

# Photovoltaic Imagination: Solar Strategies for Community Integrated Research and Graduate Training

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## ABSTRACT

Achieving a just transition to climate positive energy systems while meeting the United Nations Sustainable Development Goal (SDG) 7 of ensuring “access to affordable, reliable, sustainable and modern energy for all” will require fundamental reimagining of contemporary energy systems. As with other sociotechnical imaginaries, the material and discursive infrastructure that underlies these systems is both deep and expansive, challenging efforts to envision and enact alternatives. This paper describes a unique, ongoing, project between the University of Toronto, University of Edinburgh, and Concordia University that combines critical making practice, community engaged research, and graduate student training to unsettle prevailing energy imaginaries through situated engagement with small-scale solar technologies. Through detailed discussion of this planned research and related work, we contribute to LIMITS research in transitional systems, solar imaginaries, justice, maintenance and repair, and graduate student pedagogy.

## CCS CONCEPTS

• **Human-centered computing** → **HCI theory, concepts and models.**

## KEYWORDS

energy transitions, solar, speculation, community-based research, pedagogy

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## 1 INTRODUCTION

This paper describes an early-stage collaboration into the politics and social life of transitional energy systems between scholars at the University of Toronto, University of Edinburgh, and Concordia University. The project aims to use community-based research projects in each of the three locations as a means of examining how solar initiatives can support alternative energy imaginaries. In particular, we seek pathways that don't assume electricity is limitless, ubiquitous, or always available. Rather than viewing the constraints of such systems as deficits to be overcome, we instead view them as generative interventions that afford the opportunity to explore alternatives to dominant, unsustainable energy imaginaries. Our overall goal in the joint project is to reconsider solar energy from a socio-technical perspective, using the design, development, and dissemination of 'solar strategies' as the means to explore community-oriented research.

While each project differs as to planned outcomes, community focus, and the technical systems that will be used, three main themes orient the work. First, we are all interested in exploring how solar energy systems operate as a site to rethink abundance. Key starting points for this theme include thinking of non-abundance of energy and the limits this imposes not as a response to a crisis that will eventually be resolved, but as a steady-state for future design [23]. Second, we understand this work not just as part of a process of 'solving problems', but as a broader exploration into relations between researchers and communities. As such, the project is part of a reimagining of graduate student art, engineering, and design education at each respective university, focused on building structures to facilitate engagements between communities facing SDG related challenges and graduate students. Finally, rather than seek to produce broadly generalizable knowledge, we treat the contextual and locally-specific character of our findings as resources for expanding our knowledge of varied design settings, and for managing contradictions in design goals between issues such as affordability, cultural appropriateness, and environmental impacts [38].

In each of the research sites, these projects use design research interventions as a means of exploring the transitional energy systems and creating graduate student training experiences. In Toronto, the team is planning a co-design project with TechFugees Lebanon that may support digital employment opportunities for some of the

3 million displaced people in the country. We will explore socio-technical solutions for developing reliable, off-grid solar power necessary for remote work, using “generative justice (Eglash 2016)” as a guiding framework. In Edinburgh, the project is collaborating with a charity installing rooftop solar in order to explore transition to decentralised and commons-based electricity networks. In Montreal, the team is conducting novel experience design research into artefacts such as solar-powered webservers and gaming systems. All studies consider solar limited digital media as a tool for experimenting with alternative social interactions and imaginaries which are otherwise tied to the ideologies of inexhaustible power instantiated by the modern electrical grid.

This paper offers an overview of the project, currently in development, and a discussion of how the research connects to broader themes of the LIMITS community. We begin with a short review of SDG 7 and other relevant research. We then describe the project design and offer three speculative vignettes that provide rich descriptions of the settings at each of the research sites. The vignettes were written and discussed by the authors as a way of helping our team come to a joint understanding of the project, as well as communicating some of the complexities and stakes involved to readers. In the final section we draw on these narratives to discuss the contributions of this work to LIMITS concerns regarding transitional systems, solar imaginaries, justice, and graduate student pedagogy.

## 2 BACKGROUND AND RELATED WORK

At present, the world is not on track to meet SDG 7’s target of ensuring universal access to clean energy. Current estimates indicate that 759 million people lack access to energy, many of whom are in Sub-Saharan Africa where some evidence suggests that this number has increased in recent years [1]. While there has been marked growth in the deployment of clean energy technologies, the percent of solar, hydro, wind and other renewables in the overall energy mix has stagnated around 17 percent. Meanwhile, global improvements in energy efficiency have stalled (*ibid*). In response to this lack of progress, the United Nations launched A “Global Roadmap for Accelerated SDG7 Action” in November 2021. The Roadmap calls for tripling of global investment in renewable energies, rapid decarbonization of energy systems in order to meet the 1.5 C goal of the Paris Agreement, and sets forth a number of ambitious new targets and milestones. As is common in such documents, the solutions to these challenges it identifies are a series of financial and technological fixes [9, 18].

In alignment with prior work at ACM LIMITS [2, 26], this project examines the transitions necessary to achieve sustainable development goals while mitigating the worst impacts of climate change as socio-technical processes. Indeed, scholars of science and technology have for decades argued that energy systems are inherently bound up with, and give rise to particular forms of, social and political life. In Winner’s well-known argument, for example, he warns against nuclear energy, not because of the long term environmental consequences of waste materials, but because of the risks that the large-scale investments and centralised planning required for the construction and maintenance of such systems may lead to authoritarian forms of politics [40]. In contrast, he advocated

for small-scale, disintermediated [23], forms of energy production. From a similar perspective, Mitchell’s study of the political history of fossil fuel production identifies particular material characteristics of coal supply chains, namely worker’s ability to blockade them, that helped give rise to the labour movement. He argues that the elite backlash against this rise hastened global uptake in petroleum and contributed to labour’s eventual decline [22].

The participatory and interventionist research carried out at each site examines, at multiple scales, photovoltaic imaginaries—the forms of politics and social life that arise around small-scale solar projects. Here we draw on Jasanoff and Kim’s definition of socio-technical imaginaries as “collectively held, institutionally stabilized, and publicly performed visions of desirable futures, animated by shared understandings of forms of social life and social order attainable through, and supportive of, advances in science and technology [14].” Our research approach draws inspiration from similar studies undertaken by members of the LIMITS community [2, 26] as well as broader movements in HCI and design such as inventive methods [39], critical fabulations [31], and reflective design [32]. The project leads have each carried out community-based research on related topics; design practices of energy futures [38]; critical making and participatory design for at-risk communities [27, 28, 30], collaborative research with disaster-affected communities [34, 35], and hybrid social and technical pedagogies [29]. For each group, technical forms of practice, design methods, and humanities-based reflexive scholarship are blended in ways that encourage novel creative and critical outcomes.

As noted above, our individual and collective goals include pedagogical change within our respective institutions. While each of the team leads have engaged in community-based research, one goal with this work is to more substantially embed these types of projects within the pedagogical structures of our institutions. This follows in the tradition of a number of prior LIMITS papers, which have used graduate and undergraduate coursework as a means of exploring topics such as global disruption [37], the material consequences of computing [20] and the Capitalocene [5]. In our case, we intend to explore how research partnerships that include community organisations can create pedagogical opportunities for graduate students relevant to LIMITS themes.

## 3 PROJECT DESCRIPTION

The Photovoltaic Imagination project addresses a need to develop training for graduate students enrolled in programs that address complex societal challenges like the SDGs. In our view, any contemporary study of such challenges requires researchers to reconsider their approaches to the subject, through interdisciplinary approaches as well as sustained engagement with communities already addressing these concerns locally. In each research site, our team is currently developing relationships and research programs to these ends.

In Toronto we are exploring the development of a co-design project with a non-profit organization called Techfugees Lebanon. Lebanon hosts approximately 3 million displaced persons nationwide, many of whom are unemployed and in precarious situations. Techfugees Lebanon launched in 2019 with a goal of supporting digital employment for Syrian and Palestinian refugees in the country.

They have provided training and access to remote data labelling freelancing opportunities. However, due to frequent electricity and network blackouts, workers often have difficulty meeting the expectations of employers in Europe, US, and Canada. Our project will collectively develop socio-technical solutions intended to provide at least two forms of value. First, we will work to provide more reliable access to electricity for charging laptops and cellphones through small-scale solar. Second, we will explore what kinds of solutions produce outcomes consistent with forms of ‘generative justice’ [8] that maximise the agency and capability of Techfugees Lebanon. A starting prompt for this work is to consider how solar energy and charging operates as part of a non-abundant energy ecosystem rather than as a way to ‘fill the gaps’ in access caused by disruptions.

In Edinburgh, the project team is focusing on the social aspects of solar technological implementations, in their partnership with Edinburgh Community Solar Cooperative (ECSC), a local charity fostering community-led energy generation through facilitation of solar panel installations on rooftops across the City. The primary goal of ECSC is to allow communities to participate in, and assume some ownership of, decentralised infrastructures that contribute towards the City’s Net-Zero targets for 2030. In effect, the approach harkens a return to “the commons”, but done so with novel twists including integration with pre-existing centralised, energy infrastructures, and a definition of community situated around socio-technical artefacts and their placement, rather than urban and architectural geo-technical spaces. This project challenges conventional, “solutionist”, approaches to design interventions, and examines how community-oriented, design transitions might occur as communities and institutions move away from centralisation, either by choice or by imposition. In doing so, we will explore how design practices situated within and amongst communities might address a new approach towards a 21st century energy commons, unsettling our dependence on centralised infrastructures and exploring experiential narratives as a source of knowledge for collective design decision-making.

The Montreal project focuses on the idea of solar media through a series of prototype installations that explore solar powered experience design without the mediation of batteries. The use of batteries obviates the sun as a discrete power source since in principle batteries can be charged by any number of sources. Thus in the solar media project’s prototype solar web server inspired by the work of Labomédia (<https://labomedia.org/>) and Solar Protocol (<http://solarprotocol.net/>), the server will only be operational with a minimum threshold of sunlight. As a result, patterns of access and use practices would have to adapt to these conditions. Another prototype being developed with Alex Custodio and Michael Iantorno explores the same idea, but rather than projecting solar media as a constraint on users we instead develop its affordance as a pleasurable game mechanic. Using low power gaming devices (the Nintendo Game Boy Advance) hacked for solar power, we are designing a game which can only be played in ample sunlight and which leverages the players location in space and time (in accordance with the location of sun) as part of the game’s appeal. Both of these projects consider solar limited digital media as a tool for experimenting with alternative social interactions and imaginaries

which are otherwise tied to the ideologies of inexhaustible power instantiated by the modern electrical grid.

To support, connect, and build upon activities at each research site, the project is oriented around an interdisciplinary, cross institutional workshop series focused on the design, development, and dissemination of ‘solar strategies’. At these events social imaginaries and technical infrastructures regarding SDG 7 will be shared, explored, and debated using methods and practices drawn from art, design, and engineering fields. These workshops build on current and past projects at each research site, and extend existing collaborations between Edinburgh and Toronto. Our ambition here is to engage graduate students from our respective institutions in developing new insights and approaches to methodologies which recognize, address and critically challenge current norms, conventions and trajectories associated with solar ecologies and economies, which are often predicated on “solutionism”, derived from lack of critical attention.

Five workshops/events are planned for 2021-2022, hosted at three different sites, Milieux Institute (Concordia University, Montreal, Canada); Design for Change Studio (University of Edinburgh); Critical Making Lab (University of Toronto, Toronto, Canada). The sessions involve:

- Introduction and launch (all partners)
- Workshop 1 – Denaturalising Solar Energy practices (academic partners)
- Workshop 2 – Reframing Social Imaginaries (all partners)
- Workshop 3 – Situated Narratives (academic partners)
- Knowledge Mobilisation – Presentation and critique from Community Stakeholders (all partners)

The workshops, seminars and sessions with the community will provide an opportunity for graduate students to gain insight on community-focused design research. It also critically affords the project leads and partners the capacity to engage in a pilot study on design methods courses and supports cross institutional collaborations and shared project work. These workshops will be documented on a project website that will also serve as a portal for maintaining partnerships and collaboration between researchers and community partners across our three locations. If successful, academic publications on community-based research, art and design practice, and pedagogy will be developed through future collaboration between project partners.

## 4 SPECULATIVE VIGNETTES

### 4.1 Toronto - The sneakernet and the pico-grid

With Techfugees Lebanon, we are exploring solar-based solutions to help manage energy access in moments of power interruption. Given the preliminary state of this collaboration, the authors have developed this vignette in a future western context. The purpose of this scenario is not to define the specific socio-technical solutions that might be put in place, but instead to start to development shared narratives and perspectives to help communicate the lives, needs, and aspirations of the individuals in Lebanon with whom we are collaborating. In the below scenario we imagine a future context similar in some ways to that of the refugees in Lebanon, where a highly mobile population exists in the context of risk and energy scarcity.

Asmee looked up from their laptop, bleary eyes turned to the far distant towers of One Yorkville. Elian noticed the interruption, 'hey Asmee, don't forget the deadline on the RBC financial data.' We said we would have the full labelled set sent to them by end of day.' "No worries," Elian looked back at their friend and colleague. "Just refocusing my eyeballs. Everything blurred out for a moment." Just then, a dimming of the already flickering LED ceiling lights announced the start of another power outage. 'Damn!' said Elian, 'that's the fourth today.' 'Don't get worked up' drawled Asmee. "Check the charge state on the solar batteries."

In the year 2025, the electrical grid in the Greater Toronto Area was stretched to its breaking point. Lack of maintenance, copper thieves stealing electrical lines in the middle of the night, and the inability of city planners and Toronto Hydro to keep up with exponential population growth meant that reliable electricity was only to be found in the downtown core, the wealthy neighbourhoods close in, and the condolands that followed the Lake Ontario waterline. Even for those lucky enough to be able to afford to live in these areas, rolling blackouts and volatile costs were the order of the day. Driven in part by the slow and violent death of the petrostates, electricity abundance was quickly becoming a thing of the past.

In the 905, named from its area code, where Asmee and Elian lived and worked, access to power was even less guaranteed. Here, as in most places on the planet, alternatives to the grid had emerged. Some of these were focused on individual needs: people installed rooftop solar panels and backup generators to cover the needs of their homes or offices when the grid went down. Others provided a commercial alternative, storefronts where you could buy a few hours of charging or a pre-charged battery. Mimicking the suburban solution of propane tanks where you can exchange an empty tank for a full one, these stores allowed you to pay just for the power rather than also the storage medium - plus a convenience fee of course.

More community oriented groups created their own solar collectives. Portable solar battery chargers were distributed among the collective, with all members responsible for repairing and maintaining the systems when they went awry. Periodic collections were raised when new batteries or panels needed to be purchased, and membership fees covered the rest. Asmee and Elian belonged to one of these, the appropriately named Photovoltaic Phantoms. With power going down in their area, they would need to be ready to provide electricity for their own needs and, if called upon, to address the needs of others in their collective.

Elian walked over to the window to look at their chargers. Both Elian and Asmee had their own portable set up, each with a 20watt solar panel, connected to a converter that output the +18-20v necessary to charge up external battery packs capable of powering a laptop. Each battery pack could power a laptop for 3 or 4 hours, or charge other devices that used a +5v input, such as mobile phones, speakers, or lights. "We're both full," remarked Elian, "we were lucky to find this workspace with a south facing window." Asmee stretched. "Great, I've got just about 15 min left on the RBC data set, plenty of juice left in my laptop battery to finish up." Elian peered down at his phone. "I'll check this discord server. If no one else needs a powerup, we can use both batteries at tonight's party if the grid doesn't come back up."

The above vignette imagines a space of energy limits, where the abundance of the 'always on' universal grid gives way to more distributed and diverse forms of energy. Storage and generation, in the story above, become part of community and personal obligations, with smaller scale commercial entities added additional capacity. The vignette also makes visible the geographic and economic inequities of energy - the backdrop to SDG7. Again, it's purpose is not to start to define solutions, but to act as a jumping off point in the production of more appropriate and specific narratives that can assist our team in the ideational and eventually materially development of socio-technical interventions in Lebanon.

## 4.2 Montreal - Solar analog and digital play

In Montreal, researchers are exploring novel forms of game play in which solar energy features as a specific game element. Here the goal is not just to imagine new forms of play, but also to use play as a site to explore novel social relations that emerge when infrastructural elements are made apparent to the users. The scenario below extends beyond the relatively simple technical work that has been done thus far to imagine the completion of a shared, collaborative digital game, a specific context in which it is being played, and the ways in which environment, energy, and play are put into a novel configuration.

"Hey Noemie," yelled Liam from the kitchen, "have you reached the fourth energy disk yet?" "Not yet," grumbled Noemie. She stood on his bed, struggling to put her gameboy in the stream of sunlight coming from the skylight. "Playing Solar Quest sucks in Montreal in the winter!! It's too cold to go outside, and too damn hard when the sun is so low on the horizon." Liam came into the bedroom. "Don't be an idiot Noemie! You can't really get much juice from the sun coming through the skylight. Haven't you ever heard of UV protect film!!"

Noemie jumped off her bed. "Fuck!" She scrambled to put on her puffer. "I'm going out on the balcony. Maybe I can get the energy we need there!" "Well hurry up, you jerk." Liam looked back at the gameboard resting on the kitchen table. "The timer keeps counting down and if you can't reach the end of your current maze, we have to return to home base."

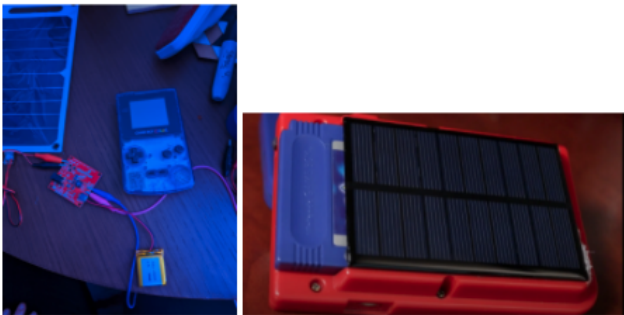
Noemie opened the sliding glass door to a blast of freezing wind. While sunny and bright, the temperature hovered just above -5C. The sounds of traffic and the din of an active city rose up to him. She maneuvered to the brightest spot on the balcony and kicked a folder chair into position. Dropping heavily into the chair, she held the gameboy up to the light and watched as the solar clock ticked forward. "Got it! I'm powered up!" Noemie quickly navigated through the simple maze depicted in black and white on the gameboy screen, reaching the end and revealing the solar disk. The screen blacked out and a large QR code appeared on the small LCD screen. "I'm coming in!" yelled Noemie. "Get ready!" She slid back into the warm room. Holding her gameboy like a trophy, she presented the screen to a small camera built into the game board. A congratulatory message played through its built-in speaker. "Awesome," Liam pounded Noemie on the back. "We can finally advance to the next section!"

The Montreal project is exploring forms of digital experience design which configure a relation between the sun, human actors,

technical intermediaries and social imagination. Challenging assumptions that ‘always-on’ energy abundance is essential for social well-being we look to digital cultural forms such as video games as vectors for imagining and practising solar limited interaction. One of our prototypes involves hacking old Nintendo Game Boy Advance handheld consoles for solar power, removing the batteries, and creating a bespoke multiplayer game scenario using the software tool GBstudio. In order to turn the intermittent quality of local solar power into a source of pleasurable play and social imagination we propose a hybrid digital-analog board game. What if the sun mediated forms of game time that could oscillate between digital and analog play?

Using the hacked gameboy players must seek out or wait for enough sunlight to play a simple maze game on the console. They must reach a series of hidden locations before they run out of power. If they make it to a location they will then unlock an element for a board game they can play in the absence of solar power. The board game will lead players to clues that will help them complete the maze on the console. The play proceeds between solar powered play and analog unpowered play and the players work together to find clues that help them to complete the maze.

A game like this proposes to put players in direct relation to the sun in order to power devices to play the game. Rather than the situation being one of either playing or not playing depending on the sun, our game uses solar power to prompt further play in the absence of solar power with the goal of inviting players to become reflexive about the infrastructural conditions of their experience.



**Figure 1: Solar Gameboy tests, Lee Wilkins, Concordia; Solar powered gameboy project, Houston Museum of Natural Science**

### 4.3 Situated Narratives - Community Energy, Urban Commons. An Edinburgh Approach

In Edinburgh, researchers have begun to explore how solar energy might fit into the specific socio-economic context of power generation and use. The scenario below begins to detail some of the specific ways in which individuals are currently navigating this increasingly complex terrain and how individual and community-led initiatives might operating to assist in energy transitions. Importantly, the scenario does not cast and entirely positive light on the advent of solar solutions, noting in particular the ways in which

current inequities might end of being reproduced in the transition to solar.

It's Saturday morning, and Iain has gotten up easily, strolling down to the corner shop and collecting the weekend edition of the national newspaper with all its special supplements. This is personal time he relishes, as he can lounge in the kitchen as he waits patiently for his first coffee, bubbling away in the large percolator pot, whilst his wife Fiona takes a bit of extra time to enjoy some added sleep. It's a time where he can catch up on global events, look through the mail that's been piling up all week, and reflect a bit about what lies ahead, imagining some projects and home improvements. Lately, though, he's been getting a bit worried about the cost of living crisis that is rapidly embracing the United Kingdom. In the past, such crises seemed to be media hyperbole — after all, both Iain and Fiona had well paying jobs, and no debt aside from a small portion of the mortgage outstanding on their historic tenement flat in Edinburgh's City Centre, and by most measures didn't really seem to be living without. But lately, Iain bemused, this particular crisis felt real. Just this week alone, the utilities company had written to outline that their gas and electricity bill was rising (again), the price of gasoline had reached £1.70 per litre, and his employer had outlined that his National Insurance contributions, automatically deducted from his monthly salary, were to increase by £50 each month. It dawned on Iain, as the percolator pot quieted and he poured his first cup of the day, that his basic household expenditures had increased by close to 10 percent per month, almost £250, in the past half year. And, if the prognosticators in the papers were to be believed, the cost of energy was only going to continue to increase.

He started to think — what more can I do? Energy efficiency could only go so far, he thought — I can't insulate further, and simply reducing consumption seemed more punishment than participation. His phone vibrated; a message had just come through his community social media channel, a small group of neighbours around the block who connected during the early stages of the pandemic to create a network of support. The channel was useful in those early days, a platform for helping each other, sharing necessities like toilet paper and bread yeast (both being hoarded during national lockdowns) and lately the discussions had turned to this energy crisis. Audrey and Anna, a lovely couple, had started a thread about having a wood stove installed and asking for advice. John joined the chat, providing a link to a news article about heat pumps. Samson, an engineer, added some thoughts, saying a heat pump in a communal tenement simply wouldn't work, a better alternative would be a community solar scheme. Angus added that he was interested in this too, noting that the collective rooftops that all the tenement flats shared would seem an interesting place to house community solar panels, if funding could be found. Samson provided a series of links, but also cautioned about the complexity of upgrading a series of flats and their electrical infrastructures from a structural and mechanical perspective. Though the prospect of a local community hub that supplemented current energy practices was exciting, Iain thought about the neighbours who he shared the stairwell with in his segment of the tenement and how difficult it was already to simply agree on keeping the common stairwell swept - how on earth would they manage a collective energy system involving rooftop panels, battery banks and charge inverters?

Iain opened a browser on his phone and pulled on his hot coffee, hearing Fiona wrestling with the cat, who had decided it was time that Fiona should pay her some attention. He started to search for “off-grid living” and found no shortage of advertisements, news articles and instructions on how to set up a home solar system. As he swiped through sites, he started to notice some interesting trends — detached houses with large roofs, massive yards, and often in idyllic rural locations. Is this what had to happen, a move to the country, to make this off-grid experience come true? He continued to scroll and came across a website to an Edinburgh based cooperative, with links to a Scottish Government initiative that advocated for increased participation in community energy schemes. Iain wondered, would his neighbourhood qualify as a community, in order to start thinking about a community energy scheme?

He walked outside, phone in hand. It was overcast, typical Scottish weather. He crossed the street and looked out at his tenement flat, his neighbours above, to either side, and down the street. He started to imagine what these community hubs might look like, where would the panels go? Where would they run the cables? Would battery stores be in each apartment, much like how current utility services were set up now? There must be a better way, Iain thought. Maybe these panels could be a feature of the estate, not the dark, black foreboding slate colour nominally found with current photovoltaics but maybe something more sympathetic, the colour of sandstone, maybe? Or maybe slate would fit into the rooflines, but instead of large panels, maybe they could be an array of smaller panels, the size of slate roofing tiles, all wired together, connected in a fashion that made them part of the building fabric, not some set of appendages bolted on in afterthought. Given the historic nature of the tenement structures and their conservation status, it would be worth examining an aesthetic perspective to future developments of solar and wind power structures that didn't require communities to conform to the technology, but facilitated and intergrated well with the fabric of the existing building stock, which was already tricky to upgrade and retrofit in accordance with City Planning permission. Maybe, there'd even be some plan to incorporate other aspects of infrastructure, like EV charging bays, even bidirectional charging, so that all these parked cars might be able to play in this new energy system, without a need to destroy the character of the street as well as the wider neighbourhood? A whole new world of electrical exchange between people, buildings, streets, cars — the whole neighbourhood infrastructure — was coming into focus for Iain. A place that was less about sustaining individuals, more akin to a village green of the future — a future energy commons that is sympathetic to its situated heritage and the stories of the neighbourhood.

The necessary development of artifacts and devices that can re-articulate our relationship to energy futures and practices of consumption through design fictions and critical making provides us a frame of reference for how individuals may contribute towards imaginaries of our solar futures. These stories are predicated on cultures of empowerment signifying “off-grid” living, and are situated narratives highlighting individual autonomy, and a degree of rejection of our current, collective infrastructures. But social trends indicate that we continue to move towards increased urbanisation

and population densities, as witnessed in cities globally where escape from centralised, collective infrastructures is problematic, if not impossible. What are the implications of these “solar imaginaries” for a large and growing segment of the global population that cannot escape from the grid, but yearn for contributing to a more equitable, and socially just, energy future?

In Scotland, the community energy movement is embedded into government policy, managed by Local Energy Scotland through their CARES Scheme (<https://localenergy.scot>), encouraging local communities and municipalities to consider and supporting implementation of novel energy systems that enable and empower these communities to contribute towards Scotland's overall net-zero ambitions and target deadlines. Groups such as Community Energy Scotland (<https://communityenergyscotland.org.uk>) and Architecture Design Scotland (<https://www.ads.org.uk>) are working with local municipalities to strategize how to best address net-zero transitions and strategies locally, while groups such as Edinburgh Community Solar Cooperative (<https://www.edinburghsolar.coop>) are operating within the city context, making implementation happen.

Despite this extensive support and localised actions, serious questions remain in relation to community transitions, notably that such transitions require a clearer understanding of how we define community, and establishing rules of engagement that benefit everyone. As part of our Solar Imaginaries project, the Edinburgh team intends to engage current communities of energy practices, examining the sociotechnical systems and their associated stories and situated narratives, re-interpreting classic anthropological methods involving “following objects [4, 13, 19]” to reveal novel approaches already being undertaken in relevant contexts to uncover insights and present opportunities to address the complex relationships between individual agency and energy autonomy, national initiatives and energy security, centred around the position of energy justice at community level, notably in environments that involve complex retrofitting of existing urban fabrics and infrastructures.

## 5 DISCUSSION

### 5.1 Relevance to LIMITS

This project will afford us the opportunity to explore several themes relevant to the ACM Limits community. First, the research at each site uses small-scale solar projects as opportunities to explore the socio-technical imaginaries of transitional systems. For good reason, studies in LIMITS have often turned to speculative practice, including art [12] and design fiction [24, 36] as a means of probing such questions. In [24], the authors use this approach as a means of envisioning household responses to instability in the electric grid brought on, in part, by a transition to renewable electricity sources. By narrating how a number of common household tasks such as laundry, cooking, or heating, might be accomplished under several different energy technology scenarios, the paper is able to identify impacts of each scenario on family dynamics, tradeoffs between them, and raise a number of concerns for designers and technologists to address through further work. The speculative vignettes offered in Section 4 are also an example, albeit a more modest version, of this approach.

As our project develops, we will also gain the opportunity to learn about transitional systems through small-scale design interventions in each site. This approach has also been a part of LIMITS discussions of transitional systems. [26], for example, show how experimental “citizen observatories” related to water management in Sweden helped to both surface complexities in water governance that might not have been otherwise apparent, but also form new publics around novel socio-technical systems. We anticipate similar outcomes in each of the sites, as collectives form around solar charging stations in Lebanon, gaming in Montreal, and home micro-grids in Edinburgh. Each effort will create new material and social relationships between people, and thus the possibility of alternative socio-technical imaginaries. Our research will examine these dynamics as well as the potential of such imaginaries for scaffolding transitions towards energy sustainability.

Second, this project builds upon prior work in LIMITS through its use of small-scale, off-grid solar as a means of engaging wider questions about life in a world where materials and resources are not assumed to be abundant. For example, Abbing [2], discusses the redesign of a website that will be hosted on a solar-powered server. Through the research, the author develops a number of design heuristics and recommendations, including the value of static, as opposed to database-driven, sites, the need to support old devices and slow network speeds, and providing options for visitors to read site content while offline [2]. In this case, the specific constraints presented by the reliance on solar power undermine Modernity’s vision of society’s domination over nature [21], helping to reassert humanity’s place within a particular ecological context. The constraints of solar can also prove generative, even delightful, as demonstrated by the novel ways in which the research in Montreal incorporates user location, time of day, and seasonality along with energy availability into game mechanics.

Third, this project contributes to prior discussions in LIMITS on the theme of justice [25] through Eglash’s concept of “generative justice [8]”. In the explication of the concept, Eglash looks to specific forms of collectivist tech projects for the potential to liberate nature and labour (and labourers) from capitalist forms of alienation. He argues that projects such as open source software or arduino may, under certain conditions, create space for unalienated relationships between and amongst people and the environment. In our project, the TechFugees Lebanon experiment will probe the opportunities for facilitating such arrangements in an industry notorious for drudgery and worker precarity [15] – data labelling. While we may prove unsuccessful in fully realising Eglash’s formulation of generative justice, we anticipate the project offering rich opportunities for exploration of the concept. We also envision opportunities for including this question in the Montreal and Edinburgh studies as the research programmes develop further in each site.

## 5.2 Graduate Student Pedagogy

As noted in the introduction, one objective of this joint project is to collaborate on the development of new graduate design curriculum in each of our respective institutions. Each of the sites offer different opportunities for students to engage with external communities in collaborative research and learning through doing. As a result,

students will gain practical experience with the necessary skills for conducting community based research in addition to engagement with the theoretical issues at stake in these complex settings. Our joint goal is to develop graduate pedagogy that speaks to biases and problematic impacts of digital technologies while looping in critical design, humanities, and social science scholarship [29].

A key starting point for our approach implies the implementation of an emancipatory pedagogy [11] that employs a constructivist, experiential approach to research training [6, 16], ideally fostered in practices of design which may include speculative design [7], critical futures and design fictions [10], participatory action research [33] and constructivist design research [17]. Currently, our views, shaped by our collective experiences in postgraduate research training in our respective institutions, involve a critique of the emphasis on “disciplinary mastery”, involving knowledge acquisition, followed by performative deployment, to highlight respective learning has been acquired, and in-doctrination into the respective research community is completed successfully. Our approach is necessarily a-disciplinary, but encourages learning by doing, engaging with “doing communities” and developing new methodological approaches that encourage “insider researcher” perspectives [3] in complex sociotechnical imaginaries.

Collectively, we leverage student driven peer-supported learning around a set of shared problems or questions that simultaneous involve technical, scientific, social scientific, humanities and design skills and expertise. In Montreal for example, as part of the solar media project (<https://www.solar-media.net>), humanities students are learning how to solder and build solar circuits from engineering and design students in the group. This is extended across the project teams in Edinburgh and Toronto through the use of discord and github to exchange knowledge, experiences and advice, software and schematics, and ultimately through the extension of our local projects into multi-sited comparative studies. More than just a capstone project or hackathon, our project aims to cultivate deeper and longer lasting interdisciplinary research-creation culture which emphasises process-based learning rather than results, demos or deliverables.

There are important lessons in this for thinking about the incorporation of experiential learning of the sort we propose into more formal curricula in our respective institutions. It is intriguing that there is no natural fit for the kinds of projects we are doing in the existing curricular structure despite repeated calls by educational experts for exactly the kind of work we are doing. Our socio-technical investigations prompt us to think more creatively about the social and material organization of experiments in collective pedagogy, peer-to-peer learning, an exploration of research group ethics and values, and so on. Interestingly, all of this stems from a fundamental concerns with solarly as a prompt for rethinking age old conventions of academic research and training. Thus, our examinations of the socio-technical aspects of small scale solar infrastructure also beg the question of what new institutional infrastructures need to be in place in the academy to support such encounters more broadly.

## 6 CONCLUSION

This collaborative research project draws on findings and concerns of prior work in LIMITS and related areas to advance critical scholarship into the socio-technical imaginaries of transitional systems. The diversity of settings examined will allow us to attend to our core questions in ways that foreground the complexity and nuance that render such projects both compelling and difficult. By incorporating aspects of graduate student training and community engaged research in the project, we also hope to create space and infrastructures at our respective institutions for a more meaningful role for academic research, and universities more broadly, in transitional systems.

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