+44 (0)1243 545818
enquiries@ans.global
ansgroupglobal.com

ANS Global details the benefits of Living Walls

We would all recognise that living walls are aesthetically pleasing, but ANS Global would like to show that the benefits are really what they say they are. Some extensive research has been carried out, and conclude the findings below.

General introduction

Since the beginning of the twentieth century, research into the use of green inside the cities has increased substantially. Nowadays, the environmental impact of buildings on the inner and outer climate becomes more and more apparent. Green buildings are designed to reduce the overall impact of the built environment on human health and the natural environment. The green building strategy in the presented research concentrates on one key aspect of the 'greening process', namely the use of plants on and around urban buildings.

Why are city dwellers becoming more and more interested in focusing on the innovative use of a green building envelope (greening of buildings with vegetation)? If you are wondering this, a walk around a city looking at facades with and without plants, looking for the enhancing effect that even a thin cover of mosses or algae can have on the visual impact of the façade, will probably provide you with the answer!

Air quality improvement

Leaves of plants provide a large surface area which is capable of filtering out particulate matter (PMx), other pollutants such as NOx (conversion to nitrate (NO_3), nitrate (NO_2)) and CO_2 in daytime. A green façade will block the movement of particulate matter particles along the side of a building and filter them. Vegetation has a large surface area and also promotes vertical transport by enhancing turbulence. When concrete, brick, stone, glass and asphalt surfaces are heated during the summer period, vertical thermal air movements (upwards) are created and dust particles found on the ground are carried and spread in the air. Particulate matter is adsorbed by the leaves, trucks and twigs and is an efficient sink for particulate matter. According to Hosker and Lindberg (1982) fine dust ($PM_{2.5}$ and PM_{10}) concentrations are reduced when particles are adhered to the leaves and stems of plants. Literature claims that by rainfall the adsorbed particulate matter is washed off into the soil or substrate below.

Heavy metal concentrations and fine particles were found on leaves of a green façade in the inner city of Dusseldorf (daily traffic level 12,500 vehicles). The same results were found by comparing ivy leaves from different sites (by counting particles on ivy leaves), the leaves from the sites exposed to a high daily traffic level, had collected a significant number of particles compared to the sites that are less exposed. Besides particle binding plants are also know to absorb gaseous pollutants through the stomata (CO_2 and NOx). Via photosynthesis CO_2 is sequestered in the leaves. Negative health effects of particulate matter pollution for human's stands for decreasing lung functions, increased respiratory problems, and other health care visits for respiratory and cardiovascular diseases. Besides these effects also durability problems are involved and include accelerated corrosion of metals, as well as damage to paints, sculptures and soil-exposed surfaces on man-made structures. The improved air quality by green facades has direct benefits for people who suffer a long disease. A decrease of smog formation will occur, and also durability or corrosion problems are reduced of urban infrastructure that is susceptible to damage from air pollution. Tree with a combined leaf surface area of 1600m² creates 1.71kg of O_2 and 1.6kg of glucose every hour (using 2.4kg of CO_2, 96kg of H_2O, and 25.5KJ heat energy). This level of production is equal to the oxygen intake of 10 humans every hour. Another study carried out by the University of Dresden (2009) with regard to the organic balance of a greened façade with 1000m² Hedera helix pointed out that in one year: 1019kg of water and 2351kg of CO_2 is consumed and bound respectively. In this reaction 5854 of organic mass (water content 4409kg and dry mass 1415kg) and 1712kg of O_2 is produced.

With the assumption of an leaf area index (ratio between leaf surface in m² and covered wall surface in m²) for Hedera helix of 2.6 up to 7.7m² leaf/m² wall (Bartfelder and Kohler, 1987). The following leaf surface area can be calculated for the façade.

> Average value of the leaf area index of Hedera Helix = 5.2m² leaf/m² wall taking a greened wall surface of 1000m² this results to: 5.2 x 1000 = 5200m² of leaf surface.

Comparing this with the investigated mature beech tree of Minke (1982) with a leaf surface of 1600m², a greened façade with Hedera Helix is more efficient to adsorb CO_2 and to produce O_2.

Ecological aspects

Vertical gardens can be designed as acceptable alternative ecological habitats. Particular species such as Hedera helix and climbing roses (Rosa) produce colourful berries enjoyed by birds in winter time. When we look at the facades or outside walls of buildings, green systems will show ecosystem characteristics, and they will function as a habitat, show structure, material and energy flows. It will also provide ecological services like breeding and resting habitat for birds which may be enjoyed by humans. Not only for micro-organisms an undisturbed habitat is created but also for smaller animals (bees, bats, birds etc) it is suitable.

Climbing plants are particularly favoured by birds and bats. Facades studied in Berlin show that mainly house sparrows, blackbirds and greenfinches are found between the climbers. Green facades functions hereby as a food source (insects) and as a nesting or breeding opportunity.

The current form of urbanisation is negative for house sparrows; since the current building design leads to a lack of nesting occasions in buildings (Vogelbescherming Nederland, 2010). A wide range of artificial structures have been used throughout the world to provide nest sites for a great range of birds and bats. Many types of these artificial nest boxes can be attached or incorporated to the outside of new or existing (green) buildings. Integrating nature on new buildings allows for the possibility to choose for built-in nest boxes which can be incorporated into the ecological design. Last but not least watching these animals can be a source of considerable pleasure to city dwellers as well. Incorporating nest boxes into green façade concepts (linking of functions) will increase the impact of these measures relatively to when applied separately.

Not only birds are attracted by green facades and roofs. A biodiversity study of 17 green roofs in Basel indentified 245 beetle and 78 spider species in the first three years after installation of the roof. Eleven percent of beetles and 18% of the spiders were listed as rare or endangered. Also Kohler (1988) concluded from his research that climbing plants (for example Hedera Helix and Parthenocissus) form an important habitat for insects. Mainly beetles, flies and spiders are found inside a green façade.

Protection against driving rain and sun radiation

Well developed green facades (closed foliage) forms an effective protection against driving rain, because it prevents that the rain will reach the surface of the façade. Investigations done by Rath and Kiebl (1989) on greened facades pointed out that with well developed foliage no rain will reach the wall surface. Rath and Kiebl (1989) also found that 50% of the solar energy was adsorbed and 30% was reflected by the foliage. Beside the adsorption and reflection they measured that approximately 20% of the radiation passes the foliage and reach the surface of the façade. This means that a plant covered façade can shield off roughly 80% of the solar radiation while a bare façade receives 100% direct exposure. This filtering of the radiation by the foliage can lead to protection or a reduction in maintenance of cladding, painting, coatings or other building materials that are sensitive to UV deterioration. As a consequence these effects also thermal stresses inside building materials will be reduced.

Temperature regulation and insulating properties

Living walls and green facades create their own specific microclimate, quite different from surrounding conditions. Due to this specific micro climate both around the building and at grade are affected. Depending on height, orientation and the location of surrounding buildings, the façade is subjected to extreme temperature fluctuations (hot during the day and cool at night), with constant exposure to sunlight and wind. The climate at the façade is comparable with arid or alpine climate and only suitable to specific types of plants.

Hard surfaces of concrete and glass encourage runoff of rainwater into the sewage system. Plants buffer water on their leaf surfaces longer than building materials, and the processes of transpiration and evaporation can add more water into the air. The result of this is a more pleasant climate in the urban area. Between façade and the dense vertical green layer (for both rooted in the subsoil as rooted in artificial soil based systems) a stagnant air layer exist. Stagnant air has an insulating effect; green facades can therefore serve as an “extra insulation” of the building façade.

Also direct sunlight on the façade is blocked by the vegetation. This blocking of the sunlight ensures that the temperature will be less high inside a house. In winter, the system works the other way round and heat radiation of the exterior walls is isolated by evergreen vegetation. In addition it is claimed in literature that dense foliage will reduce the wind speed along the façade and thus also helps to prevent that the walls will cool. As a consequence every decrease in the internal air temperature of 0.5°C will reduce the electricity use for air conditioning up to 8%. Green facades and roofs will cool local air temperatures in two different ways. First of all, walls behind greened surfaces absorb less heat energy from the sun (traditional façade and roof surfaces will heat up the air around them). This effect is clearly visible where uncovered parts of the façade are heated up and the parts covered with leaves considerable lower. Secondly, green facades and roofs will cool the heated air through evaporation of water (for evaporation of 1kg water, 2.5 MJ of energy is necessary); this process is also known as evapo-transpiration.

Most of the sun’s radiation that is adsorbed by concrete, bituminous materials or masonry is re-radiated as sensible heat. Asphalt, concrete and masonry will reflect 15 to 50% of the received radiation they receive, greening paved surfaces with vegetation to intercept the radiation before it can it hard surfaces can reduce the warming up of hard surfaces, especially in dense urban areas. In an urban heat island effect situation, even night air temperatures are warmer because of built surfaces adsorb heat and radiate it back during the evening hours.

From 100% of sunlight energy that falls on a leaf, 5-30% is reflected, 5-20% is used for photosynthesis, 10-50% is transformed into heat, 20-40% is used for evapo-transpiration and 5-30% is passed through the leaf. In the urban area, the impact of evapo-transpiration and shading of plants can significantly reduce the amount of heat that would re-radiated by facades and other hard surfaces. Besides that, the green plant layer will also reduce the amount of UV light that will fall on building materials. Since UV light deteriorates material and mechanical properties of coatings, paints, plastics etc. Plants will also have an effect on durability aspects. This is a beneficial side effect which will have a cost effective effect on maintenance costs of buildings. The denser and thicker the plant layer on the green façade, the more beneficial these effects are.

The role of insulation materials and stagnant air layers is to slow down the rate of heat transfer between the inside and outside of a building, which is a function of the difference between inside and outside temperatures. An insulation material mitigates the impact of the temperature difference between inside and outside. In winter conditions the insulation material slows down the rate of heat transfer to the outside. In summer conditions the opposite is the case; it slows down the rate of heat transfer from the outside to the inside. The greening of vertical surfaces has a beneficial effect on the insulating properties of buildings through exterior temperature regulation. The insulation value of vertical greened surfaces can be increased basically by different mechanisms.

- By covering the building with vegetation, solar radiation is prevented reaching the building skin (shading effect of leaves), and in the winter, the internal heat is prevented from escaping.
- Since wind decreases the energy efficiency of a building by 50%, a plant layer will act as a buffer that keeps wind from moving along a building surface.
- The thermal resistance of a construction can be reduced from 23 W/m^2K to 12 W/m^2K.

- The thermal insulation provided by vegetation and substrates used (mostly related to living wall concepts).

Table 1.1 Assumption done by Minke (1982) on the improvement of a green façade on the thermal insulation values.

Construction layers	1/λ	(m^2K/W)	(m^2K/W)
1/a inside	0.13	0.13	0.13
2 cm gypsum	0.02	0.02	0.02
36 cm masonry (1600 kg/m^3)	0.56	0.56	0.56
2 cm gypsum	0.02	0.02	0.02
1/a	0.04	-	-
1/a outside, changing	-	0.13	-
4 cm air cavity (a = 0.1)	-	-	0.40
Σ1/λ	0.77	0.86	1.13
R (m^2K/W)	1.30	1.16	0.88
Energy saving in %	0	11	32

Krusche claims that the air cavity between leaves and façade decrease the heat transfer from façade to the outdoor air. A green façade with a leaf cover of a size of 5cm yields a k-value or 2.9 W/m^2K which is comparable with double glazing. The k-value (denoted as the U-value), or heat transfer coefficient, is the measured value of the heat flow which is transferred through an area of $1m^2$ at a temperature difference of 1K. The U-value can be found by the reciprocal of the thermal resistance (R-Value) of a construction.

Table 2.1 Improvement of the insulating value of a well greened façade (5cm stagnant air layer between leaves and façade) depending on the U-value of the façade according to Krusche.

Façade without green	Greened façade	Improvment
U-Value	U-Value	%
1.5	1.0	33
1.0	0.75	25
0.6	0.5	16
0.3	0.27	10

This “green” strategy of increasing exterior insulation properties of vertical surfaces stimulates upgrading or retrofitting of existing (under-insulated) facades without the added cost of interior or traditional exterior insulation (see table 2.1).

The behaviour of greened facades not only influences the interior climate but also the outer climate is affected. Bartfelder and Kohler (1987) measured differences in temperature as a function of different distances in front of a façade (table 3.1). Also Rath and Kiebl (1989) measured differences in the temperature gradient across an with green covered wall up to 10°C. The corresponding factor in both researches is that at 1 m in front of the vegetation layer no temperature differences were measured between the greened and non-greened facades. However the temperature difference at the wall surface between a greened and non greened façade is approximately ca. 6°C.

Table 3.1 Measurement of Bartfelder and Kohler in summer 1982 of a bare façade and a façade greened with Hedera helix according to Bartfelder and Kohler (1987)

Green façade research Berlin summer 1982							
			Uncovered		Covered with green		
Period	Parameter	T_1	T_{01}	T_0	$T_{1\varrho}$	$T_{01\varrho}$	$T_{0\varrho}$
All days (n=133)	Max	20.8	22.2	31.0	21.4	22.2	25.2
	Min	12.4	13.1	16.7	12.6	14.1	16.3
	Amplitude	8.4	9.1	14.3	8.8	8.1	8.9
Sunny days (n=64)	Max	24.1	25.6	36.0	25.1	24.8	28.6
	Min	13.0	13.8	17.2	14.5	13.1	17.2
	Amplitude	11.1	12.2	18.8	10.6	11.7	11.4
Minimum temperature (n=133)	Max	6.2	6.1	11.2	7.9	6.8	9.9
	Min	1.0	1.2	7.0	3.0	0.9	3.8
	Amplitude	5.2	4.9	4.2	4.9	5.9	5.2
T_1	Temperature 1m before facade						
T_{01}	Temperature 10 cm before facade						
T_0	Temperature of facade						

This means that a greened façade adsorbed less heat than a non greened façade and reveal itself in less heat radiation in the evening and night. In this way a greened façade contributes in mitigation of the urban heat island effect.

Sound adsorption and noise reduction

Plants can adsorb, reflect and diffract noise, this effect could lead to a more comfortable and pleasant environment in urban areas. The efficiency appears to be dependent from the plant type, planting density, location and sound frequency. For indoor application the acoustical performance of a number of typical indoor plant species is defined by Costa (1995).

Table 4.1 Absorption coefficients for a number of single indoor plant species according to Costa (1995)

Typical absorption coefficients						
Plant Species			Sound Frequency (H^z)			
	125	250	500	1000	2000	4000
Ficus benjamina	0.06	0.06	0.10	0.19	0.22	0.57
Howea forsteriana	0.21	0.11	0.09	0.22	0.11	0.08
Dracaena fragrans	0.13	0.14	0.12	0.12	0.16	0.11
Spathiphyllum wallisii	0.09	0.07	0.08	0.13	0.22	0.44
Dracaena marginata	0.13	0.03	0.16	0.08	0.14	0.47

Schefflera arboricola	-	0.13	0.06	0.22	0.23	0.47
Philodendron candens	-	0.23	0.22	0.29	0.34	0.72
To compare						
Bark mulch	0.05	0.16	0.26	0.46	0.73	0.88
Thick pile carpet	0.15	0.25	0.50	0.60	0.70	0.70
Plasterboard	0.30	0.15	0.10	0.05	0.04	0.05
Fresh Snow, (100mm)	0.45	0.75	0.90	0.95	0.95	0.95

Green facades either greened directly, indirectly or with a modular living wall concept can be seen as a multilayered system. Due to the materials used, it is likely that the effect on sound adsorption will be larger. Research conducted at the National University of Singapore, was focussed on the effect of sound adsorption by different vertical greening systems. They measured the inertial loss and sound absorption coefficient of nine different vertical green cladding systems placed above the ground 1 m in front of the façade and 2 m behind the green wall systems. A sound calibrator was placed 2 m in front of the greened facades.

Table 5.1 Description of eight vertical greenery systems as tested in Hortpark

Vertical greenery system			Average thickness (m)		
			Substrate	Plants	Total
Green facade	Vertical interface	1	0.250	0.100	0.350
	Mesh system	2	0.080	0.010	0.090
		3	0.230	0.120	0.350
		4	0.080	0.120	0.200
Living Wall	Angled interface	5	0.070	0.110	0.180
	Horizontal interface	6	0.065	0.055	0.120
		7	0.060	0.120	0.180
		8	0.280	0.200	0.480

As plant species Nephrolepis Exaltata (Boston fern) placed in pots on wooden racks was used for this experiment. In total 140 pots of plants were defined as covering the façade by 100% with foliage, subsequently 100 and 60 plants were defined as 71% and 43% covering. The materials used for this experiment were the same as for the field measurements. The used reverberation chamber was 136m³.

From the insertion loss experiment it was found that there was a strong attenuation at low to middle frequencies due to the effect of the substrate used while a smaller attenuation was observed at high frequency due to the scattering of the greenery. The eight tested systems in Hortpark are more effective at reducing lower frequency noise source. However from table 6.1 it can be derived that the systems 1,2,5,6 & 7 have a reduction of around 5-10 dB for the low to middle frequency range, which is perceptible or even clearly noticeable for human perception in the change of sound intensity.

The sound absorption coefficient (table 7.1) of the tested vertical greenery system (three different percentages of foliage cover) in the reverberation chamber has one of the highest values compared with other buildings materials and furnishings. The substrate in the systems does most of the absorption. The green wall seems to have a lot effect on the reverberation time, especially in the range of 200 Hz – 1 KHz. The soil performs well at low frequencies and the plants perform better at high frequencies. The relationship between the greenery coverage and the sound absorption coefficient is observed that with greater greenery coverage, there is an increase in the sound absorption coefficient.

Table 6.1 Summary of insertion loss

Vertical greenery system	Insertion loss (dB)			
	Zone B: 125-1250 Hz		Zone D: 4-10 kHz	
	Lowest	Highest	Lowest	Highest
1	2.5	5.6	0.6	3.1
2	1.1	9.9	2.2	3.8
3	4.5	2.2	4.0	3.2
4	1.5	4.0	2.5	2.0
5	3.3	7.0	0.3	2.8
6	2.4	5.4	1.6	3.2
7	0.3	8.4	0.0	3.9
8	0.6	3.1	2.6	8.8

Table 7.1 Summary of sound absorption coefficient

Frequency (Hz)	Sound absorption coefficient (greenery coverage)		
	43%	71%	100%
100	0.06	0.04	0.04
125	0.12	0.10	0.09
160	0.10	0.11	0.14
200	0.17	0.18	0.18
250	0.25	0.28	0.23
315	0.31	0.30	0.29
400	0.32	0.30	0.32
500	0.51	0.47	0.49
630	0.57	0.55	0.47
800	0.50	0.44	0.41
1000	0.61	0.54	0.48
1250	0.54	0.57	0.49
1600	0.65	0.57	0.51
2000	0.66	0.56	0.49
2500	0.64	0.57	0.50
3150	0.62	0.56	0.49
4000	0.57	0.51	0.47
5000	0.58	0.54	0.48

Social impact

People seem to feel better in a green environment which is mainly related to psychological influence. This phenomenon is called biophilia and suggests that people feel better next to all that is alive and vital. It is a feeling of a bond between humans and other live forms that comes from “the connections that human beings subconsciously seek with the rest of life"

(Wilson, 1984). Studies conducted in the past show clearly the effects that plants have on human health. For instance, it is found that visiting a botanical garden lowers blood pressure and reduces heart rate. Ulrich (1991) show that the presence of vegetation will speed up recovery from stress and in earlier research Ulrich (1984) pointed out that patients with windows looking on a natural scene had shorter postoperative hospital stays. Fjeld (1998) show that in an office space the score sum of symptoms of discomfort was 23% lower during the period when subjects had plants in their offices compared to the control period.

Cost

Buildings consume 36% of total energy use and 65% of the total electricity consumption. Kula (2005) suggests that a wide scale green roof implementation could significantly impact energy savings. Mostly a building encompasses a larger façade surface than a roof surface, it seems therefore plausible that greening facades would lead to a larger significantly impact on the energy savings compared with a green roof. According to Dunnet and Kingsbury (2004) every decrease of the internal building temperature with 0.5°C may reduce the electricity use with 8% for air conditioning in summer periods. Since 1940 the temperatures in urban areas have been increased by about 0.5-3°C. For each 1°C increase in temperature in cities, the electricity demand is typically increased by 2-4%. It is estimated that 5-10% of the current electricity demand of cities is used to cool buildings just to compensate the 0.5-3°C increased temperature. Mitigation of the urban heat island effect with trees, green roofs and green facades can reduce the U.S national energy consumption for air conditioning with 20% and save more than $10B in energy use.

However there are more processes and costs involved due to lower outdoor temperatures. Lower electricity demand involves also less energy production at the power plant. If the power plant is coal fired this means also less emissions, and thus a decrease of the air pollution. If there is less air pollution this affects for example also human health with respect to lung or cardiovascular diseases caused by fine particles or smog formation. Costs are not only related to energy savings and a reduction of air pollution levels, but also for example of the real estate values in dense areas. Due to the use of more green in the neighbourhood houses can even gain up to six percent extra values due to a good tree cover in the surroundings.

The living wall systems increase the variety of plants that can be used beyond the use of climbing plants and offers much more creative potential. It is also possible to assume that, from a functional point of view, most of the living wall systems compared to green, demand a more complex design, which must consider a major number of variables (several layers are involved, supporting materials, control of water and nutrients, etc.)

Due to the maintenance needed (nutrients and watering system), the materials involved, the design complexity. It also has to be taken into account the durability of the systems, for example a panel of a Living Wall System based on planter boxes is more durable (more than fifty years). Beside this is a thorough design (details of window ledges, etc) is necessary to avoid damages, as corrosion or rot, caused by water and nutrients leakage which involves also extra costs.

Maintenance

Facades covered via a living wall system with sophisticated planting combinations may need a certain amount of maintenance. Maintenance is mainly related to the vegetation and not to the construction itself. However, the irrigation system that is needed for these systems must be deflated in winter to prevent frost damage, and additional required nutrients (plant growth) must be replenished occasionally. Maintenance of the vegetation consists mainly of pruning twice a year with a mobile crane and possibly replanting in places where the vegetation is deteriorated. This problem is mainly related to the living wall systems, advisable is to check annually the façade in spring. In some cases it is also possible to replace prefab panels with new pre-vegetated panels to reach instantly a greener result.

For further details and clarification please contact our Technical Advisor Steve McIntyre
T: +44 1243 545818
M: +44 78484 52583
E: steve.mcintyre@ans.global