Analysis of Architectural Needs for Passive Low-Tech Fog and Dew Collector Building Design: A Narrative Literature Review

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ABSTRACT

Global warming and climate change have negative effects on life on earth. One of the consequences is a water crisis or water scarcity, both in quantity and quality. Indonesia also cannot avoid this problem. Therefore it is necessary to prepare an alternative water supply solution, one of which is from water vapor (atmospheric water), especially in the form of dew and fog. This study aimed to formulate the design requirements for passive low-tech dew and fog collector building by comparing several technologies and projects in the world that have been realized recently that have a relationship with architectural science. This research used qualitative research with a narrative literature review approach. This research produced design requirements in the form of principles and technical requirements in designing and realizing dew and fog collector building, especially in terms of function, construction, and form appearance.

Keywords: *dew collector, fog collector, low-tech, water scarcity, architecture*

ABSTRAK

Pemanasan global dan perubahan iklim telah memberikan efek negatif bagi kehidupan di bumi. Salah satu akibatnya adalah krisis air atau kelangkaan air, baik secara kuantitas maupun kualitas. Indonesia juga tidak dapat menghindar dari persoalan ini. Oleh karena itu perlu dipersiapkan sebuah solusi pengadaan air alternatif, salah satunya adalah dari uap air (air atmosfer) terurama berupa embun dan kabut. Penelitian ini bertujuan untuk merumuskan kebutuhan kebutuhan desain bangunan pengumpul embun dan kabut pasif berteknologi rendah dengan megkomparasi beberapa teknologi dan proyek di dunia yang pernah direalisasikan belakangan ini yang memiliki hubungan dengan keilmuan arsitektur. Penelitian ini menggunakan penelitian kualitatif dengan pendekatan kajian literatur naratif. Penelitian ini menghasilkan persyaratan desain berupa prinsip dan persyaratan teknis dalam merancang dan mewujudkan bangunan pengumpul embun dan kabut, terutama dari segi fungsi, konstruksi, dan bentuk (penampilan).

Kata Kunci: *pengumpul embun, pengumpul kabut, teknologi rendah, kelangkaan air, arsitektur*

1. INTRODUCTION

The water crisis does not only affect certain areas, especially in unfavorable natural conditions, for example in areas with dry climates or areas with damaged natural environments. Areas with conditions like this are unable to support groundwater absorption, surface water storage, or those that are not facilitated by a formal water supply system. Water scarcity has become a threat to the whole world since global warming and climate change have hit the world recently [1]. Water scarcity also make water unaffordable for low-income household and people in developing countries due to the cost of supplying water or the lack of quantity and quality of groundwater [2] [3].
Indonesia is not free from this risk, even though this region is generally rich in water sources [4]. BMKG has issued a warning of this danger [5]. The areas predicted to experience this phenomenon are Java, Bali, and Nusa Tenggara [6].
There have been many technologies and projects in the world that have been realized, especially those using dew collector and fog collector systems. However, in Indonesia, this technology is still unfamiliar, so it has not been implemented effectively and there are still few studies discussing it. Even though Indonesia's nature is very potential because it has high humidity, which is expected to produce abundant water vapor both in the highlands and lowlands. In addition, because there is no clearer standard yet and there are so many different technologies for collecting dew and fog in the world that are still being developed, it is necessary to discuss the basic needs, especially those related to architectural science.
Therefore it is necessary to conduct research to identify the design needs of passive low-tech dew and fog collector product buildings in Indonesia, before assessing its opportunities in Indonesia and the realization of the concept and design in subsequent studies. This research is a continuation of the previous research. The bibliometric analysis showed that the scientific position of architecture on the research topic of dew and fog collectors has a very large opportunity to contribute to filling the research gap on this topic. Especially on issues of design form efficiency, locality, and community [7]. So this research tries to identify and evaluate the design needs of buildings that collect dew and fog from several projects obtained from literature data. The limitations of the technology that will be discussed are those that have a passive and low-tech approach, where it is hoped that the results of the design can be used in an affordable way by underprivileged communities.

2. METHODOLOGY

This research is qualitative research, using deductive study on basic theories related to the research topic and using inductive study on previous research and projects that have reputation. Information was collected from various literature and references. Then research and projects that had best practice technologies were selected based on result selection on bibliometric analysis and systematic literature review prior to this study. This research was conducted only on dew and fog collectors which use passive methods and low technology which is expected to be accessible to everyone.
The information was then processed using a narrative literature review to identify and evaluate patterns and coding from keywords and texts to produce criteria for the design needs of dew and fog collector buildings. Narrative literature review has limitations, such as not having to follow systematic evidence-based criteria, the nature of the method is too subjective, the possibility of misleading in drawing conclusions, and the determination and integration of complex interactions when a large number of studies are involved. This limitation has been reduced through previous research in the form of bibliometric analysis and systematic literature review.
In the design process, the first stage that must be passed is to carry out an analysis or assessment to identify and understand the needs and opportunities of a product. This is done to gain insight into problem. This stage is better known in the world of architecture as programming, to produce a design brief (or pre-design) before entering the design stage. At this stage it is necessary to conduct research and determine the design criteria for a project that is accurate and comprehensive.

Table 1. Three Attributes of Building Design

Vitruvius	Gropius	O'Gorman	Van Der Voordt and Van Wegen	Dahabreh
Utility	Function	Utilitarian	Function	Spatial
Firmness	Technics	Physical	Construction	Structural
Delight	Expression	Psychological	Appearance	Intellectual (Perceptual and Conceptual)

Source : Gropius, 1947; Morgan, 1960; O'Gorman, 1998; Van Der Voordt and Van Wegenn, 2005; and Dahabreh, 2014

For this research to remain on its goals, a research instrument was needed. There are attributes of building design that need to be reconsidered. From several theories above (see Table 1) it can be concluded that in designing a building at least it has the main aspects, namely: function, appearance, and construction [8]. However, what can be underlined are that these three aspects are influenced by the environmental context both internally and externally [9]. The dialogue model between theory and cases in this study used the "theory of the case" model. Theory is a starting point, a conceptual structure, and a unit of analysis in constructing cases [10].

3. RESULT AND DISCUSSION

Dew and Fog

Condensation is the process of changing the state of water vapor (moisture or vapor) in the atmosphere from gas to liquid [11]. Condensation plays an important role in the formation of fog and dew. Condensation occurs due to temperature changes that experience cooling (cooling) which is closely related to the dew point temperature and a certain relative humidity (RH) level. Light water droplets or water droplets are commonly called fog and are more often suspended or suspended in the air [12]. Meanwhile, the heavy one is usually called dew which is in contact with liquid or solid surfaces [13].

Fog and dew can occur at any time but are more common at night until early in the morning [14]. The conditions must meet at least several conditions: relative humidity (RH) is close to 100% saturation [15] [16], and temperature differences. Fog occurs when the ground surface temperature touches the dew point temperature, while dew will fall to the surface when the surface temperature touches the dew point temperature [17].

The dew point is the temperature at which air must be cooled to become saturated with water vapor (assuming constant air pressure and moisture content). At that time the moisture capacity is reduced. The dew point is affected by humidity. When there is more water vapor in the air, the dew point is higher [18].

Passive Dew Collectors

This technology took the principle of a passive radiative cooling for dew condenser as a basis, which was made to cool a surface by utilizing heat radiation into the sky at night. This low mass surface did not retain heat and was thermally isolated from any mass including soil. Surfaces with a maximum slope of 30 degrees caused condensation which is at a maximum height of 2 to 3 meters from the ground level. The closer to the ground the more dew was produced. High humidity, calm winds, clear skies, and relatively warm temperature conditions resulted in high dew condensation. Dew water sticking to the surface of the condenser panel which stands on the metal frame structure then flowed into the collection channel, see Figure 1. This method can also be used as a rainwater harvesting system apart from dew water [19] [20].

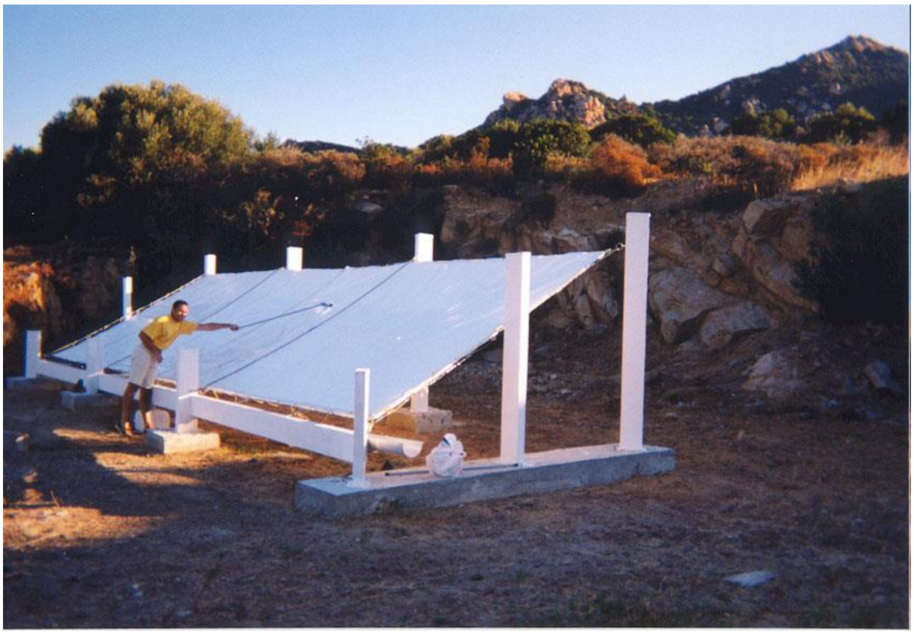

Figure 1. Big Dew Condenser in Corcica Island, France
Sumber : Bergmair, 2015

The collaborative research and projects from various disciplines have been carried out in France, India, Croatia, Chile, Morocco, and others. The application of this technology can be used on the ground and on the roof, see Figure 2. In the project in India, the roof surface material was made of Polyethylene mixed with Titanium Oxide and Barium Sulfate (PETB), and underneath was given polystyrene foam insulation to prevent heat from rising from the ground surface [21] [22]. In the project in Morocco, the polyethylene surface was coated with a hydrophilic coating paint so that more dew water would stick to the surface, since PE has hydrophobic properties [23].

Figure 2. Condenser on Roof and Condenser on Ground, India
Sumber : Sharan, 2007

In subsequent studies, research was carried out using an architectural approach to form designs. It was found that the funnel shape with a hole in the middle with a slope of 30° had a good cooling efficiency of 40% compared to 30°-inclined planar [24]. The geometry of the dew collector could affect the amount of dew yield. The hollow structure provided increased cooling because the influence of wind was prevented. The slope of the surface angle also affected the efficiency of water collection, where a slope that was too low caused water not to flow, thereby reducing dew water harvesting. Sharp surface angles also allowed for an increase in the growth rate of dew droplets. The modular approach is also used for large scale buildings [25] [26]. Many studies on this topic now are developing material surfaces with bioinspiration approaches; biomimetics and biomimicry [27].

Figure 3. Architectural orms of Dew Collector
Sumber : Beysens, 2012 and 2013

Passive Fog Collectors

The simplest initial form of this technology is the Fog Net Collector structure. The project at Dar Si Hmad in Morocco is one such project that uses this technology. This project was initiated by a combination of several national and international multidisciplinary scientists and practitioners [28]. This fog collector is named Cloudfisher, whose mesh material could withstand wind speeds of 120 kph or around 33.4 mps [29]. However, the typical wind speed for fog formation was from zero to 6 mps [30].

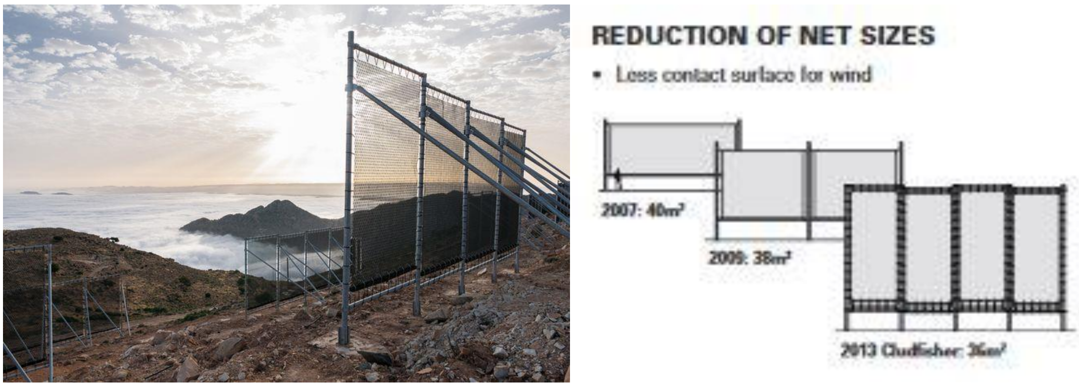

Figure 4. Fog Net Collector
Sumber : Darsihmad.org, 2022

The fog was captured by a porous vertical (perpendicular/ 90 degree) mesh surface installed at high altitudes. The saturated water then dripped from the net into the channels and flowed into conventional electric and solar powered UV filtration systems. The filtered water was then collected into a series of storage reservoirs for the needs of 500 residents in five villages and four schools below.

The next research from this project is the selection test of the collecting net. Currently they are using the Space Fabric Polyethersulfone/ PES net type. Furthermore, several types of materials are being investigated, such as Hail Net HDPE Dual Layer, Enkamat 7220 (PA6/ Polyamide/ Nylon), Slubbed Fabric Polyethersulfone/ PES, Raschet Polypropylene/ PP, and Shade Net High-density polyethylene/ HDPE. They will also examine the aspects that make it possible to apply this system according to the context of the location. Due to lack of access to water is not only a problem in arid areas or in areas with low rainfall, even in tropical climates [31].

In research with similar topics but different approaches, Fog Harp technology tried to overcome the problem of net mesh materials that are still ineffective. Fog Harp is a design product produced since 2016 by the Institute for Creativity, Arts, and Technology, Virginia Tech. This institute is a multidisciplinary research institute. Fog Harp was researched and developed by researchers with backgrounds in Biomedical Engineering and Mechanics, Mechanical Engineering, and Architecture and Design [32] [33].

Figure 5. Fog Harp
Sumber : Shi, 2018 and Kowalski, 2021

Instead of the form of a mesh, the team investigated the shape of an array of thin plastic or metal wires, which had characteristics between smooth and rough. Examples of materials used were nylon, kevlar and stainless steel, which could also be coated with Teflon. The best hydrophilic material was stainless steel, especially if it was coated with Teflon. The shape of this array, which was arranged like a harp, was effective for catching smaller fog that usually escaped from the net. In addition, its perpendicular ranks accelerated the flow of falling water with the help of gravity.
Similar technology applications are also used in Foghive but with a modular architectural design approach. Foghive was designed by researcher and architect Cristian Suau on Atacama Beach, Chile. For him, the things that determined the design of the fog collector are wind, temperature, and humidity. Where there is a lot of fog, there must be a lot of wind. The design not only produced alternative forms, but also alternative sites, materials, and arrangements. Important notes from this design are the frame and envelope must have an optimal shape against the dynamic wind direction high speed resistance and rust; the fog catcher material must have hydrophobic, elastic, and bright color against UV character; and the structure must be well supported (with tensegrity and geodesic principles) and light weight [34].

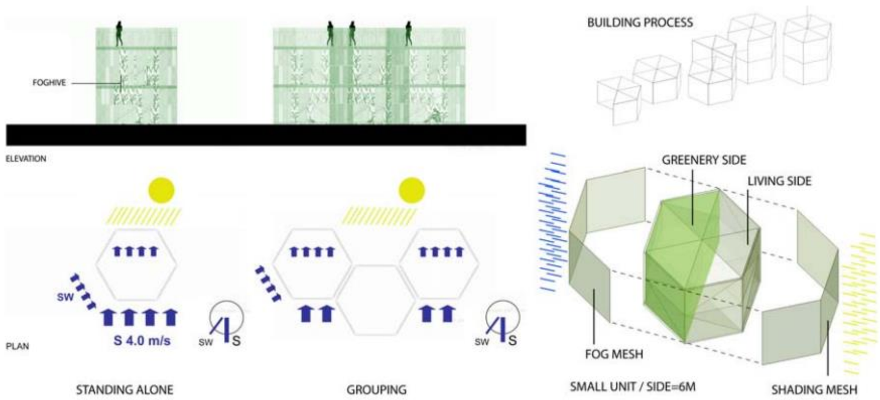

Figure 6. Foghive
Sumber : Suau, 2010

Foghive, with a hexagonal tread, was double the strength but lightweight, and with a modular frame. Then it was wrapped in a lightweight hydrophobic mesh. It also functioned as a shade or cooler and moisturised the soil. Foghive could also be disassembled and easily placed on level ground or not. The units were of various sizes, some are 12 m, 9 m, and 6 m.

Dew and Fog Collector Combination (also Rainwater)

A more radical application is found in the architectural design of WARKA Water. Warka Water Tower is a passive structure designed and built by an architect named Arturo Vittori. Its function in collecting fog, dew and rainwater is naturally by involving gravity, condensation, and evaporation. The design of the building could be adapted to the local natural and cultural environment, such as meteorological conditions, site geomorphological characteristics, local culture, bioinspiration, and available natural materials. This building can also be used as a community place to gather and study [35].

The building predominantly used natural materials and synthetic materials available on site, for example: bamboo, wood, polyester rope, natural fiber rope (for example: hemp rope, palm raffia rope, bamboo raffia rope etc.), and plastic wire netting which is recyclable and biodegradable (e.g., polyester mesh). The building structure was a temporary design that could be moved and disassembled. The building had four main parts: stable structure, shade canopy, ropes, and mesh netting. This building was about 9 meters high, about 7.3 m wide. In addition, this building was equipped with funnels and storage tanks. This building could be built in no more than 1 day.

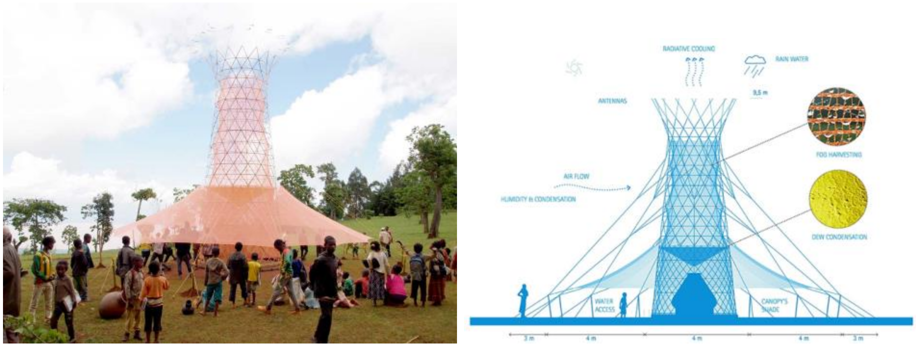

Figure 7. WARKA Water
Sumber : Warkawater.org, 2022

The building can be used anywhere it doesn't have to be in the highlands, especially those with an RH of 50-70% and temperatures of 0-40 degrees Celsius. Installing this build does not require a skilled craftsman. In 2012 prototypes were made to carry out several tests. Just in 2015, the first project was carried out in Dorze, South Ethiopia. Then in 2019 the next project was carried out in the south of Cameroon, which really uses 100% natural materials. The mesh netting was replaced with a palm frond roof.

Another interesting approach is the design of Bioinspired Water Collection. This design was developed by a professor of mechanics at Ohio State University, who was interested in biomimetics, named Bharat Bhushan. The inspiration for this tool came from the hydrophilic and hydrophobic characters that exist in nature, such as Namib desert beetles, thorny lizards, spider webs, cacti, grass, shrubs and more. From there, he developed a conical shape with a 45° and 15 mm long. Between the shape of the cone was installed with 2 mm. The placement of the cones was also adjusted, with an upward tilt of 45°, to optimize dew and fog collection [36] [37].

The material used is a strong polycarbonate. This material is then coated with methylphenyl silicone resin and SiO2NP which are superhydrophobic and superhydrophilic dots or grooves made from fluorosilane through UVO irradiation through masking.

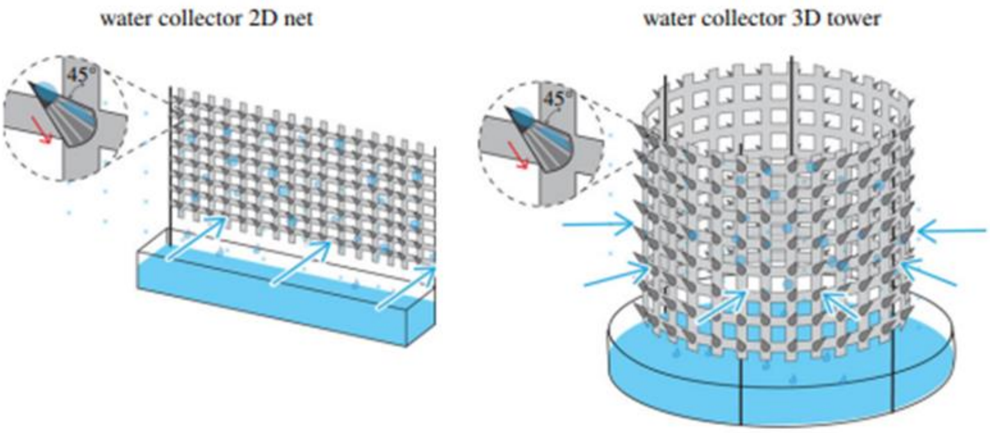

Figure 8. Bioinspired Water Collection
Sumber : Bhushan, 2019 and 2020

Design Needs for Passive Low-Tech Fog and Dew Collector Building

From the results of the analysis, the research conducted coding of the patterns of keywords and texts. Then each of these coding is connected to form a network of main categories and subcategories. Thus, design needs for Passive Low-Tech Fog and Dew Collector Building are formed, see Table 2.

Table 2. Design Needs for Passive Low-Tech Fog and Dew Collector Building

Attributes	Needs	Dew Collector	Fog Collector
Function	Utility and spaces	As the roof of the building if it is placed above the roof that shades the function of the building or any space underneath.	As the roof and walls of the building that shade and envelop the function of the building or any space underneath.
		As an additional technology outside the building if placed on the ground.	As an additional technology outside the building.
Construction	Structure and construction systems	The structure is stable, affordable, simple, moveable, modular, and knock-down.	The structure is stable, affordable, simple, moveable, modular, and knock-down.
	Material characteristics	The material has hydrophilic-hydrophobic and directional surface.	The material has hydrophilic-hydrophobic and directional surface.
Appearance	Building mass and scale	Low mass and small-scale building.	Low mass and small-scale building.
		High mass and large-scale building.	High mass and large-scale building.
	Building height	The maximum height of the building is 2-3 meters.	There is no limit to the height of the building.

Attributes	Needs	Dew Collector	Fog Collector
	Building slope	The effective slope surface of the collector is about 30 degrees.	The effective slope surface of the collector is about 60-90 degrees.
	Form and shape	Biomimetics approach. Modular. Edged or sharp form and shape. Planar shape, Concave and hollow shape.	Biomimetics approach. Modular. Edged or sharp form and shape. Perforated shape, Conical shape.

Source : Authors, 2023

In principle, these two collectors have almost similar needs. However, the dew collector has a height limitation of 2-3 meters, because dew occurs and flows closer to the ground so that it can be captured by the surface of the building. Its best tilt is only at a maximum angle of 30 degrees to catch the dew. In addition to counteracting the influence of the wind, a surface module should have a depression with holes. This small difference does not mean the combination of these two technologies cannot be done. The combination of the two can obtain more water harvesting, even coupled with rainwater harvesting technology. Moreover, there are several local contexts that must be considered, which was also found in the analysis results: natural conditions, cultural conditions, and economic conditions.

Natural conditions:

- RH humidity 50-70%
- temperature 0-40 degrees Celsius
- the height of the plains (highlands, lowlands, or coast)
- wind speed (0-6 mps)
- gravity
- natural materials

Cultural conditions:

- local knowledge: building craftsmanship
- habits and daily life of residents
- cultural space requirements for additional activities

Economic conditions:

- economic level and income
- material availability

4. CONCLUSION

This study aimed to identify the design needs of passive low-tech dew and fog collector buildings. Despite narrative literature review has limitations, however they have been reduced through previous research in the form of bibliometric analysis and systematic literature review. This research resulted in several criteria that need to be considered when designing the two collectors, namely utility and spaces, structure and construction systems, material characteristics, building mass and scale, building height, building slope, and form and shape. Apart from that, there are local contextual factors that need to be facilitated: natural, cultural, and economic conditions. Subsequent research will examine the opportunities for dew and fog collector building applications in Indonesia.

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