Exploring the Possible Role of the South African Mining Industry in the Establishment of a Sustainable Bio-Based Economy through a Transdisciplinary Dialogue in the Upper Komati Catchment Management Forum

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Water Research Commission

by

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EXECUTIVE SUMMARY

INTRODUCTION

Worldwide concern is growing about the futures of landscapes in which coal mining has taken place, is taking place or is planned to take place. In South Africa, declines in mining activity in the past have often led to environmental, health and social crises due to poor closure or abandonment of mines by the industry and retrenchment of labour. In addition, some regional resources, such as water and soil, have been impacted by the mining and will need rehabilitation. The Green economy may be based on a new, sustainable approach to economic activities, but it will depend on the resources – damaged or rehabilitated – that it inherits from the fossil fuel economy.

Important debates are taking place in popular media, as well as in specific stakeholder circles including the presidency, mining circles, labour and civil society about a just transition from coal. But solutions can never be only technical. Studies in the sociology of science and technology have argued convincingly that technologies, especially new technologies intended to support a transition to sustainable development, are shaped by the interests and agendas of social groups. In considering the introduction of technologies to remediate contaminated mine water and use it in a bio-economy, with the purpose of supporting development and the creation of jobs, it is clearly important that the perspectives and agendas of residents and stakeholders be voiced as clearly and with as much integrity as possible.

This short-term project was undertaken in support of a broader project **"A transdisciplinary, dialogic approach to exploring the possible role of the South African mining industry in the establishment of a sustainable bio-based economy"**, which is a fellowship funded by the Volkswagen Foundation and housed at the Global Change Institute at the University of the Witwatersrand. The Wits project engages with already existing but innovative technologies based on biological resources, materials and process, such as phytoremediation (the use of plants for treating contaminated water and soil) and explores how it can be applied in the setting of the Mpumalanga coalfields.

The focus of this WRC project was to understand the context in which such technology could be deployed. It specifically developed an understanding of the perspectives and agendas of stakeholders in the quaternary catchment X11B (Carolina, Mpumalanga), as an input into a conceptual model for the proposed technology interventions in remediation and using treated water in a bio-based economy, with special emphasis on the creation of job opportunities after coal mining has ceased. It thus had a very practical orientation. The conceptual model will be further elaborated in the continuing project at the Wits Global Change Institute.

The aims of this project were:

1. To test the responses of a representative group of catchment citizens including community groups, regulators from DWS and the IUCMA, mine managers and consultants to proposals to remediate and use contaminated mine water in a bio-economy application.
2. To develop transdisciplinary methodologies in water research: specifically the use of the dialogic method in expanded social learning, with Cultural Historical Activity Theory, as a shared method between social and natural science trained researchers.
3. To develop ways of communicating and working with scientific-technical knowledge in a way that supports inclusive participatory, democratic deliberation on water issues.
4. To further build the capacity of a Catchment Management Forum working group as well as capacity for co-creation of water futures.
5. To start the process of envisioning post-coal mining landscapes on the Mpumalanga Highveld, and develop a first checklist of issues relevant to water in such landscapes, for example rehabilitation, closure policies and feasible future land use options.

METHOD AND APPROACH

Since the core purpose of the conceptual model was to anticipate how the proposed technology would fit into the context of the Mpumalanga coalfields, it engaged closely with various stakeholders, their perception and understanding of the problem of contaminated mine water, their interest in the remediation of the mine water, how important it is to them (compared to other priorities), and how they think it should happen. The project also elicited concerns and warnings from stakeholders.

The centre of engagement was the Upper Komati Catchment Management Forum. It was an open and transparent forum, a neutral ground supported by the IUCMA, reasonably well supported by stakeholders (with the exception of the DMR, whose office in Witbank was closed for the duration of this project, and thus inaccessible). Invitations to workshops were issued to the general UKCMF list, but a UKCMF working group on this topic emerged. Two meetings were held with DWS officials who could not attend the UKCMF meetings in Carolina due to travel restrictions. Where the team felt that voices were underrepresented, individual interviews were undertaken, including with the Mine Water Co-ordinating Body[1] (MCWB), local government officials, a mine manager and a local farmer. A

1 The MWCB structure currently comprises representatives from the departments of Mineral Resources (DMR) and DWS, Eskom, the WRC, the Trans-Caledon Tunnel Authority, the Minerals Council South Africa (MCSA) and coal mines Anglo Coal, south 32, Exxaro, Glencore and Sasol. Source: Nadine James, in Creamers Mining Weekly.

number of corroborative or information seeking telephonic interviews were conducted. Results were reported back to the UKCMF regularly (one introductory meeting, and two report back meetings) to ensure transparency and to test the results.

Discussions were based on the principles of dialogue ("what you say can change my mind"), cognitive justice (all knowledges are rooted in specific life worlds and therefore need to be respected as valid in dialogues) and social learning (groups that deal with the same problem space from different perspectives develop shared insights). Analysis was done through identifying, from proceedings, different stakeholder voices using Cultural Historical Activity Theory (CHAT).

FINDINGS

The findings below present various stakeholders' perception and understanding of the problem of contaminated mine water, their interest in the remediation of the mine water, how important it is to them (compared to other priorities), and how they think it should happen. An important part of a conceptual model is to anticipate not only interest and contributions (what role various participants may be willing to play in the future project) but also any objections, concerns, fatal flaws, contrary or competing agendas. The project also elicited concerns and warnings from stakeholders. The following insights, that were arrived at through analysis by the team and tested in UKCMF meetings, are offered as inputs into a conceptual model.

1. Stakeholders have agendas and interest that are important for the conceptual model

The mining industry, the DWS and the IUCMA have a detailed understanding of the problem space – while the community, local government, and others like agriculture do not. However, they are clear on what their agendas are. For local government it is jobs and economic opportunities. For agriculture it is protecting or restoring the fertility of the soil for agricultural purposes. This is in keeping with the idea of a boundary object: the same issue may be viewed with depth knowledge, or only a superficial understanding. However, this does not mean that stakeholders who do not have a technical understanding, will not insist that their agendas are taken into account.

2. All stakeholders seem to share the idea that there is good legislation and rules, but that these are not, or are unevenly implemented

The dialogues pointed to a pervasive perception that there is a gap between formal rules and their application. This could create considerable uncertainty for an enterprise that deals with both remediation and an ongoing production business.

3. The mining industry has a detailed understanding of and strength in the problem space

The mining industry is well informed, has many supporting tools, and has started engaging in finding solutions. On the one hand it is promising that mining companies are taking up the issue, and that they are developing solutions that will be implementable. On the other hand it creates the risk that they will develop solutions that will suit them, without other stakeholders being able or ready to check that their own interests – and the interests of long term stability and accountability – are well served. There is a strong and understandable desire among mines for a "walk away" solution. The DWS and other stakeholders need to be aware of these strengths and be prepare to balance them.

4. Policy is in flux, but busy

The importance of dealing with mine water after closure is widely recognised. Policy to deal with it is in flux. Current proposed policy positions are general and create much space for solutions to be proposed in terms of technologies and institutional arrangements. While it may be relatively easy to conduct policy experiments and action research, there is not enough clarity to establish enterprises. There are a number of action research experiments which will support policy development.

5. Who owns the liability? This is a core problem.

This is a core problem and issues of moving liability from one actor to another remain. Unless there is legal clarity on what happens to the liability for care of mine water (e.g. decants after closure which may last for and appear decades after closure). There are however discussions, for example in Department of Environmental Affairs, about what the implications would be of a mine – or government – appointing specific entities to deal with this liability through remediation.

6. Regulators also have a detailed understanding, but practice does not match theory

Regulators have good understanding of the issues, but much frustration. The One Environmental Permitting System brings together departments with opposing agendas, which they do not seem able to work through. In addition, there are political and operational obstacles within government departments in the current uncertain area, including budget restrictions. The CMA has an on the ground presence, but is not fully mandated to deal with mine water issues.

7. Mines act as individual enterprises – not on a regional basis

Each mine owns its own liabilities and does not have to act with others in a regional strategy. Unless specifically drawn together, e.g. in the MWCB, mines will continue to act as individual enterprises.

8. Local government could play a role in local, long term passive remediation systems

Although not central to this research, it emerged that local government could theoretically play an important role as organiser of public works style maintenance and surveillance of passive treatment systems (that may otherwise be vandalised or robbed of recyclable construction materials). Local government has extensive experience in this field, and it may answer some of local government's need to provide if not jobs, at least poverty alleviation opportunities.

9. The big one: Jobs are crucial, but sensitive – be very careful in raising expectations
Community and local government are very focused on jobs, and a side interest in training (although there is some awareness of mine water issues). The proposed project or enterprise will therefore have to carefully calculate job opportunities along the production chain.

10. There is no general understanding among people of the need for a transition to a low carbon economy, or even what a green economy is
Proposals and enterprises that rely on concepts of doing things differently (sustainably) in a green economy need to realise that they won't necessarily be understood or given special support. They need to explain themselves well. There is a risk for solutions that both remediate mine water and use it to produce marketable products, to inherit the liabilities and treatment costs, thus prejudicing them. While for specialists in the field the advantages are clear of replacing, for example, chemical production from fossil fuels with the production of chemicals through green technology, this is not broadly understood. There is a need for a green industrial strategy to translate these benefits into rewards for entrepreneurs.

11. Reliance on alien vegetation such as black wattle for biomass inputs can be risky
Alien vegetation clearance programmes work on the assumption that the alien vegetation will be reduced, and therefore these do not present a reliable source. Other sources of input will eventually have to be found.

12. Large scale policy and strategy thinking is needed on a just transition to a low carbon economy, on the economics of post-mining landscapes, and on closure policy
There are initiatives, such as chapter 5 of the National Development Plan and current consultations and debates. How these debates and processes turn out will have far reaching effects, and they deserve research attention.

RECOMMENDATIONS FOR FURTHER RESEARCH

The following recommendations are made on the basis of issues which emerged during the research.

1. What are the root causes for the gap between formal rules and their application in the mine water space?

2. What are the processes for creating policy on mine water remediation and mine closure? There are currently a number of formal policy processes, a mine industry led process and experiments by academic researchers and state institutions under way. It may be useful to have an overview of these processes and how they will be integrated into policy. Such research should look carefully at the actors and agendas involved.
3. We recommend that the issue of moving liability from one entity to another be investigated as part of the further development of a conceptual model for the Wits mine water project specifically, in the light of current policy debates.
4. An investigation into the feasibility of a local government role in local, long term passive remediation systems, as organiser of public works style maintenance and surveillance of passive treatment systems (that may otherwise be vandalised or robbed of recyclable construction materials). Local government has extensive experience in this field, and it may answer some of local government's need to provide if not jobs, at least poverty alleviation opportunities.
5. Research into the role of prospects for mine water as part of a transition to a low carbon economy, or a green economy.
6. Research to support big picture policy and strategy thinking is needed on a just transition to a low carbon economy, on the economics of post-mining landscapes, and on closure policy.

ACKNOWLEDGEMENTS

There was no reference group for this short project. However, we appreciate the time and effort of a wide group of participants in the Upper Komati Catchment Management Forum, the Department of Water and Sanitation, as well as officials of the Inkomati Usuthu Catchment Management Agency, Chief Albert Luthuli Municipality, the Global Change Institute at the University of the Witwatersrand, and WRC project managers Dr Jo Burgess and Mr John Dini.

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ACRONYMS & ABBREVIATIONS

AMD	Acid Mine Drainage
CALM	Chief Albert Luthuli Local Municipality
CHAT	Cultural Historical Activity Theory
CKTS	Convergence of knowledge and technology for the benefit of society
CMA	Catchment Management Agency
DAFF	Department of Agriculture, Forestry and Fisheries
DEA	Department of Environment Affairs
DMR	Department of Mineral Resources
DST	Department of Science and Technology
DWS	Department of Water and Sanitation
ICG	Institute for Global Change, Wits
IUCMA	Inkomati Usuthu Catchment Management Agency
MWCB	Mine Water Co-ordinating Body
NDP	National Development Plan
OEPS	One Environmental Permitting System
UKCMF	Upper Komati Catchment Management Forum
VWF	Volkswagen Foundation

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CHAPTER 1: INTRODUCTION AND OVERVIEW

1.1 INTRODUCTION

Worldwide concern is growing about the futures of landscapes in which coal mining has taken place, is taking place or is planned to take place (Pullen, 2015; Limpitlaw and Briel, 2014; World Bank Multistakeholder Initiative 2010). The cessation of coal mining activities often leaves a region economically vulnerable (Wirth et al., 2012). In South Africa specifically, declines in mining activity in the past have often led to environmental, health and social crises due to poor closure or abandonment of mines by the industry and retrenchment of labour. In addition, some regional resources, such as water and soil, have been impacted by the mining and will need rehabilitation. Analysts have predicted that the coal acid mine drainage problem on the Mpumalanga Highveld will rival the gold and uranium AMD challenge on the Witwatersrand (Hallowes and Munnik, 2016).

Not only the rehabilitation of mined out areas for future, alternative land uses, but also the provision of job opportunities become particularly important. In short, there needs to be a consideration of how future land uses, especially those that form part of a sustainable, low carbon, green future (Swilling and Annecke, 2012; Scoones et al., 2015) can be facilitated in post-mining landscapes. The Green economy may be based on a new, sustainable approach to economic activities, but it will depend on the resources – damaged or rehabilitated – that it inherits from the fossil fuel economy.

There has been development and even implementation of technologies that form part of this new economy. There are also important debates, in popular media, as well as in specific stakeholder circles including the presidency, mining circles (e.g. Mine Water Co-ordinating Body formed in 2017), labour and civil society about a just transition from coal. But solutions can never be only technical.

Studies in the sociology of science and technology have argued convincingly that technologies, especially new technologies intended to support a transition to sustainable development, are shaped by the interests and agendas of social groups beyond what may be considered technically important (Bijker, 1997; Jasanoff, 2003). In considering the introduction of technologies to remediate contaminated mine water and use it in a bio-economy, with the purpose of supporting development and the creation of jobs, it is clearly important that the perspectives and agendas of residents and stakeholders be voiced as clearly and with as much integrity as possible.

The manner in which new knowledge is produced can be as important as its content. Recent developments in political ecology (Leff, 2012) and sustainable development (Gaventa, 2006; Burns,

2007) have emphasised the importance of “cognitive justice”, in which different knowledges are recognised for their own inherent wisdom, and the role they play in reflecting the realities of the social worlds of disparate participants (Visvanathan, 2009). This principle was applied in this project through a series of dialogues structured along these principles.

This study explores how innovative uses of water within an integrative approach to environmental restoration and socio-economic investment could improve the livelihoods of thousands of people living near derelict mines. The establishment of a bio-based economy with the help of the mining industry and local communities could improve the current socio-economic positions of marginalized people. Various bio-remediation technologies for treating mine wastewater exist, and can be used to stimulate a bio-based economy where biomass can be generated for subsequent valorization. (See below, chapter 2, for more detail on the proposed technologies and approach.)

This short term project was undertaken in support of a broader project **“A transdisciplinary, dialogic approach to exploring the possible role of the South African mining industry in the establishment of a sustainable bio-based economy”**, which is a fellowship funded by the Volkswagen Foundation and housed at the Global Change Institute at Wits. The Wits project engages with already existing international technology (see next chapter) and explores how it can be applied in the setting of the Mpumalanga coalfields.

The focus of this WRC project was to understand the context in which such technology can be deployed. It specifically developed an understanding of the perspectives and agendas of stakeholders in the quaternary catchment X11B (Carolina, Mpumalanga), as an input into a conceptual model for the proposed technology interventions in remediation and using treated water in a bio-based economy, with special emphasis on the creation of job opportunities after coal mining has ceased. It thus had a very practical orientation.

In terms of new knowledge, this approach provides a deepening of transdisciplinary practice, as it was required to deal with complicated, real life problems. It could also strengthen and draw into South African debates new developments in studies of sustainability transitions (Caldecott et al., 2017; Geels et al., 2016; Grin et al., 2010).

Research into post-mining landscapes, bio-remediation and creating new economic bases, will inevitably be framed by the emerging discussion of a Green Economy, which has created a space in which various visions of a sustainable future can enter into dialogue (see Swilling, Musango and Wakeford, 2016). This research hoped to make a useful contribution to the practical envisioning of a green economy.

1.2 AIMS AND OBJECTIVES

The aims of this project were:

1. To test the responses of a representative group of catchment citizens to proposals to remediate and use contaminated mine water in a bio-economy application (In order to support practical development of options to remediate and use mine water).

2. To develop transdisciplinary methodologies in water research: specifically the use of the dialogic method in expanded social learning, with Cultural Historical Activity Theory, as a shared method between social and natural science trained researchers.

3. To develop ways of communicating and working with scientific-technical knowledge in a way that supports inclusive participatory, democratic deliberation on water issues.

4. To further build the capacity of a Catchment Management Forum working group as well as capacity for co-creation of water futures.

5. To start the process of envisioning post-coal mining landscapes on the Mpumalanga Highveld, and develop a first checklist of issues relevant to water in such landscapes (i.e. rehabilitation, closure policies, feasible future land use options, etc.).

The intended outcomes were:

1. To build understanding of the need for, nature and potential of bio-remediation of contaminated coal mine water among participants in Upper Komati Forum through a co-produced conceptual model (of agendas, expectations and understandings)

2. To create understanding of the need for, nature and potential and policy implications of bio-remediation of contaminated coal mine water among policy makers, DWS mine water group, etc. – including implications for rehabilitation and closure policies

3. To develop methods for transdisciplinary work which brings together scientific, technological options with the agendas of participant groups.

4. To develop capacity in CMFs in coal mining areas to envision and plan for post mining landscapes.

1.3 CONTEXT: PART OF A BIGGER PROJECT

This project formed part of a bigger research project, which takes place in 4 phases.
Phase 1, the current phase, is aimed at producing a conceptual model for the bigger project, looking at both technical and social, economic and political feasibility. It is in this context that regulatory and planning questions for DWS arise.
Phase 2 (to March 2020) The first conceptual model will then be enriched by research into economic and social aspects, such as population and employment figures and by the quantification of the conceptual model (in terms of material flows, i.e. input quantities of biomass needed, reliable sources of such biomass (e.g. will wattle removal be sustainable?), farmers' surplus biomass, job opportunities, marketing, financial feasibility – adding up to a proposal for a pilot project.
Phase 3 would be a pilot project, an actual physical construction that tests the idea in practice, albeit on small scale, and if that shows positive results, investors and funding will be sought for a commercial treatment and production plant.
Phase 4 is strictly speaking not research, although it puts the research in action through the actual building of a factory and business, with the aims of using biotechnology to clean the water, using it in the new green economy, and providing economic activity including jobs in a post mining situation. Nevertheless, it can be regarded as research as it tests the work done before in reality.

1.4 CONTENTS OF THIS REPORT

Chapter 2 provides background and arguments on bio-remediation technologies as solutions to some of the challenges outlined above. Chapter 3 introduces the dialogue and CHAT methodology followed in the research. Chapter 4 reports on the dialogues and other engagements that provide the material for this report. Chapter 5 draws together our findings as inputs into a conceptual model. Chapter 6 reflects on the successes and limitations of this research project, and suggests some topics for future research.

CHAPTER 2: THE POTENTIAL OF BIO-REMEDIATION AND THE POTENTIAL ROLE OF THE MINING INDUSTRY

This chapter provides background on the potential of bio-remediation to address rehabilitation and post-mining issues in the regional economy. It gives a general overview of bio-remediation. It then explains which questions the broader project is asking in order to choose technologies from an engineering perspective. It concludes with an argument for integrating a social science approach in the planning of such projects.

2.1 THE POTENTIAL OF BIO-REMEDIATION

Mining operations and the associated infrastructure require complex and costly dismantling[2]. It involves technical and environmental restoration and rehabilitation measures together with socioeconomic investments to counteract retrenchment, post-closure economic downturns and other effects associated with the end of the project's productive life. An integrative approach to environmental restoration and socio-economic investment could improve the livelihoods of thousands of people living near derelict mines (World Bank Multistakeholder Initiative 2010).

Of particular concern in the South African context is the availability of water, a scarce resource which is threatened by climate change and pollution. Although South Africa is water scarce country excessive polluted mine process water is a major problem for many mines. Moreover, in certain areas, mining has exposed pyrite rock which led to the formation of large volumes acid mine drainage that poses significant risks to the environment and property (McCarthy, 2011).

This is a worldwide problem as well, and various bio-remediation technologies investigated for treating mine wastewater containing a variety of pollutants, have been investigated internationally (see Mani and Kumar, 2014). Bio-remediation technologies are desirable because they are often cheaper and more environmentally consciously designed than physical or chemical treatment options (Mani and Kumar, 2014). Bio-remediation technologies rely on various organisms including bacteria, fungi, algae and plants to remove pollutants from water through processes such as bio-degradation, mineralization and hyperaccumulation to name a few. Many bio-remediation technologies were shown to be feasible in remediating mine wastewater, reducing pollutant levels to within regulatory levels (Arvind, Shreedharan and Ambika, 2015).

2 The local population is often amazed and dismayed at seeing the demolition of "perfectly good housing and buildings" when a mining company leaves (see Munnik et al, 2010).

The value of bio-remediation of wastewater is usually measured in terms of ecosystems services provided by natural environments that were protected from pollution and the reclamation of valuable natural resources such as fresh water (Braat and de Groot, 2012; Christie and Rayment, 2012). However bio-remediation technologies could have intrinsic value if the biomass from these technologies is used as a feedstock for a bio-based economy. Phytoremediation technologies could for example produce large quantities of biomass while remediating mine wastewater. Usually mines occupy large areas of land where phytoremediation technologies such as constructed wetlands could be built.

Bio-remediation works within a bio-based economy. A bio-based economy refers to activities that make use of bio-innovations, based on biological sources, materials and processes to generate sustainable economic, social and environmental development (McCormick and Kautto, 2013). In the bio-economy the entire innovation system/network, ranging from ideas, research, development, product development and manufacturing to commercialization, should be used to its full potential in a coordinated manner. The production chain of products in a bio-based economy includes the production and collection of biomass (such as agricultural residues), processing of biomass, transport and storage and finally conversion of biomass into value added products. These may include pharmaceuticals and chemicals, food and feed, fibres and materials, as well as fuels and energy (McCormick and Kautto, 2013).

An example of a local company that has developed commercial scale bio-refinery technologies is DalinYebo in the sugar producing area of KZN. Their furfural production technologies have been employed at industrial scale at a sugar refinery not only in South Africa but also at other sites around the world. Examples of international companies include GF bio-chemical in Italy produces levulunic acid from corn. Levulunic acid is a drop-in platform chemical, i.e. it can be converted to and array of industrially important chemicals. Similarly, Bio-amber with a factory in the United States, has the capability to produce succinic acid which is also an important platform chemical.

The mining industry could be well suited for the production and processing of biomass by using bio-remediation technologies for treating mine wastewater. Mines often own or control large areas of land, which they have a responsibility to rehabilitate and return to a state where alternative land uses become possible. Mines have an interest in dealing with the liabilities around mine water in a way that they do not have a decades' long responsibility. And some mining groups are considering expanding into different streams of business, as climate change narrows the scope for coal mining in the future.

2.2 ASPECTS OF SCIENCE AND ENGINEERING RESEARCH

Aspects of science and engineering research will be taken up in the GCI Wits project that is supported by the Volkswagen Foundation. For the sake of better understanding, the approach that will be followed in that project is briefly described here. Current mine wastewater bio-remediation technologies will be evaluated using criteria that will not only include the efficacy of the bio-remediation systems in the treatment of mine wastewater but also the amount and type of biomass that can be produced. Furthermore, the steps of processing the biomass to value added products will be evaluated for energy and conversion efficiency as well as cost effectiveness which will ultimately impact the overall viability of the bio-based economy. These comparative techno-economic assessments will be performed using process engineering and/or life cycle assessment software, e.g. Aspen. A meta-analysis of literature on various mine wastewater bio-remediation technologies will also be performed. Data gathered through these actions will be consolidated in a conceptual model which can be evaluated and updated after subsequent community engagement sessions that will follow on the WRC project described in this report, as in figure 2.1 below.

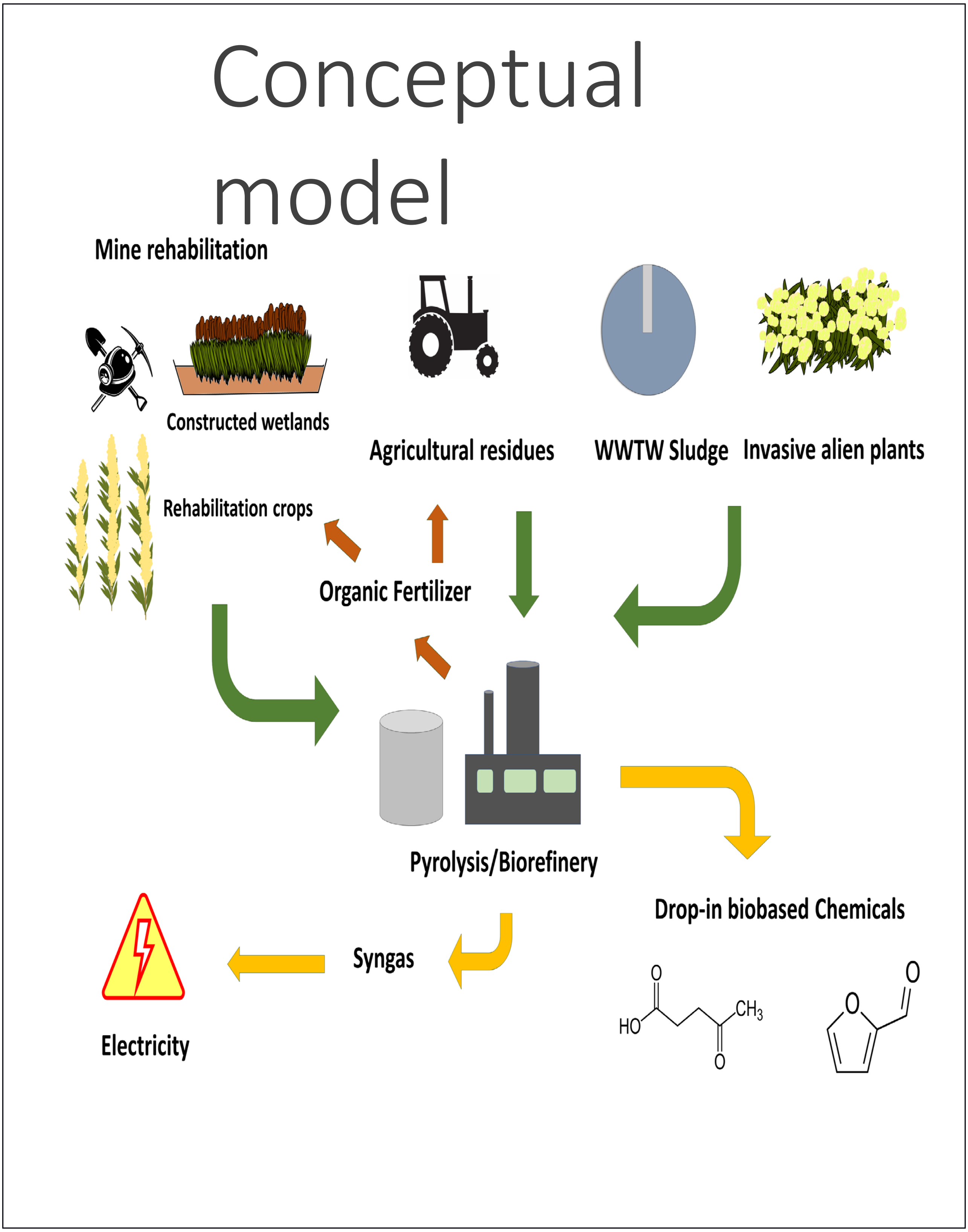

Figure 2.1. Conceptual model from production point of view (provided by Wits team).

The technology aspect of this study (the broader study to which this project contributes) uses a decision framework methodology for reviewing the various contaminant, site, regulatory, cost, and time constraints that impact technology selection. To select appropriate technologies the following information will be needed:

Applicability of technology to site contaminants: Contaminant properties can often provide a general indication about the applicability of treatment technologies to remove such contaminants from environmental media. For example, acid mine drainage (AMD) contains high concentration of iron, sulfuric acid and heavy metals. Usually the AMD is neutralized with lime which results in the precipitation of metals and creates a worthless sludge which needs to be disposed. The GCI-Wits-VWF project is currently researching alternative methods to increase the pH of AMD through bio-remediation technologies. Cellulosic biomass was found neutralize AMD while the acid also pre-treats the biomass for conversion to fermentable sugars. Through this process both the AMD and waste biomass is valorised. Research is also ongoing on bacterial processes to recover sulphur from the treated AMD stream. Other mine wastewater streams. e.g. high salinity water could be treated using halophilic algae. Algae have been identified as very promising for the production of biofuels and replacement of chemicals that are produced from fossil fuels.

Variations in technology design: Technologies can be designed and implemented in various configurations to optimize treatment effectiveness and project goals. Selection of the best technology design variation is dependent on many factors including site characteristics, design flow, regulatory requirements, and treatment objectives.

Site characteristics: The applicability of treatment technologies is highly dependent on site characteristics. For example in the context of AMD it should be taken in consideration whether wastewater is below ground or on the surface, and if the terrain surrounding the pollution site is flat or mountainous.

Regulatory acceptance of technology and required permits: Regulatory agencies have varying requirements for groundwater withdrawal, groundwater discharge, and air discharges. Much of this was covered in the WRC project that is discussed in this report.

Technology availability: various technologies are in different stages of development and even some close to market technologies may face various barriers before being implemented.

Project life-cycle costs: Project life-cycle costs consist of all expenses that are incurred for site assessment and remediation over a project's lifetime. These costs include site assessment and remediation, site engineering and design, capital costs, operation and maintenance requirements, monitoring, and project management. The remediation system having the lowest possible present value cost, which achieves project objectives in terms of both closure goals and treatment time, should be selected. Obviously, capital costs must be carefully weighed against the estimated treatment time required to achieve closure. Administrative and potential litigation costs should also be considered in selecting the remediation strategy.

These technologies can be used to stimulate a bio-based economy where biomass can be generated or treated with mine waste water such as acid mine drainage. However our knowledge on how to link bio-remediation technologies with revenue generating mechanisms and job creation is limited

2.3 INTEGRATING SOCIAL RESEARCH IS NECESSARY

Current research into transitions show that social research is a crucially important part of technology choice. A recent survey of the perception of the effectiveness of research and innovation actions in the European bio-based economy it was found that research and innovation actions are not sufficiently effective. Some of the most insufficient or ineffective actions were considered to be:

(1) "Providing a knowledge base for society expectations in the bio-based economy",
(2) "Providing a knowledge base for addressing societal challenges faced by developing countries and emerging economies" and
(3) "Translating research into behavioral change" (Netherlands Enterprise Agency, 2014).

Therefore building a bio-based economy cannot only be a technology focused endeavour. To create added value and progress, knowledge around technology and societal development needs to converge (Roco and Bainbridge, 2013). This requires bringing together all relevant areas of human, machine and natural resource capability that enable society to answer questions and resolve problems that isolated capabilities cannot. Coupled with convergence is divergence which creates and disseminates new competencies, technologies and products. Convergence of knowledge and technology for the benefit of society (CKTS) has been identified as a core opportunity for progress in the twenty first century. CKTS provides a systematic approach to connect and enable emerging technologies and then implement them in essential domains of human activity.

Convergence processes already have begun between several specific domains of science and technology (Roco and Bainbridge, 2013). Because of these convergence processes, the institutional landscape for infrastructure project planning is changing. Lenders, developers and government authorities are more aware of how social issues affect project acceptability and hence the overall capital cost. In recent years, a wider range of project lenders have placed greater emphasis on ensuring that projects are socially responsible through recognised guidelines and policy (Rowan, 2009). Initiatives by the intergovernmental organisations like the United Nation's Global Compact, the Global Reporting Initiative, generally put greater emphasis on corporate responsibility and sustainable development. Coupled with the ability of protest groups to share information more widely and rapidly, these standards influence many project developers. This resulted in greater willingness and need to thoroughly address social issues.

The next chapter takes up the challenge to provide an understanding of social challenges, societal expectations and agendas of groups with an interest in the technologies that are being forward to deal with contaminated mine water and ease a transition to a green or low carbon economy.

CHAPTER 3: METHODOLOGY: DIALOGUES AND WORKSHOPS

This chapter explains the methodological approach of the project.

3.1 DEVELOPING INPUTS INTO A CONCEPTUAL MODEL THROUGH SOCIAL DIALOGUE

The core purpose of developing the conceptual model was to anticipate how the proposed technology would fit into the context of the Mpumalanga coalfields, using the Carolina area as an example. It looked at various stakeholders, their perception and understanding of the problem of contaminated mine water, their interest in the remediation of the mine water, how important it is to them (compared to other priorities), and how they think it should happen. The project also elicited concerns and warnings from stakeholders. An important part of a conceptual model is to anticipate not only interest and contributions (what role various participants may be willing to play in the future project) but also any objections, concerns, fatal flaws, contrary or competing agendas.

Our approach took into account not only the possibilities and constraints flowing from different technologies, but also the interests and agendas of different actors in society, focused on local and community actors in a specific site. This is a complex undertaking, as it involves:

- The mining industry and its regulator, with responsibilities following from the closure of mines;
- The society in which the mine is situated, and for which a post-mining future is envisioned;
- The possibilities and constraints of various bio-remediation technologies – coupled with the ability of these technologies to create a bio-based economy post mining

All of these categories contain their own complexities. For example, the mining industry balances the agendas and interests of shareholders with those of managers, environmental managers and regulators, with decisions influenced by economic competition, economic climate and pressures and commitments to sustainability. Society can be segmented into local communities (in townships, informal settlements, in small towns and on farms), local economic and political interests, but are also oriented towards a shared future which entails preserving options for different – and possibly new – land uses.

In addition, local sites are never only local, as they are also local hubs for interests that can be regional, national or international, for example a mining company may be part of a multinational, and be dependent on global markets, inputs, etc. Similarly, local people may be organised into political parties with national reach, or as part of an environmental justice movement which is global.

The relationship between technologies and society is also complex. From empirical historical work we know that technologies are subject to various agendas, and their ultimate shape and function is determined not only by strictly technological or scientific considerations, but also and sometimes more by their role in society, and their exposure, during development, to social forces (see Bijker, 1997).

What is required, therefore, is a shared process of dialogue and exploration within society, to arrive at such a conceptual model. This project took place in a transdisciplinary space and provided the opportunity to engage with a number of theories, approaches and issues that support the building of a sustainable future.

The complexity of this question can be addressed by using the insights achieved in working with complex social-ecological systems (Folke et al., 2003) in general, and specifically in Natural Resource Management in Southern Africa (Palmer et al., 2015). These insights include the close coupling between justice and human wellbeing, the need for a dialogic approach characterised by humility, and the need for transdisciplinarity. This approach is in turn underlain by complexity theory (Cilliers et al., 2013). Real life applications to wicked problems, such as Integrated Water Resources Management, catchment management and management of ecosystems in the Kruger National Park, led to the approach of Strategic Adaptive Management (Rogers and Luton, 2011; Rogers et al., 2013). This approach supports stakeholders in agreeing on and planning for shared futures, and together devising routes of reaching them.

Dialogue and deliberative democracy practices are crucial means for arriving at a shared sustainable resource future (Romm, 2001). Generative dialogue depends crucially on the principle of cognitive justice – that is, that all knowledges are treated with equal respect, because they are embedded in people's lifeworlds and determine people's opportunity structures (Visvanathan, 2005, 2009). It also depends on the types of discursive spaces created for interaction (Munnik, 2017; Gaventa, 2006; Miraftaab, 2004). To create a 'level playing field', a citizen's science approach, which makes science available in understandable terms and accepts direction from citizens in terms of objectives, is also required (Irwin, 1995; Jasanof, 2003).

3.2 ANALYSING ACTIVITY SYSTEMS

The project used Cultural Historical Activity Theory (CHAT), based in the expanded social learning approach (Engestrom, 2001; Jonassen, 1999). This approach allows actors who may be very different in terms of their agency, role, agendas and understandings of a problem area – such as the issue of contaminated mine water – to be understood in their own terms. This is achieved by defining each actor (an actor can be an individual or a group) in terms of six aspects of activity systems. This approach also makes it possible to compare different perspectives on an issue, as shown below in diagram 3.1.

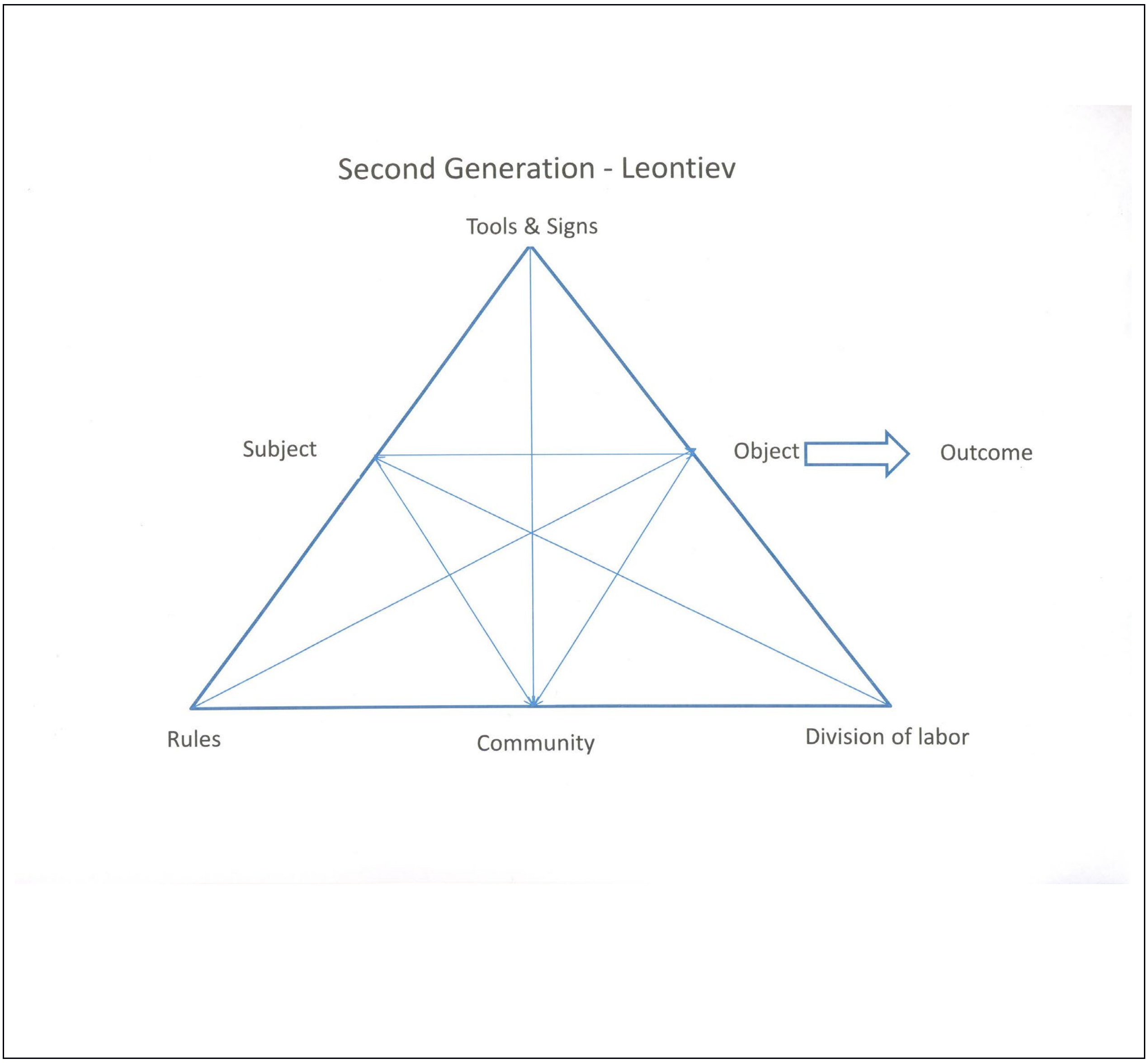

Figure 3.1 Cultural Historical Activity Theory, Wikipedia.

The six categories are:

Objects (raw material worked on, or problem space) such as the challenge of contaminated mine water within the catchment;
Subjects (or agents): the individual or subgroup whose point of view gives the perspective of the analysis;
Tools (artefacts as well as concepts): used in understanding and addressing the object;

Rules: explicit and implicit regulations, norms, conventions and standards that rule actions within the activity system;
Community: individuals and subgroups who share the same general object;
Division of labour: horizontal division of tasks in teams, vertical division of power and status.

These six categories are viewed as the outcome of historical processes, based on subjects' (participants') own expressed views. They are also supported by material analysis, based on open communication of scientific-technical information and decision making.

CHAT was introduced in the project as a boundary object in the sense that it is at the same time technically specified to insiders (e.g. the social researcher) as well as understandable and useful to other participants (natural scientists and catchment working group participants) (see Star, 2010). It used the segmented participatory approach, which allowed each group of subjects to find their own voice, such as mine managers, the community and regulators (see Burns, 2007).

3.3 CAROLINA AS RESEARCH SITE

Carolina was chosen because of numerous advantages associated with this site, when compared to the Upper Olifants Catchment, for example. Carolina is included in the Komati-Usuthu Water Management Area. As a result, it is supervised, regulated and well-studied (in terms of information gathering and consultation for the then ICMA CMS, 2012). The IUCMA has established an Upper Komati Catchment Management Forum in which Carolina and surrounding mines are included (see below). This presents a future configuration for other areas that are currently without CMAs (but are regulated by proto-CMAs in DWS or regional DWS offices). As a study site, it thus provides a "glimpse into the future", when more advanced and better resources regulation structures may become available.

Carolina experienced a dramatic Acid Mine Drainage pollution event in January 2012. Extensive historical material relating to this event is available, including administrative-legal records, such as the first inspection report (Marais et al., 2012), IUCMA records, a biophysical analysis (McCarthy and Humphries, 2012) and social analyses on impacts on the town (Tempelhoff et al., 2012). Multiple actions were taken in response to this incident: the IUCMA installed a number of monitoring points; legal directives were issued to five coal mines in the area; and a consultant firm undertook a detailed study (Golder, 2014).

For future use of our results it is important to point out that there are a number of aspects that are specific to Carolina, and would need to be adjusted for application in another coal mining area. For example, the coal mining activities are concentrated in a single ward of the Chief Albert Luthuli

Municipality, ward 21, according to the municipality's LED section. Second, the sources of acid mine drainage are all relatively small, especially the points where AMD decants. Third, the participants in this study may be much more aware and better informed than comparable citizens elsewhere in Mpumalanga.

3.4 DIALOGUES AND WORKSHOPS

The dialogue process was initiated in a first engagement with UKCMF in October 2017, where the research project was introduced and the Forum agreed to participate in the research project. In practice, a number of Forum members became regular participants in the workshops in which the dialogues took place. This was a familiar format for them, as the Forum had previously participated in a similar dialogue process as part of the WRC project K5/2355 (Munnik et al., 2017), in which it developed "a multi-sectoral integrative licensing and monitoring framework, to align and integrate biodiversity and environmental water quality, in the coal mining development life-cycle". The forum thus had considerable experience in deliberating on current coal mining and water interaction, and was well qualified to consider issues of water use in a post coal mining landscape.

The dialogue process took place in four dedicated workshops and three report back sessions. Two main workshops took place in Carolina in which four groups or "voices" were represented: (1) community representatives (2) regulators from DWS, DAFF, IUCMA and (3) mining environmental managers and consultants working with the coal mines and (4) local government staff. As a result of travel restrictions (at the time) on DWS officials from head office in Pretoria to the UKCMF, the team undertook, in addition, two dedicated workshops with DWS officials responsible for mine water and for resource planning. Additional interviews were undertaken to strengthen aspects that were under-represented (interview with mine manager in Middelburg, and interview with local government officials from Chief Albert Luthuli Local Municipality), or difficult to understand (telephonic interview with DEA manager).

From the above it is clear that the project did use the approach of segmented dialogues, both to preserve the specificity of participant groups and their interests, and out of practical necessity. Reality imposed other limitations:

1. It was difficult to find mine managers to interview. We managed to conduct an in depth interview with an environmental manager in mining with broad experience, who worked as part of a team providing services to more than one mine. Much of our insights into the response from mining companies however came from consultants to the mines, who are regular attendants in the UKCMF, and who may have a more rule-based approach (since that is their trade).

2. The DMR office in Witbank had been closed during our project, and we could not get their inputs. A similar problem was experienced during WRC project K5/2355 (Munnik et al., 2017).
3. Crucial policies regarding mine water management are still under development, but we used previously gazetted policies (publicly available) and discussions with officials to gain an understanding of subsequent developments.
4. Participants in the dialogues had different levels of understanding of terms such as bio-remediation, biotechnology and the green economy. Some participants requested capacity building on these topics, and in response we conducted the January 2019 workshop with the UKCMF working group in Carolina with this in mind. This developed into an interesting round table discussion with many interruptions, clarifications and a rich discussion with diverse opinions (see below).

3.5 PRESENTATION OF THE TECHNOLOGY IN A CONCEPTUAL MODEL

An important focus of the project was to communicate scientific and technological information in a way that would be generally understandable. In the course of the project, the following presentation was developed.

The departure point is that globally peak coal production and use is predicted to be reached by 2030, with a sharp decline afterwards. The reasons for this are an international drive to use less fossil fuels for energy and to combat climate change by reducing greenhouse gas emissions. As a result, many coal mines will be closed down in the near future. There needs to be a discussion on how these coal mining landscapes will be managed to prevent the inevitable environmental degradation and socio-economic decline.

When looking at a mine's life cycle it historically consisted of exploration, feasibility, planning and design, construction and operation phases. There was no real consideration around the environmental and socio-economic effects post mine closure. It is only relatively recently that mines were obligated to draw up plans for reclamation, closure and completion. These plans are aimed at restoring the disturbed environment to a near pristine condition, i.e. to the state it was in before mining took place.

In practice this is seldom possible due to irreversible damage caused by mining. For example, in the Mpumalanga coal fields, during mining operation the sand stone layers are removed which adversely affects the hydrology of the area. These sandstone layers cannot be replaced to the pre-mining condition.

The pollution of water resources is a significant concern for all stakeholders which rely on this resource. Remediation of mined areas is also a significant expense which mining companies would like to minimize. Therefore, they tend to use low maintenance and passive water treatment systems such as constructed wetlands. These technologies are relatively cheap to install and require less maintenance than for example reverse osmosis water treatment systems. Constructed wetlands are part of a few bio-remediation options. Another strategy of using and treating mine impacted water is to use it to irrigate remediation crops. In this way the mine impacted soil and water is used productively to produce biomass than can be used in the bio-economy.

The bio-economy refers to the conversion of low value biomass that is not being used for food, to value added products like biofuels, green chemicals and fibres. The products of the bio-economy production systems are aimed at directly competing with current products produced by the petro-chemical industry which relies on fossil fuels. Instead of an extractive industry, the bio-economy uses mostly plant based renewable resources as a feedstock for bio-refineries. Some of the chemicals that are produced by these bio-refineries could act as drop in chemicals, i.e. they are the same chemicals the petrochemical industry produces but are made from renewable biomass sources.

Bio-remediation sites can be an ideal biomass resource for these bio-refineries. The bio-economy relies on the economic collection and/or production of biomass as well as the transport and conversion thereof to a valuable and profitable product. Throughout this process we need to identify what social impact the bio-economy could have in a post mining landscape.

In South Africa there is growing interest in post mining landscapes. The mine water coordinating body came up with the idea of a “green machine” which is a regional development plant based on the beneficiation of coal mine waste, polluted resources and renewable energy production technologies.

We as a research team are interested in using the land and water resources which are often in a degraded state due to mining operations, to produce biomass. The concept we are proposing is to use the biomass of constructed wetlands and remediation crops as a reliable source of biomass feedstock for an integrated bio-refinery. These primary sources of biomass supply can be further supported with agricultural residues, waste water treatment plant sludge and invasive alien plant clearing through public work programs. The products from the bio-refinery can include organic fertilizers which can be supplied to the local farmers, electricity for the bio-refinery with a surplus being sold to the local municipality or mines in the area. The most profitable revenue stream may be through the production of drop-in bio-based chemicals.

There are a wide variety of chemical that can be produced through a bio-refinery which can be sold to markets usually served by the petrochemical industry. These markets include pharmaceuticals, textile, polymers and food additives.

A value chain analysis approach to the bio-economy implementation in post mine closure landscapes can be useful to illustrate and identify the various steps involved to establish this industry. There are the higher level business management processes like firm infrastructure, human resource management, technology development and procurement that needs to be considered. But the greatest positive social impact can potentially be realized in the day to day operation of inbound logistics, operations, outbound logistics, marketing and sales and service. It is within these activities where most job opportunities lie and where skills development are required. It is thus important to match the skills required by these business activities with the work force skill already available in the region or to upskill the workforce in order to ensure a successful business operation.

An example of a local company that has developed commercial scale bio-refinery technologies is DalinYebo in the sugar producing area of KZN. Their *furfural* production technologies have been employed at industrial scale at a sugar refinery not only in South Africa but also at other sites around the world. Examples of international companies include GF bio-chemical which produce *levulunic acid* from corn. Levulunic acid is a drop-in platform chemical, i.e. it can be converted to and array of industrially important chemicals. Similarly, Bio-amber has the capability to produce *succinic acid* which is also an important platform chemical. They developed a process which directly competes with the petrochemical production of this chemical.

CHAPTER 4: OPINIONS, VIEWS, WARNINGS – RESULTS OF THE STAKEHOLDER DIALOGUES AND WORKSHOPS

In this chapter, the results of the various workshops and interviews are given. Readers who are not that interested in the process can skip to Chapter 5, where the results are summarised and discussed. For the discussion, we follow the CHAT categories introduced earlier. Where relevant, observations from other groups confirming or questioning the views expressed by specific actors, are given.

4.1 UKCMF COMMUNITY VIEWS

The UKCMF was chosen as the prime site for community dialogues, as well as the site for reporting back. UCKMF was treated as the main partner in the dialogue, from asking for permission to invite members, to reporting back, and working with the UKCMF co-ordinator from the IUCMA. The following is based on the 24 Sept 2018 and 21 Jan 2019 sessions.

Object or problem space

The community representatives were well aware of the problems of contaminated mine water, and recalled the acid mine drainage incident in 2012. They placed the mine water problems within a broader context of water issues, particularly with drinking water provided by the municipality. As a result, mine water issues feature as only one of a series of water issues for them.

Subjects

What are the community interests in this project? The report back included the phrase "Our interest is in purifying water for human consumption – that is our only interest here." They may mean that this is the overriding interest, because the community group also commented on their observations that local coal mines have mine water dams that leak, and flow into local streams. They cautioned mines to manage their dams to avoid this. They also expressed an interest in participating in a range of forums. By all accounts they already participate in these forums, including the mines' future forums, which are required in terms of the DMR's guidelines for Social and Labour Plans (DMR, 2010).

Local government representatives reported that community organisations are also very active in forums where job opportunities are discussed, see below. In the DWS consultation of January 2019, a highly placed official commented that communities have a high awareness of water issues, while others argued that this was not supported by an in depth knowledge. Other actors reported that community participation is not consistent. In the 2014-2016 dialogues community representatives were vocal about the limitations on their participation caused by lack of resources such as transport and information technology (access to computers and Wi-Fi), and costs such as transport that they could not carry themselves.

Tools

Community participants welcomed the potential of the proposed biotechnology, but remarked that they do not have a good understanding of the terms 'biotechnology' and ‘green economy’ They stressed the need for their capacity to be built to understand these better and take part in discussions. Their support for the proposed technology was based on their expectation that it would improve water quality, sustain water resources, create jobs and diversify (options in) agriculture (through the uptake of biomass in the proposed plant).

Rules (formal and informal)

Community representatives were well aware of the rules set up by the MPRDA and NEMA, which they described as “containing criteria that the mines should follow”. They argued that the legislation was “passive”, that “enforcement of current legislation and the rules is not done”, and called for better enforcement to protect water resources.

Community

Community representatives identified a range of stakeholders who also have an interest in dealing with mine water issues in the area, namely the municipality, the agricultural sector and those responsible for rehabilitation. The community sector has direct and indirect interests in these stakeholders, e.g. in terms of municipal services and jobs in agriculture.

Division of labour

In terms of who should do what, the community demand was for opportunities for people from the area to receive training to understand and participate in the “new” economy. They also warned against raising expectations about jobs from this initiative because it is an important and sensitive issue in the area. (That this is a highly sensitive area was confirmed in the 22 January 2019 interview with local government officials.)

4.2 LOCAL GOVERNMENT VIEWS

Local government representatives from Chief Albert Luthuli Local Municipality (CALM) do participate in the UKCMF. They also participated in the working group meetings, where they were often criticised for problems with water services and waste management. The bulk of the local government response to the biotechnology proposal was elicited in an interview with the Albert Luthuli acting chief LED officer and chief town planner.

Object or problem space

Coal mining in Carolina area is confined to a single ward, ward 21. Local government officials are aware of the risk of long term environmental damage from mines, but because the municipality does not have environmental officials they are not able to deal with this issue. Their focus is on negotiating with the mines to create jobs, support the municipality and to provide training.

Subjects

The focus of LED is how to create economic activities. They relate to the coal mines in a number of forums discussing economic issues, as well as in planning processes, particularly Social Labour Plans (SLPs) and integration to the municipality's central planning process, the Integrated Development Plan (IDP), as well as occasional requests and opportunities for Corporate Social Responsibility donations and assistance. The local government is also very interested in the provision of training opportunities for local residents especially youth. CALM has extensive experiences in managing public works type programmes, including building a small wetland at the Nooitgedacht dam outside Carolina.

Tools

Local government continually negotiates with mining companies about the opportunities they can create for the local economy. However they are hamstrung by their own lack of capacity to critically review the claims by local mining companies. They expressed their frustration at this. They regard the SLPs and processes to relate them to the municipality's IDP as good instruments, but without the capacity to engage with the mines on an equal footing, it is difficult for local government officials to use these to extract maximum benefits for the local economy via employment and procurement.

Rules (formal and informal)

There are many expectations on local government, but in many of the poorest municipalities like CALM this has not been translated into reality. Officials are open in saying that there is distrust from local community, e.g. on water services issues, and in terms of jobs, there is frustration from communities against both business and local government.

Community

Local government is closely bound to the local community. They are under pressure from their voters to create more economic opportunities. The proposed biotechnology plant will be welcomed from that perspective. This should include – as explained in the proposal – local procurement opportunities, e.g. for local biomass which could include biomass from alien clearance programmes. The coal mines do not appear to them to do much local procurement, if any, so that will be a significant difference.

Division of labour

Local government is responsible for land use planning, but the power does not extend to farms, where the mines are and where such a business would be located. Their focus would therefore be on economic development.

4.3 MINING SECTOR

This section is based on the workshop of 24 Sept 2018 augmented by an interview with a mining environmental manager on 22 Jan 2019. Although invited, DMR officials do not participate in the UKCMF (as witnessed during the 2014-2016 dialogue process and confirmed by participants then). During the project time the DMR office in Witbank/eMalahleni was closed.

Object or problem space

The mining industry has a very detailed understanding and view of the problem space. "Mine water is our biggest environmental issue because it can become a long term ongoing liability and mines don't like such liabilities. If a company says we can use the resources in an economically viable way, we would like to partner with you. " But there were important practical questions about the (Wits) proposal:

> "If you construct this system on somebody's property, who will take responsibility for that property? The problem with officials, they are not sure of what will work, and doesn't work. From their side, they may partner with you, but they are the same people who will come back after 10 years and say there is a problem."

> "It is a good concept, that as a mine you can invest in it. Something that will uplift the community with jobs. But we (all) want to see if it works." [Interview 22/1/2019].

Subjects' perspective

Environmental managers at mines, and consultants advising them provided informed views. These individuals deal with the detail of management of mine water and closure plans. As a result, they are often the best informed of all participants in this process. However, they are bound by the dictates of their work. Mines are particularly reluctant to release information because they believe it may prejudice them. In general, mine employees are subject to strict workplace discipline and are circumspect in what they say.

Community (who has an interest in mine water)

The mining sector (managers and consultants) recognise a wide spectrum of other interested parties in mine water. In Carolina, mines are normally situated on farms, so farmers and farm workers have in interest in mine water and its remediation. They both get water from boreholes and therefore need the groundwater to be unpolluted. This also applies to adjacent and downstream farms. The municipality has an interest in clean water coming into municipal dams and municipal treatment plants, and contamination makes treatment difficult or expensive, as was learnt in the 2012 acid mine incident, because the treatment plant is not designed to deal with mine water.

Tools

The mine tool for managing water is the Water Use Licence (WUL) and the conditions inscribed in it. Every condition should be met, with the ultimate objective of meeting the resource quality objectives in the catchment. Mines also have access to technologies for remediation, including earth moving equipment, and knowledge of rehabilitation processes. Some of them partner with knowledgeable institutions, such as the Geosciences Council, and the University of the Free State, and the Mine Water Coordinating Body. Some have built their own passive treatment systems. According to the environmental mine manage we interviewed:

> “We have built a passive treatment system at Ilima. There is an improvement in water quality. We have also observed that black wattle works wonders in improving water quality. Normally black wattle grows when the area is disturbed. We observed that mine water flowing past the black wattle trees' roots and decanting later improved from a pH around 3 to a pH around 7. We presented the idea to DWS, they said we need a permit to plant black wattle.”

Another tool is the closure plans that the mines are obliged to have.

> “We have closure plans already. Our issue is the ongoing liability. A treatment plant can become a liability. You will have to keep on running it, you will need power, security, etc. It will need money in perpetuity. We would support plans like yours if there is a buy-in from the department (DMR), and the department accepts it as a proper closure plan, and will issue a closure certificate.”

Rules (formal and informal)

The rules (policy) say that mines should treat their own water, but for some mines this is too expensive. Some mines cannot afford this. A number of mines in the area have started building their own passive treatment systems for decanting water (e.g. South32, Ilima).

Mines need to make financial provision and calculate their liability. Mines budget for 10 years (for a small mine this may come to R2 million per year, based on a reverse osmosis package plant, with cost for staff, electricity, etc. Mine managers and their consultants have many questions about how the rehabilitation funds that they deposit with DMR as used. This mine environmental manager that was interviewed argued that concurrent rehabilitation is by far the best way to go, but conceded that not all mines do this.

Division of labour

The mining industry in Mpumalanga (and Carolina) is characterised by a division of labour: companies that own mines and thus carry liability for mine water (and closure), and companies that provide operational mining services that don't necessarily own the mines but work for a number of them. Their services may include rehabilitation especially if it is concurrent rehabilitation.

The mining industry as a whole – or a number of mines – can work together to practically develop inputs into policy making by undertaking experiments in mine water remediation and closure practices, such as the Mine Water Co-ordinating Body (MCWB).

The Geosciences Council is busy with an experiment at Witkrantz. According to Dr Coetzee at Geosciences Council it worked well but later got vandalised – the metal was stolen. This indicates that passive treatment systems cannot be left alone but need to be under surveillance, or be constructed of materials that would not be targets for theft.

4.4 THE REGULATORS: DEPARTMENT OF WATER AND SANITATION, IUCMA AND OTHERS

The most important regulator of mine water is the DWS, although it shares responsibility with both the DMR (in the One Environmental Permitting System) and with the IUCMA, the CMA directly responsible for aspects of regulation in Carolina. The voices of the regulators were distilled from 2 meetings in UKCMF, two meetings with DWS in their offices in Pretoria which included a discussion of the proposed new mine water policy gazetted for comment in 2017 (DWS, 2017a).

Object or problem space

Mine water is a very important and active problem space for the DWS, and has been for some time. DWS encourages innovation and a stewardship approach which should include all water-related actors in looking after scarce water resources. DWS is concerned about how long term contaminated water treatment will be funded, and how to respond to mines' desire for a “walk away” solution to mine water after closure. Officials were concerned to understand the contribution that mining makes to jobs and economic activity, and what would replace this contribution after mine closure. They welcome the project.

Subjects

Because of the One Environmental System (OES), DWS shares responsibility with other departments, including DMR and DOE. In practice, responsibility is also shared with the CMAs where these are active. DWS remains the lead institution as far as mine water policy is concerned, but works with other departments in terms of closure policy. DWS is aware and supportive of a number of technology options being developed and remains in a position of leadership in terms of policy formulation (more detail below). Officials felt that DWS should play a leadership role.

Tools

A Water Quality Management Policies and Strategies (Edition 2) was completed and published in 2017 (DWS, 2017b).This policy identifies contaminated mine water as one of the top water quality challenges in South Africa – another is local government wastewater works. There is a current Mine Water Management Position, with policy principles which was gazetted for comments in July 2017 (DWS, 2017a). The position contains the following principles which are important for this project because it is within them that a solution to the most difficult problem – that of what happens to the liability of the mine if it "hands over" the treatment of mine water to a project such as this one, will have to be found.

1. Government's responsibility with respect to the handling and management of mine water will be dealt with through the One Environmental System (OES) once fully implemented. (This implies that the often uncomfortable and sometimes contradictory agendas of DMR and DWS will continue to be in play.)

2. In terms of liability, the polluter pays principle will be applied to mine water in all its forms. Mine water will be addressed in context of environmental management principles in the NWA which states that "the costs of remedying pollution, environmental degradation and consequent adverse health effects of and preventing, controlling and minimising further pollution and environmental damage or adverse health effects must be paid for by those responsible for harming the environment". (This preserves the polluter pays principle in a strong form.)

3. The transfer of the mine to another company should not exonerate the selling company from their environmental obligations, unless the purchasing company can prove financial provisions to address any environmental liabilities associated with the mine they are purchasing. The application of retrospective liability will be considered. (This is an innovation to close the loophole that enabled established companies to "sell off" their liabilities to inexperienced mines who were not in a position to rehabilitate.)

4. Appropriate, context specific, cost-effective technologies that are proven for treatment should be explored. The use of tailor-made and most cost-effective treatment methods based on the situation should be adopted. Care should be taken that such a solution should be self-funding in line with the user-pays-principle. There should be no financial burden to the fiscus. The policy will not be prescriptive about technologies, but acknowledges that technologies evolve. (This position retains the lack of clarity about technology choices and how they will be paid for. This puts the proposed project in an uncertain position.)

During discussions DWS officials pointed out that they encourage experimentation and innovation, that they work with the Department of Science and Technology (through a technology platform) to evaluate proposed technologies. They are aware of a number of experiments in process, including the MWCB's Green Machine concept, and places where such experiments are ongoing.

5. Mines will be treated according to different categories, and it is likely that regulation of new mines will be stricter than that of historic mines.

6. New mining ventures should prove, beforehand, that the cost to deal with the residual impacts associated with mining (*e.g.* AMD) is catered for.

7. Responsible authorities should be able to refuse water use licenses for mines, especially those proposed for water source areas and sensitive ecosystems, where the impacts cannot be mitigated and those that would result in resource quality objectives and the reserve for water resources being breached.

8. In order to protect water resources, a legislative provision on institutional arrangements of infrastructure ownership and management/ transfer post mine closure is needed for proper infrastructure/assets transfer. Mines should provide for funding and infrastructural management plans for prior, during and post mine closure. Relevant institution/s should be in place to oversee and regulate this process. In case of insolvency, financial provision for rehabilitation of mining should be calculated accurately to sufficiently meet the technical requirements for remediation and management of all mine water residual environmental impacts, including the pumping and treatment of polluted or extraneous water (this is intended to rescue 'the environment" from its current position in the back of the queue for pay-outs when insolvencies occur.)

9. The DWS, the mining industry and research organisations (including the WRC) are looking at different technologies to treat mine water. The challenge is that when the mine has reached the end of its life span (when mining activities cease), there is no appropriate mechanism to continue to take operational responsibilities to sustain AMD Management Operations. The quality and quantity of

water in the catchment, the management of mine water should form part of integrated planning of water and wastewater treatment works with a focus on reuse. This should be part of contribution to alleviate the water shortage in the country. (This restates the problem that this project seeks to address.)

10. Because government has finite resources to deal with ownerless and derelict mines, DWS will actively promote the concept of water stewardship and encourage private enterprise to look beyond the factory fence to support Integrated Water Quality Management (IWQM) at the local and catchment scale in line with the International Alliance for Water Stewardship Standard[3] which is designed to achieve four water stewardship outcomes: (1) good water governance, (2) sustainable water balance, (3) good water quality status and (4) healthy status of important water-related areas. (This creates the space for policy innovations and experiments in the mine water problem space.)

Rules (formal and informal)

Discussions among regulators revealed several gaps between the formal rules and what happens in reality. It points to a sector that is not easy to regulate. Some examples: There should be an approach to regional closure, but in the experience of grassroots regulators (in the IUCMA in the Carolina area) each mine is concerned with its own liabilities, and there are no legal instruments to force them work from a regional perspective. While data is an important tool for the management of mine water, in some area in Mpumalanga data points are missing due to lab certification and payment issues. There are general budget issues (and issues of political instability for example a parliamentary inquiry into the department) which means that at the moment, the department is not able to fulfil all of its functions. Officials remarked that “the desire to mine can override all other considerations” for example that mining rights are granted in sensitive environments.

Community

The DWS and IUCMA are very aware that many actors are involved in water issues, including mining issues (this awareness is broadly shared across the water sector).

Division of labour

There is a complex division of labour in this problem space. The One Environmental System involves DWS, DRM and DEA. DST is involved in technology evaluation. There are a number of parties involved in developing mine water treatment technologies which are likely to influence closure policy affecting mine water. The Mine Water Co-ordinating Body is active in bringing mines together in such endeavours and have experiments in the field, for example the Mafube and Kromdraai Green Engine

3 See https://a4ws.org/about/the-aws-standard/

project, undertaken by Anglo Coal and Exxaro, where maize is irrigated with treated mine water. They are in close contact with DWS.

In Carolina there are ongoing experiments in passive treatment systems, where the Geosciences Council installed a pilot plant at Witkranz, Carolina, at the request of the DMR. It succeeded in raising PH levels and removing contaminants, with an overall removal rate of at least 90% for contaminants such as Fe, Al, Zn, Ni. Sulphate removal was up to 30%, but manganese proved recalcitrant (Mashalane et al., 2018). The plant experience sludge clogging and depletion of treatment materials, as well as an incident of vandalism.

CHAPTER 5: FINDINGS, ARGUMENTS AND INPUTS INTO CONCEPTUAL MODEL

The aim of this chapter is to highlight findings from the material collected above, and to explore their implications as inputs into a conceptual model for the Wits project. What are the various stakeholders' perception and understanding of the problem of contaminated mine water, their interest in the remediation of the mine water, how important it is to them (compared to other priorities), and how they think it should happen? An important part of a conceptual model is to anticipate not only interest and contributions (what role various participants may be willing to play in the future project) but also any objections, concerns, fatal flaws, contrary or competing agendas. The project also elicited concerns and warnings from stakeholders. The following insights are offered as inputs into a conceptual model.

5.1 Stakeholders have agendas and interest that are important for the conceptual model

The mining industry, the DWS and the IUCMA have a detailed understanding of the problem space, while the community, local government, and others like agriculture do not. However, they are clear on what their agendas are. For local government it is jobs and economic opportunities. For agriculture it is protecting or restoring the fertility of the soil for agricultural purposes. This is in keeping with the idea of a boundary object: the same issue may be viewed with depth knowledge, or only a superficial understanding. However, this does not mean that stakeholders who do not have a technical understanding, will not insist that their agendas are taken into account.

5.2 All stakeholders seem to share the idea that there is good legislation and rules, but that these are not, or are unevenly implemented.

The dialogues pointed to a pervasive perception that there is a gap between formal rules and their application. This could create considerable uncertainty for an enterprise that deals with both remediation and an ongoing production business.

5.3 The mining industry has a detailed understanding of the problem space

The mining industry is well informed, has many supporting tools, and have started engaging in finding solutions. On the one hand it is promising that mining companies are taking up the issue, and that they are developing solutions that will be implementable. On the other hand it creates the risk that they will develop solutions that will suit them, without other stakeholders being able or ready to check that their own interests – and the interests of long term stability and accountability – are well served.

There is a strong and understandable desire among mines for a “walk away” solution. The DWS and other stakeholders need to be aware of these strengths and be prepared to balance them.

5.4 Policy is in flux, but busy.

The importance of dealing with mine water after closure is widely recognised. Policy to deal with it is in flux. Current proposed policy positions are general and create much space for solutions to be proposed in terms of technologies and institutional arrangements. The Mine Water Policy Position is currently before cabinet – more than 20 months after being gazetted for comments. This adds to the uncertainty in policy. While it may be relatively easy to conduct policy experiments and action research, there is not enough clarity to establish enterprises. There are a number of action research experiments which will support policy development.

5.5 Who owns the liability? This is a core problem.

This is a core problem and issues of moving liability from one actor to another remain. Unless there is legal clarity on what happens to the liability for care of mine water (e.g. decants after closure which may last for and appear decades after closure) it will be difficult for new actors, such as the project investigated in this report, to move forward. There are however discussions, for example in Department of Environmental Affairs, about what the implications would be of a mine – or government – appointing specific entities to deal with this liability through remediation.

5.6 Regulators also have a detailed understanding, but practice does not match theory.

Regulators have good understanding of the issues, but much frustration. The One Environmental Permitting System brings together departments with opposing agendas, which they do not seem able to work through. In addition, there are political and operational obstacles within government departments in the current uncertain area, including budget restrictions. The CMA has an on the ground presence, but is not fully mandated to deal with mine water issues.

5.7 Mines act as individual enterprises – not on a regional basis.

Each mine owns its own liabilities and does not have to act with others in a regional strategy. Unless specifically drawn together, e.g. in the MWCB, mines will continue to act as individual enterprises.

5.8 Local government could play a role in local, long term passive remediation systems.

Although not central to this research, it emerged that local government could theoretically play an important role as organiser of public works style maintenance and surveillance of passive treatment systems (that may otherwise be vandalised or robbed of recyclable construction materials). Local government has extensive experience in this field, and it may answer some of local government's need to provide if not jobs, at least poverty alleviation opportunities.

5.9 The big one: Jobs are crucial but sensitive – be very careful in raising expectations

Community and local government are very focused on jobs, and a side interest in training (although there is some awareness of mine water issues). The proposed project or enterprise will therefore have to carefully calculate job opportunities along the production chain.

5.10 There is no general understanding among people of the need for a transition to a low carbon economy, or even what a green economy is.

Proposals and enterprises that rely on concepts of doing things differently (sustainably) in a green economy need to realise that they won't necessarily be understood or given special support. They need to explain themselves well. There is a risk for solutions that both remediate mine water and use it to produce marketable products, to inherit the liabilities and treatment costs, thus prejudicing them. While for specialists in the field the advantages are clear of replacing, for example, chemical production from fossil fuels with the production of chemicals through green technology, this is not broadly understood. There is a need for a green industrial strategy to translate these benefits into rewards for entrepreneurs.

5.11 Reliance on alien vegetation such as black wattle for biomass inputs can be risky.

Alien vegetation clearance programmes work on the assumption that the alien vegetation will be reduced, and therefore these do not present a reliable source. Other sources of input will eventually have to be found.

5.12 Large scale policy and strategy thinking is needed on a just transition to a low carbon economy, on the economics of post-mining landscapes, and on closure policy.

There are initiatives, such as chapter 5 of the National Development Plan and current consultations and debates. How these debates and processes turn out will have far reaching effects, and they deserve research attention.

CHAPTER 6: CONCLUSION: AIMS, OUTCOMES AND RECOMMENDATIONS FOR RESEARCH

This chapter concludes the research by considering whether and how well the objectives and aims of this research project were met.

6.1 ACHIEVING PROJECT AIMS

The aims were:

1. To test the responses of a representative group of catchment citizens to proposals to remediate and use contaminated mine water in a bio-economy application, in order to support practical development of options to remediate and use mine water.

The research did test the responses of community, mine environmental managers and consultants, local government, DWS officials involved in mine water policy, IUCMA as regulators, and was able to present both detailed responses and twelve main points into the conceptual model that will now be further developed by the Wits research project. The research has brought into focus a number of considerations, and in some cases obstacles, that need to be kept in mind in further development.

2. To develop transdisciplinary methodologies in water research: specifically the use of the dialogic method in expanded social learning, with Cultural Historical Activity Theory, as a shared method between social and natural science trained researchers.

Cultural Historical Activity Theory (CHAT) was used as a framing device to develop questions, to frame dialogue sessions, and in reporting the results. But it was not used in "expanded learning", in the sense used by Engestrom (2001), because such a process can really only be done with a coherent group, with a mandate for change and in a single institution. In the analysis there were some difficulties in separating "tools" from ""rules", particularly as the rules for the water sector are tools used by regulators and managers.

3. To develop ways of communicating and working with scientific-technical knowledge in a way that supports inclusive participatory, democratic deliberation on water issues.

As this project progressed, the team learnt to refine presentations and explanations of biotechnology and the green economy through dealing with questions during dialogues. We eventually included more basic discussions of the green economy and biotechnology in the dialogue sessions and some individual interviews. Some stakeholders did not have a good grasp of these issues, and further capacity building will be necessary.

4. To further build the capacity of a Catchment Management Forum working group as well as capacity for co-creation of water futures.

The research team did build awareness of the green economy, biotechnology, and opened up discussions in the forum about what happens after the cessation of coal mining in the area. Much more remains to be done. However, the working group, including community representatives, have a good working knowledge of the various forums that affect their economic and water futures, and participate in these.

5. To start the process of envisioning post-coal mining landscapes on the Mpumalanga Highveld, and develop a first checklist of issues relevant to water in such landscapes (i.e. rehabilitation, closure policies, feasible future land use options, etc.).

The envisioning of post-coal mining landscapes on the Mpumalanga Highveld is core to a number of current process which coincided with this project, but extend beyond it, for example the current consultations undertaken on Chapter 5, entitled *Environmental sustainability – An equitable transition to a low-carbon economy* of the National Development Plan (National Planning Commission, 2012). It is also the topic of research at the University of Cape Town's Energy Research Centre in which transitions in countries including South Africa, Indonesia, Australia, China, India, Germany and Poland are analysed (see www.coaltransitions.org). Issues that emerged from this short term research project were:

1. Solutions to mine water decant – both technical and institutional – are needed for areas like Carolina area, where there are numerous small volume sources of decant over a wide area. These sources are well suited for small, passive treatment plants. However, these plants are subject to vandalism and moreover require some degree of ongoing maintenance, and new decant points may also emerge.

2. There are also large scale, large volume AMD areas, such as the Optimum Complex which consists of both opencast and underground mines, with historic damage done by mining through the Woestalleen Spruit (see Cogho, 2012). These require solutions dealing with large volumes and areas.

3. Future uses need to be taken into account when planning remediation of water and soil. For example: while it is known that coal mining on the Mpumalanga Highveld presents a risk to national food security especially in drought years, remediation in this area typically only restores the soil to 30% of its original fertility and therefore unfit for growing maize. (Bureau for Food and Agriculture Policy, 2012). Such an approach limits future options and will have to be addressed in a Just Transition. The research team has observed a growing number of cases of farms contaminated or otherwise prejudiced by coal mining.

4. Both climate change and the transition from fossil fuels (to a low carbon or green economy) will require increased planning and other capacity from district and local municipalities to deal with water challenges, which is not currently available.

5. Current closure policies and debates do not adequately take the physical effects (changes in rainfall, for example) of climate change and the requirements of a just transition into account. Nor are participants in the UKCMF – including water managers for example – sufficiently well informed to deliberate on these issues.

6.2 ACHIEVING INTENDED OUTCOMES

Outcome 1: *Build understanding of the need for, nature and potential of bio-remediation of contaminated coal mine water among participants in Upper Komati Forum through a co-produced conceptual model (of agendas, expectations and understandings).* The research team created a project website (www.postmininglife.org), and presented explanations at UKCMF and in meetings with DWS officials. However, knowledge of biotechnology and green economy remains limited.

Outcome 2: *Create understanding of the need for, nature and potential and policy implications of bio-remediation of contaminated coal mine water among policy makers, DWS mine water group, etc.* While our particular proposal was new to them, DWS officials from mine water and resource protection divisions already had knowledge of these topics.

Outcome 3: *Developing methods for transdisciplinary work which brings together scientific, technological options with the agendas of participant groups.* The project was useful in developing shared understandings between team members, consisting of a biochemist, political ecologist and geographer, on the basis of Convergence Studies, political ecology and the Social Impact Assessment methodology. However, due to the short time span, the full social learning approach could not be implemented.

Outcome 4: *Developing capacity in CMFs in coal mining areas to envision and plan for post mining landscapes.* This is an ongoing engagement with the UKCMF building on the achievements of the previous dialogue session in WRC project K5/2355.

6.3 LIMITATIONS OF RESEARCH

This research took place over a short time span, which imposed limitations. The CHAT application was limited to an analytical framework, as the institutions we worked with were not in a position to develop social learning and move to change. The DMR was not involved in the research as the Witbank office was closed, and DMR officials do not regularly participate in the UKCMF.

6.4 RECOMMENDATIONS FOR FURTHER RESEARCH

Some of the insights in chapter 5 point to further research questions.

6.4.1. What are the root causes for the gap between formal rules and their application in the mine water space?

6.4.2. What are the processes for creating policy on mine water remediation and mine closure? There are currently a number of formal policy processes, a mine industry led process and experiments by academic researchers and state institutions under way. It may be useful to have an overview of these processes and how they will be integrated into policy. Such research should look carefully at the actors and agendas involved.

6.4.3. We recommend that the issue of moving liability from one entity to another be investigated as part of the further development of a conceptual model for the Wits mine water project specifically, in the light of current policy debates.

6.4.4. An investigation into the feasibility of a local government role in local, long term passive remediation systems, as organiser of public works style maintenance and surveillance of passive treatment systems (that may otherwise be vandalised or robbed of recyclable construction materials). Local government has extensive experience in this field, and it may answer some of local government's need to provide if not jobs, at least poverty alleviation opportunities.

6.4.5. Research into the role of prospects for mine water as part of a transition to a low carbon economy, or a green economy.

6.4.6. Research to support big picture policy and strategy thinking is needed on a just transition to a low carbon economy, on the economics of post-mining landscapes, and on closure policy.

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