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The Role of Traditional Stove-Base in Indonesia's Vernacular Architecture: Lessons from Kampung Naga

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Abstract
The study of the stove as part or element of a vernacular architecture in the literature is more widely discussed regarding cultural aspects and practical uses. This study aims to examine to what extent considerations of micro-climate and building physics are applied by the indigenous people of Kampung Naga in the configuration of the cooking stove in their houses. We select a simulation research design as the primary method of analysis. We use the Ansys Student 2025 R1 version to conduct 2D Fluent flow and 2D heat transfer simulations. The findings confirmed that the traditional stove of the Kampung Naga community which consists of Hawu and Parako reflects a genius design consideration by the local people which shows its capability to control the buoyancy-driven natural convection and heat distribution in the two burners of the stove as well as preventing the heat from affecting the surrounding wooden and bamboo materials.

Keywords*: computational fluid dynamics; ecological architecture; traditional stove; vernacular architecture*

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1. INTRODUCTION

In the context of Ecological Architecture theory, a building should be designed and built by paying attention to the conditions of the natural environment so that the building is present as part of nature itself (Couvelas, 2020).

Understanding the building elements and local environmental factors, along with their characteristics in this context, is thus important. Of the many elements of vernacular and traditional architectural buildings, most of the discussions in the literature examine the roof (Chandel et al., 2024; van Hoof & van Dijken, 2008; Zune et al., 2020), walls and wall/window/ventilation openings (Abdullah & Wang, 2012), and foundations (van Hoof & van Dijken, 2008). Meanwhile, the discussion of building elements or complementary elements of a room in vernacular or traditional architecture has not been widely discussed, for example, pillar and beam elements (structural function), stair elements (circulation function), or stove elements (domestic function) (Hermawan, 2024; Sumarlina et al., 2024).

In relation to this, one of the important things to discuss is the stove element, considering that the existence of the stove in the human activities of the inhabitants of traditional houses or vernacular buildings occupies a central position.

In the context of history, culture, social society, and architecture, the stove with its various names in various places does not only function as a cooking tool. Furthermore, historically and culturally, stoves and fireplaces also have an important position in human efforts to survive, both as a cooking tool to prepare food as a basic human need (Bartha & Cionca, 2014), as a fireplace where humans or groups of humans warm their bodies to maintain their body temperature (Ayoobi et al., 2024; Nodeh et al., 2021), and as a gathering point where humans socialize and communicate with each other (Baloch et al., 2020; Hermawan, 2014; Khafizova, 2018; Nodeh et al., 2021). In addition, the existence of a stove culturally and socially can also be a sign that a family in the house is still doing activities as usual, as indicated by the presence of smoke rising from the roof or chimney, especially in the morning or evening/cooking hours.

Some key factors indicated by previous researchers on the effective roles of traditional stove as a crucial element of architecture that supports human live are: stove orientation and placement in the room which affect the quality of the cooking and the flow of the smoke and residuals (Bruce et al., 2013; Hermawan, 2024), configuration of building elements around the stove (Hermawan, 2014; Sumarlina et al., 2023, 2024), and stove structure (freehand.co.jp, n.d.).

Discussion of the stove as part or element of a vernacular or traditional architectural house building, especially in the vernacular houses of the *Kampung* Naga community, is more widely discussed in relation to cultural aspects (Hamid, 2018) and practical uses (ease, fire prevention) (Sumarlina et al., 2024). To the best of the author's knowledge, there has not been much research that discusses in more depth the considerations of microclimate and building physics aspects in the application of stove technology to vernacular architectural houses in *Kampung* Naga. This study aims to examine to what extent considerations of microclimate and building physics are applied by the indigenous people of *Kampung Naga*, especially in the application of the configuration of the cooking stove/fireplace in their houses.

The research question that we want to address are two aspects: first, is the traditional stove of *Kampung Naga* reflect the technological advancement of the *Kampung Naga* community in controlling the fire and air flow around the stove? And secondly, what is the role of the traditional stove base ("parako") in *Kampung Naga*?

This research is intended to provide insights on the technological advancement of the traditional community of *Kampung Naga* in their traditional stove design and development, as well as the role of the stove-base part of the traditional stove in *Kampung Naga* (*parako*) in the context of the stove as one of an integrated element of architecture.

The investigation of the roles of traditional stoves, especially in the context of building science, will benefit researchers in understanding the significance of the traditional stoves in the context of ecological architecture, as well as helping architects with well-informed design decisions.

2. METHODS

This study applied a mixed-method approach. In the first step, after the literature review process, a cross sectional field visit was first conducted in *Kampung Naga*, and we did a semi-structured interview with a key informant who inherited the traditional craftsman's skills from his father and grandfather ("*palika*"). The primary data collection is done in parallel with the secondary data collection. Both processes aim to collect data and information regarding: stove functions, stove dimension, stove features, stove materials, stove structures, and the cultural aspect of local people in relation to the function of the stove. We also took photos, videos, did some observations on activities around the stove, and took some measurements of the traditional stove. The research method and procedures are described in Figure 1.

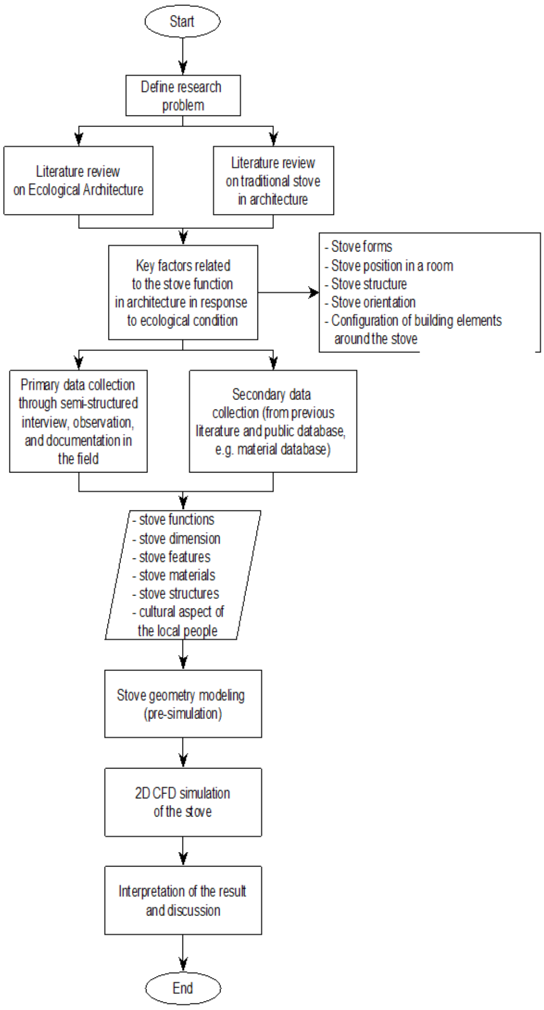

Figure 1. Research Method and Procedures

To address the research questions, we select simulation research design with deductive-quantitative approach as explained in (Groat & Wang, 2013), as the main method of analysis. We investigate both the buoyancy effect resulted as the stove being used for cooking and the thermal conduction from the upper part of the stove to the stove base ("parako") to identify its role.

We use the Ansys Student 2025 R1 version to conduct 2D Fluent flow and 2D heat transfer simulations. The steady state flow natural convection simulation scenario is selected to investigate the behavior of fluid flow and the temperature in and around the upper part of the stove, while transient heat conduction simulation scenario with a total of 1000 seconds timestep (the first 600 seconds is for simulating the cooking process and the last 400 seconds is used to simulate the condition after the cooking stopped) is selected to simulate the heat transfer behavior between the stove and the stove base ("*parako*") material.

Key factors related to the stove function found from literature in the context of architecture in response to ecological conditions, such as: stove form, stove position in a room, stove structure, stove orientation, and configuration of building elements around the stove, are then discussed in regard to the result of the simulation. Then the results of the analysis are discussed with the body of literature around this topic.

3. RESULT AND DISCUSSION

3.1. The Traditional Stove of *Kampung Naga* Community

The traditional stove of the *Kampung Naga* community is called as *"Hawu"*, which mean ashes (Hermawan, 2024; Sumarlina et al., 2024). The knowledge to build the stove have been passed through from the former generation of craftsman ("*palika*") –or traditional stove craftsman "*palika hawu*"— to the later craftsman.

The *Hawu* consist of two parrts: first, the main part/the stove/the upper part, and second, the stove base/support part or "*parako*". According to the information from the key informant, they built the main part (upper part) of the stove using local dry clay (unfired) combined with coconut fiber, ashes, and *Sadagori* (Sidaguri or *Sida rhombifolia*) leaves extract as an adhesive. The stove base part was built using a box of wood plank with a bamboo floor filled with ordinary/local dry soil. The stove base was supported with four wooden columns and two wooden beams that is placed on top of four flat river stone (see Figure 3 to Figure 7).

The main part of the stove or Hawu often equipped with two holes (on the left and right side of *Hawu*) with a size of *sajempol*.

They use their own measurement unit (Sundanese measurement unit) to measure objects, including all architectural elements, such as *sajempol* (a length of a thumb), *sakepel* (a length of a fist), *sajeungkal* (a length of a span of a palm), *sahasta*/*sasiku* (a length of a hand), and *sadeupa* (a length of two tips of a hand when spread).

The dimension (in m/metric system) of *Hawu* is ilustrated in Figure 2.

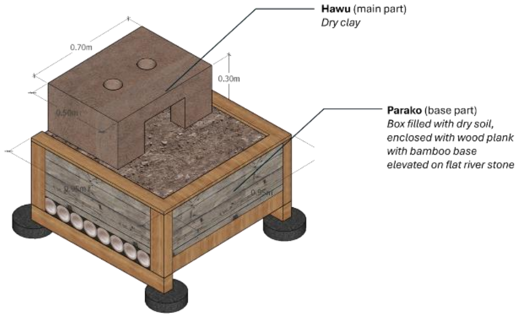

Figure 2. Dimension of *Hawu*

Figure 3. The Upper Part of The Hawu
Source: Photograph by Hariyani, D.S

Figure 4. The Base Part of *Hawu* (*Parako*)
Source: Photograph by Hariyani, D.S

Figure 5. *Hawu* During Reconstruction
Source: Photograph by Ijad (Local Craftsman/*Palika*)

Figure 6. Hawu With Parako Base Part Still Intact During Reconstruction
Source: Photograph by Ijad (Local Craftsman/*Palika*)

Figure 7. Location of Hawu in Between "*Umpak*" or Foundation Stone
Source: Photograph by Ijad (Local Craftsman/*Palika*)

This information suggests that the traditional stove in *Kampung Naga* shares some similarities with other traditional stoves in other parts of the world. If we look at some other traditional stove, such as Kamado or Irori in Japan and Bhutanese traditional stove, we can see some similarities in functions, features, dimensions, working principles, or cultural significance, to name a few (Bruce et al., 2013; freehand.co.jp, n.d.).

These traditional stoves have similarities to some extent regarding stove functions, which are used for daily cooking needs and play a role as a source of warmth in the room for the whole family (Bruce et al., 2013; freehand.co.jp, n.d.; Hermawan, 2024; Sumarlina et al., 2024). The stove's features also show similarities, such as the cooking holes on top of the stove, the firewood holes in front of the stove, and the small volume gap for collecting the ashes after cooking activity.

Table 1. Similarities of Hawu with Some Other Traditional Stove

Aspects	Traditional stove of Kampung Naga (*Hawu*)	*Kamado* stove and *Irori* (Japan)	Bhutan traditional mud stove (*Bukhari*)
Stove function	• Daily cooking • Fireplace for warmth	• Daily cooking • Fireplace for warmth	• Daily cooking • Fireplace for warmth
Stove dimensions	Dimensions of Hawu: 0.7m x 0.5m x 0.3m Dimensions of Parako: 0.95m x 0.95m x 0.5m	988mm x 494mm x 325mm *Kamawa* diameter right and left: 27cm, chimney hole diameter: 10cm	Around 200cm x 200 cm x 80cm
Stove features	Two cooking holes on the top of the stove, one firewood hole in front of the stove, and two small holes on the both side of the stove to support air flow during ccooking	Two cooking holes (*Kamawa*) on the top of the stove, two firewood holes in front of the stove, chimney hole	Generally two cooking holes on top of thes tove and one or two firewood hole(s) in front of the stove
Stove materials	Material of Hawu: dry clay (unfired) combined with coconut fiber, ashes, and Sadagori (Sidaguri or Sida rhombifolia) leaves extract as an adhesive Material of parako: box of wood plank with bamboo floor filled with an ordinary/local dry soil	Material of the stove/Kamado: ceramic bricks, commercial mortar, surface finish with plaster paste	Bricks and clay. The material sometimes used grass-reinforced clay/mud.
Stove structure	Hawu positioned on the top of parako which supported with four wood column and bamboo base on top of wood beam. The Hawu is installed above the floor level while tha Parako is under the floor level, supported with four river stones as a foundation on top of the ground.	For the Kamado: Kamado stove located on top of finished floor level (without special base part). For Irori: Irori structure is a sunken hearth filled with ashes and charcoal, located in the center of the room, with a *jizaikagi* for hanging cooking pot above the Irori when cooking,	The stove located on top of the finished floor level, without specific base support.
Cultural aspect of the usage of stove by local people	• As a gathering place for the family during meals • As a gathering place for family to get warm and share stories	• Kamado and Irori has meanings beyond their physical aspect and function • A place for seeking warmth for the family • The sitting space around the hearth is a sign of patriarch family where order should be followed by the family	• As a gathering place for the family during meals • As a gathering place for family to get warm and share stories

Source: (Bruce et al., 2013), *(Cang, 2022), (Takeda, 1973), (freehand.co.jp, n.d.)*

One aspect of these stoves that has different characteristics is the cultural aspects of the usage of the stove by the local people. In *Kampung Naga*, the stove or *Hawu* is generally used for cooking food as well as for a gathering space for the family members during meals. Besides that, the area around the *Hawu* is also used as a gathering space for families to get warmth and share stories. Meanwhile, in Japan, Kamado and the surrounding space is also a sign of a patriarch family where order often discussed and should be followed by the family members (Takeda, 1973). In Bhutan, the traditional stove more or less has the same role as the *Hawu* in *Kampung Naga*.

This confirmed the significant role of the stove and the space around the stove in a traditional architecture and social context, as explained by previous researchers (Ayoobi et al., 2024; Baloch et al., 2020; Bartha & Cionca, 2014; Hermawan, 2024, 2014; Nodeh et al., 2021; Sumarlina et al., 2024).

The similarities of the characteristics of these traditional stoves are summarized in Table 1.

3.2. The Buoyancy-Driven Natural Convection in the Hawu

Buoyancy-driven natural convection heat transfer is a significant phenomenon in various natural and engineering systems. This process occurs when fluid motion is induced by density differences caused by temperature gradients, leading to heat transfer without the need for external forces (Lienhard IV & Lienhard V, 2020).

There are significant roles of buoyancy-driven natural convection in the field of architecture.

Architects often use the principle of buoyancy to optimize natural ventilation in the buildings they design. This approach is proved to be effective in reducing energy consumption and improving indoor air quality and thermal comfort (Allocca et al., 2003; Heiselberg & Perino, 2010; Nagory & Simmonds, 2012; Simões et al., 2025).

Apart from natural ventilation, buoyancy-driven natural convection is often used in the application of the working principles of furnaces (Batmaz, 2019; Wijaya, 2019). In this context, buoyancy-driven natural convection is used to ensure that the temperature is well distributed during the use of the furnace/stove.

Information that was taken from the key informant stated that the design of the *Hawu* and the configuration of the stove in the kitchen is aimed to prevent fire, as the main material of a house in *Kampung Naga* are wood and bamboo.

In this study, we simulate fluid flow in the *Hawu* using Ansys Student 2025 R1 (Ansys Fluent) to see if the *Hawu* design accommodate good flow of buoyancy-driven natural convection as shown in Figure 8. If there is a good flow of air in the *Hawu* and the temperature in the Hawu is well distributed, it means the local community of *Kampung Naga* has the "*know how*"/knowledge on how to control the fire and the air flow.

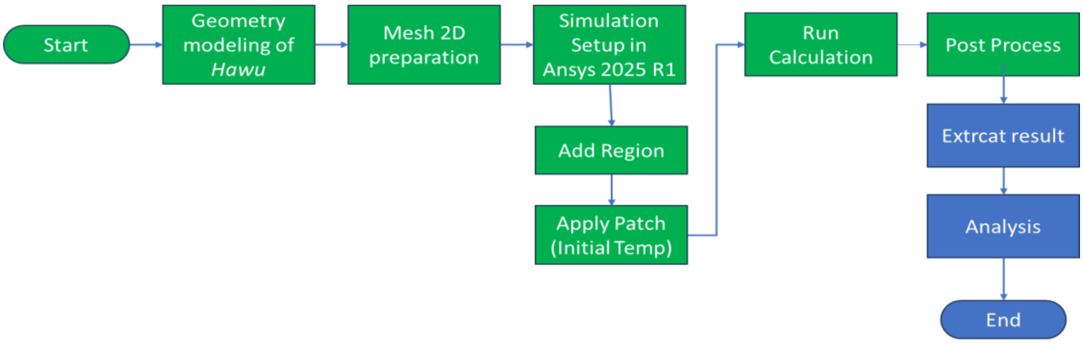

Figure 8. Fluid Flow Simulation Step

The fluid flow simulation was conducted with a steady state scenario. The boundary conditions for the right and left of the computational domain were inlet, while the upper boundary condition is outlet. The bottom boundary condition is set as ground (Figure 9).

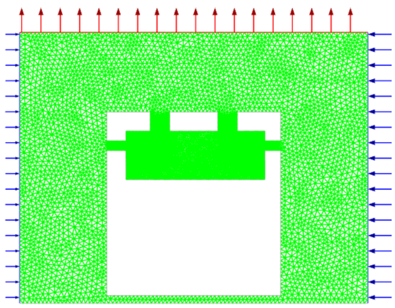

Figure 9. The Mesh Setting for *Hawu* Fluid Flow Simulation

For the simulation setup, we use an incompressible ideal gas to model the air to get accurate results yet computationally efficient (Denner et al., 2020; Yang et al., 2018). To simulate the temperature in the stove inner zone, we add a region and apply a patch with temperature initial condition of 100°C in the center of the stove space.

The simulation result (Figure 10) indicates that the two opening with the size *sajempol* facilitate and stabilize the air flow in the *Hawu*. It shows there is a buoyancy-driven natural convection flow around the computational domain.

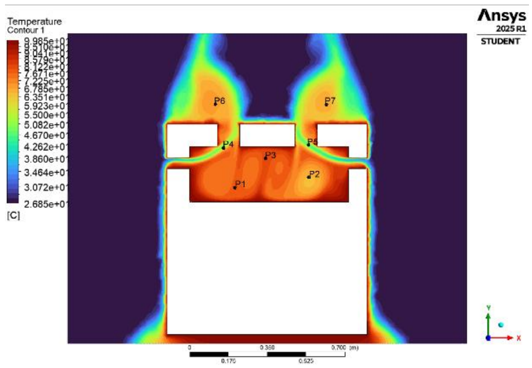

Figure 10. Steady-State Flow Simulation of Buoyancy-Driven Natural Convection in the *Hawu*

This steady air flow (Figure 11) resulted in a well controlled fire and cooking temperature distribution along the two burner, which indicates a genius design of a traditional stove by the local people.

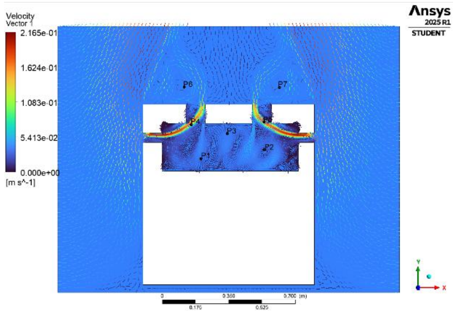

Figure 11. Air Flow Velocity in the *Hawu*

The temperature distribution in the stove inner part shows well-distributed temperatures in several point of interests (probes) as shown in Table 2.

The heat flows from the center of the stove interior to the two burners symmetrically, indicating quite good flow resulting from the buoyancy-driven natural convection due to the different pressure and temperature conditions of the fluid (Figure 12). This result indicates that the traditional stove of the *Kampung Naga* reflects the technological advancement of *Kampung Naga* community in controlling the fire and air flow around the stove.

Table 2. Temperature Distribution on Several Probes

Id	x	y	z	Loc	Temp (°C)	V (m/s)
P1	-0.145522	0.0638682	0.0068079	Under left burner	84.77	0.0242
P2	0.187577	0.111291	0.0068079	Under right burner	74.35	0.0142
P3	-0.00754509	0.196696	0.0068079	Stove center	86.76	0.0265
P4	-0.197152	0.243411	0.0068079	Left side burner	64.43	0.1308
P5	0.186641	0.257151	0.0068079	Right side burner	55.44	0.1655
P6	-0.233791	0.441261	0.0068079	Above left burner	77.63	0.0201
P7	0.267204	0.439429	0.0068079	Above right burner	76.11	0.0154

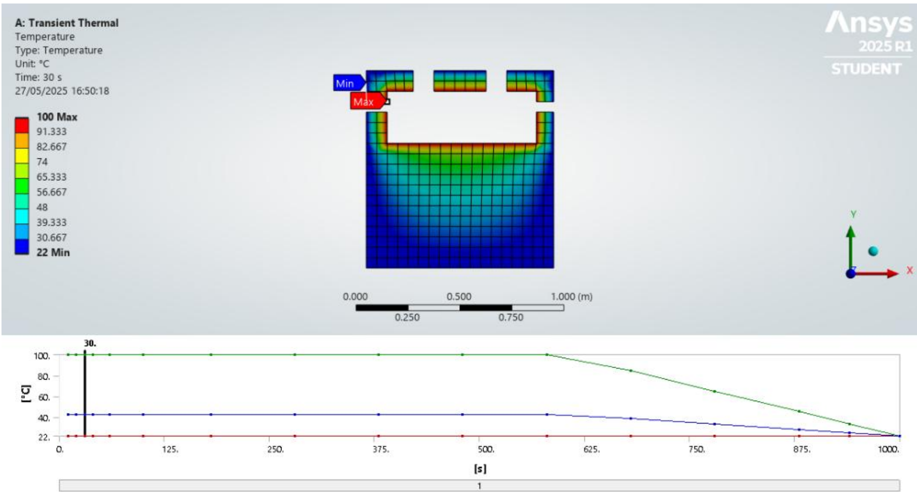

Figure 12. The Result of Transient Thermal Simulation for *Hawu* and *Parako*

3.3. The Conduction Characteristics of The *Hawu* and the Stove Base (*Parako*)

To investigate the key informant information that the configuration of the traditional stove in *Kampung Naga* is designed to prevent fire disaster, we did conduction a heat-transfer simulation using a transient thermal scenario in Ansys Workbench 2025 R1 student version.

The material setup for the computational domain is explained in Table 3. The initial temperature at the inner edges of the stove is set to 100°C, while the outer part of the stove is set to 22°C. The timestep of the simulation is set to 1000 seconds (the first 600 seconds are for simulating the cooking process, and the last 400 seconds is used to simulate the condition after the cooking stopped).

Table 3. Material Setup for Thermal Transient Simulation

Stove part	Material	Density (kg/m^3)	Thermal conductivity (W/m°C)
Hawu (main upper part of stove)	Shale clay	1.480	0.43
Parako (base/support part of the stove)	Dry soil	1.500	2.00

The result of the transient thermal simulation indicates that the heat distribution in the *Hawu* to the base part or Parako seems to equally distributed, while the base part or *Parako* are still in the low temperature.

In the real situation, it is understandable that the base part of the stove would help reduce the impact of heat transfer, which happens in the combustion chamber of the *Hawu,* to the surrounding elements or environment. This is partly because the base part or the Parako is situated under the stilt house, which enable the undisturbed air flow around the Parako that could help bring the hot temperature away from the *parako*. In this case, the parako is acting like a heat sink in an electronic or mechanical device, which helps the hot object transfer its heat to the surrounding environment, thus keeping the maximum temperature of the object remained in control.

With wood and bamboo as dominant materials of the *Kampung Naga* houses, this characteristic helps prevent the *Kampung Naga* houses from unwanted fire disaster. This confirmed the information from the key informant that the role of the traditional stove base ("*parako*") in *Kampung Naga* is to help to reduce the risk of fire disaster.

From the perspective of Ecological Architecture theory, the *Kampung Naga* community approach in the design and development of *Hawu* is proved to be in harmony with nature in the local context. The use of local materials, such as dry mud/clay, as well as *Sadagori* leaves extract and bamboo, underline the strong ecological mindset in the *Kampung Naga* community. The configuration of *Hawu* and *Parako*, as well as the configuration of bamboo *sasag* in the kitchen wall around the *Hawu,* reflects the application of ingenious strategy in controlling the natural air flow for the benefit of the occupants of the house. These characteristics highlight the key principles of Ecological Architecture, which create a balance and integration between nature and the building (Couvelas, 2020; Iriani & Subiyantoro, 2023).

4. CONCLUSION

This study aim to examine to what extent considerations of microclimate and building physics are applied by the indigenous people of *Kampung Naga*, especially in the application of the configuration of the cooking stove/fireplace in their houses.

The findings confirmed that the traditional stove of *Kampung Naga* community which consist of *Hawu* and *Parako* reflect a genius design of a traditional stove by the local people which shows its capability in controlling the buoyancy-driven natural convection and heat/temperature distribution in the combustion chamber and two burner of the stove as well as pereventing the heat from affecting the surrounding wooden materials in the house.

The structure of the *Parako* as the stove base of the *Hawu* also plays a significant role to ensure that the heat excess from the Hawu during and after cooking activity does not pose a danger to the surrounding building materials and structures.

These results reflect the application of the ingenious strategy of the *Kampung Naga* community in integrating the built environment with the natural surroundings, highlighting the application of the key principles of Ecological Architecture.

Future research can utilize the results of this study to further investigate the specific properties of the materials of *Hawu* and *Parako*, the structural advantages of *Hawu* and *Parako*, and conduct direct field measurements of the interactions between the various elements working in the and around the stove.

AUTHOR CONTRIBUTIONS

FFH were responsible for the design and development of the study, literature review, data analysis, simulation, and manuscript writing. HDS contributed to the semi-structured interviews, observations, and documentation.

EP contributed in the development process of the study and improvement of the manuscript.

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