

PERFORATING THE BUILDING ENVELOPE WITH A BREATHABLE COVER OF LIVE WALL CONCEPT

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Abstract: Facades are the main elements of the building envelope, which are effected by the heat. The LIVE WALL concept brings a layer of cover which protects it from the adverse effects. This paper contains an investigation or the detail study on GREEN WALLS/LIVING WALLS, to understand their construction process and the purpose we build them. How effectively we can use them in the built environment to reduce carbon foot prints which leads to the heat island. This paper illustrates that the green walls have been inspired by nature, that the modern system was created by a passionate French botanist who wanted to get back the green space. The paper deals with the history of its emersion, and then it presents the various benefits attributed to these structures, and more over they provide good aesthetic piece of nature in the urban area. It explains the functions and the impacts which are scientifically evidenced, as a barrier, absorb or degrade greenhouse gases, and the cooling effect. The financial aspect also welcomes them. This paper also presents how their capacity to act on the heat island effect by reducing city temperature. It will explain the decelerating factors of green wall technologies. In short it tells about how it works, growth of plants, how and where it is mounted, medium used to grow plants and the changes or developments occurred in the technologies of the walls. Finally the possible advantages and contribution of green walls to tomorrow's architecture are presented.

Key Words: Green walls, living walls, heat island, greenhouse effect, breathable environment.

Introduction: Problem Introduction: As we know that cities are the major source of economic activity, employment, and where it had attracted people to get settled in the cities, which has increased the population and there came a need of shelter which has turned the green fields into construction places and it was one of the reasons for Heat Island Effect.⁽²⁾

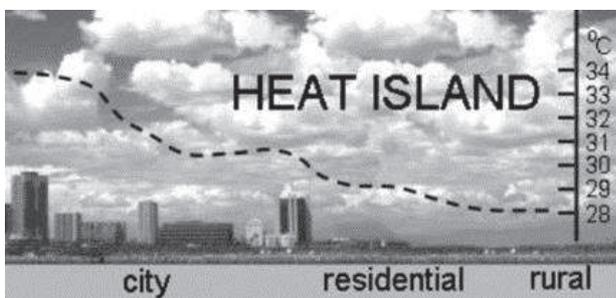


Fig: 1⁽¹⁾

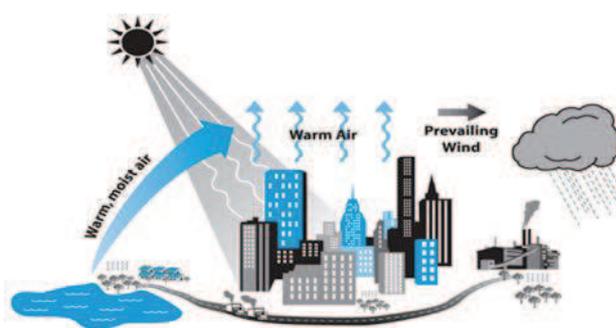


Fig: 2⁽¹⁾



Fig: 3⁽¹⁾

The major reason is the lack of evapotranspiration in urban areas. Due to declined amount of vegetation, also miss the shade and cooling effect of trees, and the removal of carbon dioxide is again a problem as there is loss of greenery. Added reasons of a Urban Heat Island are due to geometric effects. The tall buildings within many urban areas offer multiple surfaces for the reflection and absorption of sunlight, and hence increasing the efficiency with which urban areas are heated. This is called the "urban canyon effect".⁽³⁾

Stages of Research:

- Who? [The concept developer.]
- What? [Its definition]
- Where? [The placement of the wall]
- When? [Its history]
- Why? [Functions and benefits]
- How? [As a solution]
- Questions?
- Answers?



Fig: 4⁽³⁾

Research Methodology⁽⁴⁾: The type of research used is applied research. Applied research is under Fig.1 to solve a specific problem or provide a solution to a practical question. Where the specific problem is the heat island effect and the carbon footprint effects on the building envelope which can be solved by a solution of LIVING WALL/GREEN WALL. **Definition:** "Living walls or green walls are self-sufficient vertical gardens that are attached to the exterior or interior of a building. They differ from green façades (e.g. ivy walls) in that the plants root in a structural support which is fastened to the wall itself. The plants receive water and nutrients from within the vertical support instead of from the ground.." ⁽⁶⁾

Use of Plants in Walls: The modern industrial city which is hosting more than half of the world's population has a need of land which leads in the conversion of green land into grey structures so the designers, planners and architects turned to plants as they provide clean air and water, improving the living environments, health and mental wellbeing this is named as green infrastructure. The integration of the living, organic systems characterized by green walls with inorganic lifeless structures. These dominate the modern architecture with a new type named living architecture. This blends architects, landscape architects, engineers and horticulturalists. The people who practice it bind themselves in greening the cities and buildings, in the green building movement ⁽⁷⁾.

History:

History Repeating: The concept of green walls is an atavistic one, with examples in architectural history triumph back to the Babylonians - with the prominent Hanging Gardens of Babylon, one of the seven ancient wonders of the world. (fig.2).

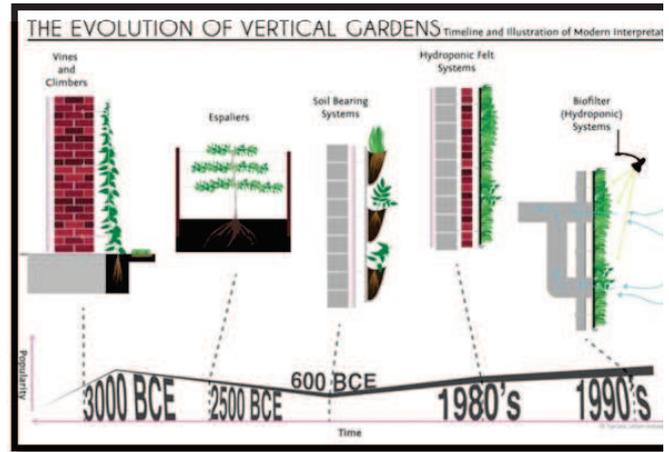


Fig: 5⁽⁶⁾

Highlights of The History Of Green Walls Are Provided Below:⁽⁷⁾



Fig.6 Babylon Hanging Gardens

Source: Hand colored engraving, Maarten van Heemskerck, Dutch

3rd C. BCE to 17th C. AD: All over the Mediterranean, Romans train grape vines (*Vitis* species) on garden trellises and on villa walls. Manors and castles with ascending roses are signs of secret gardens.

1920s: The British and North American garden city movement spread the integration of house and garden through features such as pergolas, trellis structures and self-clinging climbing plants.

1988: During this period introduction of a stainless steel cable system came into use for green facades.

Early 1990s:

And in this period Cable, wire-rope net systems and modular trellis panel systems came to the North American marketplace.

1993: First major application of a trellis panel system at Universal City Walk in California.

1994: And then there came indoor living wall with bio-filtration system mounted in Life Building in Toronto, Canada.

2002: The MFO Park, a multi-leveled 300' long and 50' high park structure opened in Zurich, Switzerland. The project highlighted over 1,300 climbing plants.

2005: And to advance green environment the Japanese federal government sponsored a tremendous Bio Lung exhibit, the centerpiece of Expo 2005 in Aichi, Japan. The wall constitute of 30 unlike modular green wall systems prevailing in Japan.

Re-Evolution Stages:

- *The concept developer* of green walls was *Patrick Blanc* in 1980's. He is a French botanist, working at French national center where he specializes in plants from tropical forests as a scientific research. He is the modern innovator of the green wall
- His works on green walls started from 1988 till 2014.
- But the actual designer is *Stanley Hart White*, a professor of landscape architecture who patented a green wall system in 1938.
- The *Babylonian Hanging Gardens* of Babylon were the proofs of green walls. They were a great source of pride to the people.
- This is possibly built by *King Nebuchadnezzar II* in 600 BC.
- Earlier there was a study done by NASA in 1970's and 1980's by B.C.Wolvert.

Patrick Blanc's Creation: In 1988 Patrick Blanc trailed a patent for a new concept of "*device to grow plants without soil on a vertical surface*"; the modern green wall was then shaped out. The device is as follow: "on a bearing wall placed a metal frame that supports an expanded PVC plate 10 mm thick, on which there are fastened two layers of polyamide felt 3 mm thick each. These layers of felt somehow mimic mosses that grow on rock faces and which support the roots of many plants. A network of pipes controlled by valves affords a nutrient solution containing the dissolved minerals necessary for plant growth. The felt is impregnated by capillary action of the nutrient solution, which descends along the wall by gravity. Plant roots will collect the nutrients they require, and left-over water is collected at the bottom of the wall by a gutter before being fed back into the piping system, the system operates in closed circuit. Plants are chosen for their ability to grow on this type of environment according to obtainable light".⁽⁸⁾

What he created here is a control environment where the plants are neither in contact with the wall or the soil anymore. Bearing walls don't need to be stronger because the metal frame carries the load of installation. The load bearing wall is only use to stabilize the installation. This idea avoids any damages made by the plants and their roots to the wall. This function is assured by the PVC plate. Mortars or cladding are no longer deteriorated, which avoid water penetration into the wall and frost

damages. The host wall is separated to the installation by an air gap so it stays ventilated. Patrick Blanc also gave freedom in the choice of plants: the creeping plants were not the only one who could grow on wall anymore.

Time shows that green wall not only become a new support to grow plants, but although that it possesses a large variety of functions.⁽⁸⁾

Types of Walls:

Folke Walls: Dual function purifying grey water and growing plants. (Green Walls)

Farm Walls: Growing of food on walls.

There are two major categories in Green walls/Folke walls: green façades and living walls .

Green façade are wall systems where climbing plants or cascading groundcovers are trained to cover specially designed supporting structures. Plant materials can be rooted at the base of the structures, in intermediate planters, or on rooftops. Green façades can be attached to existing walls or built as freestanding structures.

Living walls a living wall is in which vegetation not only is attached to a façade also is fully integrated into the facade construction where both plants and planting media are placed on the vertical surface of exterior walls. Usually, living walls are detached from the façade by a layer of waterproof membrane to protect the it from moisture. There are multiple distinctions of living walls with the most common systems termed below:

Vegetated mat living walls: This has a fabric layer annexed to a firm backup support of steel frame, cast-in-place concrete, or masonry wall. Plants pre grown in nurseries placed in holes cut in fabric layer which serves as growing medium. Vegetated mats are hydroponic systems minus soil in which water and nutrients are distributed to plant roots by irrigation pipes behind fabric layers.

Hanging pocket living walls: These are pocket-shaped fabric containers annexed to a firm support. Plants are grown in these containers packed with soil or growing medium.⁽⁹⁾

Modular living walls: This is a rigid rectangular containers packed with soil or growing media that can be annexed to an exterior wall or let isolated. The bowls are molded from metal or lightweight structural plastic and are shaped as framed boxes, wire cages, or solid boxes with precut holes. Sometimes, the containers are split into smaller single cells placed perpendicular or angled to the container's back wall. Plants are grown right in containers that are packed with soil, inorganic planting media, or natural fiber.⁽⁹⁾

Hydroponic System: In this system the growing medium takes the place of dirt/soil as the roots require strength to carry plants and the medium can be any inert material cant decay or breakdown

quickly. And the moisture and oxygen is hold by the porous material due to the frequent watering which doesn't make the roots dry. As the growing medium alone could not help the plant to grow so the water used for the irrigation or the rain water collected for the usage are added up with the nutrients. And the only thing taken care in any type of growing medium is that the root is to be moist all the time not soggy which makes the roots die out of suffocation.⁽¹⁰⁾

Key Features Of Green Walls: To use green walls as a cooling strategy, the building facade should be designed to account for facade structural necessities, green wall maintenance, and plant selection.

Support system⁽¹¹⁾:

There are two primary divisions

1. Modular trellis system
2. Cable and rope wire system

Modular trellis system: They are rigid light weight panels which are mounted to the wall or free standing and can also be used for tall buildings with intermediate planters at the heights where the climbers are physically restricted. So as the free standing green canopy trees as are replaced because of weight and space limitations.

Cable and rope wire systems: Consist of a kit of parts that contains high-tensile steel cables, wire trellises, anchors, spacers, and supplementary equipment. Vertical and horizontal wires can be joined through cross clamps to form a flexible pattern in various sizes.⁽¹¹⁾

Plant selection: Special consideration should be given to selecting suitable plants for green walls. Plants growing on vertical surfaces are more exposed to weather, specifically strong winds, than plants on the ground. The best-suited plants for green walls are hardy plant species innate to the climate zone, in which the building is situated. The climate zone and extent of the cooling season are essential criteria for selecting appropriate evergreen or deciduous plant species. Evergreen plants which retain their foliage all year are most appropriate when a continuous cooling effect is required in hot and warm climates. Deciduous plants that shed foliage through cold months are suitable for green walls in temperate and colder climates where they can offer cooling effect in the summer and allow for passive facade heating in winter.⁽¹¹⁾

Plant types: Climbers are preferred only up to a height of 10mts as they cannot reach up to larger heights where the modular or pocket systems can reach. Grass is not used as the require continuous mowing which is possible only on horizontal surfaces. Sedum greens used for green roofs require less maintenance and minimal care. It can tolerate drought well and needs water at extreme cases, so it could be a best choice for low cost green walls. Flowering plants require continuous replacement and

they are only for intense decoration. Perennials are modest and shorter flowers there application is based on of façade orientation and exposure. The rocky plants cope with sun whereas shady perennials are best at protected sites; the herbivorous plants have small root zones and live for several years. And the perennials live for 2-10 years. Sub-shrubs are with larger root system and so they cannot serve the green facades.⁽¹²⁾

Green wall installation and maintenance: The walls are mounted 3-18 inches away from the wall surface using trellis modules as their depth protects building surface from the plants attaching directly that avert problems that could compromise building's integrity. The structure helps in distribution of weight as it has anchors and tumbuckles at one end of each cable for tightening and adjustments required based on plant development. Plants require good supply of moisture, nutrients, occasional pruning, depending on species, appearance and wild life control. The plants are installed only after they are grown by hydroponic process in the green house or else it takes lead time of 6-12 months to mount the wall on site. A standard fertilizer loop is endorsed for the addition of liquid nutrients for the plants. The modular system lets panels to be taken out and substituted if required.⁽¹¹⁾

Growing medium:

Grow rock is a Lightweight Expanded Clay Aggregate (L.E.C.A.), is a type of clay which is super-fired to create a porous texture. It's heavy enough to provide support for plant's, but still light weight. Grow rocks are a non-degradable, sterile growing medium that holds moisture, has a neutral pH, and also will wick up nutrient solution to the root systems. Hydrocorn growing medium is reusable, it can be cleaned, sterilized, and then reused again.⁽¹⁰⁾

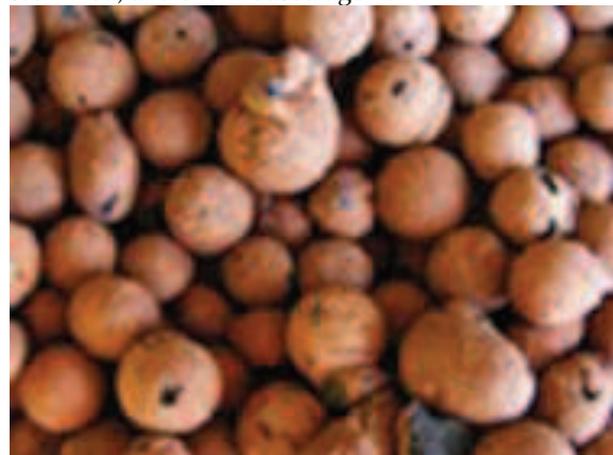


Fig: 7⁽¹⁰⁾

Coco coir or chips which are made out of outer husk of coconut it is a best growing medium although it is organic it decomposes very slowly. It also have neutral pH value it holds moisture in it for roots. As it is available in two forms it provides good aerations as

the coco chips provide gaps when placed in a pocket.
(10)



Fig : 8 (10)

Rice hulls are the by products from the rice factory these are also same as the coco coir as they are organic it decomposes slowly. The fresh rice hulls are not used because of the high probability of contaminants such as rice, fungal spores, bacteria, decaying bugs, and weed seeds, parboiled hulls are used which are been milled from them that kills any bacteria or fungi in them. (10)



Fig: 9 (10)

Nutrients (10): The composition of the nutrients is important and there are over twenty elements that are needed for a plant to grow. Carbon, hydrogen and oxygen are absorbed from the air and water. The rest of the elements, called mineral nutrients, are dissolved in the nutrient solution and need to be in the correct ratios. Any good Hydroponic nutrient should contain all of these elements; Nitrogen (N), Potassium (K), Phosphorous (P), Calcium (Ca), Magnesium (Mg), Sulphur (S), Iron (Fe), Manganese (Mn), Copper (Cu), Zinc (Zn), Molybdenum (Mo), Boron (B), Chlorine (Cl).

The nutrients designed for hydroponic system are quite different from the growing medium like soil because soil grown plants receive these elements from the soil. And Hydroponics doesn't have soil to get the elements, so they are very different in composition because they are not water-soluble. For example, Nitrogen in the form of urea is not instantly offered to a plant in hydroponics because urea is not soluble in water. For this reason Nitrogen must be transferred in its Nitrate form to be utilized in hydroponics.

One thing that is often over viewed to nutrients is the temperature. The roots of plants when they grow

underground in nature and to duplicate what they receive is different. It is very important to keep the root zone to 68-72 degrees. It is not so if the nutrient temp reaches 73 or 74 the plants will die, but it should be kept as close to 68-72 degrees. Plants with nutrient tempters high can have problems like flowers turning yellow, falling off and a lack of new growth. (10)

Cost (13): The typical material-only cost (stainless rails and framesets, recycled modules) cost approx. \$60-90 per square foot, depending upon the scale of the installation. The "all-in" cost, including plants, soil, irrigation, and installation, may cost between \$100-150 per square foot. (13)

Benefits: (14)

- Aesthetics
- Indoor air quality
- Building protection
- Energy savings
- Thermal performance
- Health and wellness
- Increased property value
- LEED
- Acoustics
- Sustainability

Aesthetics: Creating a green wall which is diverse, eye-catching, intriguing and merely a pleasure to look at is a complex task. As such when we walk on the road which is been divided with the help of a green wall creates a good feel to the person as a spectacular master piece.

Indoor Air Quality: The usual time a person spends is over 90% in the indoors. And are constantly being attacked with indoor air pollution. The good news is that all plants absorb and remove pollutants from the air. Definite tropical species are more efficient. It is all the time better to make certain that each of green walls encompasses ample numbers of the plants which are finest at improving air quality. And through which the main factor of Sick Building Syndrome is reduced.

Building Protection: These walls act as a protective shield from the natural calamities like rain, solar radiation, heavy wind, snow and storms which helps in reducing the damage caused to the building façade.

Energy Savings (15): These green walls help in reducing the surface temperature of walls by as much as 10° C which results in significant air-conditioning savings. Water savings: 40-50 % by smart irrigation systems .Energy Savings: 30-40% by cooling effect inside the building. The cooling energy savings ranged between 7 and 47 %.



Fig : 10 (15)

Thermal Performance: (15) Green wall reduce wall temperature as much as 15°F. Reduce Energy Consumption by 8%

Health and Wellness: (16) Greenery softens this hard environment, performs as a tonic to ease stress and fatigue. Green walls offer a substantial and spiritual link to nature which is omitted in the modern concrete jungle. Also reduce the effects of sick, dullness in the working space of a building.

Increased Property Value: (15) Green Wall can add up to 20% onto a buildings value. This value is reflected in the attitudes of anyone who Works, lives, or experiences Green wall.

LEED: (Positively affect 27 credits) (15)

- Storm water Management
- Heat Island Effect
- Water Efficient
- Landscaping
- Optimize Energy Performance
- Regional Material
- Innovative Design
- Recycled Content

Acoustics: (15) Studies have shown that the leaves of plants attenuate sound by reflecting, refracting and absorbing acoustic energy in small amounts. Plants and trees have been used for years as barriers against traffic and other urban noise pollution. Green walls built on the exteriors of buildings will do the same. They insulate against noise, vibrations and reduce sound penetration. In addition they help to absorb the echo bouncing off buildings and dampen the noise pollution of modern cities.



Fig: 11 (15)

Sustainability: (16) As the green walls provide all the 3 concepts of sustainability the society, economy and environment by its usage and advantages in the public places to separate and create a eye catchy element. And the usage of live art in the grey environment and the property development has a good effect on the economy (16).



Fig: 12 (15)

Barriers To Green Wall (8)

Lack of Knowledge: Green wall technology is not well known to public, construction professionals and politician so must be more informed. Construction methods and choice of plants take the major role in which people don't have the knowledge and which are causes for the deteriorate building facades. Studies regarding the influence of green wall technology on the heat island effect are missing. Also impact of green walls on environment is accepted, but it is not cost estimated; as it is with the effect of green walls on health.

Motivation barrier: The lack of knowledge creates the motivation barrier. Since the building professionals don't consider them as a part of the building and considered more as a decorative element than being an important part of building services. And there is also lack of incentives as the government does not have a knowledge about the green walls and its contribution to the atmosphere in reducing the heat island effect and adding up the government income by reducing the usage of energy.

Cost barrier: Cost is the main important barrier of all. These walls represent a kind of luxury as people lack knowledge about their functions and simplicity of installation. And this adds up to the point of maintenance and construction prices are too difficult to gain and keep the people in unfamiliar (8). But this can transform in future.

Future Development: (8) Future development of the green walls is in the hands of the public, politicians,

researchers, professionals, the society and the imagination.

Part of the society: The public necessarily be well-versed about the benefits of vertical garden. Researchers need to work and provide thorough studies about the economic impact of green walls. Proofs about the role of Green wall on rain water, the heat island effect, and greenhouse gases required to be undeniable and economically related. Experts must inform the public about their prices, their simple installation, their maintenance and their utilities.

The imaginations part: Designers know the challenges of tomorrow: overpopulation, lack of energy, lack of resources, and lack of water... Most of tomorrow's ideas are ruled by these challenges. Green wall can be a response of such problems. ⁽⁸⁾

As overpopulation rise, space will be precious. Where the green lands are also been converted to the grey structures so this concept of Green walls help in creating green space over the grey, which offer a huge surface for a slight footprint.

With the lack of energy, it will be more expensive to install air purifiers, acoustical treatments and other electrical appliances for the health and wellness of the people so these walls reduce all the expenses and save both the energy and economy

Lack of resources, as the energy production requires resources their shall be loss of resources this can be reduced as the energy requirement is reduced by the Green walls.

Green wall could also act on the **lack of water.** These walls are known to lessen evaporation and hence use of water. In addition they are able to treat grey water, which can be reused. Impurities extracted from the grey water can be used as fertilizer or as an energy source ⁽⁸⁾.

Architectural Advantage: The most important asset to the urban architecture is that the vertical landscape so the ground space is minimized which is very important in the cities where the traditional landscape is out of question due to high ratio of developed areas. The most tangible effect of green facades is their ability to trap dust. The asphalt or other hard shells of cities absorb and reradiate a huge amount of heat, which resulted in average temperature in metropolitan areas to be higher related with the peripheries. This phenomenon is stated as the urban heat island and green facades can

have a thoughtful role in regulating it. The surface temperature of a façade covered with vegetation in peak summer heat can be up to 20 C less compared to plain concrete. Even storing rain water for later use on green surfaces such as green facades has lessened the load on drainage, thus reducing the flooding of streets.

Conclusion: Green walls are the new technology which is inspired from the ancient methods of green facades and the nature itself. The history has shown its usage and later there was a small break which has been again brought back by *Patrick Blanc*. The green walls absorb heat and dust and to bring back the environment being lost which resulted in the improvement of both indoor air quality and exterior temperatures. With the reduction in temperature and the green cover on walls helps in the reduction of reflection of radiation to reduce urban heat island effect. They can be erected outside (green facade, living wall) or inside a building envelope in various countries and under various climates. These are not restricted by their feasibility; they are well designed, quick and easy to erect (around 30m²/day). They require very little maintenance and irrigated by drip irrigation. The supply of nutrients in a liquid form is a new technology known HYDROPONICS. Also green walls are evolutionary with many modern types of installations.

The nutrients and the medium used to grow the plants reduce the soil borne diseases and also control the accumulation of bacteria, algae and fungi as the porous material do not allow water to get accumulated. The installation cost or the primary investment of the green walls is high but later it has many beneficial points as they do not require much maintenance and regular replacements. These have a great impact in the reduction of the urban heat island as they have an ability obstruct heat, dust, and noise which also saves energy.

So, I conclude at the question why do we have green wall? ; The answer will be: for us, for now, for the future, which is of greater value which can help in maintaining the good air quality. This can be used on the facades of the present grey environment in order to reduce the effects of the increased grey construction. Even though they are expensive they shall reduce the future investments on energy and resources

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