DIY Homes: Placemaking in Rural Eco-Homes

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Abstract. Eco-home makers are permaculturists, artists and environmentalists who actively engage with the environment and nature in order to build self-made, sustainable homes. Through the conceptual lens of "placemaking", we draw on an ethnographic study of eco-home makers and focus on unpacking important lessons for sustainable HCI research. Engaging with 15 eco-home makers in rural Australia and China, we aim to develop an in-depth understanding of how and why they design, build and retrofit their eco-homes. Our findings show that eco-home makers apply a material-first approach, align their designs with nature and are influenced by sociality and everydayness of making. We conclude by discussing how such insights can deepen our understanding of placemaking and DIY in HCI, and open up new avenues for future design and research of computing tools to empower residents as *place-makers*, enabling them to make their own living environments sustainable.

Keywords: DIY, Making, Placemaking, Sustainability, Eco-Home.

1 Introduction

In recent years, HCI researchers have revised the traditional concept of "user" towards the "maker" [1] so to highlight people's abilities beyond using, such as upcycling, repurposing, retrofitting, fabricating, constructing and maintaining (e.g., [2–6]). In other words, instead of seeing people as passive recipients of products, designers should consider users as active makers of their own artifacts and built environments. Studies have been conducted to understand makers and makerspaces (e.g., [7–11]), and to design interactive technologies that better support DIY practices (e.g., [12–14]). More specifically, making in the domestic environment has been investigated to understand the interaction between residents and living environments [15, 16]. Subtle and incremental making and retrofitting the home fosters a reflective conversation [17] between makers and the place and cultivates the intimate relationship and complex entanglements [16].

Extensive studies have been conducted on urban DIY practices, but in rural context makers' perspectives, values, and approaches are rarely explored. Unlike urban DIY activities that rely on exiting industrial infrastructure, global supply chain, and emerging automatic tools, rural eco-home makers prefer manual tools, local materials, and low-tech primitive technology [18]. Eco-home makers are permaculturists, ecologists, architects, artists, and environmentalists who are interested in living in rural areas and eco-villages to have a self-reliant lifestyle. They completely immerse themselves in

fabrication, growing food, making artifacts, and building eco-homes by themselves. Their perspectives, visions, and methods to work with nature could enhance our understanding of sustainability, however, such type of studies is relatively rare in the HCI community.

A growing focus within HCI is designing technologies to create a meaningful integration of people, place, and history for the common good of both humans and environment [19, 20]. HCI scholars borrowed placemaking from urban planning to improve residents' experience, cherish and value where they live [21], to study sustainability [22], and to inform the design of smart cities and urban informatics [19, 23]. However, approaches to placemaking are different in the rural context, where we may interact more directly with other beings, such as wildlife, raw materials, climate, and soil among other natural things. There is a research gap in ongoing rural eco-home making. Rather, the main questions of this research are: Q1) What are eco-home makers' motivations, perspectives, visions, and methods to engage in ongoing DIY home activities? Q2) How can technologies support everyday sustainable making?

In this paper, we focus on the interaction between makers and eco-homes and examine sustainable DIY home activities. We use Desjardins et al.'s [22] three themes of Sustainable Placemaking (longevity, unfinishedness, and multiplicity) as a conceptual lens to investigate how residents design, build and retrofit eco-homes and how they constantly reimage and reconfigure. DIY activities were chosen because they reveal makers' perceptions, visions and intentions, and the potential for design implications to empower individuals to shape their own living environments. We present the results of our ethnographic study with 15 eco-home makers in Australia and China. We identify three dimensions of DIY home practices from findings: Material-first approach maps the complex factors that shape how eco-home makers make decisions and interact with various materials; Working with nature charts the multiple strategies that eco-home makers use to understand the character and qualities of the place and interact with nature to minimize the impact of environment and maximize use of renewable resources during construction and occupation; and, Sociality and everydayness of making maps two-way dynamic interaction between residents and buildings (that individuals shape buildings, and buildings shape individuals) and how eco-home makers balance residents' needs and lifestyles that are more environmentally sustainable.

This paper makes two contributions to HCI research. First, it unpacks how eco-home makers design, build and retrofit their living spaces by discussing empirical evidence from the field and how this could deepen our understanding of placemaking in a rural eco-home context. In that process, it also draws parallels between urban placemaking work within HCI [19, 21–24]. Second, it provides insights into the co-design process that involves no-humans and discusses how HCI can support eco-home practices.

2 Related Work

2.1 Sustainable Placemaking

Place and placemaking could be useful concepts to understand the intentions and interactions of eco-home makers. Place is how individuals view and experience the world, and is dynamic, unfinished, and constantly changing [25]. Tuan [26] observes that a place is a time-based phenomenon created by the human experience, which contains memories, meaning and identity. Place is also a significant theme in HCI. Harrison and Dourish point out what distinguishes place from space is inhabitants' sense-making activities: human responses to their living environment, including understandings of behavioral appropriateness and cultural expectations, make place for a cultural and social phenomenon [27]. The theory of placemaking has also been taken up and investigated in the HCI community. This theory was originally developed in urban planning by Jane Jacobs [28] and William Whyte [29], who proposed a community-centered approach, and presented neighborhood designs that promoted public interaction. Their vision embraces collaboration, transformation, community-driven initiatives, and has a clear relation to the physical and historical context of a place [30]. Given the emerging agendas of ubiquitous computing and making movement, HCI researchers suggest that placemaking could be a viable strategy to design meaningful, future smart lives by making residents value and experience the place they live in [21, 31–33].

Placemaking is to intensify lived human experience and make residents cherish the place they live in [21]. Similar to the approach of user experience in HCI [34], by living in a place, inhabitants experience it naturally through perception, touch, meaning making and interpretation, and the spatial patterns of social interaction are formed over time. Then the place becomes distinctive to the individual and may get a unique name [35]. By integrating placemaking and smart environment, HCI researchers try to explore and design for a better life. For example, in the project Livehoods, Cranshaw et al. [36] present a clustering algorithm for mapping a city by analyzing patterns of residents' movements and behaviors. The project data portrayed a dynamic view of the social flows, and described how people go about placemaking across municipal neighborhood borders. Media facades [37], media architecture [32], and ongoing urban design [24] have also applied placemaking in HCI.

Focusing on sustainability and temporal dimension, Desjardins et al. [22] utilized sustainable placemaking to investigate how everyday place makers are engaged incrementally and over time in the making of a whole environment. They discussed three themes of sustainable placemaking: longevity, unfinishedness, and multiplicity, and proposed that a sustainable place should "invite people to continuously build, transform, and engage with that place and with each other in a long-term, creative, meaningful, and ongoing manner" [22]. The forming of a mature and long-lasting relationship between a place and people takes time, which is referred to as longevity. The making of place arises through the long-term periods of living within that place and it is this long temporal quality that allows design to facilitate and sustain the placemaking process. The quality of unfinishedness underlines the need for a balance between young and mature materials and that balance is necessary to reach an ongoing long-lasting

process of creating a place – and thus achieve longevity. Through reflecting about their place, makers actively and creatively live and experience it, and are able to fluidly utilize multiple strategies to make their place. A holistic approach of placemaking is multiplicity. Place then becomes a result of the compound function of quality and people's engagement [22]. Their research work was the first step to frame sustainable placemaking in HCI community. Our study extends this work by contributing empirical insights from 15 eco-home makers, from the point of view of how they constantly reimage and reconfigure their personal living space. We show that makers interact with materials, nature, and communities and highlight the ongoing, iterative, and unfinished design and making of the place.

2.2 DIY in HCI

DIY has been a major focus of the HCI community. Researchers identified DIY as a collaborative, creative hobbyist practice, which unifies playfulness, utility, and expressiveness [38]. Makers also attempt to transform consumer goods to better fit their own needs [16]. In the last decade, HCI researchers have been studying DIY makers and maker culture to create interactive technologies that better support DIY practices of maker communities (e.g., [11, 39–41]) as well as gaining insight into designing future collaborative technologies (e.g., [10, 42, 43]).

Ethos like sharing [44], care [4, 45] and open innovation [46] have been defined as the key aspects of DIY. These nuanced perspectives can be used in ethnographic studies [45] to understand and analyze the social setting and community-based DIY practices. For instance, Toombs et al. [45] focused on hackerspaces' maintenance labors and analyzed ethnographic encounters through the lens of care ethics to better understand social aspects. To Bellacasa [47] care is things we do to constantly maintain the world we live in, which encompasses our bodies, communities, and the physical environment where everyday making practices take place. More inclusively, HCI researchers proposed post-anthropocentric design [48] to care for nonhuman stakeholders [49–51] and the nature [52, 53]. DIY in this field attempts to involve human as catalysts for collaborative sustainable making.

More specifically, DIY activities in the domestic environment have been investigated to understand the interaction between makers and living environments. For example, Wolf and colleagues [15] introduced the concept of "home worlds" to understand DIY home repair and maintenance, and how homes are embedded in communities and everyday life. Desjardins and Wakkary [16] offered six qualities of the intimate relationship between makers and the lived-in prototype by presenting an autobiographical project of converting a camper van. Subtle and incremental making and retrofitting the home fosters a reflective conversation [17] between makers and the place and cultivates the intimate relationship and complex entanglements.

HCI researchers have also explored how computing tools could be designed to support everyday making, and interpreted the complex relations among technology, home and residents [54, 55]. Shewbridge et al. [56] designed technology probes to explore how normal people might use fabrication tools in their homes. DIY kits for smart homes have launched on the market with which users can create and modify their own smart

homes by connecting various sensors, actuators, and social networks etc. [57]. Another related research area is end-user development (EUD). EUD for smart home provides a set of tools and interfaces that enable occupants shape their home environments [58]. A number of methods have been proposed: the adoption of a magnetic poetry metaphor for end-users to program their environment [59], tangible interfaces [60], end-user programming platforms [61–63].

3 Methodology

3.1 Research Settings

It is important to discuss the settings within which this research took place. An eco-home is when a maker has built or retrofitted all or some parts of his or her house to reduce environmental damage [18]. While there are various types of eco-buildings, we focused on self-built eco-home in rural settings. In our project, we wanted to engage with eco-home makers who either lived independently or in an eco-community. Our participants included makers who have no or little construction-related qualifications and experience, and those who are architects and DIY amateurs. The research involved visiting two eco-communities: one in Australian and another in China. 9 out of our 15 participants lived in eco-communities, while the other 6 participants lived on independent land that they owned. Table 1 shows a list of projects we considered as part of eco-home activity for this study.

Table 1. Project Types

Project Type	Description
Retrofitted House	Retrofitting an existing house towards sustainability
Tiny House	Caravan or shipping container house, or a house built on a trailer
Timber House	Timber as the main material to build frame, wall, and roof
Earth House	Earth as the main material to build foundation, floor, and wall – e.g., use of cob, earthbag, and clay brick
Off-Grid System	Independent from public utilities. e.g., generation of electricity and conserving water on site.
Edible Garden	Growing food in the garden, composting kitchen waste, and recycling grey water for irrigation
Eco-Community	A commune of eco-home makers, collaboratively building eco-homes and share common values

3.2 Methods and Participants

We conducted an ethnographic study in eco-homes and eco-communities. The criteria for participants recruitment were that they should have self-built (in parts) at least one home. A total of 15 participants (Table 2) from rural Australia (n=8) and China (n=7) were involved in this study to enable an international perspective, which also reflects the first authors' long-term work in DIY and sustainability. The first author had worked

on eco-homes projects in both Australia and China and used this opportunity to conduct in-depth interviews with participants. The initial recruitment was done through the first author's personal network, followed by advertising it on permaculture-based Facebook groups. In Australia, the first author visited participants' places between February 2020 to August 2020. In China, the first author visited these eco-home projects between years 2012 and 2017. Participants' ages ranged from 28 to 92.

Table 2. Participant Details (with pseudonym)

#	Name	Location	Age (DIY Years)	Project Types
1	Ben	Australia	58 (7 years)	tiny house, edible garden
2	Nathan	Australia	46 (28 years)	tiny house, off-grid systems, edible garden
3	Oliver	Australia	60 (40 years)	tiny house, off-grid systems
4	Paul	Australia	50 (32 years)	timber house, off-grid systems, edible garden
5	Lucas	China	45 (8 years)	retrofitted house, edible garden, eco-community
6	Will	China	30 (11 years)	retrofitted house, off-grid systems, eco-community
7	Iain	China	44 (11 years)	timber house, eco-community
8	Eric	China	48 (4 years)	retrofitted house, edible garden, eco-community
9	Victor	China	36 (5 years)	retrofitted house, timber house
10	John	China	39 (11 years)	retrofitted house
11	Martin	China	28 (7 years)	earth house, off-grid systems
12	Thomas	Australia	68 (45 years)	retrofitted house, off-grid systems, eco-community
13	David	Australia	75 (51 years)	timber house, off-grid systems, eco-community
14	Bill	Australia	92 (50 years)	timber house, off-grid systems, eco-community
15	Alan	Australia	82 (30 years)	timber house, eco-community

The first author visited the participants and stayed on site for several days in order to get detailed insights around DIY of eco-homes. Semi-structured interview, field observations and sketches were employed during the data collection process. The first author also joined participants' daily activities, engaging in building, repairing, making, gardening and cooking. Through living with them, we aimed to study the natural circumstances of everyday making activities, and daily interactions with eco-homes. In addition to participation and observation, we use sustainable placemaking [22] as a conceptual lens to design our contextual interviews, and aimed to learn participants' intentions, perceptions and visions of DIY home projects. Interviews focused on discussing specific DIY systems built by our participants and aimed to understand their rational in building those. Interviews also included participants' philosophical stand on environments and their role in it. Interviews were conducted in English and Mandarin Chinese. The interviews ranged in length from 40 minutes to up to 2 hours.

All interviews were translated and transcribed. Furthermore, our research data included transcriptions of interviews, photos and field notes. We conducted thematic analysis [64] on our data. We used the professional online transcription software "Trint" to transcribe all the audio recordings, and coded our data using NVivo. We started by creating initial codes through open coding, and subsequently combined relevant codes into themes. Through iteratively reviewing and refining the coding, we summarized our analysis and developed three themes of DIY eco-home practices.

4 Findings

Our findings outline three sets of DIY home practices, and reveal how makers interact with materials, nature, and communities and highlight the ongoing, iterative, and unfinished design and making.

4.1 Material-First Approach

As the choice of materials influences the life-cycle cost, environmental impact, and comfort of eco-homes, eco-home makers prioritise the selection of materials and consider peculiarities of every material, and constantly experiment and iterate to make the best use of every piece.

Use of Economical Material

For economic factors, it was common to observe that eco-home makers tried to minimize the cost of materials. Their strategies include reducing the use of expensive materials, utilizing recycled and cheap local materials, and transforming waste and garbage into building materials. For example, the main materials of Martin's (P11) house are natural materials collected in his own farm. The wall, for example, is made from earth bags, and the roof is made from thatch. He also used construction waste removed from other houses to fill the foundation instead of gravel, and incorporated second-hand glass and beer bottles to make windows, and created mosaic with broken glass and tiles. He recounted how he chose and dealt with materials in his earthbag and cob houses.

> "Due to the financial constraint, the houses we built are relatively small, and more than 90% of the materials come from within 5 kilometers of our neighborhood. When I go to a place, I get used to looking at the rubbish on the ground and start thinking about what can this be used for. There is basically nothing that can be wasted. Rubbish can be turned into useful things through some techniques and methods." (Martin, P11)

After graduating from university, Martin (P11) had always wanted to return to his hometown in the province of Hubei, rather than staying in cities. He has been interested in permaculture since 2013 and started his first natural building project in 2015. So far, he has built 5 houses using natural and waste materials. Two of these are his own small houses, while he helped his friends and relatives build the other three houses. He believes that the process of turning soil, stones, straw and other free and waste materials into building houses is full of creative accomplishment. The local climate also played an important role in the selection of specific material. Martin commented that the thermal qualities of earthbags and cob would provide resistance against different weather conditions.

In order to find cheaper or free materials, eco-home makers usually pay more attention to the waste around them, and constantly think and experiment how to use these materials. As noted by Oliver (P3), who has been living in a caravan for 15 years, he has kept materials that he thought would be useful in the future, and then recycled them in different forms over a period of time. For instance, he has kept several canvases from different billboards for 20 years and repurpose them in different ways. He recently

moved to a new place, re-glued them and made a new caravan annex roof. It is important to note here was that the quality and materiality of the canvas would enable Oliver to store it easily and re-use it to make walls, room dividers as well as to create ventilation during Australian summers. Similar behaviors are very common in DIY homes, where eco-home makers use free and cheap materials, experiment with them and re-purpose them for new situations.

Use of Natural and Local Material

As one of the main purposes of eco-homes is to reduce the impact on the environment, eco-home makers strongly consider whether the materials will cause any environmental hazards during construction and occupancy. Hence, they try to source mate-rial that is re-useable, recycled, locally available, and have suitable thermal functions. A good example would be Will's (P6) renovation of an old rammed earth house. Will is a 30-year-old artist. He left the city in 2009 to explore a self-sufficient life in the rural area and initiated an intentional community in 2015 to gather people with com-mon aspirations to practice a sustainable lifestyle. In the community, they experimented with many alternative construction methods, such as light steel, geodesic dome, earthship, timber structure, bamboo structure, and so on. This rammed earth house was an abandoned house he rented locally from 2018 and has been transformed into their residence together with other community members. The wooden structure and walls of the house had been damaged due to disrepair and the leaking roof. In the process of renovating, he tried to use local natural materials as much as possible, instead of using non-degradable materials and materials with long regeneration cycles. He followed the traditional method of using mixed soil, sand and lime to repair the wall without cement, and used tung oil for timber protection instead of industrial varnish. He also sorts and stores waste on-site for other purpose, such as building a small furnace to melt metal waste into ingots. When the accumulation reaches a certain amount, they can be melted and cast into tools again. As he commented:

> "Because we are concerned about the issue of environmental protection, and then we do this (self-sufficiency). The environment and people are one, and we respect the environment as the primary prerequisite for doing this, so basically we consider the use of natural materials as much as possible." (Will, P6)

(a) (b) (c) (d)

Fig. 1. Paul's (P4) garden and forest (a), the first house built in 1991 (b), the blacksmith workshop(c), the house they live in now (d)

Eco-home makers try to use local renewable recourses as much as possible, so that while acquiring resources, they can also maintain the local ecological balance. They

reduce the impact of human activities on the environment by managing natural recourses like trees and plants. For example, the timber used in Paul's (P4) home was cut from his own farm (Figure 1a). Most of the wood was first planted by his parents in the 1980s. He also plants new trees while cutting down. The continuous construction of his house began in 1991, starting with a small wooden house (Figure 1b), then wood and black-smith workshops (Figure 1c), and constantly built, fix, and change the houses due the birth of his children. So far, his houses are totally off-grid (Figure 1d), living with his wife and three children. As he explained:

> "My philosophy is to reduce the damage I do. And it's making people feel safer and living in a way that makes people happier. Because I think people are happier when they feel independent. Um, and they're not limited by the money. Um, and the more resilient your own life is your community life will be as much resilient." (Paul, P4)

The examples of Will and Paul show that eco-home makers strive to use natural and locally sourced materials that will have less adverse impact on the environment while being able to manage their family lives.

Easy to process and maintain

In addition to supporting the basic structure, insulation and other functions, materials also need to be easy to process, operate and maintain manually. Since eco-home makers use hand tools and lack large construction machinery, they choose relatively lightweight materials that are easy to process by hand, such as wood, bamboo, straw, earth, and light steel. Take the case of Martin's (P11) houses, the reason why he chooses cob as the main construction method is because it is extremely fluid. Hand-formed from pliable mud, cob building requires little training, no machinery, and is accessible to everyone. Bill (P14), a 92-year-old male, gave the following comment:

> "I'm a lazy Australian. Australians find the easy way of doing things. My philosophy for building a house is that it should be easy. I did most of it myself. I had some help, but I did most of the construction myself. And, zero maintenance. No paint, so there's no paint in the place anyway. All timber is left natural. Yes, easy to construction, low cost, zero maintenance, they'd be the key points. A house set for me is easy to build." (Bill, P14)

Bill built his current house during his 60s. He had similar considerations when choosing the materials for his house. He used a pole structure to build his house, which allows the efficient use of small round timber. He did most of the construction by himself except the roof, which needed some additional help from his friends. He was able to build a house with a large open kitchen and two bedrooms, where additional guest can sleep.

4.2 Working with Nature

The design of eco-homes requires a good understanding of the character and qualities of the land, its topography, soil quality, climate, sun movements, wind patterns and existing biodiversity. Based on this knowledge, houses could minimize the impact on the environment and maximize use of renewable resources during construction and occupation. In this section, we discuss how eco-home makers utilize specific aspects associated with climate and landscape in order to live sustainably.

Climate

For eco-homes, acknowledging and understanding the local climate is often the starting point of designing a house. Climate will affect comfort and often long-term costs, more than any other factors. Houses in different climatic regions have very different requirements and designs: with those in cold temperate climates needing highly insulated walls and minimal heat leakage, whereas those in tropical or rainy climates might be quite structurally open to allow natural cross-ventilation to flow through and keep the house at a cooler temperature.

An eco-home ideally reflects its climatic location by managing, harnessing and maximizing the climatic features to enable a house to benefit from natural ventilation, solar gain and passive cooling. For example, David's (P13) eco-village was located in a subtropical region of Australia, where the climate offers 40 weeks of mild-warm to hot weather and 12 weeks of cool to cold weather. Passive solar design has been used in most of the houses in the village to keep cool in summer and warm in winter. In order to utilize passive solar gain (Figure 2a), houses need to capture as much sun as possible. In the southern hemisphere, this is achieved by orientating houses to the north. By observing the sun's path throughout the year, eco-home makers could use the windows, wall and floors to collect, store and distribute heat from sunlight entering the building during the winter and exclude solar gain in summer. Like David (P13) explains:

> "This house (Figure 2b), is almost facing north. So, I built it this way to get the solar aspect. The roof goes up to let more of the sun in. Based on the design of the Queensland houses with the wide verandas, it stops the sun getting on your walls during the summertime and overheating the house." (David, P13)

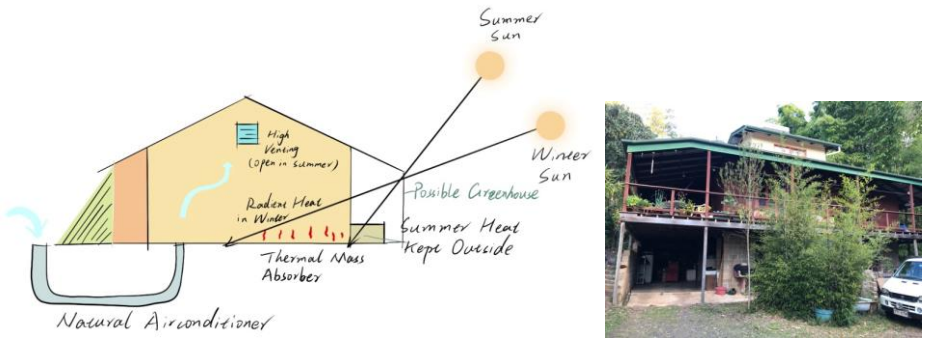

Fig. 2. Passive Solar Design (a), the passive solar design of David's house (b)

In order to make full use of natural light, eco-home makers use various methods. New houses can use large windows to improve solar gain. For retrofitted projects, especially in colder area, the usual approach is to add a greenhouse because it is more difficult to change the size of the windows. For example, in Eric's (P8) home, he built a greenhouse to connect all the rooms in a courtyard type house. Before the renovation, the bedroom and living room were separate from the kitchen and bathroom. To go to the kitchen or bathroom, one had to pass through the open-air yard, which was not convenient in cold winter and rainy summer. Attaching a solar greenhouse not only increased the indoor

space and makes it easier to move around in different rooms, the enclosed thermal mass walls can also store more heat in winter, thereby reducing the extra energy consumption of heating the rooms in winter. Eric and his family moved from the city to this rural old courtyard in 2014 because they wanted to shift to a lifestyle close to nature.

Conservation of Energy

Energy is an important part of a functioning home. It is required to heat water, heat or cool spaces of the house, cook, and provide electricity to power lights and run electrical appliances. Conventional houses often rely on fossil fuel energy sources, while eco-homes instead tend to harness less environmentally damaging renewable resources (sun, wind, water) through a variety of technologies. Most of the participants used micro-generation on-site technologies, small-scale equipment that either power a single house or an eco-community. Among our participants, the most popular technology used was photovoltaic panel, because of the simplicity in installation and use, they are often attached to old car batteries that is then used to power lights and laptops. Among other examples, Thomas (P12) made a biogas plant (Figure 3b) for cooking, and built a standalone system by recycled solar panels (Figure 3a), batteries and an inverter. As he noted:

> "I got recycled solar panels to make a roof in my patio. It was given free to me as it came as a part of electronic waste. Generally, you can get them for nothing. And they put them in outer space. So that makes a very good roof, you know, very durable. Not all of them are fully functioning but some of them actually work. I have got batteries under my house, so I can save some power for later use." (Thomas, P12)

Thomas was an organic farmer and founded a community in 1975. He sold the farm due to the back injury, and now lives in a house with 800 square meters back-yard, which he called a small farm. He has been living a self-sufficient lifestyle for 45 years, growing his own food (Figure 3d), keeping native bees, cooking from gas that is produced in his own biogas system, making biochar, collecting rainwater (Figure 3c) and generating electricity from solar panels. Almost all of these alternative projects were made by waste and recycle materials. Such as he recently experimented and built an electric bike by recycled computer batteries. He sold his car and is completely reliant on his electric bike.

(a) (b) (c) (d)

Fig. 3. Off-the-grid system in Martin's retrofitted house: (a) photovoltaic system, (b) biogas system, (c) rainwater collection, (d) edible garden

Wood energy is another solar energy and is accessible to everyone in the rural area. Using wood to cook and heat room is prevalent in eco-homes and is an easy way to achieve energy self-sufficiency. Different fireplaces and stoves were observed in this study. Eco-home makers attempt to experiment and develop appropriate methods to utilize wood and reduce the wood smoke. One approach is to increase burning efficiency. For example, rocket stoves [65] are very popular among participants' DIY projects. The goal of the rocket stove is to enable efficient wood burning in the room which reduces pollution and improves human comfort. Furthermore, the openness and flexibility of rocket stove enable eco-makers to DIY and fit their own needs.

4.3 Sociality and Everydayness of Making

To understand the effective functioning of eco-homes, one needs to attend to human behavior, practices, habits, and needs of people who inhabit those spaces. In this way, eco-homes are a balance between residents' needs and lifestyles that are more environmentally sustainable.

Sociality

Eco-homes are generally a part of larger eco-communities or eco-villages. Community members chose to work together in the pursuit of common ideas and intentions, and in this process, they help each other, share experience and provide technical support. Additionally, most eco-home methods and technologies are developed from grass-roots – via ongoing experiments involving a group of people and do not comply with contemporary building codes. It is often difficult to find professional builders to carry out the construction. Often, eco-homes are built by volunteers during the course of workshops. In this way, participating alongside other like-minded people not only saves labor costs, but also promotes the connection of individuals and the formation of communities. For example, Martin (P11) regularly holds natural building workshops and builds houses with volunteers. He started his first workshop in 2015, and gradually more people followed him, wanting to learn how to build an eco-home by themselves. He argues that teaching others in workshop is the fastest way to learn, because in the process, he would find more information and reflect on previous projects. Moreover, he feels particularly meaningful and valuable to share his skills and ideas with others. He began to try to combine construction and healing in 2020, after his journey to other eco-villages in Thailand and India. He found that building together with other people not only promotes more sincere communication among individual, but also deepens the connection between human and the nature.

In addition to the construction of individual houses, eco-communities also organize workshops to build public landscapes and infrastructure, within which participants foster the sense of belonging and engaged relationships to the place. For example, John (P10) led a children's playground construction workshop in 2018. The playground is located in a small garden in an eco-village. In order to reduce the impact on the environment, they did not use any cement or concrete. Instead, they picked more than 1,000 small wooden stakes and smashed them into the soil by hand. A lid was made on the

pit to create a primitive cave feeling. The entire construction process was completed by human labor without any machinery. As he noted:

> "We were divided into two groups, one for digging the pit and smashing stakes and one for making the lid. The two groups were separated by about 10 meters. In the end, we, about 20 people, lifted the lid together and move to the pit, and you can feel the power of the collective, and everyone worked together to accomplish this. There is individual work, and there are collective and community mutual support. We finally completed this together, which touched and shocked everyone." (John, P10)

Through building together, participants share not only physical labors but also emotional support. As we can see from cases, human well-being is also located at the central of eco-homes. Building collectively encourages makers to share their experience and stories. Then DIY eco-home becomes a convivial process and connection.

Ongoing Experiment

All the participants started DIY home from experiments. These grassroot innovations are rarely unproblematic. Eco-home makers make mistakes, learn from it and get better. Through such long-term interaction with materials, tools, nature and built environments, the relationship between inhabitants and the place which they live in is getting mature. As David (P13), who has been constantly being engaged in DIY home activities for 51 years, described his ongoing experiment:

> "I've never really finished a house yet, never will. But it's when I see something is functionally ready. I stop working on it for a small period of time. But then I start again whenever I learn something new."

Once eco-home makers start a DIY home practice, it tends to be a life-long experiment. For example, Oliver (P3), a 60-year-old maker, started an eco-community when he was young, and decided to live in a hunter-gatherer lifestyle, which he called an authentic life. 15 years ago, he began streamlining everything and started living in caravans. He had two caravans, which he later retrofitted: one for bedroom and office, one for kitchen and storage, and parked them both at his relative's place. In 2019, he moved to another place and sold one of his caravans. Now, he has divided his caravan into three parts, kitchen, bedroom and workshop. He cut the back off his caravan and put a door in, so that he could access the workshop from the rear. So that he had a large enough door to store large things. He built walls between the kitchen, the bedroom and the workshop, so that he does not smells or hear the fridge from his bedroom. He also recorded how much electricity and water he used every day to maintain his off-grid system. As He commented on his approach of this experiment:

> "I mean, I got I've got to a stage where if I want a solution and something, you know, you keep at it, and you'll find it. It's got to come out of somewhere. It's sort of like, you leave it to your subconscious to find it. And then all of a sudden you look at something down there, it is right in front of my face. I never even thought about doing it that way. Perfect. You know, that's the key, is to not try too hard to find the solution. Just let it come to you." (Oliver, P3)

Everyday Needs and Lifestyle

The most frequent word eco-home makers mentioned was the word "fit". The eco-home needs to fit into the environment, and fit around the needs of the people who live in it. What eco-home makers did firstly was to write down the basic needs of their house, so they knew what they were heading for. For instance, Bill (P14) noted that the first thing he needed is outdoor living space. Due to the climate in the east-coast of Australia (42 weeks of summer, 10 weeks of winter in a year) he wanted to spend most of his time in his verandah. He also needed a library for more than five hundred of his books, a proper kitchen space because he is enthusiastic cook, an aiding space and a living room with a big bay window. He wrote these requirements down and then did sketches of what he wanted. He wanted a house with the Japanese style, a living room with six sides, and "an engineer's cook kitchen" without drawers and cupboards (Figure 4a), so it's easy to work in and doesn't have to go looking and rummaging around in a drawer. As he commented:

> "I love challenges. I love the whole concept of starting with nothing and building something which is actually felt like the house where you actually live in it when you're finished. And I think the whole thing about this was it starts off as a dream. And I knew I needed certain things in the house. The thing about the house is that it fits my needs. It's a comfortable house to live in." (Bill P14)

Bill lived on his own, but he did have children and grand-children who would visit him from time-to-time. His house is obviously built to cater to his own needs, but he also made sure that if he had his whole family coming over to visit, he would be able to entertainment in his house.

(a) (b) (c) (d)

Fig. 4. The "engineer's kitchen" (a), the circular bay window (b), the bookshelves (c) in the six sides living room, dry composting toilet (d) in Bill's house

There are challenges for eco-home makers to balance environmental impact and comfort, such as dealing with human waste. Toilets enable us to explore the methods that makers use to live a comfortable and sustainable lifestyle. While various toilets are available on market, eco-home makers prefer to design and build composting systems by themselves. For a small household, the dry composting toilet (Figure 4d) is very common (P1, P3, P4, P5, P6, P11, P12, P13, P14, P15). By appropriate design, like a suitable location, long drop, balance moisture, and high chimney, it doesn't smell. Every year or two, when the wheelie bin under the toilet is full, people need to take out the bin and left for one more year to bury in the garden. For larger residential blocks, wet compost toilets are more efficient by introducing compost warm or biogas plants.

In both cases, recycling humanure on-site makes everyday life a circular system and broaden possibilities of comfortable sustainability in eco-homes.

5 Discussion

In this paper, we have presented our findings from an ethnographic study of eco-home makers and aimed to highlight how they design, build and retrofit eco-homes and how they constantly reimage and reconfigure. These findings have outlined three overarching sets of practices: Material-first approach maps the complex factors that shape how eco-home makers make decisions and interact with various materials.

5.1 DIY Home as Placemaking

HCI researchers have borrowed and adapted the concept of place and placemaking to understand sustainability [22], offer strategies for Smart Cities [21], and understand domestic memories [66] in the urban context. However, the idea of placemaking is quite different in rural environment. In this paper, we grounded our work in rural DIY home activities and provided detailed description to our ethnographic encounters to investigate the goal of sustainability. In line with Desjardins et al.'s [22] framework of sustainable placemaking (longevity, unfinishedness and multiplicity), we observed how eco-home makers act as place makers and engage incrementally with the place they live in.

The forming of a mature and long-lasting relationship between a place and a maker takes time, which is referred to as longevity [22]. The design of 92-year-old David's house was a good example of longevity. The use of timber as the core material ensured David's long-term engagement with his house. The design of David's house has considered his everyday needs and routines through which he is able to function well. In a sense, the making of such a space arises through the long-term periods of living within that space and it is this temporal quality that allows new designs to emerge and sustain the placemaking process.

The quality of unfinishedness refers to a state that is constantly changing, and activities that are never finished [22]. In the eco-home context, the reason why the place is unfinished is because eco-home makers started DIY home from experiments and treated their homes as laboratories. Eco-home makers enjoyed the iterative process of learning, making mistakes and refining. Through such long-term interaction with materials, tools, nature and build environments, the intimate relationship between makers and the place is getting mature. From our fieldwork, we found that Oliver, for example, had been living in caravans for 15 years, and constantly retrofitted parts of the caravan when he moved to a new place. He started with two caravans, one for bedroom and office, one for kitchen and storage. When he moved to another place and started living in one caravan, he kept materials from the old caravan that he thought would be useful in the future, and then recycled them in different forms over a period of time. Through such ongoing adjustments, the place, the off-grid caravans, progressively fitted his

needs and the environment he parked. Here, Oliver's living situation was always unfinished – as his life unfolded regularly, so did his living.

The multiplicity refers to the holistic approach that enables eco-home makers to reflect, experience and make the place [22]. All of our participants mentioned that permaculture [67] was the main method to guide their eco-home design. At the same time, they also had been learning and experimenting various techniques and methods based on their own interests and under-standings to make the place better. For example, Paul had three workshops for bicycle, woodwork, metal and mechanical work in his farm. He also grew food, raised native bees and produced wood for energy and making use. As we saw in our study, making an eco-home and living in a self-reliant lifestyle requires multiple competences. Moreover, multiple goals and strategies can co-exist to support sustainable placemaking .

However, apart from these three themes, we observed much more complex interactions between eco-home makers and their places. Eco-home makers have a deeper connection to the land and engage in a conversation with the natural world through placemaking. They hardly attempt to have an overall control of the construction and making processes, but engage in a shared autonomy with the place. Making and creating for eco-home makers also meant as reacting to nonstandard materials, complex nature, and diverse communities rather than just pleasure or executing a dream. Eco-homes became the stage that makers appreciate, where they collaborate with materials, nature, and communities and form an improvisation.

Unlike urban DIY activities that rely heavily on the use of existing industrial infrastructure and cutting-edge tools, rural eco-home makers preferred manual tools and appropriate technologies [68]. They value craftsmanship, self-sufficiency, respect unique qualities of every piece of material, and have more opportunities to access raw natural materials and heterogeneous nonstandard recycled materials. Thinking with hands [69] is the way they deal with these materials and shape their living environments. Even with specific goals, eco-home makers also reveal their personal perceptions, cultural expectations and unpredictable creativity. This kind of workflows not just give makers the sense of accomplishment but also constantly question and inspire them for further experiment and DIY to make the place better. Through these ongoing experiments and sense-making activities, an eco-home emerges as the unique spirit from inhabitants' attempts to constantly interact with materials and retrofit living environments.

For eco-home makers, human and non-humans are the stakeholders, adding natural entities, environmental surroundings and ecosystems in considerations. In order to build eco-homes to fit the environment, it usually takes a long time for makers to observe and understand the existing place, the landscape, sun movement, and various species. They believe that eco-homes should be able to minimize the adverse environment impact during construction and occupation compare to contemporary urban houses, in other words, they make the place better. Most of our participants had the options and ability to live in cities and enjoy a convenient life, but they choose to dive into ecology and care for the earth. DIY for them is not just a utility aspect but an expressiveness and sense-making feature of their lives. For example, Bill used tall frames and pole structure to build his house without any substantial excavation. He doesn't raise pets like dogs or cats so that wildlife like wallabies and kangaroos can hang around in his

garden. Nathan and Paul plant native trees for birds every year in their farm and make beehives for native bees. They reject consumerism and industrial productivity that causes damage to the environment and pursue the self-reliance lifestyle as privileging diversity and nature. HCI researchers have shifted their empathy towards non-human elements to focus on post-anthropocentric design [50, 70]. However, this field still calls for a more inclusive and pro-found multidisciplinary base of methods and theories. Our ethnographic findings reveal human's perspectives, visions and abstract values as well as the diverse ways they work along with nature, which could inform future post-anthropocentric designs.

5.2 Co-design with Non-humans

In sustainable HCI, we are seeing an increasing interest in human-nature interaction [71, 72], and designing tools to sup-port interactions between non-humans and humans [52, 53, 73, 74]. Technology in this field is designed to connect human with nature and act as catalysts for collaborative sustainable making. From our ethnographic study, we saw a post-anthropocentric perspective. For example, eco-home makers not only built home for their own needs, but also emphasized the biodiversity they have achieved through the process. The design of eco-homes was always respectful towards other species, which showed that the process of building eco-homes as a co-design process that involved non-humans. How may HCI take up similar methods to support sustainable home making? One way is to develop tools to make such insights from non-humans more visible, by providing information about local species and ecosystem, soil and compost condition, sun movement, wind patterns, among others. From this standpoint, technology can play a role of a facilitator where eco-home makers could better understand the place they live in and get feedbacks for their DIY activities. Through making invisible visible, computing tools can help makers empathize the importance of non-human beings and foster a reflexive, speculative conversation with them. Design works such as Ode to Soil [75] and Collaborative Survival [50] provide starting points for explorations.

Where we saw the life-cycle cost, resource scarcity, fluidity and malleability as considerations of materials selection in DIY homes, we may care more about the value of craftsmanship, and the long-term relationship between makers and materials. HCI researchers aimed to decentralize human makers and regard materials as design collaborators [76] and have proposed digital craftsmanship. In this sense, materials call their own forms, making means in response to the living and changing qualities of materials. Our work reveals opportunities that computing technologies might create a dialogue between heterogeneous materials, manual tools and makers by asking open questions and not necessarily providing solutions. Keeping eco-homes open to change, mature and new materials can be integrated, and new forms can emerge beyond makers' imaginations.

The build process of eco-homes is similar to the "minimum viable prototype" [77] , known in the software engineering field. They work on an assumption, build a prototype, and evaluate the idea. Keeping DIY practices at a smaller scale, not only provides flexibility for further optimization but also can be easily shared and adapted to by other

makers. One possible way to foster these practices is Distributed System [78], making alternative experiments and sustainable practices replicable and connected [79]. Although social media platforms such as Facebook, YouTube, and Live Streaming can disseminate novel eco-home practices and help novices learn essential skills, many makers reject these applications for privacy, information overload, and political reasons. Additionally, some eco-communities and eco-villages are far from cities and lack infrastructures to connect the Internet. Decentralized technologies and distributed infrastructure could connect small elements and help them build an independent and resilient system. For example, decentralized applications like Secure Scuttlebutt [80] could be implemented without commercial network infrastructure, and as the alternative platform to share eco-home practices and knowledge.

6 Conclusion

Based on an ethnographic study of rural eco-home makers, we showed how they apply a material-first approach, align their designs with nature and are influenced by sociality and everydayness of making. While we position our study alongside Desjardins et al.'s themes of sustainable placemaking [22] and other HCI studies on placemaking [21, 23, 27, 31] and DIY [1, 4, 9], this works has been able to deepens our understanding of placemaking and DIY in HCI. Moreover, it sheds lights on how eco-home makers work with nature and constantly reimagine and renovate their home to fit the environmental and their own needs. With this paper, we foresee that our work will open up new avenues for future design and research of computing tools to empower residents as place-makers, where they can creatively co-design homes with non-humans, and make their own smart environments sustainable and resilient.

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