

School of Design

SUSTAINABLE MATERIALS RESEARCH GROUP



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Sustainability challenges of the textile industry and opportunities for innovation

Dr. Richard Blackburn



@RichardBlackb18

Necessity for Sustainable Products

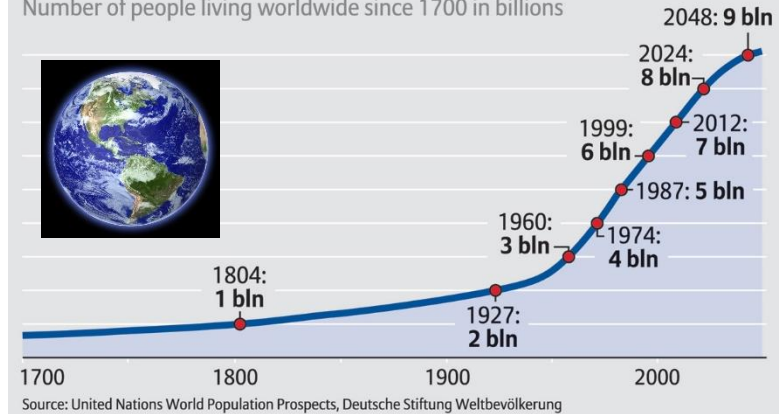


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- 2012 - world population 7 billion
- 2050 - expected to rise to over 9 billion
- Increases demand
 - food, energy, water, resources, chemicals
- Increases environmental burden
 - pollution
 - depletion of finite non-renewable resources (e.g. fossil fuels)
- **Synthetic chemical products and processes afford a significant improvement in quality of life**
- **Growing middle class want these consumer products too**

POPULATION OF THE EARTH

Number of people living worldwide since 1700 in billions

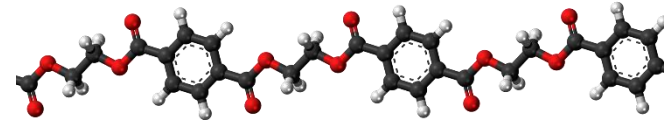
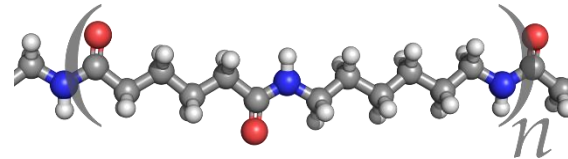


Synthetic fibre revolution



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- 20th Century polymers
 - nylon, 1935
 - polyurethane, 1937
 - polyester
 - Terylene, 1941
 - Dacron, 1946
 - acrylic, 1944
 - polypropylene and HDPE, 1951



news about NYLON

it all started with a stocking

Do Pant makes the nylon fibers used in the products shown. The manufacturer of these products use nylon because nylon products can have these outstanding properties:

- ✓ STRENGTH
- ✓ LONG WEAR
- ✓ EASY WASHING
- ✓ LIGHTNESS
- ✓ FAST DRYING
- ✓ BLENCH RESISTANCE
- ✓ FIBRE RESISTANCE
- ✓ RESISTANCE TO MOISTURE AND RESPIRATION
- ✓ CAN BE "SET" TO HOLD SHAPE

DU PONT

BETTER THINGS FOR BETTER LIVING... THROUGH CHEMISTRY

TO MANUFACTURERS: Ask about Nylon. Show us your product that you'd like to read "Nylon" in the "Nylon" column of the "Nylon" book sent free to you. Write to Nylon Division, E. I. du Pont de Nemours & Co., Inc., 1000 Market Street, Newark, N. J.

Synthetic fibre sustainability challenges



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- Non-degradable, non-renewable
- Increases oil consumption
- Contribution to anthropogenic GHGs
- **Significant oil supply issues**
- But, polyester highest share of textile market (>50m tpa)
- **Raw materials for fibres has to change**
- Recyclable – **mechanical** or **chemical**?



Definition of Sustainability



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Sustainability considerations



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**RAW
MATERIALS**

ENERGY

WATER

EMISSIONS

Public perception



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Sustainable?

Is it green?? Is it ethical??

Do I care about green issues??

What influence does media have on public opinion?



Public perception

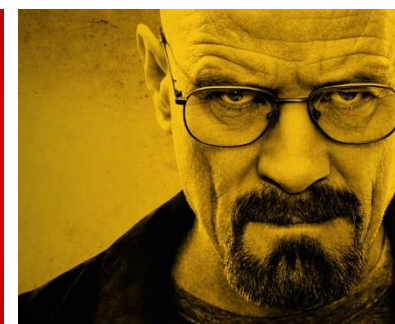


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- Demand (and rejection) for consumer products can be driven by the public and the media
- “*Biodegradable*”, “*Natural*”, “*Organic*”
 - perceived by the public to be good for the environment
- “*Synthetic*”, “*Non-organic*”, “*GM*”
 - perceived by the public to be bad for the environment
- “*Chemistry*”
 - Public perception of science...
- Do the public understand what “*Sustainable*” means?



Physics



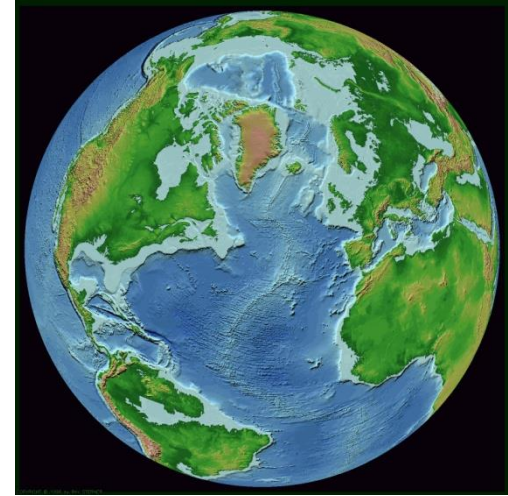
Chemistry

Definition of Sustainability



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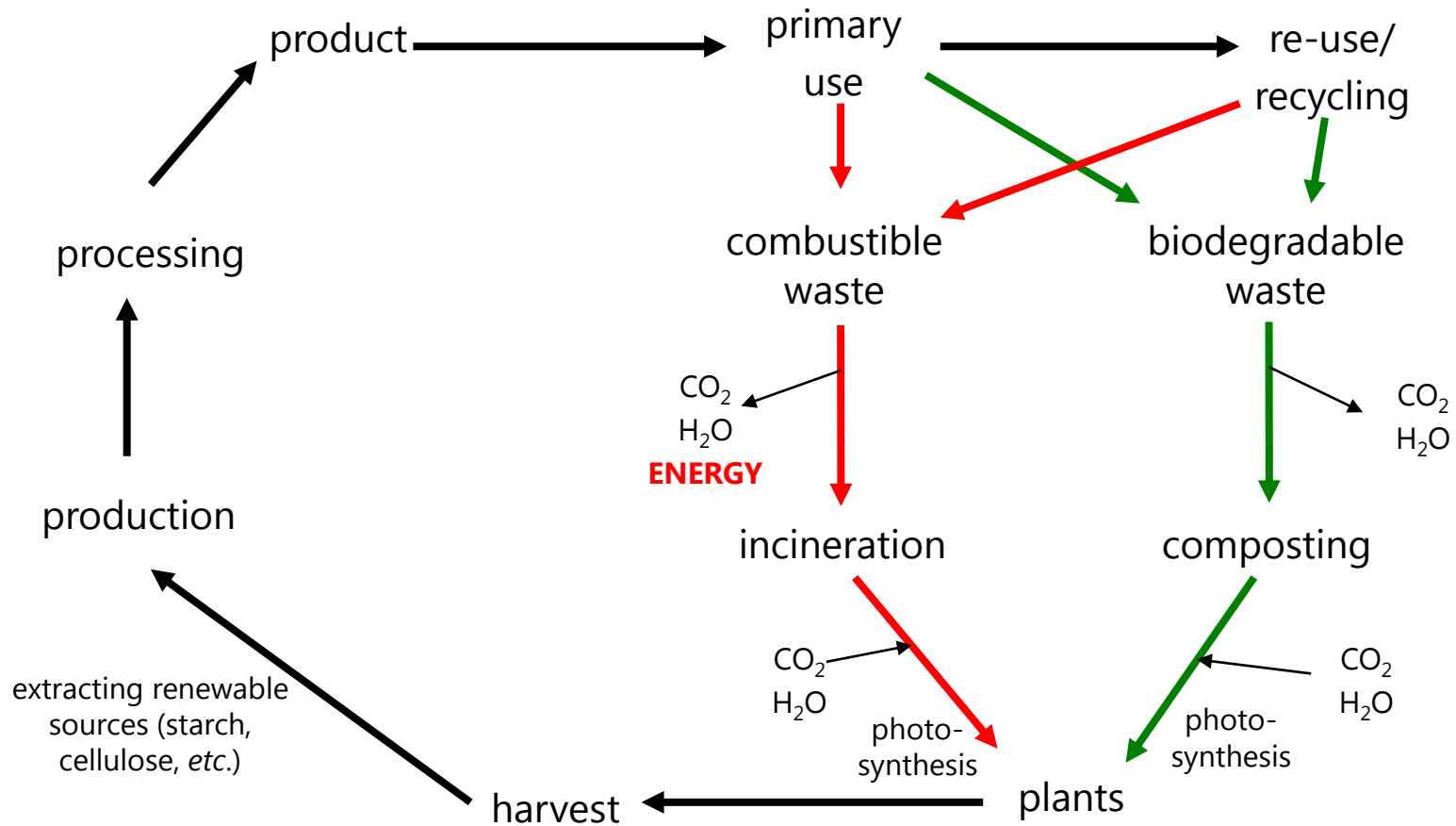
- Most important concept is ‘sustainability’
- Sustainable living is taking no more potentially renewable resources from the natural world than can be replenished naturally
- To not overload the capacity of the environment to cleanse and renew itself by natural processes
- Resources are sustainable if they cannot be used up



Sustainable Life Cycle



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Idealised life cycle of sustainable products

Polymers in the environment



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- Volume in waste disposal and landfill is very high
- Polymers do not degrade very readily
- Not just synthetic polymers!
- Landfills are decreasing in number



**Recycling of polymers is on the increase
and should be encouraged**

**Consume a significant
amount of energy &
too many different polymers**

**Necessity for biodegradable
polymers**



textiles

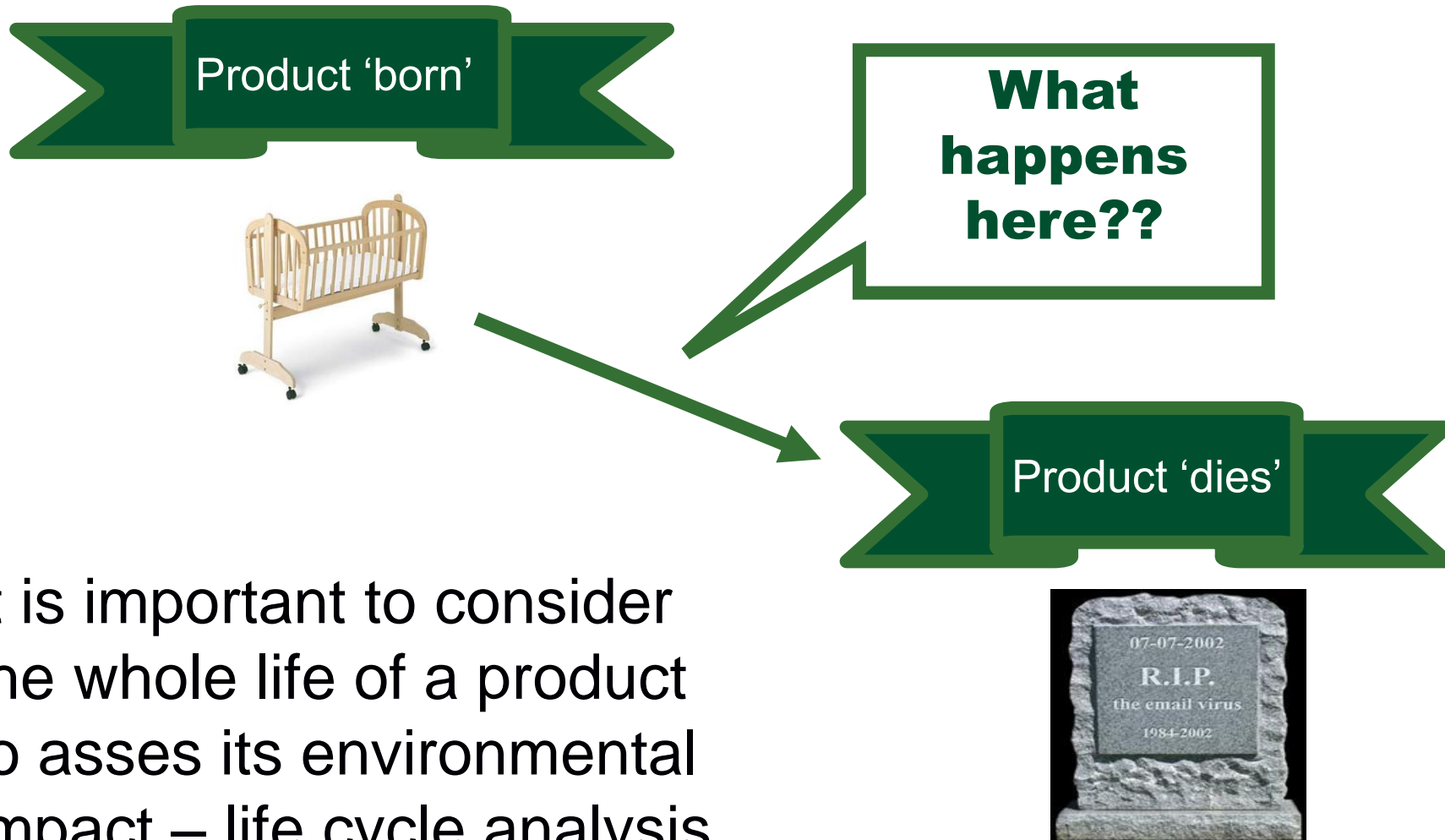
Disposal of biodegradable polymers



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- Carried out by the public through a composting mechanism
- System requires infrastructure
- Collection systems and composting facilities
- Germany has invested in compost infrastructure
- More than 60% of all German households issued organic waste bins





- It is important to consider the whole life of a product to assess its environmental impact – life cycle analysis



- Provide an **equivalent function** to the product it replaces
- **Performs as well as or better** than the existing product
- Be available at a **competitive or lower price**
- Have a minimum environmental footprint for **all the processes involved**
- Be manufactured from **renewable resources**
- Use only **ingredients that are safe** to both humans and the environment
- **No negative impact** on food supply or water

Green Chemistry Is About...



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REDUCING

Waste

Materials

Hazard

Risk

Energy

**Environmental
impact**

COST

WASTE AND THE CHEMICAL INDUSTRY



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Where does the waste come from?

Industry Segment	TONNAGE	RATIO (kg by-products/kg Product)
Oil Refining	$10^6 - 10^8$	<0.1
Bulk Chemicals	$10^4 - 10^6$	1 - 5
Fine Chemicals	$10^2 - 10^4$	5 - 50
Pharmaceuticals	$10 - 10^3$	25 - 100+

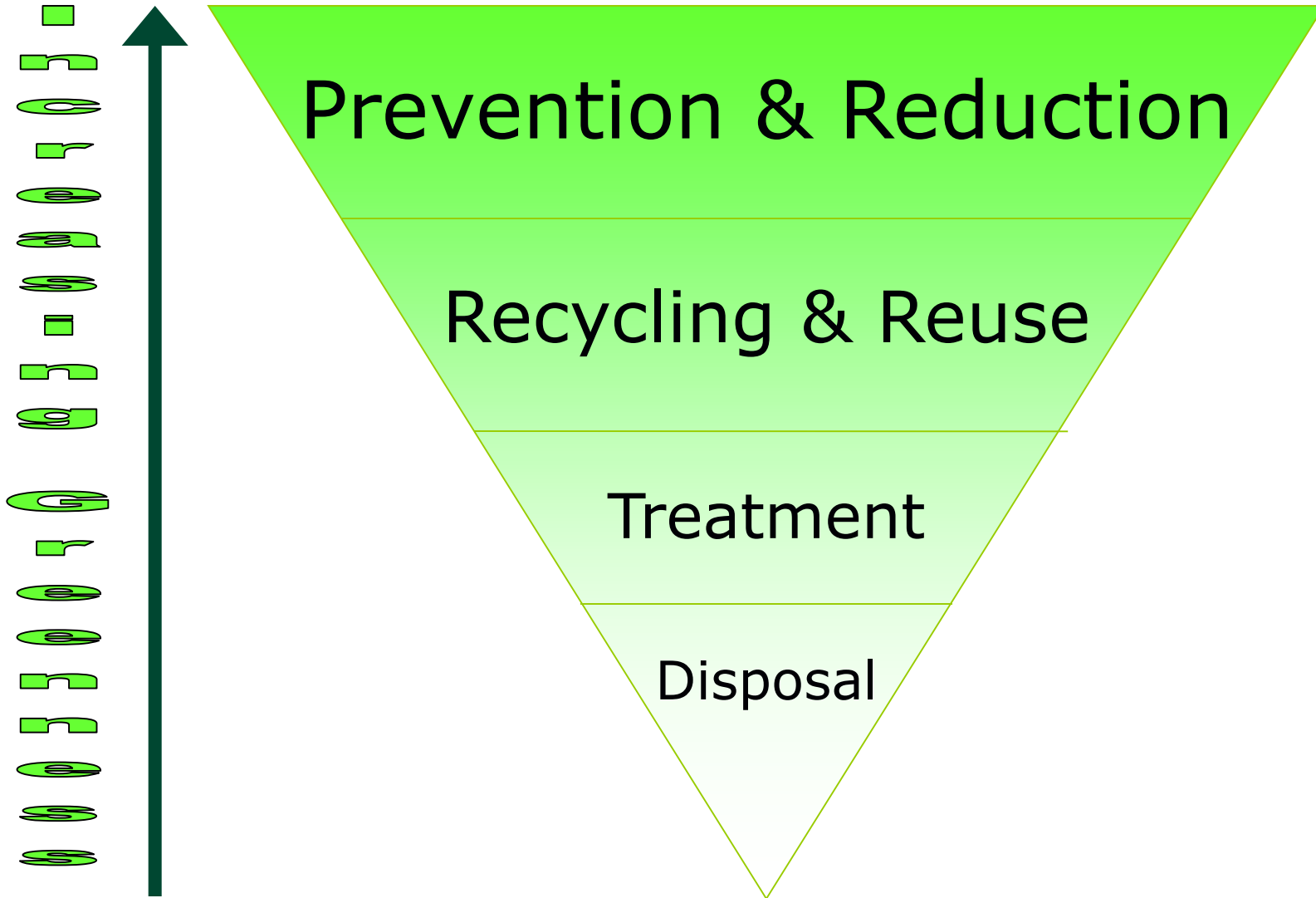
Areas traditionally thought of as being dirty (oil refining & bulk chemical production) are relatively clean - they need to be since margins per kg are low.

Newer industries with higher profit margins and employing more complex chemistry produce much more waste relatively.

Pollution Prevention Hierarchy



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CASE STUDY:

Problems with cotton



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- **NATURAL** doesn't necessarily mean sustainable
- Cotton production >25 million tpa
- High levels of pesticides (25% world total) and insecticides (11% world total)
- Very high irrigation levels
 - 1 kg of cotton fibre requires 20,000-40,000 L (water you consume in a lifetime)
- Only grows in certain climates
 - Deforestation to grow cotton
- High area of land for mass of useable fibre
- Organic cotton not a viable alternative on a global scale



Organic cotton

- Widely promoted as the answer to cotton's problems
- Global production (in over 20 countries, mainly India) only 1.1% of world cotton production (Textile Exchange)
- Must wait 3 years for land to be 'organic'
- Only genetically unmodified seed
- No herbicides or pesticides
- Ethical labour employment standards
- Requires approximately 1.4x area of land to produce same mass of fibre
- Still has very high water consumption
- Not a viable alternative on a global scale to completely replace non-organic cotton





Sustainable cotton?

Organic cotton challenges

- Limited organic insecticides
- Lower yields, crop dependent
- Yields more variable
- Higher water usage
- Labour availability
- Higher labour cost for hand weeding

Organic cotton certification

- Not based on a test
- Production practices must be documented
- Process described in Organic Systems Plan



Better cotton

- GM pest-resistant strain referred to as 'Bt cotton'
 - Naturally occurring protein (used by organic gardeners) – kills bollworm pests (moth larva)
 - Reduces pesticide sprays from 5 sprays to 0
 - Poisoning of workers virtually eliminated
 - may reduce presence of bollworm on other host crops and may decrease the need for insecticide sprays in general
 - More productive, particularly in India, Bt cotton is regarded as less 'natural'
 - Cannot be classed as 'organic'
- Better Cotton Initiative (BCI) set up to foster improvements in the sustainability of cotton production methods





Fairtrade Cotton

20 MILLION GARMENTS

10,000 farmers in West Africa and India



Worlds Largest order for Fairtrade Cotton



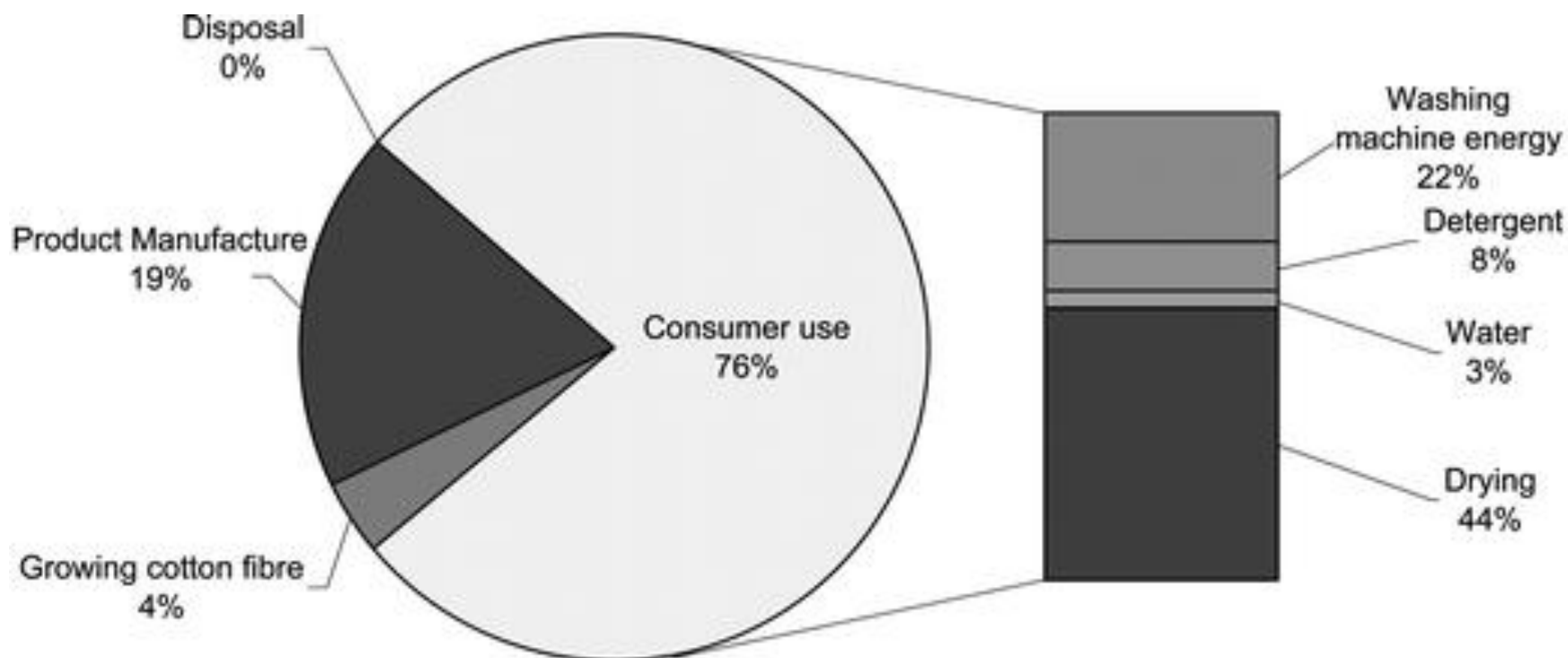
Guarantees
a **better deal**
for Third World
Producers



Greener Living

Think green. Shop smart.

Extracted energy consumption

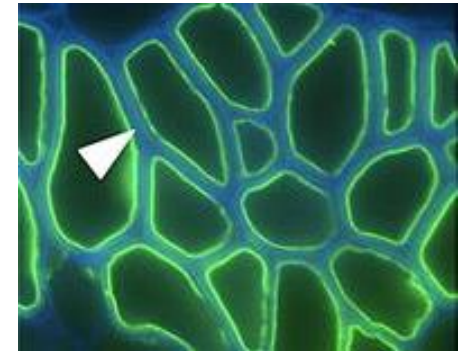


Major Sustainable Fibre Types



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- Bast Fibres
 - flax, hemp, jute, ramie, kenaf and abaca
- Regenerated cellulosics
 - Lyocell (Tencel), modal
- Poly(lactic acid) (Ingeo)
- Wool

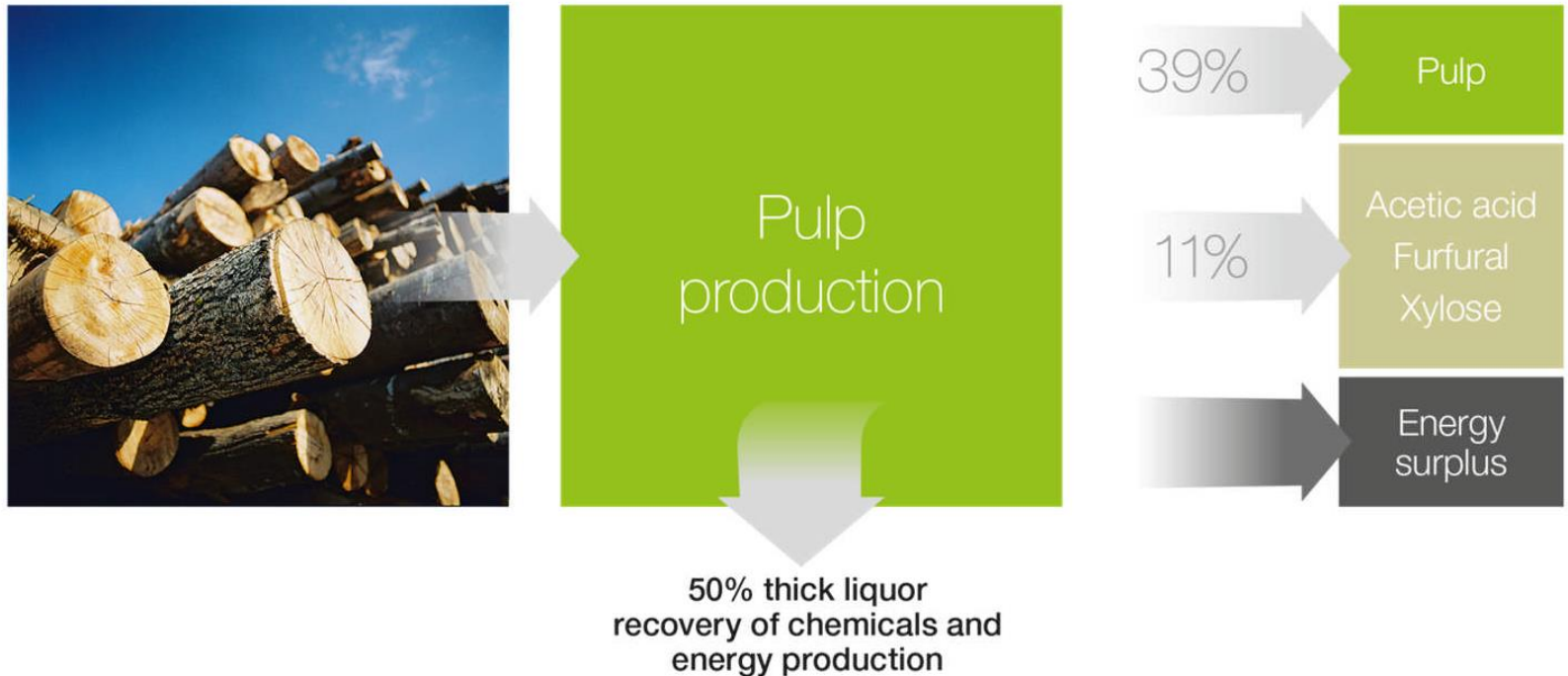


Lyocell & Modal – Highly efficient use of the raw materials



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- Lenzing manufactures lyocell
- Pulp production at the Lenzing site achieves a wood utilization rate of over 50%

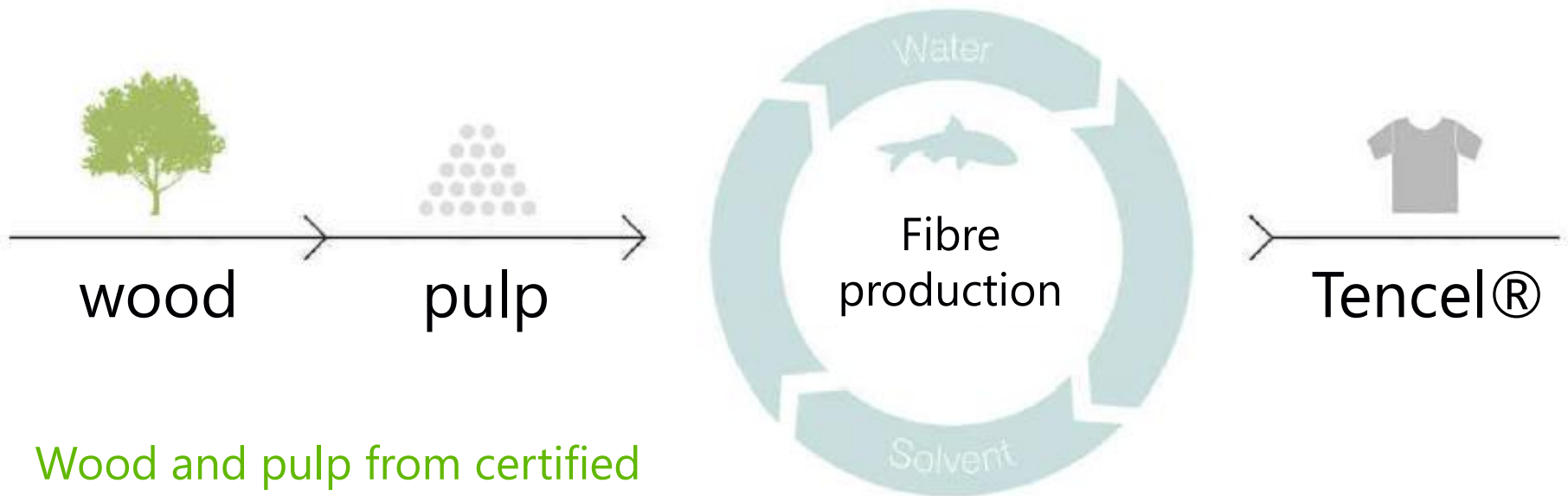




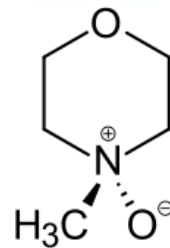
TENCEL® (lyocell) – the most sustainable fibre production process



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- Wood and pulp from certified forests
- Direct dissolution process
- *N*-methylmorpholine-*N*-oxide (NMMO)
- Closed-loop process
- >99% recovery of solvent

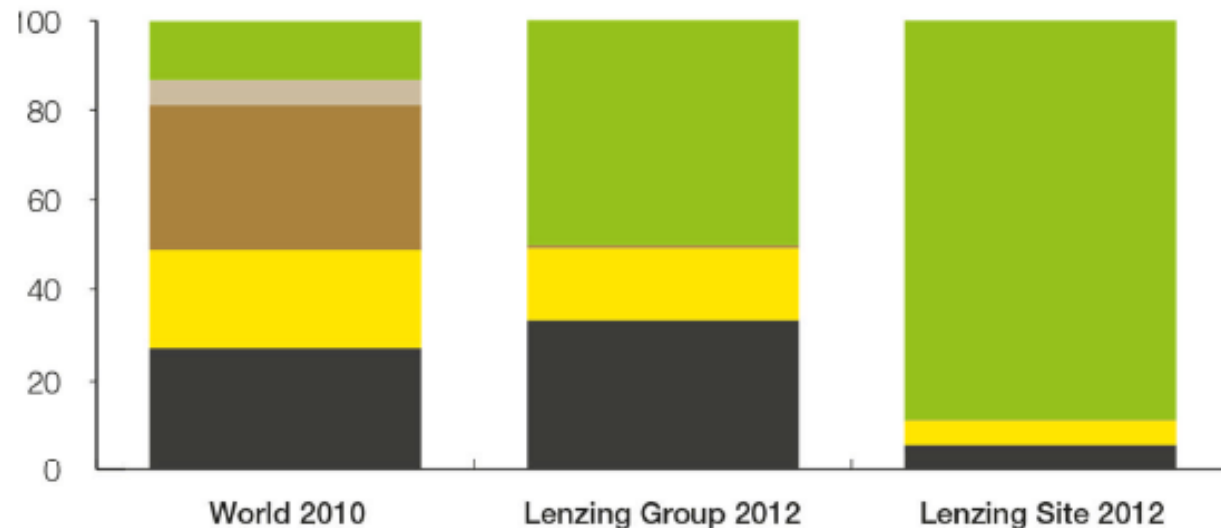


Lyocell & Modal – Comparison of energy sources



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Global,
Lenzing Group and
Lenzing Site*



*) incl. RVL

Sources: World Energy
Outlook 2012, Lenzing AG

Green footprint: significantly more environmentally than cotton



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- More than 50% of Lenzing's fuel consumption sourced from renewable resource

Required acreage for production of one metric ton of fiber

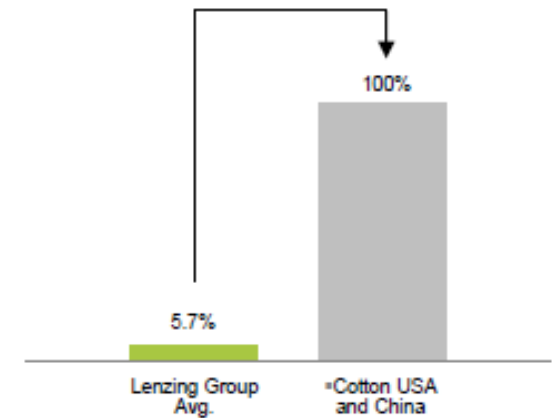
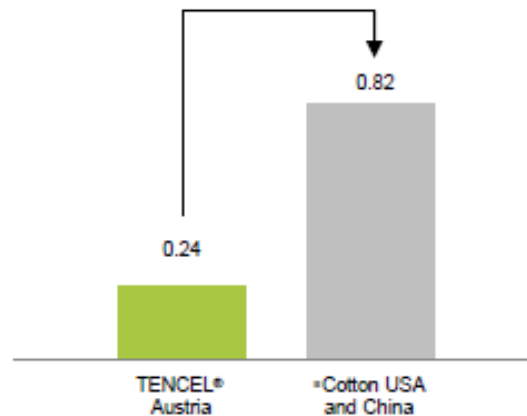
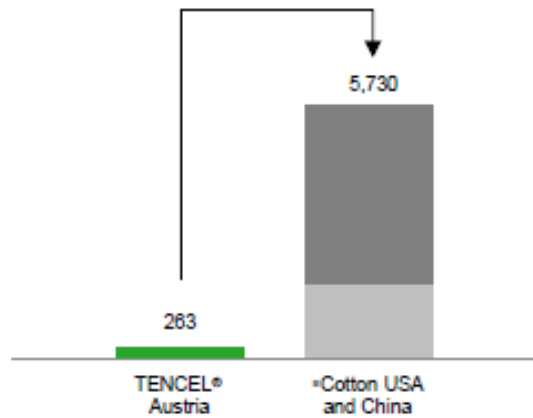
Environmental impact of production¹

Water consumption

m³ per metric ton of fiber

Hectares per metric ton and year

Relative to cotton



Process water Cooling water Groundwater irrigation Surface water irrigation

- Traditional dyeing processes use 5.8 trillion litres water p.a.
 - ~3.7 billion Olympic swimming pools
- 10-20% dye remains after dyeing (plus other chemicals), leaving potential for wastewater pollution
 - One fifth of the world's industrial water pollution (World Bank)
- 391 billion kWh energy for dyeing processes
- **Innovative technologies needed to reduce, or eliminate, water, energy and auxiliary chemicals in dyeing**





Polyester dyeing process

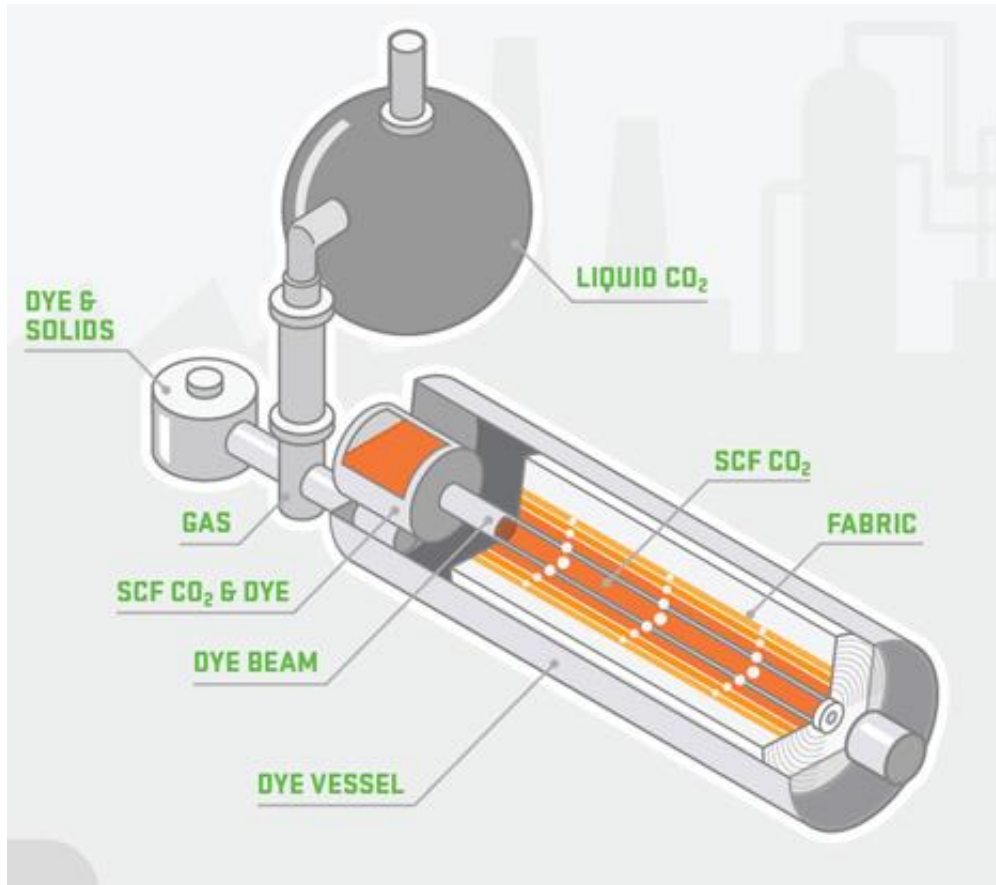
- Hydrophobic fibre dyed with hydrophobic disperse dye
- Traditional aqueous process requires dispersing agents/surfactants and high temperatures (typically 130 °C) under pressure
- Other dyeing auxiliaries often required
- Large amount of waste dye left over in effluent
- Surface dye removed with surfactants and/or reducing agents
- **Innovation in scCO_2 dyeing to completely change polyester dyeing process**



scCO₂ dyeing



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DyeCoo[®]
CO₂ Dyeing Technology

NIKECOLORDRY
REVOLUTIONARY WATERFREE DYEING PROCESS

drydy^e

Abel Kirui wins silver in London 2012 Marathon singlet in dyed using DyeCoo process

- System comparison with traditional polyester dyeing

WATER

Zero water used

WASTEWATER

Nearly 100% dye used in process.
Zero waste

ENERGY

Reduces energy consumption by 63%

PROCESS CHEMICALS

No auxiliary chemicals required

FOOTPRINT

¼ of physical footprint to dye same amount of fabric

EFFICIENCY

40% faster than traditional dyeing processes

Coloration of cotton



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- Dyeing of cotton primarily conducted using reactive dyes
- Despite development of dyes with high fixation, dyeing process has many problems:
 - **SALT**
 - **COLOUR IN EFFLUENT**
 - **WATER**
- Pre-treatment of cotton demonstrated 10-15 years ago by several research groups
- Water remains a significant problem with the vast majority used in washing processes after dyeing
- **Big opportunity for dyeing systems that do not need any washing after dyeing**
- Is water in the dyeing process cotton's biggest problem?

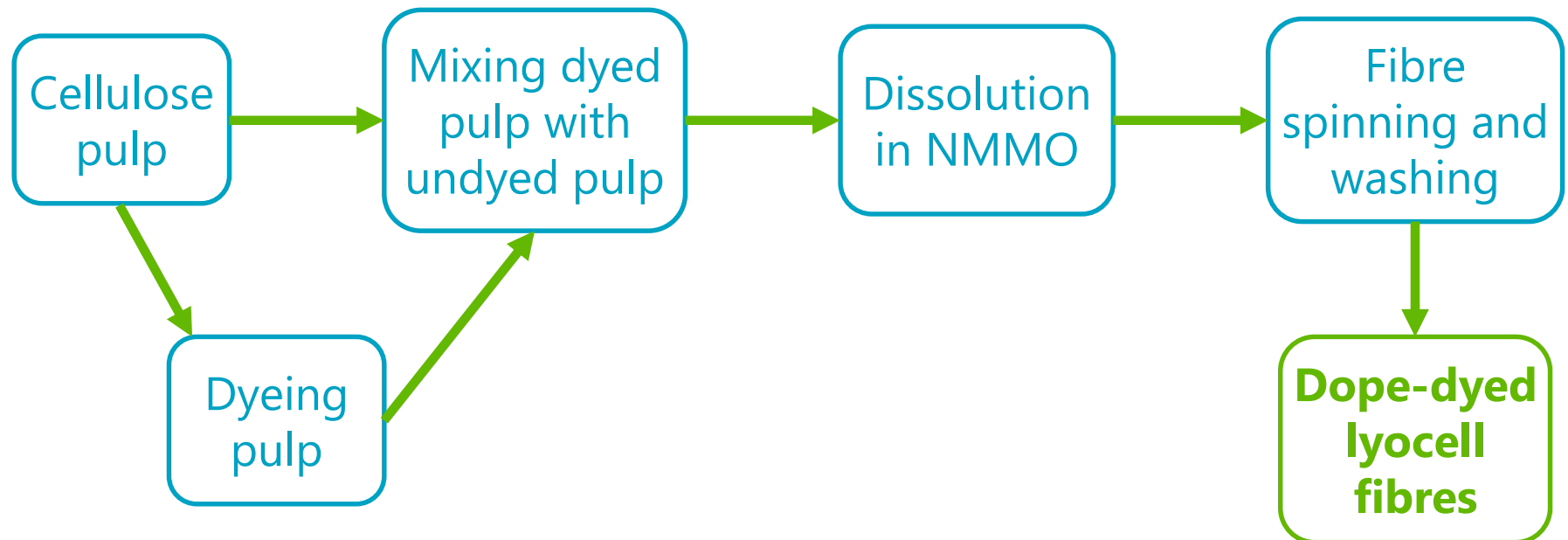


Does fibre coloration have to be through dyeing?



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- **Dope-dyeing:** incorporation of colorant into spinning process
- Lyocell process makes this possible for cellulosics

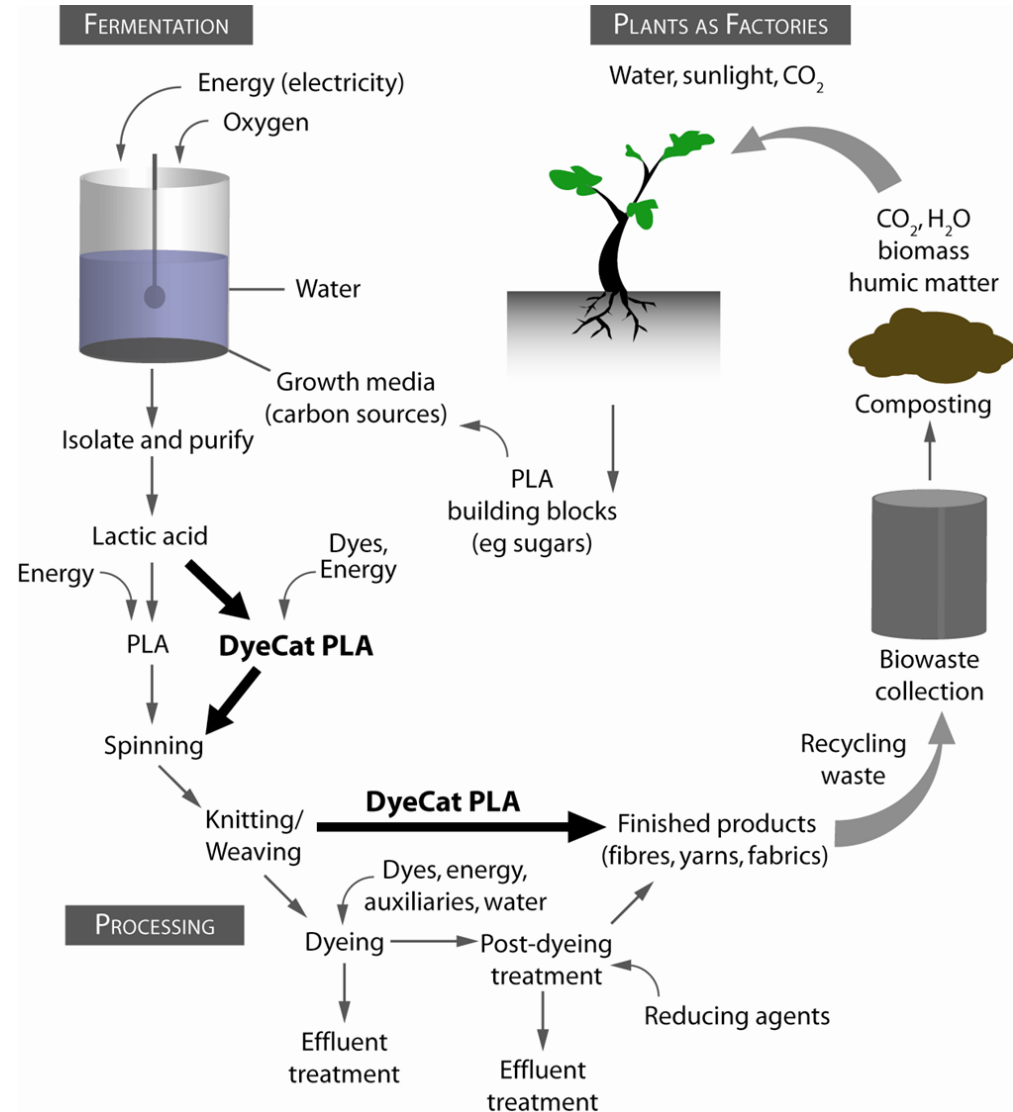


DyeCat Process



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- Catalytic process that allows colour to be integrated directly into polyesters
- Eliminates need for conventional dyeing
- Colour in fibre is generated at the same time the polymer is made
- Colours 'locked into' fibre providing a technically superior product
- No need for wasteful dyeing processes
- **DyeCat PLA fibre**
 - **Renewable**
 - **Technically superior**
 - **Saves chemicals and energy**



DyeCat Process



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- Coloration of polymer during synthesis
- Demonstrated on PLA using coloured catalysts



Best way to mix colours?



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- Nano-level
 - Mixture of different dyes in dyebath to create desired shade
- Micro-level
 - Mixture of different dyed fibres in yarn formation process to create desired shade
 - Mélange Yarn

Fast Fashion



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- Consumption of new designs as close as possible to the point of creation
- Fast, low price and disposable
- Business model: reducing time cycles from production to consumption
 - consumers engage in more cycles in any time period
- "Supermarket" market
 - Cost is the consumer's primary buying decision
 - Costs reduced by taking advantage of lower prices in markets in developing countries
 - Developing countries ~75% all clothing exports
- Environmental Impact
 - US imports >1 billion garments annually from China alone
 - UK purchasing of clothing surged by 37% from 2001 to 2005
 - Dramatic increase in environmental damage caused by the textile industry
- **An enormous change is needed in the minds and attitudes of consumers**



Fast Fashion



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- <https://www.youtube.com/watch?v=wIVqFyMmmwU>
 - Watch from 16:30



Sustainability challenges for the textiles industry



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- Greater use of sustainable raw materials
- Lower energy & water consumption and pollution generation in production
- Lower impact in use
 - Water, energy, chemicals in cleaning/laundrying
- Design for easy disassembly/disposal/ recycling
 - e.g. how to manage reuse of polycotton?
- **DESIGN FOR REDUCED CONSUMPTION AND LONGER LIFE**
 - **‘Disposable’ products unsustainable**

Sustainability challenges for the textiles industry



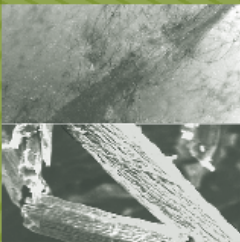
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- **Sustainability issues in the textiles industry have often been tackled in industry by tinkering and incremental change**
- **Step-change solutions are needed to bring about truly sustainable apparel and footwear products**



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WOODHEAD PUBLISHING IN TEXTILES



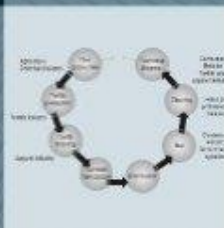
Biodegradable and sustainable fibres

Edited by R. S. Blackburn



WP

WOODHEAD PUBLISHING IN TEXTILES



Sustainable textiles

Life cycle and environmental impact

Edited by R. S. Blackburn



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Any Questions?

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