THE WOOLMARK COMPANY

WOOL AND THE CARBON CYCLE

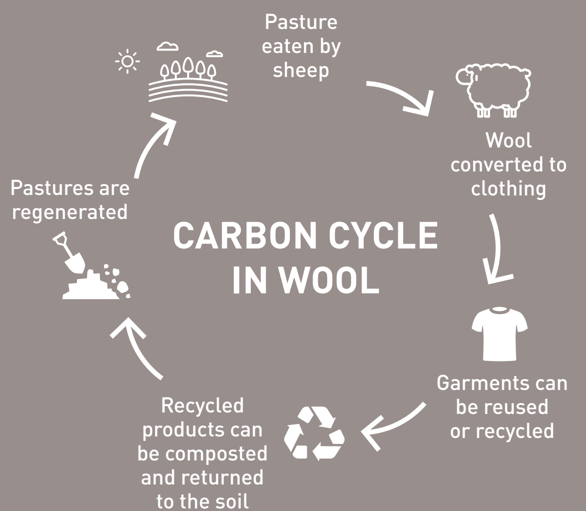
WOOL IS MADE FROM ATMOSPHERIC CARBON

Carbon is a vital building block for life and for many of the products we use every day. Many textiles and fibres are made from carbon-based products, but only some, such as wool, are made from atmospheric carbon. In addition, wool is naturally biodegradable. When disposed of, wool acts like a fertiliser by slowly releasing valuable nutrients and carbon back into the soil.

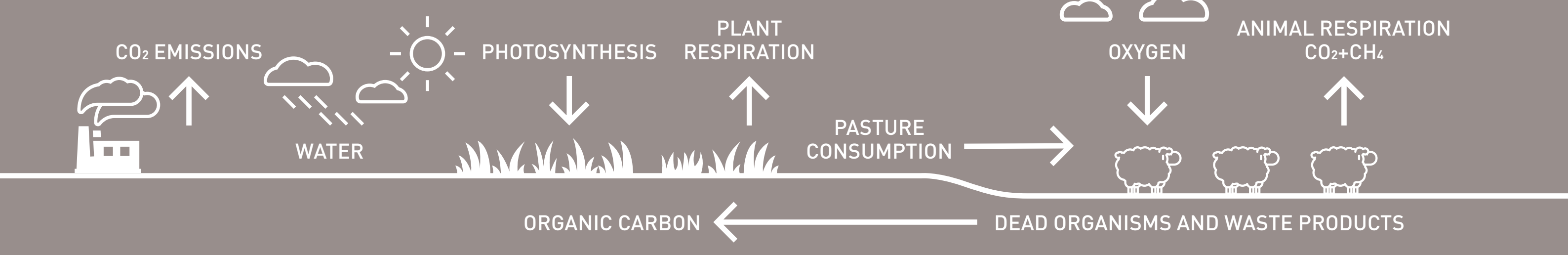
By comparison, the carbon in the major synthetic apparel fibres, such as polyester or acrylic, is extracted from fossil fuels, de-sequestering carbon stored millions of years ago.

WOOL'S CARBON IS NATURAL

Organic carbon makes up 50% of the weight of wool, which is more than cotton (40%), and wood pulp-based fibres, such as rayon, viscose and bamboo (42%). The carbon in wool is derived from the digestion of plant material by sheep. Wool, especially Australian wool, is produced in extensive pasture systems, where the diet is dominated by grasses and other pasture plants. These plants capture carbon from the atmosphere and convert it into organic compounds through photosynthesis (which supports much of the life on earth). This means that most of the carbon contained in freshly shorn wool was only removed from the atmosphere during the previous 1-2 years, and is part of a natural, renewable system.



PHOTOSYNTHESIS IN THE WOOL CYCLE



THE IMPORTANCE OF WOOL FOR THE CARBON CYCLE

Wool is a short-term store of atmospheric carbon, sequestered in a resilient, wearable form for the life of the garment. By storing the greenhouse gas carbon dioxide (CO_2), wool prevents the stored gas from contributing to climate change for the time the garment is in use. Converted into carbon dioxide equivalents (CO_2-e), 1 kg of clean wool equates to 1.8 kg of CO_2-e. Extending this concept, the 2016/17 Australian wool clip represents more than 419 million kg of CO2-e in clean wool. All this CO_2 is removed from the atmosphere for the fibre's life – from when grown on the sheep, through the wool product's use phase – until it is disposed of and biodegrades. For many wool garments, this period is greatly extended because wool is used or recycled in a variety of textiles (e.g. carpet and furnishings), which arguably have a longer useful life than many wool garments. Wool is the most reused and recycled fibre of the major apparel fibres and can be converted into new long-lasting products, such as garments, mattresses and upholstery. Even though wool represents only 1.2% of the virgin fibre supply, surveys have shown it represents about 5% of clothing donated to charity.

WHAT HAPPENS NEXT: WHERE DOES THE CARBON IN WOOL GO?

In addition to being part of the natural carbon cycle, at the end of its life wool breaks down naturally and returns to the soil, rather than accumulating in landfill, as is the case with synthetics. Because wool is composed of a biodegradable natural protein (similar to that of human hair), when disposed of, it acts like a fertiliser by slowly releasing valuable nutrients and carbon back into the soil. By contrast, synthetic fibres, such as polyester and acrylic, are derived from fuels and part of a non-renewable system. These man-made fibres are not biodegradable and contribute significantly to landfill.

WOOL IS 100% BIODEGRADABLE

Wool biodegrades readily in as little as three to four months, but the rate varies with soil type and conditions, climate and wool characteristics. Some studies found more rapid degradation after only four weeks' burial. This process releases essential elements such as nitrogen, sulphur and magnesium back to the soil, where they are taken up by growing plants.

Research has shown that processing treatments, such as dyeing and anti-shrink treatments, can affect the rate of biodegradation in soil, causing an increase in the initial resistance of wool fabric to degradation. However, this is a short-term effect, typically not persisting beyond eight weeks.

See the fact sheet Wool is 100% biodegradable for more information.

After being buried for six months, the nylon jersey fabric (left) remains relatively unchanged, whereas the wool jersey fabric (right) has significantly biodegraded.

REFERENCES

Wool biodegrades readily in as little as three to four months but the rate varies with soil, climate and wool characteristics:

- Hodgson A., Collie S. (December 2014). *Biodegradability of Wool: Soil Burial Biodegradation*. Presented at 43rd Textile Research Symposium in Christchurch – AWI Client Report.

This releases essential elements such as nitrogen, sulphur and magnesium back to the soil, able to be taken up by growing plants:

- McNeil et al. (2007). *Closed-loop wool carpet recycling. Resources, conservation & recycling* 51: 220-4.

Converted into carbon dioxide equivalents (CO_2-e), 1 kg of clean wool equates to 1.8 kilograms of CO_2-e: 1 atom of carbon representing 27.3% of the molecular weight of CO_2 (1 x C atom (mwt 12) + 2 x O atoms (mwt 2 x 16 = 32) – hence 12/(12+32) = 12/44 = 0.273). Hence, to derive the CO_2 equivalence of 1 kg of clean wool, multiply 1 kg of clean wool by 0.5 to convert to pure carbon, then divide by 0.273 to convert to CO_2 equivalents.

Of the major apparel fibres wool is the most reusable and recyclable fibre on the planet: Russell SJ et al. Review of wool recycling and reuse. Proceedings of 2nd International Conference on Natural Fibers, 2015, 4.

Organic carbon makes up 50% of the weight of wool:

- Simmonds, D. *Proceedings of the International Wool Textile Research Conference*, International Wool Textile Research Conference. Melbourne, Australia: CSIRO Publishing, 1956, C65.
- Hawkesworth, A., *Australasian Sheep and Wool: A Practical and Theoretical Treatise: From Paddock to Loom. From Shearing Shed to Textile Factory*, 1948: p. 91.
- von Bergen, W., *Wool Handbook: A Text and Reference Book for the Entire Wool Industry*. Vol. 1. 1963, New York: John Wiley and Sons Inc. 315-450.
- Causarano, H.J., et al., *Soil organic carbon sequestration in cotton production systems of the southeastern United States*. Journal of Environmental Quality, 2006. 35(4): p. 1374-1383.

Organic carbon makes up 40% of the weight of cotton: Casuarano, H.J, Franzluebbers, A.J., Reeves, D.W, Shaw, J.N. (2006), *Journal of Environmental Quality*, 35, 1374-1383.

Organic carbon makes up about 42% of the weight of wood pulp-based fibres like viscose: Viscose $C_{18}H_{32}O_{16}$ is a polymer of sodium cellulose xanthate, produced by reacting cellulose with alkali and carbon disulphide: Open Chemistry Database, *Compound Summary for CID 440950*, 2018, p.1.

The 2016/17 Australian wool clip represents more than 419 million kilograms of CO_2-e in the clean wool:

- Hawkesworth, A., *Australasian Sheep and Wool: A Practical and Theoretical Treatise: From Paddock to Loom. From Shearing Shed to Textile Factory*, 1948: p. 91.
- AWTA Key Test Data, 2016-17.

Wool is the most reused and recyclable fibre of the major apparel fibres: Russell SJ et al. Review of wool recycling and reuse. Proceedings of 2nd International Conference on Natural Fibers, 2015, 4s.

Even though wool represents only 1.2% of the virgin fibre supply, surveys have shown it represents about 5% of clothing donated to charity:

- Y Chang, H. L Chen, and S Francis, *Market Applications for Recycled Postconsumer Fibres Family and Consumer Science* 1999. 27(3): p. 320.
- G. D. Ward, A. D. Hewitt, and S. J. Russell, Proceedings of the ICE. *Fibre composition of donated post-consumer clothing in the UK*. 2012 166(1): p. 31.
- Red Book 2016: *Long term global supply/demand update*. PCI Wood Mackenzie.

Polyester, acrylic and nylon are all produced from hydrocarbons or propylene derived directly from fossil fuels, and are therefore part of a non-renewable cycle. These fibres are also non-biodegradable:

- Russell, I., *Combined insect-resist and rot resist treatments of wool insulation*. 1992, CSIRO Division of Wool Technology: Australia.
- Szostak-Kotowa, J., *Biodeterioration of textiles International biodeterioration & biodegradation*, 2004. 53(3): p. 165-170.

Some studies found more rapid degradation with marked weight loss after only four weeks' burial in soils: Hodgson A., Collie S. (December 2014). *Biodegradability of Wool: Soil Burial Biodegradation. Presented at 43rd Textile Research Symposium in Christchurch* – AWI Client Report.

Results demonstrate that chemical processing of wool fabrics does impact on the rate of biodegradation (as a result of soil burial). The short-term impact is generally that of an increase in the fabric's initial resistance to degradation, rather than an increase in susceptibility:

- Hodgson A, Collie S. (December 2014). Biodegradability of Wool: Soil Burial Biodegradation. Presented at 43rd Textile Research Symposium in Christchurch – AWI Client Report.