

# **HYDROTHERMAL CARBONIZATION**

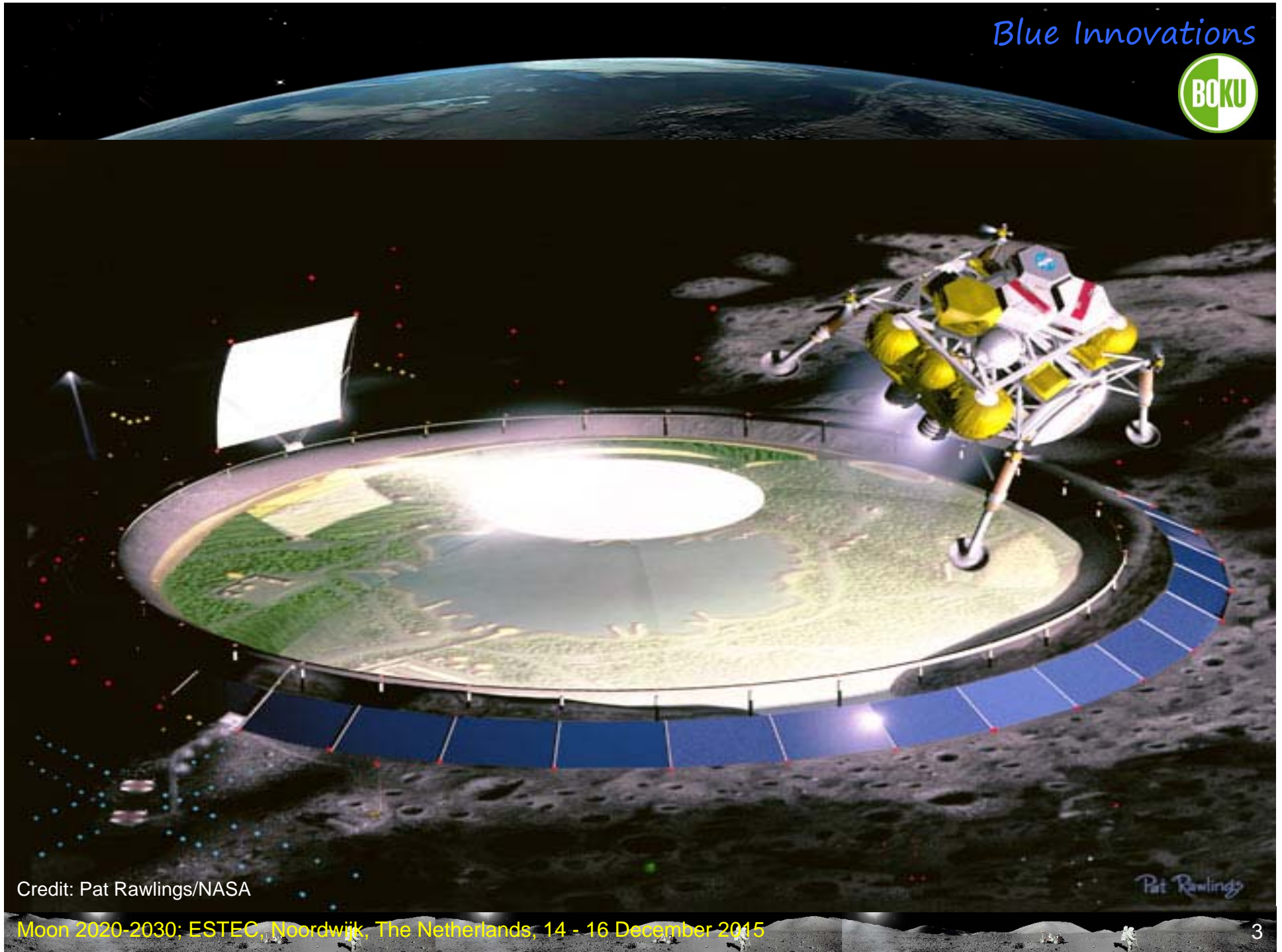
## **A KEY FOR CLOSED-LOOP LIFE SUPPORT SYSTEMS AND FOOD PRODUCTION?**

ESTEC, DECEMBER 2015

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Artwork by Nick Dragotta



Credit: Pat Rawlings/NASA

Moon 2020-2030; ESTEC, Noordwijk, The Netherlands, 14 - 16 December 2015

# Motivation

## Lunar Exploration Roadmap (LEAG)

Blue Innovations



Source: LEAG; lunar exploration roadmap (Ver. 1.3): Objective Sust-B-10

### Initiative A

Develop plant growth capability linked to the lunar gravity and solar illumination environment and including [regolith-as-soil](#), [plant nutrient production](#) and integration of plants into the atmosphere revitalization systems.





# HTC for soil amelioration

## Bio-Coal

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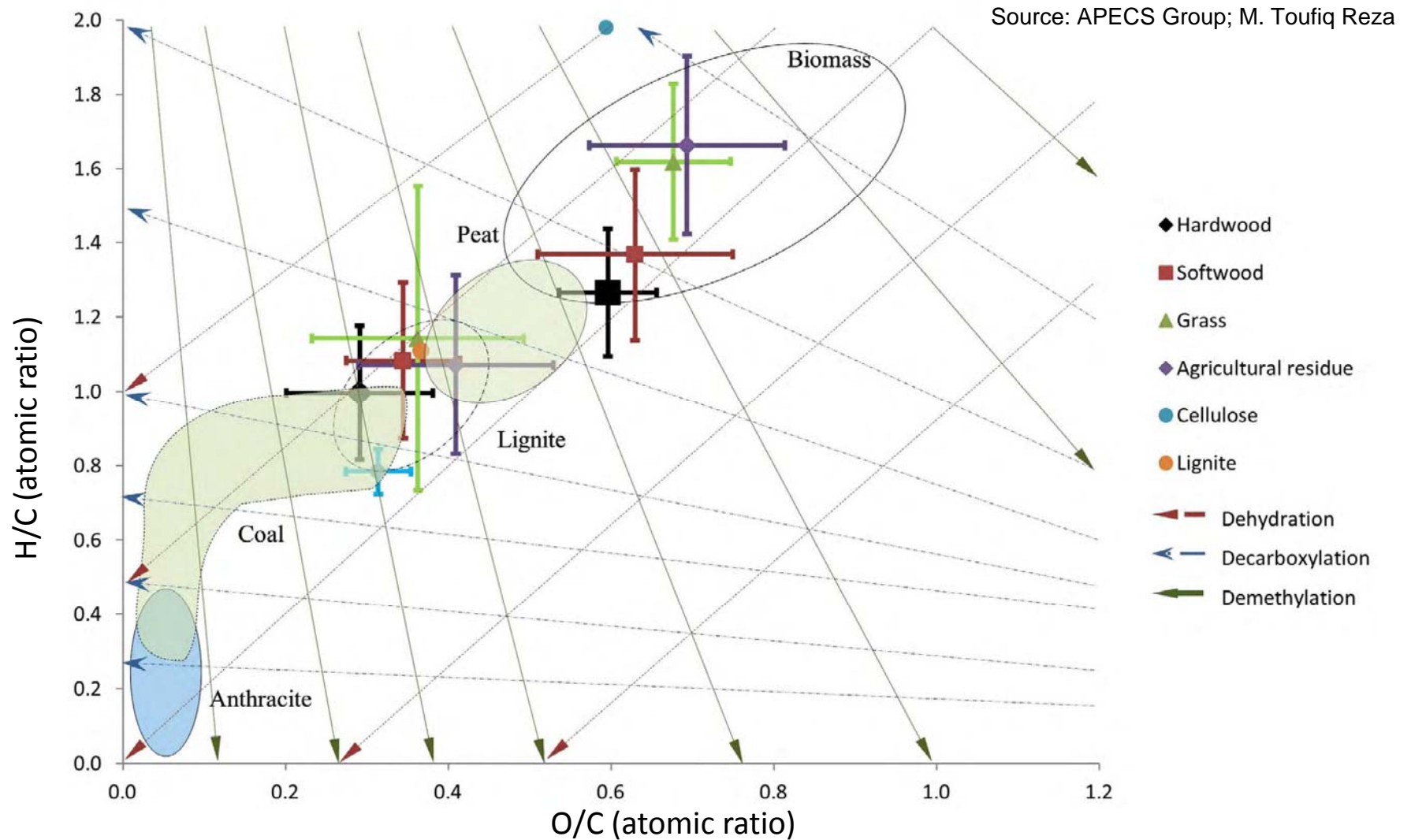
Source: Glaser, B., Haumaier, L., Guggenberger, G., and Zech, W. (2001).

The Terra Preta phenomenon: a model for sustainable agriculture in the humid tropics. *Naturwissenschaften* 88, 37-41.

# Hydrothermal Carbonization

## Van Krevelen-Diagramm

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# Hydrothermal Carbonization

## Simplified Process

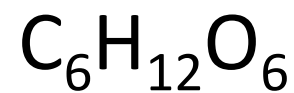
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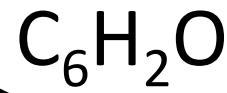
$p \sim 10 \text{ to } 20 \text{ bar(g)}$

$T \sim 170 \text{ to } 250 \text{ }^{\circ}\text{C}$

Source: Antonietti 2009

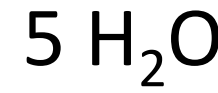


Carbohydrate



„HTC-Coal“

+

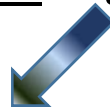


Water (+excess heat)

(~ 950 kJ/mol)

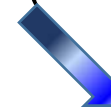
*Exothermal process*

Example: 1 kg Organic Waste (30% Dry Matter)



20 – 30 w.% HTC-Coal

(Calorific Heating Value 17 – 25 MJ/kg)



70 – 80 w.% Processwater

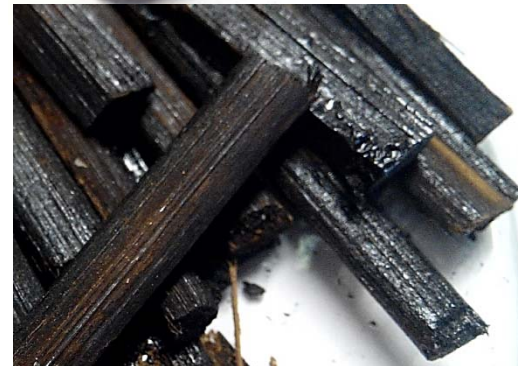
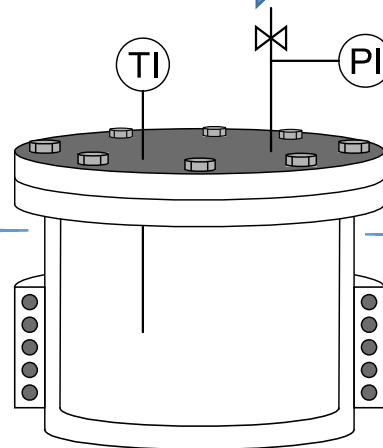
# HTC for soil amelioration

## Bio-Coal (HTC)

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180°C @ 12 bar  
90% w/w Water  
1-12 hours



Source: BOKU/Blue Innovations



# HTC for soil amelioration

## Bio-Coal (HTC)

Blue Innovations



Pistachio shells



Peanut



Wood chips



Digestate (MELLiSSA)



Source: BOKU/Blue Innovations

# HTC for soil amelioration

## Plant Growth

Blue Innovations



Busch D., Stark A., Kammann C.I., Glaser B., *Genotoxic and phytotoxic risk assessment of fresh and treated hydrochar from hydrothermal carbonization compared to biochar from pyrolysis*, Ecotoxicol. Environ. Saf., 2013, 97, 59-66.

Plant Yields from pot experiments with chinese cabbage and maize varied between 0% und 240% compared to the control group.

### Negative effects due to

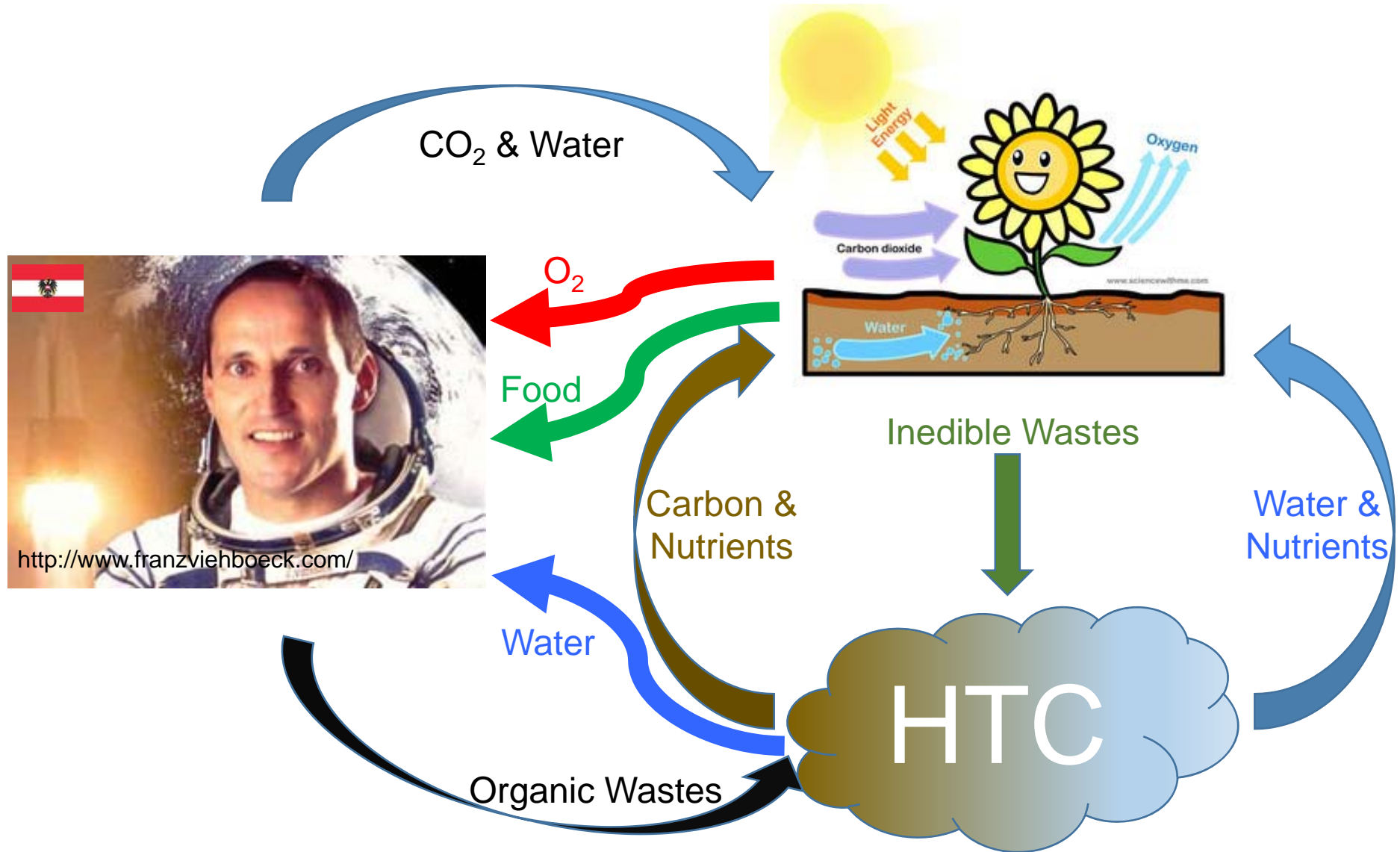
- Untreated HTC-Coal
  - Organic acids
  - Phenols
  - Polychlorinated Dibenzodioxines and Dibenzofuranes (PCDDs & PCDFs)
- High HTC application crop dose
- Type of feedstock

### Positive effects due to

- Post-treated HTC-Coal
  - Physical (e.g. drying, washing)
  - Chemical (e.g.  $H_2O_2$ )
  - Biological (e.g. co-composting)
- Lower HTC application crop dose
- Type of feedstock

# Bioregenerative LSS with HTC

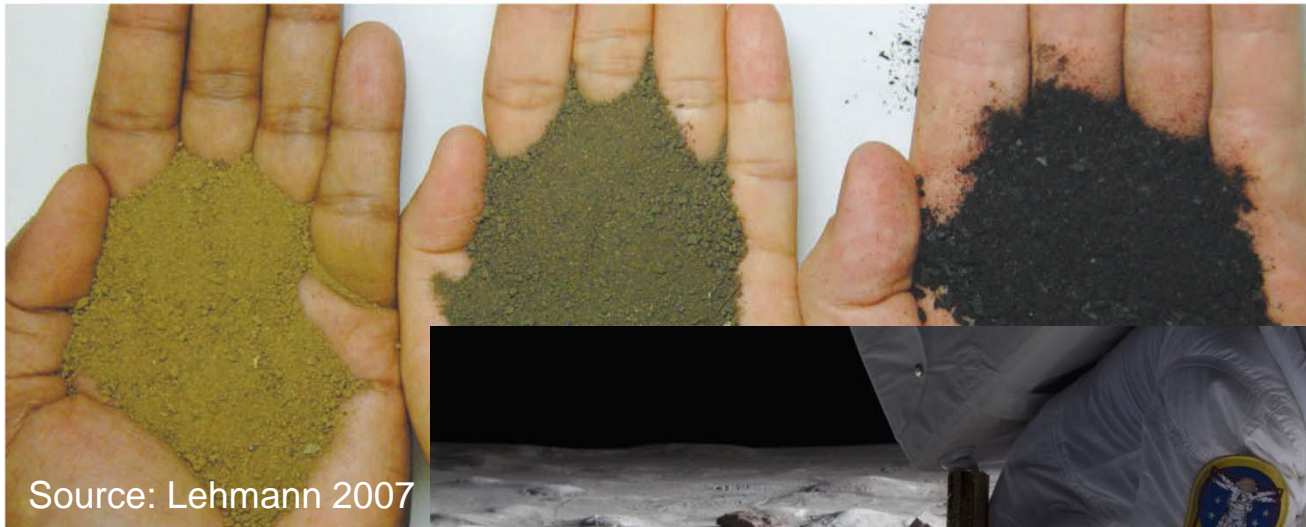
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# First Contact

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Source: Lehmann 2007

## Acknowledgements

Patrizia Stutzenstein,  
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Source: <http://blacklemag.com/technology/nasa-grows-plants-on-moon/>



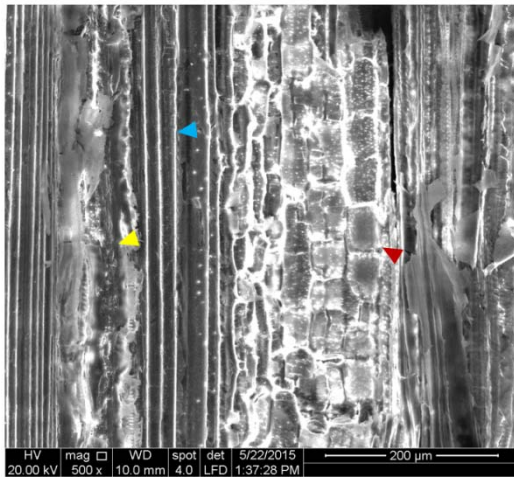
# HTC for soil amelioration

## HTC-Coal (bamboo chop sticks)

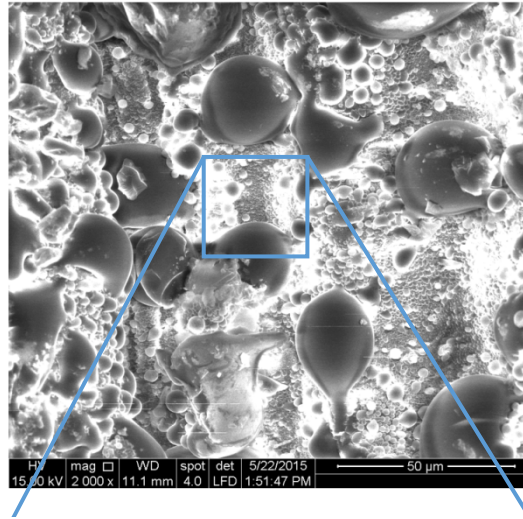
Blue Innovations



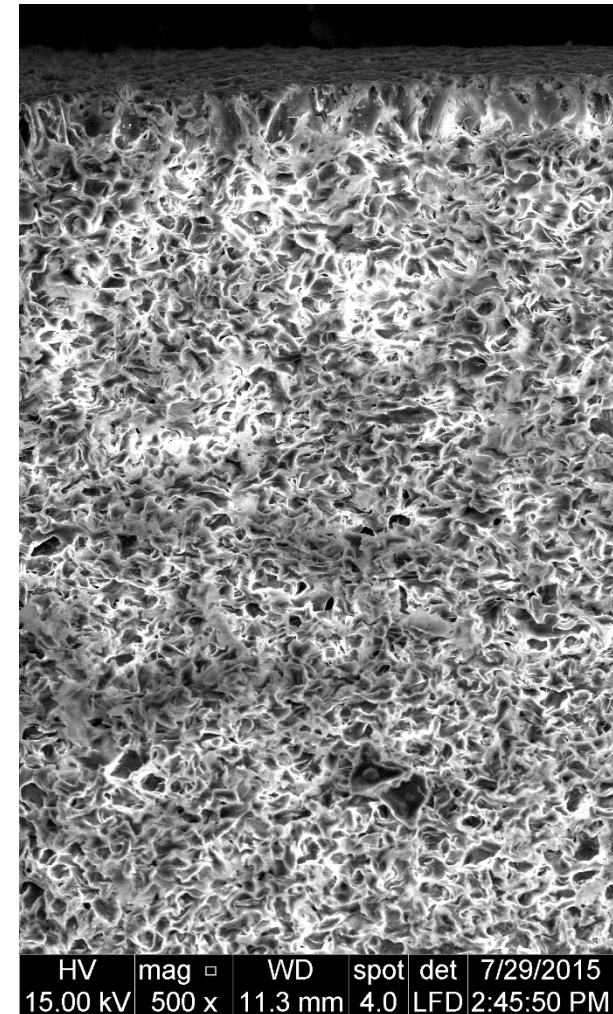
cross section, native



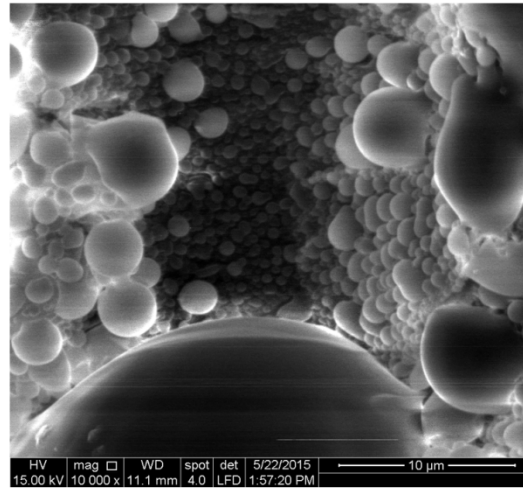
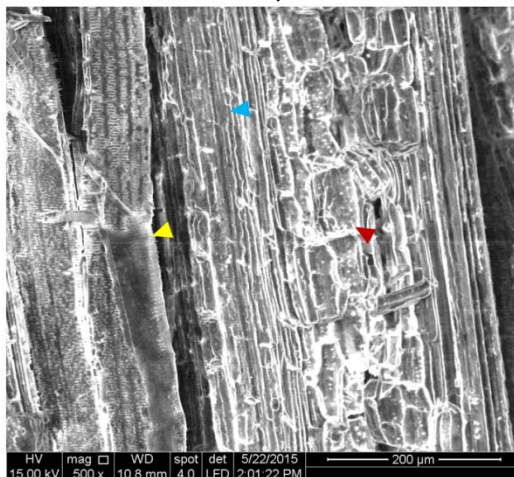
surface, carbonized



molar O/C profile



cross section, carbonized



Source: BOKU/Blue Innovations