SDGs and Transitioning to Renewable Energy with Justice: An (in)equality perspective

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Abstract: Transitioning to a low-carbon economy has achieved a lot of attention recently, which puts renewable energy at the centre. Low-carbon energy transition is not only part of climate agenda, but also the Sustainable Development Goals (SDG 7). Existing literature examines the interactions between energy transition and SDGs and the implications of energy transition on development goals. This literature, however, focusses predominantly on co-benefits/synergies and is thin on trade-offs. The literature on 'just transition', which has emerged recently, acknowledges the importance of understanding trade-offs and justice concerns but does not engage much with other SDGs. There is another set of literature that argues the importance of incorporating energy justice principles in transition. As reducing inequality is at the heart of both just transition and sustainability, this paper identifies inequality dimensions of relevant SDGs and further reviews the literature to understand the local-level impacts of solar energy transition on these dimensions. The findings of this paper help in integrating the literature and also assist policymakers to understand mechanisms needed to ensure a just transition.

Introduction:

Transitioning from fossil fuels to renewable energy, is a part of both the climate agenda as well as the Sustainable Development Goals (SDGs), namely SDG 7 (Affordable and Clean Energy). As different SDGs are interconnected, there are many interlinkages— positive (synergies) or negative (trade-offs)—between energy transition and other SDGs.[1] [2] Most studies, however, have focussed on synergies; understanding of trade-offs, although increasing, is still limited. This has evolved since the emergence of 'just transition' discourse which inherently is about the trade-offs associated with energy transition. The concept, initially

[1] Gabriela Ileana Iacobuţa et al., "Transitioning to low-carbon economies under the 2030 agenda: Minimizing trade-offs and enhancing co-benefits of climate-change action for the SDGs," Sustainability 13, no. 19 (2021): 10774, https://doi.org/10.3390/su131910774

[2] David L McCollum et al.,"Connecting the sustainable development goals by their energy inter-linkages," Environmental Research Letters 13, no. 3 (2018): 033006, 10.1088/1748-9326/aaafe3

focussed on rights of fossil fuel workers but has now evolved to include other dimensions of the transition, including employment, gender, and energy justice. [3] [4] [5]

As both just transition and sustainability focus on reducing inequalities, it becomes crucial to understand the inequality implications of energy transition. Inequality and equity discussions in the context of climate change discourse revolve around three themes. The most dominant one is concerned with unequal distribution of costs and benefits of climate change and climate action among developed and developing countries.[6] The second theme is impact of climate change on existing inequalities.[7] The literature is limited on the third theme, which is inequality implications of climate mitigation policies, including energy transition.[8] Further, the SDGs also relate with inequality, the most explicit being a separate goal designated for reducing inequalities (SDG 10- Reduced Inequalities).

The research gap that exists is that the interlinkages of just transition, SDGs, energy justice are not properly acknowledged in the literature. The literature on impact of energy transition, whether they are in respect of inequality, justice, or SDGs, is focused on global level. Studies examining local-level impacts, especially in developing countries are scarce. This paper argues that inequality can act as an entry point to connect these sets of literature and illustrates it through the local-level impacts of renewable energy on inequality dimensions of SDGs.

Renewable energy transition, SDGs, and Justice

An energy transition involves shifting from a dominant source of energy to another, historical examples of which include transition from whale oil to wood in the 19th century and shift from wood to coal during the Industrial Revolution.[9] The low-carbon energy transition refers to shift from fossil fuel to low-carbon resources, mainly renewable energy sources. This transition would need to follow a different pathway than the historical transition, by not just adding but also subtracting from the energy mix.[10] This transition is crucial for climate action and also for increasing access to clean energy and both of these agendas are part of the SDGs, explicitly as SDG 13 (Climate Action) and SDG 7 respectively. As the different SDGs are interconnected,

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[3]Newell, Peter, and Dustin Mulvaney. "The political economy of the 'just transition'." *The geographical journal* 179, no. 2 (2013): 132-140., https://www.jstor.org/stable/43868543

[4] International Labour Organization, Just transition: an essential pathway to achieving gender equality and social justice, April 2022, Geneva, ILO, 2022, https://www4.unfccc.int/sites/SubmissionsStaging/Documents/202204141910---ILO%20submission%20-%20Just%20transition%20-%20An%20essential%20pathway%20to%20achieving%20gender%20equality%20and%20social%20justice.pdf

[5] Darren McCauley and Raphael Heffron, "Just transition: Integrating climate, energy and environmental justice," Energy Policy 119 (2018): 1-7, https://doi.org/10.1016/j.enpol.2018.04.014

[6]King, Andrew D., and Luke J. Harrington. "The inequality of climate change from 1.5 to 2 C of global warming." *Geophysical Research Letters* 45, no. 10 (2018): 5030-5033, https://doi.org/10.1029/2018GL078430

[7] Hallegatte, Stephane, and Julie Rozenberg. "Climate change through a poverty lens." *Nature Climate Change* 7, no. 4 (2017): 250-256, https://doi.org/10.1038/nclimate3253

[8] Sanna Markkanen and Annela Anger-Kraavi, "Social impacts of climate change mitigation policies and their implications for inequality," Climate Policy 19, no. 7 (2019): 827-844, https://doi.org/10.1080/14693062.2019.1596873

[9] Carley, Sanya, and David M. Konisky. "The justice and equity implications of the clean energy transition." Nature Energy 5, no. 8 (2020): 569-577, https://ecology.iww.org/PDF/misc/Carley.2020_Energy-Justice-Lit-Review.pdf

[10] Newell, Richard G., and Daniel Raimi. "The new climate math: Energy addition, subtraction, and transition." *Issue Brief* (2018): 18-09, https://media.rff.org/documents/RFF-IssueBrief-NewClimateMath-final.pdf

it becomes crucial to understand the positive and negative impacts of the transition on different SDGs. There is a large set of literature, that has explored the interlinkages between climate and development goals, highlighting the synergies and trade-offs.[11] [12] [13]Table 1 provides an illustrative list of major synergies and trade-offs identified between renewable energy transition and SDGs.

Table 1: Synergies and trade-offs between renewable energy transition and SDGs

Synergies	Trade-offs
SDG 1: No Poverty: Access to modern energy services can help in alleviating poverty. Off grid solar solutions can increase energy access in remote areas **SDG 2: Zero Hunger:** Modern energy services can increase agricultural productivity which can help in ensuring food security **SDG 3: Good Health and Well-Being:** Transition to renewables can reduce injuries associated with traditional solid fuel collection and access to modern energy can improve healthcare facilities **SDG 5: Gender Equality:** Increased lighting can improve women's security and access to modern energy can increase business opportunities for women **SDG 8: Decent Work and Economic Growth:** Access to energy and transition to renewables can generate employment opportunities **SDG 10: Reduce Inequalities:** Small-scale renewable energy plants can aid in effective participation of community and increase their income	**SDG 1: No Poverty:** New energy policies that support growth of renewable energy can increase electricity prices that can disproportionately fall on poor. **SDG 2: Zero Hunger:** Large bioenergy production as well as installation of solar projects can compete with land resources **SDG 8: Decent Work and Economic Growth:** Renewable energy transition can pose a threat to jobs of fossil fuel workers **SDG 10: Reduce Inequalities:** Building renewable energy infrastructure can pose a threat to communities and can lead to their displacement

Source: Author's compilation, based on Iacobuta et al[14]; McCollum et al[15], and Nerini et al[16]

The literature is, however, broad and not very specific to transition to renewables, instead focusses on climate action in general, with major focus on synergies. There is also a lack of comprehensive empirical cases.[17] [18]

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[11] von Stechow, Christoph, Jan C. Minx, Keywan Riahi, Jessica Jewell, David L. McCollum, Max W. Callaghan, Christoph Bertram, Gunnar Luderer, and Giovanni Baiocchi. "2° C and SDGs: united they stand, divided they fall?." *Environmental Research Letters* 11, no. 3 (2016): 034022, http://dx.doi.org/10.1088/1748-9326/11/3/034022

[12] Fuso Nerini, Francesco, Benjamin Sovacool, Nick Hughes, Laura Cozzi, Ellie Cosgrave, Mark Howells, Massimo Tavoni, Julia Tomei, Hisham Zerriffi, and Ben Milligan. "Connecting climate action with other Sustainable Development Goals." *Nature Sustainability* 2, no. 8 (2019): 674-680, https://doi.org/10.1038/s41893-019-0334-y

[13] Cohen, Brett, Annette Cowie, Mustafa Babiker, Adrian Leip, and Pete Smith. "Co-benefits and trade-offs of climate change mitigation actions and the Sustainable Development Goals." *Sustainable Production and Consumption* 26 (2021): 805-813, https://doi.org/10.1016/j.spc.2020.12.034

[14] Iacobuta et al., "Transitioning to low-carbon economies"

[15] McCollum et al., "Connecting the sustainable development goals"

[16] Fuso Nerini, Francesco, Julia Tomei, Long Seng To, Iwona Bisaga, Priti Parikh, Mairi Black, Aiduan Borrion et al. "Mapping synergies and trade-offs between energy and the Sustainable Development Goals." *Nature Energy* 3, no. 1 (2018): 10-15, https://doi.org/10.1038/s41560-017-0036-5

[17] Adenle, Ademola A. "Assessment of solar energy technologies in Africa-opportunities and challenges in meeting the 2030 agenda and sustainable development goals." *Energy Policy* 137 (2020): 111180, https://doi.org/10.1016/j.enpol.2019.111180

[18] Obaideen, Khaled, Maryam Nooman AlMallahi, Abdul Hai Alami, Mohamad Ramadan, Mohammad Ali Abdelkareem, Nabila Shehata, and A. G. Olabi. "On the contribution of solar energy to sustainable developments goals: Case study on Mohammed bin Rashid Al Maktoum Solar Park." *International Journal of Thermofluids* 12 (2021): 100123, https://doi.org/10.1016/j.ijft.2021.100123

There is another set of literature on 'Just Transition', whose origin scholars date back to 1990s when the American labour union fought for the rights of its workers in the wake of environmental regulations.[19] The concept of 'just transition' has evolved since then, with initial focus on safeguarding the jobs of coal workers and can now be defined as moving towards a post-carbon society in a way that is fair and equitable with respect to justice concerns such as income, gender, ethnicity etc. [20] This stream of literature defines 'just' transition as enhancing synergies between climate goals and SDGs.[21] and incorporating various SDGs. [22] [23] However, the engagement of just transition literature with SDGs is limited, with only few studies explicitly mentioning the global goals.

Parallelly. the literature on energy transition is also evolving, moving beyond focusing on the pace of transition to also understand the positive and negative impact of transition and the justice implications. The literature has started to recognise that simply transitioning to renewable energy would not create fairer and inclusive energy systems and it is crucial to understand the inequality implications of transition.[24] This set of literature incorporates the energy justice principles and argues that energy transition policies should incorporate the three tenets of energy justice--distributive, procedural, and recognition.[25] [26] Distributive justice involves distributional impacts of transition- access and affordability of renewable energy. Procedural justice involves effective participation and democratic process whereas recognition justice involves taking care of the vulnerable and marginalised. [27] [28] This set of literature explores justice implications of renewable energy transition and argues that structural inequalities of land access, gender, employment can be reinforced or deepened, if proper mechanisms are not present. [29] There are many interlinkages between just transition and

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[19] Abraham, Judson. "Just transitions for the miners: Labor environmentalism in the Ruhr and Appalachian coalfields." *New Political Science* 39, no. 2 (2017): 218-240, https://doi.org/10.1080/07393148.2017.1301313

[20] McCauley and Heffron, "Just transition," 2

[21] Haegele, Ramona, Gabriela I. Iacobuţă, and James Tops. "Addressing climate goals and the SDGs through a just energy transition? Empirical evidence from Germany and South Africa." *Journal of Integrative Environmental Sciences* 19, no. 1 (2022): 85-120, https://www.tandfonline.com/action/showCitFormats?doi=10.1080/1943815X.2022.2108459

[22] International Labour Organization, Just transition: an essential pathway to achieving gender equality and social justice, April 2022, Geneva, ILO, 2022

[23] Sareen, Siddharth, and Amber Joy Nordholm. "Sustainable development goal interactions for a just transition: multi-scalar solar energy rollout in Portugal." *Energy Sources, Part B: Economics, Planning, and Policy* 16, no. 11-12 (2021): 1048-1063, https://doi.org/10.1080/15567249.2021.1922547

[24] Johnson, Oliver W., Jenny Yi-Chen Han, Anne-Louise Knight, Sofie Mortensen, May Thazin Aung, Michael Boyland, and Bernadette P. Resurrección. "Intersectionality and energy transitions: A review of gender, social equity and low-carbon energy." *Energy Research & Social Science* 70 (2020): 101774, https://doi.org/10.1016/j.erss.2020.101774

[25] Müller, Franziska, Manuel Neumann, Carsten Elsner, and Simone Claar. "Assessing African energy transitions: Renewable energy policies, energy justice, and SDG 7." *Politics and Governance* 9, no. 1 (2021): 119-130, https://doi.org/10.17645/pag.v9i1.3615

[26] Siciliano, Giuseppina, Linda Wallbott, Frauke Urban, Anh Nguyen Dang, and Markus Lederer. "Low-carbon energy, sustainable development, and justice: Towards a just energy transition for the society and the environment." *Sustainable development* 29, no. 6 (2021): 1049-1061, DOI: 10.1002/sd.2193

[27] Jenkins, Kirsten, Darren McCauley, Raphael Heffron, Hannes Stephan, and Robert Rehner. "Energy justice: A conceptual review." *Energy Research & Social Science* 11 (2016): 174-182, http://dx.doi.org/10.1016/j.erss.2015.10.004

[28] Muller et al., "Assessing African energy transition"

[29] Yenneti, Komali, and Rosie Day. "Distributional justice in solar energy implementation in India: the case of Charanka solar park." *Journal of rural studies* 46 (2016): 35-46,

energy justice as just transition also draws from climate, environmental, and energy justice principles and sits at the intersection of energy transition and energy justice literature.[30] [31].There is only limited literature that has combined these two sets of literature, to understand the social and justice implications of energy transition.[32] [33] Further, energy transition also sits at the intersection of many SDGs, and the literature has recognised the justice dimension of different SDGs.[34] [35] These overlaps can be used to define just transition, with respect to energy justice principles and the three pillars of sustainable development.[36] The justice and inequality dimensions of SDGs, however, are also less explored, and is often recognised as a separate set of literature. Seen from the SDG perspective, the SDG discourse has integrated inequality much more than previous development goals, the MDGs. The most explicit engagement with inequality is through SDG 10 (Reduced Inequalities). Besides this, as there are many dimensions of inequality, many other goals relate with inequality in one way or another. [37]

The existing literature does not build on the interrelatedness of these concepts, comprehensively. Inequality can be seen as a common point between just transition, energy justice, and sustainability can act as an interesting entry point to connect these different sets of literature and close the research gap. As renewable energy transition can deepen and reinforce inequalities and this transition has to take place along with fulfilling SDGs, this paper strengthens the arguments that it is crucial to understand the inequality implications of renewable energy transition. There is, however, limited literature on local-level impacts of renewable energy transition, especially in developing countries

This paper aims to close this research gap and seeks to answer the following research questions: (1) What are the local-level impacts of deployment of renewable energy on social and economic inequality dimensions of SDGs? (2) What are some mechanisms needed to reduce these inequalities?

Methodology:

To answer both the research questions, an exploratory literature review was conducted, focusing on both energy transition-SDG, and energy justice literature. The first step was to identify dimensions of renewable energy transition and that of inequality where interactions are most likely. Solar energy was chosen as the focus of this study as the main focus in the developing countries is on increasing the share of renewables, especially solar.[38]Further

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[30] Raphael J. Heffron, Darren McCauley, What is the 'Just Transition'? *Geoforum* 88, (2018), 74-77, https://doi.org/10.1016/j.geoforum.2017.11.016.

[31] Carley and Konsiky, "Justice", 570

[32] Muller et al., "Assesing African energy transition"

[33] Healy, Noel, and John Barry. "Politicizing energy justice and energy system transitions: Fossil fuel divestment and a "just transition"." *Energy policy* 108 (2017): 451-459, http://dx.doi.org/10.1016/j.enpol.2017.06.014

[34] Villavicencio Calzadilla, Paola, and Romain Mauger. "The UN's new sustainable development agenda and renewable energy: the challenge to reach SDG7 while achieving energy justice." *Journal of Energy & Natural Resources Law* 36, no. 2 (2018): 233-254, https://doi.org/10.1080/02646811.2017.1377951

[35] Haegele et al., "Addressing climate goals", 85-120, https://www.tandfonline.com/action/showCitFormats?doi=10.1080/1943815X.2022.2108459

[36] Siciliano et al., "low-carbon development"

[37] Kanbur, Ravi. "Sustainable Development Goals and the study of economic inequality." *The Journal of Economic Inequality* 19 (2021): 3-11, https://doi.org/10.1007/s10888-020-09452-9

[38] Shahsavari, Amir, and Morteza Akbari. "Potential of solar energy in developing countries for reducing energy-related emissions." *Renewable and Sustainable Energy Reviews* 90 (2018): 275-291, https://doi.org/10.1016/j.rser.2018.03.065

literature review explored the impacts of solar energy projects, Particularly the impacts on social and economic inequality.

Prior to conducting literature review, relevant SDGs were selected that focus on local-level socio-economic impacts, goals with broader implications (SDG 16, SDG 17) and environmental focus (SDG 13, SDG 14, SDG 15) were not considered. SDG 1- 12 were selected after the first filter. Second step was further narrowing down the SDGs, by selecting only those that have relevant local-level impacts associated with renewable energy transition. This was done using the existing literature on energy transition-SDGs. Third step included identification of the inequality dimensions of the selected SDGs. The inequality dimensions were identified using equality and justice related keywords, identified from dominant literature.[39] [40] Following keywords were used: inequality/ inequalities, unequal, inequity, disparity/disparities, gender, race, ethnicity, class, disability, equal, universal, equality/equalities, equity, equitable, opportunity/opportunities, inclusive/inclusion, exclusion, injustice, justice, fair/ fairness, access, participation, social protection, marginalized, vulnerable/vulnerability.

Finally, inequality dimensions of 11 SDG targets were selected. Further, literature review was conducted, using keywords “solar+inequality dimension”, following the inclusion and exclusion criteria mentioned in Table 3.

Table 3: Inclusion and Exclusion Criteria for Literature Review

Criteria	Inclusion	Exclusion	Rationale
Year of Publication	Articles published between 2015-2023	Articles published before 2015	SDGs were adopted in 2015. Also, ILO’s guidelines for just transition also came in 2015, and the concept has gained significance since then
Types of Articles	Published journal articles and limited grey literature (working papers, conference proceedings)	Reports, newspaper articles	Published journal articles provide many empirical cases and strong evidence
Dimension of Energy Transition/ Type of Renewable Energy Technology	Solar projects and other solar technologies (for e.g.: decentralised solar projects, solar parks, off-grid solar, solar pumps etc)	Other renewable energy technologies (for e.g.: Biomass, wind, hydro, geothermal etc.) Other dimensions of energy transition, such as closing of fossil fuel plants, energy efficiency etc.	Solar is the technology of choice for most developing countries
Dimension of inequality	Social and economic inequality dimensions identified from selected SDG targets	Environmental inequality and other inequality dimensions of SDG targets that are not selected	To fill the research gap. Impacts on social and economic inequalities are less studied
Type of Impacts	Local-level impacts	National and global impacts	Understanding local-level impacts are most relevant, in the context of inequality as national level impacts usually focus on net impacts and important inequality implications are missed
Type of Countries	Developing countries	Developed countries	As developing countries need to undergo renewable energy transition along with fulfilling development goals, it is most crucial for them to understand inequality implications of the transition

[39] Goastellec, Gaële. "Understanding inequalities in, through and by higher education." (2010).
[40] Cook, Karen S., and Karen A. Hegtvedt. "Distributive justice, equity, and equality." *Annual review of sociology* 9, no. 1 (1983): 217-241, https://doi.org/10.1146/annurev.so.09.080183.001245

Findings and Discussion:

The impacts of solar energy projects and other solar technologies were explored on the following inequality dimensions of selected SDGs:

Table 3: Inequality dimensions of selected SDGs

SDG	SDG Target	(In)equality Dimensions
SDG 1: No poverty	Target 1.4: By 2030, ensure that all men and women, in particular the poor and the vulnerable, have equal rights to economic resources, as well as access to basic services, ownership and control over land and other forms of property, inheritance, natural resources, appropriate new technology and financial services, including microfinance	access to basic services and economic resources and ownership, access to technology and finance
SDG 2: Zero Hunger	Target 2.3: By 2030, double the agricultural productivity and incomes of small-scale food producers, in particular women, indigenous peoples, family farmers, pastoralists and fishers, including through secure and equal access to land, other productive resources and inputs, knowledge, financial services, markets and opportunities for value addition and non-farm employment	equal access to land and income for small-scale farmers; access to finance
SDG 5: Gender Equality	5.5 Ensure women's full and effective participation and equal opportunities for leadership at all levels of decision-making in political, economic and public life 5.a Undertake reforms to give women equal rights to economic resources, as well as access to ownership and control over land and other forms of property, financial services, inheritance and natural resources, in accordance with national laws	Equal opportunities for women; effective participation, access to ownership and control over land and other resources
SDG 6: Clean Water and Sanitation	6.1 By 2030, achieve universal and equitable access to safe and affordable drinking water for all	access to water
SDG 7: Affordable and Clean Energy	7.1 By 2030, ensure universal access to affordable, reliable and modern energy services	Access to energy
SDG 8: Decent Work and Economic Growth	8.3 Promote development-oriented policies that support productive activities, decent job creation, entrepreneurship, creativity and innovation, and encourage the formalization and growth of micro-, small- and medium-sized enterprises, including through access to financial services 8.5 By 2030, achieve full and productive employment and decent work for all women and men, including for young people and persons with disabilities, and equal pay for work of equal value	Equality of employment opportunity
SDG 9: Industry, Innovation, and Infrastructure	9.1 Develop quality, reliable, sustainable and resilient infrastructure, including regional and transborder infrastructure, to support economic development and human well-being, with a focus on affordable and equitable access for all 9.3 Increase the access of small-scale industrial and other enterprises, in particular in developing countries, to financial services, including affordable credit, and their integration into value chains and markets	Access to sustainable infrastructure, access of enterprises to financial services
SDG 10: Reduced Inequalities	10.1 By 2030, progressively achieve and sustain income growth of the bottom 40 per cent of the population at a rate higher than the national average 10.2 By 2030, empower and promote the social, economic and political inclusion of all, irrespective of age, sex, disability, race, ethnicity, origin, religion or economic or other status; 10.3 Ensure equal opportunity and reduce inequalities of outcome, including by eliminating discriminatory laws, policies and practices and promoting appropriate legislation, policies and action in this regard	Equality of income, social, political, and economic inclusion

These list of SDG targets and inequality dimensions is an important finding in itself. This is because it links renewable energy transition, inequality, and SDGs and provides a list of inequality dimensions, the impact on which should be considered to ensure a just transition. This section presents the impacts of solar on the dominant (in)equality themes that emerged from the literature:

Access to basic services: The first inequality dimension is access to basic services, which is an important dimension of both inequality and poverty[41]. The literature has different empirical

[41] Mottram, Hannah. "Injustices in rural electrification: Exploring equity concerns in privately owned minigrids in Tanzania." *Energy Research & Social Science* 93 (2022): 102829, https://doi.org/10.1016/j.erss.2022.102829

cases of developing countries, showcasing different possible impacts. The role of decentralised solar projects in increasing energy access in rural areas and further access to other basic services (lighting, information, healthcare services), reducing access related inequalities is well established.[42] [43] However, the injustices associated with solar projects, where energy from solar projects was exported to the industries instead of communities, and only those with high status were able to seize opportunities, worsening situation of poor and those without access to basic services have also been documented.[44] Another important dimension that directly relates with inequality, poverty, and renewable energy transition is ownership, and access to technology and finance. The community-private partnerships in solar projects play a positive role in providing a sense of ownership to the community and increasing opportunities of those who are unable to participate individually, by providing access to technology and finance.[45] There are practical challenges of shared-ownership, lack of trust being a major one and mechanisms are needed to overcome them[46] Further, there are inequities associated with adoption of solar PV in households and has found increase in inequalities of ownership- as low-income families are often excluded.[47] However, these observations have not been examined systematically.

Opportunities for small-scale farmers:

Another important inequality dimension of local solar energy transition is the inequalities in opportunities between small-scale and large-scale farmers. For example, construction of utility scale solar parks negatively affects the small-scale farmers and landless pastoralists as they lose access to land. This is because, although the solar parks are constructed on government wasteland, it is used by farmers for grazing and village animals live on that land.[48] On the other hand, there are benefits for small-scale farmers, such as by use of solar pumps as it helps in improving agriculture productivity and further the income of farmers, and selling or leasing land for solar projects.[49] There are, however, possibilities of exacerbating inequalities as accessing these benefits and opportunities require access to various resources (land) and finance. There are also inequalities in access to finance as incentives usually target

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[42] Henry, Candise L., Justin S. Baker, Brooke K. Shaw, Andrew J. Kondash, Benjamín Leiva, Edwin Castellanos, Christopher M. Wade, Benjamin Lord, George Van Houtven, and Jennifer Hoponick Redmon. "How will renewable energy development goals affect energy poverty in Guatemala?." *Energy Economics* 104 (2021): 105665, https://doi.org/10.1016/j.eneco.2021.105665

[43] UN Secretary-General's Advisory Group on Energy and Climate Change (AGECC), Energy for a Sustainable Future: Summary Report and Recommendations, AGECC, 2010, https://www.un.org/millenniumgoals/pdf/AGECCsummaryreport[1].pdf

[44] Calzadilla and Mauger, "UN's new sustainable development agenda". 233-254

[45] Eitan, Avri, Lior Herman, Itay Fischhendler, and Gillad Rosen. "Community–private sector partnerships in renewable energy." *Renewable and Sustainable Energy Reviews* 105 (2019): 95-104, https://doi.org/10.1016/j.rser.2018.12.058

[46] Goedkoop, Fleur, and Patrick Devine-Wright. "Partnership or placation? The role of trust and justice in the shared ownership of renewable energy projects." *Energy Research & Social Science* 17 (2016): 135-146, https://doi.org/10.1016/j.erss.2016.04.021

[47] Sovacool, Benjamin K., Max Lacey Barnacle, Adrian Smith, and Marie Claire Brisbois. "Towards improved solar energy justice: Exploring the complex inequities of household adoption of photovoltaic panels." *Energy Policy* 164 (2022): 112868, https://doi.org/10.1016/j.enpol.2022.112868

[48] Yenneti, and Day. "Distributional justice"

[49] Gupta, Eshita. "The impact of solar water pumps on energy-water-food nexus: Evidence from Rajasthan, India." *Energy Policy* 129 (2019): 598-609, https://doi.org/10.1016/j.enpol.2019.02.008

landowners, exacerbating existing inequalities of land-ownership and finance.[50] These can be reduced by targeted subsidies for small-scale and marginalised farmers.[51]

Opportunities for women:

The current literature identifies both positive and negative impacts on this dimension. The positive impacts on women include increase in education and livelihood opportunities due to increased electricity and lighting hours, owing to decentralised solar projects and off-grid solutions. The most dominant positive impact is of initiatives that train women to be solar entrepreneurs (e.g.- Solar Mamas), as it can help them in entering male-dominated field and encourages effective participation of women. [52] Further, there are also empirical cases where small- scale solar projects or owning off-grid solutions help in women empowerment through increasing their decision-making power, economic independence, self-confidence etc. [53] [54] Yet, it is also acknowledged in the literature that gender inequalities will be reinforced and exacerbated, rather than reduced, if gender justice is not prioritised in renewable energy transition.[55] [56] This is because women are not able to seize opportunities as their male counterparts, because of societal norms and traditional responsibilities, which make entrepreneurial process also different and difficult for women.[57]

Access to water and energy:

With respect to water access, solar technologies such as solar based groundwater pumping can increase access to groundwater for irrigation. [58] There are also solar-driven technologies for water purification that can improve water availability and access.[59] However, the free solar energy- water nexus and overuse of pumps can deplete groundwater, impacting access. [60] There are also empirical cases in the literature that has identified negative impact of mega solar parks on water access in nearby villages as solar panels require periodic cleaning and

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[50] Closas, Alvar, and Edwin Rap. "Solar-based groundwater pumping for irrigation: Sustainability, policies, and limitations." *Energy Policy* 104 (2017): 33-37, http://dx.doi.org/10.1016/j.enpol.2017.01.035

[51] ibid

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supply for villages is often diverted to the solar parks, exacerbating water scarcity. [61] With respect to energy access, decentralised solar projects and off-grid solar help in increasing energy access as they provide electricity in rural and remote areas. [62] The literature has also identified the role of different off-grid solar technologies in reducing energy poverty- which can be defined as difficulty in accessing and affording modern energy, especially electricity. [63] The literature has also explored the impact of energy transition on energy justice principles- distributive, procedural and recognition. There are many empirical cases where these principles were not incorporated and solar projects worsened the situation for the vulnerable and marginalised. [64] Also, access to solar technologies require finance and proper subsidies and financial mechanisms should be in place for it to reach poor. [65]

Employment opportunities:

Although, employment is a dominant theme of just transition literature, it is focussed more on loss of employment of fossil fuel workers. The literature, to a certain extent, has identified the impacts of mini and mega solar projects on employment opportunities. The positive impacts include creation of job opportunities during implementation of solar projects- in construction, manufacturing etc.[66] The literature has also identified the net impact of global energy transition on employment to be positive.[67] However, this positive impact due to job creation to be temporary for unskilled workers, often only during the construction phase of solar plants. [68]Further, long-term employment would require development of skills and training.[69]

As the SDGs are interlinked, the different inequality dimensions are also interconnected. For example, the employment dimension also has a gender component, with respect to different employment opportunities for men and women. This is because energy related jobs are often considered masculine, excluding women from many employment opportunities.[70] Further, women are not able expand their livelihood, due to increased electricity access, as effectively as their male counterparts due to existing gender norms (For example- it is easier for a man to own a shop).[71]

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Access to sustainable infrastructure:

Solar mini and mega projects in themselves are sustainable infrastructure and their deployment can increase opportunities of people to access infrastructure. However, solar energy transition can cause infrastructure violence.[72] The concept of infrastructural violence stems from the concept of spacial injustice and involves social harmful effects that disproportionately impact the marginalised. There are empirical cases, in the literature, where construction of mega solar parks impacted the marginalised and residents of nearby villages as the infrastructure provisions promised were not fulfilled. [73]

Inclusion of marginalised:

Another important (in)equality dimension, that related with SDG 10 and encompasses almost all other dimension is that of inclusion- economic, political, and social inclusion. Existing structural inequalities can restrict participation of certain communities and marginalised, including poor and women in solar projects. For instance, land tenure is generally not transferred to women, restricting their participation and decision-making power, exacerbating the inequalities.[74] Further, in case of decentralised solar projects, being implemented by private companies also lead to exclusion of poor communities and remote villages and these companies prioritise profits.[75] Even in community owned projects, the existing power relations can lead to exclusion of lower income households [76] and community dialogues often involve participation of educated and wealthy. [77] Further, poor and uneducated are often excluded from off-grid solar solutions as they require financial investment and low consumer literacy can lead to buying of substandard products. [78] There are also empirical cases where construction of mega solar parks negatively impacted the less informed and uneducated and they sold their land at low price, as proper participatory procedures were not followed. [79]

Table 4 provides a summary of local-level impacts of solar transition on selected inequality dimensions and mechanism, identified in the literature, needed to reduce negative impacts on (in)equality.

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Table 4: Local-level impacts of solar transition on selected inequality dimensions

SDG	(In)equality Dimensions	Impact on Inequality	Mechanisms needed to reduce inequalities
SDG 1	access to basic services and economic resources and ownership, access to technology and finance	Community solar projects and off-grid solar solutions help in reducing inequalities in access to basic services by providing energy access in rural and remote areas. However, there are empirical cases in the literature where solar projects did not increase energy access of communities, and worsened the situation of poor and those without access to basic services, exacerbating inequalities	Community-private partnerships with mechanism to build trust,
SDG 2	equal access to land and income for small-scale farmers; access to finance	The decentralised solar projects in rural areas as well as solar pumps can yield various benefits for small-scale farmers, reducing inequality of opportunities, However, there are also various resources needed to access these opportunities (such as land, finance etc) which can reinforce existing inequalities between large and small-scale farmers. The literature has empirical cases where construction of solar plant leads to loss of land access by landless and marginalised. There is also inequality in access to finance between small- and large-scale farmers, which can be reproduced while accessing solar pumps as many subsidies favour wealthy farmers	Targeted subsidies for small-scale farmers, strategies to incorporate energy justice principles
SDG 5	equal opportunities for women; effective participation, access to ownership and control over land and other resources	There exists a possibility of reducing gender inequalities by training women to be solar entrepreneurs but also the possibility of reproducing inequality due to lack of technical know-how and traditional responsibilities. The literature has recognised that energy transition might just shift gender inequalities as men and women will differently reap the benefits of increased daylight hours, with women sacrificing their leisure time towards domestic work. Also, women will not be able to expand their livelihood opportunities as their male counterparts, owing to gendered norms	Designing interventions to include gender component; training and building capacity of women
SDG 6	access to water	On one hand, water access can improve as a result of solar pumps and it also benefits small-scale farmers, reducing inequalities. However, solar pumps can also exploit groundwater and can reduce water access. Construction of mega solar projects can also reduce water availability in nearby villages, exacerbating water scarcity	Optimal sizing of pumps; policies to incentivise effective water use
SDG 7	access to energy	Solar projects and off-grid technologies have the potential to reduce energy poverty. However, the literature has also explored distributive, procedural and recognition injustices associated with solar projects	Integration of energy justice principles, international finance subsidies
SDG 8	equality of employment opportunity	Deployment of solar can create inequality in accessing employment opportunities as there will be loss of traditional jobs and less opportunities available for those who lose their jobs as different skills are required.	Training programs and skill development
SDG 9	access to sustainable infrastructure, access of enterprises to financial services	On one hand, transitioning to renewables is explicitly linked with sustainable infrastructure and access to solar in rural areas can increase access to sustainable infrastructure. On the other hand, there are many injustices associated with development of solar infrastructure (large scale projects) and lack of access for the nearby rural areas	Strategies and policy mechanisms are needed to prioritise the vulnerable and marginalised, who are disproportionately burdened by the energy transition
SDG 10	equality of income, social, political, and economic inclusion	The community-owned solar projects can help in inclusion of community members. However, there also exist power relations within the community that can lead to only wealthy and influential people seizing the opportunity, thereby exacerbating the patterns of exclusion	Putting community at the centre and understanding of power relations and inequalities within the community

The finding presented in the study points to following interesting insights. First, it points out that the energy transition is not just a technological process but has important social implications, that impact people at the local-level. Therefore, the lack of incorporating energy justice principles into transition process can exacerbate the structural inequalities. Second, analysing the transition process through an inequality lens is a unique and important approach as it helps in identification of important trade-offs associated with energy transition and in shifting a mere transition to a 'just' transition. Third, gender is an important dimension as many of the inequality dimensions- such as land ownership, energy access, employment have gendered impacts. Therefore, energy transition policies should consider the existing gender norms and should have mechanisms to reduce negative impacts on women. Fourth, decentralised community owned solar, which is often seen as a promising opportunity can also exclude the uneducated and marginalised. Therefore, putting the community at the centre and understanding of power relations within the community is crucial. Further, the literature review conducted also pointed to important mechanisms that can support in implementing a just transition. These include: targeted subsidies, skill development and training programs, community partnerships based on trust etc.

The review also reveals certain research gaps in the academic literature. Only a few studies have explicitly acknowledged that solar energy transition has the potential to reproduce or even exacerbate structural inequalities. Most studies have simply showcased the positive and negative impacts of the transition. This paper closes this research gap by viewing all impacts from an inequality perspective. Additionally, explicit mention of 'SDGs' and ''just transition' is limited, even though the inequality impacts relate to both the concepts. The methodological approach of identifying inequality dimensions from the SDG targets closes this research gap and explicitly incorporates SDGs to define just transition.

Conclusion:

This paper has presented the impacts of solar energy transition on SDGs, in developing countries, from an (in)equality perspective. Drawing on an exploratory literature review, this paper has discussed the local-level impacts of solar energy transition on inequality dimensions of relevant SDGs and the mechanisms needed to reduce the negative impacts. The paper has cited many empirical cases, where different solar energy technologies led to exacerbating existing inequalities of land ownership, gender, energy access, employment etc. The literature reviewed has also identified the need for certain governance mechanisms- such as targeted subsidies, training programs to reduce the injustices and negative justice implications. This paper adds to and strengthens the emerging argument of the literature that if proper mechanisms are not in place, low-carbon transition will simply shift inequalities, rather than reducing them. The findings of this paper help in redefining and strengthening the concept of just transition from an inequality and SDG perspective and closing various research gaps. This paper argues that ensuring a just transition involves transitioning to renewables in a way that it does not exacerbate structural inequalities, includes marginalised, and fulfils SDGs. This paper also argues the unique approach of taking inequality as a focal point to assess local-level impacts of solar energy transition. This can act as a methodological toolbox for policymakers to design just energy transition policies. Future research can focus on designing an inequality centric just transition framework and applying it to empirically analyse the impacts of energy transition policies.