"Can the rest of the world have flush toilets? No. Composting toilets? Yes!": Mediating the Human-Nature Relations by Composting Toilets

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Abstract

Flush toilets pose challenges such as resource waste, public health, and social justice. To achieve the Sustainable Development Goal of clean water and sanitation for all, it is essential to address the complex issues around toilets and design alternative systems that effectively manage human waste. Inspired by Actor-Network Theory (ANT), this paper presents findings from a design ethnography in eco-villages about composting toilets and sustainable living. We describe three archetypal composting toilet systems and examine how they operate as creative, community-driven infrastructures that mediate human–nature relationships. We reflect on how ANT provides a useful lens for HCI to understand the socio-technical dynamics of alternative sanitation systems. We analyse how composting toilets mediate human-nature relations three interconnected processes: tinkering, linking, and becoming. We discuss the implications of fostering DIY infrastructure practices as a form of transformational creativity in the pursuit of more sustainable futures.

CCS Concepts

• **Human-centered computing** → **Human computer interaction (HCI)**; **Empirical studies in HCI**.

Keywords

Composting Toilet, Sustainability, Eco-Village, DIY, Infrastructure, Actor-Network Theory

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1 Introduction

With the promise of sustainability, emerging research in design aims to explore creative practices that can foster collective imaginaries of sustainable futures and encourage actionable reflections in everyday life [17]. However, most projects still adopt a human-centred perspective, which can result in exploitative relations with materials and the natural environment. Hence, the need to explore ways to transform human-nature relations and engage people in regenerative actions that go beyond a human-centric approach [55]. This paper employs Actor-Network Theory [30] as a lens to examine composting toilets and sustainable living in eco-villages to uncover how creative practices can mediate the relationship between humans and non-humans in sustainable living.

Despite the flush toilet's status as a symbol of modern civilisation, it faces challenges such as the waste of fresh water and humanure, and approximately 2 billion people worldwide lack access to safe sanitation systems due to the high infrastructure costs of flush toilets [59]. Sustainable Development Goal 6 aims to ensure the "availability and sustainable management of water and sanitation for all" [51]. Flush toilets should not be the only option, especially in rural areas and locations with limited freshwater resources. Researchers and designers need to explore non-sewage alternative systems that can provide a hygienic and comfortable toileting experience, avoid excrement pollution, and utilise humanure locally.

In modern society, sanitation systems are usually invisible, disconnecting people from nature. The water supply and sewers in urban areas are often hidden underground, and individuals do not participate in the decision-making process regarding the water source and sewage treatment. This isolation can make people unaware of the impact of their behaviours on the environment. Making the invisible infrastructure visible and reconnecting people to nature is crucial to foster sustainable lifestyles towards a regenerative future.

The creative redesign of essential infrastructure like toilets represents a form of transformational creativity [7] that challenges dominant paradigms and reimagines human relationships with waste. Unlike incremental innovations that might make flush toilets more water-efficient, composting toilets fundamentally reconfigure the human waste cycle, transforming a linear process of waste and pollution into a circular system of resource regeneration. This transformation involves not just technical innovation but a cognitive reframing of human-nature relations, advocating for collaborative entanglements and mutual care, rather than competition or extraction.

Recent research has focused on decentralising humans in design by promoting alternative practices that ensure fairness and justice

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for both humans and non-human entities (e.g. [4, 13, 40]). Revisiting traditional human-centred approaches, these studies assert that design is exploitative in non-human species and resources [55]. Advocates for these perspectives seek to implement practices that prioritise equity for all beings [18], proposing alternatives to hierarchical control models [33], innovation at societal margins [31], nomadic practices [54], and sustainable place-making strategies [47]. This posthumanism viewpoint aims to investigate the broader systemic interactions rather than merely focusing on interfaces, revealing the full complexity of these relationships [23]. The significance of this perspective lies in its ability to offer design approaches that are both objectively grounded and intricately detailed in specific contexts [54]. Actor-Network Theory posits that humans and non-humans are equally influential actors, co-constructing and co-evolving with one another. This theory is instrumental in analysing the intricate networks formed through the interactions between human and non-human participants, elucidating how technologies can be assigned roles to regulate, influence, or even substitute certain human behaviours [16]. ANT's value here lies in its ability to trace the heterogeneous associations - linking human practices, natural elements like microbes and soil, technical artefacts like toilets, and community values - that constitute sustainable sanitation, moving beyond purely social or technical explanations.

This paper presents findings from a design ethnography of composting toilets and sustainable living in eco-villages in remote Australia. This paper illustrates three types of composting toilets and describes how they mediate the relationships between humans and non-humans. By interacting with non-human actors such as human waste, microbes, soil, and plants, people redesign the impact of their behaviour on the environment and reconstruct the decision-making processes of community living. Composting toilets open new avenues for design research to explore how to reconnect humans with nature and transform everyday activities towards regenerative futures. We introduce the concepts of *Tinkering*, *Linking*, and *Becoming* to analyse how these DIY systems foster creative engagement and mediate human-nature relations. The paper reflects on the role of composting toilets in sustainable living and discusses how ANT can help understand their implications for fostering DIY infrastructure practices and transformational creativity.

2 Related Work

2.1 Sustainable HCI and Transformational Creativity

Sustainable HCI has consistently focused on sustainability in everyday life (e.g. [12, 36, 58]). Researchers have pointed out that people's daily choices and actions are crucial for sustainable practices [37, 46] and have emphasised the need to reflect on how we are influenced and shaped as environmental actors [14]. Håkansson and Phoebe [21] argue that sustainable living should be associated with a higher quality of life, and design can motivate family and community interaction and communication through the theme of "enough". Heitlinger et al. [24, 25], through their study of grassroots food-growing communities, have challenged the approach of designing solely for individual consumer choices, offering a possibility for achieving a sustainable future through collective action. They advocate for designing environmental conservation efforts by involving more people in food growing, waste recycling, and the sharing of knowledge and skills within the community [24]. Norton et al. [39] emphasise the importance of value elicitation in designing digital technology through their research in permaculture communities. Furthermore, this field encompasses various similar research and practices, such as computational agroecology [42], ecological thinking [6, 41], urban informatics [19, 20], home organisation [52], DIY practices [47, 49, 50, 53], and cohabitation with non-human beings [33, 34, 45] — that seek to reconfigure human-nature relations toward ecological attunement and long-term sustainability.

While exploratory creativity works within established conceptual spaces and combinational creativity merges familiar ideas, transformational creativity fundamentally changes the rules and constraints of a conceptual space [7]. Boden [7] posits transformational creativity as a process involving radical changes to a conceptual space, leading to ideas or artefacts that could not have been generated within the original space. As Light et al. [32] argue, sustainable futures demand not just new technologies, but new imaginary, values, and ways of being. In recent years, a trend in HCI has started to question the traditional human-centred notion (e.g. [4, 6, 10, 56]), drawing inspiration from posthumanism to broaden ethical and relational considerations in design.

Haraway, in her book *Staying with the Trouble* [22], further describes humans as "companion species," emphasising that humans coexist with billions of symbionts, especially within our bodies. She argues that the world we inhabit is a web of interconnected relationships, and as actors, we have a collective ethical obligation to influence this web [22]. Forlano [18] connects posthumanism with design, highlighting that non-human beings are also stakeholders in design. The focus is on how design can support the needs and values of non-human entities, from soil microbes to infrastructures, that have often been overlooked in anthropocentric frameworks. The posthumanist perspective stresses the interdependence between humans and all forms of life, advocating for collaborative entanglements and mutual care, rather than competition or extraction.

2.2 Actor-Network Theory

Actor-Network Theory (ANT) is a framework that argues that objects participate in building heterogeneous networks that bring together actants of all types and sizes, whether human or non-human [2]. This perspective suggests that society is a complex network composed of these heterogeneous entities. The core concepts in this framework include actant and heterogeneous network. An actant is whatever acts or shifts actions. Action itself is defined by a list of performances through trials, from which a set of competences with which the actant is endowed can be deduced [3]. An actor is an actant endowed with a character, often anthropomorphic [3]. A heterogeneous network brings together actants of all types and sizes, human and non-human, highlighting the interconnectedness facilitated by technical objects [3]. The principle within this view is the examination of the relationships and interactions between these actants, without pre-defining a distinction between the social and the technical [8]. The focus is on understanding the conditions and mechanisms under which the relations that define society and knowledge are susceptible to partial reconstruction through these

networks [30]. This approach challenges simple technological determinism and social constructivism by paying attention to what is brought together by the network and acknowledging the obduracy of objects [9]. In this way, ANT reveals the often-overlooked roles of the natural environment and objects, and other non-human elements in everyday sustainable practices.

Translation is a key process in ANT where actors interact with others to gradually integrate their own intentions and goals into the network, thereby aligning the interests of other actors with their own [29]. Callon pointed out that translation occurs through four stages [8]: *Problematisation*: The focal actor defines the problem and identifies other actors whose identities and interests align with its own, attempting to position itself as an indispensable role. *Interessement*: The focal actor attempts to engage other participants in the roles designated for them. *Enrolment*: The focal actor recruits various actors into the network. *Mobilisation*: The focal actor ensures that its network acts as a spokesperson for the other actors. These stages do not occur in a strict sequence but are interwoven. Each stage achieved by an actor or innovator represents progress in the ongoing negotiation process [8]. Sustainable HCI faces complex and dynamic social and environmental challenges, requiring the integration of the needs and interests of various actors. ANT provides a framework that includes diverse actors, both human and non-human, as well as technology and nature, in the understanding and design process. By analysing the complex relationships between actors in sustainable transitions from spatial and temporal dimensions (e.g. [1, 38, 57]), ANT helps us go beyond a singular focus on reducing environmental pollution, situating sustainable practices within the ever-changing activities of various actors over time. Compared to frameworks like Social Practice Theory [44], which emphasises routines and shared understandings, ANT offers a stronger lens for examining the specific roles of non-human actors and the dynamic processes of network formation and stabilisation, particularly useful for understanding the introduction and adoption of novel socio-technical systems like composting toilets.

3 Methodology

This paper is based on design ethnography, a qualitative approach to understand situated practices and the intricate relationships between people, technologies, and their environments [11]. The central concept of design ethnography is *work*, which refers to the practical effort, skill, and competence required to accomplish ordinary activities [11]. Design ethnography seeks to understand what the work of a setting consists of, the activities members do, and the assembly of ordinary activities [11]. The primary *work* studied in this paper is how eco-village members manage their sanitation through compositing toilets and integrate these DIY infrastructure practices with other aspects of their lives and the eco-village's functioning. Design ethnography is suited to studying socio-technical systems such as composting toilets, as it allows for close attention to material practices, cultural meanings, and the relational configurations that emerge between humans and non-humans. Rather than merely documenting functional use, design ethnography enables us to explore how users appropriate, adapt, and co-construct ecological technologies through ongoing practices of maintenance, negotiation, and care.

3.1 Research Setting and Participants

The empirical material presented here draws from a long-term research program on making, DIY practices, and sustainable living in remote Australia, which has been ongoing since 2020. While the broader research project involved 15 participants across multiple eco-village contexts in Australia, this paper draws specifically on data from four participants whose experiences offered the most insight into the socio-material dynamics of composting toilet design, use, and maintenance. These cases were selected through purposeful sampling for their conceptual richness, diversity of design approaches, and depth of interaction with the composting systems.

Our aim in this paper is not to provide an exhaustive account of all participant experiences, but rather to offer a thick description of key practices, meanings, and relational patterns that emerged through close engagement with a small number of cases. This approach is consistent with design ethnography and qualitative case-based inquiry, where depth, context, and interpretive insight are prioritised over breadth or statistical generalisation [11]. The remaining participant data have been analysed and presented in other publications within the same research program, each paper contributing to a different facet of sustainable design practices in eco-villages [47–49].

For this paper, we focus specifically on the ethnographic fieldwork conducted between 2020 and 2023 in remote Australian eco-villages. We present three archetypal types of composting toilets from two eco-villages. To protect participants' privacy, we used code to represent participants (e.g., P1, P2, P3, P4, representing key informants identified during fieldwork in Table. 1) and eco-villages (EV1-EV2).

Table 1: Key Informants

Participant Code	Gender	Age Group	Background
P1	M	50s	Co-founder of EV1, member of the local Greens Party
P2	M	30s	Co-founder of EV1, member of the local Greens Party
P3	M	70s	Former-chairman of the Body Corporate in EV2
P4	M	70s	Founder of EV2

Eco-Village 1. EV1 was established in 2019 on a 3.48-acre property under a not-for-profit land trust. During our first visit in 2020, four adults and two children resided there. EV1 seeks to showcase the benefits of a low-carbon, simple 'home-based economy' lifestyle, aiming to inspire broader cultural change. P1 and P2 are working to create a community where people's needs, such as connection, recognition, trust, and mutuality, are fulfilled. They aspire to empower everyone in the eco-village through active participation in making and self-governance. They view the eco-village as a journey towards simplicity and minimalism, emphasising the process over the destination, where participants can find spiritual contentment and satisfaction. They value individuals dedicated to

self-development, effective communication, and conflict resolution. They aim to foster a 'medium demand' community where residents are interconnected and involved in each other's lives. Currently, EV1 is in its start-up phase, experimenting with sustainable practices.

Eco-Village 2 EV2 was founded as an alternative community on 640 acres by P4 and his 15 friends in 1978. By 1983, the population fluctuated from around 100 to just 8, prompting the landlord to design a subdivision to allow for legal, long-term dwellings. With the assistance of four Permaculture designers, the community was legally established in 1986 following local council approval. The property includes 83 freehold residential lots and two commercial lots, which make up 20 percent of the land, while the remaining 80 percent is held in common for habitat, forestry, and sustainable agriculture. This community was awarded the World Habitat Award for its demonstration of low-impact, sustainable living. EV2 is managed by both a Body Corporate, responsible for property administration, and a Co-Operative, which functions as a public and social organisation. Today, EV2 is home to more than 200 residents.

3.2 Data Collection and Analysis

Fieldwork in this paper involved multiple extended stays in two eco-villages, where the first author participated in everyday life, including making activities, routine maintenance, and informal social interactions. This immersive, situated engagement aligns with the principles of design ethnography, which values close, embodied observation of people's interactions with technologies in context. By participating in daily practices, the researcher was able to gain insight into the tacit knowledge, values, and improvisational problem-solving that shape the use of composting toilets.

Data were collected through a combination of semi-structured interviews, photographs, and field notes. Interviews explored participants' motivations, building and maintenance practices, challenges and adaptations, as well as their broader reflections on sustainable living. Photographs and field notes served as tools to document spatial configurations, material interactions, and emergent social dynamics around the composting systems. This approach reflects the commitment of design ethnography to understanding not just what people say, but also what they do and how they inhabit complex socio-material settings [11].

After each field engagement, the first author systematically organized and annotated the data, identifying key fragments and recurring themes. These were discussed with the second author within one week of each visit, allowing for iterative interpretation and reflexive sense-making. This process enabled the development of analytical categories grounded in the material, while also allowing conceptual insights to emerge collaboratively over time.

3.3 Limitations and Positionality

We acknowledge that our focus on eco-villages means our participants were generally predisposed towards sustainability and alternative lifestyles, potentially influencing their perspectives on composting toilets. The findings are specific to these remote Australian contexts and may not directly translate to urban or different cultural settings without adaptation. As researchers interested in sustainable design, our own values may shape our interpretations, though we aimed for reflexivity throughout the analysis by grounding interpretations in specific ethnographic data and ANT's symmetrical approach.

4 Findings

4.1 Stewardship and More-Than-Human Care

A core motivation driving the adoption of composting toilets in both eco-villages was a commitment to environmental stewardship and a desire to live differently from mainstream consumer culture. This ethos shaped community governance structures and daily life.

The two founders of EV1, P1 and P2, are local Greens Party members and also the founders of Eco Villages Australia (EVA). EVA is a non-profit organization dedicated to providing a model to create communities for small groups of people. EV1 is their first eco-village, purchased and established in 2019 in remote Australia. They have developed a community model called 'Collective Stewardship' [15]:

> "All buildings (except for those on wheels), and the land is owned by non-profit which is based on a Community Land Trust. Those who can afford it, loan money to EVA, for the purchase of the land and any improvements and building. All residents rent the spaces they require. This income covers operational costs and paying back loans. If the land is ever sold, the money goes back to the non-profit company after all loans have been returned. This structure makes it impossible for individuals to benefit from the sale of land, which means that the land is essentially locked away in perpetuity for environmental care." (Eco Villages Australia)

In P1 and P2's simple living, they aim to reduce financial and ecological costs. When they purchased the property, the house had a flush toilet connected to the municipal sewage system. However, they decided not to use the flush toilet and instead DIY a composting toilet. Their goal is to achieve resource recycling. P1 and P2 mentioned that traditional flush toilet systems rely heavily on water resources and sewage treatment facilities. In contrast, composting toilets do not require any water and use natural decomposition processes to turn human waste into fertilizer, which is then returned to the soil. Initially, they conducted extensive research on composting toilets, from commercial bio-gas systems to various open-source composting toilets. Ultimately, they decided to start with the simplest option: bucket toilets. As P1 commented:

> "We have started asking the question: Can the rest of the world do this? Can the rest of the world have flush toilets? No. Composting toilets? Yes!"

This comm reflects a conscious problematisation [8] of conventional sanitation, reframing it as unsustainable and seeking alternatives aligned with their stewardship values. The choice of a simple DIY system also connects to their emphasis on participation and skill-sharing. Giving people space, time, and support, P2 thought the most exciting part of participating in making projects is sharing knowledge. P2 commented that lack of confidence and knowledge was a barrier for her to participate in making and fixing things. P2

had never picked up a hammer before, and now she can fix things on the roof and really get into it. Making is a journey for her to learn and gain confidence. They also suggest that working with others towards a shared vision is an essential need for humans. This highlights the creative and empowering aspects of DIY infrastructure within the community. They think, however, our current social systems take us further away from our needs rather than closer to our needs. Through designing and making things together, they attempted to manage power imbalances resulting from different skills, capabilities, and willingness. As P2 commented:

> "My ideal eco-village is rarely designed. I want to live in a place that is evolving in some way. You know, people sometimes ask us when will it be finished? Well, now and never is finished. That is the answer at every point. It's a resident led, consensus driven growth journey."

This quote underscores the value placed on emergent, participatory processes over fixed master plans. Similarly, P4 (the founder of EV2) strongly agrees with the Australian Aboriginal concept of the "past, present, and emerging" custodians of the country. He sees custodianship as an ongoing responsibility. Prior to 1977, EV2's land was used for excessive grazing, and the previous tenants burned part of the forest every year for grazing. After P4 took over the farm, there has never been a strategic burn again. In the earliest days of the community, P4 recalled that the care of the land was a priority, and a policy of no spraying with hormones and no use of artificial fertilisers was adopted. At the same time, early community members discovered that kangaroos, wallabies and other animals could not feel safe if dogs and cats were present in the community. Therefore, as part of their custodianship of the land, some members found other homes for their dogs, and these policies were adopted into the new structure of the community thereafter. As P4 commented:

> "The concept of custodianship resonates strongly with me. Since my teen years I have rejected our cultural concept of ownership. I have not owned anything of significance, be it land, horses or other items that were important in my life. In my mind I had a custodianship of them that allowed my interaction with, access to them and a responsibility to care for their welfare."

Here, custodianship explicitly extends to non-human actors (land, animals), influencing community rules and shaping the actor-network. The decision to ban dogs and cats demonstrates how non-human interests were enrolled into the community's structure.

In the early 1980s, P4 realised that in order for people to settle and build long-term homes, they needed a legal entity. P4 found four Permaculture experts and a development group to redesign the community based on Permaculture principles, and received council's approval. P4 transferred the land to the newly established Trust, and the deposit for the residential lots was used for the construction of infrastructure such as roads, dams, and power supply. After discussions with newly moved community members, EV2 established two different legal entities, the Body Corporate and the Coop, each with different responsibilities; the Body Corporate committee represents the landowners, and the Coop provides services to the general community. But P4 recalled that with two legal entities, the community's decision-making process became difficult or even impossible. Many times, important issues are discussed for long periods of time without reaching a decision. For years, the Coop's expenses exceeded its income, and the Body Corporate needed to provide funds to keep the Coop afloat. This illustrates the challenges of mobilisation and maintaining alignment within a larger, more complex network involving diverse human actors and formal governance structures.

P4 mentioned that the purpose of most people moving to EV2 is that "people come here to rediscover their connection to each other and their connection to the land." "Connection to each other" is compassion and understanding for all humans, not just between members of the community. The "connection to the land" is not just a connection to the soil, but a connection to all the plants, reptiles, insects, birds and animals that live on the land. P4 emphasises that "land" is not just EV2's 640 acres, but our planet Earth. After more than 40 years of development, P4 pointed out that EV2 has become a model for self-sufficient eco-villages around the world. In the current era of consumerism, P4 emphasises that EV2's role is to bring the responsibility of protecting the land into mainstream society. EV2 needs to extend experiences and lessons learned beyond the boundaries of the land. As P4 commented:

> "I have a mantra I have used during the past two years. It is 'creativity, spontaneity, and freedom of spirit'. I repeated it often. Perhaps this is adding to the present energy of change. I am aware of many individuals and groups here in the community who are involved in unselfish and deeply empathetic projects. Projects to help others both within Australia and overseas. This applies to some residents who have projects in remote Indigenous communities, In Africa, in Cambodia and other Asian countries. The potential exists here to provide an example of a community that is a true self-sustaining eco-village... Increasing numbers of people will attend courses here and take the knowledge out into mainstream society. We will employ methods and techniques that reverse the present climate change, land degradation and species extinction trends… Food production on the land will increase and we will utilise modern technology such as blockchain and crypto-currency in creative ways. We will have self-drive electric vehicles for use around the land that will come to our dwellings when requested and take us to our destination."

P4's reflections highlight the ongoing evolution of the community's goals, linking local practices to broader global concerns and emphasising creativity and adaptation as key values.

4.2 Composting Toilets

Inspired by ANT, we clustered toilet-related non-human actors into four categories (Table. 2): toilets, natural environment, information, and space. Toilet actors include excrement collection, treatment, and distribution components. Natural environment actors refer to the ecological environment elements of the community, such as soil, flora, microorganisms, topography, etc. Information actors refer to

toilet-related guidance and signs, manure disposal and environment-related information etc. Space actors refer to the environment where the toilet is located, including bathrooms and outdoor landscapes, etc.

Table 2: Non-Human Actors Related to Composting Toilets

Category	Description
Toilet Actors	Excrement collection, treatment, and distribution components
Natural environment Actors	Ecological environment elements of the community, such as soil, flora, microorganisms, topography, etc
Information Actors	Toilet related guidance and signs, manure disposal and environment related information etc
Space Actors	The environment where the toilet is located, including bathrooms and outdoor landscapes, etc.

4.2.1 Bucket Toilets (EV1). EV1's composting toilet (Fig. 1) is located in a small separate cabin next to the communal living space. Community members started with a reclaimed solid wood television cabinet and transformed it into a composting toilet. This act of repurposing exemplifies a DIY, resourceful approach. The inside of the cabinet has two separate compartments, each holding a plastic bucket for collecting excrement. Two holes were made in the top of the cabinet, and lids were installed to cover them after each use to prevent odours. The middle drawers are used for storing toilet paper and other items. A bucket of sawdust is placed next to the seat, and after each use, a layer of sawdust is spread over the excrement to control odours and provide the necessary carbon source for the subsequent composting process. Here, the TV cabinet (now toilet actor), buckets, lids, and sawdust (material actors) are enrolled alongside human users into a functional system.

To ensure hygiene and proper function of the toilet, community members have developed detailed usage and maintenance guidelines for visitors. This represents an information actor designed to 'scrip' user behaviour. After each use, users need to cover the excrement with a layer of sawdust. Every morning, residents take turns to remove the buckets, empty the excrement into the composting area, and clean the buckets. This routine maintenance is crucial for the network's stability. The composting area uses a layered method, with the bottom layer consisting of straw to help absorb liquids and promote decomposition. The composting process takes about a few months, and the resulting compost is used for gardens and bushes. This connects the toilet system directly to the local ecosystem (soil, plants, microbes). Every Sunday, EV1 hosts Working Bees, inviting surrounding community residents to experience their lifestyle. Community members also travel to other communities to spread their philosophy and teach the use of composting toilets. This represents 'mobilisation' – extending the network and enrolling others.

P1 also highlighted the economic and infrastructural simplicity: bathrooms are the most expensive rooms because of internal plumbing and waterproofing. The infrastructure to make people have a comfortable shower at night costs a lot. Thus, they decided to build an outdoor shower. The perceived sacrifice they considered is that people cannot take showers when they want to. They need to do it when the sun is ready. Hence, they usually take showers in the middle of the day. Because of the beautiful outdoor scenery, they do not think it is a sacrifice. As P1 commented:

> "Are we prepared to go backwards? What comforts are we willing to give up"

This quote addresses the 'interessement' involved in adopting alternative infrastructures, challenging notions of comfort and progress.

4.2.2 Urine Division Toilets (EV2 - P3's Tiny Houses). P3 and his partner, both musicians in their 70s, have constructed two tiny houses and are now beginning to build a third in EV2. P3 chose to build the tiny houses because he felt that investing in property was more worthwhile than keeping money in the bank. He believes it would be beneficial to create living spaces, either for his own future use or for others. His partner intended to build two additional tiny houses for their two daughters. Through word of mouth, people learned about the eco-village, visited, and inquired about leasing the tiny houses. During the COVID-19 pandemic, interest in these accommodations increased significantly as more people sought out such living arrangements. P3 thinks that the pandemic prompted people to reassess their needs. However, P3 noted that some tenants found using the composting toilet challenging. As P3 commented:

> "I did a lot of research on toilets. For me, that works fine. Because I understand it. I helped build it. But people somehow they messed it up. It's too easy just to flush it. We have to deal with our own stuff. "

This highlights a breakdown in 'enrolment' when users (tenants) do not share the same understanding or commitment as the designer (P3). The toilet's 'script' was not successfully followed by all users, revealing the fragility of the network when key actors do not perform their expected roles.

The composting toilet used by P3 is from Toilets for People (TFP). This is a small-scale composting toilet with urine diversion (Fig. 2). When users use the toilet, solid excrement and urine are collected separately. Solid excrement falls into a rotating drum, while urine is diverted through a pipe to another container. TFP provides a DIY kit similar to IKEA-style flat packaging, including all the necessary parts and allowing users to construct the outer shell themselves. This kit acts as a 'translator', enrolling users in a specific assembly process. It features a rotating composting drum and a compost tray. For 2 adults, it needs to be emptied approximately every 2 months. The manure is collected in a covered container, accessible from the front, while urine is collected in a container at the back. P3's composting toilet is equipped with a ventilation fan and is powered by a small solar battery. These non-human actors – fan, battery, solar panel – are crucial for managing odour and moisture. Since over 90% of waste entering the toilet is water, the ventilation system evaporates the moisture into the atmosphere, ensuring odourless usage and decomposition of manure. Solid excrement mixes in the rotating drum with other organic material (such as coconut coir or

Figure 1: Bucket Toilet in EV1

sawdust) and after a period of time, is decomposed into soil-like compost.

This composting toilet was originally designed and built by P3 for personal use, not for rental purposes. However, after this tiny house was completed, some people came to EV2 hoping to rent it. P3 mentioned that during the rental, some people may find it challenging to adapt to using this type of toilet. For instance, this composting toilet is designed for sitting use. However, for those who prefer standing while urinating, the urine diversion area is relatively small, making it easy to make a mess in the toilet. This illustrates a mismatch between the toilet's inscribed 'script' and the diverse practices of potential users. Additionally, some tenants may not promptly mix organic matter and clean the compost. P3 emphasises that sustainable living requires more daily maintenance. P3 also pointed out that we also need to change our mindset; while flush toilets may be convenient, through daily maintenance and managing our own composting, we may discover a more meaningful experience. This again points to the 'interessement' required to stabilise the network around non-conventional practices.

During his tenure as chairman of the Body Corporate in EV2 for a year, P3 gained insights into the community dynamics. With over 200 residents, EV2 stands out for its residents' independence compared to those outside the community. The demographic tilt towards an ageing population has attracted people seeking tranquillity, less concerned about organisational aspects. His vision of an ideal eco-village revolves around fostering communal interactions. P3 envisions clusters within the community sharing communal spaces like a well-equipped kitchen and laundry facilities, encouraging residents to come together and collaborate. He believes that a successful eco-village should strive to diminish individualistic tendencies in favour of fostering cooperation and a sense of community among its members. P3's reflections touch upon the tension between individual autonomy and collective action needed to maintain shared infrastructure and community cohesion, a key challenge in mobilising larger networks.

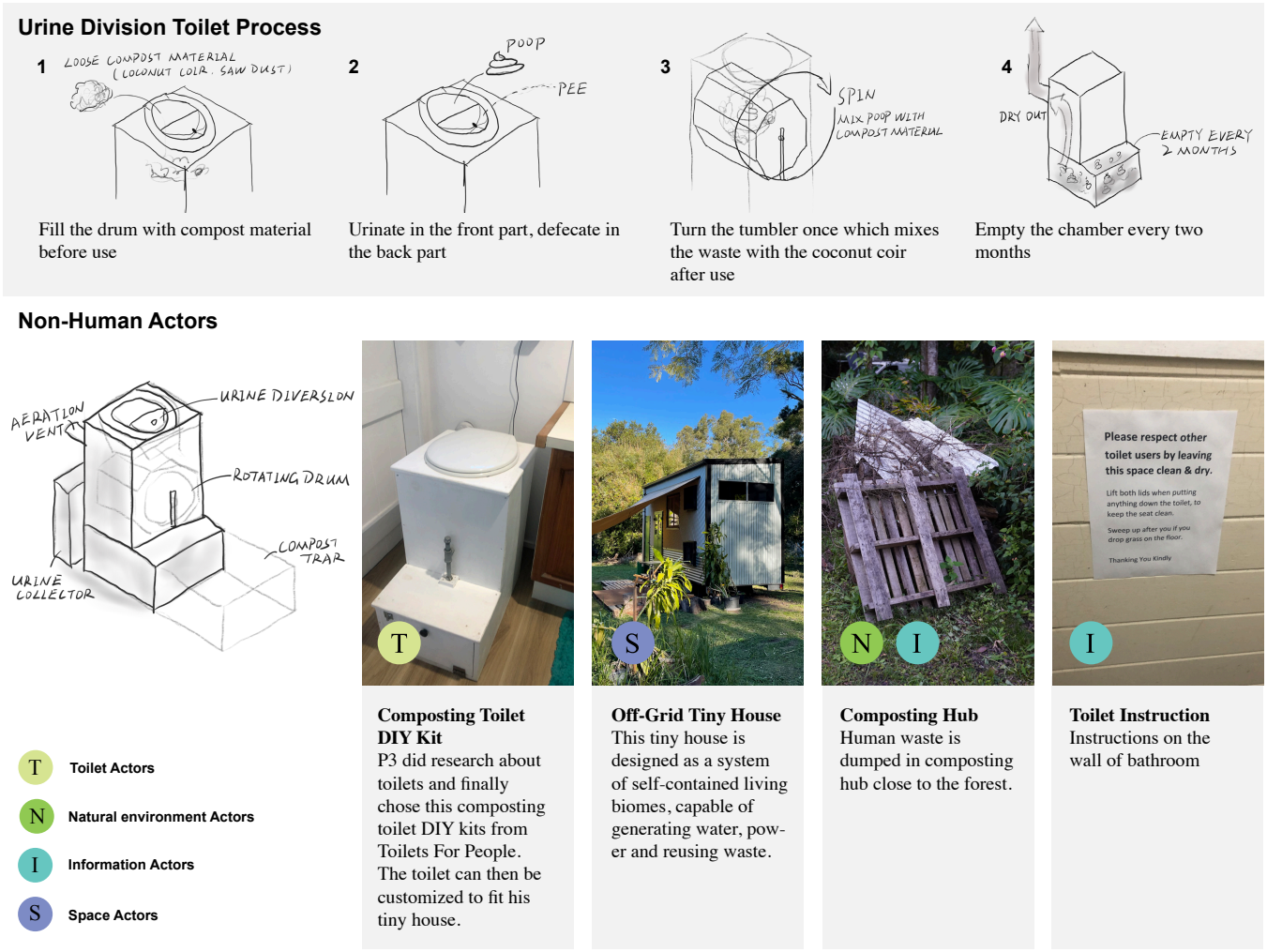

Figure 2: Urine Division Toilet in EV2

4.2.3 Desiccating Toilets (EV2 - Common Practice). The EV2 community is situated on 640 acres of land, which includes 15 various-sized dams. To protect these water resources and local ecosystems, the community strives to control any form of wastewater discharge. Since there is no municipal sewage system in the community, each household is required to manage its own wastewater. The dams' presence strongly 'interested' the community towards waterless solutions. Most residents opt for desiccating toilets (dry composting toilets), a practice that has been in place for over 30 years. This represents a long-term, stabilised network. Residents of EV2 were provided with instructions on how to design and construct sanitation systems in the owner's manual. This manual acts as a key 'translator' standardising practice. Additionally, due to abundant timber resources and the hot, humid climate, most houses are built with the elevated structure. This design not only minimises land disturbance but also provides space underneath the house for composting toilets.

Desiccating toilets (Fig. 3) typically require a certain amount of space for storing and processing waste, and the space under the elevated structure perfectly meets this need. The area beneath the elevated structure can be used for the installation and maintenance of composting toilets, avoiding the need for excavation of land. The space under the elevated structure helps with the ventilation of the composting toilet, reducing odours and promoting decomposition. Maintenance and cleaning of the composting toilet are more convenient under the elevated structure, allowing residents to easily inspect and clean the compost. Sun, chimney height, and airflow are critical non-human actors in this design.

5 Discussion

Our ethnographic exploration of composting toilets in eco-villages, viewed through the lens of Actor-Network Theory, reveals how these seemingly simple artefacts become focal points for negotiating human-nature relationships, fostering community creativity, and challenging conventional infrastructure paradigms. We first

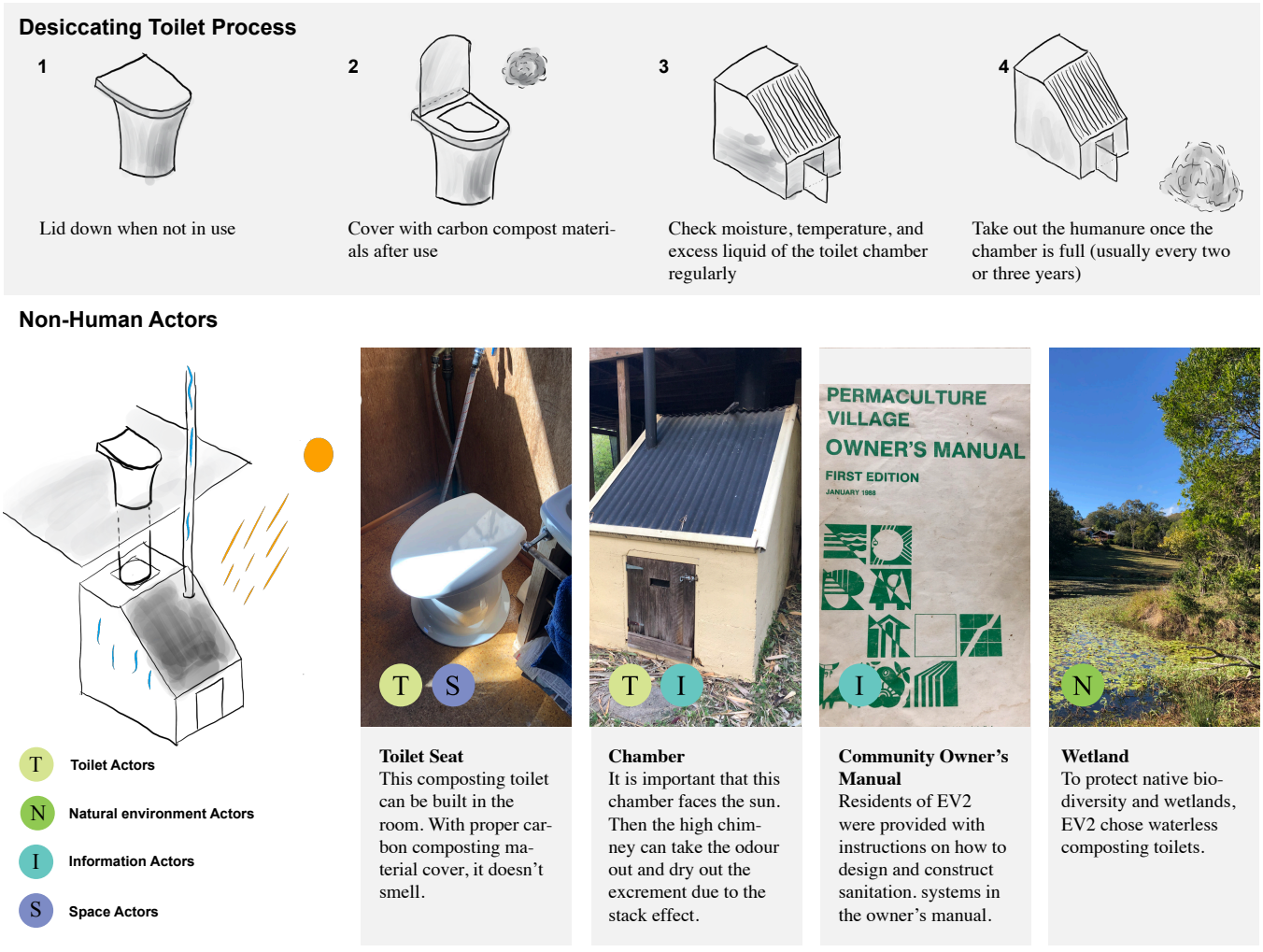

Figure 3: Desiccating Toilet in EV2

discuss how ANT helps map the complex networks involved, then introduce a framework of Tinkering, Linking, and Becoming to analyse the mediative and creative roles of these DIY systems, and finally reflect on the implications for creativity support and Sustainable HCI.

5.1 ANT on Composting Toilets

In the actor-network of the eco-village, there are both human actors, such as long-term residents and short-term visitors, and non-human actors, such as space, infrastructure, information, and the natural environment. The problems of each actor converge at the obligatory passage point before translation occurs [8]. From the residents' perspective, their problem is how to change their lifestyle to reduce the impact on their living land (problematisation stage, driven by stewardship values). From the perspective of the natural environment (represented by actors like soil, water, local ecosystems), the problem is how to integrate human activities into the ecological cycle. Both of these problems can be focused on toilets and waste management, which is the obligatory passage point. Determining the obligatory passage point can help all types of actors reach a consensus, work together to solve problems, remove obstacles, and promote the formation of the eco-village actor-network.

Participants believe that the composting toilet is the key to transforming their lifestyle. Therefore, we use the composting toilet as a clue for the translation process of the actor-network. The translation process usually includes four basic stages: problematisation, interessement, enrolment, and mobilisation. In the problematisation stage, the focal actor, the composting toilet, needs to discover the common goal of residents and the natural environment, which is to make human a contribution to the natural environment. Therefore, the composting toilet needs to endow interests to both humans and the environment: for residents, the toilet needs to provide a comfortable and hygienic defecation environment, reducing odour and health hazards caused by composting; for the natural environment, the toilet needs to reduce the pollution of untreated faeces. After interessement (e.g. showing nutrient benefits to gardens), the actors

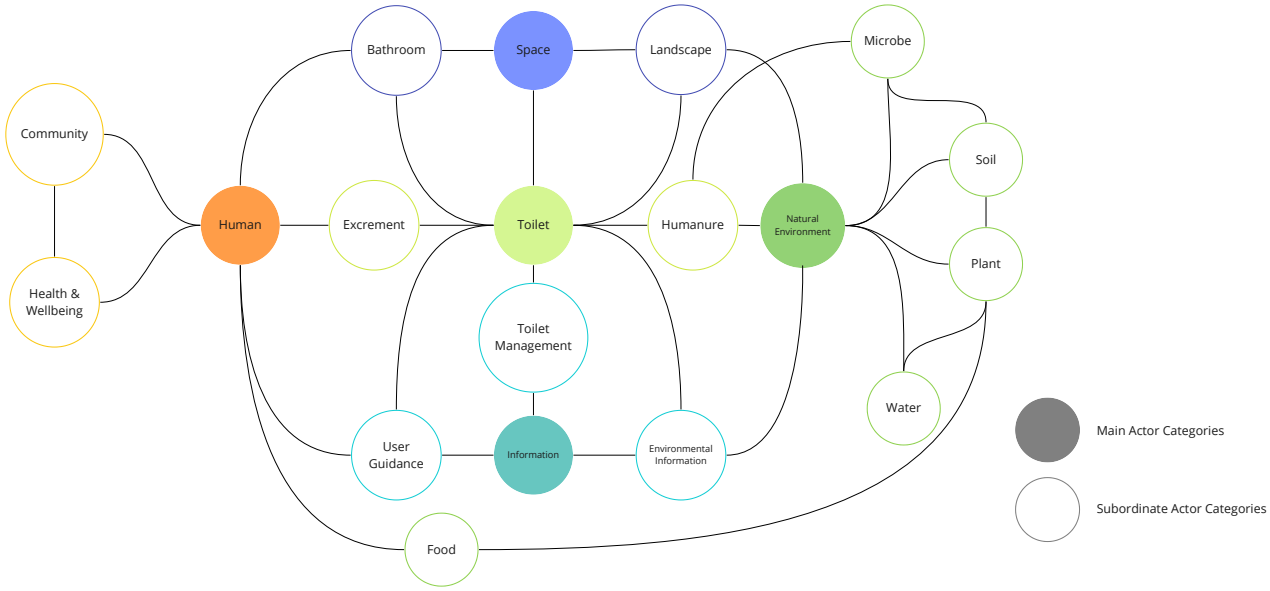

Figure 4: Eco-village's Actor-Network from Toilet's Perspective

are mobilised to take action. In the enrolment stage, human actors need to consider the cost and maintenance of making composting toilets, which is usually discussed by residents through participatory design (as seen in EV1) or adoption of established community standards (as in EV2). The discussion focuses on the defecation space experience and facility maintenance, so space becomes an actor that joins the network at this stage (e.g., the cabin in EV1, under-house space in EV2). In the mobilisation stage, temporary visitors or new residents need to be considered. As using composting toilets is a different experience from flush toilets for ordinary people, information becomes an actor that joins the network at this stage (e.g., guidelines, manuals, induction), providing guidance on the correct use of composting toilets and attempting to align their behaviour with the network's requirements (as highlighted by P3's challenges with tenants).

Inspired by ANT, we clustered non-human actors into four categories: toilets, natural environment, information, and space. Toilets transform from actors to mediators, connecting human actors with the natural environment, information, and space as a network. Space actors can be divided into indoor and outdoor: indoor space can provide users with a safe and private toilet environment; outdoor space can be used as a landscape to enhance the toilet experience. Information actors can be divided into three categories: toilet management, user guidance, and environmental information. Toilet management actors need to monitor the toilet chamber's remaining capacity and the compost pile's maturity. User guidance actors need to respond to users' needs and proficiency. Environmental information actors need to collect and analyse data on terrain, weather, vegetation, etc., to provide references for compost site selection and fertiliser distribution. Natural environment actors can be broadly divided into four categories: microorganisms, soil, plants, and water. Microorganism actors participate in the compost fermentation process and return to the soil during the fertilisation process to improve soil quality. Soil and water provide conditions for plant growth, and the food that grows can be eaten and fed back into this network through the digestive systems of humans and animals. ANT helps visualise this complex web of dependencies and translations that sustain the composting toilet system.

5.2 Mediating the Human-Nature Relations by Composting Toilets

In this section, we analyse how composting toilets mediate human-nature relations three interconnected processes: Tinkering, Linking, and Becoming. These processes work together to transform waste management from a hidden, specialised process into a visible, participatory activity that reconnects humans with ecological cycles. By embracing existing resources through tinkering, building relationships through linking, and designing for adaptability through becoming, eco-village residents create alternative infrastructure that not only manages waste but also reshapes their relationship with the natural world.

5.2.1 Tinkering: Engaging with Existing Resources and Systems. Composting toilet systems in the eco-villages often emerge through 'tinkering' – a creative process of adapting and repurposing existing materials and knowledge, akin to the concept of bricolage in Adhocism [28]. This contrasts with standardised, top-down infrastructure solutions. In EV1, the bucket toilet built from a reclaimed TV cabinet is a prime example. This approach starts by asking fundamental questions: What are the basic human needs (hygienic waste disposal, odour control)? What materials are readily available on-site or nearby (reclaimed furniture, sawdust)? How can we work with natural processes (microbial decomposition)? This tinkering makes the system's workings transparent; users understand the components (buckets, sawdust) and the process (covering waste, emptying buckets, composting). This transparency encourages participation, as seen with P2 gaining confidence through hands-on involvement. This practical, situated creativity [27] allows ordinary people to engage in the design and maintenance, fostering a sense of ownership and understanding often absent with black-boxed conventional systems. By starting with the simplest bucket toilet design rather than implementing more complex sewage systems, composting toilets allow users to test, learn, and iterate their designs based on contextual conditions.

The materials used in these composting toilets reveal how tinkering embraces locally available resources. For example, various covering materials are used in these composting toilets, such as sawdust, leaves, and coconut coir. Users choose covering materials that are easy to collect, and adjust the covering amount by observing the composting conditions. This aligns with Light et al.'s [31] concept of innovation at societal margins, where resource constraints foster creative solutions. By bringing the processes of waste decomposition into the realm of everyday attention through maintenance routines and composting systems, these toilets create regenerative visibility [35] — the ability to see and engage with ecological cycles that are typically hidden in modern infrastructure.

Tinkering also manifests in the way these systems are maintained and adjusted over time. Unlike flush toilets that immediately remove waste from sensory experience, composting toilets extend engagement with waste over time — from initial deposit through maintenance routines to eventual use as garden fertiliser. Composting toilets reconfigure temporal relationships with waste. Such recognition of waste not as inert substance but as active participant in ongoing ecological processes. It also aligns with Indigenous approaches to sustainable living highlighted by P4's reference to the Australian Aboriginal concept of custodianship, where humans are seen as working within rather than controlling natural systems. This commitment to tinkering with existing systems rather than wholesale replacement reflects a broader ethos articulated in research on posthuman design (e.g. [4, 6, 10, 56]), which advocates for working with rather than against natural processes.

5.2.2 Linking: Building Relationships Between Elements. Composting toilets link human activities with ecological cycles in ways that conventional plumbing cannot. The composting process itself creates biological linkages by fostering relationships between human waste, microorganisms, and plant growth. These linkages are not hidden but made visible and tangible through daily maintenance practices. As Haraway [22] suggests, humans are "companion species" that coexist within complex webs of relationship. Composting toilets transform the affective dimension of human-waste relations. Several participants described a profound shift in how they perceive excrement. The initial disgust or aversion to handling human waste gradually shifts toward appreciation of its role in ecological cycles.

This linking extends beyond the human-waste-soil connection. Composting toilets link residents through shared responsibilities (e.g. emptying buckets, maintaining compost piles in EV1), fostering communication and cooperation. They link individual households to community standards and knowledge networks (e.g., EV2's owner's manual). They link the tangible system (toilet, compost pile) to intangible values (stewardship, self-sufficiency, connection to land). Designing for linking means considering how resources, knowledge, and responsibilities can be shared to strengthen these networks.

Social linkages are also important in these systems. Regular public workshops and working bees are hosted in both eco-villages to create knowledge networks that extend beyond communities' boundaries. These gatherings help translate situated knowledge about composting toilets into accessible practices that can be adopted more widely. These linking practices reflect what Heitlinger et al. [24, 25] describe in their studies of grassroots food-growing communities, where waste recycling and knowledge sharing build community connections. Composting toilet systems extend this concept by making excrement, typically a taboo subject, into a provocative topic for broader community discussion and collaboration.

5.2.3 Becoming: Designing Systems that can be Dismantled and Reconfigured. For sustainability, becoming means moving away from designing for a finished product and towards designing for systems and assemblages that can be taken apart and reconfigured [43]. The physical designs themselves embody becoming through their modularity and reusability. For example, the composting toilets in our study demonstrate becoming through their adaptability, their emphasis on learning, and their capacity for disassembly and reconfiguration. The bucket toilet system can be easily disassembled, moved, and reconfigured. Even the more complex urine-division toilet comes as a kit that can be adapted to different housing contexts. This stands in stark contrast to conventional plumbing infrastructure, which typically requires professional installation and becomes a fixed, immovable element of buildings. P2's comment that her "ideal eco-village is rarely designed" and that it is "a resident-led, consensus-driven growth journey" also encapsulates the idea of becoming. The evolution of EV2 from its early days to its current established form, including the standardisation of desiccating toilets, shows a long-term becoming process. Rather than seeking a fixed endpoint, the concept of becoming values ongoing evolution and adaptation.

Becoming is also evident in how these systems accommodate learning. P3's observation that some tenants "messed up" the composting toilet because "it's too easy just to flush" highlights the learning curve involved in transitioning to alternative infrastructure. Rather than viewing this as a failure, the concept of becoming treats it as part of an ongoing process of adaptation and education. P4's vision for the future of EV2 illustrates how becoming extends beyond current practices to imagine new configurations: "We will

employ methods and techniques that reverse the present climate change, land degradation and species extinction trends... We will utilise modern technology such as block-chain and crypto-currency in creative ways." This forward-looking stance shows how eco-villages see themselves not as static exemplars but as laboratories for ongoing socio-technical evolution. The emphasis on becoming reflects on how humans are shaped as environmental actors [14]. Designing for becoming involves creating systems that are adaptable to changing needs, contexts, and knowledge. It encourages learning and experimentation as integral parts of the process – users learn about decomposition, soil health, and the impact of their actions. Ideally, these systems are also designed for disassembly and reconfiguration, allowing materials to be reused or recycled. By designing systems that can be reconfigured as understanding evolves, alternative practices such as composting toilets create an open-ended collective that embraces change, emergence, and the potential for unexpected interactions.

5.3 DIY Infrastructure: Creativity, Community, and Challenges

In modern life, infrastructure is often hidden under the interface and designed and built by the government and professionals, making it invisible to the user. In this study, we observe makers attempting to break the isolation between the infrastructure and the user interface. They rethink their needs and redesign the impact of their behaviour on the environment. Their designs typically begin with long-term observations of the surroundings and are iteratively fabricated and optimised, demonstrating situated creativity and problem-solving. Through interaction with the infrastructure, they continually accumulate knowledge of the local environment and achieve diversity in infrastructure forms. This aligns with calls in HCI community to support making [5] and recognise the value embedded in maintenance and repair [26].

DIY Infrastructure is a reflective activity. By getting hands-on with the waste they generate, individuals can understand how to be part of the ecological cycle rather than being blind to the impact of their activities. In using composting toilets, makers are not only processing human waste but also experimenting and validating different designs and technologies. This practice not only promotes environmental awareness but also encourages innovative solutions to environmental issues by individuals and communities. In this way, DIY infrastructure inspires people to think about future lifestyles and generations. Furthermore, the applications of DIY infrastructure are not limited to personal and small-scale projects. At the community level, collectives can participate in the decision-making process of infrastructure and reach consensus on alternative practices, which can enhance community cohesion and autonomy, although challenges in consensus-building and governance exist, as noted in EV2. In short, DIY practice proposes a new way of treating infrastructure, which emphasises bottom-up initiative and creative reorganisation of local resources rather than waiting for policy and top-down changes.

However, it is crucial to acknowledge the challenges and limitations associated with DIY infrastructure like composting toilets. It is important to note that the low-tech, creative designs of toilets based on eco-villages may not be directly transferable into modern urban settings due to space constraints, population density, regulatory hurdles (e.g., health codes regarding waste handling), and different cultural norms around sanitation and waste. Psychological barriers, often related to the 'yuck factor' associated with handling human excreta, can significantly hinder adoption. Power structures within communities can influence whose designs are adopted and how maintenance labour is distributed, potentially creating inequities. Economic disparities also play a role; while some DIY solutions are low-cost (like EV1's bucket toilet), more sophisticated systems or the time required for maintenance might be prohibitive for some. The success observed in the eco-villages in this study relies heavily on shared values, community commitment, and available land – factors often absent in other contexts. Furthermore, scaling these solutions requires navigating complex regulatory landscapes and potentially integrating with existing (or replacing parts of) centralised systems, posing significant political and logistical challenges.

5.4 Implications for Creativity Support and Sustainable HCI

The DIY infrastructure practices we observed embody transformational creativity [7] through their radical reconceptualisation of waste management. Unlike incremental improvements to conventional sewage sanitation systems, composting toilets fundamentally transform the conceptual framework surrounding human waste — from problem to resource, from linear to circular, from hidden to visible. This transformation requires cognitive shifts that challenge deeply held cultural assumptions about cleanliness, waste, and human relationships with bodily functions. Despite challenges mentioned above, the principles observed offer implications for design and research in sustainable HCI, particularly concerning how to foster creativity and more sustainable human-nature relations through infrastructure:

(1) Conceptual reframing from 'waste as pollution' to 'waste as nutrient' enables new design possibilities. Participants consistently described how composting toilets required them to "think differently" about waste. Such alternative concepts combine multiple value systems that are often seen as separate or contradictory in conventional design. Technical efficiency, ecological regeneration, aesthetic experience, and community building are integrated rather than traded off against each other. This hybridisation creates creative communities [32] — groups that collectively re-imagine and rebuild their material surroundings.
(2) Instead of designing infrastructure for people, explore infrastructure by people. Promote transparency in infrastructure systems, making their workings understandable and modifiable by end-users. For example, P1 and P2 keep the bucket toilet as simple as possible and try to use easy approaches to manage complexity. In this way, end-users can discuss and redesign the community infrastructure to meet their needs and ethos, fostering ongoing creative engagement. Nevertheless, building the system takes more time than purchasing ready-made solutions. Tinkering through retrofitting and reflection can lead to creativity and ingenuity.

(3) Design small, modular, and connected components that link waste to production in the local environment. Compared to modern flush toilets, all composting toilets presented in this paper are relatively small. The local environment, however, is more closely connected to them through composting. Excrement can be transformed into manure to nourish the local flora instead of being flushed away. With small components like composting toilets, food gardens, trees, and microbes connecting together, the network produces no waste within its intended cycle.
(4) Explore interaction possibilities that build relationships between humans and non-humans, fostering more-than-human care. The composting toilet facilitates engagements among diverse non-human stakeholders. The local flora and fauna are considered, even prioritised, when designing the community infrastructure (as seen in EV2's policies). The cohabitation and biodiversity achieved by composting also provide positive feedback to the residents, reinforcing their relations to the non-human world.
(5) Mobilise DIY infrastructure and ecological knowledge-sharing networks. Even though projects in this paper are highly contextual, responding to the local conditions, these toilets also show the flexibility to be adapted to other scenarios. DIY infrastructure not only serves as a possible solution for the sustainable living but can also be used as a sense-making method to co-create preferable futures and foster transformational creativity [7]. With emerging technologies, researchers should explore ways to mobilise traditional and local ecological knowledge and foster grassroots innovations while critically addressing the socio-political barriers to their wider adoption.

6 Conclusion

As sustainability issues grow, designers and researchers need to critically look at toilets. Instead of isolating human from nature and making excrement a burden on the environment, it is better to design toilets to connect human and nature, return manure to the soil, and improve the environment. This paper presents findings from a design ethnography in eco-villages about composting toilets and sustainable living. Through the lens of Actor-Network Theory, we illustrate three types of composting toilets and describe how these toilets can mediate the relationships between humans and non-humans from an object-centred perspective. Moving forward, there are opportunities to extend this work by designing novel toilets based on our composting toilet actor-network model.

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