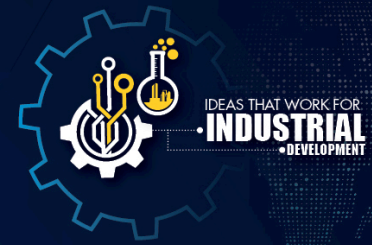


CSIR contributions to maximising the value of industry waste

Prof. Bruce Sithole

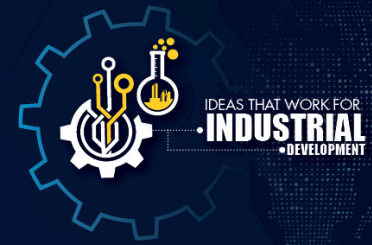
The CSIR in the waste R&D space



- The CSIR undertakes independent –
 - **Contract research**
 - **Specialist advisory support**
 - To government, industry and society, that –
 - Supports decision-making, policy development and strategy formulation, and
 - Facilitates South Africa's transition towards a green economy, embracing the principles of the waste hierarchy and of a circular economy

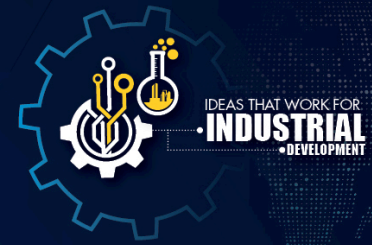


Research on industrial waste



- Current **waste research themes** include –
 - Integrated waste management
 - Waste and resource economics
 - Waste innovation (technological and non-technological)
 - Waste data and information
 - New value chains from organic waste

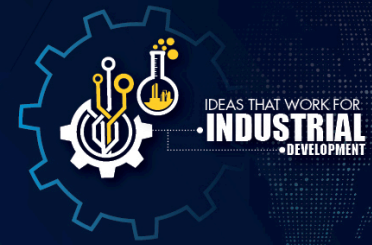
Value of waste as a resource



- Estimated resource value of the waste is R25.2 billion per annum (0.86% of GDP)
 - Recycling at $\pm 10\%$ (as at 2011 baseline) unlocked R8.2 billion/year worth of resources into the South African economy
 - There is potential to recover a further R17 billion per annum worth of resources back into the economy

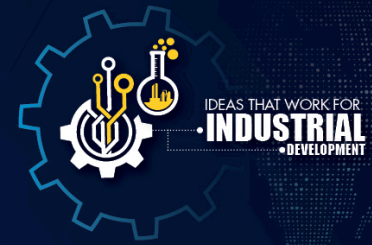
Note: 13 potentially recyclable waste streams generated in South Africa

Challenges in beneficiating industrial waste



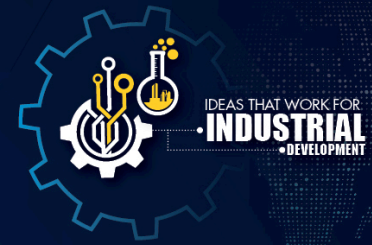
- Often not separated at source resulting in contamination and loss of value
- Expensive to transport due to high hazard rating
- High-tech solutions required
- High skills levels required to manage/operate facilities responsibly
- Large volumes of relatively low hazard waste far from markets
- Transport costs is often limiting factor to reuse/recycle
- Legislative barriers to reuse/recycle

How to beneficiate waste in SA



- Supply side
 - Investment in infrastructure for collection of waste
 - Creating entrepreneurial opportunities
 - Implementing policies and incentives to encourage beneficiation
- Demand side
 - Innovative uses of recycled materials in SA
 - Development of innovative new high quality products from waste
 - Biorefinery technologies
- Examples of CSIR R&D activities follow

Wastes in the forest products industries



Sawdust



Fly ash



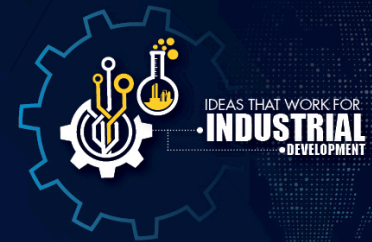
Sludge



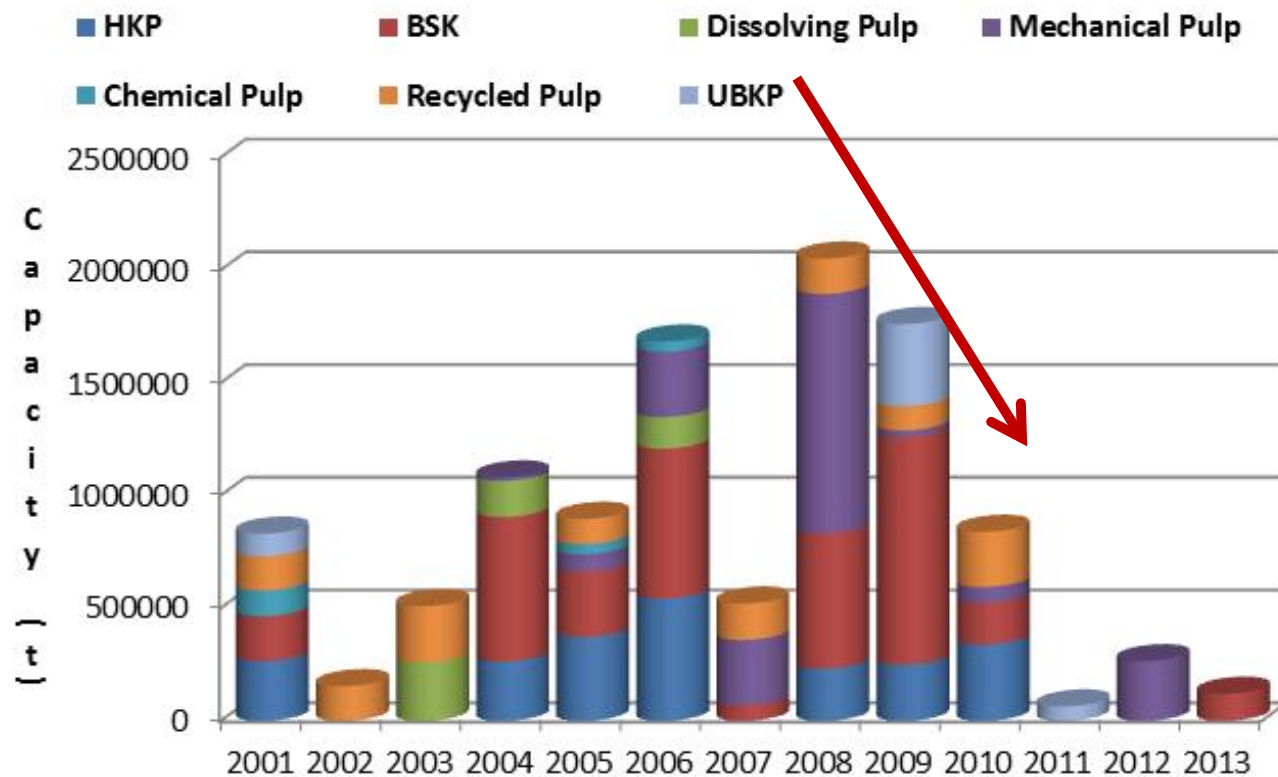
Bark



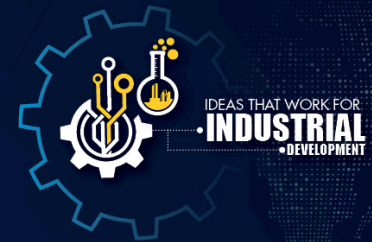
Production decline and job losses in the forestry industry



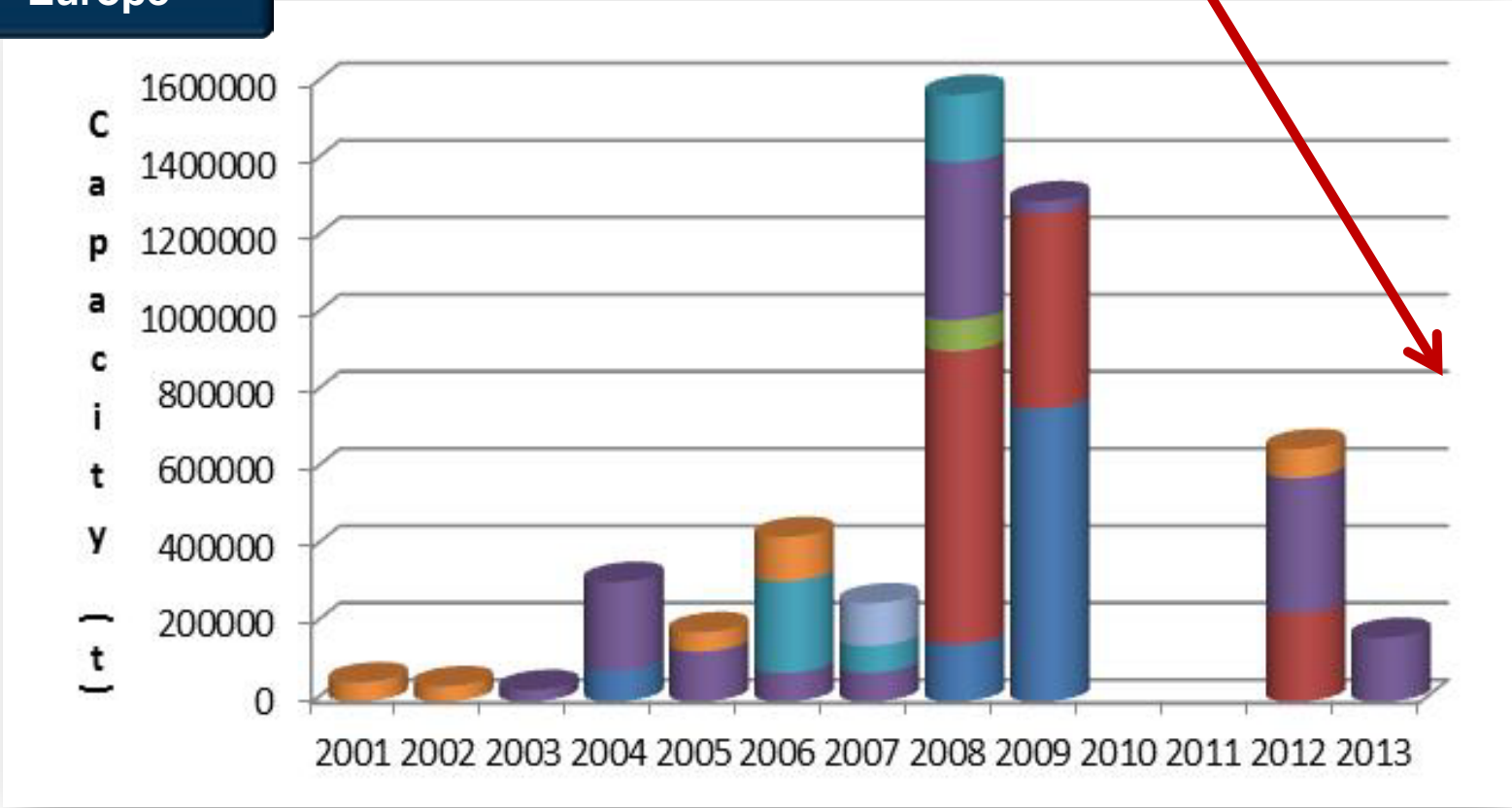
North America



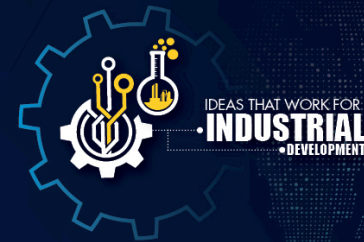
Production decline and job losses in the forestry industry



Europe



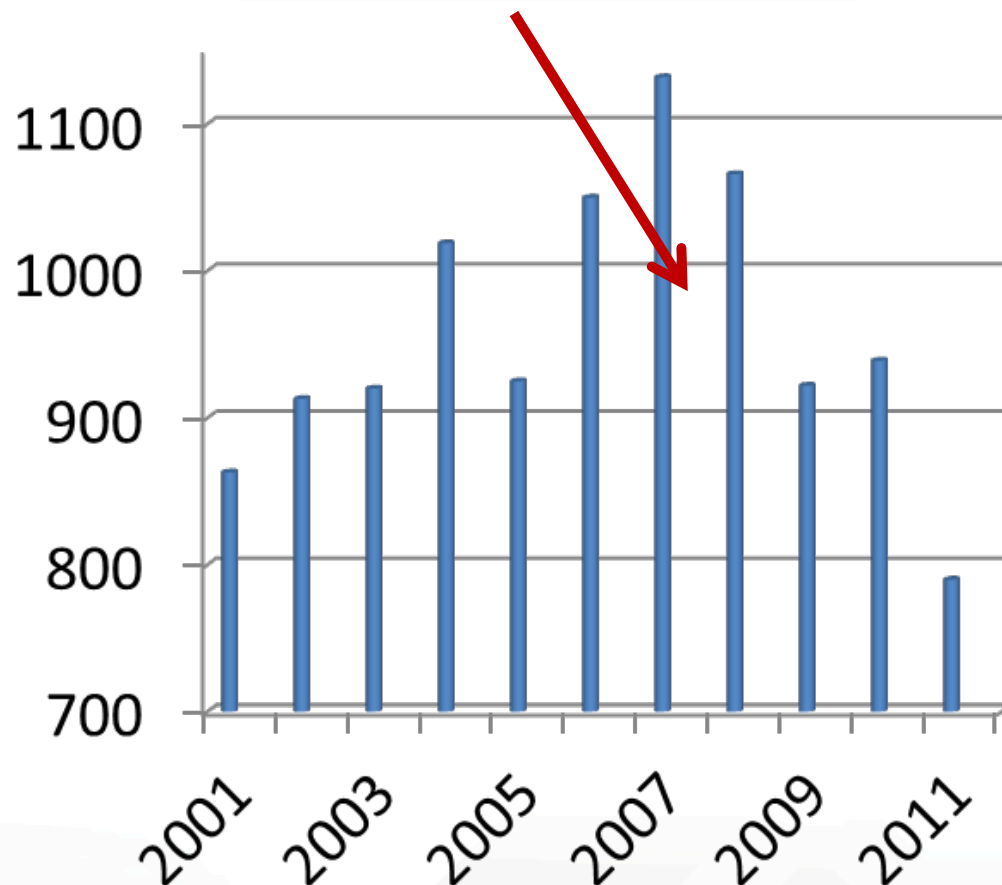
Production decline and job losses in the forestry industry



South Africa

Printing and writing papers

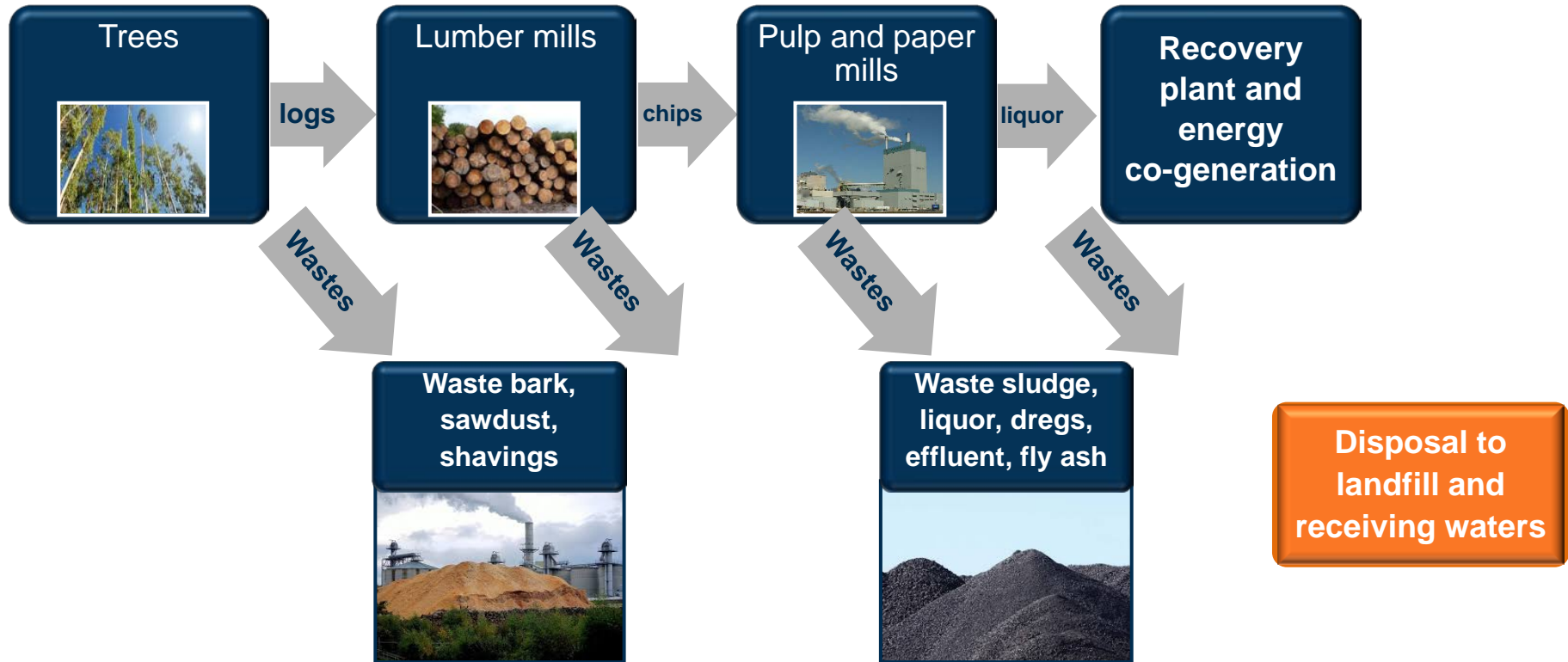
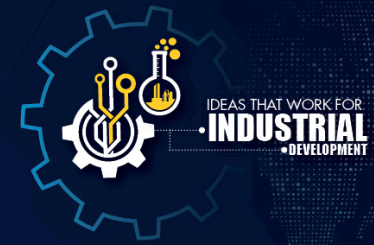
Production, tonnes



Reasons for closure

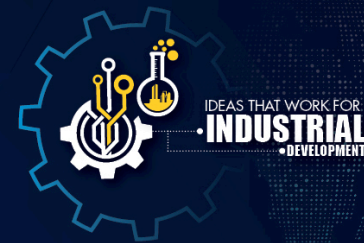
- “in response to difficult market conditions and the continuing rise of input energy, water, and fibre costs”

Current forestry sector technology is wasteful; limited products



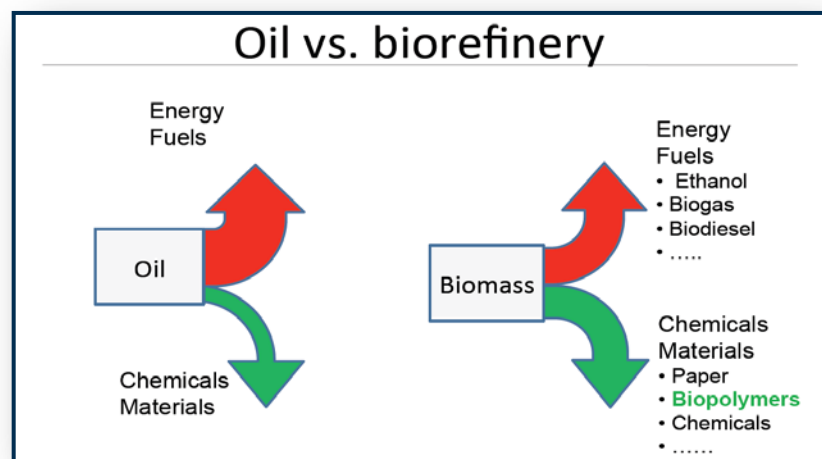
- Extracting only 47% value from trees
- A highly inefficient use of a natural resource

How to revitalise the industry

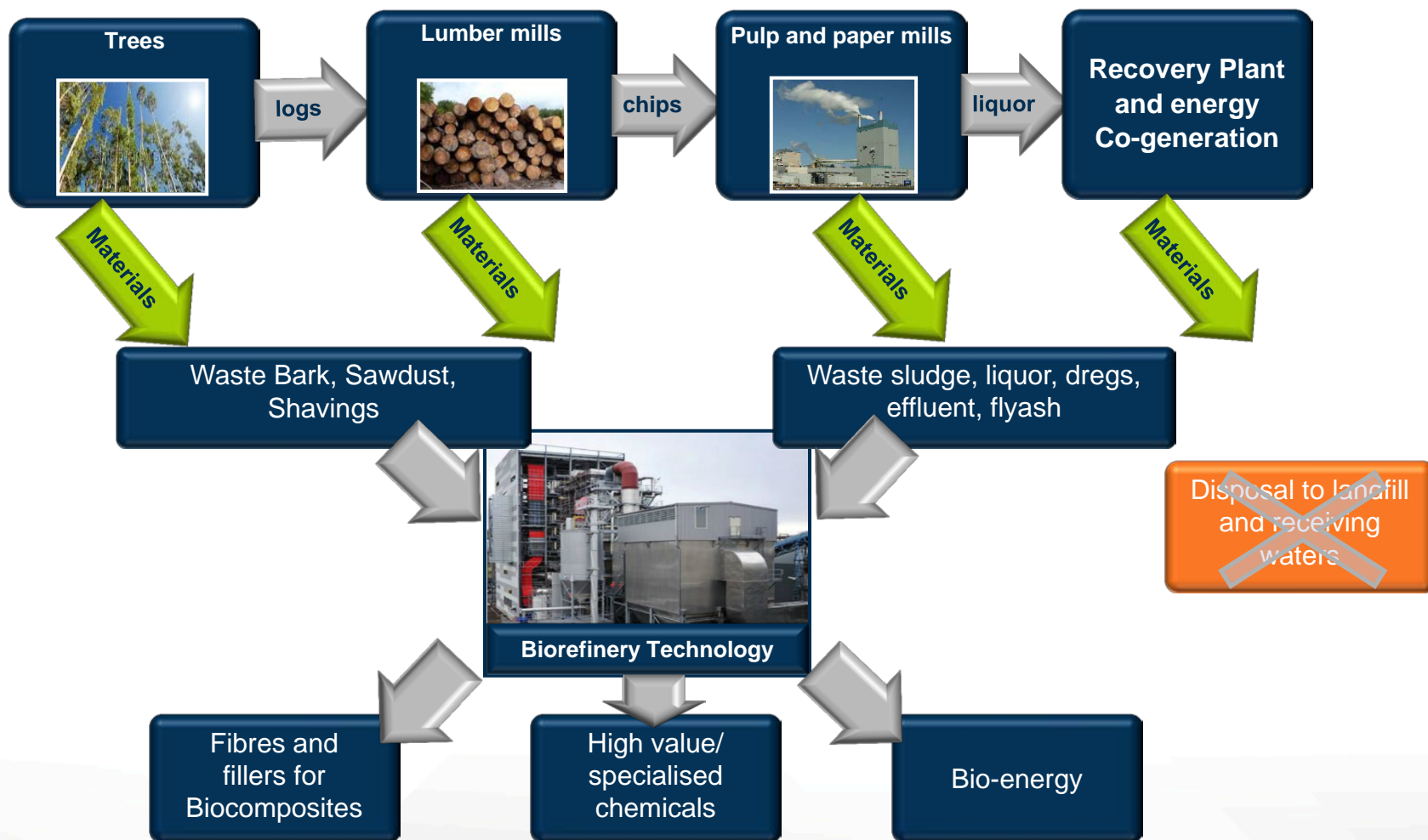
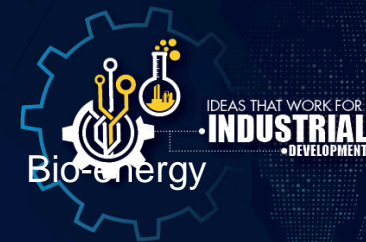


Biorefinery

- A facility that integrates biomass conversion processes and equipment to produce fuels, power, and chemicals from biomass
- Analogous to today's petroleum refineries, which produce multiple fuels and products from petroleum
- Identified as the most promising route to the creation of a new domestic bio-based industry



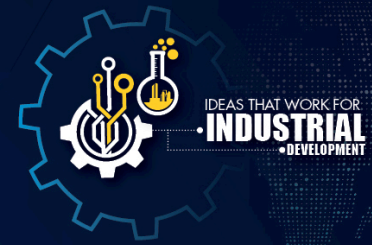
New forestry sector technology is efficient with many diversified products



> 90% tree utilisation

Diversification of products

New value streams: Valorisation of saw dust



- **Extraction of saw dust to obtain a variety of marketable chemicals**
 - Xylose for conversion to xylitol. In the South African market xylitol sells for approximately R150/kg and demand is increasing
 - A company in South Africa imports 20 tons of pine oil every 3 weeks and sells the product on the local market for approximately R40-60/kg
- **We want to enable local production of valuable chemicals**
- **We are working with SMMEs for uptake of the technologies**



Xylitol

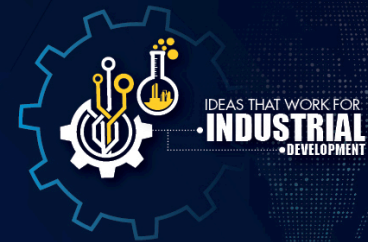


Saw dust



Pine oils

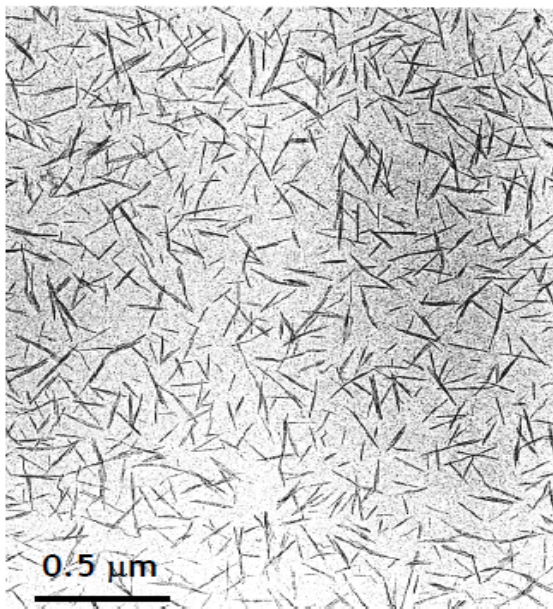
New value chains: Nanocrystalline cellulose



What happens to the fibres remaining after the extractions?

- Convert them into high-value nanocrystalline cellulose fibres

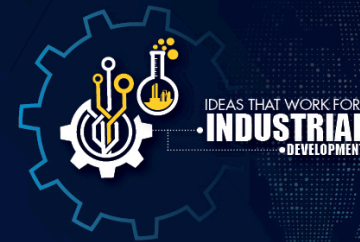
Nanocrystalline Cellulose - NCC



TEM image of dilute suspension
on carbon grid

- The nanocrystals are made up of ~25 chains of 13000 glucose units
- Whisker shaped particles
100-200 nm x 5-10 nm (also called cellulose nanowiskers or CNW)
- Highly crystalline cellulose I with
Young's modulus: 150 GPa
Tensile strength: 10 GPa
(comparable to Kevlar)
- Self-dispersing and chiral nematic in water when liberated from bleached pulp by sulfuric acid hydrolysis
- Nanocrystals have hydrophilic surfaces, but do not swell in water

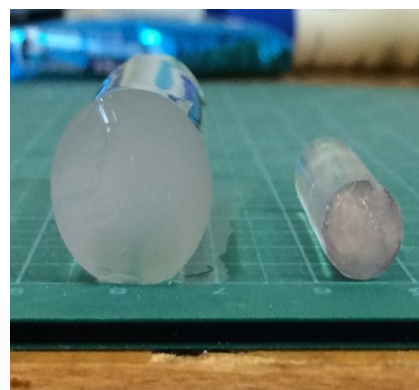
Nanocrystalline Cellulose (NCC)



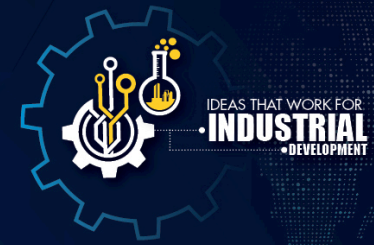
What can we make from NCC?

- Paints, varnishes, coatings
- Films
- Adhesives
- Thermosets
- Thermoplastics
- Reinforced biopolymers
- Synthetic fibres
- Nanocomposites
- Cosmetics & pharmaceuticals
- Optical devices
- Viscosity modifiers
- Catalysts
- Flexible displays
- Printed films
- Hydrogels

NCC nanocomposites prepared at the BIDF



Novel technology for production of nanocrystalline cellulose



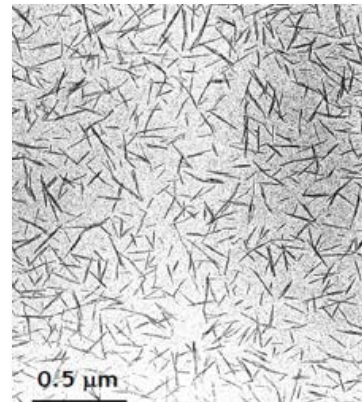
Conventional methods



Wood



Pulp
(sells for \$1200/ton)



Nanocellulose

Yield = 15%

Our technology

Waste



(Free)

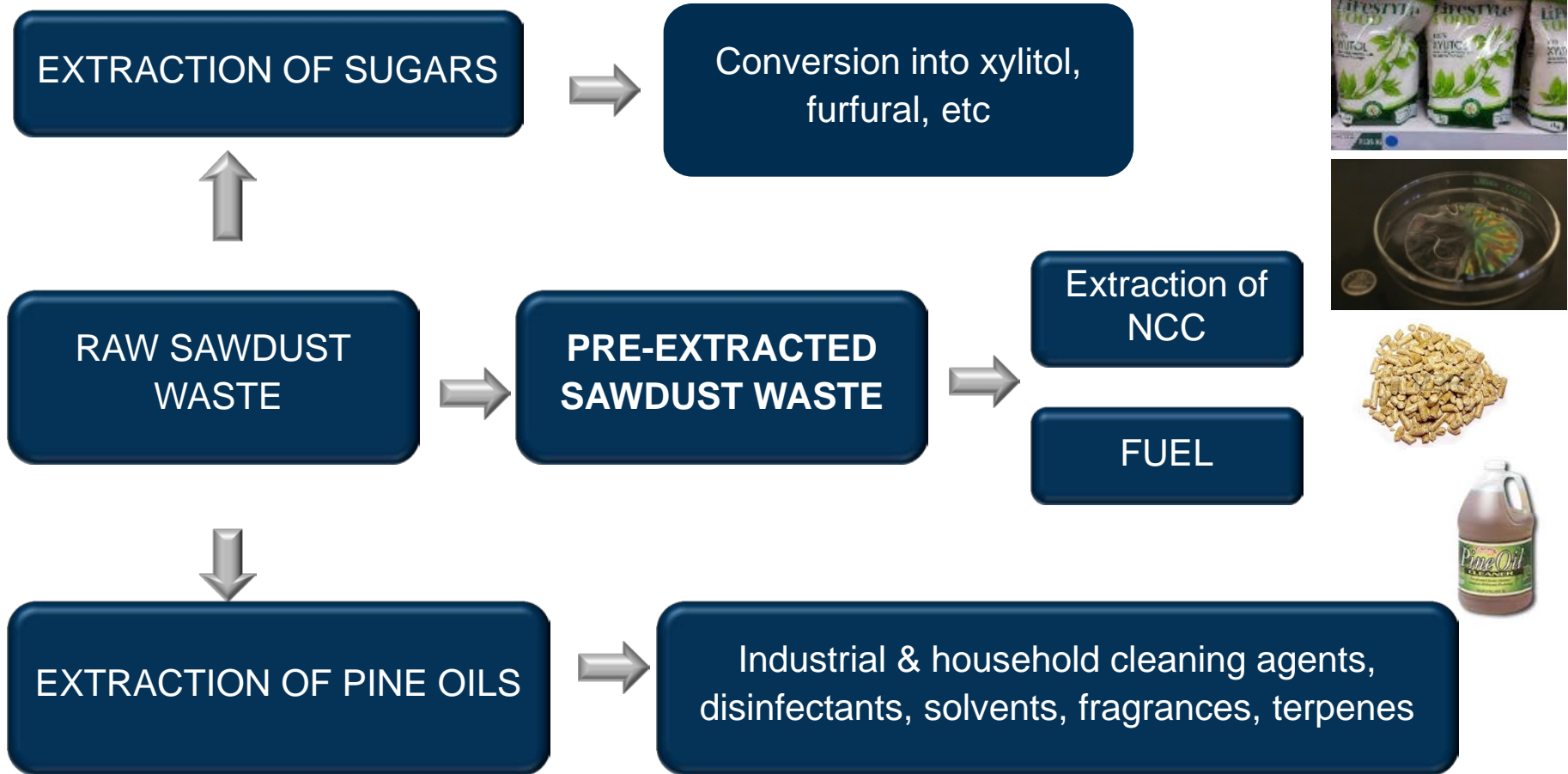
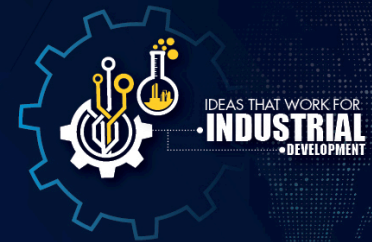


Biomass waste

Yield = 40%

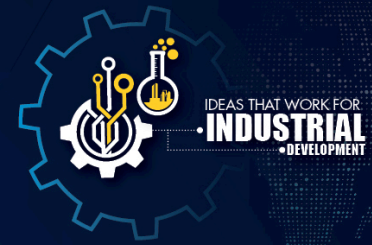
- Currently NCC sells for \$1000/kg
- BDF technology: NCC directly from wood waste
- Working on developing industrial partnerships

New value streams: Valorisation of saw mill waste



NO MORE WASTE > 95% TREE UTILISATION!

Beneficiation of mill sludge



**MILL SLUDGE CONTAINS APPROXIMATELY:
ORGANIC 60%
INORGANIC 40%**

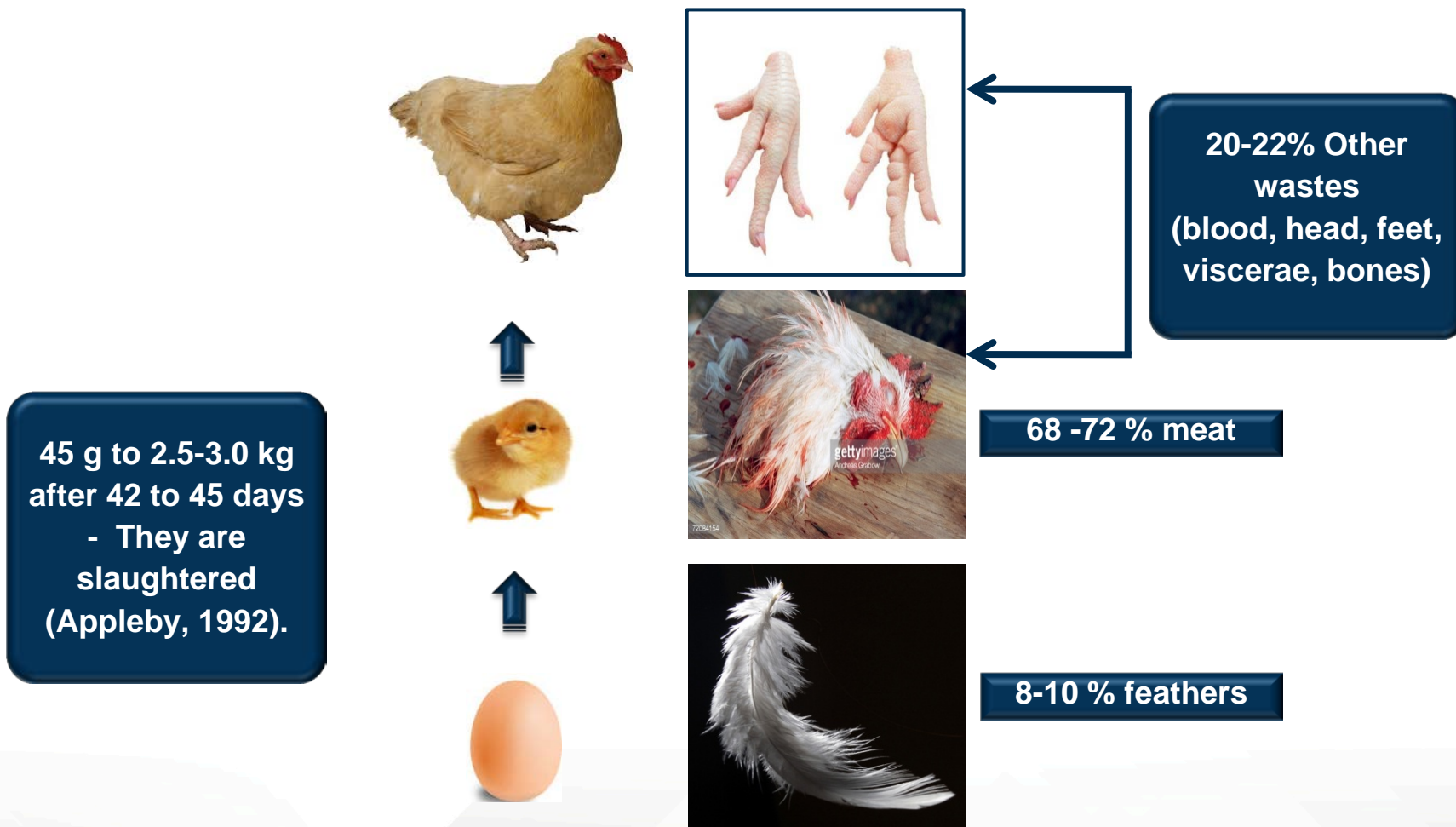
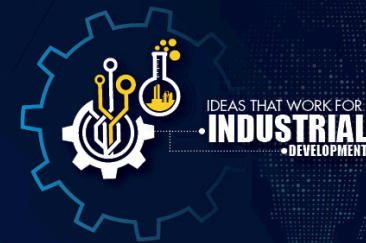
**NANOCRYSTALLINE
CELLULOSE**

**BIOPOLYMERS/
PLASTICS**

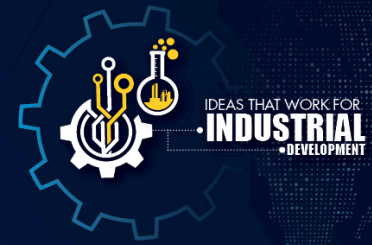
**BUILDING MATERIALS
CEMENT BRICKS**

Typical pulp mill sludge and potential valorisation products

New value streams: Valorisation of poultry wastes

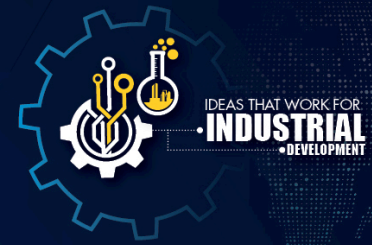


Waste chicken feathers



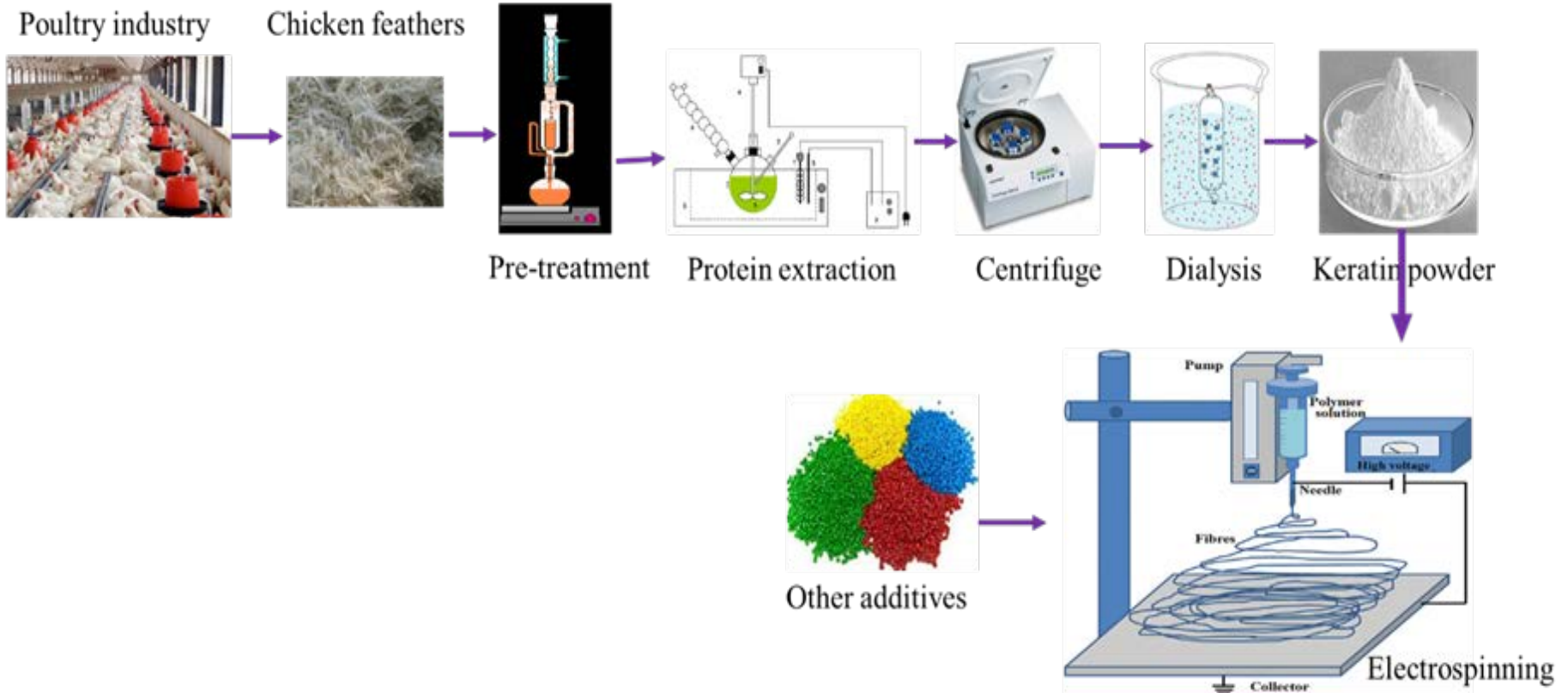
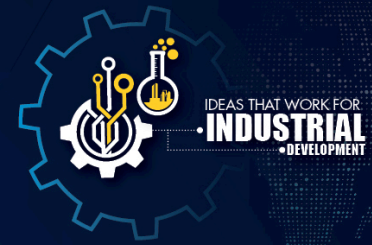
- **Worldwide:** >20 billion pounds of feathers per year
- **South Africa:** 528 million pounds/annum
- **Disposal is problematic**
 - **Incineration**
 - emissions
 - **Animal feedstuff**
 - Low digestible nitrogen content
 - **Landfilling**
 - Space shortage
 - Green house gas emissions
 - Hazardous waste – microbial contamination
 - Regulations banning landfilling

Valorisation of chicken feathers

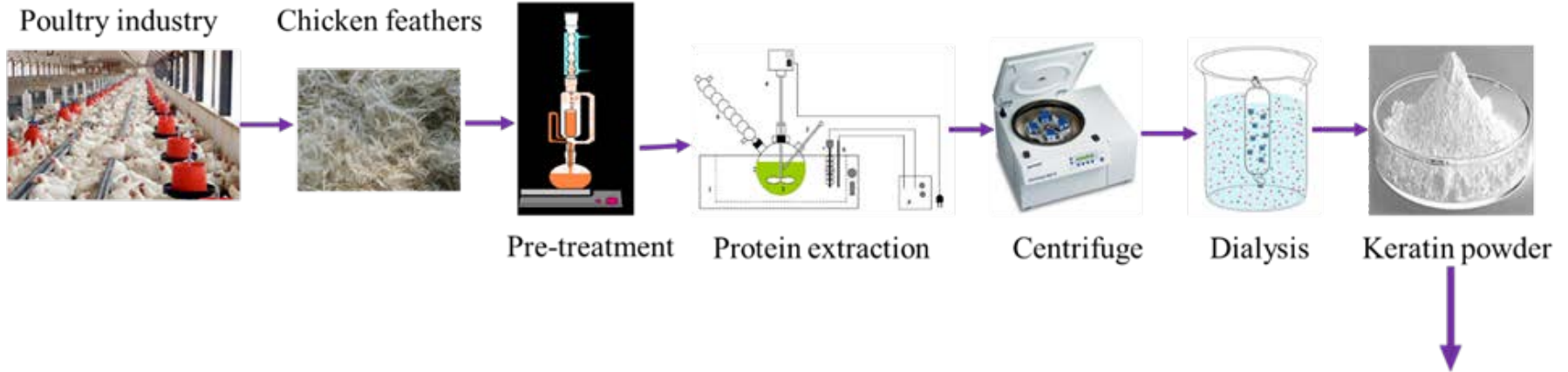
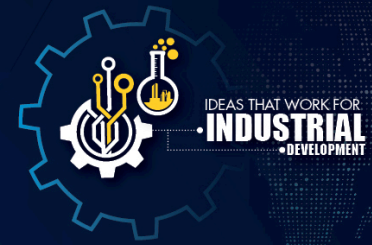


- **Composition of feathers**
 - 91 % Keratin – high value material
 - 1 % Lipids
 - 8 % water

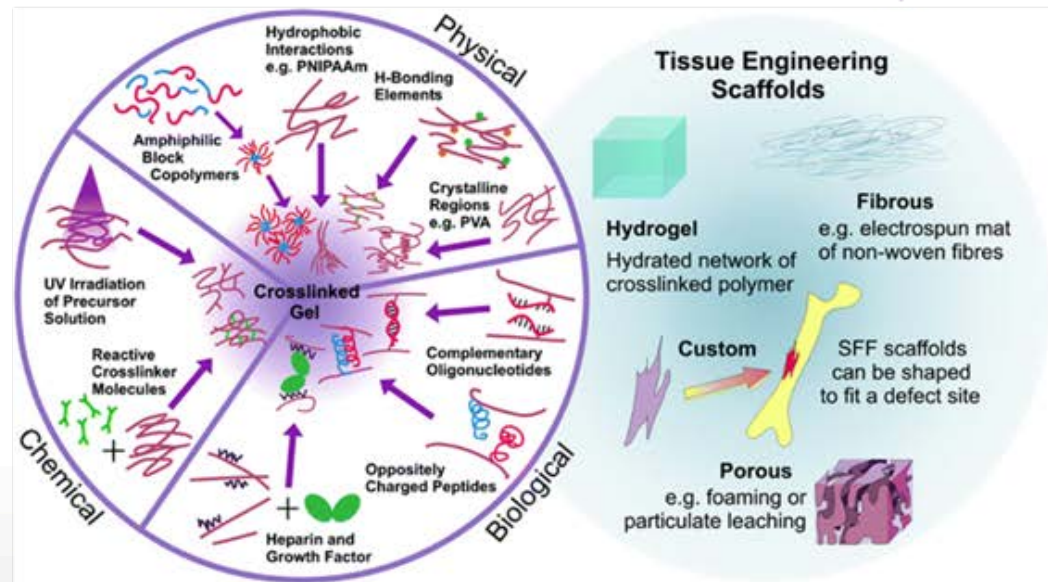
Valorisation of chicken feathers



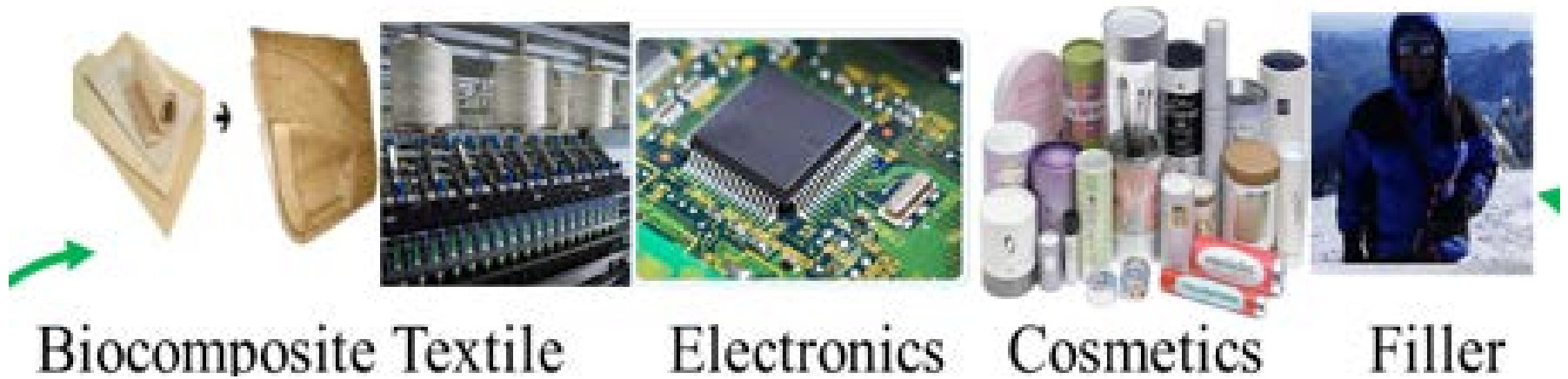
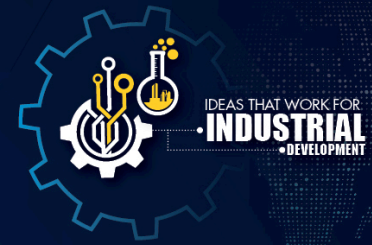
Valorisation of chicken feathers



Applications



Valorisation of chicken feathers



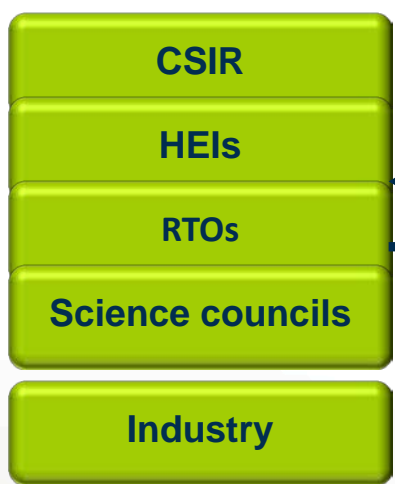
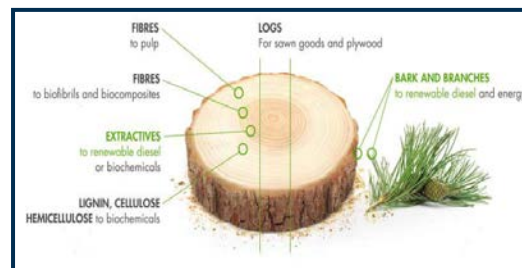
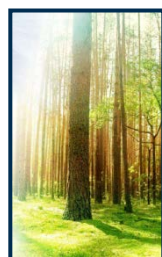
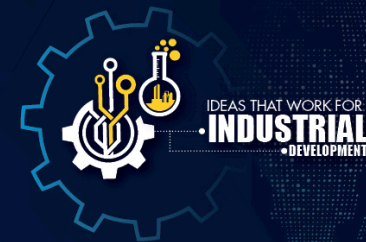
Biocomposite Textile

Electronics

Cosmetics

Filler

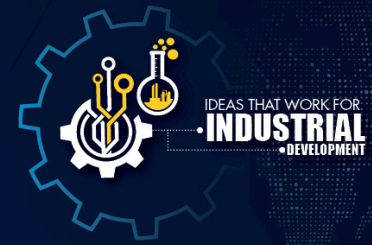
Positioning of the CSIR biorefinery technology platform in the National System of Innovation



SET question: The CSIR will reduce the cost and risk barrier for industry by provision of specialised equipment, experimental facilities, and expertise coupled with advanced human capital development



Maximising the value of industry waste



Achieved by development of:

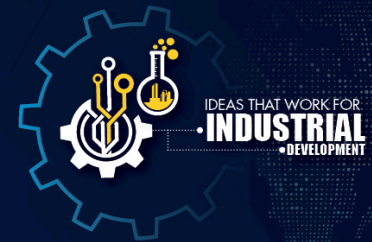
- Policies, governances, and best-practices regarding waste management
- Opportunities for technological and social innovations in waste management
- Waste resource economics: Economic instruments, determining the true costs and benefits of waste management
- Waste information management:
 - Quantification and modelling of waste streams
 - Studying human behaviour with regard to waste recycling and waste picking

Also by:

Hosting the implementation of South Africa's 10-year Waste Research, Development and Implementation (RDI) Roadmap

- aimed at guiding RDI and public and private sector investment in solid waste RDI

Summary of infrastructure and equipment

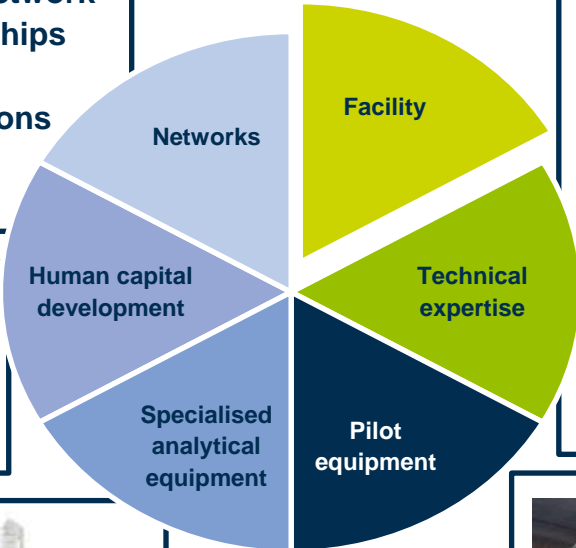


CSIR Biorefinery Industry Development Facility A national facility for development /evaluation of biorefinery technologies

Growing network of partnerships and collaborations

Human capital development to meet industry needs

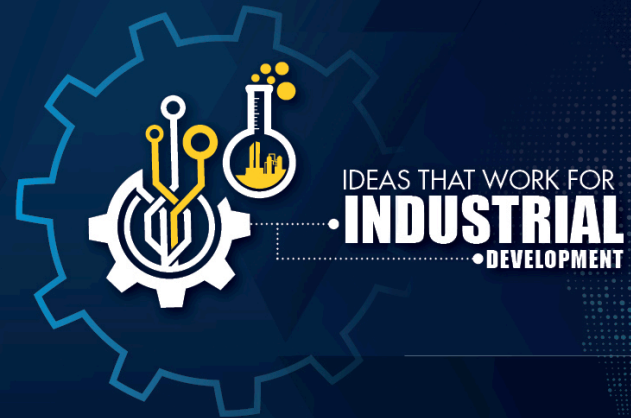
Advanced and unique analytical equipment for characterisation of biomass and products



A world-class facility central to the major biomass production region in SA

Highly trained specialist technical experts for advisory and technology development

Foundational pilot scale mills, fractionators and thermo-chemical digesters for biomass processing



Thank you for your attention

bsithole@csir.co.za

CSIR
our future through science