Supported NAMA for Sustainable Housing in Mexico -Mitigation Actions and Financing Packages-

Gobierno Federal

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Supported NAMA for Sustainable Housing in Mexico - Mitigation Actions and Financing Packages

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Supervision:
CONAVI, SEMARNAT, Mesa Transversal, GIZ: Emmanuel Carballo, Emily Castro, André Eckermann, Jakob Graichen, Andreas Gruner, Rocio Montaña

Authors:
Thomson Reuters Point Carbon: Robert Kaineg
IzN Friedrichsdorf: Georg Kraft, Rolf Seifried, Werner Neuhauss, Heiko Störkel
Passivhaus Institut: Witta Ebel, Susanne Theumer, Maria del Carmen Rivero.
Gopa Consultants: Angelika Stöcklein, Salvador Rodriguez.
Perspectives: Matthias Krey, Stefan Wehner.

Photography: GIZ/(cover)

www.conavi.gob.mx/viviendasustentable

Av. Presidente Masaryk 214, 1er Piso
Col. Bosque de Chapultepec
C.P. 11580, México, D.F.
E-mail: jlwolpert@conavi.gob.mx; tdkotecki@conavi.gob.mx
Tel.: 52 55 91389991
www.conavi.gob.mx

Av. San Jerónimo 458, 3er Piso
Col. Jardines del Pedregal
C.P. 01900, México, D.F.
E-mail: luis.munozcano@semarnat.gob.mx
Tel.: 52 55 54902118
www.semarnat.gob.mx

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List of acronyms and abbreviations

ANFAD	Asociación Nacional de Fabricantes de Aparatos Domésticos (Mexican National Association of Domestic Appliances Manufacturers)
BANOBRAS	Banco Nacional de Obras y Servicios Públicos S.N.C. (Mexican National Bank of Public Works and Services)
BMU	Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit (German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety)
BMZ	Bundesministerium für wirtschaftliche Zusammenarbeit und Entwicklung (Germal Federal Ministry for Economic Cooperation and Development)
CDM	Clean Development Mechanism
CEV	Código de Edificación de la Vivienda (Residential Building Code)
CFL	Compact fluorescent lamp
CONAVI	Comisión Nacional de Vivienda (National Housing Commission in Mexico)
CONUEE	Comisión Nacional para el Uso Eficiente de la Energía
CTF	Clean Technology Fund
CUV	Clave Única de Vivienda (Unique Housing Key)
DIT	Dictamen de Idoneidad Técnico (Technical Suitability Assessment)
DUIS	Desarrollos Urbanos Integrales Sustentables (Integrated Sustainable Urban Developments)
FONADIN	Fondo Nacional de Infraestructura (Mexican National Infrastructure Fund)
FONHAPO	Fondo Nacional de Habitaciones Populares (Mexican National Trust Fund for Popular Housing)
FOVISSSTE	Fondo de la Vivienda del Instituto de Seguridad y Servicios Sociales de los Trabajadores del Estado (Housing Fund of the Institute of Social Security and Services for State Workers)
GHG	Greenhouse gas
IDB	Inter-American Development Bank
INFONAVIT	Instituto del Fondo Nacional de la Vivienda para los Trabajadores (Institute of the National Housing Fund for Workers)

KfW	Kreditanstalt für Wiederaufbau (Germany's leading development bank)
LPG	Liquefied petroleum gas
MEPS	Minimum Energy Performance Standards
MRV	Monitoring, reporting, verification
MXN	Mexican peso
NAFIN	Nacional Financiera, Sociedad Nacional de Crédito (Mexican Development Banking Institution)
NAMA	Nationally Appropriate Mitigation Actions
NOM	Normas Oficiales Mexicanas (Mexican Official Standards)
NMX	Normas Mexicanas (Mexican Voluntary Standards)
OREVI	Organismos Regionales de Vivienda (Regional Housing Agencies)
PDL	Performance-Driven Loan
PECC	Programa Especial de Cambio Climático (Mexico's Special Programme on Climate Change)
PHI	Passive House Institute
PHPP	Passive House Planning Package
PNV	Programa Nacional de Vivienda (Mexican National Housing Programme)
PoA	Programme of Activities
PRONASE	Programa Nacional de Aprovechamiento Sustentable de la Energía (National Programme for the Sustainable Use of Energy)
RUV	Registro Único de Vivienda (Unified Housing Registry)
SHF	Sociedad Hipotecaria Federal (Mexican Federal Mortgage Company)
SOFOLES	Sociedades Financieras de Objeto Limitado (Limited Purpose Financial Institutions)
SOFOMES	Sociedades Financieras de Objeto Múltiple (Multiple Purpose Financial Institutions)

Exchange rates (11/2012)

1 MXN	=	0.06	EUR	=	0.07	USD
1 EUR	=	1.27	USD	=	16.50	MXN
1 USD	=	0.78	EUR	=	13.00	MXN

Source: Yahoo Finance (accessed 17.11.12)

Executive Summary

Nationally Appropriate Mitigation Actions (NAMA) are emerging market mechanisms that enable developing economies to align sustainable development with national economic priorities.

Mexico's Sustainable Housing NAMA is the first of its kind in the world. The NAMA mitigates emissions in the residential sector by providing supplemental finance to improve electrical, fossil fuel, and water efficiency. These improvements are achieved through deployment of eco-technologies, proliferation of design improvements, and utilization of efficient building materials.

In 2012, Mexico took important steps to advance sustainable development in the residential sector through technical capacity building, development of pilot projects, and coordinating key stakeholders in the Multilateral Committee on Sustainable Housing in Mexico (Mesa Transversal). The result has been strong progress towards deployment of the Sustainable Housing NAMA as presented by Mexico at COP 17 in Durban, South Africa. Progress has been achieved in key areas:

1. Development of simulation software and common parameters in coordination with domestic and international stakeholders
2. Development of an MRV methodology and implementation of supporting institutional frameworks and responsibilities
3. Launching pilot projects across Mexico
4. Capacity building with industrial partners and local governments
5. Development of financial models to support NAMA deployment
6. Development of a NAMA database to track progress and performance

The NAMA discussed in this document is just one of the many mechanisms being developed in Mexico to promote sustainable housing.[1]

What is the Mexican Housing NAMA?

Mexico has already taken unilateral action in the residential sector through programmes such as 'Hipoteca Verde' (*'Green Mortgage'*) and 'Ésta es tu casa' (*'This is your house'*). Both programs provide supplemental finance to cover the incremental cost of energy-efficient appliances in new homes. Furthermore, Mexico has engaged international support through developing programmatic CDM activities (PoA) to channel carbon finance towards the sustainable housing sector.

The Sustainable Housing NAMA concept, after developing the technical, MRV and financial concept, has already entered to the pilot phase. The NAMA extends and expands the scope of the on-going programmes by increasing the number of energy-efficient homes built and improving their emissions performance. To this end, Mexico and its partners[2] have developed three performance benchmarks that residential building developers can achieve, and for which home-owners can receive support. In order of increasingly aggressive efficiency standards, they are Eco Casa 1, Eco Casa 2, and the Eco Casa Max.

Unlike the previous Mexican programmes, which have focused on promoting and measuring the impact of specific eco-technologies, the NAMA approaches building efficiency from a 'whole house' approach. From this perspective, efficiency benchmarks are set for total primary energy demand based on building type and climate. Building developers and home-owners are then able to employ any combination of interventions that achieve the targeted efficiency level.

[1] www.conavi.gob.mx

[2] The Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH (German Development Cooperation) has supported the development of this NAMA on behalf of the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU). Environment Canada, The United Kingdom, and numerous development banks have also provided technical and financial support.

Such an approach has numerous benefits. It enables a simple and cost-efficient MRV system that captures the net efficiency improvements of a broad range of eco-technologies, building design, and building materials. It also enables stakeholders to find the most cost-efficient combination of these features, instead of the government 'picking winners'. Furthermore, the tiered benchmark approach enables donors to target specific activities that align with their development priorities, and provides flexibility for regulators to increase the stringency of the programme over time.

The efficiency levels of the Sustainable Housing NAMA will be coordinated with a graded labelling system to inform home buyers of the expected house performance. The label will clearly illustrate the level of efficiency, as well as the expected savings in terms of power, water, fuel and emissions compared to a reference home. This information can be used by the buyer to factor the long term cost savings into the purchasing decision.

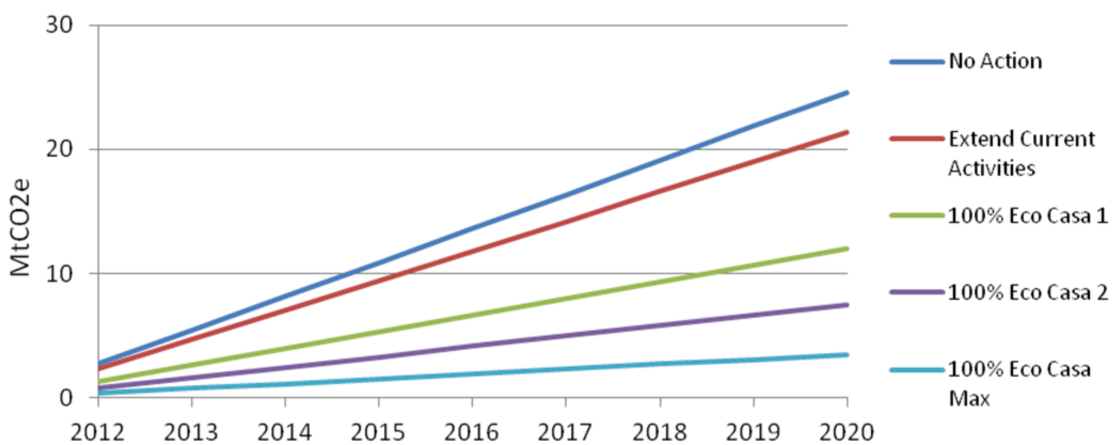
Programme Potential

Taking into account demographic growth rates, Mexico is expected to have an estimated 121 million inhabitants by 2050. It is estimated that Mexico will need to build around 600,000 new homes per year over the coming decade. Due the long life-cycle of buildings, investments made now in sustainable development will pay dividends for decades to come, from both an economic and environmental perspective. This section will indicate the extent of the opportunities the NAMA presents and the potential efficiency gains that can be achieved.

<u>Size of the opportunity</u>

Growth in the residential sector is fuelled by demographic pressure as the country's population grows, as well as the increasing affluence of the less economically advantaged Mexican population. Between now and 2020, nearly 5 million new housing units will be constructed, contributing as much as 25 Mt CO_2e of Greenhouse Gas (GHG) emissions to the country's carbon footprint in 2020.

Figure 1: Emissions from newly built houses in Mexico under select mitigation scenarios



Source: Point Carbon Thomson Reuters

<u>Efficiency potential of the NAMA programme</u>

The German Passive House Institute (PHI) has calculated the 'whole house' energy balance for Mexico, which is scalable by unit size, based on the climate zones of the country, for three unit types: single-family detached, single-family row house, and vertical multi-family. Three primary energy target values or 'standards': Eco Casa 1, Eco Casa 2 and Eco Casa Max Standard, have also been developed for each building type and climate zone.

- Eco Casa 1 represents the level of efficiency if all of the supported technologies under the current Green Mortgage scheme are adopted. This is equivalent to the level of energy efficiency achieved if 2.5cm of insulation are installed in the roof and a single wall, reflective paint, a tankless water boiler, solar water heater and an efficient A/C unit are installed.

- Eco Casa 2 represents a further level of efficiency achieved by insulating all walls, installing better windows and highly efficient appliances.
- The Eco Casa Max Standard envisages optimization of all measures to achieve the Eco Casa Max certification criteria, including extended overhangs, extensive insulation, and other design features to achieve reduction in primary energy demand.

Table 1: Annual emissions avoided in a 40m^2 house by building type and climate zone, tCO_2e

Single & Row House	Hot & Dry Climate	Hot & Humid Climate	Temperate Climate	Semi-Cold Climate
Eco Casa 1	2.0	2.0	0.8	0.8
Eco Casa 2	2.7	3.5	0.9	0.8
Eco Casa Max	3.0	4.0	1.0	1.0
Vertical (multi-family)				
Eco Casa 1	1.7	2.0	0.9	0.8
Eco Casa 2	2.2	2.7	1.2	1.0
Eco Casa Max	2.6	4.0	1.2	1.1

Source: Passive House Institute

The technical options outlined above are for descriptive purposes only; home-owners do not need to install all of the above technologies. To be eligible for NAMA funding, stakeholders must reach the level of energy efficiency that these technologies represent, but may use any combination of features. In other words, eligibility is determined by the overall energy performance of the house, not the specific technologies used.

Expected Results and Next Steps

Existing sustainable housing programmes in Mexico support only a limited segment of the newly built housing market, and efficiency levels achieved approach the Eco Casa 1 standard outlined above. The NAMA is a key instrument that the Mexican government is developing to scale up existing initiatives, both in terms of market penetration and level of efficiency. That could result in an additional 2 million tonnes of CO_2 emissions avoided per year.

In order to achieve the desired level of penetration and up-scaling, additional funds are needed beyond what the Mexican government can unilaterally provide. Carbon finance and international donors have a key role to play, and their involvement in the NAMA can be used to leverage private investment, a critical source of funds if the program is to achieve its full potential.

This NAMA creates the technical guidelines, financial structures, and reporting infrastructure needed to attract and leverage additional funding in support of sustainable development. Donors and investors interested can get involved with this NAMA through a range of options from supporting both direct actions (homes with a certain efficiency standard) and indirect (technical and institutional capacity building) ones.

A major milestone has been reached in 2012 through the implementation of pilot projects consisting of around 4,600 affordable housing units in 11 cities located in five of the seven identified bioclimatic regions, and involve seven different housing developers and OREVIs. The homes are of different types and present various design features, materials, and eco-technologies. The pilots offer an opportunity for local governments, developers, and international donors to demonstrate the value of the Sustainable Housing NAMA concept. Furthermore, empirical performance data will be collected that can be used to calibrate the simulation models and inform policy and financing decisions.

Financing the NAMA

For donors and investors interested in directly supporting new energy efficiency homes, a 'NAMA Fund' is being set up as the recipient of donor funds, whether as soft loans or as grants. While this fund is being implemented, donors can partner directly with CONAVI and optimal resource allocation will be decided by the Mesa Transversal. Funding provided for the NAMA is channelled to both the supply and demand side of the housing market. Bridge loans are provided or underwritten for housing developers to support the construction phase, and subsidies or soft loans are offered home buyers to incentivize purchase of the NAMA homes.

Table 2: Examples of financial packages for donor support

Packages				Financing Need			Benefits
Financial packages	Scale of the package	Content of the package		Subsidies to Home-owners, USD million		Total incremental construction cost USD million	Emission reductions over 30 yrs lifetime, tCO_2
		Mainstream roll-out	Eco Casa Max Pilot	Mainstream roll-out	Eco Casa Max Pilot		
Package 1	Large Scale (27,000 homes)	EcoCasas 1 & 2, 40 and 70m^2	30 buildings of 40m^2	49	0,2	165	1,711,000
Package 2	Mid-Size (13,800 homes)	EcoCasas 1 & 2, 40 and 70m^2	30 buildings of 40m^2	25	0,2	84	866,000
Package 3	Small Scale (5,200 homes)	EcoCasas 1 & 2, 40 and 70m^2	30 buildings of 70m^2	9	0,3	27	311,000
Package 4	Multi-Family (14,940 apartments)	EcoCasas 1 &2, 40 and 70m^2	780 verticals, 40 and 70m^2	27	3	94	865,000
Package 5	Eco Casa Max Pilot (890 homes)	890 Mexican Eco Casa Max (different types)		-	6	12	87,000

Source: IzN Friedrichsdorf

Donors wishing to provide indirect support can provide critical funding that will enable administrative and supportive actions directly to the Mexican government, or via bilateral cooperation initiatives. These include capacity building at the federal and local level, providing professional training services to regulators and verifiers, and establishment and maintenance of monitoring and reporting frameworks. It is estimated that approximately USD 12 million in grant financing will be needed between 2012 and 2016 to fund 'indirect' NAMA mitigation actions.

As the example packages illustrate, donors will have significant flexibility to scale the level (number of units) and type (Eco Casa 1, Eco Casa 2, and Eco Casa Max) of support, as well as to target their donations towards both direct and/or indirect measures, as per their needs, mandate, and preferences.

Table 3: Main elements of Sustainable Housing NAMA design

Item	Description
Sector	Building sector
Sub-sector	New residential houses (1st phase), primarily for low-income families, potentially for middle income housing

NAMA boundary	Entire country
Measures and activities with direct impact on GHG emission reduction	Introduction of a class of ambitious primary energy consumption benchmarks. The construction of houses according to the benchmark level is incentivized by a scaled-up financial promotion system
Measures and activities with indirect impact on GHG emission reduction	Supportive actions for NAMA implementation, operation and support of the wider transformational process in the residential building sector: introduction of energy performance requirements in the legal system and permitting process, training of planners, architects, energy advisors and manufactures, creation of model projects
Non-GHG co-benefits	In addition to reducing GHGs the Sustainable Housing NAMA will provide numerous benefits to Mexican society, including; economic savings for households, reduction in electric subsidies, creation of green jobs, improved air quality, improved comfort and health of living spaces.
NAMA timeframe	- preparation: 2010-2011 - implementation: 2012-2016 (first phase), - second phase to be scheduled
NAMA roll-out schedules	- 2012 and 2013: focus nearly exclusively on Eco Casa 1 - 2014 and 2015 some Eco Casa 2 houses envisaged. - Eco Casa Max are considered in limited numbers as pilot projects.
NAMA operation costs (supportive measures)	USD 11 650 000
NAMA type	NAMA framework consisting of unilateral and supported components
Type of support required under the NAMA	Financial, technical and capacity building

Source: Point Carbon Thomson Reuters and Perspectives

1 Introduction

Nationally Appropriate Mitigation Actions (NAMAs) are emerging market mechanisms that enable developing economies to align sustainable development with national economic and strategic priorities.

Mexico's Sustainable Housing NAMA is the first of its kind in the world. The NAMA mitigates emissions in the residential sector by providing supplemental finance to improve electrical, fossil fuel, and water efficiency. These improvements are achieved through deployment of eco-technologies, proliferation of design improvements, and utilization of efficient building materials.

In 2012, Mexico took important steps to advance sustainable development in the residential sector through technical capacity building, development of pilot projects, and coordinating key stakeholders in the 'Mesa Transversal'. The result has been strong progress towards deployment of the Sustainable Housing NAMA as presented by Mexico at COP 17 in Durban South Africa.

The NAMA discussed in this document is just one of the many mechanisms being developed in Mexico to promote sustainable housing.[3] Mexico has already taken unilateral action in the residential sector through programmes such as 'Hipoteca Verde' (*'Green Mortgage'*) and 'Ésta es tu casa' (*'This is your house'*). Both programs provide supplemental finance to cover the incremental cost of energy-efficient appliances in new homes. Furthermore, Mexico has engaged international support through developing programmatic CDM activities (PoA) to channel carbon finance towards the sustainable housing sector.

However, such programmes support only a limited segment of the newly built housing market and achieve only modest levels of efficiency. The Sustainable Housing NAMA concept, now in the pilot phase, extends and expands the scope of these activities by increasing number of energy-efficient homes built and improving their emissions performance.

To this end, Mexico and its partners[4] have developed three performance benchmarks that residential building developers can achieve, and for home-owners can receive support. In order of increasingly aggressive efficiency standards, they are Eco Casa 1, Eco Casa 2, and the Eco Casa Max.

Unlike the previous Mexican programmes, which have focused on promoting and measuring the impact of specific eco-technologies, the NAMA approaches building efficiency from a 'whole house' approach. From this perspective, efficiency benchmarks are set for total primary energy demand based on building type and climate. Building developers and home-owners are then able to employ any combination of interventions that achieve the target efficiency level. Furthermore, homeowners will be able to compare homes based on long energy and water efficiency through the energy labelling system. This will enable potential buyers to weight the upfront cost of the home with the long term cost savings.

Such an approach has numerous benefits. It enables a simple and cost-efficient MRV system that captures the net efficiency improvements of a broad range of eco-technologies, building design, and building materials. It also enables stakeholders to find the most cost-efficient combination of these features, instead of the government 'picking winners'. Furthermore, the tiered benchmark approach enables donors to target specific activities that align with their development priorities, and provides flexibility for regulators should they seek to increase the stringency of the programme over time.

In order to achieve the desired level of penetration and up-scaling, additional funds are needed beyond what the Mexican government can provide unilaterally. Carbon finance and international donors have a key role to play, and their involvement in the NAMA can be used to leverage private investment, a critical source of funds if the programme is to achieve its full potential.

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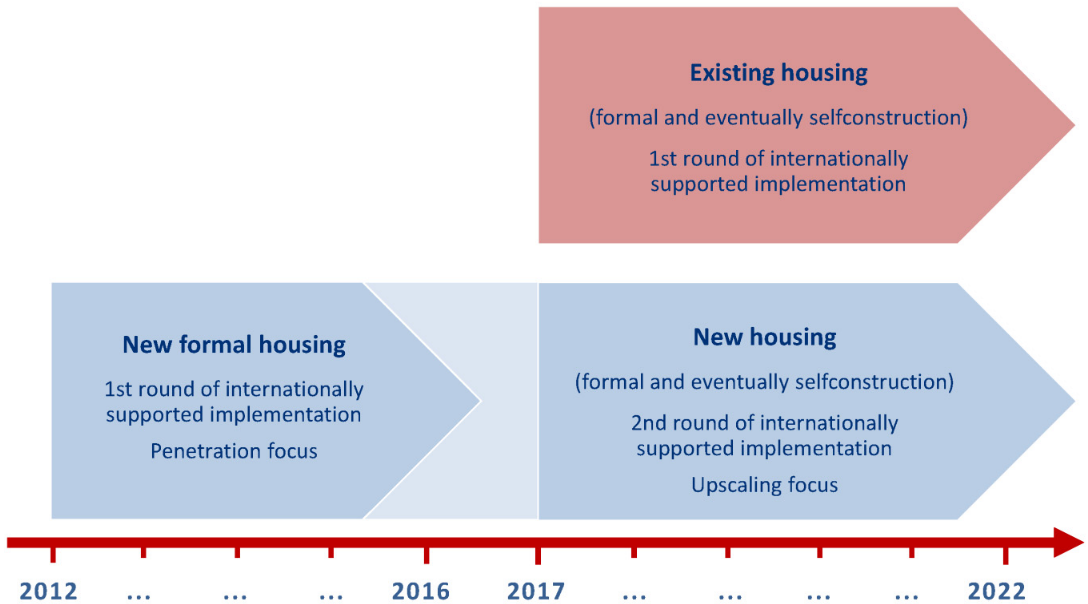
[3] www.conavi.gob.mx

[4] The Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH (German Development Cooperation) has supported the development of this NAMA on behalf of the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU). Environment Canada, The United Kingdom, and numerous development banks have also provided technical and financial support.

This NAMA creates the technical guidelines, financial structures, and reporting infrastructure needed to attract and leverage additional funding in support of sustainable development. Donors and investors interested can get involved with this NAMA through a range of options from supporting both direct actions (homes with a certain efficiency standard) and indirect (technical and institutional capacity building) ones.

Figure 2: Phase-in schedule of the Mexican Sustainable Housing NAMA



Source: GIZ

Mexico envisages the NAMA as a long-term initiative, beginning with a focus on new housing and eventually expanding to promote efficiency in the existing housing stock. The first concept for retrofit of existing homes will be presented at the COP 18 end of 2012 in Doha, and will build on the progress achieved by the Sustainable Housing NAMA.

In the first phase of the Sustainable Housing NAMA, Mexico will enhance GHG reductions by expanding the 'Green Mortgage' and 'Ésta es tu casa' programmes. As a second phase, in the medium to long term, it is envisioned that there will be a consolidation of the voluntary programmes and mandatory building codes and incentive programs, further decreasing emissions from new urban development.

The following steps define the incremental enhancement that the NAMA described in this report will achieve:

- increased penetration (more houses covered during the same time) and/or
- technology choice and up-scaling (more ambitious efficiency standards and/or inclusion of technologies currently not covered).

This report will provide an in-depth description of the NAMA concept, describe its impact on Mexico's emissions profile, discuss barriers to implementation, and explain how Mexico's actions in 2012 have advanced the deployment of the residential efficiency NAMA.

2 Overview of the Mexican housing sector

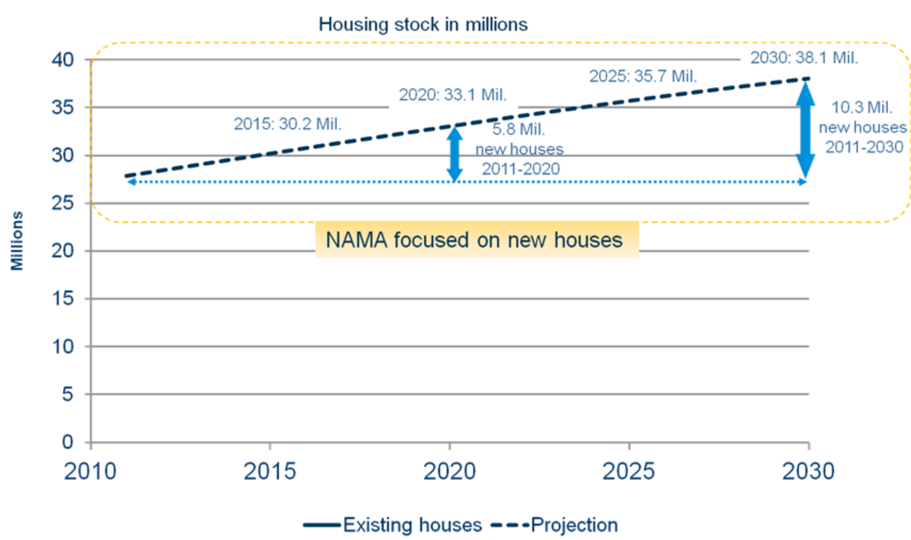
2.1 The relevance of the housing sector

Taking into account demographic growth rates, Mexico will have an estimated 121 million inhabitants by 2050. By the third decade of this century, Mexico will have nearly 40 million households. It is estimated that this will require the construction of nearly 11 million new houses between now and 2030; and an additional 9 million homes will require partial or total refurbishment in the same period.

In the context of controlling emissions growth and achieving economic targets, the residential sector has been identified by the Mexican government as a key opportunity to address national growth and development needs in a sustainable and responsible manner. Residential houses are responsible for approximately 7% of the national greenhouse gas emissions in Mexico, representing 49 Mt CO_2 per year. The long life-cycle of a residential house – minimum 30 years – contributes to the high potential for mitigation of greenhouse gas emissions in the residential sector. Regulators, developers, and financial institutions now have an opportunity to change homeowner incentives and building standards to include and promote the deployment of energy-efficient technologies, including ‘passive’ design features, and reduce total building energy consumption.

The action in the residential sector is part of a broader Mexican initiative to promote sustainable urban development, which includes unilateral actions, programmatic CDM activities and NAMA projects. The goal is to begin with newly constructed homes, and then expand the programme to existing housing, holistically including transportation, water, waste, land use and other critical urban services.[5]

Figure 3: Projected growth of the Mexican housing sector



Source: CONAVI. 2010

2.2 Housing market players and their linkages

The Mexican housing sector includes a range of key players, including public sector financiers, private financial institutions, housing developers and consumers. There are also two distinct market segments: the mortgage market, which serves the individual home-owners; and the developers’ market, which finances building developers and construction firms.

The efforts in the residential sector are being coordinated by CONAVI, as described by the housing law. CONAVI has been working to institutionalize responsibilities and efforts in order to implement sustainable housing as a policy. This work has been organized through the “Mesa Transversal”, a Multilateral Committee on sustainable housing in

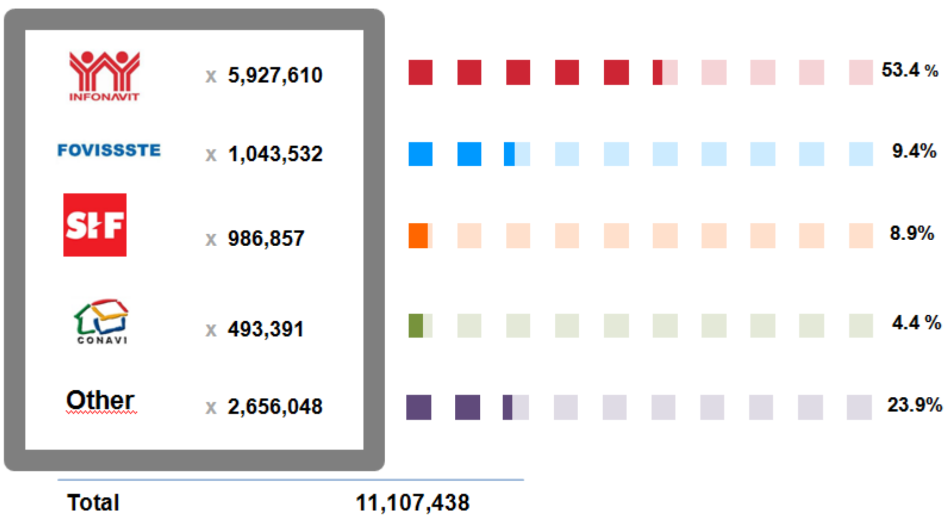
[5] For further details on the Mexico’s strategy in the housing sector, see *Sustainable Housing in Mexico*, CONAVI, November 2011.

México introduced and lead by CONAVI in 2012. The Mesa Transversal is a group of experts from domestic and international institutions from the industrial, regulatory and academic spheres interested in sustainable housing development that participate in regular coordination meetings. This committee not only shares resource, but coordinates action to avoid potential problems, incompatible designs, and overlaps.

The mortgage market is dominated by two large public housing funds, both over 30 years old, which provide long-term saving schemes based on mandatory contributions. The Institute of the National Housing Fund for Workers (Instituto del Fondo Nacional de la Vivienda para los Trabajadores, INFONAVIT) serves employees in the private sector, and the Housing Fund of the Institute of Social Security and Services for State Workers (Fondo de la Vivienda del Instituto de Seguridad y Servicios Sociales de los Trabajadores del Estado, FOVISSSTE) serves public sector employees. Both collect 5% of employees' salaries, withheld at source by the employer, through individual savings accounts. The Federal Mortgage Society (Sociedad Hipotecaria Federal, SHF) is a government-owned mortgage development bank and acts as a secondary mortgage market facility.

In addition to supplying home mortgages, federal institutions also provide public subsidies directly to low income home buyers through the National Housing Commission (Comisión Nacional de Vivienda, CONAVI) and National Trust Fund for Popular Housing (Fondo Nacional de Habitaciones Populares, FONHAPO).

Figure 4: Number of New Housing Finance Credits by Select Institutions in Mexico 1973-2012[6]

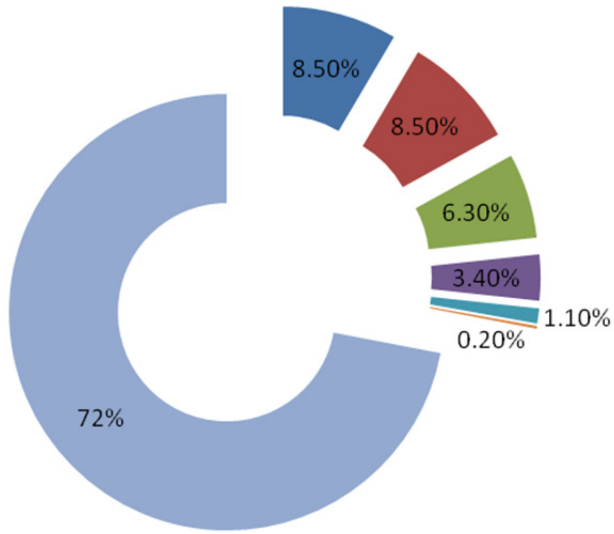


Source: CONAVI (graphic, Rosalba Cruz), 2012

Residential development is a robust and competitive business in Mexico. There were approximately ten big housing developers and around 2,000 small developers actively constructing housing units in 2010.

[6] CONAVI 2011

Figure 5: Residential market share of newly built units by developers in Mexico 2010[7]



Source: CONAVI, 2011

All new homes are registered before construction begins, and tracked until the homes are sold by the Registry of Housing Supply (Registro Único de Vivienda, RUV). RUV reflects the total number, characteristics, and location of new homes built and financed through individual mortgages granted by INFONAVIT and FOVISSSTE.

2.3 Finance for the Mexican housing sector

Mexico's financial reforms and capacity-building efforts over the past decade have solidified and stabilized the financial sector, as demonstrated during the recent global financial crisis. The limited exposure to foreign-currency risk, relatively low reliance on wholesale funding and strong liquidity left Mexican commercial banks in a comfortable position for coping with negative fallout from the European financial crisis. As a precautionary measure, Mexican authorities have tightened regulations and supervision of subsidiaries of foreign banks, including limits on dividend distribution (to avoid erosion of capital) and related party lending.

The mortgage sector is segmented according to whether the individual is a public or private worker and by the overall value of the mortgage. INFONAVIT and FOVISSSTE channel mandatory contributions into direct residential mortgage loans to their members. INFONAVIT is responsible for providing mortgages to private-sector employees, and FOVISSSTE serves employees in the public sector.

The majority of mortgages in the country originate from these two institutions, particularly INFONAVIT which in 2010 alone financed around 475,000 houses. Together INFONAVIT (loan portfolio USD 47 bn) and FOVISSSTE (loan portfolio USD9 bn) make up around two thirds of the mortgage market. INFONAVIT is also currently the only bank that financially incentivizes energy-efficient building practices through the Green Mortgage programme, which was initiated in 2007 to improve efficiency in air conditioning, lighting and water heaters.

Commercial banks also provide funding to the housing sector; their share is around a quarter of the total mortgage loan portfolio. They have managed to increase their participation in the market providing co-financing to INFONAVIT and FOVISSSTE. Commercial banks also serve housing developers by providing bridge loans to fund new housing developments.

Limited Purpose Financial Institutions (Sociedades Financieras de Objeto Limitado, SOFOLES) and Multiple Purpose Financial Institutions (Sociedades Financieras de Objeto Múltiple, SOFOMES) are private non-bank lending institutions licensed to lend to particular sectors. SOFOLES and SOFOMES play a large role in lending to consumers

7 CONAVI 2011

who are not covered by INFONAVIT and FOVISSSTE or who seek to finance a mortgage with a higher value than the maximum amount offered by the public institutions. SHF, as a secondary mortgage market facility, does not lend directly to home buyers, but lends to institutions that specialize in the mortgage sector. SHF provides lending to SOFOLES and SOFOMES, as well as microfinance institutions. SHF also capitalizes housing lenders, in particular SOFOLES and SOFOMES, as several of them have run into financial difficulties.

For housing developers, funding primarily originates from private sector banks, the stock market and SOFOLES.

2.4 Mexican housing policy in the context of climate

In support of the goals of the 2007–2012 National Development Plan (*Plan Nacional de Desarrollo*), in 2007 CONAVI initiated the National Housing Programme (*Programa Nacional de Vivienda*, PNV) for 2008-12, 'Toward Sustainable Housing Development'. The PNV sets out an aggressive plan to construct six million homes by 2012, one million of which are to be sustainable. PNV has four major objectives:

(1) Increase access to home financing for the population, particularly low-income families
(2) Promote sustainable housing development.
(3) Consolidate the national housing system through improvements in public management
(4) Consolidate Federal Government support for sustainable housing finance in the low-income population.

Environmental sustainability is a clear priority for the Mexican government and CONAVI. The PNV promotes the dissemination of eco-technologies, in addition to the development and implementation of norms and regulations standardizing green housing options with the goal of moving toward high-quality, environmentally sustainable housing.

PNV also promotes green mortgages and subsidies, as described in section 2.5. Through PNV, CONAVI has also initiated several pilot training programmes designed to raise general awareness of the benefits of sustainable housing.

Climate Change Policy

Mexico has already taken action to address climate change and reduce growth in GHG emissions. Two key initiatives in this regard are the PECC initiated in 2009, and the General Law on Climate Change, which came into effect on October 10, 2012.

The PECC having successfully completed its 2009-2012 phase, has for 2013-2020 laid out a plan to reduce emissions by more than 125 Million tons per year by 2020 from a business as usual projection of nearly 880 million tons. This ambitious agenda will be enacted through efficiency improvements, land-use, and renewable deployment across many economic sectors.

The General Law on Climate Change creates a legislative mandate to transition towards a competitive, sustainable economy with low carbon emissions that generates environmental, social and economic benefits. The law calls for the establishment of a National Policy for Mitigation of Climate Change to promote health and safety in the population through control and reduction of emissions. The law also provides for adaptation actions in the environmental ordinance of territory, human settlings and urban areas and identifies demand reduction, e.g. efficiency, as the preferred course of action.

The General Law on Climate Change also establishes a Fund for the purpose of collecting and channelling public and private resources from both national and international sources to support the implementation of actions to confront climate change. The fund can be capitalized by federal and public funds, donations, contributions by foreign governments and international NGOs, non-compliance penalties, and the value of emissions reductions generated within Mexico.

The Sustainable Housing NAMA is aligned with and complementary to both the PECC and Climate Change Law. The Fund described in the Climate Change Law could be used to fund technology deployment and capacity building. Furthermore, the implementation of the NAMA would advance key goals laid out in the Law, including:

- Promotion of sustainable production and consumption patterns across the economy
- Promotion of energy efficiency practices, particularly in real estate and assets of agencies and entities operated by federal, state, and local governments
- Drafting, executing, and complying with urban development plans that comprise energy efficiency and mitigation criteria for direct and indirect emissions
- Issuing regulatory provisions to regulate the construction of sustainable buildings, including the use of environmentally friendly materials and energy efficiency

Energy efficiency in the Building Code

CONAVI has developed a comprehensive voluntary building code (Código de Edificación de la Vivienda, CEV) that includes energy efficiency and sustainability guidelines for residential buildings. However, CONAVI is a federal agency, building standards and codes are established and enforced at the state and local level. Thus the agency cannot force the adoption and implementation of its recommendations. Therefore, CEV serves only as a model code at present. To support their adoption CONAVI, INFONAVIT, and SHF operate the "fondo de competitividad", a fund allocated to promote sustainable codes and urban development programmes.

The current Minimum Energy Performance Standards (MEPS) in Mexico correspond to the Normas Oficiales Mexicanas (NOM), which are mandatory, and the Normas Mexicanas (NMX), which are voluntary. In 2009, the National Programme for the Sustainable Use of Energy (Programa Nacional de Aprovechamiento Sustentable de la Energía, PRONASE), set a target to include all current NOMs into local building codes by 2012. In addition PRONASE are promoting the standard installation of thermal insulation for homes in relevant climatic areas. The Mexican Energy Efficiency Agency CONUEE also supports implementation of the MEPS and installation of thermal insulation. The current mandatory norms related to energy efficient housing are:

- Thermal Insulation Standard, NOM-018-ENER-1997
- Residential Building Envelope Standard, NOM-020-ENER-2011
- Phase-out of inefficient (incandescent) lamps, NOM-028-ENER-2010
- Energy efficiency standards for household appliances (some 20 standards).

Despite these initiatives, there is a low rate of adoption of MEPS into the building codes on state and municipal level. Even when the MEPS are included, monitoring and enforcement of the efficiency standards is insufficient. Therefore, there is a need to broaden the coverage of energy efficiency in the building code and increase oversight and application, one of the NAMA objectives.

Fondo de competitividad, funds allocated by CONAVI INFONAVIT and SHF in order to promote sustainable codes and urban development programs.

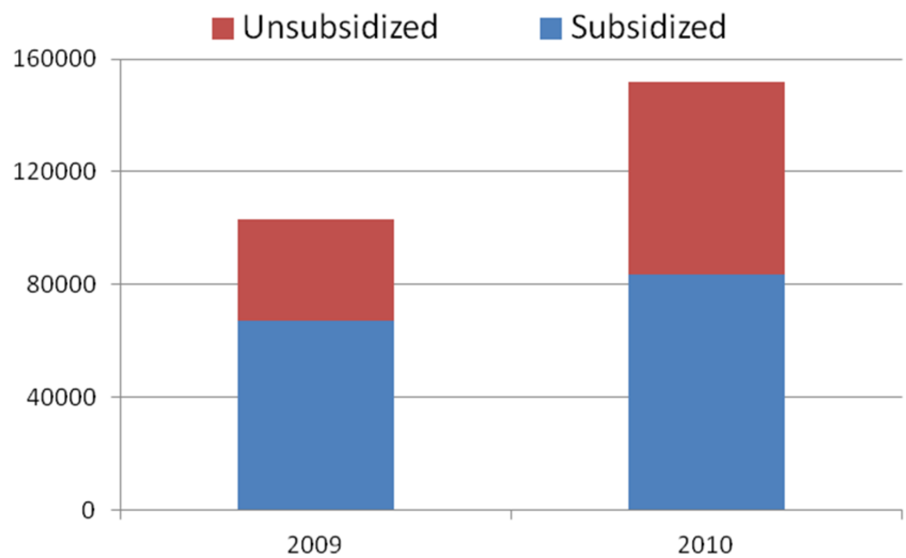
2.5 Mexican initiatives for sustainable energy in the housing sector

In addition to proposing building codes, CONAVI has developed policies and programmes to develop market conditions in support of the weaker sections of Mexican society. Its programme 'Ésta es tu casa'[8] provides a federal subsidy to lower-income families to improve their homes energy efficiency. Under 'Ésta es tu casa', CONAVI provides subsidies to housing developers in order to lower the mortgage debt incurred by home buyers. To be eligible, developers must achieve a set of minimum energy efficiency criteria. CONAVI's subsidies are linked to

[8] http://www.conavi.gob.mx/programas-estrategicos/tu-casa

energy efficient measures promoting sustainable housing developments. The volume of subsidies allocated in 2011 is expected to reach 376 million USD, with 677 million USD planned for 2012.

Figure 5: Number of green mortgages offered by INFONAVIT, 2009-2010



Source: CONAVI 2010

INFONAVIT offers 'green mortgages' that provide additional mortgage credit to INFONAVIT members buying new houses that incorporate sustainable and energy-efficient technologies; such as solar water heaters, CFLs, water-saving taps and thermal insulation, among others.[9]

2.6 International cooperation with the Mexican housing sector

Increasingly, Mexico has been able to attract international support for its national sustainability programmes in the housing sector.

The World Bank and the Inter-American Development Bank (IDB) have agreed to support various initiatives in Mexico that address climate change. To date, their support has focused on strengthening the national authorities' efforts to reduce Mexico's carbon footprint, and promoting the installation of energy-efficient lighting and home appliances.

The World Bank is not directly financing green housing. Instead, the group has contributed USD 1 bn to SHF, which capitalizes other housing lenders, and is considering an additional USD 1 bn to that organization. It has supporting the increased deployment of renewable energy (such as wind energy) and promoting the installation of energy-efficient lighting, home appliances and other electric equipment through USD 250m financing from the Clean Technology Fund (CTF). The Bank also supports regulatory reforms under the Mexican Special Programme on Climate Change (PECC),initiated by the Mexican government, through a USD 401m Low Carbon Performance-Driven Loan (PDL).

In addition to supporting SHF with USD 2.5 bn, the IDB is working with KfW to support the ECOCASA programme, discussed below, with a USD 50m CTF loan and USD 50m direct IDB loan. Moreover, the IDB intends to grant SHF an additional USD 50m CTF loan in order to give housing developers and construction companies an incentive to design and produce energy-efficient houses.

[9] http://portal.infonavit.org.mx/wps/portal/OFERENTES%20DE%20VIVIENDA/Cual%20es%20tu%20actividad/Desarrollar%20vivienda/hipoteca%20verde

The German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) has made funding available through INFONAVIT for sustainable housing in Mexico. Modelled on the successful German Market Incentive programme, subsidies are awarded to cover a part of the investment cost for up to 25,000 solar water heaters installed between 2009 and 2012. These incentives were offered through the Green Mortgage programme and demonstrate how international donors and investors can induce the scale up and penetration of energy-efficient technology through support of existing initiatives.[10]

Traditional sources of carbon finance are getting involved in the Mexican housing sector through the Programme of Activities (PoA) mechanism. The housing PoA, which is still pending registration by the UNFCCC, promotes small-scale activities to provide subsidies and/or increased loans for the purchase of homes that use energy-efficient and/or renewable energy technologies to reduce GHG emissions and generate carbon credits.

2.6.1 Supporting Actions Specific to the Sustainable Housing NAMA

In addition to the general support for sustainable residential development in Mexico, outlined above, there are many initiatives targeting the Sustainable Housing NAMA specifically. This section covers the many co-financing efforts already providing support to the Sustainable Housing NAMA.

ECOCASA Programme
approx. EUR 168 million, 2012-2019

The ECOCASA Programme is currently the largest effort directly supporting the government of Mexico's efforts to develop a sustainable housing sector. The Programme combines funding from BMZ, KfW, the CTF, the IDB, and the Latin American Investment Facility (LAIF) of the European Commission.

The ECOCASA Programme is a partnership with SHF that offers financial incentives for project developers, such as low cost bridge loans, in addition to providing green mortgages and grants to home buyers. The current investment goal is some 27,000 Eco Casa 1 houses and 800 Eco Casa Max homes.

ECOCASA also funds technical capacity building through a joint programme with SHF that provides training and guidance to housing developers.

Sustainable Energy Programme for Mexico
EUR 7 million, 2009-2013 and EUR 6 million, 2013-2017

GIZ and GOPA continue to provide technical assistance to CONAVI, INFONAVIT, SENER and CONUEE on the topic of sustainable energy in the housing sector. This work has been conducted under the Sustainable Energy Programme financed by the German Federal Ministry for Economic Cooperation and Development (BMZ). The programme has multiple capacity development objectives:

- developing a classification system for energy and water performance (Sistema de Evaluación de Vivienda Verde, SISEVIVE)in INFONAVIT financed houses;
- improving the efficiency level and penetration of the Green Mortgage programme;
- implementing sustainable energy guidelines in building codes at the state and municipal levels;
- developing a benchmarking system for administrative buildings; and,
- providing training for local authority in sustainable housing and energy efficient building regulations.

[10] For more details see www.infonavit.org.mx.

Mexican German Programme for NAMA
EUR 7 million, 2011-2015

The German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) has commissioned GIZ to support the development of Mexico's NAMAs more generally under the Mexican–German Programme for NAMA (ProNAMA).

ProNAMA's goal is to support SEMARNAT and CONAVI develop large-scale NAMAs to reduce GHG emissions in the residential building sector, small and medium enterprises, and road freight business with focus on small private enterprises ("hombres-camión"). To achieve this goal, GIZ and partner organizations support the development of the technical designs and MRV systems for these NAMAs, including institutional and technical capacity building. Furthermore, ProNAMA supports the development of mechanisms that can both fund NAMA implementation and help SEMARNAT and CONAVI procure additional international co-financing.

3 Barriers to a low carbon housing sector in Mexico

Mexico faces many barriers to implementation of large scale energy efficient housing in Mexico. Through the 'Mesa Transversal" and stakeholder outreach, CONAVI and its partners have been working to refine the technical, institutional, financial, and operational design of the Sustainable Housing NAMA; and to develop tools and guidance for local governments and housing developers.

Key barriers identified in the 2011 Sustainable Housing NAMA report included: lack of knowledge and experience with energy efficiency in construction, subsidized energy prices, high costs of the necessary building materials and technical equipment, and a weak regulatory environment. This section will focus on the major barriers and identify the actions taken by CONAVI in 2012 to overcome them.

Lack of knowledge and awareness: Home-owners, developers, planners and local administration lack information about energy-efficient buildings, how to assess them, and how to implement them. Furthermore, building professions in Mexico know relatively little about energy efficiency of buildings. Today's home-buyers and builders have almost no models to emulate to push for energy-efficient construction.

To address these issues, the Mesa 'Transversal' is developing a common simulation tool that developers can use to assess the energy impact of efficient housing design. As part of this work, interested stakeholders have come together to develop a common set of parameters and emissions coefficients so that various initiatives will work from a common baseline and achievements between them will be comparable.

With support from INFONAVIT and GIZ/GOPA, 40 instructors have been trained as trainers certified by the PHI to offer SISEVIVE courses. These instructors are professional with experience in residential efficiency and come from academia, the construction industry, material developers, and consulting groups. Training materials were tailored to Mexico, and were developed by INFONAVIT, GIZ, and GOPA.

The first phase of SISEVIVE courses for developers will run from October to December 2012, training nearly 400 professionals in the following locations: Mexico City, Veracruz, Morelia, Guadalajara, Aguascalientes, Reynosa, Monterrey, Puebla, Chiapas, Quintana Roo, and Campeche. There is an online platform that course participants can use to exchange ideas and receive update to the SISEVIVE tool.

Most critically, CONAVI incepted multiple pilot projects in 2012 with major housing developers across Mexico's climate zones and utilizing all types of housing. These pilots will provide real experience for developers and local governments and a source of empirical data for the calibration of models and policy.

Lack of Incentives: Highly subsidized energy prices, especially for the lower-income groups, provide disincentives to home-owners to look for more energy-efficient solutions. In addition, energy efficient homes require addition up-front cost to developers, who may not be willing to take the risks that homes will not sell.

To combat these risks, CONAVI is reviewing numerous models that connect the environmental performance of NAMA homes to the financial performance for homeowner and housing developers. These are discussed in greater detail in Chapter 6.

In addition to creating financing models, CONAVI's outreach to industry partners ensures that these stakeholders' concerns are addressed through the design process. International funding partners have also been identified, and many governments and international NGO's have pledged financial support towards the Sustainable Housing NAMA.

Technical barriers: The technologies and design features that produce energy efficient homes are not novel, which is to say that major technical barriers are related to sourcing of these materials and the expertise to install them properly. In addition, developers and local authorities may not understand the impact of features, or be able to choose between alternatives in an informed manner.

To address these barriers, CONAVI and its partners will be utilizing a 'comprehensive' MRV system in a portion of pilot homes to measure and compare the performance of specific materials, technologies, and designs in the context of Mexico's seven climate zones.

Expertise with these technologies will also be gained through their installation. Finally, as the programme proceeds to national scale, it is expected that local sources for eco-technologies and efficient materials will emerge to serve the demand generated by the NAMA. The NAMA may also generate economies of scale that will reduce the cost of homes in the long run, and creating additional economic opportunity for Mexican businesses.

Regulatory and institutional issues: There are no comprehensive and formal regulations for energy efficiency in housing. CEV, the voluntary comprehensive building code developed by CONAVI, is only a model code at present, since CONAVI as a federal agency cannot enforce its adoption and implementation. Existing norms, such as MEPS, the minimum energy performance standards, do not cover all aspects of construction and building equipment and are not yet fully included in the relevant building codes.

The houses built by developers – to which this NAMA is to be applied – are built on the basis of permits. The 'Mesa Transversal' has included in the MRV design a formal process for registering of efficiency technologies and features in the RUV. In addition, trained auditors or verifiers will ensure that the house is being built to design specifications. Compliance with these steps will be a necessary step to receive supplementary funding, creating a clear incentive for housing developers to achieve the NAMA standards.

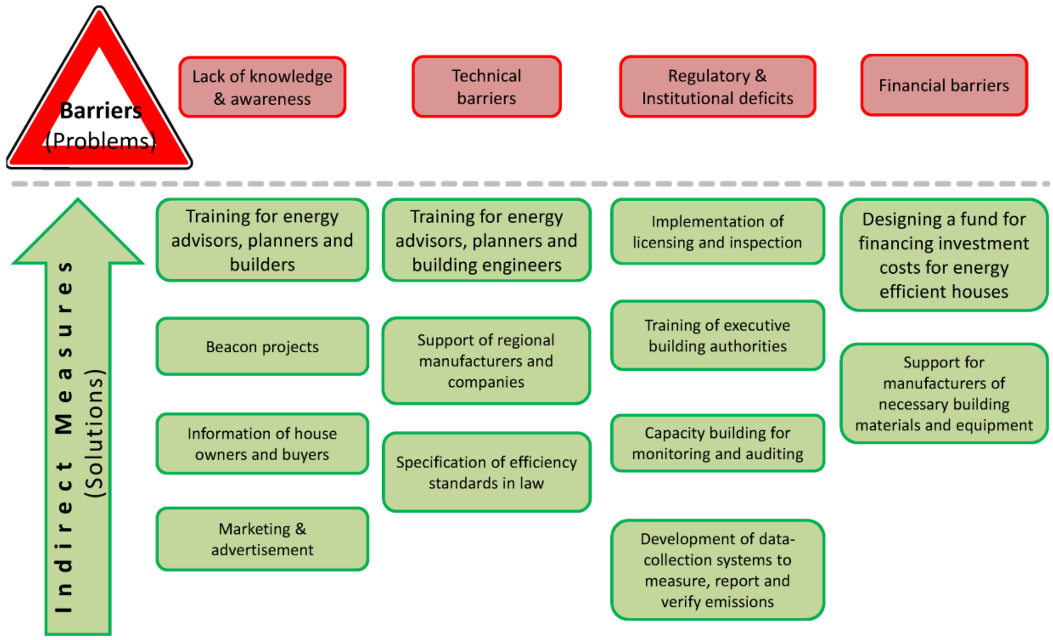
SEMARNAT is also working with GIZ to develop a NAMA office, which will coordinate actions and provide funding across Mexico's NAMA initiatives, which include the Sustainable Housing NAMA. Clear roles and responsibilities are being developed for both the federal authorities, housing developers, and regional governments so that all parties will clearly understand their obligations and can work together to successfully implement sustainable design features to the housing sector.

Financial barriers: The economic benefits of energy efficiency for home-owners accrue over the medium to long term. Builders and buyers, however, focus on up-front acquisition costs and not on life-cycle economics, particularly if they do not intend to occupy the property beyond the payback period of energy-efficient equipment.

As previously mentioned, CONAVI has been working with stakeholders to develop financial models that support both the supply and demand side of the housing market, and which channel the economic value created by the NAMA back towards sustainable activities. These are discussed in greater detail in Chapter 6.

Figure 6 illustrates the barriers as a rationale for the chosen indirect and supportive measures, described in Chapter 4.

Figure 6: Barriers to low carbon housing in Mexico and measures proposed to overcome them



Source: IzN Friedrichsdorf

4 The NAMA: Potential, Objective and Actions

4.1 The Mexican NAMA for Sustainable Housing

At the centre of the proposed NAMA is the enhancement of the financial system to promote the construction of new residential buildings with high energy performance in the national mortgage market. The financial incentives will be linked to minimum primary energy target values for the entire house ('whole house approach') for a set of classified domestic building types. The NAMA targets typical low-income residential dwelling units and introduces target values for minimum primary energy demand as regards three building types: Eco Casa 1, Eco Casa 2 and Eco Casa Max Standard (best energy performance).

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 where most the growth is expected. Since buildings have an extremely long life-cycle, the increased penetration of energy efficiency buildings achieved by this programme will have a significant impact on Mexico's cumulative GHG emissions, and can represent an attractive solution for achieving sustainability goals.

The NAMA has been designed as a framework consisting of unilateral and supported components. Unilateral components are those implemented and financed by the Mexican government and constitute Mexico's contribution to international climate change goals. Supported components are those for which donor funding is needed for the incremental costs of strengthening penetration of Mexico's actions, or achieving more ambitious performance standards. International support may also take the form of technical assistance and capacity building.

The Sustainable Housing NAMA is aimed at enhancing GHG emissions reductions by building on the 'Green Mortgage' and 'Ésta es tu casa' programmes. It differs from the CDM PoA by adopting a whole-house approach, described below, whereas the PoA focus on specific technologies. In the medium to long term, it is envisioned that the Sustainable Housing NAMA will expand in scope, leading to further decreasing emissions from new urban development, to be introduced through an Urban NAMA.

The following steps define the incremental enhancement through the NAMA described in this report:

- increased penetration (more houses covered during the same time) and/or
- technology choice and up-scaling (more ambitious efficiency standards and/or inclusion of technologies currently not covered).

4.2 Whole House Approach

The existing initiatives discussed in Chapter 2 have focused on the implementation of a specific technology or intervention. The Sustainable Housing NAMA introduces 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.

By targeting values for total building energy demand instead of specific technologies, the NAMA has the following advantages:

- target values represent an incentive to reduce total energy consumption, since they take into account the interaction between different measures
- the house-builder is free to choose any technical measures as long as they can achieve the target value for the whole house
- target values promote further technical development and adaptive cost effective solutions
- target values can be tightened, step by step, in line with environmental policies and technical development
- target values allow the establishment of different support levels in parallel.

The whole house approach also greatly simplifies the MRV requirements, reduces overall programme costs, and allows flexibility for building developers and home-owners seeking to achieve efficiency targets.

4.3 Objective of the NAMA

The aim of NAMA is to supplement on-going initiatives for energy-efficient housing as laid out in the PECC and as currently operated by INFONAVIT.

The design challenge of the NAMA is to accommodate Mexican development priorities while also attracting support from Annex 1 countries. In this regard the NAMA needs to target the mortgage market and provide financial incentives for the construction of residential homes with an energy performance above present Mexican programme standards.

The first priority of the Mexican government is increasing penetration, or expansion of basic energy efficiency improvements into further market segments, beyond the INFONAVIT market. Specific targets include the FOVISSSTE market and the SHF-refinanced segment. The next stage of the NAMA is technology up-scaling, or stepwise tightening of efficiency standards in all market segments and the realization of Eco Casa Max pilot projects.

The houses to be constructed under the NAMA will pave the way for the dissemination of new technologies and approaches in the building sector. In the long term, this will have positive spill-over effects on the Mexican building industry, creating demand for local suppliers of efficient technologies and materials.

4.4 Scope of the NAMA

The NAMA will target the Mexican mortgage market which finances annually some 600,000 new residential homes per year, of which around 50% are financed by INFONAVIT.

The NAMA will operate in parallel with the Green Mortgage programme and will be open for participation from INFONAVIT, FOVISSSTE, SHF and other financial institutions. Initially, the NAMA will target only new and formal homes. The NAMA is currently being extended to cover the existing housing stock, and later the entire mortgage market in addition to formal and informal housing (self-construction).

NAMA measures will concern only the building and its technologies, not urban planning issues or aspects in the direct environment of a house (e.g. local street lighting). However, it is envisioned that this approach to efficient housing could, in the future, be nested into a more holistic approach to urban sustainability. This goal is already being pursued through the Urban NAMA proposal to the Partnership for Market Readiness.

The NAMA provides financial incentives to two distinct customer groups (i) house-buyers/owners and (ii) construction companies. The financial incentive framework under the NAMA will ensure that:

- the better the level of energy efficiency achieved, the more favourable the financial support conditions;
- house-buyers/owners will receive a subsidy to the loan granted by a financial institution (e.g. reduced interest or lower reimbursement instalments, or redemption grant), if they purchases a house built in accordance with whole-house energy efficiency standards under the NAMA in order to cover a part of the additional investment costs;
- construction companies (developers) receive a subsidized 'bridge loan' provided they commit themselves to build a house according to one of the whole-house energy efficiency standards under the NAMA; this must be proven when the house is finished.

The possible technical measures for reaching the energy benchmarks under the NAMA are described in the next chapter. Table 4 illustrates the design of the NAMA.

Table 4: NAMA design elements (1)

Item	Description
Sector	Building sector

Sub-sector	New residential houses (1st phase), primarily for low-income families, potentially for the middle income housing sector
NAMA boundary	Entire country
Measures and activities with direct impact on GHG emission reduction	Introduction of a class of ambitious primary energy consumption benchmarks. The construction of houses according to the benchmark level is incentivized by a scaled up financial promotion system
Measures and activities with indirect impact on GHG emission reduction	Supportive actions for NAMA implementation, operation and support of the wider transformational process in the residential building sector: introduction of energy performance requirements in the legal system and permitting process, training of planners, architects, energy advisors and manufactures, creation of model projects
NAMA type	NAMA framework consisting of unilateral and supported components
Type of support required under the NAMA	Financial, technical and capacity building

Source: Point Carbon Thomson Reuters and Perspectives

4.4.1 Energy efficiency standards for houses under the NAMA

The three 'standards' for maximum energy demand – Eco Casa 1, Eco Casa 2 and Eco Casa Max – have been developed in cooperation with the German Passive House Institute (PHI). Three unit types typical of the Mexican market have been analysed of approximately 40m² and 70m² in floor area:

- **'Aislada',** a single unit detached house,
- **'Adosada',** a row housing unit,
- **'Vertical' units**, multi-storey housing units consisting of six floors with an average of two apartments each.

To develop the efficiency standards, preliminary design of the buildings was examined and an energy balance of the three building types in four basic climate zones in Mexico was determined[11]. (See figure 5 below.) Energy demand of the baseline buildings was then calculated with the help of the Passive House Planning Package (PHPP).[12] Finally, the possibilities of optimizing buildings in energy efficiency without fundamentally changing the building design were analysed.

On the basis of this analysis, three different energy efficiency standards for houses under the NAMA were defined, two intermediate cases and the ultra-low energy Eco Casa Max:

- The first intermediate housing concept, **Eco Casa 1**, incorporates all the measures of the current Green Mortgage scheme: Approx. 2,5cm insulation in the roof and on one of the walls of the building, reflective paint, use of tankless gas boiler, solar water heating and efficient A/C, as needed. In addition, various efficient appliances were considered, such as efficient lighting and cooking facilities.
- The second intermediate case, **Eco Casa 2**, represents a further optimization towards the Eco Casa Max Standard through insulation, better insulated windows and highly efficient appliances.
- Finally, the **Eco Casa Max** envisages optimization of all measures achieving the most ambitious standard based on the basic criteria of the German Passive House Standard adjusted for the Mexican climate and building conditions.[13]

[11] When the NAMA is deployed nationally, seven climate zones will be used.

[12] The Passive House Planning Package (PHPP) is a software developed by the Passive House Institute to support the design of energy efficiency housing. More information about the tool is available at: http://www.passiv.de/.

[13] For more information, see the website of the Passive House Institute: http://www.passiv.de/07_eng/index_e.html

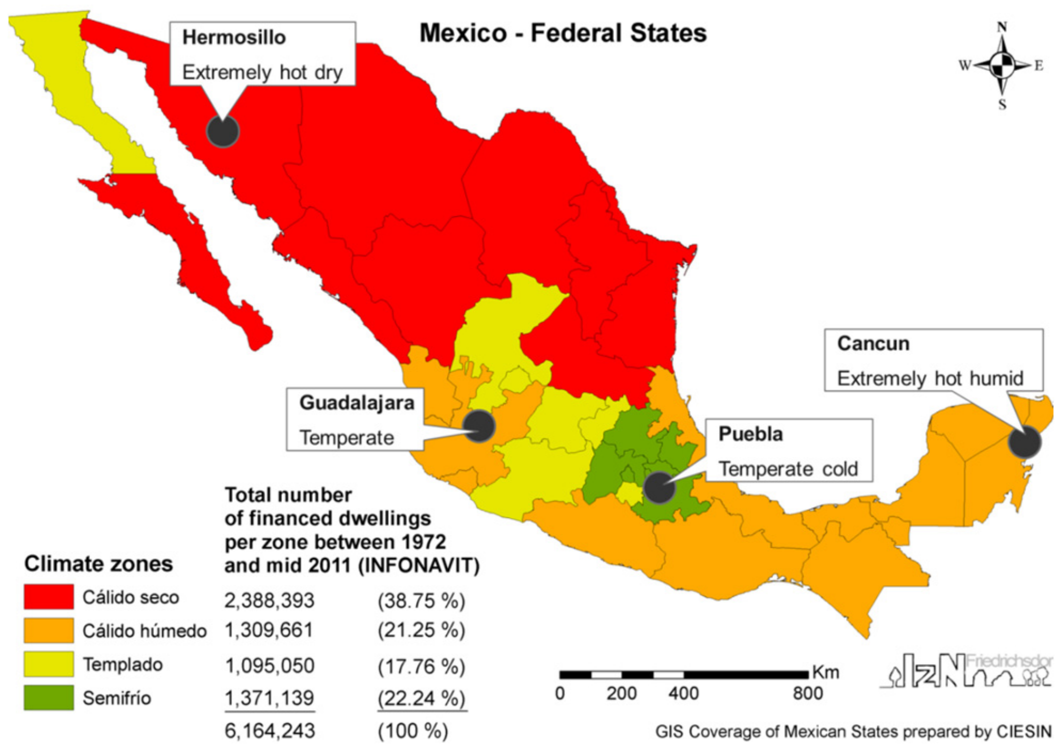
Given that the Mexican government's current priority is the penetration of basic energy efficiency improvements into further market segments, the following roll-out schedule is proposed for the energy efficiency standards under the NAMA (see Table 5):

Table 5: NAMA design elements (2)

Item	Description
NAMA roll-out schedules	- 2012 and 2013: focus nearly exclusively on Eco Casa 1 - 2014-2016: Eco Casa 2 grows quickly. - Eco Casa Max are considered in limited numbers as pilot projects.

Source: Point Carbon Thomson Reuters and Perspectives

Figure 7: Mexican climate zones utilized for the NAMA calculations[14]



Source: IzN Friedrichsdorf

Actual emissions performance of NAMA houses will be impacted by urban design, in addition to building design. However, in order to compare building types, a business as usual was assumed and energy measures (insulation, air-tightness, improved u-values of windows and doors, ventilation system or similar) were applied. The most compact building type is vertical and therefore it is used as an example to present the PHPP results.

[14] Initial design work was performed using four basic climate zones, the national-scale NAMA will use seven

4.4.2 Mitigation options under the NAMA energy efficiency standards

The following section provides a brief overview of the results of the energy balance modelling considering the measures to be undertaken for the buildings analysed (Vertical, Aislada and Adosada) in four locations (Hermosillo, Guadalajara, Puebla and Cancun)[15]. Specific energy demand was tracked across four uses: space heating, space cooling, dehumidification, and all other demand – which includes water heating, cooking, and appliances. The results are illustrated and exemplified by the vertical building type, but similar results, with more demanding values, were achieved for the other house types, Aislada and Adosada. Interested donors will have access to these data.

Demand for heating, cooling, and dehumidification vary significantly between climate zones. Specific primary energy demand is generally much higher in hot climates than in the temperate regions. Because of these regional differences, the types of mitigation options employed are specific to each of the climates encountered in Mexico. As shown in Table 6, this can mean using entirely different types of technologies, or that interventions such as insulation and glazed low-e windows are scaled to the demands of the region. As the NAMA pilots progress and performance data is analysed, these figures may change.

Table 6: Mitigation options by climate type for vertical building type

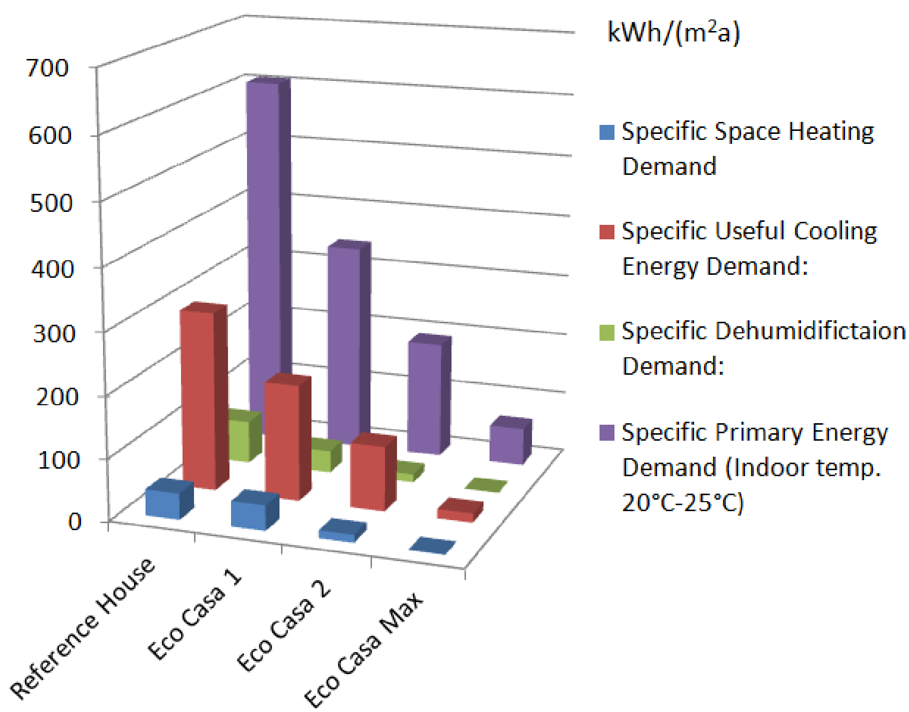
	Hermosillo (extremely hot and dry)	Cancun (extremely hot and humid)	Guadalajara (temperate)	Puebla (temperate cold)
Exterior Walls	10cm (Vertical)-30cm (Aislada) insulation, Reflective paint	7.5cm insulation Reflective paint	5cm insulation	5cm insulation
Roof	30cm insulation Reflective paint	10cm insulation Reflective paint	18cm insulation-	25cm insulation
Windows	Triple glazing with sun protection	Triple glazing with sun protection	Double glazing	Double glazing
Floor	10cm insulation	10cm insulation	-	12.5cm insulation
Heating, ventilation, air conditioning	Energy recovery ventilation, Recirculation cooling	Energy recovery ventilation, Humidity control, Recirculation cooling	Pure extract air system Natural ventilation	Pure extract air system
Other	10cm (Vertical)-30cm (Aislada) insulation, Reflective paint	7.5cm insulation Reflective Paint	5cm insulation	5cm insulation
Efficient Appliances	CFL lamps, Solar water heater Tankless gas boiler Ceiling Fan	CFL lamps Solar water heater Tankless gas boiler Ceiling Fan	CFL lamps Solar water heater Tankless gas boiler Ceiling Fan	CFL lamps Solar water heater Tankless gas boiler
Baseline Emissions	88kg/(m²a)	125kg/(m²a)	47kg/(m²a)	54 kg/(m²a)
Min. achievable emission level	14kg/(m²a)	19kg/(m²a)	11 kg/(m²a)	11 kg/(m²a)

Source: Passive House Institute

The result of implementing these mitigation actions is illustrated in Figure 8, which shows energy savings for vertical housing units in a hot and dry climate.

[15] As a boundary condition, a temperature range of 20°C to 25°C was chosen.

Figure 8: Specific energy demands for Vertical units in Hermosillo (hot & dry), 40 m^2

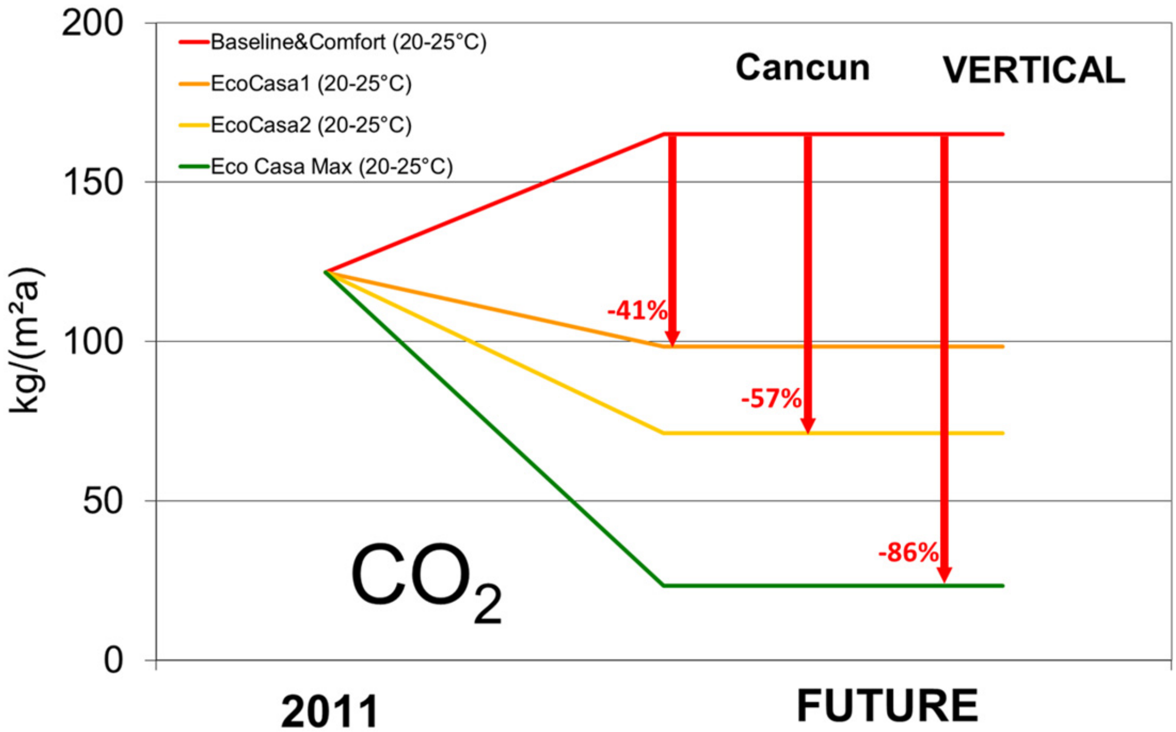


Source: Passive House Institute

Demand for specific energy uses changes drastically across the climate regions, as one would expect. In general, energy demand is much higher (more than 2x) in hot regions than in the temperate and cool climate zones. Therefore, there is a higher potential to reduce energy demand and associated emissions reductions in the hot regions than in the more temperate areas, where energy efficiency is more easily achieved.

Figure 9 presents various energy efficiency scenarios under the standards elaborated for the NAMA on the example of Cancun in relation to a good comfort level (20-25°C).

Figure 9: CO_2 levels under various energy efficiency scenarios in Cancun (vertical, 40m^2)



Source: Passive House Institute

4.5 Mitigation potential

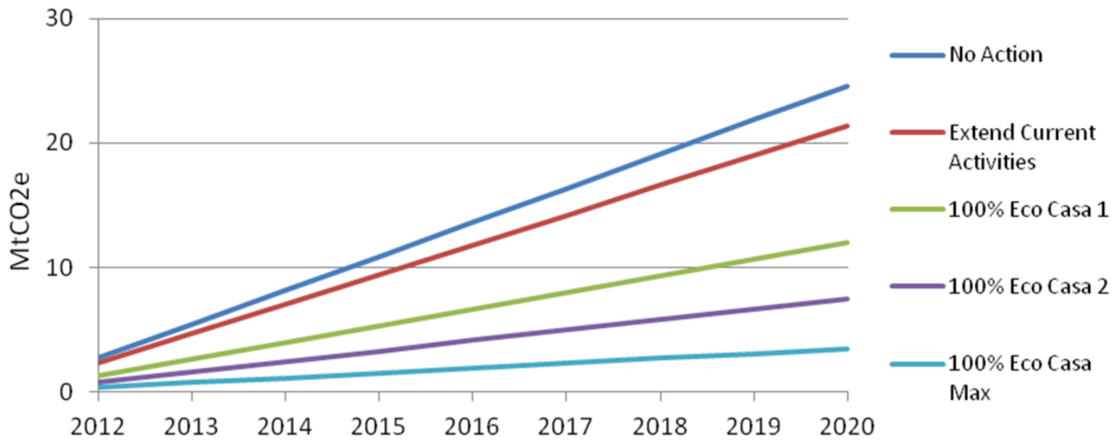
The calculation of the mitigation potential will follow three NAMA scenarios representing a 100% penetration of the efficiency standards Eco Casa 1, Eco Casa 2, and the Eco Casa Max across all climate zones and building types. To provide a frame of reference, two baseline scenarios were calculated, one which represents an extension of current Mexican efforts with no scale-up of activities,[16] and a 'No Action' scenario in which it is assumed that existing programmes cannot be sustained.

In practice, the actual emissions reductions achievable by the NAMA will be highly dependent on the level of financing that can be attracted. Instead of forecasting our expectations for the programme, this section provides general scenarios that illustrate the overall potential of the NAMA to affect the long-term emissions profile of the Mexican housing sector.

Emission reductions are shown for the implementation period assuming 600,000 houses are built each year and that they will remain at the same level of efficiency over the lifetime of the houses. Houses are assumed to be 40m^2 and to have 2 occupants.

Figure 10: Emissions from newly built houses in Mexico and select mitigation scenarios

[16] Estimated as continuation of Green Mortgage programme with the current level of penetration.



Source: Point Carbon Thomson Reuters

The CO_2 emissions of the baseline and the NAMA have been calculated based on information about the mix of fuel and power consumption in typical houses, provided by CONAVI. For the grid emission factor a value of 0.49 t CO_2e/MWh[17] has been applied. Combined with 18% distribution losses[18] in the Mexican grid, this yields an effective grid emission factor 0.58t CO_2e/MWh.

The resulting analysis shows that cumulatively, assuming 100% penetration of a particular pathway represented in Figure 9 above, the NAMA can achieve emission reductions ranging from 63 $MtCO_2e$ (Eco Casa 1) to 105 $MtCO_2e$ (Eco Casa Max) by the year 2020.

4.6 Non-GHG Benefits

NAMAs should result in benefits other than GHG emissions reductions. Whereas in the CDM activities, additional objectives serving the promotion of sustainable development were presented once, the NAMA concept seeks demonstrable effect on sustainability through a measurable and traceable procedure, ideally included in the MRV system. In general terms, both the sector-wide and integrated actions approach of NAMAs suggests an additional contribution that can lead to a sector transformation towards sustainable development.

To this end, CONAVI is developing a co-benefit assessment framework for the Sustainable Housing NAMA, particularly for sustainable development benefits. The objective is to develop a monitoring process for the sustainability impacts resulting from the NAMA implementation.

The co-benefits framework is still in development by the MRV Working Group of the Mesa Transversal and builds on parameters commonly used in existing sustainable housing and sustainable development assessment, such as the recently launched Index of Sustainable Housing (ISV)[19] and the Gold Standard[20].

To date a list of co-benefits has been preliminary selected and the precise monitoring procedures will be designed. These co-benefits will most likely include contributions to following scopes:

17 SEMARNAT, 2012. Factor de emisión eléctrico 2010. Available at: http://www.geimexico.org/factor.html [Last visited: 14/11/2012]

18 CFE, 2012. Programa de Obras e Inversiones del Sector Eléctrico 2012-2026. Subdirección de Programación Coordinación de Planificación, CFE. On line]. Available at: http://www.cfe.gob.mx/ [Last visited: 14/11/2012]

19 In March 2012 members of the Asociación de Vivienda y Entorno Sustentable (VESAC) signed a joint declaration to strengthen the sustainability within the housing sector, in addition to the presentation of the Index of Sustainable Housing (ISV). This index provides a performance analysis of homes in economic, social and environmental aspects. The executive summary of ISV is available at: http://centromariomolina.org/desarrollo-sustentable/evaluacion-de-la-sustentabilidad-de-la-vivienda-en-mexico/

20 The Gold Standard is recognised certification standard for carbon mitigation projects and is recognised internationally as the benchmark for quality and rigour in both the compliance and voluntary carbon markets. renewable energy and energy efficiency carbon offset projects.

Table 7: Select Co-Benefits of Sustainable Housing NAMA

Economy	• Economic savings for households reflected in electricity and water bills • Reduction on energy subsidy costs • Increase in number of green jobs and companies
Environment	• Air quality • Land use
Social	• Comfort • Access to clean energy services • Education and awareness of sustainability for housing developers and householders • Human and institutional capacity building

Source: Mesa Transversal

The next steps are to define the final parameters and propose a monitoring procedure suitable for each one. A possible method for compiling and reporting data could be through the development of periodic studies that assess the impact of the benefits gained on these scopes through the NAMA implementation.

4.7 Supportive and administrative actions

The application of a promotional system via the NAMA will have positive effects on the whole system of energy efficiency in the building sector in Mexico:

- It will demonstrate that it is possible to introduce primary energy demand target values into the Mexican building sector, encouraging the further development of building regulations. Furthermore, as the licensing and planning procedures for new buildings increasingly incorporate energy efficiency concerns, it may become feasible to include statutory requirements as to energy efficiency of new buildings in the permitting process.
- It will create a demand for energy advisors, energy auditors and qualified architects able to apply specific calculation and design tools. Thus it will lead to additional employment and strengthened capacities while building on existing platforms and personnel such as RUV and housing verifiers (verificadores).
- It will also create demand for more energy-efficient buildings and building equipment and more appropriate construction materials. Energy-efficient equipment and construction material which have to be imported today could then be produced in Mexico and be offered at more attractive prices on the local market, thus making energy-efficient houses more competitive.
- Eco Casa Max pilot projects will demonstrate the feasibility of very advanced energy efficiency standards for residential buildings for low-income families.

In order to overcome the barriers outlined in chapter 3, these developments will need to be supported by information campaigns, training and advisory services during the implementation of the NAMA. Table 7 shows the supportive and administrative actions that will be required during the first implementation phase (2012–2016):

Table 8: Supportive and administrative actions

No.	Action
1.	**Institutional set-up and NAMA administration**
1.1	Designing fund for financial resources, incl. legal agreements
1.2	Develop Sustainable Housing Steering Committee and Technical Working Groups
1.3	Designing, establishment and operation of "NAMA Programme Office Unit"
1.4	Baseline, MRV and additionality framework
1.4.1	Development of data-collection systems to accurately measure, report and verify emissions: Set up and operation of a comprehensive data base (baseline and MRV) of houses and energy consumption and demand

1.4.2	Capacity building and capacity build-up for monitoring and auditing Establishment of a professional and specialized inspection and supervision system
1.4.3	Comprehensive household monitoring and auditing surveys (i.e. simulation using data base and detailed surveys)
1.3	Technical Assistance to FOVISSSTE and SHF in the establishment of their institutional set-up for the implementation of the NAMA
2.	**Building Codes and permitting procedures**
2.1	**Technical Assistance to local governments** and organizations at state and municipal level for introduction of a minimum energy performance standard, the whole building approach and target values for primary energy consumption as well as sustainability criteria. Elaboration of a national guideline for Building Code adaptation.
3.	**Capacity building**
3.1	**Training for energy advisors, planners and construction workers** on energy efficiency building mainly through the PHPP tool
3.1.1	Scaling up of university/commercial school curricula on EE buildings and RE in buildings with focus on supporting for the NAMA implementation and operation
3.1.2	Translation and adaptation of European/PHI training material to Mexican climate and building traditions; check after experience
3.1.3	Training through a 'Train the trainer approach' with local partners. The local partners consecutively, provide training and design of energy-efficient buildings (eco-casa, PHPP) for developers and planners throughout Mexico and special training for construction workers
3.2.	**Training to local authorities and stakeholders**
3.2.1	CONAVI will also perform capacity building for local, state and federal authorities by attendance courses, virtual learning and the construction of an inter-institutional platform. Objective: local authorities and stakeholders are able to introduce and implement sustainability criteria in their daily processes and decisions involved in housing master plans and house construction level
3.3	**Training to house-owners/users**
3.3.1	Production of a manual for house-owners/users in order to understand and optimize the use of energy-efficient houses
3.3.2	Campaigns to increase awareness of energy efficiency not only for buildings but also with appliances
3.4	**Encouragement and support of regional manufacturers and companies** to increase the availability of suitable products
3.4.1	Guideline and support for manufacturers through local partner and international advisory
3.4.2	Adaptation of certification criteria for local Mexican products
4.	**Beacon Projects and software adaptation**
4.1	Quality assurance of all Eco Casa Max design and construction; and adaptation/implementation of PHPP calculation and design tool
4.2	Technical assistance in design and construction of Beacon Projects in different locations in Mexico
4.3	Monitoring of Beacon Projects and transfer of results and lessons learned into capacity building, demonstration projects and dissemination
5.	**Marketing and advertising**
5.1	Website (development & maintenance)
5.2	Mass media campaign (TV, radio, newspaper)
5.3	Promotion for participation (brochures and marketing material)
5.4	Demonstration and dissemination: make success visible

Source: IzN Friedrichsdorf

4.7.1 Institutional set-up and NAMA administration

The goal is to establish an inter-institutional platform that can articulate the requirements for sustainable housing. This can be achieved by establishing a coordinating agent, or an even wider body, with the establishment of an inter-sector commission where government, private industry and social organizations collaborate to implement the different programmes for sustainable housing. To address this issue, CONAVI and the Mesa Transversal envisage the establishment and operation of a 'Housing NAMA Office'[21]. Technical Assistance will be also provided to FOVISSSTE and SHF for establishing their institutional set-up for NAMA implementation. Administrative issues to be dealt with will include developing the legal arrangements for the NAMA Fund, the set-up and operation of the MRV system, including development of data-collection systems, relevant data bases, and capacity building for monitoring and verification. While the NAMA office is operational, the NAMA will be coordinated directly by CONAVI with support of the Mesa Transversal.

4.7.2 Integration with RUV

A key component of measuring and reporting the impact of the Sustainable Housing NAMA will come from integration with the current system for tracking new homes, RUV. During 2012, the technical groups have worked to expand RUV's capacity to track the installed appliances, design features, and materials used in new home construction. This effort will continue with the development of a template that uses standardized criteria to track the characteristics of each new house. This template will allow the developers to input specific data, subject to a verification process managed by the RUV that will include critical data and be identified by a unique key Housing (CUV).

GIZ and CONAVI are currently developing a database to house measurements collected by the Sustainable housing NAMA and other initiatives. The goal is to have a centralized source of information that will compile information from across many programs, so that regulators, researchers, and industry professionals can evaluate and compare performance of sustainable housing developments.

The NAMA database will be communicate with existing data sources maintained by RUV, CFE, and INEGI, and track key parameters such as location, square footage, type, level of efficiency, projected estimates of energy consumption and water, environmental technologies, etc. This data will be differentiated by climate zone, housing type, and efficiency standard. In addition, the NAMA database will track information collected by survey, which can be used to track habits in terms of energy and water consumption.

The data, in aggregate form, will be publicly available. However, information related to specific homes or developments will be restricted to protect the privacy of NAMA participants. Reports can be automatically generated on an annual or semi-annual basis, and data will be downloadable in Excel format. Additional functionality, such as pre-generated graphs, is currently under consideration.

4.7.3 Development of mandatory building codes and licensing procedures

As discussed in Chapter 2, the building codes applied in the Mexican housing sector do not cover the full spectrum of potential energy efficiency measures. Moreover, weak enforcement of building codes contributes to low levels of energy efficiency in standard newly built houses.

The NAMA will introduce clear efficiency standards and associated technical guidance that housing developers can follow to access supplemental NAMA funding. Because local governments have the authority regarding

[21] This office will coordinate action specific to the Sustainable Housing NAMA. It will sit underneath the Federal NAMA office, once that body is established.

enforcement of the building codes, additional outreach is underway to ensure that NAMA standards are compatible with local mandates.

4.7.4 Capacity building

One of the key prerequisites to achieving the objectives of the NAMA is the transfer of knowledge and experience related to energy efficiency in buildings. This can be achieved on several levels: through specific training, broader educational experiences, and capacity building and outreach.

CONAVI has already initiated the 'Mesa Transversal' to share and increase the knowledge about energy efficiency among building professionals, development agencies, academia, and the public and private sector; and involve them in the NAMA development process. This process has produced a modelling tool that can be used by architects, engineers, developers and constructors to compare and implement sustainable designs.

In order to promote the 'whole house' efficiency approach in buildings and environmental friendly development, there is also a need for capacity building at municipal and state level regarding the Public Sustainable Housing Policy. Therefore, CONAVI has developed a National 'Capacity Building Strategy for Sustainable Housing and its Surroundings' (CONAVI, 2011) targeting local authorities as well as social and institutional agents with competence in these issues. Implementation foresees involvement of the Regional Housing Agencies (Organismos Regionales de Vivienda, OREVIs) and agents of the construction housing sector. In the medium term, local academia as well as training institutions should also be attracted as multipliers.

Consideration should also be given in the context of the NAMA to the supply-chain in the building sector. These stakeholders need reliable information, individual support (consultancy), and clear criteria in order to develop solutions and orient their business activities towards sustainable investments.

Additionally, building up local production and installation of energy-efficient building materials and equipment can be supported by information and training of interested enterprises, construction technicians (non-academic background), plumbers, masons, electricians, building service installers, among others.

4.7.5 Simulation Tool

The NAMA, when fully operational, will use the SISEVIVE tool, which combines the SAAVI tool covering water efficiency with the DEEVI tool covering energy efficiency. Currently SISEVIVE is still under development and is in the process of being parameterized for the Sustainable Housing NAMA. During the first pilot implementation phase in 2012, CONAVI is moving forward with a number of pilot projects with various partners, and each of these pilots are using different tools; namely, the PHPP for Mexico, HOT 2000, and Edge.

The purpose of these tools is two-fold. The first is to assist housing developers and local governments simulate the impact of eco-technologies, design elements, and materials to choose the most appropriate for their projects and municipalities. The second is to estimate the overall impact of the Sustainable Housing NAMA to potential investors and international stakeholders.

4.7.6 Pilot Projects: Demonstrating the Sustainable Housing NAMA

In order to make quality and energy efficiency visible, several pilot projects are being implemented by CONAVI, SHF and INFONAVIT, with support from international donors and domestic housing developers. These projects will not only provide an excellent training opportunity, but will provide valuable data for the development of the planning tool and an opportunity to calibrate the MRV system.

(1) Pilot Projects

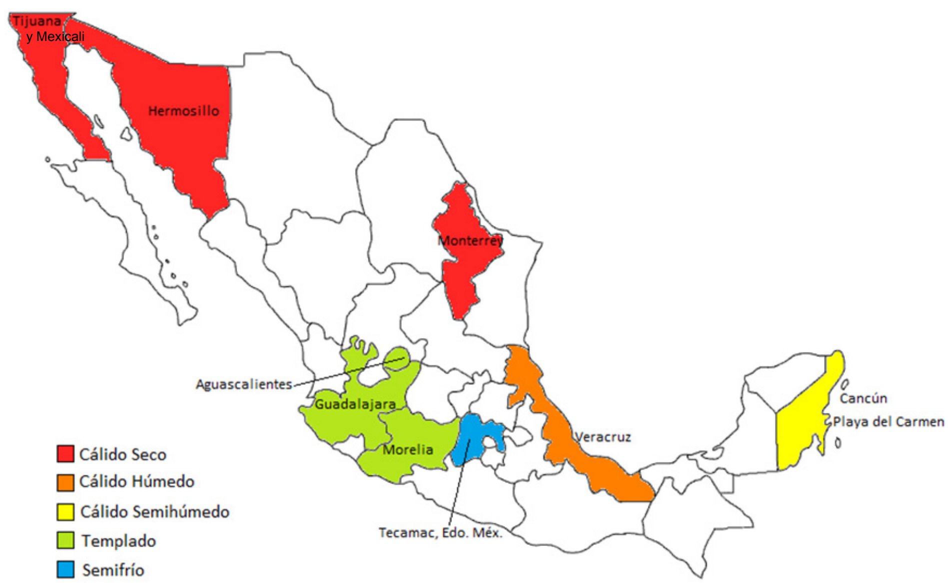
The pilot projects consist of around 4,600 affordable housing units in 11 cities located in the five most representative bioclimatic regions, and involve seven different housing developers and OREVI. The homes are of different types and present various design features, materials, and eco-technologies that will results in different incremental efficiency levels relative to the baseline. The MRV systems for these pilot projects have been agreed between the actors and may not be identical to each other, or with the proposed "GHG Monitoring" proposal for the nationally deployed NAMA. However, the pilot projects include all critical stages: simulation, registration, verification, monitoring, reporting and validation and are going to contribute to further develop financial incentive mechanisms for the NAMA implementation.

The pilot projects will have the following distribution of energy efficiency:

- 80% of the homes will be built to 'Eco Casa 1' efficiency levels; 1, 1.2 and 1.5 – similar to the incremental costs of the "Hipoteca Verde" programme.
- 15% of the homes will be built to the 'Eco Casa 2' efficiency levels; 2, 2.1 and 2.5 – and will include additional investment beyond "Hipoteca Verde" levels to include advanced materials, technologies, and/or renewable generation.
- 5% of the homes will be built to the 'Eco Casa Max' efficiency level – and will have the highest incremental cost as they will zero carbon, or passive houses.

The 4,600 pilot homes launched in 2012 will cover many states in Mexico:

Figure 11: Map of Sustainable Housing NAMA Pilot Projects Initiated in 2012



During the first pilot implementation phase in 2012, the following Sustainable Housing NAMA pilot projects are being implemented.

"ECOCASA Programme"

This initiative between SHF, the World Bank, the IADB, CTF and KfW will span 8 years and be rolled out in four phases. As of October 2012 the CTF resources are expected to provide 50 million dollars for the construction of 3,570 homes in coordination with the following housing developers.

1. GEO (320 apartments in Aguascalientes)
2. URBI (1,000 dwellings in Tijuana)
3. SADASI (850 homes in Cienega de Flores, NL)
4. Vinte (200 homes in Tecámac)

5. ARA (1,200 homes in Veracruz)

Mexicali, 1,000 house "Thermal Isolation Pilot Project"

The Mexicali project is funded by a CONAVI's subsidy of 33 times minimum wage SMGV (Salario Mínimo General Vigente) for each dwelling for passive eco-technologies supplement by 16.8 million pesos from SENER's "Fund for energy transition and sustainable use of energy" for active eco-technologies. MRV in 5 homes will be funded by Environment Canada.

"Mexican-German Programme for NAMA"

Within the framework of the housing component of the NAMA Programme, GIZ supports CONAVI through a pilot project aimed at testing and demonstrating the scope (efficiency standards, financing and MRV) and the potential of the Sustainable Housing NAMA in Mexico.

Specifically, the project aims to support the implementation of measures and activities for the planning, development and construction of approximately 77 social housing with low energy consumption. These homes will be monitored for at least 2 years, following the MRV system scheme defined by the NAMA. The pilot will develop housing with different levels of efficiency:

- Eco Casa 1 / Green Mortgage +: Optimized energy efficiency measures with the same incremental cost of the Green Mortgage.
- Eco Casa 2: Increase the energy efficiency and comfort with stricter level with the chance to replicate this model on a large scale.
- Eco Max House: will demonstrate potential savings and mitigation provided by a highly efficient house.

For this purpose, DEREX and HERSO- were selected as developers for the pilot projects to be built in Hermosillo, Morelia and Guadalajara, which represent different bioclimatic regions (dry and warm dry) and types (aislada, adosada y vertical).

"Low Carbon Housing Project"

The Canadian Government through Environment Canada is providing finance and technical assistance in Building Science for planning, design and construction of around 100 new housing units in Aguascalientes, Cancun, and Playa del Carmen, working with the State Housing Institute IVSOP in Aguascalientes, as well as the housing developers GEO, SADASI and HOMEX.

4.7.7 Raising public awareness

The Mesa Transversal is developing an 'internal' marketing strategy in Mexico using several communication channels to raise general awareness and obtain broader participation. This could be done through mass media campaigns on TV, radio and newspapers as well as the distribution of information brochures and marketing material. In addition, the creation of a website to explain and promote the benefits of the NAMA is suggested. The pilots are also an excellent means to promote the concept: a built example offers better proof than any brochure, publication, or discussion.

4.7.8 Training and Capacity Building

For the Sustainable Housing NAMA to succeed, it is critical that stakeholders such as citizens, housing developer and regional governments understand the value and benefits that can be generate through pro-active efforts to improve housing sustainability. To this end, the NAMA working groups have spent 2012 working with these constituencies to improve understanding of the Sustainable Housing NAMA and the benefits this approach can bring in terms of cost-savings, local industry, and public health.

Local governments in particular, must be involved in the decision making process when it comes to urban planning and housing improvements. To achieve meaningful participation in this manner, it may be necessary to educate local governments on the benefits of a sustainable housing strategy and the types of technologies that can be employed to produce the desired results. CONAVI and its partners have been working in 2012 to reach out and build capacity with local governments through the following initiatives:

- Developing, initiating and monitoring institution building to support the implementation of the Sustainable Housing NAMA
- Logging and tracking a participatory decision-making process to ensure continuity between local regimes
- Promoting awareness, in local authorities, of the importance of mitigating climate change and the impact that simple actions can achieve
- Making available the tools and expertise for local governments to analyse the impact of potential mitigation actions
- Reducing barriers to implementation and promoting sustainable development in harmony with current systems and infrastructure
- Strengthening state's and municipality's ability to track performance of implementation actions, ensuring that initiatives can be adapted as data is collected and the impact is understood.
- Training municipalities, and community working groups, presenting the lessons and results to promote changes in legislation and alignment of incentives within municipalities.

Local authorities have responded to this initiative by:

- Scheduling awareness training and entering in mentor-protégé arrangements with federal institutions
- Building local capacity and engaging with industry representatives
- Participating in existing federal programs (DUIS, Green Mortgage, etc…)

The goal of this initiative is help local government update and adapt territorial instruments, such as those listed below, to support the implementation of low carbon homes and communities.

  - Urban development plans
  - Land management plans
  - Building regulations
  - Sectoral programs
  - Instituting Local NOMS

Industry groups are also important stakeholders in this process, as they will be installing the technologies, improving the designs, and purchasing the materials that will ultimately result in desired sustainability achievements. To this end, CONAVI has been actively engaging the housing developers, as well as supplier groups such as the Asociación Nacional de Fabricantes de Aparatos Domésticos (ANFAD), the Mexican National Association of Domestic Appliances Manufacturers ANFAD.

The goal of this engagement is to raise awareness and build capacity in the industry so that Mexican business can effectively respond to actions taken at the federal level to improve the performance of homes. The goal is to build homes that reflect a common concept of sustainability, i.e. reductions in consumption of water, gas and energy – and that ultimately reduce the emissions from the occupants.

To this end, funds from KfW, CTF, and the IDB have been used to:

- Improve the SISEVIVE tool to be suitable for Mexican developers[22]
- Provide workshops and training to developers on low carbon Mexican houses
- Coordinate information exchange with international experts experienced in sustainable housing
- Creating standards and training for verifiers so that industry stakeholders can internally monitor their performance relative to EcoCasa standards, ensuring their compliance with the initiatives.
- Publishing educational materials focused in specific industry and stakeholders groups for the use and maintenance of environmental technologies.
- Generated media in written form and on the internet

Environment Canada has also been supporting industry outreach and has funded a number of activities, including:

- Training workshops in Aguascalientes and Cancun.
- Technical workshops for developers based on measured data.
- Producing handouts and other materials with the knowledge acquired through workshops and industry outreach.
- Monitoring of 5 "Hipoteca Verde" houses in Aguascalientes as a reference case.

To inform these programmes, CONAVI has partnered with international institutions, such as GIZ and ICLEI, to leverage their expertise to ensure that sustainable housing lessons learned around the world can be brought and adapted to the Mexican context. Additional support is being received from the UK in order to evaluate technological performance per climate region. Specific technical training with the simulation software will be forthcoming in 2013.

[22] The British Embassy, through Fundacion IDEA are calibrating the SISEVIVE tool through monitoring of baseline house performance.

5 The MRV system: Monitoring, Reporting and Verification

The primary purpose of an MRV system of any NAMA would be to measure the impact of the measures implemented, with the view to assessing their contribution towards the national and international energy and climate policy objectives. The general consensus appears to be that the MRV of NAMAs should allow for more flexibility and simplicity than the current approaches under the CDM, and that MRV procedures should be practical, rather than a burden or a barrier to the implementation of the NAMA. The Sustainable Housing NAMA as presented in this document is a 'supported' action. However, in the long term, it may become possible to generate carbon credits from the Sustainable Housing NAMA. To that end the MRV system has been developed with enough fidelity that it may be transitioned to a credited program, should international negotiations advance in this area.

In this section we discuss the progress and decisions that have been made towards developing a comprehensive methodology for calculating the emissions impact of the Sustainable Housing NAMA and the system to measure, report, and verify the data needed to support this methodology.

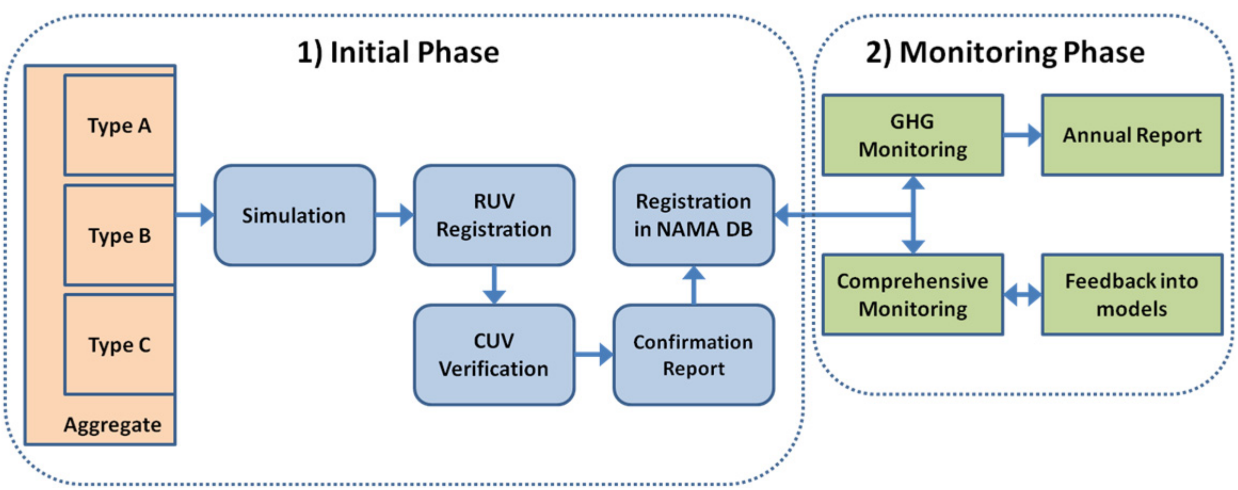
The objectives of the MRV system of the Whole House Approach

The technical design of the Sustainable Housing NAMA makes it both possible and practical to conduct an estimate of resulting emission reductions through the use of a limited number of metrics which also lend themselves to *ex post* monitoring as part of an MRV methodology. In the context of the Mexican residential sector, the MRV system could be used to track the energy subsidies avoided, and this information used to build support and solicit funds (from avoided subsidies) within the government.

When discussing the progress made it this area, it is important to understand that the Sustainable Housing NAMA is one of many initiatives aimed and improving the sustainability of the built environment in Mexico. To that end, stakeholders across various initiatives needed to agree on the nature and frequency of data collection, the use of common parameters and emissions factors, and common baseline adoption. MRV and methodology development under the "Mesa Transversal for Sustainable Housing in Mexico" is currently underway to develop a system of data collection and reporting that can support the wide variety of actions being pursued in the housing sector. The MRV system is based on existing institutions and attributions, optimizing existing financial and institutional resources.

For the Sustainable Housing NAMA, the process of certification, qualification and MRV consists of two distinct phases, as detailed below:

Figure 12: Monitoring System Concept



Source: CONAVI for the Mesa Transversal

1) Initial Phase

The first phase occurs during the design and construction of the homes. The developer defines the parameters of their sustainable housing project, and simulates the results using the SISEVIVE simulation tool. The homes are then registered with the RUV, which records the eco-technologies, features, and materials which constitute the sustainable design – and designated a unique Clave Única de Vivienda (Unique Housing Key, CUV) to identify the house. During construction, a qualified auditor ensures that the construction is conforming to the features of the simulated design, and that the design submitted to RUV is accurate. Once this has been confirmed and the house is complete, the home is entered in the NAMA database.

2) Monitoring Phase

Once the home has been purchased, it can participate in one of a two types of MRV systems. The first, which might be called the "GHG Monitoring" system, is focused on collecting the necessary data to calculate the emissions impact of the Sustainable Housing NAMA. The second, which might be called the "Comprehensive Monitoring" system, is focused on collecting a broader range of indicators that can be used to calibrate emissions models and track non-GHG variables, which are important to policy development and technical standards, but are not necessarily relevant for the tracking of the GHG impact.

(2) Details of the GHG Monitoring (simple) MRV System

The GHG MRV system will track a representative sample of monitored homes, and estimate within a 90% level of confidence the emissions performance of these homes by tracking four key parameters. Measured consumption data collected by the "GHG Monitoring" system will be multiplied by emissions factors to calculate the emissions performance of the NAMA homes. The resulting emissions profile will be compared against the performance of "reference" houses, i.e. those of the same type (aislada, adosada, vertical) in the same bioclimatic zone – and the calculated difference will be amount emissions reductions.

The following table contains the key parameters that will be collected by the MRV system in order to calculate home emissions.

Table 9: Details of GHG Monitoring System

Parameter	Unit	Frequency of collection	Source	Collected by
Electricity Consumption	kWh	Bimonthly Aggregated annually	CFE Electricity Meter	CFE
Gas Consumption	Litres	Annually	Gas Meter (to be installed) or simulation	DIT
Water Consumption	Litres	Aggregated annually	CONAGUA water Meter	DIT
Occupancy	Persons	Annually	Survey	Survey

Source: Mesa Transversal

Utility data will be collected through partnerships with the relevant utilizes. For water and gas consumption, meters may need to be installed in the NAMA and reference homes. A survey will be distributed to residents to track behavioural and habit driven parameters such as the number of inhabitants, and whether they use the home during the night and day. In addition, this survey will be used to confirm that efficient appliances and other eco-technologies are still in the home and being used.

In addition to the periodically collected data, the following data will be collected for registration of the home:

i. Water heater, type and capacity

ii. Solar system, type and capacity

iii. Refrigerator, type and capacity

iv. Major appliances, type and capacity

v. Lighting, type and capacity

vi. Estimated Savings from design features.

The NAMA database will be used to store this information, which can be shared with other programs to ensure comparability.

Example of Monitoring System Sample size

- Universe: 500 Homes
- For GHG Monitoring with 90/10 precision: A sample of 60 houses is required
- Comprehensive Monitoring corresponds to 3% of GHG Monitoring sample: two homes

Source: CONAVI, SEMARNAT. MRV System for the 'Sustainable Housing NAMA' in Mexico. Mexico City 2012, Table 16

Baseline sample characteristics by region

- The NAMA will select baseline homes from throughout implementation region, and with the support of local authorities.
- Implementers support the monitoring of baseline homes in a number agreed with the 'Mesa Transversal', seeking to achieve a representative sample by city.

Selection process of baseline homes

- To consolidation the baseline measurements across various initiatives the NAMA will conform to the geographic criteria of the Housing PoA.

(3) Details of the Comprehensive MRV system

In a first phase, the comprehensive system will be implemented in 3% of monitored houses and collect data which can be used to calibrate GHG models, track non-GHG benefits, and measure "overall house performance" which can be used to inform policy choices and technology design. The objective of the comprehensive monitoring system is to constantly improve the technology, design, and material performance for each climate zone. Data will also be used to ensure that benchmarks are accurately defined, and resources are being optimized per housing type and climate zone.

Each home under the comprehensive monitoring system will, at a minimum, be tracked for 14 months in two continuous cycles. Collected measurements will be recorded in the NAMA database.

Data will be collected through direct measurements as well as through surveys distributed to home owners and housing developers.

Table 10: Details of the Comprehensive Monitoring System

Parameter	Unit	Frequency	Direct Measure	Survey
Measurements in each dwelling:				
Electric power consumption	kWh	hour, monthly, aggregated annually	X	
Gas consumption (in temperate and cold)	Cubic meters	monthly, aggregated annually	X	X
Water consumption	litres / person / day	monthly, aggregated annually	X	X
Indoor temperature inside the house	° C	hour, monthly,	X	

		aggregated annually		
Inner wall temperature greater coexistence	° C	hour, monthly, aggregated annually	X	
Outdoor temperature	° C	hour, monthly, aggregated annually	X	
Indoor relative humidity	%	hour, monthly, aggregated annually	X	
Outdoor relative humidity	%	hour, monthly, aggregated annually	X	
Electric power consumption breakdown:				
Air conditioning	kWh	hour, monthly, aggregated annually	X	
Electricity consumption for lighting	kWh	hour, monthly, aggregated annually	X	
Electricity consumption for Strength (major appliances)	kWh	hour, monthly, aggregated annually	X	
Water consumption of the main devices of water:				
Sprinkler	litres / person / day and frequency of use	For bathing, monthly, aggregated annually		X
Kitchen faucets				X
Washing Machine				X
For housing in temperate and cold or AC				
Tightness of the housing	bpm	Once	X	
CO_2 levels	# Of air changes / hour at 50 Pa	Once	X	

Source: Mesa Transversal

The following table shows in detail the parameters that must be monitored by different projects, considering the priority level (1 to 4)

Table 11: Common Parameters Across Sustainable Housing Initiatives

		Monitored Element	Unit	Region	Min. Period	How it's measured	Priority
Electricity	1	Electricity consumption of housing	kWh	All	Hourly, Daily, Monthly, Annually	Data Logger / G-meter	1
Electricity	2	Electricity consumption for cooling	kWh	Hot climates	Hourly, Daily, Monthly, Annually	Data Logger / G-meter	1
Electricity	3	Electricity consumption for heating	kWh	All but warm / humid	Monthly, Annually	identified relationship between HDD's & consumption	3
Electricity	4	Electricity consumption for refrigerator	kWh	All	Hourly, Daily, Monthly, Annually	Data Logger / G-meter	2
Electricity	5	Electricity consumption for lighting	kWh	Where installation permits	Hourly, Daily, Monthly, Annually	When the lighting installation has an independent electrical circuit	4
Electricity	6	Electricity consumption for appliances	kWh	Where installation permits	Hourly, Daily, Monthly, Annually	When the appliance installation has an independent electrical circuit	4
Gas	7	Gas consumption	m^3	All (prioritize temperate and cold areas)	Monthly, Annually	Meter installed on intake pipe / G-meter	1

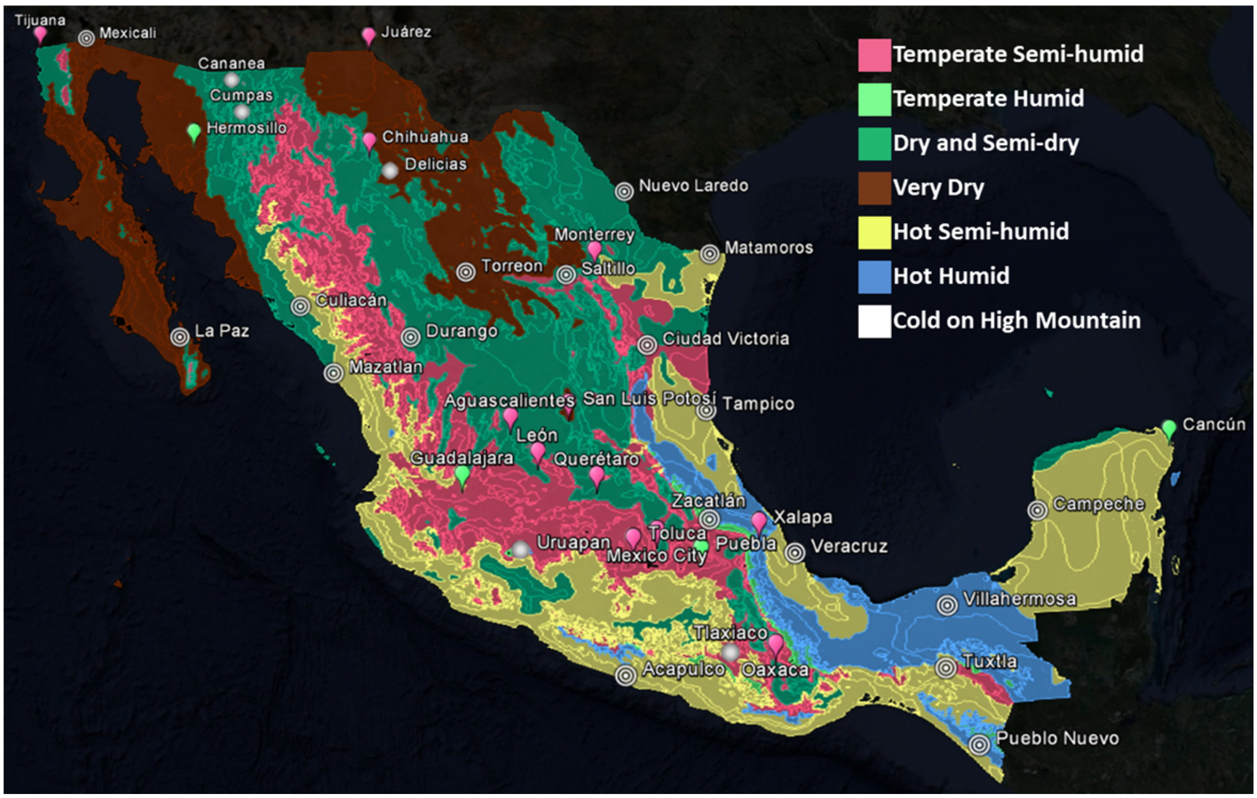
Water	8	Water consumed	Litres / person / day	All	Monthly, Annually	Meter installed on intake pipe / G-meter	1
	9	Water consumed by washing machine	Litres / person / day & frequency of use	All	Per load, Monthly, Annually	Deduction: survey, electrical monitoring and water volume consumed	3
	10	Water consumed for shower	Litres / person / day & frequency of use	All	Per bathroom, Monthly, Annually	Deduction: survey, hourly consumption and volume of water consumed	3
	11	Water consumed for toilet	Litres / person / day & frequency of use	All	Per load, Monthly, Annually	Deduction: survey and technology characteristics	3
	12	Water consumed for drinking	Litres / person / day	All	Monthly	Not measured	3
Comfort and Health	13	Interior house temperature	°C	All	Hourly, Daily, Monthly, Annually	Interior sensor in a high use area	1
	14	Interior wall temperature	°C	All	Hourly, Daily, Monthly, Annually	Interior sensor on the sunniest side of the house	1
	15	Interior roof temperature	°C	All	Not measured	Sensor	3
	16	Interior floor temperature	°C	All	Not measured	Sensor	3
	17	Exterior temperature	°C	All	Hourly, Daily, Monthly, Annually	Sensor, Weather station	1
	18	Interior relative humidity	%	All	Hourly, Daily, Monthly, Annually	Sensor	1
	19	Relative humidity of interior walls	%	All	Hourly, Daily, Monthly, Annually	Interior sensor in a high use area	3
	20	Exterior relative humidity	%	All	Hourly, Daily, Monthly, Annually	Sensor on the least sunny side of the house	1
	21	Interior CO_2 levels	ppm	All (particularly in airtight houses)	Not measured	Data logger mounted in living room	3
	22	Tightness	Air exchange rate	Mexicali, Cancun, & Auguascal.	One sample	A one-time blower door test	2

Source: Mesa Transversal

Baseline estimation

Since the proposed NAMA concerns energy efficiency on a whole-house level, the most natural approach for both baseline setting and monitoring would be to adopt a key performance indicator and measuring achievements towards a benchmark. With building efficiency programmes, a key performance indicator is commonly expressed in GHG emissions or energy consumption per gross floor area of a building and is established based on actual energy consumption data obtained from a sample of buildings.

Figure 13: Climate Zones for National-Scale NAMA



Source: INFONAVIT

(4) Baseline / Reference Conditions

Key decisions have been made regarding the characteristics that will constitute the business as usual case against which the NAMA performance will be measured.

From a methodological perspective, the baseline will reflect the passage of NOM020 and the following factors:

- 3 types of homes (single, connected, vertical)
- 7 bioclimatic zones
  - Templado subhumedo (Temperate Semi-humid)
  - Templado húmedo (Temperate Humid)
  - Seco y semiseco (Dry and Semi-dry)
  - Muy seco (Very Dry)
  - Calido subhumedo (Hot Semi-Humid)
  - Calido húmedo (Hot Humid)
  - Frio de alta montaña (Cold on High Mountain)

- homes are assumed to have a floor area of 40m^2
- It is a life cycle of 30 years
- Homes are assumed to have an occupancy of 2 persons (because the occupants are not using the property 100% of the time)
- homes are assumed to maintain a "comfortable" temperature range of between 20°-25° Celsius (this figure may be updated as pilot data is collected)
- Base case homes should not be more than 3-5 years older than NAMA houses

Housing Construction materials:

- floor and slabs of concrete with reinforced concrete walls or concrete masonry
- a single glass windows with aluminium frames, without any insulation.

From a technical perspective it has been agreed that reference homes will have the following characteristics.

Table 12: Reference Home Characteristics

Illumination Type	Compact Fluorescent Lamps 20W
Electric Domestic Appliances	Refrigerator 2.68 kWh/d Television 0.19 kWh/d Washing Machine 0.32 kWh/d Microwave Oven 0.17 kWh/d Source: Infonavit 2011a, Infonavit 2011b, Luz y Feurza n.d., SENER 2011.
Water Heater	Instantaneous Water Heater, Gas or LP (e.g. CINSA CDP 06)
Cooking Stove	Gas or LP Stove
Internal Heat Gains	5.3 W/m^2
Tightness (Air Exchange)	5 h-1
Primary Energy Factors	Electric Mix: 2.7 kWhPrim/kWhFinal Gas / LP: 1.1 kWhPrim/kWhFinal Source: Enerdata *et al.* 2011 and PHPP

Source: Mesa Transversal

In terms of baseline sampling frequency, the main approach used is to update the baseline sample every three to four years, to capture changes in energy-use patterns in the baseline group. In between these years the baseline is only adjusted for climatic variations using adjustments for cooling degree days.

Additional calibration will be undertaken throughout the measurement cycle, comparing the same projects against the baseline via simulation tools. Their efficiency results will be analysed in order to establish adjustment parameters for the software as necessary, and interpret simulation results adequately.

(1) Update of Key Parameters

The technical working group's progress developing common methodological and simulation approaches hinges on the use of common parameters and emissions factors to ensure that all parties are arriving at the same results when using the same data. Furthermore, there are many initiatives which are targeting to the housing sector, ensuring that all of these programs are using the same parameters allows Mexico and key stakeholders to simplify data collection and reporting across these actions.

Key parameters and emissions factors that have been identified for harmonization include the emissions intensity of delivered power and water. Below, two tables outline the common parameters that will be used for simulation and the emissions factors that will be used to translate these data into their emissions impact.

Table 13: Common Emissions Factors and Calorific Data[23]

Parameter	Description	Value	Unit	Source	Comment
EF_{NG}	Emissions Factor Natural Gas	55.82	tCO_2e / TJ	INE, IPCC (1996)	These factors are multiplied directly by the factor of oxidation and conversion to CO2 so that do not need to account for fuel storage
EF_{LPG}	Emissions Factor Liquefied Petroleum Gas	62.436	tCO_2e / TJ	INE, IPCC (1996)	
$EF_{Gasoline}$	Emissions Factor Gasoline	68.607	tCO_2e / TJ	INE, IPCC (1996)	
EF_{Diesel}	Emissions Factor Diesel	72.326	tCO_2e / TJ	INE, IPCC (1996)	
EF_{Grid}	Emissions Factor Delivered Electricity	0.5862 0.425	tCO_2e / MWh tCO_2e / MWh	SEMARNAT (2010), CFE (2012) CMM (2012) - BC	National Electric System Baja California
EF_{Water}	Emissions Factor Delivered Water	1.32	kWh / m^3 delivered water	CMM (2012)	Only in the Valley of Mexico[24]
NCV_{NG}	Net Calorific Value Natural Gas	48	TJ / Gg	2006 IPCC Guidelines for National Greenhouse Gas Inventories – Volume 2 - Energy	
NCV_{LPG}	Net Calorific Value Liquefied Petroleum Gas	47.3	TJ / Gg	2006 IPCC Guidelines for National Greenhouse Gas Inventories – Volume 2 – Energy	
NCV_{Diesel}	Net Calorific Value Diesel	43	TJ / Gg	2006 IPCC Guidelines for National Greenhouse Gas Inventories – Volume 2 - Energy	
$NCV_{Gasoline}$	Net Calorific Value Gasoline	44.3	TJ / Gg	2006 IPCC Guidelines for National Greenhouse Gas Inventories – Volume 2 - Energy	

Source: Mesa Transversal

Another area where stakeholders are engaged is the improvement of classification of the bioclimatic zones. In the original classification, each state was classified as having a single climate type, by first classifying each municipality's climate and then aggregating the number of towns in each climate type. The majority was then attributed to the entire region. CONAVI and its partners are working to improve the granularity of the bioclimatic classifications to account for climate differences within states, it is expected that seven climate zones will be used for national-scale implementation.

Barriers and challenges

[23] These factors will be updated periodically based on data collected by the comprehensive monitoring system and harmonized SEMARNAT factors to be published within the next 2 years

[24] Additional regional factors are under development

The major barrier to implementation of the MRV system tends to be access to data. Lack of necessary institutional frameworks and procedures, trained personnel, and/or resources can provide additional challenges.

The Sustainable Housing NAMA has made great strides towards accessing the data needed to operate the GHG MRV through a series of formal agreements with utility providers such as CFE, CONAGUA, and DTI. The issue becomes more relevant for housing units served by off-grid generation or small-scale dispersed fuel suppliers. The access question may become more complex in the case of the reference homes where incentives may have to be introduced to gain access to the same amount of data.

Another challenge involves balancing the need for robust and reliable estimates and the need to maintain flexibility, simplicity and cost-effectiveness of the MRV system of the proposed NAMA. The NAMA MRV system would ideally be as accurate as necessary and as simple as possible. When guidance developed by the UNFCCC, which may take many years, specific requirements for registration under an international regime can be incorporated into the proposed MRV system.

This challenge primarily concerns such methodological issues as selection of baseline approach, selection of the monitoring data collection methods, selection of monitoring metrics and their monitoring frequency.

In the coming months, as the proposed NAMA concept is refined and developed further, additional analyses will be conducted to establish data availability, suitability of the identified approaches, and the possibilities for synergies arising from the need for coordination between the various climate initiatives in the housing sector in Mexico.

The database currently under development will be a centralized source of information that regulators, researchers, and industry professionals can evaluate and compare performance of sustainable housing developments.

6 Financing the NAMA: Required resources and institutional set-up

6.1 Incremental investment costs and energy savings

The investment costs were calculated through a cost estimation of the additional measures for each case, from Eco Casa 1 to Eco Casa Max. A first estimate, 'current costs' reflects the costs incurred if the enhanced building standards were instituted immediately. This presumes that Eco Casa Max components such as efficient windows and ventilation units with heat recovery are not offered on the Mexican market and are thus very expensive.

A second scenario builds on the (more realistic) assumption that once energy-efficient building has become common in Mexico through the NAMA, the costs of components would reduce significantly through local production of building components and a competitive market situation. This scenario is called 'future (investment) costs'.

Moreover, from an economic point of view, in addition to capital investment costs, energy supply costs and other operating costs should always be factored in when assessing enhanced energy efficiency measures. As shown in the following graphs, reduced energy supply costs (and reduced subsidies) outweigh higher investment costs for the construction of more energy-efficient buildings.

In the following graphs, the life-cycle costs of the buildings are depicted as the annuity of the investment costs and the energy costs over the lifetime of the building. The basic assumptions for the calculation are shown in Table 9).

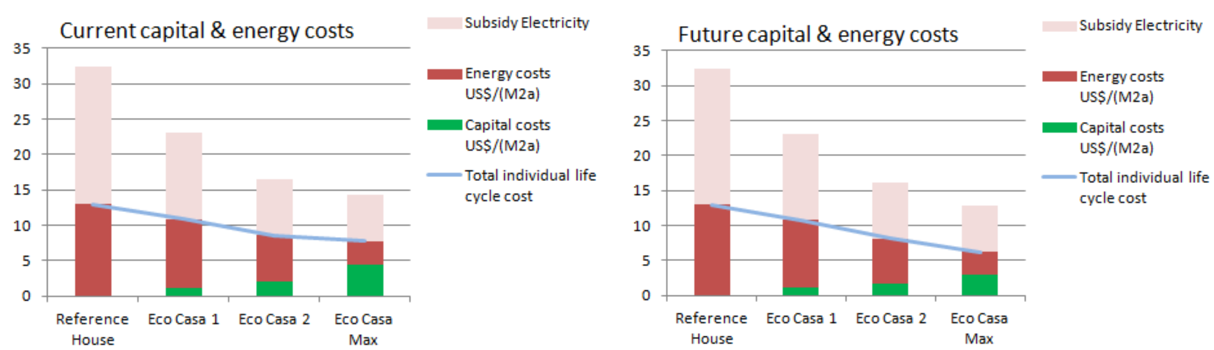
Table 14: Boundary conditions for calculating life-cycle costs

Indicator	Value	Unit
Real interest rate	2.00%	p.a.
Life cycle	30	Years
Gas price	1	MXN/kWh
Gas price increase	2.1%	p.a.
Electricity price	1.1	MXN/kWh
Electricity price increase	4.0%	p.a.
Electricity price subsidy	1.9	MXN/kWh
Subsidy increase	6.0%	p.a.

The following graphs demonstrate the incremental life cycle costs of vertical buildings in four climate zones. Compared to the base case, annual incremental capital costs (annuities) are shown in green, average energy costs for the individual owner are shown in red, while implied annual subsidies for the energy consumption of the owner are shown in dotted red.

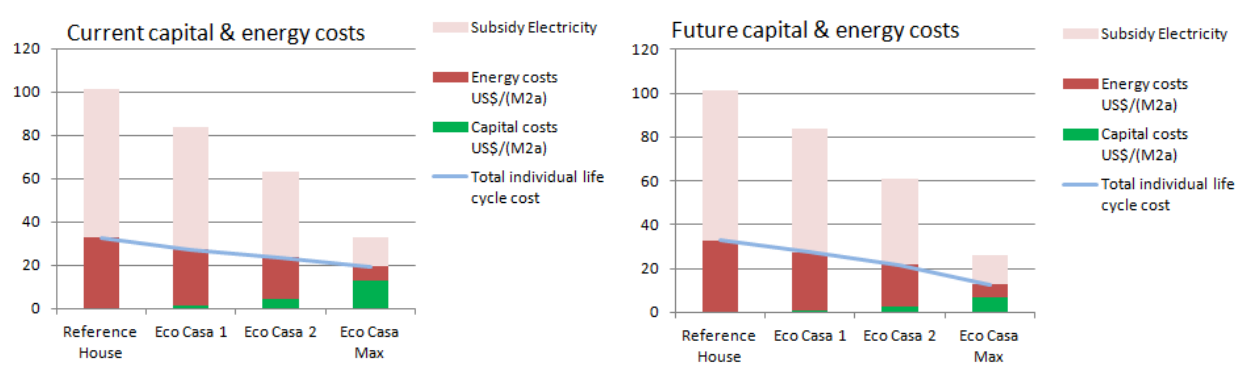
Introducing energy efficiency measures brings significant energy savings. The savings achieved affect also the total life-cycle cost of the house; however, part of it is a saved subsidy, which does not directly reach the home-owner. The most economical are the two intermediate energy efficiency standards, Eco Case 1 and Eco Casa 2. The incremental costs for them do not differ significantly regardless of the climate zone. The most expensive option in capital costs is the Eco Casa Max, although this cost is ultimately offset by the savings in energy cost and subsidies, making it the most economical option in the long term. Over time, it is expected that the costs of upscaled options such as Eco Case 2 and Eco Casa Max will decrease due to the gradual decrease in the cost of materials and associated services.

Figure 14: Current and future costs for energy efficiency measures in Guadalajara (vertical, 40m^2)



Source: Passive House Institute

Figure 15: Current and future costs for energy efficiency measures in Cancun (vertical, 40 m2)



Source: Passive House Institute

6.2 Required resources for NAMA implementation

6.2.1 Direct mitigation actions

Table 10 below summarizes the actual financing needs (grants to make subsidies available to partly cover additional investment costs) and associated benefits (savings in energy expenditure for the households, in subsidies for the government and CO_2 emission reductions) for implementation of the three energy efficiency standards under NAMA in an illustrative manner per 1,000 housing units of differing size and type.

Table 15: Investment costs for three energy efficiency standards per 1,000 housing units

	Houses	Total additional costs	Cost (grant amount) for house owner	Total CO_2 savings over lifetime	Saved energy costs (individual)*	Saved energy costs (electricity subsidies)**
Aislada + Adosada	# House units	USD mio.	USD mio.	tCO_2	USD mio.	USD mio.
Eco Casa 1 40m^2	1000	1.72	0.34	26 052	5.134	7.094
Eco Casa 1 70 m^2	1000	2.55	0.51	38 752	7.636	10.552
Eco Casa 2 40 m^2	1000	5.31	1.59	53 982	10.637	14.699
Eco Casa 2 70 m^2	1000	7.90	2.37	80 298	15.823	21.864
Eco Casa Max 40 m^2	1000	14.45	7.22	70 242	13.841	19.126
Eco Casa Max 70 m^2	1000	21.49	10.75	104 485	20.589	28.450
Vertical	# flat units	USD mio.	USD mio.	tCO2e	USD mio.	USD mio.
Eco Casa 1 40 m^2	1000	2.10	0.42	10 212	2.012	2.781
Eco Casa 1 70 m^2	1000	3.13	0.63	15 190	2.993	4.136

Eco Casa 2 40 m^2	1000	4.73	1.42	44 772	8.822	12.191
Eco Casa 2 70 m^2	1000	7.04	2.11	66 598	13.123	18.134
Eco Casa Max 40 m^2	1000	10.90	5.45	80 100	15.784	21.811
Eco Casa Max 70 m^2	1000	16.21	8.10	119 149	23.479	32.443
Total		97.54	**40.92**	**709 833**	**140**	**193**

Source: PHI and IzN Friedrichsdorf

6.2.2 Indirect mitigation actions (supportive actions)

The cost of supportive actions was estimated for the first phase of the NAMA from 2012 to 2016. The estimates were based on assumption of total roll-out of approximately 60,000 houses over five years under various standards. Because of the nature of the NAMA, the cost of supportive actions is not likely to increase significantly in case of faster roll-out. At levels of up to 200,000 houses, the costs are likely to remain stable, although they can increase at higher levels.

Several donors and bilateral/multilateral agencies for development cooperation (GIZ, UK embassy, etc.) are currently implementing activities in Mexico. The realization of supportive actions will need to be coordinated with these efforts.

Table 16: Supportive actions cost

No.	Type of supportive actions	Financing Need
1	Institutional set-up and NAMA administration	USD 3 009 000
2	Building Codes and permitting procedures	USD 910 000
3	Capacity building	USD 4 482 000
4	Beacon Projects and software adaptation	USD 1 830 000
5	Marketing and advertising	USD 1 419 000
	TOTAL	USD 11 650 000

6.2.3 Mexican contribution

México already uses CONAVI's subsidy programs to promote energy efficiency. For example, Esta es Tu Casa is linked directly to Hipoteca Verde and Paquete básico. This demonstrates that Mexico is able and willing to offer substantial co-financing. In addition, savings in energy achieved through the NAMA will reduce costs for the Mexican government.

Estimates of additional donor support for the financing of the NAMA are based on the two following premises with regards to the Mexican contribution:

- NAMA grants on the demand side cover only a part of the additional investment costs (20%, 30% and 50% depending on the standard Eco Casa 1, Eco Casa 2, and Eco Casa Max).
- Likely amount of subsidies that CONAVI will have for 2012 is MXN 9,000m (USD 677m), compared to MXN 5,000m or USD 376m in 2011)

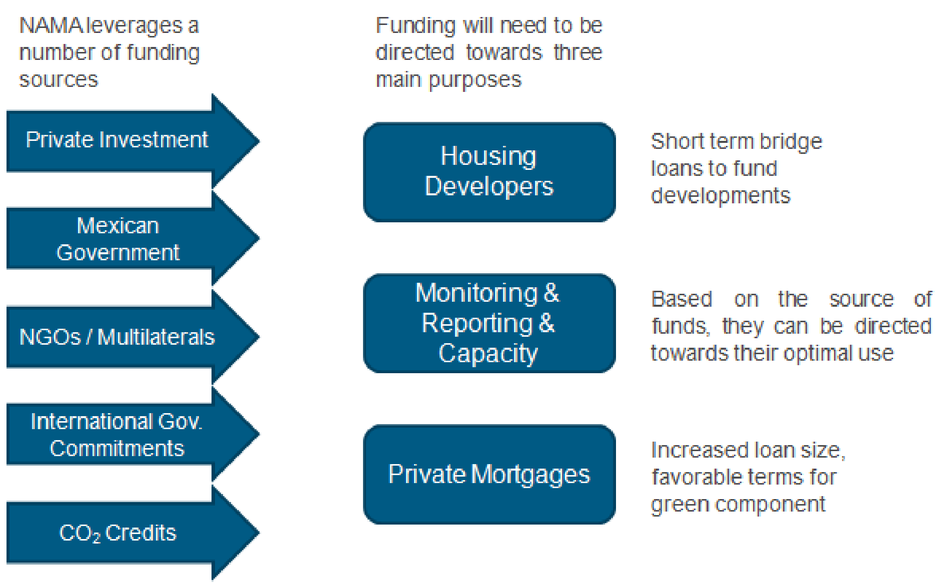
6.3 Financing scheme for the Sustainable Housing NAMA

A financial vehicle the 'NAMA Fund' will be set up to be the initial recipient of donor funds, whether in the form of soft loans or grants. The initial contribution will be made by the Mexican government. However, additional funds are needed beyond what the Mexican government can provide to achieve a high level of penetration and up-scaling. Carbon finance, international donors, and private investment will all be potential sources of funding for the Sustainable Housing NAMA. While the NAMA fund is being established, donors can partner directly with CONAVI, which will provide assistance directed by the Mesa Transversal.

In order to determine how best to attract and leverage public and private finance, the "end-uses" of NAMA funding should be examined and enunciated so that potential payback options can be aligned with financial stakeholders with desired project outcomes.

In general, funding for the NAMA can be directed towards three end-uses: supporting the supply of NAMA houses (developers), supporting demand for NAMA houses (mortgages), and providing MRV & capacity building services that enable NAMA operation.

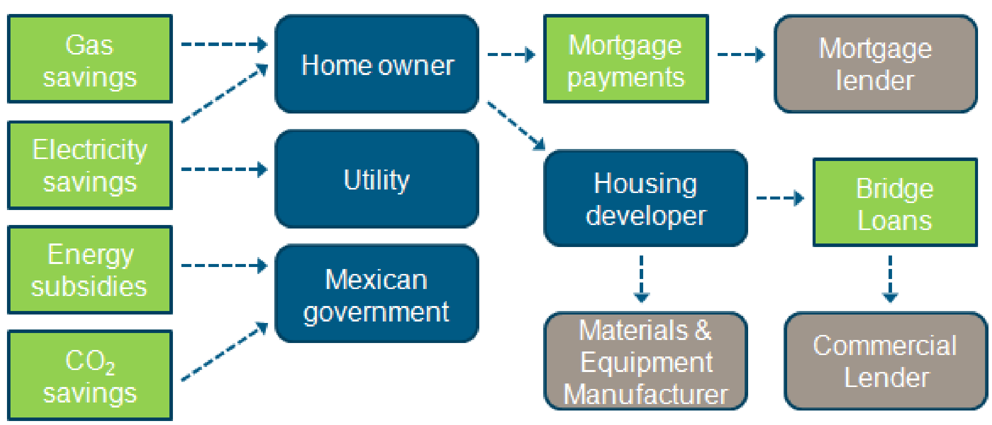
Figure 16: NAMA Funding Needs



Source: Point Carbon Thomson Reuters

It is clear that decreasing the overall energy consumption creates savings that have real economic value. However, in order to leverage public and private finance, and create a conduit for performance based payments, it is necessary to evaluate where stakeholders can capture value. Ultimately this analysis will inform structures needed to channel created value to support sustainable NAMA activities.

Figure 17: Value Captured by NAMA Stakeholders



Source: Point Carbon Thomson Reuters

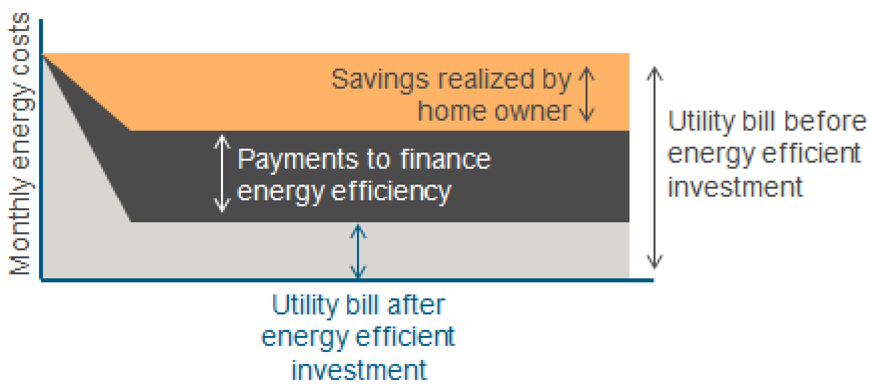
6.3.1 Financial Support for the Demand Side

The mortgage component is one of the most important parts of the NAMA design because it drives demand for energy efficient homes. Without demand, even the most favourable conditions for developers will not result in a successful program. Furthermore, if a strong market demand can be generated, less assistance will be required for suppliers as it implicitly reduces the risk that homes will not sell.

The NAMA ultimately achieves emissions reductions through decreasing consumption of electricity, natural gas and water per unit of housing. Returns on residential energy efficiency investments are driven by the technology performance and resulting avoided costs for power, gas and water.

Under a 'traditional' energy efficiency financing model, the amount saved on these recurring costs is enough to offset the financing cost of the installed equipment. This model is based on two assumptions (1) that the home owner is able and willing to secure the capital to purchase the equipment and materials, and; (2) that the value of the avoided cost to the home owner is sufficient to pay (and ideally exceeds) the monthly payments on the equipment.

Figure 18: Traditional Energy Efficiency Financing Model



Source: Point Carbon Thomson Reuters

Without the NAMA, neither of these assumptions is likely to hold. As **Figure 17** illustrates, the government, not the homeowner, benefits from the reduction in subsidy payments. In Mexico, on average, 60% of residential energy costs are covered through federal subsidies[25]. This reduces the payback received by the homeowner, and thus the revenue stream that can be used to secure financing for the equipment.

Subsidized mortgage assistance, covering all or some of the incremental cost of the energy efficient features, can overcome this challenge by reducing the investment cost to homeowners, and the amount of savings needed each month to make the investment attractive.

6.3.2 Financial Support for the Supply Side

The supply of NAMA housing is dominated by housing developers that construct the buildings in the first instance. Unlike the 'Hipoteca Verde' program, in which loans for new houses are followed by the incorporation of energy efficiency technologies into existing units, NAMA houses must be built according to certain efficiency standards (Eco Casa 1, Eco Casa 2, Eco Casa Max) starting from the initial design phase onward.

While some of the largest stakeholders in this market are able to self-finance, most building developers have to solicit short term loans in order to purchase land and construct housing developments. This market is currently

[25] World Bank. Residential electricity subsidies in Mexico: exploring options for reform and for enhancing the impact on the poor. Washington, D.C. 2009

served by commercial banks, and interviews with industry representatives indicate that developers pay between 15% and 20% interest on bridge loans to fund new developments. When building sustainable houses, developers and lenders take on risks that the houses will not sell, or that homes will remain on the market for an uncertain period of time. Ultimately it is the developer who takes the risk for the additional cost of energy efficient equipment and materials until they are completely paid when the house is purchased.

Because of the direct linkages between lenders and builders, the supply side of the market is easier to serve as evidenced by the international multilaterals that have already pledged soft loans (i.e. a loan with an interest rate below-market rate) to support this segment of the market. For the building developer, there are two key risks that need to be addressed: (1) energy efficient homes are more expensive to build than "normal" homes but are targeted at the same group of consumers with the same capacity of payment and home value and (2) the demand for energy efficient homes is uncertain at the moment. However, preliminary studies show a faster (up to 50%) uptake of energy efficient houses compared to traditional houses without Hipoteca Verde.

In order to serve this segment of the market, the NAMA fund has to offer solutions to make financing available at more favourable rates, provide subsidies to cover the cost of energy efficient materials and equipment, or create demand through supply side actions that decrease the risk to developers.

6.3.3 Financial Support for Capacity Building & MRV

In order to achieve, measure, and report impacts, the NAMA will also require funds for administrative capacities and support to develop and apply the MRV system. As there are no revenue generation opportunities under this end-use it is not well suited to attracting private investment, however a robust MRV system is critical to demonstrating emission reductions for finance regimes that leverage avoided subsides.

Technical assistance for supportive and administrative actions can be channelled in three ways:

- payment in the international NAMA Fund and operation by a specific agency (be it national, international or both);
- implementation of new bilateral programmes for technical assistance between a certain host country and Mexico implemented according to standard procedures used by the different donor countries;
- implementation by GIZ on behalf of a certain donor country in form of a co-financing to current GIZ bilateral programmes that were commissioned by the German Federal Ministry for Economic Cooperation and Development (BMZ) or the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) in the frame of the German–Mexican bilateral cooperation.[26]

6.4 Potential Approaches

In order to achieve nation-wide deployment, private sector investment will be required. Potential investors in the Sustainable Housing NAMA face a number of risks related to the project, country and technologies used to achieve emission reductions. In order to justify taking on these risks, some of the value created through NAMA activities needs to be channelled back to investors to provide return. This section will define the elements of this equation in order to identify mechanisms that can be used to create links between the NAMA activities and potential investors so that their capital can be attracted and leveraged to support Mexico's sustainability goals.

Returns can be defined in a number of ways, but in this case the focus is on saving money, generating new cash flows and creating valuable assets. Saving money is the most obvious benefit of the NAMA investments, both in terms of energy consumption by homeowners and through avoided energy subsidies at the government level.

[26] Such co-financing needs approval by the respective ministry (BMZ, BMU).

The challenge for the NAMA fund will be to find creative ways of channelling value creation to reduce risk or increase returns. A few approaches are currently under review by CONAVI and its partners.

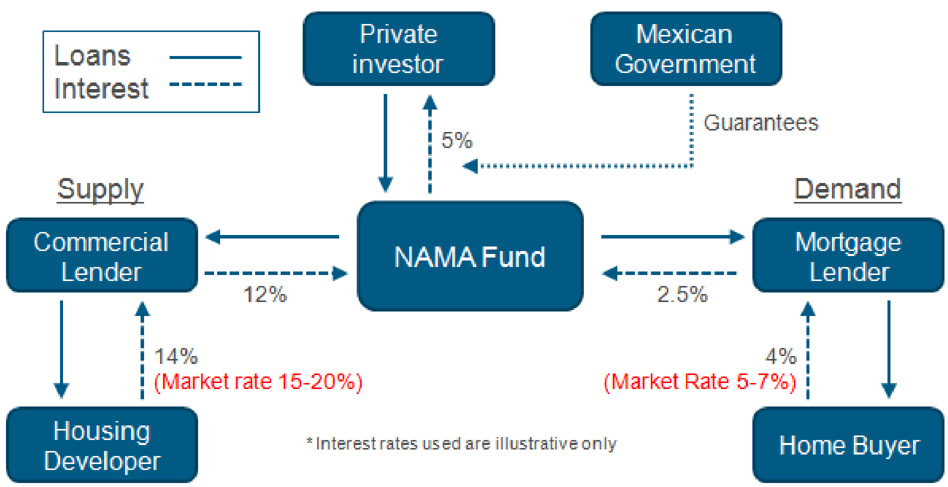
6.4.1 Underwriter Model

The underwriter model leverages the Mexican Government's ability to borrow money at a low cost to finance the NAMA fund. Under this approach, the borrowed money is used to promote lending to housing developers and home buyers that build and purchase energy efficient homes by providing loans or loss protection to financial intermediaries that serve this market.

The NAMA fund will be able to leverage low interest rate financing to offer below market interest rates to bridge loan marketers and mortgage issuers. On the supply side, companies that offer loans for energy efficient housing development will use the lower rates secured from the NAMA fund to then pass on the savings to the developers, as a form of subsidy. On the demand side, preferential rates loaned to the mortgage issuers will subsidize the mortgages issued to the buyers, resulting in either lower rates to the home buyer, or reduced loan size.

The relative discount offered to the supply or demand side will need to be studied carefully. Higher rate discounts (more support) to the supply side will reduce the visible sticker price of the house, but the homebuyer will not personally enjoy the benefits in terms of cheaper or discounted mortgages. If more discounts are provided to the demand side, then the buyer will see a higher sticker price, but will also benefit from cheaper rates or discounts from the mortgage company. The relative amount of discount applied to the respective sides should be decided by the behaviour of potential home buyers and the ease of implementation and oversight.

Figure 19: The Underwriter Model



Source: Point Carbon Thomson Reuters

The primary advantage of this model is that it is in theory self-sustaining, since the fund locks in profit by borrowing at a lower rate and lending it out at a higher risk adjusted rate. Aside from guaranteeing the payments in case of default, the government does not necessarily need to finance the NAMA fund directly. This therefore reduces political risk, since the "health" of the fund is not directly dependent on government payments.

6.4.2 Subsidy Driven Models

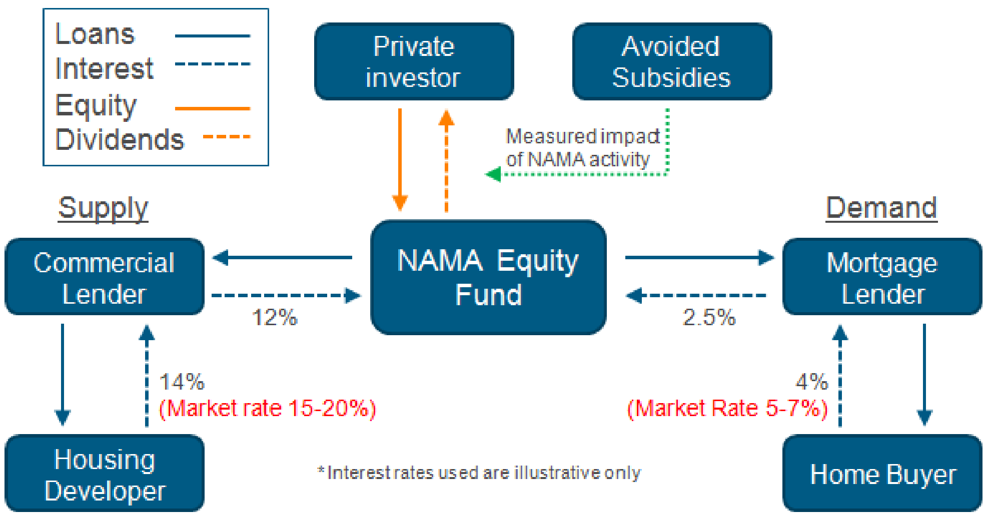
Energy subsidies are a key cost savings generated by the NAMA. By monetizing a portion of the Mexican subsidies for residential energy use, either by (1) providing a prescribed percentage (i.e. 1%) of annual subsidies to the NAMA fund, or; (2) leveraging a portion of the subsidies avoided by the NAMA activity (quantified through the

MRV system) - the NAMA fund can access an additional source of performance base funding that can be used to attract private investment.

The so-called "subsidy models" channel a portion of funding used to subsidize residential consumption of electric power and natural gas into the NAMA. Three uses of these funds are being considered: (1) using avoided subsidies to pay back investors, (2) reinvesting avoided subsidies into NAMA activities, and; (3) using subsidies to reduce risk for private investors.

Under this approach, private investors get involved by purchasing ownership shares of the NAMA fund and are paid back based on programme performance. This performance payment can be augmented by a portion of avoided subsidies, if necessary, to ensure sufficient returns for investors.

Figure 20: The Equity Model

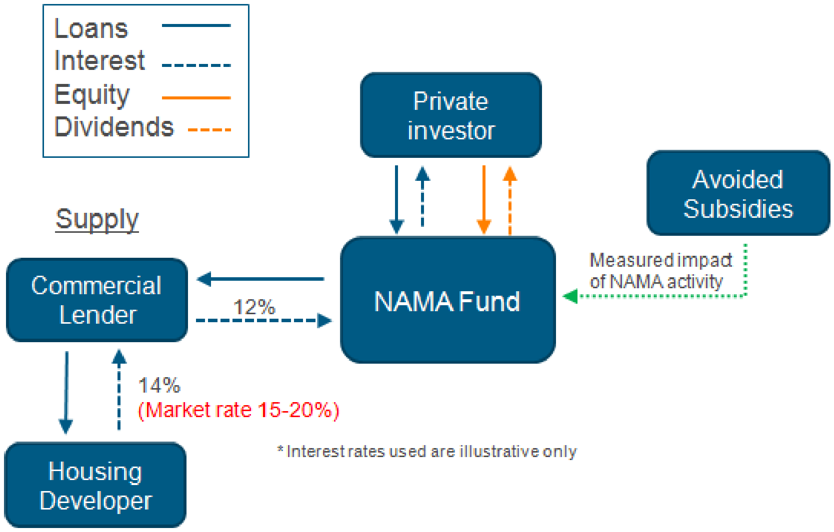


Source: Point Carbon Thomson Reuters

Value to the equity holder could also come in the form of carbon emission reductions. Based on the owner's percentage of ownership, the owners could claim ownership of their share of GHG reductions associated with the programme and claim it as part of their actions to reduce the Mexican climate change target.

Under this approach, private investors get involved by providing debt or equity financing to the NAMA fund and payback is generated based on fund performance. However, unlike the equity model described above, energy subsidies are not used to pay back investors, but instead are re-invested into the fund driving further energy efficiency gains that result in improved fund performance.

Figure 21: The Reinvestment Model



Source: Point Carbon Thomson Reuters

The key benefit to these approaches is that they enable the NAMA fund to pay directly for some or all of the additional energy efficiency equipment by capturing the full or great part of the value of avoided energy costs in both government and consumer savings.

6.4.1 The Loss Protection Model

Under the loss protection model, savings in energy subsidies are not distributed to the NAMA fund or to investors. Instead a portion of the energy subsidies are held by the government and set aside in an insurance fund that provides loss protection guarantees to private investors. Alternatively, the government could choose to purchase insurance directly from the market.

This approach operates by lowering the investment risk, thus reducing the required payback needed to attract investment in the NAMA. Loss protection in this context can take a number of forms. One option would be to limit potential losses in the case of default, where for example investors are guaranteed 80% of principal. Another option would be to provide performance guarantees for projects and equipment.

This approach is, in many ways, similar to the underwriter model described earlier in this document with the main difference that there is a clear and definite link between the performance of the NAMA and the amount of additional private financing that can be supported based on energy cost savings.

6.4.2 Corporate Social Responsibility (CSR) Model

The concept behind NAMAs is that the reductions represent the contributions of the host country towards fighting climate change, thus the emission reductions generated by the project should ultimately count towards Mexico's goals and not be transferred outside of the country for use as offsets. Although the emissions reductions achieved cannot be sold or traded through the carbon market, there are still buyers that perceive value in emissions reductions and in demonstrating their commitment to sustainable development. Examples include large multinationals operating inside Mexico that wish to demonstrate goodwill, Mexican companies that have non-binding mandates to reduce emissions in Mexico, or investors with a mandate to invest in green funds.

Under the CSR model, companies can provide soft loans or provide benefits such as NAMA employee housing and be rewarded with a "claim" to Mexican emissions reductions. A system could be set up to track the emissions resulting from their investments such that large domestic firms may be able to claim a certain amount of the emissions benefit towards their CSR or emissions reduction goals (e.g. "PEMEX's investment in the NAMA fund contributed 3 million tons to the government's emissions goals and provided a return"). This claim would be substantiated through MRV systems and could serve as an important motivator to attract financial support.

6.5 NAMA financing packages offered to the international donor community

Analysis of the performance of various types of houses shows that the specific savings (reductions of primary energy demand per square metre of living surface) are much more favourable with terraced houses (Adosadas), multi-storey buildings (Verticals), compared to the traditional single freestanding or detached family homes. Vertical housing units in particular prove not only to be more efficient as to the performance of the building itself, but also allow urban settlements to remain closer to the city centre, thereby avoiding undesirable urban sprawl.

On the basis of the above, five financing packages have been formulated as an example of how international support could advance the NAMA, presented in Table 13. Financing needs are split into three categories: subsidies to home-owners, bridge loans to developers in the form of soft loans and support required for the implementation of the passive house pilot. The financing needs indicated in the table cover only a part of additional investment costs: 20% in case of Eco Casa 1, 30% of Eco Casa 2 and 50% of Eco Casa Max houses, the rest of the subsidy financing needs will be covered by the home-owners and/or the government of Mexico. These estimates do not include the operational costs of the NAMA (supportive actions) described in Section 6.1.2.

Table 17: Soft loan revolving fund for bridge financing, million USD

	2012	2013	2014	2015	2016	Total
Accumulated revolving fund size	5.68	12.67	24.64	50.51	98.97	192.47
Additional financing requirement per year	5.68	6.99	11.97	25.87	48.46	
Minimum grant component required	1.14	1.40	2.39	5.17	9.69	

The total incremental cost of construction indicated in Table 13 is equivalent to the volume of soft loans that the developers would require in the form of bridge financing in order to build the houses to higher energy efficiency standards. By their nature, the bridge loans are short-term, the developers will be able to repay them as soon as the house is sold on the market. Considering the quick construction cycle in Mexico, the loans are expected to be repaid within a period of six months. This creates opportunity for a revolving fund for bridge financing. Such a revolving fund may combine a blend of commercial funds and government grant money, aimed at creating soft conditions for lending. Table 12 shows the accumulated and per year requirements for the revolving fund on assumption of joint implementation of all five financing packages. An estimate of the minimum grant element for qualification as a soft loan is provided in the last line.

Several important considerations apply for the financing packages presented above:

- **Flexibility of grant packages:** The packages shown below have the character of example packages. Actual packages can be shaped to fit specific requirements of interested donors (e.g. adjustments can be made in terms of financial volume, type of buildings and efficiency standards covered, etc.).
- **Combi-packages:** The Mexican government is willing to offer combinations of grant packages for subsidies to home-owners, soft loans for bridge finance to developers and/or grant packages for supportive actions.
- **Mexican priorities between soft loan and grant packages:** The implementation of the NAMA is critically dependent on the support of the international donor community for subsidies to home-owners and supportive actions ensuring the functioning of the NAMA. The soft-loan component of the NAMA has a complementary character, and represents an important element in the overall finance strategy. The Mexican government has a clear priority to ensure grant financing first, and will try to obtain soft-loan financing in parallel.

Table 18: Examples of financial packages for donor support

Packages				Financing Need			Benefits		
Financial packages	Scale of the package	Content of the package		Subsidies to Home Owners, USD million		Total incremental construction cost USD million	Saved energy costs (individual)* USD million	Saved energy costs (subsidies)** USD million	Emission reductions over 30 yrs lifetime, tCO_2
		Mainstream roll-out	Eco Casa Max Pilot	Mainstream roll-out	Eco Casa Max Pilot				
Package 1	Large Scale (27,000 homes)	EcoCasas 1 and 2, 40 and 70m^2	30 buildings of 40m^2	49	0,2	165	337	466	1,711,000
Package 2	Mid-Size (13,800 homes)	EcoCasas 1 and 2, 40 and 70m^2	30 buildings of 40m^2	25	0,2	84	171	236	866,000
Package 3	Small Scale (5,200 homes)	EcoCasas 1 and 2, 40 and 70m^2	30 buildings of 70m^2	9	0,3	27	61	85	311,000
Package 4	Multi-Family (14,940 apartments)	EcoCasas 1 and 2, 40 and 70m^2	780 verticals, 40 and 70m^2	27	3	94	170	236	865,000
Package 5	Eco Casa Max Pilot (890 homes)	890 Mexican Eco Casa Max (different types)		-	6	12	17	24	87,000

* saved energy costs (individual; at household level) as Net Present Value over 30 years for the households' total energy demand (electricity and LPG)

** saved subsidies (government perspective) as Net Present Value of saved subsides for electricity over 30 years (conservative approach, since saved subsidies on LPG are not considered)

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Annex I. Detailed overview of costs of supportive and administrative actions

Annex II. Technical Annex: Evaluation of social housing building types in Mexico.

No.	Activity	2 012	2 013	2 014	2 015	2 016	Subtotal
1	**Institutional set-up and NAMA administration**	**988 000**	**658 000**	**455 000**	**454 000**	**454 000**	**3 009 000** USD
1.1	Designing fund for financial resources, incl. legal agreements	210 000	-	-	-	-	**210 000** USD
1.2	Designing, establishment and operation of "NAMA Programme Office Unit"	238 000	238 000	155 000	154 000	154 000	**939 000** USD
1.3	Baseline, MRV and additionality framework						
1.3.1	Development of data-collection systems to accurately measure, report and verify emissions: Set up and operation of a comprehensive data base (baseline and MRV) of houses and energy consumption and demand	150 000	35 000	35 000	35 000	35 000	**290 000** USD
1.3.2	Capacity building and capacity build-up for monitoring and auditing - Establishment of a professional and specialized inspection and supervision system	90 000	50 000	20 000	20 000	20 000	**200 000** USD
1.3.3	Comprehensive household monitoring and auditing surveys (i.e. simulation using data base and detailed surveys)	210 000	245 000	245 000	245 000	245 000	**1 190 000** USD
1.4	Technical Assistance to FOVISSSTE and SHF in the establishment of their institutional set-up for the implementation of the NAMA	90 000	90 000				**180 000** USD
2	**Building Codes and permitting procedures**	**280 000**	**210 000**	**210 000**	**210 000**	**-**	**910 000** USD
2.1	Technical Assistance to local governments and organizations at state and municipal level for introduction of a minimum energy performance standard, the whole building approach and target values for primary energy consumption as well as sustainability criteria. Elaboration of a national guideline for Building Code adaptation	280 000	210 000	210 000	210 000	-	USD
3	**Capacity building**	**1 376 800**	**1 069 800**	**699 800**	**667 800**	**667 800**	**4 482 000** USD
3.1	Training for energy advisors, planners and construction workers on energy efficiency building mainly through the PHPP tool						**-** USD
3.1.1	Scaling up of university/commercial school curricula on EE buildings and RE in buildings with focus on supporting for the NAMA implementation and operation	65 800	65 800	65 800	65 800	65 800	**329 000** USD
3.1.2	Translation and adaptation of European/PHI training material to Mexican climate and Building tradition; check after experience	66 000	66 000	20 000	10 000	10 000	**172 000** USD
3.1.3	Training through a "Train the trainer approach" with local partners. The local partners consecutively, provide training and design of energy efficient buildings (eco-casa, PHPP) for developers and planners throughout Mexico and special training for construction workers	100 000	60 000	30 000	30 000	30 000	**250 000** USD
3.2	Training to local authorities and stakeholders						**-** USD
3.2.1	CONAVI will also perform capacity building for local, state and federal authorities by attendance courses, virtual learning and the construction of an inter-institutional platform; objective: Local authorities and stakeholders are able to introduce and implement sustainability criteria in their daily processes and decisions involved at housing master plans and house construction level	840 000	700 000	420 000	420 000	420 000	**2 800 000** USD
3.3	Training to house owners/users						
3.3.1	Production of a manual for house owners/users in order to understand and optimise the use of the energy efficient houses	50 000	25 000	25 000	25 000	25 000	**150 000** USD
3.3.2	Campaigns in order to increase the consciousness of energy efficiency not only for buildings but also for the use of efficient appliances	150 000	75 000	75 000	75 000	75 000	**450 000** USD
3.4	Encouragement and support of regional manufacturers and companies to increase the availability of suitable products						**-** USD
3.4.1	Guideline and support for manufacturers through local partner and international advisory	70 000	50 000	50 000	28 000	28 000	**226 000** USD
3.4.2	Adaptation of certification criteria for local Mexican products	35 000	28 000	14 000	14 000	14 000	**105 000** USD
4	**Beacon Projects and software adaptation**	**310 000**	**310 000**	**450 000**	**410 000**	**350 000**	**1 830 000** USD
4.1	Quality assurance of all Passive House design and constructions; and adaptation/implementation of PHPP calculation and design tool	250 000	100 000	70 000	50 000	50 000	**520 000** USD
4.2	Design and construction of Beacon Projects in different locations in Mexico (Construction --> direct measures, not included here)	60 000	110 000	80 000	60 000	-	**310 000** USD
4.3	Monitoring of Beacon Projects (--> experience, also necessary for learning, capacity building, demonstration and dissemination)	-	100 000	300 000	300 000	300 000	**1 000 000** USD
5	**Marketing and advertisement**	**277 000**	**289 000**	**289 000**	**289 000**	**275 000**	**1 419 000** USD
5.1	Website (development & maintenance)	42 000	14 000	14 000	14 000	-	**84 000** USD
5.2	Mass media campaign (TV, radio, newspaper)	200 000	200 000	200 000	200 000	200 000	**1 000 000** USD
5.3	Promotion for the participation (Brochures and marketing material)	35 000	35 000	35 000	35 000	35 000	**175 000** USD
5.4	Demonstration and dissemination: make success visible	-	40 000	40 000	40 000	40 000	**160 000** USD
	TOTAL	**3 231 800**	**2 536 800**	**2 103 800**	**2 030 800**	**1 746 800**	
	ACCUMULATED	**3 231 800**	**5 768 600**	**7 872 400**	**9 903 200**	**11 650 000**	**11 650 000**

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".

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

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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 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.

The specific task of the Passive House Institute, 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

The contribution of the Passive House Institute 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 m² lying inside its thermal envelope with a treated floor area of 38.4 m². The sample house was based on a real social housing project for Mexico and was provided by GIZ/GOPA 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.

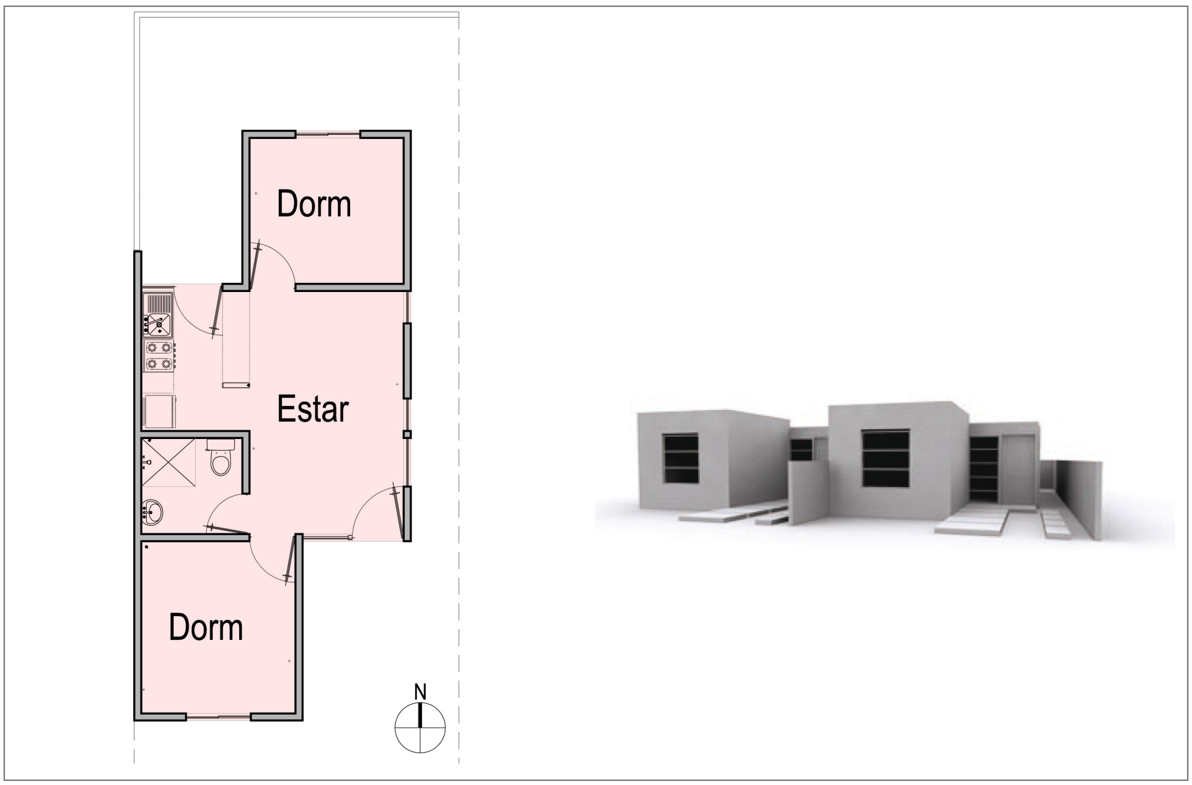


Figure 1: Aislada building type. Floor plan and 3D model, no scale
Source: [Campos 2012]

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

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.

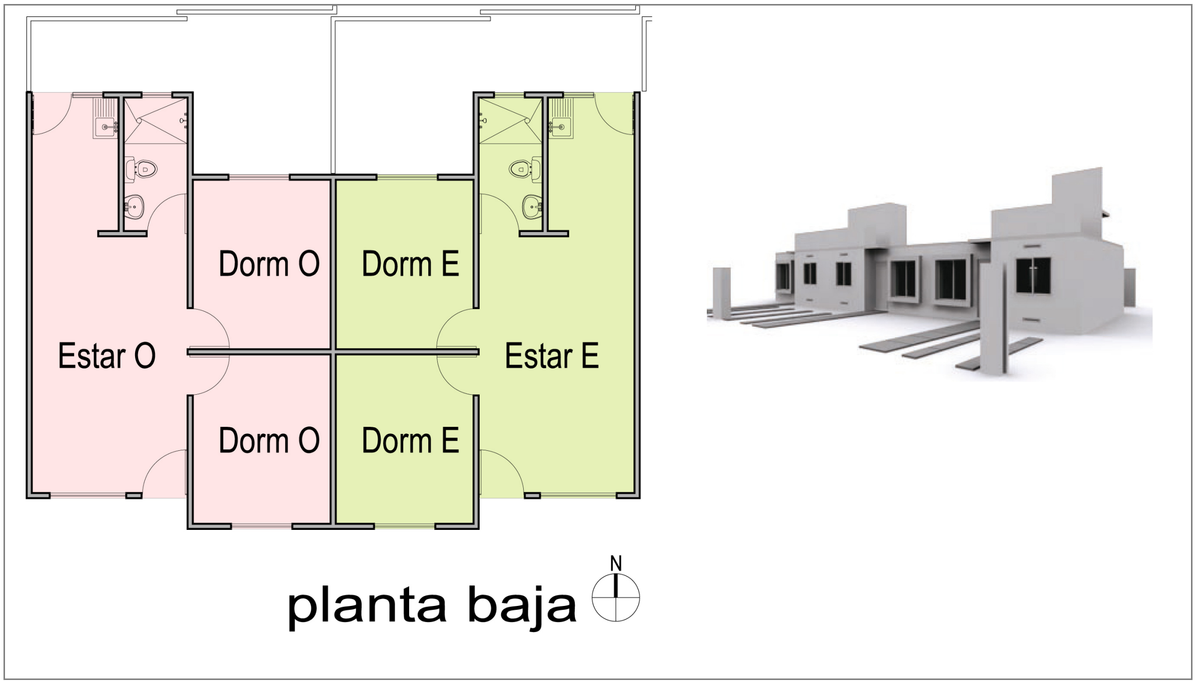


Figure 2: Adosada building type. Floor plan and 3D model, no scale
Source: [Campos 2011]

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.

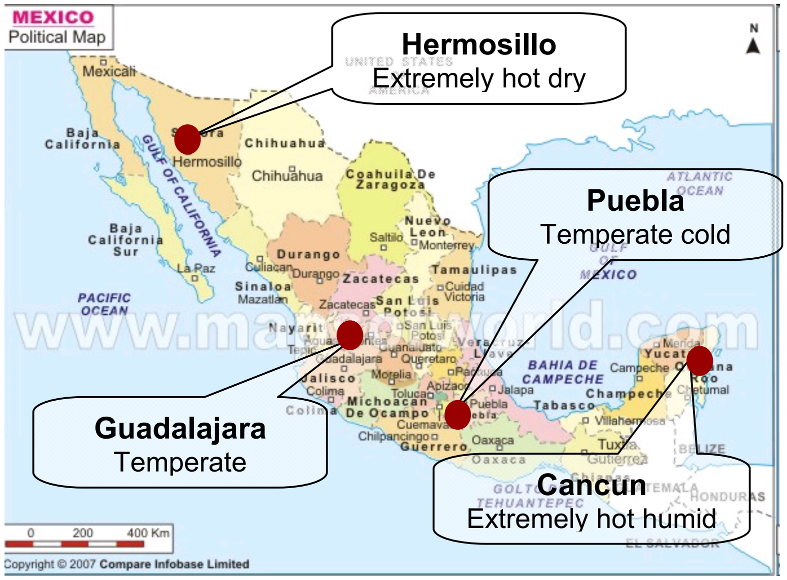


Figure 4: Map of Mexico showing the four locations and corresponding climate zones
Source: Compare Infobase Limited with adaptation by the Passive House Institute

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. Source: Passive House Institute

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
Temperature limit winter10	20°C
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 for the NAMA has been alternatively called EcoCasaMax), 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 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

[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.*

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.

The different energy efficiency standards calculated correspond to different energy efficiency levels of the Sisevive qualification system, which is currently being developed, being the baseline the level F and the Passive House Standard/EcoCasaMax, the level A.

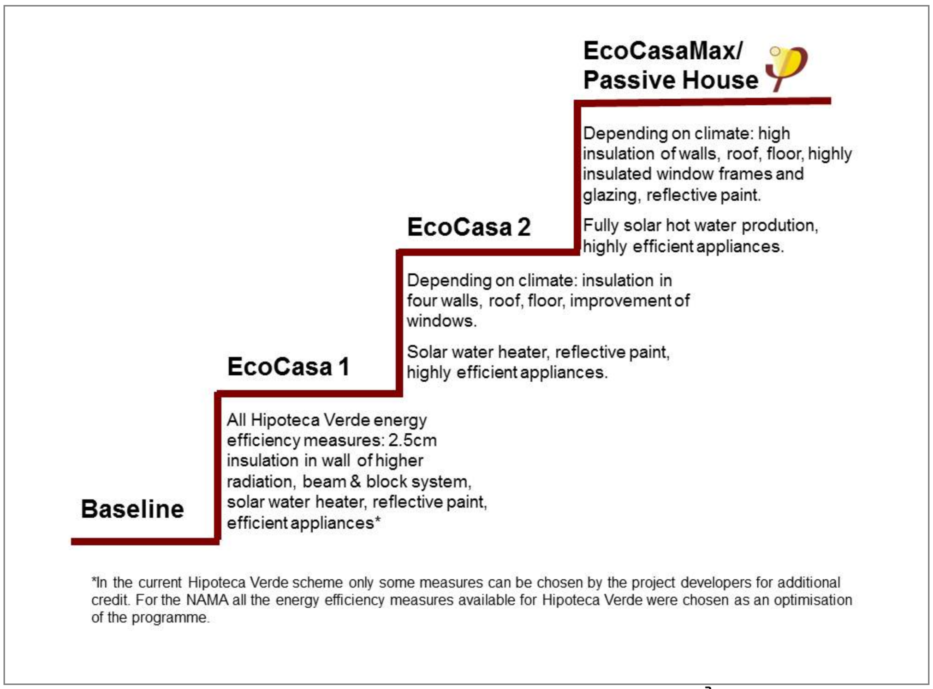


Figure 5: Energy efficiency cases for the Mexican NAMA[2]
Source: Passive House Institute

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.

[2] In the NAMA main document, to which this annex is attached, the EcoCasaMax is based in the Passive House Standard. For more information about the Passive House Standard please go to www.passivehouse.com

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. This 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.

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.

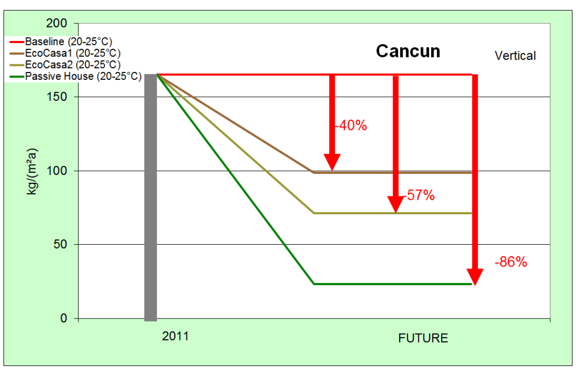


Figure 6a: CO_2 emission reduction estimation for Vertical building type in Hermosillo.
Source: Passive House Institute

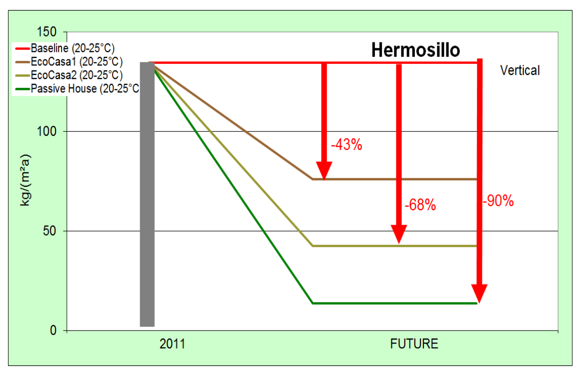


Figure 6b: CO_2 emission reduction estimation for Vertical building type in Cancun.
Source: Passive House Institute

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.

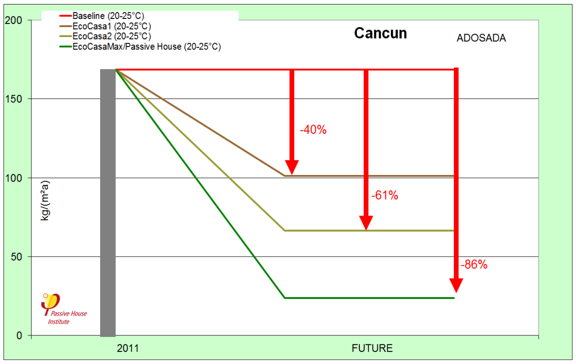


Figure 7a: CO_2 emission reduction estimation for Adosada building type in Hermosillo.
Source: Passive House Institute

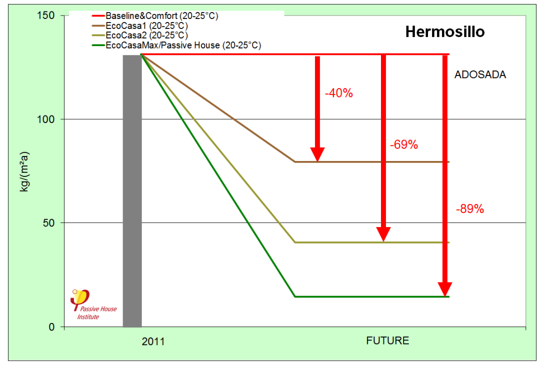


Figure 7b: CO_2 emission reduction estimation for Adosada building type in Cancun.
Source: Passive House Institute

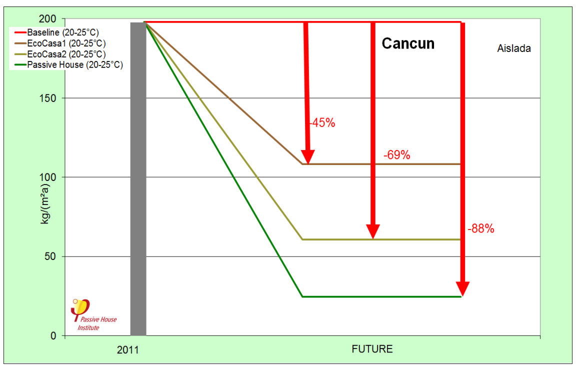


Figure 8a: CO_2 emission reduction estimation for Aislada building type in Hermosillo.
Source: Passive House Institute

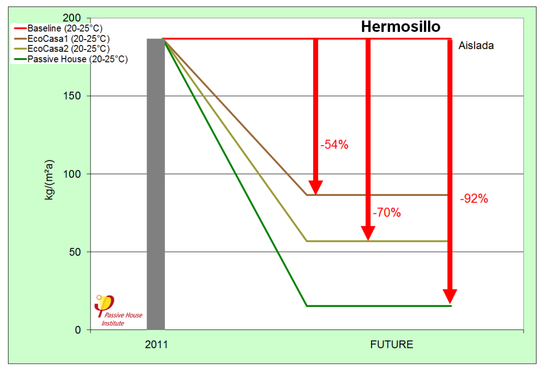


Figure 8b: CO_2 emission reduction estimation for Aislada building type in Cancun.
Source: Passive House Institute

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/EcoCasaMax, 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: Passive House Institute

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/EcoCasaMax 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..

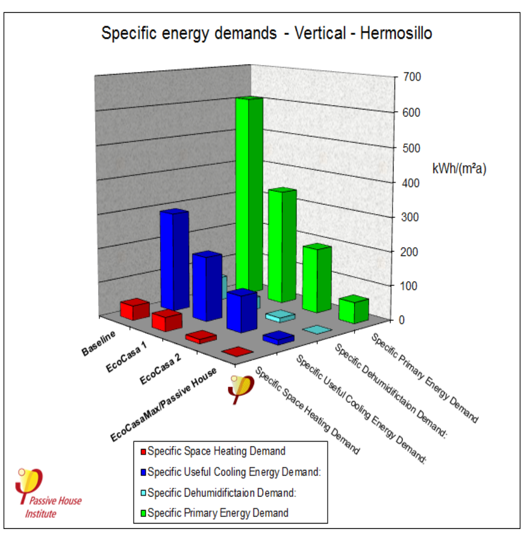


Figure 9a: Specific energy demands for Vertical building type in Hermosillo.
Source: Passive House Institute

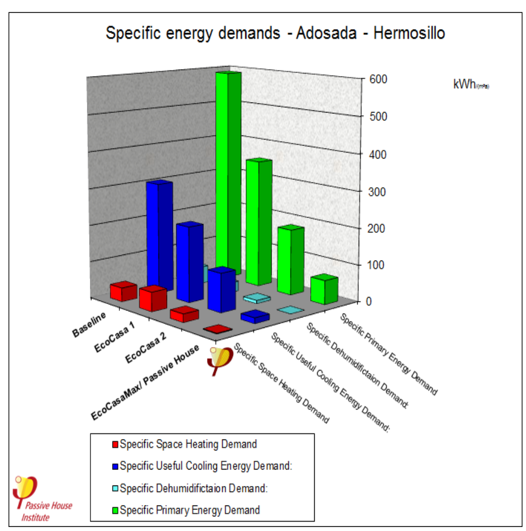


Figure 9b: Specific energy demands for Adosada building type in Hermosillo.
Source: Passive House Institute

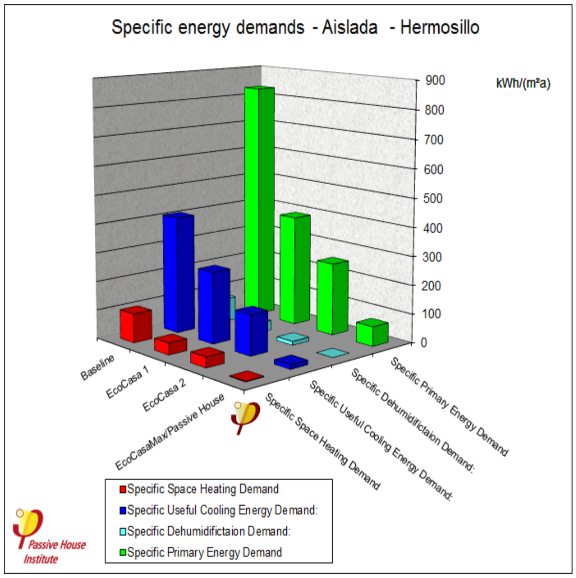


Figure 9c: Specific energy demands for Aislada building type in Hermosillo.
Source: Passive House Institute

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

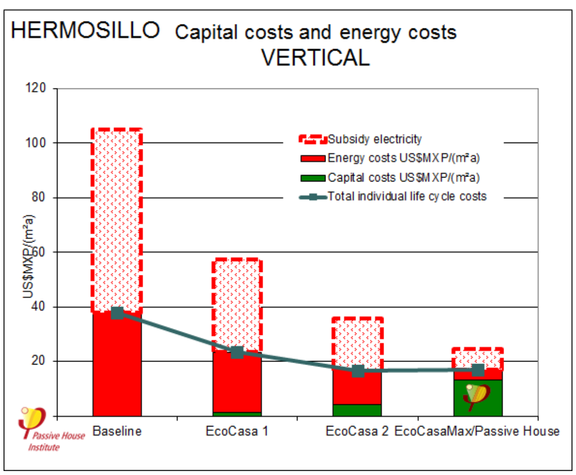


Figure 10a: Current capital and energy costs of Vertical building type compared, from baseline to Passive House in Hermosillo.
Source: Passive House Institute

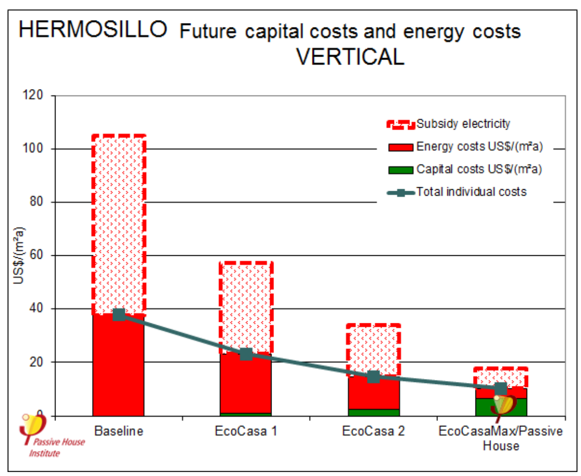


Figure 10b: Future capital and energy costs of Vertical building type compared, from baseline to Passive House in Hermosillo.
Source: Passive House Institute

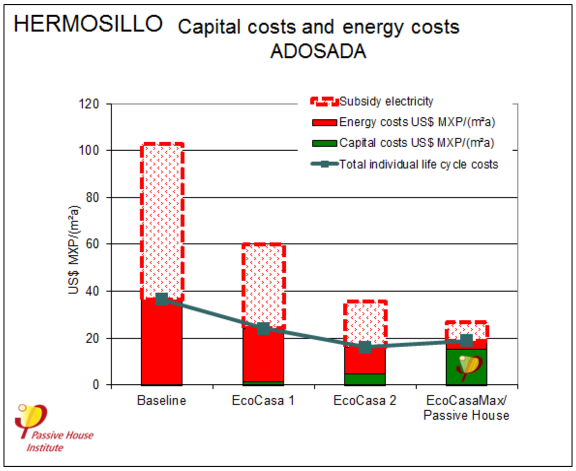


Figure 11a: Current capital costs and energy costs of Adosada building type compared, from baseline to Passive House in Hermosillo. Source: Passive House Institute

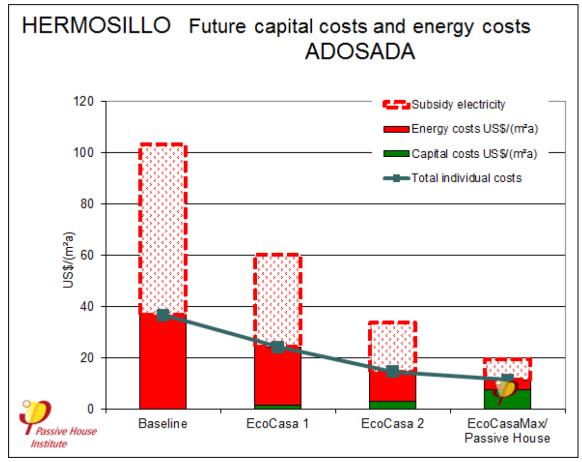


Figure 11b: Future capital costs and energy costs of Adosada building type compared, from baseline to Passive House in Hermosillo. Source: Passive House Institute

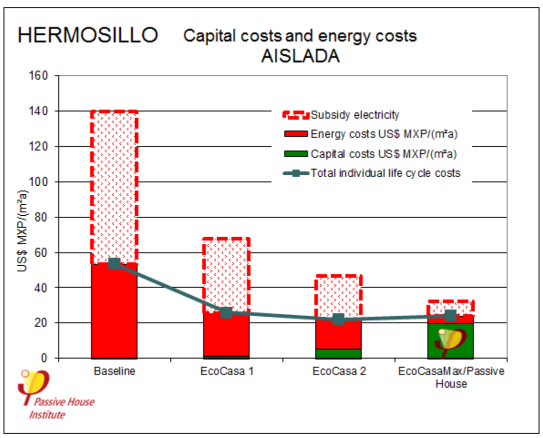


Figure 12a: Current capital costs and energy costs of Aislada building type compared, from baseline to Passive House in Hermosillo. Source: Passive House Institute

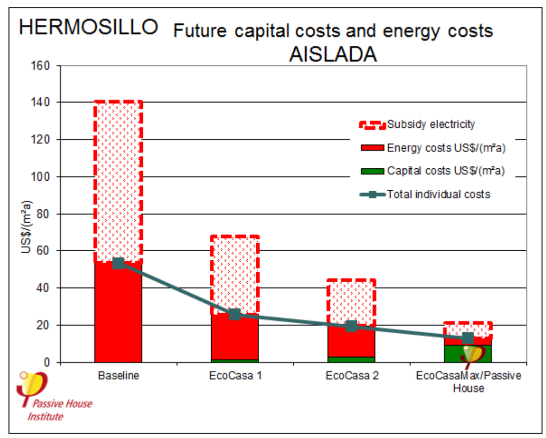


Figure 12b: Future capital costs and energy costs of Aislada building type compared, from baseline to Passive House in Hermosillo. Source: Passive House Institute

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/EcoCasaMax 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/EcoCasaMax 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/EcoCasaMax 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/EcoCasaMax 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/EcoCasaMax here. The different energy efficiency values for each of the cases can be seen in figures 13a through 13c.

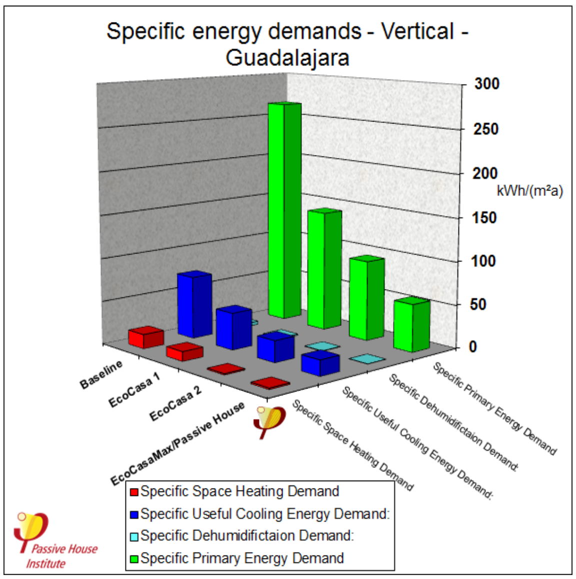


Figure 13a: Specific energy demands for Vertical building type in Guadalajara.
Source: Passive House Institute

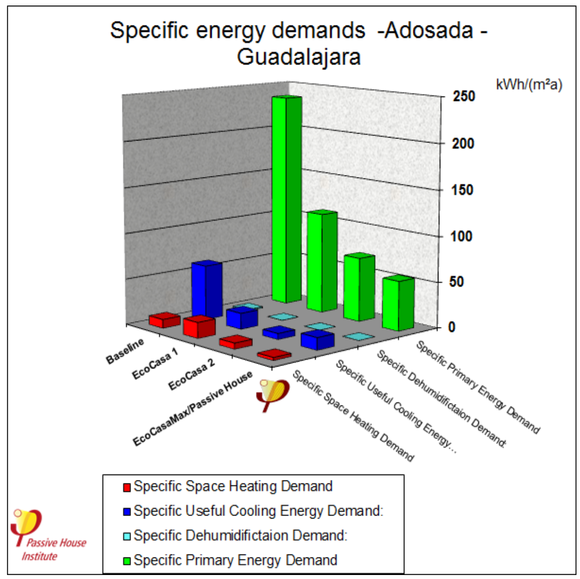


Figure 13b: Specific energy demands for Adosada building type in Guadalajara.
Source: Passive House Institute

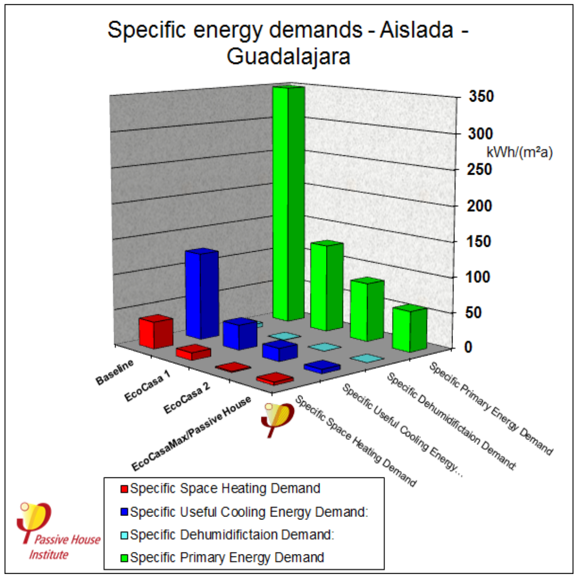


Figure 13c: Specific energy demands for Aislada building type in Guadalajara. Source: Passive House Institute

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.

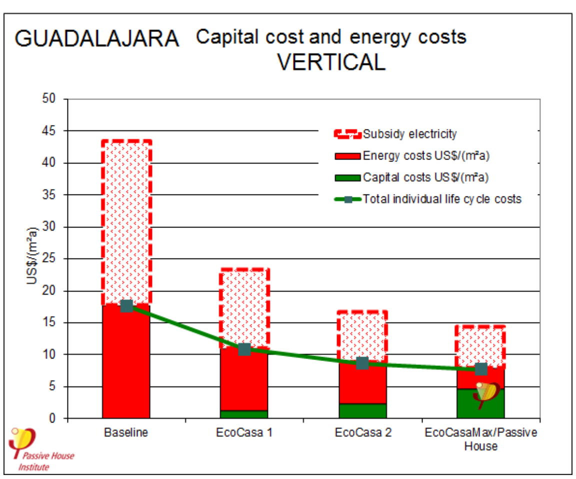


Figure 14a: Current capital costs and energy costs of Vertical building type compared, from baseline to Passive House in Guadalajara.

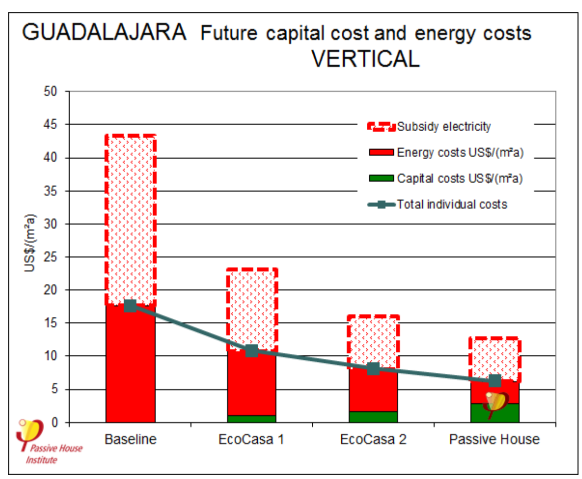


Figure 14b: Future capital costs and energy costs of Vertical building type compared, from baseline to Passive House in Guadalajara.

Source: Passive House Institute

Source: Passive House Institute

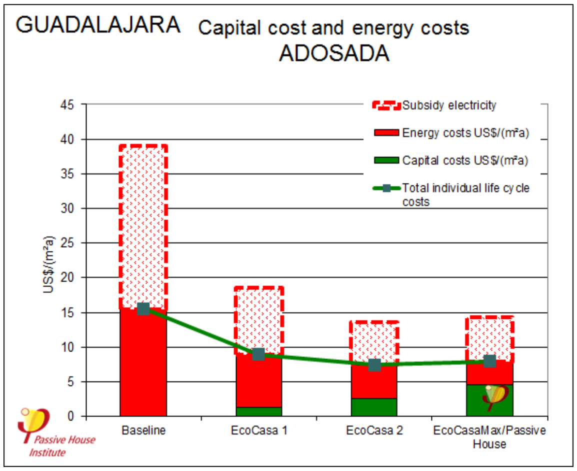


Figure 15a: Current capital costs and energy costs of Adosada building type compared, from baseline to Passive House in Guadalajara. Source: Passive House Institute

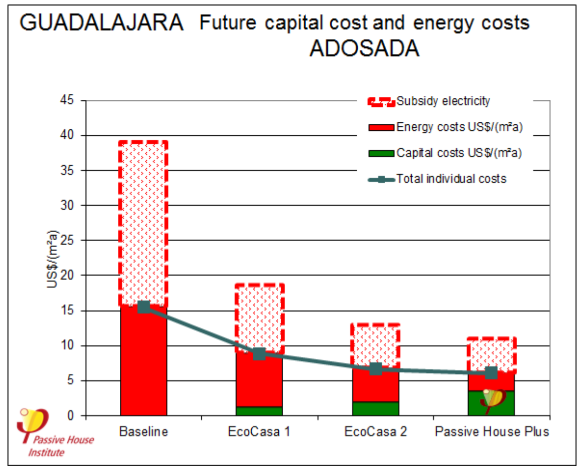


Figure 15b: Future capital costs and energy costs of Adosada building type compared, from baseline to Passive House in Guadalajara. Source: Passive House Institute

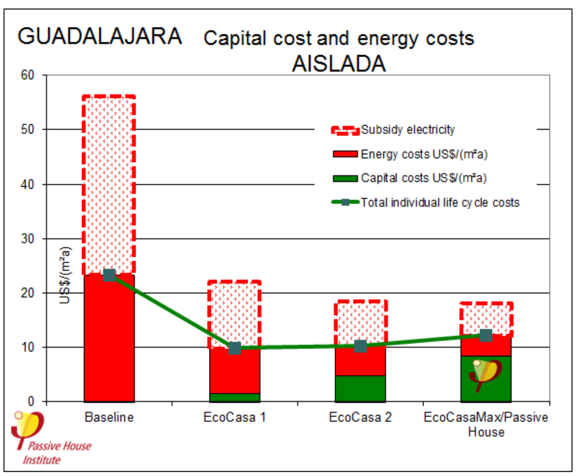


Figure 16a: Current capital costs and energy costs of Aislada building type compared, from baseline to Passive House in Guadalajara. Source: Passive House Institute

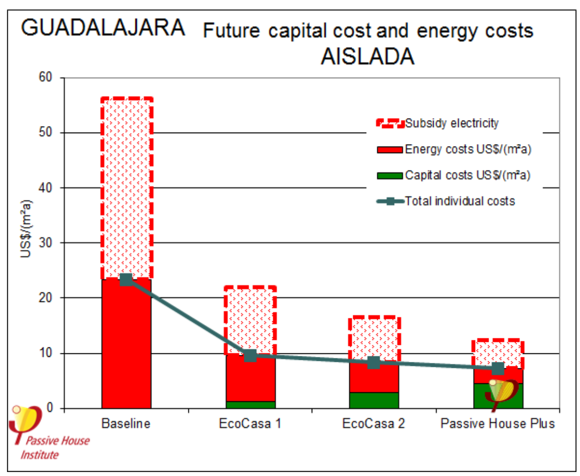


Figure 16b: Future capital costs and energy costs of Aislada building type compared, from baseline to Passive House in Guadalajara.
Source: Passive House Institute

As can be appreciated in figures 14b, 15b and 16b, the Passive House/EcoCasaMax 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/EcoCasaMax in comparison to the other energy efficiency cases.

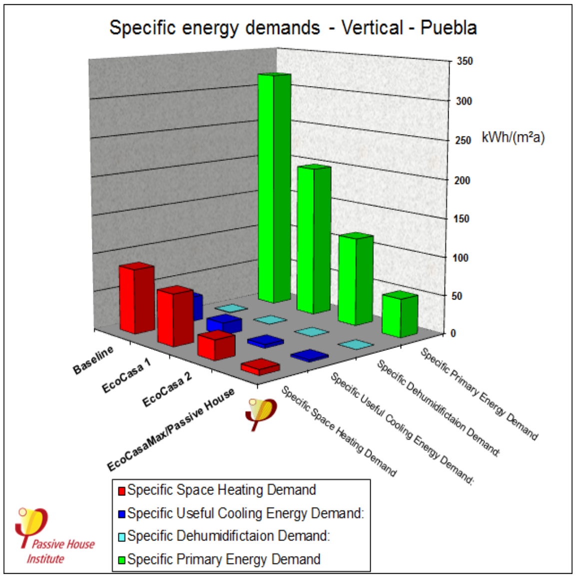


Figure 17a: Specific energy demands for Vertical building type in Puebla.
Source: Passive House Institute

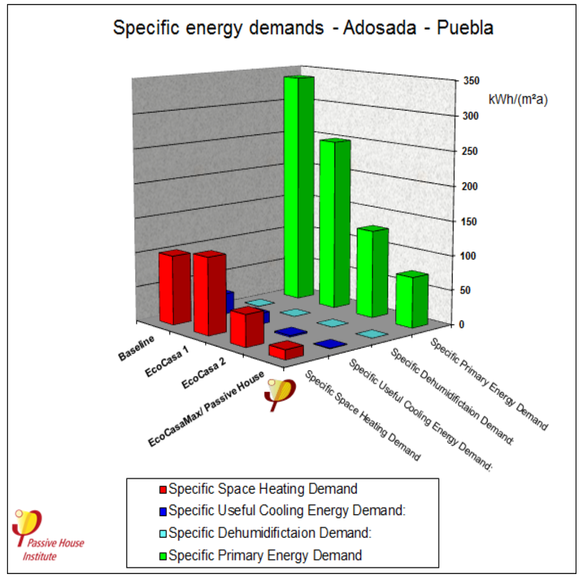


Figure 17b: Specific energy demands for Adosada building type in Puebla.
Source: Passive House Institute

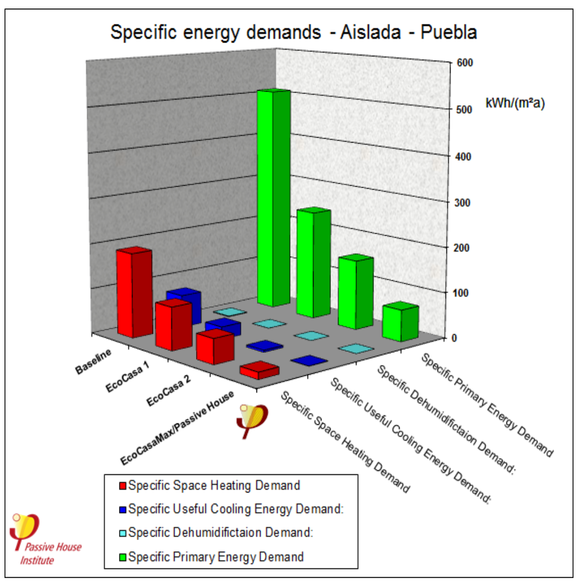


Figure 17c: Specific energy demands for Aislada building type in Puebla.
Source: Passive House Institute

As can be observed in figures 17a through 17c, the primary energy and space heating demands of the baseline are significantly higher than the rest of the energy efficiency standards, having the Passive House Standard/EcoCasaMax the lowest energy demand.

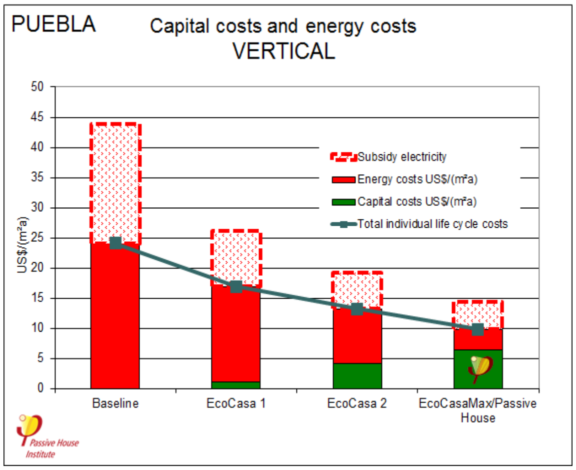


Figure 18a: Current capital costs and energy costs of Vertical building type compared, from baseline to Passive House in Puebla.
Source: Passive House Institute

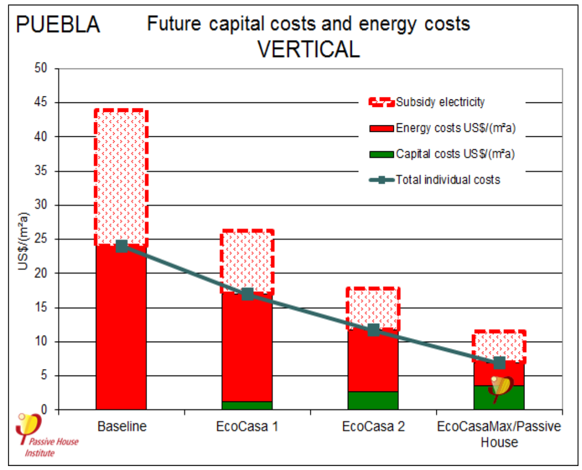


Figure 18b: Future capital costs and energy costs of Vertical building type compared, from baseline to Passive House in Puebla.
Source: Passive House Institute

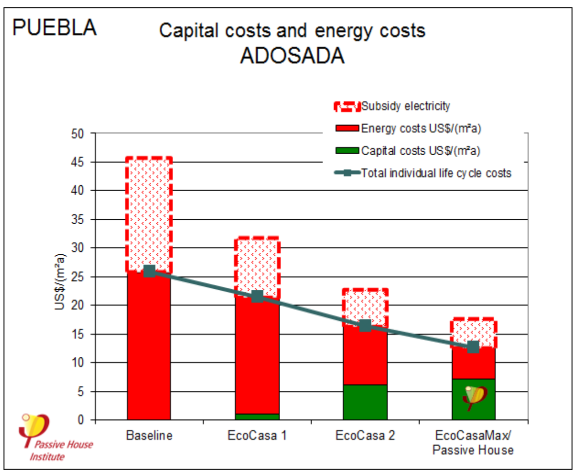


Figure 19a: Current capital costs and energy costs of Adosada building type compared, from baseline to Passive House in Puebla.
Source: Passive House Institute

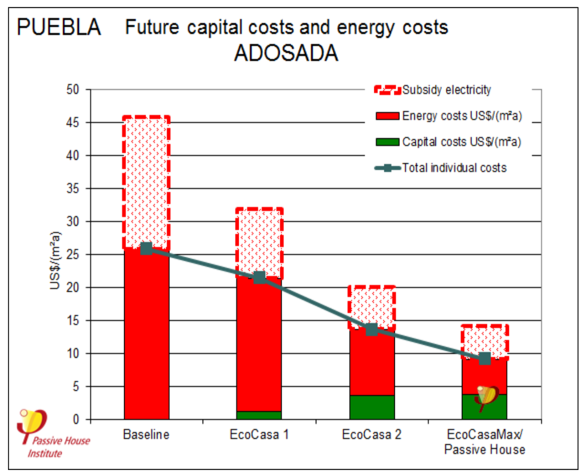
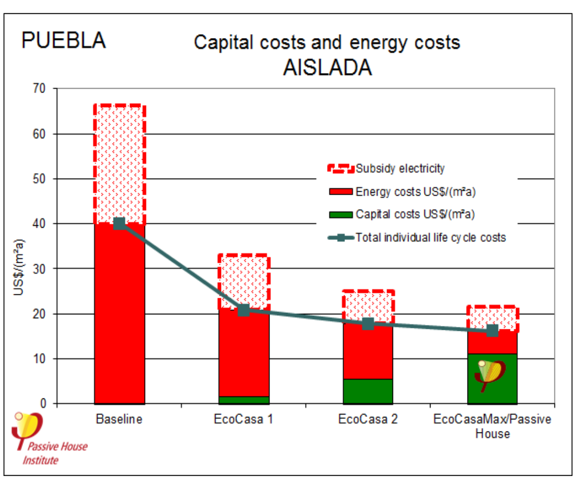


Figure 19b: Future capital costs and energy costs of Adosada building type compared, from baseline to Passive House in Puebla.
Source: Passive House Institute



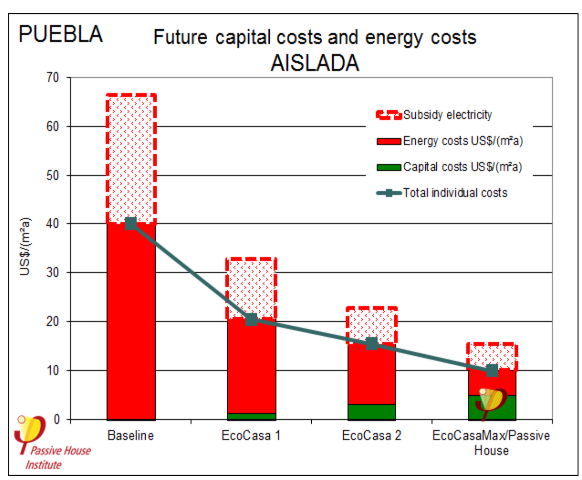


Figure 20a: Current capital costs and energy costs of Aislada building type compared, from baseline to Passive House in Puebla.
Source: Passive House Institute

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

The economical superiority of the Passive House/EcoCasaMax 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/EcoCasaMax 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.

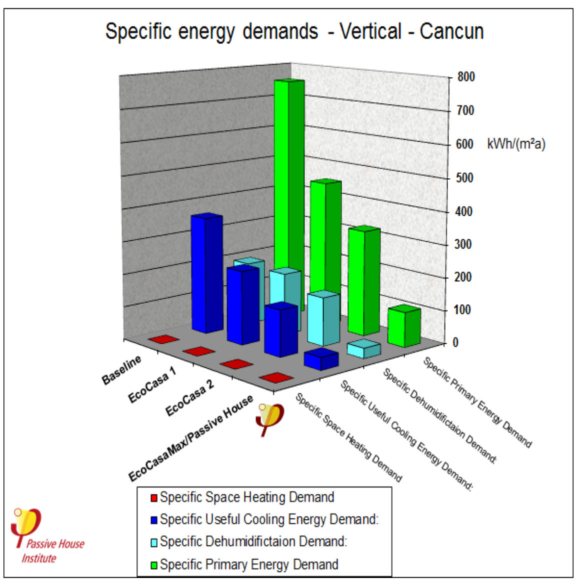


Figure 21a: Specific energy demands for Vertical building type in Cancun.
Source: Passive House Institute

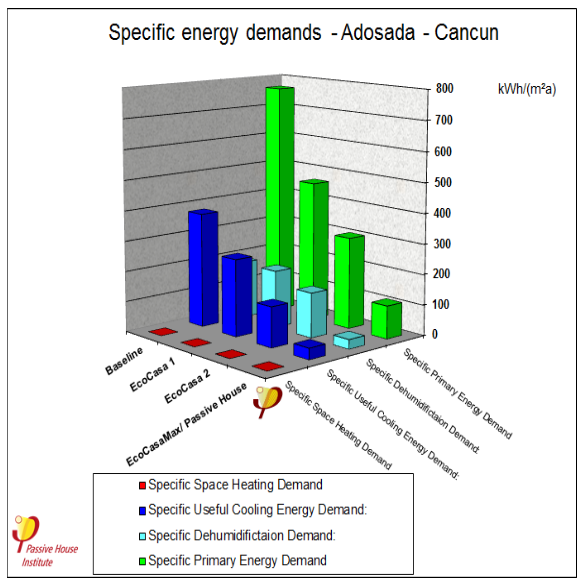


Figure 21b: Specific energy demands for Adosada building type in Cancun.
Source: Passive House Institute

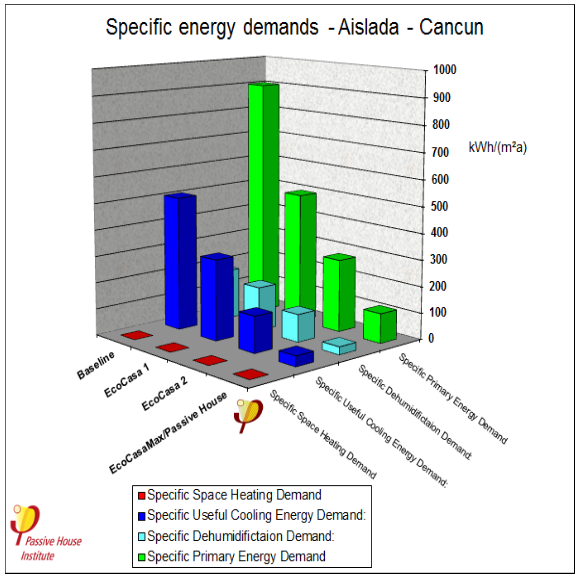


Figure 21c: Specific energy demands for Aislada building type in Cancun.
Source: Passive House Institute

Figures 21a through 21c present the results in terms of the energy efficiency of the different building cases, from baseline to Passive House/EcoCasaMax, 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.

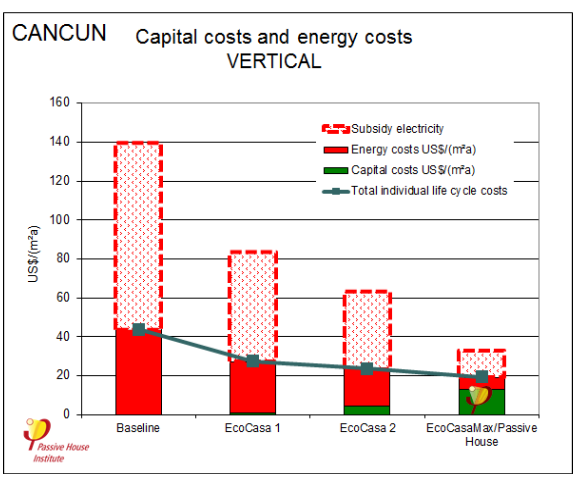


Figure 22a: Current capital costs and energy costs of Vertical building type compared, from baseline to Passive House in Cancun.
Source: Passive House Institute

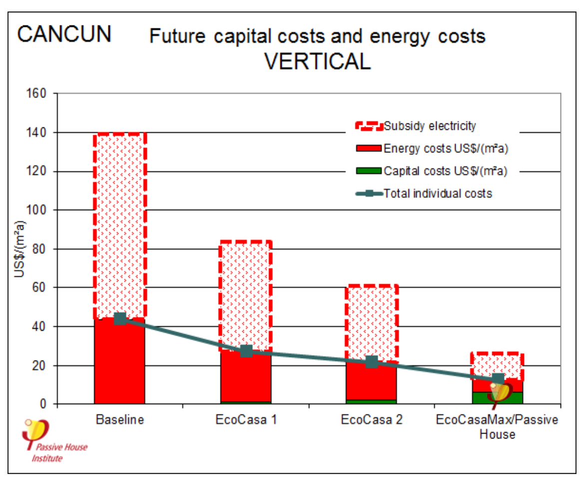


Figure 22b: Future capital costs and energy costs of Vertical building type compared, from baseline to Passive House in Cancun.
Source: Passive House Institute

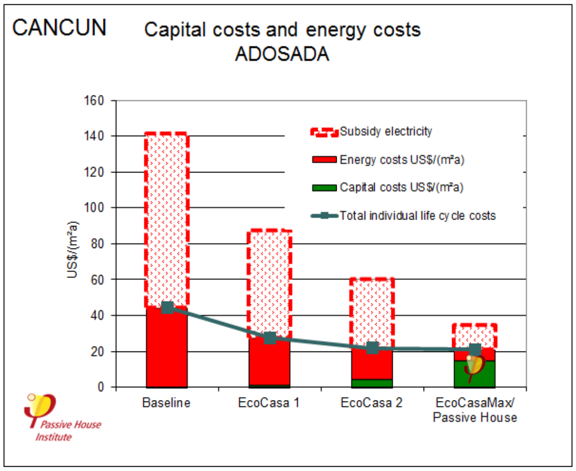


Figure 23a: Current capital costs and energy costs of Adosada building type compared, from baseline to Passive House in Cancun.
Source: Passive House Institute

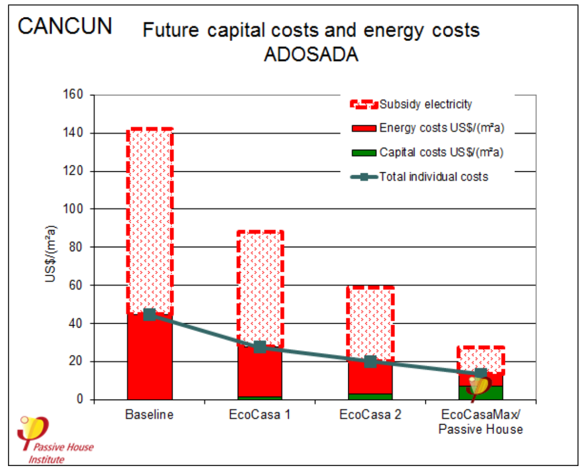


Figure 23b: Future capital costs and energy costs of Adosada building type compared, from baseline to Passive House in Cancun.
Source: Passive House Institute

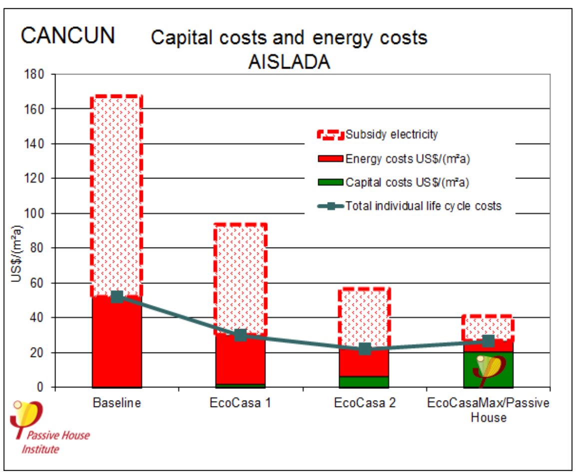


Figure 24a: Current capital costs and energy costs of Aislada building type compared, from baseline to Passive House in Cancun.
Source: Passive House Institute

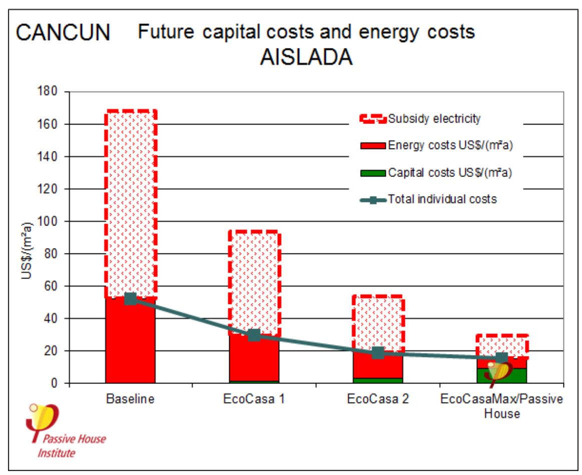


Figure 24b: Future capital costs and energy costs of Aislada building type compared, from baseline to Passive House in Cancun.
Source: Passive House Institute

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/EcoCasaMax 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.

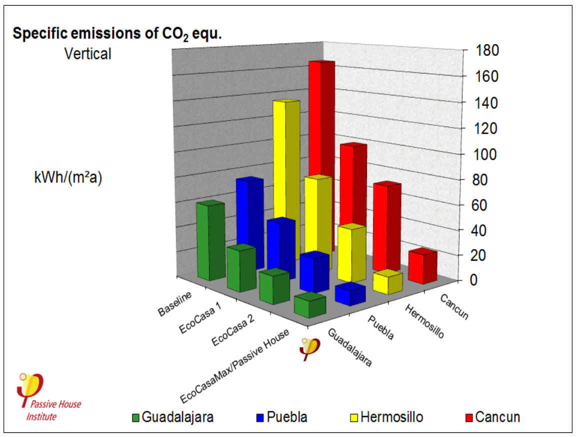


Figure 25a: specific CO_2 emissions for the different efficiency levels of the NAMA in the different locations, Vertical building type.
Source: Passive House Institute

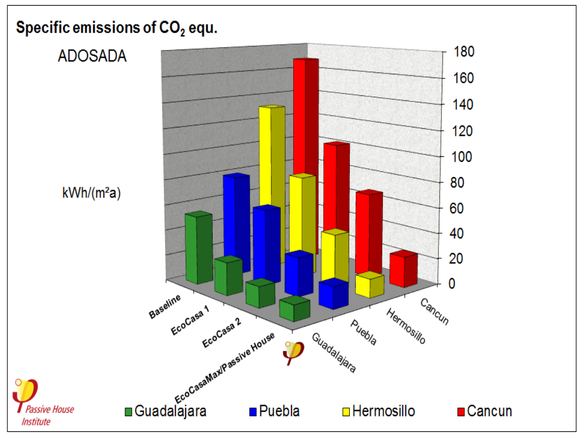


Figure 25b: specific CO_2 emissions for the different efficiency levels of the NAMA in the different locations, Adosada building type.
Source: Passive House Institute

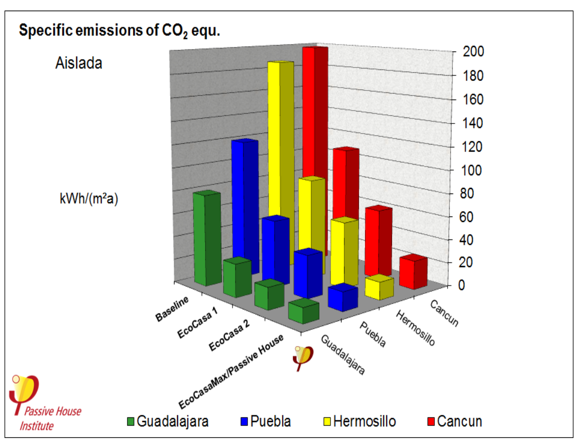


Figure 25c: specific CO_2 emissions for the different efficiency levels of the NAMA in the different locations, Aislada building type.
Source: Passive House Institute

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/EcoCasaMax 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/EcoCasaMax 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.

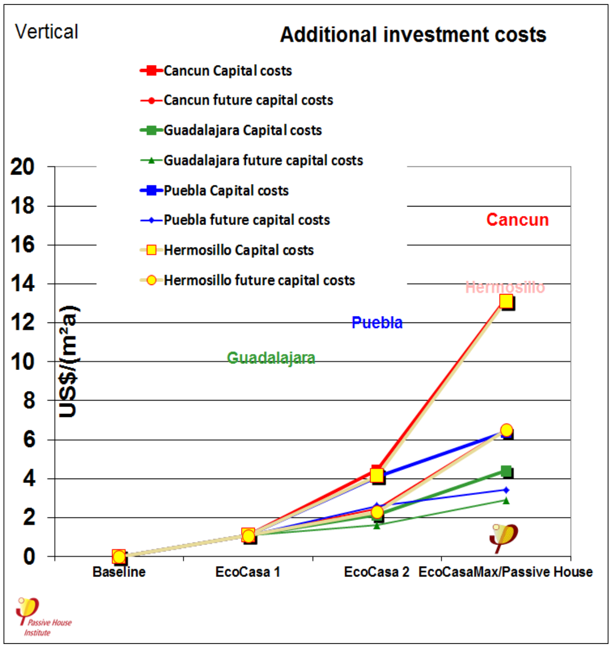


Figure 26a: Estimated additional investment costs, both current and future scenario, for all energy efficiency levels, for the Vertical building type.
Source: Passive House Institute

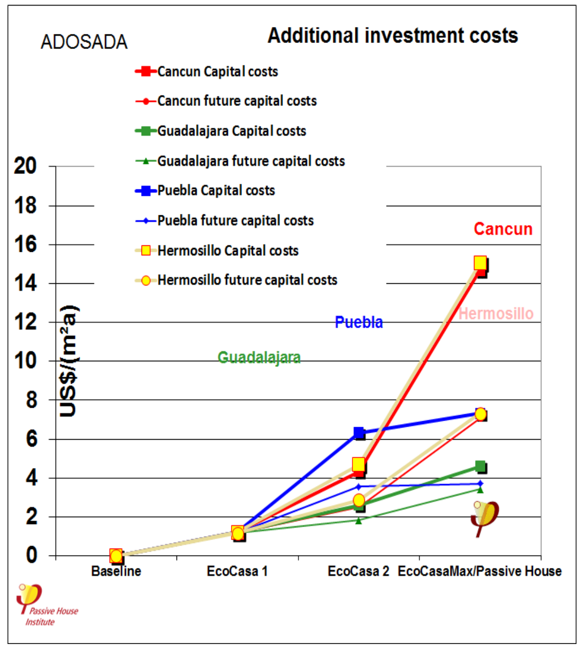


Figure 26b: Estimated additional investment costs, both current and future scenario, for all energy efficiency levels, for the Adosada building type.
Source: Passive House Institute

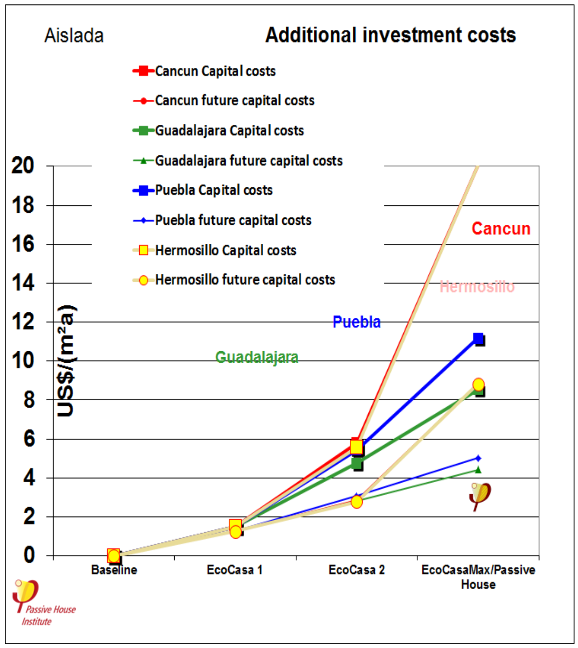


Figure 26c: Estimated additional investment costs, both current and future scenario, for all energy efficiency levels, for the Aislada building type.
Source: Passive House Institute

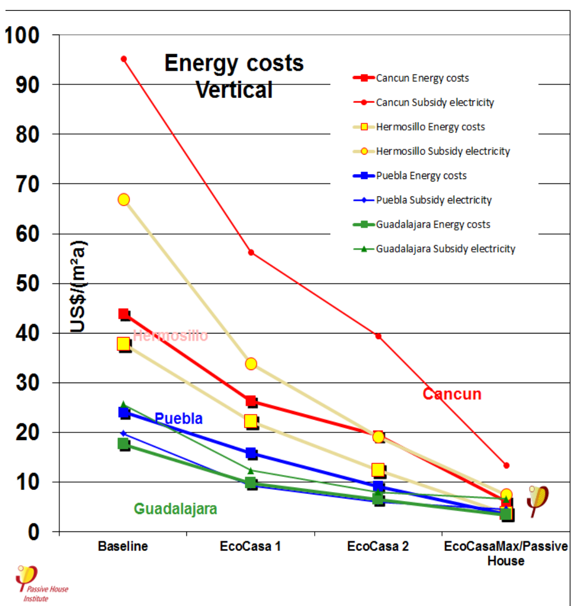


Figure 27a: Estimated energy costs for all the energy efficiency levels for the Vertical building type.
Source: Passive House Institute

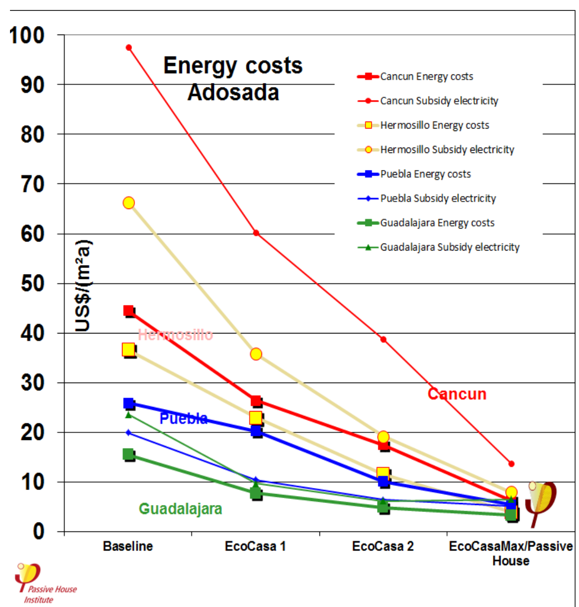


Figure 27b: Estimated energy costs for all the energy efficiency levels for the Adosada building type.
Source: Passive House Institute

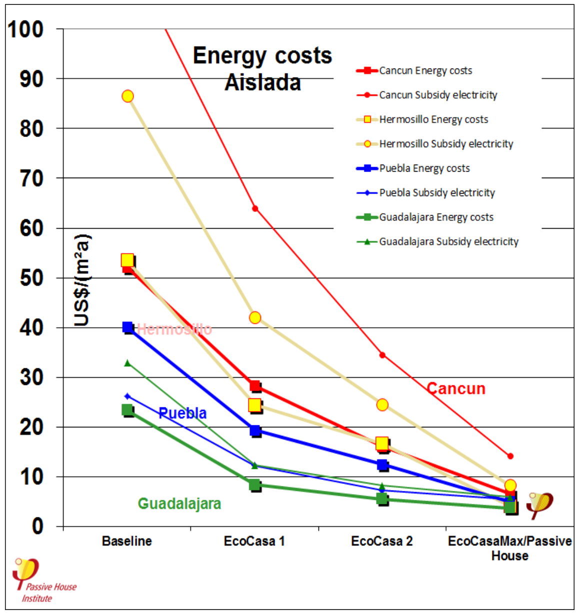


Figure 27c: Estimated energy costs for all the energy efficiency levels for the Aislada building type.
Source: Passive House Institute

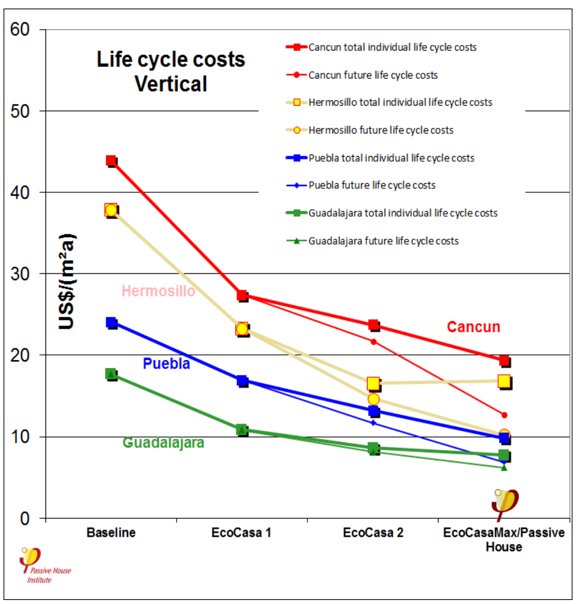


Figure 28a: Estimated lifecycle costs for all the energy efficiency levels for the Vertical building type.
Source: Passive House Institute

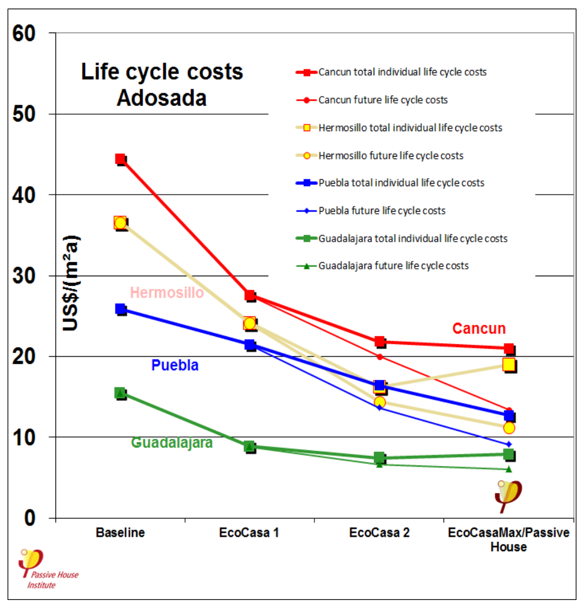


Figure 28b: Estimated lifecycle costs for all the energy efficiency levels for Adosada building type.
Source: Passive House Institute

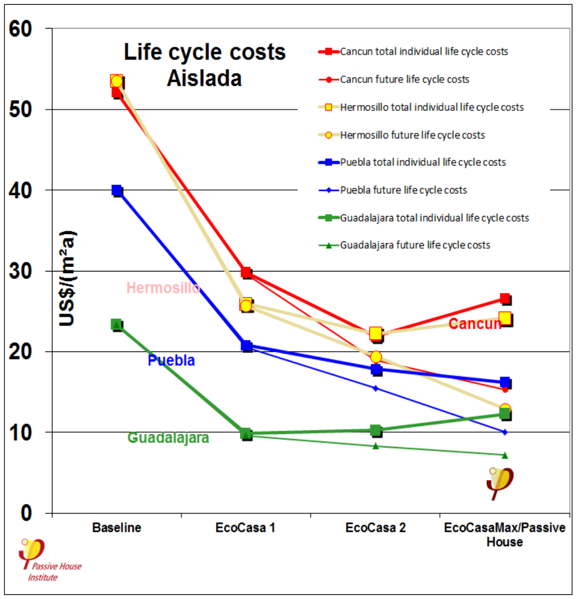


Figure 28c: Estimated lifecycle costs for all the energy efficiency levels for the Aislada building type.
Source: Passive House Institute

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*
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/EcoCasaMax	3.2	3,9	1.5	1.4
Adosada	**Hermosillo**	**Cancun**	**Guadalajara**	**Puebla**
savings per unit	*t/a*	*t/a*	*t/a*	*t/a*
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/EcoCasaMax	2.5	3.8	1.3	1.5
Vertical	**Hermosillo**	**Cancun**	**Guadalajara**	**Puebla**
savings per unit	*t/a*	*t/a*	*t/a*	*t/a*
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/EcoCasaMax	2.9	4.0	1.3	1.6

Summary for Passive Houses:

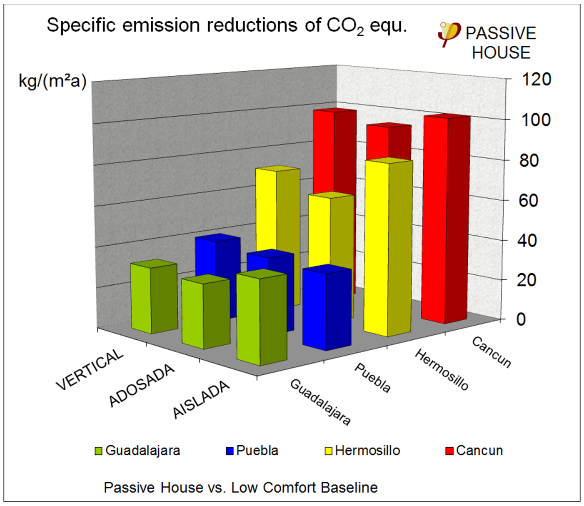


Figure 29a: Passive House/EcoCasaMax in different climate zones: Savings of CO_2 emissions vs. Baseline.
Source: Passive House Institute

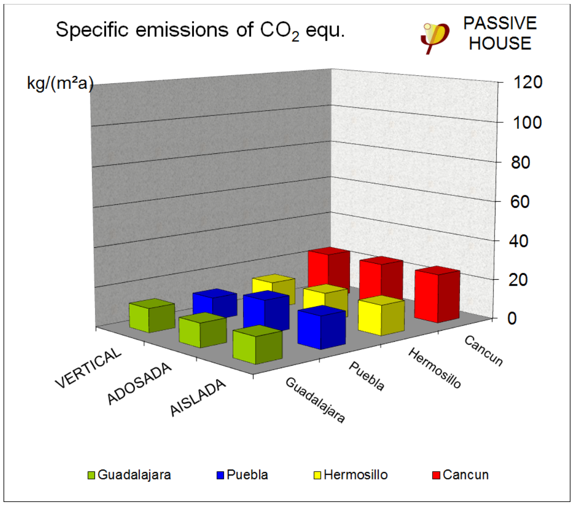


Figure 29b:Passive House/EcoCasaMax in different climate zones: Specific CO_2 emissions.
Source: Passive House Institute

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.

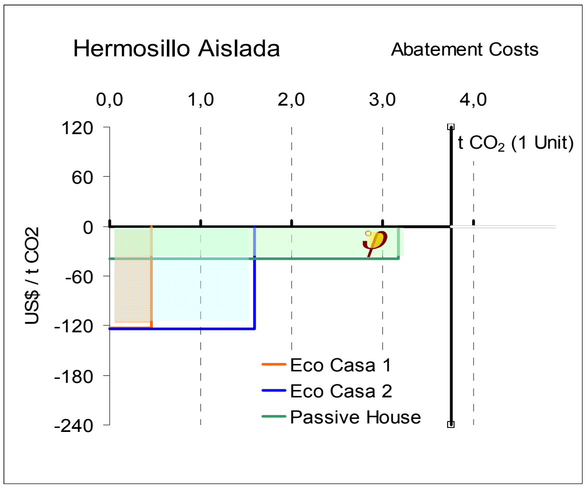


Figure 30a CO_2 abatement costs (only individual costs) in Hermosillo, vs. Baseline.
Source: Passive House Institute

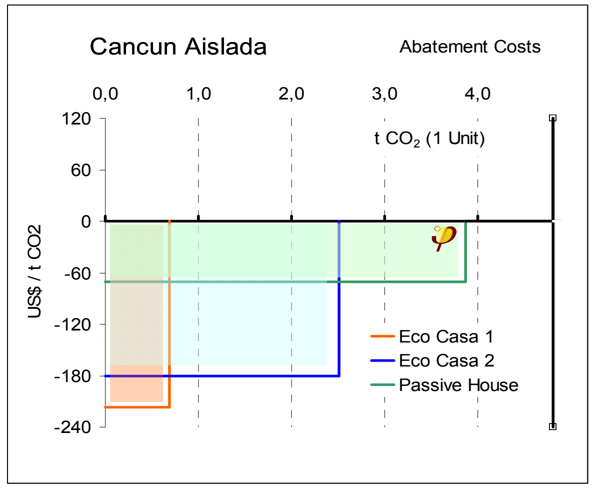


Figure 30b: CO_2 abatement costs (only individual costs) in Cancun, vs. Baseline. Source:
Passive House Institute

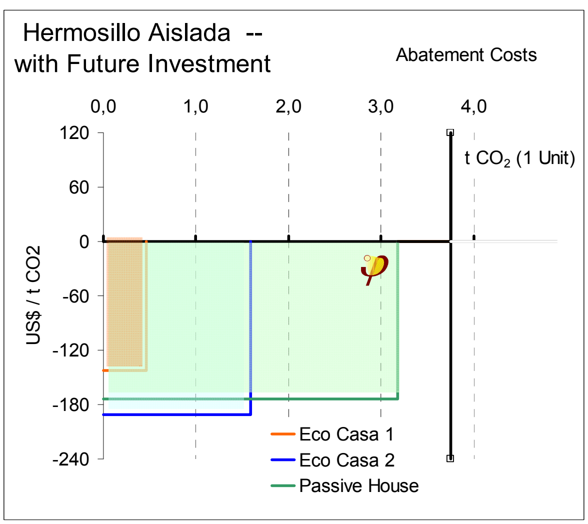


Figure 31a : Future CO_2 abatement costs in Hermosillo, vs. Baseline.
Source: Passive House Institute

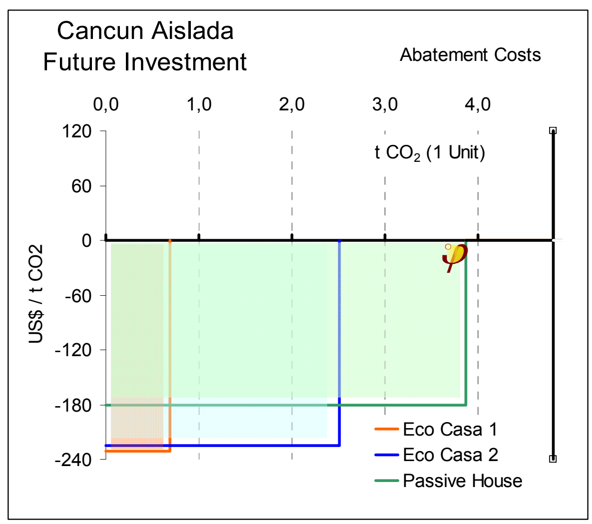


Figure 31b: Future CO_2 abatement costs in Cancun, vs. Baseline.
Source: Passive House Institute

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.

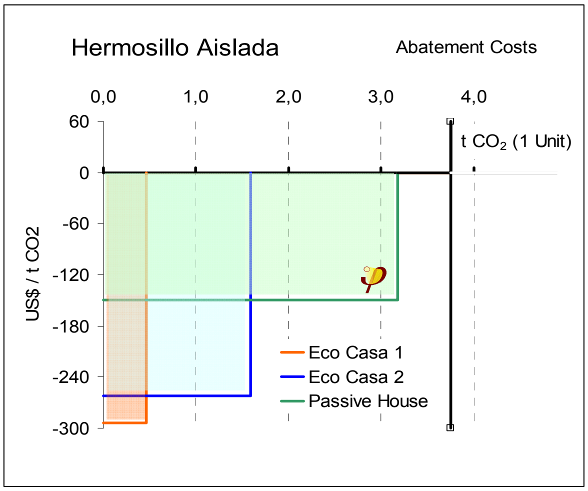


Figure 32a CO_2 abatement costs (public perspective) in Hermosillo, vs. Baseline.
Source: Passive House Institute

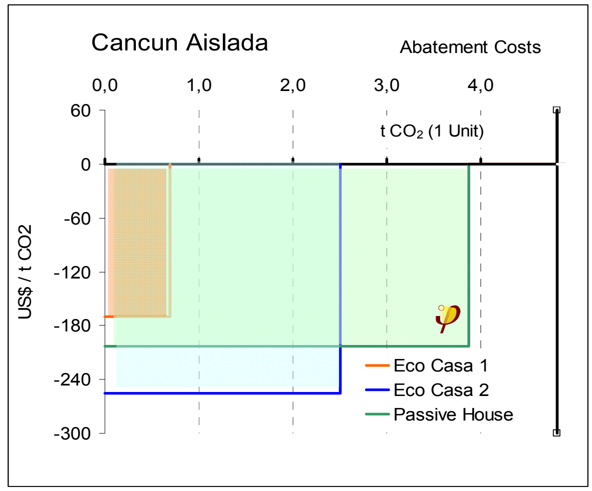


Figure 32b: CO_2 abatement costs (public perspective) in Cancun, vs. Baseline.
Source: Passive House Institute

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/EcoCasaMax) 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/EcoCasaMax 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

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Annex I. Detailed result tables

VERTICAL

Occupation: 2 persons/unit**		13,3 $MXP/$US																	
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 Hemosillo	Vertical EcoCasa 1 Hemosillo	Vertical EcoCasa 2 Hemosillo	Vertical Passive House Hemosillo	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
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	$ 38	$ 23	$ 17	$ 17	$ 18	$ 11	$ 9	$ 8	$ 9	$ 24	$ 17	$ 13	$ 10	$ 12	$ 44	$ 27	$ 24	$ 19
Life Cycle Costs (Basis future investment costs)	$ US/(m²a	$ 38	$ 23	$ 15	$ 10	$ 18	$ 11	$ 8	$ 6	$ 6	$ 24	$ 17	$ 12	$ 7	$ 7	$ 44	$ 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

Climate data		EXTREME HOT DRY				TEMPERATE					TEMPERATE COLD					EXTREME HOT HUMID			
		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 EcoCasa 3 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
Additional Investment costs (entire building)	$ 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 (entire building)	$ 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 per dwelling unit (current costs)	$ US	$ -	$ 93	$ 357	$ 1.145	$ -	$ 93	$ 199	$ 351	$ 441	$ -	$ 93	$ 480	$ 556	$ 1.029	$ -	$ 93	$ 330	$ 1.115
Additional costs per dwelling unit (future costs)	$ US	$ -	$ 90	$ 218	$ 557	$ -	$ 90	$ 140	$ 230	$ 261	$ -	$ 90	$ 270	$ 283	$ 456	$ -	$ 90	$ 192	$ 539
Life Cycle Costs (energy&additional capital costs)	$ US/(m²a)	$ 37	$ 24	$ 16	$ 19	$ 15	$ 9	$ 7	$ 8	$ 8	$ 26	$ 21	$ 16	$ 13	$ 17	$ 44	$ 28	$ 22	$ 21
Life Cycle Costs (Basis future investment costs)	$ US/(m²a)	$ 37	$ 24	$ 14	$ 11	$ 15	$ 9	$ 7	$ 6	$ 6	$ 26	$ 21	$ 14	$ 9	$ 9	$ 44	$ 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	White paint	White paint	Cool colours	Colour paint	White paint	White paint	Colour paint	White paint	Colour paint	Colour paint	Colour paint	Colour paint	Colour 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	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		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	Single glazing, aluminium frame	Single glazing, aluminium frame	Single glazing, aluminium frame	Single glazing, aluminium frame	Double glazing insulated, pvc frame	Double glazing insulated, pvc frame	Double glazing sun protection	Single glazing, aluminium frame	Single glazing, aluminium frame	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

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
		EXTREME HOT DRY				TEMPERATE					TEMPERATE COLD					EXTREME HOT HUMID			
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
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
Additional costs per dwelling unit (current costs)	$ US	$ -	$ 108	$ 397	$ 1.426	$ -	$ 108	$ 339	$ 607	$ 669	$ -	$ 108	$ 386	$ 796	$ 1.005	$ -	$ 108	$ 412	$ 1.426
Additional costs per dwelling unit (future costs)	$ US	$ -	$ 90	$ 198	$ 628	$ -	$ 90	$ 202	$ 306	$ 314	$ -	$ 90	$ 218	$ 357	$ 426	$ -	$ 90	$ 203	$ 628
Life Cycle Costs (energy&additional capital costs)	$ US/(m²a	$ 54	$ 26	$ 22	$ 24	$ 23	$ 10	$ 10	$ 12	$ 12	$ 40	$ 21	$ 18	$ 16	$ 19	$ 52	$ 30	$ 22	$ 27
Life Cycle Costs (Basis future investment costs)	$ US/(m²a	$ 54	$ 26	$ 19	$ 13	$ 23	$ 10	$ 8	$ 8	$ 7	$ 40	$ 21	$ 16	$ 10	$ 11	$ 52	$ 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.

** 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

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Contact: Jorge Wolpert. General Subdirector of Sustainability. National Housing Commission
jlwolpert@conavi.gob.mx

Tomasz Kotecki Golasinska. Manager of Sustainability. National Housing Commission
tdkotecki@conavi.gob.mx