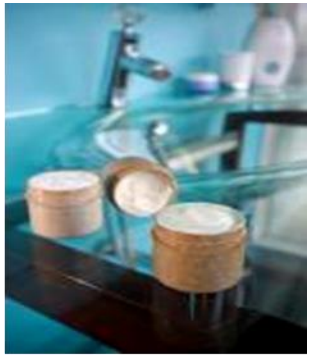
Forests and the Bioeconomy

Elspeth MacRae, GM Manufacturing and Bioproducts, Scion; IUFRO Asia Pacific
Beijing 27 October 2016



- **Global Challenges**
- **Trends**
- **Bioeconomy/Circular Economy**
- **Forests and Bioeconomy: Exemplars**
- **The Opportunity**

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Global Challenges

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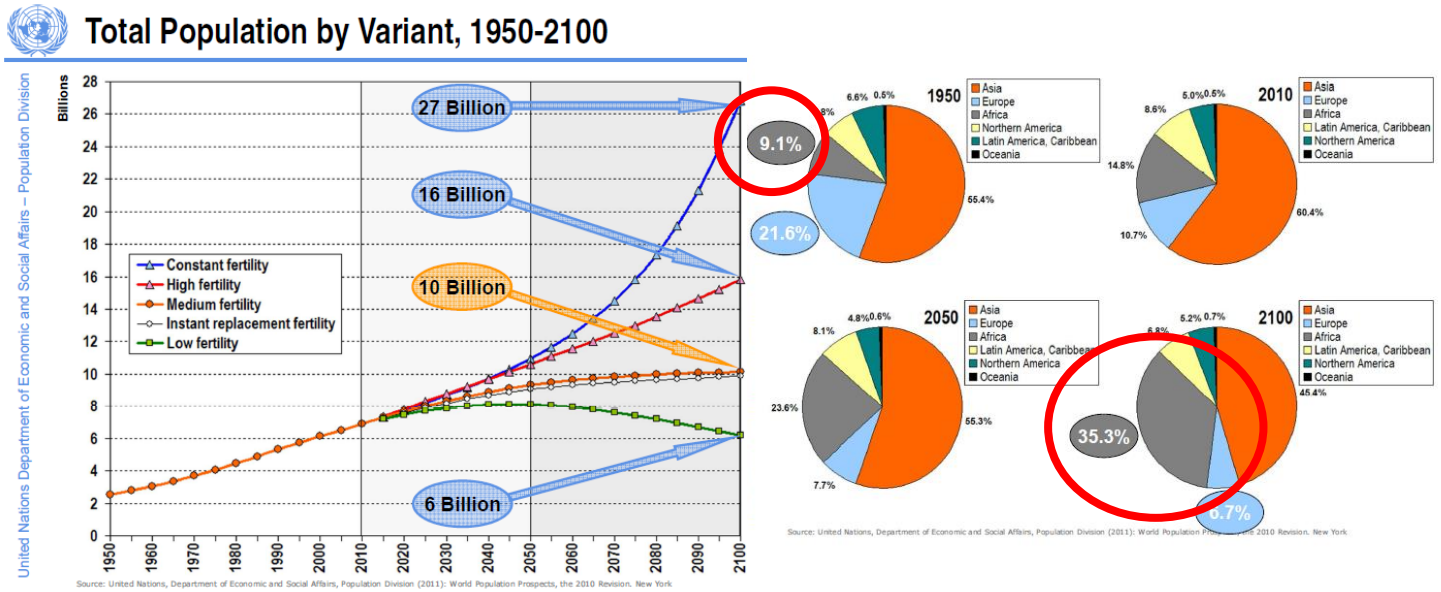
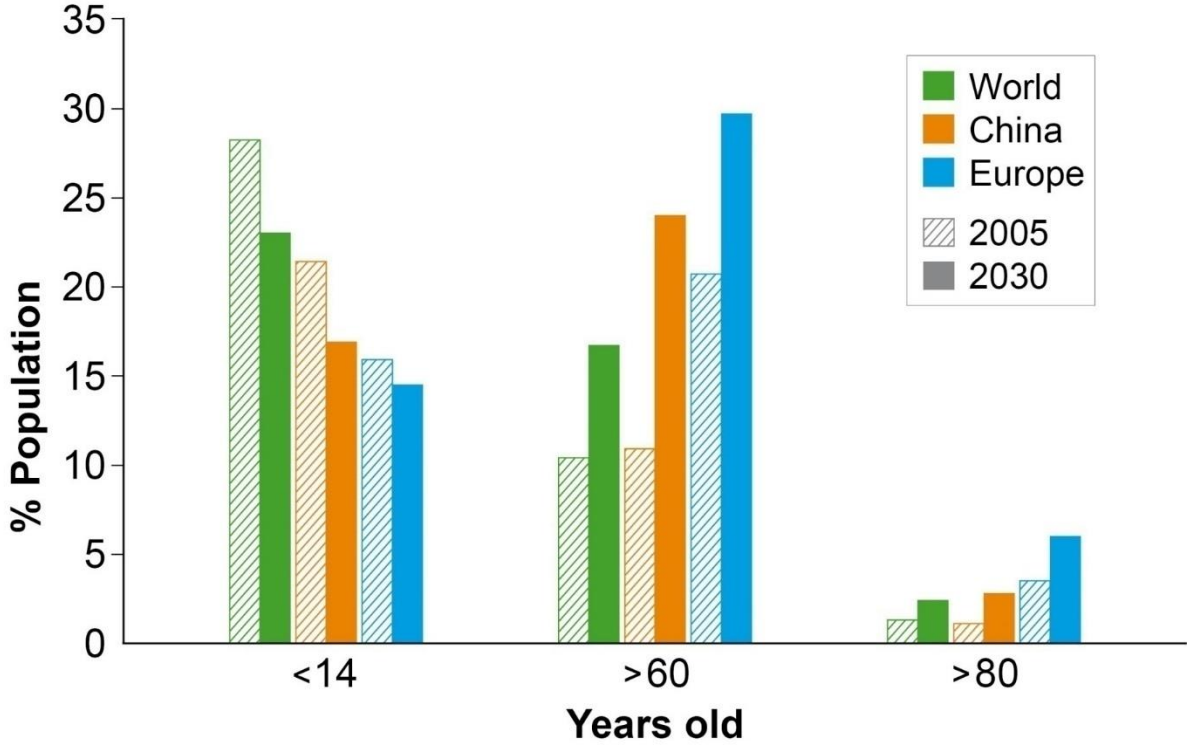
Population predictions – Africa growth impact

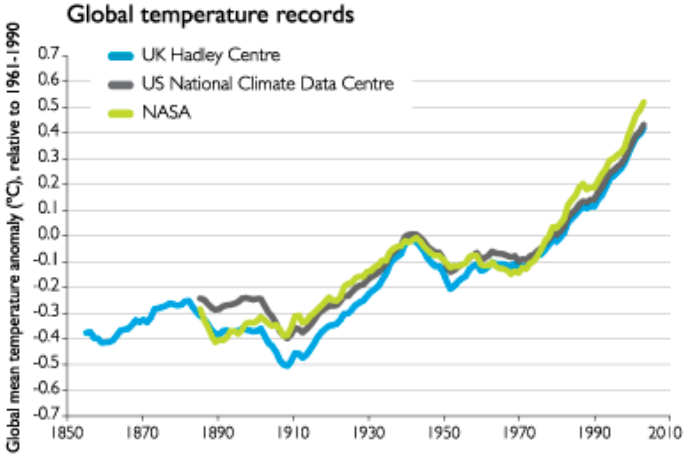


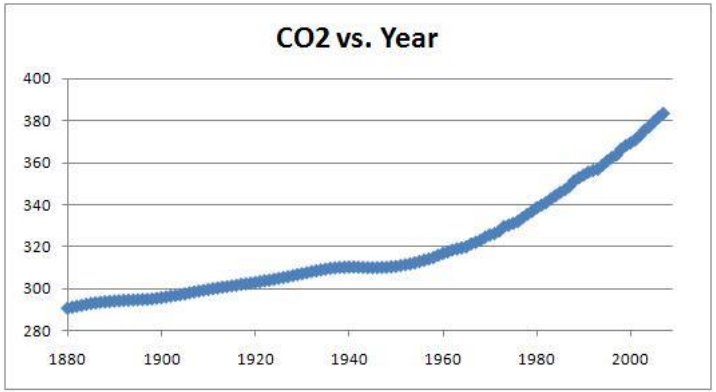
Population aging

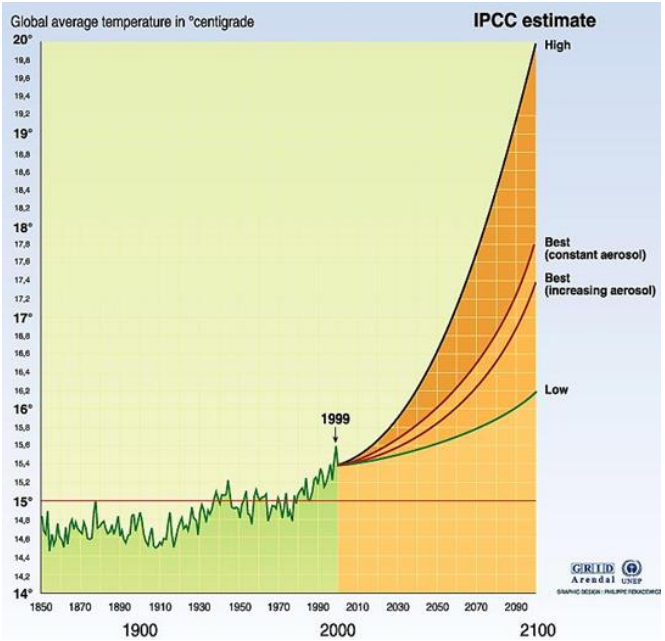


UN Dept Economic and Social Affairs

Climate Change – temperature, GHG emissions







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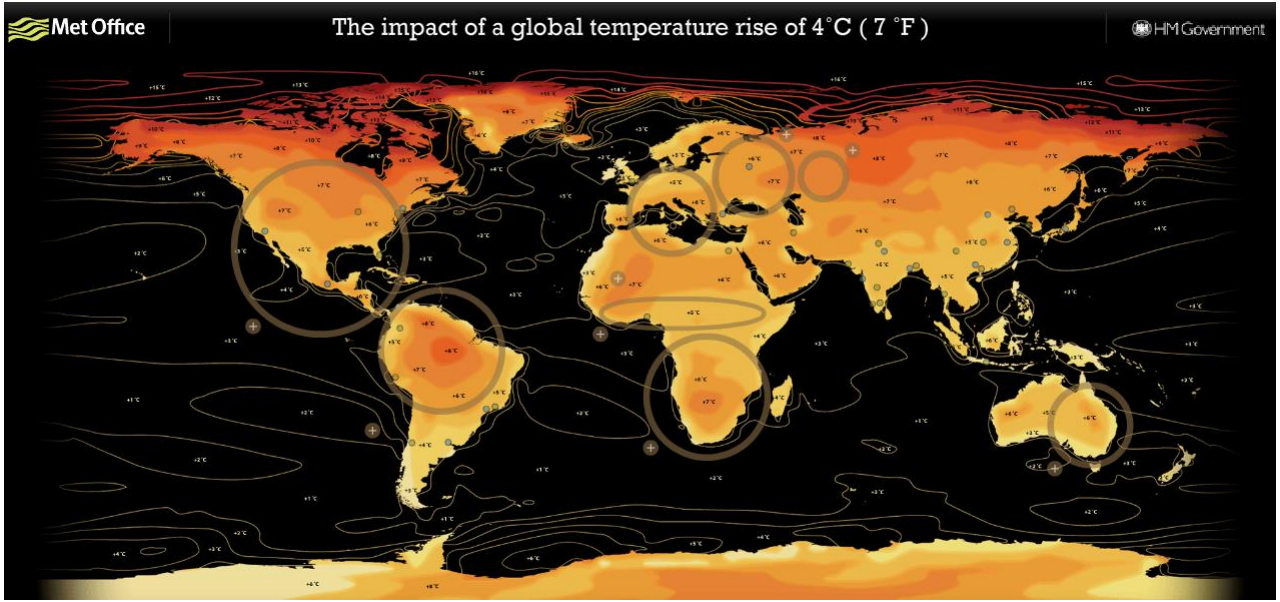
Climate change - fire



Forest fires

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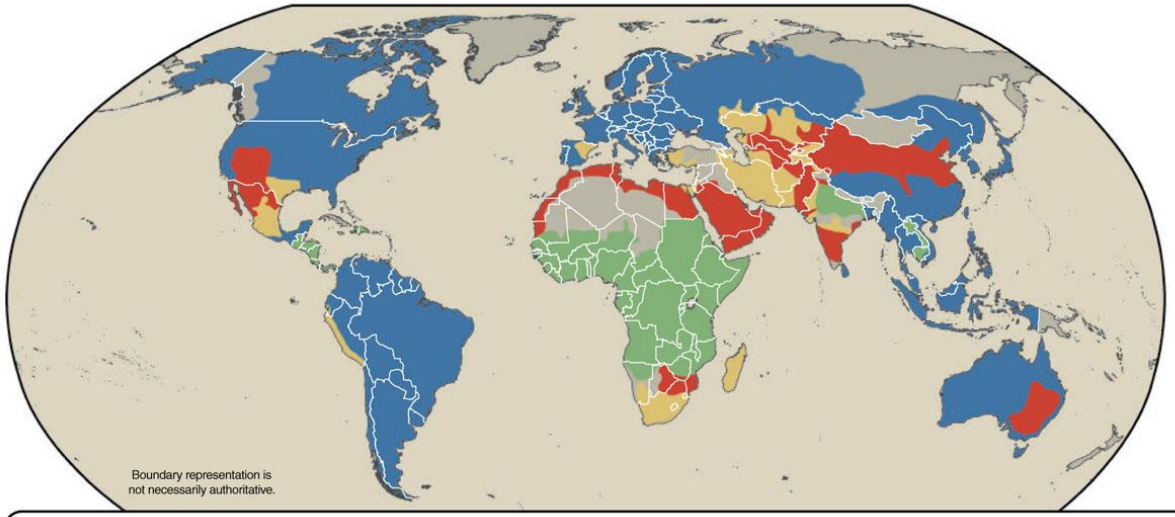
Climate Change – water

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.

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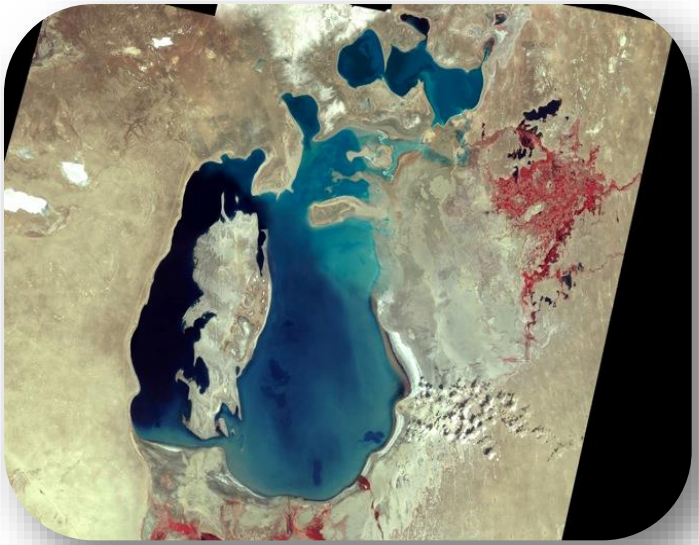
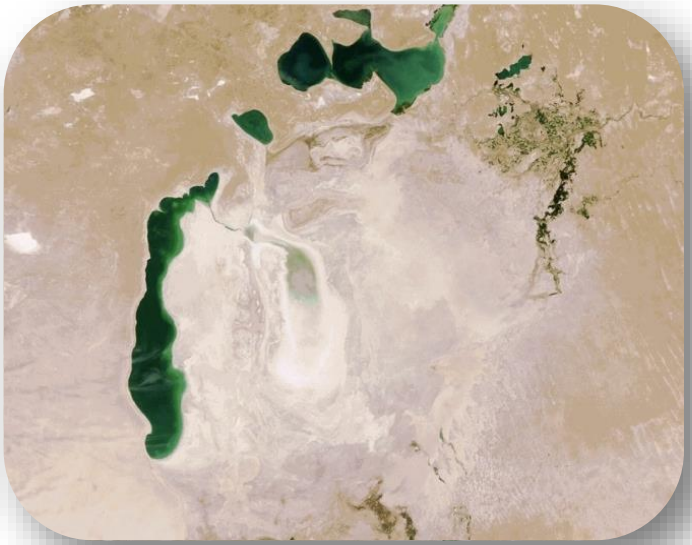
Example – impact of irrigation on water

Aral Sea 1973



Aral Sea 2012



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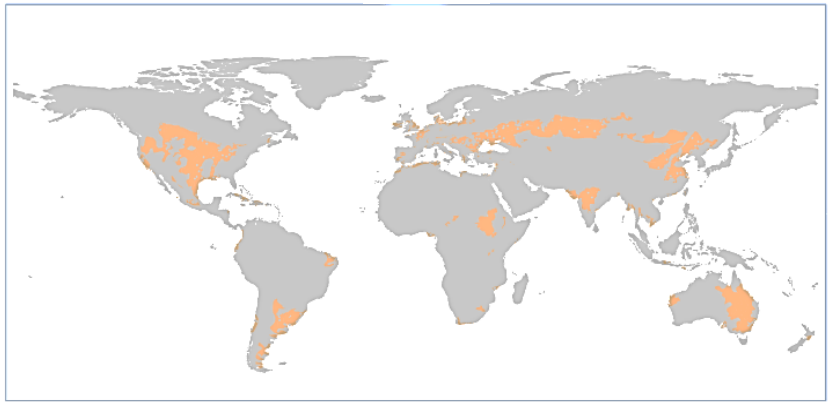
Land and Soil Fertility

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. Jones 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

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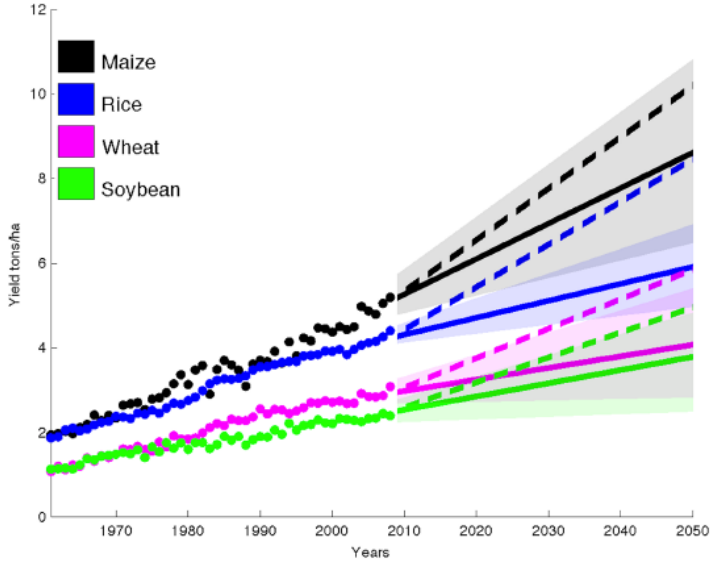
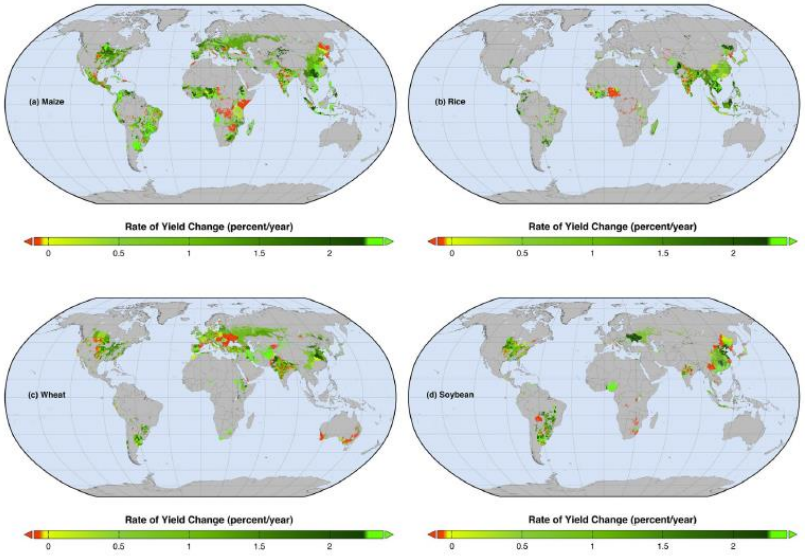
Productivity gains needed for major crops by 2050

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

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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.**

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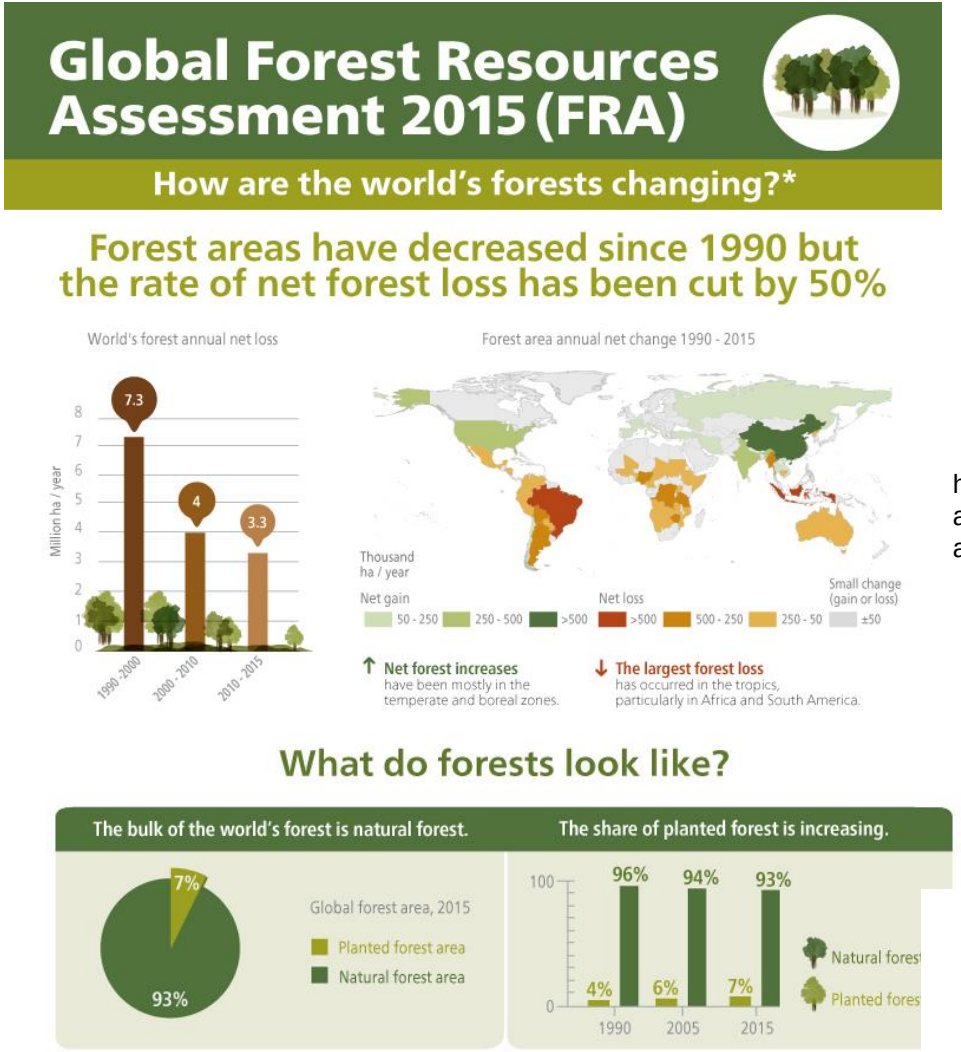
Todays forests

More planted forests a solution?

What kind of planted forests?



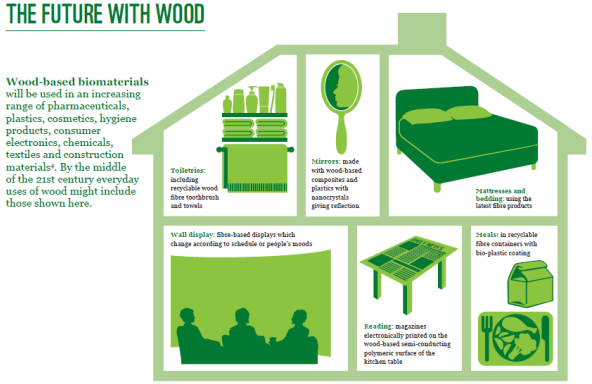
37% global land = arable (2013)

http://www.fao.org/forest-resources-assessment/current-assessment/maps-and-figures/en/

30% global land = forests (2015)

A shortage of fibre

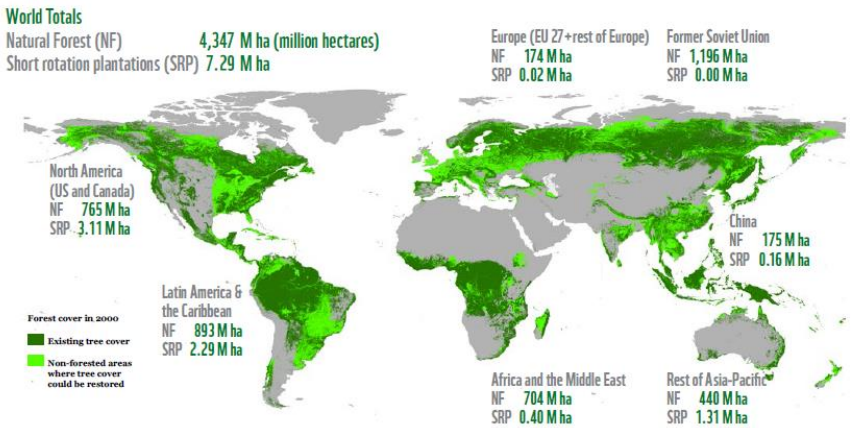
"Humanity will likely use more wood in more ways as the future unfolds. If production forests are managed sustainably and wood products are used efficiently or replace others with a heavier footprint, this should be good for the planet." *(WWF 2012 The Living Forest report)*



>300% more fibre needed by 2050

	FAO 2010	LIVING FORESTS MODEL 2030		2050	
		Do Nothing	Bioenergy Plus	Do Nothing	Bioenergy Plus
Saw logs & veneer logs	853	1,444	1,444	1,763	1,773
Pulpwood*	527	754	754	905	893
Other industrial roundwood**	153	153	153	153	153
Energy wood	1,868	2,753	3,138	6,317	8,209
Household fuelwood		2,064	2,064	2,218	2,054
Total wood supply	3,401	7,168	7,553	11,356	13,082

Units: millions of cubic metres (roundwood equivalent)



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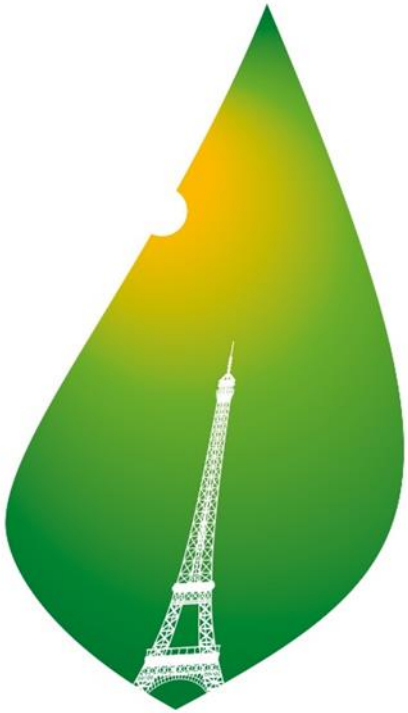
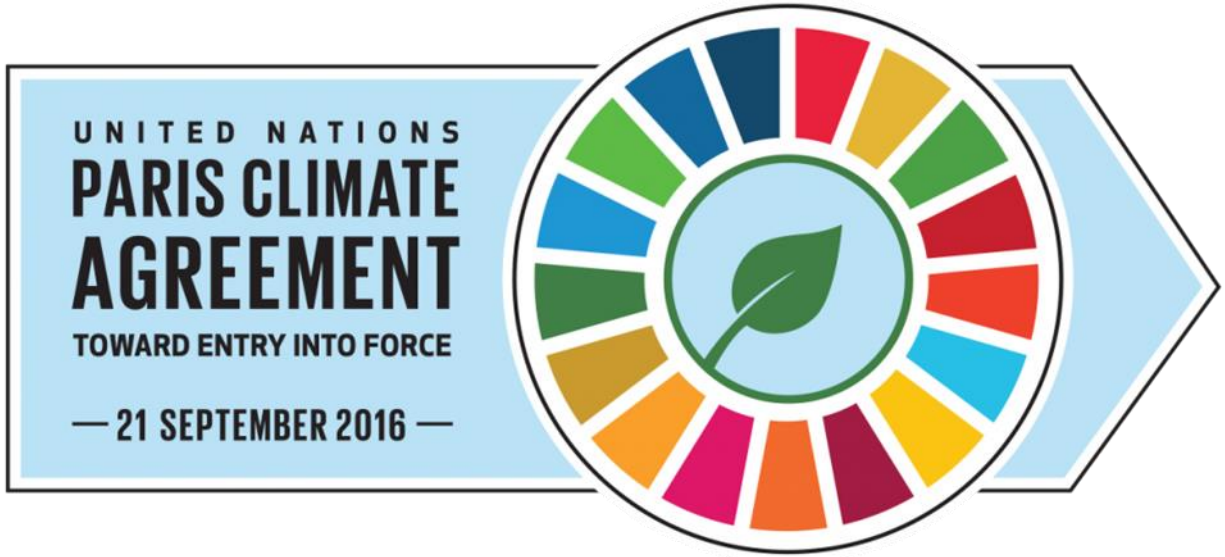
Intergovernmental agreements



COP21 · CMP11
PARIS 2015
UN CLIMATE CHANGE CONFERENCE



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Trends that impact

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Cities and economic growth – new markets

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

GDP per capita hotspots for growth

McKinsey predictions 2011

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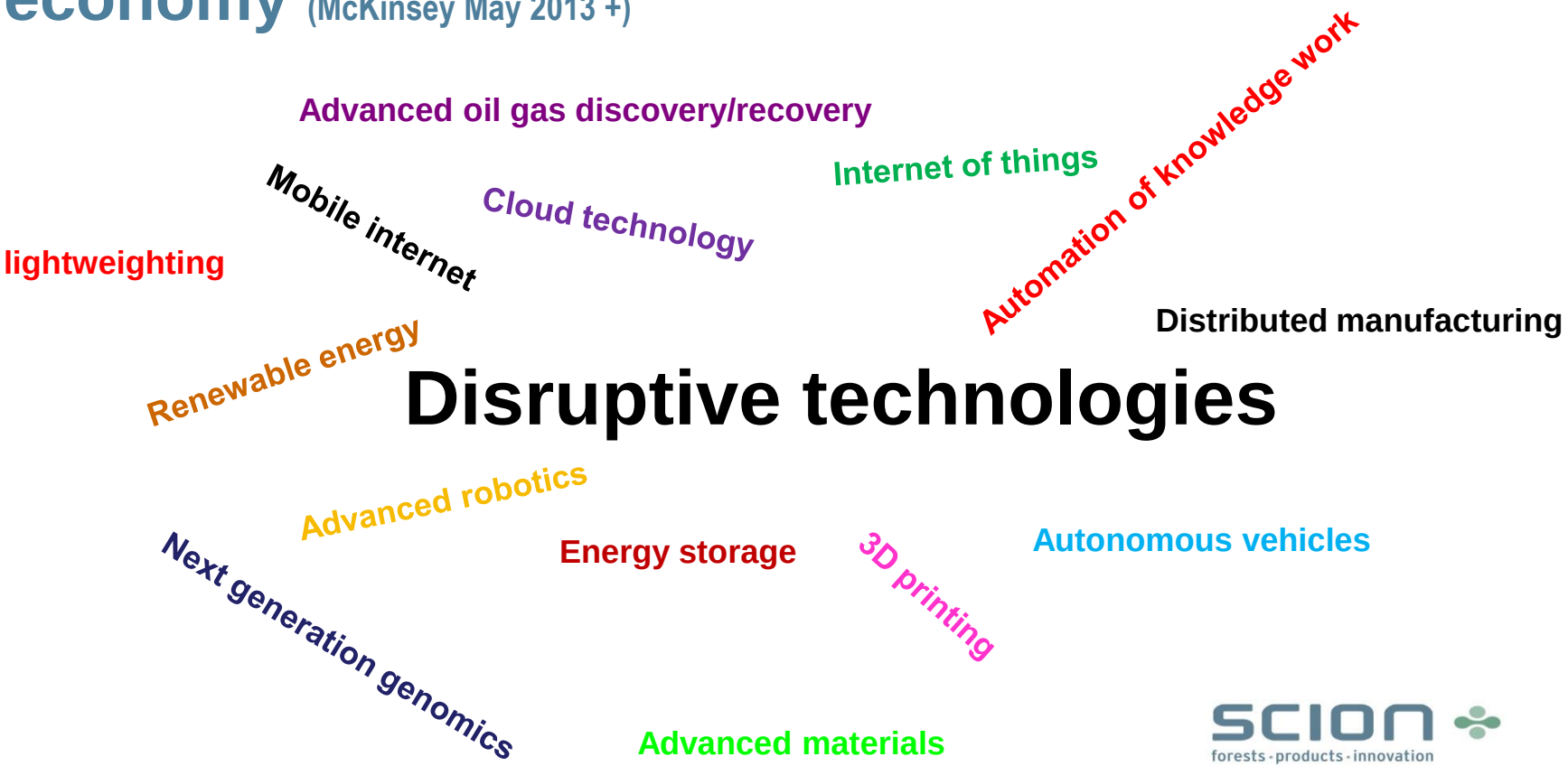
Transformation of life, business and global economy (McKinsey May 2013 +)



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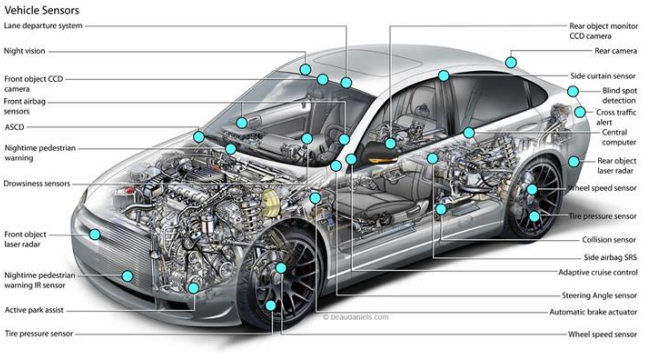
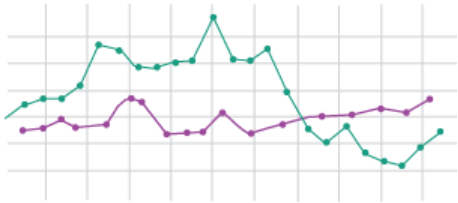
Smart cities and big data

- Efficiency versus privacy
- Internet of things
- Social networks – information flow





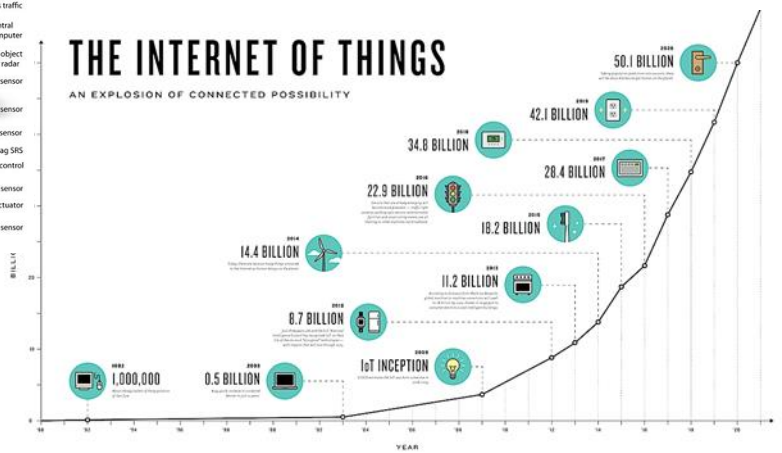


FIGURE 1 **A potential consumption time bomb**[1]
2010-2025

1 Estimate based on the comparison [illegible] income countries or population segment (e.g., India) and middle/high income countries and segments (e.g., US)
SOURCE: World Bank, Ellen MacArthur Foundation [illegible]

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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!

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New industrial sectors (industrial biotech, clean tech, green tech, renewables……)

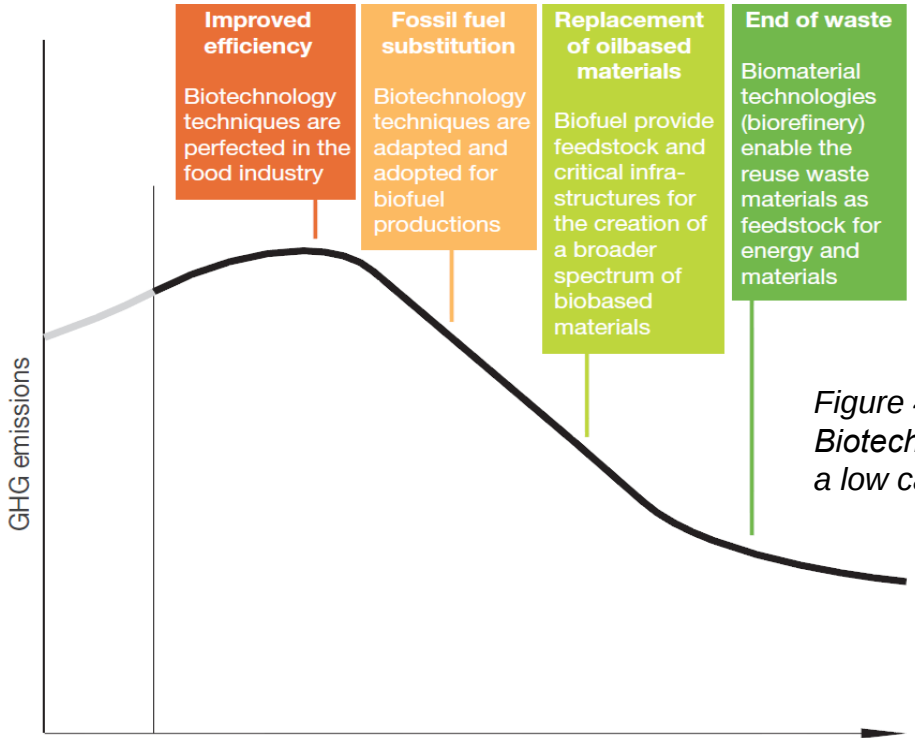

Figure 4: Industrial Biotechnology's path to a low carbon economy.

WWF report Industrial Biotechnology 2009

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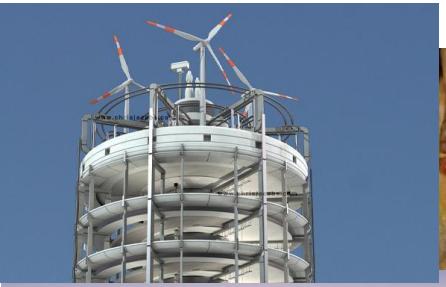
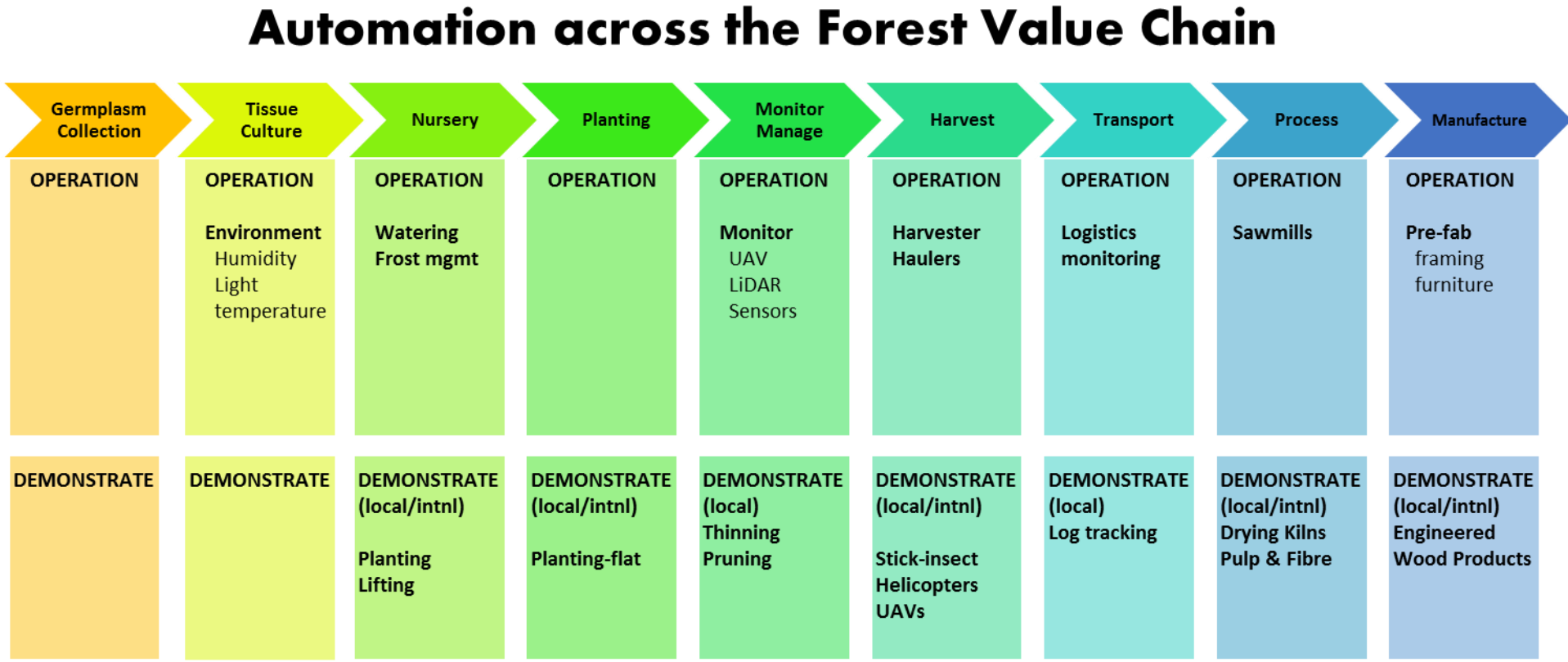
Distributed manufacturing – eg 3D printing

Intensification and greening



Automation



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Bioeconomy/Circular Economy

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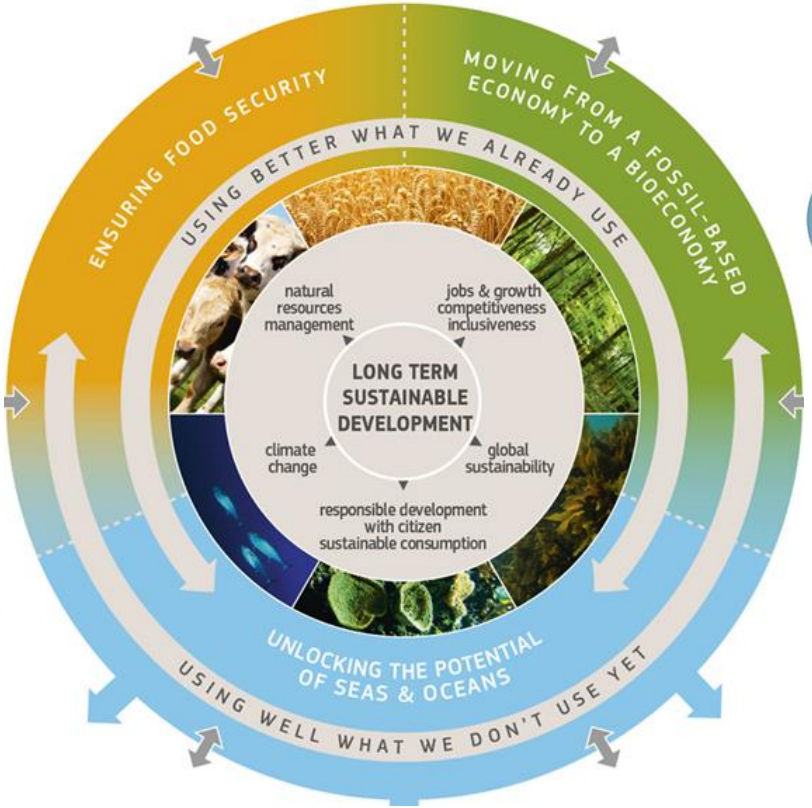
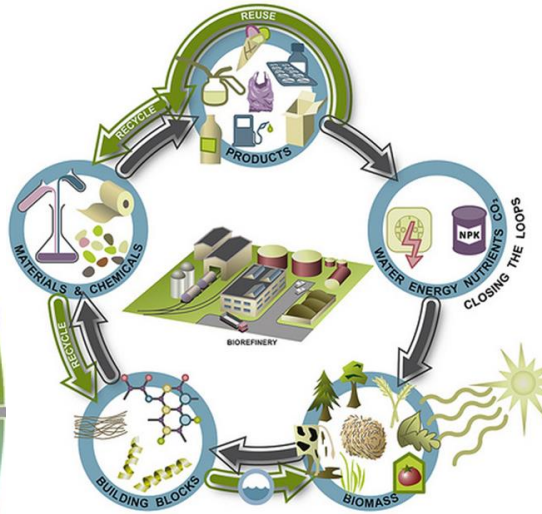
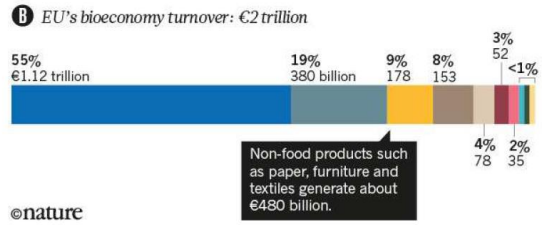
The Bioeconomy

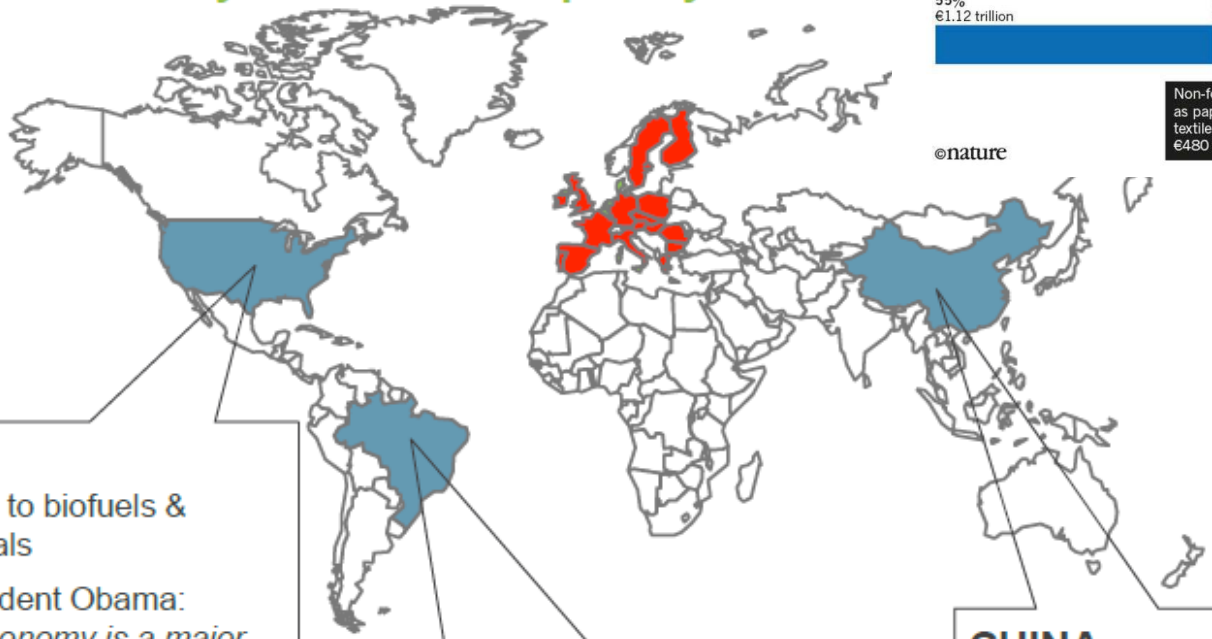




is the **production of renewable biological resources and their conversion into food, feed, bio-based products and bioenergy**

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"*

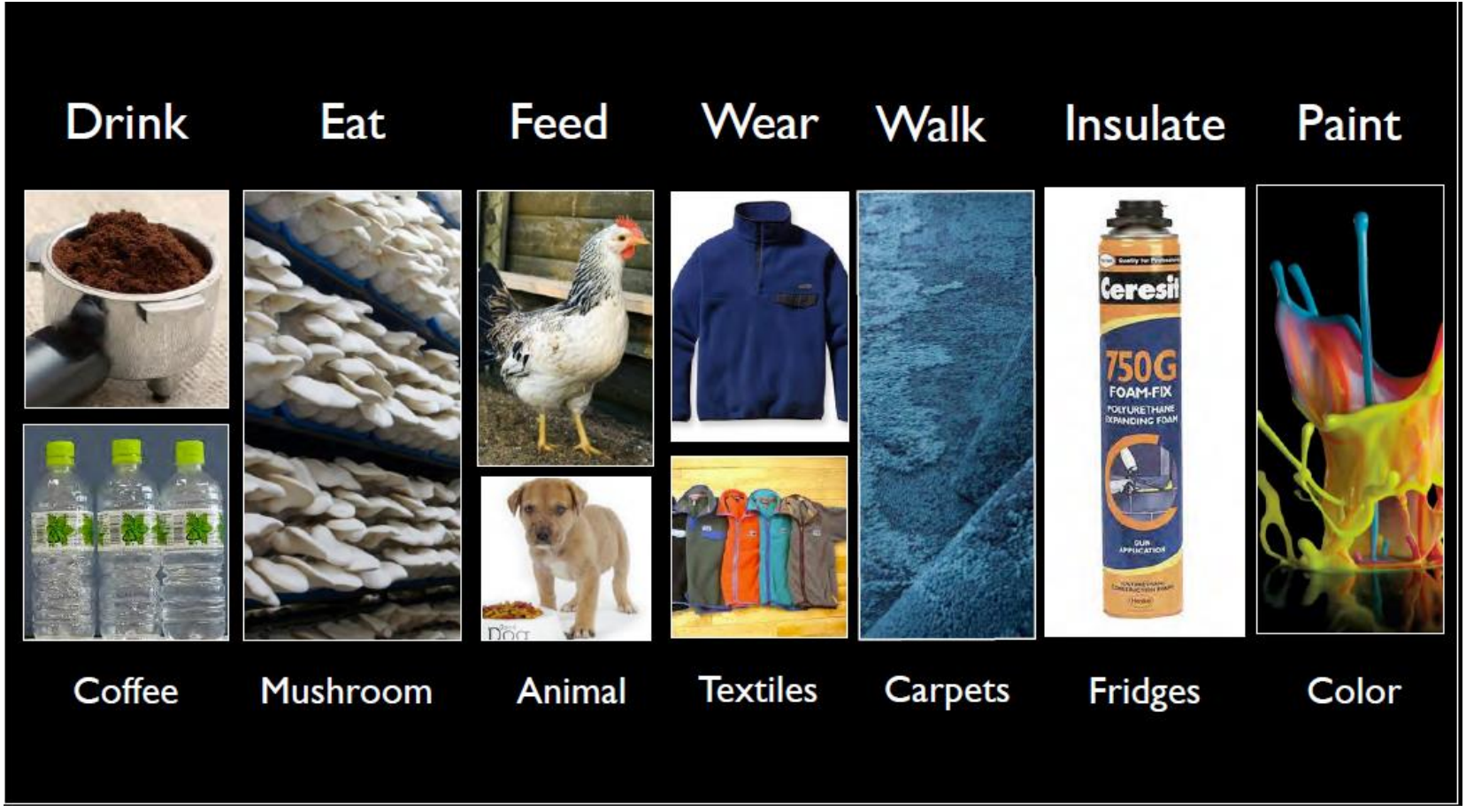
BRAZIL

- 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

The Gunter Pauli coffee story



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

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Forests and the bioeconomy

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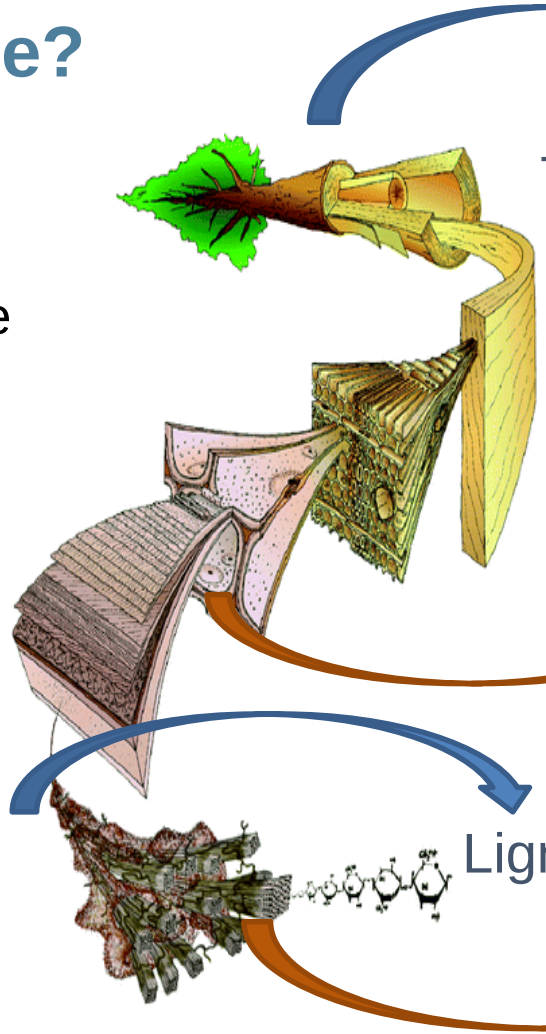
What is a tree?

A renewable chemical factory



Tannins / Suberins

Resin acids & Terpenes

Lignin

Cellulose

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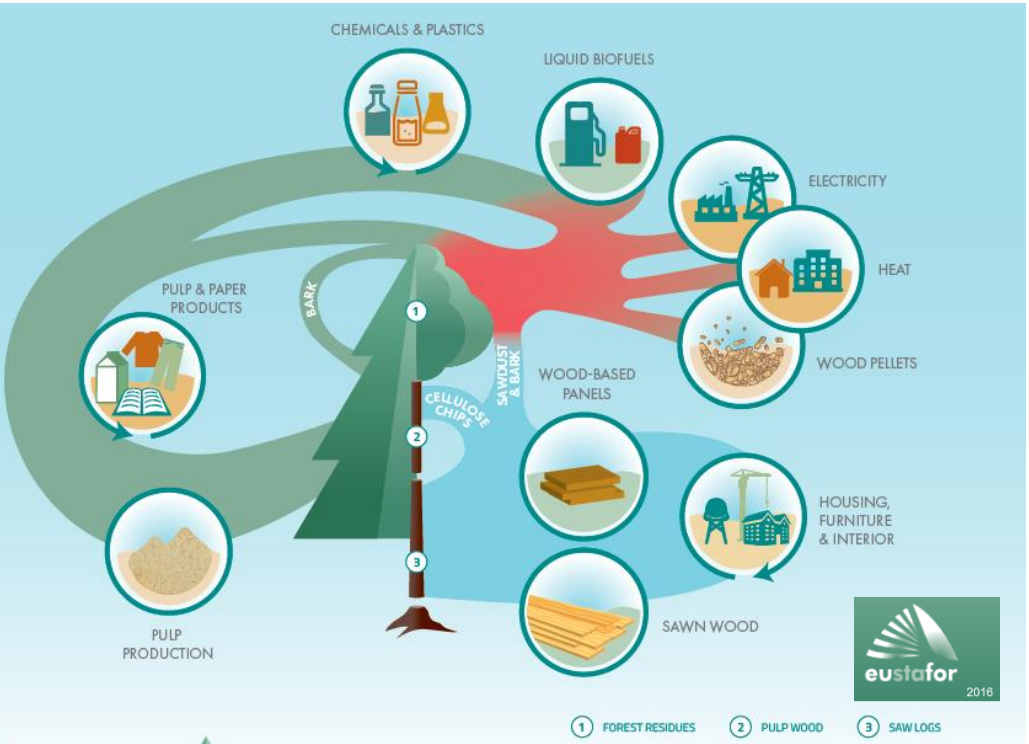
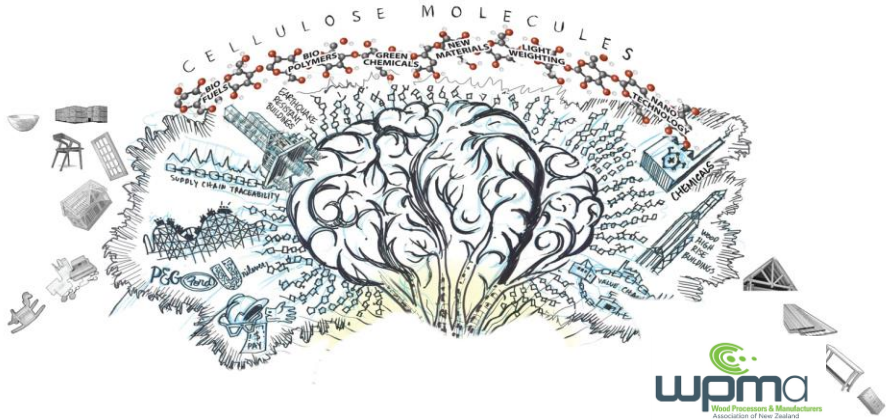
Two examples of biorefinery concepts using trees





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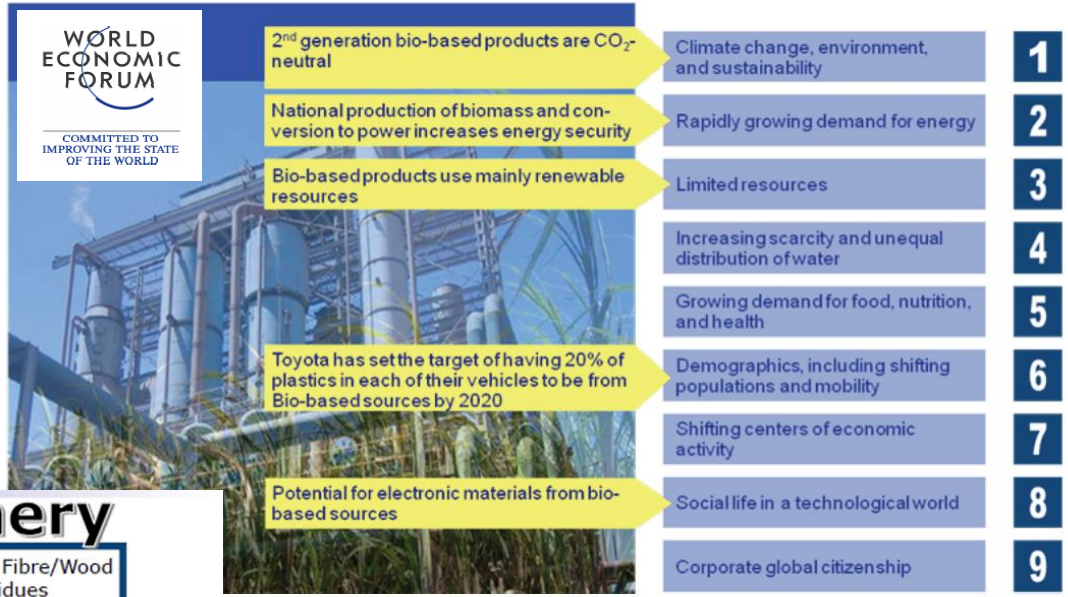
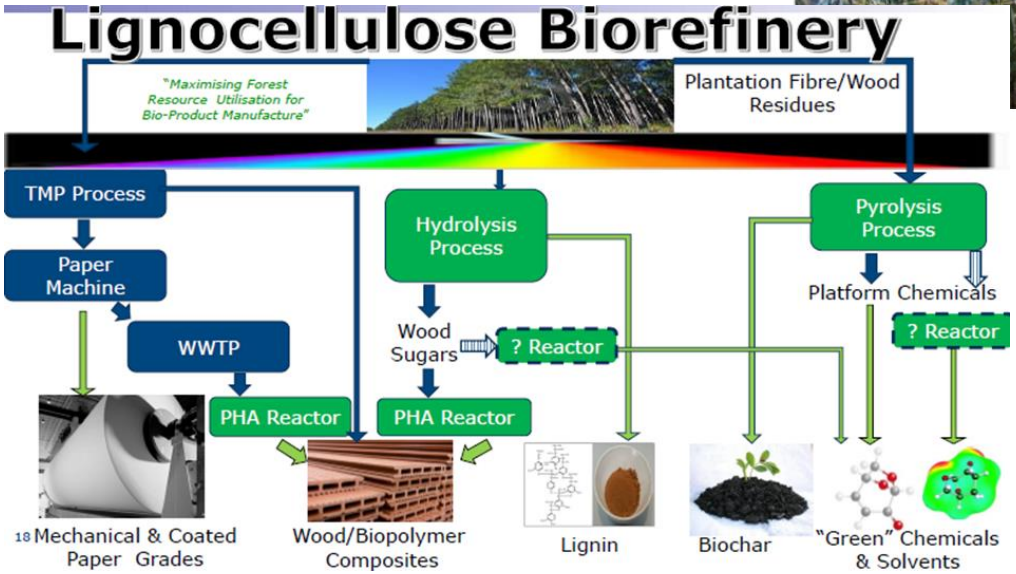
New products,
New materials,
New opportunities





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The value chain challenge

Drop-in

newBBBB

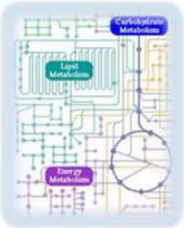
Business case	Solid	Hypothetical
Investment	High *"on cost, on spec" via high volume production*	Stepwise *as business grows*
Breakthrough potential for "added functionality"	Low *existing products*	High *game-changing nature*
Business segment	Commodity	Specialties *Potential to commoditize*
Management style	"Control & operate"	"Steer & create"

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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Making wood fibre reinforced plastics

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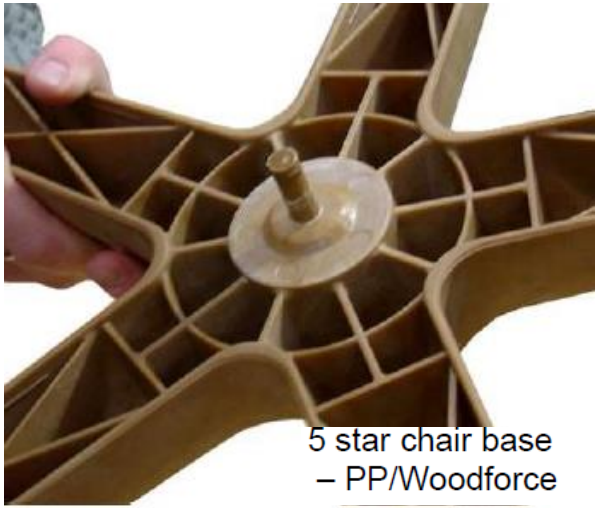
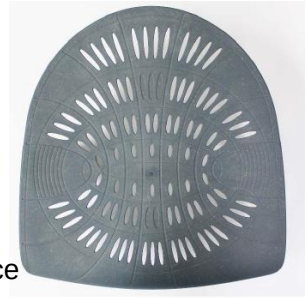
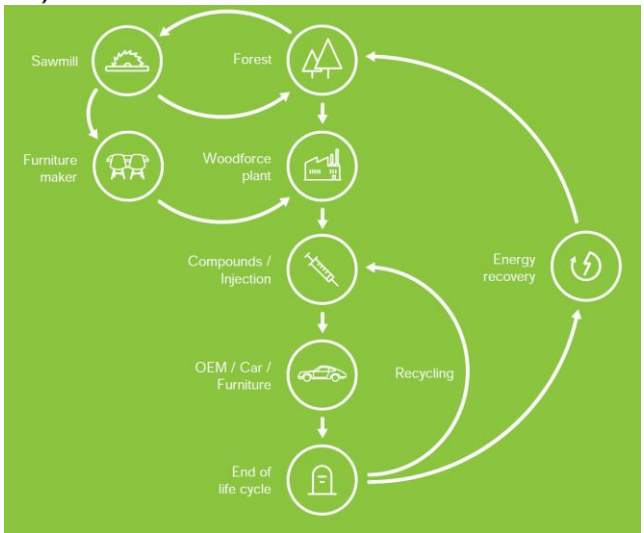
- Commercial advantages over ‘agri-fibres’
  - Industrial supply and scale
  - Consistency
  - Odour
- Leading Suppliers
  - Woodforce – Scion/Sonae (HTMP)
  - Thrive* – Weyerhaeuser (kraft)
  - Formi* – UPM (kraft)
  - Fribomer* – Mondi (kraft)
  - Symbio* – Sappi (kraft)
  - Greencore*


Respirator fan
PBS/Woodforce


5 star chair base
– PP/Woodforce


Chair seat
PP/Woodforce



Making Carbon Nanofibres

Formulate Lignin → Electrospin nanofibres → Carbonise → Product development

Lignin
- low cost (<$1/kg)
- high C content
- non-toxic
- renewable

Lignin nanofibre mat

Two steps
- Stabilisation
- Carbonisation

- Energy storage
- Electronics
- Coatings
- Air filters
- Composites

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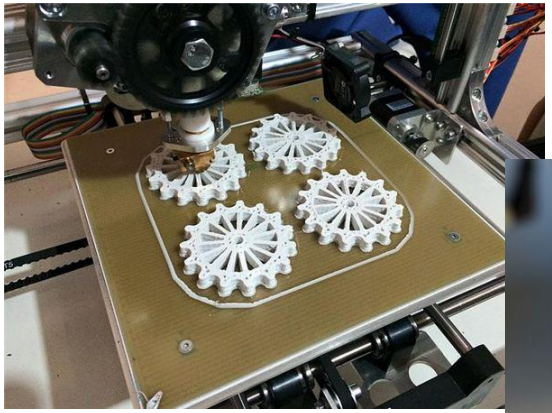
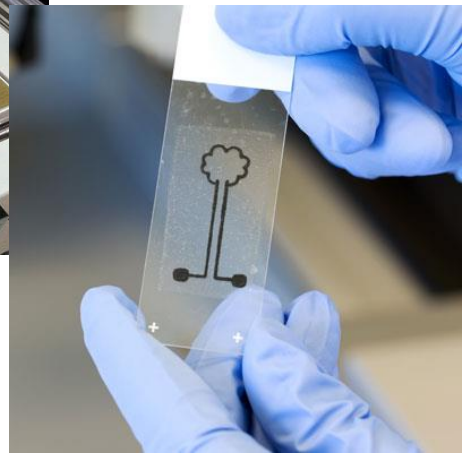
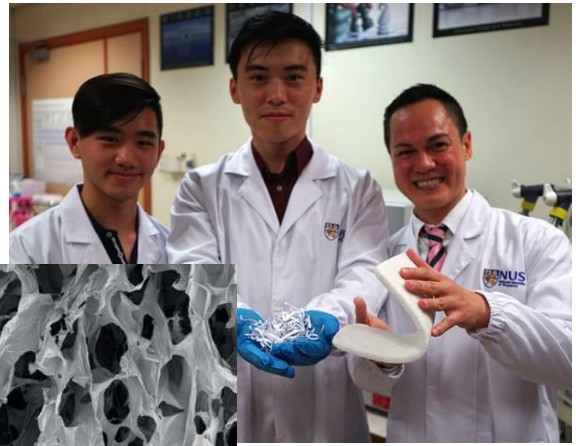
Cellulose







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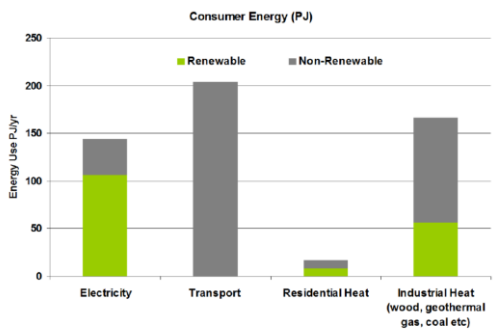
3D printing with designers

David Trubridge

Biodegradable cosmetic pots and net clips – using waste

Bioenergy from trees



Bioenergy

Solid biofuels *electricity & heat*

Liquid biofuels *transport*

Briquettes | Pellets | Torrefied pellets | Bio-oils | Ethanol

Sawdust, chips





Jet fuel, butanol, diesel

Drop-in biofuels

Can replace fossil fuels in existing equipment without major modification

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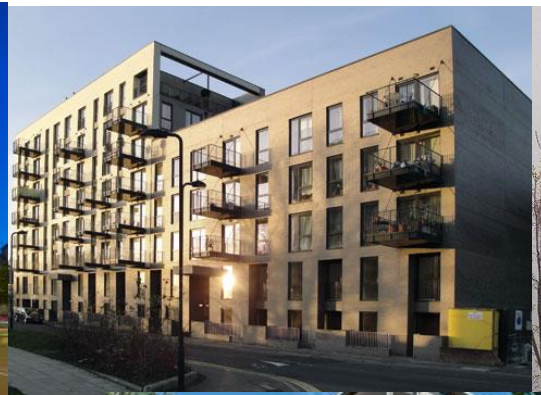
Tall wooden buildings



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)

SEQUESTRATION OPTIMISATION + **STORAGE MAXIMISATION** + **EMISSION MINIMISATION**

SEQUESTRATION

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

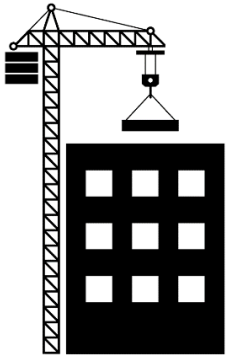
STORAGE

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

SUBSTITUTION

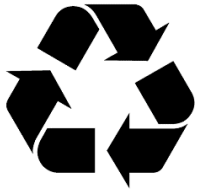
Substitution of building materials could save 38% to 65% of cradle to gate carbon emissions in manufacturing building materials compared with business as usual.

AVOIDANCE



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

END OF LIFE



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

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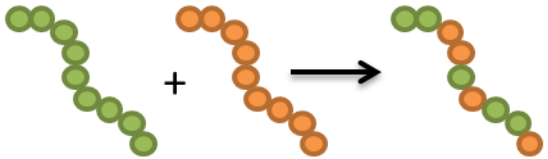
What is Genomic Selection?

Goal: Double productivity in radiata pine

- **Sequence radiata genome**
- **Find many SNPs and related phenotypes**
- **Halve breeding cycle to 10 to15 years**

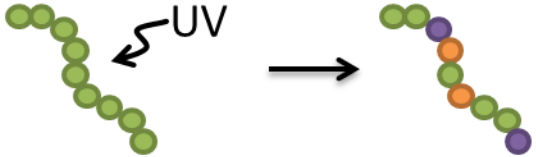
What is Genetic Modification (GM)

BC



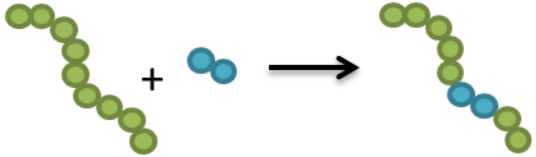
Conventional Breeding
- 'traditional' selective breeding and cross breeding
- Introduces random genetic material into host genome

1950s



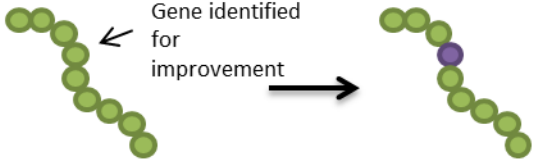
Random Mutagenesis
- Host organism subjected to radiation or chemicals
- Random mutations in DNA

1990s



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

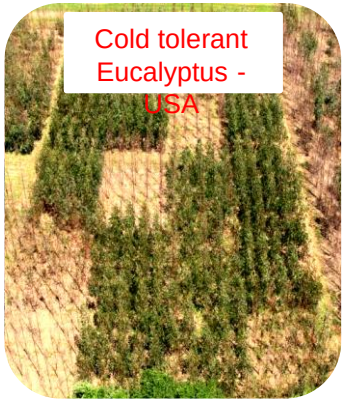
Today



Modern Gene Editing Technology
- Selected gene of host genome altered
  - Precise
  - Predictable
  - Safe

Commercial plantings of biotech trees?

GM poplar in China
Insect resistance



Cold tolerant Eucalyptus - USA

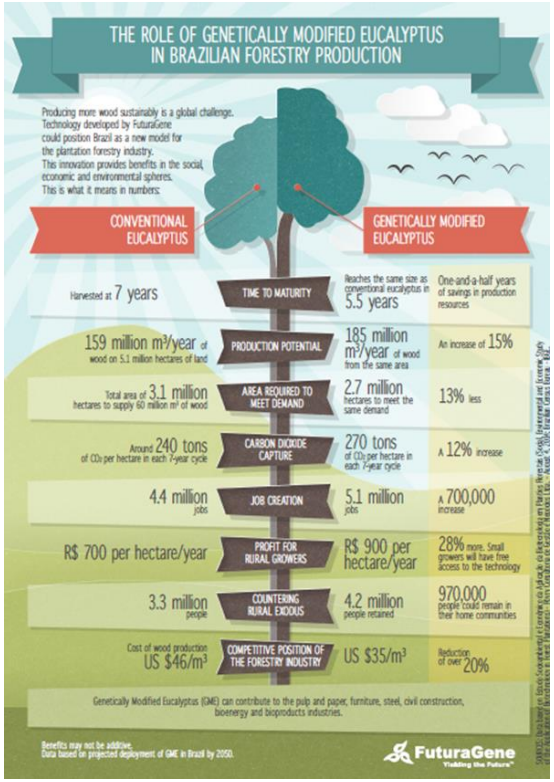
American Chestnut
billions of trees killed
Chestnut Blight
GM solutions tested

>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

SweTree Technologies
Innovators in Forest Biotechnology

(Sweden, Brazil, China)
Screened >1000 genes; 35 in field trials



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Gene editing – regulated?

nature International weekly journal of science

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

Canada ✓
USA ✓
Australia ✓
Argentina ✓
Europe ?
NZ x

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

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?

Magnetic resonance

Biodegradation & compostability

Industrial Fermentation

Nutrient recovery

Scion's Vision: Prosperity from trees

Trees as living factories

Biospifes from kiwifruit

New indigenous forestry

TERAX pilot plant

Thank you

www.youtube.com/scionresearch