Windternet

Designing grid-liberated servers for regenerative energy communities

Eric Snodgrass
Department of Design
Linnaeus University
Växjö, Sweden
eric.snodgrass@lnu.se

Helen Pritchard
Institute of Experimental Design
and Media Cultures (IXDM)
Basel Academy of Art and Design
FHNW
Basel, Switzerland
helen.pritchard@fhnw.ch

Miranda Moss
mirandamoss.com
Växjö, Sweden
miranda.and.a.moss@gmail.com

Daniel Gustafsson
Department of Design
Linnaeus University
Växjö, Sweden
daniel.gustafsson@lnu.se

Jorge Luis Zapico
Computer Science and Media Technology
Linnaeus University
Växjö, Sweden
jorgeluis.zapico@lnu.se

ABSTRACT

Imaginations of server practices that depend on renewable energy, such as wind or solar, highlight alternative paradigms to the fossil fuel intensive, resource hungry computation of cloud regimes. More often than not, the materials used to maintain off-gridness, such as batteries and solar panels, depend on intensive resource extraction, land grabbing and damage to soil dependent ecosystems. This raises important questions of how both renewables and computing are dependent on extractive practices. In response, the Windternet project explores how regenerative commitments can act as resource "limits" capable of challenging and generating alternative approaches in computing otherwise, renewables and sustainable technological prototyping more generally. Following propositions of regenerative agriculture and related approaches that start from a point of not only sustaining but actively improving socioecological relations, we outline an account of the design practice of a grid-liberated, hybrid solar and wind powered regenerative energy community server. Transversing across different imaginaries of limits and abundance, we discuss how components in the designs of regenerative prototypes can be substituted, eliminated or repurposed. This includes growing compost-promoting wind turbine blades from mycelium, repurposing e-waste generators and developing a custom low-cost, open source hybrid charge controller for low power servers. In doing so, we explore what it can mean to center regenerative commitments when practicing with technological and computational tools for the resourcing of community infrastructures.

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1 Against energy and computational monocultures

In this paper we discuss Windternet, a recently initiated collaboration between two ongoing projects: Regenerative Energy Communities (https://regenerative-energy-communities.org) and Solar Internet (https://solarinternet.org/). Our collaboration focuses on building practices for small-scale and low-powered solar-wind microgeneration prototyping. To date, this has involved working with both off the shelf and regenerative materials (such as mushroom mycelium) for what we describe as the "speculatively functional" purpose of powering a cloud- and grid-liberated server for local experimental farming communities in Småland, Sweden. The project crosses art, design and computer science approaches

with those of farming and bottom-up DIY energy experimentation. The solar-wind prototype at the center of the research aims to propose alternative material possibilities for renewable energy prototyping and to highlight the potential of regenerative principles to challenge and reframe paradigms around what can constitute genuinely sustainable progress and innovation in fields such as renewable energy and computing – working towards practices that can be built on life and earth affirming infrastructures.

The work of the Regenerative Energy Communities (REC) project is situated around the Brände Udde ("burnt peninsula") farming site in Växjö, Sweden, a small-scale site of experimental communal farming that has over its six years of existence included farming collectives such as the Feminist Farmers, TheDirt and other local individuals and families. Working on this 6,000 square meter plot of land, these groups have over the last six years experimented with growing methods inspired by regenerative farming, permaculture and other forms of creative soil-based practices for sustainable and community-minded growing. In the care for practices of farming, food and community that we saw on this student-driven farm, we, as educators, artists, designers and technologists, were inspired to explore what kind of alternative energy infrastructure might be able speak to the regenerative practices and imaginaries that we saw on this space.

Doing so felt especially necessary in an age of Big tech & Big oil [1] critical mineral extraction, resource hungry server farms and the largely limited imaginaries of the current "energy crisis". In specifically bringing together the fields of energy and agriculture, the project aims to think through what are multiple and largely destructive overlaps within practices of energy and agriculture (including those of renewables), with their modes of extraction, capitalist expansion over land and ongoing depletion of ecological health [2, 3, 4, 5] (see also Smil [6] for a history of practices of agriculture read through a framework of energy). In response to this, a guiding question for REC's ongoing series of workshops and prototyping experiments has been *how can we make space for communities to feel that both food (farming) and energy (electricity + electronics) are not something that is done to us, but that we do?* A method of collective experimentation that pushes against energy (and computational) monocultures and towards the opening of spaces for a plurality of possible energy communities and prototypes.

The Solar Internet project has been exploring solar servers both in practice and as a design tool for discussing the predominant limitless growth paradigm in computing. During the project different off-grid solar servers and on-grid solar-aware servers have been created, and the constraints, possibilities and risks explored [7].

Environmental sociologist Ryan Alan Sporer highlights how the term "off-grid" has an important dual quality in its usage, namely the way in which it refers to "material components and social relations [...] It is an apolitical technical term for components. And it is a social term for everything in between violent anti-society extremists to teenager discursive hyperbole" [8]. We are weary of certain toxic and isolationist cultures that have developed around off-gridding [9] and propose a terminology of grid-liberated as an alternative way of speaking of elements of the Windternet prototype. At a practical level, there is the potential of being loosened from certain constraints or negative elements of electricity grids, with one able to engage with resources and communities that lie outside of any particular grid's affordances. But a shift in emphasis from off-grid to grid-liberated also aims to emphasize a sense of collective, from below modes of communal infrastructuring, resourcing, knowledge sharing and making. As Stephanie Wakefield points out, disaster response communities can be instructive for "their interrogation of infrastructure", an interrogation that might include questions that "get at the heart of any transformation in ways of living" [67]. Things are always in relation, but rethinking the collective potentials of material components and their social relations can be instructive for the kinds of liberation-oriented potentials in practices focused on supporting sustainable and empowering forms of collective sufficiency, diversity and regeneration – as can be found in examples such as agroecology (discussed further below), Right to Repair movements [68, 69] and further afield.

Our research projects aim to address what can be understood as a crisis of infrastructure and imagination in current approaches to energy provision through designerly and creative computational approaches to community engagement with technological alternatives that stand in contrast to mainstream research and development methods and attitudes towards technological innovation [10, 11, 12, 13, 14, 15]. However, although both projects work very specifically with addressing infrastructural practices and planetary limits, there is a creative friction in our approaches. Whereas the Solar Internet project focuses generatively on "constraints" and computer science methods, REC is informed by approaches to agroecology and sustainability attuned to modes of care, growth and abundance, queer theory and trans*feminist practices (cf. [16, 14, 17]). Windternet is an attempt to bring these two ways together, and to work with some elastic solidarities [18, 19] towards our respective approaches and as a different way for both projects to think across disciplines and practices.

1.1 Regenerative approaches

We see the approaches of alternative sustainable farming practices as being a strong and challenging starting point for exploring potentially more progressive, or at least very different, approaches to community engagement with technological alternatives. In Windternet we commit to regenerative approaches, not as a set of principles to be distilled and applied, but as a way to address the political ecologies of "limits" in computing, renewables and regenerative energy – including what it means, who is posing the question and who gets to respond [14].

Regenerative approaches and agroecology have attracted some attention in recent years within the context of technology practices and designing infrastructures. As political agroecologist Maywa Montenegro de Wit [14] writes, feminist agroecology, regenerative approaches and indigenous foodways provide groundings to more-than human approaches. They also provide ways to counter some of the people-free discourse in plant and soil science, rejecting the

separations of human and non-human living worlds. As part of a decolonial, queer and feminist approach to knowledge practices, regenerative approaches can also foreground the importance of plurality, diversity, interdependence, care, nonviolence and love. A focus on regenerative approaches and indigenous food pathways might furthermore provide ways to not "merely hijack existing computational forms; but to transform them at every level", as Ron Eglash et al. [20] articulate in their work on plant alliances and decolonial computing (see also Ali [21]). And as Michelle Westerlaken, Jennifer Gabrys and Danielo Urzedo [22] discuss in their work, practices of "digital gardening" might inform an approach to design digital technology towards epistemological justice in forest and agroecological environments. Such approaches are also explored in discussions on food production and the necessity of critically engaging with the "digitalization" of various forms of farming [73, 74, 75, 76]. Extending across these and related approaches is an attempt to cultivate a relationship with and practice of technology that "acknowledges and respects diverse contexts and improves power dynamics by centering the agency and biocultural knowledge of diverse farmers and communities" [74].

At another end of the spectrum of discussions on regeneration, design consultant and educator Daniel Wahl, author of the book *Designing Regenerative Cultures* [23], speaks of designing regenerative approaches that work "to pay more attention to systemic relationships and interactions", with an overarching view "to support the resilience and health of the whole system, to foster diversity and redundancies at multiple scales, and to facilitate positive emergence through paying attention to the quality of connections and information flows in the system" [24]. Wahl draws inspiration from design process facilitator Bill Reed, who wrote the well-known piece "Shifting from 'sustainability' to regeneration", in which he describes how shifting from sustainability to regeneration "moves our frame of discourse from 'doing things TO nature' to one of participation as partners WITH and AS nature" [25]. The article includes the oft-cited "Trajectory of Environmentally Responsible Design" diagram, with its six levels of environmental responsibility that progress from "Conventional Practice" at the bottom up (positioned here as a "degenerating system") to "Regenerative" at the top. Such broad and generalised systems-thinking style takes on regeneration (which Reed characterises as "whole systems and living systems thinking") are typical of many approaches invoking the regenerative as a concept for rethinking approaches to sustainability.

Regeneration as a framework for computing has previously been proposed in a LIMITS context in a 2018 paper by Mann, Bates, Forsyth and Osborne titled "Regenerative Computing: De-limiting hope" [26]. Beyond its primary focus on outlining the need for "a 'positive' approach to limits", the paper includes a list of recommendations for moving towards a regenerative approach to limits within computing. These include "developing narratives and stories of technology and computing that are more closely intertwined with nature", moving "beyond efficiency as the primary lever available to computing", and integrating inclusive, mutual and reciprocal "ecological worldviews into computing's narratives and processes" [26].

1.2 Permaculture approaches

Another notable example from our perspective of attempting to rethink and experiment with alternative modes of sustainable technological prototyping in relation to sustainable modes of farming is that of "permacomputing", an active community whose contributions have featured as papers and ongoing discussions within recent LIMITS gatherings and other forums (https://permacomputing.net). A blend of the words permaculture and computing, permacomputing "asks the question whether we can rethink computing in the same way as permaculture rethinks agriculture" [27]. The term was initially proposed by programmer and demoscene coder-artist Ville-Matias Heikkilä (Viznut) in a 2020 post [28] on the term and later 2021 update [29], though several earlier examples, such as software engineer Kent Beck's proposal of "Programming as a garden: Permaprogramming", are also cited as predecessors to the concept [1]. In these posts, permaculture principles and values are treated as helpful paradigms for reframing ongoing issues for sustainable ICT, with Heikkilä highlighting several useful potential problems areas within ICT that might be addressed by a permacomputing approach [28].

Permacomputing as "a potential field of convergence between technology, cultural work, environmental research, and activism" [31] has since been taken up by several wanting to explore it as a framework for more sustainable modes of computing. In their LIMITS 2023 paper "Permacomputing Aesthetics: Potential and Limits of Constraints in Computational Art, Design and Culture", Aymeric Mansoux, Brendan Howell, Dušan Barok and Heikkilä call for approaches that can help to "facilitate a transition from a system in which practitioners use the latest digital tools and media regardless of the environmental consequences, to a more strategic system in which digital tools and media of all generations, are carefully combined, crafted and used to form a less extractive practice" [31]. In this iteration, permacomputing is particularly focused on questions of reuse and repurposing, while also (as with approaches in permaculture) working to craft "continuously evolving design principles" that can "guide that very reuse and repurposing, but also to inform the development of new software and hardware when reuse and repurposing are not possible or relevant" [31]. The article also highlights an important distinction for thinking about limits (whether speaking of permacomputing or regenerative prototyping), namely that of how "our design constraints will exist in the grey area between these two categories, self-imposed and externally imposed" [31].

One noticeable element of permacomputing from the perspective of REC's focus on working with propositions of

[1] See Beck's [30] archived 2009 post on "The Permaculture design principle of Succession" for a sense of how Beck was thinking of permaculture as a model for software design.

regenerative agriculture is that, with a few exceptions, those involved in these discussions have not engaged as much as might be done with more the concrete, ground-level practices of farming and growing that guide permaculture, focusing instead on how the more systems-level design principles of the practice might inform practices of computing. Systems-oriented approaches can of course be very valuable for working towards enduring sustainable models of practice, however in REC we have found it useful to engage with histories and practices of regenerative agriculture and agroecology, not just as metaphor, but as a concrete way of rooting practice. In our case, by focusing on modes of prototyping aimed at supporting practices centered around soil and ecosystem health. We work with the regenerative commitment that all our approaches in infrastructure should not only take up regenerative computing as a (generative) metaphor but also should nurture soil and ecosystem health. Doing so can unearth unexpected and alternative ways of approaching a technological practice.

1.3 Crossings for rupture and repair

Given the ongoing spread in awareness and uptake of alternative growing practices such as permaculture and regenerative agriculture, one might expect such crossings of knowledges to filter further into discussions and software production. Take the following example of a comment by software developer Paul d'Aoust on a blog post by Dan Palmer [32] titled "On the Relation between Designing and Implementing in Permaculture", in which d'Aoust states "I'm a software developer by day (permaculture designer wannabe on the weekends)" and goes on to think aloud on how software development methodologies of agile development might draw inspiration from longer term planning perspectives of permaculture. Or how Marloes de Valk, in their conversation with Heikkilä on permacomputing [27], stops to reflect on practices of sustained observation in permaculture:

> The hard part, it seems, is understanding that in terms of sustainability, most of it comes down to not doing, not buying, not adding, yet the initial response is often an impulse purchase of a solar panel and a Raspberry Pi... In certain cases a valid investment, but not always, and careful observation of a problem might lead to different conclusions and solutions. This made me think of a section in a book on permaculture that explained how the first year with a new piece of land you do nothing but observing. Only after having seen the land and all its inhabitants in the process of all seasons can you know what could be done with minimal waste of energy for all species involved, human and nonhuman.[2]

And so on. Fermenting crossings seeping through, possibly to take root within approaches to computing.

In proposing to explore practices from regenerative agriculture in relation to technology, we acknowledge that this is no easy task, and it is not surprising that the potential connections in crossing practices of technology with those of alternative modes of farming have not been explored as much as they might be. As Jorge, who is himself a practicing permaculture farmer, pointed out when discussing our collaboration and REC's focus on regeneration, if one looks at where the concept of regeneration and the regenerative comes from in agriculture, one is working with regenerative natural systems to begin with, systems whose ecological qualities are intrinsically regenerative. In this sense, applying a regenerative approach to farming is essentially working to let such inherently regenerative processes flourish. This is of course very much not the case for technology, and technological "ecosystems" currently don't have anything like this quality, which presents a deep tension and challenge to anyone wanting work with technology. One can attempt to experiment with properties of mycelium or other biodegradable materials and possibilities in fields such as organic and bio-electronics that may progress towards such a goal, but we are not there yet.

Questions surrounding the materiality of technology and renewables are especially present for projects in Sweden, where energy transitions in the Nordic regions have long-standing histories and ongoing practices of what indigenous Sámi parliament president Aili Keskitalo and many others term as "green colonialism" [33]. A form of colonialism that in Swedish and other contexts includes the dispossession of indigenous territories and ways of living with the land in the name of ecomodernist energy transitions through energy intensive forms of mining, corporate extractivism and ecocidal poisoning of land [34, 35, 36].

Deep-rooted rifts of ecological and social damage such as these require urgent work in supporting what de Wit describes as "pathways for further rupture and repair" [37]. Regenerative practices in farming begin from a core set of explicit and intentful closures, specifically the closure of damaging practices of tillage, pesticide and fertilizer use. Any regenerative practice, including a regenerative energy practice, will similarly necessitate identifying intentful practices and commitments to closure, such as the closures of colonial and extractivist practices as they continue to gather steam in the present energy moment, where the "urgency" of a "green energy transition" is prioritised over thorough environmental and cultural impact assessments. Sweden and Europe have been working to rush forward new laws (such as the Critical Raw Materials Act) that pave the way for even more intense and expansionist forms of mining and extraction [38], as well land appropriation for the installation of monumental renewable energy and associated infrastructures on an ecosystem-shifting and culture-inhibiting scale [36]. From the beginning, REC have centred the need to counteract such momentums, even at a micro and local scale, and our focus on experimental uses of alternative regenerative materials is grounded with these struggles of materials, imagination and ecology in mind.

[2] In the same interview de Valk also highlights the importance for permacomputing approaches to think through alliances with other computing otherwise practices, such as Trans*feminist computing [63] and the Feminist Server Manifesto [62].

2 Windternet

In putting forward an unstable microgeneration energy source that will inevitably be limited in the amounts of energy that can be consumed on it, Windternet, as an experiment in applying regenerative approaches to energy prototyping, intentionally sets out from what can be understood as a flipside to dominant forms of energy provision and consumption within practices of energy, agriculture and technology more generally.

Practically speaking, the collaboration involves developing a Vertical Axis Wind Turbine constructed from fungal mycelium, reconfiguring e-waste motors into generators and designing a custom 5v hybrid charge controller for reconditioned batteries – with the goal of running a raspberry pi based low energy internet server. One identified risk for off-grid solar servers is that constraints can be avoided just by oversizing battery and solar system size, which opposes the primary environmental goal [7, 70]. Being able to generate energy with wind in addition to solar would reduce the need of battery size during the winter, which is a central problem for solar in Sweden, where there is a high degree of seasonality, and could be a central positive environmental impact of an off-grid/grid-liberated system.

The aim of the Windternet is to create a situated alternative energy source that, in its current arrangement, can host digital resources for experimental farming communities and facilitate a space for resourcing imaginaries otherwise. The project includes the following research questions as focal points for the research:

- How can a wind component supplement a solar server in the extended and dark periods of Swedish winters?
- How can new additive fabrication techniques and regenerative materials (e.g., mycelium-based 3D printed materials) be designed and developed for practical use in the field in a way that is open and accessible to the public?
- How can experimentation with alternative, regenerative materials and energy-conscious computational practices inspire further collaborations between the fields of design and computer science in ways that promote sustainable practices of innovation across both fields?

Despite being aware of the limitations of off the shelf solar panels and a raspberry pi for regenerative practices (as noted by in the earlier citation of Marloes), within REC we have learnt that some approaches push into new imaginaries for renewables and regenerative computing. The repeatability of the solar servers enables a transitional infrastructure and a way to start the conversation between the two approaches of the solar server and REC. Thus Windternet is being carried out along two overlapping tracks. The first works with off the shelf components – almost all of which were composed of the standard toxic materials of computing and energy generation – for a standard version that we could get up and running for initial hands-on working. This consists of:

- Hybrid solar-wind 12V MPPT controller.
- 12V 100W standard solar panel.
- Permanent magnet generator.
- LiFePo battery for cold weather.
- 3D printed Vertical Axis Wind Turbine.
- Raspberry Pi 4.

Based on this setup, the concurrent second track explores how to develop a more regenerative version in which (as much as possible given our constellation of knowledges) we would work to swap in more regenerative components into the overall design. This will include:

- Downsizing from camper van capacity of charging setup to pocket battery pack capacity with a self-made DIY charge controller that could be shared and made by others.
- A homegrown, non-extractive mycelium material for the turbine blades.
- Repurposing of locally sourced e-waste motors.
- Raspberry Pi Zero/ Scavanged Pi's.

2.1 Charge controller

In conjunction with a small raspberry pi server from the Solar Internet project, we discovered early on that we couldn't find any open source, small scale (5 volt) hybrid power management and charge systems for wind generators and solar panels on the market that were not glued shut in a finished, ready-for-glamping product. Despite not being especially familiar with electrical engineering, we have delved into the rabbit hole of analogue power electronics, focusing on developing a low cost, easily replicable, open source[3] USB compatible system which could work with, as opposed to against, all the intermittencies and inefficiencies of a small generator. This resulted in Energy Meadow, a circuit that has been designed so that it can work not only with wind and solar, but various other types and scales of electrical generators (e.g., homemade piezoelectric generators, microbial fuel cells) which can be "daisy chained" to each other.

Surveying what was out there as an off-the shelf possibility, we purchased the smallest ready to use wind turbine hardware we could find that didn't have turbine blades so that we could test our mycelium turbine. This hardware (expectedly) ended up being unnecessarily large to run a raspberry pi, geared as it was to off-grid living and camper vans. It was both heavy and expensive – but far too cheap if one incorporates its true social and environmental costs. Interesting to note is that while we couldn't find many small-scale options for wind generators, we were advertised the possibility to purchase an entire monumental offshore wind turbine for a million Swedish crowns.

Since any use of a chemical battery will have the largest negative environmental impact from a life cycle perspective, our aim has been to try to minimize the use of one as much as possible.

[3] Documentation available at https://github.com/m0Ssss/hybrid_charge_controller

Learning from the results of the solar server project [7], which was down for a few weeks on the first winter (and then much more the second winter, as the battery lost capacity and was damaged from being charged during the freezing outdoor temperatures), the use of wind in a hybrid ("energy meadow") system would rely on just topping up what the solar could relatively steadily generate. We are also however ok with down-time.

Special care was paid to battery protection circuitry, as existing designs for battery protection for 5v systems are far more focused on over temperature than under temperature charge protection (presuming indoor charging), as well as overcharge (presuming high and steady power) as opposed to over-discharge (running a raspberry pi as long as possible without damaging the pi or the battery). The off the shelf setup, on the other hand, is well equipped for these scenarios (we purchased a self-heating battery) and the charge controller hosts many options for setting charge specifications.

Despite having a microcontroller already in the 5v set-up, we opted to not use this to manage the power. This is partly due to wanting to learn and make decisions about discrete components, along with their material capabilities and problematics, and to not design a black box system, but rather a narrative circuit that can be used in an educational way. As highlighted in the publication *Autonomy in the Face of Agtech*, narratives in a context of technology and farming tend to be dominated by stories of corporate accumulation, know-how and control, but these narratives can be undone and replaced [73] – from the level of community to circuits.

Figure 1: "Energy Meadow" - solar/wind hybrid charge controller development board. Photography, Regenerative Energy Communities, 2024. CC4R.

Another benefit of the design is that the charge controller can be used for other lower cost applications where a microcontroller is not present and can be assembled partly with scavenged components. We also aim to charge e-waste lithium batteries, which can be found in many old appliances, and as such our circuit incorporates the functionality of 0v charging, which allows for the regeneration of severely depleted/badly cared for batteries.

Functionalities of the many power management ICs we have been looking at, which are relatively new to the market and geared toward solar applications, demonstrate to us how much the technology that is available is in many ways due to fashion and market dynamics. We unearthed a few components with interesting low power functionalities which were developed decades ago but fell out of fashion due to the development of CMOS and are now relegated to specialty (i.e. expensive and hard to get) status. As non-engineers delving into circuit design, we also see how important it is for the foundations of electrical engineering that a constant, clean power source can be assumed. Functionalities we feel a kinship with however include Energy Harvesting, Bootstrapping and "Sleep-in" mode, which speak more to pluralistic, submergent, queer, crip time and bottom-up energy generation possibilities, where rest and recovery are also situated as integral parts of the energy generation process itself.

2.2 Homegrown mycelium turbine

In working early on to interpret and attend to regenerative commitments of the farming community we were centered around, it became clear that their stated commitments ostensibly ruled out off the shelf energy sources (reflecting, in a smaller scale, the damaging practices around mineral extraction and the environmentally hazardous end of life issues for wind and solar). With this in mind, we began to explore what kinds of regenerative materials and biodiverse relations we could instead cultivate and work with.

The design of the blades of the turbine brings together the possibilities of combining computer aided design with biomass and natural power in the root-like system of fungi, also known as mycelium. Essentially the turbine blades consist of saw dust (collected from a wood workshop waste container) and are bound or held together through the introduction of mushroom spores. By using a 3D printed mould the mycelium is allowed to grow in a particular (turbine) shape, which structurally and slowly engineers a solid (turbine) body.

Even if horizontal axis wind turbines (HAWT) have undoubtedly gained more popularity compared with vertical axis wind turbines (VAWT), our design decision opting for a VAWT style is based on our situated context and geographical location as a whole. As the direction of wind changes often at the farm, the turbine design is made to be omni-directional, meaning the ability to receive wind from any direction, which is made easier with a VAWT over HAWT. Being able to accept wind from any direction, the omni-directional turbines are favourable for placement in turbulent places, such as rooftops or urban areas [71]. Another benefit of VAWT over HAWT is that they are deemed more silent, which is relevant for a socially active site such as the farm and other similar sites and activities where such a turbine might be implemented. Additionally, by placing the generator in the bottom,

maintenance and installation and the general design of cables, housing and fittings becomes more efficient and convenient. We also deem that the slow speed and relatively large surface area, coupled with the ability to position it very low to the ground, significantly decreases the risk for impacting wildlife, such as collision for birds and bats.

In terms of negatives, our experienced difficulties and limits to date have mainly been with the design of the actual blades. Specifically, the challenge of making a mould in which the mycelium could grow in, as the overhang of the design causes the ends to fall off. Another disadvantage is that our shape of blade, known as savonious shape, requires more material than other designs.

In addition to producing small amounts of wind-generated energy, as it deteriorates over time into the soil, the mycelium turbine concurrently has the potential to contribute to soil health via processes of mycoremediation of heavy metals and other contaminants from the farm's adjacent highway and the stimulation of mycorrhizal networks whose topsoil nutrient highways create even less of a need for fertilizer. The choice of mushroom variety is a point for experimentation, with certain varieties being faster or easier to grow, and others more or less suited to the ecosystem in question. This kind of farming/growing of technological materials, with their own timeframes and rhythms of tending and growing, has created a different relation and understanding of what it means to work with designerly and computational processes. Inspired by the experimental and intentional practices of the farmers on the site, we have found ourselves unlearning and recalibrating our own relations to the materials, tools and processes of design and computation.

Figure 2: Mycelium wind turbine and e-waste motor. Photography, Regenerative Energy Communities, 2024, CC4R.

2.3 E-waste motor

While small scale solar power management systems have developed considerably and are now ubiquitous in the consumer and hobbyist market – running all sorts of IOT projects and USB chargers on many scales (from municipal to hobbyist level) – we have struggled to find something like this for wind. One hears that massive wind turbines need to be as large as they are because of efficiency reasons, but not being focused on efficiency per se we aim to find out what this gap in the market is all about. Sticking to regenerative commitments as much as possible has led to using e-waste motors as a basis for generators to clean up our local hardware ecosystems (e-waste bins), as well as not feeding into the market of new neodymium magnets and kilometers of freshly spun copper wire, or the aforementioned issues surrounding rare earth mining and indigenous land-grabbing in Nordic and other regions. While challenging, a further benefit of designing with e-waste is that it can be assembled by people in many different contexts.

2.4 Server and hosted content

The most minimal server explored in the Solar Internet project consisted in a Raspberry Pi Zero 2W running Nginx and static sites compiled using Jekyll (https://solarinternet.org/servers/offgrid). The power usage of this setup is minimal – around 100mA idle to 140mA load (0.5W to 0.7W) – and with the Windternet we will continue to explore minimum-energy hosting.

Given the highly non-regenerative, negative resource nature of several of the components used for the Windternet setup, we see the content hosted on it as serving an important role if it is to be worth the using of such resources. As soon as the setup is ready to be tested and put to use, we will collaborate with farmers and others to explore what can be served by the server. An initial goal of the server is to act as an active repository of regenerative resources and practices of different kinds, similar to the library format that REC used in our recent Energy Giveaway at the Humuspunk Libary exhibition in Zurich, Switzerland[4]. As the server is running off-grid and in situations without internet connection, the server can provide a local repository of knowledge for situated regenerative practices in a farm or community garden. But as the project develops, new needs for on-site computational tools may arise that the server could help with, for instance, biodiversity monitoring, a local sensor gateway, recipes and other resources for regeneration.

The setup at the moment uses Raspbian Bookworm, NginX as HTTP server and Accesspopup for creating a WiFi Hotspot. The content is provided as static sites pre-compiled in Jekyll. The users connect to the server's WiFi hotspot and the server is then located at http://windternet.local This type of situated local server builds in the tradition of tools like Splinter [39], who work with feminist servers, situated publishing, active archives, extitutional networks, (re)learning situations, hackable devices, performative protocols, solidary infrastructures and other spongy practices to stake out

[4] Documentation of the exhibition available here (https://www.weareaia.ch/energy-giveaway/) and here (https://regenerative-energy-communities.org/energy-giveaway).

paths towards speculative, libre, intersectional technologies (SPLINT).

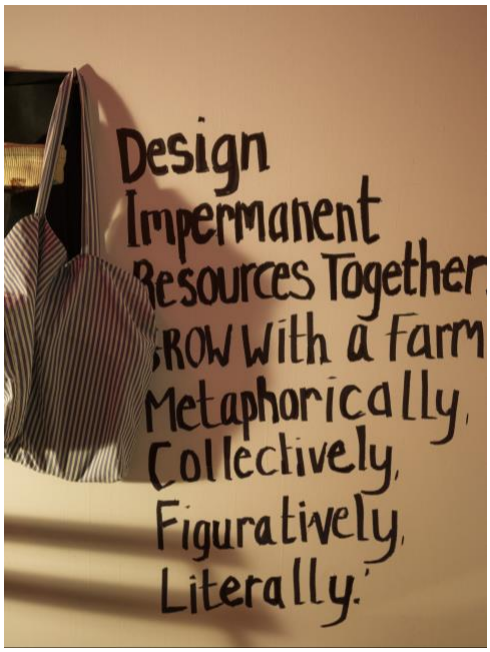

Figure 3: Wall text by TheDirt as part of their "500sqm of municipal land lease" piece at the Energy Giveaway at the Humuspunk Library exhibition in Zurich, Switzerland. Photography, Nicolas Petit, 2023, CC4R.

Windternet is an attempt at making something appropriate for a small group of experimental community farmers and trans*feminist organisers. It is not trying to power a house, nor spending far above its energy means for running a software project. It is not aimed at further fleshing out ecomodernist or glossy technosolutionist "smart" aesthetics and practices, with their tendencies of reliance upon and reproduction of normative benchmarks and efficiency measures [40, 41] that themselves carry with them longer histories and violences of calculation [42] and dispossession [74]. Nor is it interested in off-grid prepperism and isolationist ecofascist imaginaries. Instead, the server explores what practices can work within sustaining limits and a community-oriented spirit of hosting and sharing regenerative resources that might inspire further experimentation with the challenges that current practices of technology, computation and farming present.

3 Regenerative propositions for regenerative prototyping

When experimenting with sustainable energy prototyping of any kind, it is hard not to be taken by a strong sense of how sedimented and repetitive certain norms and imaginaries around sustainable energy have become, especially in the defaulting to renewables in their most iconic forms: the monumental wind turbine, the rooftop solar panel, the hydroelectric dam – even if it is also the case that such paradigms are being challenged by a range of different communities, actors and DIY flourishings. As Daniel from the REC team put it while reflecting back on two years of working on the project, one thing that we felt already early on, and which has come to the fore in working with regenerative energy alternatives is the question of what is being lost in sustainable energy transitions as they are currently envisaged. While community-driven alternative energy-based practices have rightly gained more attention (e.g., [43, 44]), there are still so many perspectives and possibilities that are not commonly part of the sustainable energy transition conversation [45, 46]. In contrast to the hyper rapid cycles of innovation visible across many other technologically oriented terrains, the field of sustainable energy remains centered around what could be seen as relatively fixed formats. If nothing else, in the work on Windternet, we want to create further space for the emergence of prototypes and practices that, even if not entirely field ready, are nevertheless replicable starting points for contributing to collectively reimagining what methods and forms alternative energy experimentation could take.

Figure 4: Early Windternet testing at Jorge's farm in Skärbäck, Sweden. Photography, Regenerative Energy Communities, 2024, CC4R.

If renewables have often defaulted to a notion of replacing fossil fuels without overtly challenging underlying and constantly increasing energy needs [47], nor the problematic nature of the materials that underpin renewables, our experiments with a regenerative mode of prototyping that works towards not only sustaining but actively repairing and improving the health of soil-based ecosystems and their communities is partly an attempt to challenge notions of what can constitute more genuinely sustainable innovation within practices of energy and ICT more generally. As with regenerative farming, doing so pushes one to working with ecological processes of regeneration as opposed to extraction. It is an approach that can deliberately challenge and decenter [48] normative ideas around, for instance, what materials one might work with in technological prototyping and who or what can be included in practices around energy innovation.

In Windternet, this has involved processes of foraging for and salvaging second hand and discarded electronics for repurposing as components in the overall wind turbine setup – an intervention into

and regeneration of e-waste ecosystems. It has also meant growing materials from regenerative sources, as in the case of the mycelium materials used for the turbine blades – a changing of technological paradigms from off the shelf (with all of the multiple distances and extractions involved) to one of from the soil, or from your/our garden. And it means designing for end-of-life issues for the components involved, most noticeably in this case of the compostable and mycoremediation supporting elements of the turbine. A form of what we describe as companion prototyping [72] that, similar to practices of companion planting [49], strives to cultivate diverse and interdependent communities of relations amongst microorganisms and biotic life through micro regenerative energy experimentations within technoecological limits. It is likely a way to go until compostable circuits become convention, but modes of reuse and rethinking of materials and their potentials for being grown and later composted (rather than extracted and then polluting) is a step in this direction.

Regenerative prototyping involves attending to the seemingly straightforward fact that nothing is outside the ecological and ecosystem cycle, and an overarching aim of this research is to explore what possibilities lie in practices that aim to be regenerative. We find regeneration a rich and complicated concept to work with [50]; one that, in addition to its merits, is in need of critical attention for the ways in which it can be appropriated and/or shed of its community and political commitments [51, 52, 53]. The project has learned from the on the ground practices of the local farmers we work with on the farm site, as well as contemporary and longer standing practices of regenerative and sustainable farming, including agroecology and more recent practices evolving alongside or out of such practices [54, 55, 25, 56, 16, 37, 57, 58].

Regenerative principles and commitments inherent to such farming practices are helpful for the way in which they give a concrete directive for prototyping and ways of working together, while also carrying within them an implicit critique of approaches aimed merely at sustaining things as they are [25]. Principles, commitments and propositions, whether from regenerative farming, permaculture or other practices, have a potential to act as grounding points for accountable collective action and decision making. In their capacity to frame and address both urgent and longer terms questions of solidarity [59] and transformational ecological practices [60], they can serve as practical guidelines, vision statements and/or open-ended invocations for alternative ways of being and making together.

4 Going forward

There are a rich spectrum of historical and recent examples that one might turn to as touchstones for developing one's own sets of commitments for practice. For example, the Black Panthers' Ten-Point Platform and Program [61] and its forcefully holistic approach to achieving justice; the collectively written A Feminist Server Manifesto's outline for situated and "awkward" relational technological practices [62], as well as its attentive follow-up (or fork in the technological sense), the Wishlist for Trans*feminist Servers [63]; the Design Justice Network's principles for "ways designers can support social justice" [64] and the CLEAR Lab's manual for "intentional (rather than incidental) laboratory culture" [65]. As T.L. Cowan and Jas Rault observe, community manifestos and commitments might be said to be the Central Processing Unit for all the "heavy processing" [66] needed for regenerative practices.

In our work, we have seen how regenerative principles and propositions cultivate commitments. The defining and setting of limits are a defining of commitments. A simple step of growing materials such as mycelium for technological tasks and processes will immediately involve a commitment to a growing and cultivation process. While challenging, working with principles and propositions of regeneration has in retrospect not felt like a hinderance or limit. Rather, we are learning to trust the capacities of these principles and propositions to take us in exciting and positive change-oriented directions. At the same time, we also understand that there are moments and instances that we can't break away from them for reasons of practicality and keeping energy capacities manageable.

The value of a prototype does not necessarily need to be seen in what it achieves or does, but rather what it sets out to be and how it makes people feel and question in imaginative, troubling and thoughtful ways. Windternet embodies several questions, such as what would it look like if we grew our own energy source, and what is at risk of falling out of consideration in the pursuit of sustainable energy transitions? As team member Miranda put it, this and other REC prototypes in their current iterations – with their intermittent, micro levels of energy generation – can alternatively be thought of as being speculatively functional and functionally speculative. As prototypes they can be stimulative for rethinking energy paradigms, but also potentially stressful in a moment of an energy crisis (i.e., how will this help cut costs in my electricity bill). It is difficult to hold spaces of possibility and alternative ways of practice in the face of such tensions and pressures. But these intermittent social/material/technical/ecological energies that the prototypes harvest and electrify can stimulate reflections on current energy practices and the efficiencies and inefficiencies of energy-consuming devices, such as what are they made efficient for (e.g., size, speed, turbo-capitalisms). In other words, functionally speculative in relation to what and for whom?

As design and computer science practitioners, we increasingly experience (with mixed emotions) a democratisation of computer aided software and hardware. As their possibilities and energy needs increase at a rapid pace, this begs the question, what are we going to use them for? What doors are being opened and closed with these approaches in technology? The regenerative mycelium material, charge controller and other recovered and repurposed elements of the turbine strive to be a small yet unfolding response to this question. They point to materials, methods and modes of making that are not limited to servers, solar or wind. As implemented in Windternet, they intentionally address difficult questions of hardware and materials that continue to lie at the core of sustainable energy and ICT. But this implementation represents only a fraction of what such tools could be used for, and one

increasingly doesn't need have to expert knowledge to do so, though the material barriers to entry continue to create divides. With such tools becoming more accessible, they point to alternatives and favourable futures where industry doesn't have to dictate what we can do, and instead that we make what we think is preferable from a perspective of usability, sustainability and other "limits".

In sourcing regenerative materials grown directly from soil and salvaged from various local sites and ecosystems (farms, e-waste containers, second-hand stores) we have found ourselves and those who have participated in working on the different regenerative prototypes produced in REC to date (https://regenerative-energy-communities.org/prototypes) forming a different relation to matter and energy. It is a challenging but inspiring shift to imagine energy (but also art, design, computer science, DIY hacking, etc.) communities starting from communal soil and ecosystem health rather than modes of control and monitoring of energy use.

A recurring theme for our research has been how working with regenerative materials and systems has a cascading effect in which one material, scale, cycle or relation within these experiments highlight how much more there is to learn and unlearn. In such a regenerative approach, we have experienced a sense of art, design, energy and technology as being on the terms of something like a mycelium mold taking hold, an unreliable water pump, a questioning workshop participant, a seasonal weather pattern or other processual forms of making and companionship. For artists, designers and programmers, but also for many other disciplines and approaches, one typically starts from seeing things on one's own terms, or the discipline's terms, or the terms of the materials normally presented as what one should work with when it comes to a specific problem. Opening onto the terms of an ecosystem or collective conditions and commitments of a community supports and sustains other possibilities for resourcing, relating and making.

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REFERENCES

[1] TITiPI. 2024 (forthcoming). Frontier: a bugreport. *Logic(s)* 21. INCITE:Columbia. Available at https://logicmag.io/

[2] Ryan Stock and Trevor Birkenholtz. 2021. The Sun and the Scythe: Energy Dispossessions and the Agrarian Question of Labor in Solar Parks. *The Journal of Peasant Studies* 48, 5, 984–1007. https://doi.org/10.1080/03066150.2019.1683002

[3] Daniel Heath Justice and Jean M. O'Brien. 2022. *Allotment Stories: Indigenous Land Relations Under Settler Siege*. University of Minnesota Press, Minneapolis.

[4] Josefa Sánchez Contreras, Alberto Matarán Ruiz, Alvaro Campos-Celador and Eva Maria Fjellheim. 2023. Energy Colonialism: A Category to Analyse the Corporate Energy Transition in the Global South and North. *Land* 12, 6. https://doi.org/10.3390/land12061241

[5] Naimat Chopra. 2023. "Fuel, Food, and Fertilizer: The Interwoven Impacts of the Russia-Ukraine War". *Kleinman Center for Energy Policy*, May 5. Retrieved from https://kleinmanenergy.upenn.edu/news-insights/fuel-food-and-fertilizer-the-interwoven-impacts-of-the-russia-ukraine-war/

[6] Vaclav Smil. 2017. *Energy and Civilization: a History*. The MIT Press, Cambridge, Massachussetts.

[7] Martin Stojanov, Daniel Pargman, Mike Hazas, Rob Comber and Jorge Luis Zapico. 2023. How do we arrive at constraints?: Articulating limits for computing. *LIMITS, Ninth Computing within Limits 2023*. https://doi.org/10.21428/bf6fb269.a317d18f

[8] Ryan Alan Sporer. 2018. *The Politics of Circumvention: The Off-Grid Eco-Housing Movement of Earthships*. Dissertation. University of Illinois at Chicago, Chicago.

[9] Cynthia Belmont and Angela Stroud. 2020. Bugging Out: Apocalyptic Masculinity and Disaster Consumerism in Offgrid Magazine. *Feminist Studies* 46, 2, 431-458. https://doi.org/10.1353/fem.2020.0019

[10] Marianne Ryghaug, Tomas Moe Skjølsvold and Sara Heidenreich. 2018. Creating energy citizenship through material participation. *Social Studies of Science* 48, 2, 283–303. https://doi.org/10.1177/0306312718770286

[11] Jennifer Gabrys. 2013. *Digital Rubbish: A Natural History of Electronics*. University of Michigan Press, Ann Arbor.

[12] Benjamin K. Sovacool. 2014. What are we doing here? Analyzing fifteen years of energy scholarship and proposing a social science research agenda. *Energy Research & Social Science* 1, 1-29. https://doi.org/10.1016/j.erss.2014.02.003

[13] Lucy Lippard and Stephanie Smith. 2007. *Weather Report: Art and Climate Change*. Boulder Museum of Contemporary Art.

[14] Maywa Montenegro de Wit. 2022. "Can agroecology and CRISPR mix? The politics of complementarity and moving toward technology sovereignty". *Agriculture and Human Values* 39, 2, 733-755. https://doi.org/10.1007/s10460-021-10284-0

[15] Jane Prophet, Jane and Helen Pritchard (eds.). 2023. *Plants By Numbers: Art, Computation, and Queer Feminist Technoscience*. Bloomsbury Visual Arts, London.

[16] Leah Penniman. 2018. *Farming While Black: Soul Fire Farm's Practical Guide to Liberation on the Land*. Chelsea Green Publishing, White River Junction.

[17] Sins Invalid. 2015. 10 Principles of Disability Justice. Retrieved from https://www.sinsinvalid.org/blog/10-principles-of-disability-justice

[18] Patricia Hill Collins. 2017. On violence, intersectionality and transversal politics. *Ethnic and Racial Studies* 40, 9, 1460–1473. https://doi.org/10.1080/01419870.2017.1317827

[19] TITiPI. 2023. Slogans for Counter Cloud Action. Retrieved from https://titipi.org/wiki/index.php/Slogans

[20] Ron Eglash, Audrey Bennett, Lionel Robert Jr, Kwame Porter Robinson, Matthew A. Garvin and Mark Guzdial. 2024. Decolonization, Computation, Propagation: Phyto-Human Alliances in the Pathways Towards Generative Justice. In Jane Prophet & Helen V. Pritchard (Eds.). *Plants by Numbers: Art, Computation, and Queer Feminist Technoscience*. Bloomsbury Visual Arts, London, 141-160.

[21] Ali, Mustafa. 2016. A brief introduction to decolonial computing. *XRDS: Crossroads, The ACM Magazine for Students* 22, 4, 16–21. https://doi.org/10.1145/2930886

[22] Michelle Westerlaken, Jennifer Gabrys and Danielo Urzedo. 2022. Digital Gardening with a Forest Atlas Designing a Pluralistic and Participatory Open-Data Platform". *Participatory Design Conference 2022: Volume 2*. https://doi.org/10.1145/3537797.3537804

[23] Daniel Christian Wahl. 2016. *Designing Regenerative Cultures*. Triarchy Press.

[24] Daniel Christian Wahl. 2017. Sustainability is not enough: we need regenerative cultures. *Medium* blog post. Retrieved from: https://designforsustainability.medium.com/sustainability-is-not-enough-we-need-regenerative-cultures-4abb3c78e68b

[25] Bill Reed. 2007. Shifting from 'Sustainability' to Regeneration. *Building Research & Information* 35, 6, 674-680. https://doi.org/10.1080/09613210701475753

[26] Samuel Mann, Oliver Bates, Glenys Forsyth and Phil Osborne. 2018. Regenerative Computing: De-limiting hope. *LIMITS '18: Proceedings of the 2018 Workshop on Computing within Limits*. https://dl.acm.org/doi/abs/10.1145/3232617.3232618

[27] Marloes de Valk and Ville-Matias Heikkilä. 2022. Permacomputing. *COUNTER-N*. https://doi.org/10.18452/25609

[28] Viznut. 2020. Permacomputing. Retrieved from: http://viznut.fi/texts-en/permacomputing.html

[29] Viznut. 2021. Permacomputing Update 2021. Retrieved from: http://viznut.fi/texts-en/permacomputing_update_2021.html

[30] Kent Beck. 2023 [2009]. First One, Then Many. Retrieved from: https://tidyfirst.substack.com/p/first-one-then-many

[31] Aymeric Mansoux, Brendan Howell, Dušan Barok, and Ville-Matias Heikkilä. 2023. Permacomputing Aesthetics: Potential and Limits of Constraints in Computational Art, Design and Culture. *Computing within Limits*. https://doi.org/10.21428/bf6fb269.6690fc2e

[32] Dan Palmer. 2017 On the Relation between Designing and Implementing in Permaculture – Part 4. *Making Permaculture Stronger* (website), February 13. Retrieved from: https://makingpermaculturestronger.net/inquiry2-post4/

[33] Arctic Circle. 2020. Arctic-Global Indigenous Dialogue on Indigenous Guardianship and Self-Governance. Video, January 17. Retrieved from: https://www.youtube.com/watch?v=Dpbh4ED_NPA&feature=youtu.be

[34] Josefa Sánchez Contreras, Alberto Matarán Ruiz, Alvaro Campos-Celador and Eva Maria Fjellheim. 2023. Energy Colonialism: A Category to Analyse the Corporate Energy Transition in the Global South and North. *Land* 12, 6. https://doi.org/10.3390/land12061241

[35] Eva Maria Fjellheim and Florian Carl. 2020. 'Green' colonialism is ruining Indigenous lives in Norway. *Al Jazeera*, 1 Aug. Retrieved from: https://www.aljazeera.com/opinions/2020/8/1/green-colonialism-is-ruining-indigenous-lives-in-norway

[36] Eva Maria Fjellheim. 2022. Green colonialism, wind energy and climate justice in Sápmi. *The International Work Group for Indigenous Affairs (IWGIA)*. Retrieved from: https://www.iwgia.org/en/news/4956-green-colonialism,-wind-energy-and-climate-justice-in-s%C3%A1pmi.html

[37] Maywa Montenegro de Wit. 2021. What grows from a pandemic? Toward an abolitionist agroecology. *The Journal of Peasant Studies* 48, 1, 99-136. https://doi.org/10.1080/03066150.2020.1854741

[38] Karin Nutti Pilflykt. 2023. Sámi rights must not be sacrificed for green energy goals of Europe. *Mongabay*, 20 March. Retrieved from: https://news.mongabay.com/2023/03/sami-rights-must-not-be-sacrificed-for-green-energy-goals-of-europe-commentary/

[39] https://constantvzw.org/site/-About-Constant-7-.html

[40] Deepak Malghan. 2019. Efficiency. In Ashsish Kothari, Ariel Salleh, Arturo Escobar, Federico Demaria, Alberto Acosta (Eds.), *Pluriverse: A Post-Development Dictionary*. Tulika Books, New Delhi.

[41] Jennifer Karns Alexander. 2008. *The Mantra of Efficiency: From Waterwheel to Social Control*. The John Hopkins University Press, Baltimore.

[42] Katherine McKittrick. 2014. Mathematics Black Life. *The Black Scholar* 44, 2, 16-28. https://doi.org/10.1080/00064246.2014.11413684

[43] Jens Marquardt and Laurence L. Delina. 2018. Reimagining energy futures: Contributions from community sustainable energy transitions in Thailand and the Philippines. *Energy Research & Social Science* 49, 91-102. https://doi.org/10.1016/j.erss.2018.10.028

[44] Myles Lennon. 2017. Decolonizing energy: Black Lives Matter and technoscientific expertise amid solar transitions. *Energy Research & Social Science* 30, 18-27. https://doi.org/10.1016/j.erss.2017.06.002

[45] Shannon Elizabeth Bell, Cara Daggett and Christine Labuskic. 2020. Toward feminist energy systems: Why adding women and solar panels is not enough. *Energy Research & Social Science* 68. https://doi.org/10.1016/j.erss.2020.101557

[46] Benjamin K. Sovacool, Shannon Elizabeth Bell, Cara Daggett, Christine Labuski, Myles Lennon, Lindsay Naylor, Julie Klinger, Kelsey Leonard and Jeremy Firestone. 2023. Pluralizing energy justice: Incorporating feminist, anti-racist, Indigenous, and postcolonial perspectives. *Energy Research & Social Science* 97. https://doi.org/10.1016/j.erss.2023.102996

[47] Richard York and Shannon Elizabeth Bell. 2019. Energy transitions or additions? Why a transition from fossil fuels requires more than the growth of renewable energy. *Energy Research and Social Science* 51, 40–43. https://doi.org/10.1016/j.erss.2019.01.008

[48] Seeta Peña Gangadharan and Jędrzej Niklas. 2019. Decentering technology in discourse on discrimination. *Information, Communication & Society* 22, 7, 882-899. https://doi.org/10.1080/1369118X.2019.1593484

[49] West Coast Seeds. 2021. *Guide to Companion Planting*. Available here: https://www.westcoastseeds.com/pages/companion-planting

[50] Helen Pritchard, Eric Snodgrass, Miranda Moss and Daniel Gustafsson. 2023. Tending to 2030m3: How to regenerate regeneration? How to unasphalt asphalt? In: Jane Prophet and Helen V. Pritchard (Eds.), *Plants by Numbers: Art, Computation, and Queer Feminist Technoscience*. Bloomsbury Visual Arts, London.

[51] Pablo Tittonell, Veronica El Mujtar, Georges Felix, Yodit Kebede, Luciana Laborda, Raquel Luján Soto and Joris de Vente. 2022. Regenerative agriculture—agroecology without politics?. *Frontiers in Sustainable Food Systems* 6. https://doi.org/10.3389/fsufs.2022.844261

[52] IPES-Food. 2022. Smoke & Mirrors: Examining competing framings of food system sustainability: agroecology, regenerative agriculture, and nature-based solutions. Available here: http://www.ipes-food.org/pages/smokeandmirrors

[53] Bryony Sands, Mario Reinaldo Machado, Alissa White, Egleé Zent and Rachelle Gould. 2023. Moving towards an anti-colonial definition for regenerative agriculture. *Agriculture and Human Values* 40, 1697–1716. https://doi.org/10.1007/s10460-023-10429-3

[54] Masanobu Fukuoka. 2009 [1978]. *The One-Straw Revolution: An Introduction to Natural Farming*. New York Review Books, New York.

[55] Miguel Altieri (Ed.). 2019. *Agroecology: The Science of Sustainable Agriculture. 2nd edn*. Practical Action Publishing, Warwickshire.

[56] Hannah Wittman. 2009. Reworking the metabolic rift: La Vía Campesina, agrarian citizenship, and food sovereignty. *Journal of Peasant Studies* 36, 805–826. https://doi.org/10.1080/03066150903353991

[57] Sofie Isager Ahl. 2023. *Regeneration: Gesindigt Helende Praksisser i en Ny Jordbrugsbevægelse*. Laboratoriet for Æstetik og Økologi, Copenhagen.

[58] Common Ecologies. 2023. *Transforming Agriculture & Beyond: Infrastructures, tools and tactics for agroecological struggles and their allies*. Common Ecologies. Available here: http://commonecologies.net/texts/transforming-agriculture-book/

[59] After Oil Collective (Ayesha Vemuri and Darin Barney, Eds.). 2022. *Solarities: Seeking Energy Justice*. University of Minnesota Press, Minneapolis. Available here: https://manifold.umn.edu/read/solarities/section/710e425f-e782-4f65-8dee-d1de60790bb3

[60] Katya García-Antón, Harald Gaski and Gunvor Guttorm. 2020. *Let the River Flow: an Indigenous Uprising and its Legacy in Art, Ecology and Politics*. OCA / Valiz, Oslo.

[61] Huey P. Newton and Bobby Seale. 1967. What We Want Now! What We Believe. *The Black Panther Party Newspaper*, May 15. Available here: https://www.marxists.org/history/usa/pubs/black-panther/

[62] Are You Being Served? 2014. A Feminist Server Manifesto 0.01. Available here: https://areyoubeingserved.constantvzw.org/Summit_afterlife.xhtml

[63] Cell for Digital Discomfort. 2022. A Wishlist for Trans*feminist Servers. Available here: https://www.bakonline.org/prospections/a-wishlist-for-transfeminist-servers/

[64] Design Justice Network. 2018. 10 Ways Designers Can Support Social Justice. *Design Justice Issue 3: Design Justice in Action*. Available in original form here: https://designjustice.org/zines and since updated as a living document that has been translated in multiple languages here: https://designjustice.org/principles-overview

[65] CLEAR Lab. 2021. *CLEAR Lab Book: a living manual of our values, guidelines, and protocols (Version 3.0)*. Available here: https://civiclaboratory.nl/clear-lab-book/

[66] T.L. Cowan and Jas Rault. 2023. *Heavy Processing*. Punctum Books, Goleta.

[67] Stephanie Wakefield. 2020. *Anthropocene Back Loop: Experimentation in Unsafe Operating Space*. Open Humanities Press, 89.

[68] Grey Moran. 2022. In the battle over the right to repair, open-source tractors offer an alternative. *Civil Eats*, April 27. Retrieved from: https://civileats.com/2022/04/27/right-to-repair-open-source-tractors-john-deere-oggun-farms-profitability-technology

[69] Michael Carolan. 2016. Agro-Digital Governance and Life Itself: Food Politics at the Intersection of Code and Affect. *Socilogia Ruralis* 57, 1, 816-835. https://doi.org/10.1111/soru.12153

[70] Roel Roscam Abbing. 2021. "This is a solar-powered website, which means it sometimes goes offline": a design inquiry into degrowth and ICT. *Seventh Workshop on Computing within Limits 2021*, LIMITS. https://doi.org/10.21428/bf6fb269.e78d19f6

[71] Sandra Eriksson, Hans Bernhoff and Mats Leijon. 2008. Evaluation of Different Turbine Concepts for Wind Power. *Renewable & Sustainable Energy Reviews*, 12, 5, 1419-1434. https://doi.org/10.1016/j.rser.2006.05.017

[72] Eric Snodgrass, Miranda Moss, Daniel Gustafsson and Helen Pritchard. 2024. Companion prototyping. *A Collection of Change*. https://designportfoliolnu.se/publications/a-collection-of-change/companion-prototyping

[73] Nyéléni Forum for Food Soverignty. 2019. The digitalization of the food system. *Nyéléni Newsletter*, 37. Available here: https://viacampesina.org/en/the-nyeleni-newsletter-digitalization-of-the-food-system/

[74] Hannah Wittman, Dana James and Zia Mehrabi. 2020. Advancing food sovereignty through farmer-driven digital agroecology. *International Journal of Agriculture and Natural Resources*, 47, 3, 235-248. https//dx.doi.org/10.7764/ijanr.v47i3.2299

[75] ETC Group. 2023. Autonomy in the Face of Agtech: Tools for Challenging Industry Narratives. Available here: https://www.etcgroup.org/content/autonomy-face-agtech

[76] Jen Liu and Phoebe J. Sengers. 2021. Legibility and the Legacy of Racialized Dispossession in Digital Agriculture. *Proceedings of the ACM on Human-Computer Interaction*, 5, Issue CSCW2, 480, 1-21. https://doi.org/10.1145/3479867