Towards symbiotic university-adjacent edge spaces for sustainability transitions and computing: a design imaginary with some material and financial feasibility

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ABSTRACT

While universities and academic systems can help in sustainability transitions as edge spaces, existing academic and funding systems have evolved to serve and mirror unsustainable capitalist systems and resist transition. This paper proposes a design imaginary for creating transitional edge spaces to support the research and practice of sustainability transitions and computing for sustainability and environmental justice. The key idea is to bootstrap the space symbiotically off of existing universities, while centering 1) student empowerment by acquiring land for students for housing owned by students through debt-based financing, and 2) ecology via agroecology/permaculture design principles. The design imaginary involves successions of progressively more sustainable and environmentally just configurations. We conduct a financial and legal feasibility analysis based on a specific site for sale in 2022 near the University of Maine in the traditional lands of the Penobscot people. We found 1) initial feasibility for a single faculty person to buy the land and a combination of barely feasible ways to increase student pay to qualify for loans, and 2) significant feasibility if co-signers or third parties took out small loans with no downpayment and rented at cost to students over a 5 year term. If the land and plot improvements were donated, the annual yield in student asset creation appears to be 30-45% (when assuming no agricultural yield). We then present an initial analysis/justification of the overall design and succession, using existing principles from just sustainability design. We explore potential ideas for just sustainability computing research and new paradigm development placed in the seed space. We conclude with limitations, critique, and discussion.

KEYWORDS

transition, land ownership, student-owned housing, debt, just sustainability design, design imaginary, agroecology, permaculture

1 INTRODUCTION

Navigating transition during our sustainability and environmental justice crisis will require cultural, political, institutional, and economic changes, as well as spaces on the edge [1] of existing practices that enable experimentation in transitions.

While universities and academic spaces can help in this transition as edge spaces, existing academic and funding systems have evolved to serve and mirror unsustainable capitalist systems and resist transition; **transdisciplinary movements for sustainability** like indigenous knowledge systems, farmers' movements, and permaculture **have been resisted and instead have mostly developed through lived experimentation enabled by access to and relationship with land**. Indigenous knowledge and lifeways were developed through access to land and lived experimentation. Drawing on that wisdom, permaculture was created outside academic research in Australia by a senior tutor (lecturer) in a Psychology department and a student at a Tasmanian post-secondary agricultural vocational school. While permaculture also draws on academic research in ecology and conceptual work on complex systems and embodied energy [45], holistic design processes for agroecological systems development has almost entirely been done outside universities [21, 22]. For example, the "first ever" systematic investigation of permaculture farm productivity was published in 2017 [23, 31]. Lastly, while some work in universities in agroecology has similar transdisciplinary ecological, social, and political scale as permaculture, that strand grew out of farmers' movements in Brazil in the 1970s around sovereignty, autonomy, and alternatives to industrial agriculture [3, 66]. Transdisciplinary academic agroecology work has become more common since the 2000s and is important, but it is still marginalized in universities compared to the focus on industrial-scale fossil-fuel big agriculture [38, 66].

While universities and education can serve a great role in changing culture, community, knowledge, skills, and values, **pragmatically within capitalism education systems often lead to students with a lack of flexible assets and access to land** (or worse, very high levels of debt). Without land access and assets, it is more difficult for students and graduates to take risks to explore and participate in sustainability transitions [4]. Undergraduates lack capital or financing to direct their money to building assets; for example, they must rent instead of building equity in a home.

Even in Europe [20], students graduate with no or few financial and material assets, but without those, in our capitalist systems, one must often participate in current unsustainable systems via employment. While graduate students may be paid, they do not often build assets that can support themselves to work at the intersection of fields and areas, or to have pragmatically a material place-based safety net in a time of disruptive transition (even if moreso a psychological "in principle I could" safety net).

How might we transition from neo-liberal institutional structures of universities, which accumulate assets by extracting value from students by tuition and student living expenses and from faculty research grants by owning acquired assets and grant overhead, to instead grow new edge spaces that create assets for students, faculty, and local communities and indigenous groups?

How might such edge spaces support the research and practice of sustainability transitions and continued new paradigm development for computing for sustainability and environmental justice?

The goal of this paper is to take a step beyond utopic visioning, to propose and analyze feasibility of a **pragmatic materially-specified design imaginary for new landed edge spaces** adjacent to the edge spaces of universities, to support sustainability transitions and research. The design imaginary is primarily about designing for succession - for progressively more sustainable and environmentally just configurations. The succession begins by centering 1) student empowerment by acquiring land for students for housing owned by students through debt-based financing, and 2) ecology via permaculture design principles. As a transitional space, to initiate, it leverages status quo capitalist elements like individual land ownership and use of unsustainable manufacturing infrastructures. To support transition, most of the land is reserved initially and over time successively larger portions of land and ecological community are stewarded through a local community-based sustainability and environmental justice focused design process that develops over time (which should be in partnership with local indigenous communities). We describe this succession as a high level outline, which requires much more future work. In this paper we focus on pragmatic material and financial feasibility for starting the space, by bootstrapping symbiotically off of existing universities.

Transitions for sustainability and environmental justice can be viewed as a wicked problem which does not have generalizable solutions [50]; no paper can discursively define a method or process for "solving" them globally in all contexts. Thus, this design imaginary and paper focuses primarily on USA institutional contexts and specific land situated near the Univeristy of Maine on the traditional lands of the Penobscot nation. While this paper is an imaginary, the land discussed was listed for sale from February to August 2022, and in this paper the financial and other feasibility analyses use actual figures, local laws, policies, and interest rates.

The contribution of the paper is the holistic intersection of:

(1) design imaginary for edge space succession *(see Section 3)*
(2) design for starting the edge space, for redirecting existing material and financial flows in the university system into assets outside that system. The key ideas are:
  (a) give students land in the space to own housing on
  (b) increase student pay by paying for more than 20 hours of work per week and/or writing higher salaries into grant requests *(see Section 5 and 6)*
  (c) lower grant overhead rates by using non-university owned office space on the edge space; redirect that into higher student pay (commonly called the "off-campus" overhead rate in the United States which is about 35% vs. on campus 50%) *(see Section 6)*
(3) feasibility analyses grounded in an actual prospective site showing some feasibility *(Section 4 thru 7)*
(4) initial analysis / justification of the overall design and succession, using existing principles from just sustainability design [6] *(Section 7)*
(5) ideas for just sustainability computing research and paradigm change placed in the edge space, and limitations and critiques *(Section 8 and 9)*

Positionality: I am a white disabled non-binary 39 year old, raised Catholic in a small town in the Upper Peninsula of Michigan. My father worked in the pulp and paper indusry and my mother in dental hygiene. At a young age I was diagnosed with ADHD and IBS, and after college gained an autoimmune disorder. As a disabled person who lost one job from disability, I found there was no legal recourse or support, and I was influenced by feelings of precarity seeing needs of disabled people mostly profoundly ignored during the pandemic. In 2020 I realized the similarity with sustainability issues, and my interests included exploring deepening relationship with nature and not just relationship to capitalist academic institutions. I came to this work through permaculture, which is a western way of expressing (and sometimes appropriating) indigenous knowledge and practices (e.g. the Spanish pig food forests, tropical forest gardens, North American indigenous agricultural systems such as polyculture of the sacred three sisters maize, beans, squash). Experiencing LIMITS 2021, 2022, a virtual transitions incubator class, and a retreat hosted by Invisible College in 2022 (an alternative academic institution), made exploring such alternatives feel more feasible. I made a final loan-based offer on the 20 acre parcel in the feasibility analysis in Fall 2022 at the asking price of $175k, which was turned down as the seller changed to selling only the entire 124 acres for $475k.

2 RELATED WORK

2.1 Sustainable computing & HCI within limits

Our work draws on rich prior ethnographic, design, and participatory action research on designing technology for values of environmental justice and permaculture. Ethnographic research and participatory design has the great strength of centering existing community; our design imaginary includes centering that increasingly over time. For example, Norton et al did a five year participant observation of two permaculture communities to elicit values and worked with them to create technology aligning with those values [42]. Other great work exists on design, for example, facilitating a local community interest company in an economically deprived urban neighborhood in the UK [10].

Within action research, our work has a different focus: how to initiate and fund new material spaces with existing resources and academic institutions. In some ways our work is part of developing hybrid paradigms for participatory action research that grows into being but with more praxis for creating physical spaces [17]. Prior LIMITS work explored poignant small space on campus [16]. Our work imagines redesigning academic systems to be more regenerative rather than extractive. That idea is not novel, but to our knowledge our analysis and design for doing it practically is.

Other related work on sustainable computing and computing within limits and patterns in that work directly inspired and led to our design imaginary, such as Lion's Gate [16]. There are many works on transitional systems [26, 27, 41, 49, 67] even in university spaces [16], and also technology built by and for people in partnership with communities, such as NkhukuProbe [29]. Our work furthers development of answers to "How might nascent or fragile worlds be given freedom to develop?"[27]. Scuri et al called for more focus on the economic angle in sustainable HCI [51]. We found some evidence that more rural space for research might enable more of that work: a review found ~80% of studies involving a person and computer interacting outdoors were in urban settings, versus 12% rural [30]. We discuss additional related work in Section

8 on research our imagined edge space might support, particularly more diachronic longitudinal work [32, 42].

2.2 Housing, land access, and permaculture

Prior work has proposed a variety of legal and social structures such as community land trusts and limited equity cooperatives for spaces with similarity to our design imaginary [18, 24], and the potential for their role in climate transition [33, 34]. Student [35, 47] and rural housing is comparatively understudied academically. For example, the first comprehensive study on rural eviction prevalence was published in 2024 [25]. There are sub-fields of housing policy focusing on environmental justice and climate resilience (and sometimes transition); this work tends to try to engage planners and policy and tends to conceive of income groups as in opposition to each other (not inaccurate in capitalism), instead of considering edge spaces where people with more money and assets might enable those with less, due to shared values around sustainability. Land access (and housing access in general) is a major barrier for young people exploring more sustainable ways of living [4]. There is some work on student housing co-operatives [47] but it usually does not lead to students owning the housing asset.

Our work is inspired by work from environmental sociology on sustainability transitions and other transition movements and spaces. For example, similar to how people will support organic and local agriculture just because they want tastier food, we want systems supporting transition that make sense within existing capitalist norms and logics while supporting tranisitioning from them [11, 38]. Our transition seed space is an example of a "shadow structure" to universities for navigating transition [38].

To our knowledge, our design imaginary is novel in how it integrates these ideas along with permaculture and designing across housing and university system boundaries, such as addressing student income barriers by finding practical ways to increase student pay. Our understanding is that most work focuses on remodeling or acquiring existing housing as it is cheaper and is already zoning conformant (it is also from a sustainability perspective much less energy intensive). Retrofitting also has a rich design history in permaculture [28]. While our design imaginary is much less sustainable initially, other approaches are less incremental and startable (for example, you usually can't buy one plot in a manufactured housing community, owners only sell the whole thing). While these are not our areas of traditional expertise, as an anecdote, consulting in Summer 2022 with a permaculture design consultant who has designed several university building and land systems, he was not aware of a similar project. It's also important to note that permaculture is a combination of re-invention and appropriation of indigenous techniques and widsom, new invention, and a systematic articulation of those from a hybrid Western perspective [39].

Our work can also be framed as a *real utopia* designed for *symbiotic transformation* as in Wright pg. 240 [68]. In utopias the enabling step is often grants or new state programs, with unclear feasibility. Our feasibility analysis goes beyond the norm by analyzing a new professor's potential position to do this, and ways they can increase their students' pay within existing systems. We do also calculate the potential return on a grant or donation, in terms of student asset creation, which appears to be a 30-45% annual yield, which exceeds the average stock market return of 10% [52].

3 SUCCESSION DESIGN FOR AN EDGE COMMUNITY NEAR A RURAL UNIVERSITY

The design moves through three successions which integrate and consider more local community needs over time. The initial design community could be a single person (e.g. new faculty member) who has worked and saved enough for a down-payment on the land, or other community structure such as a community land trust. We designed for something in the order of magnitude that a new computer science faculty member could initiate the space. An experienced agroecology/permaculture practitioner should reside and found (or co-found) the space, with additional outside mentorship. The majority of the land is set aside for a later, better community design process to manage, due to the significant time, effort, and investment required for those connections with local communities, including local indigenous communities. Seed fundraising by forming a non-profit or community land trust could also be done.

The first succession focuses on providing space for students to build housing assets while starting agroecology/permaculture work and the broader community design group and process formation. Part of the land is permanently offered/gifted directly to the local indigenous community in consultation with them (this does not exclude them from working in the design process for other parts). Design community and processes for the larger set-aside areas begin and develop. There is experimentation with methods for building office and community space by building smaller spaces like sheds. Potentially there is building of office space and other space for research, as a potential source of revenue for the space (e.g. via research grants, paying a community land trust holding the land of the space or parts of the space). A program of assessing ecological health (soil health, well-being of plants, animals, and humans) for the space and local communities is started to integrate into design process and evolves over time.

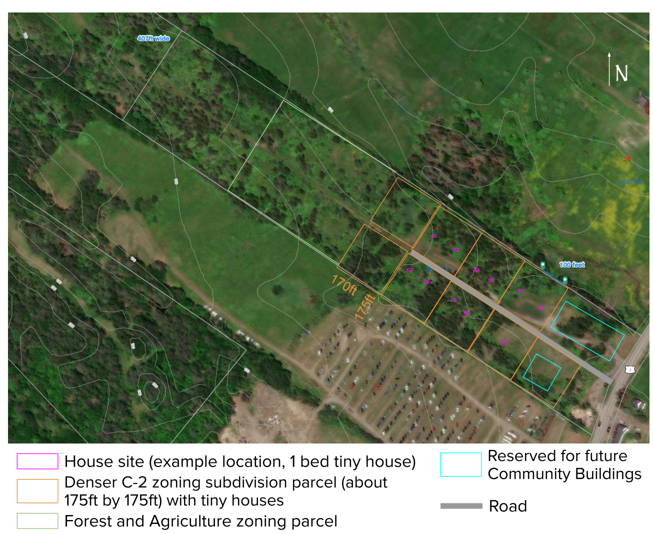

Figure 1: Succession 1 (Years 1-5): Early Housing and Permaculture focus (10 foot contour lines, land slopes southeast)

The second succession involves opening a U-Pick food forest/food orchard [8, 44] with sliding scales for prices for the local community, and creating space for experimenting and learning sustainable building techniques. Space and a building for students to build their own housing might be created now or in latter successions; even if there is not enough space to live in it in the seed space, it could be transported. Sustainable use of the back forested areas is implemented. Land use proposals and institutional arrangements (e.g. community land trusts) are designed to help form student political support and organizing for more just and affordable housing and zoning in the rural university municipality students can vote in (and potentially outnumber non-students). Outside funding could be organized over time to buy adjacent land, via pooled funds raised by donation, pay raises from reduced grant overhead, and U-pick proceeds.

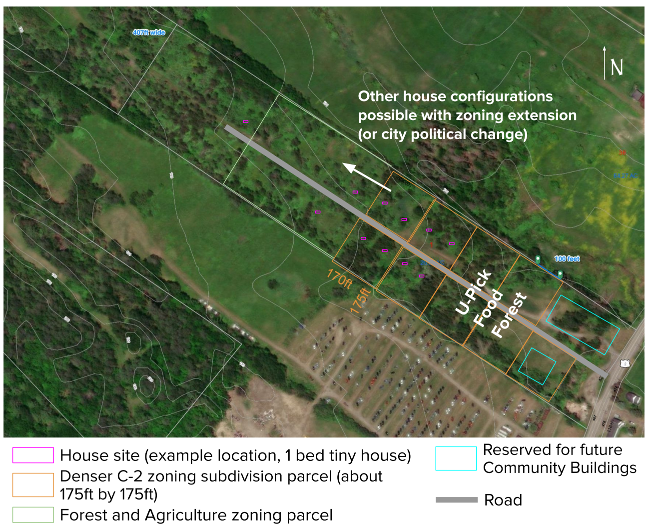

Figure 2: Succession 2 (Years 5-10): Housing, Local Community U-Pick food forest (10 foot contour lines)

The third succession involves wider use, continued configuration and reconfiguration, according to the community design process. Successful uses are refined and expanded. Different values and visions can manage different parts to allow experimentation and exchange by different groups with different philosophies and values. Transition continues to more sustainable housing techniques using site materials.

4 CONTEXT FOR INITIAL FEASIBILITY ANALYSIS

To evaluate feasibility of this design, we focused on basic financial constraints, in a case study applied to a particular rural university in Maine - University of Maine, the flagship Orono campus area, situated on traditional lands of the Penobscot (where issues and disputes are ongoing). We do not consider how commonly available land like this is elsewhere or imply common similar conditions elsewhere. The considered site is close to UMaine and was listed for sale from Feb-August 2022 with 124 acres listed in two parcels for combined $475k, which is $3,800 per acre. Of this 62-70 acres is

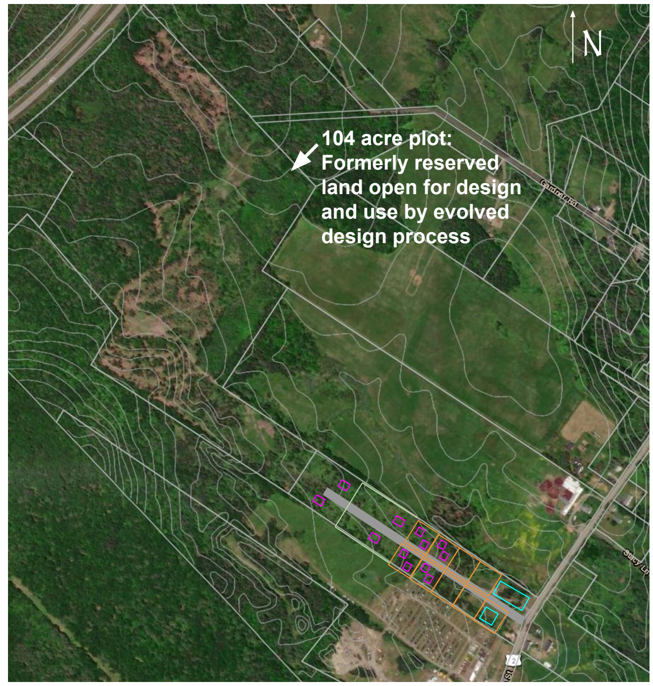

Figure 3: Succession 3 (Year 10-100): Housing, Local Community U-Pick food forest, rest of land for design (10ft contours)

potentially suitable for building sites and (non-exclusively) 60-90 for food and forest production. Most of the site is in various stages of forest development. The 20 acre parcel was $175,000, which we model as purchased by faculty to start Succession-1 (instead of assuming a grant) with back 104 acres for $300k purchased during Succession-2 or 3 (not part of the initial feasibility analysis).

The regional area is relatively well-positioned for climate change and sustainability challenges. There are moderating ocean winds from the south, and ground and surface water is plentiful. In a lower energy future UMaine is basically accessible by boat from the Atlantic via the Penobscot river. The population density is low. For the United States the political culture is moderate and does not fit neatly into left-right distinctions. Tiny houses are legal single-family dwellings in Maine (one of the few states in the USA), and city zoning laws allow them by default due to state legislation.

The University has existing research facilities and infrastructure; students and faculty could go between via car, public bus, or bike in 10-20 minutes. The site is visible on the way from campus to Bangor, a larger city where many live and commute from, with 400ft of frontage on US-2. The land is located in the town of Orono, where students outnumber non-students and can vote [60], allowing in the long term for political organizing of students to mitigate political and regulatory risks/barriers such as zoning. The land is at the top of a watershed which mitigates risk for neighbors using their land poorly with dangerous levels of fertilizers or other pollutants running off onto the land. The land is already zoned for a mix of commercial/dense residential and agricultural use, an uncommon combination. More typical rural land zoning is around 1-2 houses per 2-4 acres.

5 COST FEASIBILITY AND COMPARISONS

5.1 Method and Scenario

We modeled our feasibility scenario financially using basic interest and loan repayment calculations updated for 2024 interest rates, university cost figures, and from us in 2022 reading local zoning laws, consultations with local zoning officials, discussions and quotes from local contractors, and discussions with a permaculture design consultant. The results of our calculations are included in Tables 1-3 (full calculations are available online here). Beyond the cost of buying the land, the main costs are **plot improvements**, mostly required by zoning laws e.g. a road, septic systems (detailed more in the "Per Plot" section) and **house loan payments**. The scenario discussed in this paper is 1) the land buyer (assumed to be a faculty person) saves the loan down-payment, then buys the land, and pays to improve a single .67 acre orange plot to live on and a tiny house, all using loans, and 2) each student is gifted half of an orange land plot and takes out loans to pay for the improvements and their own tiny house (up to two houses per orange plot). An additional ~$50k of the land is modeled as given to the local indigenous community as part of Succession-1 (this is not discussed or designated more since if, what, and where would need to be discussed with them). For the scenario in the paper, the loan rates for students are generally assumed to be the "with poor credit" rates, but others are included for reference.

While the goals of a transition seed space are not capitalist net worth, for initiating the space, we evaluate 1) feasibility for paying loans, and 2) compared to renting, within capitalist logics, would students and faculty be better off in terms of net assets? We evaluated 2) mindful of uncertainty. For example, not including potential benefits and uses of the space, such as replacing food expenses with food grown in the space (or selling that). Fundamentally, when redirecting rent into a housing asset via a loan, the limit for increasing assets is *what would have been rent payment - loan interest*; for example, if loan interest was zero, all of the rent payment goes towards into the asset. **The discussed design decisions and constraints are examples of the types of constraints that are prevalent everywhere, though some details may vary. There are hundreds of design constraints.**

Table 1: Single faculty monthly land, house, and single plot improvements (PI) loans payment, and assets after payoff

	Loan monthly payment (in thousands $USD)		
15 year land loan	**Studio**	**1 Bed**	**1 Bed 2 Lofts**
5 yrs house, land, PI (1 house plot) 10yrs land and PI (1 house plot)	2.9 1.93	3.14 1.93	3.75 1.93
Pay loans off in 7yrs House, land, and PI (1 house plot)	3.26	3.45	3.749
Pay loans off in 5yrs *Infeasible*	4.13	4.37	4.98
Assets	**Assets after payoff**		
House, single orange plot, and half of F&A zoned land	131	143	173
Land given for students	61.25		
Example amount for land value given to local indigenous community	52.5		

Table 2: Student pay raise needed to qualify for loans, and *pay increase required for discretionary income after all housing costs to be same as if renting university housing.* Wages can be increased by paying 40 hours per week for certain periods vs. USA typical 20 hours for graduate assistantships.

Loan Scenario	**Months paid 40hrs per week**		
	Studio	**1 Bed**	**1 Bed 2 Lofts**
No co-signer, poor credit House + PI loan House (external gift pays PI)	 12 months Summer	 12 ms + 10% 6 months	Infeasible (post-doc rate) 12 ms + 15%
Good credit e.g. w/ co-signer; or 3rd party takes loan then student rents to own at cost *House+PI payment*	*.5 Summer*	*Summer*	*6 months*

5.2 Overall Results

To start the space, for a scenario with no outside gift funding, a new CS faculty member could finance it if they lived like a graduate student for two to three years; this would improve after they got research grants which in the USA pay added summer salary. Graduate students could live in the space with the same take-home monthly income compared to renting, if they are paid for 40 hours per week (double the usual $2.22k per month), with more house options with an additional 10% pay raise.

The challenge is that graduate students with poor credit would only qualify for the needed tiny house + plot improvement (H+PI) loans with no downpayment for a studio tiny house via being paid 40hrs the whole year; another 10% annual pay raise would enable a 1 bedroom. The main challenge qualifying for loans are bank limits based on debt-payment-to-income ratios, which are not published but generally max out at 36% and sometimes 50%. Graduate students might qualify for loans with downpayments or more niche government and non-profit-based loan programs for rural housing, but those are complex.

However, if outside people were willing to take a no-downpayment H+PI loan and "rent to own" at cost to the students (or serve as co-signer), feasibility would dramatically improve. A co-signer is also liable to pay the loan if the primary does not; contracts could be made that the underlying assets would change ownership to the co-signer if that happened. For undergraduate students getting any loans without an external co-signer would likely be infeasible.

For a scenario with outside funding, if the land parcel and plot improvements were instead paid for by external funds (e.g. donation), the effective "investment" yield of the donation, per year, in student assets built, is 30 to 45% per plot per year (rent student would have lost otherwise - their student house loan interest expenses), for students with poor credit (and yield increases as house loan interest rates decrease).

Table 3: Per student/person house+plot improvements (H+PI) loans monthly payment; monthly pay increase required for discretionary income after all housing costs to be same as if renting university housing; and resulting assets (H+PI).

Credit, Loan term (Plot type)	**Loan monthly payment** (in thousands $USD)			**Monthly pay increase required for discretionary income after all housing costs to be same as if renting**		
Poor Credit for Loan	Studio	1 Bed	1 Bed 2 Lofts	Studio	1 Bed	1 Bed 2 Lofts
5 year term (2 house shared plot)	1.422	1.751	2.449	.351	.680	1.38
7 year term (2 house shared plot)	1.318	1.623	2.258	.247	.552	1.19
Good Credit (or co-signer with)						
5 year term (2 house shared plot)	1.323	1.566	2.171	.252	.495	1.1
5 year term (1 house plot)	1.678	1.921	2.526	.607	.85	1.45
	Asset Gain after payoff			**Comparison: Asset Gain if just had pay increase, rented, and saved extra pay (poor credit, 5 year term)**		
Asset Gain (shared 2 house plot)	63.25	75.25	105.25	21.06	40.8	82.68
Asset Gain (single house plot)	78.50	90.50	120.50	*(left blank; poor credit 5 year financing for single plot infeasible)*		

-Assumes plot land gifted; if not, a no-interest loan from land buyer would add $.073k over 5 years for two house plot, $.146k if single

5.2.1 Land. With several years of work by a new faculty member in computer science, or facilitated by other fundraising, a downpayment for a loan for the 20 acre parcel or larger parcel has some feasibility. Private land loan issuance prefers larger downpayments of 20-30%, which is $35-52k for 20 acres and $47.5-142.5k for the 124 acres. There are USDA government loans which could have lower interest rates and even no downpayment but have more legal complexity, often shorter terms, and restrictions. Private land loan interest rates are higher than house mortgage rates. In 2022 the first author, with an offer letter showing an annual salary of $95k, qualified for a 15 year land loan for the 20 acre parcel with monthly payment $1.27k and downpayment $47.5k, before starting as a new assistant professor at UMaine in Computer Science. For 2024 local bank interest rates, the monthly payment would be $1.57k [59].

5.2.2 Tiny house loan. There are all-electric tiny homes by a reputable manufacturer in Wisconsin in studio (48k [56]) and 1-bedroom sizes (60k [57]), that have some feasibility, particularly for graduate students, with financing not requiring a downpayment. We chose mobile tiny houses to give students optionality to stay at the end of their education, relocate, or sell at cost their house (and/or land) to a new student. A recreational vehicle (RV) loan secured by the tiny house (like how a home is collateral in a traditional mortage) has the lowest rates, with the high end for poor credit at 13.74%. Another option is an unsecured personal loan; for excellent credit, the rates are similar, for example, 13.99% for a 1 bed + 2 lofts larger "tiny" house 400sqft sized potentially for a couple with one child (90k [58]). Critically, the example tiny houses modeled are also certifiable as recreational vehicles so they can qualify for a lower-rate RV loan. Unsecured loan rates are quoted from Lightstream, although peer-to-peer loan marketplaces might have lower rates. While not in the table, the 1-bed plus two lofts 70k [55]) eOne model is the lowest cost per usable square foot; versus the 60k it costs 17% more ($200 more per month), but without a downstairs bedroom/office area with closeable doors (less suitable for two adults with a child).

We also discuss in our limitations that there are less certain but lower cost and more sustainable house-building options, especially when labor is done even partly by the owner. In general more permanent immovable housing is cheaper to build and finance at lower interest rates. Tiny houses do enable lower coupling and might act like physical seeds for people to move and start a new transition seed space.

5.2.3 Succession-1 Plot. Our overall analysis uses $15.25k per student, the midpoint of the range for improvements for an orange plot with the maximum two tiny houses, paid via an unsecured loan with no downpayment. Costs for plot expenses (e.g. septic, road, concrete pad for each house) include labor and materials and are from conversations and quotes from local service providers contacted by the author in Fall 2022. The range for minimum plot improvements is $24k to $36k for the lowest cost road, i.e. $12-18k per house for a plot with two houses; this includes: septic $5-15k, road $7.5-28k, concrete pad for house $3.5-4.5k, and agricultural improvements $5k. Agricultural improvements (permaculture, agroecology, etc) are order of magnitude estimates for material costs (seeds, trees, share for community tools, earthworks) without labor (we assume student residents, faculty, students, and local community members will do work for learning, share of yields, and/or volunteer). Each plot can have an added "accessory dwelling unit" pad to have two houses on a plot. These costs can be paid and done incrementally with two plots sharing each road segment. This could potentially be lower if labor costs were supplemented with volunteer labor. The longest lasting concrete road costs the most, while asphalt road types can be done at the low range (gravel roads would be cheaper but current Orono zoning requires asphalt or concrete). The road quality discussion here is included as an example of one of many sustainability trade-offs in the design imaginary which are also restricted by zoning regulations and a compromise for feasibility.

Alternatively but with less certainty, there are also specialized federal, state, and non-profit grant and loan programs for low-income and rural home and land development financing that might provide much better terms, even with no downpayment. For example, the address is in a qualifying area for 2 year loans for development of housing sites (plot improvements) for low to moderate incomes 50-110% of median income; for 2022 that was $26,219 to $60,303.7 annual income, each for individual lots [65]. However, loans beyond "buy or build a house" have significant other requirements and restrictions for the types of land improvements. For building small permanent houses, including self-built housing, the programs are much less restrictive. Tiny houses might still qualify since they now comply with local code and permits in Maine but that is uncertain. We have not gone into more detail here as there is enough uncertainty to require domain-specific legal expertise and ultimately actually trying to obtain funds through those mechanisms [48, 64].

5.2.4 Student comparison with university student housing. We calculated the student monthly pay increase required for their monthly discretionary income after all space housing costs (house & land improvements), to be the same discretionary income as if they rented university housing (monthly .898k undergraduate, 1.02k graduate [61]). Table 3 shows pay would need to be increased by ~$350-800 per month for a studio or 1 bed house. This is in the realm of feasibility just by paying them 40 hours per week during the summer instead of 20 hours per week (which is equivalent to an annual pay increase of 25-33% (3-4 extra months of pay in the summer)); at UMaine that is equivalent to an extra $587 per month spread out over the year. See Table 3 bottom for a comparison of assets if a graduate student instead was paid more and saved all that extra pay. A valid critique here is that, even just renting, student incomes are already rent-burdened and should be higher, particularly for students with children, needing to support family members, extra costs due to disabilities, and other factors.

5.2.5 Faculty comparison to buying a house. If one faculty person was willing to live like a graduate student for a few years, it is feasible to start the space using a significant amount of their income. We base this on the accelerated 7 year land loan payoff in Table 1. It would take 1.8 years to save $2k per month for the land downpayment, assuming a monthly budget of 3.3k versus 5.3k in take home income. After starting the space and moving to an individual plot, they would worst case live on monthly discretionary income after housing costs of 1.3k (similar to / in solidarity with local graduate students, who have $1k). However, in the USA faculty usually increase their salary with "summer salary" paid via research grants; in the UMaine case spread over the year that would double faculty discretionary income to $2.6k. If instead the land was purchased with outside fundraising e.g. twenty people giving 9k each, the faculty member would not need to pay $2k per month for land loan.

In comparison, if the faculty member bought a $300k house with the same downpayment and lived on the same discretionary income, they would pay off the house in 7 years and own a $300k asset, versus with the space at the same monthly payment, they'd have $173k in assets, a difference of asset gain roughly equal to the land given away (modeled as $113k) plus $15k in higher interest costs. The assets would be a $90k tiny house, a single orange land plot and improvements, and half of the Forest & Agriculture zoned land ($52.5k). From a non-financial lens, there could be a lot of meaning and joy, and also stress and added time and emotional labor demand, for coordinating and forming the space, although some could overlap with research.

6 LEGAL AND POLICY FEASIBILITY

6.0.1 City. The proposed tiny houses, sub-division, and land uses fall under existing zoning laws. Critically, local laws do not restrict dwellings being counted as houses based on minimum square footage (a common issue even if tiny houses are considered legal).

6.0.2 University and research grant funders. The student pay increase via paying 40 hours a week during the summer (or all year) appears feasible based on existing funder and university policies. There are policy barriers to paying students post-doc or higher rates at the grant funder level, but university policies tend to only set minimum pay levels for students. While anecdotal, during job interviews at 7 North American institutions we asked chairs and deans about paying students more and nearly all said it was doable - at one there was an inability to pay more than union negotiated rates to grad students (despite the many other benefits of unions). The first author was successful in paying a graduate student at 40 hours per week during the summer at UMaine, which to their knowledge was the first time that was done there. While we could not find any surveys, other North American schools such as University of Washington do pay CS graduate students double rates during the summer frequently.

For grant funders, there are often "reasonable rate" provisions for salaries; if challenged for computer science students it could be argued using the relatively high starting salaries in industry, to pay similar rates. Searching policies for NSF and NIH grants and consulting the UMaine office of research grants, we could only find a strong limit in NIH grants. Even in those cases "rebudgeting" the grant by the department is commonly done to pay more [63], with the limit actually being first-year postdoc pay [40].

While our feasibility analysis did not require this technique (as one can write higher salaries into grant applications), in principle one can redirect grant overhead savings via using non-university owned office space on the seed space. For UMaine the off-campus overhead rate is 26% (of the entire grant) versus on-campus 47.7% [62]. That could be a large source of funds for increased student pay. On the university policy side, even if there were restrictions on per hour pay, a potential avenue for feasibility is to justify the increase as pay for more hours per week, for example 40 hours per week per student instead of the on paper"20 hours" per week status quo (which graduate students routinely exceed anyways). It is illegal to tell graduate assistants to work more than the hours they are paid.

For grant funders, rent payment for the student's housing as a home office workspace is explicitly unallowable, but if an explicit office space (or general community space) was built, there is some possibilty that the grant could pay market-rate rent for that to a non-profit related to the seed space, which may avoid conflict of interest compared to property owned by university faculty. Rent payment from grant funds is an allowable direct cost in NSF grants (see C.3 here [43]); for example, paying for field research offices.

7 ANALYSIS OF DESIGN FROM JUST SUSTAINABILITY DESIGN PERSPECTIVE

This section is our attempt to perform an initial analysis and justification for the design, using principles from the just sustainability design framework [6].

(1) **Constructive and critical:** Reorients design of debt-forming education systems to empower students as owners, making space for transition, and for local community needs and groups, including indigenous people.
(2) **Systemic:** Considers what is in the system and outside the system. For example, we make space in Succession-2 for space for undergraduates to build housing, as faculty and grad students indirectly depend/extract from undergraduate tuition flows. For some systems the status quo extracts from, we make at least space for that population/group extracted from, and also witness and explain why that space is there. The initial 20 acre community up to Succession-2 is roughly below the space limits for potential food production based on 16 acres (6.4ha) at 3-8 people per ha of mature temperate food forest [44], but not for energy and other external material and financial consumption flows. Our modeled student plot size of a .67 acre orange plot with two students each, is barely within the high end of that food forest production range but probably a little over it when accounting for uncertainty.
(3) **Dialectic:** In our analysis we focused on material and pragmatic feasibility, and economic empowerment. The way this paper's framework engages with other positions and ways of reasoning, is to have land for people from different areas and epistemologies, having agency with that land. But some groups may not want to own land directly, and instead prefer to be part of a governing body for land that is shared or otherwise governed by, for example, indigenous principles. We haven't engaged deeply with indigenous people yet, and are going through that dialogue with respect and humility, acknowledging settler positionality and the history of white people expecting them to participate in projects that may or may not benefit them. In this work we are still beginning to engage with critical friends [36] (for more see [6, p.128]).
(4) **Diachronic:** The design is considered through time, transitioning in shifting towards ideals and change in values. For example, most of the land space is for the future and communal processes to consider and decide later while being used sustainably for yield in the meantime without strongly restricting future use.
(5) **Contingent:** The design narrative is aware of its frankly more capitalist leaning analysis and focus on cost and legal feasibility. It is "a proudly incomplete project, fashioned to learn and evolve." [6, pg.216].
(6) **Legitimate:** The design attempts to balance internal needs serving "legal owners" and broader community including indigenous, by organizing different parts of land for those purposes and value systems. The space needs a constantly evolving design process. A base justification is that material emancipation in a capitalist system requires becoming owners of material assets or structures. It is unclear at this time to us how to make newer arrangements practical e.g. a community land trust and balance precarity, that those in control of the land trust could remove and evict people from land. Our way to justify design choices without a "correct choice" is to have multiple design choices for the design community stewarding different parts of land. Before implementing any design, members of each of the communities should be involved, especially the indigenous community.
(7) **Reasonable rather than rationalist:** Computational design will be experimented with and one of many voices and eyes [5, 9, 46] with which to perceive and grow ecological relationships of mutual aid and cycles. By over time increasing the local sustainable production component and systems relationships, the "argument" made will be whether it actually works in practice. Part of this could be reified in dissolution structures in a community land trust if evaluations at specific points in future time do not align with values of sustainability and ecology, which is an attempt to reify ecological needs and health of the land, plants, and animal stakeholders.
(8) **Replicable, rather than repeatable:** The community design tries to empower members to have assets like mobile tiny houses to then spread and attempt to replicate the design process again. The design for spreading does not include legally linking the "parent" community structures with seeds that fix and force perpetuation of its structure.

8 JUST SUSTAINABILITY DESIGN AND COMPUTING THE EDGE COMMUNITY MIGHT ENABLE: RESEARCH AND NEW PARADIGM DEVELOPMENT

From the LIMITs community there are already many ideas and extensions of ideas that could sprout in the transitional edge space.

The space could serve as a "test kitchen" for edge and transitional technologies, to allow more radical, uncertain, and risky experimentation than is sometimes politically feasible or ethically appropriate [12]. There is a tension with navigating established practices, existing values and practices (often hard-won sophisticated values that should not be ignored), and power in doing computing research for building systems; the edge space could afford broader creativity while including "is this really useful" and living and experiencing unintended consequences of ideas. The space might use technologies before crises required them or enact crises and harms. The failure of certain technologies could be intentionally demonstrated to create stronger counter-narratives. The space might host transitional housing for computing practitioners that were too radical in practicing "technology development as politics by other means"[53]and lost their job, or find other ways to serve as a psychological back-up plan and sometimes material safety net for exploring transitions.

As a concrete example of transitional technology to experiment with, the space design process might draw on computational design and simulations for successional land use design. For example, computing part of the restrictions present design decisions will place on future design decisions in later successions. Such a system might notice and recommend to instead make a larger centralized septic system for the initial housing and permaculture focused Succesion 1, so that future more dense community spaces can be permitted, instead of making individual septic fields obsolete and interfere with future agroecological design. By using these methods for actual projects in the seed space, this research might avoid or lessen recruiting external land partners and putting risks onto them. This work could also support computational tools for searching combination of land availability and regulation, location and transportation networks, community networks, and university locations, to enable new edge spaces like this one and other kinds of transition spaces.

The space could be a site for replication of prior work and adaptation of prior work. Traveling exhibitions of design research objects/installations and design worshops could be hosted at the space and University of Maine, and the space could be a site for a small-scale solar project and be a site for remote graduate education [54]. Urban designs could be adapted and tried in rural settings [7]. The space could facilitate work engaging with questions raised by design imaginaries and critical analyses of LIMITS work; for example, how to integrate place-based, bio-regional, and planetary views of transitions [27].

Residing in or visiting the space could facilitate longitudinal work on inner transition, mental health, care, and support, being a site on the edge of the possible. Inner work, care, and pathways to caring are required when realizing the scope and scale of our sustainability and climate crisis [13, 19, 53].

Beyond individual areas and ideas, the transitional edge and succession space might be soil for new paradigms of sustainable computing, just computing design, and applied sustainability and environmental justice transdisciplines. These might emerge at the intersection of student, indigenous, local community, animals, plants, soil, mycelium, ecology, faculty, and academic research spaces.

While computing as a transdiscipline needs to both work with and defer to expertise in sustainable production systems, such as indigenous knowledge systems, well-being and health, and food systems and agroecology experts, how much more richly might computing practitioners transform and reconceptualize sustainable computing by having the same kinds of landed experiences that were essential for people like Bill Mollison and David Holmgren to grow beyond their more traditional Western thinking and conceptualize permaculture? Major learning theories such as constructivism and communities of practice say people need to construct what they learn through experience. Speaking personally, my own relating and understanding of permaculture and sustainabiilty has depended upon acting on it through (hobbyist at best) work in my lived gardening practice.

Perhaps sustainable computing cannot be conceptualized or practically emerge separately from an intimate connection to land [4], place-based flows of energy and materials [37], and lived experimentation with transitions of the scale needed for our ongoing crises. There are no sustainable processes without conceiving of them in a place and an ecology.

Residing in the proposed space, even if not fully self-sustaining in practice, could unlock peoples' thinking and ability to conceptualize new ideas and do work beyond the constraints of existing economic and political structures. In the space people are definitely not independent of existing economic and political structures, but it is a space where one might think: *well in principle I could just live here in this community and be fairly self-sustaining if my circumstances really required that. I can worry less about how the status quo will react and do more radical work.* Even without achieving that sustainability in practice, the "in principle" feasibility might help unlock our thinking and ability to conceptualize new things and systems beyond our existing sociopolitical ecologies.

Beyond specific types of sustainable computing research and continued new paradigm development for sustainable computing and just sustainability design, the transitional edge spaces could produce seeds to materially propagate. For example, if a student used the housing construction building (from Succession-2) to build a tiny house, then graduated and got a job somewhere, they could more easily start a new space there by bringing their tiny house.

9 LIMITATIONS AND CRITIQUES

The design imaginary is limited by focusing on more capitalist logics. It does not consider the constraints and possibilities in urban spaces, due to higher land costs. It does not engage with repurposing existing university-owned land, or other more distributed forms of sharing or access to community-owned land that may be better even if more politically uncertain to start. The imaginary stays within legal boundaries, versus transition spaces such as guerilla gardening and urban foraging.

To increase potential replicability of the design, our analysis included a scenario for a single new faculty person starting the space, something that did not assume gift, existing family support, etc. Even within that the creation of new faculty jobs in computing is a systemic bottleneck for replicability. Fundamentally any transition space community design is coupled to larger existing systems.

In practice outside funding and grants should be pursued. Alternative financing mechanisms internal or external to the transition seed space would also help improve access. Faculty bootstrapping is not required, and can be augmented or replaced by other people and groups via loans or gifts supporting land acquisition, plot improvements, etc. We did not model potential mechanisms like revolving loan fund pools with lower interest rates. Lacking expertise in financing structures, this paper has likely not considered better alternatives.

For the cost feasibility analysis, we assumed loan approval given rates available online. While we used common debt-to-income ratios used by banks, we could not make fake loan applications with nominal student income and credit scores to test approvals. Minimum incomes are not published usually by lenders, and incomes can change the interest rates quoted. This can be somewhat mitigated by co-signers with better credit, who also assume the risk of the loan, but many people do not have access to that.

To participate in a new space like this would feel and be stressful and risky; care and mental health support structures should be designed more explicitly [53]. Students often drop out of graduate school. While there is prior work on structuring community land trusts for people coming and going, the potential high rate of this needs more design. A student might sell their tiny house back to the seed faculty member(s) or seed space non-profit, who would float servicing the debt until a new student enters. Hopefully with more security and connection with land and many communities, students would thrive more, find more meaning, and have less mental illness. Having trial periods before house purchase, application criteria and processes that included passion about the sustainability crisis and other factors, and other prior community mechanisms can help but this is still a major challenge for design. Marginalized and underprivileged students should especially be designed for and accomodated by those processes.

In the design students have access to land but there is nothing in the design requiring them to do agroecological labor/production on the land. They just have the option. None of the feasibility analysis assumes for feasibility the land is being agriculturally productive. For example, a community group could run the U-Pick food orchard similar to how community groups run shared gardening space.

While tiny houses are legal under zoning laws in this area in Maine, tiny house legality varies within countries, and buying tiny houses is comparatively expensive, less sustainable, and energy intensive versus the many alternative sustainable building methods which are more permanent (such as hempcrete, or even aircrete domes, as an example of what can be suprisingly possible). These alternative methods do present more permitting challenges and require more labor and training to use. However, those could dramatically increase accessibility for undergraduate students and less privileged students. The Succession-1 design experiments with these during summers and for building office space, and Succession-2 might implement them (potentially financing them by selling the tiny houses). However, placing that in stage 2 is an example of balancing trade-offs which is a value-laden process affected by our positionality and lack of knowledge. Ideally students could decide this with mentorship, but would likely lack expertise, confidence, and certainty without proven local examples. Sustainable building methods are also highly climate and site specific. There are also more traditional non-moveable building methods designed for labor learnability and ease of building via standardized parts, for example, the Seed Eco-home with a 1,300 sq ft 3 bed 2 bath build materials $60k with a “swarm” build in 2 weeks with 15-30 people (mostly novices) depending on size and experience [15].

Loan-based financing is vulnerable to interest rates, and although peer-to-peer lending is a possibility for increasing access, central bank interest rates and loan practices in our capitalist system will greatly affect feasibility and present risks. We updated the analysis done in Fall 2022 for loans and interest rates, and with the increase to current levels it got less feasible over time, increasing loan payments about 20-30%.

Structurally, students’ tuition is a source of funding for the space through faculty and graduate student salaries related to teaching, which can be unjust. The design tries to account for this via space in later successions for undergraduates build tiny houses on site even if they may not have space to live there. The design might be improved by more space specifically for undergraduates, especially prioritizing indigenous and other marginalized undergraduates.

10 DISCUSSION AND FUTURE WORK

Within the paradigm of just sustainability design, the design imaginary in this paper is a systemic attempt to expand the system of education for computing, involving computing and computing research, to include asset building to build agency for students and local communities within existing capitalist systems. It also centers place and landedness to build soil for new computing research and continued new paradigm development for sustainable computing and just sustainability design. Our initial cost and legal feasibility analysis found:

- **Partial feasibility without outside funding** - a single new comptuer science faculty person could buy the land and use a combination of barely feasible ways to increase student pay to qualify for loans by paying them for 40 hours per week instead of 20 hours per week.
- **Significant feasibility if co-signers or third parties took out a no-downpayment loan then rented at cost to a student over a 5-year term** - a student could keep the same discretionary income vs. renting with a feasible half or full summer paid at 40 hours a week, **graduating with $63-75k in assets**.
- **Significant feasibility with outside funding paying for land and plot improvements, and competitive returns on donation of 30-45% per year.** If the land and plot improvements were donated, students with a full summer paid at 40 hours per week could qualify for house loans independently. The effective return on the donation “investment” would approach 30-45% per year. That is a lower bound that assumes zero agroecological production.

While it seems normal for students to graduate with few material assets, our design shows how we might create material assets to support students and student agency after graduating. If graduating students owned their own housing and had land for sustainable production, they would have more options to do sustainability work. They might feel more safe to take risks and do more unconventional work. Would that be more just for our students? How might that influence the work done in our fields and systems of research? Could moving to a rural university in your country have unique advantages if it enabled having a seed space like our imaginary, for your students?

While this analysis takes place in the US neoliberal context which is extreme, the differences are a matter of degree. Even in Europe, students graduate with no or few financial and material assets. Without those assets, in our capitalist systems, one must often participate in current unsustainable systems via employment, posing limits on what students can do after graduating. Even in exciting sustainable computing courses, our students can struggle with this gloomy prospect that they want to help the planet in some way, but they will need a job. They will need to pay down their mortgage and any debt. But in spaces like our design, on a very material basis they can be more free in their actions.

What’s the version of this work that leverages community resources better instead of starting with buying land? Students in new backyard ADUs or renting a little but their rent goes towards funding a community project? There are many existing distributed community approaches that should be considered and integrated to expand the imaginary, such as permablitzes [2] (like a day long barn raising but for a garden), which also yield community, learning, and hope building.

Let us consider a model for seed spaces with more feasibility at urban universities. Other work has mentioned a prioritization of perspectives from the global north [14] (which this paper falls into); let us consider some of the potential for the key ideas now, that future work might explore with those people. In our design imaginary, students move to the space, but instead they could stay at home to earn more assets and do work in their local community, especially students from the global south and other places where a remote graduate assistantship salary in local terms could go farther. Faculty and university programs might relax constraints for their students to need to live nearby, exploring variations of remote and in-person that would enable students building housing assets or other exploration and engagement with rural and urban-rural edge communities. For example, the first two years of a PhD in person, the rest flexible. This is an inversion of ideas from nomad lifestyles of "wage arbitrage" where people from the global north work remotely from places in the global south. Would students be interested in that as an option? One constraint is many government research funding programs are nationalist and explicitly restrict funds going outside the country.

Should we perhaps advise undergraduate students and prospective graduate students interested in research to instead work for a few years at a high salary, save money, and then have more assets and potentially more power through financial security like owning and paying on a home during graduate school?

While this paper's design imaginary is particular, at its core is a more general idea for designing at the systems level: expanding our research mindset from depending on academic institutional funding flows for research, to include building assets that enable us to do research - similar to changing from fertilizer-intense farming, to building soil and crop rotations that don't require external inputs. For example, the financial flow engineering in our design imaginary applies the permaculture design principle of retaining nutrient and energy flows - instead of having grants pay student salaries that then flow out via rent to landlords, our space retains that into student housing assets and land.

We see exciting work ahead trying to design with the key idea of material student empowerment from the design imaginary, applied in cities and other less rural areas. What other creative ways might exist to support students and sustainability work, that we already have the power to do, but haven't realized or thought to try yet?

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