GREEN ROOFS AND LIVING WALLS – BENEFITS AND CHALLENGES

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ENVIRONMENTAL AND ECOLOGICAL IMBALANCES:
URBAN HEAT ISLAND
RAINWATER MANAGEMENT
AIR QUALITY
BIODIVERSITY LOSS
ECOSYSTEM HEALTH

URBAN AREAS
BENEFITS OF VEGETATION
INTENSIVE GREEN ROOF
Ewha Woman's University, Dominique Perrault, Seoul
**SEMI INTENSIVE GREEN ROOF**

**LIBRARY DELFT UNIVERSITY OF TECHNOLOGY, MECANOO, DELFT**
**EXTENSIVE GREEN ROOF with solar panels, Freiburg**

**GREEN ROOFS**
GREEN ROOFS – BENEFITS: BUILDING ENVELOPE

- **Energy saving for air conditioning**: shading and evaporation
- **Energy saving for heating**: extra insulation and wind protection
- **Roof protection**

http://commons.bcit.ca/greenroof/faq/why-green-roofs-benefits/
According to Rosenzweig et al. (2006) with 50% of roofs in NYC covered by vegetation, UHI could be reduced by 0.8°C.

Green roofs – benefits: UHI mitigation
GREEN ROOFS – BENEFITS: WATER MANAGEMENT

Relative performance of the three roof alternatives in terms of equivalence factors in the ozone layer depletion, acidification, eutrophication, and global warming impact categories.
INPS GREEN FACADE PILOT PROJECT. GENOA, ITALY
Rhincosperma jasminoide
Phlomis fruticosa
Buxus sempervirens rotundifolia
Dorycnium hirsutum

Nerium oleander
Euonymus bravo
Teucrium chamaedris
Viburnum tinus eve price

Cistus Jessami beauty
Atriplex halimus
Cistus crispus
Hebe franciscanus

INPS GREEN FACADE PILOT PROJECT
Evaluation of the environmental, economic, and social benefits of green envelopes in dense urban areas

Main objectives of the research:

- Plant species selection and monitoring
  - Effectiveness of plant species for air quality improvement
  - Effectiveness of plant species for energy performances
  - Plant species health and growth
Evaluation of the environmental, economic, and social benefits of green envelopes in dense urban areas

Main objectives of the research:

- Plant species selection and monitoring
- Quantification of air quality improvement (fine dusts, NO$_2$)

in collaboration with the Delft University of Technology, Dr. Marc Ottelé

- Collecting capacity of fine dusts
- NO$_2$ monitoring
Evaluation of the environmental, economic, and social benefits of green envelopes in dense urban areas

Main objectives of the research:

- Plant species selection and monitoring
- Quantification of air quality improvement (fine dusts, NO$_2$)
- Energy performances improvement of the building envelope

In collaboration with Ricerca sul Sistema Energetico (RSE) S.p.A. (Research on energy system)

- Monitoring the cooling potential of green facades (energy demand for air conditioning)
- Monitoring the insulation properties of green facades (energy demand for heating)
Evaluation of the environmental, economic, and social benefits of green envelopes in dense urban areas

Main objectives of the research:

- Plant species selection and monitoring
- Quantification of air quality improvement (fine dusts, NO$_2$)
- Energy performances improvement of the building envelope
- Evaluation of users’ social perception

- Qualitative and quantitative analysis
- Surveys and interviews to INPS employees, residents and workers in the area
Evaluation of the environmental, economic, and social benefits of green envelopes in dense urban areas

Main objectives of the research:

- Plant species selection and monitoring
- Quantification of air quality improvement (fine dusts, NO$_2$)
- Energy performances improvement of the building envelope
- Evaluation of users' social perception

Evaluation of economic impact of vertical greening systems

CBA: analysis of costs (installation and maintenance) in relation to economic benefits
Evaluation of the environmental, economic, and social benefits of green envelopes in dense urban areas

Main objectives of the research:

- Plant species selection and monitoring
- Quantification of air quality improvement (fine dusts, NO$_2$)
- Energy performances improvement of the building envelope
- Evaluation of users' social perception

Evaluation of economic impact of the vertical greening system
Evaluation of environmental impact of the vertical greening system

LCA: evaluation of the environmental burden of vertical greening related to microclimatic and environmental benefits

INPS GREEN FACADE PILOT PROJECT
Phase 1: quantitative analysis 3 months before the installation of the INPS green facade

July 2014

59 people interviewed:

- People working and/or living in the neighbourhood (44.1%)
- INPS employees (55.9%)
Survey on green facades of the University of Genoa, Department of Architectural Science (conducted in Italy, original version language Italian)

☐ Employee of INPS office in Sestri Ponente, Genoa
☐ Person working in Sestri Ponente, Genoa
☐ Person living in Sestri Ponente, Genoa

Some examples of green facades
Have you ever seen one or more?
☐ yes ☐ no
Have you ever heard about it?
☐ yes ☐ no

Select the importance of each of the POSITIVE EFFECTS of green facades in a city rating from 1 to 5 (highest):

More nature in cities
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
Visually enhanced cityscape
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
Better wellbeing of citizens
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
Increase of biodiversity (small animals)
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
Air quality improvement
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
Shading and cooling in summer
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
Thermal insulation during winter season
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
Improvement of the city environment
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
Reduction of noise pollution
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
Environmental education
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
Building aesthetic
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

Select the importance of each of the NEGATIVE EFFECTS of green facades in a city rating from 1 to 5 (highest):

Frequent maintenance
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
Problems related to falling leaves
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
Problems with building restoration
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
Obstruction of gutter or standpipes
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
Less daylight inside the building
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
Damages to the facades
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
Dirty due to the presence of animals
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
More insects
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
Management problems
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
Additional costs
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
Higher danger of theft
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

[Image of green facades]
Phase 1: quantitative analysis 3 months before the installation of the INPS green facade

July 2014

59 people interviewed

INPS GREEN FACADE – USERS PERCEPTION
Phase 1: quantitative analysis 3 months before the installation of the INPS green facade

July 2014

59 people interviewed:

- People working and/or living in the neighbourhood (44,1%)
- INPS employees (55,9%)

Most recognised positive effect: air quality improvement

Most recognised negative effect: more insects

Total scores:

- People working and/or living in the neighbourhood: 56,8% positive - 43,2% negative
- INPS employees: 47,4% positive - 52,6% negative
COSTI E BENEFICI
I fondi investiti per questa opera verranno recuperati nel tempo grazie alla riduzione dei costi per la climatizzazione estiva.

RISPARMIO ENERGETICO
Risparmiare energia significa una minore dipendenza dalla importazione di idrocarburi e la riduzione delle emissioni inquinanti in atmosfera. È dovere di tutti e gli enti pubblici devono dare il buon esempio.

SOSTENIBILITÀ AMBIENTALE
La valorizzazione delle capacità tecnico economiche del nostro Paese deve combinarsi con una riduzione dell’uso di risorse di disponibilità limitata e di importazione, come i prodotti petroliferi e il gas naturale.

QUALITÀ DELL’ARIA
La vegetazione assorbe polveri sottili ed inquinanti migliorando la qualità dell’aria nelle città, controllando anche il tasso di CO₂ presente in atmosfera.

RICERCA E INNOVAZIONE
La collaborazione tra Università e enti pubblici crea sinergie utili a mettere a punto soluzioni tecnologiche utili per migliorare la qualità ambientale nelle città e la qualità di vita dei cittadini.
Phase 2: qualitative analysis 6 months after the installation of the INPS green facade

May 2015, with Roberta Prampolini

21 semi-structured interviews to a significant sample

- Residents in the neighbourhood – 106 answers
- People working in the neighbourhood – 85 answers
- INPS employees – 55 answers

Investigation topics:

1. Photo elicitation to favour a dialog on the INSP Green facade
2. Green areas in the neighbourhood
3. Vertical green in other areas of the city
Phase 2: qualitative analysis 6 months after the installation of the INPS green facade

May 2015, with Roberta Prampolini

Investigation topics:

1. Photo elicitation to favour a dialog on the INSP Green façade
   - Reduced knowledge of the technology
   - Positive opinion due to: aesthetic, wellbeing, environmental and energy effects
   - Negative effects (less) due to: insects and maintenance needs
   - Critics arise during the installation were mentioned – only 3 of 21 highlight negative opinions
Phase 2: qualitative analysis 6 months after the installation of the INPS green facade

May 2015, with Roberta Prampolini

Investigation topics:

1. Photo elicitation to favour a dialog on the INSP Green facade

2. Green areas in the neighbourhood
   - Not enough

3. Vertical green in other areas of the city
   - Public funds

   - The results show that communication plays a key role
   - Younger people show positive opinion about the project
Phase 2: qualitative analysis 6 months after the installation of the INPS green facade
May 2015, with Roberta Prampolini

- to improve the area in a very busy street, I think it was built there for a reason!
- something positive for air pollution
- I was curious when I saw the facade.. I thought it was a waste of money then I understood this is a smart idea!
- A building with flowers with an aesthetic value only, a modern project, let's say!
- some green.. Something new!
- It could be positive!
- .. In addition it could also protect the facade, so..

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Quantification of air quality improvement
PM collecting capacities
Quantification of air quality improvement
PM collecting capacities – UNIGE-DSA with TUDelft

\textit{Rhincosperma jasminoide}

\textit{Phlomis fruticosa}

\textit{Hedera helix}

\textit{Cistus Jessami beauty}
Quantification of air quality improvement
PM collecting capacities – UNIGE-DSA with TUDelft

ESEM analysis
Quantification of air quality improvement
PM collecting capacities – UNIGE-DSA with TUDelft

ESEM analysis – IMAGE J counting

INPS GREEN FACADE – AIR QUALITY
INPS GREEN FACADE – AIR QUALITY
Quantification of air quality improvement
PM collecting capacities – UNIGE-DSA with TUDelft

Number and size (µm) of particles in 1 mm² for *Hedera helix, Cistus jessamy beauty, Phlomis fruticosa, Rhyncospermum jasminoide*, based on 100x, 250x, 500x magnifications

INPS GREEN FACADE – AIR QUALITY
Energy performances improvement of the building envelope

In collaboration with Ricerca sul Sistema Energetico (RSE) S.p.A. (Research on energy system)

Monitoring the cooling potential of green facades

SOURCE: PERINI ET AL., 2016 IN PRESS
Energy performances improvement of the building envelope

In collaboration with Ricerca sul Sistema Energetico (RSE) S.p.A. (Research on energy system)

Monitoring the cooling potential of green facades

Comparison between external surface temperatures in presence and in absence of the vertical greening system

INPS GREEN FACADE – ENERGY
Evaluation of economic impact of vertical greening systems

CBA: analysis of costs (installation and maintenance) in relation to economic benefits

Evaluation of environmental impact of the vertical greening system

LCA: evaluation of the environmental burden of vertical greening related to microclimatic and environmental benefits

INPS GREEN FACADE
Life cycle analysis of greening systems: environmental burden profile in relation with the energy savings for air conditioning and heating

Calculation of the environmental impact of:
- production
- use-maintenance
- disposal-waste

Greening systems analysed:

A. direct greening system
B. indirect greening system (stainless steel mesh)
C. LWS based on planter boxes
D. LWS based on felt layers

Energy saving for heating
A. Direct green: 1.2%
B. Indirect green: 1.2%
C. LWS planter boxes: 6.3%
D. LWS felt layers: 4%

Energy saving for cooling in Mediterranean climate: 43% (Alexandri and Jones, 2007).

Source: Ottele and Perini, 2011

VERTICAL GREENING – ENVIRONMENTAL SUSTAINABILITY
Vertical greening systems and economic sustainability
CosteBenefit Analysis of an office building designed for the study located in Italy (dense city).
- Initial costs (installation)
- Maintenance costs
- Disposal costs

(Economic) benefits related to the installation of vertical greening systems:

Personal
- Energy saving: heating (additional insulation) and air-conditioning
- Longevity: cladding durability
- Real estate: increase of property value
- Incentives and support: tax reduction

Social
- Climate change: carbon dioxide reduction
- Air quality improvement: NO2, PM10, SO2 reduction
- Habitat: increase of biodiversity
- Urban heat island: air temperature reduction
- Aesthetic: increase of area value

Source: Perini and Rosasco, 2015
Vertical greening systems analysed:
1: direct green façade
2A: HDPE indirect green façade
2B: steel indirect green façade
3A: HDPE indirect green façade combined with planter boxes
3B: steel indirect green façade combined with planter boxes
4: living wall system

Net Present Value (NPV) of the systems analyzed - the discounted value of the sum of costs and benefits that occur within the period of life considered (50 years).
Thank you

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http://www.ecosystemics.eu