TECHNICAL PAPEL
Action C4: Prioritisation Methodologies and ownership by the demonstrative City Halls

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Autores del Documento:

Leire Barruetabeña, Gaiker

Javier Etxebarria, Gaiker

Itxaso Gomez Coca, Factor

Soraya Cuesta, Factor

Julie Urban, Factor

María Jesús Muñoz, Factor

Juan Carlos Gómez, Factor

Jon Laurenz, Ekinn

Irati Alonso, Createlli

Noemí Llorente, Ayuntamiento de Amurrio

Gorka López, Ayuntamiento de Balmaseda

Inma Hernández, Ayuntamiento de Legazpi

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1. METHODOLOGY

In Action C4 CBA method has been applied in order to compare global benefits of the adaptation measures identified, quantifying the avoided impacts associated to climate change, as well as the implementation, maintenance and sustainability costs. This tool incorporates environmental and social indicators, obtained from the additional analysis performed in the action.

In fact, as support for the CBA, and in order to validate the sustainability of the measures implemented, different environmental and social assessment indicators have also been proposed.

Finally, a specifically adapted multicriteria method has been developed, so the municipalities can use it for the evaluation of future measures. This method has been applied to analyse adaptation measures, getting to a prioritization according to global sustainability and citizen's requirements.

1.1. Social and Environmental evaluation

The project has evaluated and selected the most suitable indicators for the characterization of environmental and social implications of potential adaptation measures. Life Cycle Assessment has been taken as starting point for selecting impact indicators, but it has been complemented with additional indicators to model specific aspects or the solutions and to represent key social features from local stakeholders' point of view.

The final list of social and environmental indicators selected are listed below in Table 1.

Table 1. Environmental and social indicators selected

Environmental indicators	**Quantitative indicators based on LCA:** - Global Warming Potential (kg CO2 eq), calculated according to the methodology developed by the International Panel for Climate Change. - Resource depletion ($), based on the Recipe Endpoint Life Cycle Impact Assessment method. The reference unit is the USD, since the method reflects the additional cost of the extraction of a resource, considering that the scarcer a resource is, the more costly is its extraction. - Ecosystem damage (species*year): based on the Recipe Endpoint Life Cycle Impact Assessment method. It represents the number of species affected due to the exposure to contaminants. **Semi quantitative indicators:** - Reducing local pollution in air and water, from 0 (no reduction) to 2 (high reduction) - Runoff level - Green corridor creation, from 0 (no effect), to 1 (contributes to the creation of green corridors, supporting vegetation or soils with permeability >0.25), and 2 (when the area constitutes a green corridor).

Social Indicators	**Quantitative indicators based on LCA:** - Human health Damage (DALY): based on the Recipe Endpoint Life Cycle Impact Assessment method. The unit is DALY (Disability Adjusted Life Years) and reflects the life years lost due to mortality or morbidity associated to certain contaminants. **Semi quantitative indicators:** - Thermal comfort in public areas: reflects the way the measures contribute to this aspect, from 0 (no effect), to 1 (low-medium effect) and 2 (high effect). - Green areas: 0 (no effect), 1 (compatible with green areas), 2 (constitutes a green area).

1.2. Cost Benefit Assessment

The Cost Benefit Analysis (CBA) determines in each case if the benefits obtained from a measure exceed the costs and enables selecting the options with higher benefits.

Benefits are described as anything that improves human welfare and they are monetized based on the risk that could be avoided due to the proposed measures. Costs, on the other hand, are elements that reduce that very same welfare.

The damages considered within this study include the following ones: material cost and installation costs, maintenance costs and externalities.

Damage to Human Health has been considered an externality, accounted as the monetization of a DALY (Disability Advanced Life Year). The DALYs reflect the years of life lost due to disability, illness or death in relation to a certain process or measure. During the development of the action the possibility to assess and monetize damage to ecosystem has also been considered, but the complexity of this issue is still too high, and therefore, it has not been included in the CBA.

The CBA provides the economic indicators that will be considered in the Multicriteria Analysis (MCA). The Net Present Value (NPV) is the most common result of the CBA, however, this study presents also other indicators for a complete overview. The indicators chosen are detailed below:

- Net Discounted Cost (€): present and future costs of the measure, updated to the present value.

- Net Discounted Benefit (€): future benefits of the measure, updated to the present value.

- Net Present Value (€): net present value of future cash flows (difference between benefits and costs).

- Pay-Back (number of years): number of years necessary to recover the investment.

- Cost-Benefit Ratio: division between benefits and costs.

1.3. Multicriteria Analysis

A multicriteria analysis method has been developed based on the key results identified through the evaluation process, and also taking into account the feedback from different public bodies surveyed during the project. The criteria proposed for the multicriteria analysis are defined in the following table:

Table 2: Criteria for MCA.

CRITERIA		
Reduction of floods caused by extreme rain events	Reduction of the heat island effect	Reduction of water consumption
Reduction of energy consumption	Reduction of GHG emission	Increasing pollutant retention
Green corridor creation	Increasing thermal comfort in publica areas	Increasing leisure alternatives
Acceptance from citizens	Easy maintenance	Alignment with local legislation
Technical viability	Easy financing	Monitoring feasibility

This criterion can be assigned different weighting factors according to the priorities in each location. The weighting is done in a binomial base. In order to do so, each criterion (Column A) is weighted against the rest (column B), building a matrix. This matrix defines which criterion is more or less important than the other. The weighting values are shown in Table 3.

Table 3: Criteria weighting system

How is A compared to B?	Assigned Index	
	If A is more important than B	If A is less important than B
Equally important	1	1
Slightly more important	3	1/3
More important	5	1/5
Much more important	7	1/7
Remarkably more important	9	1/9

The type of matrix used for the MCA in C4 is shown in Figure 1.

Ponderación binomial de criterios	Reducción de la vulnerabilidad al cambio climático	Reducción de GEI	Co-beneficios	Viabilidad financiera	Viabilidad de MRV & ME	Aceptación social / sectorial
Reducción de la vulnerabilidad al cambio climático	1,00	1,00	7,00	1,00	3,00	9,00
Reducción de GEI	1,00	1,00	7,00	1,00	3,00	9,00
Co-beneficios	0,14	0,14	1,00	1,00	1,00	1,00
Viabilidad financiera	1,00	1,00	1,00	1,00	3,00	9,00
Viabilidad de MRV & ME	0,33	0,33	1,00	0,33	1,00	9,00
Aceptación social / sectorial	0,11	0,11	1,00	0,11	0,11	1,00

Figure 1: type of matrix used for the MCA in Action C4 for binomial weighting of criteria

2. RESULTS

2.1. Environmental and social evaluation

During Action C4 environmental and social indicators have been calculated for all proposed measures. The evaluation has been performed first by reference unit (E.g. M2 of bioretention area) and in a second step by design dimensions in the pilot site within the project. The calculations have been performed for a specific location, and may vary depending on the site and conditions (runoff, type of soil, depth of SUDs…)

In some cases (urban gardens and vegetable roofs) it has not been possible to quantify the benefits in LCA indicators, since no energy consumption is directly avoided, and the quantification of the impacts on Human Health during the use phase have presented too much complexity. For this reason, these two measures have not been included in this summary.

The following graphs summarize in a comparative way the results obtained for the impact category Climate Change.

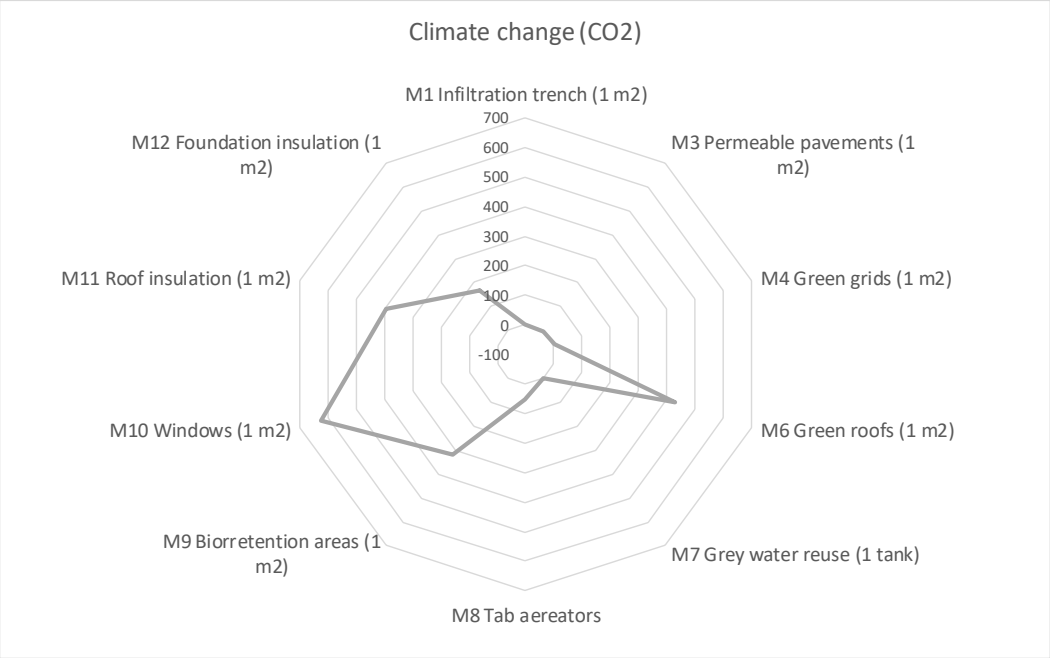

Figure 2: Life Cycle Assessment results per reference unit of the different adaptation measures solutions evaluated for the impact category Climate Change.

2.2. Cost Benefit Assessment

Based on the costs and benefits influenced by each measure, Net Discount Costs and the Net Discount Benefits of the selected measures have been calculated, considering their customization to the analysed neighbourhood (calculations are based on the specific implementation dimensions foreseen in the pilot sites). Table 4 shows in the monetized benefits quantified for each measure.

Table 4: Benefits assessed in the CBA[1]

Influence: High, Medium or Low	M1	M2	M3	M4	M5	M6	M7	M8	M9	M 10	M 11	M 12
Water demand reduction							High	High	Low	Low	Low	Low
Energy demand reduction						High				High	High	High
Avoided damages from floods	High		High	High	Low	Low			High			
Avoided sanitary costs		Med			Med	Med				Low	Low	Low
Avoided mortality costs		Med			Med	Med						

The results enable to configure the Regret table shown in Figure 3, where measures are classified as “Low impact and no regret”, “High impact and no regret”, “Low regret” and “Potential High regret”.

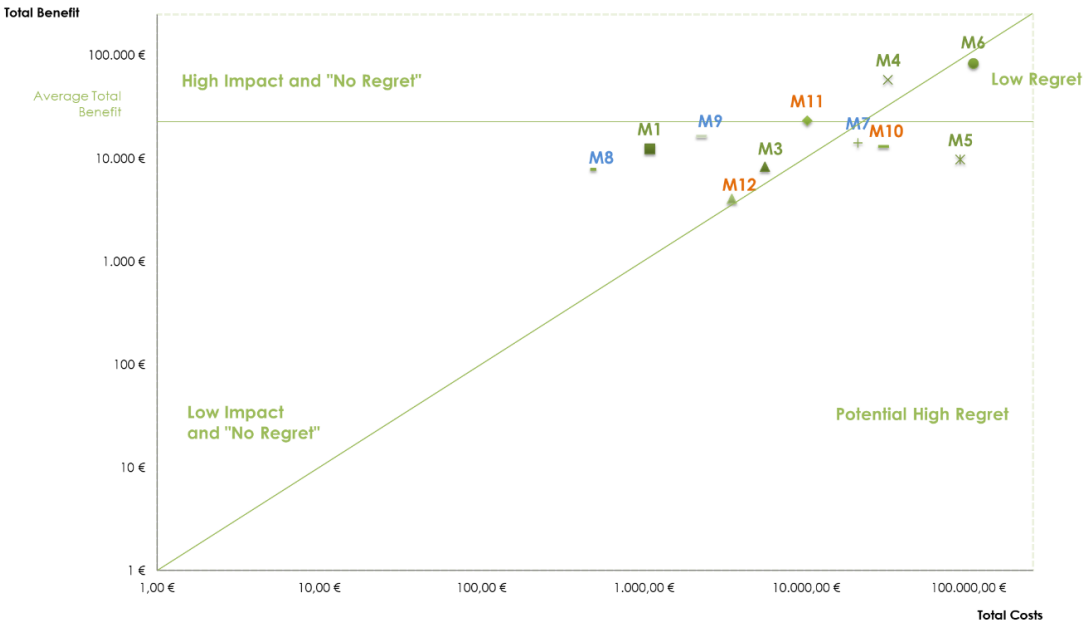

Figure 3: Regret table of the customized measures in the pilot sites[1].

[1] *M1 Infiltration trench, M2 Urban gardens, M3 Permeable pavements, M4 Green grids, M5 Green shading, M6 Green roofs, M7 Grey water reuse, M8 Tap aerators, M9 Bio retention areas, M10 Windows, M11 Roof insulation, M12 Foundation insulation*

The classification groups represented above can be interpreted as follows:

- "Low impact and no-regret": measure without significant benefits, but economically justified, even without considering positive impacts on the climate change.
- "High impact and no regret": measure with high economic benefits and justified even without considering positive impacts on the climate change.
- "Low regret": measure not fully economically sustainable, but with benefits.
- "Potential High regret": not fully economically sustainable, without significant benefits.

As Figure 3 shows, measures 1 to 6 and 9 (related to green infrastructures) report benefits associated to the reduction of flood impacts, due to lower runoff volume and/or velocity. Measures 2, 5, and 6 also help reducing morbidity and mortality costs related to extreme heat events, lowering ambient temperature. On the other hand, the only benefit quantified in relation to measures 7 and 8 (water management measures) is the direct reduction of water consumption. Measures 10, 11 and 12 (also 6 to a lower extent) mainly lead to lower energy demand for heating and cooling. Measures 9 to 12 may also help reducing water demand by increasing thermal comfort.

It is also noticeable that some measures have much higher costs and benefits, since dimensions of the application site (pilot site) are much larger. Measure 6 is an example, since it is planned to be applied in a sport installation (court for pelota or frontón) in Balmaseda, covering 2100 m2.

2.3. Multi-criteria Analysis

The weighting of the criteria is a key aspect within the MCA methodology. For this reason, the proposed weights were validated with stakeholders during the Good Local Adapt European Event (8-9-10 of May 2019). As result the following weighting system has been proposed.

Table 5: MCA criteria weighting

	Criteria	Weighting
1	Potential for reduction of floods	0,19
2	Potential for reduction of heat island	0,14
3	Potential for reduction of water consumption	0,06
4	Potential for reduction of energy consumption	0,11
5	Potential for reduction of GHG	0,05
6	Increasing pollutant retention	0,04
7	Green corridor creation	0,02
8	Increasing comfort in urban areas	0,04
9	Increasing leisure activities	0,04
10	Acceptance from citizenship	0,06
11	Technical viability	0,12
12	Maintenance	0,07
13	Financing possibilities	0,03
14	Alignment with local regulation	0,02
15	Monitoring potential	0,01

The table below summarizes the main results of the MCA method applied to the proposed measures. The results represent a prioritization, showing the preferred measures from green to red.

Table 6: MCA based prioritization		
Measure		**Global results**
M1	Infiltration trench	**2,26**
M2	Urban gardens	**2,34**
M3	Permeable pavements	**2,08**
M4	Green parking	**2,26**
M5	Green shadows	**2,39**
M6	Green roofs	**2,32**
M7	Grey water reuse	**0,96**
M8	Tap Aerators	**1,64**
M9	Bio-retention	**2,39**
M10	Windows	**1,91**
M11	Roof insulation	**1,81**
M12	Foundation insulation	**1,58**

Urban gardens (M2) and green shadowing (M9) both get very high score, since they meet the criteria with highest weights, like the contribution to reduce rain floods and heat island. The results obtained for urban gardens are especially significant, since they are very high compared to the results obtained in CBA and environmental and social indicators. According to the perspective of the participants, urban gardens provide a high dose of comfort and leisure, and citizen's acceptance is remarkable.

Looking at the results obtained per solution group, the measures related to green infrastructure present the most positive results. Insulation related measures also get high scores in general, but stakeholders don't identify them as main contributors to key adaptation goals (avoiding floods and heat islands). Their high score is related to the energy saving and the easy maintenance, but they still constitute the second group in importance. Water saving measures are not very well scored by stakeholders, since they are not considered to fulfil relevant functions (probably due to the relatively high availability of water in the region). Especially the greywater reuse measure shows very low results due to its cost and complexity.

The following figures show the results obtained for some key measures regarding the evaluation criteria.

Figure 4: Measures pondered according to the selected and weighted criteria.