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Transitioning towards a circular economy solar energy system in Northern Australia: insights from a multi-level perspective

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ABSTRACT

Increasing resource efficiency and decreasing waste by 2030 through prevention, reduction, recycling and reuse is one of the 17 United Nations Sustainable Development Goals. Australia is predicted to have up to 145,000 t of solar panel waste by 2030 and many large-scale solar systems are proposed to be built across Northern Australia. Research suggests that solar panel consumption and waste patterns are not dissimilar to other forms of e-waste such as mobile phones. Consequently, there is a need to rethink how the end of life of solar panels is managed. In this paper we raise the question of how Northern Australia should plan for managing solar panel waste arising from these huge installations in the future. This paper draws on the multi-level perspective, as a framework for conceptualising the transition challenges associated with promoting a circular solar energy system in the region. Adopting this approach facilitates consideration of social, technical and political drivers of solar panel waste and their implications for governance and planning in regional Australia. It is suggested that planning activities aimed at strategic, tactical and operational levels can help Northern Australia transition into a sustainable regional future.

Practitioner pointers

- Need to develop planning system/framework/process for waste arising from solar farms.
- Usefulness of the multi-level perspective for identifying the range of stakeholders, barriers and drivers.
- Rethinking regional development of Northern Australia through a new industry space between the solar and waste sectors.

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KEYWORDS
Solar energy systems; circular economy; multi-level perspective; regional development

Northern Australia, a future wasteland of solar panels?

Northern Australia gained international attention when it was announced it would be home to the world's largest solar farm (Reuters 2019). This region encompasses multiple jurisdictions and covers 53% of Australia's landmass but is inhabited by only 5.3% of Australia's population (DITRDCA 2022). Northern Australia is attractive for developing large scale solar (LSS) installations, popularly known as solar farms, that require large tracts of land and plenty of sunshine. However, this remote, sparsely populated landscape poses challenges for service delivery with very long distances between settlements, limited and poorly maintained infrastructure, extreme and variable weather, and high transport costs (NTEPA 2015).

In this paper we raise the question of how Northern Australia should plan for managing solar panel waste arising from these huge installations in the future. We use the Multi-Level Perspective (MLP) as a framework to explore ways of transitioning towards renewable energy in a more sustainable way. We begin with a brief overview summarising the context of Northern Australia, expansion of solar energy systems in Australia, and waste arising from solar panels. Conceptualising solar energy systems as socio-technical systems, we then suggest using the MLP as a useful framework to interrogate ways of transitioning towards a circular economy in LSS systems. In the following discussion we identify aspects of this transition that benefit from using MLP. We conclude with a discussion of governance activities that would lead to a more sustainable regional future.

The importance of a circular solar energy system in Northern Australia

Two factors that significantly impact development in Northern Australia are its geography and global influences. Accordingly, the region is not immune from the

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need to transition to sustainable energy systems and participate in the circular economy. Australia is a signatory to the United Nations 17 Sustainable Development Goals (SDGs) which are seen as 'the blueprint to achieve a better and more sustainable future for all' (UN 2016). SDGs provide a long-term vision and are at the core of national planning and decision-making processes. Participation in renewables and the circular economy has been identified by the three northern state/territory jurisdictions as potential economic drivers (Energy Policy WA 2021; Northern Territory Government 2022; Queensland Government 2022; Waste Authority n.d.). Beyond recognising that renewables, including solar, will play an important ongoing role in the development of the North (CoA 2015, 92), there is no broader consideration of solar policy in the White Paper on developing Northern Australia, nor any consideration of the associated waste issues.

The Australian Energy Update 2020 reported a 17% increase in renewable generation in 2018–2019 in Australia, with a 50% increase in solar generation (DISER 2020). Such high growth is mostly due to rapid development and expansion of LSS's, which played an increasingly significant role in achieving the Australian Government's mandated Renewable Energy Targets (RET) by 2020 (ARENA 2022). At the end of 2020, there were 22 commissioned projects and 52 projects under construction or proposed (CEC 2022). Some examples include: Suncable (17-20GW) in the Barkly region of the Northern Territory; Fortescue Future Industries' Uaroo Renewable Energy Hub (3.33GW) in the Pilbara of Western Australia; and Clarke Creek Wind and Solar Farm (400MW) in Queensland. We can expect to see even greater policy and program commitment towards solar energy after the Australian Prime Minister's pledge to cut carbon emissions by 43% by 2030 through boosting renewables and helping build community-owned solar power projects (Carroll 2022).

A key point to note here is, while solar energy systems are attributed with only positive impacts, there is a significant environmental burden and loss of resources when solar energy systems become waste. Additionally, as the number of solar installations increase, so will the waste. This is important since the SDG's also urge increasing resource efficiency and decreasing waste. Unfortunately, Australia's 2020 SDGs progress update identified that our per capita material footprint is increasing and is one of the highest in the world (70% above OECD average). This is problematic at a time when China has implemented its new waste import policy, 'Blue Sky', whereby it has set import restrictions, essentially excluding 99% of the recyclables that Australia previously sold to China (Downes and Dominish 2018). Therefore, finding ways for dealing with solar panel waste onshore is important for achieving resource efficiency obligations required by the SDGs.

The WEEE (Waste Electrical and Electronic Equipment) directive of the European Union mandates European countries to adopt solar energy waste management programs in which producers are responsible for disposal and recycling of the panels they sell (PV Cycle 2023). However, there are no recycling targets set yet due to the long lifespans of the modules and the variation in number of installed panels across European countries. In the United States, each state has its own recycling laws, ranging from Extended Producer Responsibility (similar to WEEE) to just landfill diversion policy (Curtis et al. 2021). The regulations in Asian countries are still in nascent stages with no specific guidelines to regulate solar waste in India, it is early stages in development and setting up of guidelines in Japan (Nain and Kumar 2022), and there is no current legislation in China since they are not considered electronic waste yet (Weckend et al. 2016).

Australia is predicted to have 30,000–145,000 t of solar panel waste by 2030, with more than one million solar panels requiring disposal from 2010 to 2034 (Mahmoudi et al. 2018). Worldwide solar industry growth and end-of-life management of solar photovoltaics is now a global concern. The 2016 International Renewable Energy Agency (IRENA)'s report identifies ways industry, government and other stakeholders can prepare for the increased volumes of waste solar panels (IRENA and IEA-PVPS 2016). This report urges countries to take policy action and form enabling frameworks better suited to the needs and circumstances of each region. It advocates adoption of a circular economy to face this new environmental challenge and 'to create value and pursue new economic avenues' (IRENA and IEA-PVPS 2016, 11).

A new framework, inclusive of context, is required for implementing a solar panel circular economy. Solar panels need to be conceptualised as socio-technical objects, since they are created through social, political and technological processes (Mathur, Gregory, and Hogan 2021). At the same time, they are also situated in broader socio-ecological systems since they use natural resources and their waste impacts eco-systems. A more integrated and systemic understanding of challenges and response options is required for regional governance, since no single sector has a clear understanding of the issue (Bosomworth, Cooke, and Coffey 2017). The production, consumption and discard of solar panels is not separate from social, ecological and political realities and should be addressed through a relevant framework.

Multi-level perspective (MLP): a framework to conceptualise the issue

In this section we outline Geels' multi-level perspective as a way for conceptualising socio-technical transitions and explain why it is applicable to the case being discussed. Geels (2002) presents the Multi-Level Perspective (MLP) as an actor-based approach to study the complexity that is present in technological transitions. He argues transitions entail major changes in 'socio-technical systems' that provide societal functions. Such systems consist of an interdependent and co-evolving mix of polices, technologies, networks, markets, infrastructures, user practices, and cultural meanings. Evolving over long periods of time, the stability of such systems results from the strong linkages between different elements, leading to path dependencies and resistance to change (Geels et al. 2017).

The MLP approach as described by Geels (2002) is a model formed by three linked levels: technological niches (the micro-level unit of analysis), socio-technical regimes (the meso-level unit of analysis), and landscape developments (the macro-level unit of analysis). The *socio-technical regime* accounts for the stability of socio-technical configurations. On the other hand, *niches* are ideal spaces for incubation of radical innovations. These innovations are able to gain a foothold in established systems because they are protected in a specific constrained context or helped by targeted policy support (Geels et al. 2017). The *socio-technical landscape* refers to broader contextual developments external to the socio-technical regime but that have influence over it, such as war, pandemic or political changes. 'Socio-technical' transitions involve interactions between the incumbent regime, radical 'niche innovations', and the 'socio-technical landscape' (Ros, Nagelhout, and Montfoort 2009).

The strength of this framework is that it provides an integrated and systemic perspective for characterising and exploring socio-technical change and is sensitive to the contribution of niche innovations. According to Markard and Truffer (2008), MLP can be used to explain the interconnectedness of governance mechanisms at the regime level. This can then provide evidence on ways prevailing socio-technical regime(s) often lead to path dependencies and locking-in of certain solutions to a specific policy problem (Bulkeley et al. 2011). MLP can also be used to identify the range of actors involved, their associated power and capacity to influence policy at niche and landscape levels (Bulkeley et al. 2011). Lastly, the MLP emphasises the system's transitions and innovations within the multi-dimensional interactions of government, industry and society (Markard and Truffer 2008).

MLP has been criticized for not showing enough concern for actors and lack of agency (Smith, Stirling, and Berkhout 2005) but Geels (2011) has responded that while stylized representations of MLP do not explicitly show actors, there is agency since the various levels are enacted by social groups. The socio-material ontology of the MLP framework, devoid of power and politics, has also been critiqued and a politico-material ontology offered instead. Avelino et al. (2016, 560) argue that power 'is not concentrated at a particular level (e.g., 'niche' or 'regime') or within specific actors, but that different dimensions of power are dispersed across interrelated agents at numerous levels'. Further, the conceptual ambiguity inherent in the understanding of actors and location of powers is also questioned since it is unclear whether the actors referred to in the MLP are specific individuals or organizations (Grin, Rotmans, and Schot 2011; Avelino and Wittmayer 2016).

The relations between the conceptual levels of niche, regime and landscape were found to be more complex than earlier versions of the MLP implied (Smith et al. 2020). Successful niches can result in not just displacement of the regime but could also result in a variety of syntheses and reactions between niche elements and regime components. It also underscores that different regimes can interact in a transition analysis rather than just a homogenous incumbent regime challenged by a niche.

Lastly, the role of places and spatial scales in transition processes have not been an explicit issue of concern in the MLP. The tendency has been to address regimes at a national scale which ignores the challenges faced by regional and remote towns in transforming their energy, waste and mobility systems into more sustainable forms. Agendas set by international organisations and national organisations place the task on meeting sustainability agendas through 'processes that operate beyond their jurisdictions' (Smith, Voß, and Grin 2010, 443).

We hope to mitigate some of the limitations of the MLP by contextualising the transition in Northern Australia, thus incorporating the geographical, socio-political and spatial characteristics of the region. Notwithstanding these critiques, we argue that the MLP is a useful framework for understanding drivers, barriers and possible pathways for transitioning towards both renewables and a circular economy. MLP has been widely applied to socio-technical transitions in electricity systems, sanitation, water resource management, transport policy and planning, and the MLP framing of niches and regimes will provide a useful conceptual framework to interrogate the circular economy of solar energy systems.

Exploring transitioning towards a circular economy of solar panels using MLP

Earlier transition studies suffered from limited representation of the range of actors involved, and

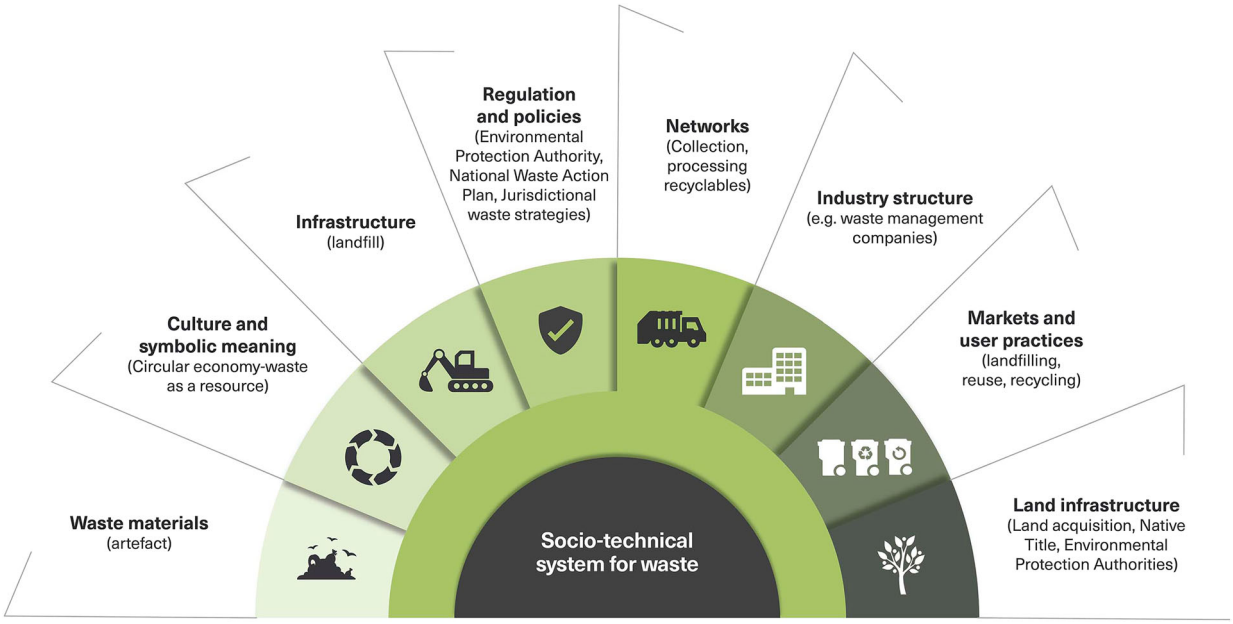

Figure 1. Socio-political system of waste.

conceptualised transitions as a simple process, identifying one optimal dimension of the process (Geels et al. 2017). For instance, the primary interest of the renewables sector is to increase penetration of renewables and that of the waste sector to collect and manage waste. Using the MLP acknowledges the wider societal system in which these activities occur and helps identify the range of actors involved in both waste and renewables systems (Figures 1 and 2). Figures 1 and 2 also show waste and energy systems currently operating as discrete systems, with little overlap in their entrenched systems. Each set of actors have different interests, capabilities, and viewpoints of the world. At *niche* level, a common understanding and alignment of interests of various actors is an important precondition for transitioning towards a new regime (Walrave et al. 2018).

Transitioning to circular economy models from generic waste management practices is still nascent, riddled with lock ins. For example, if we conceptualise the waste sector as a specific socio-political regime, it is characterised by waste collection systems, a professional culture of civil engineering solutions, organizational structures which are localised (local governments), strong state regulation and waste generators. Business as usual practices instil strong path dependencies. Planning and decision procedures are explicitly tailored to maintain and perpetuate these regime characteristics. Using the MLP exposes the well-developed barriers set up by incumbent actors

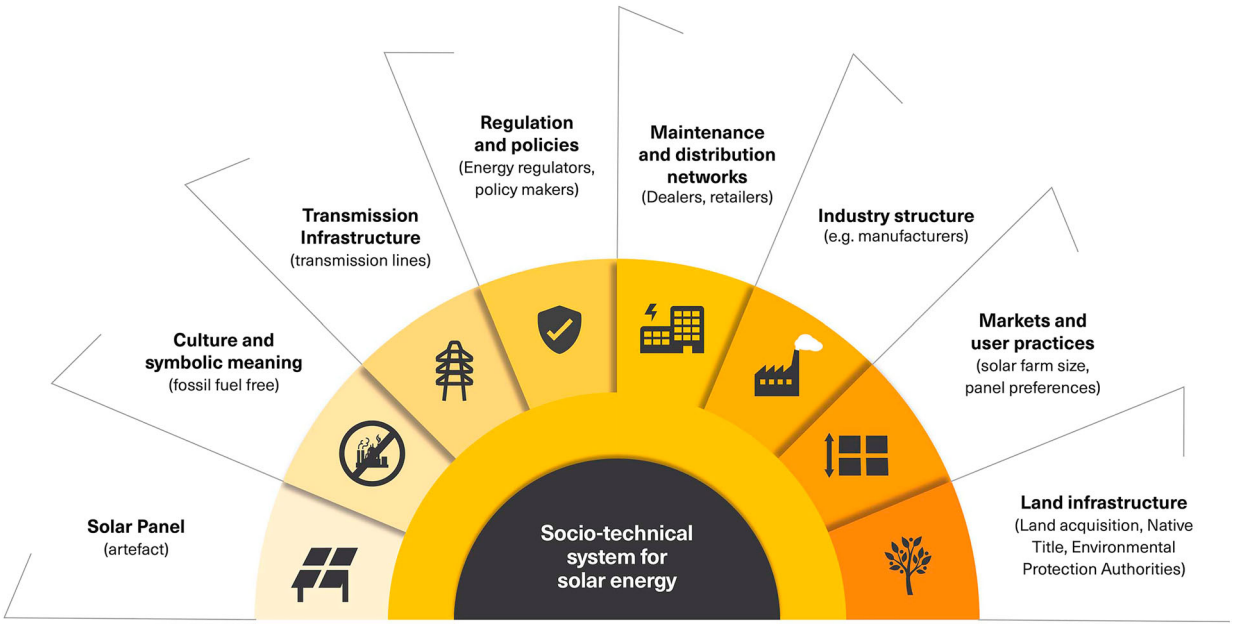

Figure 2. Socio-political system of solar energy systems.

and identifies challenges new practices must overcome to gain acceptance.

As pointed out by Lindberg, Markard, and Andersen (2019), sustainability transitions are also affected by different policies and actors. Policies could range from sustainability targets, emission reduction pledges and/or commitment to research and development in new technologies. Frequently, such policies focus primarily on one sector (for example energy, waste, transport), failing to recognise the increasing connection and inter-sector dependencies that exist not only within Northern Australia, but at a national and global level. For example, the Australian Government's policy of increasing energy from renewables is through the RET scheme, which is completely independent of the National Waste Policy or White paper on developing Northern Australia.

Building on the MLP framework aids in identifying practices and relations that can act as drivers for the transitions to occur. Morone et al. (2016) mention pressures that trigger transition towards sustainable innovations as global actors (such as European Commission), international institutions (such as United Nations) as well as local actors like media and grass root organizations. Their combined pressure on the dominant regime can impact technologies, processes and policies (Figure 3), particularly when global problems are to be addressed locally.

Traditionally, waste management has been the purview of local governments. Across Northern Australia many of these constituencies are characterised by vast areas (for example, the land mass of the Barkly Local Government Area is approximately the same as the state of Victoria) but have a relatively small rate payer base and limited infrastructure. A key issue is the capacity of local government to manage the significantly larger volumes of solar panel waste generated by LSSs in the future, during both operational and decommissioning phases. Expanding the MLP perspective, through an analysis of power relations and the spatial scale of development may provide a better framing of new regulatory structures that encompass multiple jurisdictions across Northern Australia.

From service delivery to sustainable regional futures

The challenge is then to operationalise the MLP governance concepts to transition into a sustainable regional future. The four governance activities through which this can be achieved are strategic, tactical, operational and reflexive (Loorbach 2010; Raynor, Doyon, and Beer 2017).

As a strategic activity, a long-term goal aligning with the UN SDGs and international practices/commitments is needed to show commitment to transitions in both renewables and waste sectors (Figure 4). No longer just a service delivery issue, either in providing energy or removing waste, the nexus of these two sectors has potential to support a new industry inhabiting the middle space between the existing sectors as shown in Figure 3. By adopting the MLP framework as a lens through which to consider the issue of solar panel waste, we can conceive of this waste, not as waste to be managed under a traditional service delivery model that falls largely within the realm of local government, but as the raw material for the development of a new industry across Northern Australia, based on recycling, re-purposing, and re-using discarded solar panels.

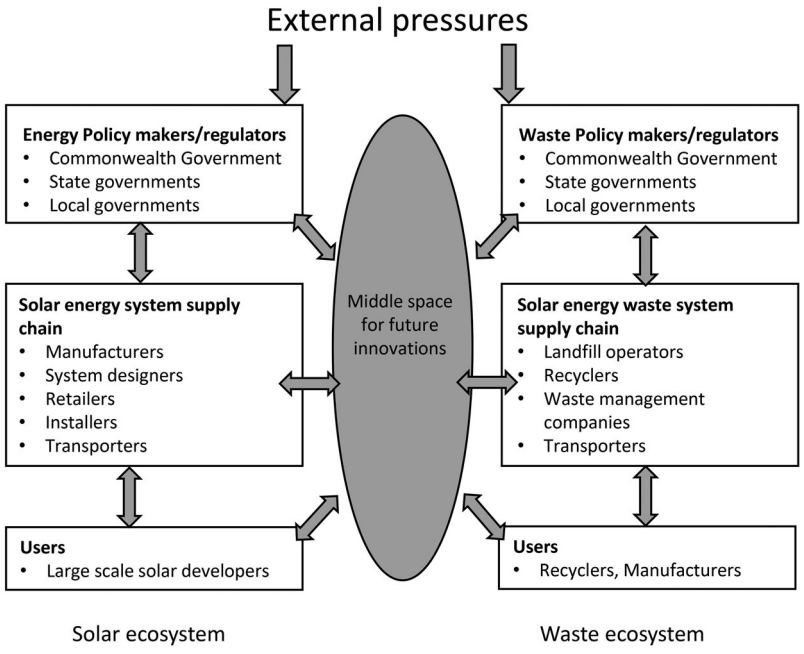

Figure 3. Actors, organizations and influences in waste and solar ecosystems.

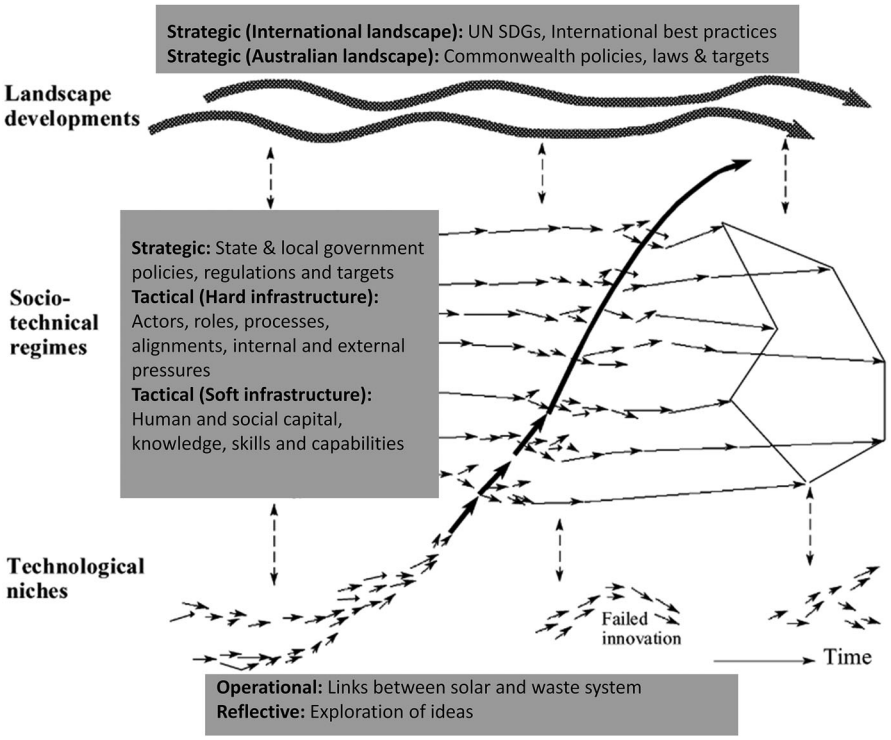

Figure 4. Multi-level perspective on Socio-Political Transitions (adapted from Geels 2002).

Planning for this middle space will be at the tactical level, requiring an identification of all the actors, their roles and alignments, the internal and external pressures they put on the system, as well as their path dependencies. While individual northern Australian jurisdictions have identified the desirability of participating in the circular economy and finding innovative ways to address waste generally, to date these efforts occur in isolation from their interstate counterparts. As Loorbach (2010) identifies, subsystems within which different actors operate might have strategic visions at the level of the organization but, from the perspective of transitions, this leads to fragmentation. We suggest a cross-jurisdictional regulatory and planning approach across northern Australia that utilisies the MLP, may be more appropriate. Such an approach would, for example, potentially help overcome economy of scale issues experienced by smaller jurisdictions and mitigate risks posed by inconsistent regulatory frameworks. This, in turn, requires a shift in mindset; planning for a new industry in the region involves additional considerations beyond the geographic land use and spatial infrastructure requirements. Such planning should also consider the 'soft' infrastructure required, such as the human and social capital, that includes knowledge, skills, and capability of the region to host this new activity. Using an MLP approach can help ensure that all levels of government, industry and business groups are included in the planning process, along with the communities critical to providing the human and social capital required both at the local level and broader regional scale. Such inclusion is critical to foster a greater sense of regional community support which any new industry will require and will represent a significant step towards ensuring that the benefits of the new industry are maximised and retained within Northern Australia.

It can be argued that operational activities such as niche innovations that build links between the two systems need to be developed and trialled. Such niches could provide the 'protective spaces' needed to develop radical alternatives that are afforded protection from the markets and are demonstration projects for early adoption and leaning (Smith, Voß, and Grin 2010, 440). They could further help in 'building of social networks and the enrolment of more actors', thus expanding the resource base of niche-innovation (Geels 2011, 28). Engaging new actors as intermediaries is one of the ways suggested to trigger sustainability transitions (Frantzeskaki & Bush 2021). Intermediaries that contribute towards connecting, coordinating, and aligning across institutions and actors to bring about transition could potentially address institutional lock-ins acting as key agents causing change. Finally, reflexive activities need to be socially embedded to prevent further lock-in and allow for future visions and explorations of new ideas.

In summary, a modified MLP framework is relevant for understanding and planning pathways for transitions towards a circular economy of solar panels in the very specific setting of remote and regional Australia. Addressing some of the limitations of the MLP framework in governance activities allows a more nuanced understanding of the two sectors and

identifies ways the in-between space can be productively used to transition towards a more sustainable regional future.

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