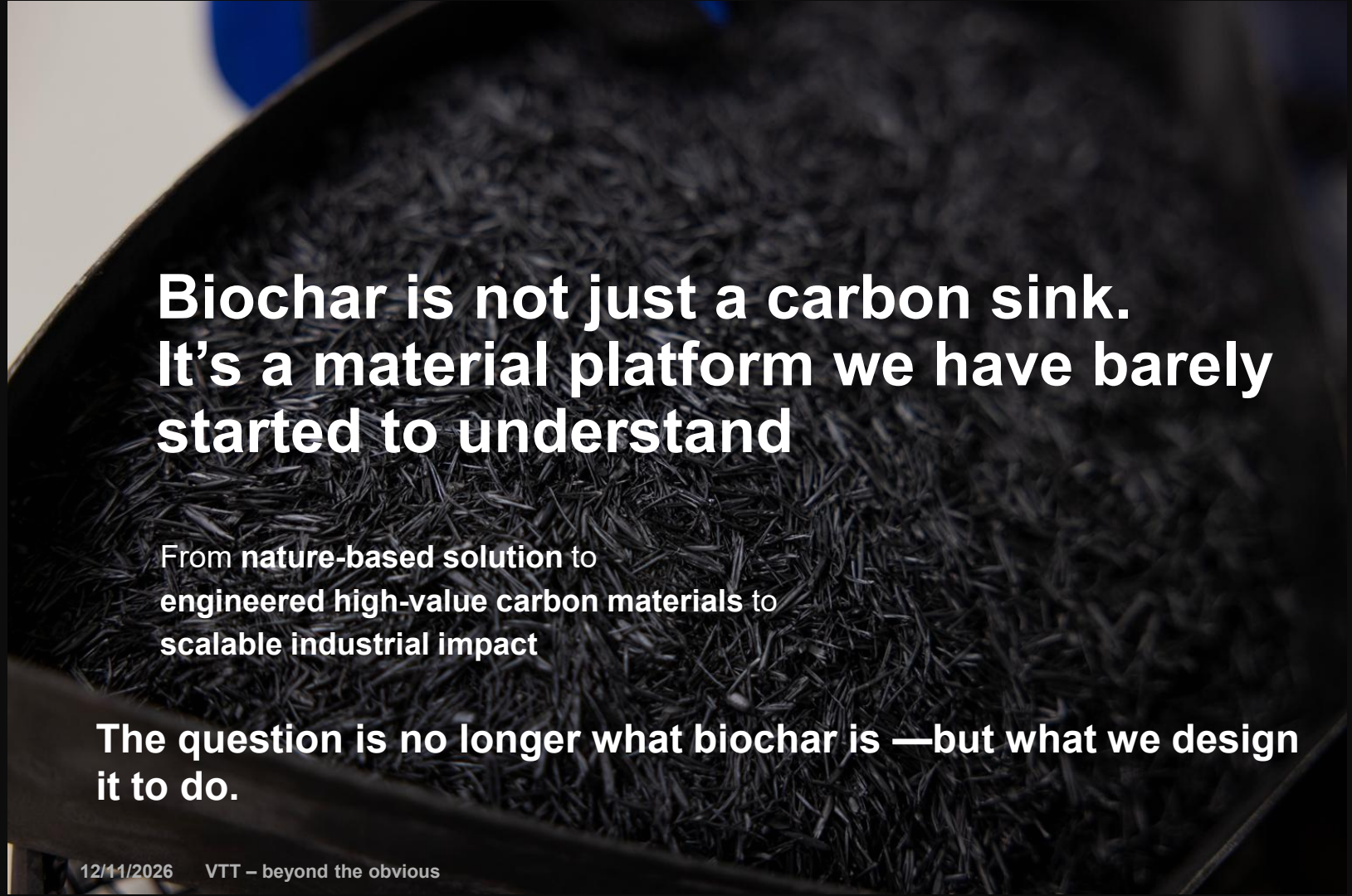
Biochar and Biobased Activated Carbon Development for High-Value Application

Virpi Siipola

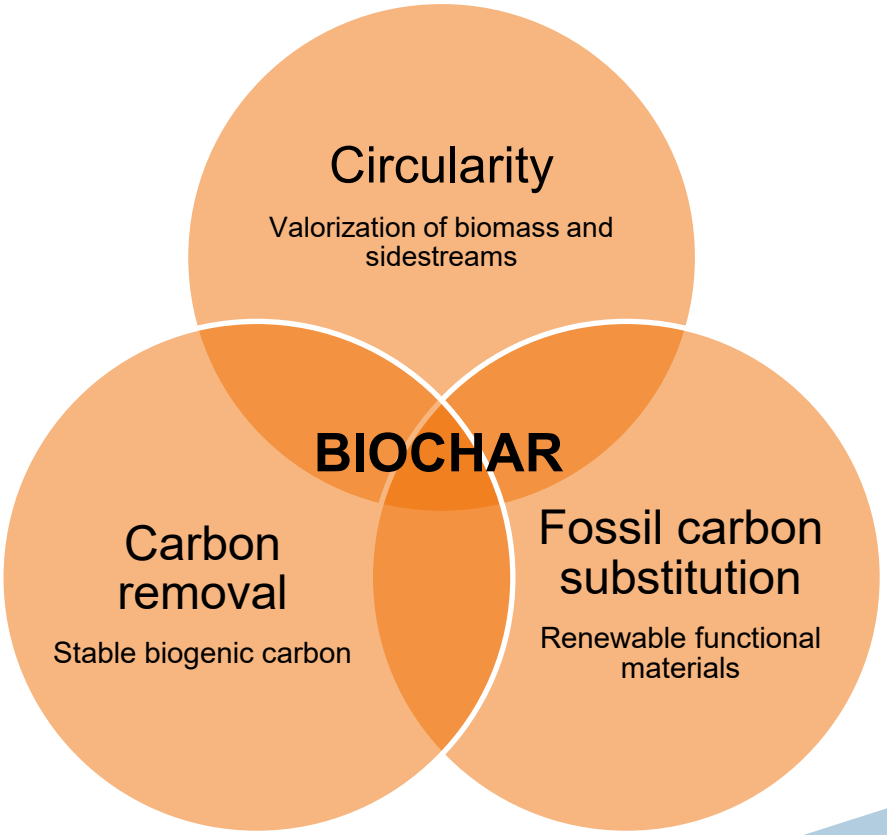


Biochar is not just a carbon sink. It's a material platform we have barely started to understand

From **nature-based solution** to
engineered high-value carbon materials to
scalable industrial impact

The question is no longer what biochar is —but what we design it to do.

Biochar connects three transitions



Its full impact emerges when these three roles are considered together.

Climate value +

Resource value +

Material value

Biochar is a family of materials

Woody biomass → agricultural residues → lignin → sludge









Biomass → Biochar → Activated Carbon → Application-specific material

Biochar is not a material. It is a family of materials — and we decide what it becomes.

Are we asking the right question about biochar?

Current question:

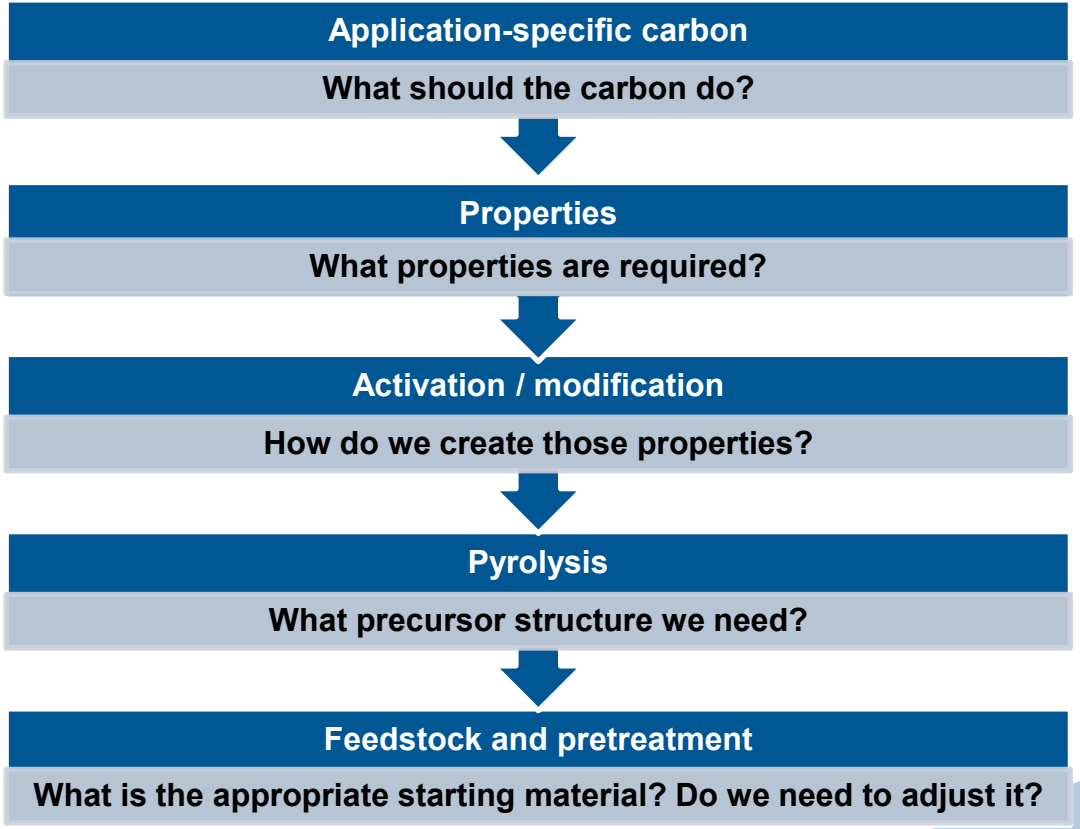
Where can we use the biochar we produce?

Better question:

What properties does the application require, and how do we design the carbon accordingly?

Change of thinking: From finding uses for a product to designing materials for a purpose.

Designing backwards from function



Start from the function. Then design the material backwards

Performance is engineered, not inherent

1. Feedstock

- Biomass type
- Ash and minerals
- Initial structure

2. Conversion

- Pyrolysis conditions
- Temperature
- Residence time

3. Activation & post-treatment

- Steam / CO_2 / chemical activation
- Washing and purification
- Surface modification

Feedstock x **Process** x **Post-treatment = Material Performance**

What properties do we actually control

Porosity
- Surface area
- Pore volume
- Pore-size distribution

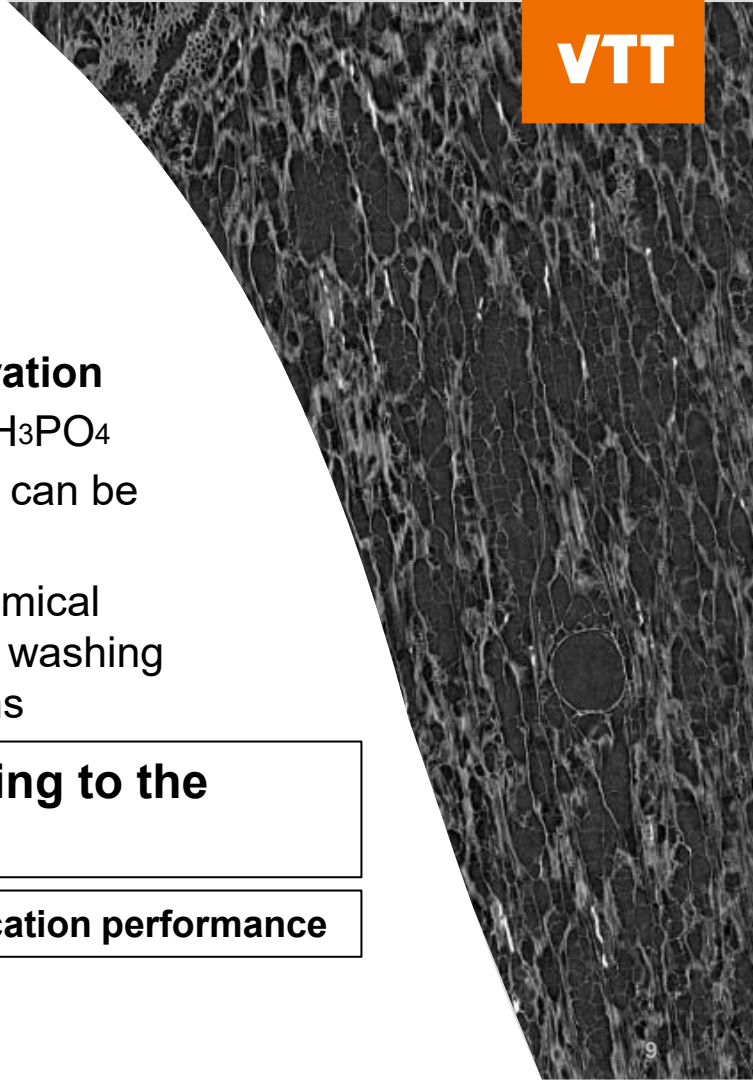
Surface chemistry
- Functional groups
- Acidity and basicity
- Surface charge

Composition
- Carbon content
- Minerals and ash
- Impurities

Bulk properties
- Density
- Strength
- Conductivity
- Particle size

Different applications prioritize different combinations of properties

Activation opens the pore structure



Physical activation

- Steam or CO_2
- Robust and scalable route
- Porosity develops through controlled gasification

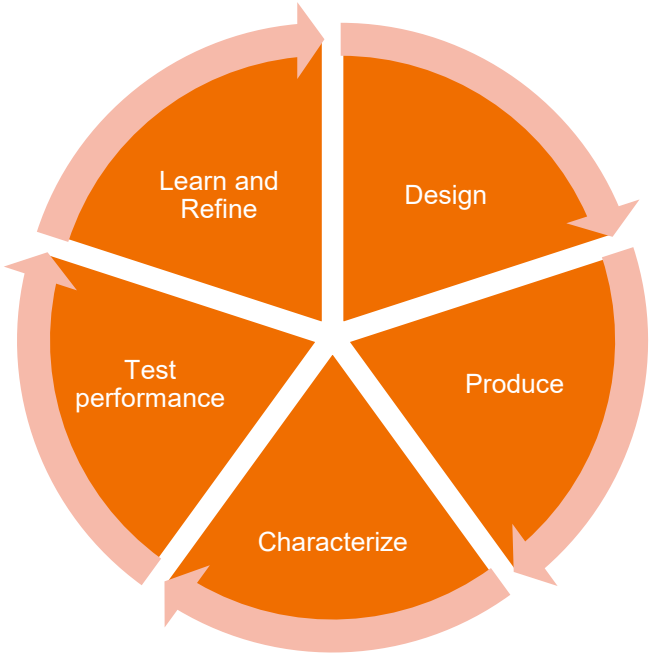
Chemical activation

- e.g. KOH or H_3PO_4
- High porosity can be achieved
- Requires chemical recovery and washing conciderations

The activation route must be selected according to the feedstock and the intended function

High surface area does not automatically mean high application performance

Characterization must guide design



- Composition and ash
- BET and pore size distribution
- Surface chemistry
- Thermal behavior
- Application testing
- Mass and energy balances

Characterization is valuable only when it informs the next design decision

Where can tailored biocarbon create value?

Water & air

Adsorption, filtration and purification

Energy

Electrochemical and conductive carbons

Materials and industry

Construction, composites and fossil carbon substitution

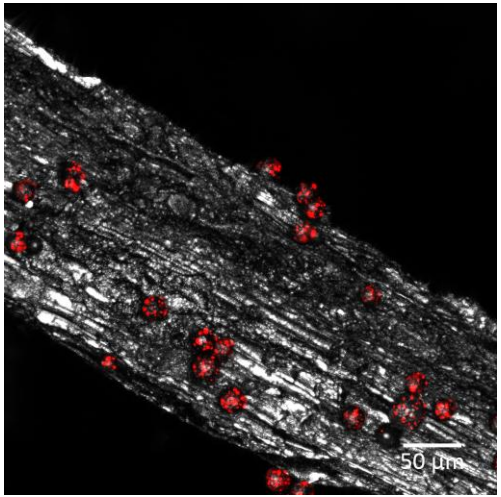
Different applications require different carbons

Case 1: Water purification

The important question is not whether biochar can adsorb pollutants. We already know that it can.
The interesting question is why one carbon performs better than another.

Wastewater

- Micropollutants
- PFAS
- Microplastics
- Biocides, pesticides
- ...



Clean water

The best adsorbent is not universal. It is matched to the contaminant and the water matrix

Case 2: Biochar in construction

Construction: storing carbon while providing function

Side stream

→ Engineered biochar

→ Construction material

→ Long-lived carbon storage + functional performance

Potential application routes

- Cementitious materials
- Asphalt and bituminous products
- Insulation and acoustic products
- Lightweight and non-load-bearing composites

The biochar must be compatible with the host material.

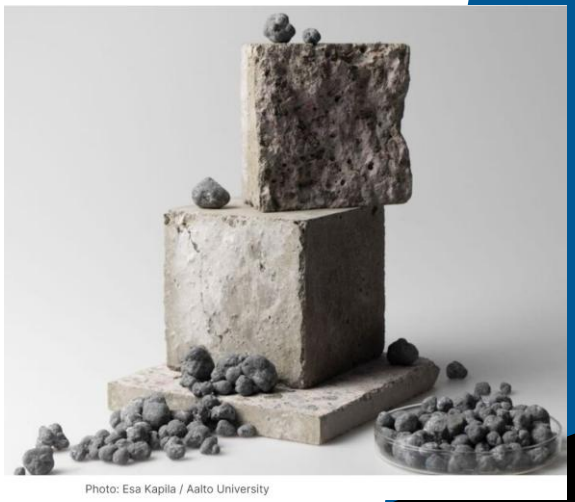


Photo: Esa Kapila / Aalto University

Construction combines material function with the possibly long-term carbon storage

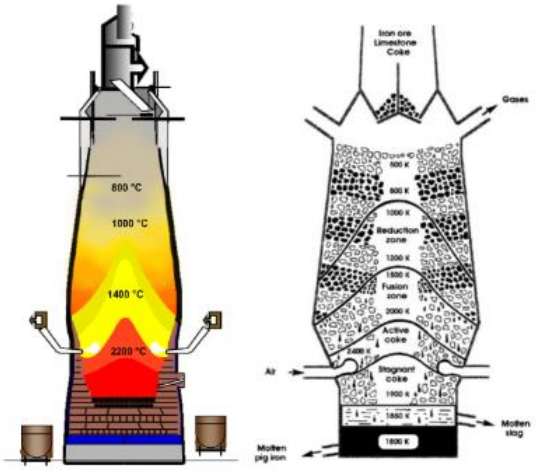
Case 3: Replacing fossil carbon

Renewable origin is not enough

Industrial carbon must deliver

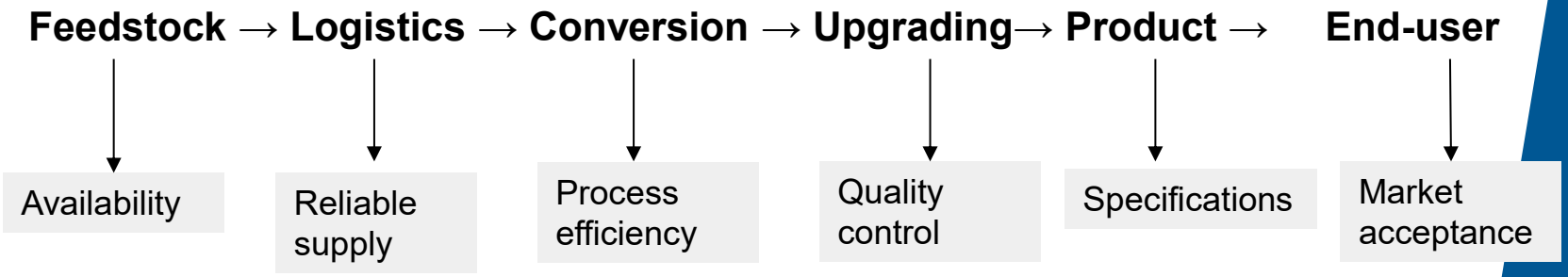
- Defined carbon content and purity
- Appropriate reactivity
- Mechanical and handling properties
- Process compatibility
- Consistent quality and supply

Biochar can replace fossil carbon only when it fulfils the required industrial function.



Blast furnace in metallurgy, ForMet report T351 VTT

Biochar will not scale without value chains



A technically good material has no impact without functioning route to its user.

Rethinking biochar: from solution to system

1. Biochar is more than a carbon sink

→ A **material platform** for multiple high-value applications

2. Value comes from material design

→ Performance is **engineered, not inherent**

3. Impact requires value chains

→ Scaling happens through **markets, not just pilots**

The future of biochar is not defined by what it is —but by what we choose to make it

VTT

beyond

the obvious

Thank you!

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