ENVIRONMENTAL RETROFITTING OF PUBLIC BUILDINGS ACCORDING TO THE OBJECTIVES OF THE EUROPEAN DIRECTIVE 20-20-20 CASE STUDY OF IPARRALDE CIVIC CENTER IN VITORIA

[1]Higueras García, Ester; [1]Carretero Monteagudo, Jorge
[1]Universidad Politécnica de Madrid
e-mail: ester.higueras@upm.es jmcmarq@hotmail.com

ABSTRACT

The current report focuses in the analysis of a theoretical case of ecological refurbishment applied on the Iparralde Civic Center in Vitoria Gastéiz. This analysis, which was focused in the accomplishment of the aims within 20-20-20 Directive, has as main objective the demonstration of the efficacy of mixed solutions of refurbishment. Whereas, an analysis of a supposed refurbishment on Iparralde Center was performed, using both green roofs and photovoltaic roofs. Within this analysis, the benefits that these refurbishment operations can have towards the environmental objectives of 20-20-20 Directive were considered. Once this study was done, it was established as conclusion, that best solutions facing environmental refurbishment are the ones including various sorts of retrofitting techniques.

Keywords: refurbishment, europe 20-20-20, buildings, Vitoria

1.- State of the art study

The issue of energetic efficiency related to construction and retrofitting is today a topic of importance around the whole world, this appointment is held on the current environmental problems.

Of course, all of the operations on the buildings aimed to improve energetic efficiency can be or not included within a legal context with objectives to be achieved. This legal context is aimed to encourage different governments around the world to improve the energetic efficiency of the buildings with a single achievement, the reduction of energy consumption and pollution in both urban and rural areas.

The European Directive 20-20-20 (2008), Is a measure related to the European Union, whose objectives are a 20% reduction in the emissions of greenhouse gases and energy consumption, in addition to the coverage of the total energy demand with renewable energies in at least a 20% [1]. Furthermore, The report of the European Commission 20-20-20 makes buildings responsible of approximately the 40% of energy consumption and the 36 % of European Union CO2 emissions. It also appoints that by reducing the energy consumption in a 30% related to the current energy consumption, would achieve a reduction of a 11% of total energy consumption of the European Union. A challenge that nowadays is qualified as reliable.

This directive also appoints that the responsibility of reducing energy consumption and emissions is of the member states. What makes important to take measures towards this achievement. Whereas the European Commission is committed to launch initiatives for the encourage and development of sustainable building means [2], [3]. By this way, it is an issue of interest the research of possible building retrofitting techniques, these techniques may be focused on achieving the objectives of the formerly mentioned European directives.

In Spain. During the last years, public authorities have promoted the building retrofitting. However, most of the interventions are mainly aimed to constructive or aesthetic improvement of the building, and the energetic efficiency improvements are not considered with the importance they must have.

The second part of the background study is based on the review of the current regulations in Spain. Currently new regulations have been established aimed to the improvement of the energetic efficiency. Law 8/2013 of BOE, despite mentions the commitment towards the objectives of 20-20-20, and the importance of energetic efficiency improvement through rehabilitation, it does not propose measures to be taken or guidelines facing the reduction of environmental impact [4].

As a result of this law, there are the ordinances applied in autonomous regions, provinces and municipalities concerning the protection of the urban environment. These ordinances consider the environmental issue more or less. For instance , the Ordinance concerning the maintenance of Urban Environment establish by Madrid local council (1985, last updated in 2001) focuses mainly in maintaining the sanitation of the city. Disappointedly this ordinance little considers the issue of reducing, carbon dioxide, energy consumption, and the insertion of renewable energies, (the basis of the 20-20-20 objectives). These lacks are mainly because of the age of the ordinance, which seems not to have been updated including these issues in a concrete way [5]. With the intention of supplying some of these lacks, the Madrid Council in 2003 approved another ordinance focused on the usage of solar thermal energy , assuming a minimum contribution according both the characteristics of the building and the number of inhabitants [6]. Even though, the Community of Madrid in 2011 approved a plan to promote renewable energy, being this plan not currently in effect [7].

In the city of Vitoria-Gasteiz, which is the place where we did the current research, the municipal environmental ordinances are focused in the sanitation of the city, air quality, and waste treatment facilities (2005-2013), not setting guidelines on retrofitting or energy savings [7]. Moreover, the council of Vitoria-Gasteiz offers grants for the retrofitting of residential buildings, which are focused mainly on issues of improving the building envelopes and facilities, the ordinance ruling these grants, scarcely considers the issue of environmental improvements proposed by the 20 -20-20 objective [8]. Also the character of this ordinance is partial, because it is focuses exclusively on residential buildings, preferably in the ones run down.

To sum up, the Spanish legislation, concerning the issue of environmental improvements is focused from a very concrete view, proposing very specific measures, which rarely consider multiple solutions or the combination of technologies. At a first way, combined solutions seems to be the most efficient method when undertaking an environmental retrofitting of a building of any kind, either public or private. Whereas, the main point of this research was to consider the effects of combined retrofitting techniques, facing a possible reduction of carbon dioxide emissions , energy consumption, and the inclusion of renewable energies. Seeing by this way the possibilities of an approaching towards the objectives of the 20-20-20 Directive. Being the case of buildings, a reduction of about a 30%.

The European challenge of 20-20-20, and their possible aftermaths both in a national or international background (Possible topic for future research), is an extraordinary opportunity of carrying out an applied research, considering the most appropriate measures could be taken towards the environmental retrofitting of both architecture and urban spaces. Therefore, the present research was focused on the analysis of some of these measures, applied to achieve the former mentioned objectives of the 20-20-20 European Directive. This study was focused on the environmental retrofitting of large public buildings, which seem to be are a great opportunity for an analysis of how the objectives formerly mentioned could be achieved.

In South America also exists directives aimed to reduce the energy consumption of buildings. To put an example, the Chilean Government developed in 2005 the "PPEE Program" (Programa País Eficiencia Energética). Considering the energy consumption reduction, in a simimar way of 20-20-20 European Directive. However, the reduction for building and construction established in this program is only a 0.9%, related to the 30% stablished in 20-20-20 European Directive. Trevilock M. In the paper "Percepción de barreras a la Incorporación de Criterios de Eficiencia Energética en las Edificaciones" also establish the different facts that discourage the usage of construction methods aimed to energy consumption reduction in Chile. [15] As well as the research group composed by O. Escorcia, R. García, M. Trebilcock, F. Celis and U. Bruscato carries out with a research, with the objective of establishing a criteria of sustainable and healthy design for housing developments. In which both the shape of the building and its constructive composition is considered. Two scenarios of energetic efficiency analysis on buildings are considered, including both the constructive composition and the energy savings [16].

The current paper was focused on the application of different environmental retrofitting techniques, on a case of a public building with an aim: to evaluate the opportunity of giving a green response to major facilities within the city facing the objectives of the 20-20-20 Directive, thereby reducing energy consumption and CO_2 emissions. Three environmental retrofitting methods were evaluated:

1-. By transforming the roof and public spaces surrounding the building in green areas .
2-. By the introduction of photovoltaic cells on the roof, in the places where feasible.

3-. By applying a combination of the two proposals mentioned above.
For this study, the following hypothesis was established

- The combination of green roofs and photovoltaic tiles provides more benefits for buildings of large area, such as public buildings.

By this way, the analysis done in this paper was focused on the corroboration of the currently mentioned hypothesis . Doing by this way a case study about a public building, which is the Iparralde Civic Center in the city of Vitoria-Gasteiz.

2.- Methodology

For the current paper, related to Iparralde Center, the studio will be done for the roof, the southwest facade and the public plaza. The previous analysis for the case study, was to establish the areas to study, in addition to the features of them and other data of interest according to further analysis.
The first step in the analysis, was the making of an analysis of sun exposed hours on different points in the studied areas of Iparralde Center. This analysis was done by the usage of solar masks, being the result the number of sun exposed hours per year. In this solar masks, data concerning both buildings and cornice height were considered.
The second step in the analysis was to convert the sun exposed hours formerly calculated in stereographical cards, in energy units concerning solar irradiation. To achieve this, a spread sheet done by the Professor Javier Neila of the Polytechnical University of Madrid (2010) was used, inserting on it the data concerning the features of the areas to be studied, the climatic conditions of the city of Vitoria, and the sun exposed hours.
The third step is to estimate what amount of the energy irradiated data by the sun can be used to cover the iparralde Center energy needs. To achieve this aim, different statistics about the performance of photovoltaic cells in transforming solar energy were studied, inserting also the data concerning solar irradiation obtained before. The data concerning solar cells performance in generating energy for consumption was provided by the Intemper technical service.
The fourth step is the analysis of the carbon dioxin absorption done by plants. The data concerning this issue was obtained by the analysis of former research studies done on this matter (Figueroa, Getter, Micaela). This is going to be the basis of the analysis of green roof retrofitting. The data resulting of this step was established in tons of carbon dioxin absorbed per year.
The fifth step is to establish different scenarios of retrofitting. This is aimed in the set up of the effects, concerning the possible application of the two retrofitting measures explained before (photovoltaic and green roofs). The scenarios will consider different combinations of both measures, which are going to be applied on different areas. The results of this step were the reduction of carbon dioxin by the usage of green roofs in tons per year, and the generation of clean energy by the application of solar cells in kW/h. this data is important facing the conclusive analysis.
The sixth and last step was conceived as a previous step towards the conclusions. In this step the energy consumption and carbon dioxin emissions of the Iparralde center were estimated, obtaining by this way the necessary data to establish a minimum of relevance. To obtain these data, the CE3X computer program (2013) was used, considering its current state without applying any retrofitting.
Finally, the positive results obtained from the analysis of retrofitting scenarios were compared with the energy consumption and the carbon dioxine emissions generated by the Iparralde Center. The results obtained from this comparative analysis headed towards the final conclusions. Furthermore, a minimum of relevance was established,

that in the case of this case study, were the objectives of the 20-20-20 directive explained before.

3.- Case study

For this research, the case study was focused on the building of the Iparralde Civic Center placed in the center of the Town of Vitoria Gastéiz in Northern Spain.

Fig. 1 “Placing of Iparralde Center”. Source: Bing Maps.

The Iparralde Civic Center was opened in 1989 as a public equipment. Inside the center there is a theatre, a public pool, some rooms and a social center. Concerning the materialization of the building, the structure is made of a frame of pillars and beams made of concrete, the large void spaces placed within are covered with sloped roofs made of light metallic elements, The walls are mostly made of brick, using stone tiling facing exterior, and cement cover or ceramic tiling depending on the usage, then a constructive detail is shown placed on the area of the covered pool. (Figure 2).

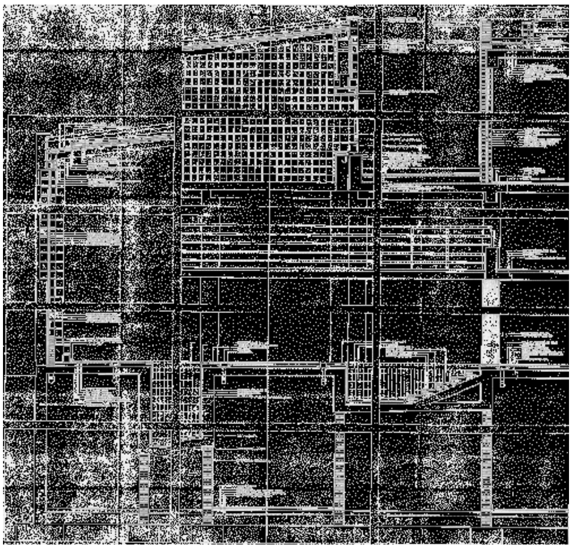

Fig. 2 “Constructive detail of the Iparralde Center”. Source: Project.

Before starting any analysis, areas for the retrofitting study on the Iparralde building were fixed, as well as the points related to solar irradiation analysis. (Figure 3).

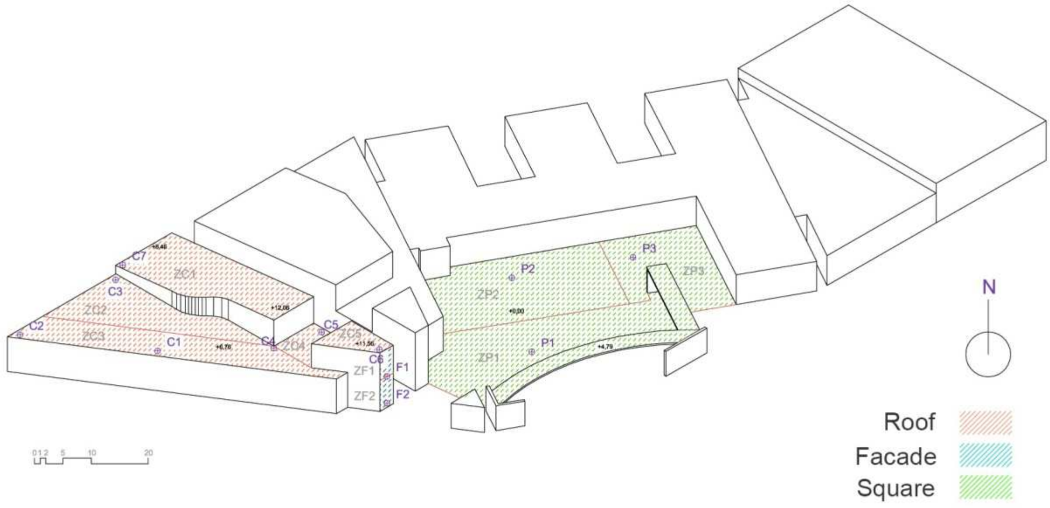

Fig. 3 **"**Points and analysis areas of Iparralde Center". Source: Own elaboration.

Being of importance too for this analysis, the architectural and bioclimatic features of each area of analysis. (table 1).

AREA A: SQUARE	Cornice height (m)	Surface (m2)	Refference points	Slope	Azimuth
Roof 1 (ZC1)	12,06 a 8,63	380,88	C7-C8	6º	-135º
Roof 2 (ZC2)	6,76	329,27	C1-C2	0º	0º
Roof 3 (ZC3)	6,76	276,36	C3-C4	0º	0º
Roof 4 (ZC4)	6,76	81,45	C5	0º	0º
Roof 5 (ZC5)	11,56	54,56	C6	0º	0º
AREA B: FACADE	Cornice height (m)	Surface (m2)	Refference points	Slope	Azimuth
Facade 1 (ZF1)	5,9 a 11,56	18,48	F1	90º	45º
Facade 2 (ZF2)	0 a 5,9	18,48	F2	90º	45º
AREA C: SQUARE	Cornice height (m)	Surface (m2)	Refference points	Slope	Azimuth
Square 1 (ZP1)	0	762,84	P1	0º	0º
Square 2 (ZP2)	0	590,62	P2	0º	0º
Square 3 (ZP3)	0	339,7	P3	0º	0º
Canopy 1 (ZM1)	4,79	127,91	P2	0º	0º
Canopy 2 (ZM2)	4,79	65,47	P2	0º	0º

Table 1 "Characteristics of the areas to analyze". Source: Own elaboration.

3.1.- Sun exposure analysis

In order to calculate the sun exposure analysis, and lately the irradiated energy for this case study, thirteen different points were placed on the different areas to analyze (eight on the roof, two on the façade and three on the public square), within each one, shadow masks were calculated. This sun exposure analysis was done by the usage of solar stereographical cards of latitude 42º N (Latitude of Vitoria), inserting both draft plan data and cornice heights into the stereographical cards. By this way sun exposed hours were fixed concerning each reference point placed on the areas of analysis. In (Figure 4) three representative points of the different areas of analysis are shown.

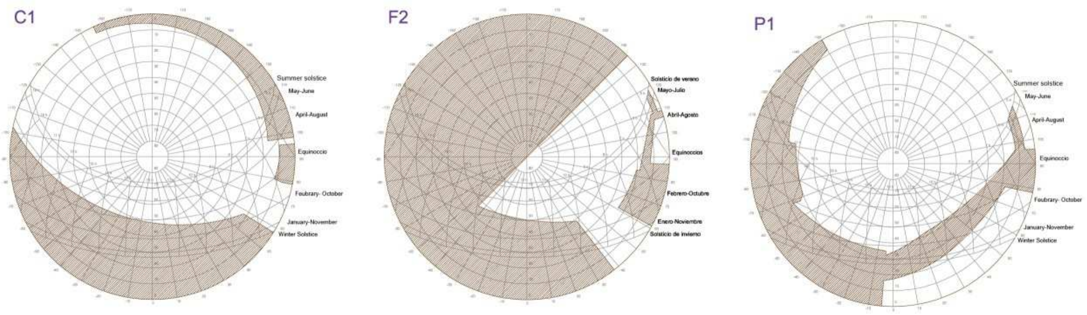

Figure 4 “Solar Masks”. Source: Own elaboration.

The stereographical cards show the fact that during the coldest months the sun irradiance received is less, because the obstruction of sunrays by the surrounding buildings. Towards the calculation of solar energy irradiated, it was necessary a count of sun hours parting from the stereographical cards, establishing by this way the yearly sun exposed hours. (Figure 6).

Point	Yearly Sun Hors	% related to year time
C1	2623,5	0,60
C2	2837,5	0,65
C3	2904,5	0,66
C4	2592,5	0,59
C5	2174,5	0,50
C6	3559,5	0,81
C7	3894,5	0,89
C8	3849,5	0,88
P1	2710,5	0,62
P2	3165,5	0,72
P3	3119	0,71
F1	2264	0,52
F2	1938	0,44

Table 2 “Yearly sun exposed hours”. Source: Own elaboration.

3.2.- Solar irradiation calculus

The Calculation of solar irradiance is the basis to estimate the energy obtained by the usage of photovoltaic means of energy generation. For to calculate energy irradiated by the sun, a spreadsheet done by the professor Javier Neila in 2010 (Polytechnic University of Madrid) was used. In this spreadsheet both climatic and geographical data of Vitoria Gastéiz were inserted, in addition to the data related to cloud coverage, azimuth and inclinations of different areas.

Once solar irradiation was calculated on each area, it was necessary to apply a criteria of sun exposure areas on each zone to be retrofitted, because the spreadsheet used to calculate the solar irradiance does not considers obstacles facing sun exposure. By this way sun exposed hours obtained in the solar mask analysis were considered, by the application o a recuction percentage on the data obtained in the spreadsheet. By this way, the energy received was estimated for each area.

4.- Results related with the analysis of retrofitting means

4.1.- Analysis of the performance of a supposed retrofitting using photovoltaic panels

The calculation of the energy balance caused by the application of the photovoltaic roof is closely linked to the solar irradiation received on the surface formerly estimated (Figure,7). The calculation of the energy generated by the usage of photovoltaic panels, was based on the data Intemper company technical service provided. This data was related to the amount of energy for consumption that can be converted from sun irradiance. In the case of the Iparralde Center, Intemper technical

service estimated approximately 44984.36 kW/h, for an area of 500 square meters considering the climatic conditions of Vitoria. (55 kW, using the photovoltaic slab model Filtrón I 40). But nonetheless, to conduct the analysis in a more specific way, it was necessary to perform an interpolation between the data provided by the technical service of Intemper, and the data obtained in the formerly done solar analysis. (Figure 8)
In order to overcome this, the first operation was to put the values of energy generated by the Filtron I 40 in kW/h per square meter. This was done by dividing the monthly totals given by Intemper between the standard surface considered (500 m²). Once this data was obtained, this standard monthly values were multiplied by the percentage of total sun hours per zone. The following figure puts the results of this calculation. The solar panels were of application for the roof, the southwest facade, and the canopy placed on the southwest edge of the public square.

4.2.- Parting data for green roof retrofitting analysis
The retrofitting with green elements is an important part of this case study, because green elements can be used within the cities to reduce the carbon dioxin present in the atmosphere. The first step was to establish the amounts of carbon dioxin per square meter, that different green elements can assimilate. (green walls, intensive green roofs and extensive green roofs).
The carbon dioxin absorption value for green extensive roofs was established parting from the data of the results of different research studies, the studies considered, such as the ones done by K.L. Getter Ea, Carbajal Micaela or Manuel Figueroa Clemente [10], [11], [12], explains the capabilities of different plant species in carbon dioxin absorption. Once the capabilities of carbon dioxin absorption were established for plants, next step is to establish a carbon dioxin absorption rate per square meter of extensive green roof. To obtain this rate, first the number of plants a square meter of extensive green roof can contain was considered, multiplying this value per the carbon dioxin absorption rate per plant. By this way, the carbon dioxin rate of a square meter of green extensive roof was established in 1350 grams or 0.00135 [10], [11] tons of carbon dioxin per year. Green extensive roofs were considered as compatible with the roof areas 1,2,3 and 4, and the areas 1, 2 and 3 in the public square. The economical cost of this intervention was established according to the Intemper company fares for 2012.
Despite the green wall is not a retrofitting operation aimed to roofs, for the current work this retrofitting operation was considered as an adaptation of the green extensive roof to facades. For the calculation of the carbon dioxin absorption of green walls, (only reliable for application on the areas of the facade 1 and 2) carbon dioxide balance formerly calculated for the extensive green roofs was considered for green walls. The cost of this intervention was established according to the Intemper company fares for 2012.
The calculus of the Green intensive roof carbon dioxin rate was performed within a similar process as the done formerly for extensive green roofs. For this analysis bushy vegetation was considered as plants for intensive green roofs, in order to avoid high overload. This way, the studies done by Enrique Figueroa and Susana Redondo Clemente Gomez at the University of Sevilla [13], defined as more efficient species within carbon dioxin reduction, the laurustinus shrubs (46 kg CO_2/year) and palm (40 kg CO_2/year). The study of the dimensions of these shrubs (1sqm wide), helped to estimate the absorption per year of each square meter of intensive green roof for the current analysis; which was established with the value of 40 kg or 0.04 tons of carbon dioxin absorbed per square meter and year of intensive green roof. It also became important to consider the structural conditions of the slab when applying

this sort of intervention, considering intensive green roofs only compatible for roof areas 2,3 and 4, and areas 1, 2 and 3 of the public square. For the estimation of the cost of the square meter of intensive green roof, the unitary prices of the application of a waterproofing, plus a geo textile, and 50 cm substrate for plants, established by Intemper in 2012 were considered. Being also this prices compared with another sources of own research.

5.- Analysis of scenarios

Once the effects of different retrofitting operations considered were defined, as well as the areas of application, next step is the setting of retrofitting scenarios, in addition to the effects of each one. For the present case study, three scenarios were defined.
5.1.- Scenario 1: Transformation of both roof and public square in green surfaces.
In this scenario, the option was the application of both extensive and intensive green roofs where possible, on the roof and public square. By this way the rates of green roofs carbon dioxin absorption were of application, being this data multiplied by the surface of each area. The resume of the effects of green surface application is specified in the table, moreover the total amount of carbon dioxin tons assimilated per year by the green surfaces (Table 3).

GREEN ROOFS SCENARIO	Retrofitting applied aplicada	Tons of Co2 assimilated per year
Roof 1 (C1)	Extensive G.R.	0,514188
Roof 2 (C2)	Extensive G.R.	11,0544
Roof 3 (C3)	Intensive G.R.	13,1708
Roof 4 (C4)	Intensive G.R.	3,258
Roof 5 (C5)	Intensive G.R.	0,073656
Facade. 1 (F1)	Green Wall	0,024948
Facade. 2 (F2)	Green Wall	0,024948
Square 1 (P1)	Intensive G.R.	30,5136
Square 2 (P2)	Intensive G.R.	23,6248
Square 3 (P3)	Intensive G.R.	13,588
Canopy. 1 (M1)	Extensive G.R.	0,1726785
Canopy. 2 (M2)	Extensive G.R.	0,0883845
TOTAL		**96,108403**

Table 3 “Partial results of the carbon dioxin analysis, related to green roofs scenario”. Source: Own elaboration.

5.2.- Scenario 2: Photovoltaic cell application

In this scenario, photovoltaic cells were applied on the areas with good sun exposure conditions. The effects of this retrofitting operation, as well as the balance of this application are shown in (Table 4)
Related to this scenario, despite the placement of solar cells is compatible with the public square in a constructive way, this operation is unreliable because of projected shadows and transit of people which reduces considerably its reliability concerning energy generation.

PHOTOVOLTAIC ROOFS SCENARIO	Applied retrofitting	kW/h generated per year
Roof 1 (C1)	Compatible	25698,027
Roof 2 (C2)	Compatible	20377,467
Roof 3 (C3)	Compatible	18801,74
Roof 4 (C4)	Compatible	4512,54
Roof 5 (C5)	Compatible	3608,57
Facade. 1 (F1)	Compatible	662,58
Facade. 2 (F2)	Compatible	503,75
Square 1 (P1)	Uncompatible	X
Square 2 (P2)	Uncompatible	X
Square 3 (P3)	Uncompatible	X
Canopy. 1 (M1)	Compatible	7541,23
Canopy. 2 (M2)	Compatible	5047,92
TOTAL		**86753,824**

Table 4 “Partial results of the energy generated, related to photovoltaic roofs scenario”. Source: Own elaboration.

5.3.- Scenario 3: Combination of photovoltaic cells and green surfaces

For this scenario, a combination of green roofs (Figure 9), and photovoltaic cells was applied depending on the area. By this way, both green and photovoltaic roofs were applied on the areas whose placement was more reliable, according to the formerly mentioned scenarios.

6.- Environmental balance of the scenarios

Once the three scenarios explained above were analyzed, next step is to establish the criteria towards the conclusions.

6.1.- Calculation of carbon dioxin emissions and energetic consumption

This criteria will be based on the energy consumption of the center and the carbon dioxin emissions generated by it. Related to Carbon Dioxin emissions, an estimative analysis of the Iparralde Center was done with CE3X program. Obtaining the data concerning carbon dioxin emissions derived from energy usage. It also may to be considered that the application of green roofs and facades, will produce an energy consumption reduction when increasing isolation. In order to see this reduction, the methodology of application was the insertion of the features of the green roof within the program. This analysis is going to be estimative, because the characteristics of the facilities of Iparralde Center are not clear. By this way the insertion of the facilities in CE3X program is going to be applied with the following features:

- Sanitary water and heating using mixed gas furnace of 400 kW, with middle isolation.
- Illumination composed of compact fluorescent light bulbs.
- Refrigeration by the usage of electric air conditioning equipment.

By this way the estimated emissions of Iparralde Civic Center, according to the formerly mentioned facilities, were approximately of 56,37Kg/m m^2 of carbon dioxin ton per square meter. Considering a useful surface of approximately 2258 m^2, the total emissions are about 127283,46 kg of carbon dioxin. (127 Tons). Considering the increase of isolation derived from the application of green roofs, the emissions of Iparralde Civic Center were of 55,23 kg/ m^2 of carbon dioxin, and applying the formerly mentioned surface emissions are of 124709 kg of co2 (124 Tons, 3 tons less because of the isolation capabilities of green elements applied).
Related to the analysis of energy consumption, and the reduction achieved by the application, is going to be necessary to compare the energy generated by the usage of photovoltaic cells with the energy consumption of the Iparralde Center. The program CE3X stablished an energy consumption of 239,38 kW/h m^2, being the surface of Iparralde Center 2258m^2. By this way the consumption of Iparralde Center is 540520 kW/h per year. The application of green roofs also supposes a reduction of energy consumption by increasing isolation.
Once both the emissions of carbon dioxin and energy consumption of Iparralde center were estimated, next step is to see if a relevant carbon dioxin reduction have been achieved or a considerable part of the energy demand of Iparralde Center have been achieved, according to the objectives of the 20-20-20 directive.

6.2.- Environmental balance of green roof application

As mentioned formerly, the application of green roofs also supposes a reduction in energy consumption due to isolation improvement. Doing an estimation of this reduction with CE3X program, was possible to achieve a reduction of 32000 kW/h per year by using green roofs.

However, the bigger contribution green roofs have facing carbon dioxin emissions, is their capability of absorption, Which was calculated in 96 yearly tons of carbon dioxin (see point 5.1).
Green roofs are not going to be considered within the issue of clean energy generation.

6.3.- Environmental balance of photovoltaic roof application

Considering energy saving, is of importance to consider that photovoltaic roofs does not have isolation capabilities, so their application is not going to produce any energy save by their addition on roofs and walls.
Related to carbon dioxin reduction, is true photovoltaic roofs are going to propice it because they are a clean energy source. However this balance is not going to be considered, because the author does not know the source of the energy used in Iparralde Center, in addition to the knowledge and source necessaries to establish a study about the emissions of means of energy generation, this can be an issue of future studies.
For this study, the strong point of the photovoltaic roofs is the apportion of 86753,82 yearly kW to cover the energetic necessities of the Iparralde building.
Mixed solution scenario includes the reductions of both green and photovoltaic roofs.

6.4.- Comparative analysis of scenarios

By this way, once comparative data for conclusions was obtained, a comparison was done considering carbon dioxin reduction by the usage of green roofs, reduction of energy consumption and energy generated by renewable sources. To carry out with this comparison, a minimum of relevance was established , considering for this case a 20% in the reduction of energy consumption, the assimilation of the 20% of the emissions generated by the building, and a coverage of the 20% of energy demand using renewable sources. All according to the European directive of 20-20-20. (Table 5) (Figure 5)

				REDUCTIONS APPLIED IN SCENARIOS			
		SCENARIO 1 (Green Roofs)		ESCENARIO 2 (Photovoltaic roofs)		ESCENARIO 3 (Mixed solution)	
	EDIFICIO SINBUILDING WITHOUT RETROFITTING	ABSOLUTE REDUCTION BALANCE	PERCENTAGE OF REDUCTION	ABSOLUTE REDUCTION BALANCE	PERCENTAGE OF REDUCTION	ABSOLUTE REDUCTION BALANCE	PERCENTAGE OF REDUCTION
ENERGY CONSUMPTION, yearly kW/h	540520	32000	**5,92%**	0	**0,00%**	15000	**2,78%**
CO2 EMISSIONS, Yearly tons	127,283	98,7	**77,54%**	0	**0,00%**	95,22	**74,81%**
RENAWABLE ENERGIES, Yearly kW/h generated	0	0	**0,00%**	86753	**16,05%**	82241	**15,22%**
COST IN EUROS		374742,22		206304,68		521177,61	

Table 5 “Comparison of the results between the scenarios according to the 20-20-20 objectives”. Source: Own elaboration.

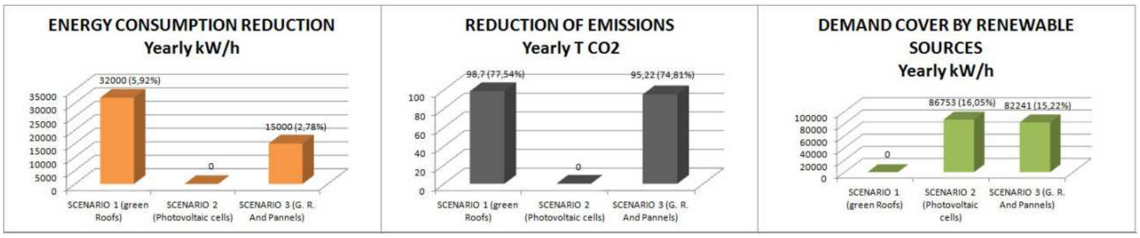

Fig. 5 “Graphs of comparison between the scenarios according to the 20-20-20 objectives”. Source: Own elaboration.

According to the shown in the table, combined solution is the best solution facing an environmental retrofitting according to the 20-20-20 objectives, this is because combined solution covers both carbon dioxin reduction and energy reduction and generation.

Mixed solution offers a slightly lower reduction rates because of the incompatibilities among the two different sorts of retrofitting. However, this solution is the most efficient one if the retrofitting mean is applied on each area, according to the environmental and constructive features of each.
However, the price of the mixed retrofitting is almost a 40% more expensive than the price of the complete retrofitting with green roofs, and a 150% more expensive than the retrofitting by the usage of photovoltaic cells. Whereas is recommendable to consider the economic condition to choose the most suitable retrofitting mean. The cost can also be a fact to consider towards the efficacy of the retrofitting means related, studing how big can be the balance achieved per euro. (Table 6). For this study, The balances higher than the middle will suppose the reliable means for each area:

ECONOMIC RELIABILITY	Green roof applied	Tons of Co2, assimilated per euro	kW/h generated per euro using photovoltaic roofs
Roof 1 (C1)	C.V. Extensiva	0,000045	0,243574513
Roof 2 (C2)	C.V. Intensiva	0,00056338	0,266192151
Roof 3 (C3)	C.V. Intensiva	0,00056338	0,206141822
Roof 4 (C4)	C.V. Intensiva	0,00056338	0,200009308
Roof 5 (C5)	C.V. Intensiva	0,00056338	0,238770684
Facade. 1 (F1)	Muro Verde	0,0000027	0,129436448
Facade. 2 (F2)	Muro Verde	0,0000027	0,098408661
Square 1 (P1)	C.V. Intensiva	0,000727657	X
Square 2 (P2)	C.V. Intensiva	0,000979522	X
Square 3 (P3)	C.V. Intensiva	0,000250879	X
Canopy. 1 (M1)	C.V. Extensiva	0,000045	0,212842288
Canopy. 2 (M2)	C.V. Extensiva	0,000045	0,278349441
Mid		**0,000362665**	**0,156143776**

Table 6 "Balance obtained per euro invested in retrofitting according to the features of each area. All result obtained with values higher than the mid are pointed in red as being the most effective retrofitting choices". Source: Own elaboration.

7.- Conclusions

The conclusion related to the first hypothesis, is that mixed solutions are going to be the most efficient ones, but only if sun irradiation and constructive capabilities are studied and applied to choose the most correct mean of retrofitting. The consideration of This study when projecting an environmental retrofitting can be a good guide towards the achievement of the addaptation of the buildings to 20-20-20 directive.
In addition, it becomes evident that public buildings must be an example of correct energy management, following by this way exemplar solutions for the city. According to Trevilcock M (2011). *"In Chile, the public sector have pointed its policies of buildings towards the energetic efficiency and the usage of non conventional renewable energies" (introduction chapter)*[33]. [15] By this way, the studio done on the Iparralde Civic Center in Vitoria Gastéiz, demonstrates both the opportunity, and the benefits of combining green and photovoltaic roofs, this combined solution covers the following benefits: reduction of carbon dioxin, reduction of energy consumption generated from environmentally harmful sources, temperate of heat island, and generation of clean energy by the usage of photovoltaic cells.

REFERENCES

[1] Comunicación de la Comisión Europea, de 13 de noviembre de 2008, denominada "Eficiencia energética: alcanzar el objetivo del 20%" [COM(2008) 772 – no publicada en el Diario Oficial]. Directiva de la Unión Europea (2009).
[2] Energy Performance of Building Directive,2002/91/EC. Unión Europea (2002).

[33] Trevilcock M. (2011). Percepción de Barreras a la Incorporación de Criterios de Eficiencia Energética en las Edificaciones. Revista de la Construcción, Volume 10, April 2011 p 4-14.

[3] Directiva 2010/31/EU Del Parlamento Europeo. Unión Europea (2010).
[4] Ley 8/2013 del BOE, relativa a la rehabilitación, regeneración y renovación urbanas. Gobierno de España (2013).
[5] Ordenanza de Protección del Medio Ambiente urbano del Ayuntamiento de Madrid. Ayuntamiento de Madrid. (1985, última actualización en 2001).
[6] Ordenanza Sobre Captación de Energía Solar Para Usos Térmicos. Ayuntamiento de Madrid (2003).
[7] Plan de Impulso de las energías renovables de la Comunidad de Madrid. Comunidad de Madrid (2011).
[8] Normativas medioambientales de Vitoria Gastéiz, Ayuntamiento de Vitoria Gatéiz (2005).

[9] Norma reguladora de las ayudas a la rehabilitación de viviendas y edificios residenciales en el Centro Histórico de Vitoria-Gasteiz. Ayuntamiento de Vitoria Gastéiz (2012).

[10] Arquitectura Bioclimática en un Entorno Sostenible. Francisco Javier Neila González, Munilla Lería (2004).

[11] Carbon Sequestration Potential Of Extensive Green Roofs. K.L. Getter (2009).
[12] Carvajal, Micaela. (2011). Investigación Sobre La Absorción Del Co2 Por Los Cultivos Más Representativos De La Región De Murcia. *CSIC, Revista Horticultura, año XXVIII. n. 294*. *(pág 58-63).*
[13] Ciudad Y Cambio Climático, 707 Medidas Para Luchar Contra El Cambio Climático Desde La Ciudad. Figueroa Clemente, Manuel Enrique, Suárez Inclán, Luis Miguel. (2009): Universidad de Sevilla, Muñoz Moya Editores.
[14] Los Sumideros Naturales De Co2: Una Estrategia Sostenible Entre El Cambio Climático Y El Protocolo De Kyoto Desde Las Perspectivas Urbana Y Territorial. Figueroa Clemente Manuel Enrique, Redondo Gómez Susana.(2007): Universidad de Sevilla, Muñoz Moya Editores.