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Gasteizmografia: Thermographic Map of Vitoria-Gasteiz's façades

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Abstract

This paper presents the project "Gasteizmografia.com , thermographic map of Vitoria-Gasteiz".

The main characteristic of this project is a massive use of thermographic IR images which allows us to show openly, via web, how buildings are in Vitoria-Gasteiz; related to thermal energy consumption. The objective is to encourage citizens to transform their buildings into NZEB standards.

The paper will show and illustrate different aspects of the project like: thermographies of Vitoria-Gasteiz buildings, comparison with constructive systems through thermography, the divulgative process to encourage citizens to safe energies via transforming the buildings, and an explanation of how this work was carried out by their authors.

1. Introduction

This research project is one of the selected activities proposed for an open call for citizens' initiatives with the aim to divulge environmental concerns and activities as a way to celebrate consequently the award of 2012 European Green Capital. According to that, this activity has been funded for its first phase with nearly 8,500€ by Vitoria-Gasteiz council through CEA office (Centro de Estudios Ambientales).

Gasteizmografia.com project is showing more than 350 thermal pictures of Vitoria-Gasteiz cities buildings. Most of the pictures are high quality ones. Some of them have been composed and joined to conform 360º pictures or large panoramic pictures. There have been many other pictures that either are still being prepared for being published or do not match the standards for being illustrative or understood by citizens.

There have been also developed aerial images, taken thanks to a captive helium zeppelin. This technique has allowed us to show the thermal performance of many buildings at the same time, including 360º panoramic views.

1.1. Objective

The main objective of this project has been making citizens realize about the thermal losses of the buildings, so we can encourage citizens to start refurbishing their buildings in order to achieve NZEB standards [1]. To comply that issue we have also studied the approximate cost of transforming buildings into NZEB and other standards including the actual Spanish building technical code (CTE db HE) [2], so economic comparisons can be made.

In order to facilitate citizens understand thermographic images, we have prepared simple documentation to understand building thermographies. This documentation has been based in several publications including [3,4,5,6].

Gasteizmografia.com pretends to disclose the excessive thermal energy consumed by buildings in Vitoria-Gasteiz; as seen in [9,10]. Thermographic images are the tool for citizens to see clearly energy losses.

Interpretation of thermal images let us know easily thermal fluxes, so we can estimate thermal isolation.

We can then see thermal bridges, lack of tightness on windows, water or humidity leakages, and other thermal related characteristics like heating distribution losses. With that information we pretend citizens to understand why buildings loss so many energy and to realize that they can transform them to NZEB.

Fig. 1. *Thermographic view of Vitoria-Gasteiz's medieval Town form the town of St Maria old Cathedral*
Source: Iker Gómez Iborra and Itziar Gorosabel (ig karratu arkitektura, 2013)

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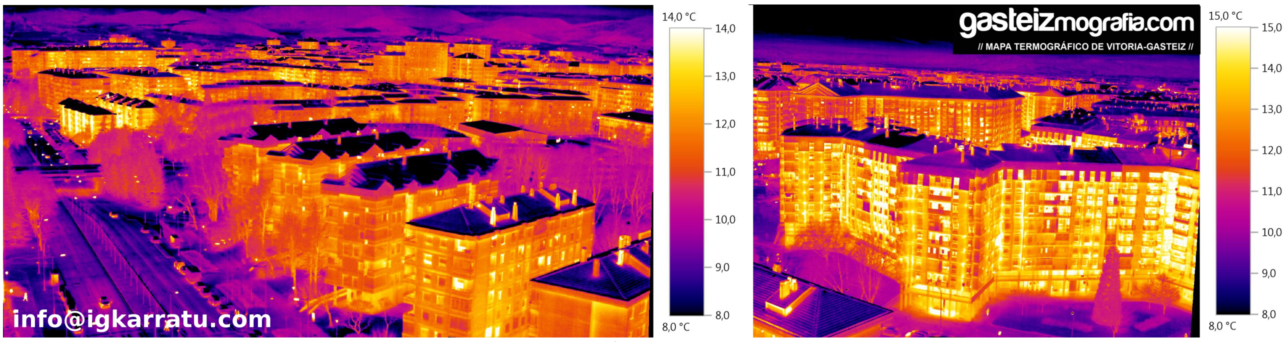

Fig. 2. *Thermographic view of Aranbizkarra (70's) Neighborhood*
Source: Iker Gómez Iborra and Itziar Gorosabel (ig karratu arkitektura, 2013)

We expect citizen to react and save energy and money while improving thermal comfort in buildings.

According to that we have prepared some information to show which options can be taken to improve and transform buildings to different energy demand standards. This information compiles a brief description of what can be done, the costs involved, the economic funding or help, and the amortization period due to the savings.

So in deed, the main objective of Gasteizmografia is to start motivating citizens to refurbish and transform their buildings into passivhaus or NZEB standards; directly or through phase to phase procedures.

1.2. Conditions

Thermographic imagining requires certain weather conditions for been useful for a scientific usage.

Within the actual standards we find ASTM C1060–11a or ISO6781, UKTA practice code [7], or literature made by AETIR (Asociación Española de Termografia Infrarroja) and thermal equipment manufactures such as Testo [3] or others.

In those literature it is recommended that solar radiation must be controlled, that cannot be an excessive wind and that façades must be dry and thermal stabilized. Temperature difference within indoor-outdoor should be more than 10ºC. If not possible we would take some beautifull pictures; but won't be loyal to thermal behaviour of envelopes. If it is raining, or snowing, nor beauty can be achieved in the images, because image is fuzzy. Rain, or snow, homogenizes and make colder the temperature of the façades. Wind disperses energy so thermal hot spots cannot be seen so clearly.

Thermal images have been taken mostly during January 2013. Due to weather conditions of Vitoria-Gasteiz we have been obliged to take thermographies during night (to avoid Sun radiation) and to select those nights in which facades could be considered dry enough to be thermally stabilized. Windy days has also been avoided. So although having hired TESTO equip for almost three weeks (20 days) we have been able to operate it only during 6 nights.

Favorable Weather conditions made us, thanks to Xabier's equip, take some thermal photos in December 2012 including aerial ones.

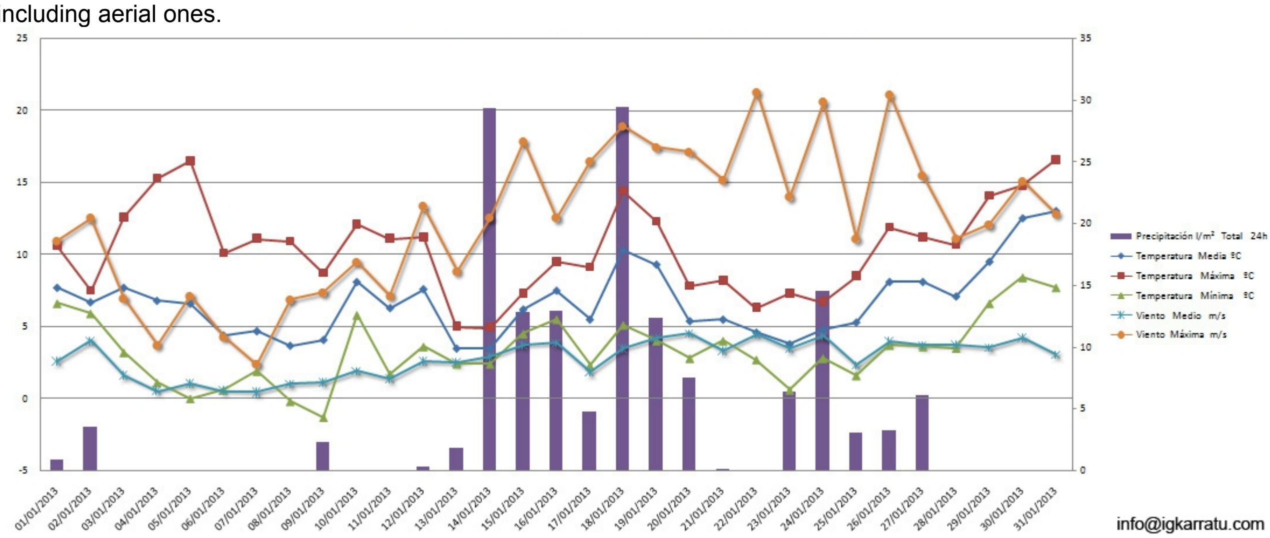

Fig. 3. *Vitoria-Gasteiz. weather conditions, January 2013*
Source: data obtained from C040 weather station, Vitoria-Gasteiz. www.euskalmet.euskadi.net; edited by Iker Gómez Iborra and Itziar Gorosabel (ig karratu arkitektura, 2013)

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1.3. Gasteizmografia in numbers

To develop this project we have made near 10,000 thermal pictures which have been useful to obtain 1,500 images. From them more than 300 have been selected, edited and map positioned so they can be found through our website (www.gasteizmografia.com).

We must admit that although there have been projects that have thermographied a lot of buildings [20], due to the decision to make thermographies website accesible we think that this could be an original project.

1.3.1 Vitoria-Gasteiz's climate conditions

Vitoria-Gasteiz is the political capital of the Basque Country. It is considered Atlantic climate and quite cold during winter. It has average temperatures, according to CTE [2], are of 7,5ºC in November, 5,0ºC in December 4,6ºC in January, 6,0ºC in February, 7,2ºC in March or 9,2ºC in April. July and August average temperatures are about 18,4ºC

1.3.2. IR cameras and Tools

The cameras used for developing those IR images have been both 640x480 pixel: a TESTO 890-2 and a FLIR B660. Also a Flir T400 (320x240 px) has been used to contrast and seek for the emissivities of materials and other purposes.

Testo 890-2 was equipped with 42ºx32º and 15ºx11º lenses. The use of telephoto lens has allowed us to achieve great quality images although the distance of the building. Twato 890-2 has also the SuperResolution feature (SR) which allows to join directly a matrix of 3 images of 640x480 px resolution. Additional photo-mounting of images has been needed to show whole buildings, or panoramic photos is good resolution. Testo equipment has been hired to Gimateg company. This equip was operated mostly by Iker Gómez Iborra, Ms. Architect, and PhD candidate. Itziar Gorosabel Fernández, Ms. Architect has also operated this equip.

We have also used FLIR B660 thermal camera (640x480 px) with 24º lenses, this camera has been mostly used for aerial photos thanks to the captive helium Zeppelin. The captive zeppelin is a sensitive alternative to UAVs [8] This equip was provided and operated by Xabier Saénz de Castillo, thermographer and founder of PREST STA company. PREST STA is dedicated to thermographicall services; especially aerial ones.

1.3.3. Editing IR Images

Editing images for public comprehensive has taken several hours; more than those needed to take the pictures.

Itziar Gorosabel has edited with, Testo provided software, the IR images taken with TESTO equipment, according to emissivity of materials, weather conditions and infrared reflection of surfaces.

Open software like GIMP and plug-ins has been used to develop panoramic thermal images.

Xabier Saénz de Castillo has edited with Flir provided software, the IR images taken with FLIR equipment.

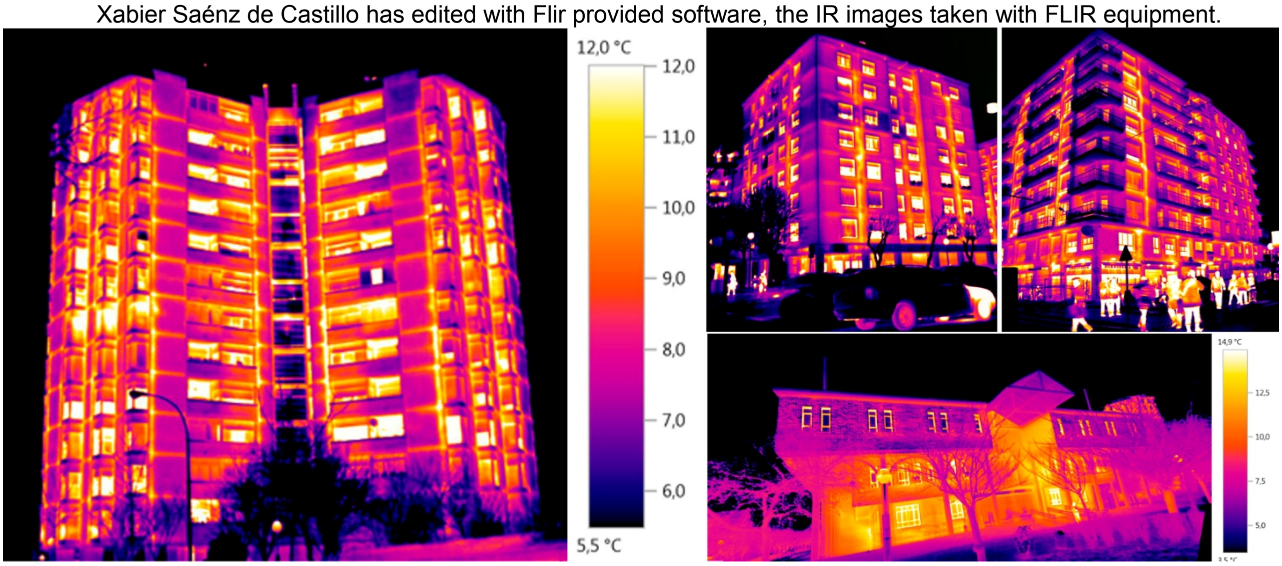

Fig. 4. *Thermographies of Gazalbide and Txagorritxu Neighbourhoods (70`s)*
Source: Iker Gómez Iborra and Itziar Gorosabel (ig karratu arkitektura, 2013)

1.3.4. Authors

Iker Gómez Iborra, Ms Architect and PhD candidate, does research in industrialized systems for refurbishing buildings in order to match NZEB standards. He studied Architecture at “Universidad de Navarra”, obtaining the title in

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2006. He continued studying for PhD. At Polytechnic University of Madrid, Department of Building and Architecture Technology, Madrid. He has several publications and participated in international congresses. He has also co-found ig karratu architecture cooperative with Itziar Gorosabel in order to start offer and develop his knowledge.

Itziar Gorosabel Fernández, Ms Architect has obtained her degree at Donosti Higher School of Architecture (Basque Country University). She is also a co-founder of ig karratu architecture.

Xabier Saénz de Castillo is an engineer and a credited thermographer. He has found PREST - STA (Aerial thermographic services) which uses thermographies to find building sickness.

2. Understanding Thermographies for buildings

Thermographic images show infrared radiation emitted by surfaces, so we can know emitted temperature and understand real temperature and thermal fluxes. Thermography is a very useful technique in building and in other fields.

For a correct interpretation in building science these images must be adjusted according to the temperature and humidity of the air, emissivity of surfaces, distance, solar radiation, and last but not least, reflected radiation. Then, temperature if the surfaces can be seen so energy fluxes can be understood and heat (money) losses can be seen.

It is necessary to explain the importance of reflected radiation (or reflected temperature). i.e. glazing, metal sheets and other very low infrared emitting surfaces behave like mirrors for infrared. So we cannot thermography their real temperature but the temperature from the reflection on them. Sometimes sky is being reflected on them so a temperature of -40ºC is being reflected, making them appear as really cold while they are not. For similar reasons the same happens when thermographing roofs and façades at the same time: roofs generally are reflecting sky temperature so they seem much more cooler than façades while they are not.

Nevertheless, the same radiometric image can be adjusted to reduce the impact of reflection on roofs; but façades wont be shown properly with those adjustments.

The issue of reflection and emissivities is really hard to be understood by people who are not used to thermography nor science.

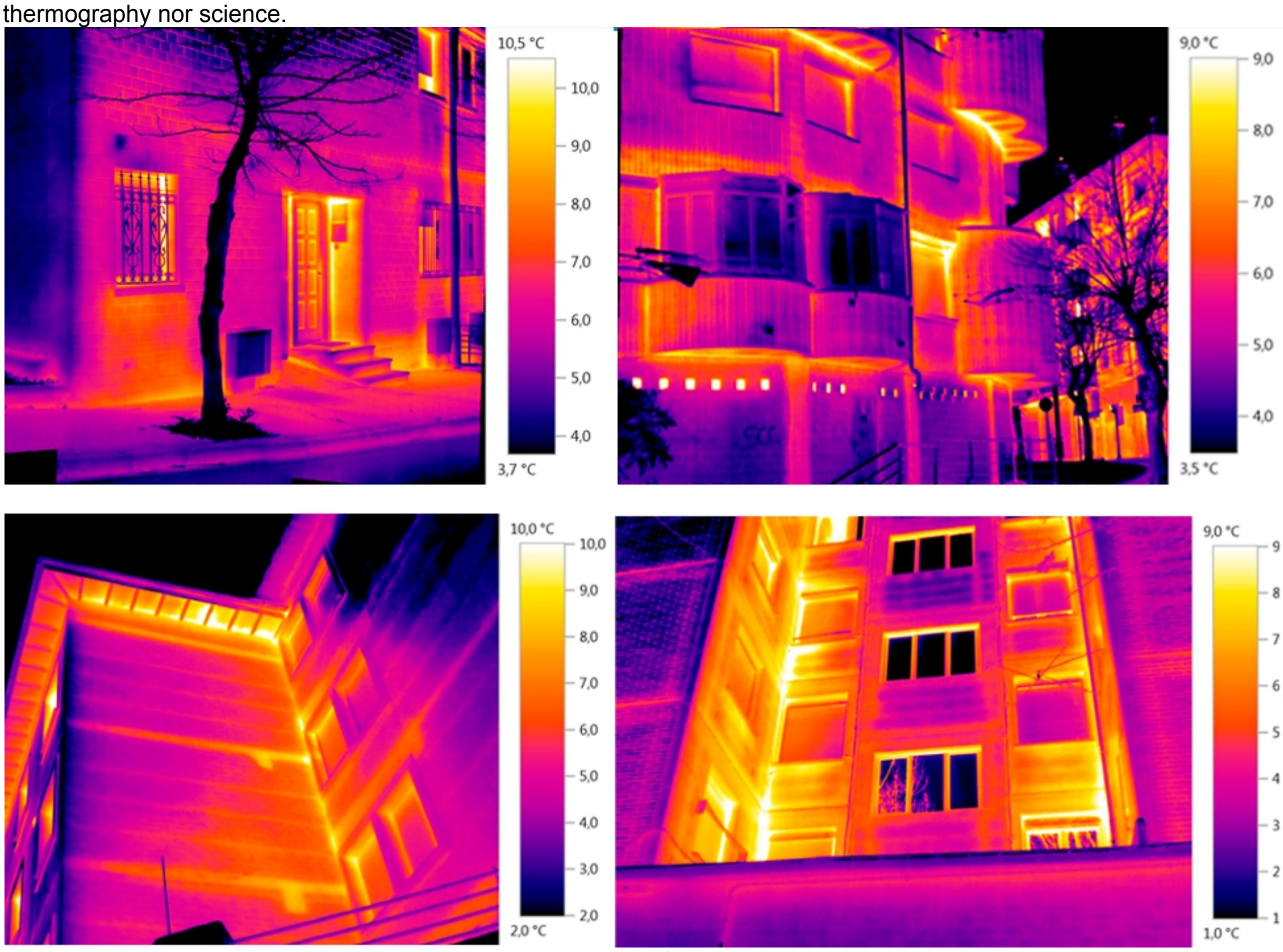

Fig. 5. *Thermographic images of Abetxuko (60's) and Adurza*
Source: Iker Gómez Iborra and Itziar Gorosabel (ig karratu arkitektura, 2013)

Although complexity of thermodynamics, thermal behaviour of buildings, explained by iron scale, seems easy to be understood by most of citizens.

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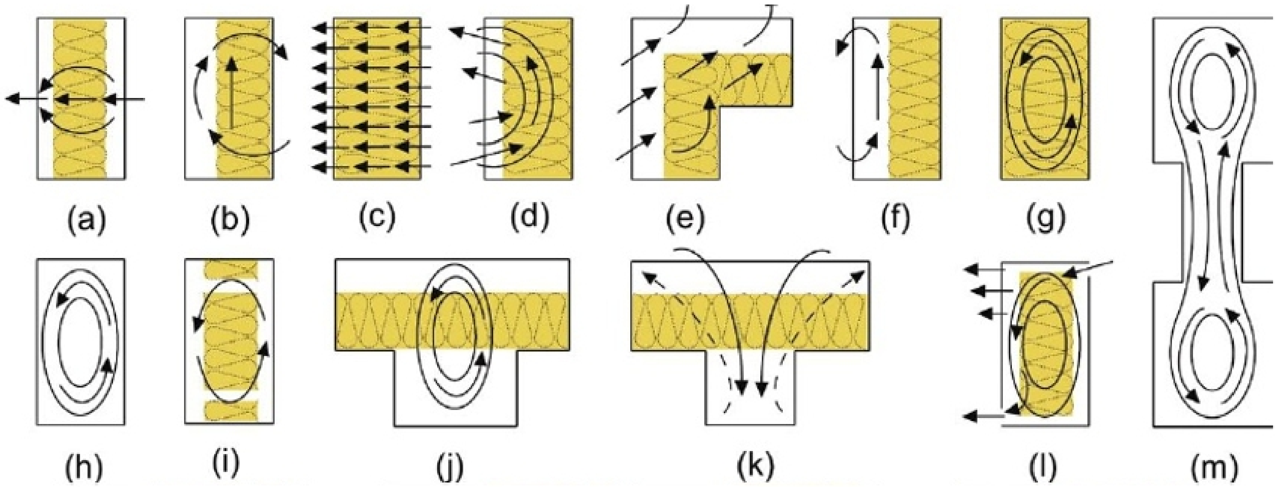
3. Poor thermal resistance, lack of tightness, thermal bridges and by-passes are main heat losses.

It is remarkable that it is always been said that building quality in Vitoria-Gasteiz has been superior to cold cities from Spain. Nevertheless heat losses keep showing through envelopes; as buildings have not been prepared to save heat properly.

In some buildings from 60's, 70´s and 80´s, thermal isolation was some times doubled from what standard obliged. In example there can be found some building projects including façades with 3, 6 cm or more of glass wool filling the cavity of the façade [9], but in new quarters, standard seemed the limit. So we can find buildings before CT-79 with less heat losses than new ones. CT-79 is the energy efficiency standard, valid from 1979 to 2006, for building in Spain. Somehow, and although some efforts are being introduced, previous and actual standards are still far away from zero energy consumption buildings.

In addition, many buildings based on cavity walls are influenced by thermal by-pass phenomena [11,12]. Thermal bridges and lack of tightness within its cavity make great energy losses; so external walls look colder than they should be if system would be built to work properly. This doesn't mean that energy is being saved, but the opposite.



[11] Mark Sidall: Common air flow patterns with insulated and uninsulated cavities:
(a) air leakage through gaps **(b)** infiltration of intetrnal air by batural air convection **(c)** difusse air leakage **(d)** infiltration of external air by natural or forced (wind) convection **(e)** wind washing at corner/edge **(f)** ventilation or venting **(g)** air rotation by natural convection within insulation **(h)** air rotation by natural convection in an uninsulated cavity **(i)** air rotation by natural convection in an insulated cavity **(j)** air rotation by natural convection through insulation **(k)** infiltration of external air by natural or forced (wind) convection through insulation **(l)** mixed pattern **(m)** air rotation by natural convection between two regions.

Fig. 6. *Thermal By Passes at buildings. Source: Mark Sidall [11]*

For more than 30 years there have been systems and techniques that can help reducing most thermal bridges that can happen in a building. Nevertheless none of them have been used frequently, not even in new buildings.

Although many new buildings claim to be energy efficient, due to bad construction, thermal bridges and by-passes that can be seen via thermography [19,22].

Thermal related disturbances, can increase real U-value of envelopes up to 3 or 4 times higher than theoretical.

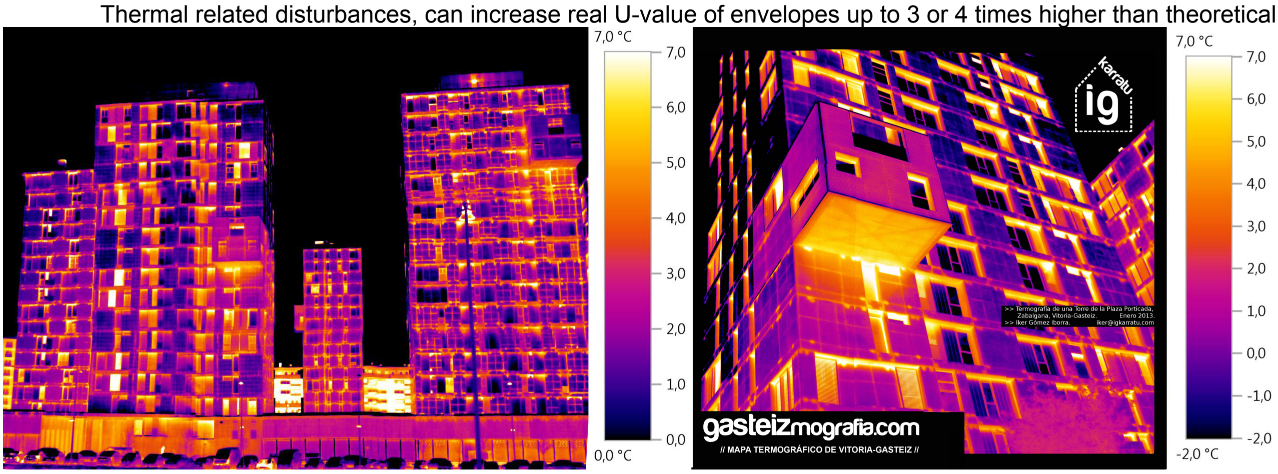


Fig. 7. *Thermographies of Zabalgana, 2000 developed new quarter in Vitoria-Gasteiz: GRC envelope towers which may have some problems related to GRC [21]*
Source: Iker Gómez Iborra and Itziar Gorosabel (ig karratu arkitektura, 2013)

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4. Energies, thermal comfort and energy poverty.

The observation and interpretation of many thermographies have shown us a worrying phenomena related with façade emitted temperatures.

With an outdoor air temperature near 5ºC many façades showed a temperature of 14-16ºC. This means that those façades don't have thermal isolation, (or it doesn't work properly).

Those dwellings are consuming a lot of thermal energy and fossil fuels, to keep indoor and outdoor thermally balanced, in order to obtain something similar to thermal comfort. And that comfort is almost impossible to obtain due to asymmetry radiation inside the room. Nevertheless these dwellings still can afford that heating energy, that can cost up to 1.800-2.000€/year per dwelling (90m^2) [9]

It is more worrying to know that, as seen in thermographies, many dwellings show a temperature below the temperature needed to reach some thermal comfort. That can be seen easily when, in a building with individual heating systems, there are zones with a really higher temperature than the others (some can afford heating the whole dwelling but others not).

According to studies about energy poverty for 2006-2010 period [13], nearly a 9% of families in Spain uses more than 10% of their income to pay energy for thermal comfort (although they could not reach it). In the Basque country it is nearly a 5% and in Navarra about 12%. So we estimate that Vitoria-Gasteiz will be near 8%.

Nevertheless thermographic images suggest that if we study the cost of the energy needed to reach thermal comfort (not the energy consumed), energy poverty in Vitoria-Gasteiz could rise up to 15% or more.

Living with no thermal comfort is unhealthy and reduces life expectancy. It must be said that energy poverty increases health costs; due to related illnesses.

In order to reduce energy poverty we suggest to transform buildings gradually to reach NZEB; or passivhaus standard.

5. Residential buildings and transformation potential for saving energies; CTE or PH/NZEB

According to EUSTAT (2010) [15,16], in Vitoria-Gasteiz, there are 107,024 dwellings, distributed in 13,632 buildings. About 14,850 dwellings are empty (no water is being used).

Average dwelling in Vitoria-Gasteiz is about 85m^2, 5 rooms (3 bedrooms) and with an average age of 39 years; so it has not fulfilled thermal standards like CT-76 or CT-79. So it can be possible for them not to have thermal isolation.

According to EVE (Ente Vasco de la Energía) [10], home energy cost in Basque country is about 1.000 €/dwelling·year. If we quit the number of dwellings that are empty and we focus on what happens in a weather like Vitoria-Gasteiz we could say that approx 700€/year dwelling are used to pay heating energy.

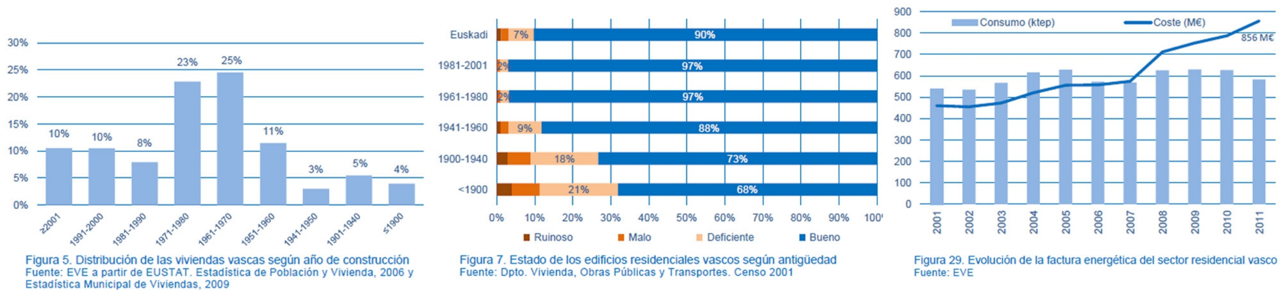

Fig. 8. *Dwellings at Euskadi, age and energy costs distribution in residential sector*
Source: EVE through Dpto. Vivienda, Obras Públicas y Transporte [10] (Censo 2001) and EUSTAT [15,16].

According to other previous studies studies carried by the author of this communication (while working for Sarkis Lagunketa construction group) [9] almost 8.900 kWh/dwelling·year are used to reach thermal comfort due to energy losses trough envelopes, that means about 500-900€ per year & dwelling depending on energy cost. We could reduce more than a 70% of that energy consumption.

The potential for saving energy in Vitoria-Gasteiz is enormous [9]. Solar gains can fullfil energy needs of the city [17,18].

In Gasteizmografia we think that this whole potential should be achieved. That is the other main objective of this project: to show that transformation can be possible; and cost effective.

In order to show that to citizens we have prepared some economic studies which deal with the cost of refurbishment operations in order to reach different standards according to the energy used per m2. More money invested means less energy used.

Standards go from A+ (PH/NZEB: 15 kw·h/m2·year) to D (strictly CTE standard: 110 kw·h/m2·year) or not doing anything (250-300 kw·h/m2·year).

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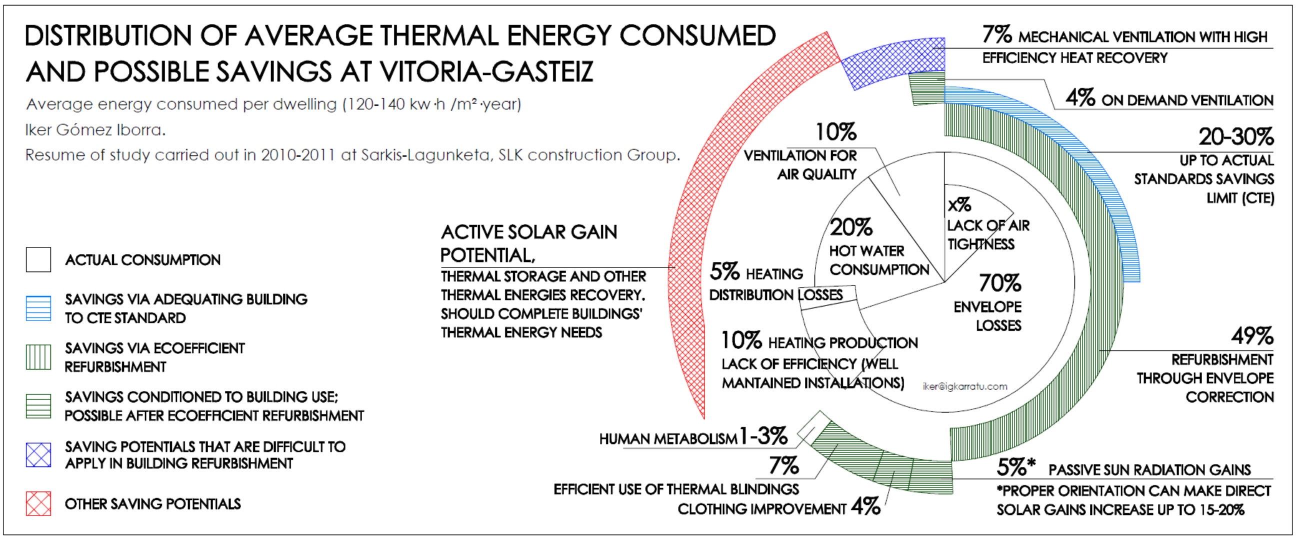


Fig. 9. *Thermal energy used on dwellings and saving potentials in Vitoria-Gasteiz*
Source: Iker Gómez Iborra (at Sarkis-Lagunketa gr.) Poster published for CONAMA 2010. [9]

Data to calculate pay back of investment is conservative; and based on averages:

1.- 39 year old, 3 bedroom and 80-90m² dwelling.

2.- Cost of operations for a medium high standard quality level with margin errors for innovation and a +2% for future Rdi operations (including improving for heating and hot water systems, and in some cases solar gains). Within some time and in big operations these prices could get 5-10% lower. Reducing more these prices could lead us to a worse quality and consequently not reaching the objectives.

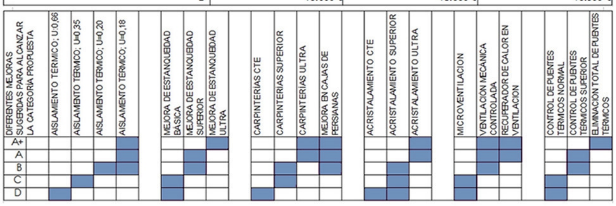
3.- 25% of the operation is funded; due to helps to reduce fossil fuel consumption, and a credit is asked for the rest at a 7% of interest rate (As Maria de Pablo from Triodos bank recommends).

4.- Natural gas as fossil fuel energy (N.G. Is known to be a "cheap" energy), cost rising 5% annually.

It is necessary to remember that cost of operations depend on many factors and each real case should be studied specifically. The objective of this section is to make an approach for citizens to let them know about refurbishment operations cots and pay back of the average dwelling (without cheating to attract interest).

EJEMPLO DE INVERSIÓN NECESARIA PARA LA REHABILITACIÓN DE UNA VIVIENDA TIPO
(vivienda en bloque de unas 3 habitaciones y 80-90m2 de superficie útil)

EL OBJETIVO DE LA REHABILITACIÓN ES ALCANZAR UNA CATEGORÍA DE:	COSTE MÍNIMO	COSTE MÁXIMO	COSTE MEDIO
A+	25.000 €	30.000 €	27.500 €
A	23.000 €	28.000 €	25.500 €
B	20.000 €	23.000 €	21.500 €
C	18.000 €	20.000 €	19.000 €
D	15.000 €	18.000 €	16.500 €

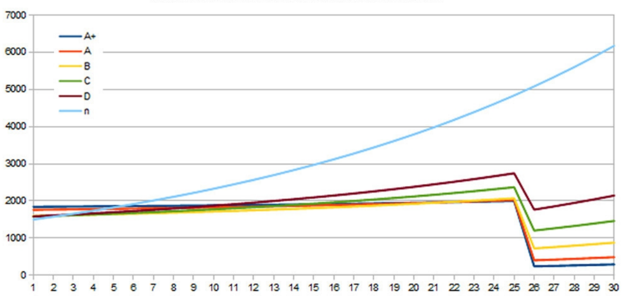


COMPARATIVA AMORTIZACIÓN

PARÁMETROS	A+	A	B	C	D	n
INVERSIÓN	27.500,00 €	25.500,00 €	21.500,00 €	19.000,00 €	16.500,00 €	0,00 €
SUBVENCIÓN	25,00%	25,00%	25,00%	25,00%	25,00%	0,00%
Nº vecinos	1	1	1	1	1	1
Importe préstamo	20.625,00 €	19.125,00 €	16.125,00 €	14.250,00 €	12.375,00 €	0,00 €
Período amortización	25 años	25 años	25 años	25 años	25 años	0,00 €
Consumo mensual/propietario actual sin realizar inversión	125,00 €	125,00 €	125,00 €	125,00 €	125,00 €	125,00 €
Consumo mensual/propietario actual tras inversión	5,92 €	9,87 €	17,77 €	29,61 €	43,43 €	125,00 €
COSTE ANUAL TRAS INVERSION/VIV	71,06 €	118,44 €	213,19 €	355,32 €	521,14 €	1.500,00 €
cuota mensual propietario amortizacion	147,50 €	136,83 €	115,31 €	101,90 €	88,50 €	0,00 €
incremento de coste energías	5,00%					
interés	7,00%					

info@igkarratu.com

COSTE ANUAL DE ENERGÍAS TÉRMICAS + AMORTIZACIÓN



GASTO ACUMULADO ENTRE ENERGÍAS Y AMORTIZACIÓN DE OPERACIONES

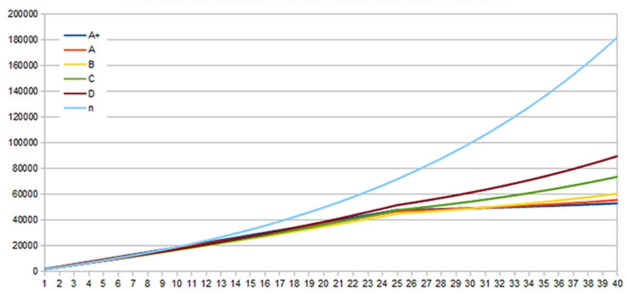


Fig. 9. *Example of investment and pay pack for refurbishing an average dwelling into different standards.*
Source: Iker Gómez Iborra (2013)

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As a resume of the comparative following can be said:

1.- Transforming buildings into PH/NZEB results to be the best choice at long term.

2.- The worst options at all term are not doing anything or transforming just for CTE.

3.- The choice for short and medium term is prepare isolation, tightness and windows as if they were PH/NZEB, so buildings can be transformed whenever it will possible.

4.- The best of transforming a building into an NZEB (or almost) is that solar radiation can be enough for heating the building during 80-90% of the year.

6. Conclusions

6.1. Conclusions about thermographic images interpretation

Thermographies allow citizens to understand heat losses trough envelopes, so it is an easy tool to enlighten the problem of the excessive thermal energy used at buildings.

Thermographies of buildings at high resolution can lead us to problems and heat losses in envelopes and heat distribution.

Thermal bridges and by-passes, air leakages and other related problems can increase real U-value up to 2 or 3 times theoretical U-value.

Thermographies of entire buildings let us perceive easily energy poverty through comparison.

Many of Vitoria-Gasteiz's buildings burns a lot of energy and fossil fuels without reaching thermal comfort.

Buildings of Vitoria-Gasteiz are far away from fullfilling NZEB standards.

Most of the new buildings (2000-2010) have not avoid thermal bridges nor thermal by-passes.

6.1. Conclusions about Vitoria-Gasteiz's buildings and improve potential

A lack of concern among avoiding thermal losses and a lack of accuracy to correctly develop new buildings' envelopes, mainly on its project phase, has lead us to a city which should be entirely transformed to match NZEB standards to face a chance to provide thermal comfort and quality of life to its citizens.

Vitoria-Gasteiz climate condition is not far away from being ideal for NZEB purpose.

Living without no thermal comfort is harmful for users, reduce life expectancy and increases social health costs.

Refurbishing of buildings in Vitoria-Gasteiz into PH/NZEB should improve local economy.

More support and funding is needed from governments to develop big refurbishment operations.

When starting a refurbishment operation we must consider transforming it into PH/NZEB standard undoubtly.

In case of not being able to pay that standards it is convenient that tightness, thermal isolation and windows will let the building reach PH/NZEB standards in an evolutive way; as enerphit standards propose.

More information about the project can be found at www.gasteizmografia.com and related social nets.

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