RE-CORD

Renewable Energy COnsortium for Research & Demonstration

Energy transition, circular economy, agricolture

Biochar: a challenge for innovation and climate

Caterina Borchi, BU Raw Materials and Carbon Recycling

Politecnico di Torino

UNIVERSITÀ DEGLI STUDI FIRENZE

European Week of Regions and Cities

SQUARE Brussels Meeting Centre, Silver Hall

10 October 2023

WHO WE ARE

THE **RE-CORD CONSORTIUM** IS A MIXED PUBLIC-PRIVATE, NON-PROFIT RESEARCH CENTER.

RE·CORD

WE ARE A **MULTI-DISCIPLINARY TEAM** MADE UP OF 23+ RESEARCHERS COVERING A WIDE RANGE OF SKILLS: ENGINEERING, CHEMISTRY, BIOTECHNOLOGY, AGRONOMY, ETC.

WE CARRY OUT **INDEPENDENT RESEARCH** TO SUPPORT INNOVATIVE INDUSTRIES IN THE DEVELOPMENT OF NEW SUSTAINABLE PROCESSES.

Headquarter
Laboratory & offices
Scarperia (FI)

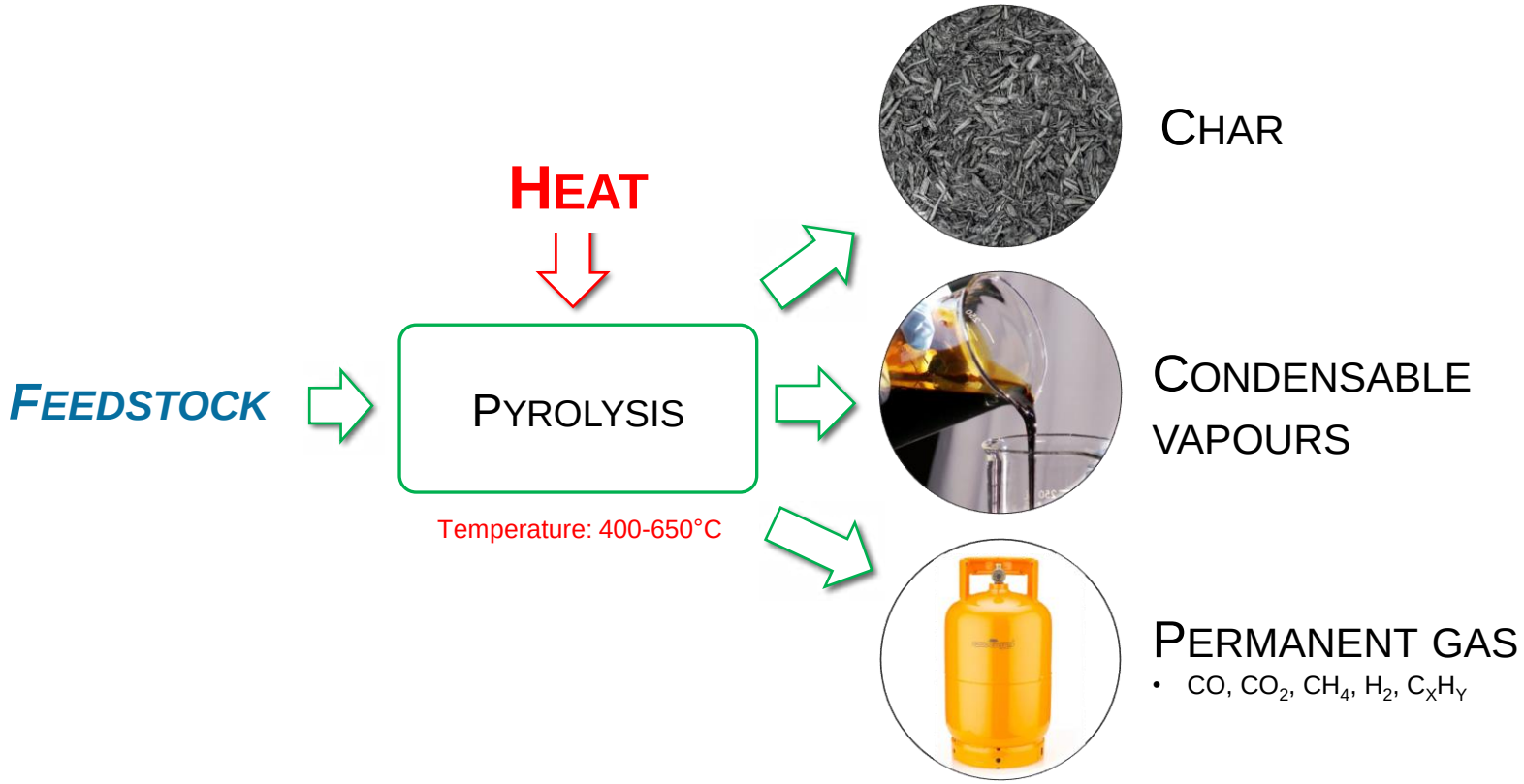
REC PARK
Experimental Area (1000 m²)
Scarperia (FI)

EC projects office @UNIFI
Department of Industrial Engineering
Firenze

Experimental area AGRO-BIO
Agricultural field trials
San Casciano Val di Pesa (FI)

Pyrolysis process

Pyrolysis is a process of **thermochemical decomposition** of organic materials, achieved by the application of heat and in the absence or limited presence of oxygen.



Three different types of pyrolysis:

- ❑ **Slow pyrolysis**
  - Very long solid residence time (hours to days)
  - Char production is promoted
  - **Char yield up to 35 wt.%**

- ❑ **Intermediate pyrolysis**
- ❑ **Fast pyrolysis**
  - Short solid residence time
  - The production of organic vapours (Bio-oil) is promoted
  - **Bio-oil yield up to 60-70 wt.%**

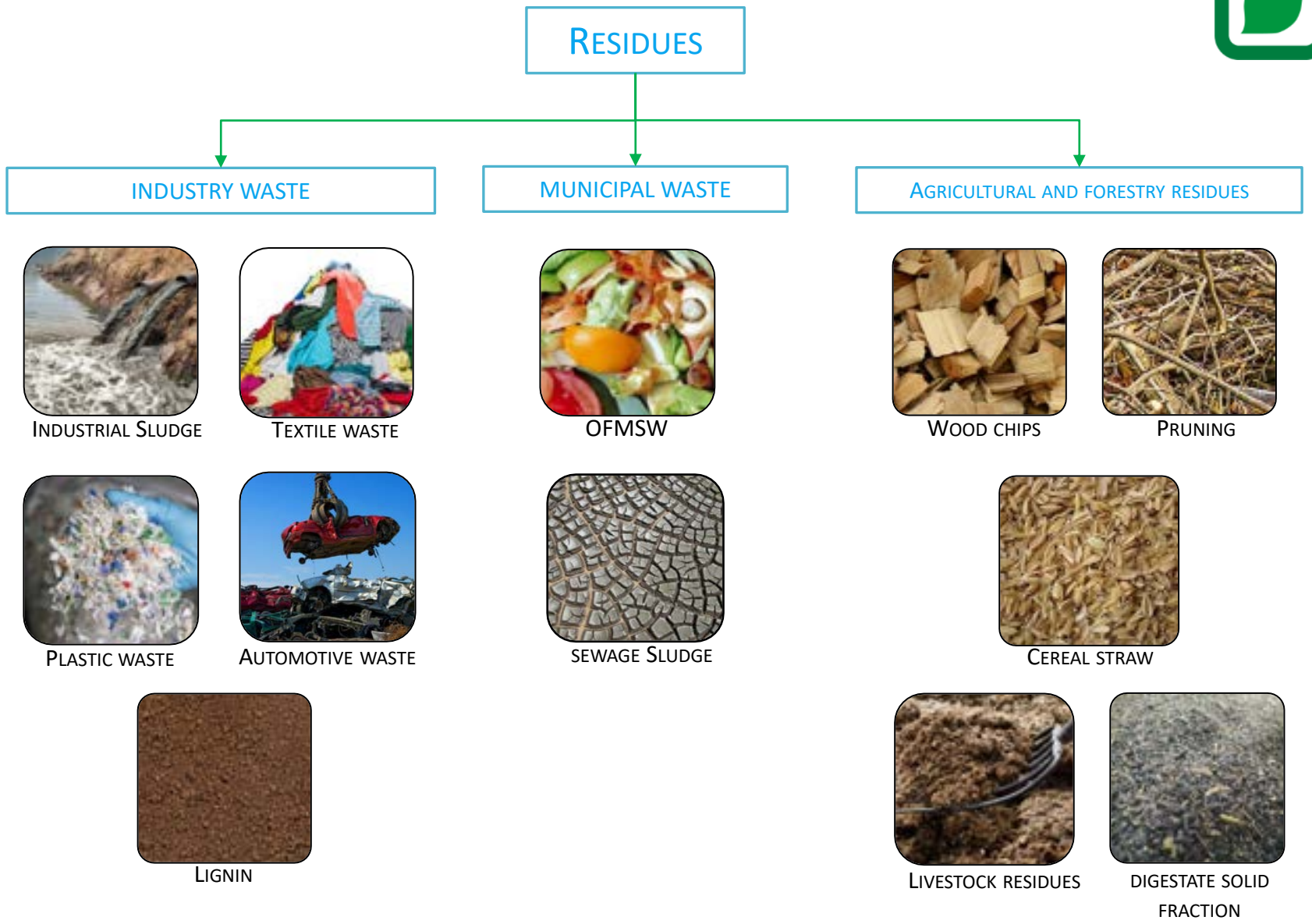
Conversion of wide range of feedstocks in high value products

POTENTIAL FEEDSTOCKS

A VARIETY OF DIFFERENT FEEDSTOCKS CAN BE USED TO PRODUCE CHAR VIA PYROLYSIS PROCESS.

IN OUR RESEARCH ACTIVITY, WE INVESTIGATE CHAR PRODUCTION **FROM RESIDUAL STREAMS.**

WASTE VALORIZATION

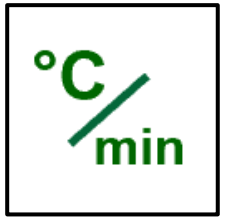


Char Quality and Potential applications

PROCESS PARAMETERS

TEMPERATURE

RESIDENCE TIME



HEATING RATE

MOISTURE CONTENT

Main biochar physical and chemical properties

- Porosity
- Organic carbon content
- Ash content
- Stability
- pH
- Surface functional groups (CEC)

MULTIPLE APPLICATIONS

AGRICULTURE FORESTRY

CARBON STORAGE

ANAEROBIC DIGETSION

WATER TREATMENT

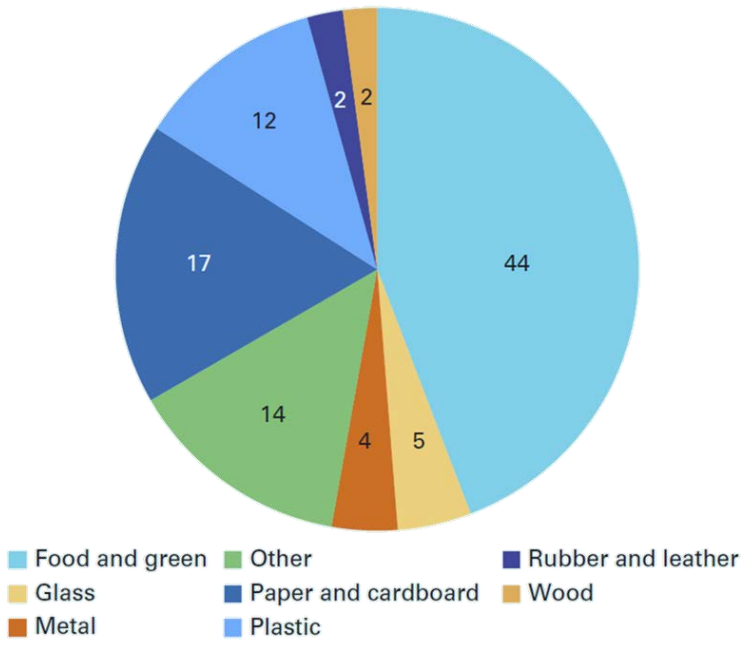
ELECTROCHEMICAL APPLICATIONS

CONSTRUCTION MATERIALS

CATALYSIS

POLYMER FILLERS

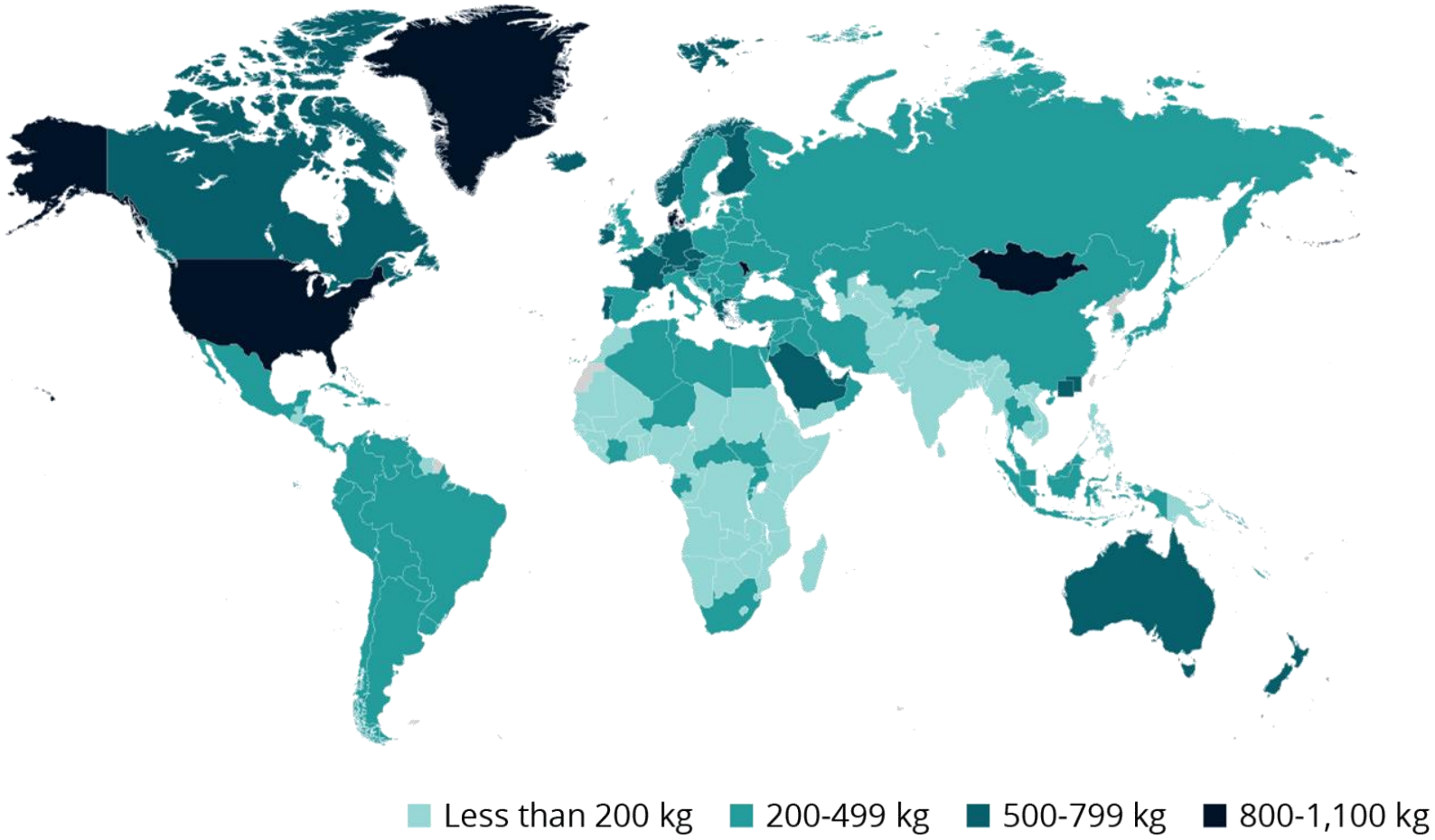
A World of Waste



2.01

BILLION TONNES PER YEAR

Municipal solid waste produced per year per capita



CHAR FROM INDUSTRIAL WASTES AND SLUDGE

WASTE FLOWS


TEXTILE


PLASTIC


AUTOMOTIVE


SEWAGE SLUDGE

INPUT

SLOW PYROLYSIS REACTOR

+ POSSIBLE UPGRADING

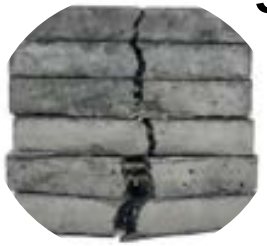

CHAR / BIOCOAL

REGULATION (EU) 2019/1009


CHAR IN SOIL

CARBON STORAGE

VOLUNTARY CARBON CREDIT


FILLER IN CONSTRUCTION MATERIALS

CARBON STORAGE


PRECURSOR FOR ELECTRODES

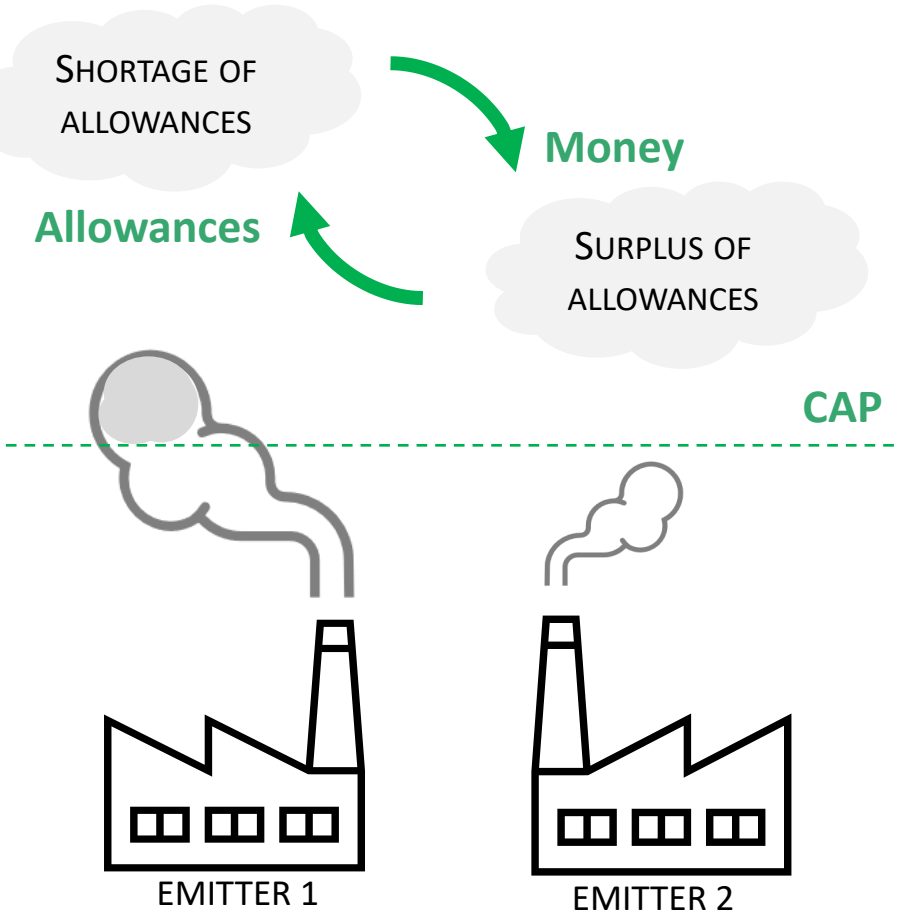
CARBON SAVING

ETS


SUBSTITUTE OF FOSSIL COAL IN STEELMAKING SECTOR

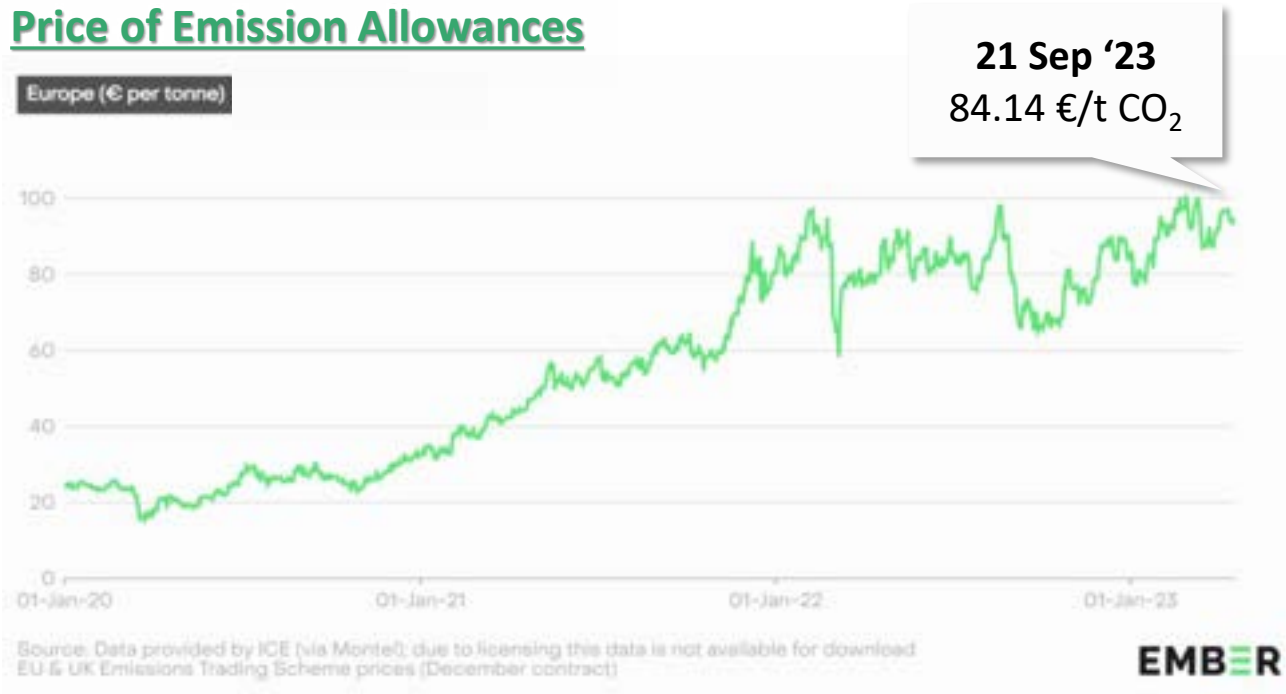
EU EMISSION TRADING SYSTEM – ETS

THE **EU ETS**, IS A MARKET MECHANISM THAT GIVES A PRICE TO **CO_2** AND CREATES INCENTIVES TO REDUCE EMISSIONS IN THE MOST COST-EFFECTIVE MANNER.

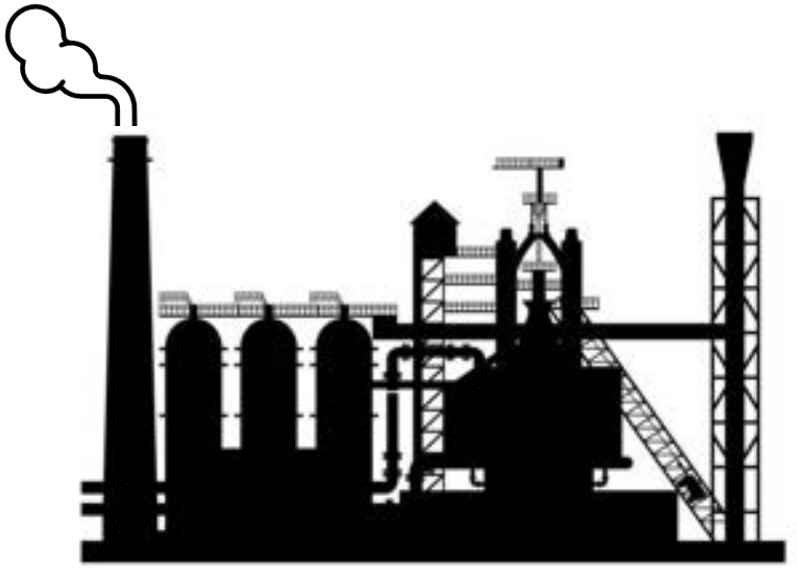


- EU ETS COVERS EMISSIONS **FROM AROUND 10,000 INSTALLATIONS** IN THE ENERGY SECTOR AND MANUFACTURING INDUSTRY, AS WELL AS AIRCRAFT OPERATORS;
- THE SYSTEM HAS HELPED REDUCE EMISSIONS FROM THESE SECTORS BY ABOUT **35 %** BETWEEN 2005 AND 2021.

Price of Emission Allowances



Decarbonisation of Steelmaking industry



Volumes of Steel sector*

- World steel production ⇨ **1 961 Mt**
- Europe Steel production ⇨ **152.6 Mt**

Data referring to year **2021*

CO_2 emissions of Steel sector*

CO_2 emission per ton of steel produced by Blast Furnaces	**2.3 t CO_2/t steel**
Steel sector contribution to global CO_2 emissions	**6%**

Carbon saving

Biocoal

- The use of **BIOCOAL** is made economically attractive by the Emission Trading System.
- Maximum estimated **CO_2 emission** reduction is 91 Mt per year (42%)[1] for bio-based fuels.

[1] *Source: H. Mandova et al., "Possibilities for CO2 emission reduction using biomass in European integrated steel plants", https://doi.org/10.1016/j.biombioe.2018.04.021.*

Char as a Filler to improve the mechanical properties of cementitious compounds

Recent studies[1] have demonstrated the potential application of char as **cement replacement** n cement pastes, mortars and concretes, improving their **mechanical properties** such as resistance to compression and ductility.

Parameters of interest

- Carbon and silicon content;
- Water absorption capacity;
- Elasticity module;
- Resistance capacity.

Char sample from sludge pyrolysis

Parameter	Value	U.M.
Fixed carbon (C)	36.32	% d.b.
Silicon (Si)	118136	mg/kg s.s
Surface area	145	m^2/g

- Incorporating **1% char** into cementitious compounds could sequester approximately **0.5 Gt of CO_2** per year[2] from the concrete industry

Carbon storage

Source:[1]HAman, A.M.N.; Selvarajoo, A.; Lau, T.L.; Chen, W.-H. Biochar as Cement Replacement to Enhance Concrete Composite Properties: A Review. Energies 2022, 15, 7662. https://doi.org/10.3390/en15207662
[2]Mensah, R.A et al, "Biochar-Added Cementitious Materials—A Review on Mechanical, Thermal, and Environmental Properties". Sustainability 2021, 13, 9336. https://doi.org/10.3390/su13169336

CRITICAL RAW MATERIALS – CRM

CRITICAL RAW MATERIALS (CRMS) ARE THOSE RAW MATERIALS WHICH ARE **ECONOMICALLY AND STRATEGICALLY** IMPORTANT FOR THE EUROPEAN ECONOMY BUT HAVE A HIGH-RISK ASSOCIATED WITH THEIR SUPPLY.

❖ PHOSPHORUS

71% PHOSPHORUS FROM KAZAKISTAN
27% PHOSPHATE ROCK FROM MOROCCO

❖ COKING COAL

27% COAKING COAL FROM POLAND
25% COAKING COAL FROM AUSTRALIA

❖ NATURAL GRAPHITE

40% OF NATURAL GRAPHITE FROM CHINA

❖ COPPER*

19% OF COPPER FROM POLAND

❖ MAGNESIUM

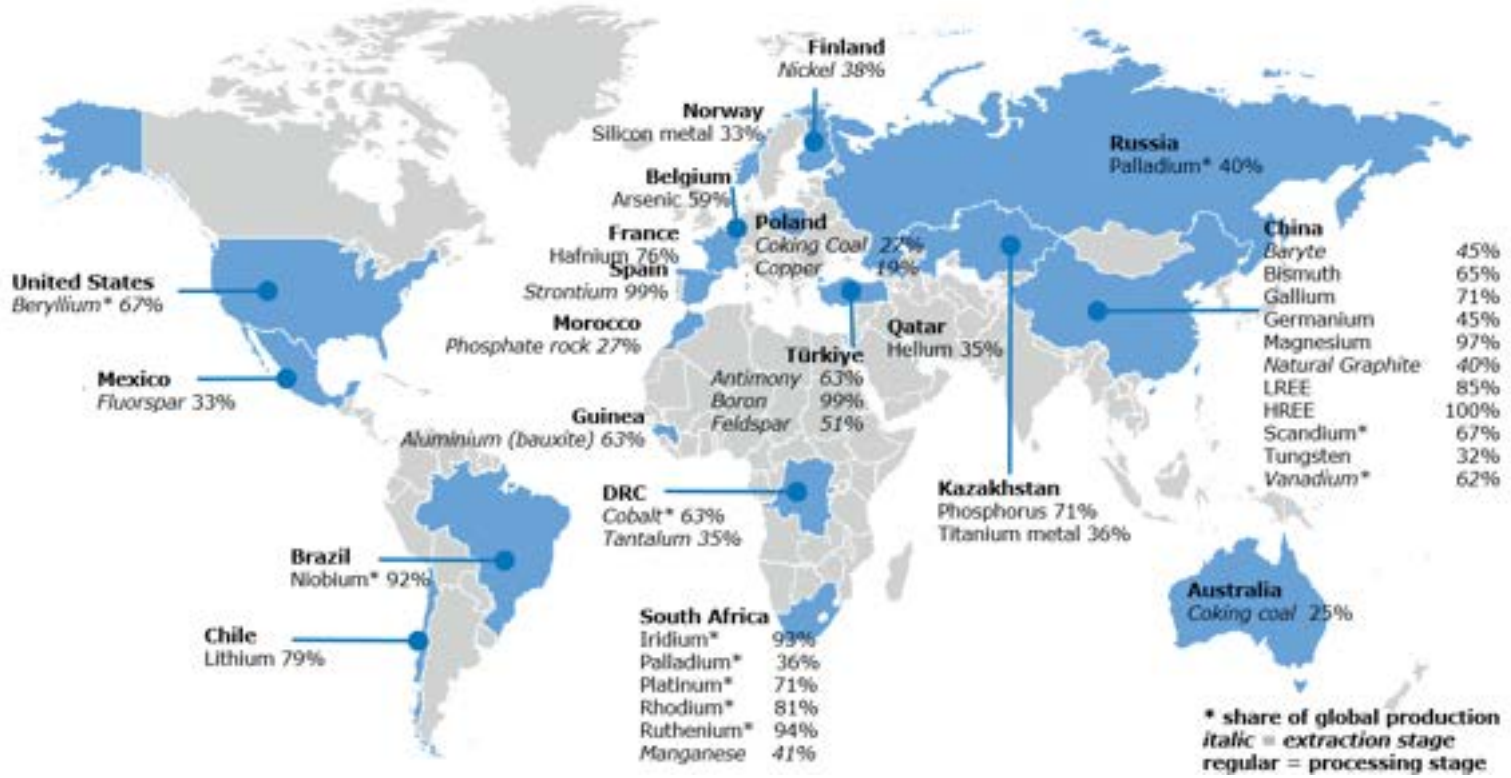
97% OF MAGNESIUM FROM CHINA

❖ ALUMINIUM

63% OF ALUMINUM (BAUXITE) FROM GUINEA

INCLUDED AS STRATEGIC RAW MATERIAL (SRM)

MAJOR EU SUPPLIERS OF CRMS



SOURCE: "EUROPEAN COMMISSION, STUDY ON CRITICAL RAW MATERIALS FOR THE EU 2023 – FINAL REPORT"

Critical Raw Materials – CRM

Critical Raw Materials (CRMs) are those raw materials which are **economically and strategically** important for the European economy but have a high-risk associated with their supply.

❖ Phosphorus
71% phosphorus from Kazakistan
27% phosphate rock from Morocco

❖ Coking coal
27% coaking coal from Poland
25% coaking coal from Australia

❖ Natural graphite
40% of natural graphite from China

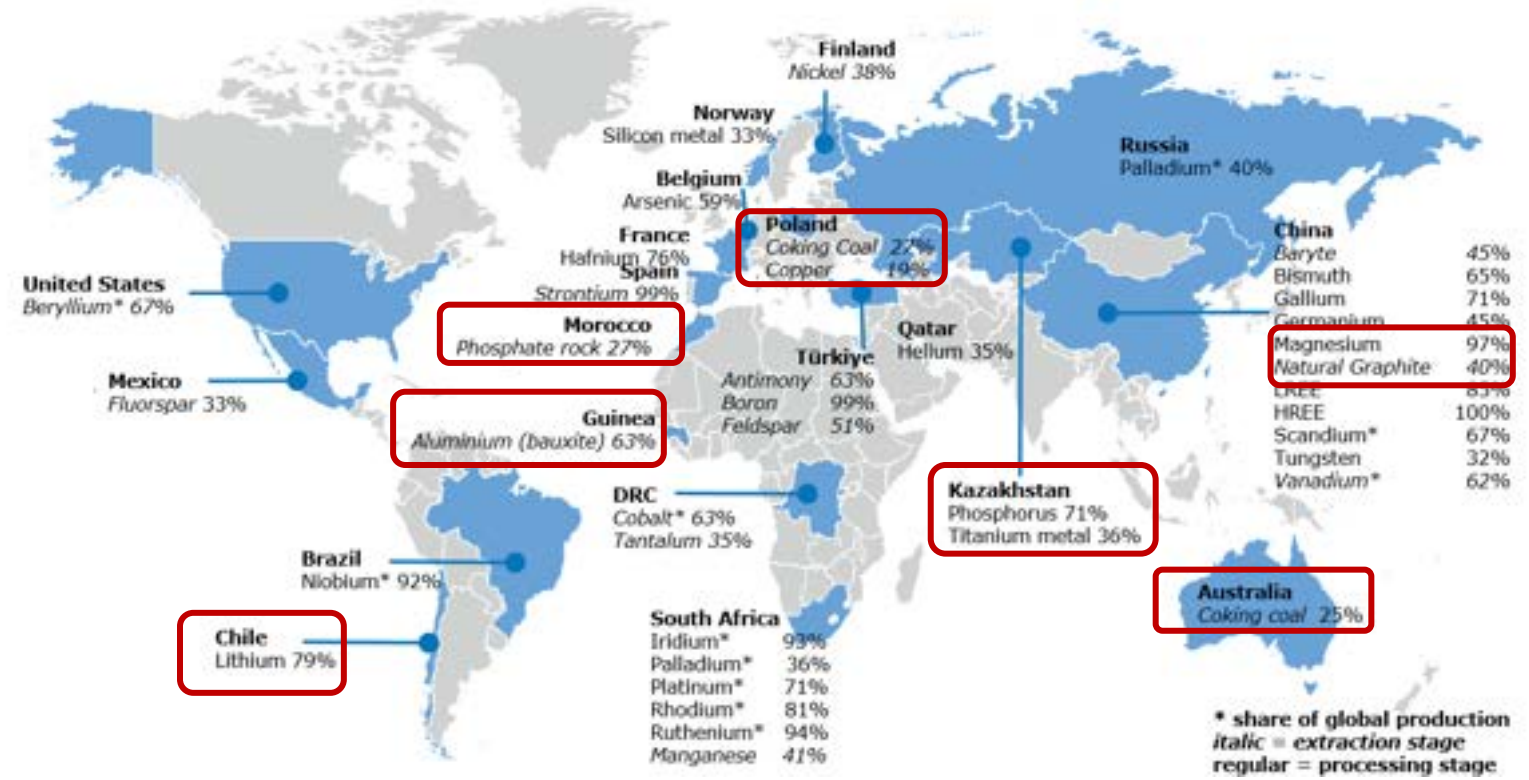
❖ Copper*
19% of copper from Poland

❖ Magnesium
97% of magnesium from China

❖ Aluminium
63% of aluminum (bauxite) from Guinea

**Included as strategic raw material (SRM)*

Major EU suppliers of CRMs



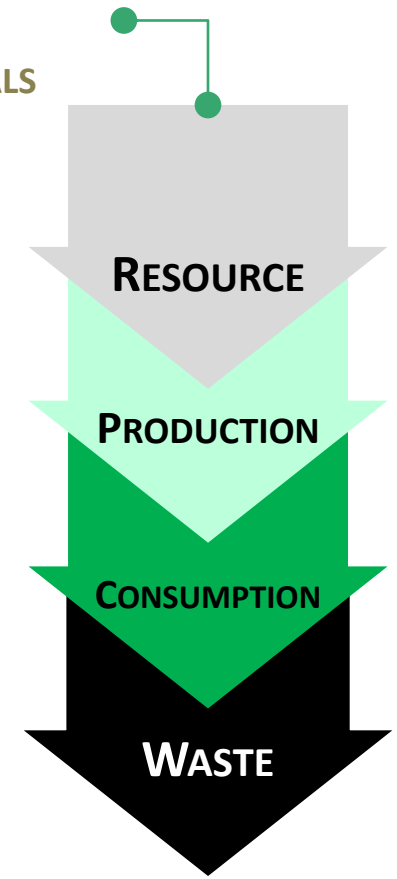
Source: "European commission, study on Critical Raw Materials for the EU 2023 – final report"

From linear economy to circular economy

The Commission's proposal for a **Critical Raw Materials Act** sets benchmarks for the diversification of the EU supply of critical raw materials.

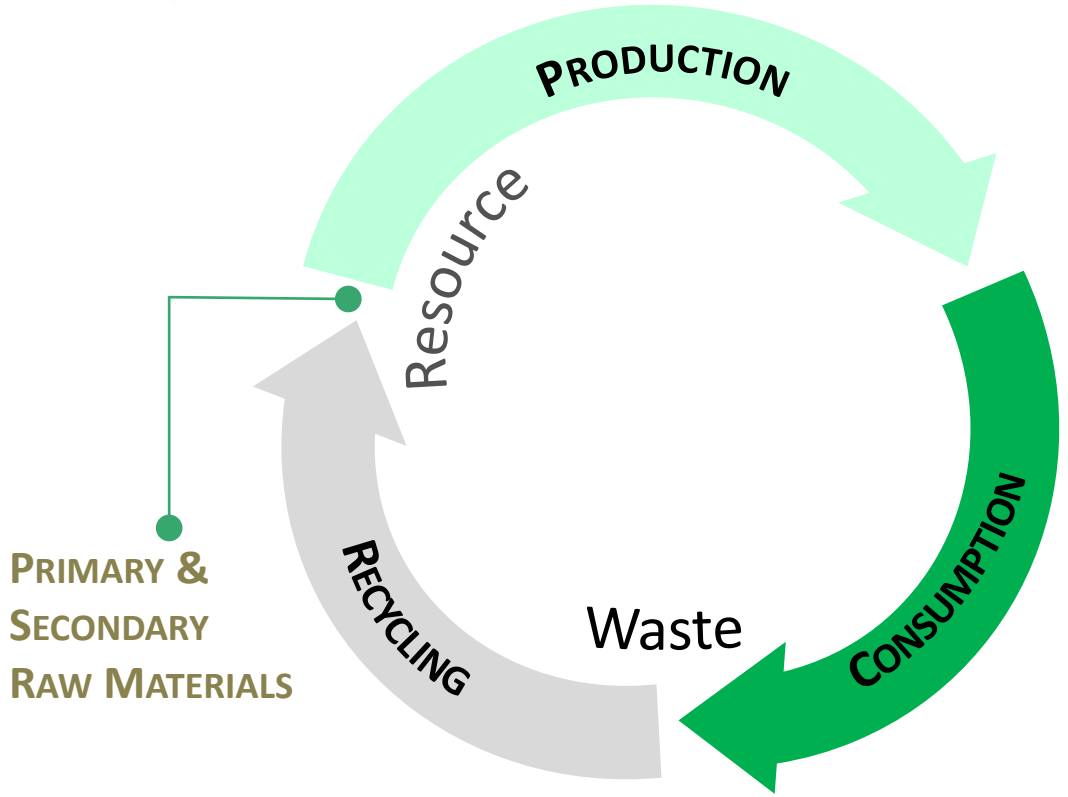
- **At least 10%** of the EU's annual consumption **for extraction**
- **At least 40%** of the EU's annual consumption **for processing**
- **At least 15%** of the EU's annual consumption **for recycling**
- **No more than 65%** of the EU's annual consumption **from a single third country**

Linear Economy



CRMs Act

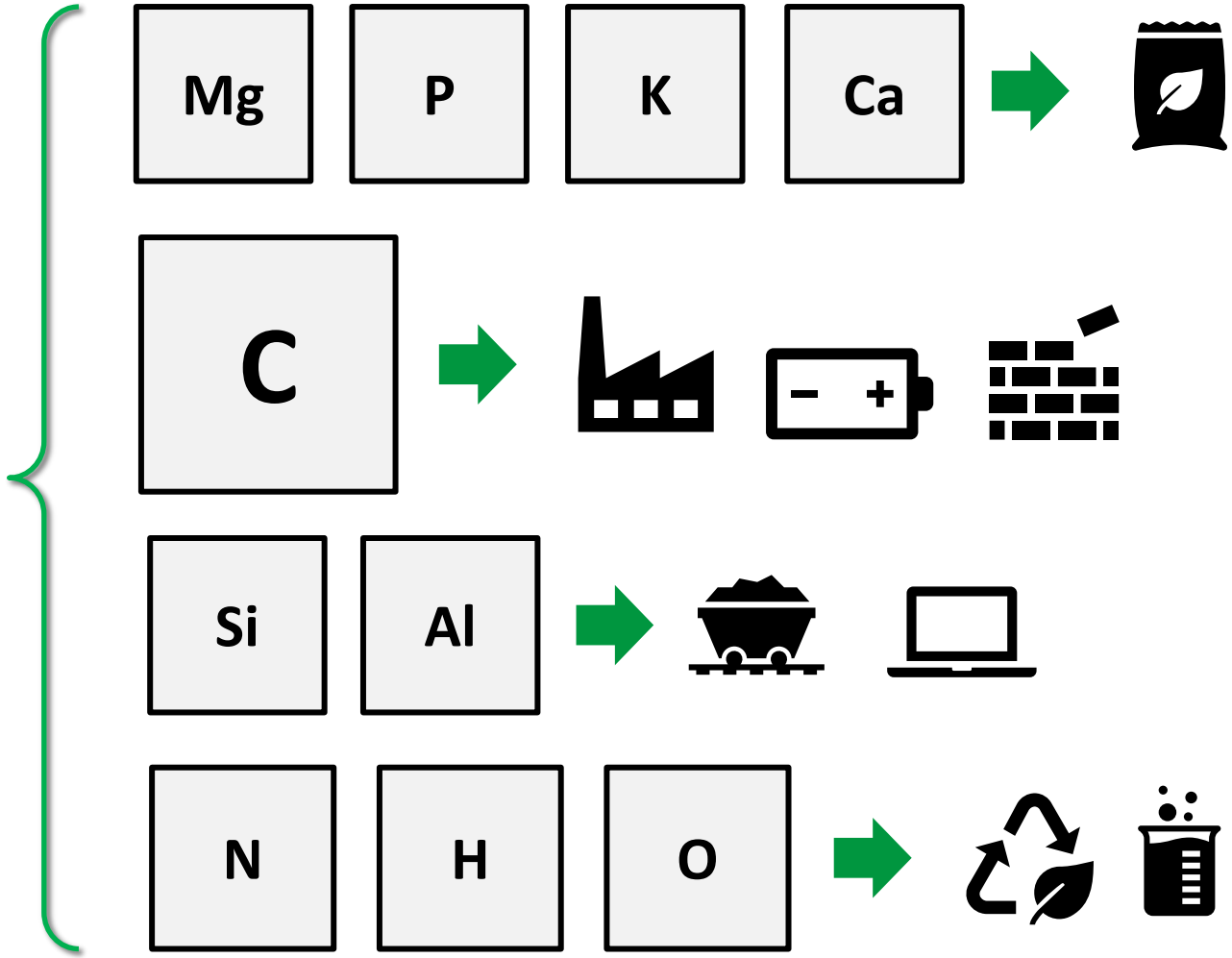
Circular Economy



Recovery of Critical Raw Materials from Waste

Sludge
(Municipal/Industrial)

Industrial wastes
(plastic, textile, ...)



INTEGRATION OF SLOW PYROLYSIS & CHEMICAL LEACHING

INDUSTRIAL SLUDGE

CIRCULAR ECONOMY

DRYING

DRY SLUDGE

- C
- P, Ca, K, Mg
- Fe

PYROLYSIS

CHAR (BIOCOAL)

ACID LEACHING

REAGENTS

ELUATE

CHEMICAL PRECIPITATION

REAGENTS

INORGANIC SOLID

- P, Ca, K, Mg
- Fe

RECOVERY OF RESOURCES

FERTILIZERS PRODUCTION

UPGRADED BIOCOAL

C

RECOVERY OF RESOURCES

FOSSIL COAL SUBSTITUTE

INTEGRATION OF SLOW PYROLYSIS & CHEMICAL LEACHING

AUTOMOTIVE WASTE

CIRCULAR ECONOMY

PYROLYSIS

CHAR

CHEMICAL TREATMENT

REAGENTS

COPPER (CU)

ALUMINIUM (AL)

IRON (FE)

RECOVERY OF RESOURCES

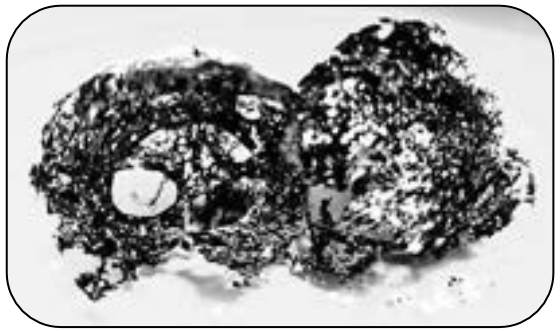
MOST RECENT RESULTS

PATENTED INTEGRATED THERMO-CHEMICAL PROCESS FOR SULPHUR, PHOSPHORUS RECOVERY AND BIOCOAL PRODUCTION FROM BIOWASTE AND SLUDGE

INTEGRATED RECOVERY SYSTEM FOR EXTRACTION OF CARBON AND ALUMINIUM FROM INDUSTRIAL PLASTIC WASTE

CONVERSION OF TEXTILE WASTE IN ADVANCED CARBON MATERIALS

RECOVERY OF SILICON-RICH CARBON FROM SEWAGE SLUDGE



THANK YOU!

Caterina Borchi
caterina.borchi@re-cord.org