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TOOLS
ENERGY TECHNOLOGIES & DIGITAL AWARENESS

Solar Biota
Co-Living with Solar Ecologies

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Abstract
Solar energy (technology) has often become synonymous with the solar photovoltaic (PV) panel within global decarbonisation efforts, leading to a disproportionate focus on the anthropogenic and techno-economic benefits of solar energy use within modern consumption patterns. However, solar PV could otherwise be understood as a technoecological phenomenon – broadly conceived as indeterminate associations of living and non-living ways of being. Through the lens of artistic research combined with the new materialist tradition, this article elaborates on a multispecies ethnographic study which was conducted over a five-month long period. The study is based on a multispecies (co)living with the SunSpider: a prototyped, small-scale, solar PV *thing*, installed in the outdoor context of an intimate domestic environment. The results of the study offer poetic insight into the entangled ecological, weather and climatic narratives that ensued in place, explained through a medium of multispecies storytelling. Importantly, the discussion relates to the notion of care, and how the SunSpider's form and function fostered an emotional attunement between the human and non-human study participants. The central question to this study is thus – *How might a relational adoption of solar PVs increase multispecies flourishing?* The article culminates in the explanation of 'solar ecologies', which offers a point of departure in exploring relational complexities in co(living) *with* solar PV – and solar energy symbolically, at large.

1. Introduction

Due to the nature of the study (its intimate proximity and epistemological standing), I adopt a first-person perspective and voice to the narration of this study. *Solar Biota* is a multispecies ethnographic research study carried out over five months within an intimate domestic context (i.e., the personal setting of my home). *Biota*, as part of the project's name, signifies a direct focus on the (co)constitutive ecology of flora, fauna and fungi that live and flourish *with*, and alongside, the SunSpider – a temporarily installed solar photovoltaic (PV) prototype – on the Thuja tree in the front lawn. The study seeks to understand and appreciate the tensions and alignments between *things* and naturecultures, while seeking to disintegrate the binary separation of the two – specifically in relation to solar PVs. The central question to this study is thus – *How might a relational adoption of solar PVs increase multispecies flourishing?* The resulting storytelling of the experiences from the study is based upon my human positionality, as I embrace my human ethico-onto-epistem-ology (Barad, 2008); the inseparability of my ethics, ontology and epistemology in scientific knowledge production. Thus, in the Method section, I clarify my journey from sensitising the body to the visceral sensorial confrontations with the SunSpider in order to aid in the understanding and storytelling of its co-constitutive surrounding solar ecology.

Concerning the SunSpider prototyping, its form solidified over a process of iterative tinkering, which is explained further in the section on Prototyping. After which, I continue to explain the installation of the SunSpider in the Thuja tree on the front lawn, and document its unfolding, entangled narrative with

weather and seasonality, and with its multispecies companions (such as the Great Tits and the Eurasian Magpie birds). These findings lead to reflections upon the theme of care, its accompanying tensions and politics, states of "*living*" in reference to technologies, and discussion on an emergent sense of responsibility *to care*. Finally, I elaborate on the term *solar ecologies* and conclude why studying its (un)formation processes is essential to providing richer meaning to the future of PV design and global decarbonisation efforts.

2. Being (More-Than-)Human: A Method in Itself

> The human body, with its various predilections, is, to be sure, our inheritance, our rootedness in an evolutionary history and a particular ancestry. Yet it is also our insertion in a world that exceeds our grasp in every direction, our means of contact with things and lives that are still unfolding, open and indeterminate, all around us. Indeed, from the perspective of my bodily senses, nothing appears as a completely determinate or finished object. Each thing, each entity that my body sees, presents some face or facet of itself to my gaze while withholding other aspects from view.
> (Abram, 1997, p. 49)

In *The Spell of the Sensuous*, David Abram (1997) discusses ecological philosophy emerging from the human senses' reflective, intimate, and sensitive use. Such intentional use of the senses resonates with the art of "noticing", as coined by posthumanist thinker Anna Tsing, who posits a method and mode for how society might descale our senses and our thinking to embrace the power of observation and natural history

to grasp better the fragility and contingency of human and nonhuman survival (Latour et al., 2018; Tsing, 2015).
The human body – with all our senses – remains certain as a starting point for more-than-human sensibilities and awareness, which is a necessary tool in multispecies discovery and storytelling. The boundaries between the human and nonhuman are, as Abram (1997) expounds above, "unfolding, open, and indeterminate", and in this particular occasion, the making and interactions with the SunSpider is part of this evolving process.

This study utilises such posthumanist thinking as a bedrock, upon which a multispecies ethnography is performed to gather data. Multispecies ethnography as a method, represents a more-than-human approach to sociocultural anthropology that asserts that we cannot adequately understand humanity in isolation from nonhuman species entangled in human life (Locke, 2018). It is concerned with the limitations of anthropocentric thinking, and recognises the agency of nonhuman species in how they are socially, historically, and ecologically intertwined with the environments moulded and shared by humans and other earthlings; what Kohn (2013) defines as "anthropology beyond the human." In other (simpler) words, "humans cannot survive by stomping on all the others" (Tsing, 2015, p. vii).

This multispecies ethnography study with the SunSpider is rooted in a four-year doctoral journey on understanding the relationality of solar energy. The dissertation explored embodied, sensorial and emotional perspectives on human-solar relationships (Törnroth, 2023). This more-than-human approach was drawn from the will to appreciate things and materials as more than

isolated, static items – rather, to be lived with and experienced. Diverse theoretical perspectives also recognises such vitality of materials (Bennett, 2010; Ingold, 2007) and also the significance of *things* in framing and participating in everyday experiences (Miller, 1987). Things, here, being referred to as active objects of engagement as opposed to passive objects of fascination (Ehn, 2008). These perspectives raise important epistemological and methodological questions on how the non-verbal, latent, and tacit properties of things (in relation to the social and biophysical worlds around them) may be experienced, captured, and studied (Woodward, 2016).

The multispecies ethnography of this SunSpider was, in practice, carried out daily over the span of approximately five months (December 2023 to April 2024). I practiced undisturbed observation from my kitchen window every morning ranging between the times of 8am to 10am, and approached the Thuja tree to perform direct sensorial confrontations – if weather and conditions permitted – around noon daily. In the night, I would often visit the tree once again between the times of 6pm to 10pm, to check if the SunSpiders' lights have lit up. When days with longer daylight approached (beckoning the Summer months), I had to increasingly delay my visitation until it was completely dark outside (i.e approximately 10pm). I would often photograph, film and audio record moments and situations I found particularly interesting, fascinating, or poignant in some way. For example, I filmed the SunSpider as it swayed, detached and broken, in the blistering winds of Storm Ingunn. I audio-recorded The Great Tits' song on numerous occasions and documented temperature readings from the local thermom-

eter. I wrote field notes to immediately document how I was feeling, the weather, what I saw, smelled, heard, touched, and the conditions of the tree, and other multispecies companions. In line with qualitative traditions, *thick* and *rich* descriptions within the study, was considered key (Merriam, 1988). For a detailed overview of the observations, refer to Table 1.

	December 2023	**January 2024**	**February 2024**	**March 2024**		**April 2024**
Morning observation	9 to 10am (Sunrise ranged between 9.09 to 9.55am)	8 to 9am (Sunrise ranged between 9.50 to 8.29am)	8 to 9am (Sunrise ranged between 8.25 to 6.45am)	8 to 9am (Sunrise ranged between 6.41 to 4.52am)		8 to 9am (Sunrise ranged between 5.45 to 3.54am)
Afternoon observation	11am to 12pm	12 to 1pm	12 to 1pm	12 to 1pm		12 to 1pm
Night observation	6 to 7pm (Sunset ranged between 1.30 to 1.04pm)* *Winter solstice occurred on 22nd December	7 to 8pm (Sunset ranged between 1.19 to 3.05pm)	7 to 8pm (Sunset ranged between 3.04 to 4.43pm)	7 to 8pm (Sunset ranged between 4.47 to 6.20pm)		9 to 10pm (Sunset ranged between 7.27 to 9.04pm)
Monthly temperature	High: 2 °C Low: -20 °C	High: 6 °C Low: -37 °C	High: 5 °C Low: -30 °C	High: 6 °C Low: -20 °C	**Daylight savings time shift**	High: 9 °C Low: -19 °C
Main data collected	Photographs of SunSpider's prototyping process, placement in the tree, and illumination in the darkness. Field notes: Reflections on the tinkering process and on the daily sensorial confrontations.	Attempts at capturing the Eurasian Magpies and the Great Tits on photograph, film, and audio recordings. Field notes: Reflections on the harsh winter conditions and how the snow and ice build-up affected the SunSpider's operation and inhibited opportunities for daily sensorial confrontations.	Filming the affects of Storm Ingunn on the Thuja tree and SunSpider. Field notes: Attempted restorations and maintenance of the SunSpider in place, after destruction from the storm.	Photograph, film, and audio recordings for early comparisons from when the SunSpider was initially placed. Field notes: Daily sensorial confrontations, particularly over the health of the Thuja tree due to low temperatures and heavy snow build-up.		Photograph, film, and audio recordings. Field notes: Daily sensorial confrontations and final reflections on the changes that occurred in the SunSpider and its situated ecology.

Table 1. Detailed overview of observations, weather conditions, and data collection.

Figure 1. SunSpider form and placement within the Thuja tree.

3. Prototyping the SunSpider

Humans have, over time, co-evolved with things – that we are "prosthetic creatures" so tied to technology, matter, and nonhuman beings that these are essential parts of our identity, culture, and behaviour (Wakkary, 2021; Wolfe, 2010). The making of the SunSpider was thus motivated by a combination of considerations (Fig. 1):

- to mimic a recognisable earthling by form to create a parallel to the state of "living";
- to design something discrete that could blend into the pre-existing and situated (solar) ecology;
- something accessible and tangible to the everyday human (myself);
- to show the basic functionalities of the solar panel (i.e., the LED lights that turn on and off);
- a form that provokes a question of how solar energy technologies might exist in our living environments.

To build the SunSpider, I followed iterative rounds of *tinkering* (Mol et al., 2010) with aluminum metal wires, LED lights, and basic electrical engineering within the solar panel device, which I had purchased as a ready-made solar module giving 2W. Tinkering is a practice of "attentive experimentation" (Mol et al., 2010, p. 13) that focuses on making things work on a day-to-day basis – to *do* while thinking so that materials might *talk back* to us (Schön, 1983) and that we might learn from them; iteratively stumbling forward. Persistent tinkering is a messy yet creative process, especially suited to "a world full of complex ambivalence and shifting tensions" (Mol et al., 2010, p. 14).

It is often utilised as a form of exploration and discovery within technoscience topics due to the necessary initial process of familiarisation, learning, adapting, and attuning to seemingly detached and strange technologies (Kirksey et al., 2014; Lindtner & Avle, 2017).

Tinkering was necessary for this process as well because I iteratively experimented on the form of the SunSpider – its function,

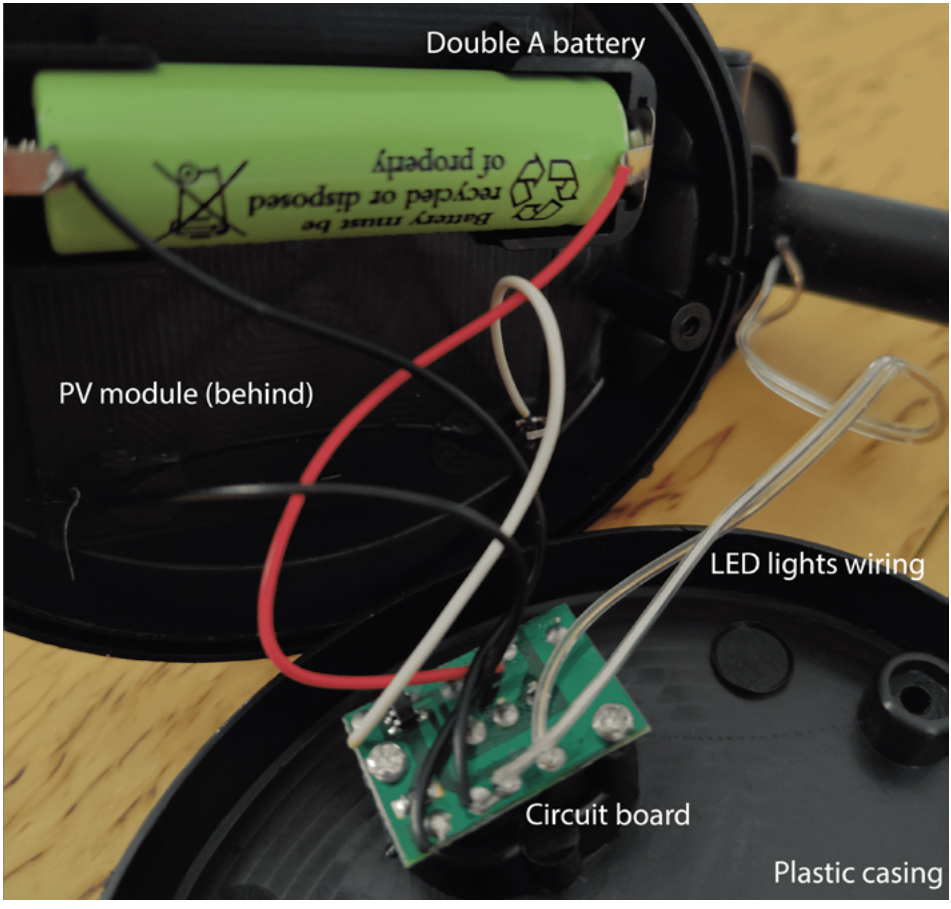

Figure 2. Detailed PV system set up within the computing body of the SunSpider.

however, was clear to me from the start; the underlying intention was to symbolise a state of "living" through the LED lights turning on after a day of solar access. After some time, I finally understood how to secure the solar module to the LED lights and aluminum metal legs. The solar module was connected to a double A battery, and the wiring for the LED lights was via a circuit board (Fig. 2). I then successfully tested the SunSpider's operation with artificial UV lamps I had at home. The process took two days to design and test before it could be installed outside in the Thuja tree. I then created a second SunSpider and installed both prototypes in the Thuja tree, close to one another, to increase the chances for a longer survival of either one. The SunSpider invited its name through its form, with a central computing body with eight malleable metal "legs".

4. (Co)Living with the SunSpider: A Storytelling of Experience

In this section, I describe, through storytelling, the results of the five-month-long experience. I attempt to build a vivid imagery of the process through thick descriptions, in order to situate the reader in place. I do not, however, attempt to speak for my multispecies companions, for fear of running the risk of being a ventriloquist – a consistent debate within multispecies storytelling (Kirksey et al., 2014). Therefore, I situate the multispecies storytelling from my own sensorial experiences borne from this ongoing relationship.

4.1. "Together We Are Weathering the World"

I lived with the SunSpider for over five months, between December 2023 to May 2024. The seasons changed, from the darkest night, the winter solstice, to when daylight becomes

longer at the spring equinox. Living in the subarctic, according to the Köppen Geiger climate classification system, meaning that the coldest month averages below 0°C or – 3°C and only a mere 1-3 months averaging above 10°C. The coldest recorded temperature where the SunSpider was installed was – 35°C, and that was in February 2024. Precipitation in the form of snow had the largest impact on the tilt and exposure of the SunSpider to solar access. On days with high snowfall, the SunSpider would often be covered with snow, so it does not receive any solar access, and therefore, its LED lights would not illuminate at night. The branch that the SunSpider's "legs" wrapped around would also tilt downwards due to the weight of the snow, and the SunSpider – already covered in snow – would receive negligible solar energy due to the position of its solar panel (Fig. 3).

In the colder winter months, I was forced to resort to window-watching for extended periods of time, where I would then film and capture moments through the transparent glass barrier, in the comfort of my own home. The relationship to the prototype here was purely visual, juxtaposing the background of warmth and light of my home to the biting cold and darkness outside. On the 20th of February, at –25°C and after a week of temperatures below –25°C, the LED lights on the SunSpider had not lit up for over a week. It was difficult to locate the prototype in the dark to watch it, and the prototype continued to remain hidden among the tree branches for another week until warmer temperatures and sunnier days arrived. In this period, I found myself watching the Thuja tree instead, where the SunSpider resided on.

Figure 3. Snow build-up on the Thuja tree affecting tilt of the SunSpider and access to sunlight.

How it swayed in the wind, how it captured snowflakes where their branchlets were densest, how its branches fractured under the weight of heavy snow, and how its morphology fluidly shifted between a cone-shape to the shape of a blossomed flower as snow collected, drifted away, or melted. Such visual appreciation of the SunSpider's living environment was important understanding the entangled existence in which the SunSpider, the Thuja tree, and my multispecies neighbours, live in.

Figure 4. SunSpider illuminating in the darkness.

When Storm Ingunn hit in January, the SunSpider was put to a different meteorological test: strong winds. One of the two prototypes of the SunSpider expectedly lived a much shorter life than the other; the winds had dismembered it. The attached solar PV panel fell to the ground while the LED "legs" continued to wrap themselves on the tree branch. I tried retrieving the broken panel but was blocked by a wall of snow and ice. When the warmer months approached, with some days providing temperatures above 0°C, the snow began to melt quickly. This allowed the solar panels to be exposed to sunlight again and began illuminating at night (Fig. 4). The snow wall between myself and the broken prototype began melting – yet not enough to access the broken panel. It was clear that the weather and climatic factors played an essential role in determining the electricity production for the LED lights to illuminate and how I could approach and interact with the prototype.

As warmer months followed, I could conduct my ethnographic activities up close, through sensorial confrontations. These sensorial confrontations included approaching the tree daily to smell it. It would often carry the identifiable smell of fresh, crisp winter air, hinted with musky undertones. I would also approach the tree to gently examine its branches and leaves, particularly looking at the health of the branches on which the SunSpider was wrapped on. Through this, I appreciated its hardened skin and robust bounce on which birds and the SunSpider would make their homes. Running my fingers on the bumpy branches, I noticed the leaves are arranged like a flattened fan, decorated with miniature cones, which, upon researching, are identifiable traits of the Thuja tree.

The season's warmth afforded me this privilege: to stand outside for extended periods, to *notice*, linger and appreciate. Akin to Neimanis and Walker's experience, "we are not masters of the climate, nor are we just spatially "in" it. As weather-bodies we are thick with climatic intra-actions; we are makers of climate-time. Together we are weathering the world," (2014, p. 558).

4.2. My Multispecies Neighbours

My multispecies neighbours, as I call them, were many. I focused my observations on three species of earthlings that emerged and were present most visibly throughout the five-month study. The *Great Tit (Parus major)* family takes residence in the Thuja tree in front of my house, on which the SunSpiders were installed. The Great Tit is a small passerine bird in the tit family Paridae, and they commonly do not migrate except in extremely harsh winters. I learned that they are mainly insectivorous in the summer but will consume a broader range of food types in winter. The *Thuja* tree, on which the Great Tit resides, is a genus of coniferous tree or shrub in the Cupressaceae (cypress family). Thuja species are used as food plants by the larvae of some Lepidoptera species, which includes the autumnal moth and the juniper pug – both of which exist in subarctic Sweden. Occasionally, the *Eurasian Magpie* or common magpie (Pica pica) visits the Thuja tree, asserting dominance by aggressively confronting the Great Tits that reside in it. The Eurasian Magpie is one of several birds in the crow family (corvids), and they are known to be intelligent – it is believed to be one of the most intelligent of all non-human animals (Prior et al., 2008). Magpies

are often sedentary and spend winters close to their nesting territories. However, those that live near the northern limit of their range, such as in Sweden, Finland, and Russia, might move south during harsh winters.

With a longer study period, I would have liked to *notice* a little deeper – additionally, the vast microbiome that makes up the Thuja tree. On the morning of the installation of the two SunSpider prototypes (December 20th 2023), the family of Great Tits (Parus major) that live in the Thuja tree on my front lawn exuded apprehension. They dispersed in their usual fashion, watching me from afar as I walked towards the Thuja tree and installed the SunSpider prototypes, carefully wrapping each branch with the SunSpiders' legs. They did not return to the tree for a few days after that, which was unusual for them. I had feared that my installation – no matter how seemingly inconspicuous – had caused a disruption and disturbance to their everyday lives. Finally, after five days of watching and waiting every morning, they returned to the tree. They were noticeably hesitant; they did not hop around as easily as they usually did and stayed far away from the affected branches. After 20 minutes, one brave Great Tit slowly approached a SunSpider, one small hop at a time. Upon nearing it, it paused and then pecked cautiously on the SunSpider's malleable metal legs. Soon after, the bird relaxed and continued its usual routine. This distinctive realization changed the course of the Great Tit's life for months to come – almost every day after that, the Great Tit sought something amongst the SunSpider's metal legs. I suspect that the SunSpider's legs had provided a feeding ground of larvae for the Great Tit to feast on, as the birds often spent

extended periods with their beaks down, rummaging between the legs of the SunSpider. Unexpectedly, the metal legs that consist of tiny cracks and crevices might serve as protective spaces against the harsh winters, thereby creating local micro-climates in which microbiomes (such as the Lepidoptera larvae) might flourish. Additionally, it appeared as if the SunSpider's legs provided a good grip for the Great Tit to cling to as it sat, watching, from the tree (Fig. 5).

Figure 5. A Great Tit perches on the SunSpider's legs.

Apart from spotting the territorial behaviour of the Eurasian Magpie family that often visits the Thuja tree during the first week of the SunSpiders' installation, I had not seen them for the following four months. I believe they have migrated south to avoid the harsh winter – temperatures in February 2024 dropped as low as -40,8°C in the Sápmi mountain regions, with average temperatures being the coldest since ten years ago (SMHI, 2024). However, in the final week of April 2024, I heard them singing as I stood in my kitchen. I looked outside, and alas, they had returned. The snow was melting, the temperature was an average of above 0°C that week, and the sun had come out. Their bird song was identifiable: a low but loud and harsh, repetitive chattering, not unlike someone viciously shaking a rattle. *Chak-chak-chak*, they go. Sometimes followed by a higher-pitched descending squealing sound. These were not necessarily pleasant sounds, but I greeted and welcomed the birds back anyway into our situated solar ecology. They, however, remained ever cautious of the SunSpider – never approaching it.

5. Discussion: Interventions of Care? Centralising Relationality in PV Design

The distinction between lively biological and intrinsic processes of the Thuja tree, the Great Tits, and the Eurasian Magpies was in stark contrast to the rigid, dual states of the SunSpider's "living." Its LED lights illuminated at night and showed successful solar energy absorption during the day – or the simple opposite, where its LED lights did not light up. These two states were synchronised to daylight and the night's darkness, drawing parallels to a biological circadian rhythm. "Living", for the Sun-

Spider, was purely functional – it did not fear predators, it did not feel hunger or thirst, and did not reproduce. Yet, it continued to survive, alongside complex earthlings, by the whim and instruction of the human – in this case, myself. There has been a sentimental dimension of needing to care for it – I needed to perform activities to ensure its "living". There was a clear emotional investment, not unlike the feeling one gets to protect and care over something valuable. For example, I brushed off snow from the solar panels on days of heavy snowfall to facilitate solar access and picked up pieces of the prototypes that fell on the ground and restored them (when possible). It was the continuous process of tending to the SunSpider that I noticed was in direct contrast to the naturally occurring, robust survival of the other multispecies companions. Human *care* and intervention seemed necessary to keep this technology alive. Technologies, in a broader sense, can get lost, break, and deteriorate – in the words of Mattern (2018), "[n]ow breakdown [of technologies] is our epistemic and experiential reality" (np.).

However, I reflected on the intrinsic yearning to care – was it my *responsibility* to care? At the very least, I recognise and acknowledge the traditions of care that normalises invisible labour – women's work, domestic and reproductive labor, and all acts of preservation and conservation, formal and informal (Mattern, 2018). Beyond that, romanticising maintenance and repair is also dangerous, because:

> Care is a selective mode of attention: it circumscribes and cherishes some things, lives, or phenomena as its objects. In the process, it excludes others. Practices of care are always shot through with

> asymmetrical power relations: who has the power to care? Who has the power to define what counts as care and how it should be administered? (Martin et al., 2015, p. 627)

But care, in this scenario, went both ways. It was a bidirectional sense of duty: the SunSpider absorbed solar energy and gave life to the LED lights, provided a feeding ground and a gripping surface for the Great Tits, and offered a sense of warmth and solace during cold and dark winter nights. Thus, to respond to the central question to this study – *How might a relational adoption of solar PVs increase multispecies flourishing?* – the SunSpider took lead from the Thuja tree: it did not impose itself. It was malleable and inconspicuous, weaved delicately across branches so as to not impede solar access to the Thuja's leaves. Its gentleness and fragility were perhaps a direct contrast to the rather large and rigid solar PVs often seen around human living environments, thereby presenting a more relational way of designing PV. It is also perhaps this gentleness and fragility that had invited the fostering of a sense of care – for myself to care over its sustainable use and life, and for the SunSpider to, in turn, care for its situated ecology by enabling ecological flourishing through its sensitive embeddedness. It belonged to an environment larger than itself. Scaling up, this could inspire larger solar PV systems to be adaptable, approachable, and sensitive to flourishing: designed with relational thought in the centre. For example, agrivoltaic systems – solar parks that combine agricultural food production with large-scale solar PV production, signal a step forward in this direction. However, much more creativity, innovation and sensitive thought is required in developing this trajectory.

The SunSpider is a humble prototype preaching an appreciation and awareness of the interconnectedness of a solar ecology, its design open for re-development in different forms and scales according to the situated ecological context.

6. Conclusion: The (Un)Formation of Solar Ecologies

Unformation is not a word but signals something evolving– the potential formation and unformation of solar ecologies. It signals something temporary and ordered, even within a messy and chaotic context (i.e., solar ecologies). The word reflects an inherent relationship: as easily as the prefix *un-* is tagged on to indicate dissolution, can the central term *"formation"* still exist in a seemingly dichotomous parallel. It is this indeterminate association of living and non-living ways of being (Lorenz-Meyer, 2017) that make up the solar ecology. Solar ecologies are thus:

- a celebration of the vitality of materials (SunSpider's malleable LED legs);
- an invitation for multispecies interaction (e.g. The Great Tit);
- a microclimatic sanctuary and habitat (e.g. The Great Tit feeding off a SunSpider's leg);
- a light in the dark;
- a facilitator of circadian rhythms;
- an active collaborator *with* weather and seasons;
- and a participant in the human politics of care (e.g., emotional relationship with the human in context).

Engaging with the SunSpider attentively and longitudinally revealed the meaningful nuances in which solar PVs might offer human and non-human living environments, such that they are

attuned to multispecies flourishing – as opposed to decontextualised and detached megastructures (i.e solar parks) (Wilhite & Wallenborn, 2013). An appreciation for solar ecologies is necessary for the latter to reorient production practices. A consequent question that logically follows is: *What powers might I – and society as a whole – as humans, have in influencing the narrative of solar ecologies in place?* It is the continued study of the (un)formation of situated solar ecologies, beyond this article, that will thus aid in the breaching of boundaries of current traditional PV design.

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IV

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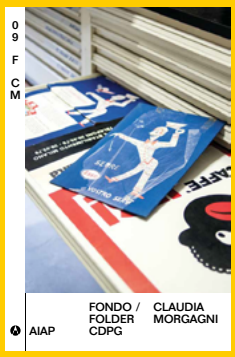

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