# Wool That Breathes: Integrating Porous Micro-Crystals and Structural Modelling on NZ Wool to Develop the Foundation for Passive CO2 Capturing Textiles

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Mitigating climate change requires carbon dioxide removal, but conventional Direct Air Capture is prohibitively expensive. A scalable alternative is distributed, passive capture: embedding CO2-absorbing capabilities into everyday materials. Recently, Metal-Organic Frameworks (MOFs) have gained research attention for ambient CO2 sorption, making them ideal for textile integration. Simultaneously, New Zealand's strong wool sector faces economic depression. Using wool as a substrate for MOF functionalisation creates a dual-impact solution: forming distributed carbon sinks while revitalising a struggling commodity. Developing this material is a multi-scale engineering challenge requiring micro-scale chemical bonding and macro-scale structural coordination. First, laboratory synthesis established a repeatable pathway for functionalising complex biological keratin. Through 17 iterations, ambient in-situ growth of Zeolitic Imidazolate Frameworks (ZIF-8 and ZIF-67) was achieved on merino fibres. SEM, EDS, and XRD confirmed robust crystal nucleation, proving MOFs preferentially anchor to rough cuticle edges. Second, because physical weaves dictate airflow and CO2 access, a computational pipeline was developed to generatively design fabric architecture. Focused on 3D weft knitting and trained on real-world topological data, the model uses a physics simulation module to estimate theoretical CO2 sorption. This acts as an optimisation feedback loop, iteratively tweaking parameters to maximise capture capacity. Outputs are mathematically validated to ensure designs are structurally realistic and "machine-knittable". Integrating chemical feasibility with digital textile generation provides a blueprint for climate-positive fabrics.

**Awards Won:**