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Micro-solutions to global problems: understanding social processes to eradicate energy poverty and build climate-resilient livelihoods

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Abstract

This research explores the agent dynamics, learning processes, and enabling conditions for the implementation of microscale win-win solutions that contribute to energy poverty eradication and climate resilience in a selection of low-income rural and peri-urban communities in India, Indonesia, and South Africa. We define these micro-solutions as energy-related interventions and resilience services or products—used at community, household, small production unit, or business level—that yield both economic and climatic gains. Our analysis identifies five elements critical for the robust design of these interventions: (i) The ability to collaborate and share different kinds of expertise with a range of networks operating at multiple levels of activity; (ii) The application of place-based systems-learning perspectives that enable project participants to integrate different types of solutions to meet different needs at the same time; (iii) The ability to yield tangible short-term benefits as part of long-term strategic visions and commitment; (iv) The use of novel technologies and financial instruments in ways that foreground the needs of poor populations; and (v) The inclusion and empowerment of economically marginalised groups through institutional and technological innovations and responsible business models. We conclude that the most critical aspect of successful micro win-win solutions is support for communities' own endogenous transformative capacities as this helps ensure that solutions are shared and continuously adapted to changing conditions over time.

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1 Introduction

Ensuring universal access to affordable, reliable, and modern energy services for all by 2030, as called for in the UN Sustainable Development Goals (SDGs), means bringing energy to the 1.1 billion people currently without electricity plus clean cooking fuels and technologies to the nearly 2.8 billion people who have no access to these (IEA 2017; UN 2015). Expanding energy access using conventional fossil fuel and existing biofuel solutions will further compromise the attainment of the Paris Agreement's target of limiting global warming to below the 1.5 to 2 °C threshold by the end of this century. However, green and sustainable technologies that can simultaneously meet energy-access and climate-change commitments are rapidly being deployed. The growing deployment of these technologies in low-income urban and rural contexts provides a suite of new opportunities for 'win-win alliances' for those involved in climate and sustainability actions.

The potential effectiveness of small-scale, de-centralised energy interventions, aligned with sustainable resource management and climate resilience objectives, is well documented (Halff et al. 2014). However, realising the full benefit of these interventions requires special attention be paid to understand the specific social processes that can enable or constrain the emergence (Sovacool 2012). In our research, we examine the kinds of conditions, opportunities, and social-learning dynamics that might be involved in enabling the successful implementation of small-scale green innovations that are appropriate to local contexts and meet the real needs of intended beneficiaries by contributing to energy poverty reduction and supporting climate resilience (Speranza et al. 2014). In particular, a set of cases are presented to explore the concept of 'micro win-win solutions'. These focus on the community-oriented orientations of organisational, product, or service innovations, as well as associated partnerships emerging in several low-income rural and urban informal contexts in India, Indonesia, and South Africa. Based on these cases, we propose that micro win-win solutions, constituted by small-scale interventions implemented at a community, household, or production-unit level, that yield economic and climate-change benefits should be better supported. We show that such solutions offer observable short-term gains and carry the potential for ongoing development as they are adapted and evolve over time.

2 Addressing energy poverty, climate resilience, and sustainable development

Energy poverty can be defined by the lack of access to energy services below a specified threshold. This is related to income poverty but is not necessarily directly reflective of income poverty (Khandker et al. 2010). Where the appropriate threshold for energy poverty lies is contested and dependant on local contextual factors. Any useful definition of energy poverty must consider the integration of social development and local end-user perspectives with existing institutional structures, instead of focusing only on technical outcomes and financial factors (Pachauri and Spreng 2011). This applies also to interventions that aim to alleviate energy poverty, as well as to monitor and evaluate frameworks. Additional challenges to be considered when designing interventions are the interrelationships between energy poverty and other dimensions of poverty as well as the fundamental problems that climate change poses for the way these issues have been, and can be, addressed.

Furthermore, 'climate-change impacts are projected to slow down economic growth, make poverty reduction more difficult, further erode food security, and prolong existing and create new poverty traps' (IPCC 2014: 21). Whilst climate change might not be the dominant driver behind global poverty by 2030, its impact is likely to be significant. As climate-related hazards become more prevalent and extreme, they are already exacerbating other stressors, negatively affecting the livelihoods of low-income people, intensifying inequalities, and triggering new vulnerabilities linked to community and individual development (Olsson et al. 2014). However, awareness, anticipation, and responsiveness to climate change are also kindling new opportunities.

The International Energy Agency, along with other international development agencies and donors, is advocating for decentralised and medium- and small-scale renewable energy solutions as the most flexible and cost-effective mechanism for meeting the energy needs of up to three-quarters of currently unserved households. These solutions include solar photovoltaic (PV) home systems, mini-grid systems, and clean and safe cooking technologies (Anenberg et al. 2013). Alternative sources of renewable energy, such as small solar and wind power plants, biomass, and where appropriate, micro-hydro, are also bound to play a significant role. The climate resilience benefits of using these technologies to eradicate energy poverty and enable fuel switching can be amplified by simultaneously addressing safe and sustainable water access and use, as well as moving towards conservation and smart agriculture (Agoramoorthy and Hsu 2016; Ahlborg and Sjöstedt 2015; Chandra et al. 2017; Pradhan et al. 2018). Whilst small-scale solar PV, in particular, has been deployed with significant success in low-income urban and rural contexts, many households that have some access to electricity still rely on biofuels (mainly) for cooking being traditional biomass fuels the primary source of energy of about two billion people (UNEP 2015a). For this reason, the production of small-scale biofuels for use at household and local levels can be seen as a significant opportunity. In addition, where these biofuels are deployed, co-benefits such as the empowerment of women, wider access to education, livelihood opportunities, and the reduction of indoor pollution are evident, thereby enhancing community sustainability and resilience (Halff et al. 2014).

International agencies generally acknowledge that to achieve sustainable development outcomes, strategies to eradicate energy poverty must engage with climate risks and opportunities. For so-called development practice to recognise and capitalise on these opportunities, it must rapidly orient itself to be genuinely inclusive and climate informed (Hallegatte et al. 2016). For energy poverty eradication, this means grappling with the complex interactions between sustainable development and climate adaptation and mitigation (Leichenko and Silva 2014). Access to energy addresses only one of the many dimensions of poverty; comprehensively addressing and reducing poverty depends on many other structural factors, including access to education, job opportunities and political influence.[1] Because of the interrelationships between various dimensions of poverty, overcoming energy poverty in a long-lasting way is also dependent on these other structural factors being addressed and can be supported by the deployment of local technologies that meet other urgent needs (Bhide and Rodriguez Monroy 2011; Guruswamy 2011). Therefore, addressing energy poverty requires a multi-level, multi-dimensional approach that integrates different perspectives as well as new and existing development support. In particular, integrated strategies ought to (i) support local

[1] See the Global Multidimensional Poverty Index at https://ophi.org.uk/multidimensional-poverty-index/; for instance, in South Africa, some informal settlements have state-subsidised access to municipal electricity.

transformations in energy policy, energy consumption, and production patterns whilst improving energy-systems efficiency and resilience; (ii) ensure environmental quality and long-term sustainability via the use of a mix of energy resources; (iii) foster the adoption, diffusion, and transfer of clean energy services, technologies, and fuels; (iv) explore cross-cutting energy policy measures, including those related to international finance, investments, trade, and local capacity building; and (v) assess equity and distributional issues, particularly, those pertaining to inequalities based on gender, race, or ethnicity (GNESD 2013; UNEP 2011; 2015b).

To this end, the right mix of incentives and an adequately enabling policy environment are needed to ensure collaboration between project promoters, implementers, and investors. Transforming vicious cycles of poverty into virtuous cycles via actions directed at enhancing climate resilience and sustainability is a crucial imperative facing communities, governments, and non-governmental organisations. It is critical that we identify specific strategies that meet communities' energy needs at local and micro-levels and that help to lift people out of poverty traps in rural and informal urban areas in sustainable, climate-resilient ways (Haider et al. 2017; Lade et al. 2017).

3 Micro win-win solutions: concept and overview of cases

In this research, we developed the concept of 'micro win-win solutions' to describe interventions targeted at the level of a community, a household, a small production unit or business, with their associated services and products, and which yield both economic and climate gains.[2] Our primary focus was on identifying solutions that contribute to energy poverty eradication and climate mitigation, adaptation, and resilience at this level and on understanding why they work. The overall purpose was to examine the networks of agents, learning dynamics, and enabling conditions that led to the emergence of such solutions in several cases in India, Indonesia, and South Africa. In these three locations, exploratory workshops and analyses were carried out involving a wide range of stakeholders, from local policymakers, green business owners, development NGOs, and project beneficiaries in neighbourhoods and villages, as shown in Table 1.[3] The numbers in brackets of this table indicate the case contributions to the five key main insights and messages as explained in section 4.

An essential aspect of this research has been to learn from the experiences of local networks and organisations already involved in developing sustainable and climate-sensitive development strategies. In India, we reviewed a selection of processes aimed at building capacity for the implementation of solutions supported by the Development Alternatives Group, a social enterprise that incorporates the Society for Technology and Action for Rural Advancement (hereafter referred to as TARA-DA) and its affiliates. TARA-DA promotes 'public–private–people collaborations' that aim to grow local capacities in ways that create the conditions for extending economic well-being in rural areas. Their engagement with local communities and local entrepreneurs seeks to generate solutions that align themselves with the principles of the

[2] A related concept is the 'no regrets option' (see http://www.ipcc.ch/ipccreports/tar/wg3/index.php?idp=292). However, in contrast to this concept, we do not assume a single economic equilibrium producing inevitable trade-offs between economic growth and reductions in greenhouse gas emissions, or that any economy operates at its optimal level. The notion of win-win solutions, especially at a micro level and in poor and informal contexts, assumes the existence of multiple equilibria and much room in which it is possible to achieve higher levels of economic growth and meaningful reductions in greenhouse gas emissions (Jaeger et al. 2012).

[3] See the supplementary material for more detailed descriptions of each case.

Table 1 Case study examples of micro win-win solutions for energy poverty alleviation and climate resilience from South Africa, India, and Indonesia

Project, location	Scale/scope/main contribution to key message	Focus	Type	Description	Investment or funding	Agents involved
Zonke Energy Cape Town Western Cape, South Africa zonkeenergy.com	Neighbourhood, in an informal settlement (1),(3),(4),(5)	Basic solar PV provision—urban informal	Green business selling safer, cheaper and green electricity to off-grid households that were reliant on paraffin and candles	Delivery of basic energy services using solar PV panels	Electricity access is supplied on a pay-as-you-go basis in an informal settlement. The company's director funded the initial investment	Local, municipal, and national; mostly private but with some public support
The Sun Exchange Cape Town, Western Cape, South Africa thesunexchange.com	Local and community-level installations with national, regional, and international investors, including from other African countries (1),(3),(4),(5)	Solar PV generation—community level	A firm selling affordable shares in solar PV installations	A crowdfunding platform that uses blockchain technology to finance small-scale renewable energy for schools, businesses, etc.	Leveraging crowdfunding through an online platform. Additional funding has been secured from the US-based investment firm, Network Society Ventures	Local and international, private only. Beneficiaries include small companies, charities, and schools
Genius of Space Langrug, Western Cape, South Africa https://www.flow.org. Leveraging public funding through a government-funded climate project	Participatory project for implementing basic community infrastructure for the management of solid waste and treatment of grey water	National and multilateral development banks plus government equity funds. No private investment	Local community and NGOs with national and provincial government departments	za/portfolios/genius-of-space-gos2/	Neighbourhood, in an informal settlement (1),(2),(5)	Wastewater management—urban informal
Kruistementvlei Farm Piketburg, Western Cape, South Africa http://ksvfarm.co.za	Farm and household (2),(3),(5)	Organic farming integrated with renewable energy systems	Family-run green business/cooperative with several integrated solutions that minimises waste, uses heat from compost, and reduces water consumption	Compost-powered household water-heating system, combined with other organic farming and green activities, including ecotourism. It also offers skills and employment opportunities to youth in the surrounding area	Self-funded, and this strategy is reducing energy and farming costs while delivering higher-value farm produce	Private (farm owners) with some in collaboration from some state partners, such as Working For Water, a state-run alien--vegetation clearing programme
Govindnagar community water system Bundelkhand Madhya Pradesh, India	Three poor rural communities (1), (2),(3),(4),(5)	Expanding access to clean water and renewable energies through empowerment of local agents (including women)	Community-run business assisted by the Development Alternatives Group	Community-owned and operated supply of drinking water powered by solar energy	A monthly fee covers annual maintenance and repair, but international donors provided initial investment	Local community agents and international donors linked by the intermediary work of

Table 1 (continued)

Project, location	Scale/scope/main contribution to key message	Focus	Type	Description	Investment or funding	Agents involved
						Development Alternatives Group
Fly ash brick and ecokiln community producers Madhya Pradesh, Bihar and Delhi, India	Local communities in several states (1), (2),(3),(5)	Providing sustainable innovations in the construction sector	Independent green businesses initially supported by the Development Alternatives Group	Production of low-carbon, low-energy, and low-environmental-impact bricks	Initially supported by the Development Alternatives Group, but new branches become financially viable	Local community plus state/regional actors and intermediaries from the Development Alternatives Group
Bheldi Renewable Energy Bihar, India	Local community and neighbourhood (1),(2),(3),(5)	Solar PV plus a biogas minigrid that supports local entrepreneurs' solar picogrid businesses	Green entrepreneurs initially supported by the Development Alternatives Group	Privately run business in partnership with the Development Alternatives Group	After initial financial support from the Development Alternatives Group, entrepreneurs breakeven by selling green energy services to the local community	Local community plus state/regional actors and intermediaries from the Development Alternatives Group
Munger organic waste recovery Bihar, India	Peri-urban neighbourhood linked to nearby communities (1),(2),(3)	Creating economic opportunities for marginalised people and contributing to several environmental / climate wins by reusing organic waste	Ad hoc green partnership and new green business initially supported by corporate social responsibility funding	Organic waste collected from peri-urban neighbourhoods and made into high quality compost benefits poor people in nearby communities.	Supported initially by corporate social responsibility funds but now self-sustaining by from the sale of compost	Local municipalities, local NGOs, and intermediaries responsible for corporate social responsibility projects
Laliyadih biogas, vermicompost and drip-irrigation Bihar, India	Single household (1), (2),(3)	Improving the eco-efficiency of the farm by integrating several win-win strategies	Family-owned farm implementing simple win-win technologies to increase the use of renewable energy and save water	Use of biogas as a renewable source for cooking and the use of drip irrigation	Initial payment by international donors and NGOs, and now income is generated from the sale of farm produce	Local municipalities, local NGOs, and intermediaries from international NGOs such as OXFAM
Su.re.coffee Jembrana, Bali, Indonesia	Farm and community level (1),(2),(3),(5)	Coffee and biogas production to reduce vulnerability to climate change by diversifying produce (moving beyond rice) and switching to sustainable energy sources	Green business with a social and environmental orientation	The development and distribution of biogas digesters, supporting smart agriculture and helping to create a market for green agricultural products (chocolate and coffee)	Initial support from the European Commission's GREEN-WIN project as an example of action research. Supported also by Udayana University.	GREEN-WIN researchers with local NGOs and (for dissemination and policy dialogue) the Indonesian Ministry of Planning Development

triple bottom-line: people, planet, and profit. Their strategies have shown the positive impacts of innovations derived from, among other things, implementing decentralised renewable energy solutions, using green materials in the construction sector, and building small check dams to provide water for local livelihoods and ecosystem restoration. In the case of decentralised energy, a model has been developed that provides electricity to local communities whilst simultaneously advancing entrepreneurship in the region by supporting local green-energy enterprises. TARA-DA has also developed a model for the production of fly ash bricks that are cheaper to make and produce less waste and fewer GHG emissions than cement and concrete.

In South Africa, four cases were analysed. First, we examined the implementation of renewable energy micro-grids by the social enterprise Zonke Energy in the City of Cape Town. This is an example of the private provision of clean and affordable energy to informal urban settlements where conventional electricity infrastructure is not available, practical, or financially feasible (Brown and McGranahan 2016).

Second, we considered the social-purpose start-up, Sun Exchange, which leverages fintech innovation to connect individuals to local investment opportunities for small-scale renewable energy infrastructure. Sun Exchange uses blockchain technology to enable secure financial transactions for investment in solar PV installations. Using both fiat and cryptocurrency, they store and manage asset information in a public, transparent, and distributed ledger. By decreasing transaction costs and refining project-vetting processes, this organisation finances community-based renewable energy projects that fall through the cracks of conventional financing opportunities. Its investments have the potential to provide clean and affordable energy to marginalised rural and urban communities, as well as to small enterprises.

Third, the 'Genius of Space' project was examined as an example of a 'green infrastructure solution', in which the focus is on developing climate resilience through providing innovative grey water treatment and solid waste management in an informal settlement. The Genius of Space is a government-supported project initiated by the community using an appreciative inquiry approach. This allows for community participation to drive context-specific, incremental community development solutions to real needs defined by community members themselves. In addition, biomimicry principles, based on solving complex social-ecological problems through mimicking the dynamics of ecological systems, informed this project. Participants link this approach to their ability to meet local needs adaptively.

A fourth case, Kruistementvlei Organic farm applies the principles of the circular economy to a suite of integrated solutions that contribute to both climate mitigation and adaptation. These solutions also deliver various additional benefits, including enhanced employability for local youth and subsequent poverty reduction.

In Bali, Indonesia, an action-research approach was used to explore the potential of linking sustainable coffee and biogas production to climate-smart agriculture. For this, an ad hoc company, su-re.co (short for Sustainability and Resilience) was established with Udayana University. This initiative aimed to support several local farming communities and help them expand the market for green products. Biogas produced from cow manure and agricultural waste was used for roasting the coffee beans, whilst the bio-slurry (a sub-product of biogas production) was applied as organic fertiliser, thus replacing energy-intensive mineral fertilisers. Through this project, new jobs were created; crops that are more drought resistant are being grown and processed using clean, renewable energy. During the pilot project, some farmers transitioned from rice to coffee production, thus generating more income and reducing both poverty and their vulnerabilities to climate change (see also Takama et al. 2015).

4 Social learning and the conditions for micro win-win solutions

Our review of these cases showed that the most critical factors in the implementation of micro-solutions are related to understanding and supporting the complex social contexts that make them possible. In particular, supporting such social processes depends on careful assessment and awareness of the available opportunities and capacities of local agents and communities to transform the system conditions in which they operate. The continuous emergence of different solutions and their ongoing adaptation to changing circumstances depends on such endogenous transformative capacities, and in this respect, we identified five elements as critical for the successful design and uptake of micro win-win solutions in particular. These elements are not only critical for successful outcomes but also help to prevent potential conflicts and resistance linked to project implementation. They are (i) the ability to collaborate and share different kinds of expertise with a range of networks operating at multiple levels of activity; (ii) the application of place-based systems-learning perspectives that enable project participants to integrate different types of solutions to meet different needs at the same time; (iii) the ability to yield tangible short-term benefits as part of long-term strategic visions and commitment; (iv) the use of novel technologies and financial instruments in ways that foreground the needs of poor populations; and (v) the inclusion and empowerment of economically marginalised groups through institutional and technological innovations and responsible business models.

4.1 Network building and collaboration

A common component in the implementation of the projects we reviewed was the involvement of multi-actor partnerships connected by a shared social purpose or mission. Collaborations were established between government agencies, community actors, and other transnational agencies or social enterprises working across multiple levels (Spagnoletti and O'Callaghan 2013; Tosun and Schoenefeld 2017). Philanthropic foundations, corporate social responsibility programmes, local NGOs, and university researchers worked collaboratively, often coordinated by a prominent actor or a designated organisation. Such networks combined the work of 'grassroots innovation' (Gupta 2016) with new green technologies as well as with new forms of service provision, funding, and investment. In turn, partnerships between private, public, and community actors—as in the case of the Genius of Space project in South Africa or the renewable energy project in Bihar—even triggered innovations within the formal public institutions that engaged in these interventions.

Nevertheless, building such transnational and 'translocal' networks is time-consuming and human-resource intensive. For instance, the work carried out by TARA-DA shows that, before capacity building can even start, the local situation must be carefully assessed. This entails identifying and mapping local NGOs, individual champions, and other agents who might be able to lead projects in the field. In the case of green businesses, conditions must be established that enable local demand for green products and services to be sustained.

Across all the cases we studied, it was clear that a process of trust-building underpins the building of local capacities and the consolidation of 'win-win alliances' between those who hold different types of knowledge (Marshall et al. 2018). This process can take years. The cases also show that the motivations of all actors need to be clarified and understood, so that incentives and net gains can be tailored to secure their long-term collaboration. This is especially true for intermediaries involved in knowledge facilitation, integration, and activation (see Tosun and Schoenefeld 2017). In short, the success and continuity of these win-win strategies require that participants' interests, performative requirements and resources, are as

carefully considered as those of intermediaries such as academics and donors who operate outside of the local communities.

4.2 Place-based systems-learning

Most of the micro solutions described here developed in 'co-evolutionary' ways, That is, different actors involved in the projects adapted their goals, systems, and procedures in symbiotic ways. Social learning, underpinned by the principles of sustainability, has been critical to these co-evolutionary processes (Tàbara and Pahl-Wostl 2008). Almost all the interventions started out as narrow responses to an immediate need (such as managing greywater in an informal settlement). As they achieved some success, they became more responsive to other community problems and aspirations, gradually adopting a more comprehensive and integrated approach. This meant they could begin to tackle issues such as food security, education, and welfare from a longer-term perspective.[4]

Integrated, place-based development made continuous adjustment and uptake possible for each project. Communities generally knew what they needed but not how they could meet those needs. Solutions often emerged through trial and error, with the first stages largely experimental and followed by a capturing of lessons learned. Whilst processes and outcomes were formulated, their final shape was often unclear. In time, however, the use of social-learning strategies allowed positive synergies to emerge and, as mentioned, projects then began fulfilling various interconnected socio-economic needs. The range of positive and adaptive responses available to these organisations (in relation to challenges such as shocks in the local economy or shifts in climate patterns) expanded. Tangible benefits for health and sanitation, shelter, and basic community services were achieved, alongside improvements in social cohesion or the inclusion of formerly marginalised groups.

From our analysis, it is evident that synergies developed when solutions proposed addressed the nexuses of energy–poverty–climate and/or water–energy–food–health (Rasul and Sharma 2016; UNIDO and ADA 2017). Of course, at a local level, many nexus combinations are possible. No universal formula governs the selecting of domains for inclusion in a given development nexus and no single criterion makes such domains coherent. Ultimately, the components of integrated-learning processes that develop win-win strategies depend on the unique social and ecological conditions from which the solutions emerge. Furthermore, most of the case studies provide 'imperfect' solutions that need constant adjustments so that they meet changing local requirements and capacities.

In informal urban settlements and marginalised rural contexts, standardised designs or high-tech approaches may not be available. They can also be too rigid, not fit for purpose or too expensive. For example, in the communities we studied in India and South Africa, many community-run businesses are robustly informal. This means that few of their financial transactions are, or can be, carried out through formal banking channels or via monetary payments. This obviously affects the shape and content of solutions they choose to meet their needs. Similarly, products and services that contribute to alleviating poverty at a micro level, such as for water treatment in an informal settlement, may not always conform to the standards defined for more affluent urban settings but they can still be a useful step in improving basic living conditions.

[4] The Kruistementvlei Integrated Organic Farm in South Africa is a good example of how integrated learning is contributing to community empowerment while promoting renewable energy use, environmental health, and organic food production.

This incremental approach (Pieterse 2008) is often the result of actors responding to specific needs that become urgent at particular times; in such contexts, solutions are improvised in the absence of more formal plans. Place-based solutions are often cobbled together, using the patchwork of service providers, products, and materials that happen to be available in a particular time and place. Unpredictability in both content and shape is common, and few specific deadlines or milestones drive such solutions' ultimate delivery. The extent to which these solutions then go on to deliver a range of other benefits to the community depends on whether their transformative capacities can be refined and broadened over time. This slower but steadier approach may be a key factor in securing sustainability in the long term.

4.3 Tangible short-term benefits help secure longer-term visions and commitment

In the micro win-win solutions profiled here, individual leaders, NGOs, and visionaries played crucial roles in the early stages. Actors with long-term policy visions or organisational missions are often necessary to guide and connect collective actions to broader ethical principles. However, for such initiatives to survive, vision setting has to be coupled with firm commitments from all participants to deliver tangible results in the short and the long term (see Ahlborg and Sjöstedt 2015). In addition, the long-term success of such initiatives cannot depend on the will or the views of any single individual or agency; open and adaptive management systems are essential to ensure continuous learning, transformation, and revising of the original goals (Tàbara et al. 2018).

A wider discourse on sustainability seems to have shifted away from meeting needs in ways that do not compromise future generations towards the achievement of goals. The SDGs (UN 2015), for example, are a set of goals that can be used to orient policy development towards win-win strategies at the national level. However, the SDGs might be too broad and distant from local practices and local actors to sufficiently engage communities, production units, and households. However, an essential precondition for the successful implementation of high-level policy targets like the SDG is that they translate into specific actions at a community level such as in the form of micro win-win solutions.

Our research shows that, especially in contexts with high levels of poverty, many of the supposed trade-offs between climate adaptation and mitigation, as well as between emission targets and economic goals, could be overcome at a local level by focusing on practical solutions. Such solutions can indeed contribute to the achievement of the SDGs (Granoff et al. 2015) even if they are not necessarily triggered by them. However, to do so, such strategies need to deliver both short-term and long-term socio-economic benefits as defined by local communities' own visions, needs, and perspectives.

This was true, for example, for cases we reviewed in India, where strategies aimed both to support basic sustainable livelihoods and to combat illiteracy and make knowledge accessible to economically excluded communities. In South Africa, many interventions are striving to improve living conditions in informal settlements whilst simultaneously creating livelihood opportunities using renewable energies. Future monitoring of countries' integration of the policy regimes advocated by the Paris Agreement and Agenda 2030 could consider taking into account a two-tier approach based on identifying and supporting endogenous transformative capacities within the broader frameworks of such policy targets.

4.4 Using supportive technologies

Current economic globalisation, based on information and communication as well as financial technologies (ICT and fintech), is creating a broad array of opportunities for inclusive economic development. Shackleton et al. (2015) argue that ignoring these financial opportunities constrains climate-compatible development. Whilst the ICT revolution can have adverse, disruptive effects on local economies, both ICT and fintech have the potential to play a significantly positive role in meeting the needs of low-income populations in sustainable ways. For instance, microfinance and microcredit innovations can support novel micro win-win strategies. Such innovations include collective bank accounts and new forms of community-based time-banking currencies, where users reciprocally exchange units of time for services instead of using money. In one concrete example from the Bundelkhand region in India, self-help groups open collective bank accounts to empower women to run community-based renewable energy projects.

In a similar way, Selco, a business in India that was not included in our set of cases, works with a network of banks to provide financing options to make decentralised renewable energy affordable for people from low-income communities. Since most commercial banks refuse to give loans to individuals in these communities, they formed a joint liability group that certain banks were willing to engage with. The group then went on to secure financial backing from three foundations (one American and two European) that invested in Selco with the aim of creating some positive long-term social impacts rather than short-term profits.[5]

In South Africa, Sun Exchange's secure blockchain-based transactions allow private actors or organisations anywhere in the world to make micro-investments with as little as US$10. These investments are then combined to finance sustainability-oriented projects that are too small to comply with all the due diligence processes required for a conventional bank loan. In our Indonesian case study, the aim was to avoid relying on donor funding by monetising the social and environmental values derived from biogas production and synergising these with the commercial production of organic chocolate and coffee.

In sum, the case studies revealed that when new financial modalities are linked with the provision of climate resilience and renewable services, they can play a crucial and beneficial role in the generation and development of new development opportunities. Were these solutions to be mainstreamed and reached a critical mass, they have the potential to support socio-climate resilience in fast-changing socio-economic and bio-physical conditions.

4.5 Including and empowering marginalised groups

Securing the economic inclusion of formerly marginalised groups, using a right-based and socio-ecological understanding of inclusiveness (Gupta and Pouw 2017), is central to ensure sustained engagement with, and the long-term implementation of, win-win solutions in low-income contexts. In the cases described, inclusion has been achieved by developing strategies that help to reduce inequalities. Most of the projects involve empowering women and girls, the elderly, and the displaced, as well as communities marginalised on the basis of race or ethnicity in deprived rural areas or informal urban settlements.

[5] https://www.nytimes.com/2016/01/03/business/energy-environment/electrifying-india-with-the-sun-and-small-loans.html

In India, the solar energy projects in rural communities supported by TARA-DA in Madhya Pradesh are run by a council of women. They have been involved in managing the provision of renewable energy facilities, the building of sanitation infrastructure, and in sharing knowledge and information about livelihood opportunities that helps individuals and communities to thrive. In this respect, micro-solutions that also support education and training can be particularly useful. Education is obviously critical to lessen poverty alleviation and climate vulnerabilities (Muttarak and Lutz 2014). In the context of micro-solutions, it can help transform attitudes and behaviours that might otherwise hinder the implementation of more inclusive and locally transformative strategies.

In the cases reviewed, technological and institutional innovations at a community level, as well as responsible business models working in partnership with 'trans-local' or transnational networks, helped to make inclusivity possible. We saw how the rapid emergence of cryptocurrencies, and the overall drive for the democratisation of money, opened an array of new means for people outside of the formal economy (and with no active bank accounts) to carry out local transactions. The same factors could also play a decisive role in democratising and greening the energy sector.

Such new forms of collective action help to expand the original range of development opportunities and allow formerly marginalised groups to 'be part of the solution'. This requires acknowledging local capacities and harnessing these in designing transformative systems and solutions rather than encouraging passive consumption of externally provided services and products. As shown in our action-research case in Indonesia, existing community-run businesses, cooperatives, social enterprises, and other innovative 'prosumer' (production-consumption) models are especially open to more inclusive organisational configurations.

A key challenge is to secure such inclusiveness in the long term. Acceptable solutions will have to be institutionalised in terms of governance and economic arrangements, thus creating new (hybrid) business models that incorporate the vision and principles of sustainability. In the case of green businesses, sustained demand for green products and services must be secured, although this can be difficult in the early stages of business development. In the long term, green businesses cannot rely on donor support; they have to be financially viable and economically competitive.

5 Conclusion

Given the vast challenges posed by the Paris Agreement targets and the SDGs, it is unrealistic to expect a sudden and mass deployment of standardised, one-size-fits-all solutions. Micro win-win solutions exist and can play a crucial role in accommodating the considerable diversity of the world's energy-poor communities and climate-vulnerable populations. To this end, we propose a nuanced approach, oriented to improve our understanding of the complex and unique social processes and capacities that make the widespread emergence of locally adaptive solutions possible.

The growing interconnectivity of communications, and the availability of data on financial, economic, and other global systems, creates new opportunities for transformation (Pereira et al. 2018). We have more space in which to co-develop our transformative capacities across broader alliances and to create positive synergies between addressing the impacts of climate change and enhancing sustainability.

Of course, strategies that operate at a micro scale only are unlikely to generate sufficient transformative synergies to address the climate and development problems as urgently as the Paris Agreement and the SDGs demand. Therefore, in the absence of strong and effective global climate governance institutions, we suggest that private actors and intermediary networks of donors and researchers who operate across various sectors need of targeted support. Mapping out the structure and dynamics of such alliances, particularly, in relation to unveiling their interests and expectations will shed much light on the potentials and limitations of mobilising transnational cooperation and knowledge transfer. In the long term, win-win strategies are not the result of 'bottom-up' initiatives alone but are instead almost always the result of complex networks of actions and interactions at multiple levels. For this reason, we propose that selective incentives (Olson 1971) oriented to sustainability transformation be provided and coordinated at policy, private-sector, and community levels to avoid possible resistances and conflicts within and between such networks.

The cases reviewed reveal a high level of diversity in project design, business models, and partnership configurations. Whilst most cases focus at the micro or local level, they are inspired by a range of different organising criteria or ideologies. For instance, the notion of the circular economy inspired the owners of the Kruistementvlei Farm in South Africa, whilst biomimicry principles were what primarily influence the Genius of Space project, also in South Africa. In India, TARA-DA subscribes to the triple-bottom-line approach whilst insights shared by the founder of Barefoot College[6] showed that many approaches can be effective in reducing poverty, contributing to climate mitigation and adaptation, and supporting the SDGs. The very diversity and adaptability of such strategies is where their strength and capacity to embrace growing socio-climate complexities lies. That is, the shape, content, and effects of the micro win-win solutions profiled here are remarkably diverse, but they share an understanding of climate action as an open social entrepreneurial challenge.

Moreover, many of the micro-solutions we analysed were responsive to existing local initiatives that emerged from a wide range of contexts. These grassroots solutions and projects are indeed in generating new lessons and new skills that could potentially be transferred to other contexts without requiring a massive centralised rollout. However, given the diversity of principles and unique local conditions in which these solutions were developed, they are unlikely to be replicated elsewhere in the same way. In fact, trying to scale up or transfer any single solution from one place to another might encounter obstacles. Thus, rather than aiming to scale up or design a standard solution to fit all contexts, a focus on building communities' endogenous transformative capacities will allow the emergence of unique suites of solutions relevant to chart clear development pathways in different places and moments in time. To achieve this, we suggest that a two-tier approach, based on promoting and supporting such endogenous transformative capacities and taking advantage of the broader policy framework set out in the SDGs and the Paris Agreement (but not depending on the latter to operate as top-down drivers) might be advisable. However, this approach demands empowering processes that, in turn, depend on a range of actors being willing to learn how to attract, and successfully collaborate with, many different potential allies at multiple levels of action at the same time.

[6] During the first GREEN-WIN workshop, see www.barefootcollege.org

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