UNLOCKING AND RETAINING JOBS IN THE ALIEN VEGETATION ADDED VALUE CHAIN THROUGH INDUSTRIAL SYMBIOSIS: CASE STUDY ON WOOD PELLETS

Nicola Jenkin and Shakespear Mudombi

March 2018

Nicola Jenkin
Pinpoint Sustainability, Director

Shakespear Mudombi
TIPS, Researcher: Sustainable Growth

info@tips.org.za
+27 12 433 9340
www.tips.org.za

ABOUT THIS PUBLICATION

This report is one of three case studies published under a two-year initiative and collaboration on *Unlocking Green Jobs: A Catalytic Intervention* between the World Wide Fund for Nature, South Africa (WWF-SA) and Trade & Industrial Policy Strategies (TIPS).

It is complemented by a Synthesis Report and two other case studies titled:

- Essential Amathole: A Case Study of Unlocking Green Jobs in the Bioprospecting Sector; and
- Protecting and Unlocking Jobs Through Water Stewardship: A Case Study Linked to the Umbogintwini Industrial Complex, eThekwini.

The synthesis report and the case studies are based on work and inputs from numerous individuals, including:

- A Project Steering Committee, including Glenda Raven (WWF-SA); Gaylor Montmasson-Clair (TIPS); Eureta Rosenberg (Rhodes University, Environmental Learning Research Centre), and Olivier Grandvoinet (Agence Française de Développement [AFD]);
- A Working Team, including Thabo Thulare (TIPS/GreenCape); Daryl McLean (Rhodes University, Environmental Learning Research Centre); Shakespear Mudombi (TIPS); Mike Ward (Creating Sustainable Value); and Nicola Jenkin (Pinpoint Sustainability); and
- A group of experts who kindly reviewed the case studies (see Annexure A) and participants at various research sites, who kindly gave their time and information to assist in developing the case studies.

This document has been produced with the financial assistance of the WWF Nedbank Green Trust and the AFD. The contents of this document are the sole responsibility of the authors and can under no circumstances be regarded as reflecting the position of the funders.

EXECUTIVE SUMMARY

Invasive Alien Plants (IAPs) represent a serious environmental challenge in South Africa, impacting on biodiversity and water supply. A set of national strategies for clearing IAPs and beneficiating the biomass have been implemented over the past decade, with mixed success in job creation, enterprise development and poverty alleviation. This case study explores the reasons for success and failure, and suggests that:

- State strategy should focus on a more diversified value chain;
- Multi-criteria analysis rather than cost-benefit analyses should be used to plan, implement and report on such initiatives;
- An industrial symbiosis model should be adopted, implementing a range of initiatives close to alien infestations, in ways that improve efficiencies; and
- Coordination between a set of policy and strategy levers may be needed to incrementally roll out sustainable employment.

In particular, the case study highlights the potential to create jobs in relation to wood-pelleting and eco-matting, and suggests that there are wider social arguments that should be taken into consideration when evaluating policy options for the beneficiation of alien biomass. Thus, Petrie (2014, p23), in her study on *South Africa: A case for biomass?*, notes

> *"the biggest potential local market for wood pellets as fuel is among low-income households in peri-urban and mainly rural areas. Sustainability, health and safety, and price provide the three most compelling reasons to develop this market."*

The case study modelled the job creation estimates using Vensim diagrams (graphical representations of stock and flow as well as causal relationships, underpinned by data sets and equations). A summary of the analysis suggests that if the manufacture of wood pellets from IAPs could be realised, and households adopted their use at an incremental rate of 5% per annum, approximately:

- 1 480 000 direct person day jobs could be created by 2028, which in turn …
- could result in the clearance of an estimated 2.3 million Ha of IAPs, and
- 1 060 000 households converted from dirty fuel use to wood pellets.

Combining potential job creation for clearing IAPs and the manufacture of eco-matting products and wood pellets from IAPs, an estimated total 6 million-person days could be created by 2028, and 6.8 million by 2035.

While the manufacturing of wood pellets in South Africa is currently in disarray, with all facilities being mothballed as of November 2017, the industry has predominantly focused on large-scale production for the export market. This paper proposes a more decentralised and localised business model to combat some of the barriers associated with large scale production, such as transport costs. Such a proposition supports the need for localised economies, which encourages entrepreneurialism and in this case the creation of a localised industry of wood pellet production, and associated products or distribution networks to service surrounding towns and households. Key benefits would be:

- Contributing to the eradication of IAPs and adding value to vegetation harvested by the Working for Water programme;
- Facilitating industrial symbiosis (circularity) by adding value to sawdust and wood residue by-products generated at IAP-based manufacturing sites;
- Creating employment in rural areas (where IAP-relevant feedstock exists and is readily available) through community-based and/or localised and decentralised wood pellet manufacturing;
- Fostering increased market penetration for South African manufactured cooking, heating and lighting technologies which can use wood pellets as an energy source, in turn generating employment opportunities associated with the manufacturing and maintenance of technologies; and
- Encouraging local research and development, manufacturing and maintenance of wood pellet technologies, without having to rely on technologies, knowledge or skills from outside the country.

Some of the barriers and systemic issues that could hinder the production of wood pellets produced from IAPs for South African households are:

- Inadequate and misaligned government policy, which currently does not recognise the use of IAPs as a biomass feedstock. Policies tend to focus on biomass fuel generated from sources, such as sugar cane or agricultural waste, and crops grown specifically for fuel;
- A poor local market due to the domination of and access to coal-fuelled electricity and paraffin, which has an embedded network of easily accessible outlets;
- Cost of production is impacted by access to feedstock and transport costs associated with feedstock delivery to the manufacturing facility, and distribution for retail and use;
- A lack of suitable IAPs (an estimated 32% of IAP volume is suitable for wood fuel) and consistent supply for manufacturing plants (large and small) to operate at capacity and respond to potential increased demand;
- The absence of recognition of small-scale technologies and entrepreneurs, especially in the cooking stove sector, and that solutions do not have to be large-scale, and reliant on overseas expertise or manufactured machinery.

Over the past 15-20 years, investment has been made in South Africa in the manufacturing of wood pellets (albeit large-scale) and technologies that can use wood pellets, such as cook stoves. However, there appears to be a disconnect between government, not-for-profit and private entities, which has prevented a collaborative approach to effectively introduce wood pellets into the South African market.

A quadruple-helix intervention (Carayannis, Grigoroudis, & Pirounakis, 2015) of collaborative actors is proposed whereby government, business, research and academic institutions and civil society (both the users of wood pellets and not-for-profit entities aiming to introduce cleaner stoves and fuels) would work together and share knowledge more effectively to significantly increase wood pellet manufacturing (and associated products) and use. The unlocking of the wood pellet value chain could create green job opportunities for those employed in the fossil fuel sector, paving the way for people to move horizontally into the renewable energy sector, thereby increasing their long-term job security.

TABLE OF CONTENTS

ABBREVIATIONS

ACE	African Clean Energy
AFD	Agence Française de Développement
DEA	Department of Environmental Affairs
DME	Department of Minerals and Energy
DWA	Department of Water Affairs (now Department of Water and Sanitation
FAO	Food and Agriculture Organization
IAP	Invasive Alien Plant
SAEON	South African Environmental Observation Network
TIPS	Trade & Industrial Policy Strategies
WfW	Working for Water
WWF-SA	World Wide Fund for Nature, South

1. INTRODUCTION

Invasive alien vegetation in South Africa represents a significant environmental challenge. This case study describes the nature of the challenge and explores two components of a diversified value chain for how alien vegetation can be cleared and the biomass beneficiated, wood-pelleting and eco-matting.

Several strategies for clearing and beneficiating the biomass from invasive alien plants (IAPs) are already in place in South Africa, yet evaluation findings, including this report, suggest there are challenges in creating sustainable jobs. The case study explores these challenges and makes recommendations as to what can be done to overcome some of these challenges.

Introductions of alien vegetation began in the 1600s, peaking in the 1800s, leading to an abundance of an estimated 8 750 plant species listed as damaging to South Africa's agricultural, tourist and ecological contexts by the early 2010s (FAO, 2003; Moran, Hoffmann, & Zimmermann, 2013). Since their introduction, IAPs have become a scourge of South Africa's landscape, having significant environmental (such as water absorption and biodiversity degradation), social (such as negative impacts on agricultural livelihoods and food security) and economic (such as negative aesthetic impacts on tourism and eradication costs) implications.

Various attempts have been made to halt the growth of or eradicate IAPs. One of these initiatives has been the Department of Environmental Affair's (DEA) Working for Water (WfW) programme[1]. Launched in 1995, the programme identified significant potential to provide job creation, notably through the removal of IAPs (DEA, 2017). Both a socio-economic development and environmental intervention, the WfW programme is a key component of the country's green economy initiatives.

Being viewed as a success story (Bek, Nel, & Binns, 2017), the WfW business model has been expanded and replicated into a variety of other "Working for/on …" programmes. Particularly pertinent to this study is the value-addition potential associated with the material cleared in the programme, thereby transitioning the material from a waste generated from clearing to a harvested feedstock for products. Such activities, to date, have focused on, for example, the production of (eco-)furniture.

While the clearing of IAPs has been a significant component of the DEA's WfW programme, a missed opportunity exists in adding value to the woody biomass that is removed in the clearing process (Stafford, Blignaut, Lotter, le Maitre, & Forsyth, 2016) or produced as a by-product during the manufacturing of IAP-based products. This woody biomass (including trees and woody plant matter, such as leaves, needles and branches) can be utilised in the production of a full range of products, including timber and lumber, wood fuels, composite wood products, soil enhancers, food nutrients, medicines and bio-energy (Forests & Rangelands, 2017; Stafford, 2017). Given the potential volumes, types of species and form (trunks, branches, leaves) cleared, a real opportunity lies in exploring viable options for using the harvested product for a more diverse range of products. The harvesting, processing, manufacturing and use of these products create further opportunities to unlock a variety of jobs.

[1] Part of a larger suite of programmes implemented by the Natural Resource Management (NRM) division.

For the purpose of assessing value-add opportunities for IAPs, three useful variants of a woody bioproducts value chain and/or hierarchy have been proposed by Lee (2015), Toma-Now (2016) and Stafford et al. (2016). These have been amalgamated with various other references to bio-based products and potential value assessments to reflect the potential value-add for IAPs in South Africa. Figure 1 illustrates the categorisation and diversity of products that could be manufactured from IAPs. Five main categories can be identified and are listed in terms of the complexity and/or simplicity of production or manufacturing. Adjacent to the hierarchy of products, four categories of potential value have been identified:

- Production volume, such as the amount of product that could be generated and/or produced;
- Financial value, such as the cost per volume of product sold and/or purchased;
- Job numbers, such as the potential number of jobs that could be created through the manufacture and sale of products; and
- High skills, such as the level of skills and knowledge required to develop, manufacture and sell the products generated.

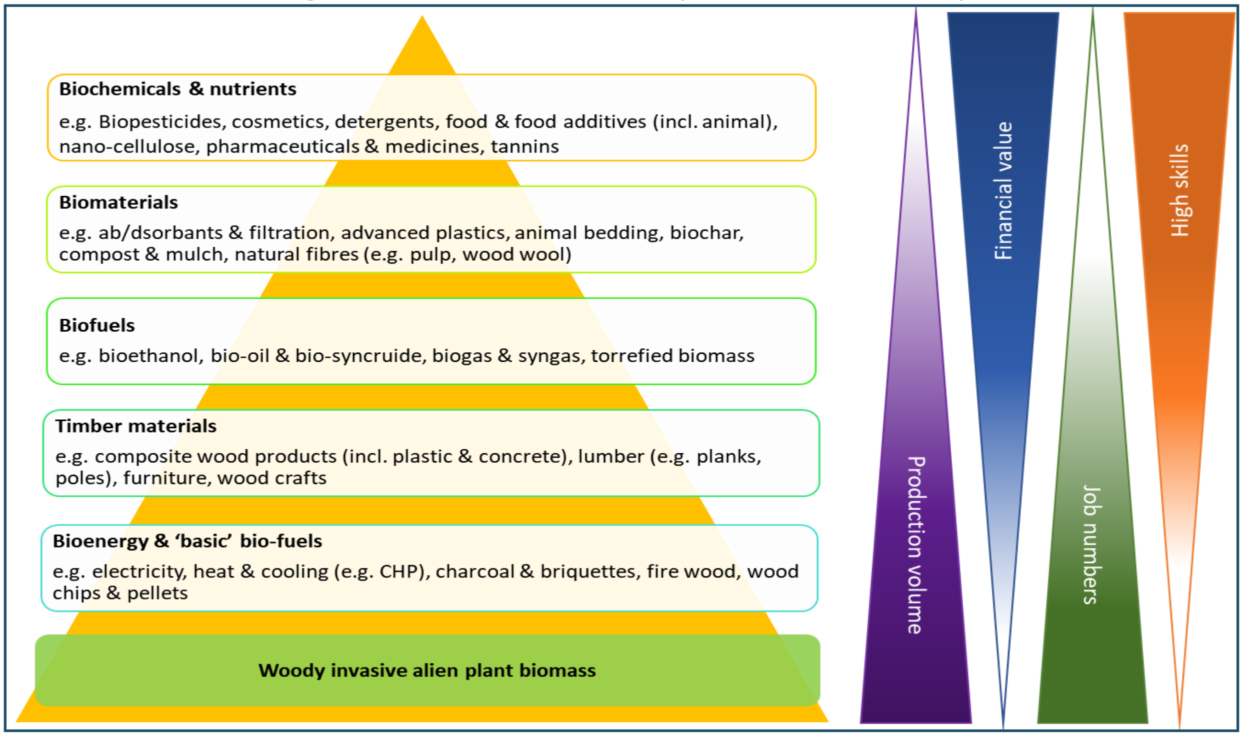
The first two categories, i.e. production and financial values, are the most commonly reported. Job creation and skills are seldom considered, despite constituting important dimensions and requirements of South Africa's transition to an inclusive and green economy.

While South Africa's government has spearheaded several large-scale initiatives to unlock green jobs in the alien vegetation value chain, such activities are not the preserve of the public, with several private or non-governmental entities also active, or attempting to be active, in this space, for example in the manufacture of compost (Reliance, 2015), biochar and briquettes (Eden to Addo, 2017; Vuthisa, 2017), and medicinal treatments and cosmetics (Maema, Potgieter, & Mahlo, 2106; Syringa Bioscience, 2017).

Most added-value activities have focused on basic bio-fuels, such as the production of charcoal, firewood, wood chips and pellets, as well as timber materials for lumber, wood crafts and furniture. A variety of criteria have tended to steer activities in this direction, such as government intervention and support (e.g. eco-furniture), job creation for the unemployed (e.g. eco-furniture, charcoal and firewood), reducing the reliance on state-provided electricity (wood chips and pellets), and relatively low-level technical complexity and capital investment.

Emergent opportunities and more frequent research and development (R&D) activity is occurring on biofuels (torrefied biomass), biomaterials (biochar, filtration, absorbents and insulation), and biochemicals and nutrients (lignin, tannins, cosmetics and chemicals). While the financial output per unit produced is appealing, these options require other triggers to enable commercial and/or market viability, such as a higher level of skills, such as engineering and technical knowledge, market acceptance and trust in biomass as an alternative to fossil fuel, leading to the need for more pilots and trials, heightened quality and standards, and increased capital expenditure.

Figure 1: Invasive Alien Plant bioproduct value hierarchy



Source: Authors, and derived from Lee, 2015; Mugido et al., 2014; Stafford et al., 2016; Toma-Now, 2016; Vundla et al., 2016

What is clear from cost-benefit analyses (see Honsbein, 2014; Stafford, 2017; Stafford et al., 2016; Toma-Now, 2016; Van Wilgen, Richardson, le Maitre, Marais, & Magadlela, 2001; Vundla, Blignaut, Nkambule, Morokong, & Mudavanhu, 2016) is the significant potential of IAP added-value products for the South African economy, such as:

- Economic: local manufacturing of machinery, ZAR revenue generated from waste by-products;
- Social: a diverse range of skills and occupational needs, ability for those working in harvesting or lower-skilled jobs to vertically progress into higher-skilled occupations, or horizontally into other sectors (such as renewable energy or ecosystem restoration);
- Environmental: industrial symbiosis/circular economy interventions (turning waste streams into valuable by-products).

This study builds on these cost-benefit analyses by using a multi-criteria assessment to develop a deeper understanding of the associated environmental and social benefits linked to potential job creation.

Two case studies have been selected[2] to illustrate the potential of IAP in unlocking opportunities in South Africa:

1. The production of wood pellets as a fuel and electricity source to replace paraffin and wood fuel for cooking, heating and lighting in non-electrified households as a primary case study; and
2. The production of eco-matting and associated products for land restoration as a secondary case study.

[2] The process for selecting these two cases is outlined in Appendix 1.

2. BIOENERGY THROUGH WOOD PELLETS

South Africa generates the majority of its energy from coal (StatsSA, 2015b), but with the global issue of climate change and international obligations to reduce Greenhouse gas emissions ever-pressing, does recognise the need to transition to a low-carbon future. This has resulted in the development of a number of policies, such as the Government's *White Paper on Renewable Energy* (DME, 2003)*, Biofuels Industrial Strategy* (DME, 2007)*, Biomass Action Plan for Electricity Production* (McQueen, 2013)*, Bioenergy Atlas for South Africa* (SAEON, 2015), *Integrated Energy Plan* (DoE, 2017), and *Bioenergy Atlas for South Africa* (SAEON, 2015); and interventions, such as the Renewable Energy Independent Power Producer Procurement Programme (REIPPPP) and hosting in 2017, an international *Biomass Trade & Bioenergy Africa* conference to enable such a transition (GBEP & IEA Bioenergy, 2016; Honsbein, 2014; Mavuso, 2017).

This study explored the potential for using IAP biomass as one component of a diversified value chain, in ways that produce wood pellets to generate electricity and heat in the home as a safer alternative to paraffin and firewood.

Box 1: A key reason for a focus on wood pellets

Socio-political benefits could be realised using wood pellets, particularly in non-electrified homes, by eliminating or partially replacing the use of paraffin and fire wood for cooking, heating and lighting. As an indicator of scale, 68% of the 3.4 million non-electrified households in South Africa use paraffin for lighting, cooking and heating, and 74% use firewood for cooking (Diederichs et al., 2014).

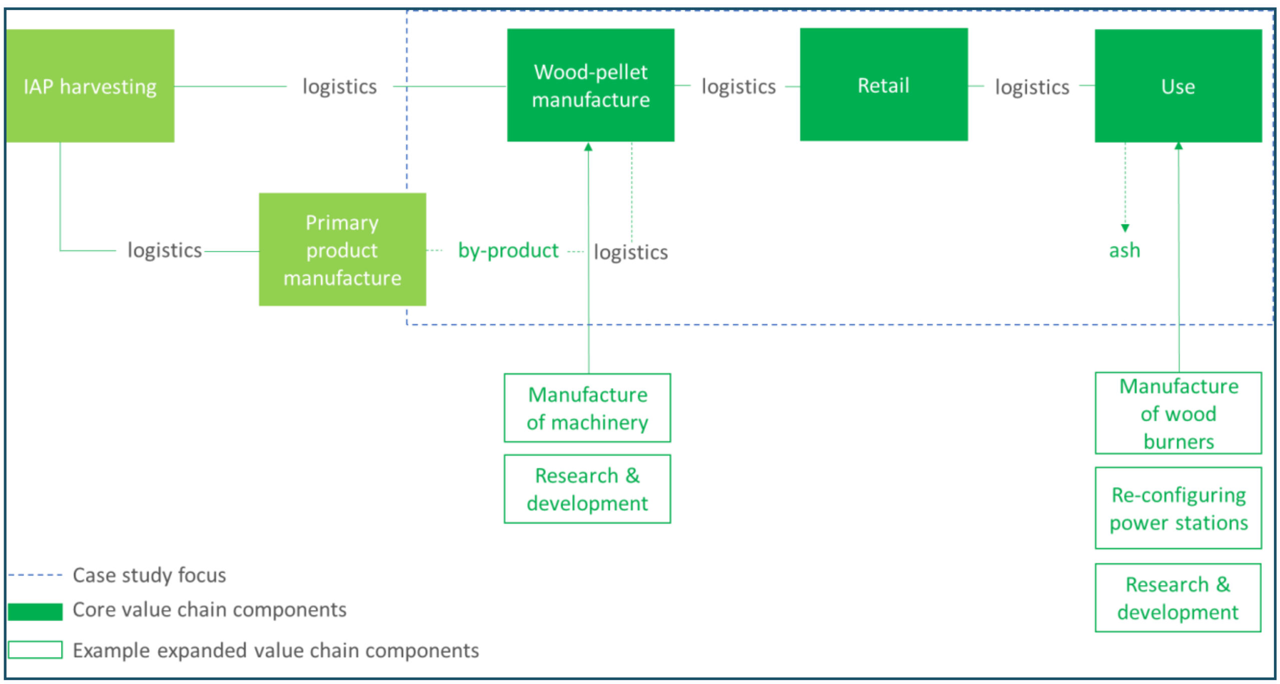
The side effects of this high usage of paraffin and firewood (from cooking smoke and fumes) can cause lung diseases, such as cancer, pneumonia and acute lower respiratory infection, and cataracts (ACE, 2017). In addition, cooking on open fires and the use of paraffin increases the risk of house fires, with an estimated 45 000 house fires and 3 000 deaths caused annually due to the use of paraffin in South Africa (ACE, 2017). From an environmental perspective, fire wood sourced from forests or commercial plantations can be replaced by wood pellets produced by IAPs, thereby potentially reducing commercial plantation feedstock and firewood use, and contributing to the eradication of IAPs (Ecozoom, 2017).

Wood pellets are made of compressed and extruded sawdust or fine shavings of wood that bind the material into a cylindrical shape (6-10mm) (Africa Wood Pellets, 2011; EE, 2015; Rural Energy, 2015). Three types of pellets are manufactured, wood, torrefied and steam explosion (Beekes, Cremers, & Witkamp, 2014), using a relatively well established and developed technology (Pirraglia, Gonzalez, & Saloni, n.d.). They are predominantly used for heating and power generation, on a large (co-firing of coal power stations), medium (combined heat and power systems for buildings, swimming pools and gyms) and small (household stoves and wood-burners) scale.

The main stages of the wood pellet value chain are illustrated in Figure 2, which highlights some examples of beneficiation opportunities:

1. The use of by-product (saw dust and wood residue) from manufacturing facilities that use IAPs as feedstock to produce eco-furniture, and
2. The potential to increase and unlock jobs through the local production of machinery used to manufacture wood pellets, the manufacturing of wood burners or cook stoves, the development of R&D to inform innovations, and at scale, the re-configuration of coal-fired plants to utilise wood pellets. These possibilities have been suggested by other studies, although challenges exist in terms of regional mismatches between IAP location and processing plants.

Figure 2: The main elements of a potential IAP wood pellet value chain



Source: Authors

The use of by-products from the production of IAP primary products illustrates the potential for industrial symbiosis[3] whereby by-products are considered to have a value instead of going to landfill or waste (Ellen MacArthur Foundation, 2013; GreenCape, 2017; Husgafvel et al., 2015). In the case of woody biomass, an estimated 20% of an IAP log is utilised. The rest of the tree is left in the field as waste and is a potential fire hazard (Anon, 2017d). This waste can be used for pellets.

[3] Industrial symbiosis is the identification and realisation of business opportunities enabled by utilising unused or residual resources (materials, energy, water, assets, logistics, expertise) to enhance and add value to business profitability and sustainability (GreenCape, 2017). Contemporary discourse refers to this activity as circularity within an economy (aka circular economy)(Ellen MacArthur Foundation, 2013).

Figure 3: Examples of sawdust, woody residue, and waste wood generated at the Howick eco-furniture sawmill and factory

Source: Howick Eco-furniture Factory, 2017

The production of wood pellets in South Africa is not as positive a story as that witnessed in Europe, where the demand for biomass for heat and electricity is rapidly growing (Ernsting, 2014). South Africa had six wood pellet production plants which have all been mothballed over the last 15 years (Petrie, 2014). When operational, they mainly produced pellets for British, Dutch and Danish power stations (Ernsting, 2014), and a small local market (such as for heating gyms and swimming pools) (Joubert, 2017). Reasons for closure vary from a lack of raw material (Argus Media, 2012), transport and maintenance costs (Ernsting, 2014), to an underperforming local market and decreasing export prices (Ernsting, 2014). Mills, such as EC Biomass, located in the Coega Industrial Development Zone outside Port Elizabeth, attracted significant investment (R70 million) and could produce 50 000 tonnes of wood pellets (Toma-Now, 2016; Treecycle, 2014). Evidence of a small plant exists in Pietermaritzburg, but the pellets appear to be mainly marketed for animal bedding and cat litter (HVE Woodpelleting, 2017), as opposed to energy.

Even though South Africa's wood pellet market has been turbulent and disrupted, wood pellet production and use could be significant in this country, if certain barriers were overcome.

3. JOB CREATION POTENTIAL

In line with the Government's renewable energy and employment creation commitments, the production of wood pellets has the potential to create some sustainable employment, notably in South Africa's rural areas (Calderon, Gautheir, & Jossart, 2016; VEDA, n.d.).

When operating at full capacity, a relatively large-scale wood pellet manufacturing plant consuming approximately 10 000 wet tonnes of biomass per month can employ 90 people, operating four 8-to-12-hour shifts (Anon, 2017b). This includes management, supporting staff, and factory production labour. It illustrates the potential employment offered by one plant, should it source solely from IAP feedstock.[4]

An assessment of the types of jobs employed along the wood pellet-manufacturing value chain suggests that the majority are low- to medium-skilled jobs, with most allocated to harvesting and pellet manufacturing (Anon, 2017b). However, high-skilled design and engineering jobs could be created if the localised production of machinery to produce the pellets, the conversion of power-stations, and the manufacturing of end-use products, such as stoves and heaters, was realised. An estimated minimum of 120 people could be employed in the harvesting and manufacturing of pellets through one manufacturing facility. At a minimum, an additional 20 jobs could be sustained in the production of eco-furniture or the manufacturing of primary IAP products to collect, store and deliver by-product for use in pellets.[5] This supports the argument for an industrial symbiosis approach.

On a smaller decentralised scale, for instance at the location of IAP harvest, a pelletiser can employ up to four people. However, this figure could not be confirmed, and needs to be explored further to assess how many smaller pelletisers could viably operate in the country, in addition to an assessment of the types of available technologies.

[4] See Appendix 2 for a detailed list of indicative jobs associated directly and indirectly with the manufacturing of wood pellets.

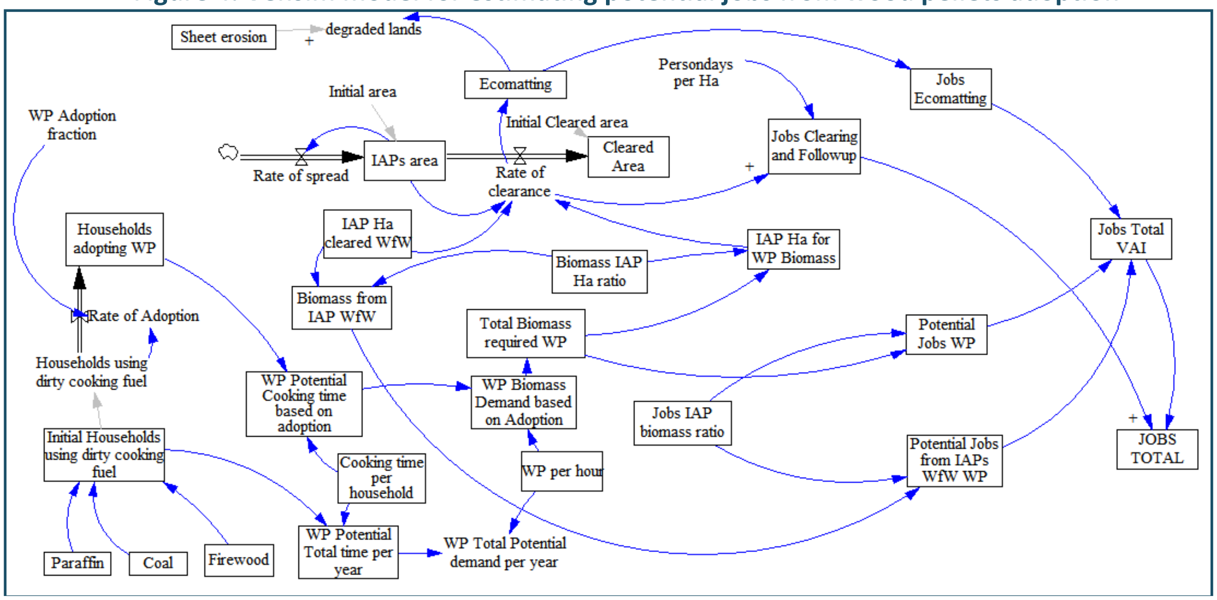
[5] This is clearly an underestimate, given the potential for job creation in the wholesale and distribution of pellets and machinery, appliance and power plant activities.

4. A MULTI-CRITERIA ASSESSMENT OF THE IAP ADDED VALUE

Figure 4 illustrates the analytical framework used to estimate the job creation potential. It relies on the following factors:

- Number of households currently using dirty cooking fuel and therefore potential demand for wood pellets;
- Availability of IAPs, rate of clearance and amount of biomass required to manufacture wood pellets; and
- Potential jobs (person days) for harvesting IAPs and manufacturing wood pellets.

Figure 4: Vensim model for estimating potential jobs from wood pellets adoption



Source: Authors, derived from Barnes, Ebright, Gaskin and Strain, 2015; DWA, 2001, 2017; eThekwini Municipality, n.d.-b; Le Maitre and Forsyth, 2011; Jorge Maia et al., 2011; Stafford, 2017; Stats SA, 2015a, 2017; Vundla et al., 2016

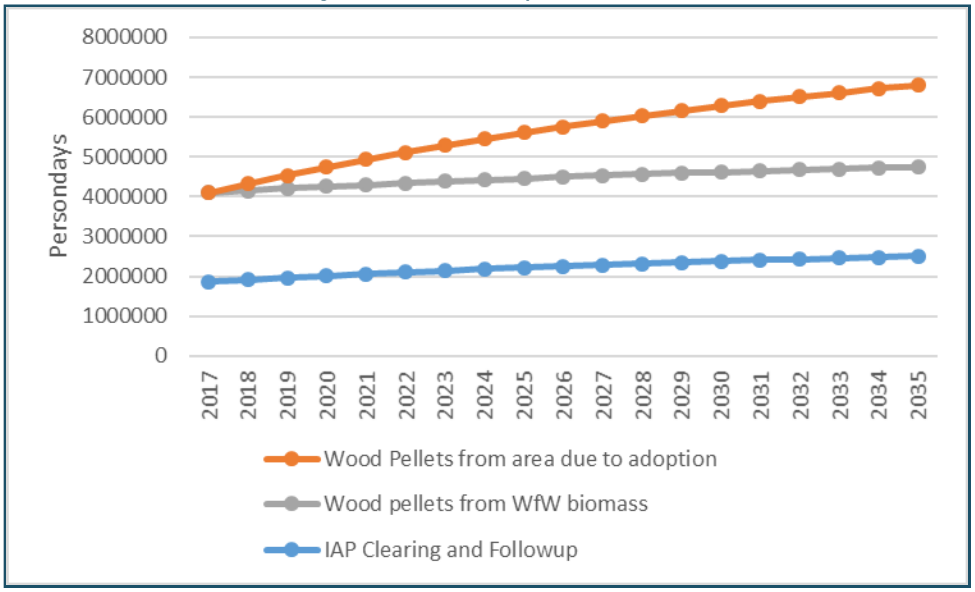
A summary of the analysis suggests that if the manufacture of wood pellets from IAPs could be realised, and non-electrified households adopted their use at an incremental rate of 5% per annum, approximately:

- 1 480 000 direct person days could be created by 2028, which in turn …
- could result in the clearance of an estimated 2.3 million hectare of IAPs, and
- 1 060 000 households converted from dirty fuel used for cooking to wood pellets.

The data sources and methods of calculation to reach these findings are provided in Annexure A.

Figure 5 illustrates the job creation potential in terms of person days, for the clearing of IAPs and manufacture of wood pellets and eco-matting from IAP feedstock. Combining the potential of these two activities, an estimated total 6 million-person days could be realised by 2028, and 6.8 million by 2035.

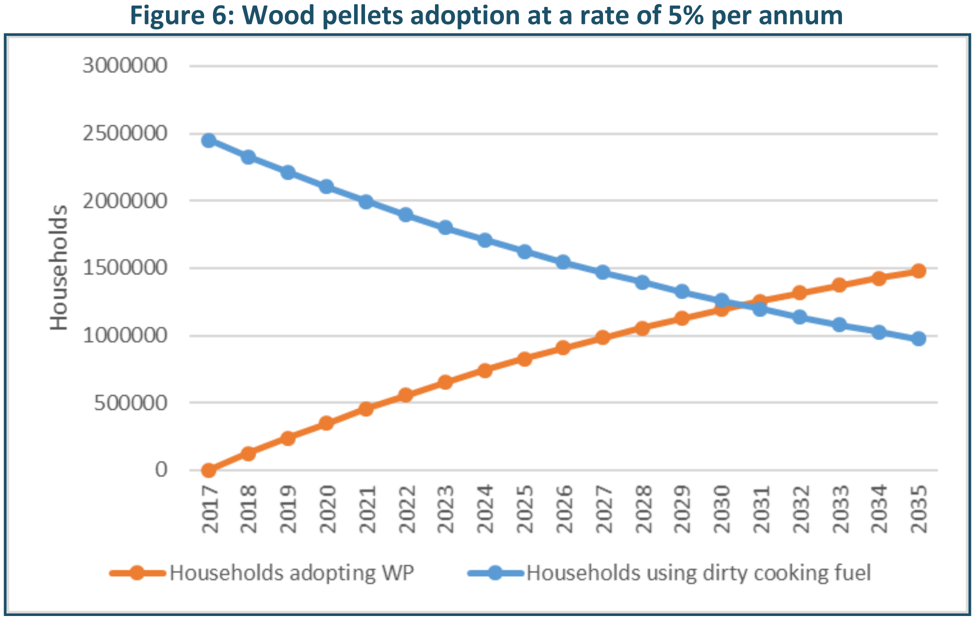
Figure 5: Potential jobs created



Source: Authors, based on DWA, 2017

Figure 6 illustrates that if wood pellets are adopted at a rate of 5% per annum the number of non-electrified households using wood pellets would exceed those using dirty fuel by 2030. While not an elimination of the use of dirty fuels, this should have a marked impact on the health and safety of those currently living in non-electrified homes. This could lead to reduced costs for the Department of Health in treating those affected by the inhalation of fumes and smoke, and burns and deaths from fires caused using firewood, coal and paraffin. The argument proposed here is that such a shift in demand to wood pelleting would require support and coordination across a number of policy domains and departments.

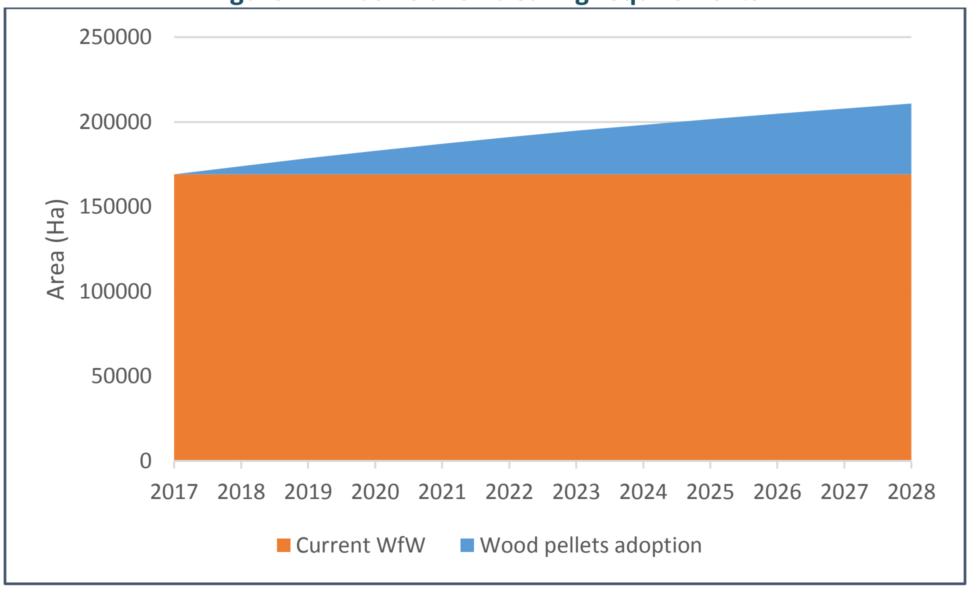
Figure 6: Wood pellets adoption at a rate of 5% per annum



Source: Authors, based on Stats SA, 2015a

One of the critical variables for this initiative to succeed is access to suitable volumes and quality of IAPs to manufacture the volume of wood pellets required to replace dirty fuels. Figure 7 suggests that if current rates of IAP clearing undertaken by the WfW programme were to remain constant the volumes harvested would not be sufficient to meet wood pellet use and demand. As such, rates of efficiency and therefore volumes would need to increase from the current 170 000ha to almost 211 000ha a year, in conjunction with improved access to the appropriate feedstock and an improved logistics and manufacturing plant infrastructure. This may require working outside the confines of the WfW programme.

Figure 7: Invasive alien clearing requirements



Source: Authors, based on eThekwini Municipality, n.d.

From a qualitative perspective, certain social, environmental and economic criteria emerged from the research as key indicators to either hinder or enable the production and use of wood pellets. Figures 6 and 7 provide an indicative scaling of the potential, should the production and use of IAPs for wood pellets reach its potential. In addition, it can bring significant social benefits, such as improved health and safety through the reduced use of firewood and paraffin (ACE, 2017; Ecozoom, 2017; Petrie, 2014), and environmental benefits, such as lower greenhouse gas emissions than coal (VEDA, n.d.), a reduced dependency of fossil-based fuels (Ernsting, 2014), and a reduced reliance on trees for fire wood (Petrie, 2014; Sander, 2012).

5. EMERGENT SYSTEMIC CHALLENGES

Given the significant potential for wood pellet production from IAPs and use in this country, the question arises as to what barriers are prohibiting the expansion of what appears to be an obvious added-value product. Emergent challenges to implementation, or success thereof, identified from the analysis are:

- Funding / business model;
- Government intervention (and as customer and client);
- Efficiencies of production (cost);
- IAP suitability and consistency of supply; and
- Local versus export market (a localised economy)

Challenges, such as funding implications and government interventions, also speak to the eco-matting case study developed in Box 2.

6.1. Funding / business model

When Government funding is not received due to slow decision-making or a backlog in payment, the production entity, the contractor, is often faced with either carrying the cost of production, including salaries, or reducing/stopping production. This has various implications, such as cash flow strain, reduced output and employee dissatisfaction.

6.2. Government intervention (and as customer and client)

While government policy does support biomass-derived renewable fuels, Government intervention is weak, with institutional [policy] barriers (Petrie, 2014), such as a continued focus on coal as a source for energy, dependence on the importation of petroleum products (Braude, 2014); and biofuel policy focus on agri-product feedstock such as sugarcane (thereby neglecting opportunities for IAPs). This is not helped by the lack of willingness of Eskom to facilitate appropriate power purchase agreements (PPAs) for biomass-based fuels, as witnessed at the Howick Bio-Tech wood pellet plant, where a stand-off with Eskom led to its failure. This included failure to negotiate a suitable and viable price, and not enabling the plant to supply power to the national grid (Petrie, 2014). However, private entities have seen the benefits of using forestry and sawmill waste as a by-product for internal combined heat and power (GBEP & IEA Bioenergy, 2016; Mail & Guardian, 2017). In this context, the use of biomass as a fuel source is well-practised, mainly as an energy cost-cutter.

O'Malley (1996) suggests that in South Africa, Government is the only entity with a "great enough" source of capital reserves to "significantly dent" unemployment and provide jobs. Eskom and the DEA are these sources of capital. In addition, Government also plays the role of an entrepreneurial venture capitalist by providing funding to construct and/or support activities e.g. the manufacture of wood pellets and associated technology and can drive demand for products as the customer e.g. wood pellets for co-firing of Eskom power stations. At a localised scale, Government can invest in and support localised sourcing of IAP feedstock and production of wood pellets using decentralised mobile technologies in rural locations.

This will improve rural community energy security, increase land availability for food production due to the eradication of IAPs, and create much needed jobs.

6.3. Efficiencies of production (cost)

The cost of using wood pellets as a fuel source is favourable. It is estimated to be 40% cheaper to produce hot water, steam and heat using wood pellets than fossil-based fuels such as electricity (SA Forestry, 2010) Calderon et al (2016) argue that the efficiency and quality of pellet production and logistics, heating appliance and technology efficiencies need to be improved. For example, production can be localised close to alien infestations. This is a key driver for a financially stable wood pellet business, alongside the management and forecasting of spend, which includes salaries.

Another cost inhibitor is logistics. Manufacturing should not be far from the market, as transport can be prohibitive (Argus Media, 2012; VEDA, n.d.). As a wood pellet manufacturer interviewed, noted, "it's all about transport!" (Anon, 2017b). To mitigate transport and logistics costs, the following should be considered:

- Decentralise manufacturing, placingproduction and storage of product close to IAP feedstock;
- Strategically locate distribution hubs for nation-wide markets or identify markets close to point of manufacturing, e.g. wood pellets used by local communities.
- Optimise packaging and transport packing ratios to maximise the volume of product that can be transported in one trip; and
- Consider backhauling opportunities.

By improving transport efficiencies, costs can be reduced. This could alleviate pressures on cash flow when funding back-logs exist.

6.4. IAP suitability and consistency of supply

IAPs should be assessed according to their availability and suitability for any added-value products. All IAP species should not be allocated or aggregated into a homogenous IAP category. For example, poplar is more suitable for eco-matting as it contains no tannins, while black wattle is most suitable for tannin extraction and use in the leather industry. The size and quality of the biomass also needs to be considered to maximise the use of the plant, tree or woody residue. In addition, knowledge of and skills in handling the feedstock are important. As noted by a wood pellet manufacturer (Anon, 2017a), wood is a live product with dynamic variables, such as moisture, which need to be well understood and managed. This refers directly to competencies and knowledge required to perform certain tasks in the production of wood pellets. Lack of recognition of the specific skills needs of jobs provided in mass job creation projects could have negative consequences, such as production failures and poor-quality product output.

The need for consistent supply of suitable IAP is critical, as illustrated in the closure of the wood pellet plant in Coega, which cited limited access to feedstock as one of the reasons for shutting down. The relationship between the feedstock provider and the manufacturer is therefore critical. Should this collapse or become unstable, the operation could fail, and have repercussions on job stability. Therefore, management negotiation and relationship skills ("soft skills"), supply forecasting, and procurement planning are imperative.

6.5. Local versus export market (a localised economy)

Large-scale operations in South Africa have predominantly focused on a European market. Fluctuating exchange rates and resultant market uncertainty were cited as key reasons for the closure of the large wood pellet facility in Coega (Argus Media, 2012; Ernsting, 2014) and Howick (Petrie, 2014). When commenting on the failure of the South African operations, a local wood pellet manufacturer (Anon, 2017b) noted the "biggest issue is the market, and we are clutching at straws. The domestic market is small, and poor. People just want the cheapest".

Given the volatility of the export market and significant local market potential, production for a domestic market would appear to be obvious. However, according to a local pellet manufacture, "unfortunately, some entities have given pellet production in South Africa a bad name" (Anon, 2017a). Such a statement intimates that given the potential of the industry, a gold rush of activity has created an environment in which those not necessarily knowledgeable about the process or operations entailed have tarnished the industry. Due to the complexity of the South African market and the lack of government support, an entrepreneur who manufactures wood burners and cookers in South Africa has been promoting his products in India, where his products and their benefits are being well received (Anon, 2017g).

The current disadvantages of wood pellets in comparison to typically used fuels are their high cost and poor penetration into remote markets. This is largely due to the dominance of the current fuel supply chain actors, such as Eskom and municipalities in the electricity market, and oil and gas companies in the LPG and paraffin market, and their distributors, which are well established (Anon, 2017g). For example, the paraffin industry is able to make its fuel accessible through a wide range of rural and urban outlets (Petrie, 2014), and users perceive paraffin as affordable compared to other fuel sources (Diederichs et al., 2014).

As a solution, a South African supplier of cook stoves suggests the two most important factors to successfully introduce the use of wood pellets as a source of fuel in the home in South Africa are relative price and availability, in comparison to other sources such as paraffin or firewood (Anon, 2017g). He notes the use of a cleaner stove is almost a secondary issue compared to these two important factors.

Box 2: A case study within the case study:
Eco-matting and associated products

The manufacturing of eco-matting from IAPs further illustrates the potential for unlocking jobs along the IAP value chain. Eco-matting is used to restore and rehabilitate land to mitigate erosion, associated infrastructure damage and silting of dams.

This box provides an indicative overview of the job potential and environmental benefits of rolling out the production of eco-matting from IAPs, should the current usage of eco-matting be taken to scale in areas affected by sheet rill erosion (see Figure 9).

Eco-matting and fibre rolls are produced by shredding smaller IAP logs into wood-wool and, in the case of the mat, sandwiched between a layer of biodegradable netting. Pegs are produced from IAPs to secure the matting and fibre rolls to affected areas.

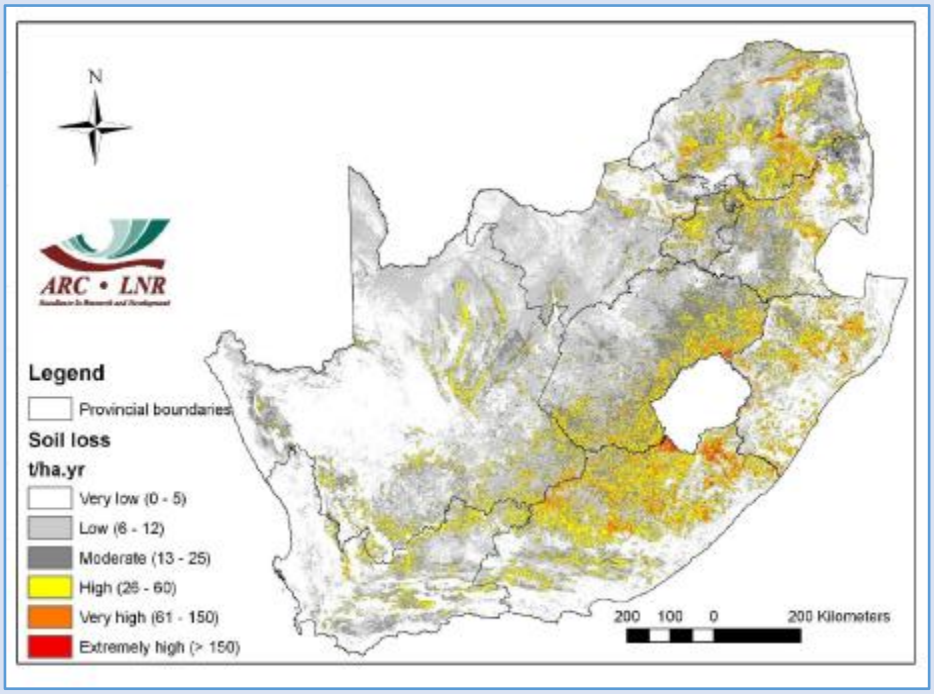
Figure 8: Illustration of the eco-matting product 1) eco-matting, 2) fibre-rolls and 3) pegs

Source: Anon, 2017c

When operating to fulfil recent demands, a sawmill and manufacturing plant employs approximately 46 people, operating one eight-hour shift.

This includes management and supporting staff and factory production labour, with additional beneficiary jobs associated with logistics and application.

Figure 9: Areas affected by sheet rill erosion in South Africa



Source: Le Roux, 2011

Suitable customers and markets for eco-matting could be government departments, such as the Department of Agriculture, Forestry and Fisheries, the Department of Water and Sanitation and the Department of Transport, as well as municipalities situated in high-risk land degradation areas, such as those affected by sheet rill erosion (Figure 9).

A more in-depth description of the potential is provided in Appendix 3.

6. CONCLUSION

The harvesting of IAPs as feedstock and a material for added-value products has significant potential to unlock a diverse range of jobs, requiring diverse levels of skill. Opportunities for beneficiation are also possible, with the local manufacturing and maintenance of machinery, tools and systems to support the core IAP added-value chain. For example, machinery for producing eco-matting is currently imported from Germany, and if it needs repairing, German technicians are called upon (Anon, 2017f). This activity, if skills were available, should be undertaken by local workers.

Of significance to this case study are the benefits associated with switching from dirty fuel for use in non-electrified homes to wood pellets. This will improve the health of householders, and depending on the technology can also provide improved access to lighting (via, for example, a USB port in the stove) and reduced medical and fire damage costs. It is critical that these benefits should also be highlighted as a benefit to users, and across government departments, such as the Departments of Health and Energy

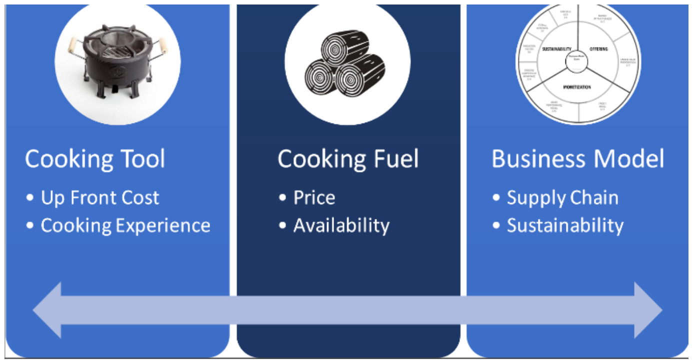
The job potential of wood pellet production extends beyond the manufacturing plant, and includes activities such as IAP clearing and machinery manufacture. As witnessed by government-led programmes, such as the WfW, activities like harvesting can be labour intensive and provide much-needed employment in the country. In addition, the use of IAPs as a biomass fuel has the potential to attract those who are working in a declining fossil fuel sector and who have transferable and necessary skills to enhance the manufacturing of added-value IAP products.

The prospects for unlocking jobs is clear, however major barriers currently inhibit the realisation of this potential. Core business management decisions and strategies are critical, such as clearly assessing logistical and efficiency costs and market analysis prior to the implementation of activities. However, this research clearly points towards Government as one of the main inhibitors to expansion. Yet, Government is also a major player in enabling growth in this sector. Recommendations therefore are:

- Policy, practice and support needs to be aligned to enable renewable energy to flourish, for example reduced policy support for coal and nuclear and increased policy and support for renewable energy opportunities.
- Government funding is critical for the success of many of the IAP added-value interventions. Funding should be longer-term to alleviate financial, operational and workforce livelihood insecurity. Wages should be fair and reflect market rates.
- Iterations of the “Working for” programmes should respond to a stronger form of the green economy, by recognising both the environmental and developmental objectives, and economic impact of returns on investment, and not focus solely to job creation.
- Cross-departmental co-ordination for developing cohesive enabling policy(ies), and procurement of IAP added-value products.

Going forward, it is recommended, based on the research findings, that given the potential to use IAP as a feedstock for wood pellets and eco-matting, and unlock jobs within a local South Africa economy the following model for a successful cooking market using wood pellets would rest on three basic pillars: 1) the cooking tool (or stove), 2) cooking fuel, and 3) the business models (as illustrated in Figure 10 below).

Figure 10: Three basic pillars of the wood pellet cooking market



Source: Anon, 2017g

The key focus of this case study is creating job potential through the manufacture of wood pellets. Given the ineffectiveness of previous attempts at production in this country, it is imperative that there is a shift in the current business model which has focused on large-scale investment in manufacturing plants for the export market. Costs associated with this business model, such as transport, as well as a lack of continuous supply of feedstock have been these initiatives' downfall. This research therefore suggests a switch to a more decentralised small-scale model feeding a local market which is easy to access through a wide range of rural and urban outlets, and therefore should be considered as more appropriate and more likely to succeed, with added socio-economic benefits (Anon, 2017a, 2017g; Petrie, 2014).

Cooking tool technologies currently exist in South Africa, for example those sold by Ecozoom, and African Clean Energy (ACE). Upfront costs for the user might be higher than the purchase of currently used stoves, but the benefits and extended life-span of the stoves need to be promoted to the users. In addition, any stove that replaces the traditional stove needs to have improved functionality on the norm in terms of cooking efficiency and heat generation. In the case of a clean stove being promoted by ACE, a USB port is built into the stove and can be used to charge a small light and electrical items, such as phones. This is a clear additional benefit.

The purchase price of wood pellets needs to be cheaper than, or the same as, competing fuels, such as paraffin, and easily accessible. According to a clean wood stove manufacturer, wood pellets can be produced for a third of the price of electricity, and much more cheaply than paraffin or liquid-petroleum gas (LPG) (Anon, 2017g). Therefore, to unlock wood pellet potential, it is important to have a good understanding of competitor fuels in terms of suppliers, price and ease of access prior to developing the local market.

To fully appreciate the potential of wood pellet production and use in South Africa, a more in-depth multi-criteria analysis is recommended to understand and assess:

- The market and penetration potential of wood pellets in South Africa;
- The feasibility (cost, distribution, etc) of introducing wood pellets into non-electrified homes for cooking and lighting (in relation to current supply chains and actors providing dominant fuel sources), particularly in more rural areas;
- The features of feedstock for wood pellet manufacture (IAP type, volume and quality, location, by-product from IAP manufactured products/sawmills);
- The feasibility and potential to provide decentralised, localised, manufacture of wood-pellets to mitigate distribution and storage costs, assessing distribution models and use of intermediaries; assessing different, localised business models, such as community-driven initiatives;
- Return on investment (social and environmental value) for manufacturers and households to produce and use wood pellet cooking stoves and lighting technologies, with a focus on expanded beneficiation opportunities, such as the local manufacturing of technologies;
- South Africa's capacity to research, develop, manufacture, install and maintain stoves and lighting technologies that can use wood pellets; and
- Current policy inhibitors and enablers to provide recommendations for improved policy to support wood pellet use interventions.

The South African Government has committed to a green economy, which it views as a path towards sustainable development, addressing economic growth, social protection and protection of the environment. A component of the green economy programmes is to ensure that they are practical and implementable, and pro-employment. This case study reflects this position and illustrates the significant potential wood pellets manufactured from IAPs can have on creating green jobs, improving the health of some of the poorest in the country, providing access to a renewable fuel source, and clearing alien vegetation to improve our natural resource base. Given this potential, it is recommended that dialogue with representatives across the value chain, including beneficiation activities, is undertaken to realise this potential. The aim of such a dialogue will be to:

a. Provide a baseline/current context of the wood pellet situation in South Africa, and potential opportunities.
b. To engage, workshop and identify with stakeholders a viable way forward (i.e. a roadmap for action), this could include e.g.
    - Identification of suitable funding sources and incentive schemes to invest in wood pellet/machinery manufacture.
    - Market penetration and marketing research, including a marketing strategy.
    - Understanding South Africa's capabilities and capacity to support and make this transition, including knowledge production and diffusion, and skills, along the expanded value chain.

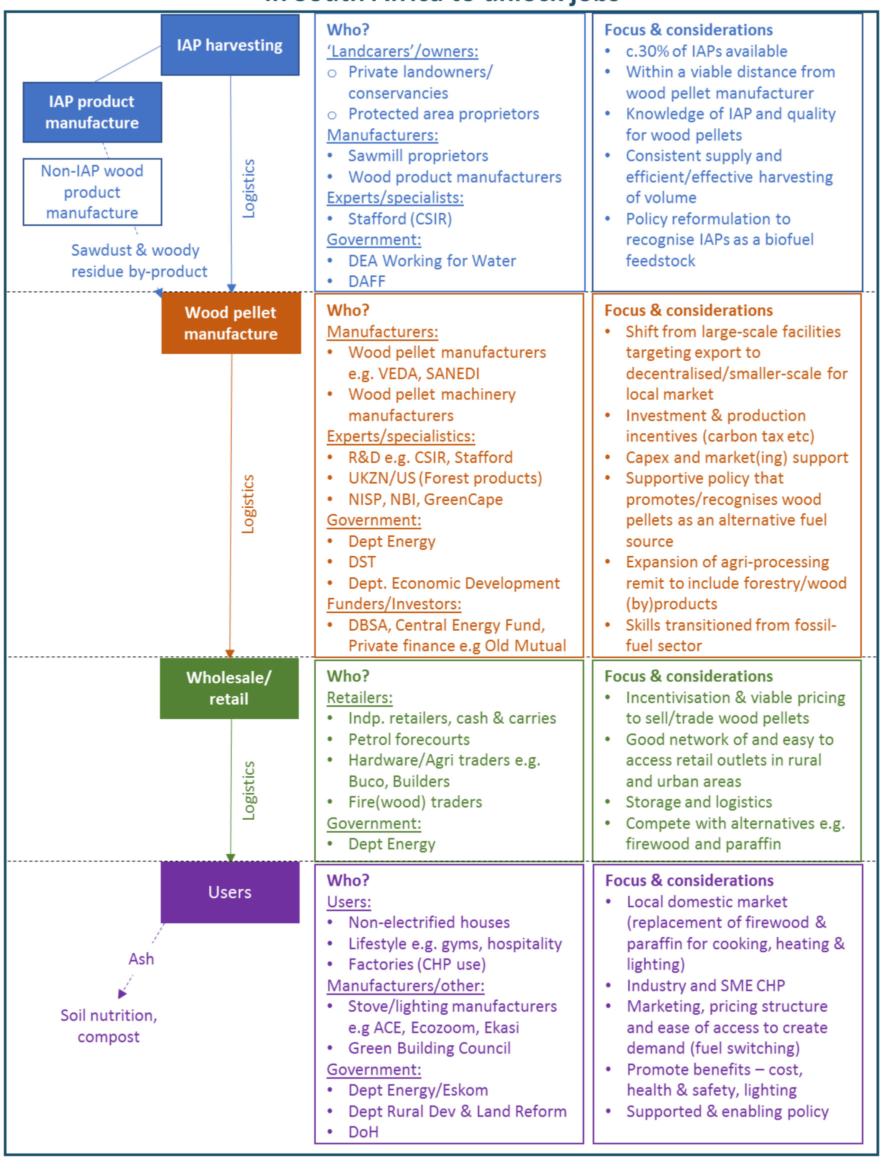
- Review of policy and adjustment pricing structures to enable the use of IAPs as biofuel feedstock, and the manufacture and use of wood pellets as a replacement for firewood and paraffin in the home.
- Identification of appropriate implementation activities to create demand e.g. trials, incentives and campaigns.

c. Set actions, tasks and responsibilities which are undertaken, monitored and fed back to stakeholders, including the wider network.

d. Set up a forum and/or Steering Group to co-ordinate activities and direction.

The suggested role players in such an advocacy process are mapped in Figure 11 below.

Figure 11: Advocating the manufacture and use of wood pellets in South Africa to unlock jobs



Source: Authors

BIBLIOGRAPHY

ACE. (2017). *The problem. African Clean Energy.* Retrieved from http://www.africancleanenergy.com/the-problem/.

Africa Wood Pellets. (2011). *Africa Wood Pellets.* Retrieved from http://icmholdings.co.za/pellets/.

Anon. (2017a). Interview: Wood pellet manufacturer 2.

Anon. (2017b, October 17). Interview: Wood pellet manufacturer 1.

Anon. (2017c, October 21). Email: Wood pellet manufacturer 3.

Anon. (2017d, October 23). Interview: Eco-matting manufacturer 1.

Anon. (2017e, October 24). Interview: Knysna application example.

Anon. (2017f, October 24). Interview: Eco-matting manufacturer 2.

Anon. (2017g, November 20). Conversation with a wood burner and cook stove manufacturer.

Argus Media. (2012). *IDC closes South African wood pellet plant January*. *Canadian Biomass*, (22 January). Retrieved from https://www.canadianbiomassmagazine.ca/news/idc-closes-south-african-wood-pellet-plant-3918.

Barnes, A., Ebright, M., Gaskin, E. and Strain, W. (2015). *Working for Water: Addressing Social and Environmental Problems with Payments for Ecosystem Services in South Africa*. South Africa: Wildlife Conservation Society, Forest Trends, The Earth Institute & TransLinks.

Beekes, M., Cremers, M. and Witkamp, J. (2014). *Biomass co-firing and full conversion 1 Opportunities for bioenergy in South Africa*. Presented at the IEA Task 32 Workshop on Bioenergy in South Africa, South Africa.

Bek, D., Nel, E. and Binns, T. (2017). Jobs, water or conservation? Deconstructing the Green Economy in South Africa's Working For Water Programme. *Environmental Development*. Retrieved from http://dx.doi.org/10.1016/j.envdev.2017.07.002.

Braude, W. (2014). *Regulatory Constraints to the Development of a Fuel Ethanol Market in SADC* (Case study No. 02). Johannesburg, South Africa: South African Institute of International Affairs (SAIIA). Retrieved from https://www.saiia.org.za/special-publications-series/606-sadc-business-barriers-case-2-regulatory-constraints-to-the-development-of-a-fuel-ethanol-market-in-sadc/file.

Calderon, C., Gautheir, G. and Jossart, J.-M. (2016). *European Bioenergy Outlook 2016: Key findings* (Aebiom Statistical Report). Brussels, Belgium: Aebiom: European Biomass Association.

Carayannis, E., Grigoroudis, E. and Pirounakis, D. (2015). Quadruple Innovation Helix and Smart Specialisation Knowledge Production and National Competitiveness. *Tech Monitor*, (July-Sep), 19–27.

Chan, J., Day, P., Feely, J., Thompson, R., Little, K. and Norris, C. (2015). Acacia mearnsii industry overview: current status, key research and development issues. *Southern Forests: A Journal of Forest Science*, *77*(1).

Department of Environmental Affairs (DEA). (2015a). *Assessment of the potential to produce biochar and its application to South African soils as a mitigation measure*. Pretoria, South Africa: Department of Environmental Affairs. Retrieved from https://www.environment.gov.za/sites/default/files/reports/biocharreport2015.pdf.

DEA. (2015b). *DEA's Working for Water Programme celebrates 20 years of job creation & environment sustainability*. Department of Environmental Affairs. Retrieved from https://www.environment.gov.za/mediarelease/workingforwater_20yearsjobcreation_environmentsustainability.

DEA. (2017). Working for Water (WfW) programme. Department of Environmental Affairs. Retrieved from https://www.environment.gov.za/projectsprogrammes/wfw

Department of Water Affairs (DWA). (2017). *WfW regional-level historical database*. Retrieved from http://www.dwaf.gov.za/wfw/Control/docs/WfW regional-level historical database up to 2009-10.xls

Diederichs, N., McKenzie, M. and Knox, A. (2014). *Draft Guideline on Technologies for Reducing Energy Poverty in Low-income Households* (SALGA Energy Guideline Series). Pretoria, South Africa: South African Local Government Association (SALGA).

Department of Minerals and Energy (DME). (2003). *White Paper on Renewable Energy*. Pretoria, South Africa: Department of Minerals and Energy. Retrieved from https://unfccc.int/files/meetings/seminar/application/pdf/sem_sup1_south_africa.pdf

DME. (2007). *Biofuels Industrial Strategy of the Republic of South Africa*. Pretoria, South Africa: Department of Minerals and Energy.

DoE. (2017). *Integrated energy plan: Overview.* Department of Energy. Retrieved from http://www.energy.gov.za/files/iep_frame.html

DWA. (2001). *Working for Water Programme: Development of Secondary Industries Options Analysis: Draft Report of the Transaction Advisor*. Department of Water Affairs.

DWA. (2017). WfW Regional-Level Historical Database. Department of Water Affairs. Retrieved from http://www.dwaf.gov.za/wfw/Control/docs/WfW regional-level historical database up to 2009-10.xls

Ecozoom. (2017). Portable wood burning cook stoves. Ecozoom. Retrieved from www.ecozoomstove.com

Eden to Addo. (2017). *Alien vegetation management*. Plettenberg Bay, South Africa: Eden to Addo Corridor Initiative. Retrieved from http://edentoaddo.co.za/library/

EE. (2015). Co-firing biomass with coal for power generation. *EE Publishers*. Retrieved from http://www.ee.co.za/article/co-firing-biomass-coal-power-generation.html

Ellen MacArthur Foundation. (2013). *Towards the Circular Economy Vol. 1: an economic and business rationale for an accelerated transition*. United Kingdom: Ellen MacArthur Foundation. Retrieved from https://www.ellenmacarthurfoundation.org/assets/downloads/publications/Ellen-MacArthur-Foundation-Towards-the-Circular-Economy-vol.1.pdf

Ernsting, A. (2014). *A new look at land-grabs in the global South linked to EU biomass policies*. Biofuel Watch.

eThekwini Municipality. (n.d.-a). *General Invasive Alien Plant Control: Insight into Best Practice, Removal Methods, Training & Equipment* (Guideline Document). Environmental Planning and Climate Protection Department, eThekwini Municipality.

eThekwini Municipality. (n.d.-b). General Invasive Alien Plant Control: Insight into Best Practice, Removal Methods, Training & Equipment." Guideline Document. Durban: Environmental Planning and Climate Protection Department, eThekwini Municipality. eThekwini Municipality.

Food and Agriculture Organization (FAO). (2003). S*tatus of invasive tree species in southern Africa.* Food and Agriculture Organization of the United Nations. Retrieved from http://www.fao.org/docrep/005/AC846E/ac846e06.htm.

Forests and Rangelands. (2017). *Overview: Woody Biomass Utilization and the WBUG. Forests and Rangelands.* Retrieved from https://www.forestsandrangelands.gov/Woody_Biomass/overview.shtml.

GBEP and IEA Bioenergy. (2016). *Examples of Positive Bioenergy and Water Relationships*. Global Bioenergy Partnership (GBEP) and IEA Bioenergy.

GreenCape. (2017). *Connecting industry, creating opportunity.* GreenCape. Retrieved from http://greencape.co.za/wisp/.

Honsbein, D. (2014). *Bioenergy modelling for South Africa: Benchmarking Namibia and South Africa*. Aston University, Birmingham, United Kingdom.

Howick Eco-furniture Factory. (2017, October 23). Site visit: Job creation potential from using sawdust and woody biomass generated at an eco-furniture factory.

Husgafvel, R., Nordlund, H., Heino, J., Makela, M., Watkins, G., Dahl, O. and Paavola, I. (2015). Use of Symbiosis Products from Integrated Pulp and Paper and Carbon Steel Mills. *Journal of Industrial Ecology*.

HVE Woodpelleting. (2017). HVE Woodpelleting. HVE Woodpelleting. Retrieved from http://www.hvewoodpelleting.co.za/.

le Maitre, D. and Forsyth, G. (2011). *Invasive alien plants biomass assessment*.

Le Maitre, D. and Forsyth, G. (2011). *Invasive alien plants biomass assessment (Appendix 2)*.

Le Roux, J. (2011). *Monitoring soil erosion in South Africa at a regional scale* (No. GW/A/2011/23). Pretoria, South Africa: Agricultural Research Council. Retrieved from http://www.geoscience.org.za/images/geohazard/erosion.pdf.

Lee, J. (2015). *Bioproducts value hierarchy*. Presented at the 1st Annual BiorProducts AgSci Cluster Workshopt, Canada. Retrieved from https://i.ytimg.com/vi/791v5HZHROQ/maxresdefault.jpg.

Maema, L., Potgieter, M. and Mahlo, S. (2106). Invasive alien plant species used for the treatment of various diseases in Limpopo Province, South Africa. *African Journal of Traditional, Complementary and Alternative Medicines*, *13*(4), 223–231.

Maia, J., Giordano, T., Kelder, N., Bardien, G., Bodibe, M., du Plooy, P., Jafta, X., Jarvis, D., Kruger-Cloete, E., Kuhn, G., Lepelle, R., Makaulule, L., Mosoma, K., Neoh, S., Netshitomboni, N., Ngozo, T., Swanepoel, J. (2011). *Green jobs: an estimate of the direct employment potential of a greening South African economy*. Industrial Development Corporation, Development Bank of Southern Africa, Trade and Industrial Policy Strategies.

Mail & Guardian. (2017). Looking at the availability of biomass in South Africa. *Mail & Guardian*, (31 March). Retrieved from https://mg.co.za/article/2017-03-31-00-looking-at-the-availability-of-biomass-in-south-africa.

Mavuso, Z. (2017). African conference strives to boost bioenergy industries. *Engineering News*, (18 August). Retrieved from http://www.engineeringnews.co.za/article/african-conference-strives-to-boost-bioenergy-industries-2017-08-18.

McQueen, D. (2013). *South African biomass energy: little heeded but much needed* (IIED Briefing). London, United Kingdom: IIED. Retrieved from http://pubs.iied.org/pdfs/17165IIED.pdf.

Moran, V., Hoffmann, J. and Zimmermann, H. (2013). 100 years of biological control of invasive alien plants in South Africa: History, practice and achievements. *South African Journal of Science*, *109*(9/10). Retrieved from http://www.sajs.co.za/sites/default/files/publications/pdf/Moran_News%20and%20Views.pdf.

Mugido, W., Blignaut, J., Joubert, M., de Wet, J., Knipe, A., Joubert, S., … van der Vyfer, M. (2014). *Determining the feasibility of harvesting invasive alien plant species for energy*. Pretoria, South Africa: Department of Economics, University of Pretoria.

Muzondo, F. (2016). *The State of the Expanded Public Works Programme in South African Cities*. Johannesburg, South Africa: South African Cities Network. Retrieved from http://www.sacities.net/wp-content/uploads/2016/Uploads/State%20of%20EPWP%20in%20SA%20Cities%20(2015-16).pdf.

O'Malley, P. (1996). Job creation - the role of the public sector. *African Communist Journal Extracts*, *144*(Second Quarter). Retrieved from https://www.nelsonmandela.org/omalley/index.php/site/q/03lv02424/04lv02730/05lv03005/06lv03006/07lv03119/08lv03124.htm.

Petrie, B. (2014). *South Africa A case for biomass?* London, United Kingdom: International Institute for Environment & Development (IIED).

Pirraglia, A., Gonzalez, R., & Saloni, D. (n.d.). Wood Pellets: An Expanding Market Opportunity. *Biomass Magazine*. Retrieved from http://biomassmagazine.com/articles/3853/wood-pellets-an-expanding-market-opportunity.

Reliance. (2015). About Reliance Compost. Reliance. Retrieved from http://www.reliance.co.za/aboutus.html.

Rural Energy. (2015). Wood chip vs wood pellets: The benefits of different types of biomass wood fuel. Rural Energy. Retrieved from http://www.ruralenergy.co.uk/insight/wood-chip-vs-wood-pellets-benefits-different-types-biomass-wood-fuel.

SA Forestry. (2010). Pellet plant raises 'green' opportunities in South Africa. *SA Forestry Online*, (31 December). Retrieved from http://saforestryonline.co.za/articles/sawmilling_and_processing/pellet_plant_raises_green_opportunities_in_south_africa/#disqus_thread.

South African Environmental Observation Network (SAEON). (2015). *Bioenergy Atlas for South Africa.* South African Environmental Observation Network. Retrieved from http://bea.dirisa.org/

Sander, K. (2012). *Wood-Based Biomass Energy in Sub-Saharan Africa: Issues & Approaches*.

Sishuba, S. (2016). SA's soil erosion crisis. *Farmer's Weekly*, (27 July). Retrieved from https://www.farmersweekly.co.za/bottomline/sas-soil-erosion-crisis/.

Stafford, W. (2017). Value-Added Industries: opportunities for local and embedded energy, wood fuels and other products from Invasive Alien Plant biomass. Council for Scientific and Industrial Research (CSIR).

Stafford, W., Blignaut, J., Lotter, D., le Maitre, D., & Forsyth, G. (2016). *Value-Added Industries on the Agulhas Plains: Techno-economic feasibility study for the production of wood-fuels, heat, electricity and biochar from Invasive Alien Plant biomass* (No. CSIR/NRE/GES/ER/2016/00015/B). Stellenbosch, South Africa: Council for Scientific & Industrial Research.

Statista. (2017). Number of hours spent cooking per week among consumers worldwide as of June 2014, by country. Retrieved November 21, 2017, from https://www.statista.com/statistics/420719/time-spent-cooking-per-week-among-consumers-by-country/.

Stats SA. (2015). *General Household Survey 2015* (Statistical Release No. P0318). Pretoria, South Africa: Statistics South Africa.

Stats SA. (2015a). *General Household Survey 2015* (Statistical Release No. P0318). Pretoria, South Africa: Statistics South Africa.

Stats SA. (2015b). *The importance of coal.* Statistics South Africa. Retrieved from http://www.statssa.gov.za/?p=4820.

Syringa Bioscience. (2017). Syringa Bioscience. Syringa Bioscience. Retrieved from https://www.facebook.com/pg/SyringaBioscience/about/?ref=page_internal.

Toma-Now. (2016). *Biomass value chains: Creating value from invasive alien vegetation. Tomorrow Matters Now.* Retrieved from http://www.toma-now.com/toma-now/wp-content/uploads/2016/04/Biomass-beneficiation-TOMA-Now-case-study.pdf.

Treecycle. (2014, May 22). *Bio-mass Pellets from Green Waste.* Treecycle. Retrieved from http://www.treecycle.co.za/biomass-2/.

Van Wilgen, B., Richardson, D., le Maitre, D., Marais, C., & Magadlela, D. (2001). The Economic Consequences of Alien Plant Invasions: Examples of impacts and approaches to sustainable management in South Africa. *Environment, Development and Sustainability*, *3*, 145–168.

VEDA. (n.d.). The value of biomass in alien eradication. Viking Energy Development Africa.

Vundla, T., Blignaut, J., Nkambule, N., Morokong, T., & Mudavanhu, S. (2016). *The opportunity cost of not utilising the wood invasive alien plant species in the Kouga, Krom and Baviaans catchments in South Africa*. *SAJEMS*, *19*(5), 814–830.

Vuthisa. (2017). Vuthisa products. Vuthisa. Retrieved from https://vuthisa.com/products/.

APPENDIX 1: CASE STUDY SELECTION PROCESS

The selection process of the case studies was an informative exercise, as it illustrated the realities and feasibility implications of transitioning theory and quantitative assessments (such as cost-benefit analyses) into practice. The initial intention was to identify two case studies which reflected, for example, a diversity of skill-level options, number of potential jobs per activity and a scaling of financial profitability (as per Figure 1).

Initial research had identified South African production activities (from IAPs) in tannin extraction, biochar and cosmetics production, and furniture manufacture. Due to an abundance of attention already received by the eco-furniture programme, it was decided to identify opportunities that were less explored, particularly on the unlocking of jobs potential.

While publicly available, secondary information existed on high-end technical interventions, primary investigation of these opportunities revealed a lack of suitability for further exploration in this study, for example:

- Extraction of tannins: While South Africa is one of the largest producers of tannins from black wattle (*Acacia mearnsii*), the feedstock is sourced from commercial plantations cultivated by farmers (approximately 80% of total area) (Chan et al., 2015) and little, if any, evidence was available on extraction from IAPs harvested as part of alien clearing practices.
- Cosmetic and medicinal products: Various references were made on-line to a few operations in South Africa producing cosmetic and medicinal products from IAPs (see Maema et al., 2106; Syringa Bioscience, 2017), however further investigation was unable to locate or engage with the producers, suggesting that these ventures may have ceased.
- Biochar: As with the above, biochar activities were referenced, however the uncertainty of the understanding of its application as an absorber of carbon and/or nutrient-additive to the soil suggested that its potential is still immature in this country. Nevertheless, results of its use in the agricultural sector are promising, and this opportunity is worth exploring further, as it provides a platform to add value to the more typical production of charcoal, with wider benefits.

It was therefore, through the research and case study identification process, that the eco-matting for land restoration (emergent activity) and wood-pellets (tried but stagnating activity) emerged as illustrators of potential for unlocking jobs, yet highlighting the opportunities and barriers for such interventions.

APPENDIX 2: INDICATIVE DIRECT AND INDIRECT JOBS ASSOCIATED WITH PELLET MANUFACTURE

Table 1 reflects a potentially typical large-medium scale manufacturing plant, including job types and numbers employed at a plant handling and processing IAP biomass into wood pellets.

Table 1: Indicative jobs associated with harvesting and manufacture of wood pellets

Management & supporting staff	No. employed
General manager	1
Financial officer, debtors, creditors	3
Ops manager - R&D	1
Logistics manager and team	16
Data collection	1
Production manager - Quality	1
Sales manager and team	4
Maintenance manager	1
Safety, Health, Environment and Quality officer	1
Storeman	1
Cleaner	1
Security	5
Production foreman	1
Assistant production foreman	1
Front end loader/forklift	2
Quality control assistant	1
Sweepers/cleaners	2
Manager	
Assistant	
Drivers	
Driver assistant	

Source: Anon, 2017a, 2017b

When taking the value chain into account, and the use of by-product from an eco-furniture factory, Table 2 provides an indication of the type of jobs, number, skills required, daily wage rate and hours worked per day to work with the material that could be turned into wood pellets.

Table 2: Indicative job types and numbers associated with the IAP feedstock harvesting and by-product sawdust and wood residue from an IAP eco-furniture factory

Job type	No. employed
Harvesting IAP feedstock	
Contract harvesters	24-48
Handling sawdust & wood residue at an eco-furniture factory	
General labour	7 (dry mill) 10 (wet mill)
Forklift driver	1
Supervisor/contractor	1
Health & Safety	1

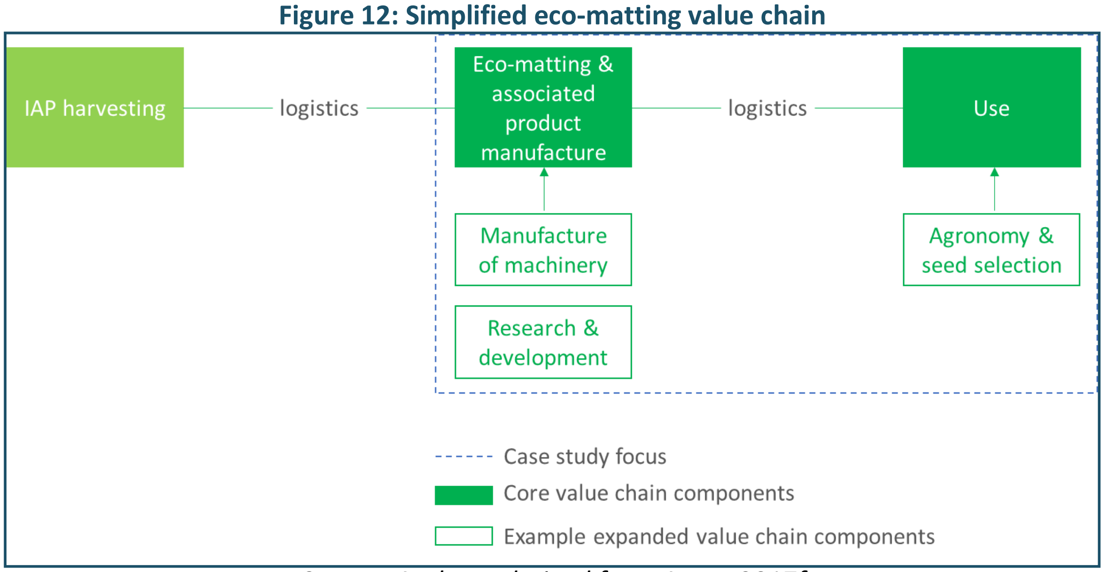
Source: Anon, 2017a, 2017b

APPENDIX 3: BIOMATERIALS: ECO-MATTING AND ASSOCIATED PRODUCTS

Soil erosion and land degradation are a major problem in South Africa, resulting in run-off into rivers and the silting of dams, and reduction of soil productivity, thereby reducing the soil's ability to support agricultural, especially food, production (le Roux, 2011). The current droughts, large scale fires and mismanaged lands exacerbate soil degradation (Sishuba, 2016). Interventions are sought in this country to mitigate the effects of soil run. Eco-matting and fibre-rolls are such a mitigation measure, particularly for steep slopes affected by, or predisposed to, sill erosion, such as upstream of dams affected by silting and post-fire damage control for infrastructure protection (Anon, 2017d, 2017e). Matting could also be used for mine rehabilitation, or roadside maintenance.

Currently eco-matting and associated products are being manufactured by Wood@heart who through a tender process received funding from the Department of Environmental Affairs to develop the matting. Wood@heart have experience in delivering IAP product manufacture and running of associated saw mills through, for example the production of eco-furniture, under the auspices of the WfW programme. The eco-matting is currently being produced at two of their sawmill/manufacturing sites in Ficksburg, Free State and Pretoria, Mpumalanga. Wood@heart have been producing the matting for almost two-years, with it having been used in Knysna as part of the post-fire rehabilitation and dam restoration. The DEA is the client, coordinating and identifying state users. Landowners, predominantly in the vicinity of the Wood@heart operations, supply the IAP feedstock, which is harvested under WfW teams contracted by the private sector or conservancy groups (Bek et al., 2017).

Figure 12: Simplified eco-matting value chain



Source: Authors, derived from Anon, 2017f

The value chain for eco-matting, is relatively simple, consisting of 1) harvesting of IAP feedstock, 2) transportation of the product from site of harvest to 3) the facility where the products are made. 4) transportation of the finished product to 5) site of application and use. For the purposes of this study, it is useful to expand the value chain to identify the wider beneficiation opportunities for unlocking further jobs associated with the production of the primary product. Some key beneficiation activities include, for example, the potential to manufacture the eco-matting machinery in South Africa (it is currently manufactured in Germany), research and development in improvement, adaptation and development of related products (such as hydro-mulch), and the use of agronomists and ecologists to advise on types of seeds to add to the eco-matting to encourage vegetation regrowth.

To date, the matting has been applied in a few areas, notably Knysna by the Garden Route Rebuild Initiative to protect infrastructure (such as housing) and mitigate landslides, and by the Gamtoos Irrigation Board to prevent further silting of a dam.

Job creation potential

When operating to fulfil recent demands, a sawmill and manufacturing plant employs approximately 46 people, operating one eight-hour shift. This includes management and supporting staff, factory production labour, with additional beneficiary jobs associated with logistics and application. Table 3 below provides an indication of people employed in manufacturing matting and associated products, and the application thereof. Managerial and operational jobs can be assumed to be the same as those indicated in a typical wood pellet plant (see Appendix 2, Table 1), and harvesting beneficiation jobs (see Appendix 2, Table 2).

Table 3: Indicative jobs associated with the manufacture and application of eco-matting and associated products

Job type	No. employed
Production foreman	1
Assistant production foreman	1
Front end loader/forklift	2
Peg makers	10-20
Wood wool machine operator	4
Eco-matting machine operator	1
Quality control assistant	1
Sweepers/cleaners	2
Project manager	1
Eco-matting application	
Supervisor	1
Team leader	1
Installation team	30-40
Ecologist/agronomist	1

Source: Anon, 2017d, 2017f

The following images illustrate the various activities associated with the manufacture and application of eco-matting and associated products:

Eco-matting, rolls and peg manufacture

Wood wool for matting

Completed matting ready for delivery

Fibre roll sorting

Fibre roll manufacture

Making pegs – stage 1 (automatic slicing)

Making pegs- stage 3 (manual)

Wood fibre mulching

Application

Soil preparation

Laying the matting

Applying water to soak the matting

An assessment of the types of jobs suggests that the majority of jobs are low- to medium-skilled, with most being allocated to harvesting, peg making and installation (Anon, 2017d). Harvesting, one of the most labour intensive activities, includes e.g. ground-truthing, harvesting, spraying, chipping and transport (Anon, 2017c, 2017d).

Application of the matting requires soil preparation (clearing and scarification), pegging and seeding the matting. For very steep slopes, as is the case with the Knysna rehabilitation, opportunities existed to draw on the skills of the WfW's High Altitude Team, who are trained in rope work (Anon, 2017e).

Additional skills required (and therefore job opportunities) lie in the selection of seeds applied to the matting. This is often determined by an ecologist, who suggests indigenous seeds applicable to the geographic location (Anon, 2017d, 2017e). This was witnessed in the rehabilitation work in Knysna. Mechanisation, particularly in the harvesting and application phases could be introduced. Neither are currently very heavily mechanised. If job creation is the focus of such operations, these activities are labour intensive, and the impact of mechanisation needs to be assessed. However, an eco-matting manufacturer interviewed (Anon, 2017d) suggested that by introducing hydro-mulching as a mechanised application process, a lot more degraded land could be covered in a day, and a lot more people could be employed, therefore more land could be restored.

Barriers and challenges to unlocking jobs

The scale of land degradation and therefore mitigation measures suggest that the need for products such as eco-matting is unquestionable. In addition, the manufacture and application of the product could have the added benefits of:

- Improving livelihoods through employment of the previously unemployed (an objective of the development state). For example, Sishuba (2016) recommends incorporating soil conservation into poverty relief programmes, such as Working for Water.
- Reducing alien vegetation and improving water retention, tourism, etc.,
- Improving soil quality and condition, thereby:
    - Reducing impact on infrastructure and maintenance and restoration costs associated with land-slide and silting damage, and
    - Enabling increased food production to boost food security.

With such potential questions arise as to the feasibility of scalability and potential. Interviews and secondary research suggest that there are a few barriers and challenges associated with realising this potential (see conclusion for comment and recommended mitigations):

- **Funding implications** - which cover a cluster of issues, such as reliance on Government funding to initiate activity, the short-term nature of funding and contracts (Bek et al., 2017), and timeliness of funding selection and payments. Theron (2017) notes that one of the core issues is contract renewal, and the stop-start nature of funding. The implications of this are cash flow, and ensuring the operation can accommodate periods when awaiting receipt of funding. Fixed costs, such as payment of the salaries of senior staff, need to be covered.
- **Job creation versus product output** – The Government's "Working for …" programmes very specifically focus on job creation and making processes as labour intensive as possible. As such the creation of jobs can override productivity. A number of interviewees suggested this meant that common-practice business models of efficiency and production-driven outputs were often to the detriment of job creation. It is almost as if "unproductivity is encouraged". This focus results in production labour not always operating at maximum efficiency as product output ratios per hours worked is not a key driver of production, or when there is an operational hiatus due to a

lack of Government funds, employees tended to go-slow. According to two interviewees, this has fundamental repercussions on the psychological state of the employees, who are in a constant state of fear, wondering if they will lose their jobs if production halts. As such, production labour may start to:

> "… work slower and become less productive as they know they are likely to be sent home if production ceases. They would far rather work slowly than not work at all. We have tried to avert this through self-funding. … we now know this, and as a private company we can help with the cashflow, and work around the budget shortfalls."

During go-slow periods, activities such as peg making can continue, in order to build up a stock-pile, or activities such as maintenance and cleaning are carried out (Anon, 2017f). An implication of losing people if funding ceases is not only a loss of numbers, but also skilled people who have received specific training to undertake a job. This is an investment loss for the company.

- **Government as customer and client** – the opportunity to open the market exists for eco-matting. However, the Government is the coordinator, funder and customer or client of the product. The DEA instructs where products should be sent, with Government-funded projects receiving the products free of charge (Anon, 2017d). The subsidisation of manufacture and job creation focus of the current business-model would need to be adjusted for applicability to a private market. This would not necessarily mean a reduction in jobs. The opposite could occur, with salaries for example likely to replicate the going market rate for the different employment-grade day rates (which under the "Working for …" programme are considered low and below the agricultural minimum (Bek et al., 2017)).
- **Recognition of the role of private entrepreneurialism** – as witnessed with eco-matting, the drivers of the activity were the originators of the idea, having seen eco-matting adopted in the United States and identifying the potential to use IAP as a source material for job creation and manufacture in this country. Government funding and convincing took time to materialise, as Government's focus was on the production of eco-furniture. Government realised the potential of eco-matting and supported the capital investment to import machinery from Germany and initiate production in South Africa (Anon, 2017d). The reliance on Government to seed entrepreneurial activities of this type can delay introduction and potential to increase job creation. This story also indicates the vital role private entrepreneurs play in bringing ideas to the table. However, business models of productivity and profitability differ between State and private entities. Private entity focus could also be drawn to private and export markets, such as Australia and other southern African countries, or for activities such as mine rehabilitation (Anon, 2017d, 2017e, 2017f). This market has not been developed yet.

- **IAP suitability and consistent supply** – According to Theron (2017) not all IAPs are suitable to produce eco-matting and associated products. Poplar is preferred as it contains no tannins and is a softer wood containing fibres ideal for matting. It is also not hard on machinery, thereby limiting maintenance costs. Another consideration is access to supply, especially given the implication of transport costs, and locally sourced IAP is desirable. In the case of one of the eco-matting operations, feedstock is identified and sourced through a local farmer's union. Until recently farmers have been keen to participate, however following a recent incident in which a farmer decided to reap the financial benefits of harvesting for himself and "stole the timber", there has been difficulty in sourcing feedstock. Given that it is a legal requirement for landowners to clear their land of IAPs, it is recommended that the DEA "should do more to get farmers to do this. The problem is the enforcement and clarity of the law".

APPENDIX 4: VARIABLES USED IN THE VENSIM MODEL FOR ESTIMATING POTENTIAL JOBS FROM WOOD PELLETS ADOPTION

Table 4: Variables used in the Vensim model

Variable	Value	Source
IAPs area	over 10 million hectares 1 736 438 condensed hectares	Stafford, 2017
Biomass	The woody biomass of dense plant invasions varies from 32 to 198 t/ha (dry biomass), and we have estimated the total woody biomass to be 167 million tonnes from the NIAPS conducted in 2010 (Le Maitre and Forsyth, unpublished).	Stafford, 2017
IAPs spreading rate	5–10% per annum	Stafford, 2017
	7.4% and 15.6% (depending upon species)	DEA, 2015b
Working for Water activities clearing	169 086 ha per annum	Stafford, 2017
	Average cost of R9 000/ha (condensed or 100% invaded)	
	35-person days to clear one hectare Total cost of R15.3 billion for alien plant clearing.	Stafford, 2017
Cost of controlling IAPs	R600 million a year over 20 years	
IAP suitability for wood pellets	Only a portion of the harvestable woody IAP biomass is available for bioenergy, since some of the biomass will be used for higher-value uses. Applying the suitability ratios for Pinus, Acacia and Eucalyptus IAP biomass for VAI wood products, for Agulhas it was estimated that: • 53% (338 995 tonnes) is available for bioenergy (heat and electricity). • 32% (207 850 tonnes) is suitable for wood-fuels (firewood, charcoal, wood pellets, woodchips, torrefied wood-chips and torrefied pellets), engineered wood and wood composites (wood-wool, fibre-board and wood-cement and wood-plastic composites). • 1.5% is available for lumber, large poles (>5cm diameter). • 3% is available for small poles and droppers (droppers=3–5cm diameter and slats=1–3cm diameter). • 10% of the woody biomass (twigs) is left in-field after harvesting as residue.	Stafford, 2017
Water impact - IAPs waste	7% of our water resources	Barnes, Ebright, Gaskin and Strain, 2015.
Current IAP clearing rate	6.7% reduction in MAR	Versfeld et al., 1998
	1,444 million m3/annum or 2.9% of the country's MAR	Le Maitre et al. 2013

	Assumed an average of 200 000 ha per year are cleared in the short-term 560 000 ha in the medium term 1 450 000 ha in the long term			Maia et al., 2011
	2.8 million hectares cleared			DEA, 2015b
	1 person can clear 13.8 ha (Dependent on density) The number of jobs required for the 100 000 t/a wood production is 121 (based on 1 667 hectares to be cleared at a rate of 13.8 hectares per person).			DWA, 2001
Total available IAP biomass	Total invasive alien plant biomass is estimated to be about 165 million Mg spread over about 44 million ha, giving a mean IAP biomass standing stock of about 3.7 Mg/ha with a range from 0-228 Mg per ha.			Le Maitre and Forsyth, 2011
Wood pellets				
Average hours spent cooking per week	9.5 hours			Statista, 2017

Table 5: Jobs (person days) per cleared area

	Average 2005-2010
Person days/Area cleared (Ha)	11.0
Area cleared (Ha)/Person days	0.1
Person days/Area cleared + Follow up (Ha)	2.3
Area cleared + Follow up (Ha)/Person days	0.4

Source: Author's calculations based on DWA, 2017

Table 6: Estimated areas that can be cleared daily per person and per 12-member team

Control method	Extent (m2) cleared by 1 person per day	Extent (m2) cleared by 12-member team per day
Light (mechanical & chemical)	850 – 900	10 800
Medium (mechanical & chemical)	550 – 650	7 800
Heavy (mechanical & chemical)	250 – 350	4 200
Extra heavy (mechanical & chemical)	100 – 150	1 800
Special weeds (e.g. Pereskia)	As required	

Source: eThekwini Municipality, n.d., 59

Table 7: Household energy use for cooking

Energy for cooking	Number (Thousand)
Electricity from mains	12 597
Electricity from generator	394
Gas	560
Paraffin	867
Wood	1 505
Coal	80
Candles	20
Animal dung	14
Solar energy	27
Other	36
None	23
Total	**16 122**

Source: Stats SA, 2016