Green Is Not Enough.

Why can't the emerging renewable energy sector implement regenerative practices throughout its global supply chain?

Map the System 2021 Competition

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Background

In 2015, 196 parties representing virtually all sovereign states of the world adopted the Paris Agreement, a legally binding treaty to limit global average temperature to well below 2ºC.[1] According to the United Nations Framework Convention on Climate Change, achieving this long-term goal will require global peaking of greenhouse gas emissions as soon as possible, with the aspiration of reaching net zero emissions by 2050. This global transition will lead to immense and universal demand for new renewable energy projects. Where will the raw materials critical to building these new technologies be sourced from? How do we train our workforce to design, manufacture, install, and maintain these projects? What end-of-life considerations can be taken to minimize the environmental and social impacts of waste after the useful life of these new energy projects?

[1]United Nations Framework Convention on Climate Change, "The Paris Agreement," accessed April 2, 2021, https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement.

Purpose

We seek to understand and map the high-risk supply chain implications of building new renewable energy projects. In other words, our report concerns the manufacturing, implementation, and decommissioning of three major renewable energy technologies: wind power, solar power, and electrical storage technologies, such as lithium ion batteries. Our report is not focused on the technical implications of integrating renewables into electricity grids as this topic is already well-researched.

"Why can't the emerging renewable energy sector implement regenerative practices throughout its global supply chain?" We use the term 'regenerative' to refer to Regenerative Sustainability, a philosophy that aims for healthy socio-ecological systems where all forms of wellbeing improve. Advancing regenerative sustainability requires "fundamental shifts supported by more awareness and education, theoretical and practical development, leadership, and empowering communities".[2] Because this viewpoint of sustainability is holistic and multifaceted compared to conventional or contemporary sustainability definitions, it was chosen to analyze the renewable energy supply chain.

[2] Leah V. Gibbons, "Regenerative—The New Sustainable?," Sustainability 12, no. 13 (January 2020): 5483, https://doi.org/10.3390/su12135483.

Research Methodology, Knowledge Equity, and Limitations

Our research draws upon multiple sources: primary academic literature; government, nongovernmental organizations, think tank, and industry white papers; news articles; blog posts; and interviews with academics, activists, and industry professionals.

Our team's worldviews have been predominantly shaped by a Western knowledge system; a knowledge system is a collection of ideas that determines "how we know, how we learn and teach, how we innovate, and how power [flows between actors]."[3] Many scholars note how Western knowledge systems have devalued and dismissed other knowledge systems,[4] especially marginalized and indigenous ones.[5] Thus, to develop a regenerative global supply chain, Western knowledge systems alone are inadequate. When imagining how supply chains can better the lives and landscapes of affected communities, it is imperative that we give equitable weight to and seek meaningful partnership with their knowledge. To this end, our method of identifying gaps and challenges were shaped by the following guiding questions, which placed externalities at the centre of a hub-and-spoke turbine model:

- What perspectives are we privileging in our research and what perspectives are we missing?
- Under what conditions are we interacting with non-Western knowers?
- What lens are we using to interpret and incorporate perspectives of frontline communities and is this being done respectfully?

Our decision to focus on the top three renewable technologies by forecasted power use (wind, solar, and batteries) was a limitation driven by time and research expertise constraints. Similarly, more work must be done to understand perspectives of local communities affected firsthand by the renewables chain. Lastly, renewable energy supply chain interventions are greatly affected by black swans in global geopolitics and technological change, making it difficult to make robust recommendations.

3 Laurelyn Whitt, "Indigenous Knowledge, Power, and Responsibility," in Science, Colonialism, and Indigenous Peoples: The Cultural Politics of Law and Knowledge (Cambridge: Cambridge University Press, 2009), 29–56, https://doi.org/10.1017/CBO9780511760068.005.

4 Michel Foucault, "Orders of Discourse," trans. Rupert Swyer, Social Science Information 10, no. 2 (April 1, 1971): 7–30, https://doi.org/10.1177/053901847101000201.

5 Kerstin Knopf, "The Turn Toward the Indigenous: Knowledge Systems and Practices in the Academy," Amerikastudien / American Studies 60, no. 2/3 (2015): 179–200, http://www.jstor.org.login.ezproxy.library.ualberta.ca/stable/44071904; Stephen A. Marglin, "Towards the Decolonization of the Mind," in Dominating Knowledge: Development, Culture, and Resistance (Oxford: Oxford University Press, 1990), doi.org/10.1093/acprof:oso/9780198286943.001.0001.

Understanding the Problem

Stakeholder Analysis

The supply chain for renewable energy technologies forms the basis of the stakeholder map, alongside four periphery categories: Financiers, Regulators, Labour and Educators, and Civil Society and Citizens; power dynamics between each are shown on the visual map.

Key insights from this stakeholder analysis are that: (1) supply chain networks are a source of competitive advantage, which means that pursuing a system reset must provide an alternate economic incentive; (2) fringe stakeholders are trapped in positive feedback loops of social and environmental exploitation which create further gaps to equity; and (3) accountability is paradoxically lost when stakeholders share responsibilities, which perpetuates the tragedy of the commons.

Because of these three ingrained patterns, stakeholders' interactions have created interconnected cycles of apathy and relapse for renewables. These cycles are reinforced by the perception that all renewables are wholly regenerative when compared to fossil fuel energy, and are realized in competitive attitudes that disincentivize companies from sharing best practices for regenerative supply chains with each other.

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Challenge Landscape: The Turbine Model

Our stakeholder analysis led us to identify three main gaps that comprise the challenge landscape. Cultural and Mental Divides form foundational worldviews that stymie progress for renewables' growth and deployment. Knowledge and Skill Gaps create voids with little information and a lack of competencies needed to obtain that information. Policy and Resource Shortfalls encompass a lack of incentives for breaking obstacles in the path to a circular supply stream. Finally, these gaps converge into Externalities: global spillover effects that extend beyond the chain and that cause vast, inequitable harm.

These gaps do not exist in isolation: they belong in an ecosystem that connects all stakeholders across geographies and power structures. Each gap presents its own set of problems for the renewables supply chain, but also compounds and exacerbates every other gap — while multiplying the Externalities of each. Therefore, this "turbine model" not only explores gaps, but also probes the reinforcement mechanisms that perpetuate them; it breaks down the multi-layered feedback loops that prevent the renewable energy sector from being regenerative.

Understanding the Problem

Gap 1: Mental and Cultural Divides

Cultural and Mental Divides form foundational worldviews that stymie progress for renewables' growth and deployment.

One of the common beliefs in the field of sustainability is that it is impossible to grow the economy while protecting the environment. This is captured by the Kuznets Curve,[6] which implies that high-income countries are better at protecting their environments and that lower-income countries must harm their environment to achieve higher income levels. Both these assumptions have been disproven based on evidence from high-income energy producers and emerging income-energy decoupling in developing nations. However, this debunked belief is entrenched and still perpetuates the non-regenerative aspects of the growing renewables sector.

Transparency is another obstacle. As minerals and materials are passed on from one stakeholder to another, a lack of accountability and traceability means that the deployment of renewable energies indirectly causes upstream forced labour and perpetuation of conflict.[7] When governments and environmental groups promote renewable energies, a blind eye is often turned to such hidden issues because of their difficulty to quantify, track, and combat.

6 David I Stern, "The Rise and Fall of the Environmental Kuznets Curve," World Development 32, no. 8 (August 1, 2004): 1419–39, https://doi.org/10.1016/j.worlddev.2004.03.004.

7 Clare Church and Alec Crawford, "Green Conflict Minerals: The Fuels of Conflict in the Transition to a Low-Carbon Economy" (International Institute for Sustainable Development, August 2018), https://www.iisd.org/story/green-conflict-minerals.

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Gap 2: Policy and Resource Shortfalls

Policy and Resource Shortfalls encompass a lack of incentives for breaking obstacles in the path to a circular supply stream.

Capital requirements are a common and significant barrier for renewable energy projects, primarily due to gaps in funding. Capital is often allocated to shovel-ready projects, thus excluding emerging economies as their projects are halted in early stage development. Many of these projects have high renewable energy potential, especially in sub-Saharan Africa.[8]

Furthermore, exponential growth in the demand for critical minerals worsens geopolitical tensions. Political disputes with producing regions can cause supply shortages; for example, a 2010 territorial dispute resulted in China cutting exports of rare earths to Japan.[9] China currently exerts major dominants over all aspects of the electric vehicle and solar supply chain, meaning any geopolitical risks can significantly disrupt these chains.[10] Additionally, many metals are produced from mines concentrated in certain countries (e.g. cobalt, rare earths, and tellurium)[11] meaning that sourcing is vulnerable to bottlenecks. For example, global cobalt markets have been impacted by supply restrictions in the Democratic Republic of the Congo during civil unrest.[12]

Finally, incentives for international coordination on sourcing materials and manufacturing capacity are lacking. Many countries are unwilling to cooperate on what is perceived as a low priority issue,[13] and the high costs of early stage innovation discourage nations from making necessary investments into research and development.[14] Finally, vested interests impede collaboration as countries aim to promote their own industries internationally.[15]

[8] Alyssa Pek, "Wind Power Blows into Africa," Global Wind Energy Council (blog), May 30, 2013, https://gwec.net/wind-power-blows-africa-2/.
[9] Marc Schmid, "Rare Earths in the Trade Dispute Between the US and China: A Deja Vu," Intereconomics 2019, no. 6 (2019): 378–84, https://www.intereconomics.eu/.
[10] Kenneth Rapoza, "How China's Solar Industry Is Set Up To Be The New Green OPEC," Forbes, March 14, 2021, https://www.forbes.com/sites/kenrapoza/2021/03/14/how-chinas-solar-industry-is-set-up-to-be-the-new-green-opec/?sh=4bf1aed81446.
[11] Metalpedia, "Rare Earths: Resource Distribution and Production, Reserves, Supply and Demand," accessed April 2, 2021, http://metalpedia.asianmetal.com/metal/rare_earth/resources&production.shtml#:~:text=They%20are%20distributed%20mainly%20in,South%20Africa%20and%20other%20countries.
[12] InvestorIntel, "Congo Violence, Lundin Mining and the Global Cobalt Supply," accessed April 2, 2021, https://investorintel.com/markets/technology-metals/technology-metals-intel/violence-destabilizing-global-cobalt-supply/?print=print.
[13] Cédric Philibert, "International Energy Technology Collaboration and Climate Change Mitigation" (OECD Environment Directorate and International Energy Agency, 2004), http://www.oecd.org/env/cc/32138947.pdf
[14] "Global Status of Clean Energy Innovation in 2020" (International Energy Agency, July 2020), https://www.iea.org/reports/clean-energy-innovation/global-status-of-clean-energy-innovation-in-2020.
[15] Chuyu Liu and Johannes Urpelainen, "Why the United States Should Compete with China on Global Clean Energy Finance," Brookings Institution (blog), January 7, 2021, https://www.brookings.edu/research/why-the-united-states-should-compete-with-china-on-global-clean-energy-finance/.

Understanding the Problem

Gap 3: Knowledge and Skill Gaps

Knowledge and Skill Gaps create voids with little information and a lack of competencies needed to obtain that information.

As many renewable technologies are still in relatively early phases of implementation, data deficiencies exist across the supply chain. A prime example lies in auditing projects, where countries such as the Democractic Republic of the Congo have insufficient infrastructure to collect this data. In tandem, private monitoring organizations may lack the necessary relationships with local producers to vet projects.[16]

Additionally, end-of-life and waste management represent large gaps in skills, technology, and knowledge, as a focus is primarily shifted on installation of renewables (as opposed to their disassembly and reuse). For example, the failure rates and causes of renewable systems and socioeconomic analyses on the impacts of renewables' supply chains (for consideration of the social determinants of health, for instance), require more attention.[17]

Finally, a skills gap manifests in a lack of an adequately-trained and diverse workforce for the clean energy transition. These occupations require greater scientific knowledge and technical skills than the average job,[18] and the resultant labour shortages are especially severe in emerging economies.[19] Additionally, low participation rates in the field by womxn, black and indigenous peoples, and communities of colour suggest barriers to accessing education and job opportunities.[20]

[16]Patrick Heller and Ted Lamm, March 29, 2021.
[17]WindEurope, Cefic, and EuCIA, "Accelerating Wind Turbine Blade Circularity," May 25, 2020, https://windeurope.org/data-and-analysis/product/accelerating-wind-turbine-blade-circularity.
[18]Mark Muro et al., "Advancing Inclusion through Clean Energy Jobs" (Washington, DC: The Brookings Institution, April 18, 2019), https://www.brookings.edu/research/advancing-inclusion-through-clean-energy-jobs/.
[19]Hugo Lucas, Stephanie Pinnington, and Luisa F. Cabeza, "Education and Training Gaps in the Renewable Energy Sector," Solar Energy 173 (October 1, 2018): 449–55, https://doi.org/10.1016/j.solener.2018.07.061.
[20]Muro et al., "Advancing Inclusion through Clean Energy Jobs."

Understanding the Problem

Gap Convergence: Externalities

Externalities are global spillover effects that extend beyond the supply chain.

While exports from rare earths mines are exported internationally, waste products from mining operations are often left local to the communities near the site.[21] These sites also worsen the social determinants of health for these communities due to occupational and environmental hazards. As mining for critical minerals in the energy transition accelerates, more communities may be exposed to toxins, suffer from poor air quality, and experience multi-generational health inequities.[22]

Renewable energy project developers often inadequately consult affected local communities or engage in activities that fall short of true consent-seeking. This erodes their Social License to Operate (SLO), and causes conflicts over land use and the fair distribution of benefits such as jobs and investment. For example, while impact-benefit agreements are commonly used to gain the approval of local communities,[23] in practice they may fail to acknowledge the power imbalance between companies and communities and inadvertently pressure communities to consent.[24]

Eroded SLO puts long-term financial uncertainty on new projects, making it difficult to attract investors and assure low-cost capital.

Downstream in the supply chain, as the deployment of renewable technologies accelerates, waste managers' ability to properly dispose, reuse, and recycle new types of renewable waste is becoming outmatched.[25] This contributes to externalities when disposed materials are improperly dealt with.

[21]"Cobalt Mining Legacy," accessed April 25, 2021, http://www.cobaltmininglegacy.ca/backgrounder.php.
[22]Franklin W. Schwartz, Sangsuk Lee, and Thomas H. Darrah, "A Review of the Scope of Artisanal and Small-Scale Mining Worldwide, Poverty, and the Associated Health Impacts," GeoHealth 5, no. 1 (2021): e2020GH000325, https://doi.org/10.1029/2020GH000325.
[23]Eric Adebayo and Eric Werker, "How Much Are Benefit-Sharing Agreements Worth to Communities Affected by Mining?," Resources Policy 71 (June 1, 2021): 101970, https://doi.org/10.1016/j.resourpol.2020.101970.
[24]Eric Werker, April 23, 2021.
[25]James Gignac, "Cracking the Code on Recycling Energy Storage Batteries," Union of Concerned Scientists (blog), 2020, https://blog.ucsusa.org/james-gignac/recycling-energy-storage-batteries.

Current Attempted Solutions

Several stakeholders have attempted to solve issues that fall within their own spheres of influence.

Upstream solutions are to problems at the beginning of the chain, such as mining and material processing.

Upstream, the focus has been on implementing global reporting standardization[26] and auditing programs[27] to combat human rights violations in raw material mining. Additionally, some acknowledgement of health inequities generated[28] in mining has been attempted.

Midstream solutions encompass renewable energy technology design, manufacturing, and the related labour.

In renewables' design and manufacturing, legislation has been introduced to mandate producers to take carriage of their finished products.[29] Regional renewable energy manufacturing strategies[30] have been attempted to reduce distribution problems. Government-funded initiatives to prepare the workforce such as job training for renewables[31] and skills standardization criteria are being developed.[32]

Downstream solutions are implemented at the installation and waste management phases of renewable energy technology.

Some examples include community support of mining and energy companies through benefits-sharing agreements.[33] Regulations have created a drive for new recycling technologies to handle the complex components of turbines and solar panels.[34]

Current Attempted Solutions

The abundance of solutions demonstrates that the sector is taking tangible steps towards a regenerative supply chain. However, the complexity and interconnectedness of the gaps nullify these efforts because they either exist in isolation or require a stakeholder with the bargaining power to enforce or incentivize them. Deeper, structural-level changes are required: these are the levers of change.

[26] Organisation for Economic Co-operation and Development, "OECD Due Diligence Guidance for Responsible Supply Chains of Minerals from Conflict-Affected and High-Risk Areas," April 2016, https://www.oecd.org/corporate/mne/mining.htm.
[27] "EICC® and GeSI Launch Conflict-Free Sourcing Initiative," May 1, 2013, https://www.csrwire.com/press_releases/35565-eicc-and-gesi-launch-conflict-free-sourcing-initiative.
[28] "Health & Safety," International Council on Mining & Metals, accessed April 25, 2021, https://www.icmm.com/en-gb/health-and-safety.
[29] "Waste from Electrical and Electronic Equipment (WEEE)," European Commission, accessed April 2, 2021, https://ec.europa.eu/environment/topics/waste-and-recycling/waste-electrical-and-electronic-equipment-weee_en.
[30] "Building a European Battery Industry," European Battery Alliance, accessed April 2, 2021, https://www.eba250.com/.
[31] "Wage Subsidy Programs," ECOCanada, accessed April 25, 2021, https://www.eco.ca/wage-subsidy-programs-fr/.
[32] European Centre for the Development of Vocational Training, "Skills for Green Jobs: 2018 Update" (CEDEFOP, April 15, 2019), https://www.cedefop.europa.eu/en/publications-and-resources/publications/3078.; Ministère de la Transition écologique, "L'observatoire national des emplois et métiers de l'économie verte," Gouvernement de la République française, March 23, 2021, https://www.ecologie.gouv.fr/lobservatoire-national-des-emplois-et-metiers-leconomie-verte
[33] "Local Content Policies" (Intergovernmental Forum on Mining, Metals, and Sustainable Development), accessed April 25, 2021, https://www.igfmining.org/our-work/local-content/.
[34] International Renewable Energy Agency and International Energy Agency Photovoltaic Power Systems, "End-of-Life Management: Solar Photovoltaic Panels," June 2016, https://www.irena.org/publications/2016/Jun/End-of-life-management-Solar-Photovoltaic-Panels.

Levers of Change

Levers of change represent measures which can be taken to bridge existing gaps and truly achieve the goals that current attempted solutions aim to resolve. Levers of change are organized by four themes, which, if accomplished, can form the basis of a regenerative renewable energy supply chain.

Theme 1: Enhancing Supply Chain Transparency

Enhancing supply chain transparency ensures that only ethical minerals and labour are used in the renewables supply chain.

Harmonizing and enforcing international standards is important for achieving this theme. Non-OECD (Organisation for Cooperation and Development) countries like India and China,[35] which represent fast-growing renewable energy markets, need their own parallels to the OECD's Due Diligence Guidance for Responsible Supply Chains of Minerals from Conflict-Affected and High-Risk Areas. The OECD can help share their standards while adjusting them to non-OECD country-specific needs. Harmonized standards for ethical sourcing will also benefit from on-the-grounds verification and enforceability.[36] This hinges on renewable energy component manufacturers establishing local monitoring and auditing networks and even using blockchain technology for minerals tracking.

[35] "World Energy Outlook 2020" (International Energy Agency, October 2020), https://www.iea.org/reports/world-energy-outlook-2020.
[36] Patrick Heller and Ted Lamm, interview.

Levers of Change

Theme 2: Coordinating Design and Development

Coordinating design and development helps reduce waste preventatively, and optimize total material requirements.

Cross-stakeholder innovation and policies to improve international cooperation can help coordinate the development of renewable energy technologies and waste management infrastructure. Innovation ecosystems such as industrial hubs[37] and business incubators are proven to convene stakeholders in supply chains of other industries, and can be used to tackle the material efficiency and end of life management problems in renewables. Similar to border carbon tax adjustments[38], government incentives can help renewable energy manufacturers produce sustainable components without the risk of being driven out of international markets by competition on the basis of cost.

[37]Edlam Abera Yemeru, "Industrial Hubs, Urban Systems, and Economic Development," in The Oxford Handbook of Industrial Hubs and Economic Development, ed. Arkebe Oqubay and Justin Yifu Lin (Oxford University Press, 2020), doi.org/10.1093/oxfordhb/9780198850434.013.8.
[38]"Border Adjustments," Carbon Tax Center, accessed April 25, 2021, https://www.carbontax.org/issues/border-adjustments/.

Levers of Change

Theme 3: Building Human Capital

Building human capital improves the accessibility, diversity and equity of the clean energy workforce.

Resourcing, educating and including people is vital to building human capital within renewable energy supply chains. Enhancing access to early career training within the clean energy sector, done by renewables companies in cooperation with educational institutions and government funding, can help attract talent to an industry facing critical human resource shortages.[39] When governments or financiers procure or provide loans for renewable energy, they should also require equity and diversity measures to involve underrepresented groups[40] (womxn, black and indigenous peoples, or other persons of colour) within renewable energy companies. Finally, taking advantage of the decentralization trend of renewable energy, development agencies and governments should ensure that financing and capacity building is provided to communities to themselves lead the creation of distributed clean energy projects.[41]

[39] "The Global Energy Talent Index 2021: Opportunity from Uncertainty" (Airswift and Energy Jobline, 2021), https://www.airswift.com/geti/.
[40] "Renewable Energy: A Gender Perspective" (International Renewable Energy Agency, January 2019), https://www.irena.org/publications/2019/Jan/Renewable-Energy-A-Gender-Perspective.
[41] Jenna Gall, "The Benefits of Community-Owned Renewable Energy Projects," Renewable Energy (blog), April 10, 2018, https://renewableenergy.usask.ca/news-articles/the-benefits-of-community-owned-renewable-energy-projects.php.

Levers of Change

Theme 4: Achieving Geographic Harmonization

Achieving geographical harmonization ensures that regenerative renewable energy supply chains thrive globally.

While navigating critical mineral geopolitics, countries in Europe and North America can use regional co-operation and trade to diversify rare earths and lithium production beyond China.[42] In their National Determined Contributions to achieving climate goals, developed nations can fund multilateral banks to support clean energy and energy efficiency deployment in developing nations to overcome spending hurdles.[43] To reconcile health inequities near mines, upstream and preventative health interventions by nongovernmental organizations can improve workplace environments.[44] To reinvigorate their social license to operate, mining and energy project developers can seek true buy-in via long-term relationships rather than the current negotiated acquiescence.[45]

42 Jane Nakano, "The Geopolitics of Critical Minerals Supply Chains" (Center for Strategic & International Studies, March 11, 2021), https://www.csis.org/analysis/geopolitics-critical-minerals-supply-chains.
43 Deborah Murphy and Jo-Ellen Parry, "Filling the Gap: A Review of Multilateral Development Banks' Efforts to Scale up Financing for Climate Adaptation" (International Institute for Sustainable Development, November 30, 2020), https://www.iisd.org/publications/filling-gap-financing-climate-adaptation.
44 David R. Williams et al., "Moving Upstream: How Interventions That Address the Social Determinants of Health Can Improve Health and Reduce Disparities," Journal of Public Health Management and Practice 14, no. 6 (November 2008): S8, https://doi.org/10.1097/01.PHH.0000338382.36695.42.
45 Eric Werker, interview.

Final Insights

The iceberg model summarizes our research by retracing apparent events to their invisible root causes: fundamental problems in the global renewables' supply chain. At the events layer, there are concerns about available raw materials, workforce readiness, and persistent stakeholder conflicts for new projects. These events occur because of behavioural patterns including a disconnection of circular practices within the renewable energy industry, inconsistent standards for managing waste and monitoring human rights, and inaccessible clean energy training. These patterns have been entrenched by deep-rooted value systems: energy companies are often granted impunity on waste and social issues due to "green" perception;[46] community approval is treated as a hurdle rather than an opportunity by renewable developers and miners;[47] educational institutions move too slowly due to bureaucratic pacing;[48] and non-carbon externalities are marginalized due to climate urgency.[49]

Initially, we believed that the supply chain could only exist as a binary: the problematic status quo or a regenerative ideal. Through our research, we learned that actors are arranged on power hierarchies and the distribution of consequences and benefits is disproportionate. We now believe that a truly regenerative supply chain will need to undergo multiple iterations of system resets through ongoing learning and collaboration. It is critical that we understand that communities and human capital need to be invited to the centre of supply chains to ensure distributional fairness in the energy transition.

Final Insights

Likewise, regulatory actors with control over multiple segments of the supply chain must use economic and policy incentives to create regenerative practices. And finally, global inequities in renewable energy supply chains must be addressed with knowledge and resource sharing, ensuring equitable resource stewardship.

As we journeyed to map this system, it was essential for us to be epistemically humble; the complexity of our problem combined with our limitations means that there is ample room for future work. Future researchers should consider the regenerative nature of other emergent renewable energies like hydropower, geothermal, and hydrogen. Furthermore, as sustainability researchers, we need deeper consideration of the perspectives of local communities which are often difficult to capture via academic approaches. As well, advanced modelling techniques can be employed by future investigators to account for the effect of unpredictable changes in global geopolitics and technology on the regenerative nature of renewable supply chains. This represents an opportunity for our team, as part of the community tackling climate change, to further investigate questions pertinent to a climate systems reset.

[46]Fred Pearce, "Greenwash: How a Wind Farm Could Emit More Carbon than a Coal Power Station," The Guardian, August 13, 2009, sec. Environment, http://www.theguardian.com/environment/2009/aug/13/wind-farm-peat-bog.
[47]Ted Wong et al., "3 Hurdles to Racial Justice in Clean Energy – and 3 Ways U.S. Cities Can Overcome Them," World Resources Institute (blog), September 2, 2020, https://www.wri.org/blog/2020/09/3-hurdles-racial-justice-clean-energy-and-3-ways-us-cities-can-overcome-them.
[48]David E. Blockstein, Catherine H. Middlecamp, and John H. Perkins, "Energy Education: Easy, Difficult, or Both?," January 10, 2015, http://www.susted.com/wordpress/content/energy-education-easy-difficult-or-both_2015_01/.
[49]L. Bennun et al., "Mitigating Biodiversity Impacts Associated with Solar and Wind Energy Development" (International Union for the Conservation of Nature, 2021), https://portals.iucn.org/library/node/49283.