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Article

Transitions in Theory and Practice: Managing Metals in the Circular Economy

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Abstract: Transitioning from current resource management practice dominated by linear economic models of consumption and production, to circular models of resource use, will require insights into the stages and processes associated with socio-technical transitions. This paper is concerned with transitions in practice. It explores two frameworks within the transitions literature—the multi-level perspective and transition management theory—for practical guidance to inform a deliberate transition in practice. The critical futures literature is proposed as a source of tools and methods to be used in conjunction with the transition frameworks to influence and enable transitions in practice. This enhanced practical guidance for initiating action is applied to a specific context—transitioning the Australian metals sector towards a circular economy model. This particular transition case study is relevant because the vision of a circular economy model of resource management is gaining traction internationally, Australia is significant globally as a supplier of finite mineral resources and it will also be used in a collaborative research project on Wealth from Waste to investigate possibilities for the circular economy and metals recycling.

Keywords: transitions; multi-level perspective; transition management; circular economy; metals recycling; critical futures; sustainable futures; Australia

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1. Introduction

One of this century's greatest challenges is to foster prosperity in a world of finite resources. Whilst continuation of traditional models of business and governance continue to cause pressure on existing resource management systems, a re-imagining of how resources are used to realise sustained value from the natural resource base is occurring across multiple sectors of society.

The term "global problematique" refers to the set of global systemic problems that were seen to be emerging in the 1970s at the time of publication of the classic Limits to Growth [1] including growing signs of physical, environmental and social stresses such as poverty, air and water pollution, biodiversity loss and ecological decline caused by continuous drawing on finite resources. The limitations on linear systems of production, consumption and disposal of products derived from primary resources were becoming apparent.

These fundamental challenges within key systems such as production and distribution of energy, food, water, minerals and other resources are examples of "messy" or "wicked problems". This term arose from the social ecology field to describe complex real-world problems that occur within dynamic, adaptive social-ecological systems. In this way, no problem ever exists in complete isolation; rather they are part of a set of interrelated problems [2]. Typified by long timeframes, multiple stakeholders, large scale and uncertainty about what the nature of the problem actually is as well as possible solutions [3], these systemic problems have continued to emerge and grow, giving rise to a vast array of tools and practices being applied to address associated social and environmental impacts [4].

Strategic responses to these issues are therefore complex and require fundamental shifts in how a system or set of interacting elements function and interact with each other and various other elements in society. The field of *transitions research* is informative in this context as it investigates complex interactions in social-technical systems and how change occurs in such systems over long timeframes [5–9]. According to this set of theories, transitions of socio-technical systems involve a broad range of actors and extensive changes along different dimensions: technological, material, organizational, institutional, political, economic, and socio-cultural [10,11].

Transitions literature emerged in the past two decades and is quickly gaining momentum on the global front by researchers, scientists and policymakers [8,12]. For example, it has been applied in practice in the Netherlands and Japan within the waste sectors.

In this paper we undertake a review of two frameworks within the transition literature, the multi-level perspective (MLP) first posited by Rip and Kemp [13] and further developed by Geels [14], which provides an analytical tool that identifies three distinct levels operating with transitions and outlines the interactions and timing between these levels to identify possible pathways for long-term change. More recently the Transition Management literature developed by Loorbach and Rotmans [15–17] offers insights into deliberately influencing the pathways that long-term change might take based on theory and practical case studies.

We explore these frameworks to identify key themes, approaches and lessons that may inform a transition in practice—specifically the case of the Australian metals sector and opportunities for enabling pathways towards a new paradigm of a circular economy. This development is timely as it contributes to a collaborative research program between the Australian Commonwealth Scientific and

Industrial Research Organisation (CSIRO) and five university partners, established to investigate the potential for a more innovative, circular economy approach to resource management.

The paper begins by providing an introduction to the MLP and the Transition Management literature. Critiques of these frameworks and of those regarding the transitions literature in general are analysed to identify the potential of these frameworks to contribute to long-term transitions in practice. This analysis highlights a need for practical methods to contribute to furthering the praxis of successful transitions. For this purpose we identify a complementary set of methods within the critical futures literature, which has evolved from a history of theoretical and practical endeavours related to generating desired futures. We conclude by proposing a framework of action to guide a transition, which deliberately enables pathways towards managing metals in the circular economy for Australia.

2. Transitions Literature—Theoretical Perspectives on Socio-Technical Transitions

Transitions literature encompasses theories and frameworks that enable insight into how change occurs in systems over long periods of time [5–9]. The value of this field of literature, in the context of deliberately influencing resource systems, for example toward a circular economy, rests largely in the insights it provides into the dynamics at play within complex systems and innovation processes. A key focus of transitions literature is the examination of *historical* transitions from a socio-technical systems perspective, to identify and analyse the complexity of interplays at work within and between factors that enabled, challenged or drove those transitions. Additionally, it offers guidance in identifying leverage points and areas of convergence for sustainable transitions, thereby enabling insight into *future* transitions.

Socio-technical systems consist of actors (individuals and organizations) operating within institutions (social and technical norms, regulations and standards of good practice) and shaped by existing knowledge and technologies [11].

We focus our review on two of four current sub-fields within the transitions literature—the Multi-Level Perspective (MLP) on socio-technical transitions, and Transition Management". The former is valuable for identifying interactions within large-scale transitions, and identifying the nature of particular transition pathways. The latter is valuable for gaining insight into how to deliberately enable pathways that could facilitate a transition. It focuses on agency and the potential for actors to influence the future towards desired outcomes. However, there is complementarity between the two perspectives; viewing a transition from a multi-level perspective can inform and illumine the way actors and agency interact within a dominant system and how these interact with cultural norms and values, thereby guiding future transitions [18].

2.1. The Multi-Level Perspective

First posited by Rip and Kemp [13] and further developed by Geels [14], the MLP perceives transitions as outcomes of alignments between developments at multiple levels [13,19,20]. Identification and examination of socio-technical system elements, across and within the MLP levels, provides a useful tool for better understanding the interactions of existing systems. This framework may also support the identification of leverage opportunities to influence future outcomes towards

transition goals. Three levels are outlined in the MLP: the landscape, the socio-technical regime and niche-innovations [13,14,21].

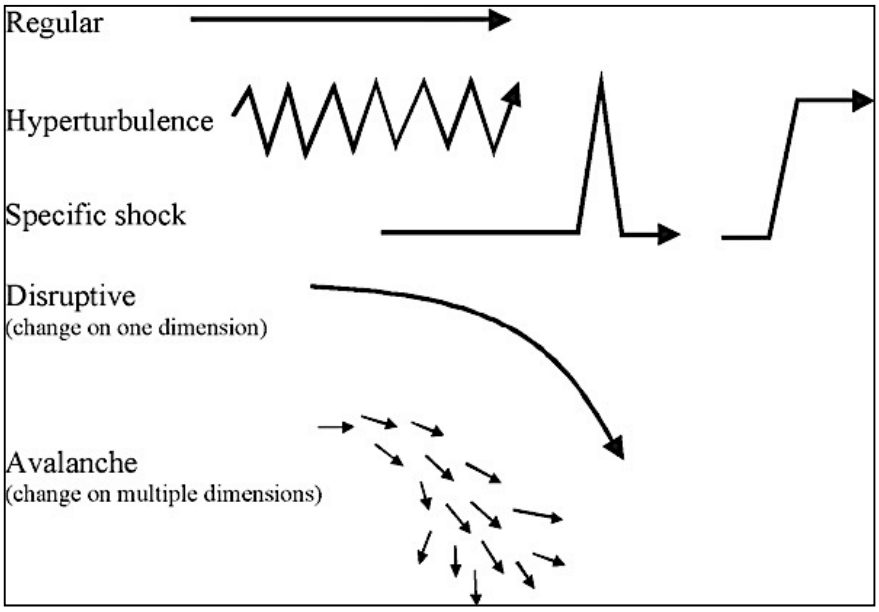
- The landscape (macro-level) forms an exogenous environment, which provides a broader structural context in which changes usually take place slowly (decades) [10,21]. Landscape components can be considered as "gradients of force", which influence the interaction of local practices [21] through translation by various actors. Landscapes are considered an external context, as actors cannot influence them in the short term. However, they are dynamic, in the sense of relatively slow changes (e.g., climatic variations) compared with the regime and niche-innovations.
- The regime (meso-level) is a relatively stable, yet complex, arrangement of dominant structures (social, technological, economic, environmental and political) that shape the system. A significant characteristic of regimes is that they embody established institutions and actors with strongly held convictions and interests concerning technological practices [22].
- Niche-innovations (micro-level) are sites of innovation and transformative change across a range of system components including technological, social, economic, cultural, business and governance. Niche-innovations develop through small networks of actors, often on the fringe.

Generally speaking, landscape changes exert pressure on the regime in varying ways, which can destabilize the regime. This creates windows of opportunity for niche-innovations to move into a position where they can compete with, modify or replace the regime. Within the MLP framework, transitions can only be fully realized if a niche is sufficiently developed to take advantage of those windows of opportunity brought about by landscape changes [21]. Transitions are therefore special cases of long term development—a result of a particular co-evolution between niche, regime and landscape level [23].

Of particular interest, in identifying leverage points for transitioning to an envisioned future, is the nature and timing of interactions between the three MLP levels. Nature and timing will strongly determine the patterns of change within the system, and thus significantly influence the range of transition pathways that emerge [21]. Typologies of multi-level interaction and transition pathway have been developed [21,22]. Smith *et al*. [22] identify a quadrant approach related to governance of a transition with the axes of low to high coordination and internal or external resource locus. Although this is useful from a perspective that accepts the ability of a top-down approach to governing transitions, we find the broader typology suggested by Geels and Schot [22] more informative for initiating a transition to resource use in a circular economy. From this perspective transitions occur through different combinations of four identified dimensions of environmental change—frequency, amplitude, speed and scope. From these different combinations, four typologies of transitions emerge (see Figure 1):

- Regular—where change in the environment is low intensity and gradual;
- Specific shock—caused by individual and high intensity events, which may dissipate or lead to a step change;
- Disruptive—changes do not occur very often (historically) but lead to a significant change in direction; and
- Avalanche—change here occurs in a similar way to shocks but the key characteristic is that this type of change leads to changes in multiple dimensions rather than just one.

Figure 1. Typology of Transitions (Reproduced with permission from [21]).



We note that in this description Geels and Schot [21] also describe high frequency and high speed change in one dimension as a category, which they refer to as "hyperturbulence", however this is not included in their typology for landscape dynamics as it sits more within market dynamics.

The power of illustrating these possible pathways is that they remind us that each transformation is historically contingent and therefore, for our purposes, useful to guide future direction. For example Späth and Rohracher [18] have used the MLP as a prospective tool in considering energy futures in Austria. Considering how these change arise will be important for planning and developing governance strategies as they reveal different types of opportunities, as well as the distribution of these across various actors. Thinking through the environmental, social or economic outcomes of different types of transitions may motivate early and strategic action toward futures that present greater opportunities. It is reasonable to anticipate environmentally sustainable transitions following diverse pathways [10] but with foresight we may act to avoid disruptive change and "shock" situations.

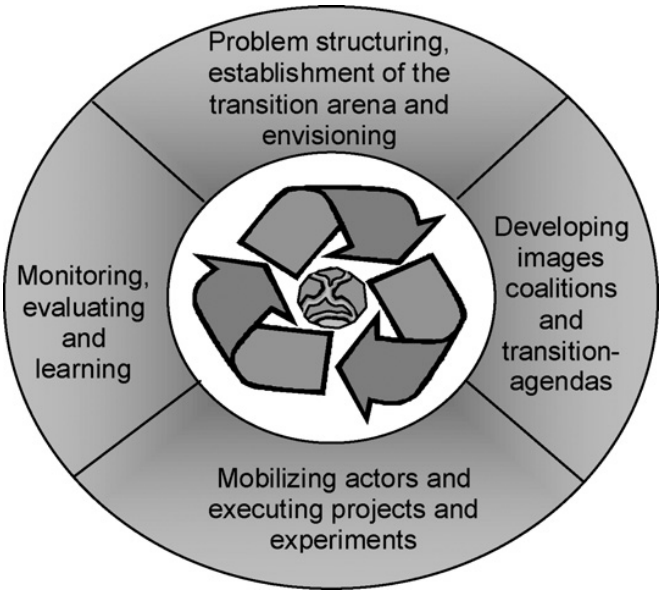
2.2. Transition Management

Transition Management is concerned with deliberately managing and influencing the direction of transitions and focuses on governance towards sustainability. The concept of "managing" a transition is founded on a fundamental question—"How do we influence, coordinate and bring together actors and their activities so that they reinforce each other to such an extent that they can compete with dominant actors and practices?" [16] (p. 239). From this perspective, the transition process and path is deliberately set out with the aim to influence governance and civil society to accelerate change towards definitive collective goals, such as sustainable futures. It is based on the assumption that actors have agency, *i.e.*, the capacity to influence the future, but acknowledges complexity associated with structures and governance that may be barriers to long-term change towards sustainable goals. This recent and growing transdisciplinary field of study is informing the application of Transition

Management in practice. For example, in the Netherlands, UK and Belgium, transition policies are being developed in areas such as energy, building, health care, mobility and water management [16].

Loorbach and Rotmans' [16] Transition Management Cycle (MLP) (Figure 2) provides guidance on practical implementation for a managed transition. Drawing on theoretical principles and lessons from practical case studies including regional transition arenas, the Dutch national energy transition program and two different transition arenas on resource transition and sustainable housing in Belgium, four governance types relevant to societal transitions are described: strategic, tactical, operational, and reflexive. The first phase is ultimately about identifying and exploring the problem, as well as the desired future. The second phase involves extensive collaboration amongst actors to form agendas and strategies to achieve the desired future. The third phase involves enabling actors to implement strategies and participate in activities to achieve the desired future. Phase 4, the last phase, is the learning phase. Here, actors monitor and evaluate the success of their actions and reflect on and learn from the past three phases—Loorbach and Rotmans have identified this cycle as an iterative and social learning process. It is worth acknowledging two key points here—the cycle visualizes the need to connect activities and presents some possible logical connections but is not intended to suggest a sequential order of activities [24] and this approach to change is grounded on a particular perspective—it focuses predominantly on influencing governance and policy activities. In this approach, transition management is defined as a "deliberative process to influence governance activities in such a way that they lead to accelerated change directed towards sustainability ambitions".

Figure 2. The Transition Management Cycle (Reproduced with permission from [24]).



Although this perspective incorporates specific assumptions about change through top down governance, it provides a generic framework that is open enough to allow for a range of actors and leadership that acknowledges the need for diverse viewpoints while applying to diverse local contexts. We explore the application of the TMC in Section 6 for the purposes of guiding collaborative action towards transitioning the management of resources and metals in Australia towards a circular economy.

2.3. Transition Literature Key Concepts

In looking at transitions literature to inform practical outcomes and pathways, we can refer to four key concepts underpinning socio-technical transitions identified by Smith *et al.*, (2010) in [25]):

i. systems co-evolve in a process of cyclical and iterative change [10] (p. 4);
ii. transitions occur within and between three levels: niche (micro); regime (meso); and landscape (macro) (this is the multi-level perspective) [19,21,26];
iii. transition pathways have multiple phases [10] (pp. 126–131); and
iv. sustainable transitions engage processes of co-design and social learning [10]. In other words, successful sustainable transitions require knowing and doing that is both reflexive and shared.

These offer valuable guidance for identifying opportunities to influence socio-technical transitions, in our case, a more circular and restorative use of resources. Specifically:

- The systems concept highlights the fact that diverse elements are closely interrelated and dependent on each other. This has critical implications for the dynamics the systems exhibit, and especially for system transformation [11]. From a socio-technical systems perspective, the analyst engages more holistically with both the system and nature of the transition process, as well as to the complex interrelationships between system components.
- The concept that socio-technical systems occur within and between the micro, meso and macro levels facilitates the process of identifying system components and leverage points for influencing and catalyzing transitions.
- The concept that transitions unfold over particular phases enables stakeholders to engage in activities that may facilitate progression through these phases.
- The concept of co-design and social learning processes in socio-technical transitions encourages stakeholders to initiate and support multi-stakeholder participatory activities and collaboration.

Before applying these in practice, we consider some of the critiques that have been identified within the transitions literature.

3. Key Critiques and Responses to the Transitions Literature

In the following section we identify a number of key critiques relevant to our later application of MLP and Transition Management to a practical case study for the Australian metals sector within a circular economy.

3.1. Key Critiques of Transitions Literature

Although there are many critiques of transitions literature, a number of recurring themes emerge. Three in particular are relevant to our aim of transitions in practice.

Smith [10] and Geels [27] identify that greater ontological investigation into transitions work is needed. Ontological perspective strongly influences the outcome of all aspects of a transition. Farla *et al.* [6] and Stirling [28] make significant contributions to the literature in response to this critique. Their contributions highlight analytical implications of viewing systems through different

ontological lenses. For example, reflecting on the role of politics at each MLP level can highlight its significance for transitioning socio-technical systems., At the landscape level politics influences the general economic climate and the ways technologies are deployed (through political projects). At the regime level, legislation and regulation play a significant role in supporting or challenging dominant regimes [29]; the regime (including rules, resources and actor configurations), will privilege particular practices over others [23]. At the niche level, specific government programs can support or undermine niche innovations. When looking through the ontological lens of "conflict and power" opportunities emerge for working through diverse stakeholder interests [27]. Creating space for open dialogue around different interpretations of sustainability and interests in the subject of transition is of great importance [6,28].

Secondly, there has been a call for greater attention to the impact of worldviews on shaping transitions. Geels [27] recognises that all sustainability transitions require deep shifts in worldviews, from ones that view economic growth as an end goal in itself, toward an adoption of approaches rooted on "deep ecological" values. Whilst the significance of ignoring the role of worldviews in shaping transitions is acknowledged in the literature, little practical methods or tools can be found to enable practical action on this matter.

A further criticism of transitions in general is the lack of attention to actor dynamics. Greater analysis of transition processes would be facilitated by increased appreciation of actor dynamics, including how diverse, and potentially conflicting, interests affect transitions [6,10]. Contributions to the transitions literature that have responded to this critique demonstrate awareness that effective collaboration, for the purpose of achieving a system transition goal, requires an appreciation of social and experiential learning. The emerging field of reflexive governance, in which "transforming the plurality of interests into coordinated action through forms of network governance", is identified as an area of potential for Transition Management [30]. This is particularly relevant for considering future directions of a system in change.

3.2. Key Critiques of the Multi-Level Perspective

In addition to these three overarching challenges, the MLP, whilst a reputable framework, has been subject to considerable critique and review [7,10,23,27,29]. Key areas of critique include:

- conceptual challenges, in terms of defining the unit of analysis [21,22];
- analytical challenges in addressing bias towards the technological [10], structural power, agency, and geography; and
- practical challenges in appraising the governability of socio-technical transitions [10].

The critique that MLP lacks guidance on defining the unit of analysis is significant. Selecting and applying system boundaries is a crucial step in not only analysing a socio-technical system, but in building shared understanding of the issues and possible responses. The literature identifies that system delineation is challenging, due to the reality that multiple systems are intertwined and often operate on a continuum [8], and that greater guidance is needed. In meeting this challenge analysts are encouraged to be guided by the purpose of the analysis when drawing boundaries [8], and to be mindful of the uncertainties involved in analyzing systems that involve emerging technologies [8]. It also offers

support by encouraging practitioners and researchers to approach boundary setting flexibly and via iterative multi-stakeholder learning practices [5]. Whilst these are valuable recommendations there is again a need for practical tools to assist practitioners in exploring and agreeing on system boundaries together.

A related issue to system boundaries is the recognised risk that the abstract nature of the MLP may lead to an oversimplification in interpreting these complex systems [6,10,21]. The literature, in response, encourages us to engage in multi-stakeholder iterative learning processes [5,8,29], which may expose complex system dynamics.

More specifically, MLP has been criticised for not drawing significant attention to issues of agency [10,27] or politics [31]. Within regime dynamics, agency and politics have been identified as critical to how a system performs and changes over time. Agency dynamics are important to consider given the "pivotal role" that agency plays during particular transition phases [23]. On top of this is the increasingly recognised importance of enabling citizens to influence their future [32–34].

The role of the government, together with other actors such as business, academic institutions and communities, require explication. This can be facilitated by the process of developing a shared vision with clarity of roles and responsibilities between stakeholders, with respect to the long-term orientation, that then serves as the basis for coordination toward the desired goal. Shared visioning processes, particularly when reflected in actors' individual strategies, are significant enablers for driving sustainability transitions [6]; and as collaboration is an essential ingredient for developing shared visions, barriers to collaboration are particularly important constraints to be aware of in developing transition pathways.

In response to the critiques around oversimplification and lack of attention on agency and politics, we are encouraged to examine socio-technical systems, using the MLP framework, in conjunction with insights from complementary fields. Recent contributions that have strengthened the field of transitions include those that have weaved in complementary concepts from sociology [27], political science and governance theory [9,28,29,31], and futures literature [16,35,36]. Bergek also identifies sociology of technology and organisational theory, which together highlight the complex dynamics at play within systems and the political nature of innovation processes [5].

3.3. Key Critique of Transition Management

To what extent processes of governance towards desired outcomes can be deliberately managed—despite their multi-level, multi-actor character—is an open question central to the critique of Transition Management [18]. Geels and Schot [21] argue that no transition is ever planned and coordinated from the outset. On the other hand, it is acknowledged that at some point every transition becomes coordinated through a process of aligning stakeholder visions and activities. Practical lessons from the Dutch waste management transformation support the claim that transitions cannot be "managed" per se, but rather come about through the aligning of key enabling factors. Kemp [37] suggests that transitions cannot successfully be controlled in a top-down command and control approach, "different developments have to come together to sustain each other". Recommendations relate predominantly to generating shared visions using collaborative processes for incorporating

multi-stakeholder views. This is one view, however moving away from a western world-view, may show that other cultures are more able to successfully implement top-down transitions.

Although tensions are present regarding the agency of individuals or groups to influence and bring about selected futures in a deliberately managed way, our position is aligned with that of Meadowcroft ([38], p. 484): "although transitions cannot be controlled in any absolute sense, they can be influenced (encouraged, re-oriented, or sped up) through deliberate intervention." Our philosophical premise is that the future is not fixed but a space of negotiation between structures and within and between actors and that these actors have agency to influence the future that emerges.

3.4. Principles Emerging from the Transitions Literature

Transition literature therefore provides useful guidance and context on the strengths and weaknesses of an approach to socio-technical transitions. Reflecting on the four foundational concepts identified in Section 2.3 and responses to the critiques, we have synthesized a number of key principles from the transitions literature that can be applied to inform practical methods and design of a transition. These are:

- Recognition of uncertainty in the "problem" and "solutions", and taking an approach that avoids "solutions" and rather looks to make improvements in the system.
- Mapping of the "problem" by diverse stakeholders including setting appropriate boundaries for the system of analysis and associated actions.
- Incorporating iterative processes that involve shared and experiential learning including feedback loops into the governance and decision making to continually refine and adapt the system over time.
- Collaborative and deliberative approaches used throughout all phases of the transition, which open up issues and provide multiple perspectives while drawing out hidden politics and power relations within and underlying the system interactions.
- Designing governance actions that are reflexive while recognizing that structural change may be necessary to achieve desired outcomes.
- Co-development of a shared long-term vision that guides strategy and local action amongst stakeholders and actors.
- Establishment of networks of communication through multi-stakeholder dialogues.

These principles, further inform approaches to deliberately transition a system.

4. Critical Futures and Transitions—Further Responses to the Transition Critiques

We now introduce the critical futures literature as an informative and complementary field that can provide a set of resources for practitioners looking to deliberately enable transition pathways towards a desired vision. Critical futures, pioneered by Richard Slaughter, Jim Dator, and Sohail Inayatullah [36,39–41], builds on a history of practical tools and techniques for enabling collective movement toward desired futures.

The value we see in critical futures for deliberately transitioning the Australian metals sector rests largely in the practical tools and methods it offers and their ability to respond to some of the key

critiques (outlined in Section 3) and contribute to achieving the principles for successful transitions (outlined in Section 2.3). These are briefly addressed below.

Awareness of and reflection on one's own ontology is important, however we note that the futures literature has "decisively moved on from ontological concerns" about how the world works to "epistemological concerns about the knowledge interests in varied truth claims about the future" [42]. Moving from a positivist approach to prediction of the future, to the interpretivist concern with the meanings we give to data, to, more recently, the poststructural approach which looks at what is "missing" from particular images of the future, is significant for the transitions literature. From this perspective "politics is acknowledged and self-interest disclosed through the research process" [42] facilitating a more robust approach to designing a preferred future.

In relation to drawing out and challenging worldviews and perspectives on the future, a futures tool Causal Layered Analysis (CLA) [40] is available. CLA is a framework used to deepen perspectives and investigate underlying worldviews, and thereby enables greater depth of analysis. Like MLP, CLA takes a layered perspective and helps to frame complex societal issues. The four layers are described:

- the litany of the day-to-day future;
- the systemic causes of events, issues, problems;
- the cultural, or worldviews, which shape our view of the world and that underlie the two surface layers; and
- the deep (often unconscious) stories, or metaphors, which underpin societal foundations.

The issues identified at each layer are often different and, thus, likely to require different types of responses—simple and short-term at the surface, and becoming increasingly complex and interrelated as they move down through the layers. Layered approaches do not argue for preferencing one layer of analysis over any other; rather, "all levels are required and needed for fulfilling valid and transformative research" [42]. Through CLA, researchers and practitioners are encouraged to challenge the assumptions underpinning action, whether it be strategy development, research design, or even the researchers thought patterns and worldviews.

Transitions work must incorporate acknowledgement of the unknown, the existence of uncertainty, and experimental and reflexive processes. The unknown is "central" to futures research [42]. The application of futures analysis tools is encouraged to enable greater insight into the political nature of the system [35,41,43]. These may also assist in identifying and appreciating the significance of issues of agency. They are particularly effective, for the purpose of influencing socio-technical transitions, when used in multi-stakeholder settings.

An instructive theoretical framework for responding to many of the gaps and critiques of the transition literature can be found in Inayatullah's [35] "Six Pillars for futures thinking". These pillars are linked to methods and tools, while being developed through praxis. The six pillars are: mapping, anticipating, timing, deepening, creating alternatives and transforming, each with a set of tools and methods that can be used to facilitate pathways to desired futures. Table 1 describes these and associated methods.

Table 1. Process and methods for transforming the future (Adapted from [35]).

Futures pillar	Description	Associated methods
Mapping	Mapping methods involve identifying where we have come from and where we are going to—mapping the past, present and future in relation to an issue, topic or system.	Futures Triangle, Shared History, Futures Landscape
Anticipating	Anticipation methods look at the consequences of current activities over longer-time periods or where new social innovation may emerge.	Emerging Issues Analysis, Futures Wheel
Timing	Timing methods question what the future looks like over macro scale time periods to look at patterns of change.	No specific method. Questioning stakeholders—macrohistorical view of time, the future and change
Deepening	Deepening the future requires unpacking assumptions through questioning dominant discourses and images of the future by exploring underlying worldviews and stories.	Causal Layered Analysis, Four Quadrant Mapping
Creating Alternatives	Scenarios are the dominant tool facilitating the generation of alternative futures—through exploring the range of uncertainty and opening up the present.	Nuts and Bolts (structural functional analysis of organisations), Scenarios
Transforming	Transforming is related to the achievement of the preferred future that is identified through the principles used for the other pillars. It involves identifying the necessary steps to create the preferred future.Creative visioning, together with backcasting, are two complementary tools, which help to do this.	Creative visualization methods, Backcasting, Transcend Method

These pillars are strongly aligned with the purpose and approach of Transition Management in particular. Anticipatory Action Learning (AAL) [41] underpins many of the critical futures methods discussed here. This approach focuses on participatory approaches to creating desired futures, thus it is aligned with the shared, experiential learning approaches recommended by the transitions literature. AAL requires that the participants within the "action learning" project are foundational and the futures focus is about creating confidence in individuals' and systems' abilities to creatively adapt to new challenges. This anticipatory and participatory approach is therefore particularly relevant for deliberately transitioning a system towards a desired outcome—it's focus on foresight and engaging the human creative capacity to deliberately design preferred futures, while reflecting on process in a cycle of action learning, is of particular relevance to transitions.

We draw on the methods introduced in Table 1 further in Section 6.

5. Towards Transitions in Practice: Case Study of Metals in Australia within a Circular Economy

So far we have provided an overview of a selection of key theoretical perspectives, critiques and lessons from the transitions literature, and have identified tensions within the descriptive nature of the MLP and the prospective approach of the TMC. Given the purpose of transitions literature—to look at how change occurs in systems over long time periods, and to influence how change occurs, we have identified complementary frameworks and methods from critical futures. In this section we introduce a practical context that is suitable for testing a framework incorporating these proposed approaches. We

have selected the case of transitioning the Australian metals sector from the current linear model toward a circular economy approach. This case is relevant for a number of reasons:

- The circular economy approach to resource management is a rapidly growing field of study and practice, which is yet to be applied in the Australian context;
- Australia is a major global supplier of many valuable metal-containing minerals; therefore changes to methods of production and supply are significant in the global context;
- The "regime" of production and consumption of metals in Australia is a mix of linear and circular;
- Despite this, a number of successful examples of reuse and recycling are present in parts of the Australian metals and metal waste sectors, however these occur where economic signals are present, but are not system-wide or integrated;
- This issue has been prioritized at the national research level through a three-year, Wealth from Waste collaborative research cluster, to investigate the potential for transitioning to a more sustainable system for metals in Australia.

We first introduce the circular economy concept as a sustainable resource management vision for transitioning the Australian metals sector.

5.1. The Circular Economy as a Vision for Sustainable Resource Management

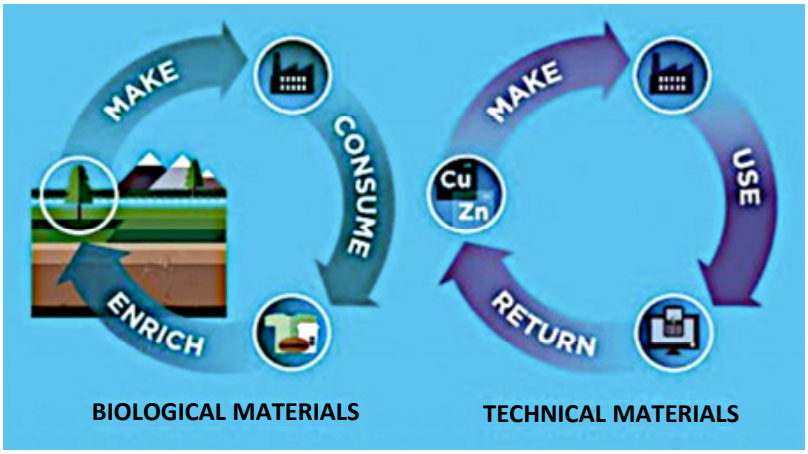
The concept of the circular economy was popularised through the industrial ecology movement as a response to the traditional open-ended economy [44]. In a linear economic model, the physical environment is treated as a receptacle for waste products from the economy, and recycling and reuse are not fundamental parts of the system. This is inefficient from a socio-ecological and socio-economic systems perspective because at each point along the production and consumption chain, including at end-of-life, resources in the form of materials, energy, water and emissions, are lost to the environment and flow out of the economic system.

Waste in various forms can contribute to upstream and downstream social and environmental impacts. Recently, many companies have also begun to notice that this linear system increases their exposure to risks, most notably higher resource prices and supply disruptions. Resource markets are becoming more volatile with more and more businesses challenged by rising and less predictable prices while high competition and stagnating demand for certain sectors add to the uncertainty [45].

A circular economy on the other hand is an industrial system that is restorative or regenerative by intention and design [46]. It is founded on the principle of the earth as a closed economic system, where the environment and economy are linked in a circular relationship. The circular nature refers to materials flowing within this closed-loop to be reused again and again [47,48] in [44]. Within this model, waste is materially, environmentally and economically inefficient and hence, designed out. The "end-of-life" concept of products is replaced with restoration, while renewable sources of energy underpin all processes, the use of toxic chemicals, which impair reuse, are eliminated and the lifecycle design of materials and products is considered along with broader systems, including models of business [45].

This model essentially replaces a material-centric approach to a product-centric approach, whereby optimization of recycling of entire products at their end-of-life occurs, rather than solely the materials contained in them [49]. Outputs from various processes typically treated as waste, are used as inputs to other processes or systems—much in the way that nutrients cycle through an ecosystem—thereby creating an efficient industrial ecosystem and generating additional value across the lifecycle. Figure 3 represents the ideal of a circular economy, in which biological and technical materials flow continually through the system in various forms.

Figure 3. A circular economy for the Australian minerals resource sector (Reproduced with permission from [45]).



Examining the challenge of a circular economy reveals significant opportunities for a more prosperous future. However, it does not explicitly challenge the global economic growth paradigm and technical and institutional challenges remain. Businesses can create competitive advantage [45], communities can invest in new sources of employment, old products become new resources for the economy or for nature. However, this ideal requires a significant shift in thinking and practices across many actors within relevant sectors and more broadly. For the metals sector, many challenges need to be overcome including the nature of the existing metals systems of production, processing, transport and consumption, associated capital infrastructure investment, institutional structures and embedded social habits of practice.

Despite these challenges, the relatively recent emergence of circular economy principles means that significant opportunities globally exist. A recent UNEP report [49] investigated the opportunities around metals recycling at the global scale and found that only around one-third of the 60 metals showed a global end-of-life recycling rate of 25% or more. For metals with already high recycling rates, significant value is lost—ranging from annual losses of USD 52 billion for copper and USD 34 billion for gold, to USD 15 billion for aluminium and USD 7 billion for silver. The significance of strategic mineral resource management is now widely recognized [45,49–52].

5.2. The Case for Transitioning the Management of Metals in Australia

Australia's wealth of mineral resources has allowed the Australian mining sector to be a strong contributor to the export market, accounting for 48.5% of GDP in 2011–2012 [53]. However, the

Australian mining and metals sector is now facing a unique and complex "sustainability problématique" [54], in which Australia is a net importer of products (many of which incorporate minerals originating in Australia) and is also increasingly reliant on the mining sector for international trade [52].

The sector has been described as operating on a "Dig and Sell" model [55] in which, rather than processing and manufacturing higher value goods domestically for re-sale and/or export, relatively low value commodities (dominated by unprocessed bulk iron ore and coal) are exported. This model also exposes Australia's vulnerability to global shifts in commodity prices and demand, and reduces resilience to shocks, increased competition from overseas markets and increasing costs of production and transportation [52]. Across Australia and other mineral rich nations existing mine operations are experiencing a decline in mineral ore quantity and quality [50,54,55], and as ore grades decline costs of production increase [50,51]. This reality, along with community concerns and environmental repercussions, together with key export trade areas such as China, Japan and Europe preparing to transition to resource efficient economies (where recycling plays a greater role), are all elements that signal a requirement to rethink how Australia's resources are viewed, utilized and managed.

The management of metals in Australia involves a number of sectors, from mining and metals production, to manufacturing, design of infrastructure and products to waste management, remanufacturing and recycling. Recent research [50,51,55] has identified impending economic, social and environmental challenges to a traditional linear model of operation and significant opportunities for a more sustainable management of metals in Australia through a circular economy. Examining Australia's metals system, and how a transition toward a circular economy might be managed, is in Australia's long-term national interest [52].It is also significant on a global scale, highlighted by the fact that Australia is a major global supplier of many valuable metals (for example, Australia's contribution to global supply in 2012 included: gold 18%; iron ore 25%, lead 40%, nickel 25%, zinc 27% [56]). Adding to the case for strategic management of Australia's metals is the growing global demand for metals, driven by increasing global GDP growth and increasing per capita consumption patterns [51].

There is evidence to illustrate that Australia is already recognising the need to change the way metal resources are managed. Various mechanisms and partnerships have been implemented at different jurisdictional levels to encourage product stewardship. Emerging business models are driving metals reuse and recovery in Australia and contributing to a shift from a consumer culture and the perception of unavoidable waste, to one of waste as a resource with indefinite value.

However, much of the potential value of Australia's resources is not being realized. Value opportunities are currently being lost as Australia exports many resources in their primary ore form. For example, in the mining of raw materials for steelmaking, Australia is overwhelmingly an export producer, with more than 90% of iron ore, metallurgical coal, manganese ore and zinc being exported [56]. In relation to its above ground resources Australia is also currently overlooking many value add opportunities, as it exports potentially reusable resources such as e-waste, while significant volumes of materials are being diverted to landfill. The principles of a circular economy—to design out waste and take a product-centric approach across all phases of a product lifecycle, supported by models of business and governance and consumer practices, are still fledgling in Australia.

6. Towards a Practical Approach for Enabling Transition Pathways in Australia's Metals Sector

So far in this paper we have explored both the transition management and the MLP strands of transitions literature for the potential to contribute to practical outcomes for transitioning a socio-technical system. Although MLP is used as a descriptive analytical tool, we follow [18] in applying MLP prospectively and complementary to the TMC which also contains both analytical and prospective elements. In addition we aim to further bridge the gap between theory and practice by incorporating specific methods from the critical futures literature (introduced in Section 4) to provide a comprehensive action framework for initiating a transition towards managing metals in a circular economy for Australia.

Table 2 outlines this action framework, which incorporates the four management phases described in the TMC. The table also includes research questions for the Australian case study in metals that align with these phases, and a list of research methods that may be useful in addressing these research questions.

In the following sections we draw out some key activities associated with the action framework described in Table 2. Although the transition management phases are not necessarily sequential, Phase 1 is a good place to begin thinking about designing this transition as it deals with fundamental framing issues and sets up initial networks, including a leadership group required to establish and communicate the issue for further action. Previously we noted that the difficulty in deliberately transitioning an existing socio-technical system toward a more sustainable one is that shifting from one system to another requires not only the introduction of new technological artefacts, but also new markets, user practices, regulations, infrastructures and cultural meanings. This suggests that change cannot be brought about through technological innovation alone but rather requires institutional and socio-cultural transformations to occur [19]. Essentially, a coordinated and collaborative effort is required, dependent upon the mobilization of all actors in the value chain, from operators in the primary production of metals and metal-containing products, to the recycling and collection industry, to the consumers [49]. Given this focus on participatory and social learning processes that need to be established early, Phase 1 will be the focus here as the following phases will be in some way dependent upon how the issues and vision are collectively defined.

Table 2. An action framework for transitioning the management of metals in Australia.

TMC Phase	Aims	Tasks	Related research questions	Possible research methods (Adapted from [40])
1	Problem structuring, establishment of the transition arena and envisioning.	Map the issues, set the system boundaries of investigation, identify and map stakeholders, and generate a shared vision.	What champions will commit to leadership on this issue? What are the boundaries of the sectors involved in managing metals we seek to transition? What and who constitutes the landscape, regime and niche-innovation levels? What is a picture of the Australian metals sector in terms of patterns of change? What changes have occurred? What enablers and challenges for transitioning to a circular economy exist within the established boundaries? Who are the stakeholders that will be involved and/or affected by this transition? What is the type of change sought and/or avoided? regular? disruptive? shocks *etc,* or total transformation or technological substitution in certain industries? What are the emerging issues and weak signals that signify change in a certain direction? What is the metals sector's guiding vision? Who is not being represented in the process of establishing this vision/whose voice is dominant?	Stakeholder and systems mapping, Shared history, Futures Triangle, Futures Landscape, Environmental Scanning, Emerging Issues Analysis, Weak Signal Analysis, Futures Wheel, Causal Layered Analysis, MLP, Guided Visioning.
2	Developing images coalitions and transition agendas.	Clearly establish the transition agenda in networks, coordinate stakeholders into generating shared future direction and strategic action plans, and identify key actors in the process.	How will this vision be achieved? What are the changes across the categories of social, technological, environmental, economic and political/governance that will be required and when? Who are the actors that need to be mobilized to achieve these changes? What are key leverage points that are a must for improvements to be achieved?	Deliberative engagement processes, Scenario development, Creative processes to developing scenarios e.g., Scenario Art and Backcasting.

Table 2. *Cont.*

TMC Phase	Aims	Tasks	Related Research Questions	Possible Research Methods (Adapted from [35])
3	Mobilising actors and executing projects and experiments.	Collaboratively design appropriate scale projects/experiments to facilitate the desired vision (these may be at social, technical, economic, political or environmental focus drawing from the range of stakeholders from business, civil society, industry, government).	How can the broad category strategies by actioned by sub-sectors? What networks need to be established or strengthened for this purpose? What information is missing? What support mechanisms such as government policy, incentives or funding need to be put in place? What institutional factors may accelerate or form barriers to a circular economy for metals in Australia to be realized? How could values, supportive of sustainability, be incorporated into the process?	Deliberative engagement processes, and strategic planning connected to governance models.
4	Monitoring, evaluation and learning.	Each project, as part of a broader vision to incorporate program logic or other evaluation frameworks, which can be evaluated at regular intervals, outcomes fed back to stakeholders and revisioning of process, strategies and aims as required.	What lessons are being learnt through each of these processes and experiments at the individual What are the different actors telling us is working and not working? What changes have occurred in the system and is this moving towards the envisioned future? What needs to shift course? How can we share what we are learning with others? At what points can learning be reflected on and fed back into the processes of change at different levels?	Iterative and Shared Learning approach, M&E tools including Program Logic Evaluation, Reflective processes, Anticipatory Action Learning.

6.1. Problem Structuring

The aim of Phase 1 is to clearly establish the issues of relevance and how these are interrelated, as well as setting up the foundations of the long-term transition. Mapping the issues is an early task, however this requires input from stakeholders with enough knowledge of the technical, social, cultural and governance practices associated with the existing metals sector that the outputs are useful. One of the foundation activities suggested by Loorback and Rotmans is to identify and establish a cross-sectorial group of champions called "frontrunners". Frontrunners have influence in their related spheres, and are able to consider complex problems without pushing their own agendas. They are able to think collaboratively on the issue and with an open mind and viewpoint. These champions should be spread across different segments of society, government, business, NGOs, knowledge institutes, and intermediaries. Within the Australian metals context, some of these frontrunners are in place through establishment of the Wealth from Waste Cluster in late 2013. However, a broader cross-section of business, government and civil society is required. This will be a priority task to progress further action.

The transition leadership group in particular can benefit from use of methods such as CLA. By unpacking the issue in the early phases of the TMC at the four different CLA levels, we can deepen and broaden perspectives and open up possibilities for new solutions to emerge. For example, greater insight into what drives and influences the behaviours of the regime components may provide a richer picture of the different ways, and best timing, to open the windows of opportunities to transition. This approach supports Stirling's call for approaching sustainability transitions as "deliberative social learning processes" [28]. Early application of this method can contribute to diverse viewpoints being incorporated into any later processes such as visioning, strategies and actions, thereby adding to the robustness of the approach.

As this is a deliberative social learning process, CLA can be conducted regularly by both researchers and frontrunners, or more formally incorporated into stakeholder workshops at various phases to ensure diverse viewpoints are being considered in the program of action.

Consideration of possible future pathways of change that could occur is also necessary to identify and illustrate possible issues. In Section 2.1 we introduced a number of different transition pathways identified by Geels and Schot [21] each with potentially positive and negative impacts for various actors and the system as a whole. However, defining these impacts will impact on the perspective that is taken. Although disruption or shocks may be damaging for existing businesses within the dominant sectors, it may open up possibilities for radical change, which are required for the system to become more sustainable in the longer-term. For example, the eventuation of peak oil or peak minerals could be one such a disruption in the context of the resources sector and management of metals in Australia [50], others could include declining terms of trade, or the radical deployment of a low carbon economy.

Regular change is more difficult to define in the context of the future of metals recycling in Australia. Given the rapidly changing landscape—social, political and economic drivers, business as usual in the future will likely incorporate very different modes of operation to deal with a different set of drivers. Although risk management and future scenario development are well resourced, established and accepted methods in business, designed to plan for possible shocks and disruptive elements that are likely to impact on the future of a business or industry, historical trend analysis may not provide the breadth of analysis to indicate possible future pathways. This is because drawing on historical trend

data will not necessarily pick up disruptive future elements (e.g. internet of things, 3D production systems). Mapping of stakeholders, issues, and reflecting on possible emerging issues and trends through the methods of mind-mapping, environmental scanning, emerging issues analysis or weak signal analysis are useful here to provide indications of possible disruptive future elements and establishing the lay of the land.

The MLP can also be applied at this point as an analysis tool—the MLP approach is predominantly located within the systems level in the CLA framework, however, there is some overlap with CLA's worldview layer and the cultural and longer-term patterns, which are located within MLP's landscape level. To provide an illustration of the implications of this framework for application to transitioning Australia towards a circular economy for the management of metals, we apply the three levels from the MLP as an analytical tool to think about the problem definition and focus as recommended in Phase 1 of the TMC.

The process adopted to select the boundary of the system is important, as it will have ongoing impacts for identifying the likely interactions between the landscape, regime and niche-innovations. It will also impact the identification of possible future pathways of change and therefore outcomes for relevant actors.

Table 3 illustrates that application of different analytical boundaries provide variations in what is present within each of the levels. The boundaries selected here are a distinction of scale between (i) commodity (ii) industry (iii) domestic economy levels. However, it should be noted that there are many other ways of defining the transition of the metals sector in Australia, including sectoral, geographical, or technological delineations for example. Note also that a transition in one part of the metals value chain in one country is inextricably linked to the global system within a circular economy and therefore will impact and be impacted by other parts of the value chain in other countries.

Table 3 is included for illustrative purposes, to demonstrate the importance and complexity of boundary definition and the types of actors a transition at this level could encompass. A core principle of transitions work is for collaborative and deliberative stakeholder engagement for the purpose of fostering a common language and vision, understanding challenges and opportunities, and establishing strong ownership and networks. Therefore as part of Phase 1, the process of populating such a table to establish boundaries and the content within the MLP would be conducted with stakeholders, identified by the initial research process, not by researchers in isolation.

By focusing on the commodity level in Table 3 for example, we find that the types of stakeholders to be engaged in actions to support or develop innovations (such as for supporting new technologies for processing and production or niche businesses) will be different than if the focus is on the industry level (where supporting and developing niches might require support networks for consumers to be able to recycle products at "end-of-life"). While at the national level, an example of a niche-innovation may include collaborations across government and industry to develop and commercialise new technologies for specific processing or production needs, or large-scale investment to allow new sustainable industry models to emerge and establish.

Table 3. Multi-level perspective applied to different functional units of analysis for metals management in Australia.

Possible Boundary for Transition	Landscape Pressures Examples	Socio-Technical Regime Examples	Niche-Innovation Examples
(i) Australian resources level in the economy	Default linear economy; Assumed model of continuing economic growth; Tyranny of distance' Lucky-country mentality; (Emerging) sustainable development pressuring the regime; Peak minerals (minerals are finite resources and cost of extraction increase as the quality and quantity of ore grades decline)	Dig and sell business model with limited local value add; Industry privately (and often foreign) owned; Minerals owned by States in Australia; Government has dual role of approvals and monitoring compliance (e.g., environmental)—benefits accrue via royalties and taxes	Technology for remote tele-operation of mining equipment; Extended producer responsibility legislation for television and computers; * Waste levy (some states)
(ii) Australian waste industry (metals and other materials)	Default linear economy; Increasing rates of waste generation; Decreasing land available for landfill; Consumer culture of consumption (throwaway society); (Emerging) sustainable development pressure	Waste industry run by "blokes and trucks"; Landfill spaces constrained; National waste policy; International conventions guide trade practices e.g., Basel -hazardous waste	Container Deposit Legislation; Waste to energy technologies e.g., pyrolysis; Community collection stations for products# Collaborative consumption and sharing economy business models
(iii) Commodity Level e.g., steel	Steel is the underpinning of a country's industrialization—buildings, transport; Global demand for steel rising with growth of China and India; Iron is a major component in steel and it is estimated that Australia's iron ore production will peak in around twenty years	Limited technological innovation globally, limited culture of R&D by industry nationally (mainly government funded); Australian steel making has declined; No longer industry assistance packages for steel (unlike car industry); Australia exports iron ore, rather than finished steel	Iron ore—automation in mining. Steel Stewardship Forum^—responsible supply chain certification, mapping the steel value chain footprint

Notes: * The New South Wales Extended Producer Responsibility Statement (NSWEPR), was introduced as a concept in 2001 through the Waste Avoidance and Resource Recovery Act 2001 (WARR Act) [57]. At the national regulatory level the issue has culminated in the Australian National Waste Policy 2009 and the *Product Stewardship Act, 2011* and associated suite of regulations and guidance, including specific product stewardship regulations for televisions and computers, guiding the reduction of waste and recovery of resources from end-of-life. The 2010 NSWEPR recognized the need for urgent action for e-waste and other non-metal commodities such as tyres, packaging and plastic bags, paints, timber and mercury containing lamps [57]. # Mobile Muster [58]—is a product stewardship collaboration by the mobile phone industry in Australia aiming to reduce mobile phones and accessories going to landfill through collection, processing and reuse of mobile equipment. It is estimated that 1014 tonnes of mobile phones & accessories have been collected through the program over the 15-year period to June 2013 [59]. ^ The Steel Stewardship Forum (SSF), an association primarily driven by industry with government support, was initiated in 2007 to create a best practice system for steel reuse and recovery. In Australia approximately 90% of steel for recycling is recovered while for structural steel recycling rates are approximately 95% this is classified around the best in the world [60]. The SSF was initially driven by two key projects—a Responsible Steel sustainability certification scheme, and mapping Australia's steel value chain footprint [60]. The Responsible Steel certification scheme design is underway while the mapping project has been completed.

Other important context setting methods can be employed within stakeholder workshop sessions that explore the present through historical (shared history) and futures perspectives (Futures Triangle) helping to develop a plausible future which can then be drawn upon in the visioning process. It is likely that in developing a vision that is locally relevant, actionable, and representative of stakeholder views, the concept of a circular economy will be useful as a starting point but will need to be interrogated and collaboratively developed.

Visioning processes such as guided visioning and scenario development are being used with more creative processes such as Scenario Art [43] to tap into the creative collective wisdom to generate preferred futures. For complex large-scale, multi-actor, multi-level systems in transition, such visions will be diverse and contentious, and will depend on the resources allocated to the task. The literature does however point to examples where visions and discourses can develop in a remarkably consensual way [18]. It requires skilled facilitation to explore points of contention and transcend these to arrive at an acceptable direction that all stakeholders can buy into. Ownership of the vision is essential for success in the following phases, although the iterative and social learning approach points to ongoing modification and adaptability of the vision over time to incorporate new lessons and input.

6.2. Establishing Transition Networks and Agendas for Action

The second phase involves extensive collaboration amongst actors to form transition agendas and strategies to achieve the desired future. Once a shared vision for more sustainable metals management in Australia has been established, the TMC points to establishing localized action plans linking to the overarching vision. The backcasting approach will be valuable here. Among futures studies methods, backcasting is useful for dealing with complex issues and is a promising method in developing action plans for sustainability [61]. Backcasting differs from forecasting in that it starts with the preferred future vision and works backwards to define a pathway to achieving that vision. Backcasting can use different methods [61], but essentially works from a systems and futures perspective to open up a variety of options by encouraging the searching for new development paths when the conventional paths do not seem to solve the problem.

6.3. Enabling Implementation Strategies

The third phase involves enabling actors to implement strategies and participate in activities that build a circular economy model. Following on from the identified pathways in sub-sectors, action plans owned by relevant stakeholders can be put in place—whether at a geographical planning approach or sectoral (again dependent upon decisions made in earlier phases). Backcasting again will be useful, but at a more localized level. Methods in this phase relate particularly to continuing the anticipatory action learning theme introduced with the futures methods in Phase 1 and 2 and continuing with more localized definition of strategies and actions across stakeholders at regional or local levels.

6.4. A Cycle of Learning and Iteration

The learning phase is where actors monitor and evaluate the success of their actions and reflect on, and learn from, the other three phases. Given the social learning narrative throughout Transition

Management, we assume that the iterative and cyclical nature of this framework implies learning through reflection and feedback loops as a core part of any activity within the transition. With an anticipatory action learning approach, a reflexive process of questioning, creation and questioning adds an anticipatory dimension to the social learning process, which allows for preferred futures to continually evolve with actor engagement. Coordination between sectorial or geographical elements will need to be managed and reflective process built in to project implementation to ensure that social learning commitments are adhered to.

Transitioning complex socio-technical systems requires lengthening time horizons; acceptance and acknowledgement of uncertainty; multiple methods and tools of intervention; more participatory and reflexive forms of governance with input of diverse actors and knowledges; social learning through the building of networks among innovative stake-holders; a focus on sectorial dynamics; and "internalization of economic, social and environmental considerations in product, process and policy design" [9,31].

By employing a process guided by the transitions literature and built on tried and tested methods from the critical futures literature, actors may be able to employ a foresight process that is flexible and adaptive enough to identify potential shocks and disruptions to the system while guiding action towards a sustainable future that builds resilience, prosperity, supports innovation and responds to environmental and social challenges. Essentially we believe this approach can contribute to achieving a successful long-term transition to a new paradigm for the management of metals in Australia from above- and below-ground stocks, which may have flow on effects globally.

6.5. Wealth from Waste—An Opportunity for Further Practice

The Wealth from Waste Cluster is a three-year (2013–2016) collaboration aiming to investigate opportunities arising from harnessing value from above-ground stocks of metal-containing resources within a circular economy [62].

It offers an opportunity to apply parts of the process identified in this section to the Australia's metals sector. The purpose of the research program is to facilitate transitions toward more sustainable systems of metals processing and management in Australia (thereby enabling Australia to generate "wealth from waste"). The program involves four interlinked research programs, one of which focuses on transitions pathways. The transition pathways program is using a range of analytical techniques, from physical and social sciences, to assess the present state of knowledge regarding:

- Trends in interest and commitment to greater resource efficiency amongst key stakeholders at local, regional, national and global scales; and
- Success factors in transitions from linear to more circular patterns of production and consumption including:

  i. Economic, social and environmental drivers towards increased recycling;
  ii. Spatial and socio-economic determinants of existing systems of resource use and disposal at end of life;
  iii. Socio-technical systems that can or do provide support for present and future resource management; and
  iv. Business and innovation models that support different levels of resource efficiency.

The Wealth from Waste Cluster is expected to contribute significantly to identifying (i) and (ii) over the next three years, for the purpose of setting up strong networks and foundations to deliver (iii) and contribute to (iv).

It will provide an opportunity to further employ and test the theory behind transitions and iteratively refine theory to reflect and inform practice.

6.6. Limitations of This Paper

Several limitations in this paper should be acknowledged.

Firstly, whilst this paper has identified tools and methods from the futures literature to assist in problem structuring and other phases of the TMC, having the resources, and agency to assemble relevant stakeholders and implement change within established political processes remain a challenge.

Secondly, whilst orienting towards a circular economy including for metals, is a discourse with increasing traction, the practicalities and even inconsistencies with this ideal, depending on the geographical scale of implementation, are a work in progress and require a parallel transition in the global management of metals. This has been highlighted in a recent UN International Resource Panel report [63].

Thirdly, the proposed methods to facilitate progression through the transition phases were identified in response to existing critique on MLP and Transition Management. As transitions literature is relatively new, having emerged in the past two decades, we acknowledge that further critique to the literature is likely and that this may expose further weaknesses that would need to be addressed.

Finally, the metals sector involves a wide range of stakeholders who encompass a diverse and often conflicting range of interests. While one can employ methods to break down stakeholder barriers and work to overcome conflicting interests there is the possibility that overcoming this cannot be achieved.

7. Conclusions

Australia is not unique in its linear economy thinking to production and consumption regarding metals. However, significant challenges now exist that require a radical rethink of how valuable resources are managed. The circular economy approach could be one response to these challenges that will add value to all components along the metals value chain. The complementary frameworks of the MLP and Transition Management within the transitions literature support identification of system components and functions, and investigation of the dynamics at play during system transitions. MLP in particular is useful for looking at macro patterns of change and how the internal components of a system, both dominant and emerging, might interact to inform managing a transition. Transition Management offers guidance in identifying leverage points, particularly in processes of governance and areas of convergence in sustainable transitions. Together they build on the notion that a holistic or systemic shift (rather than just incremental improvement) will be required to make practices in key economic sectors sustainable.

Our approach to facilitate a transition to a more sustainable circular economy model for metals management in Australia, builds on the TMC and MLP by offering *methods* from the critical futures literature that are anticipatory, reflexive and allow for social learning that challenges underlying assumptions and power relations for transformation of systems. Further, these methods are

underpinned by an anticipatory action learning approach that is both participatory, to activate the agency of all actors during the transitioning process, and future focused to generate preferred visions of the future. Given the emphasis in the transitions literature on shared vision, collaboration and the necessity to investigate and challenge worldviews, futures methods align closely with the aim of transition management and can enrich transitions in practice. Through this combination of theory and practice we aim to implement an iterative approach to transform the sustainability problematique that currently exist within Australia's metals sector into a successful example of transition management in practice through the Wealth from Waste research program.

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Author Contributions

Melissa Jackson and Aleta Lederwasch worked collaboratively on the content of the paper, contributing to all sections relatively equally. Melissa Jackson was the primary author of the section on futures and Section 6 discussion. Aleta Lederwasch was primary author of Section 3, which provides a critique on the transitions literature. Damien Giurco contributed to the section on the Australian context for metals and the concluding section, and provided a review of the paper.

Conflicts of Interest

The authors declare no conflict of interest.

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