# HAZ[OTEA] PROJECT

**An estimate of rooftops' potential for increasing urban Sustainability and suggestions for maximizing this potential by normative regulation**

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This research work was developed by the author as part of the practical application in his Doctoral Thesis project "Meta[S]. A Strategic Model for the Transformation of Settlements for their Sustainability" undertaken under direction of Dr. José Fariña Tojo.

This text is authors' personal translation of original manuscript published in Spanish as

*Proyecto Haz[Otea]*, Cuadernos de Investigación Urbanística nº 107, Editado por Instituto Juan de Herrera, Madrid

**SUMMARY**

For some time now, it has become increasingly common hearing about the great potential transforming urban rooftop spaces poses for increasing cities' sustainability, in a speech usually encouraging their adaptation into green roofs or use for locating renewable energy generators. However, it is currently extremely difficult assessing to what extent these statements are correct:

- Available information and assessments of these rooftops' types describe technical issues and/or focus on specific aspects of their impact on reality [thermal insulation, rain water retention ...] being hardly relatable to the impact a general transformation of an urban area's rooftops would imply for the area's overall state.
- The impact of some technological solution/design may be different in different urban areas.
- Rooftops may host several uses, yet we have found no document providing an extensive comparison of the impact of each of them.

To assist in this debate, in this text we estimate the expected impact of the hypothetical transformation of all available rooftops in an existing urban area: Palos de Moguer neighborhood in Madrid. In order to do so, we use Meta[S] model proposed by the author as PhD Thesis project, which assesses 64 dimensions of urban reality.

The assessment allows us to highlight three key issues:

- Not all possible rooftops transformations produce the same benefit for cities/urban areas, and in urban consolidated environments rooftop transformations that allow people's use may pose higher collective benefit.
- Rooftops transformations benefit maximization requires individual analysis of each urban area, relating its particular needs with available rooftop surface characteristics.
- The number of different rooftops possible uses and their ease of implementation can be greatly increased if some previsions are incorporated in Urban Planning/Building Codes

These last two issues allow us to state the interest of both updating national Building & Design Codes and that municipalities regulate the conditions and use of rooftop spaces. In the Conclusions we list some issues we believe should be incorporated by different rooftops' regulations.

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## 1 INTRODUCTION

Several authors/companies have long been insisting on the negative effects for cities of rooftop areas in their currently most frequent condition [e.g., Heat Island Effect, HIE] against the numerous beneficial effects Green Roofs generalization would have. Among these are often cited: improved bioclima [Heat Island Effect and Air Pollution mitigation], increased biodiversity [green corridors], reduced buildings' energy consumption [as both consequence of bioclima improvement and thermal insulation increase], hydrological cycles' improvement....

In addition, some authors have proposed using rooftop spaces for urban agriculture in order to reduce cities' pressure/negative impact on the environment/non-urban territory[I], or to locate solar panels on rooftops, with the goal of replacing part of current consumption of energy produced by non-renewable sources NRE by energy produced by renewable sources RE.

However, these proposals are not the only possible rooftops' uses. Since the beginning of civilization [and with greater intensity since the beginning of 20$^{th}$ century][II], there have been many examples of rooftops' uses and many of them have some features that makes them interesting from the *Sustainability* perspective.

Therefore, in this text in addition to considering rooftops uses currently designated as 'sustainable' [i.e., extensive green roofs, agricultural or renewable energy production], we assess a broad spectrum of alternative uses/ transformations.

In addition, we estimate the positive impact of using 'other available roof surfaces' which have two qualities that make it interesting their joint review with rooftops:

- In many cities there is a *large available area of these types of surfaces.*
- Many of the uses *competing* for urban rooftops can also be located on these surfaces, so their joint design/planning allows achieving an optimal solution.

For the estimation we use the Meta[S] model [Alvira, 2015], which allows us to assess each use' suitability both in isolation and in various combinations, considering its implementation in an existing urban area: Palos de Moguer neighborhood in Madrid. In this Area there are many small rooftops distributed among its almost 600 buildings[III]. Since surfaces/buildings are mostly privately owned, we follow the approach of considering that our goal is to lay the groundwork for normative regulation of rooftop spaces.

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[I] These authors argue that local food production eliminates/reduces energy consumption associated with food transportation. In addition, it could be argued that some countries exceed the unsustainability threshold [0,560Hag-eq] in land/agricultural biocapacity consumption. Transforming roof spaces would be a way to increase [a bit] total available 'bio-productivity', reducing [a bit] current unsustainability without the need of reducing consumption.

[II] For an interesting review of rooftops uses throughout history, see Martinez [2005].

[III] Of the nearly 600 buildings in the area, less than 11% are publicly owned. Therefore, we will follow the usual approach of the Public Administration to intervene on privately owned spaces; by Legislation / Regulations.

In the analysis we partially incorporate Atocha station area [owned by public company Adif] located in the NE edge of Palos de Moguer neighborhood[IV], which currently has a large available rooftop surface. This will allow us also assessing the impact of using rooftop spaces in large size unique buildings, which can be found with some frequency in the urban fabric.

The estimation suggests it would be possible achieving a significant impact on assessed area's sustainability by using/transforming its currently available rooftop spaces, and that the impact would be maximized for a given [not any] distribution of possible uses. This makes proper Code regulation by Public Administration of these spaces [and their possible uses] becoming important.

The large number of issues we review in this [necessarily] short text makes it convenient outlining the script we follow:

- *We briefly describe Meta[S] model main features* and application methodology.
- *We assess current neighborhood's state* and define intervention priorities.
- *We review rooftops possible uses* from a large group of examples.
- We relate possible rooftop uses with neighborhood's priorities.
- We review the *characteristics of existing rooftops in the area* [surface, admissible load, thermal insulation condition...] that determine both potential uses and full benefit of each intervention type.
- As a result of the above, *we design assessment scenarios* corresponding to implementation proposals for each of the possible uses which can be a priori considered 'beneficial' incorporating in the area, and assess each of them impact, up to the combination of uses we consider optimal for the Area.
- Finally we outline some basic *conclusions and recommendations the results suggest building regulations should incorporate.*

Let us therefore begin by briefly reviewing the model.

## 2 BRIEF DESCRIPTION OF META[S] MODEL

Meta[S] model is a model designed by the author[V] as a tool to assist in the usual city formation/transformation processes. It can be direct transformation processes [urban transformation projects design] or indirect transformations [Codes and Regulations drafting]. The model breaks down urban sustainability into three dimensions and several indicators:

[IV] Although Atocha station does not belong to Palos de Moguer but Atocha District, the low population density of this last district and its elongated geometry -parallel to train tracks- allows, for practical purposes, integrating Atocha Station with Palos de Moguer district to a greater extent, and with Embajadores and Pacifico to a lesser extent. Therefore we include it in our study, allocating 50% of its surface to Palos de Moguer district and splitting the remaining 50% between the other areas of influence.

[V] Meta[s] model has been developed by the author as doctoral thesis in the PhD program of the Urban and Regional Planning Department of ETS Architecture of Madrid, Universidad Politécnica de Madrid. It was finished in August 2015, though certain administrative requirements have prevented its reading to date. The Spanish term 'Meta' means 'goal'.

TABLE 2-1_ META[S] MODEL INDICATORS

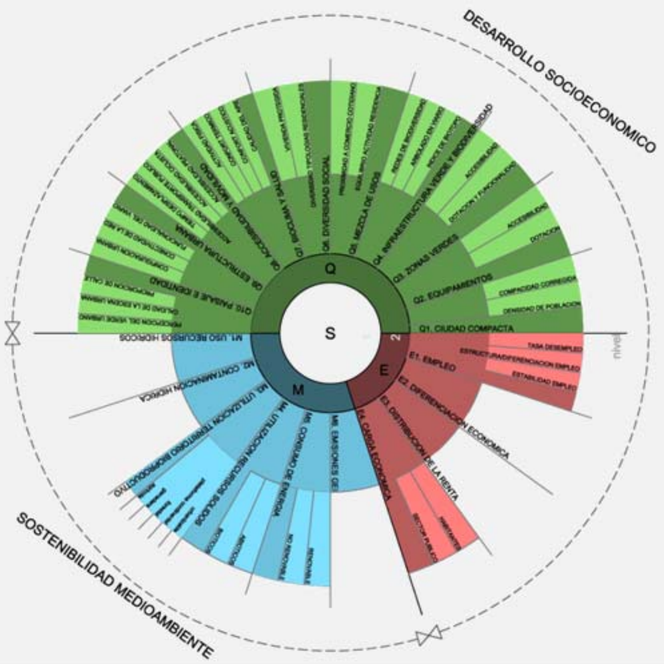
| | OVERALL INFORMATION INDICATORS | | DETAILED INFORMATION INDICATORS (2) | |
|---|---|---|---|---|
| | LEVEL 0 (1) | LEVELS 1 Y 2 | LEVEL 3 | LEVEL 4 |
| SUSTAINABILITY INDICATORS | ΔQ | Q _ QUALITY AND HABITABILITY OF THE URBAN AREA | C_ Compact City | PD/HD_ Population /Housing Density |
| | | | | AC_ Adjusted Compactness |
| | | | PF_ Public Facilities Accessibility and Provision | PFP_ Public Facilities Provision |
| | | | | AEP_ Accessibility to Local Public Facilities |
| | | | GA_ Green Areas Accessibility and Provision | GAFP_ Green Areas Functionality and Provision |
| | | | | GAA_ Green Areas Accessibility |
| | | | BGI_ Biodiversity and Green Infrastructure | IB_ Biotope Index |
| | | | | ST_ Street trees |
| | | | | GNB_ Green networks and Biodiversity |
| | | | MU_ Mixed uses | EQ_ Economic Activities/Housing balance |
| | | | | PLS_ Proximity to Local Shops |
| | | | HD_ Housing Diversity | TD/SD_ Typologies/Surface diversity |
| | | | | HCD_ Housing Cost Diversity |
| | | | BH_ Bio-clime and Health | AQ_ Air Quality |
| | | | | AC_ Acoustic Comfort |
| | | | | TC_ Thermal Comfort |
| | | | | PA_ Physical Activity |
| | | | AM_ Accessibility and Mobility | PA_ Pedestrians Accessibility |
| | | | | CA_ Cyclists Accessibility |
| | | | | APT_ Access to Public Transportation |
| | | | | CT_ Commuting Time |
| | | | UE_ Urban Structure | SF_ Streets Functionality |
| | | | | NC_ Network Connectivity |
| | | | | UC_ Urban Configuration |
| | | | CI_ Cityscape and Identity | SP_ Street Profile |
| | | | | USQ_ Urban Scenery Quality |
| | | | | UGP_ Urban Greenery Perception |
| | ΔM | M _ URBAN METABOLISM | UW _ Use of Water | |
| | | | WP_ Water Pollution | |
| | | | UB_ Use of Bioproductive Land | Crop Land |
| | | | | Grazing Land |
| | | | | Forest Land |
| | | | | Fishing Ground |
| | | | | Built up Land |
| | | | SR_ Use of Solid Resources | BR_ Biotic Resources |
| | | | | AR_ Abiotic Resources |
| | | | EC_ Energy Consumption | NRE_ Non-Renewable Energy |
| | | | | RE_ Renewable Energy |
| | | | GHG_ Greenhouse Gases | |
| | ΔE | E_ ECONOMY | EM_ Employment | UR_ Unemployment Rate / Urban Variety |
| | | | | LD/LS_ Labor Differentiation/Structure |
| | | | | ES_ Employment Stability |
| | | | ED/ED_ Economic Differentiation/Structure | |
| | | | ID_ Income Distribution | |
| | | | EB_ Economic Burden | PAEB_ Public Finance |
| | | | | CEB_ Citizens |
| | ΔS | S_ SUSTAINABILITY | | |
| ECONOMIC INDICATOR | | EE_ ECONOMIC EFFORT | | |

SOURCE: Alvira, 2015. Meta[s] model is designed according to Mathematical Theory of Sustainability and sustainable development [Alvira, 2014a]. It complies with Axioms systems and Theorems states in such Theory.

(1) Level 0 indicators monitor system's variation. They allow assessing the sustainability of its development/evolution.

(2) We do not include Level 5 to7 indicators.

Alternatively, we can represent indicators as:




**Graphic 01: Meta [s] model indicators' Structure**

*Q Dimension is shown in Green, M Dimension in Blue and E Dimension in Red*

*Levels 5 to 7 indicators; variation indicators [not belong to the hierarchical position decomposition] and indicator 'Economic Effort' are not represented.*

The model works with the following assessment scenarios:

- *E00 scenario.* It describes current situation
- *E0T scenario.* It describes the foreseeable situation if the system maintains its current trend.
- *E-XX scenarios.* They describe each transformation to be assessed.

The first step is to assess E00/0T scenarios; i.e., to assess the current/foreseeable urban area state if no special intervention is undertaken. Using this assessment/forecasting, we set *intervention priorities* for the urban area, assessing both the *unsustainability degree* in every dimension and its influence on overall system status.

Based on these intervention priorities, we pre-select possible urban transformations we think can higher increase priority areas' sustainability. Then we design Assessment scenarios corresponding to each of these possibilities [the more disaggregated the better], and we model these Assessment scenarios, calculating and evaluating for each of them the following 7 parameters/dimensions:

TABLE 2-2_ URBAN TRANSFORMATIONS ACCEPTANCE CRITERIA

| | |
|---|---|
| Economic Effort [EE] | EE<5%RD (1) |
| Sustainability Increase [ΔS] | $\Delta S>0$ |
| Dimension Variation [ΔQ, ΔM y ΔE] | $Q_2>0{,}7$ o $\Delta Q\geq 0$<br>$M_2>0{,}7$ o $\Delta M\geq 0$<br>$E_2>0{,}7$ o $\Delta E\geq 0$ |
| Economic Burden Variation [ΔCE] | $CE_2>0{,}6$ o $\Delta CE\geq 0$ |
| Income Distribution variation [ΔDI] | $DI_2>0{,}75$ o $\Delta DI\geq 0$ |
| Sustainability Indicators Variation [ΔI] (2) | $I_2>0{,}5$ o $\Delta I\geq 0$ |

SOURCE: Compilation from Alvira, 2015

(1) This is the only condition that must be specifically defined for each evaluation/context. In several examples we used 5% threshold obtaining consistent results, but in other contexts a different value can be chosen.

(2) Adaptation of Pareto Criterion to multivariable decision making. It states that a reduction in the value of any Sustainability indicators can only be accepted if its value in the final state is greater than or equal to 0.5, that is, if in the final state [State 2] the indicator assigns the system higher or equal membership to 'Sustainability' that to 'Unsustainability' space.

This will allow us to pre-select strategies [each of one represented by an Assessment Scenario], and discard or combine them until arriving the optimal Area overall transformation [equivalent to Area's final image].

Let us therefore begin by assessing current Area' status

## 3 ASSESSMENT OF PALOS DE MOGUER NEIGHBORHOOD

In order to use Meta[S] model the first thing is to assess current/expected situation of the urban area which transformation we are designing, what we do by modeling and evaluating *two baseline scenarios*:

- E00 describing *Area's current status.*
- E0T describing *foreseeable Area's status in a future point in time* if no specific intervention is undertaken[VI].

The analysis will allow us to assess both Area's current state and foreseeable future. Identify main Area's shortcomings and set intervention priorities. This information will allow us to pre-select possible urban transformation strategies.

In addition, E00 is the baseline scenario against which we later compare Assessment Scenarios obtaining the expected impact on the Area of each of them.

### 3.1 DESCRIPTION OF ASSESSED AREA

The area we analyze is Palos de Moguer Neighborhood located in central Madrid city. It is a consolidated urban area, belonging to Madrid 19th century Enlargement designed in 1860 by Carlos Maria de Castro, and which construction started a few years later.

**Image 01: Palos de Moguer Neighborhood, Madrid.** *The highly consolidated built environment and lack of Green Areas is evident, leading to a population high density that places the Area among ten densest Madrid neighborhoods.*

*The edge formed by Mendez Alvaro St. separates it from Atocha Station, which boundary character provides it great visual impact [and contact length] with the neighborhood.*

[VI] In many cases it is not possible to design E0T with sufficient certainty, and it is preferable considering it is equal to current situation E00. In addition, Q dimension refers often to the physical environment, whose future status is in many respects equal to the present [unless intentional transformations are undertaken]. The future situation in Dimension M has been valued in Meta[S] model itself incorporating for all indicators Dimension M biocapacity limits [and expected world population] referred to sufficiently distant deadlines [2050/2150] making it feasible to consider the assessment over E00 is equivalent to assessment over E0T using 2015 limits/population. We consider E Dimension is inherently unpredictable beyond its implicit overall assessment embedded in E present value. Therefore, for the present work we consider E00 is equal to E0T.

It is a typical 19th century Enlargement area, highly consolidated, compact blocks most of them divided into several lots, buildings 5 to 7 floors high and inner block yards frequently occupied by auxiliary constructions [workshops, industries, medium big retail...].

TABLE 3-1_ PALOS DE MOGUER NEIGHBORHOOD: OVERALL DATA

| | | | |
|---|---|---|---|
| Total Area | | 64,35 | Ha |
| Number of Inhabitants | | 27.845 | Inhabitants |
| Number of Housing | | 13.852 | Houses |
| Number of homes [Main dwelling + secondary] | | 11.760 | Houses |
| Gross Density | | 215,26 | Houses/Ha |
| Nº inhabitants per house | | 2,37 | Inhabit/house |
| Total gross Built up area [m2] | Residential | 1.160.060 | m2 |
| | Retail | 402.910 | m2 |
| | Institutional | 132.031 | m2 |
| | Housing m2/Housing unit | 83,75 | m2 /House |
| | Retail & Institutional m2/ Housing unit | 29,09 | m2 /House |
| Built up area per land [ratio] | Gross | 2,63 | m2 / m2 |
| | Net | 4,21 | m2 / m2 |
| Land Areas | Streets | 227.444 | m2 |
| | Public Open Spaces | 13.320 | m2 |

SOURCE: Compilation from Madrid City Hall Data and measuring on plan.

### 3.2 QUANTITATIVE ASSESSMENT: RESULTS

We assess current Area situation obtaining the following indicators' values:

TABLE 3-2_ PALOS DE MOGUER NEIGHBORHOOD: CURRENT STATUS ASSESSMENT

| INDICATORS LEVELS 1 Y 2 | LEVELS 3 Y 4 | E00_CURRENT STATUS | INFLUENCE IN EQUILIBRIUM STATE (1) | POTENTIAL FOR IMPROVEMENT (2) | | |
|---|---|---|---|---|---|---|
| **Q _ QUALITY AND HABITABILITY OF URBAN AREA** | | 53% | 33,33% | 15,58% | | |
| Q1. COMPACTNESS | | 51% | 3,33% | | 1,64% | |
| | Population Density | 85% | 1,67% | | | 0,25% |
| | Adjusted Compactness | 31% | 1,67% | | | 1,15% |
| Q.2. PUBLIC FACILITIES | | 66% | 3,33% | | 1,12% | |
| | Public Facilities Provision | 73% | 1,67% | | | 0,46% |
| | Local Public Facilities Accessibility | 61% | 1,67% | | | 0,65% |
| Q.3. GREEN AREAS | | 25% | 3,33% | | 2,51% | |
| | Green Areas Provision | 10% | 1,67% | | | 1,51% |
| | Green Areas Accessibility | 46% | 1,67% | | | 0,89% |
| Q4. BIODIVERSITY | | 22% | 3,33% | | 2,59% | |
| | Biotope Factor | 21% | 1,11% | | | 0,87% |
| | Street trees | 77% | 1,11% | | | 0,26% |
| | Green Corridors | 0% | 1,11% | | | 1,11% |
| Q5_MIXED USE | | 87% | 3,33% | | 0,43% | |
| | Economic Activities/ Housing Balance | 100% | 1,67% | | | 0,00% |
| | Proximity to Local Shops | 77% | 1,67% | | | 0,39% |
| Q6. HOUSING DIVERSITY | | 84% | 3,33% | | 0,53% | |
| | Housing Typologies/Surface diversity | 84% | 1,67% | | | 0,26% |
| | Housing cost diversity | - | 1,67% | | | |
| Q7.BIO-CLIME AND HEALTH | | 42% | 3,33% | | 1,94% | |
| | Air Quality | 52% | 0,83% | | | 0,40% |
| | Acoustic comfort | 34% | 0,83% | | | 0,55% |
| | Thermal Comfort | 43% | 0,83% | | | 0,48% |
| | Physical activity | 41% | 0,83% | | | 0,49% |
| Q8. ACCESSIBILITY AND MOBILITY | | 45% | 3,33% | | 1,84% | |
| | Pedestrians Accessibility | 90% | 0,83% | | | 0,08% |
| | Cyclists Accessibility | 3% | 0,83% | | | 0,81% |
| | Access to Public Transportation | 86% | 0,83% | | | 0,12% |
| | Commuting Time | 48% | 0,83% | | | 0,43% |
| Q9.URBAN STRUCTURE | | 87% | 3,33% | | 0,45% | |
| | Streets functionality | 78% | 1,11% | | | 0,24% |
| | Network Connectivity | 95% | 1,11% | | | 0,05% |
| | Urban Configuration | 88% | 1,11% | | | 0,13% |
| Q10.CITYSCAPE AND IDENTITY | | 84% | 3,33% | | 0,55% | |
| | Street Profile | 100% | 1,11% | | | 0,00% |
| | Urban Scenery Quality | 51% | 1,11% | | | 0,47% |
| | Urban greenery perception | 99% | 1,11% | | | 0,01% |
| **M _ URBAN METABOLISM** | | 13% | 33,33% | 29,01% | | |
| M.1. USE OF WATER | | 26% | 5,56% | | 4,12% | |
| M.2. WATER POLLUTION | | 72% | 5,56% | | 1,56% | |
| M3. USE OF BIOPRODUCTIVE LAND | | 17% | 5,56% | | 4,63% | |

| | | | | | |
|---|---|---|---|---|---|
| Crop Land | 0% | 1,11% | | | 1,11% |
| Grazing Land | 21% | 1,11% | | | 0,88% |
| Forest Land | 86% | 1,11% | | | 0,15% |
| Fishing Ground | 0% | 1,11% | | | 1,11% |
| Built up Land | 60% | 1,11% | | | 0,44% |
| M4 USE OF SOLID RESOURCES | 22% | 5,56% | | 4,34% | |
| Biotic Resources | 8% | 2,78% | | | 2,55% |
| Abiotic Resources | 41% | 2,78% | | | 1,64% |
| M5 ENERGY | 12% | 5,56% | | 4,91% | |
| Non-Renewable Energy | 9% | 4,87% | | | 4,42% |
| Renewable Energy | 98% | 0,68% | | | 0,01% |
| M6 GHG EMISSIONS | 0% | 5,56% | | 5,56% | |
| **E_ ECONOMIC SUSTAINABILITY** | 41% | 33,33% | 19,70% | | |
| E1. EMPLOYMENT | 66% | 8,33% | | 2,86% | |
| E2. ECONOMIC DIFFERENTIATION | 53% | 8,33% | | 3,92% | |
| Labor Differentiation | 66% | 4,17% | | | 1,40% |
| Economic Activity Differentiation | 43% | 4,17% | | | 2,40% |
| E.3 INCOME DISTRIBUTION | 40% | 8,33% | | 5,01% | |
| E4. ECONOMIC BURDEN | 18% | 8,33% | | 6,86% | |
| Public Administration Economic Burden | 33% | 2,10% | | | 1,42% |
| Citizens Economic Burden | 14% | 6,23% | | | 5,39% |
| **S_ SUSTAINABILITY DEGREE** | 32,9% | 100,00% | 67,13% | | |

SOURCE: Calculations using Meta[s] model.

(1) It is the influence of each indicator on the overall sustainability value [Alvira; 2014ª. Annex VI]

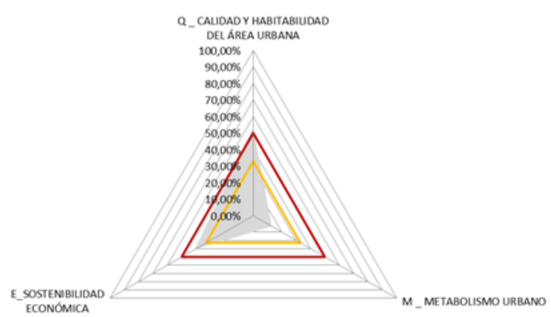
(2) It matches the concept of 'possibility' as possible improvement by each indicator's value modification. For simplicity, we have considered indicator's influence in equilibrium state [i.e., in the event all indicators' values were the same], although it would be more correct calculating indicators' values for the specific case [the potential increases for indicators with lower than S value and reduces for indicators with higher than S value]

We obtain a reduced sustainability degree for the area [ca. 33%], being necessary detailed indicators analyses in order to set priorities that allow us choosing intervention areas and proposing Assessment scenarios.

## 3.3 SETTING INTERVENTION PRIORITIES

In order to more clearly appreciate which are the less sustainable dimensions of the assessed urban area and sett intervention priorities, let us graphically represent above data, starting by Levels 1 and 2 indicators:

### *3.3.1 OVERALL SYSTEMS' INFORMATION INDICATORS: LEVELS 1 & 2*




***Graphic 02: Levels 1 and 2 indicators***

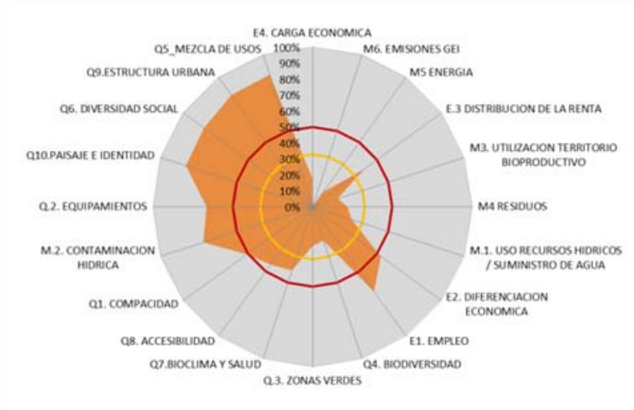
*In light gray we draw area's current status. In Red, we draw the threshold implying greater Unsustainability than Sustainability.*

*Orange line indicates area's Sustainability Degree [Global indicator S], highly penalized for the reduced Sustainability of Urban Metabolism*

The graph shows clearly the intervention priority should be done following this order: Urban Metabolism [M], Economic Sustainability [E] and Quality/Livability [Q]. However, to design assessment scenarios and intervention strategies we need to review lower level indicators.

### *3.3.2 URBAN AREA DETAILED INFORMATION INDICATORS: LEVELS 3 & 4*

In order to more easily detect the dimensions on which intervention can provide greater benefits / further reduce Area's Unsustainability [therefore, intervention is priority], we represent level 3 indicators ranked by their influence/potential for improvement:

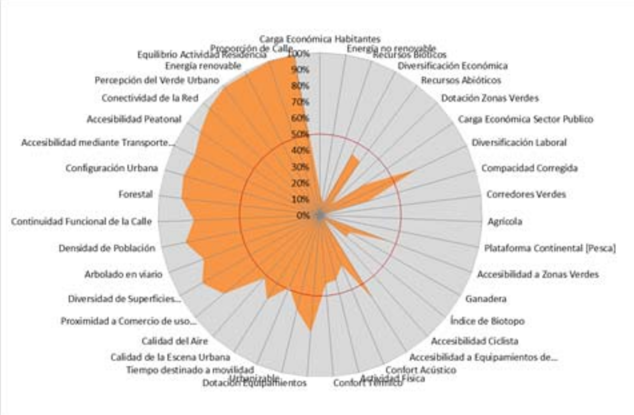



**Graphic 03: Level 3 Indicators.**

*We arrange indicators clockwise from higher to lower improvement potential. Orange area shows their current value. We highlight:*

- *Economic Burden*
- *GHG emissions*
- *Energy Consumption*
- *Use of Bioproductive Land*
- *Solid Resources/Waste*
- *Use of Water*
- *Economic Differentiation*

However, some indicators still involve some aggregation of aspects that do not necessarily have the same state, being necessary to review lower level indicators:




**Graphic *04:* Level 4 *Indicators according their improvement potential***

*Red line marks the 50% value; lower indicator values express greater Unsustainability than Sustainability. We see indicators values are not sufficient to establish their higher or lower intervention priority. It may be less priority acting on an indicator with reduced value yet little influence on the overall value [e.g., Green Corridors] that on an indicator with higher value but much more influence on global value [e.g., Economic Activity Differentiation].*

Among Level 4 indicators two indicators appear which reduced value joins with their high influence on the overall value implying a high potential for improvement: Citizens Economic Burden [CEB] and Non-Renewable Energy consumption [NRE].

### 3.4 CONCLUSIONS AND SUMMARY OF PRIORITIES

From the results of the assessment we can define the following intervention priorities:

TABLE 3-3_ SUMMARY INTERVENTION POSSIBILITIES/PRIORITIES

| ELEMENTAL INDICATOR | | LEV-EL | INDICATOR VALUE | INFLUENCE ON OVERALL VALUE | POTENTIAL FOR IMPROVEMENT (1) |
|---|---|---|---|---|---|
| GHG | Greenhouse Gases Emissions | 3 | 0,00% | 5,56% | 5,56% |
| CEB | Citizens Economic Burden | 4 | 13,93% | 6,23% | 5,36% |
| ID | Income Distribution | 3 | 39,93% | 8,33% | 5,01% |
| NRE | Non-Renewable Energy | 4 | 2,69% | 4,87% | 4,74% |

| | | | | | |
|---|---|---|---|---|---|
| UW | Use of Water | 3 | 25,84% | 5,56% | 4,12% |
| EM | Employment | 3 | 65,68% | 8,33% | 2,86% |
| BR | Biotic Resources | 4 | 8,24% | 2,78% | 2,55% |
| EAD | Economic Activity Differentiation | 4 | 42,47% | 4,17% | 2,40% |
| AR | Abiotic Resources | 4 | 41,00% | 2,78% | 1,64% |
| WP | Water Pollution | 3 | 72,00% | 5,56% | 1,56% |
| GAP | Green Areas Provision | 4 | 9,57% | 1,67% | 1,51% |
| PAEB | Public Administration Economic Burden | 4 | 32,62% | 2,10% | 1,42% |
| LD | Labor Differentiation | 4 | 66,31% | 4,17% | 1,40% |
| AC | Adjusted Compactness | 4 | 31,03% | 1,67% | 1,15% |
| GC | Green Corridors | 4 | 0,00% | 1,11% | 1,11% |
| UCL | Use of Crop Land | 4 | 0,00% | 1,11% | 1,11% |
| UFG | Use of Fishing Ground | 4 | 0,00% | 1,11% | 1,11% |
| GAA | Green Areas Accessibility | 4 | 46,34% | 1,67% | 0,89% |
| UGL | Use of Grazing Land | 4 | 20,88% | 1,11% | 0,88% |
| BF | Biotope Factor | 4 | 21,37% | 1,11% | 0,87% |
| CA | Cyclists Accessibility | 4 | 3,31% | 0,83% | 0,81% |
| PFA | Local Public Facilities Accessibility | 4 | 61,02% | 1,67% | 0,65% |
| AC | Acoustic comfort | 4 | 33,60% | 0,83% | 0,55% |
| PA | Physical activity | 4 | 41,17% | 0,83% | 0,49% |
| TC | Thermal Comfort | 4 | 42,64% | 0,83% | 0,48% |
| USQ | Urban Scenery Quality | 4 | 50,84% | 1,11% | 0,47% |
| PFP | Public Facilities Provision | 4 | 72,62% | 1,67% | 0,46% |
| UBL | Use of Built up Land | 4 | 60,18% | 1,11% | 0,44% |
| CT | Commuting Time | 4 | 48,44% | 0,83% | 0,43% |
| AQ | Air Quality | 4 | 51,88% | 0,83% | 0,40% |

SOURCE: Calculations using Meta[S] model

(0) Prioritization of action should refer to basic indicators, as any aggregate indicator represents a summary of dimensions which intervention priority may be different. We only include indicators whose improvement potential exceeds 0.40%.

(1) Value obtained by multiplying indicator value by its influence on global equilibrium state.

Once priority intervention areas have been established, let us review difference rooftop use possibilities that allow acting on such priority areas.

## 4 POSSIBLE USES OF BUILDINGS ROOFTOPS SPACES

Rooftops are a type of space whose uniqueness makes them ideal to accommodate many applications that benefit from its *controlled but open space character* [views, sun, rain, and wind].

Since the beginning of buildings construction we find many examples of rooftops use in warm/temperate climates. In other types of climates, its use mostly begins from 1900/1910, facilitated by increasing construction industrialization [generalization of industrial concrete structures and waterproofing systems].

The review of examples in different climatic zones and historical moments provides a long list of rooftops' possible uses, whose review we organize according to the access they have/require[VII]:

- Public access [payment may be required].
- Access restricted to residents in the building.

[VII] The aim of this classification is operational, allowing assessing the uses that can be implemented in an area using easily accessible from data [surface available for each type of building use/access and construction date of each building]. Once the possible uses in an area are known, we can design the Assessment Scenarios which therefore satisfy the first condition required in the design/evaluation of scenarios; their feasibility [designing from existing/built examples, implies assessed uses feasibility has been already tested].

- Access restricted to personnel working on the rooftop.
- Access restricted to rooftop maintenance staff.

## 4.1 ROOFTOP SPACES WITH PUBLIC ACCESS AND USE

In this group, we include rooftop uses involving public access which often require the building where they sit has public access and use [i.e., it is a Public Facility], although there are some exceptions. We find a wide range of possible uses: parks, sports courts, lookouts, art exhibitions, concerts, cinemas, community or educational orchards...

**TABLE 4-1_ ROOFTOP SPACES WITH PUBLIC ACCESS**

[01.1]

New Kimball Arts Centre

[01.02]

Metropolitan Museum

[01.03]

Circulo Bellas Artes

[01.4]

La Terraza de La Casa Encendida

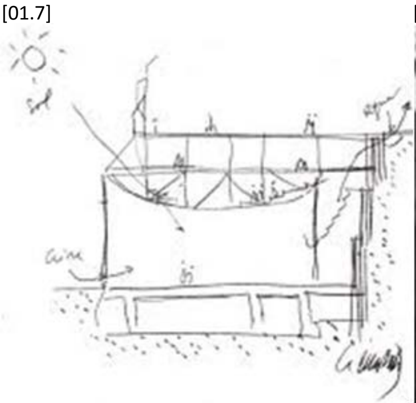
[01.5]

Rooftop Cinema Curtin House (1)

[01.06]

Reichstag

[01.7]



Colegio Maravillas Gimnasium

[01.8]

Chopera Sports Center

[01.9]

Tidemill School

[01.10]

Casa Encendida

[01.11]

Harlem Community Rooftop Farm

[01.01] a [01.05] Cultural / Multi-functional spaces and Viewpoints
[01.7] a [01.9] Sport Spaces
[01.10] [01.11] Community or educational orchards
[01.12] a [01.20] Green Areas and Open Spaces
[01.21] a [01.23] Health Gardens
[01.24] a [01.26] Restoration spaces

[01.12]

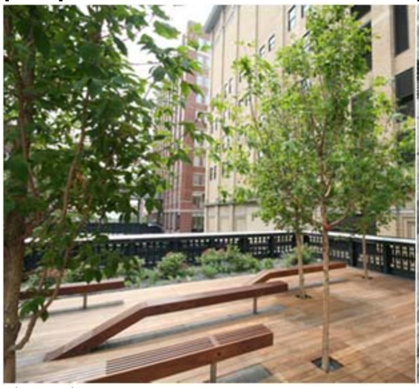
Ewha women University

[01.13]

National Opera and ballet

[01.14]

Hypar Pavilion

[01.15]

The High Line

[01.16]

Yokohama Maritime Terminal

[01.17]

Kaiser Roof Garden

[01.18]

Varsovia University Library 2002

[01.19]

Museo del Prado Enlargement

[01.20]

Chateau Cheval Blanc [winery]

[01.21]

Ulfelder Healing Garden

[01.22]

Schwab Rehabilitation Roof Garden

[01.23]

Harrison Hospital Roof Garden

[01.24]

San Anton Market

[01.25]

Escuelas Pías

[01.26]

El Batel Auditorium

It is also convenient compiling design features of above reviewed uses, which help us to estimate their design/usability requirements and impact on the city.

TABLE 4-2_ ROOFTOP SPACES WITH PUBLIC ACCESS AND USE

| ROOFTOP USE | MAIN FEATURES AND DESIGN CRITERIA (0) (1) | ACCEPTABLE DEPENDING ON BUILDING USE |
|---|---|---|
| Viewpoints | The 'viewpoint' function is in general implicit in the rooftop condition, even if main use may be different. In locations with high quality views, it may be the dominant use. | Public Facilities, Institutional… |
| Public Facility | Specific features according to use [sports, cultural...]. Depending on the use, it should be assessed installing mobile light elements [textile covers or other] designed to protect from weather (2) | Public Facilities |
| Green Areas and Open Spaces | We set a differentiation between Open Space and Green Area whereas the latter must have between 30 and 40% of its total area covered by vegetation [this ratio allows self-sufficiency in irrigation if all rainwater received on the rooftop is recovered and stored, while making a significant reduction in the absorption of solar radiation]<br>In not landscaped areas, Solar Reflection Index [SRI] for a three years period must be greater than or equal to 75, to reduce Heat Island Effect (3)<br>The use of shading elements and misting systems during hot months can contribute to improved local and surrounding bioclima. | Public Facilities, Infrastructures... (4) |
| Green Areas in Health Facilities | We split this type of rooftops from above Green Areas because though they are 'public use' access is often restricted.<br>Gardens are located on hospitals and their goal is providing patients an easily accessible vegetated outdoor space. | Hospitals, Public Facilities related to Healthcare |
| Community Orchards | Rooftop spaces dedicated to agriculture with shared character, seeking to combine food production, social welfare/relationships, physical activity, integration, increase urban biodiversity.<br>In landscaped solution or elevated boxes, with special cultivation substrates and thickness between 0.10-0.15 to 0.30 cm. | All Buildings |
| Restoration Spaces | Although usually they are not [or should not be] the primary use of a rooftop in a public space, the inclusion of this type of spaces may be desirable both because they are a service for users and they can provide income increasing projects' economic viability. | Public Facilities, Restaurants/Hotels |

SOURCE: Own elaboration with the following comments:

(0) We include in this group public use buildings [Public Facilities] whether they are publicly or privately owned. We exclude institutional buildings as though they are publicly owned their use is similar to tertiary.

(1) Overloads required for public use are generally much greater than required for private uses, so implementation of herein reviewed uses usually requires individual structural analysis for each project.

(2) A target can be enabling the use of spaces for at least 9 months/year [better if it is the whole year].

(3) SRI Value set in 'City of Los Angeles Cool Roof Ordinance' for flat roofs. Only small areas of auxiliary solar panels installations roofs are exempted.

(4) In general, few public buildings will be suitable for the location of Public Green Areas use on them since these areas require good accessibility, large surface area and specific geometries, so they are limited to large-scale easily accessible buildings.

## 4.2 ROOFTOP SPACES WITH ACCESS RESTRICTED TO BUILDING OCCUPANTS

We include in this group rooftop spaces designed to be used by building occupants. Among the most frequent are Community Gardens, Gyms, multipurpose rooms, pools, community gardens... They locate on buildings with access restricted to occupants [residents or workers]: Residential Buildings [collective housing, student residences, hotels ...], Tertiary and Institutional [offices ...]. What we designate as R&T&I buildings.

**TABLE 4-3_ ROOFTOP SPACES WITH PRIVATE ACCESS OR RESTRICTED TO BUILDING OCCUPANTS**

[02.1]

Unité d'Habitation

[02.2]

Community Rooftop [BIR]

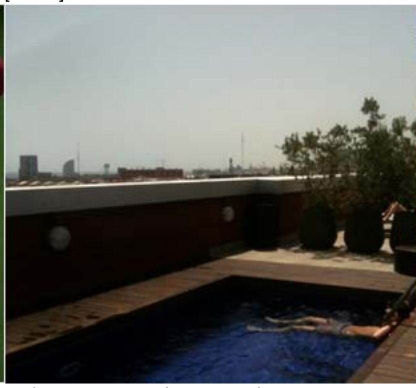
[02.03]

Society of Landscape Architects.

[02.04]

Minigolf

[02.05]

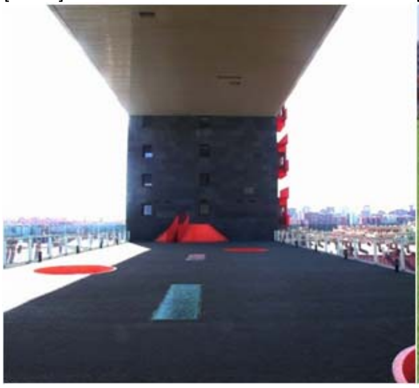


Melon District Students Residence

[02.06]

West View 'Condos'

[02.07]



Edificio 'Mirador'

[02.08]

'Algodonera' Residential building

[02.09]

Roch Offices

[02.10]

Saint Marie de La Tourette Convent

[02.11]

Rockefeller Centre

[02.1] a [02.11] Community Rooftops / multi purpose salons / Health Spaces [in ghousing buildings]

[02.12] a [02.16] Restoration/Health Spaces [in hotels]

[02.12]

Café Arab

[02.13]

ME Hotel

[02.14]

Oscar Room Mate Hotel

[02.15]

Diagonal Hotel

[02.16]

Central Hotel

It is equally interesting a compilation of the main design features we later consider in order to estimate the impact on the city of each of above uses:

TABLE 4-4_ ROOFTOP SPACES WITH PRIVATE ACCESS OR RESTRICTED TO BUILDING OCCUPANTS

| ROOFTOP USE | MAIN FEATURES AND DESIGN CRITERIA | ACCEPTABLE DEPENDING ON BUILDING USE |
|---|---|---|
| Community Green Areas / Gardens | Design criteria are the same as for Public Green Areas | R&T&I (1) |
| Community Orchards | Design criteria are the same as for Public Community Orchards | All Buildings |
| Community Multipurpose Rooms | Community use rooms, with surface between 25 and 50 m2 and possible use as gym. | R&T&I (1) |
| Community sports or health spaces | They can accommodate small gyms, spa [sauna, steam room, jacuzzi] and pools. | R&T&I (1) |
| Restoration Areas | They may have several uses [staying, swimming pool, restaurant, bar ...].<br>It is estimated that 50% of the total area matches conditions stated for green areas amounting to a 15% total surface covered by vegetation.<br>SRI must meet above stated conditions. | Hotel / Restoration Buildings |

SOURCE: Own elaboration with the following comments:

(1) In this group we include residential buildings [collective housing, students' residences, pavilions in hospitals, convents…] tertiary, commercial [inside the city], institutional, clean industry and hotels.

## 4.3 ROOFTOP SPACES WITH ACCESS RESTRICTED TO WORKING PERSONNEL

In this group we include rooftop spaces with an economic/productive nature not involving public access. We exclude therefore catering uses and include spaces dedicated to urban agriculture with productive intention.

**TABLE 4-5_ ROOFTOP SPACES WITH ACCESS RESTRICTED TO WORKING PERSONNEL**

[03.1]

Liozhou Master Plan

[03.2]

Brooklyn Grange

[03.3]

Uncommon Grounds Restaurant

[03.4]

Gotham Greens

[03.5]

Bright Farms

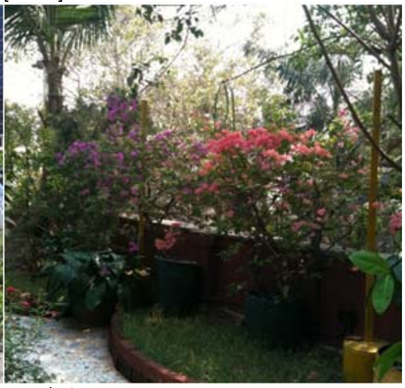
[03.6]

Lufa Farms

[03.07]

Fairmont Waterfront Hotel

[03.08]



Mumbai Port Trust

[03.1] a [03.3] Outdoor Irrigated Agriculture

[03.4] a [03.6] Greenhouse Hydroponic Agriculture

[03.07] a [03.08] Edible gardening

[03.09] a [03.11] Beehives in Rooftops

[03.09]

Vancouver Convention Center

[03.10]

Fairmont Waterfront Hotel

[03.11]

Opera Garnier

And the design features considered are:

TABLE 4-6_ ROOFTOP SPACES WITH ACCESS RESTRICTED TO WORKING PERSONNEL

| ROOFTOP USE | MAIN FEATURES AND DESIGN CRITERIA | ACCEPTABLE DEPENDING ON BUILDING USE |
|---|---|---|
| Outdoor Irrigated Agriculture (1) | In landscaped or drawers solution with special cultivation substrate for 'terraces' and limited 80-120 mm thickness. | All Buildings (0) |
| Greenhouse Agriculture | Aeroponic or hydroponic in Greenhouse.<br>Its implementation implies some increase in surface albedo [Campra et al, 2008] so we consider they help somewhat reduce the Heat Island Effect.<br>We assume ventilation is naturally done and heating during the cold months is done with waste heat from thermal processes in the building, so there is no energy consumption increase. | All Buildings (0) |
| Edible gardening | Landscaped areas using edible species with productive intention.<br>In general, the 'productive' character will be able to materialize in any garden area by simply choosing species whose production can be eaten (3) or used for some purpose. | All Buildings |
| Beehives | It may be necessary to protect other building users from accessing the beehives and channeling bees flight in certain directions by suitable means [Spanish legislation deems appropriate -in rural environments- protection height greater than 2 m] (4) | All Buildings |

SOURCE: Own elaboration with the following comments:

(0) We exclude buildings linked to public use of space [i.e., Public Facilities]

(1) They differ from Community Orchards because their use is restricted and production-oriented [i.e., agricultural areas with business management criteria]. They pose no social purpose, while they may have other indirect benefits on society [employment opportunities for local population, greater access to vegetables and fruits –healthier food habits-...]

(2) Area buildings' characteristics analysis indicates the proposed uses are possible on most buildings without structural reinforcement needed.

   a. To this end the depth of substrate should be limited, which in turn require protections and specific working tools to avoid accidentally damaging waterproofing.

   b. In the case of greenhouses, hydroponics cultivation is posed with reduced substrate weight and light plastic enclosure to minimize structural loads.

(3) Productive garden areas can be designed so they can be accessed by the public or with the intention of visual enjoyment but limiting access to maintenance personnel [e.g., Fairmont Waterfront Hotel]

(4) Although Spanish legislation currently prohibits placing Beehives within urban centers, in other countries/cities it is accepted

[Paris, Copenhagen, New York ...] regulating accepted types of bees and some design features. An important highlighted issue is not to exceed the carrying capacity of the surrounding vegetation [i.e., avoiding installing too many hives] which can lead to reduced productivity and/or aggressive bees' behavior [beehaviour]

## 4.4 ROOFTOP SPACES WITH ACCESS RESTRICTED TO MAINTENANCE

In this category we include rooftops to which access is sporadic for the sole purpose of maintenance. The most common types are Extensive Green Roofs and solar panels installations. Sometimes rooftops are used or designed for art installations or with an artistic intention [e.g., the 'Water Mirror' at Miró Foundation].

**TABLE 4-7_ ROOFTOP SPACES WITH ACCESS RESTRICTED TO MAINTENANCE**

[04.01]

California Academy of Sciences (1)

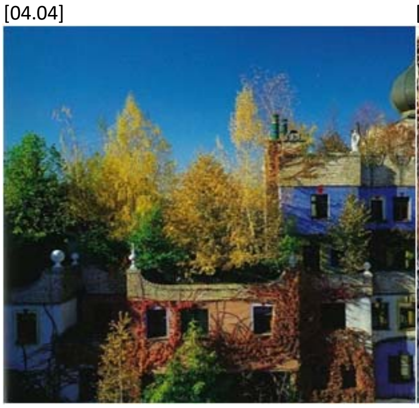
[04.02]

Caja de Badajoz

[04.03]

Chicago City Hall

[04.04]



Krawina House

[04.05]

Vancouver Convention center

[04.01] a [04.05] Green Roofs, with the goals of both ecological/ symbolic and visual enjoyment

[04.06] a [04.08] Solar panels integrated in the architecture

[04.09] a [04.11] Combination of solar panels and green roofs (3)

[04.12] a [04.14] Artistic Rooftops

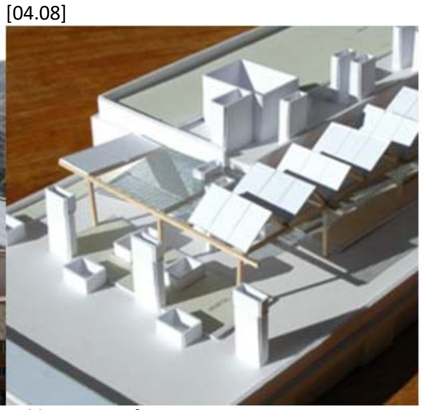
[04.06]

Solar Panels in a rooftop

[04.07]

Pablo VI

[04.08]



Public Houses for rent

[04.09]

MTZ Technological Center

[04.10]

Freiburg

[04.11]

Scholl in Unterensingen

[04.12]

Milá House

[04.13]

Miro Foundation

[04.14]

MoMA

SOURCE: images sources/authors are included in the References chapter. Notes:

(1) Although it is questionable whether it is a flat or sloping roof, we prefer to include it in this group. The roof space is part of the 'exhibition' of the Academy of Natural Sciences, and there is a small platform to which visitors can access to see the plant species located on it.

(2) Combination of solar panels and green roof is a strategy to avoid reducing the albedo / increasing Heat Island Effect that could produce a high concentration of PV panels [Milstein & Menon, 2010]. Authors suggest by mitigating the warming, green roof reduces panels' loss in performance [0.5% reduction in efficiency for every degree above 25°C]. Therefore, PV performance can increase up to 20% [on a hot summer day] that if placed on conventional roof paving.

And the main design features considered are:

TABLE 4-8_ ROOFTOP SPACES WITH ACCESS RESTRICTED TO MAINTENANCE

| ROOFTOP USE | MAIN FEATURES AND DESIGN CRITERIA | ACCEPTABLE DEPENDING ON BUILDING USE |
|---|---|---|
| Extensive Green Roofs | It is a type of green roof with Sedum vegetation type needing minimal maintenance [supervision once or twice a year]. | All Buildings and Large Light roofs (1) |
| Solar Panels (2) | We consider space conditioning is limited to substructure and elements necessary for laying panels, being no other modification undertaken on the roof / cover | All Buildings Rooftops and Large Light roofs with S +/-15º orientation |
| Artistic installations (3) | This is art installations that are designed to be seen from other taller buildings so they are not accessible to the public. | Mainly Cultural Public Facilities |

SOURCE: Own elaboration with the following comments:

(1) We consider green roofs solutions 70-100mm thickness have allowable loads on all roofs if the existing pavement is removed, although it is necessary to make checks on light covers.

(2) A large area of solar collectors could potentially produce a decrease in surface albedo and thus an increase in the Heat Island Effect [Milstein & Menon, 2010]. This can happen especially if the panels' performance is reduced. Therefore it is more common in Photovoltaic [PV] than in Solar Thermal Panels.

(3) The latter category is not used for the Assessment Scenarios due to the difficulty in quantifying its effects.

## 4.5 OTHER TYPES OF USABLE ROOFS

We include in this category other types of roofs that do not necessarily fall into the category of roof-top, but whose joint analysis we are interested because they can accommodate some [but not all] of reviewed rooftop uses, reducing the number of competing uses for occupying rooftops' surface. We include some types of sloping roofs and small size flat roof surfaces:

- *Sloping roofs*
    - *Large size light roofs, generally linked to retail uses [hypermarkets, neighborhood markets, garages…]. We consider they can be improved by adapting them as green roofs or by cold roof treatment*
    - *Average size regular sloping roofs, linked to residential use which can accommodate solar panel installations.*
    - *Auxiliary structures over penthouses' terraces, which can also accommodate solar panel installations.*
- *Small Roofs [generally flat] of stairs/lifts cores,* whose small size prevents locating uses involving regular access of people, but allows the installation of certain types of solar panels with little maintenance.

**TABLE 4-9_ OTHER TYPES OF USABLE ROOFS**

[05.01]

Yazzie Residence

[05.02]

Groningen University

[05.03]

'Central Park' Residential Complex

[05.04]

Santorini Villas

[05.05]

Housing Complex

[05.01] a [05.03] Green Roofs, with the goals of both ecological/ symbolic and visual enjoyment

[05.04] a [05.05] Cold Roof treatment

[05.07] a [05.09] Solar panels in sloping roofs

[05.06]

Single family house

[05.07]

Barceloneta Market

[05.08]

Single family house

[05.09]

Make it right foundation (1)

[05.10]

Stair and lift roof

[05.11]

'Eaton Rise' Single family house

SOURCE: Own elaboration with the following comments:

(1) We include it in this category because the type of structure on which panels are placed resembles the deck structures used in many penthouses' terraces.

We have seen the large number of possible uses of roof spaces. Let us now assess the suitability of implementing each of them in the area of Palos de Moguer.

### 4.6 POSSIBILITY OF INCREASING AREA'S SUSTAINABILITY BY TRANSFORMING ITS ROOFTOPS

The review of current Area's status [E00] has allowed us to set intervention priorities, and we can now assess each of revised rooftop uses' suitability by comparing their 'foreseeable' effect on intervention dimensions sorted from higher to lower priority [from larger to smaller potential improvement space] for the Area [i.e., according to E00].

TABLE 4-10_ AREA'S IMPROVEMENT POTENTIAL THROUGH ROOFTOPS TRANSFORMATION

| INDICATOR | | GOALS | POSSIBLE USES | IMPROVEMENT POTENTIAL |
|---|---|---|---|---|
| GHG | Greenhouse Gases Emissions | Energy Consumption Reduction | • All uses that involve increasing roof thermal insulation and/or albedo | 5,56% |
| | | Fossil Energy substitution by Renewable Energy | • Solar Panels<br>• Uses generating biomass [outdoor / greenhouse agriculture] | |
| CEB | Citizens' Economic Burden | Elements generating income or reducing the Cost of Living | • Edible / Productive Gardening<br>• Beehives<br>• Outdoor/Greenhouse Agriculture<br>• Energy savings [insulation or | 5,39% |

| | | | | |
|---|---|---|---|---|
| | | | albedo increase]<br>• Energy Production [solar panels and biomass] | |
| ID | Income Distribution | Elements generating income or reducing the Cost of Living | • Edible / Productive Gardening<br>• Beehives<br>• Outdoor/Greenhouse Agriculture<br>• Energy savings [insulation or albedo increase]<br>• Energy Production [solar panels and biomass] | 5,01% |
| NRE | Non-Renewable Energy Consumption | Transition from Non Renewable to Renewable Energies | • Energy Production [solar panels]<br>• Uses producing biomass [Outdoor and Greenhouse Agriculture]<br>• Energy savings [insulation or albedo increase] | 4,42% |
| UW | Use of Water | Rain Water retention in roofs and use for agriculture | • Outdoor and Greenhouse Agriculture<br>• Edible/Productive Gardening | 4,12% |
| EM | Employment | Uses implying employment generation | • Outdoor and Indoor Agriculture<br>• Beehives | 2,86% |
| BR | Biotic Resources | Uses requiring organic fertilizers | • Garden Roofs [non extensive]<br>• Outdoor irrigated Agriculture [no Greenhouse] (1) | 2,55% |
| EAD | Economic Activity Differentiation | Uses implying types of Economic Activity with current scarce presence in the Area. | • Outdoor irrigated and Greenhouse Agriculture<br>• Beehives | 2,40% |
| WP | Water Pollution | Rain Water retention in roofs and use for watering [benefit is increased if water is used for agriculture] | • Green Roofs [extensive]<br>• Green Roofs [gardens]<br>• Outdoor irrigated and Greenhouse Agriculture | 1,56% |
| GAP | Green Areas Provision | Uses combining vegetation and public stance. | • Gardened Public Rooftops | 1,51% |
| PAEB | Public Administration Economic Burden | Uses implying Economic Activity [i.e., taxes] and Employment [taxes and quotes] | • Outdoor irrigated and Greenhouse Agriculture<br>• Beehives<br>• Restoration Spaces (2) | 1,42% |
| LD | Labor Differentiation | Uses implying Employment categories with current scarce presence in the Area. | • Outdoor irrigated and Greenhouse Agriculture<br>• Beehives | 1,40% |
| AD | Adjusted Compactness (3) | **Positive impact**: Uses implying outdoor stance spaces<br>**Negative impact:** Uses increasing space occupied by 'built elements' | • Gardened Roofs, Community Orchards, solariums…<br>• Greenhouse Agriculture<br>• Multipurpose rooms, Acclimatized Swimming pools | 1,15% |
| GC | Green Corridors | Uses implying vegetation | • Green Roofs [extensive]; Gardened Roofs, Agriculture… | 1,11% |
| CLB | Crop Land Biocapacity Use | Uses implying agricultural production | • Outdoor irrigated and Greenhouse Agriculture<br>• Edible / Productive Gardening Beehives | 1,11% |
| GAA | Green Areas Accessibility | Uses combining vegetation with Public access and staying. | • Public Gardened Rooftops | 0,89% |
| BF | Biotope Factor | Uses increasing green areas surface | • Extensive and Intensive Green Roofs and Agriculture. | 0,87% |
| PFA | Local Public Facilities Accessibility | Uses equivalent to Public Facilities | • Public Facilities in Public Rooftops | 0,65% |
| AC | Acoustic comfort | Uses increasing surface of Public Open Areas without noise (4) | • Public Gardened Rooftops | 0,55% |
| PA | Physical activity | Uses implying citizens' physical activity | • Community Orchards<br>• Multipurpose rooms [used as gyms], Acclimatized Swimming pools | 0,49% |
| TC | Thermal Comfort | Uses increasing Green Areas surface and/or roofs albedo [reducing Heat | • Green Roofs [extensive and intensive] and outdoor agriculture. | 0,48% |

| | | | | |
|---|---|---|---|---|
| | | Island Effect] | • Cold Roofs | |
| USQ | Urban Scenery Quality (3) | **Positive Impact:** Uses implying stance spaces and vegetation | • Garden Rooftops | 0,47% |
| | | **Negative Impact:** Uses increasing space occupied by 'built elements' | • Greenhouse agriculture<br>• Multi-purpose rooms, acclimatized swimming pools… | |
| PFP | Public Facilities Provision | Uses equivalent to Public Facilities | • Public Facilities in Public Rooftops | 0,46% |
| BLB | Built up Land Capacity use (5) | - | • - | 0,44% |
| TOTAL IMPROVEMENT POTENTIAL | | | | 47,13% |

SOURCE: Calculations using Meta[S] model.

(1) Although it seems feasible to use organic waste to produce liquid fertilizers that could be directly used in hydroponic/aeroponic agriculture, we have not found this technology currently sufficiently documented/developed. On the other hand, organic waste composting has high development and can be easily made in rooftops.
(2) However, it is necessary to assess the impact on Economic Activity Differentiation of increasing number of restaurant areas in the neighborhood, since the Area already has some specialization in the restoration sector.
(3) We highlight Adjusted Compactness and Urban Scenery Quality indicators, in which reviewed rooftop uses can pose both positive and negative impacts.
   a. The vegetation of the landscaped areas on rooftops is often visible from the street having a positive effect
   b. By contrast, the construction of multipurpose rooms, indoor swimming pools or greenhouses for agriculture could have a negative impact, so in all cases specific project and license should be required.
(4) Although private roof spaces are also stance areas free from traffic noise, we do not account them precisely due to their private nature.
(5) Although introducing agricultural biocapacity in urban areas should reduce the area of land considered urbanized [and therefore increase the area of land whose development is still possible], at present this is an understudied matter, so we do not account it in this study. Data suggests Spain has already used/built 80% of the territory that marks the border between optimal and worst possible states [Alvira, 2015]

We see big potential improvement space [47.1%] which can be reduced by intervention on currently unused rooftop spaces according to reviewed priorities/uses. And to estimate the expected reduction of this 'space' [which will be smaller], we design different assessment *scenarios equivalent to the final state the Area would reach undertaking different implementations of the above uses* and assess the suitability of each using the model.

Previously it is necessary to review the characteristics and surface of Area's rooftops, which determine the possibility/cost/appropriateness of implementing each of revised uses.

## 5 AREA'S ROOFTOP CHARACTERISTICS AND AVAILABLE SURFACES

To characterize and quantify current Area's surface of available Rooftop spaces, we proceed in two steps:

- First, we *quantify surface of currently available [i.e., unused] rooftops*, indicating the use and access type of the building on which rooftop is located, which allows us to relate available surfaces with above revised uses.
- Second, *we review the characteristics of the building on which each rooftop is located*: construction date, condition, roof structural capacity, thermal insulation... This will allow us to assess the feasibility and effort required, as well as possible benefits of implementing the different possible uses.

We begin by reviewing available rooftop surface according to the above categories.

## 5.1 SURFACE OF AVAILABLE ROOFTOPS

We measure the surface of available roofs differentiating them in correspondence with above classification categories. In addition we review currently existing surface of 'Other types of usable roofs', differentiating also large size 'light roofs'.

**Image 02: Distribution of available rooftops by use of the building**. *Large size light roofs are represented in light blue. The large size of Atocha Station roofs can be easily appreciated.*

TABLE 5-1 _ ROOFTOP AND LARGE LIGHT ROOFS SURFACES ACCORDING TO USE

| | PALOS DE MOGUER | | | | | ATOCHA STATION | |
|---|---|---|---|---|---|---|---|
| | Public Facility (1) | Hotels | Other Types of Buildings | Large light Roofs | Other type of roofs (2) | Heavy weight rooftop | Light roof |
| **SURFACE [m2rf]** | 11,435 | 2,482 | 95,427 | 16,807 | 98,655 | 29,921 | 20,614 |
| **Nº ROOFTOPS / BUILDINGS** | 11 | 3 | 316 | 15 | - | 3 | 1 |

SOURCE: Own elaboration measuring on map. NOTES:
(1) Within this category we account 1,494m2rf of Health care Facility
(2) The figure includes lift roofs, lightweight structures in penthouse light roofs and roofs facing south.

We see the surface of available Rooftops and Large Size Light Roofs reaches [excluding Atocha] 17% and 2.6% respectively of total neighborhood surface; i.e., almost 1m2rf from every 5m2, advancing the large potential impact of their transformation.

In addition to the constraints arising from buildings’ use and access type, two additional issues affect the usability of available rooftops:

- *Each rooftop surface* which allow or not certain uses implementation. The high fragmentation of lots in the Area leads to small buildings and consequently small rooftops size, with the following average surfaces:
  - 300 $m^2$/rooftop in Residential & Tertiary & Institutional

- 830 $m^2$/ rooftop in Hotels
- 1.050 $m^2$/ rooftop in Public Facilities

- *Each rooftop's shape/configuration* also limits the uses that can be implemented on it. Rooftops shape is mostly the result of lower spaces distribution and heights, which often generate complicated and/or discontinuous geometries. In some cases relatively large surfaces do not allow theoretically possible uses.

Therefore, we need to individually review if each a priori possible use for some type of rooftops is compatible with the limitations imposed by each rooftop's shape and surface. The large roof of Atocha Station Long Distance Terminal with almost 28,000 m2 and perfect rectangular shape stands as great opportunity to locate virtually any use.

## 5.2 BUILDINGS' CHARACTERISTICS

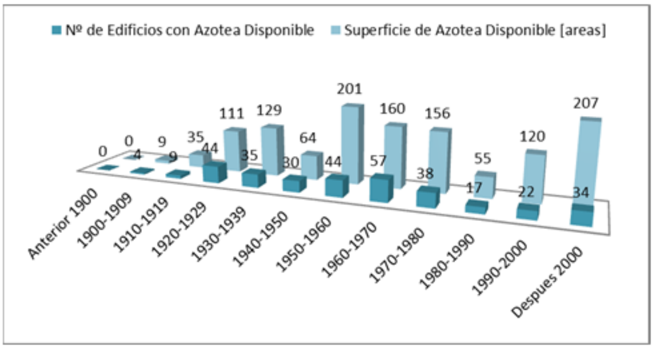
There are two features of building which have great importance for assessing both rooftops possible uses and its impact on the building:

- *Building/roof structural strength* that may allow or not direct implementation of different uses, or require structural reinforcements or design solutions that minimize loads.
- *Building/roof thermal insulation* that will determine achieved thermal improvement / energy savings by the adequacy of the rooftops.

To assess both issues first we review *Area's buildings' construction date and condition*, and subsequently *buildings' structural and thermal characteristics* that we deduct from normative values at each building's construction date.

### *5.2.1 BUILDINGS' CONSTRUCTION DATE AND CONDITION*

We find the following surfaces of available roof according to construction date[VIII]:




***Nº of buildings and surface of roof available depending on building's construction date.*** *Own elaboration measuring over map and construction dates from Catastro [Ministry of finance and public administrations]. For visualization clarity, we indicate the surface in 'areas' [m2 can be obtained multiplying by 100]. Due to its singularity, we do not include Atocha Station surface in this graph [28 areas built in 1992]*

We see more recently buildings have generally greater rooftop surface by building [they are bigger constructions].

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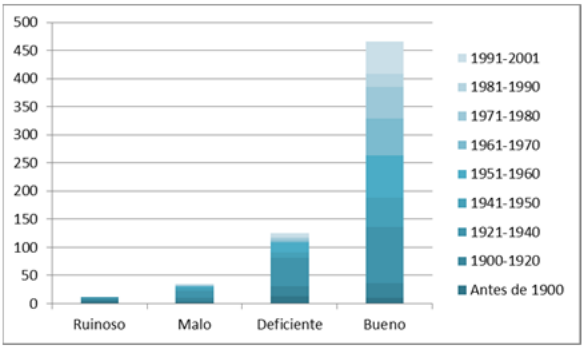
[VIII] Palos de Moguer analysis was made mostly between years 2012/2013, when *2011 Buildings and Housing Census* was still not available. Although it would be possible to update this work after the publication of such data [in year 2015], the high effort required challenges the interest of this task since Area's buildings are mostly pre-2001.

Complementarily, it is necessary to review buildings' condition, also in relation to their construction date.




**Graphic 05: Palos de Moguer buildings' condition according to construction date.** *Own elaboration based on INEbase [2001 Building and Housing Census] data. We do not assess post-2001 buildings, but we assume their condition is good.*

In the graphic, we can see some interesting issues:

- 73% of the buildings are in good condition and we consider their structure maintains their designed load bearing capacity.
- 19.6% of the buildings have some conservation deficiencies. These buildings must be individually reviewed to be able to assess the impact of these deficiencies on each building's structural capacity, but we consider their insulation has completely lost its functionality.
- The remaining 7.5% buildings are in bad condition or ruin, and require integral rehabilitation and individualized analysis prior to the implementation of any of herein proposed uses.

### *5.2.2 STRUCTURE'S LOAD BEARING CAPACITY*

We consider each building' structural capacity can de deduced from two issues:

- *Building condition.* We consider structure of buildings in good condition maintains its design bearing capacity, while the rest of buildings require individual review.
- *Structure design bearing capacity values*. It depends on normative structural calculation values at building's construction date. Four dates stand as important:
  - o 1941. DGA-41, first Spanish legislation setting values for building structures' calculation.
  - o 1962. MV 1962 is enacted
  - o 1988. NBE-AE-1988 is enacted
  - o 2006. CTE-DB-SE is enacted

The calculation values interesting for our scope are:

TABLE 5.2 _ USE/SNOW OVERLOADS ACCORDING TO DIFFERENT REGULATIONS [Kg/m2]

| | | DGA41 | MV-1962 | NBE-AE-88 | CTE-DB-SE |
|---|---|---|---|---|---|
| SNOW | | 80 | 80 | 80 | 100 |
| USE | Without Use | 150 | 100 | 100 | 100 |
| | Private Use | 150 | 150 | 150 | 100 |
| | Public Use | Depending use | Depending use | Depending use | Depending use |

SOURCE: Compilation from DGA-41, MV-1962, NBE-CT-88 and CTE-DB-SE

(1) In the case of public uses, individualized study of each roof is required, since surcharges vary depending on usage. 'Use overload' values are generally significantly higher than those for roofs without use [a wide range is found, varying from 300 Kg/m2 for areas with tables and chairs up to 500 Kg/m2 for sport areas, exhibitions, etc.], which would in general require structure re-

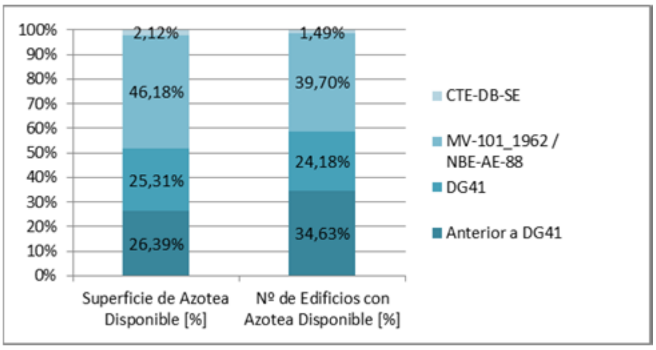
inforcement. However, this can be offset in some cases if project accounted overloads for machinery that finally were not installed or that can be relocated.
(2) For buildings designed/built prior to 1941, individual analysis is required in all cases

And it is necessary to assess the impact of the variation of loads involved in each use's implementation in conjunction with the previous table, being possible to state the following:

- If transforming rooftop space involves removing existing pavement, an equivalent weight to retired can be added [usually 80-120 kg/m2][IX], allowing in most cases to install pavement and/or gardened solutions with light substrates and thickness between 80-120 mm[X].
- In 'private use' rooftops built between 1942 and 2006, we can generally account 50 kg/m$^2$ of available bearing capacity due to use overloads reduction.
- Snow overload has increased from 80 to 100 kg/m$^2$, which should be reviewed in each case since it reduces 20 kg/m$^2$ from rooftops loading capacity.

If implementing uses implies bigger load than considered for buildings' design it may be necessary reinforcing its structure or designing specific solutions carrying load directly to columns. This should be individually studied and could limit design options or increase their cost.

We are interested therefore grouping buildings according the four above periods:




**Graph 06: percentage of available rooftop surface and number of buildings according to intervals of application of Structural Codes** *[we account only buildings that have available rooftop space]. Buildings' Construction dates the have been obtained from Catastro.*

We see more than 65% of buildings/73.5% of rooftop surface is built according to any of above Regulations. From this percentage, 86% is in good condition and therefore can be used according above mentioned constructive criteria and uses. The rest of the buildings require individually reviewing their structural capacity.

[IX] The weight depends on current pavement type. As guidelines, we provide the following: conventional pavement [80 kg/m2]; 5 cm of gravel protection -density of 1900 kg/m3- [95 kg/m2]; ventilated Catalan type roof [120 kg/m2].

[X] We have considered a saturated weight of 880 kg/m3 [Hahn et al, 2002], with a 12% increase to account the weight of waterproofing, insulation, and protections.

### *5.2.3 THERMAL INSULATION*

We consider buildings rooftops' thermal insulation is deductible from two issues.

- *Buildings' condition.* If the building is in good condition, we assume it maintains projected thermal insulation capacity, while if building condition is poor, bad or ruined, we consider thermal insulation capacity is lost.
- *Buildings' design thermal insulation value*. This value depends on normative maximum thermal transmission values at buildings' construction date. Three dates are important:
    - 1975. Decree 1490/75 is promulgated. First Spanish Regulation regarding buildings' thermal performance.
    - 1979. NBE-CT-79 is enacted
    - 2006. CTE DB-HE is enacted

Maximum thermal transmission values set by above Regulations interesting us from the point of view of rooftops are:

TABLE 5-3_ THERMAL TRANSMISSION OF ROOFTOPS ACCORDING DIFFERENT REGULATIONS

| | Before 1975 [no insulation] (1) | 1.490/75 Decree [1976 to 1980] (2) | NBE-CT-79 [1980 to 2006] | CTE-DB-HE [after 2006] (3) |
|---|---|---|---|---|
| WEIGHTED ROOFTOPS' THERMAL TRANSMISSION [w/m2ºk h] | 1,62 | 1,04 | 0,90 | 0,38 |
| ESTIMATION POTENTIAL INSULATION IMPROVEMENT [%] | 76,59% | 63,46% | 57,78% | 0,00% |

SOURCE: Own elaboration with the following comments:

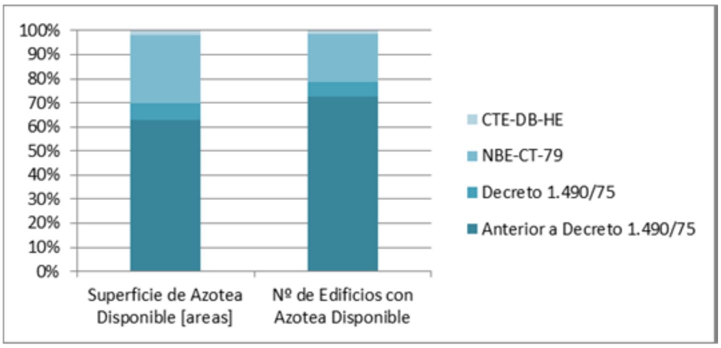
(1) The values of the elements for buildings prior- 1975 are those of the constructive elements whereas they lack insulation. We also consider the same value for buildings in poor condition, bad or ruined. We have calculated an average value for three types of usual rooftops constructive solution in Madrid.

(2) 1.490/75 Decree does not specify thermal transmission limiting values for each enclosure. Since this Decree was forerunner of NBE-CT-79, we have estimated them by deducting them from the limits established by the latter, using a proportion according to the relation between the limit values of the global KG in 1.490/75 and those established by NBE-CT-79. It seems an acceptable simplification, given the low percentage of affected surface.

(3) CTE-DB-HE1 values are for Madrid, D3 climate zone.

Above Table suggests thermal improvement can be very important in buildings prior to 1975, and somewhat lower but still significant in between 1975 and 2006buildings. In post-2006 buildings the rooftops transformation will not produce insulation increases or they will be reduced.

We are interested therefore in grouping buildings into four periods corresponding to above dates:




**Graphic 07: percentage of number of buildings and available rooftop surface according different thermal regulations** *[nor buildings without available rooftop' surface are not accounted neither it is - due to its singularity- Atocha station]. Surfaces are obtained by measuring on map. Buildings' construction dates are from Catastro.*

We see almost 73% of buildings [63% of total rooftop surface] have been built before 1975 and therefore do not incorporate thermal insulation. To that percentage we add 3% of post-1975 buildings with condition is poor or bad[XI].

According to these data, if all the rooftops are transformed upgrading their thermal insulation to currently required values, an average rooftop thermal transmission reduction of 71% would be achieved and correspondent energy consumption savings obtained.

We have characterized available rooftop spaces in Palos de Moguer area, now we proceed to formulating Assessment Scenarios.

## 6 POSSIBILITIES FOR URBAN TRANSFORMATION

We review the design process of an urban area transformation maximizing its Sustainability increase, by jointly considering two issues:

… We relate *uses that increase Area's Sustainability with available rooftop surfaces by designing assessment scenarios*. These assessment scenarios are proposed in the more disaggregated possible manner, for maximizing later combination possibilities.

… We value *synergies, repetitions and complementarities/exclusions among such uses*, which limit their possible combinations or condition the impact of their joint implementation [sometimes increasing it and sometimes reducing it].

Let us start by the first one.

### 6.1 DESIGNING ASSESSMENT SCENARIOS

Starting from above revised issues we can formulate Assessment Scenarios, which are adaptations of possible uses [see chapter 4] to Area's intervention priorities [see chapter 3] and characteristics of available rooftops [see chapter 5].

Previously, it is convenient to make a small reflection on the possible combinations of different possible uses. *All of them have some incompatibility [they are a priori at least partially exclusive] since they 'compete' for occupying the same space.*

If all uses needed to occupy all available space in case implemented, analysis would greatly simplify since it would be sufficient to assess each use expected impact, then choose the most beneficial [the one most increasing Area's Sustainability]. However, this is not so, and in addition several intermediate situations happen:

… *Not all options can be placed on all buildings uses [i.e., not all uses can be located on all surfaces], so not all of them actually compete for the same space.*

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[XI] According to Census data, there are no post-1975 buildings in ruinous condition.

- … *Not all possible uses need to occupy all rooftop space;* most can occupy only some space and leave space for other uses. However, some uses have minimum surfaces below which its implementation is not optimal or it is not possible.
- … *Not all uses can occupy all rooftop space*; some uses have maximum areas which need not, cannot or should not exceed[XII].

Therefore, in each assessment scenario description we detail two issues:

- on which *types of buildings* can each use locate
  - Buildings with public access
  - R&T&I [Residential, Tertiary and Institutional] buildings
  - Other types of buildings …
- What is the *possible/required surface for the implementation of each use/scenario*, which in general will be one of the following options:
  - a fixed part
  - a minimum surface
  - a maximum surface
  - variable from 0% [0 m2] to 100% [all rooftop available surface in the Area]
  - variable between a minimum [different from 0] and a maximum [different from 100%]

For the use of the proposed methodology [Alvira, 2015] we start from the more disaggregated scenarios possible, so subsequently combining them up to finding the most preferred/optimum combination. Therefore, we start from an initially high number of assessment scenarios [15] that correspond to each use whose effect we 'intuit' can be beneficial for the Area.

Let us therefore describe the characteristics/values considered for each assessment scenario.

### *6.1 SCENARIO A01. EXTENSIVE GREEN ROOFS*

- Areas with vegetation not usable by persons.
- Can locate on any roof [building use is not relevant].
- Its main functions are: bioclima and biodiversity improvement and reducing metabolism consumption [energy and water savings].
- It can occupy from 0% up to 100% of rooftop surface.
- It is the landscaping of the roof with the following characteristics:
  - draining base with rainwater retention [36 l/m2]
  - reduced substrate layer [thickness between 70 and 120 mm]
  - species of vegetation type 'sedum' or some species of grasses
  - no maintenance required [just a couple control reviews per year]

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[XII] Additionally, the beneficial impact of any use shows decreasing marginality. It is greater if small surface is dedicated to such use and it declines as this surface is increased. Therefore its replacement cost - the amount of other use required to obtain an equivalent benefit - has the reverse logic. This decreasing marginality is in general a constant in any Sustainability dimension [Alvira, 2014a. Th06] and usually significantly complicates the design process.

### *6.2 SCENARIO A02. INTENSIVE GREEN ROOFTOPS: COMMUNITY ROOFTOP GARDENS*

- Community gardens for buildings' occupants.
- Can be placed on R&T&I buildings.
- Their main functions are: stance and contact with nature, improving bioclima and biodiversity and reducing metabolism consumption [energy and water savings].
- Although theoretically they could occupy from 0% to 100% of rooftop surface, we state some limits:
  - We set a minimum 30 $m^2$ or 2.5$m^2$/house surface.
  - Given the average number in the area is 20houses/building we arrive to a 50 $m^2$ surface type.
  - We limit maximum area[XIII] to 100 $m^2$
- It is the landscaping of the rooftop with the following characteristics:
  - garden area:
    - Substrate layer thickness between 150 and 400 mm[XIV]
    - Variety of vegetation species.
  - paved area: SRI ≥75
- They require frequent maintenance [irrigation, fertilization and pruning]

### *6.3 SCENARIO A03. INTENSIVE GREEN ROOFTOPS: PUBLIC GREEN AREAS*

- Green Areas accessible to all citizens.
- They can be placed on public use buildings.
- Their main functions are: stance and contact with nature, improving bioclima and biodiversity, reducing metabolism consumption [energy and water savings], social cohesion and physical activity.
- Their dimensions shall be defined depending on the type of Green Area to be created[XV]:
  - Vicinity >500$m^2$
  - Neighborhood >5.000$m^2$
  - Neighborhood-City >1Ha
  - City > 10 Ha

  Complementarily, all PGA except Vicinity areas must allow inscribing a 30 m diameter circle.
- Design. Rooftop landscaping with the following characteristics:
  - garden area:
    - draining base with rain water retention [36 l/$m^2$]
    - Substrate layer thickness between 150 and 1,000 mm[XVI]

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[XIII] They must be complementary spaces to Public Green Areas [PGA], without replacing them because that would remove Public Spaces' integration role. For this reason, we establish a limited size for these areas. They are interesting in urban areas with PGA deficit [e.g., historical centers and Enlargements] but should be avoided [or at least limited] if there is PGA excess [e.g. urban peripheries].

[XIV] Thickness recommended by different manufacturers. Load limitation imposed due to intervention on existing rooftops can make preferably considering more reduced 'type' thicknesses [substrate of 120 mm] and use pots or punctually increase depth by creating 'slopes' for plantation of some species that need greater depth.

[XV] Surfaces from Rueda [2012: 610]. The only rooftop complying with these conditions in the Area is Atocha Station Long Distance Terminal.

        - Variety of vegetation species including small/medium size trees
    - paved area: SRI ≥75
- They require frequent maintenance [irrigation, fertilization and pruning]

### *6.4 SCENARIO A04. INTENSIVE GREEN ROOFTOPS: OUTDOOR AGRICULTURE*

- Agricultural rooftop spaces planned as business.
- Although they can be located on any type of building [building use is not relevant], we exclude public buildings [facilities and infrastructures] due to their business nature[XVII].
- Their main functions are: income generation, improving bioclima and biodiversity, reducing metabolism consumption [energy and water savings, and Crop Land biocapacity reduction], social cohesion and Physical activity.
- They can occupy from 0% up to 100% rooftop surface.
- Design. Rooftop landscaping with the following characteristics:
    - Variable thickness substrate layer [between 100 and 300 mm][XVIII].
    - Productive vegetation species [mostly vegetables].
    - Requires constant maintenance [including irrigation, fertilization, collection...]

### *6.5 SCENARIO A05. INTENSIVE GREEN ROOFTOPS: COMMUNITY ORCHARDS*

- Community Orchards accessible to building occupants, whose priority function is not agricultural production but being places for social gathering and outdoor physical activity.
- They locate on R&I use buildings [publicly owned community orchards are included in the equipment/PGA uses].
- Their main functions are: stance and contact with nature, physical activity, improving bioclima and biodiversity, reducing metabolism consumption [energy and water savings] and social cohesion.
- Theoretically they can occupy from 0% to 100% rooftop surface, but we impose some limitations:
    - We establish a minimum surface of 15m$^2$ or 2.0 m$^2$/house
    - For the average 20 houses/building, we arrive to 40m$^2$ type surface.
- Design. Rooftop landscaping with the following characteristics:
    - Variable thickness substrate layer between 100 and 300mm [preferible≥200mm]. It can also be planned in boxes [width approx. 1.10 m and variable length]
    - Productive vegetation species: mainly vegetables, but it can also be floriculture.
    - It requires constant agricultural maintenance [irrigation, fertilizing and collection].

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[XVI] Thickness recommended by manufacturers. Limitation of load imposed by the fact we are working on already existing roofs may lead to being more convenient using smaller 'type' thickness [120 mm substrate] and use pots or creating small 'hills' for species requiring greater depth.

[XVII] It does not seem acceptable promoting a profitable use of public surface in an area with deficit of public services. However, in urban morphologies with excess of Public Facilities Provision, it may be convenient to assess the productive use of these roofs [increases Public Administration Income and improves Urban Metabolism sustainability]

[XVIII] Although some manufacturers suggest substrate thickness preferably ≥ 200 mm, there are examples in operation with thickness from 50mm, or combining reduced thickness in maintenance areas with increasing thickness in growing areas [e.g., Brooklyn Grange].

### *6.6 SCENARIO A06. BEEHIVES*

- Exploitation of hives with business purpose.
- They can be located on any rooftop, regardless building use [building use is not relevant] [XIX].
- Their main functions are: income generation, improvement of plants pollination, reducing Crop Land biocapacity use.
- They requires little surface [2-3 m2/hive], however there are at least two limitations to the maximum number of hives:
    - The first arises from the *necessity of production demand.* Since Palos de Moguer area is not an appellation, we consider production is for domestic consumption, and calculate the number of hives to obtain up to 75% current honey consumption by Area's inhabitants, arriving to 218 hives[XX].
    - the second is from the *vegetated area required for bees to produce honey,* that allows to hold approximately 2 hives/Ha with vegetation [AYG/2155/2007], resulting in the following figures:
        - 49 hives based on currently existing vegetated area accessible to bees from Palos de Moguer [approx. 24.3 has] [XXI].
        - 29 hives more if the entire available surface of roof and light covers [approx. 14.4 Ha] is transformed into Green roofs.

      We obtain a maximum possible total of 78 hives.

  The second figure is lower, so it is the one we initially consider for the assessment[XXII]. The production of honey would be 31.8% of local consumption, allowing us to consider there would be sufficient demand.

### *6.7 SCENARIO A07. SOLAR PANELS [OPTION 01]*

- Solar panels Installation for generating energy to be used in the building.
- They locate on residential buildings[XXIII].
- Their functions are: reducing GHG emissions, replacing of NRE by RE and economic savings.

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[XIX] Spanish legislation currently prevents locating beehives in cities [RD 209/2002. Article 8]. The existence of numerous examples in other cities [e.g., Paris, Copenhagen...], some with specific regulations [e.g., New York], leads us to include them as possible to use.

[XX] We consider a 0.44 kg/inhab/year honey consumption [MAGRAMA, 2005] and a 50 kg/hive/year honey production [EEA]

[XXI] For the calculation, we have established a perimeter of 900 m from the edge of the Area, in such a way that the first block and the start of the second are at a distance less than or equal to 1 km, distance usually recommended the bees must not exceed to collect pollen [the maximum possible distance is 3km]. We have discounting 50% of the surface of garden areas which should be shared with other neighboring areas, and applied a second deduction as a function of the ratio vegetated/artificial surface.

[XXII] According to reviewed literature, an excess of hives leads to a shortage of food, productivity reduction and sometimes aggressive bees' behavior. Therefore, this figure should not be exceeded. Obviously, if the entire surface is not vegetated, the figure must be reduced. The obligation to apply for a city permit stands as easy way to check limits are not exceeded. We anticipate that the scenario which we propose from the evaluation would provide a total of approx. 8.3Ha vegetation, which will hold up to 17 extra hives, limiting total to 66 hives [approx. 1 hive /Ha].

[XXIII] Excessive concentration of solar panels in an area can have consequences on air temperature [Milstein & Menon, 2010]. Therefore we exclude analysis of not R&T&I buildings, whose extensive adaptation for solar panels seems not recommended given Area's high local temperatures in the summer. In addition, the specificity of non-residential buildings consumption makes it more convenient reviewing the appropriateness of installing solar panels in each case. Therefore we focus the analysis on consumption associated with residential use.

- We consider only residential consumption, for which approx. 10 $m^2$/house [Rueda, 2007][XXIV] are needed. Given the average Area 20 house/building, we obtain an average of 200 $m^2$ solar panels/building
- To achieve a combination of Thermal and Photovoltaic [PV] panels in order to cover the following percentages of consumption [Rueda, 2007]:
  - 70% domestic hot water consumption
  - 40% heating consumption
  - 60% air conditioning consumption
  - 100% common building uses consumption electricity [we estimate an average of 120 kWh by housing and year common services consumption: lighting, lift, parking]
- The resulting percentage is 88% Thermal and 12% PV

### *6.8 SCENARIO A08. PRIVATE COMMUNITY USES: COMMUNITY MULTI PURPOSE ROOMS*

- A minimum 3 m setback from rooftop perimeter, light materials enclosure, cover SRI≥75, architectural project and municipal license are in all cases required.
- Built indoor multi-purpose spaces to be used by building occupants.
- They can locate on residential buildings [collective housing]
- Their main function is social, yet can host sport activities….
- Dimensions are variable:
  - As minimum surface we consider 25$m^2$ or 2.5 $m^2$/house
  - For the average 20 house/building, we arrive to a 50$m^2$ type surface which we set as maximum[XXV].

### *6.9 SCENARIO A09. PRIVATE COMMUNITY USES: SWIMMING POOLS, SOLARIUM, SAUNA*

- Spaces linked to outdoor staying, sports and health.
- They can be located on R&T&I buildings.
- Their main functions are: Social and Physical activity/health.
- We consider the following surfaces:
  - pool 12 x 2.5 m [30$m^2$]
  - solarium [30$m^2$][XXVI]
  - sauna + dressing rooms [20$m^2$]

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[XXIV] The ratio m2 panel solar/viv calculated by Rueda [2007, annex 8.2: 32] for the city of Seville is 10m2 roof occupied by panels/house [assuming 3 inhabitants/house occupation]. The data calculated for Palos de Moguer area, considering the increased heat consumption due to local climate, less solar radiation and real dwellings occupation [2.7 hab/viv considering only occupied dwellings], results in an area of 9.85 m2/viv. For ease of calculation [and providing some capacity for inhabitants increase] we maintain the 10 m2/viv.

[XXV] Excessive Area compactness leads us to choose the maximum built surface which [according to municipal criteria for computing total built area] does not increase Area's total built Surface [50m2/building for community uses].

[XXVI] We consider the solarium integrates a band surrounding the pool of at least 1m x [2.5+12+2.5=17m]. Though the Sun can have negative effects on the body [e.g., skin cancers...] it also has many positive effects. In summer, between 7 and 9 minutes of exposure to the Sun tend to meet the needs of the body, while in winter months, the time needed is increased up to 2-3 hours week [2007 CCA] or 40 to 47 minutes a day [Lucas, 2006]. It is important to indicate that 'solarium' use is -at least partly- implicit in Community Orchards and landscaped Areas, and can be explicitly introduced as part of the latter, even if pool area is not enabled.

- In the case of incorporating enclosure for use throughout the year, a minimum 3 m setback from roof perimeter is required, walls with lightweight materials, cover SRI≥75, and specific architectural project/municipal license in all cases.
- It presents synergies with garden community gardens and multi-purpose community rooms, since the joint complex is able to attract more building occupants[XXVII].

### *6.10 SCENARIO A10. PUBLIC USES: PUBLIC FACILITIES*

- Public facility spaces which use complements that of the building on which rooftop they are located [cultural, artistic, sports, multifunction, viewpoints, health...].
- They locate on buildings with public use.
- They occupy all available rooftop space.

### *6.11 SCENARIO A11. OTHER PRODUCTIVE USES: RESTAURANTS AND LEISURE SPACES*

- Spaces that complement Restauration offer, with catering area, possible pool area and garden elements.
- They can be located on buildings with Restauration use.
- They can occupy all available surface
- Design and construction requirements are the same than A02 to A09.

### *6.12 SCENARIO A12. OTHER PRODUCTIVE USES: GREENHOUSE AGRICULTURE*

- Spaces for greenhouse agriculture with business purposes.
- Although they can be located on any type of building [building use is not relevant], due to its business purpose we exclude Public Facilities and public infrastructure[XXVIII].
- Their main functions are: income generation and reducing metabolism consumption [energy and water savings, and reducing use of Crop Land biocapacity].
- They can occupy from 0% up to 100% rooftop surface, being necessary preserving setbacks or special design solutions for the strip edge.
- They involve conditioning of the roof with the following characteristics:
    - Greenhouse with plastic cover and light substructure.
    - Hydroponic or aeroponic agriculture
    - Productive vegetation species [mainly vegetables]
    - It requires constant maintenance, although it involves a high degree of 'automation'.

Finally, let us add three scenarios that use 'other usable deck surfaces':

### *6.13 SCENARIO A13. SOLAR PANELS IN SLOPING ROOFS AND STAIRS/LIFTS ROOFS*

- Solar panels Installation for generating energy to be used in the building [or surrounding buildings].

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[XXVII] However, this use presents the problem that an excessively attractive community spaces could empty of people public spaces/ facilities; and generate an excessive buildings' desirability, leading to an Area gentrification. This should be watched in any case.

[XXVIII] For the same abovementioned reason for A04

- They locate on roof surfaces not fitted for other purposes: staircase/lifts roofs [reduced size / difficult access], light penthouses canopies and buildings' regular slope roofs with South orientation.
- Their main functions are: reducing GHG emissions, replacing NRE by RE and economic savings.
- We establish the same production energy goal than for panels located on horizontal surface [A07]. Given the minor loss of space in the occupation of inclined planes –there is no need for walking corridors between panels- resulting required space reduces to approx. $5m^2$/house, which for the average 20 house/building it is an average of $100m^2$ solar panels/building[XXIX].
- We set as consumption targets those explicit in A07, and obtain the same result of 88% of thermal panels and 12% photovoltaic.

### *6.14 SCENARIO A14. LARGE SIZE LIGHT COVERS TRANSFORMATION INTO 'GREEN ROOFS'*

- Areas with vegetation not usable by persons.
- Located on large size light decks existing in the area, usually belonging to industrial and commercial buildings.
- Their main functions are bio-clime and biodiversity improvement, and metabolism consumption reduction [energy and water saving].
- 100% available surface is conditioned this way.
- It is the landscaping of the roof with the following characteristics:
  - Reduced thickness substrate layer [ca. 60 mm] with water retention.
  - 'Sedum' type vegetation species and some species of grasses

### *6.15 SCENARIO A15. LARGE SIZE LIGHT COVERS TRANSFORMATION INTO COLD ROOFS*

- High effectiveness coating for large size light decks.
- Its main goals are: bio-clime improvement [HIE reduction], economic savings, replacing ENR by ER and reducing GHG emissions.
- 100% available surface is conditioned this way[XXX].

A last scenario is to use **productive plant species for intensive roofs landscaping**. We do not assess this option as an independent scenario, but as an option we can superimpose to any use including gardened intensive areas. Its effects are increasing Crop Land Biocapacity, reducing Hydric Footprint, income generation....

For the present analysis we consider a Life cycle of 25 years for all rooftops[XXXI], including the case where no special transformation is undertaken. As consequence, we consider 4.0% of total surface is renovated each year [100% each 25 years]

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[XXIX] For assumed 11.760 houses and 594 residential buildings. If we include non-occupied homes in the calculation, the ratio amounts to 23.3 houses / building, being an average surface of 116.5 m2/building required.

[XXX] For materials technical characteristics, refer to LBNL http://energy.lbl.gov/coolroof/

## 6.2 COMPLEMENTARITIES [SYNERGIES AND REPETITIONS] AND EXCLUSIONS BETWEEN SCENARIOS

Prior to the application of the methodology, it is essential reviewing proposed scenarios and to establish the relationships between them:

TABLE 6-1_ COMPLEMENTARITIES [SYNERGIES AND REPETITIONS] AND EXCLUSIONS

| | | |
|---|---|---|
| A01_Green Extensive Rooftops | Synergies | • **A06.** The increase in vegetation provides pollen to bees and bees can contribute to plants' pollination. |
| | Repetitions | • - |
| | Exclusions | • **A02, A03, A04, A05, A07, A08, A09, A10, A11, A12.** They compete for the same spaces. |
| A02_ Community Gardens | Synergies | • **A05, A08 y A09.** By increasing the number of possible uses, roof spaces become more attractive for a greater number of users, contributing to greater functionality and better maintenance<br>• **A06.** The increase in vegetation provides pollen to bees and bees can contribute to plants' pollination. |
| | Repetitions | • - |
| | Exclusions | • **A03** They compete for the same users. An excessive area of private gardens could reduce public spaces users. Although Palos de Moguer high Compactness /reduced Green Areas minimizes this problem [it does not seems likely public spaces will be 'empty'] public spaces' integration function [increasing 'cohesion' and reducing 'polarization'] could be somehow lost. In order to minimize this risk, we set a limit to their maximum surface. They can only compete with small dimension green areas [vicinity], but not with the largest [neighborhood/City] green areas.<br>• **A01, A04, A05, A07, A08, A09 y A12.** They compete for the same spaces (1) |
| A03_ Pubic Green Areas | Synergies | • **A05.** By increasing the number of possible uses, roof spaces become more attractive for a greater number of users, contributing to greater functionality and better maintenance<br>• **A06.** The increase in vegetation provides pollen to bees and bees can contribute to plants' pollination. |
| | Repetitions | • - |
| | Exclusions | • **A01 y A10.** They compete for the same spaces.<br>• **A02.** They compete for the same users |
| A04_ Outdoor Agriculture | Synergies | • **A05.** A generalization and greater understanding of urban agriculture is expected to lead to better appreciation and acceptance [higher demand] of local production by inhabitants.<br>• **A06.** The increase in vegetation provides pollen to bees and bees can contribute to plants' pollination. |
| | Repetitions | • - |
| | Exclusions | • **A01, A02, A05, A07, A08, A09, A11, A12.** They compete for the same spaces |
| A05_ Community Orchards | Synergies | • **A04.** A generalization of urban agriculture most likely will imply greater knowledge and technical improvement; higher availability of agricultural product [fertilizer, tools…]<br>• **A02 y A03.** By increasing the number of possible uses, roof spaces become more attractive for a greater number of users, contributing to greater functionality and better maintenance<br>• **A06.** The increase in vegetation provides pollen to bees and bees can contribute to plants' pollination. |
| | Repetitions | • - |
| | Exclusions | • **A01, A02, A03, A04, A07, A08, A09, A10, A11, A12.** They compete for the same spaces (2) |
| A06_ Beehives | Synergies | • **A01, A02, A03, A04, A05 y A14.** The increase in vegetation provides pollen to bees and bees can contribute to the pollination of the plants. |
| | Repetitions | • - |
| | Exclusions | • Although hives installation requires little space, depending on the specific location, it may be necessary to define a protected area. In this case, some incompatibility appears with other applications that could use the space (3). |
| A07_ Solar Panels Option 01 | Synergies | • - |
| | Repetitions | • - |
| | Exclusions | • **A01, A02, A04, A05, A08, A09, A12.** They compete for the same spaces (4). |
| A08_ Multi-purpose community Rooms | Synergies | • **A02, A05 y A09.** By increasing the number of possible uses, roof spaces become more attractive for a greater number of users, contributing to greater functionality and better maintenance |
| | Repetitions | • - |
| | Exclusions | • **A01, A02, A04, A05, A07 y A09.** They compete for the same spaces (5) |
| A09_ Swimming Pools, | Synergies | • **A02, A05y A08.** By increasing the number of possible uses, roof spaces become more attractive for a greater number of users, contributing to greater functionality and better maintenance |

[xxxi] Some authors estimate shorter renovation 20-25 years periods for non-gardened roofs [Ngan, 2004:7] or even 10-15 years [OAA, 2003: 12]. Other authors consider 30 years renovation for non-gardened rooftops and between 40 and 60 years for gardened rooftops [Soemy, 2008:28]

| | | |
|---|---|---|
| Solarium and Sauna | Repetitions | • |
| | Exclusions | • **A01, A02, A04, A05, A07, A08 y A12.** They compete for the same spaces (6) |
| A10_ Public Facilities | Synergies | • **A01, A02, A03, A04, A05 y A14.** Increasing vegetation is expected to reduce Heat Island, increasing spaces thermal comfort [and most likely their use] during hot weather months**.** |
| | Repetitions | • |
| | Exclusions | • **A01 y A03.** They compete for the same spaces |
| A11_ Restauration Spaces | Synergies | • - |
| | Repetitions | • - |
| | Exclusions | • **A01, A04 y A12.** They compete for the same spaces |
| A12_ Greenhouse Agriculture | Synergies | • - |
| | Repetitions | • - |
| | Exclusions | • **A01, A02, A04, A05, A07, A08, A09 y A11.** They compete for the same spaces |
| A13_ Solar Panels Option 02 | Synergies | • - |
| | Repetitions | • **A08, A09.** New deck surface can be designed to locate these types of panels since construction, reducing installation cost. |
| | Exclusions | • - |
| A14_ Green Slope Roofs | Synergies | • **A02, A03, A04 y A05.** It increases the variety of plant species. Its joint effect is increase the range of different biotopes capable of acting as Green Corridors or sustaining a wider range of Biodiversity.<br>• **A06.** The increase in vegetation provides pollen to bees and bees can contribute to plants' pollination. |
| | Repetitions | • - |
| | Exclusions | • **A15.** They compete for the same spaces. |
| A15_ Cold Roofs | Synergies | • - |
| | Repetitions | • - |
| | Exclusions | • **A14.** They compete for the same spaces. |

SOURCE: Own elaboration with the following comments:

(0) We have not indicated economic synergies, i.e., the fact that certain uses involve income, and its combination with uses that do not generate income may be fundamental for the whole transformation feasibility.
(1) In fact, since we have limited surface to 50m2, in the majority of cases it is fully compatible with A05, A08 and A09.
(2) In fact, since have limited the size to 40m2 in the majority of cases it is fully compatible with A02, A08 and A09. Nor does it seem to be incompatible with A03, since it can be implemented perfectly occupying small percentage of surface and contributing to create more attractive spaces for a greater number of inhabitants.
(3) In general, we have considered A06 does not compete with other uses for the space, even though it is clear that except for A01 and A04 uses, it may be required creating safety areas that involve more space than 3 m2.
(4) In fact the competition with A01 is relative; Since we have seen there are solutions that integrate both uses even if they are somewhat more expensive
(5) In fact, since we have limited size to 50m2 in the majority of cases they are compatible with A02, A05 and A09.
(6) Its 80m2 surface makes them actually compatible in most cases with A02 and A05-A08. The higher difficulty lies in its high cost, since in many cases structure reinforcement may be required. Sometimes intermediate solutions can be proposed, only incorporating solarium and sauna, less structural 'demanding' uses.

We have reviewed scenarios compatibility mostly from the perspective of their competition in terms of spaces/users. But there is another competition underlying to reviewed uses; *they all compete for the same economic resources.* From that perspective, we can attribute a scale of major/minor compatibility between uses building on two issues:

- *Their implementation cost:* uses with lower implementation cost are more compatible with the rest of applications, since they leave greater amount of unused/available economic resources.
- *The generation of economic benefits:* uses generating economic benefits that allow recovering their implementation cost [shorter return on investment] are more compatible with the rest of uses, since they soon return used economic resources or even generate new income.

Later we assess both issues.

The information obtained from the review of all the assessment scenarios can be integrated into an 'interactions' matrix:

TABLE 6-2_ INTERACTIONS MATRIX

| | A01 | A02 | A03 | A04 | A05 | A06 | A07 | A08 | A09 | A10 | A11 | A12 | A13 | A14 | A15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **A01** | - | -/-/PE | -/-/PE | -/-/PE | -/-/PE | S/-/- | -/-/PE | -/-/PE | -/-/PE | S//PE | -//PE | -//PE | - | - | - |
| **A02** | | - | -/-/PE | -/-/PE | S/-/PE | S/-/- | -/-/PE | S/-/PE | S/-/PE | S/-/- | - | -//PE | - | S/-/- | - |
| **A03** | | | - | -/-/- | S/-/- | S/-/- | - | - | - | S//PE | - | -//- | - | S/-/- | - |
| **A04** | | | | - | S/-/PE | S/-/- | -/-/PE | -/-/PE | -/-/PE | S//PE | -//PE | -//PE | - | S/-/- | - |
| **A05** | | | | | - | S/-/- | -/-/PE | S/-/PE | S/-/PE | S/-/- | - | -//PE | - | S/-/- | - |
| **A06** | | | | | | - | - | -/-/- | -/-/- | -//- | -//- | -//- | | S/-/- | - |
| **A07** | | | | | | | - | -/-/PE | -/-/PE | - | -/-/- | -/-/PE | - | - | - |
| **A08** | | | | | | | | - | S/-/PE | - | - | -//PE | - | - | - |
| **A09** | | | | | | | | | - | - | - | -//PE | - | - | - |
| **A10** | | | | | | | | | | - | - | -/-/- | - | - | - |
| **A11** | | | | | | | | | | | - | -//PE | - | - | - |
| **A12** | | | | | | | | | | | | - | - | - | - |
| **A13** | | | | | | | | | | | | | - | - | - |
| **A14** | | | | | | | | | | | | | | - | -//PE |
| **A15** | | | | | | | | | | | | | | | - |

SOURCE: Own elaboration with the following comments:
(0) When several uses may occupy the same space in different combinations, the 'exclusion' is 'partial' [PE]

The amount of interactions between scenarios/uses is very high, and a differentiating feature appears from assessments included in Alvira [2015]: *many scenarios are compatible, but it is necessary to define in which order and in what proportion/mode should they be combined,* something that notably complicates the assessment.

### 6.3 RESULTS OF THE ASSESSMENT

We seek to establish the optimum combination of above uses and that leads to three fundamental issues to address the problem:

- *It is combinatorial problem and therefore it belongs to NP complexity class*. This class does not support algorithmic [step by step] solutions other than the calculation [and individual assessment] of all possible combinations, and therefore if we would like to define what is the best possible 'finished' image of the Area [i.e., its 'optimal' state], we would have to calculate all possible combinations between above reviewed uses. Since we have posed 15 uses, and almost all have *partial exclusions*, a priori we would have to calculate all their possible combinations [approx. 32,752].
- *Many indicators' limits are fuzzy*, and are actually variable ranges of values. Its formulation has required setting defined values, which should not be considered exact borders, but sufficient approximation. This means that very small differences between two options should not be taken into account [with all the 'subjectivity' that the term 'very small differences' implies].
- *Some of the uses* we have reviewed can be implemented in different degree between 0 and 100%, and that means that strictly speaking they *can be implemented in infinite percentages* [as there are infinite points in a 1m line].

Strictly speaking, the problem cannot be solved [comparing infinite options requires infinite computation time]. But also another fundamental issue appears, we are reviewing the transformation of spaces that are largely privately owned, and therefore it is necessary to preserve some individuals' freedom of choice on the uses to be implemented.

As consequence, we do not need to establish which the 'optimum final state' of the area would be, because the only way to achieve it would be imposing it on the inhabitants [something that would be questioning its character of 'optimum solution'], but to establish a 'sufficiently' wide range of beneficial solutions 'enough' close to the best for the area, from which inhabitants can choose.

We can make a first assessment of the problem by comparing the impact of the transformation of a 'type' surface for all above uses:

### *6.3.1 ASSESSMENT TYPE SURFACE*

We evaluate each one possible use for a 10,000 m2 type surface obtaining the following results:

TABLE 6-3_ ASSESSMENT 10,000 m2 TYPE SURFACE

| | | A01_Green Extensive Roof-tops | A02_ Community Gardens | A03_ Pubic Green Areas | A04_ Outdoor Agriculture | A05_ Community Orchards | A06_ Beehives | A07_ Solar Panels Option 01 | A08_ Multi-purpose community Rooms | A09_ Swimming Pools, Solarium and Sauna | A10_ Public Facilities | A11_ Restauration Spaces | A12_ Greenhouse Agriculture | A13_ Solar Panels Option 02 | A14_ Green Slope Roofs | A15_ Cold Roofs |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ΔS≥0 | Complies | YES | YES | YES | YES | YES | YES | YES | NO | YES | YES | YES | YES | YES | YES | YES |
| | Value | 0,06 | 0,16 | 0,69 | 0,13 | 0,28 | 0,18 | 0,02 | -0,01 | 0,07 | 0,06 | 0,42 | 0,10 | 0,05 | 0,08 | 0,02 |
| Q>0,7 or ΔQ≥0 | Complies | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES |
| | Value | 0,28 | 0,68 | 3,25 | 0,28 | 1,00 | 0,00 | 0,00 | 0,02 | 0,38 | 0,26 | 0,64 | 0,08 | 0,00 | 0,37 | 0,05 |
| M>0,7 or ΔM≥0 | Complies | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES |
| | Value | 0,01 | 0,03 | 0,04 | 0,11 | 0,13 | 0,23 | 0,04 | 0,01 | 0,01 | 0,01 | 0,01 | 0,07 | 0,09 | 0,01 | 0,01 |
| E>0,7 or ΔE≥0 | Complies | YES | NO | YES | YES | YES | YES | YES | NO | NO | YES | YES | YES | YES | YES | YES |
| | Value | 0,00 | 0,00 | 0,00 | 0,04 | 0,01 | 0,24 | 0,02 | -0,06 | -0,05 | 0,01 | 0,93 | 0,15 | 0,03 | 0,00 | 0,01 |
| DI>0,75 or ΔDI≥0 | Complies | YES | NO | YES | YES | YES | YES | YES | NO | NO | YES | YES | YES | YES | YES | YES |
| | Value | 0,01 | -0,01 | 0,00 | 0,03 | 0,03 | 0,17 | 0,03 | -0,11 | -0,09 | 0,01 | 0,00 | 0,04 | 0,06 | 0,01 | 0,02 |
| CE>0,6 or ΔCE≥0 | Complies | YES | NO | NO | YES | YES | YES | YES | NO | NO | YES | YES | YES | YES | YES | YES |
| | Value | 0,01 | 0,00 | 0,00 | 0,02 | 0,02 | 0,12 | 0,02 | -0,08 | -0,06 | 0,01 | 0,00 | 0,03 | 0,04 | 0,00 | 0,01 |
| I>0,5 or ΔI≥0 | Complies | YES | NO | NO | YES | YES | YES | YES | NO | NO | NO | YES | NO | YES | YES | YES |
| | Indic. | | ID CEB | PAECB | | | | | AC ID CEB | ID CEB | PAEC | | AC | | | |
| EE<5%RD | Complies | YES | YES | YES | YES | YES | YES | NO | NO | NO | YES | YES | NO | NO | YES | YES |
| | Value (3) | 0,45 | 0,79 | 1,78 | 0,45 | 0,46 | 0,28 | 1,16 | 4,77 | 3,78 | 0,79 | 1,78 | 2,26 | 2,31 | 0,66 | 0,33 |
| | Value (4) | 4,97 | 1,24 | 2,29 | 4,95 | 0,57 | 0,01 | 7,28 | 7,52 | 9,53 | 0,90 | 0,44 | 24,67 | 7,28 | 1,11 | 0,56 |

SOURCE: Own elaboration using Meta[S] model.
(0) We highlight in red non complied criteria.
(1) All values are expressed as percentage 0-100. EE is expressed as percentage over total Available Economic Resources.
(2) We consider 3m2/beehive for A06.
(3) Type surface.
(4) We assess the whole scenario implementation.

SCENARIOS ECONOMIC FEASIBILITY

We see many strategies require using high percentage of Available Economic Resources [A01, A04, A07, A08, A09, A12, A13[XXXII]]. Temporary fractioning is the simplest solution for almost all of them, which we review below[XXXIII]:

[XXXII] From Above scenarios, high EE linked to A04 and A13 are less relevant since their implementation would have to be designed following business criteria.

- For **public buildings** rooftops uses
    - *Public Facilities.* Since the use of these roofs responds to general interest criteria and their surface/EE is reduced we do not propose their temporary fractioning.
    - *Public Green Areas.* The only available rooftop for implementing this type of use is the large Atocha Station Long Distance Terminal rooftop, whose temporary fractioning seems -a priori- inappropriate. In addition, its uniqueness makes advisable to design an intervention that enhances its urban landmark character, whose overall cost can therefore be attributed to city level. Therefore, we include its EE, but we do not consider it as being decisive.
- For **R&T&I buildings'** rooftops:
    - *Applications that require replacing current pavement.* The optimum time for their implementation is matching rooftops natural renovation periods [we consider 20/30 year period].
    - *Solar panels.* Replacing current pavement is not required, so implementation fractioning does need not coincide with roofs renovation. Given current high unsustainability in Non-Renewable Energy consumption/GHG Emissions we set a 10 years period.
- For **hospitality buildings**, given their entrepreneurship character and its moderate surface and number [3], we do not consider necessary temporary fractionation.
- For **large size light covers**, if habilitation is matched with renovation needs, cost of 'cool roofs' disappears [it is approximately the same cost than regular renovation][XXXIV], while transformation into 'green roofs' is reduced

TABLE 6-4_ ECONOMIC EFFORT FRACTIONING STRATEGIES IMPLEMENTATION

| | A01_Green Extensive Rooftops | A02_ Community Gardens | A03_ Pubic Green Areas | A04_ Outdoor Agriculture | A05_ Community Orchards | A06_ Beehives | A07_ Solar Panels Option 01 | A08_ Multi-purpose community Rooms | A09_ Pools, Solarium and Sauna | A10_ Public Facilities | A11_ Restauration Spaces | A12_ Green-house Agriculture | A13_ Solar Panels Option 02 | A14_ Green Slope Roofs | A15_ Cold Roofs |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Complies without fractioning | YES | YES | YES | YES | YES | YES | NO | NO | NO | YES | YES | NO | NO | YES | YES |
| Value | 0,45 | 0,79 | 1,78 | 0,45 | 0,46 | 0,28 | 1,16 | 4,77 | 3,78 | 0,79 | 1,78 | 2,26 | 2,31 | 0,66 | 0,33 |
| EE (1) | 4,97 | 1,24 | 2,29 | 4,95 | 0,57 | 0,01 | 7,28 | 7,52 | 9,53 | 0,90 | 0,44 | 24,67 | 7,28 | 1,11 | 0,56 |
| Implementation period | 25 | 25 | 1 | 25 | 25 | 1 (4) | 10 | 25 | 25 | 1 | 1 | 25 | 10 | 25 | 25 |
| EE (2) | 0,20 | 0,05 | 2,29 | 0,20 | 0,02 | 0,01 | 0,73 | 0,30 | 0,38 | 0,90 | 0,44 | 0,99 | 0,73 | 0,04 | 0,02 |
| Complies Fractioning | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES |

SOURCE: Own elaboration with the following notes:

(1) EE without fractioning implementation
(2) EE fractioning the implementation according to considered period.
(3) We have considered LC=25 years for all roofs [even though gardened solutions are expected to have much longer life]
(4) Its small EE leads us to not propose fractioning implementation even though it would actually be interesting to do so, given the lack of experience on this issue in Spanish cities.

We see fractioning implementation allows for all scenarios bringing their Economic Effort below proposed limit [5% Available Economic Resources]. Let us now review compliance with rest of criteria.

[XXXIII] In order to optimize effort, we review all strategies, since it is possible the chosen scenario is a combination including strategies that individually are lower than EE limit, yet they as a whole surpass the limits!

[XXXIV] We do not assess for herein analysis [due to lack of data/difficulty] the greater need for maintenance [specially cleaning] required in order to maintain light colors.

COMPLIANCE WITH REST OF URBAN TRANSFORMATION APPROVAL CRITERIA

Despite the implementation fractioning, several strategies breach multiple approval criteria, being necessary individually reviewing such breaches:

- **A02 [Community gardens]:** it implies a reduction of E, ID [Economic Sustainability, Income Distribution] since it increases the Cost of Life, and of CEB [reduction of the sustainability of Citizens Economic Burden].
- **A03 [Public Green Areas]:** it implies a reduction of PAEB [sustainability of Public Administration Economic Burden] which we consider acceptable given its reduced value [- 0.1%].

Both breaches are related to the economic cost of rooftops transformation making it convenient to review an already commented option. **Productive/edible gardening** allows garden areas to generate economic benefits without increasing their implementation cost or requiring additional space. If we re-assess both scenarios whereas productive/edible gardening, we obtain the following values:

TABLE 6-5_ GARDENED AREAS SCENARIOS: PRODUCTIVE vs NON PRODUCTIVE GARDENING

| | | NON PRODUCTIVE GARDENING | | PRODUCTIVE/EDIBLE GARDENING | |
|---|---|---|---|---|---|
| | | A02_Community Garden Rooftops | A03_Public Green Areas | A02_ Community Garden Rooftops (2) | A03_ Public Green Areas |
| ΔS≥0 | Complies | YES | YES | YES | YES |
| | Variation | 0,16% | 0,69% | 0,16% | 0,70% |
| Q>0,7 o ΔQ≥0 | Complies | YES | YES | YES | YES |
| | Variation | 0,68% | 3,25% | 0,68% | 3,25% |
| M>0,7 o ΔM≥0 | Complies | YES | YES | YES | YES |
| | Variation | 0,03% | 0,04% | 0,03% | 0,04% |
| E>0,7 o ΔE≥0 | Complies | NO | YES | YES | YES |
| | Variation | 0,00% | 0,00% | 0,01% | 0,02% |
| ID>0,7 o ΔID≥0 | Complies | NO | YES | YES | YES |
| | Variation | -0,01% | 0,00% | 0,00% | 0,02% |
| EB>0,6 o ΔEB≥0 | Complies | NO | NO | YES | YES |
| | Variation | 0,00% | 0,00% | 0,00% | 0,01% |
| I>0,5 o ΔI≥0 | Complies | NO | NO | YES | NO |
| | Breaches | ID<br>CEB | PAEB | | CEP |
| EE<5%RD | Complies | YES | YES | YES | YES |
| | Value (3) | 0,79% | 1,78% | 0,79% | 1,78% |
| | Value (4) | 1,24% | 2,29% | 1,24% | 2,28% |

SOURCE: Own calculation using Meta[S] model

(1) Productive gardening is linked to the origins of gardens, and has left great examples in Spain throughout history [e.g., the Alhambra…]. In USA it has been greatly encouraged in the works of Rosalind Creasy [e.g., "Edible Landscaping"].

(2) Productive gardening should not necessarily be managed by own occupants of the building. For example, companies could be created that provide maintenance of landscaped spaces in Exchange for holding their production.

A02 meets now all approval criteria, while A03 improves on many parameters. Therefore, in both cases, we consider productive/edible gardening.

The following two uses that violate several projects approval criteria are:

- **A08 [Community Rooms]:** it implies a reduction of S, E, ID [it increases the cost of the life] and CEB [-0.2%]. Therefore, we discarded the interest of promoting it from the Public Administration. In some cases it may be acceptable as individual initiative, yet its impact on AC required fulfilling alignment/setbacks conditions, architectural project and urban license in all cases.
- **A09 [Pool, Sauna, Solarium]:** it implies a reduction of E, ID [the Cost of Living rises] and CEB [-0.2%]. Therefore, we also discard promoting it from the Public Administration. However, it meets the ΔS≥0 criterion so it is acceptable as individual initiative. From the three proposed

uses, 'solarium' use presents lower reduction of the indicators, so it may be individually developed or integrated into Community Gardens.

Noteworthy, in both cases the most important breached criteria is economic. If they were implemented widespread in the Area, its currently not-so-high economic Sustainability would even further reduce. But this situation may change in the future reducing thus current importance of these transformations' negative impact on E/ID and CEB[XXXV].

Therefore, to preserve individual freedom, in the overall scenario that we asses we leave a vacant space in each building as provision in case neighbors' communities may want to implement any of them in the future.

The following two uses violating one approval criterion each are:

- **A10 [Public Facilities public]:** it implies a decrease of the sustainability of Public Administration Economic Burden acceptable given its reduced value [-0.1%].
- **A12 [intensive agriculture]:** it implies an increase of the Area's Compactness [ΔAC=0.4%]. Since it meets all the other projects' approval criteria, it can be acceptable in some cases. It is to be required fulfilling alignment/setbacks conditions, architectural project and urban license in all cases.

Therefore, of all assessed uses/scenarios, A08/A09 scenarios stand a priori as non-acceptable and we exclude them for the rest of the analysis. A12 scenario/use will require individual project and license and A02/A03 scenarios/uses considerably benefit of productive landscaping.

SUSTAINABILITY INCREASE MAXIMIZATION

We arrange scenarios according to proposed evaluation criteria [maximum Sustainability increase, more balanced dimensions' values and smaller Economic Effort, EE].

TABLE 6-5_ TYPE SURFACE: PREFERENCE ORDERING

| | | A03_ Pubic Green Areas | A11_ Restoration Spaces | A05_ Community Orchards | A06_ Beehives | A02_ Community Gardens | A04_ Outdoor Agriculture | A12_ Green-house Agriculture | A14_ Green Slope Roofs | A09_ Pools, Solarium and Sauna | A10_ Public Facilities | A01_Green Extensive Roof-tops | A13_ Solar Panels Option 02 | A07_ Solar Panels Option 01 | A15_ Cold Roofs | A08_ Multipurpose com-munity Rooms |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SURFACE | | 12.825 | 2.481 | 12.600 | 234 | 15.750 | 109.343 | 109.343 | 16.807 | 25.200 | 11.435 | 109.343 | 31.500 | 63.000 | 16.807 | 15.750 |
| ΔS | | 0,70 | 0,42 | 0,28 | 0,18 | 0,16 | 0,13 | 0,10 | 0,08 | 0,07 | 0,06 | 0,06 | 0,05 | 0,02 | 0,02 | -0,01 |
| ΔQ | | 3,25 | 0,64 | 1,00 | 0,00 | 0,68 | 0,28 | 0,08 | 0,37 | 0,38 | 0,26 | 0,28 | 0,00 | 0,00 | 0,05 | 0,02 |
| ΔM | | 0,04 | 0,01 | 0,13 | 0,23 | 0,03 | 0,11 | 0,07 | 0,01 | 0,01 | 0,01 | 0,01 | 0,09 | 0,04 | 0,01 | 0,01 |
| ΔE | | 0,02 | 0,93 | 0,01 | 0,24 | 0,01 | 0,04 | 0,15 | 0,00 | -0,05 | 0,01 | 0,00 | 0,03 | 0,02 | 0,01 | -0,06 |
| ΔDI | | 0,02 | 0,00 | 0,03 | 0,17 | 0,00 | 0,03 | 0,04 | 0,01 | -0,09 | 0,01 | 0,01 | 0,06 | 0,03 | 0,02 | -0,11 |
| ΔCE | | 0,01 | 0,00 | 0,02 | 0,12 | 0,00 | 0,02 | 0,03 | 0,00 | -0,06 | 0,01 | 0,01 | 0,04 | 0,02 | 0,01 | -0,08 |
| I>0,5 o ΔI≥0 | | NO | SI | SI | SI | SI | SI | NO | SI | NO | NO | SI | SI | SI | SI | NO |
| | | CEP | | | | | | CC | | DI CEH | CEP | | | | | CC DI CEH |
| EE | (2) | 1,78 | 1,78 | 0,46 | 0,28 | 0,79 | 0,45 | 2,26 | 0,66 | 3,78 | 0,79 | 0,45 | 2,31 | 1,16 | 0,33 | 4,77 |
| | (3) | 2,28 | 0,44 | 0,02 | 0,01 | 0,05 | 0,20 | 0,99 | 0,04 | 0,38 | 0,90 | 0,20 | 0,73 | 0,73 | 0,02 | 0,30 |
| Dev. | (4.a) | 0,183 | 0,169 | 0,172 | 0,169 | 0,172 | 0,174 | 0,170 | 0,171 | 0,172 | 0,170 | 0,179 | 0,167 | 0,168 | 0,169 | 0,169 |
| | (4.b) | 3,360 | 2,868 | 2,969 | 2,842 | 2,962 | 3,031 | 2,878 | 2,915 | 2,950 | 2,876 | 3,204 | 2,802 | 2,811 | 2,851 | 2,841 |

SOURCE: Own calculations using Meta[S] model

[XXXV] As hidden 'risks' of implementing these uses still remains they could lead to a certain loss of the 'shared' character of Public Green Areas, if some inhabitants stop using them, and to certain inhabitants polarization [since only those with greater income could implement them, public space could be relegated to lower income users], and increase houses value resulting in a 'gentrification' of the Area.

(1) All values are expresses as percentage 0-100. Economic Effort, EE is expressed as percentage over total Available Economic Resources.
(2) EE Type Surface
(3) EE Whole Scenario considering fractioning implementation above indicated
(4) Being equal ΔS value [and therefore S2 value], scenarios that present less deviation between dimensions are preferable. To assess deviation, any statistical deviation measure [e.g., standard deviation, criterion 4A] can be used. Alternatively, we subtract S value to the arithmetic mean of the values Q, M, and E [criterion 4B]. Both criteria orderings necessarily match.

Above Table allows us to see some interesting issues:

The first is that *more frequently present options in the Sustainability discourse - A01 [extensive green rooftops] and A07 [solar panels] scenarios- arise lower collective benefit/preference than numerous options usually not included in such discourse*:

- A01 is generally less collectively preferred than uses incorporating productive vegetation.
- A07 is generally less collectively preferred than almost any other possible rooftops use, and since similar results can be achieved using others roof surfaces [A13], we discard it as option for the rest of the analysis.

The second is that *there are several scenarios for which net benefit –as Sustainability- maximization criterion [ΔS] is not enough to determine the preference, being necessary reviewing additional criteria:*

- A10 [Public Facilities public] and A01 [extensive green roofs] scenarios have both ΔS=0.06%. We assign higher preference to A10 than to A01 due to greater dimensions' balance in the final State [0,170 vs 0,179].
- A07 [Solar Panels option 01] and A15 [Cold Roofs] scenarios have both ΔS=0.02%[XXXVI]. The deviation between dimensions is virtually identical [A07=0.168 vs A15=0.169], but the Economic Effort needed to implement A07 is much greater than for A15.

Therefore all strategies/scenarios are ordered following the approval criteria: Net Benefit /Sustainability Increase [ΔS]; balance in final State [Q, M, and E more similar values] and [EE] Economic Effort/feasibility. This allows us to establish the following *preference ordering* among the different possible use for each type of space:

TABLE 6-6_PREFERENCE ORDERING BETWEEN USES FOR EACH BUILDING TYPE

<table>
<tr><th></th><th>ΔS</th><th></th><th>ALL BUILDINGS</th><th>PUBLIC BUILDINGS</th><th>HOTELS</th><th>R&T&I BUILDINGS</th><th>LARGE SIZE LIGHT DECKS</th></tr>
<tr><td>01</td><td>0,70</td><td>A03</td><td></td><td>Public Green Areas (1)</td><td></td><td></td><td></td></tr>
<tr><td>02</td><td>0,42</td><td>A11</td><td></td><td></td><td>Restaurant and Leisure Spaces</td><td></td><td></td></tr>
<tr><td>03</td><td>0,28</td><td>A05</td><td></td><td></td><td></td><td>Community Orchards (2)</td><td></td></tr>
<tr><td>04</td><td>0,18</td><td>A06</td><td colspan="4">Beehives</td><td></td></tr>
<tr><td>05</td><td>0,16</td><td>A02</td><td></td><td></td><td></td><td>Community Gardens (3)</td><td></td></tr>
<tr><td>06</td><td>0,13</td><td>A04</td><td></td><td></td><td colspan="2">Outdoor Agriculture (4)</td><td></td></tr>
<tr><td>07</td><td>0,10</td><td>A12</td><td></td><td></td><td colspan="2">Greenhouse Agriculture</td><td></td></tr>
<tr><td>08</td><td>0,08</td><td>A14</td><td></td><td></td><td></td><td></td><td>Green Decks</td></tr>
<tr><td>09</td><td>0,07</td><td>A09</td><td></td><td></td><td></td><td>Pools, solarium, sauna</td><td></td></tr>
<tr><td rowspan="2">10</td><td rowspan="2">0,06</td><td>A10</td><td></td><td>Public Facilities</td><td></td><td></td><td></td></tr>
<tr><td>A01</td><td colspan="4">Extensive Green Roofs</td><td></td></tr>
<tr><td>11</td><td>0,05</td><td>A13</td><td></td><td></td><td></td><td>Solar Panels Option 02</td><td></td></tr>
<tr><td rowspan="2">12</td><td rowspan="2">0,02</td><td>A15</td><td></td><td></td><td></td><td></td><td>Cold Roofs</td></tr>
<tr><td>A07</td><td colspan="4">Solar Panels Option 01</td><td></td></tr>
</table>

SOURCE: Own elaboration with the following comments:
(0) We exclude A08 for above commented reasons.

[XXXVI] Although they do not compete for the same space, we may have to choose between the two due to scarcity of economic resources

(1) Only Atocha Station Long Distance Terminal can be adapted to this use, so it does not compete with A10 for the rest of Public Buildings.
(2) It occupies only 40m2, so it is compatible with A0 and A02.
(3) It only occupies 50m2, so from the 300 m2 average R&T&I rooftop, approx. 210m2 remain available.
(4) It is the first use that can occupy all the remaining available space in R&T&I

This preference ordering allows us to see several issues:

Preferred Rooftops' uses are the following:

- Preference ordering for **public buildings** is:
  - First, *Public Green Areas*, which can only be located on Atocha Long Distance Terminal roof.
  - second [though quite far back] *Public Facilities*
- However, for the rest of buildings the ordering is more difficult to establish, because even if there is a clear collective preference ordering, they are private spaces in which owners must maintain some capacity to choose between those uses acceptable for the city.
- For **Hotel/restoration buildings**, the preference is the *hospitality/restoration use* so employment is generated and HIE is reduced following above explained design solutions. Alternatively, *Outdoor Irrigated Agriculture*, sometimes *Greenhouse Agriculture*, *Extensive Green Roofs* and *Solar Panels* uses would also be beneficial for the city/urban area.
- For **R&T&I buildings**, the preference is *Community Orchards + Community Gardens + Outdoor Irrigated Agriculture*. Alternatively, *Greenhouse Agriculture, Pool-Solarium-Sauna, Extensive Green Roofs* and *Solar Panels* are in some instances admissible.

In **sloping roofs**, Area's high Compactness makes preferable Green Roofs [0.08] to Cold Roofs treatment [0.02], even though both are admissible.

Finally, the comparison between Solar Panels Option 01 [rooftops] and Option 02 [slope roofs facing South, lift/stairs roofs and canopies], shows Option 02 is preferable to Option 01 [0.05 vs 0.02]. This preference adds up to the fact that Option 02 allows allocating rooftop surfaces to other more preferred scenarios/uses.

Above preference ordering provides an approximation to the expected impact of different uses on Urban Sustainability, however, two issues complicate the process:

The first is that the *assessment refers to impact on current situation, but as we implemented each of the possible uses, 'current status' would modify and it would be possible that at some point the preference ordering changes*[XXXVII].

For example, it maybe that A14 [Green Roofs] is preferred to A15 [Cold Roofs] due to current Area's naturalized spaces scarcity, but if we implement each scenario following above ordering, when we arrive at 08 place [A14] we already would have enabled a large Public Green Area on Atocha station rooftop [25,000m2 of which 12,500m2 we assign to Palos de Moguer], 15,750m2 Community Gar-

[XXXVII] If we linearly increased the surface of any use which implementation improves the value of certain indicators, obtained sustainability increase shows decreasing marginality. A use which is now preferred to others, may cease to be so when we introduce it in large quantity. It relates to the utility diminishing marginality and the progressive reduction of replacement cost.

dens, 12,600m2 Community Orchards, and 45,000m2 Outdoor Agriculture. Therefore, the Area would be having a noticeable provision of naturalized spaces so it would be likely that lower Economic Effort of Cold Roofs makes them preferable in order to preserve Citizens' Economic Capacity.

And the second is that *it does not seem appropriate imposing inhabitants to implement certain use [or combination of uses] in their private space.* Once uses with negative impact for the city/urban area are excluded[XXXVIII], citizens/owners should be free to choose among remaining uses.

For example, a Hotel company can decide they have sufficient common gardened areas in their facilities or a good Garden on the ground floor, and prefer using their roof differently to A11.

In the case of collective housing buildings, rooftop surface is split between 315 buildings [approx. 50% of the buildings in the Area], and -if we assume their property does it similarly- it involves almost 14,000 inhabit/315 neighbors communities. It is clear each neighbors' community may have different preferences and if these preferences do not imply negative impact for the Area/city, they should be a priori accepted.

We therefore have a problem whose [even simplified] resolution implies high computation effort while providing little interest because the only way to achieve the 'optimum state' for the area would be eliminating individual freedom to choose in the range of possible uses. If we respect individual freedom, there are many possible combinations whose assessment provides little utility since all of them are acceptable.

Therefore, the process we follow is formulating an overall scenario E00' which corresponds to the situation the Area would reach if above uses/scenarios are implemented following described preference ordering: E00+A03+A11+A05+A06+A02+A04+A14+A13. This will allow us to estimate the potential that intervention on Area's rooftops presents as a means to increase its sustainability.

Given that A08 and A09 uses tend to be 'desirable' for the inhabitants, and could become interesting in the future if economic situation improves, we leave an unused average area in provision, equivalent to 50% of R&T&I buildings with rooftop enabling a Community Multipurpose room and the other 50% enabling an Pool-Solarium-Sauna area [total 65m$^2$/Bldg. unused space].

[XXXVIII] For example, uses that increase Compactness or worse some streets profiles.

## 6.4 MOST PREFERRED SCENARIO

We arrive to a most preferred scenario E00' which is:

E00+A03+A11+A05+A06+A02+A04 +A14+A13

The assessment of this scenario provides the following results:

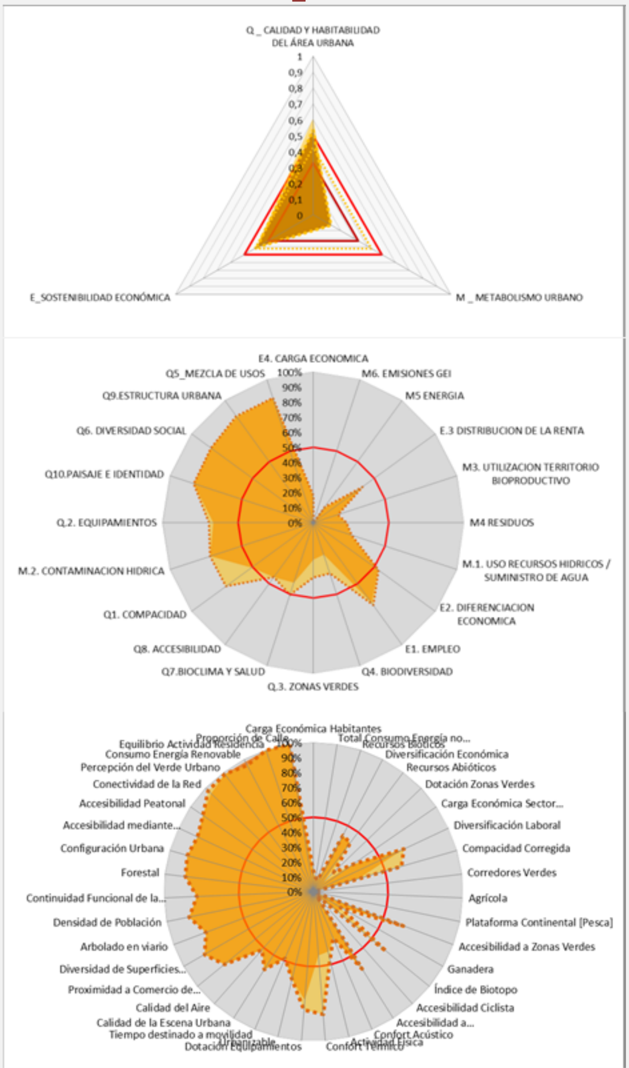
TABLE 6-7_ ESTIMATED IMPACT OF MOST PREFERRED SCENARIO

| | E00_BUSSINESS AS USUAL | E00'_ MOST PREFERRED SCENARIO | |
|---|---|---|---|
| | Value | Value | Variation |
| **Q _ QUALITY AND HABITABILITY OF URBAN AREA** | 53,3% | 61,3% | 8,0% |
| Q1. COMPACTNESS | 50,7% | 71,8% | 21,1% |
| Population Density, PD | 85,0% | - | 0,0% |
| Adjusted Compactness, AC | 31,0% | 61,4% | 30,4% |
| Q.2. PUBLIC FACILITIES | 66,5% | 69,3% | 2,9% |
| Public Facilities Provision, PFP | 72,6% | 79,3% | 6,7% |
| Local Public Facilities Accessibility, LPFA | 61,0% | - | 0,0% |
| Q.3. GREEN AREAS | 24,6% | 36,4% | 11,8% |
| Green Areas Provision, GAP | 9,6% | 18,8% | 9,2% |
| Green Areas Accessibility, GAA | 46,3% | 64,4% | 18,1% |
| Q4. BIODIVERSITY | 22,3% | 35,4% | 13,2% |
| Biotope Factor, BF | 21,4% | 63,0% | 41,6% |
| Street Trees, ST | 76,9% | - | 0,0% |
| Green Corridors, GC | 0,0% | - | 0,0% |
| Q5_MIXED USE | 87,1% | - | 0,0% |
| Economic Activities/ Housing Balance, EB | 100,0% | - | 0,0% |
| Proximity to Local Shops, PLS | 76,8% | - | 0,0% |
| Q6. HOUSING DIVERSITY | 84,2% | - | 0,0% |
| Housing Typologies/Surface diversity , HTD | 84,2% | - | 0,0% |
| Housing cost diversity, HCD | - | - | 0,0% |
| Q7.BIO-CLIME AND HEALTH | 41,9% | 52,9% | 11,0% |
| Air Quality, AQ | 51,9% | - | 0,0% |
| Acoustic comfort, AC | 33,6% | 41,1% | 7,5% |
| Thermal Comfort, TC | 42,6% | 82,2% | 39,6% |
| Physical activity, PA | 41,2% | 46,6% | 5,4% |
| Q8. ACCESSIBILITY | 44,7% | - | 0,0% |
| Pedestrians Accessibility, PA | 90,0% | - | 0,0% |
| Cyclists Accessibility, CA | 3,3% | - | 0,0% |
| Access to Public Transportation, APT | 85,9% | - | 0,0% |
| Commuting Time, CT | 48,4% | - | 0,0% |
| Q9.URBAN STRUCTURE | 86,6% | 87,3% | 0,7% |
| Streets Functionality, SF | 78,1% | - | 0,0% |
| Network Connectivity , NC | 95,1% | 97,8% | 2,7% |
| Urban Configuration, UC | 87,9% | - | 0,0% |
| Q10.CITYSCAPE AND IDENTITY | 83,6% | - | 0,0% |
| Street Profile, SP | 100,0% | - | 0,0% |
| Urban Scenery Quality, USQ | 50,8% | - | 0,0% |
| Urban Greenery Perception , UGP | 98,7% | - | 0,0% |
| **M _ URBAN METABOLISM** | 13,0% | 14,1% | 1,2% |
| M.1. USE OF WATER, UW | 25,8% | 26,7% | 0,8% |
| M.2. WATER POLLUTION, WP | 72,0% | 72,1% | 0,1% |
| M3. USE OF BIOPRODUCTIVE LAND, UPL | 16,6% | 17,1% | 0,5% |
| Crop Land, CLB | 0,0% | 1,6% | 4,4% |
| Grazing Land, GLB | 20,9% | - | 0,0% |
| Forest Land, FLB | 86,5% | - | 0,0% |
| Fishing Ground, FGB | 0,0% | - | 0,0% |
| Built up Land, BLB | 60,2% | - | 0,0% |
| M4 WASTE | 21,9% | 26,7% | 4,8% |
| Biotic Resources, BR | 8,2% | 15,7% | 7,4% |
| Abiotic Resources, AR | 41,0% | - | 0,0% |
| M5 ENERGY | 11,7% | 12,9% | 1,2% |
| Total Non-Renewable Energy Consumption, NRE | 9,3% | 9,7% | 0,4% |
| Renewable Energy Consumption, RE | 98,3% | 95,7% | -2,6% |
| M6. GHG EMISSIONS | 0,0% | 0,0% | 4,7% |
| **E_ ECONOMIC SUSTAINABILITY** | 40,9% | 41,5% | 0,6% |
| E1. EMPLOYMENT, EM | 65,7% | 67,8% | 2,1% |

| | | | |
|---|---|---|---|
| E2. ECONOMIC DIFFERENTIATION, ED | 53,0% | 53,4% | 0,5% |
| Labor Differentiation, LD | 66,3% | 67,0% | 0,7% |
| Economic Activity Differentiation, EAD | 42,5% | 42,8% | 0,3% |
| E.3 INCOME DISTRIBUTION, ID | 39,9% | 40,3% | 0,4% |
| E4. ECONOMIC BURDEN | 17,7% | 18,0% | 0,3% |
| Public Administration Economic Burden, PAEB | 32,6% | 32,8% | 0,2% |
| Citizens Economic Burden, CEB | 13,5% | 13,9% | 0,3% |
| **S_ SUSTAINABILITY DEGREE** | 32,9% | 35,2% | 2,4% |
| SOURCE: Own calculations using Meta[S] model. | | | |

Alternatively, we can graphically revise the foreseeable impact of the proposed transformation:

TABLE 6-8_ GRAPHIC ANALYSIS OF EXPECT IMPACT OF E00' IMPLEMENTATION




***Levels 1 2 indicators***

*In dark brown we represent Area's current state, and light Brown E00'. Red color is the threshold value which implies greater membership to Unsustainability than to Sustainability class.*

*The impact of the transformation focuses in Q Dimension, showing very small improvements in M and E dimensions.*

**Level 3 indicators**

*The main benefits would be reducing Compactness, increasing Green and Biodiversity Areas, and Bio-Clime & Health improvement.*

*The red line marks the 50% value, and we see that despite the transformation, almost half of the indicators remain below it.*

***Level 4 indicators***

*Most significant benefits would be Green Areas Provision improvement, Compactness reduction, Thermal Comfort improvement [reduction of the Heat Island Effect] and a predictable increase in the Physical activity of Area's inhabitants.*

SOURCE: Own elaboration using Meta[S] model.

(0) Red line marks the 50% value, threshold below which an indicator implies greater Unsustainability than Sustainability.

If we revise it in relation to building uses, we have the following preferred applications:

**R&T&I Rooftops.** The choosing order for uses for building the global scenario E00' is: A05 [40m$^2$], A02 [50m$^2$], A04 [rest - 160m2/Bldg.]. 65 m2/Bldg. are left unused with SRI≥75 [Roof Cold treatment] to enable future implementation of A08/A09 uses by inhabitants. A13 is to be implemented in 'Other usable deck surfaces'.

**Hotel roofs.** All available space is to be used as *A11 Restoration and Health Areas.* If some surfaces remain unused [for example, a roof on a level not accessible by the public], the optimum use would be A04 [it occupies the entire surface] and lastly A01.

**Buildings Public Rooftops:**

- For Atocha Long Distance Terminal rooftop, *A03_ Public Green Area*
- For other Public Buildings, *A10_ Public Facilities*.

For **Large Size Light Roofs** A14 stands as most beneficial use [it occupies the entire surface].

**Beekeeping** occupies little space and has synergies positive with the vegetation, so we consider it suitable in all cases, being municipal license required in all cases.

## 7 CONCLUSIONS

For greater clarity, we structure the conclusions in two sections;

- First we summarize the most relevant issues that can be drawn from the estimation of rooftops' transformation expected impact on our cities.
- Secondly, we summarize some issues the assessment suggests it is interesting to regulate through legislation.

### 7.1 SOME RELEVANT ISSUES DEDUCED FROM THE ANALYSIS

The analysis has provided us with an estimate of the appreciable beneficial impact [i.e., Sustainability increase] we could achieve by transforming currently available rooftop spaces in our urban areas. But it has also allowed us to see some issues that deviate from nowadays most widely accepted ideas:

- The first is that *the most beneficial uses for each urban area depend on its specific situation.* Therefore they are not a priori eligible without detailed study of each area status, setting intervention priorities and reviewing the surface and characteristics of its available rooftops. *We can't state that one or another use are the best rooftop uses in all cities, and even analysis can lead us to different preference orderings for different morphological areas within a city.*
- The second is that in the reviewed area, the two most frequently mentioned uses in the Sustainability discourse -Extensive Green Roofs and Solar Panel installation- generate much smaller collective benefit than transformations that incorporate some activity.

This second issue advances us that in many contexts uses involving some activity in rooftop spaces lead to higher urban sustainability increase. For this reason we have designated this project as 'Haz[otea]'[xxxix] that refers to *rooftops positive impact maximization is usually achieved when some type of activity is added to its most oldest function [looking out].*

Likewise, assessment allows us to appreciate two very important issues:

[xxxix] In Spanish, *Haz* from *Hacer* meaning 'to do' and *Otea* from *Otear* meaning 'to look out'

- Deviation between dimensions' values in starting situation E00 [Area's current status] is smaller than in any of assessed final scenarios. This is because *improvement does not equally split between all Dimensions*, concentrating much on Dimension Q, less in the Dimension M and little in Dimension E.
- The results of the analysis show that *transformation is beneficial for the Area/City, but its impact prioritize dimensions in Q/M/E ordering, departing thus from intervention priority detected for the area which is M/E/Q.*

We therefore have an urban transformation whose foreseeable effects would be good, but which does not fully respond to Area`s priorities. And it is interesting to review some complementary issues:

The first is that **Q Dimension** *corresponds largely to the Development concept as it is commonly used nowadays, so it* **is a parameter that** *[in absolute not percentage terms]* **can indefinitely grow**. The situation we now consider being optimal for our cities will necessarily be different [and generally implying more variables and higher values] in the future.

This forces us to bear in mind a danger of urban transformations that above all increase Q value. Societies tend to increase their expectations regarding cities' quality and livability [Q Dimension]. This could lead to indefinitely increase of Q dimension objectives so we would never intervene on the M and E Dimensions[XL].

The second is **the fact that improvement focuses on Q Dimension and relatively little affects M and E dimensions** collides with one of the main arguments in favor of urban rooftops transformation, which is NRE consumption reduction. The assessment shows that, given current developed countries urban systems high environmental unsustainability, transforming roofs has a reduced capacity of approaching urban metabolism to sustainability situations.

According to herein reviewed data, *the hope deposited in rooftop transformation for reducing cities' environmental unsustainability seems clearly excessive.* Reducing current cities economic and metabolism unsustainability requires that rooftop transformation is accompanied by other strategies that focus their impact on M & E Dimensions.

However, we see a remarkable ability to improve urban quality and livability, and many authors [Rueda, Frey, Farina,...] agree that increasing open gardened spaces in cities indirectly reduces their inhabitants' pressure on the environment [reducing second residence demand, sprawl and trips...]. In this sense, the large surface of vegetated areas the proposal includes [approx. 40,000m$^2$] allows us to think part of the resulting Environmental Sustainability increase would be indirect[XLI].

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[XL] In our view, this is the most fundamental reason for the unsustainability of our current Development model.

[XLI] "Greenery vastly increases the desirability and livability of cities, which ultimately counteracts the impulse towards sprawl. Putting numbers to these effects would be extremely useful" [Kerr & Yao 2004, p.6 in DDC, 2007, p. 67]. The absence of data in this aspects prevents us from currently propose an estimation of this possible impact [it is not valued in the present study]. Development and future evaluation of integrated intervention in urban areas could provide data that allow establish correlations between both issues.

The third is that **Q and E Dimensions evaluate the variables which largely inform us of cities' desirability,** and this means that a transformation with a high increase in some of them [better if it is both of them] will be a transformation largely 'desired' by the inhabitants.

If we relate this to the second commented issue, we see that acting on rooftops can accompany other urban transformations so their joint implementation has greater impact on the M and E Dimensions, providing a high desirability component.

The fourth and last issue is that **most roof [rooftops or other usable surfaces] uses involve very high Economic Effort**, and try to implement them in small periods of time could put at risk the economic sustainability of most urban areas[XLII]. In this sense, herein analysis shows us two important issues for reducing the Economic Effort linked to these interventions:

- Matching rooftop transformations with their renovation periods reduces the Economic Effort linked to new uses implementation, since the effort implied in regular maintenance is saved.
- Foreseeing future rooftop spaces possible uses from the own construction and design of new buildings would considerably reduce the Economic Effort of their subsequent implementation[XLIII].

Additionally, the model also shows that not only economic savings linked to energy consumption reduction are important. There are other uses that could significantly reduce transformations return on investment period and even transform rooftops in income and employment generating spaces [e.g., hives, productive vegetation, urban agriculture...].

Several of the issues reviewed/discussed can be easily incorporated in Spanish regulations, making interesting to do a brief recap of the main issues we believe should be considered for rooftops normative regulation.

## 7.2 MOST RELEVANT ISSUES THAT COULD BE INCORPORATED IN REGULATIONS

Although we have already indicated the contextual character of many variables[XLIV], it is possible to advance some recommendations on issues common to the majority of cities/contexts. For clarity, we group them into three sections: admissible uses, design and construction aspects, and public grants.

### *7.2.1 POTENTIAL USES OF ROOFTOPS AND OTHER USABLE DECKS*

We have seen a procedure that allows us to define a collective preference ordering over potential rooftop uses according each Area unique characteristics, which shows the benefit that can be obtained for different uses can be very different.

[XLII] Current situation of high leverage (private and institutional) in Spain [low values PAEB/CEB], and the fact the financial savings resulting from the increase in thermal insulation imply a return on the investment higher than 5-7 years, show the difficulty of attempting a generalized rooftops habilitation.

[XLIII] Also, it eliminates the negative impact on the environment that involves building once then demolishing then building again.

[XLIV] This implies it not can be our goal proposing a 'Rooftop Code', but compiling a priori interesting issues in the Spanish context, whose fitness should be evaluated specifically for each context.

This highlights the interest that our cities' Zoning Codes also regulate in this regard[XLV], including specific regulations for private rooftops/penthouses[XLVI]:

- Limiting **uses that may have negative impacts for the urban area/city.** For example, in the assessed area, A08 and A12 uses may have negative impacts on Compactness and Street Profile. In these cases, it seems necessary architectural project proving compliance with alignment/setbacks, building conditions...
- **Encouraging**, *within the set of beneficial uses for the urban area/city,* **the most beneficial ones,** which can be done **through an appropriate grant policy** [we briefly review it at the end].

### *7.2.2 BUILDING DESIGN AND CONSTRUCTION STANDARDS*

Especially important have proven to be issues relating building design, construction and horizontal property division, whose later adaptation is always more expensive and complicated, and between which we consider Normative should regulate the following:

- **Limiting proprietary use [penthouse terraces] surface:** a reference may be to set a minimum between 30%-50% percentage of rooftop net area to be usable by all neighbors[XLVII].
- **Accessibility:** buildings' lift/stairs cores should allow accessing rooftops in the same accessibility conditions than dwellings, and must meet fire evacuation requirements for an occupation according to possible uses.
- **Structural strength**:
  - *Rooftops'* structure must be calculated to allow for gardened rooftop solutions with average 200mm thickness and overload use equal or greater than dominant building use.
  - *Sloping roofs* structure must support - at least - the superimposition of a layer of solar panels.
- **Facilities.** Rooftop spaces should be provided with at least the following facilities:
  - *A water intake, electricity outlet and lighting point.* All of them connected to common counter and if possibly one for each lift/stairs core to optimize installation.
  - *Connection to separate sewage network.*
- **Surface finishing:** the surface finishes of building covers must have the following Solar Reflection Index [SRI] to minimize Heat Island Effect[XLVIII]:

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[XLV] In order to do so, in addition to Meta[S] model proposed by the author used in this text, there are other models that can be currently used [e.g., Casbee for Cities].

[XLVI] For the assessed Area, we have measured 21,950.5 m2 of private use rooftops -penthouses-. It represents 3.41% of the surface of the area and 20% of total rooftops surface.

[XLVII] We adopt the value proposed in NYC Zoning Resolution: 15-12. Open Space Equivalent which establishes that "at least 30 of the gross area of deck area of any building containing more than 15 houses should be dedicated to recreational use [leisure]. For each additional property, must add up to 100 square feet [9.3m2], up to a maximum of 50% of the gross surface cover. This area should be accessible to all the occupants of the building and their guests"

[XLVIII] For sloping roof we adopt value from USGBC, 2009. LEED. Credit 7.2. Heat Island Effect. [Roof]. For rooftops, we adopt the value from City of los Angeles Cool Roofs Ordinance, USA.

- *Sloped roofs ≥29*
- *Rooftops ≥75*

The issues detailed in these last three conditions [structural strength, facilities and surface finishing] should also apply to private use covers/rooftops.

### *7.2.3 PUBLIC SUBSIDIES FOR ROOFTOPS ADAPTATION*

The evaluation of possible rooftop uses reveals high use of economic resources, and this leads us to briefly reviewing public subsidies as one of the main Public Administration tools for increasing the likelihood that residents implement to a greater extent most beneficial uses for the city/urban areas:

… They allow reducing transformations Economic Effort share assumed by citizens, making them accessible to low income inhabitants.
… They increase the 'desirability' of subsidized uses vs non-subsidized uses.

In both cases, Public Administration should design a grant system that fosters more collectively preferred uses [promoting their greater implantation] without endangering Public Economic Sustainability and we can relate this to the Externality concept.

Several rooftops/deck uses we have reviewed involve *positive externalities for society. In other terms, private roofs conditioning involves individual costs but generates benefits for the whole city/urban area, without individuals being -a priori/necessarily- compensated for them.* In this sense, the study allows us to review two issues:

- *It allows independently assessing monetizable and non-monetizable externalities.* If some rooftop use improves bio-clime and Thermal Comfort, it is thus a non-monetizable externality [which is valued in dimension Q], but if as a result of the above the energy consumption of nearby buildings reduces and thus their maintenance cost, this is a monetizable externality [and therefore it is valued in the Dimension E].

  And it is important to consider the different nature of both, since *economically compensating non-monetizable externalities may endanger Public Administration Economic Sustainability;* i.e., it can lead to non-sustainable grant systems.

- *It allows assessing temporal Sustainability of subsidies schemes*. To do this, we need to incorporate subsidies as public expenditure in the assessment of the scenario whose subsidies we are calculating, and we can find two limiting situations:
  - In systems with *high Economic Sustainability of Public Administration* [Public Administration Economic Burden $PAEB_2 \geq 0.6$], this allow us to review the impact of subsidies policies on the whole system, always with a maximum limit, that leading to $PAEB_2=0.6$[XLIX] value.

[XLIX] It is the maximum sustainable limit, but it not necessarily must be completely used.

- in *systems with low Economic Sustainability*, [$CEP_2$<0.6] this brings us to a 'natural' limit for such subsidies; that figure that absorbs all the economic externalities received by Public Administration as consequence of Rooftop adaptation.

We see that based on data from each scenario assessment, it is simple to propose an environmental, social and economically 'sustainable' subsidies policy:

- Progress towards *Sustainability* takes us to subsidize only those transformations that meet the project approval criteria, and to a greater extent those which most increase Area' Sustainability; i.e., whose positive effect for the urban area is greater.
- Maintaining or increasing Economic Sustainability leads us to determine subsidies so they are sustainable over time. As a simple criterion, if we include subsidies as Public Administration costs in each scenario assessment, it must continue to meet one of the following two conditions $PAEB_2 \geq 0.6$ or $\Delta PAEB \geq 0$.

The criterion proposed to establish the amount of subsidies is stricter than usually accepted by economists nowadays[L], we justify it for two reasons:

- The review of the evolution of the countries of the EU 28 in the debt crisis presents a value E≈0.6, as the threshold below which the economic vulnerability of countries is too high [Alvira, 2015. Annex]. *It does not seem acceptable to establish subsidies systems which reduce the economic resilience of countries below such threshold.*
- *A considerable group of revised uses meet this criterion* and it seems therefore unnecessary and inappropriate [sub-optimal] using a less restrictive approach.

Complementarily, the model allows us to assess at any time the impact on each type of transformations' Sustainability, establishing higher subsidies for those changes that higher increase city Sustainability when the assessment is made.

And this brings us to another important issue; most authors agree that urban reality should be monitored every 3-5 years [sometimes each year] to detect and measure deviations between forecasts and reality. Given that we have established an E00' implementation period of 25 year, the assessment will provide a periodic monitoring of the effects achieved by the transformations.

And is possible that within 3-5 years priorities/more beneficial rooftop uses are different, both due to the implementation of uses already undertaken by inhabitants, and to different transformations that can happen in the area [and even in others areas][LI]. For this reason, both Regulations and the subsi-

[L] Economist usually state that State's social role admits granting also non-monetizable externalities, but we prefer limiting it to situations where the sustainability of Public Economic Burden is high, i.e., if it meets EB2≥0.6.

[LI] We do this comment because all metabolism sustainability indicators allude to world capacity, and therefore they are also sensitive to what can happen in areas far away in the planet.

dies system must be regularly reviewed and updated, always looking for the highest possible efficiency/collective benefit.

This allows us to respect individuals' choice freedom and at the same time increase the individual desirability of options which are more beneficial for the whole society without endangering its Economic Sustainability.

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## 8.4 CARTOGRAPHY

For practical application the following sources of maps have been used:

Digital Cartography

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Cartography for the analysis has also been completed with onsite visits.

## 8.5 IMAGES, GRAPHICS AND DIAGRAMS

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# 9 ANNEXES

## 9.1 MEASURING AVAILABLE ROOFTOP SURFACE

In Palos de Moguer neighborhood there is considerable surface of currently unused rooftop. This large rooftops available area is due to several issues:

- Area's centrality has led to a great Compactness; about 65% of the Area is privately owned. Lots are highly built with services buildings in courtyards. Almost all lot's surface is built and therefore has some sort of cover/roof.
- Most buildings have been built after 1900, when flat roof is first introduced, so neighborhood buildings have been built in parallel to flat roof generalization.

We have not found data of rooftop surface, so we measure it on map.

### *9.1.1 CARTOGRAPHY USED AND DOUBLE CHECKING PROCEDURE*

We have used digital Cartography of year 1999 at 1:500 scale, obtained using Difusor program [Madrid, Gerencia Municipal de Urbanismo, GMU]. The elapsed time since cartography was prepared has made necessary updating some areas. In order to do so, we have used cadastral maps, aerial images [Google Maps] and images of Madrid city urban planning visualization web page.

Once updated the map, we have visually revised images from Google Maps/Google Earth and classified rooftops in three types: occupied by facilities, currently in use, and currently without use [available]. In some cases identification has presented some difficulty for various reasons:

- *Difficulty in some cases to visually determine whether a roof is sloped or not.*
- *In some collective housing buildings it is difficult differentiating whether roofs have private use [penthouse terraces], have any collective use or do not have any use [are available].* The criteria we used in order to do so was the presence of furniture or umbrellas and the use of adjacent terraces in a similar way [for detecting private use]; swimming pools [in the case of collective use of the roof]. In the latter case, a verification visit to the building or by calling rental ads has been undertaken.
- *Inaccuracy of mapping, since terraces flights over public space are in general not incorporated in plans.* In these cases, the actual usable area might be slightly greater than represented in plans.
- *Existence of certain amount of dispersed machinery facilities, pipes... Impossible to reliably measuring on plan.* In these cases, actual usable area will be somewhat lower than measured.

It seems therefore acceptable considering that some errors come to compensate the others, giving high [or at least, sufficient] reliability to our measurements.

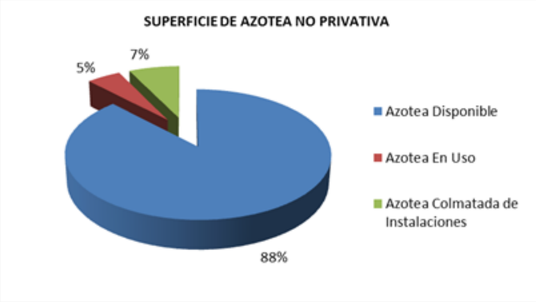
### *9.1.2 TYPE OF ROOFS CONSIDERED*

We have sought sufficiently differentiating rooftops types in order to make an optimum intervention proposal, considering the following types:

- *Rooftops highly occupied by services.* We include in this group rooftops -or large sloped roof areas- mostly occupied by building facilities. Their interest for the present study is that they could become available surfaces at some future time if facilities were refurbished[LII].
- *Rooftops currently in use.* We include in this group rooftops where we find some type of community or shared use of the space, whether public [schools, Public Facilities] or private [housing offices…]. We do not include in this group privately used penthouse terraces, or spaces for drying racks.
- *Rooftops currently available.* We include in this group completely empty rooftops or where only some scattered facilities [antennas parabolic…] appear. Some may be currently in use as common drying racks. We do not include privately used penthouse terraces. Lift/Stairs roofs are not accounted due to lack of access, except if surface is larger than 50 $m^2$, since we consider from that size surface won outweighs lost surface in order to provide access.
- *Usable light Decks.* We include in this group medium or large surface light sloping roofs. Some are occupying block yards, having considered only those with sufficient sunlight. In case their transformation is decided, structural capacity and generated thermal improvement will have to be individually assessed.

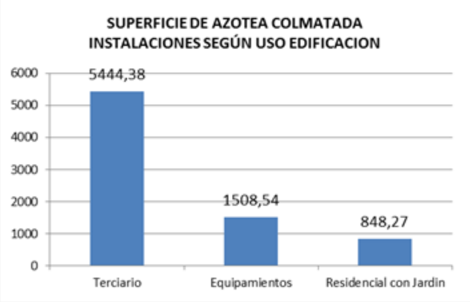
### *9.1.3 ROOFTOPS/USABLE DECKS SURFACE*

**Surface of rooftop without private use**, we find a 7% occupied by facilities [0.91 Ha], 5% currently in use [0.61 Ha], and 88% is available [11.01 Ha].




**Graphic 08: Rooftop surface without private use**. *88% of the surface is available for transformation.*

**Rooftops collapsed by facilities** locate mainly on Tertiary buildings and to a lesser extent on Public Facilities. In residential buildings we only detect some in recent promotions with garden and swimming pool.




**Graphic 09: Rooftops collapsed by facilities according to buildings use**

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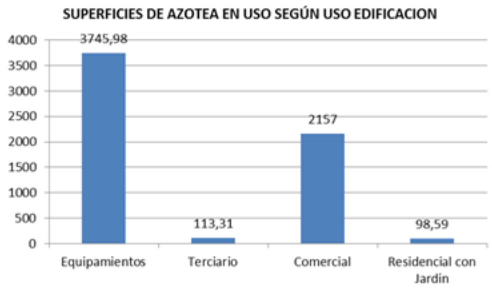
LII For example by installing district heating/cooling networks

For **currently in use Rooftops**, we find most area is occupied by sports tracks, a cars dealer/garage parking and two small community areas with solarium and pool, one located on top of an office building and the other on top of a collective housing building.




**Graphic 10: Currently in use rooftop surface according to building use** *[m2] Noteworthy, there is almost no community use in housing building, where the predominant trend/design is assigning rooftop collectively owned spaces for penthouse owners' private use [98.95m2 community use vs 21,950.5m2 private use].*

For more clarity, in order to assess/measure **available rooftop surface**, we divide the Area into three zones and number the blocks belonging to each of them:

- • *Zone 01:* bounded by the Rondas de Atocha and Valencia, Paseo Santa María de la Cabeza and Embajadores Street.
- • *Zone 02:* bounded by Paseos de las Delicias, Santa Mª de la Cabeza and Ferrocarril Street.
- • *Zone 03:* Bounded by Paseo de las Delicias, Méndez Álvaro to the North East and Bustamante Street.

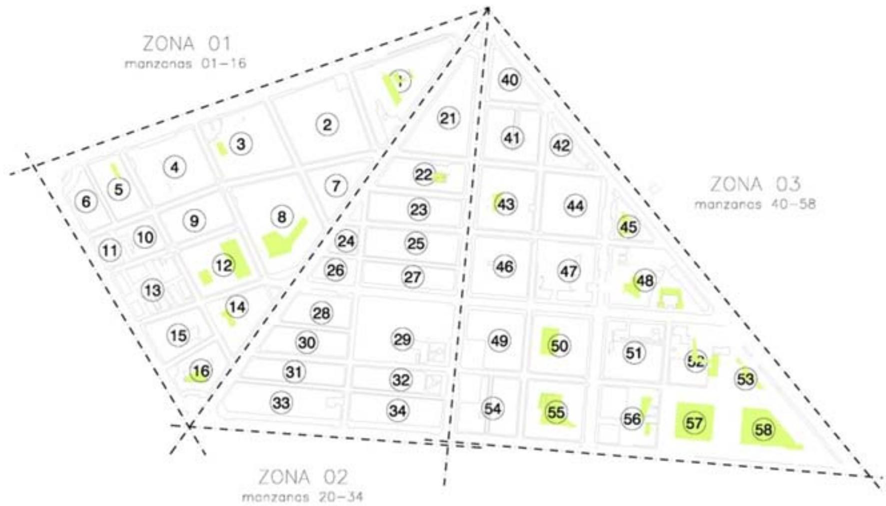



***Image 03: Codes for Zones and Blocks***

Available rooftop areas in each Zone are the following:

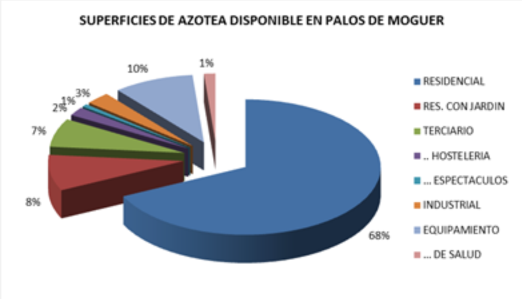
TABLE 9-1_ NUMBER OF BUILDING AND AVAILABLE ROOFTOP AREA BY ZONE AND USES

| ZONE | Number buildings with Rooftop | AVAILABLE ROOFTOP | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Housing. | Housing with community garden. (1) | Tertiary | Hotels | Entertainment | Industry | Public Facilities. | Health Facilities | Total |
| 01 | 97 | 18,075 | 2,560 | 5,311 | | | 695 | 6,465 | 481 | 33,107 |
| 02 | 122 | 29,631 | | 1,824 | 531 | | 283 | 2,009 | 0 | 34,279 |
| 03 | 126 | 27,051 | 6,881 | 373 | 1,723 | 782 | 2,267 | 2,152 | 1,012 | 41,231 |
| TOTAL [m2] | 345 | 74,758 | 9,442 | 7,509 | 2,255 | 782 | 3,247 | 10,627 | 1,494 | 108,619 |
| TOTAL [Ha] | 345 | 7.48 | 0.94 | 0.75 | 0.23 | 0.08 | 0.32 | 1.06 | 0.15 | 10.86 |

SOURCE: Own elaboration measuring on map.

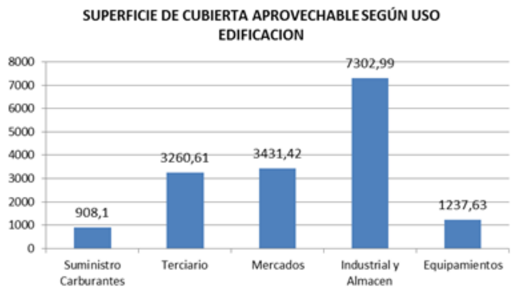
(1) We differentiate 'Collective housing with community garden' because in these buildings it may be less interesting generating rooftop community gardens.

The available rooftop surface represents 17% of total Palos de Moguer surface, being 74% of this available rooftop surface located on collective housing buildings.




***Graphic 11: Available rooftop surface according building use***

Finally, the **large extension light decks surface,** are located primarily on industrial and tertiary buildings, and on top of two district markets, being a lower percentage on top of Public Facilities and two fuel supply station.




**Graphic 12: large extension light decks surface according to building use** *We obtain a total of 2,5 Ha.*

The spatial distribution of above reviewed rooftop/decks types in the Area is as follows:

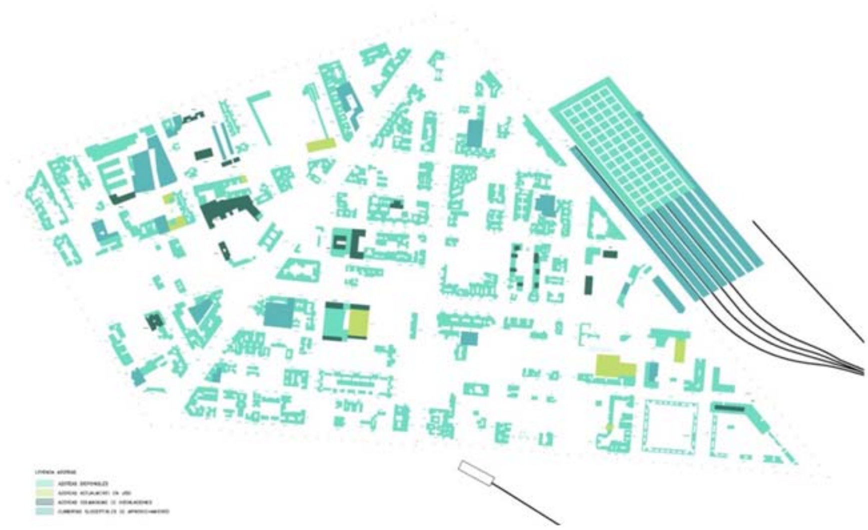


***Image 04: Currently in use, collapsed by facilities and available rooftops, and light decks.***

## 9.2 INDICATORS CALCULATION CRITERIA AND SIMPLIFICATIONS

The use of any model for assessing reality requires making many decisions regarding criteria to assess available/missing information... We include a brief summary of adopted criteria in this work.

### *9.2.1 CURRENT STATE ASSESSMENT [SCENARIO E00]*

TABLE 9-2_ ASSESSMENT CRITERIA FOR E00_ CURRENT STATE/BUSINESS AS USUAL

| **DIMEN-SION/INDICATOR** | SPECIFIC ASSESSMENT CRITERIA / CALCULATION PARAMETERS |
|---|---|
| Q _ QUALITY AND HABITABILITY OF URBAN AREA | |
| Q1. COMPACT-NESS | |
| Population Density | The area has a Gross Population Density of 432.71 inhabit/Ha |
| Adjusted Compactness | We consider the following building floor-to-floor heights:<br>• Residential 3m<br>• Non Residential 3.5m<br>We have made an estimate of average lot built surface percentage in the Area obtaining a 77.9% value.<br>We assign incidence level to each space type following below criterion:<br>• **High incidence:** Pedestrian Streets, Avenues, Boulevards, Parks and Gardens larger than 5,000 m2<br>• **Medium Incidence:** Promenades, Parks and Gardens between 1,000 y 5,000 m2; Block yards; large squares.<br>• **Low incidence:** Wide sidewalks, Esplanades larger than 4 Ha, small squares.<br>In the perimeter we only account sidewalk on the side of the Area. |
| Q.2. PUBLIC FACILITIES | |
| Public Facilities Provision | |
| Local Public Facilities Accessibility | |
| Q.3. GREEN AREAS | |
| Green Areas Provision | Stance spaces in wide sidewalks are not accounted here since they do not have 50% gardened surface. |
| Green Areas Accessibility | Accessibility calculation has been made considering population is uniformly distributed throughout the Area [therefore, calculation has been made as surface of lots complying accessibility conditions divided by total Area surface].<br>(1) Accessibility to Green Areas larger than 10 Ha. We consider the following means of access: Walking for distances smaller than 750m. cycling or public transport for distances up to 2,000m. Public Transport for distances larger than 2,000m.<br>(2) Accessibility to Green Areas larger than 1 Ha. We consider the following means of access: Walking for distances smaller than 750 m; Cycling for distances larger than 2,000m. |
| Q4. BIODIVERSITY | |
| Biotope Factor | We set as a BAF=0.30 target value, recommended for mixed use areas more than 50%occupied by buildings. We have accounted tree grates as 1m2/tree. |
| Street trees | There are no streets in the Area with width smaller than 8 m [where it would not be necessary planting trees according to City Code]<br>For trees with width between 8-10m, it is only necessary planting trees on one side, therefore one sidewalk is not accounted |
| Green Corridors | Currently there are no green corridors in the area, since all streets have higher than accepted noise levels. From the three indicators explained in 'Green Network and Biodiversity' we have only accounted the indicator Urban Green Corridors. |
| Q5_MIXED USE | |
| Economic Activities/ Housing Balance | |
| Proximity to Local Shops | |
| Q6. HOUSING DIVERSITY | |
| Housing Typologies/Surface diversity | |
| Housing cost diversity | This indicator has been reviewed after this analysis was undertaken, in a work which will be published in 2017 [Spatial Segregation by Income in Spanish Cities]. An estimate of actual value according new indicator design is 82% vs 84% obtained with the herein used indicator. Therefore, indicator re-design does not seem to affect the result. |
| Q7.BIO-CLIME AND HEALTH | |
| Air Quality | It has been calculated as arithmetic mean of partial indicators for the following nearby stations:<br>• NO2/O3: Escuelas Aguirre, Fernández Ladreda & Méndez Álvaro<br>• PM10/PM2.5: Escuelas Aguirre & Méndez Álvaro<br>• SO2: Escuelas Aguirre. |
| Acoustic comfort | Data from Arganzuela acoustic map [2011]. According to Municipal studies, noise in the district is mainly produced by motorized traffic. |
| Thermal Comfort | We have considered the following design parameters:<br>**Pavements complying with design conditions:** Hydraulic tiles, vegetated surfaces, permeable pavements.<br>**Pavements not complying with design conditions:** Asphalt |

| | |
|---|---|
| Physical activity | Data from Encuesta Nacional de Salud 2006. http://www.ine.es/colencine/colencine_enchog_salud.htm |
| Q8. ACCESSIBILITY | |
| Pedestrians Accessibility | |
| Cyclists Accessibility | We have excluded from the assessment the number of cycles parking spaces due to calculation difficulty. |
| Access to Public Transportation | Access to bus routes has been calculated using Stop maps available at http://www.emtmadrid.es/mapaweb/emt.html<br>**Deduction due to lack of Pedestrians Accessibility:** Public transportation always implies some part of pedestrian movement, therefore we discount the percentage of buildings not complying Pedestrians Accessibility conditions [currently it is 14% of buildings].<br>**Accessibility during night time:** We account areas with Access to two or more bus lines [heading in both directions], or to a bus stop and another transportation means [metro, train or BSS]. Currently the area without night time coverage is 102.615 m2 |
| Commuting Time | |
| Q9.URBAN STRUCTURE | |
| Streets functionality | |
| Network Connectivity | |
| Urban Configuration | |
| Q10.CITYSCAPE AND IDENTITY | |
| Street Profile | |
| Urban Scenery Quality | We have considered the following parameters:<br>• Visual field height 8 m<br>• Cars average height 1,4 m<br>• Surface of trees' leaves 28 m2<br>To assess buildings condition we have used data from 2001 Building and Housing census [INE, 2001], setting the following weightings:<br>• Ruin 0,10<br>• Bad state 0,25<br>• Deficient state 0,50<br>• Good 0,90<br>If we apply it to number of buildings included in each type [12/28/116/428, respectively] we obtain a global value of 0,77 [where 0 is worst possible and 1 is optimum]. In a more detailed study it would be convenient to account each building's facade area, visual contamination… |
| Urban greenery perception | |
| M _ URBAN METABOLISM | To set Sustainability/Unsustainability limits, we have used the following criteria:<br>• Inequality admisible ratio 7:1-1,75<br>• World Population 7,350,000,000 [2015] / 8,250,000,000 [2050] |
| M.1. WATER USE | We have considered average Blue Footprint in Spain 278.95m3/inhabit/year [own calculation based on Mekonnen & Hoekstra, 2011. Appendix IX-3] |
| M.2. WATER POLLUTION | We have considered average Grey Footprint in Spain 293.55m3/inhabit/year [own calculation based on Mekonnen & Hoekstra, 2011. Appendix IX-3] |
| M3. USE OF BIOPRODUCTIVE LAND | Data for year 2011 from Global Footprint Network, 2015. Public Data Package, being the following: |
| Crop Land | Average Spain Footprint: 1.00 hag-eq |
| Grazing Land | Average Spain Footprint: 0.18 hag-eq |
| Forest Land | Average Spain Footprint: 0.21 hag-eq |
| Fishing Ground | Average Spain Footprint: 0.33 hag-eq |
| Built up Land | Average Spain Footprint: 0.06 hag-eq |
| M4 WASTE | Waste data from Madrid City Hall 2010 |
| Biotic Resources | |
| Abiotic Resources | Construction and Demolition Waste for Spain from INEbase 2015 |
| M5 ENERGY | Consumption for each Energy source has been calculated from total Spain Consumption in 2012 of 128,212,400 TEP [MARMA, 2014:334], applying ratios stated in said book.<br><br>Though current state is considered as BAU, in the period 1990-2007 energy consumption trends in Spain has experimented a sustained 3.8% yearly increase [Mendiluce & Del Rio, 2010:216 quoting European Commission]. Therefore, assumed criterion does not completely assess the foreseeable unsustainability of Spain energy consumption, which is somehow bigger. |
| Non-Renewable Energy | |
| Renewable Energy | We have considered annual consumption of energy produced by biofuels of 4,073 MWh/year [own calculation based on APPA, 2010 for year 2010]. |
| M6. GHG EMISSIONS | We have considered 7.25 TmCO2eq /inhabit/year [own calculation based on Eurostat for 2012].<br><br>We have not discounted any CO2-eq emissions percentage as being compensated [forest absorption] since we do not know which would be this figure. Therefore, actual sustainability is slightly lower.<br>However, we have not accounted the increasing emissions trend. For instance, during the 1990-2007 periods GHG emissions produced by transport have grown 89% [Mendiluce & Del Rio, 2010: 217-219]. This implies almost 5% of average annual grow, which |

| | |
|---|---|
| | takes us to think the foreseeable unsustainability in GHG emissions is in fact somehow bigger than calculations. |
| E_ ECONOMIC SUSTAINABILITY | As GDI we have considered 18,988 €/inhabit/year [Instituto de Estadística, Comunidad de Madrid, for 2009]. |
| E1. EMPLOYMENT | |
| Employment Stability | We have not valued employment stability due to lack of data. However, currently values in Spain are closer to unsustainability [30%] than to sustainability [5%] limits. |
| Unemployment rate | Data for Palos de Moguer district 31 December 2013, from Dirección General de Estadística del Ayuntamiento de Madrid [quoting INE] |
| E2. ECONOMIC DIFFERENTIATION | |
| Labor Differentiation | The size of Palos de Moguer does not allow assessing its Economic Activity in terms of Structure but of Differentiation.<br>And absence of data referred to Gross Added Value [GAV] forces us to assess it not in terms of GAV+IC [Intermediate Consumption] concentration but of number of shops ascribed to each category. It is a very big simplification so in order to provide higher consistency we modify model indicators' structure, so we jointly assess Economic Activity and Employment Differentiation. |
| Economic Activity Differentiation | |
| E.3 INCOME DISTRIBUTION | We consider Gini Coefficient value for Spain 0.34 [Eurostat, for 2011]. |
| E4. ECONOMIC BURDEN | |
| Public Administration Economic Burden | Difficulty of modelling GDP variations leads us to assess only Debt-to-Income ratio [Data from Eurostat, for Spain 2013]. The resulting value is somehow bigger [33% vs a 22%] therefore the priority of improving Area Economic Sustainability is bigger than present analysis shows. |
| Citizens Economic Burden | Data: Housing and Transportation Expenditure, and Income Distribution by quintiles from Eurostat for 2010, updated with HIPC [Access May-August 2015] |
| S_ SUSTAINABILITY DEGREE | |
| SOURCE: Own Elaboration | |

### *9.2.2 TRANSFORMATION ROOFTOP IMPACT ESTIMATION*

TABLE 9-3_ A0X SCENARIOS ASSESSMENT CRITERIA_ ROOFTOP USES SCENARIOS

| DIMENSION/INDICATOR | SPECIFIC ASSESSMENT CRITERIA / CALCULATION PARAMETERS |
|---|---|
| Q_ QUALITY AND HABITABILITY OF URBAN AREA | |
| Q1. COMPACTNESS | |
| Population Density | |
| Adjusted Compactness | We consider rooftop uses involving stance space increase mitigating space [reduce Compactness], assigning them the following 'incidence level':<br>**Community Rooftop Uses:** low incidence. It comprises:<br>• Community Gardens<br>• Community Orchards<br>• Other outdoor stance spaces [pools, solarium,..]<br>• Hotels<br>**Public Uses:** Incidence level according to area. For Atocha Station Long Distance Terminal [Surface 29,000m2], its transformation into a Green Area would imply high incidence.<br>Noteworthy, current high Area Compactness difficults rooftop use for greenhouse agriculture, since it would increase compactness. |
| Q.2. PUBLIC FACILITIES | |
| Public Facilities Provision | • We have accounted only 50% rooftops Public Facilities area, up to a maximum value of 30% optimum Public Facilities surface for the whole Area. |
| Local Public Facilities Accessibility | • We consider rooftop use as Public Facilities maintains their spatial distribution in the area, therefore Accessibility remains unchanged. |
| Q.3. GREEN AREAS | |
| Green Areas Provision | • Garden Areas on top of Public Facilities or publicly accessible buildings is accounted 100% in corresponding category. |
| Green Areas Accessibility | • - |
| Q4. BIODIVERSITY | |
| Biotope Factor | • We have considered the following Biodiversity indexes:<br>o 1 for Atocha Station Long Distance Terminal as Green Area [2.9 Ha]. |

| | |
|---|---|
| | o 0.7 for the following uses: Green Extensive Roofs, Gardened Areas [we reduce their area by 50%, since not all their Surface is gardened], Community Orchards and Outdoor Agriculture.<br>o 0.21 [30% of above] for Greenhouse Agriculture. |
| Street trees | |
| Green Corridors | Though Green and gardened roofs highly increase Street Surface complying with Biotope Factor condition, the high noise currently existing in the Area prevents any of them from fulfilling the Green Corridor condition. |
| Q5_MIXED USE | |
| Economic Activities/ Housing Balance | Though some rooftop uses imply increasing productive space, we do not account them since we think the sought balance refers to two issues impact:<br>• Of reduced inhabitants number when a high percentage of buildings is used for productive uses [urban areas which remain unused by night] what we link to the use of built space [it is therefore independent of rooftops use].<br>• Of the high number of workers when a high percentage of buildings are used for productive uses, which generates high traffic in rush hours, … The reduced ratio workers/m2 of agriculture uses assigns them scarce impact also on this issue. |
| Proximity to Local Shops | |
| Q6. HOUSING DIVERSITY | |
| Housing Typolo-gies/Surface diversity | |
| Housing cost diversity | |
| Q7.BIO-CLIME AND HEALTH | |
| Air Quality | Although the vegetation increase would probably generate an Air Quality improvement [pollutants reduction], we have not assessed this issue since we have not found data. The only contaminant which reduction we have assessed has been CO2, which is assessed under GHG emissions Indicator. |
| Acoustic comfort | The private nature of Community Gardens makes preferably not accounting them to assess improvement of Acoustic Comfort in Public Space. We only account for this indicator Public rooftop gardens [i.e., Atocha Station]. |
| Thermal Comfort | In Public and Community Rooftop Gardens we consider 50% it is gardened and the other 50% paved with materials complying SRI condi-tions.<br>In solutions incorporating Solar Panels we consider an albedo 0.15 for PV and 0.45 for thermal panels, obtaining an average albedo of 0.41 for the proposed combination of panels [12,15%/87,85% respectively]. |
| Physical activity | • We consider Community Orchards lead to an increase in Physical Activity including some citizens currently not reaching advisable levels. Since it is possible install them in 315 buildings R&T&I [53% of such type buildings], population having Access to them would be 15.019 inhabit. From this figure, we consider 1 of 10 citizens uses these spaces, being people which before did not reach WHO suggested physical activity level.<br>• We do not assign Physical activity to pools, solarium, and sauna due to diversity of factors intervening for defining a figure. |
| Q8. ACCESSI-BILITY | |
| Pedestri-ans Accessi-bility | |
| Cyclists Accessi-bility | |
| Access to Public Transpor-tation | |
| Commut-ing Time | |
| Q9.URBAN STRUCTURE | |
| Streets function-ality | |
| Network Connec-tivity | We only need to assess intervention on Atocha Station, where a good design may allow a slight increase in Palos de Moguer-Pacifico neighborhood connection. |
| Urban Configu-ration | |
| Q10.CITYSCAPE AND IDENTITY | |
| Street Profile | Using 100% of rooftops for greenhouse agriculture could worsen some street profiles [e.g., Tarragona Street, which profile is already quite narrow]. In these cases it always shall be required compliance with alignments and setbacks, or using design solutions that reduce height in perimeter strip.<br>For Community rooms, their small Surface usually allows locating them sufficiently far from alignment, so they do not worsen Street profiles. |

| | | |
|---|---|---|
| | Urban Scenery Quality | We have not accounted [due to modelling difficulty] two expected positive impacts of rooftops transformation:<br>• Garden Rooftops' vegetation is often visible from streets, leading to an improved Urban Scenery Quality<br>• Generating elevated stance areas implies creating new urban landscapes, which could provide high quality views specially if rooftop gardening is generalized.<br>On the contrary, greenhouse agriculture stands as a use with high impact on urban scenery, discouraging its use in this area ... |
| | Urban greenery percep-tion | We have not accounted the expected vision of rooftops' vegetation from streets, since it is difficult to estimate it. |
| M _ URBAN METABOLISM | | |
| | M.1. WATER USE | For watering estimation, we have considered garden areas are self-sufficient [for 30 - 40% total Surface with plants, yearly received rainwater equates plants water consumption, being necessary to design storage procedures], and that extensive green roofs do not need watering. Regarding greenhouse agriculture, besides rainwater collected, they need supplementary watering, which should be done using recycled water. An equivalent water savings is therefore obtained which amounts to the water these production would need if they were produced outside the city [however, we are considering urban production substitutes agriculture in water scarce locations, not that it increases global production. If this last was the case, then accounting should be differently done].<br><br>For calculation we consider the following ratios:<br>• Yearly rainwater in the Area: 419 L/m2/year [Aemet]<br>• Average watering for Outdoor Agriculture/Community Orchards: 2,45 l/m2/day<br>• Average watering for Greenhouse Agriculture: 2,58 l/m2/day<br>• Average watering for Productive/edible Gardens: 2,28 l/m2/day<br>We have not discounted the reduction in hydric resources consumption inked to energy consumption because it is a small figure, not easily computable [depends on ratio of energy production allocated to each energy source] |
| | M.2. WATER POLLUTION | We consider 'Air Pollution' indicator as a measure of rainwater conversion into Grey Water. Due to its current value 51.88%, it implies each 1 m3 rainwater would produce 0.52 m3 Grey water. Given the filter effect of Green roofs, to above value we discount the percent-age of gardened area in each scenario. |
| | M3. USE OF BIOPRODUC-TIVE LAND | |
| | Crop Land | We consider the following annual productivities:<br>• Outdoor irrigated agriculture 3.7 kg/m2 [MARM, 2010. TABLE 13.6.2].<br>• Hydroponic/Aeroponic Agriculture 18.5 kg/m2 [Wilson, 2005]<br>• Beehives production 50 kg honey /hive<br>For productive Gardens we estimate a 0.50 reduction factor in relation to outdoor irrigated agriculture. |
| | Grazing Land | |
| | Forest Land | |
| | Fishing Ground | |
| | Built up Land | Though it seems introducing Green areas in rooftops should reduce somehow the degree they are accounted as built area, we do not take it into account for herein assessment due to lack of some criterion regarding how it should be done. |
| | M4 WASTE | |
| | Biotic Re-sources | We have discounted Organic Waste susceptible of being composted locally for garden areas, considering the following ratios:<br>• Garden Areas compost consumption 3.38 kg/m2/year<br>• Outdoor agriculture compost consumption 6.75 kg/m2/year<br>Since Greenhouse Agriculture uses mostly liquid fertilizers mixed with watering, we have not assigned them any organic waste reduction. However, it seems it would be convenient to develop some kind of locally reusing Organic Waste also for greenhouse hydropon-ic/Aeroponic. |
| | Abiotic Re-sources | |
| | M5 ENERGY | • We consider all rooftop transformations include thermal insulation upgrade to current normative values. Solar Panels are excluded. Nonresidential uses are also excluded.<br>• For scenarios were energy consumption reduces, we consider the percentage generated by Renewable Energy Sources is preserved; i.e., variation is reflected by decreased Non Renewable Energy Sources reduction, especially fossil fuels, whose elasticity in production is bigger. |
| | Non-Renewa-ble Energy | We have accounted energy saving achieved due to the following issues:<br>• Reduction in transportation km due to local vegetable production.<br>• Heat Island Effect mitigation /bio-clime improvement.<br>• Waste diverted to landfills reduction [Organic Waste locally used for compost].<br>• Rooftops thermal insulation increase.<br>• Non Renewable Sources substitution by Renewable Sources. |
| | Renewa-ble Energy | We account the production increase due to solar panels and locally generated biomass:<br>• For biomass, we consider the following ratios:<br>  o Biomass energy production: 3,000 kcal/kg<br>  o Greenhouse Agriculture Residues: 30,000 Kg/Ha<br>  o Outdoor Agriculture Residues: 25,000 kg/Ha<br>  o Edible Gardening [50% Outdoor Agriculture]: 12,500 kg/Ha<br>In all cases we consider dry organic matter is 50% of above figures<br>• For Solar Energy, we consider the following issues:<br>  o Average annual radiation in Madrid: 1,600 kWh/year/m2<br>  o Percentage of space occupied by panels: Rooftops=40%/Sloping roofs=80%<br>  o Panels characteristics:<br>    ▪ PV: Performance 10%=160 kWh/year/m2panel<br>    ▪ Thermal Panels: Performance 40%=640 kWh/year/m2 |

| | |
|---|---|
| | o Production<br>▪ PV = 64 kWh/year/m2rooftop - 128kWh/year/m2 sloping roof<br>▪ Thermal Panels = 256 kWh/ year/ m2rooftop – 512 kWh/year/m2 sloping roof |
| M6. GHG EMISSIONS | We have considered the following concepts:<br>• Emissions reduction due to energy savings due to ….<br>o Rooftops thermal insulation increase.<br>o transportation km reduction due to local food production<br>o Heat Island Effect reduction / bio-clime improvement<br>o Waste diverted to landfill reduction [organic waste composted locally].<br>• Emissions reductions due to other causes than energy…<br>o CH4 emissions in landfills reduction as consequence of reduction in organic waste diverted to landfills. We consider 30% of 400m3CH4/Tm organic waste is not recovered in landfills, with a density of 0.95 kg/m3 and conversion factor of 21.<br>o C02 emissions absorbed by vegetation<br>• Non Renewable Energy Sources substitution by Renewable Energy Sources.<br>o Biomass: we consider there is Carbon balance.<br>o Solar: we consider the following emissions savings:<br>▪ PV: 0.40 TmCO2/MWh<br>▪ Thermal Panels: 0.20 TmCO2/MWh |
| E_ ECONOMIC SUSTAINABILITY | The high Economic Effort of rooftop transformations has lead us to consider in all cases transformation matches usual renovation/maintenance periods, for a 25 years life cycle.<br>We exclude Beehives which can be located over existing roofs. Considered costs have been:<br><br>(A) (B)<br>Extensive Green Rooftops 55 80 €/m2<br>Community Gardens 95 120 €/m2<br>Public Green Areas 215 240 €/m2<br>Outdoor Agriculture 55 80 €/m2<br>Community Orchards 55 80 €/m2<br>Beehives - 100 €/hive<br>Solar Panels (1) - 140 €/m2<br>Community Rooms 575 600 €/m2<br>Health Spaces (2) 455 480 €/m2<br>Public Facilities 95 120 €/m2<br>Restoration 215 240 €/m2<br>Greenhouse [€/M2] 275 300 €/m2<br>Solar Panels - 280 €/m2<br>Green Roofs 95 120 €/m2<br>Cold Roofs - 25 €/m2<br><br>(A) Cost matching usual renovation<br>(B) Cost if transformation does not match usual renovation periods<br>(0) As average renovation/maintenance cost we consider 25€/m2<br>(1) We consider a unitary price 350€/m2 panel, which we convert into a ratio €/m2 rooftop/sloping roof ratio using above stated occupation ratios.<br>(2) We have estimated a global ratio considering 600 €/m2 for pools and saunas and 120 120 €/m2 for solarium.<br><br>In all cases GAV has been calculated for a discount tax of 3%. In some cases were we have found other economic calculations, we have found sufficient resemblance between Return on Investment periods. |
| E1. EMPLOYMENT | |
| Employment Stability | We do not assess employment stability due to difficulty of estimating stability of newly generated employment. |
| Unemployment rate | We have considered the following employment generation ratios:<br>• Restoration 1 employment /50m2rf<br>• Greenhouse Agriculture 1 employment/500m2rf<br>• Outdoor Agriculture 1 employment/3000m2rf<br>• Beehives 1 employment /150hives<br>Though the stability of generated employment has not been assessed, except for restoration use we believe it is mostly sustainable employment.<br>We have not assessed employment directly linked to rooftop transformation, though it would be appreciable. Additionally, by designing scenario implementation in a fractioned manner similar to renovation periods, it would be mostly sustainable employment. |
| E2. ECONOMIC DIFFERENTIATION | Same comments as above |
| Labor Differentiation | • Negligible concentration of labor activity in the agricultural sector [2 people/0.02%] implies any agricultural uses in rooftops increase labor differentiation.<br>• On the other hand, there is some labor specialization in the restoration sector [720 people/7.8%] making recommendable monitoring the increase in this sector's employment, admissible yet for being a high centrality Area. |
| Economic Activity Differentiation | Due to lack of data we have considered differentiation between economic entities/shops is an indirect measure of its economic resilience. To account number of entities, we have used the following data:<br>• Each 5,000m2 Greenhouse agriculture rooftop or each 30,000 m2 outdoor irrigated agriculture rooftop have been considered a new shop [equivalent space to generate 10 employments].<br>• Each restoration rooftop [in independent building] has been considered as a new restoration shop [since they almost always function as restaurant open to public from outside the hotel]. |
| E.3 INCOME DISTRIBUTION | • - |
| E4. ECONOM- | We have consider the following ratios: |

| | | |
|---|---|---|
| | IC BURDEN | Energy Savings:<br>• Electricity savings: 133.10 €/MWh<br>• Gas Savings: 66.55 €/MWh<br>• Fuel Savings: 1.5428 €/l<br>We consider the benefit provided by energy produced by Biomass or directly from sun is already accounted in saving of other Energy sources.<br>• Agriculture production: 1.33€/kg<br>• Beehive production: 3.1€/kg |
| | Public Admin-istration Economic Burden | Increase in income/expenditure reduction accounted for Public Administration are the following:<br>• Water Cleansing = 1.57 €/m3<br>• Waste management = 47.81 €/m3<br>• Energy Consumption / Solar Energy production [see above]<br>• GHG emissions 20 €/Tm$CO_2$<br>• Agricultural/Beehives production [see above]<br>It has not been possible assessing savings produced from the expected improved citizens' health due to pollution reduction and Physical activity increase [Social Security cost reduction]. |
| | Citizens Economic Burden | The increases in income/expenditure reduction accounted for citizens have been:<br>• Energy Consumption / Solar Energy and Biomass production [see above]<br>• Agricultural/Beehives production [see above] |
| S_ SUSTAINABIL-ITY DEGREE | | |

SOURCE: Own Elaboration