Forests and the Bioeconomy

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• Global Challenges

• Trends

• Bioeconomy/Circular Economy

• Forests and Bioeconomy: Exemplars

• The Opportunity
Global Challenges
Population predictions – Africa growth impact
Population aging

UN Dept Economic and Social Affairs
Climate Change – temperature, GHG emissions
Climate change - fire

Forest fires
Climate Change – water

Projected Global Water Scarcity, 2025

Physical water scarcity: More than 75% of river flows are allocated to agriculture, industries, or domestic purposes. This definition of scarcity — relating water availability to water demand — implies that dry areas are not necessarily water-scarce.

Approaching physical water scarcity: More than 60% of river flows are allocated. These basins will experience physical water scarcity in the near future.

Economic water scarcity: Water resources are abundant relative to water use, with less than 25% of water from rivers withdrawn for human purposes, but malnutrition exists.

Little or no water scarcity: Abundant water resources relative to use. Less than 25% of water from rivers is withdrawn for human purposes.

Not estimated

Source: International Water Management Institute
Example – impact of irrigation on water

Aral Sea 1973

Aral Sea 2012
99% of our calories come from the land

Two-thirds of the planet’s surface is water – only 1% of global calories come from the sea (FAO figures)

How much of the land can be used for food production?

Source: A.R. Jonas, JRC from FAO Map of World Soil Resources 1:25 000 000

What remains (in orange) are the naturally highly-fertile soils that feed the world

In reality, this amounts to around 13% - 18% of the land surface
Productivity gains needed for major crops by 2050

Global projections of yield trends and needs
Ray, Mueller, West and Foley PlosOne Vol8 2013

Observations of %yield changes per year
Fluorescent green – sustained will reach 2050 target
Ray, Mueller, West and Foley PlosOne Vol8 2013

CHALLENGING
Food and Water and People (UN/FAO) “Water is the new Oil”

• By 2030, food demand is predicted to increase by 50% (70% by 2050)
• Roughly 30% of the food produced worldwide – about 1.3 billion tons - is lost or wasted every year
• Producing 1 kilo of rice, for example, requires about 3,500 litres of water, 1 kilo of beef some 15,000 litres, and a cup of coffee about 140 litres.
Todays forests

More planted forests a solution?

What kind of planted forests?

Global Forest Resources Assessment 2015 (FRA)

How are the world’s forests changing?*

Forest areas have decreased since 1990 but the rate of net forest loss has been cut by 50%

![Graph showing forest areas and rates of net loss](http://www.fao.org/forest-resources-assessment/current-assessment/maps-and-figures/en/)

37% global land = arable (2013)

30% global land = forests (2015)
A shortage of fibre

“Humanity will likely use more wood in more ways as the future unfolds. If production forests are managed sustainably and wood products are used efficiently or replace others with a heavier footprint, this should be good for the planet.” (WWF 2012 The Living Forest report)

>300% more fibre needed by 2050
Intergovernmental agreements

UN Climate Change Conference - COP21

Paris Agreement -向进入生效

21 September 2016
Trends that impact
Cities and economic growth – new markets

Projected cumulative contribution to global GDP growth, 2007-2025, %

- The City 100 will account for 35% of global growth
- The City 600 is expected to account for 62% of global growth
- The City 1,000 will account for 68% of global growth
- The total pool of 2,000+ metropolitan areas is expected to contribute 75% of global growth

Megacities >10 m inhabitants
Megaweights 150k-10m inhabitants

GDP per capita hotspots for growth

McKinsey predictions 2011
Transformation of life, business and global economy (McKinsey May 2013+)

Disruptive technologies:

- Advanced oil gas discovery/recovery
- Mobile internet
- Cloud technology
- Internet of things
- Automation of knowledge work
- Distributed manufacturing
- Renewable energy
- Advanced robotics
- Energy storage
- 3D printing
- Autonomous vehicles
- Lightweighting
- Advanced materials
- Next generation genomics
Smart cities and big data

• Efficiency versus privacy
• Internet of things
• Social networks – information flow
A potential consumption time bomb
2010-2025

1.1bn more people

1.6bn more middle-class consumers

Dramatic shift to packaged products

A greater waste at end of life

Food: Caloric consumption
Food spending
Packaging
End-of-life materials

+24%  +57%  +47%  +41%

1 Estimate based on the comparison of per capita consumption in countries or population segments (e.g., India) and middle/high income countries and segments, as indicated.

Talent competition and other manufacturing trends  (McKinsey Manufacturing report 2012)

- **Shortage** of high and medium skilled workers by 2020:
  - 15% globally;
  - 10% in advanced economies

- **Excess** of low skill workers by 2020:
  - 10% globally;
  - 11% in advanced economies

- **Onshoring** – regional manufacturing supply chain challenges

- **Complex trade flows** (east-west), multi lateral trade deals

- **New materials**: nanomaterials, light weighting, biotech and biologics

- **New manufacturing** – additive or 3D short run, specific, home made!
New industrial sectors (industrial biotech, clean tech, green tech, renewables…….)

**Figure 4: Industrial Biotechnology’s path to a low carbon economy.**

WWF report Industrial Biotechnology 2009
Distributed manufacturing – eg 3D printing
Intensification and greening
Automation across the Forest Value Chain

**Germplasm Collection**
- Operation: Environment
- Demonstrate: Planting

**Tissue Culture**
- Operation: Humidity
- Demonstrate: Lifting

**Nursery**
- Operation: Light temperature
- Demonstrate: Planting

**Planting**
- Operation: Frost mgmt
- Demonstrate: Thinning

**Monitor Manage**
- Operation: UAV LiDAR Sensors
- Demonstrate: Stick-insect Helicopters UAVs

**Harvest**
- Operation: Harvest Haulers
- Demonstrate: Log tracking

**Transport**
- Operation: Logistics monitoring
- Demonstrate: Drying Kilns Pulp & Fibre

**Process**
- Operation: Sawmills
- Demonstrate: Engineered Wood Products

**Manufacture**
- Operation: Pre-fab framing furniture
Bioeconomy/Circular Economy
The Bioeconomy is the production of renewable biological resources and their conversion into food, feed, bio-based products and bioenergy.
The bio-economy is a world wide priority

US
- ~$50 billion to biofuels & bio-chemicals
- 2012, President Obama: “The bio-economy is a major engine for American innovation and economic growth”

BRAZIL
- Aims to be N°1 Global Bio-economy
- R$ 3,3 billion for 2nd generation bioethanol, bio-chemicals and biomass gasification technologies

CHINA
- > $300 billion in Science & Technology with biotech as a major priority over 2011-2015
- Substitute 20% of crude oil imports by 2020

EU’s bioeconomy turnover: €2 trillion
Non-food products such as paper, furniture and textiles generate about €480 billion.
The Gunter Pauli coffee story
Transformation of life, business and global economy (McKinsey May 2013)

Disruptive technologies

- Advanced oil gas discovery/recovery
- Mobile internet
- Cloud technology
- Internet of things
- Automation of knowledge work
- Distributed manufacturing
- Lightweighting
- Renewable energy
- Advanced robotics
- Energy storage
- 3D printing
- Autonomous vehicles
- Biobased from trees
- Advanced materials
- Next generation genomics
- SCION
Forests and the bioeconomy
What is a tree?

A renewable chemical factory

- Cellulose
- Tannins / Suberins
- Resin acids & Terpenes
- Lignin
- Cellulose
Two examples of biorefinery concepts using trees
New products,
New materials,
New opportunities
# The value chain challenge

**Drop-in**

**newBBBB**

<table>
<thead>
<tr>
<th>Business case</th>
<th>Solid</th>
<th>Hypothetical</th>
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<tbody>
<tr>
<td>Investment</td>
<td>High “on cost, on spec” via high volume production</td>
<td>Stepwise as business grows</td>
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<tr>
<td>Breakthrough potential for “added functionality”</td>
<td>Low existing products</td>
<td>High game-changing nature</td>
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<tr>
<td>Business segment</td>
<td>Commodity</td>
<td>Specialties Potential to commoditize</td>
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<tr>
<td>Management style</td>
<td>“Control &amp; operate”</td>
<td>“Steer &amp; create”</td>
</tr>
</tbody>
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**Fossils**
- 2 dominant atoms (C, H)
- Linear chains / benzene ring
- No chirality

**Nature’s diversity**
- 4 dominant atoms (C, H, O, N)
- Variety of structures
- Chirality dominates Life

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[Image: Scion forests - products - innovation]
Making wood fibre reinforced plastics
• Commercial advantages over ‘agri-fibres’
  – Industrial supply and scale
  – Consistency
  – Odour

• Leading Suppliers
  – Woodforce – Scion/Sonae (HTMP)
  – Thrive* – Weyerhaeuser (kraft)
  – Formi* – UPM (kraft)
  – Fribomer* – Mondi (kraft)
  – Symbio* – Sappi (kraft)
  – Greencore*
Making Carbon Nanofibres

- **Formulate Lignin**
  - low cost (<$1/kg)
  - high C content
  - non-toxic
  - renewable
- **Electrospin nanofibres**
- **Carbonise**
- **Product development**
  - Energy storage
  - Electronics
  - Coatings
  - Air filters
  - Composites

Two steps:
- Stabilisation
- Carbonisation

Lignin nanofibre mat
Cellulose
3D printing with designers

David Trubridge
Biodegradable cosmetic pots and net clips – using waste
Bioenergy from trees

Bioenergy

Solid biofuels
- electricity & heat
  - Briquettes
  - Pellets
  - Torrefied pellets

Liquid biofuels
- transport
  - Bio-oils
  - Ethanol

Sawdust, chips

Jet fuel, butanol, diesel

Drop-in biofuels
Can replace fossil fuels in existing equipment without major modification
Tall wooden buildings
Building in Renewables and Recyclables
An Auckland (NZ) Urban Equilibrium Case study to reduce carbon emissions by 40% by 2040 – 25% faster with wood (Stocchero et al 2016)

Trees used in solid timber construction sequester up to 6.6% of Auckland 2009 emissions (YRSx at the 30th year).

Long term carbon storage in solid timber buildings (YBS) corresponding to 6.6% of Auckland’s 2009 carbon emissions.

Substitution of building materials could save 38% to 65% of cradle to gate carbon emissions in manufacturing building materials compared with business as usual.

Prefabrication techniques can save up to 13% of construction carbon emissions compared with usual onsite construction.

Either permanent sink of 2.9% of 2.3% Auckland’s 2009 carbon emissions by landfilling timber waste or avoidance, by fossil fuels substitution of 2.3%.
Increased demand – how do we service it – Biotechnology?

- Oligonucleotide Directed Mutagenesis (ODM)
- Zinc Finger Nuclease Technology (ZFN) comprising ZFN-1, ZFN-2 and ZFN-3
- TALEN
- CRISPR-cas9
- Cisgenesis and Intragenesis
- Grafting
- Agro-infiltration
- RNA-dependent DNA methylation (RdDM)
- Reverse breeding
- Synthetic genomics

- Genomic Selection
What is Genomic Selection?

Goal: Double productivity in radiata pine

- Sequence radiata genome
- Find many SNPs and related phenotypes
- Halve breeding cycle to 10 to 15 years
What is Genetic Modification (GM)

**Conventional Breeding**
- ‘traditional’ selective breeding and cross breeding
- Introduces random genetic material into host genome

**Random Mutagenesis**
- Host organism subjected to radiation or chemicals
- Random mutations in DNA

**Transgenic Genetic Modification**
- Selected genes inserted into host genome
- Used extensively throughout the world

**Modern Gene Editing Technology**
- Selected gene of host genome altered
  - Precise
  - Predictable
  - Safe
Commercial plantings of biotech trees?

GM poplar in China
Insect resistance

American Chestnut billions of trees killed
Chestnut Blight
GM solutions tested

>700 field trials of GM (traditional) trees globally
  • herbicide tolerance
  • sterility
  • wood-pulp properties (better products)
  • more biochemicals
  • pest resistance
  • disease resistance
  • wood density
  • productivity
  • drought resistance

(Sweden, Brazil, China)
Screened >1000 genes; 35 in field trials
Gene editing – regulated?

Gene-edited CRISPR mushroom escapes US regulation
A fungus engineered with the CRISPR–Cas9 technique can be cultivated and sold without further oversight.

DuPont corn more resistant to drought

CRISPR-Modified Corn May Soon Be Ready For Market

CRISPR-Modified Cabbage
A meal recently by Swedish scientists and journalists

Canada ✔
USA ✔
Australia ✔
Argentina ✔
Europe ?
NZ ✗

Goats with improved fibre
Future forest products sector(s)

INPUTS
- Land
- People
- Values
- Plants
- Energy
- Sunshine
- Soil
- Water

FORESTS

PRODUCTS and Services
- Biodiversity
- Timber
- Pulp & Paper
- Smart packaging
- Bioenergy
- Ecosystem services
- Biomaterials
- Biocomposites
- Food
- Fine chemicals
- Pharmaceuticals
- Fertilisers
- Waste utilisation
- Electronics
- Water
- And more
CAN WE HAVE ALL OF IT?