FINAL REPORT

BUSINESS MODEL FOR BIOCHAR, ACTIVATED CARBON AND WOOD VINEGAR ("BAW") PRODUCED FROM CLEARED ALIEN INVASIVE PLANTS IN THE KARATARA RIVER CATCHMENT

18 MARCH 2021

Document Information

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Version	Final 18 March 2021
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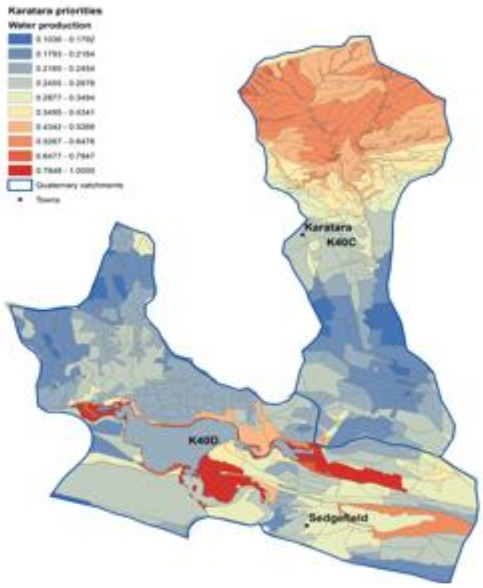
Contents

1. Alien Invasive Plants and water security

The benefits of clearing Alien Invasive Plants (AIP) in catchment areas are multiple, but it is **critical for water security** and economic growth in the area, as well as benefiting local communities. Figure 1 below provides a graphical understanding of the landscape through which the Keurbooms river flows. Map 1 below displays the water production areas in the Karatara Catchment. [1]

Figure 1 Keurbooms River February 2020



Map 1 Water production areas in the Karatara catchment indicating potential for streamflow returns from clearing invasive plants.

Alien invasive plants (AIPs), such as wattle, Port Jackson, and pine, are a threat to water security due to their presence in key catchment areas. The AIPs utilise more water than the native species in the area and impacts on the amount of water available to the catchment and for human use.

The clearing of invasive alien plants in the Keurbooms and Karatara River Catchments can greatly contribute to the additional availability of water to the catchment. The volume of water lost through the current distribution of IAPs in the region is estimated to be in the order of 25 000 Mℓ per year (approximately 20% of the capacity of Berg River dam).[1]

As a result, the value of additional water is estimated to fall between R25.1 million and R307.3 million per year[2]

Developing a biomass value chain through alien vegetation removal can offset clearing costs, create new jobs and be used to develop innovative carbon-based products using efficient technology solutions. An industry-based biomass value chain can support applications like biochar, activated carbon and wood vinegar (BAW) production, as well as biomass to energy and other applications.

[1] Source: Western Cape Department Environmental Affairs and Development Planning. (2018) BUSINESS CASE FOR KEURBOOMS AND KARATARA RIVER CATCHMENTS

This business model for the products and by-products of cleared AIPs will:

1. Create jobs and economic activity in areas where there is an abundance of alien and forestry-derived biomass
2. Reduce the overall cost or prove the profitability of clearing alien invasive plants
3. Result in greater areas cleared with the same quantum of investment, by creating sources of revenue from the products of such clearing
4. Create opportunities for food and water security, contract farming, and rehabilitation of cleared areas

2. Availability of biomass

Western Cape is 129 462 km^2 area and has **42 million dry tonnes invasive biomass**, but only 24 million oven dry tonnes accessible at less than 20 degrees slope[3]. The distance to road will reduce available volumes further, but this depends on location of processing or value-adding plant from the biomass. Access to additional biomass beyond these parameters will largely depend on economic value created from value-adding industries.

The project team has engaged with the Department of Environmental Affairs & Development Planning (DEA&DP) and the Council for Scientific and Industrial Research (CSIR) and have noted the available data limitations on the exact densities, geo-spatial location, and classification of AIPs in the Karatara catchment. However, there is high confidence that sufficient AIP biomass exists in the catchment area for this business model based on the expertise of AIP advisors within the Catchment. Further, we have confirmation of confidence from a technology owner who has established a manufacturing plant in the area. The following is from a personal communication with Pam Booth, Environmental Manager, Knysna Municipality

"I have worked in invasive plant management and catchment management for more than 20 years and lived in the Karatara catchment for 15 years, from 2003 until 2018. Having worked in the Palmiet and Keurbooms river catchments as a Working for Water Project Manager and more recently in the Karatara catchment assisting landowners to manage alien vegetation from both a co-operation and an enforcement perspective it is imperative for me to be able to accurately assess alien vegetation densities, species, and age classes and by association the volume of biomass in each area. The dominant species and age class in the lower reaches of the catchment is mature black wattle. Along large stretches of the river form the causeway approximately 5km upstream there is little else. Due to the availability of water, sunlight, and good soil the trees grow fast and tall providing high volumes of biomass. Higher up in the catchment and onto the plateau the mix of species includes mature Eucalyptus spp., Blackwood, Pine, Rooikrans and other woody and herbaceous species. In summary, the Karatara catchment has an extremely high volume of alien biomass that poses a distinct streamflow reduction and fire risk".

This is supported by a study undertaken by Ninham Shand where it was stated that: "Alien invasive plants are the largest water consumer in the study area, accounting for about 50% of total water use" (Hydrology of the Karatara and Homtini catchments, 2002) and more recently the Management Unit Control Plan (MUCP)drafted by the CSIR showing species, density, and age class.

The MUCP maps justify that there is sufficient AIPs for the execution of the business model. GIS maps are available in the form of MUCP, but these are subject to further refinement.

For the purposes of the pilot project implementation, a density assessment and AIP classification was done on 5 March 2021. However, the project team recommended that the budget allocation for the pilot project must include commissioning of a further detailed, fine scale AIP density assessment at both compartment level (i.e., MUCP) as well as cadastral level in the Karatara catchment. Previous experience in the catchments suggests that, given the rapid rate of change for AIPs in a given landscape, the duration of usefulness of AIP data for planning and budgeting purposes is limited.

In the catchment area it is estimated that annual expansion of AIP cover ranges between 6-10% (depending on rainfall & excluding any clearing activities)[4]. The catchment has been demarcated into more than 158 compartments in the MUCP tool during previous density analysis exercises with varying levels of alien infestation and density in each compartment. Density per compartment is visible using the data collated during the Ecological Infrastructure Investment Framework project, and modelled using the Department of Forestry, Fisheries, and the Environment (DFFE) Natural Resource Management (NRM) MUCP tool[2]. Government public works programme champions (Expanded Public Works Programme – EPWP, Working for Water etc.) estimate that there is AIP stock within the catchment that would require consistent clearing for at least the next 20 years.[5] Figure 3 is an illustration of clearing all known AIPs on private and public land excluding South African National Parks (SANParks) and CapeNature over a 20-year period. This includes the optimal budget requirement for a consistent density reduction over the 20-year period.

Forward planning for AIP clearing by Knysna Municipality's Planning and Economic Development directorate indicates that a **minimum three-year investment** would be required:[6]

- to clear 16 072 ha
- cost of R 9,9 million annually
- create 31 733 person days of work (labour-intensive clearing regime)

[2] https://sites.google.com/site/wfwplanning/monitoringandevaluation

[3] Western Cape Government (2021) MANAGEMENT UNIT CONTROL PLANS FOR THE HOLSLOOT, KARATARA AND KEURBOOMS CATCHMENTS

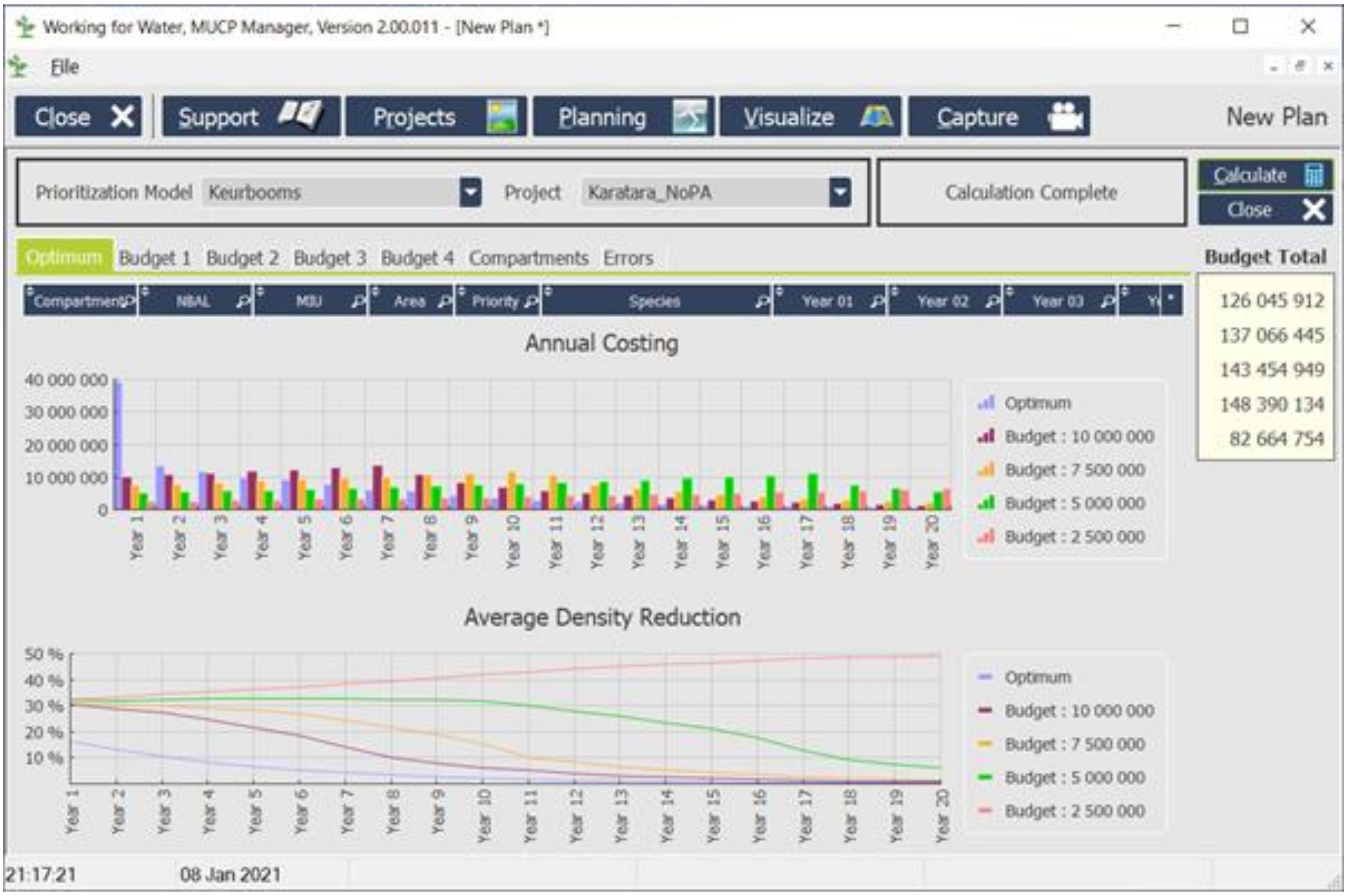


Figure 2 MUCP manager extract. Projected density reduction based on AIP clearing budget scenarios over a 20-year period.

3. Scenarios for implementation

In the evaluation of the technologies available in the catchment area, the implications for the whole value chain were taken into consideration. Thus, two scenarios that can be implemented in a pilot project have been suggested:

Scenario 1: Single technology, producing BAW, where the technology owner takes responsibility for the entire value chain from primary processing to packaging and distribution, including producing all three identified products in the scope of this project. The technology owner retains control over quality assurance, however the inclusion of Small Medium Micro Enterprises (SMMEs) along the value chain is not completely accounted for. A way to mitigate this is the proposed incubation model for the BAW business plan to ensure adequate technical capacity among the SMMEs included. Ownership/partnership models explored to support SMME inclusion.

Scenario 2: Multiple technologies at various scales for an inclusive value chain. The pilot project could be used to trial out various scales of technologies, creating a cooperative biomass eco-industrial park model. This scenario could include a collaborative approach that produces energy with biochar as by-product, as well as the production of compost from green biomass, to be enriched with biochar as a value-add. A central anchor would house the most pertinent technology (high quality BAW production) with various support industries for up and down the value chain (primary processing, kilns for processing on site, composting, packaging/distribution) that include SMMEs. The variations in input/output would be mitigated as the end-markets for the products are differentiated. The SMMEs would still be supported with an incubation model for capacity building to ensure the ongoing development of businesses - as the eco-park could potentially produce for small- and large-scale applications there would be scope for growth.

On review with the project advisory team, Scenario 1 was recommended as the most prudent approach. Accordingly, this scenario was developed into a pilot implementation model (details are available in the accompanying Pilot Project Implementation Plan).

4. BAW Value chain

This business model adopts a decentralised, localised model that directly benefits the catchment area in terms of job creation and water security. This approach avoids some of the barriers associated with large scale production, such as transport costs. This document outlines the BAW value chain with the *types* of costs that can potentially be incurred. The input, throughout costs and profitability associated with the business model are listed in detail in the Pilot Project Implementation Plan based on an actual pilot scenario.

A strong coordinated approach has been instilled in the model to optimise clearing and processing activities. As such, the business model feeds into MUCP for the area, which is critical. The business model requires that data related to biomass availability and species distribution is updated and verified on a regular basis and shared with key product value chains. This will ensure the necessary production planning and go-to-market strategies are reflective of available source material. This extends to communication across the value chain should any unforeseen situations arise, which may lead to the non-availability of AIPs biomass. It is critical that feedstock supply, production capacity, and secured market demand, are balanced, with the necessary buffers and redundancies considered.

AIPs are regarded as primary feedstock for the production of BAW, however other utilisable sources exist that the existing technology can be converted to BAW and related products. Although the project scope is specifically focused on BAW production, the BAW processing facilities would be well equipped to also produce compost and related products from biomass that is not suitable for BAW production processes. The complimentary feedstock sources available in the catchment and wider region includes:

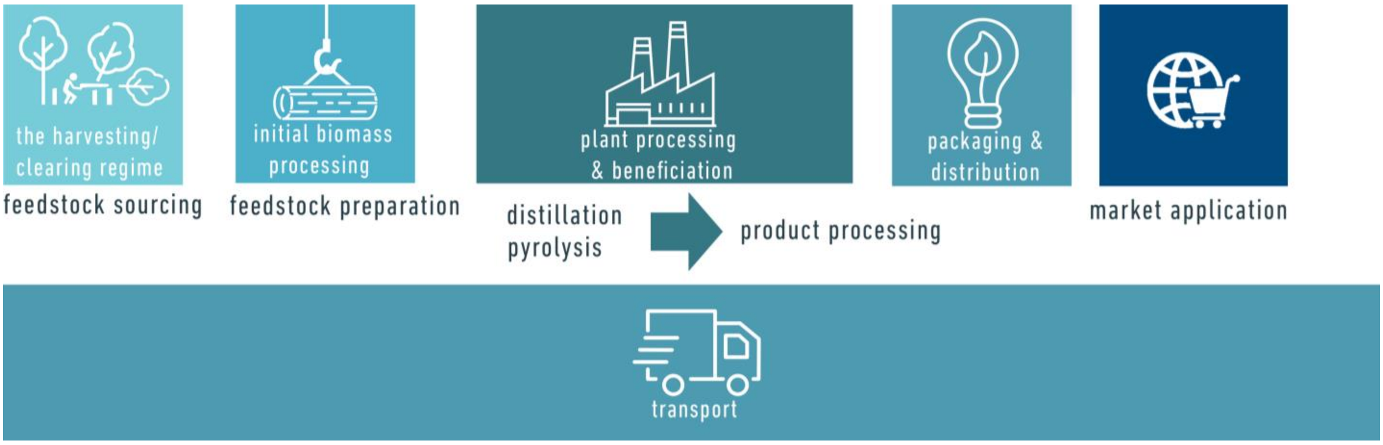
- charcoal sourced from the Western Cape and other provinces that can be enhanced,
- wood chips and related by-products from local sawmills,
- garden waste from farms and households, and
- forestry waste from local plantations.

The proposed model relies on tried-and-tested technologies. Not only will this support the localisation and job creation strategy taking local context into account, but it will also facilitate a more responsive support and maintenance system. This approach ensures a diversified revenue model beyond direct product sales to sales and/or licensing of technology, support and maintenance of these systems and training programmes.

Finally, the model considers the scale of application end-use. Typical customers range from municipalities with large-scale water treatment facilities, to an adaptive model for agricultural application. Suitable end-markets for biomass products have been identified: water purification applications for activated charcoal and soil conditioning and fertilisers for biochar and wood vinegar (WV). The phased approach addresses the need for a more holistic understanding of how to combine various potential uses at different scales and distances to markets, for optimal value to be created to further support clearing and create a water-secure future for South Africa.

In the accompanying slide deck, there are examples of local and international biomass beneficiation practices that are of relevance to this project.

The business model follows a holistic approach and activities are subdivided across the value chain:



4.1 The harvesting/clearing regime

In the case of AIPs, the biomass clearing regime is a key outcome of the business model.

Considerations

The clearing mechanisms are dependent on the location of the AIPs. This will determine the feasibility of mechanical clearing (which requires specialised skilled labour) or whether manual clearing will be required due to lack of accessibility to road infrastructure. Manual clearing is labour-intensive, and at the speed of growth, not optimally effective. The mechanical clearing option is hampered by accessibility, as well as weighing up the unskilled labour employment creation opportunities that can be created in the area at this phase of the value chain.

Activities

A strategic inclusive clearing schedule is the first step to coordinate activities with biomass users. Information needed includes distance from clearing zone to processing centre with this distance decreasing over time. New extraction technologies giving access to additional biomass sources by addressing the challenge of clearing on steep slopes and difficult-to-access riparian areas is needed, such as cable skidders and/or skyline cable yarders. Strategic planning and clearing scheduling could justify additional costs for innovative extraction methods through economies of scale.

Jobs created

Clearing/sustainable removal using a long-term rehabilitation strategy[4], was estimated to, on average, deliver 337 (estimated in 2018)[7] jobs for labourers created over next five years. The type of jobs created includes:

- Chainsaw operator
- Herbicide applicator
- Biomass processing
- Woodchippers
- Mobile wood processing machines
- General worker
- Health and safety officers

[4] Rehabilitation is defined here as the continued actions required for the restoration of an impacted system

- Team supervisor/contractor
  - Driver

Equipment

Specialised equipment may be required

Cost

Wages – The business model proposes that on average clearers are paid R385 per tonne, which might increase to R500 per tonne as the value chain and off-take agreements develop.
Procurement of necessary equipment and Personal Protective Equipment (PPE).

4.2 Initial biomass processing

Considerations

Storage requirements are logistically challenging, given the seasonal nature of alien clearing. Fire hazard needs to be considered, as well as potential blockage of rivers by cleared biomass.

Activities

- Chipping/mulching biomass
- Densifying
- The cleared biomass is processed either on site (dependent on access and location) or transported to local processing facilities.

Jobs created

Truck drivers (truck with crane); Bell operators; tractor drivers.
Further, it will create opportunities for small businesses running the chipping plants.

Equipment

Mobile processing systems (chippers, kilns etc.) to be employed where scale allows, which would improve transport efficiencies of raw biomass needing to be moved by reducing the volume associated therewith.

Cost

Operational costs and vehicle maintenance

4.3 Transportation

Considerations

Transport barriers that have been noted include accessibility of the clearing sites to road or truck access, proximity to tarred roads and proximity to rail. One of the key topics highlighted was road condition. A fair amount of the biomass is hard to reach locations, so a mechanism to remove and process the biomass needs to be considered.
An option to explore is collaborative transport schemes (e.g., several freight trucks or railcars are transported empty through these areas, on the way to collect produce).

Activities

Short distance forestry transport solutions
Long-haul freight (road and rail)

Jobs created

Truck drivers, chipper/mulcher operators. Transport of raw biomass to processing site or primary processing at roadside and then transport to secondary processing site.

Equipment

Trucks, truck with crane, other freight

Cost

Processing close to source and creating processing plant in catchment areas, will mitigate the cost of transport and develop local rural economies.

4.4 Processing

Considerations

The technology solutions currently being used in the market are in principle very similar. However, it is the quality and moisture of product into the processing, as well as the temperature and efficiency of the processing machines that will determine the yields and quality of the output.

Activities

- Processing biomass to BAW and other by-products
- Technology development

Jobs created

- Small contractors with chippers and/or larger contractors with conveyor belt mulchers.
- Engineers
- Mechanics (specify)
- Electricians (specify)
- General workers (Manufacturing, packaging, labelling)

Equipment

Pyrolytic technologies such as kilns at various scales, wood carbonisers, WV extraction, wood gasification.

Cost

Technology hire/acquisition/import

4.5 Packaging and distribution of products

Considerations

Packaging will vary substantially depending on whether it is for bulk products or specialised for retail. This business model has assumed that products will be sold in bulk.

Activities

Sales and marketing, distribution of end-products to market.
Markets identified include municipal and agricultural applications.
Biochar product is packaged via a mechanised process either into 20 kg branded double film paper or polyethylene bags onto pallets as well as double lined branded bulk bags with a 250 kg load capacity. WV is piped from the plant to on-site stainless-steel storage tanks where WV settles by means of sedimentation over a period of 3 months. WV is packaged in 5ℓ and 25ℓ containers which will be palletised for collection or transportation respectively.

Jobs created

- Packaging
- Warehouse logistics
- Packers
- Forklift operators
- Professional business services in relation to product marketing, sales, and distribution.

Equipment

Product is moved via forklift to the facility warehouse on site to meet required handling and storage criteria per specified material safety data sheets (MSDS). Bulk storage Intermediate Bulk Container plastic tanks of 1000ℓ will also be utilised for bulk orders and for safe handling and distribution.

Cost

- Wages
- Health and Safety
- Emergency response preparedness
- Freight and warehousing

5. Market intelligence

Priority market needs and applications have been identified as water purification and soil conditioning with a focus on breaking import dependency by the replacement of imported BAW products with local products.

Biochar

- Typically found in soil from vegetation fires & historic soil management practices.
- Can be an important tool to increase food security and cropland diversity.
- Improves the soil's water quality and quantity by increasing soil retention of nutrients and agrochemicals.

Market Value

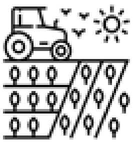
The global biochar market size in 2018 was worth **USD 1.3 Billion** whilst estimated **demand was 395.3 kilo tonnes**.

Source: Grandview Research

- Sustainable biochar practices can produce oil and gas by-products that can be used as fuel for clean, renewable energy.
- Biochar and bioenergy co-production sequesters carbon in stable soil carbon pools and may also reduce emissions of nitrous oxide.
- Multiple applications in various fields, with key outcome of enriched soil for improved yield and nutrient content.[8]

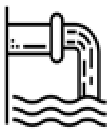
APPLICATION OF BAW PRODUCTS

Agriculture



- Local agricultural market is relatively small with predominantly organic farmers utilising biochar for soil conditioning. This option becomes more viable if a market can be developed.
- Experts expect a market growth of 12 to15 % per annum. However, these off-takers are looking for specialised and high-quality products.
- Domestic markets could include farmers growing grapes, blueberries, dates, livestock, dairy, or mushrooms.[9]
- Pasture restoration. Considering the role of dairy farming in the region (Karatara Catchment) this procedure may be of interest: It involves feeding biochar to livestock and allowing dung-beetles to distribute and bury the biochar-loaded faeces. This has the dual benefit of soil conditioning as well as increased feed-usage efficiency and weight gain of cattle.
- With global interest in low-nitrogen fertilisers there is opportunity for biochar and wood vinegar as fertiliser.

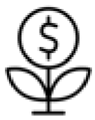
Water purification



Current processes that require biochar and activated carbon, such as water recycling, largely rely on imported sources, which are accompanied by considerable carbon emissions because of transportation. **Locally produced alternatives will have a much lower carbon footprint due to the reduced distance from source to use.**

- The use of biochar for the treatment of municipal stormwater and wastewater
  - An example of applicability is the Knysna Sustainable Drainage Systems – SuDS project - a (current) revegetation project[10] which includes tree-clusters for stormwater treatment being planted on layered substrate of builders' rubble, **biochar**, and compost.

Activated carbon



Market Value

- Higher value commodity[11] that lends itself to scale.
- **Presents an elegant solution** with removal of alien vegetation to create activated carbon for water purification.

The global activated carbon market size is projected to reach USD 14 Billion by 2027.

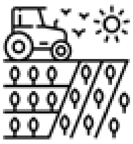
Source: Grandview Research

Drivers of demand

Short term	Long term
• The high demand for activated carbon is anticipated to grow due to the demand in mercury control technology for industrial air purification applications • Due to higher prices of powder activated carbon and granular activated carbon imported products, increasing demand will be placed on securing product from local companies. • The need for carbon offset credits by corporations in the South African market will become a driver for local producers to register projects to enable access to the carbon credit economy and contribute to carbon sequestration.	Research and development activities of activated carbon producers enable them to develop better products for specific applications such as for hydrogen sulphide removal, while competing with the existing products offered by competitors such as powder activated carbon and granular activated carbon for water filtration and purification, food, and beverage industry as well as the health and beauty sector applications.

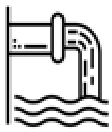
PRODUCT APPLICATIONS

Agriculture



- Current uptake of wastewater treatment in the agricultural sector is relatively limited. However, internationally, food and beverage companies are increasingly seeing the benefits of creating value from wastewater. This is largely driven by a growing pressure to meet or exceed environmental standards, tightening wastewater regulations, increasing water stress and the risk of brand damage if local communities are affected by their wastewater. The re-use of wastewater or cascading use of water aligns with the associated policies of the Western Cape Government (specifically the Sustainable Water Management Plan).

Water purification

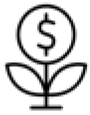


Current processes that require biochar and activated carbon, such as water recycling, largely rely on imported sources, which are accompanied by considerable carbon emissions because of transportation. **Locally produced alternatives will have a much lower carbon footprint due to the reduced distance from source to use. Examples include:**

- Mining: adsorption for mining sludge treatment [12]
- Municipal: George Municipality in collaboration with the Water Institute of South Africa (WISA) implemented an ultra-filtration plant (2010) which converts wastewater to potable water using a number of filtration mediums, one of which is activated carbon.
- In 2000, the town of Suurbraak in the Western Cape faced a serious issue regarding poor drinking water quality for its rural communities. A drinking-water treatment process was developed where a membrane- based process was uses for pre-treatment, upflow filtration and activated carbon filtration.[13]
- Point of use (domestic water filters). As conscious consumers are more inclined to plastic- or waste-free lifestyles these are becoming more commonplace. Lifestyle markets would be a good entry point.
- There is also interest in the use of water purification devices to deliver clean water to rural communities, where the supply of treated and purified water is limited or non-existent.[14]

Wood vinegar

- Higher value commodity[15]
- Multiple applications in various fields, with key outcome of enriched soil for improved yield and nutrient content.



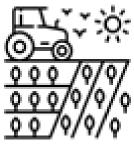
Market Value

The global wood vinegar market is projected to reach USD 6.7 Million by 2022

Source: NewsWire

PRODUCT APPLICATIONS

Agriculture



Pesticide

- Pesticide against two species of rice hoppers[16], cowpea weevil[17], rice brown plant hopper[18], armyworm[19]
- Pesticide against red mites in poultry farming[20]
- Antifungal/antibacterial agent against seven fungal and three bacterial species[21 22 23]
- Animal feed for weanling pigs[24]

Soil conditioning

- Some research has indicated that fruit yield was increased with co-application of both biochar and wood vinegar and nutritional quality had been improved (e.g., increased vitamin C and decreased titratable acidity)[25]
- Critical factors that influence **productivity in blueberry cultivation** include water quality, climate, as well as **well-drained and semi-acidic soils**. Many growers that do not have access to these soils often plant their blueberries in bags or containers with substrate mixes of any of the following materials: pine bark, sand, cocopeat (coir) and perlite.[26] Wood vinegar could be an additional additive to improve yield
- Export market for blueberries from the Western Cape is established in the UK and EU, with current attempts to try and expand the Asian market to Japan, Taiwan, and South Korea.[27]

Table 5 Market interest

Product	Average local price	Average international price	Use	Detail	Interested parties
Biochar	R13,00- R17,00 /kg	R34,00 /kg	The use of biochar for the treatment of municipal stormwater and wastewater.	Sustainable Drainage Systems – SuDS - (Knysna) - a (current) revegetation project which includes tree-clusters for stormwater treatment. The vegetation is being planted on layered substrates: builders' rubble, biochar, and compost.	Local, district and metropolitan municipalities.
			Pasture restoration	Considering the role of **dairy farming in the region** (Karatara Catchment) this procedure may be of interest: It involves feeding biochar to livestock and allowing dung-beetles to distribute and bury the biochar-loaded faeces. This has the dual benefit of soil conditioning as well as increased feed-usage efficiency and weight gain of cattle.	Organisations that have indicated an interest in investigating the benefits of biochar
			With global interest in low-nitrogen fertilisers there is opportunity for biochar and wood vinegar as fertiliser.		Organisations that have indicated an interest in investigating the benefits of biochar
			Animal feed	Localised trials have been undertaken with sheep to validate market literature where this form of supplement has been shown to provide improved feed conversion rates and healthier rumen.	
Wood vinegar	R 150,00 /ℓ Bulk R 225,00 /ℓ Small	R 359,00 /ℓ	For wood vinegar, agricultural uses have been identified that can be explored to establish a robust local market for wood vinegar.	Pesticide against two species of rice hoppers, cowpea weevil, rice brown plant hopper, armyworm Pesticide against red mites in poultry farming Antifungal/antibacterial agent against seven fungal and three bacterial species Animal feed for weanling pigs	
Biochar/Wood vinegar			Soil enrichment and substrate	Research has indicated that fruit yield was increased with co-application of both biochar and wood vinegar and nutritional quality had been improved (e.g., increased vitamin C and decreased titratable acidity)	Potential interest from berry producers

Activated Carbon	R24,00- R33,00 /kg	R 37,00 /kg	Water filtration and purification.	Activated carbon is currently the most widely used example of purification substrate that incorporates nanoscale features and tailorable chemical properties. It is often applied for POU? devices, with many commercial systems utilising this material for home applications.	
			Agri-processing	Current uptake of wastewater treatment in the sector is relatively limited. However, internationally, food and beverage companies are increasingly seeing the benefits of creating value from wastewater. This is largely driven by a growing pressure to meet or exceed environmental standards, tightening wastewater regulations, increasing water stress and the risk of brand damage if local communities are affected by their wastewater.	Local, district and metropolitan Municipalities.
			Mining sector	Adsorption for mining sludge treatment	
			other uses	Cosmetics Health Wine fining Food and beverage	

Note:

Identifying a willing buyer was not required as the City of Cape Town has indicated their willingness to buy by putting out a tender for water purification application of biochar.

It has been demonstrated through engagement with local seedling growers that there is local interest and willingness to purchase wood vinegar from the technology provider. WV has already been purchased by and supplied to several growers in the Western Cape over the last 12-month period. These are relationships which have developed over time and the application and use of our wood vinegar in their operations has resulted in additional orders.

The demand for biochar to be utilised in the agricultural sector has been evidenced by direct engagement of local farmers and growing medium suppliers for the purchase of biochar from the technology provider. Engagement has been through site visits and emails substantiated by Requests for Quotations and the subsequent issue of quotations for purchase.

Product	Market Segment	Tonnage/ CBM	Pricing
Biochar Wood Vinegar	Organic Fertiliser Organic Fertiliser	10 CBM / 1.5 Tons Monthly 5000 Lt Monthly North West	R3000 / CBM R25 / Lt
Powder Activated Carbon	Water Filtration/ Purification	10 Tons Monthly Corporate - JHB	R23000/ Tonne
Powder Activated Carbon	Water Filtration/ Purification Municipal (Local)	45 Tons Monthly Local CPT	R23000/ Tonne
Wood Vinegar	Topical application- Seedlings Germination - Paarl		

6. Risks & Barriers

RISK	IMPACT
Cost of clearing/harvesting	Severe
Accessibility of biomass and transport constraints	Moderate
Landowner interests	Moderate
Lack of financing channels	Moderate
Lack of comprehensive data mapping (location, volumes, and species)	Severe
Unreliable feedstock supply	Severe
Lack of central coordinating hub	Moderate
Localised quality control and testing facilities	Moderate
Quality implications for end-products, based on AIP input	Severe

- Poorly mapped and captured data: On the state of AIPs spread continues to be a barrier. It is essential that data related to biomass availability and species distribution is updated or groundtruthed on a regular basis and shared with key product value chains. This barrier limits the determination of the location of AIPs and their densities within the catchment, which necessitates the reliance on field knowledge of existing alien clearing operations managers (such as Knysna Municipality, Southern Cape Fire Protection Association etc.) to inform the clearing regime for the pilot project implementation plan. This barrier creates challenges for creation of an overall clearing regime and for confidently estimating the cost of clearing the entire catchment at this stage.
- Transportation: Barriers have been noted include accessibility of the clearing sites to road or truck access, proximity to tarred roads and proximity to rail. One of the key topics highlighted was road condition. A fair amount of the biomass is in hard-to-reach locations, where novel mechanisms to remove and process the biomass would be needed.
- Technology affordability**:** Initial capital outlay for production systems is inhibiting small start-ups and even more major operations are finding the cost to be prohibitive. A robust business model must take consideration of ownership models that enable localised beneficiation. The capital outlay needs to be addressed, possibly considering leasing, or shared and partnering models. Consideration should be given to separating primary and secondary processing. A mobile unit could be owned by a small entrepreneur out in the field, while the primary technology that manufactures the BAW is centralised.
- Market access: Individual producers and co-operatives of producers face a significant challenge to enter the market due to the need for market access and visibility and not necessarily having the

economies of scale to build a reputation in the industry. Consistency of supply, quality and reputation are key.

- Availability of skills: Of consideration should be the required engineering and technical skills to manufacture the final product (and quality management) as well as that needed in clearing and processing.
- Ownership of biomass: Complexities arising from the ownership of cleared AIPs biomass should be considered.

7. Socio-economic impact

In order for a locally driven, green recovery to be realised, SMMEs across the value chain need to be included in the business model for biomass beneficiation. With a 32% unemployment rate[28], the catchment is in dire need of programmes that create additional employment opportunities. Opportunities include the establishment of clearing cooperatives, forestry transport services for primary processing, and the upskilling of local industries for skilled jobs.

Job creation and expansion

To ensure positive economic development and impact to the Karatara catchment, active inclusion of SMMEs in the business model is essential. It is suggested that preference be given to impact driven small businesses that can play a myriad of roles in the supply chain - from clearing initiatives that may be developed with EPWP, through to product distribution models. A phased approach that takes advantage of quick wins by first focusing on existing SMMEs that have had to retrench staff linked to forestry sector decline and the impacts of the coronavirus pandemic will accelerate the process. Later phases will be supported by an incubation model for local SMMEs that makes use of established institutions in the area.

Phase 1: Support existing SMMEs

Phase 2: Expanding existing SMMEs and their offerings

Phase 3: Creating new ventures

The portfolio of SMME opportunities has been limited to those directly connected to the scope of work.

1. Harvesting AIPs
2. Chipping and mulching
3. Transport harvested biomass to processing plant
4. Supplying BAW products to nurseries
5. Seed balls using biochar
6. Repacking of biochar with vegetable seed packs
7. New growing programs that make use of biochar
8. Decentralised bush-charcoal makers

The job creation potential can be unlocked by a holistic approach to beneficiation, considering the value chain both up- and downstream. Several factors need to be considered which may impact the job creation potential of the BAW value chain:

- Complexity and length of the value chain.
- The quantum of utilisable biomass and production capacity of processing and manufacturing.

- The level of mechanisation of the harvesting regime and production processes.
- Technology applied in manufacturing of BAW.
- Availability of necessary skills such as required engineering and technical skills to manufacture the final product (and quality management) as well as that needed in harvesting and processing; and
- BAW market conditions and the size of off-take.

The table below provides a high-level summary of job creation potential at various points in the value chain.

Table 6 Job Creation Potential

Value Chain Component	Clearing Operation	Harvesting and transport to roadside	Processing & Logistics/Transport (At all intersects)	Manufacturing & Packaging	Marketing & Business Services
Stakeholder/Employer/ Business Type	Knysna Municipality SANParks CapeNature Private Landowners DFFE - NRM Western Cape Department of Agriculture (LandCare) Southern Cape Fire Protection Association	Private forestry transport companies	Transport & logistics companies (freight forwarding etc.) Forestry primary processing contractors	Technology owners/BAW manufacturers	BAW producers Marketing and sales agents
Direct Job opportunities	Chainsaw operator Herbicide applicator Biomass processing Woodchippers Mobile wood processing machines General worker Health and safety officers Team supervisor/contractor Driver	Truck drivers (truck with crane); Bell operators; tractor drivers.	Truck drivers, chipper/mulcher operators. Transport of raw biomass to processing site or primary processing at roadside and then transport to secondary processing site. Small contractors with chippers and/or larger contractors with conveyor belt mulchers.	Engineers Mechanics (specify) Electricians (specify) General workers (Manufacturing, packaging, labelling)	Professional business services in relation to product marketing, sales, and distribution.
Indirect benefits to local SMMEs	PPE suppliers; Tools, machinery, and equipment suppliers; chainsaw/machinery maintenance, servicing, and repairs; Vehicle rental; Consumables – parts, spares, fuel, oil etc	Vehicle and machine maintenance, repairs, consumables etc	Vehicle and machine/plant maintenance, repairs, and consumables.	Input suppliers (components for technology). Service and maintenance. Product branding & packaging specialists.	Business support services
Work Opportunities Estimate	31 500 per annum*	To be concluded	To be concluded	To be concluded	To be concluded
Skills requirement	Valid chainsaw operator certificate; Pest Control Officer; Health and safety training; first aid training; Herbicide applicator training; Valid driver's licence	Bell, tractor, and heavy truck drivers' licences	Semi-skilled (chipper operators) to skilled (mulcher and grinder operators)	Skilled and semi-skilled	Skilled
Wage band (per day)	<R170 -R430>	<R170	<R464	< R170	<R 500

*Work opportunities estimates are based on Knysna Municipality three-year AIP clearing budget and EPWP reporting target only. Note that these are person day jobs in terms of public employment programme methodologies for calculating what constitutes a work opportunity.

SMME Incubation

SMMEs will be supported through supplier development programmes focusing on building supply chains that are beneficial to localised small businesses and aligned to the green economy. The identification, training, and support of these local entrepreneurs will be key in being able to uplift and empower.

SMMEs across the value chain can be capacitated through an incubation model realising a holistic approach to the development of their business, from technical expertise to basic business skills to market development. Potential incubator partners include:

- The South African Breweries (SAB) Foundation
- South Cape College
- Nelson Mandela University George Campus (Previously Saasveld)
- GreenCape / South African Renewable Energy Business Incubator (Sarebi)
- Cape Agency for Sustainable Integrated Development in Rural Areas (CASIDRA)
- Technical Vocational Education Training (TVET) Colleges
- Small Enterprise Development Agency (SEDA) / Department of Small Business Development
- Knysna Municipality Local Economic Development (LED) department

The Knysna Municipality has run an incubator programme over the last decade that could ideally support this incubation approach. The Knysna Municipality's LED department, SEDA, CASIDRA and other partners already have the basic SMME incubation proposition and curriculum in place. Corporate partners (Nedbank, SAB etc.) can also fund specific, customised "biomasspreneur" incubation.

The details can be developed based on the identified and future potential needs of the product value chain, as they evolve - these can incorporate clearers to processors and pilot-scale producers. Experience suggests that the timeframe of an incubation programme to produce tangible results is a minimum 18 months per intake. Funding for incubation could come from government or private sector partners or a combination of both, as has been the case with the Knysna Municipality LED programme.

8. Funding Models

There are several investment requirements for unlocking the full value of the value chain, that, while outside the direct costs, will be the difference between success and failure. Specialised or impact funding may be the best route to explore. The focus is on **cultivating a low carbon economy.** This can become a key and effective driver for the private sector to invest in the biomass value chain.

The various costing models for the business model include consideration of:

- Subsidised feedstock arising from government investment in clearing alien invasive plants e.g., the public works programme.
- Commercially funded harvesting (no government subsidy, manufacturer pay Rx per tonne). This is also highlighted as a potential risk regarding ownership of AIP biomass after clearing.
- Incorporating the cost of clearing through "biomasspreneurs" into the value of the resulting products.
- Transactional mechanisms associated with the products, and beneficiaries.
- Carbon funding
- Impact investment

Payment for Ecosystem Services

Payment for Ecosystem Services (PES) opportunities with the local municipalities where the water gained through alien clearing could be offset through a payment scheme that re-invests in further ecosystem restoration activities must be explored. In the Keurbooms and Karata Catchment, the business case for PES has outlined possible economic instruments that are feasible. However, the exact location and community, as well as the proposed end market for the product will determine final implementation. For a successful PES programme, the financial incentives as well as ecological benefits need to be realised. For AIP clearing in the area, the specific PES instruments proposed[29] include:

Water tariffs - AIP clearing water charge Best case, the cost of clearing provides a minimum water charge which is equivalent to R1,00 /kl. Estimated potential value of additional water: between **R25,1 and R307,3 million per year.**	**Disaster regulation - Fire risk premium.** Removal of AIPs will mitigate the fire risk in the area = reduce insurance risk premiums. Dependant on cooperation amongst landowners as well as between landowners and a collective of insurers.	**Habitat support - Alien Clearing Incentive** A contentious approach. Suggests biodiversity credit trading, which could realise the benefits that are indirect to economic decision-making, such as ecosystem integrity and indigenous species resilience.

Carbon financing for BAW

Carbon trading and tax can develop an alternative revenue stream for the Karatara and Keurbooms community. Carbon finance could provide a dual source of income and investment; firstly, from the sale of carbon credits, most notably in the Voluntary Emissions Reductions (VER) market, and secondly from Corporate Social Responsibility (CSR) and Environmental Social Governance (ESG) financing of one or more business enterprises within the BAW production value chain.

Carbon credits

For BAW production activities to access carbon finance, project registration needs to take place under the Verified Carbon Standard (VCS). The VCS has an existing soil carbon methodology that is applied and a VCS methodology for biochar and related products is in the process of being developed. It is expected that there will be some overlap between the new biochar methodology and the existing soil carbon methodology, however the biochar methodology is only set to be completed by September 2021.[30] Once the VCS biochar methodology is in place a better estimate will be available for the value of a carbon credit per ton of biochar, activated carbon or wood vinegar applied.

- The qualifying emissions reduction activity is the application of the product (i.e., BAW) and not simply production thereof.
- The VCS requires that transparent communication and engagement takes place with members of the public or any stakeholder directly affected (whether positively or negatively) by the BAW production process and product application. The principle is that **no nett harm** (social, environmental, economic) is caused by a VCS certified project.
- The emissions produced during the biochar production process will also be accounted for in the new biochar methodology currently in development stage. It is estimated that, in terms of the existing VCS soil carbon methodology, a carbon credit is worth approximately R350 per tonne biochar or activated carbon applied.

Carbon Tax

Carbon Tax Act was promulgated in June 2019. Provision is made for a range of phase-in allowances. Government activities appear not to be exempt *prima facie*, but the Commissioner is empowered to prescribe modifications to the implementation by publication of rules.

Mitigation and offsets: Biochar in the soil reduces atmospheric greenhouse gases by at least four mechanisms:

- Perdurable sequestration of atmospheric CO_2 in the form of recalcitrant elemental quasi-graphitic carbon in the soil.
- Cycled sequestration of atmospheric CO_2 in the form of the carbon fraction of incremental quantities of plant material and macro- and microbiota.
- Reduced emissions of CH_4 and N_2O from soil.
- Reduced emissions of Green House Gasses (GHGs) attributable to the reduced or eliminated consumption of synthetic fertilizers and fossil fuels for tilling.

Carbon sequestration opportunities

Alien vegetation biomass is considered to be carbon neutral[31], which is increasingly important for industries that need to offset their carbon footprint. Biochar production could have global potential for annual sequestration of atmospheric CO_2 at the billion-tonne scale per year, within 30 years. It is identified, however, that the underlying evidence arises mainly from small-scale studies that do not support generalisation to all locations and all types of biochar (Sohi et al., 2009). The case for carbon sequestration depends on several variables and requires a source to sink systems evaluation. AIPs are mapped against the Carbon Sinks Atlas (CSA), a web-based data and information tool aimed at providing spatial distribution of carbon stocks and fluxes across South Africa.

Carbon offset

National government has been requested, in terms of the Carbon Tax Act, to introduce norms and standards for a South African carbon trading mechanism. One of the outcomes of this process could enable the exchange of carbon credits on the Johannesburg Stock Exchange (JSE) and trading opportunities in the ESG market in future.[32]

9. Recommendations

- A key recommendation from this project is that the budget allocation for the pilot project must include commissioning of a further detailed, fine scale AIP density assessment at both compartment-level (MUCP) as well as cadastral-level in the Karatara catchment.
- The prospective density assessment must include cadastral-level data, such as property ownership, and willingness to participate in clearing initiatives, to aid the planning of the alien clearing priorities, compliance monitoring, and follow-up clearing and ecological restoration work.
- The proposed model relies on tried-and-tested technologies. Not only will this support the localisation and job creation strategy taking local context into account, but it will also facilitate a more responsive support and maintenance system. This approach ensures a diversified revenue model beyond direct product sales to sales and/or licensing of technology, support and maintenance of these systems and training programs.

Acronyms and initialisms

Abbreviation	Definition
AIP	Alien Invasive Plants
BAW	biochar, activated carbon, and wood vinegar
CSA	Carbon Sinks Atlas
CSR	Corporate Social Responsibility
DEADP	Department Environmental Affairs and Development Planning
DEDAT	Department Economic Development and Tourism
DFFE	Department of Forestry, Fisheries, and the Environment
EI	Ecological Infrastructure
EPWP	Extended Public Works Programme
ESG	Environmental Social Governance
GHG	Green House Gas
JSE	Johannesburg Stock Exchange
LED	Local Economic Development
MAR	mean annual run-off
MSDS	Material Safety Data Sheets
MUCP	Management Unit Control Plans
PES	Payment for Ecosystem Services
PPE	Personal Protective Equipment
SANParks	South African National Parks
SuDS	Sustainable Drainage Systems
RFQ	Request for Quotation
VAI	Value-added industries
VCS	Verified Carbon Standard
VER	Voluntary Emissions Reductions
WMA	Water Management Authority
WV	Wood vinegar

Glossary of terms

Term	Definition
Activated carbon	Is characterized as a carbonaceous material with a highly porous internal structure, which is usually derived from the pyrolysis and chemical treatment of sources including wood, coal, nutshells, bamboo,

	and other organic materials. The activation process, usually performed at high temperature by chemical or steam treatment, generates an extensive porous network within the carbonaceous material
Biochar	Biochar is manufactured by burning various organic material in a reduced or oxygen free environment through a process of pyrolysis. The product can be used as an energy source, used in water treatment, added to animal feed and chicken litter, and in many other applications. One of the main interests in biochar globally is in its potential to be applied to the land, thereby both capturing the carbon in the biochar for extensive periods of time, and at the same time improving soil quantity whilst facilitating plant growth.
Coppicing	Coppicing is a traditional method of woodland management which exploits the capacity of many species of trees to put out new shoots from their stump or roots if cut down. In a coppiced wood, which is called a copse, young tree stems are repeatedly cut down to near ground level, resulting in a stool. New growth emerges, and after a few years, the coppiced tree is harvested, and the cycle begins anew.
Ecosystem services	Benefits people obtain from ecosystems. These include provisioning services such as food, water, timber, and fibre; the regulating services that affect climate, floods, disease, wastes and water quality; cultural services that provide recreational, aesthetic, and spiritual benefits, and supporting services such as soil formation, photosynthesis, and nutrient cycling.
Green recovery	An economic recovery (post-covid) based on environmental and social benefit
Hive approach	An approach to collaboration where the industries function like a hive. Close proximity. Based on the idea of a hive industries.
Industrial symbiosis	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).
Invasive alien plants	The top 10 invasive alien plants affecting the Western Cape are: Rooikrans Black wattle Port Jackson Silky hakea Long-leafed wattle Stinkbean Australian myrtle Spider gum Cluster pine Blackwood
Rehabilitation	The continued actions required for the restoration of an impacted system
Restoration	The renewal of ecological functionality (in this report restoration is synonymous with IAP clearing)
Wood vinegar	This term (henceforth abbreviated to WV) is the default and is useful in the current report, but elsewhere it may be referred to as “pyrolysis liquids… pyrolysis oil, bio-oil, bio-crude-oil, bio-fuel-oil, wood liquids, wood oil, liquid smoke, wood distillates, pyroligneous tar, pyroligneous acid, and liquid wood” (von Doderer, 2012). The WV will be extracted from the process at the specified temperatures to meet specific product application specifications.

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