	5	3	1	359	224	141	38
Specific Dehumidifictaion Demand:	kWh/(m²a)	70	36	13	0	4	1	1	0	0	1	0	0	0	0	192	189	148	31
Cooling load	W/m²	131	99	54	15	16	8	6	4	0	0	0	0	0	0	62	43	24	7
Specific Primary Energy Demand (Indoor temp. 20°C-25°C)	kWh/(m²a)	606	339	190	62	266	141	94	55	39	318	198	116	50	40	755	450	324	106
Specific Emissions CO2-Equivalent (Indoor temp. 20°C-25°C)	kg/(m²a)	134	76	43	14	60	32	21	12	9	74	47	27	11	9	165	98	71	23
Specific Primary Energy Demand (Indoor temp. 18°C-28°C)*	kWh/(m²a)	382				198					225					555			
Specific Emissions CO2-Equivalent (Indoor temp. 18-28°C)*	kg/(m²a)	85				44					52					122			
Additional Investment costs (entire building)	$ US	$ -	$ 12.126	$ 45.605	$ 144.088	$ -	$ 12.126	$ 23.531	$ 48.392	$ 69.163	$ -	$ 12.126	$ 45.234	$ 70.084	$ 102.678	$ -	$ 12.126	$ 48.718	$ 144.899
Future additional Investment costs (entire building)	$ US	$ -	$ 11.862	$ 25.344	$ 71.416	$ -	$ 11.862	$ 17.823	$ 31.832	$ 37.114	$ -	$ 11.862	$ 28.674	$ 37.689	$ 48.506	$ -	$ 11.862	$ 26.841	$ 71.686
Additional costs per dwelling unit (current costs)	$ US	$ -	$ 1.011	$ 3.800	$ 12.007	$ -	$ 1.011	$ 1.961	$ 4.033	$ 5.764	$ -	$ 1.011	$ 3.769	$ 5.840	$ 8.556	$ -	$ 1.011	$ 4.060	$ 12.075
Additional costs per dwelling unit (future costs)	$ US	$ -	$ 988	$ 2.112	$ 5.951	$ -	$ 988	$ 1.485	$ 2.653	$ 3.093	$ -	$ 988	$ 2.390	$ 3.141	$ 4.042	$ -	$ 988	$ 2.237	$ 5.974
Life Cycle Costs (energy&additional capital costs)	$ US/(m²a)	$ 24	$ 23	$ 17	$ 17	$ 13	$ 11	$ 9	$ 8	$ 9	$ 16	$ 17	$ 13	$ 10	$ 12	$ 33	$ 27	$ 24	$ 19
Life Cycle Costs (Basis future investment costs)	$ US/(m²a)	$ 24	$ 23	$ 15	$ 10	$ 13	$ 11	$ 8	$ 6	$ 6	$ 16	$ 17	$ 12	$ 7	$ 7	$ 33	$ 27	$ 22	$ 13
Wall /Roof insulation	mm	0 / 0	0 / 0	25 / 25	100 / 50	0 / 0	0 / 0	25 / 25	25 / 25	50 / 25	0 / 0	0 / 0	25 / 25	50 / 25	175 / 125	0 / 0	0 / 0	50 / 50	100 / 100
Floor slab insulation	mm	0	0	25	75	0	0	0	0	0	0	0	0	25	125	0	0	50	100
Exterior surface absorption coefficient (exterior walls)	-	Colour paint	White paint	White paint	Cool colours	Colour paint	Colour paint	Colour paint	Colour paint	White paint	Colour paint	Colour paint	Colour paint	Colour paint	White paint	Colour paint	White paint	White paint	Cool colours
WINDOWS																			
Window frame: Uf-value	W/(m2K)	5,5	5,5	1,8	0,72	5,5	5,5	5,5	5,5	1,8	5,5	5,5	5,5	1,8	0,72	5,5	5,5	1,8	0,72
Window glazing: g-value	-	0,87	0,87	0,78	0,33	0,87	0,87	0,87	0,87	0,78	0,87	0,87	0,87	0,78	0,64	0,87	0,87	0,78	0,33
Window glazing: Ug-value	W/(m2K)	5,6	5,6	3	0,6	5,6	5,6	5,6	5,6	3	5,6	5,6	5,6	1,05	0,6	5,6	5,6	3	0,6
Window description		Single glazing, aluminium frame	Single glazing, aluminium frame	Double glazing insulated, pvc frame	Triple glazing sun protection, PVC insulated frame	Single glazing, aluminium frame	Single glazing, aluminium frame	Single glazing, aluminium frame	Single glazing, aluminium frame	Double glazing insulated, pvc frame	Single glazing, aluminium frame	Single glazing, aluminium frame	Single glazing, aluminium frame	Double glazing sun protection	Triple glazing sun protection, PVC insulated frame	Single glazing, aluminium frame	Single glazing, aluminium frame	Double glazing insulated, pvc frame	Triple glazing sun protection, PVC insulated frame
VENTILATION																			
Heat recovery rate	%	0%	0%	0%	90%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	90%
Ventilation type - Pure Extract Air	-	0	0	0	0	0	0	0	x	x	0	0	x	x	x	0	0	0	0
Ventilation type - Balanced PH Ventilation	-	0	0	0	x	0	0	0	0	0	0	0	0	0	0	0	0	0	x
SHADING																			
Reduction factor z for temporary sun protection	%	No additional shading	No additional shading	No additional shading	Additional moveable shading	No additional shading	No additional shading	No additional shading	No additional shading	No additional shading	No additional shading	No additional shading	No additional shading	No additional shading	No additional shading	No additional shading	No additional shading	No additional shading	Additional moveable shading
ELECTRICITY & AUX ELECTRICITY	v.e.																		
Percentage of CFLs	%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Household appliances (refrigerator, washing machine, microwave oven, consumer electronics and small appliances)		Regular /bad efficiency appliances	Efficient appliances	Highly efficient appliances	Highly efficient appliances	Regular /bad efficiency appliances	Efficient appliances	Highly efficient appliances	Highly efficient appliances	Highly efficient appliances	Regular /bad efficiency appliances	Efficient appliances	Highly efficient appliances	Highly efficient appliances	Highly efficient appliances	Regular /bad efficiency appliances	Efficient appliances	Highly efficient appliances	Highly efficient appliances
Miscelaneous Auxiliary Electricity (ceiling fan)		Ceiling fan				Ceiling fan					Ceiling fan					Ceiling fan			
SUMMER VENTILATION & COOLING UNITS		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Corresponding air rate for night ventilation (source SummVer	1/h	0,5	0,5	0,5	2	0,5	0,5	0,5	0,5	2	0,5	0,5	0,5	0	0	0,5	0,5	0	0
Humidity recovery	%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	65%
Anual cooling COP		2,5	3,08	3,08	3,08	2,5	3,08	3,08	3,08	0	2,5	3,08	3,08	0	0	2,5	3,08	3,08	3,08
DHW & SOLAR DHW		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Solar Collector Area	m²	0	10	10	Fully solar	0	10	10	Fully solar	Fully solar	0	10	10	Fully solar	Fully solar	0	10	10	Fully solar

* This calculation is made with an indoor temperature assumption of between 18°C - 28°C only to calculate CO2 emissions. The rest of the results use a comfort range between 20°C - 25°C.

** Although each dwelling unit is thought to be occupied by 4 persons, the value of 2 is taken as an average value, under the assumption that the dwelling unit will not be occupied to it's 100% percent capacity all the time, considering a life cycle of 30

ADOSADA

Occupation: 2 persons/unit**		13.3 $MXP/$US																	
ADOSADA																			
40,7 m² row house		EXTREME HOT DRY				TEMPERATE					TEMPERATE COLD					EXTREME HOT HUMID			
Climate data	.	Adosada Baseline Hermosillo	Adosada EcoCasa 1 Hermosillo	Adosada EcoCasa 2 Hermosillo	Adosada Passive House Hermosillo	Adosada Baseline Guadalajara	Adosada EcoCasa 1 Guadalajara	Adosada EcoCasa 2 Guadalajara	Adosada Passive House Guadalajara	Adosada Passive House Plus Guadalajara	Adosada Baseline Puebla	Adosada EcoCasa 1 Puebla	Adosada EcoCasa 2 Puebla	Adosada Passive House Puebla	Adosada Passive House Plus Puebla	Adosada Baseline Cancun	Adosada EcoCasa 1 Cancun	Adosada EcoCasa 2 Cancun	Adosada Passive House Cancun
Specific Space Heating Demand	kWh/(m²a	38	53	23	2	10	17	7	3	0	100	112	46	14	5	0	0	0	0
Specific Useful Cooling Energy Demand:	kWh/(m²a	304	207	106	15	60	18	7	13	3	30	16	2	1	0	377	254	133	37
Specific Dehumidifictaion Demand:	kWh/(m²a	47	28	9	0	1	0	0	0	0	0	0	0	0	0	189	189	148	31
Cooling load	W/m²	154	134	64	19	13	0	0	3	0	0	0	0	0	7	74	59	28	10
Specific Primary Energy Demand (Indoor temp. 20°C-25°C)	kWh/(m²a	590	353	181	66	236	111	70	54	42	338	249	128	73	51	767	462	303	109
Specific Emissions CO2-Equivalent (Indoor temp. 20°C-25°C)	kg/(m²a)	131	79	41	15	53	25	16	12	9	79	59	30	17	11	168	101	66	24
Specific Primary Energy Demand (Indoor temp. 18°C-28°C)*	kWh/(m²a	354				200					248					543			
Specific Emissions CO2-Equivalent (Indoor temp. 18-28°C)*	kg/(m²a)	79				45					57					120			
Additional Investment costs (one dwelling unit)	$ US	$ -	$ 1,119	$ 4,279	$ 13,738	$ -	$ 1,119	$ 2,391	$ 4,209	$ 5,289	$ -	$ 1,119	$ 5,765	$ 6,675	$ 12,345	$ -	$ 1,119	$ 3,961	$ 13,382
Future additional Investment costs (one dwelling unit)	$ US	$ -	$ 1,075	$ 2,620	$ 6,685	$ -	$ 1,075	$ 1,679	$ 2,761	$ 3,138	$ -	$ 1,075	$ 3,241	$ 3,394	$ 5,476	$ -	$ 1,075	$ 2,302	$ 6,462
Additional costs entire building (current costs)	$ US	$ -	$ 2,238	$ 8,558	$ 27,476	$ -	$ 2,238	$ 4,782	$ 8,418	$ 10,579	$ -	$ 2,238	$ 11,531	$ 13,350	$ 24,689	$ -	$ 2,238	$ 7,923	$ 26,764
Additional costs entire building (future costs)	$ US	$ -	$ 2,149	$ 5,240	$ 13,370	$ -	$ 2,149	$ 3,357	$ 5,522	$ 6,275	$ -	$ 2,149	$ 6,482	$ 6,788	$ 10,951	$ -	$ 2,149	$ 4,605	$ 12,925
Life Cycle Costs (energy&additional capital costs)	$ US/(m²a	$ 22	$ 24	$ 16	$ 19	$ 13	$ 9	$ 7	$ 8	$ 8	$ 18	$ 21	$ 16	$ 13	$ 17	$ 32	$ 28	$ 22	$ 21
Life Cycle Costs (Basis future investment costs)	$ US/(m²a	$ 22	$ 24	$ 14	$ 11	$ 13	$ 9	$ 7	$ 6	$ 6	$ 18	$ 21	$ 14	$ 9	$ 9	$ 32	$ 28	$ 20	$ 13
Wall /Roof insulation	mm	0 / 0	0 / 0	25 / 25	125 / 150	0 / 0	0 / 0	25 / 25	25 / 0	25 / 25	0 / 0	0 / 0	25 / 25	100 / 150	300 / 300	0 / 0	0 / 0	25 / 25	125 / 125
Floor slab insulation	mm	0	0	25	100	0	0	0	0	0	0	0	25	25	225	0	0	25	125
Exterior surface absorption coefficient (exterior walls)	-	Colour paint	Colour paint	White paint	Cool colours	Colour paint	Colour paint	White paint	White paint	Colour paint	White paint	Colour paint	Colour paint	Colour paint	Colour paint	Colour paint	Colour paint	White paint	Cool colours
WINDOWS																			
Window frame: Uf-value	W/(m2K)	5.5	5.5	1.8	0.72	5.5	5.5	5.5	5.5	5.5	5.5	5.5	1.8	1.8	1	5.5	5.5	1.8	0.6
Window glazing: g-value	-	0.87	0.87	0.78	0.3	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.78	0.78	0.78	0.87	0.87	0.78	0.33
Window glazing: Ug-value	W/(m2K)	5.6	5.6	3	0.6	5.6	5.6	5.6	5.6	5.6	5.6	5.6	3	3	1.05	5.6	5.6	3	0.6
Window description		Triple glazing sun protection, PVC	Triple glazing sun protection, PVC	Double glazing insulated, pvc frame	Triple glazing sun protection, PVC	Triple glazing sun protection,	Triple glazing sun protection,	Triple glazing sun protection, PVC	Triple glazing sun protection, PVC	Triple glazing sun protection, PVC	Triple glazing sun protection	Triple glazing sun protection, PVC	Double glazing insulated, pvc frame	Double glazing insulated, pvc frame	Double glazing sun protection	Triple glazing sun protection,	Triple glazing sun protection,	Double glazing insulated, pvc frame	Triple glazing sun protection, PVC
VENTILATION																			
Heat recovery rate	%	0%	0%	0%	90%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	92%
Ventilation type - Pure Extract Air	-	-	-	-	-	-	-	-	x	x	-	-	x	x	x	-	-	-	-
Ventilation type - Balanced PH Ventilation	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	x
SHADING																			
Reduction factor z for temporary sun protection	%	No additional shading	No additional shading	No additional shading	Additional moveable shading	No additional shading	No additional shading	No additional shading	No additional shading	Additional moveable shading	No additional shading	No additional shading	No additional shading	No additional shading	No additional shading	No additional shading	No additional shading	No additional shading	Additional moveable shading
ELECTRICITY & AUX ELECTRICITY	v.e.																		
Percentage of CFLs	%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Household appliances (refrigerator, washing machine, microwave oven, consumer electronics and small appliances)		Regular /bad efficiency appliances	Efficient appliances	Highly efficient appliances	Highly efficient appliances	Regular /bad efficiency appliances	Efficient appliances	Highly efficient appliances	Highly efficient appliances	Highly efficient appliances	Regular /bad efficiency appliances	Efficient appliances	Highly efficient appliances	Highly efficient appliances	Highly efficient appliances	Regular /bad efficiency appliances	Efficient appliances	Highly efficient appliances	Highly efficient appliances
Miscelaneous Auxiliary Electricity (ceiling fan)		Ceiling fan				Ceiling fan					Ceiling fan					Ceiling fan			
SUMMER VENTILATION & COOLING UNITS		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Corresponding air rate for night ventilation (source SummVer	1/h	0.5	0.5	0.5	2.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0	0	0.5	0.5	0	0
Humidity recovery	%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	65%
Anual cooling COP		2.5	3.08	3.08	3.08	2.5	3.08	3.08	3.08	0	2.5	3.08	3.08	0	0	2.5	3.08	3.08	3.08
DHW & SOLAR DHW		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Solar Collector Area	m²	0	2	Fully solar	Fully solar	0	2	2	Fully solar	Fully solar	0	2	2	2	Fully solar	0	2	2	Fully solar

* This calculation is made with an indoor temperature assumption of between 18°C - 28°C only to calculate CO2 emissions. The rest of the results use a comfort range between 20°C - 25°C.

** Although each dwelling unit is thought to be occupied by 4 persons, the value of 2 is taken as an average value, under the assumption that the dwelling unit will not be occupied to it's 100% percent capacity all the time, considering a life cycle of 30

AISLADA

Occupation: 2 persons/unit**		13.3 $MXP/$US																	
Aislada																			
Isolated housing unit. Smallest building type. 38m² TFA		EXTREME HOT DRY				TEMPERATE					TEMPERATE COLD					EXTREME HOT HUMID			
Climate data	-	Aislada Baseline Hermosillo	Aislada EcoCasa 1 Hermosillo	Aislada EcoCasa 2 Hermosillo	Aislada Passive House Hermosillo	Aislada Baseline Guadalajara	Aislada EcoCasa 1 Guadalajara	Aislada EcoCasa 2 Guadalajara	Aislada Passive House Guadalajara	Aislada Passive House Plus Guadalajara	Aislada Baseline Puebla	Aislada EcoCasa 1 Puebla	Aislada EcoCasa 2 Puebla	Aislada Passive House Puebla	Aislada Passive House Plus Puebla	Aislada Baseline Cancun	Aislada EcoCasa 1 Cancun	Aislada EcoCasa 2 Cancun	Aislada Passive House Cancun
Specific Space Heating Demand	kWh/(m²a	102	41	37	2	38	11	2	4	2	187	95	55	15	15	0	0	0	0
Specific Useful Cooling Energy Demand:	kWh/(m²a	408	250	142	15	124	35	18	6	2	72	28	5	1	0	506	306	137	39
Specific Dehumidifictaion Demand:	kWh/(m²a	83	34	14	0	6	0	0	0	0	1	0	0	0	0	189	165	105	30
Cooling load	W/m²	210	131	80	16	23	1	1	0	0	0	0	0	0	0	95	58	29	8
Specific Primary Energy Demand (Indoor temp. 20°C-25°C)	kWh/(m²a	832	387	252	69	348	126	83	58	45	509	244	155	70	70	902	494	275	112
Specific Emissions CO2-Equivalent (Indoor temp. 20°C-25°C)	kg/(m²a)	187	86	57	15	79	28	19	13	10	120	57	37	16	16	198	108	61	25
Specific Primary Energy Demand (Indoor temp. 18°C-28°C)*	kWh/(m²a	443				234					234					573			
Specific Emissions CO2-Equivalent (Indoor temp. 18-28°C)*	kg/(m²a)	99				52					52					126			
Additional Investment costs (entire building)	$ US	$ -	$ 1,290	$ 4,760	$ 17,110	$ -	$ 1,290	$ 4,065	$ 7,283	$ 8,026	$ -	$ 1,290	$ 4,638	$ 9,547	$ 12,060	$ -	$ 1,290	$ 4,949	$ 17,110
Future additional Investment costs (entire building)	$ US	$ -	$ 1,082	$ 2,377	$ 7,532	$ -	$ 1,082	$ 2,427	$ 3,675	$ 3,772	$ -	$ 1,082	$ 2,618	$ 4,279	$ 5,117	$ -	$ 1,082	$ 2,440	$ 7,532
Life Cycle Costs (energy&additional capital costs)	$ US/(m²a	$ 27	$ 26	$ 22	$ 24	$ 15	$ 10	$ 10	$ 12	$ 12	$ 15	$ 21	$ 18	$ 16	$ 19	$ 34	$ 30	$ 22	$ 27
Life Cycle Costs (Basis future investment costs)	$ US/(m²a	$ 27	$ 26	$ 19	$ 13	$ 15	$ 10	$ 8	$ 8	$ 7	$ 15	$ 21	$ 16	$ 10	$ 11	$ 34	$ 30	$ 19	$ 15
Wall /Roof insulation	mm	0 / 0	0 / 25	25 / 25	250 / 300	0 / 0	0 / 25	25 / 25	50 / 100	100 / 175	0 / 0	0 / 25	50 / 50	150 / 275	300 / 300	0 / 0	0 / 25	25 / 25	250 / 200
Floor slab insulation	mm	0	0	25	125	0	0	0	25	50	0	0	25	125	225	0	0	50	225
Exterior surface absorption coefficient (exterior walls)	-	Colour paint	White paint	White paint	Cool colours	Colour paint	White paint	White paint	White paint	White paint	Colour paint	Colour paint	Colour paint	Colour paint	White paint	Colour paint	White paint	White paint	Cool colours
WINDOWS																			
Window frame: Uf-value	W/(m2K)	5.5	5.5	1.8	0.72	5.5	5.5	5.5	1.8	1.8	5.5	5.5	5.5	1.8	1.8	5.5	5.5	1.8	0.72
Window glazing: g-value	-	0.87	0.87	0.78	0.33	0.87	0.87	0.87	0.78	0.78	0.87	0.87	0.87	0.78	0.78	0.87	0.87	0.33	0.33
Window glazing: Ug-value	W/(m2K)	5.6	5.6	3	0.6	5.6	5.6	5.6	3	3	5.6	5.6	5.6	3	3	5.6	5.6	1.05	0.6
Window description		Single glazing, aluminium frame	Single glazing, aluminium frame	Double glazing insulated, pvc frame	Triple glazing sun protection, PVC	Single glazing, aluminium frame	Single glazing, aluminium frame	Single glazing, aluminium frame	Double glazing insulated, pvc frame	Double glazing insulated, pvc frame	Single glazing, aluminium frame	Single glazing, aluminium frame	Single glazing, aluminium frame	Double glazing insulated, pvc frame	Double glazing insulated, pvc frame	Single glazing, aluminium frame	Single glazing, aluminium frame	Double glazing sun protection	Triple glazing sun protection, PVC
VENTILATION																			
Heat recovery rate	%	0%	0%	0%	90%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	92%
Ventilation type - Pure Extract Air	-			-				x	x	x			x	x	x			-	
Ventilation type - Balanced PH Ventilation	-				x				-				-	-					x
SHADING																			
Reduction factor z for temporary sun protection	%	No additional shading	No additional shading	No additional shading	Additional moveable shading	No additional shading	No additional shading	No additional shading	No additional shading	No additional shading	No additional shading	No additional shading	No additional shading	No additional shading	No additional shading	No additional shading	No additional shading	No additional shading	Additional moveable shading
ELECTRICITY & AUX ELECTRICITY	v.e.																		
Percentage of CFLs	%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Household appliances (refrigerator, washing machine, microwave oven, consumer electronics and small appliances)		Regular /bad efficiency appliances	Efficient appliances	Highly efficient appliances	Highly efficient appliances	Regular /bad efficiency appliances	Efficient appliances	Highly efficient appliances	Highly efficient appliances	Highly efficient appliances	Regular /bad efficiency appliances	Efficient appliances	Highly efficient appliances	Highly efficient appliances	Highly efficient appliances	Regular /bad efficiency appliances	Efficient appliances	Highly efficient appliances	Highly efficient appliances
Miscelaneous Auxiliary Electricity (ceiling fan)		Ceiling fan				Ceiling fan					Ceiling fan					Ceiling fan			
SUMMER VENTILATION & COOLING UNITS		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Corresponding air rate for night ventilation (source SummVer	1/h	0.5	0.5	0.5	2.8	0.5	0.5	0.5	1	1	0.5	0.5	0.5	1	1	0.5	0.5	0.5	0
Humidity recovery	%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	65%
Anual cooling COP		2.5	3.08	3.08	3.08	2.5	3.08	3.08	3.08	0	2.5	3.08	3.08	0	0	2.5	3.08	3.08	3.08
DHW & SOLAR DHW		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Solar Collector Area	m²	0	1.5	1.5	Fully solar	0	1.5	1.5	Fully solar	Fully solar	0	1.5	1.5	Fully solar	Fully solar	0	1.5	1.5	Fully solar

* This calculation is made with an indoor temperature assumption of between 18°C - 28°C only to calculate CO2 emissions. The rest of the results use a comfort range between 20°C - 25°C.

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