

SOCIO-ECONOMIC FEASIBILITY OF GREENING ENTRECAMPOS RAIL STATION, LISBON

WGIC 2017:

World Green Infrastructure Congress | DESIGN WITH NATURE

Berlin, Germany, June 2017

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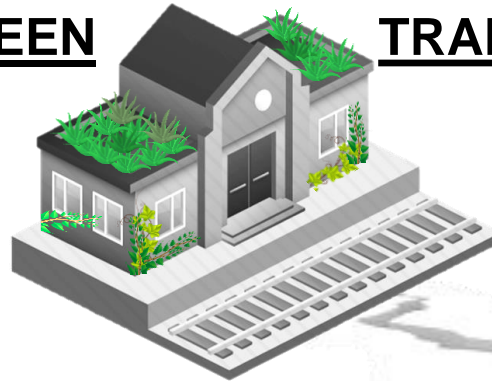
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Inês Teotónio

INTRODUCTION



GREEN



TRANSPORT INFRASTRUCTURES

- JOB CREATION
- INDUCED DEMAND
- SPACE OPTIMIZATION
- INCREASE OF LIFESPAN
- URBAN NOISE ABSORPTION
- PHOTOVOLTAIC PERFORMANCE
- USER'S SATISFACTION/WELL-BEING
- THERMAL AND SOUND INSULATION
- URBAN HEAT ISLAND EFFECT MITIGATION
- **INFRASTRUCTURE VALUATION** (AESTHETICS AND NEW SPACES)
- BIODIVERSITY PRESERVATION AND CREATION OF HABITAT
- STORM WATER MANAGEMENT (RETENTION AND DELAY OF RUN-OFF)
- AIR AND WATER RUN-OFF QUALITY (ABSORPTION OF CO₂ AND POLLUTANTS)



- INSTALLATION
- MAINTENANCE
- DEMOLITION
- REPLACEMENT



ATTEMPTS TO QUANTIFY THE ECONOMIC MERIT OF GREENING TRANSPORT INFRASTRUCTURES

Lack of research on greening existent transport infrastructures



METHODOLOGY

TO PERFORM COST-BENEFIT ANALYSIS WITH APPLICATION TO RAIL STATIONS





INFRASTRUCTURE

- **INSTALLATION**
- **MAINTENANCE**
- **DEMOLITION**
- **REPLACEMENT**
- PHOTOVOLTAIC PERFORMANCE
- **INFRASTRUCTURE VALUATION**
(AESTHETICS AND NEW SPACES)
- INCREASE OF LIFESPAN
- **SPACE OPTIMIZATION**
- JOB CREATION
- **INDUCED DEMAND**



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(AESTHETICS AND NEW SPACES)
- INCREASE OF LIFESPAN
- SPACE OPTIMIZATION
- JOB CREATION
- INDUCED DEMAND



USER

- **USER'S SATISFACTION**
- THERMAL COMFORT
- NOISE REDUCTION
- AIR QUALITY
(ABSORPTION OF CO₂ AND POLLUTANTS)

METHODOLOGY



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ENVIRONMENT

- **URBAN NOISE ATTENUATION**
- **AIR AND WATER RUN-OFF QUALITY**
(ABSORPTION OF CO₂ AND POLLUTANTS)
- **URBAN HEAT ISLAND
EFFECT MITIGATION**
- **BIODIVERSITY PRESERVATION
AND CREATION OF HABITAT**
- **STORM WATER MANAGEMENT**
(RETENTION AND DELAY OF RUN-OFF)



ECONOMIC EVALUATION

SOCIOENVIRONMENTAL

ECONOMIC

FINANCIAL

INFRASTRUCTURE

USER

ENVIRONMENT

- | | | |
|--|--|--|
| <ul style="list-style-type: none"> ▪ INSTALLATION ▪ MAINTENANCE ▪ DEMOLITION ▪ REPLACEMENT ▪ PHOTOVOLTAIC PERFORMANCE | | |
| <ul style="list-style-type: none"> ▪ INFRASTRUCTURE VALUATION (AESTHETICS AND NEW SPACES) ▪ INCREASE OF LIFESPAN ▪ SPACE OPTIMIZATION | <ul style="list-style-type: none"> ▪ USER'S SATISFACTION ▪ THERMAL COMFORT ▪ NOISE REDUCTION (INDOOR) | |
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INFRASTRUCTURE

USER

ENVIRONMENT

ECONOMIC EVALUATION

SOCIOENVIRONMENTAL

ECONOMIC

FINANCIAL

- **INSTALLATION**
- **MAINTENANCE**
- **DEMOLITION**
- **REPLACEMENT**
- PHOTOVOLTAIC PERFORMANCE

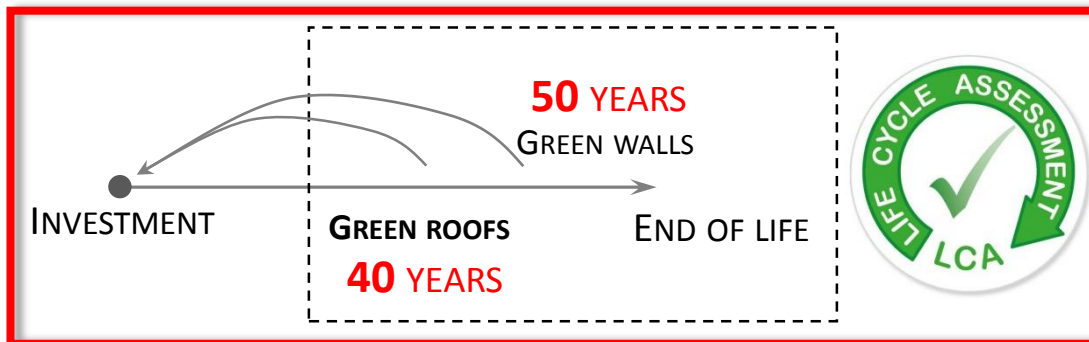
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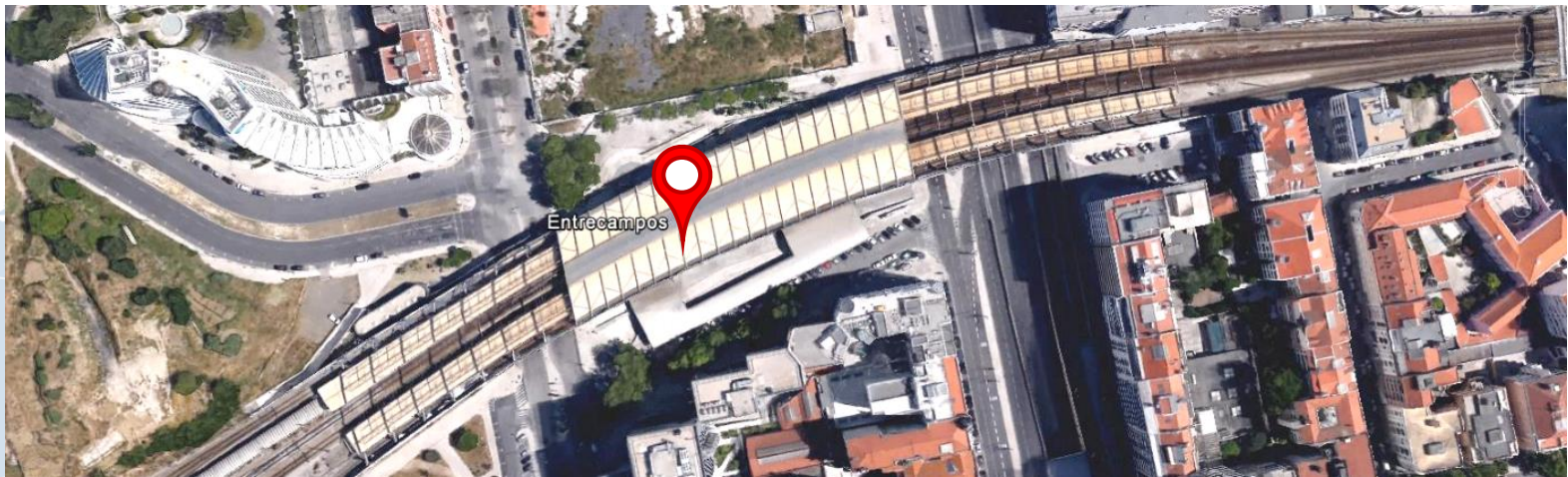
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LOCATION



PORTUGAL

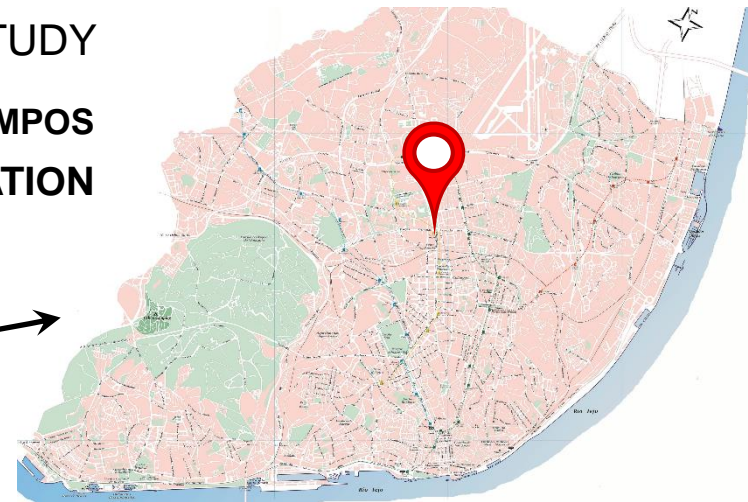
SOUTHWEST EUROPE

LISBON

CAPITAL OF
PORTUGAL

CASE STUDY

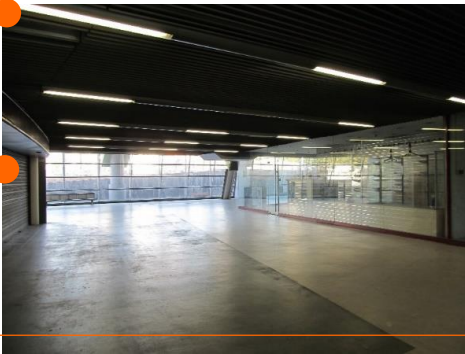
**ENTRECAMPOS
RAIL STATION**





STATION PROBLEMS

UNDER-EXPLOITED AREAS



POOR LIGHTED AREAS



LOW VISIBILITY
(MONITORING PROBLEMS)



NOISE / VIBRATIONS

STRONG POINTS

- Ideally located
- High passengers turnover
- Large areas

VISUAL POLLUTION

STORMY, UNCOMFORTABLE ATMOSPHERE

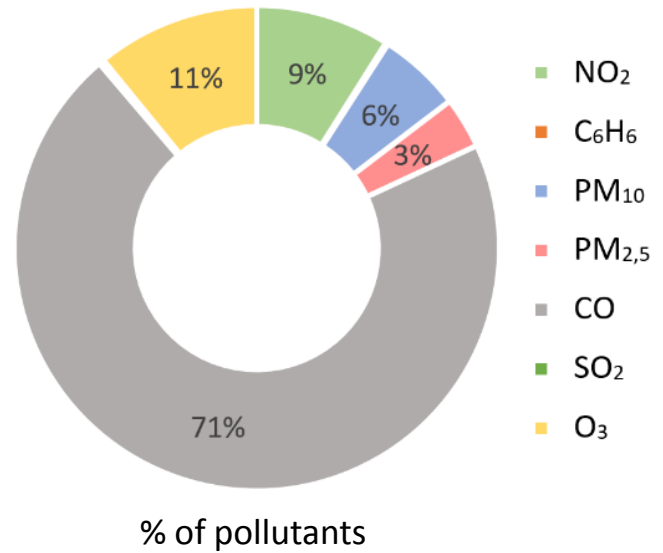
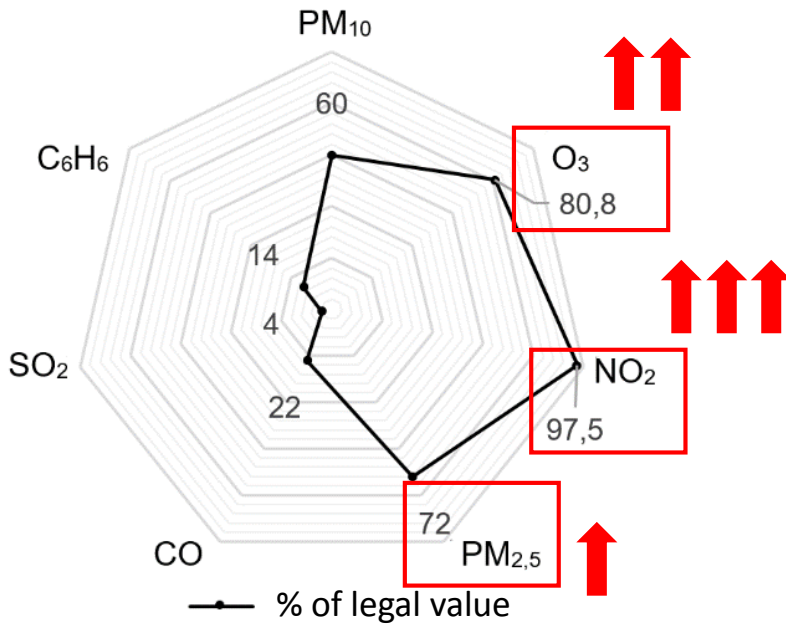
WATER INLET (PLATFORM)

OVERLOAD AT PEAK TIMES



ENVIRONMENT PROBLEMS

AIR POLLUTION



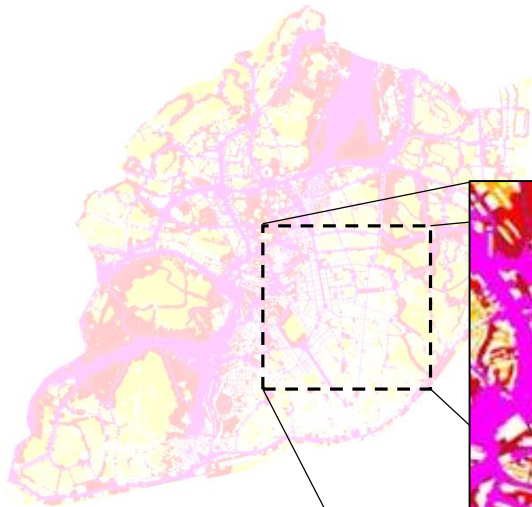
ENTRECAMPOS,
DATA FROM 2015



ENVIRONMENT PROBLEMS

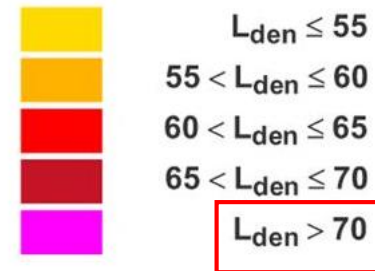
AIR POLLUTION

NOISE



ENTRECAMPOS RAIL STATION

L_{den} - dB(A)



CITY SCALE,
DATA FROM 2014

CASE STUDY: SOLUTIONS PROPOSAL

	SCENARIO I	SCENARIO II	SCENARIO III	SCENARIO IV	SCENARIO V
LOCATION					
BEFORE					
AFTER	  <p>GREEN FAÇADE (CLIMBERS) OR LIVING WALL</p> <p>Scenario I_c Scenario I</p>				
	EXTERNAL ENVIRONMENT	190 m ² of green area			INTERNAL ENVIRONMENT

	GROUND FLOOR	RAISED FLOOR	CIRCULATION AREAS	OPPORTUNITY AREAS
BENEFITS	<ul style="list-style-type: none"> AESTHETICS IMPROVEMENT AIR RENEWAL FAÇADE PROTECTION 	<ul style="list-style-type: none"> RUNOFF MANAGEMENT NOISE REDUCTION (OUTSIDE) SENSE OF COMFORT 	<ul style="list-style-type: none"> USER'S SATISFACTION NOISE REDUCTION (SOUND ABSORPTION) LEGIBILITY OF SPACES 	<ul style="list-style-type: none"> SPACE FOR NEW INITIATIVES AESTHETICS IMPROVEMENT SENSE OF SECURITY

CASE STUDY: SOLUTIONS PROPOSAL

	SCENARIO I	SCENARIO II	SCENARIO III	SCENARIO IV	SCENARIO V
LOCATION					
BEFORE					
AFTER			<p>GREEN EXTENSIVE ROOF COMBINED WITH SKYLIGHTS</p>		
	EXTERNAL ENVIRONMENT		INTERNAL ENVIRONMENT		
	GROUND FLOOR	RAISED FLOOR	CIRCULATION AREAS		OPPORTUNITY AREAS
BENEFITS	<ul style="list-style-type: none"> AESTHETICS IMPROVEMENT AIR RENEWAL FAÇADE PROTECTION 	<ul style="list-style-type: none"> RUNOFF MANAGEMENT NOISE REDUCTION (OUTSIDE) SENSE OF COMFORT 	<ul style="list-style-type: none"> USER'S SATISFACTION NOISE REDUCTION (SOUND ABSORPTION) LEGIBILITY OF SPACES 		<ul style="list-style-type: none"> SPACE FOR NEW INITIATIVES AESTHETICS IMPROVEMENT SENSE OF SECURITY

8000 m² of green area

CASE STUDY: SOLUTIONS PROPOSAL

	SCENARIO I	SCENARIO II	SCENARIO III	SCENARIO IV	SCENARIO V
LOCATION					
BEFORE					
AFTER	<p>GREEN FAÇADE (CLIMBERS) OR LIVING WALL</p>			Scenario II_c	Scenario II
	380 m² of green area			INTERNAL ENVIRONMENT	

	GROUND FLOOR	RAISED FLOOR	CIRCULATION AREAS	OPPORTUNITY AREAS
BENEFITS	<ul style="list-style-type: none"> AESTHETICS IMPROVEMENT AIR RENEWAL FAÇADE PROTECTION 	<ul style="list-style-type: none"> RUNOFF MANAGEMENT NOISE REDUCTION (OUTSIDE) SENSE OF COMFORT 	<ul style="list-style-type: none"> USER'S SATISFACTION NOISE REDUCTION (SOUND ABSORPTION) LEGIBILITY OF SPACES 	<ul style="list-style-type: none"> SPACE FOR NEW INITIATIVES AESTHETICS IMPROVEMENT SENSE OF SECURITY

CASE STUDY: SOLUTIONS PROPOSAL

	SCENARIO I	SCENARIO II	SCENARIO III	SCENARIO IV	SCENARIO V
LOCATION					
BEFORE					
AFTER	Scenario IV_c	Scenario IV			
	EXTERNAL ENVIRONMENT			INTERNAL ENVIRONMENT	

10 m² of green area

	GROUND FLOOR	RAISED FLOOR	CIRCULATION AREAS	OPPORTUNITY AREAS
BENEFITS	<ul style="list-style-type: none"> AESTHETICS IMPROVEMENT AIR RENEWAL FAÇADE PROTECTION 	<ul style="list-style-type: none"> RUNOFF MANAGEMENT NOISE REDUCTION (OUTSIDE) SENSE OF COMFORT 	<ul style="list-style-type: none"> USER'S SATISFACTION NOISE REDUCTION (SOUND ABSORPTION) LEGIBILITY OF SPACES 	<ul style="list-style-type: none"> SPACE FOR NEW INITIATIVES AESTHETICS IMPROVEMENT SENSE OF SECURITY

CASE STUDY: SOLUTIONS PROPOSAL

	SCENARIO I	SCENARIO II	SCENARIO III	SCENARIO IV	SCENARIO V
LOCATION					
BEFORE					
AFTER		<p>Scenario V_c</p> <p>Scenario V</p> <p>GREEN FAÇADE (CLIMBERS) OR LIVING WALL</p>			
	EXTERNAL ENVIRONMENT			INTERNAL ENVIRONMENT	
	GROUND FLOOR	RAISED FLOOR	CIRCULATION AREAS		OPPORTUNITY AREAS
BENEFITS	<p>AESTHETICS IMPROVEMENT</p> <p>AIR RENEWAL</p> <p>FAÇADE PROTECTION</p>	<p>RUNOFF MANAGEMENT</p> <p>NOISE REDUCTION (OUTSIDE)</p> <p>SENSE OF COMFORT</p>	<p>USER'S SATISFACTION</p> <p>NOISE REDUCTION (SOUND ABSORPTION)</p> <p>LEGIBILITY OF SPACES</p>		<p>SPACE FOR NEW INITIATIVES</p> <p>AESTHETICS IMPROVEMENT</p> <p>SENSE OF SECURITY</p>

98 m² of green area

CASE STUDY: SOLUTIONS PROPOSAL

SCENARIO I

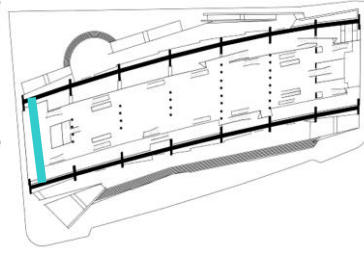
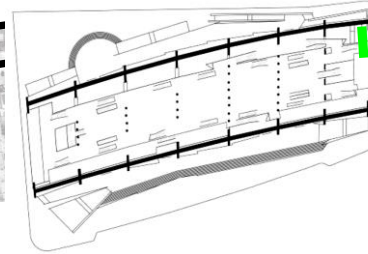
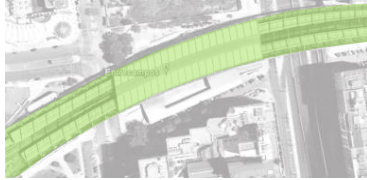
SCENARIO II

SCENARIO III

SCENARIO IV

SCENARIO V

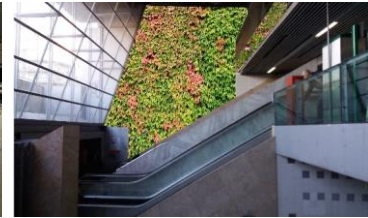
LOCATION



BEFORE



AFTER



EXTERNAL ENVIRONMENT

INTERNAL ENVIRONMENT

GROUND FLOOR

RAISED FLOOR

CIRCULATION AREAS

OPPORTUNITY AREAS

BENEFITS

AESTHETICS IMPROVEMENT
AIR RENEWAL
FAÇADE PROTECTION

RUNOFF MANAGEMENT
NOISE REDUCTION (OUTSIDE)
SENSE OF COMFORT

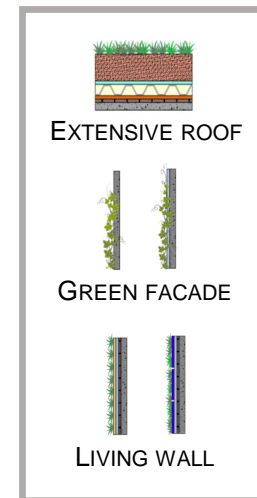
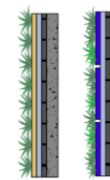
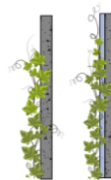
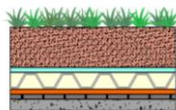
USER'S SATISFACTION
NOISE REDUCTION (SOUND ABSORPTION)
LEGIBILITY OF SPACES

SPACE FOR NEW INITIATIVES
AESTHETICS IMPROVEMENT
SENSE OF SECURITY

LITERATURE REVIEW



GREEN INFRASTRUCTURES COSTS AND BENEFITS



INSTALLATION COSTS

65 €/m²

35 to 150 €/m²

600 €/m²

MAINTENANCE COSTS

2,5 €/m²/year

3 €/m²/year

20 €/m²/year

DEMOLITION COSTS

35 €/m²

35 to 125 €/m²

200 €/m²

REPLACEMENT COSTS

50 €/m²

500 €/m²

500 €/m²

PHOTOVOLTAIC PERFORMANCE

Benefit

-

-

INFRASTRUCTURE VALUATION

Benefit

Benefit

Benefit

JOB CREATION

1.251 x 10⁻⁴ employee/m²

USER'S SATISFACTION/WELL-BEING

101 €/year (80% of users)

NOISE ATTENUATION (STATION)

-

2 dB

5 dB

AIR QUALITY

0.0072 to 0.10 kg/m² (NO₂)
+ 0.378 to 6.47 kg/m² (CO₂)

65% of 0.0072 to 0.10 kg/m² (NO₂)
+ 0.378 to 6.47 kg/m² (CO₂)

NOISE ATTENUATION

5 to 10 dB

5 dB

5 dB

RUN-OFF RETENTION

55%

-

-



CASE STUDY



GREEN INFRASTRUCTURES COSTS AND BENEFITS

CASE STUDY CONVERSION



INSTALLATION COSTS

65 €/m²

35 to 150 €/m² Price in Portugal

MAINTENANCE COSTS

2,5 €/m²/year

3 €/m²/year Price in Portugal

DEMOLITION COSTS

35 €/m²

Not considered (included in replacement costs)

REPLACEMENT COSTS

50 €/m²

500 €/m² Price in Portugal

PHOTOVOLTAIC PERFORMANCE

Benefit

22.5% x production x price of electricity

INFRASTRUCTURE VALUATION
(AESTHETICS + NEW SPACES)

Benefit

((% aesthetic improvement/10%) x number of users x % exposed users)
+ (rental value x area of new spaces)

JOB CREATION

1.251 x 10⁻⁴ employee/m² x GDP/employee



USER'S SATISFACTION/WELL-BEING

80% of exposed users x 50 €/year x ¼ for benefit (excluding aesthetics)

NOISE ATTENUATION (STATION)

(2 to 5) dB reduction x price of externality x number of exposed users

AIR QUALITY

0.0072 to 0.101 g/m³ (NO₂)
+ 0.378 to 6.47 g/m³ (CO₂)

Pollutants removal (kg/m²) x price of CO₂ equivalent

NOISE ATTENUATION

5 to 10 dB

Cost of intervention in Lisbon/m² x π100² x dB reduction (% green area)

RUN-OFF RETENTION

55%

55% x rainfall in rail station x waste-water drainage and treatment costs







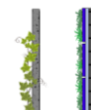
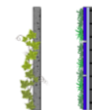
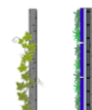
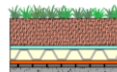
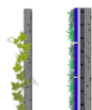
CASE STUDY



MODELLED COSTS

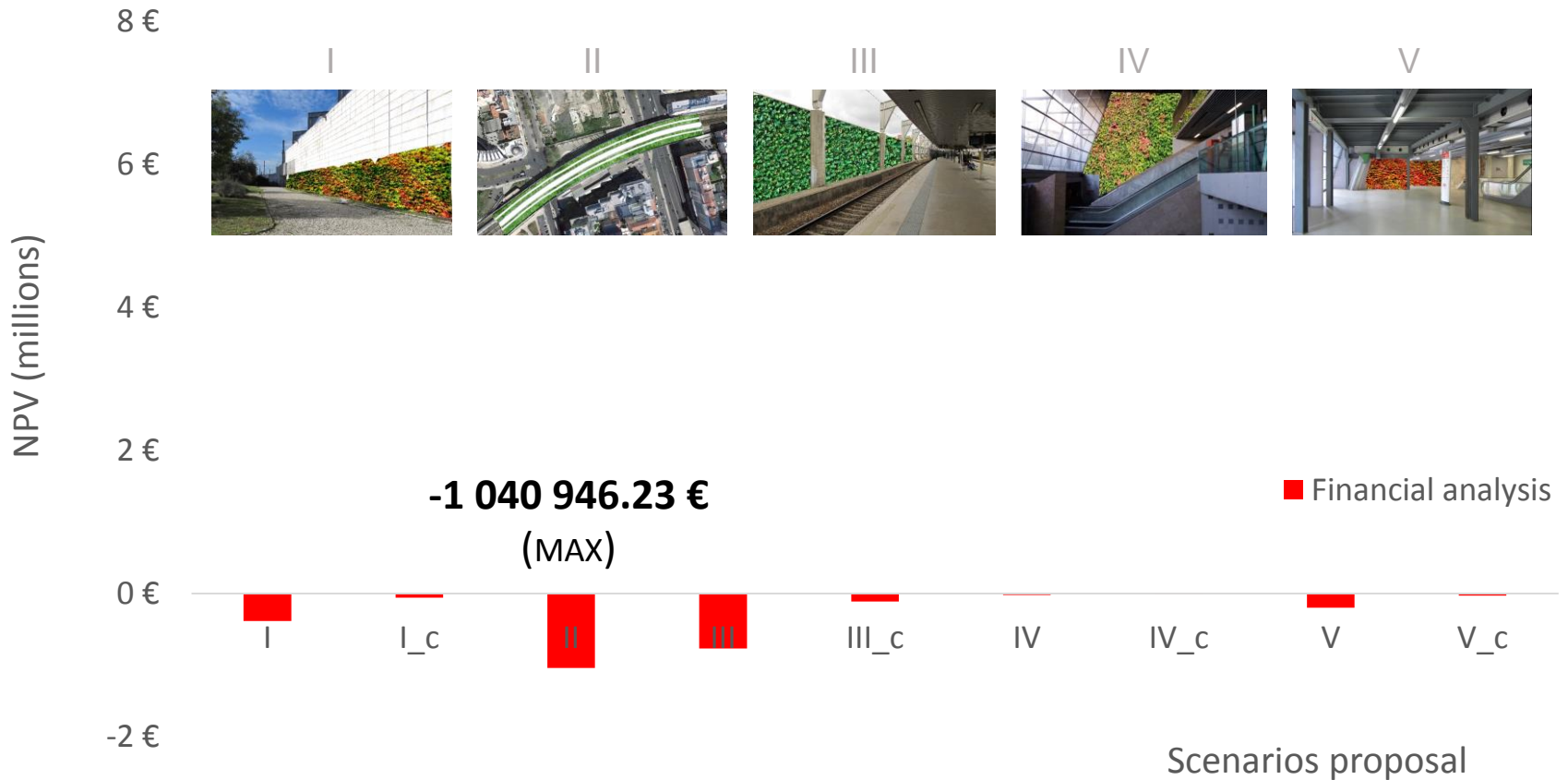


	<i>SCENARIO I</i>	<i>SCENARIO II</i>	<i>SCENARIO III</i>	<i>SCENARIO IV</i>	<i>SCENARIO V</i>
INSTALLATION COSTS €/m ²	- 90 / - 600	- 55	- 90 / - 600	- 90 / - 600	- 90 / - 600
MAINTENANCE COSTS €/m ² /year	- 3 / - 48	- 2.5	- 3 / - 48	- 3 / - 48	- 3 / - 48
REPLACEMENT COSTS €/m ²	- 500	- 50	- 500	- 50	- 500
PHOTOVOLTAIC PERFORMANCE €/year	-	708.97	-	-	-
INFRASTRUCTURE VALUATION:					
AESTHETICS €/year	50 700 / 72 429	-	215 667 / 308 096	12 692 / 18 132	3 058 / 4 369
NEW SPACES €/month	-	-	-	-	4309.20
JOB CREATION 	513	21 600	1 026	27	264.60
USER'S SATISFACTION €/year 		462 960	15 432	3 704	1 852
NOISE ATTENUATION €/year 				13 361 / 33 343	4 112 / 10 260
AIR QUALITY €/year 	13.59	880	27.17	0.72	7.01
NOISE ATTENUATION €		11 153	1 115		
RUN-OFF RETENTION €/year		820.38			





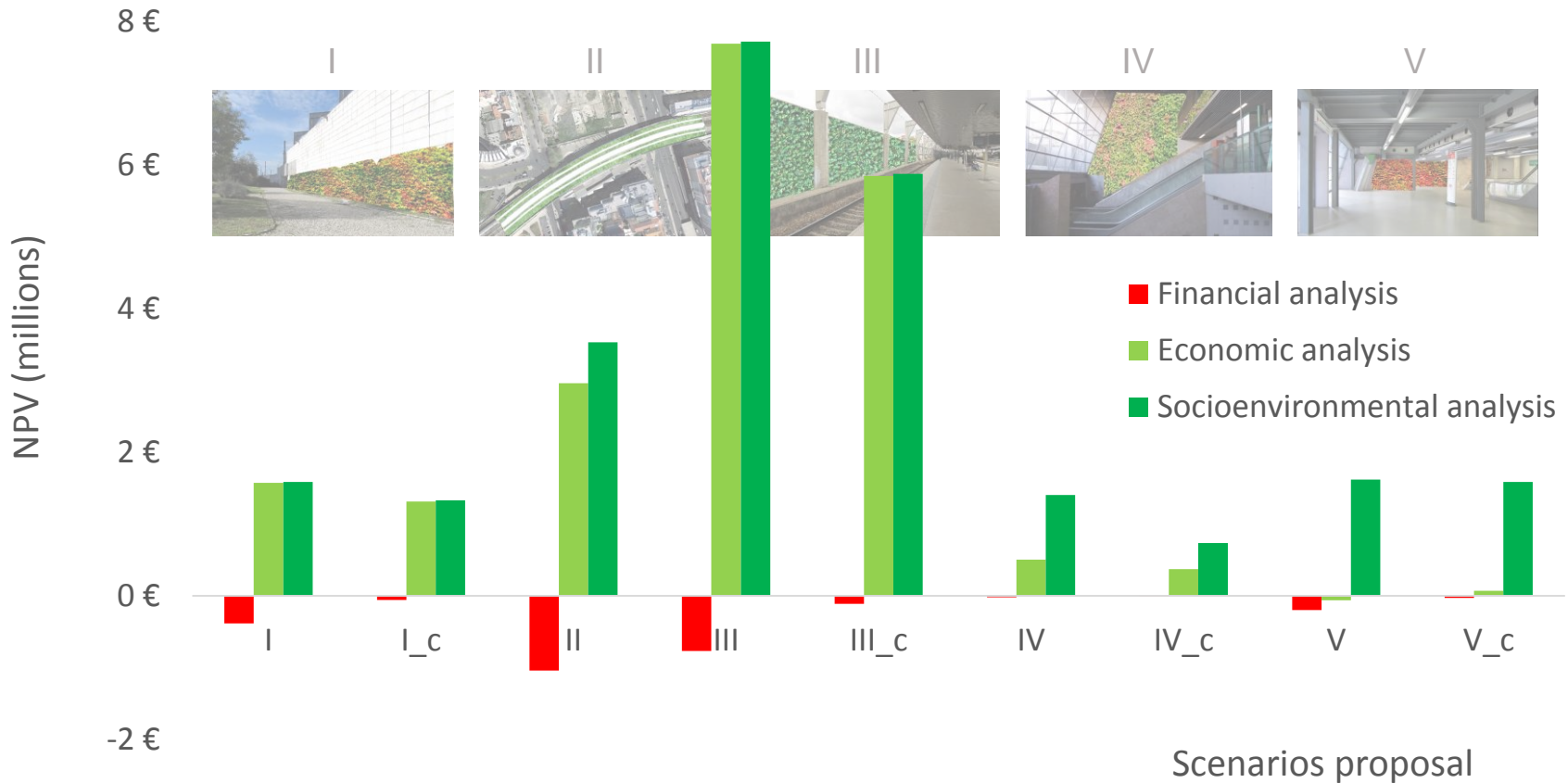
FINANCIALLY NON-VIABLE





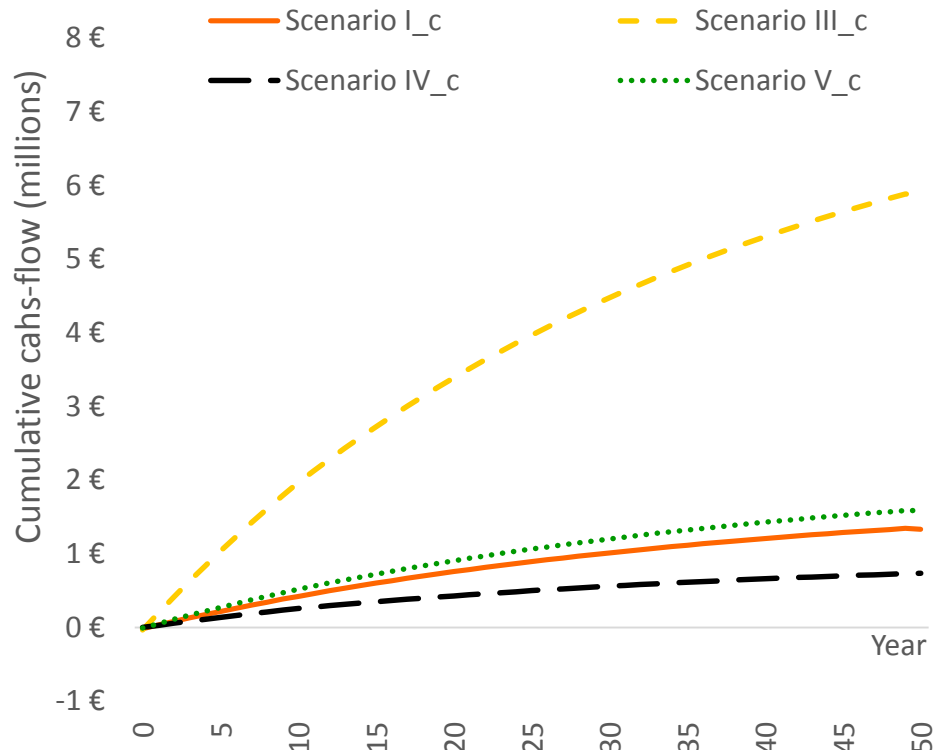
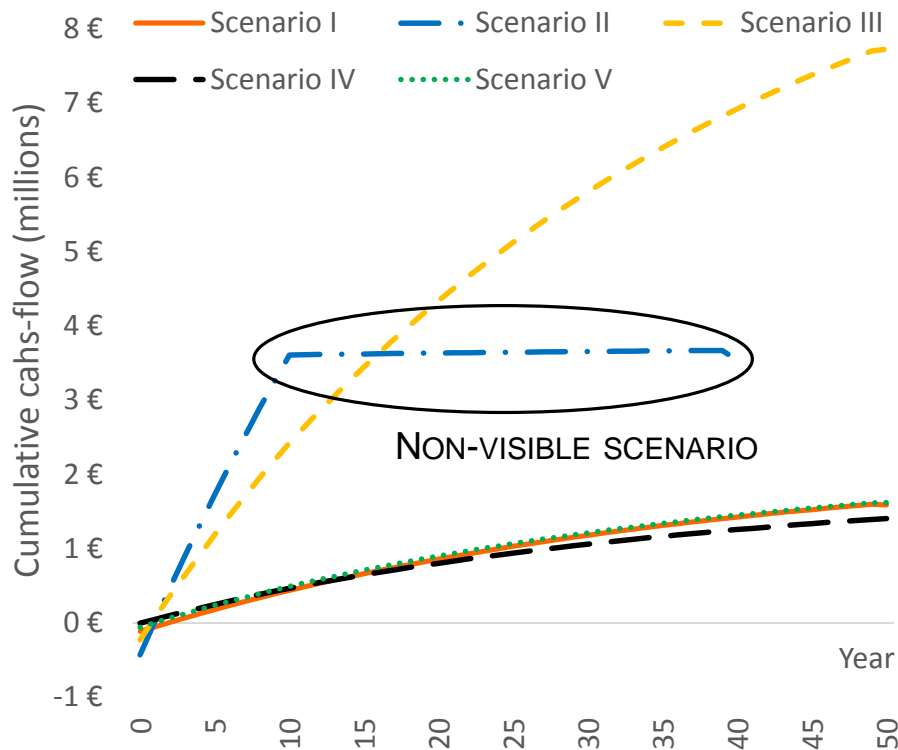
FINANCIALLY **NON-VIABLE**

ECONOMICALLY AND SOCIOENVIRONMENTALLY **VIABLE**

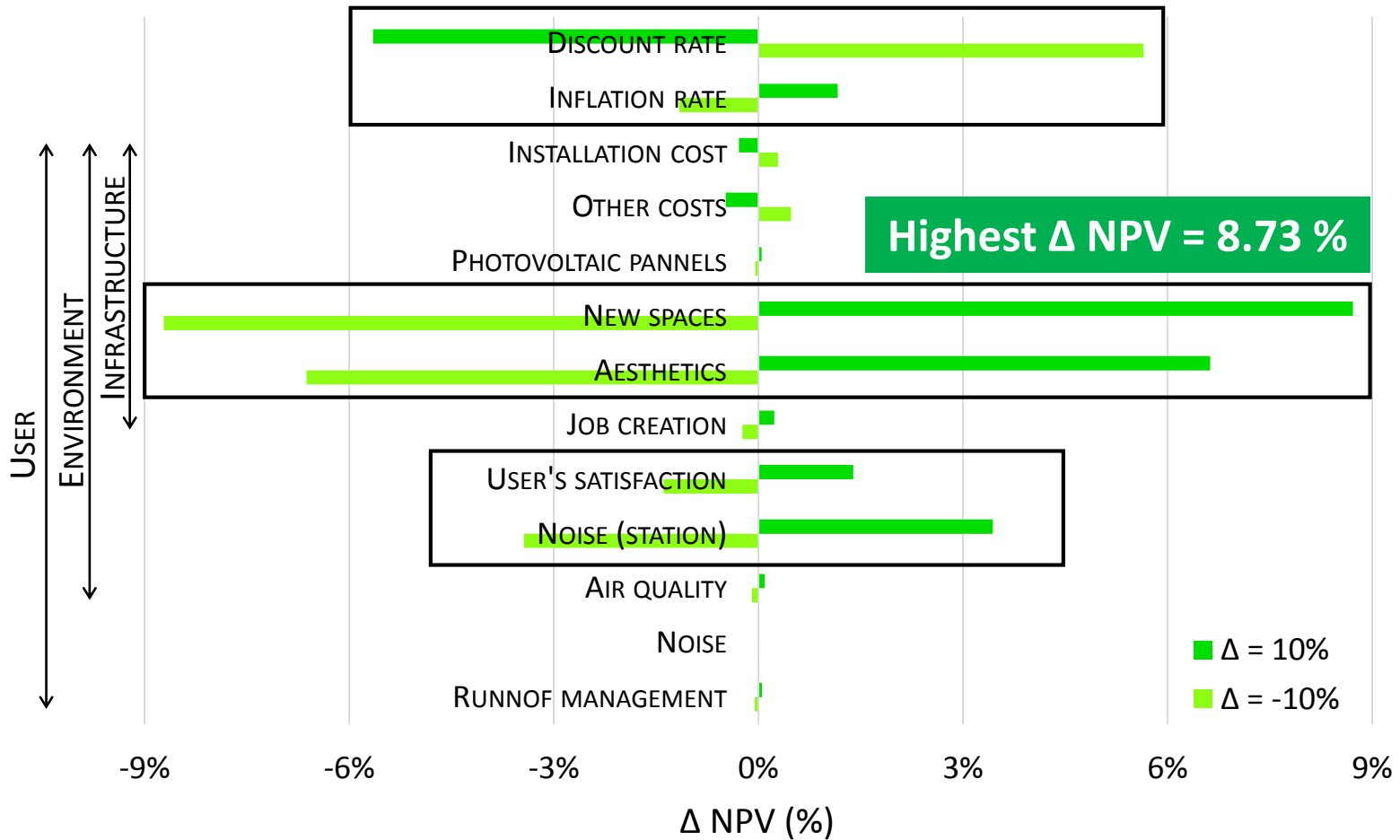




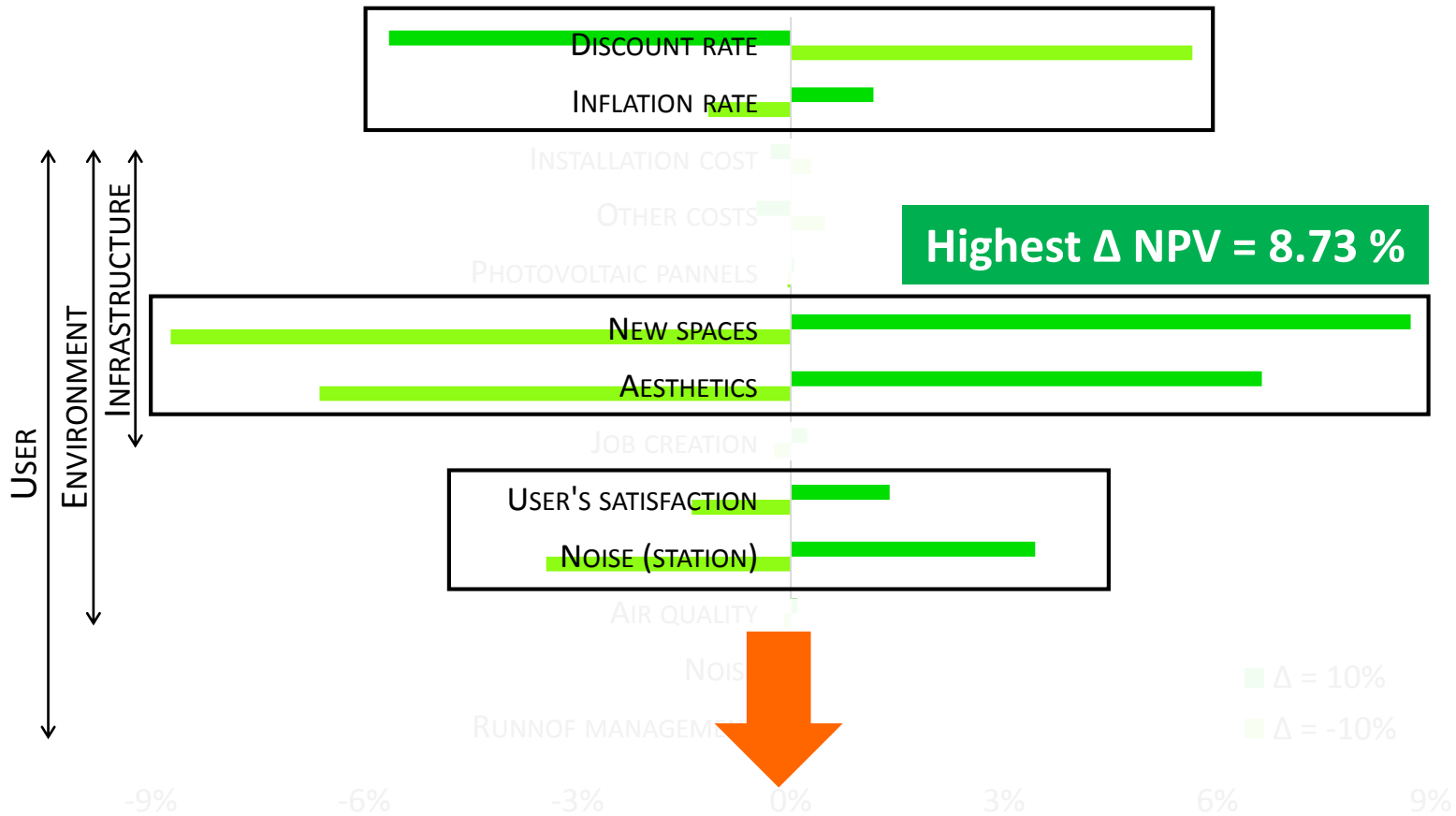
NPV 734 524.39 € to 7 726 612.99 €



SENSIBILITY ANALYSIS



SENSIBILITY ANALYSIS



Sensibility analysis is limited to significant parameters (higher elasticity)

SENSIBILITY ANALYSIS



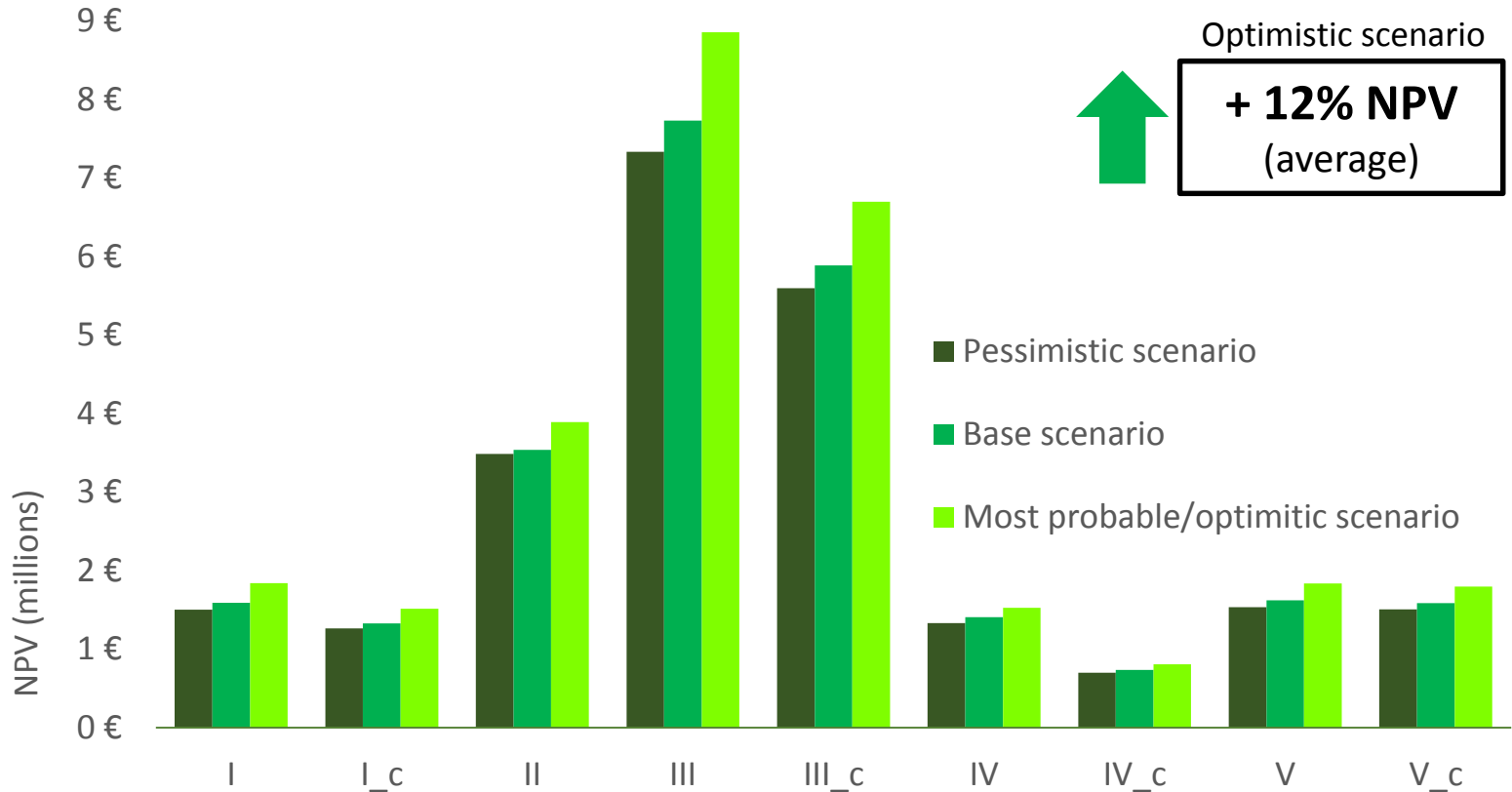
MOST PROBABLE SCENARIO
8 852 614.38 €

Pessimistic scenario

- 4% NPV
(average)

Optimistic scenario

+ 12% NPV
(average)





- Greening Entrecampos rail station, Lisbon, is a feasible investment at economic and socioenvironmental levels;
- No gains expected at financial level;
- Proposed green infrastructures would lead to social NPV ranging from 734,524.39 € (scenario IV) to 7,726,612.99 € (scenario II);
- Most visible scenarios, with a great number of exposed users, lead to higher NPV values;
- Living walls generate the highest absolute gains; green facades generate the greatest relative – cost-benefit – gains (5 times higher than living walls, on average);
- New spaces, aesthetics improvement, users' satisfaction and station's noise reduction benefits are the most relevant parameters for the economic evaluation outcomes;
- NPV varies up to 8.7% by individually varying the parameters 10%.

THANK YOU!