Scaling the Power of Biochar

"360" Solution for a Healthy, Sustainable and Resilient World

Dominique Lueckenhoff, Senior Vice-President for Corporate Affairs, EHS & Sustainability, Hugo Neu

North American Biochar and Bioenergy Conference 2022, Morgantown, WVA, August 9, 2022

How to scale?

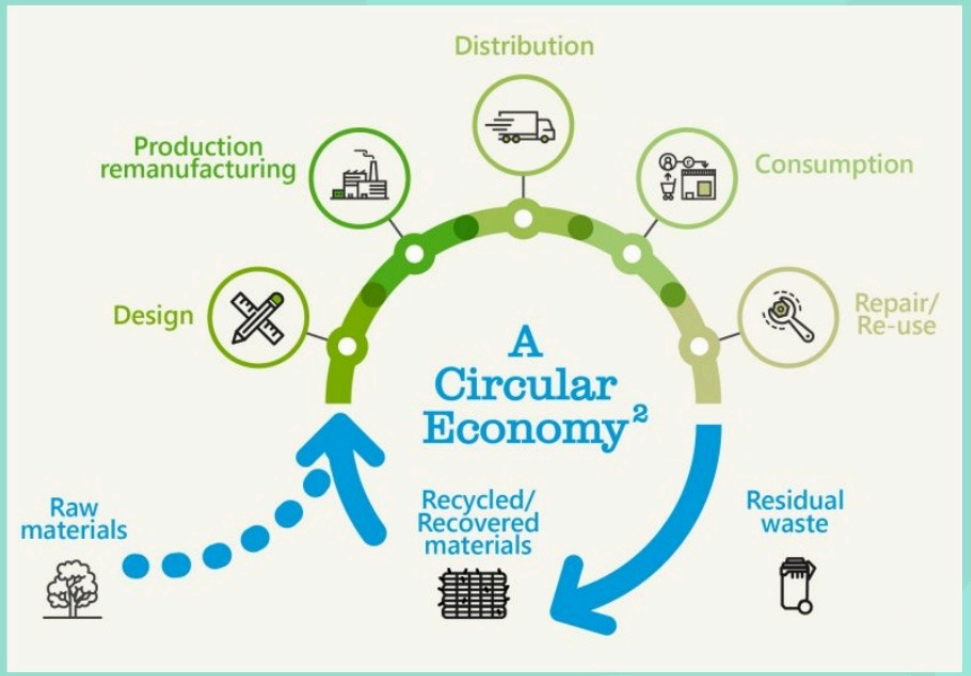
Like this?

This?

Or Like this?

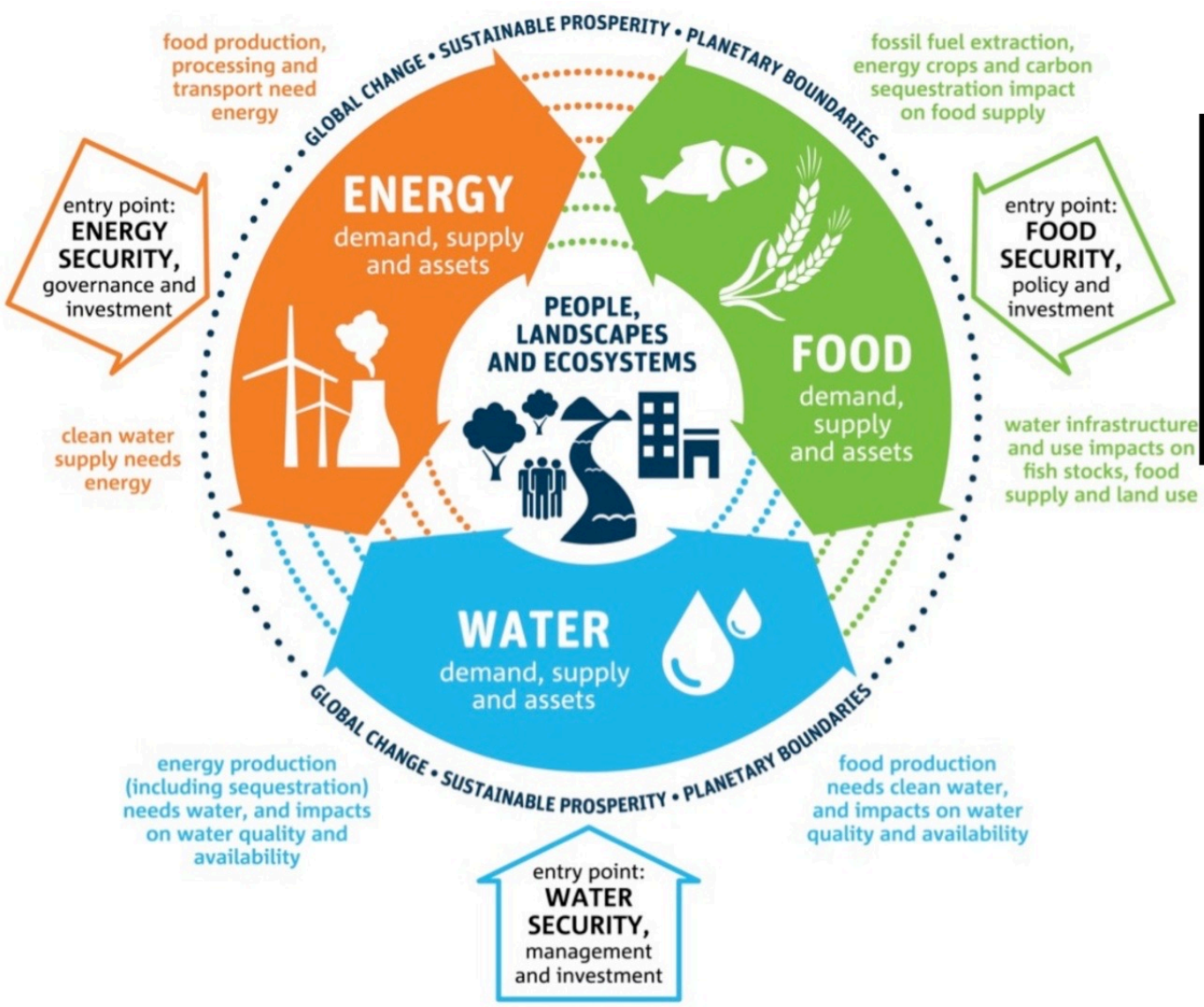
WHAT IS A CIRCULAR ECONOMY?

- The circular economy is based on three principles, driven by design:
- Eliminate waste and pollution
- Circulate products and materials at their highest value
- Regenerate nature



Diverse, Equitable, Inclusive

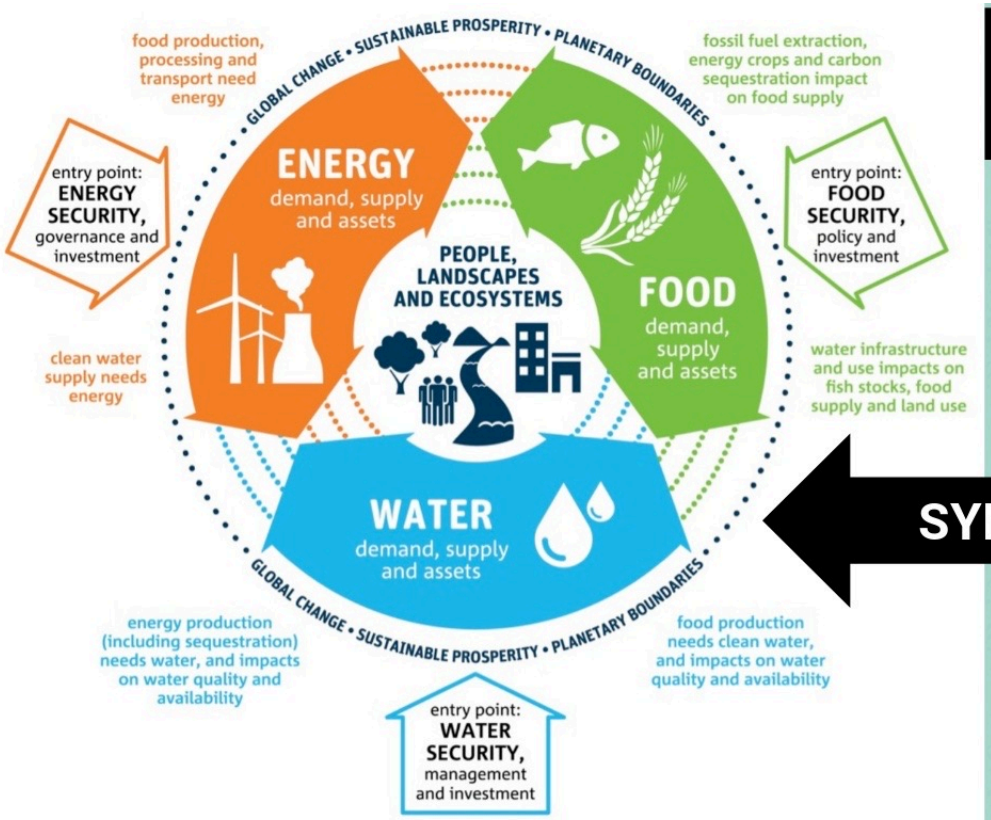
DRIVEN BY SUSTAINABLE DEVELOPMENT



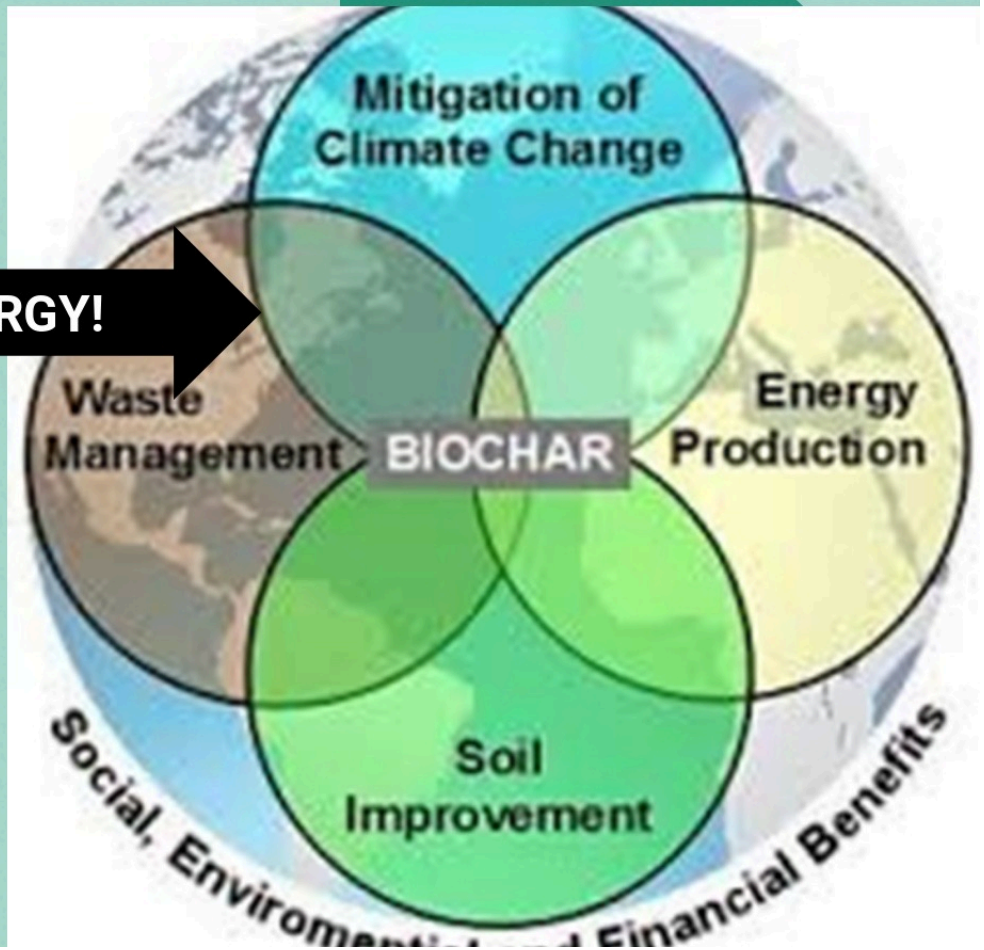
CIRCULARITY IS IMPORTANT FOR THE *WATER-ENERGY- FOOD* NEXUS

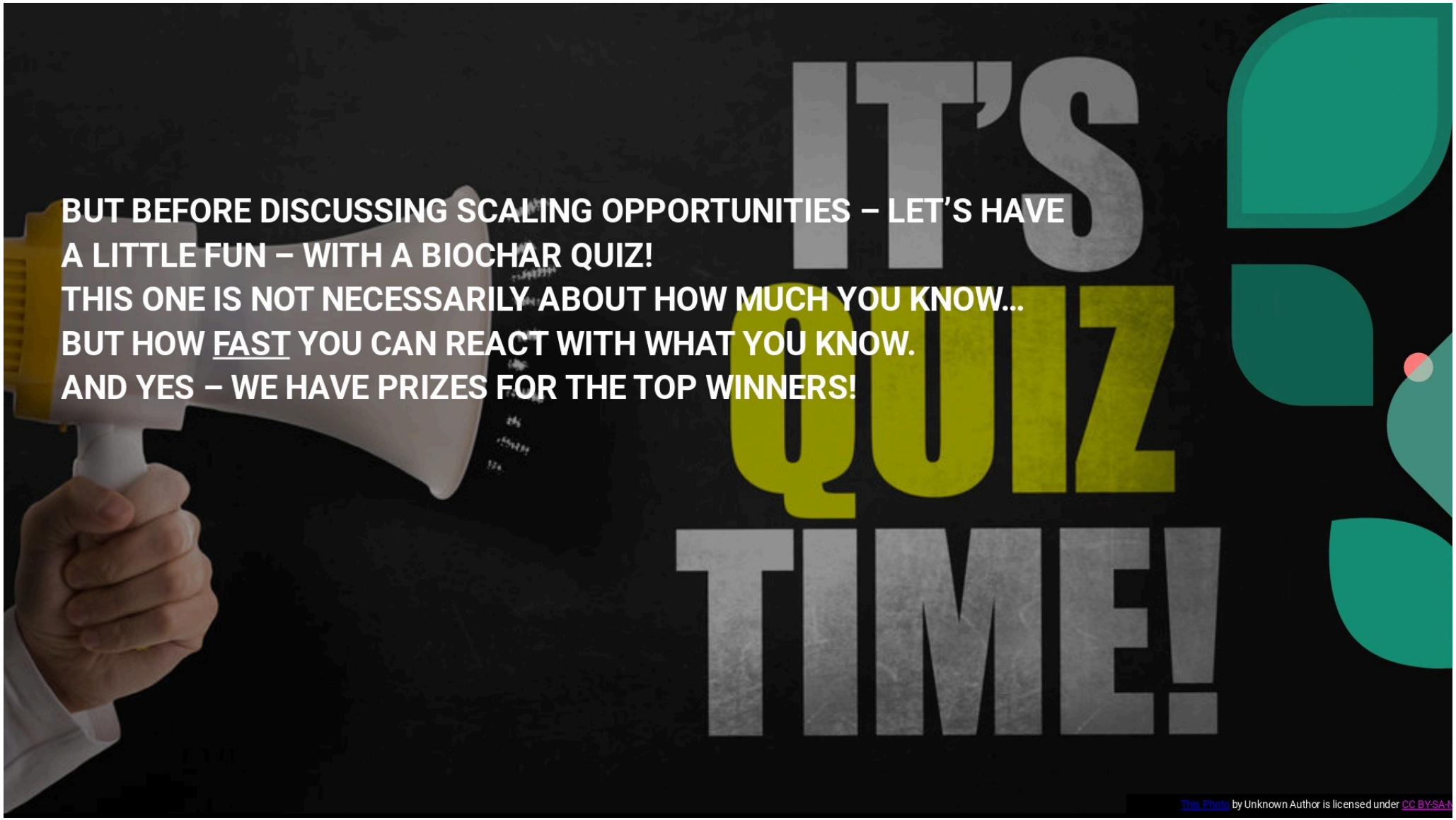
W.E.F.

A BIOCHAR ECONOMY SUPPORTS THE W.E.F. NEXUS !



SYNERGY!





BUT BEFORE DISCUSSING SCALING OPPORTUNITIES – LET'S HAVE A LITTLE FUN – WITH A BIOCHAR QUIZ!

THIS ONE IS NOT NECESSARILY ABOUT HOW MUCH YOU KNOW…

BUT HOW FAST YOU CAN REACT WITH WHAT YOU KNOW.

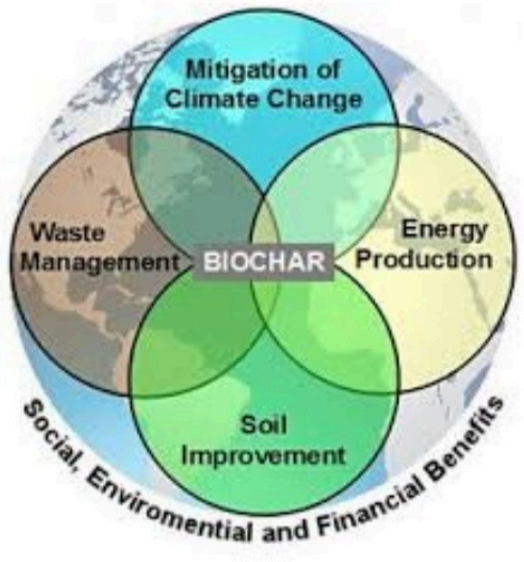
AND YES – WE HAVE PRIZES FOR THE TOP WINNERS!

SCALING THE BIOCHAR CIRCULAR ECONOMY – IMPORTANT MARKET LEVERS

- R&D
- Technology
- Finance
- Business Models
- Policy
- Awareness, Outreach & Education

THINK-ACT-SCALE!

RMI



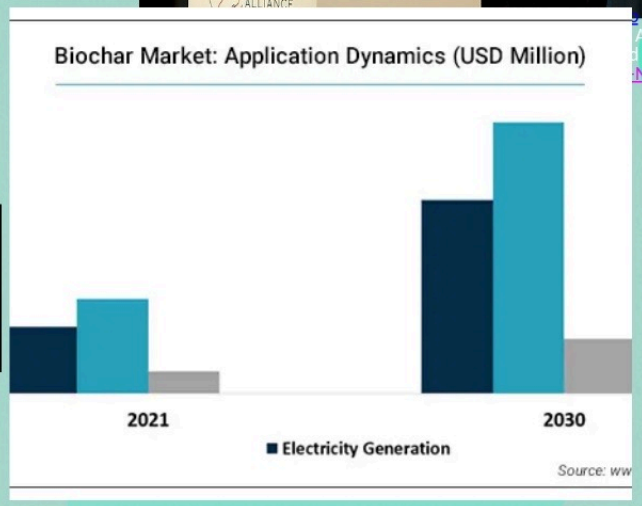
Key Factors Fueling Market Growth for Biochar

- **Environmental concerns & key applications**
- **Cheaper cost and carbon negative upcycling as substitute for raw materials**
- **Cohesive government policies for waste management**

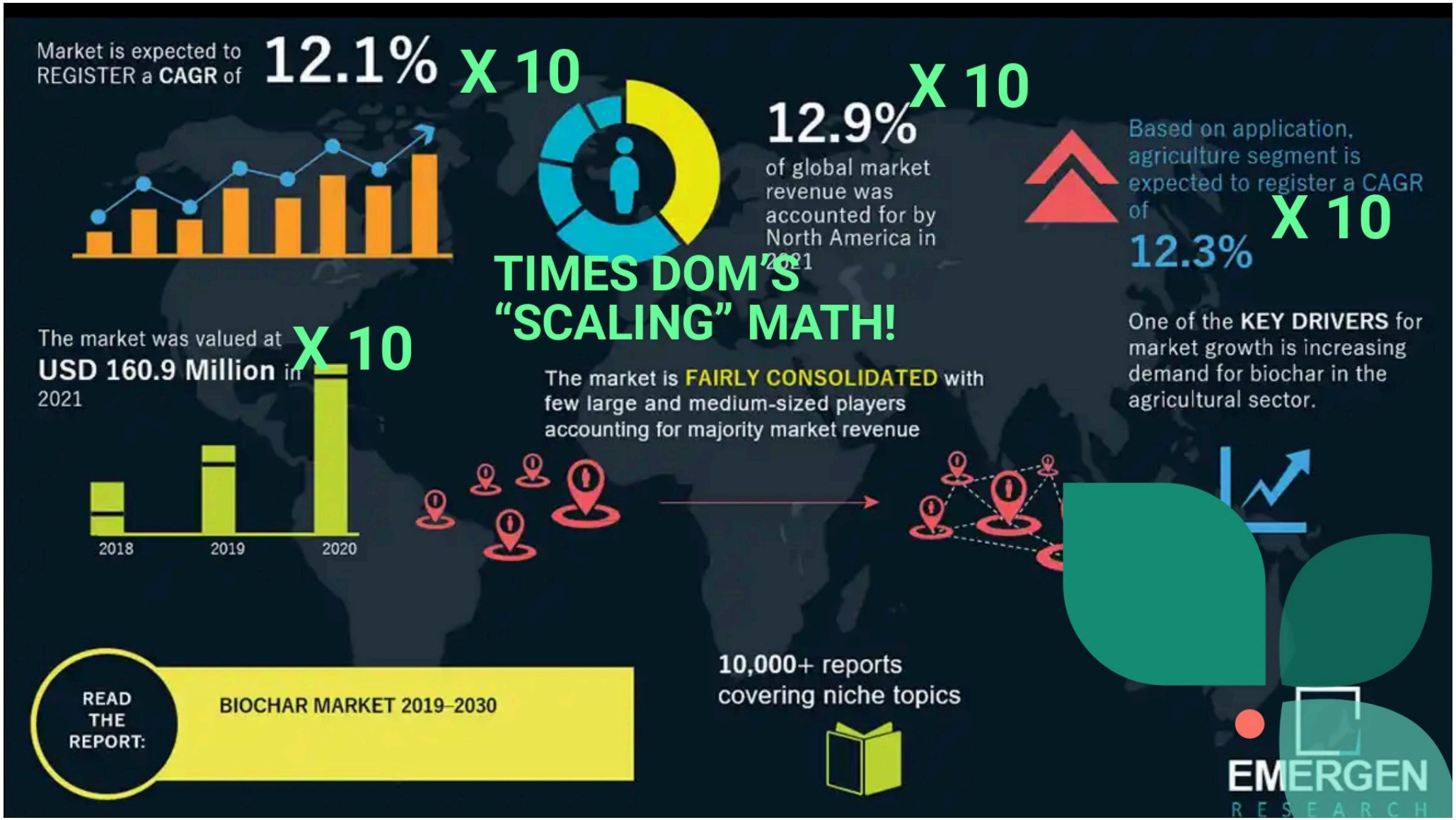
Biochar Market Outlook – Forecasted to Quadruple in the Next 10 Years

The global biochar market reached a valuation of US$ 8 M in 2020 - about 0.23% share of the overall charcoal market.

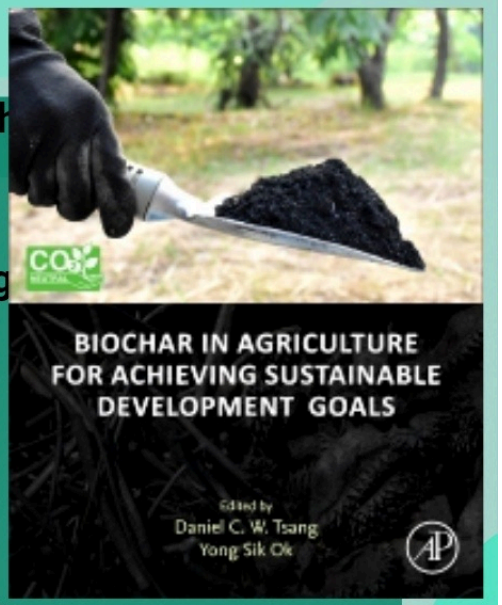
- Biochar Market Size Value in 2020 – US $ 8M
- Sales Forecast for Biochar by 2031 – US $ 23 M
- Global Market Growth Rate (2021 to 2031) - 12.3% CAGR
- U.S. Market Valued at $161 M in 2021



Demand for **pyrolysis & gasification technology** in biochar is set to increase at a CAGR of 10% across the assessment period of 2021 to 2031.


Market is expected to REGISTER a CAGR of 12.1%
X 10
12.9% of global market revenue was accounted for by North America in 2021
X 10
Based on application, agriculture segment is expected to register a CAGR of 12.3%
X 10
TIMES DOM'S "SCALING" MATH!
The market was valued at USD 160.9 Million in 2021
X 10
2018
2019
2020
The market is FAIRLY CONSOLIDATED with few large and medium-sized players accounting for majority market revenue
One of the KEY DRIVERS for market growth is increasing demand for biochar in the agricultural sector.
READ THE REPORT:
BIOCHAR MARKET 2019–2030
10,000+ reports covering niche topics
EMERGEN RESEARCH

Largest Market for Biochar - Agriculture



- **Improved carbon content and regenerative soil conditioning - enhanced soil health reduced need for fertilizers, pesticides, chemicals.**
- **Biochar reduces the danger of soil erosion - prevents fertilizer runoff, maintaining moisture.**
- **Reduced GHG's - Carbon negative**
- **Reduced nutrient runoff and adverse impacts to surface & ground water.**
- **Animal Health - Rising regulatory checks on non-therapeutic use of antibiotics. When used as a feed additive or supplement, biochar serves to prevent infections and effectively conveys the growth and performance benefits.**
- **Adoption of chemical-free farming techniques is becoming more popular as people become more aware of the health benefits of organic food.**
- **Expanding the use of biochar in chicken production to reduce litter and ammonia. Odors. Biochar can absorb liquids, gases, and ammonia to neutralize odors**

OPPORTUNITIES TO SCALE!

THE G.O.A.T

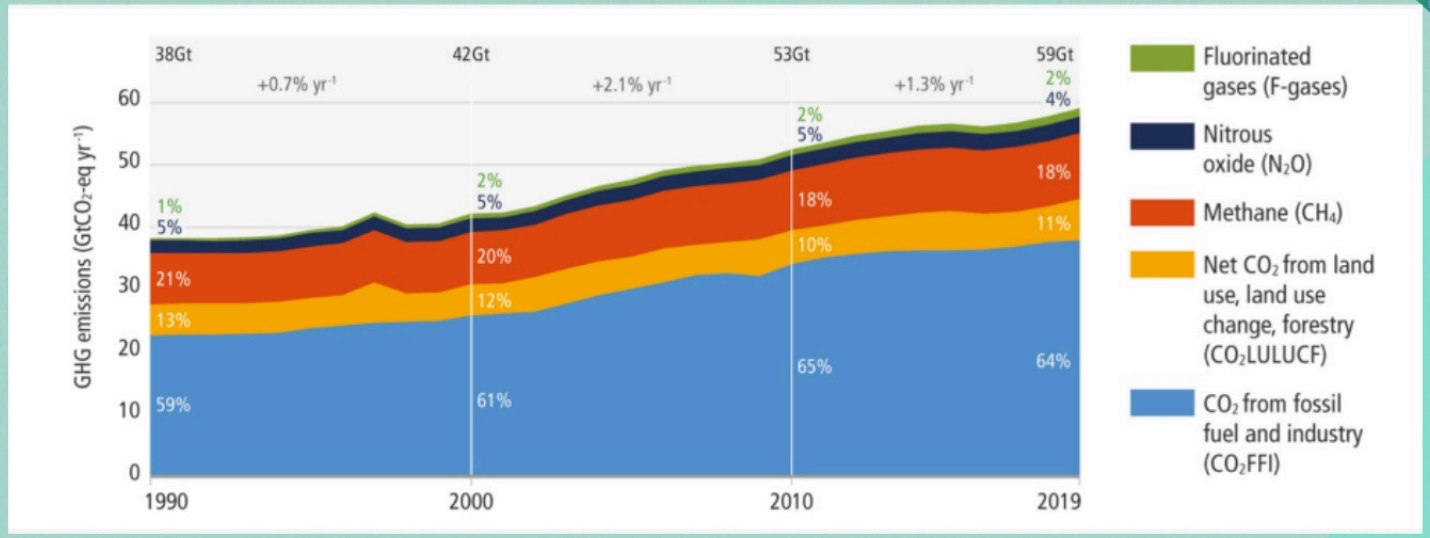
BIOCHAR – THE "G.O.A.T." FOR NEXT-GENERATION CLIMATE-FRIENDLY ENVIRONMENTAL SOLUTIONS

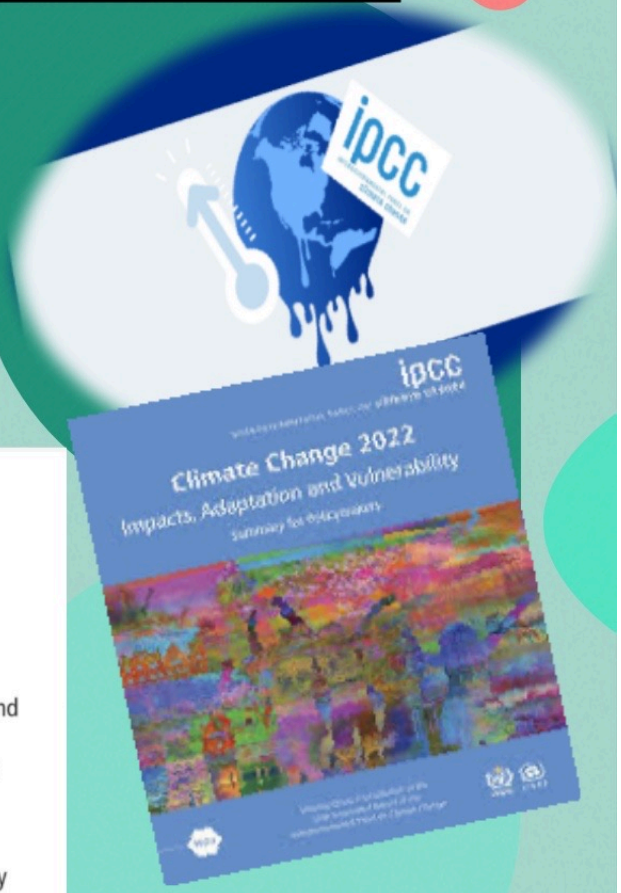
"G.O.A.T" – Greatest Of All Time

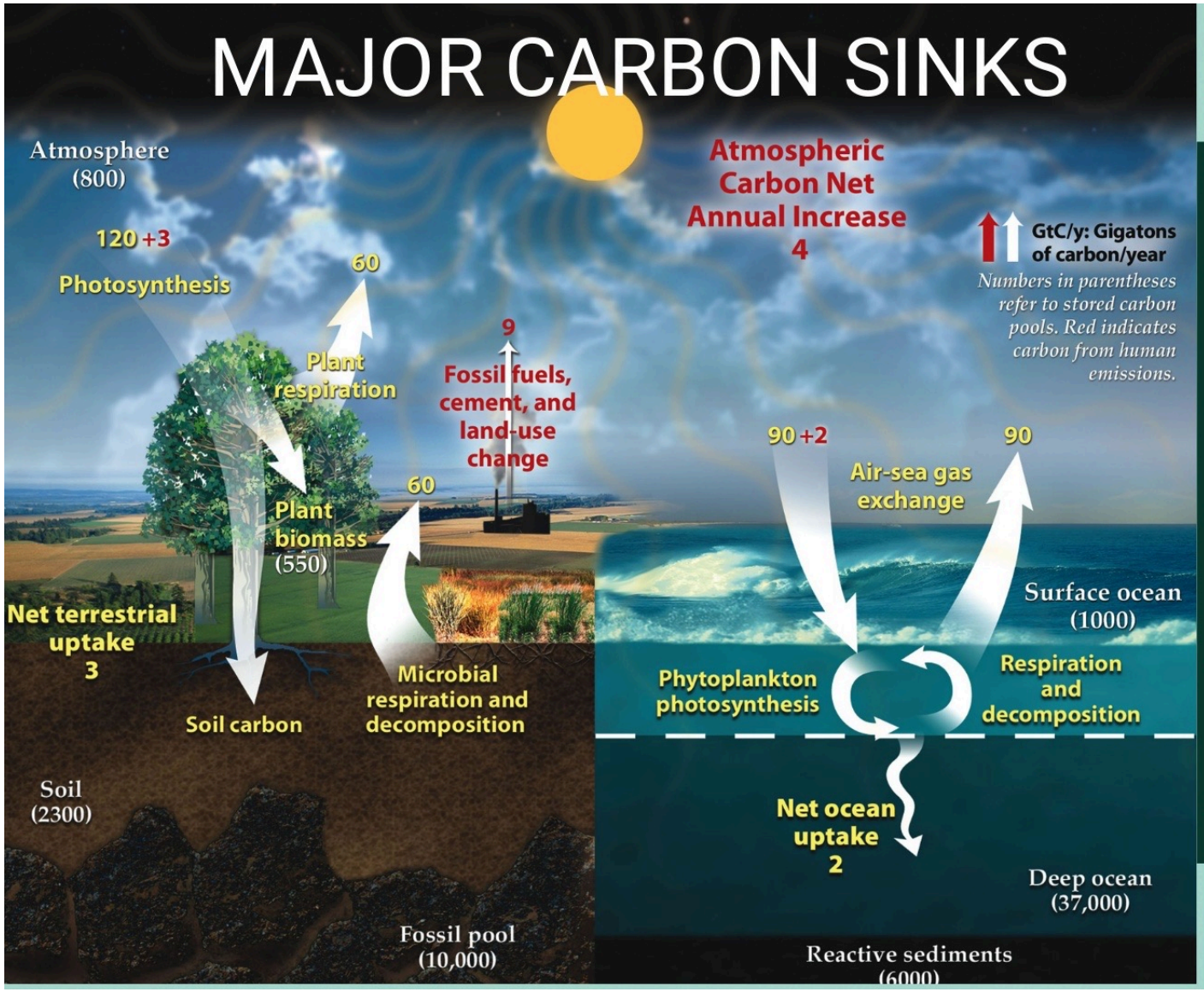
CLIMATE CHANGE - Temperature Check!

According to the latest IPCC Report (#3):

- **We are set to pass the 1.5°C threshold by 2040.**
- **Humans are the main drivers of climate change.**
- **We need to take notice of methane levels.**
- **We are close to reaching irreversible tipping points.**







MITIGATION & REGENERATIVE ROLES FOR BIOCHAR

- ATMOSPHERE (800 GtC/Y)
- SURFACE OCEAN (1000 GtC/Y)
- SOIL (2300 GtC/Y)
- REACTIVE SEDIMENTS (6000 GtC/Y)
- FOSSIL POOL (10,000 GtC/Y)
- DEEP OCEAN (37,000 GtC/Y)

CLIMATE RISKS: 1.5°C VS 2°C GLOBAL WARMING

EXTREME WEATHER

100% increase in flood risk. | vs | 170% increase in flood risk.

SPECIES

6% of insects, 8% of plants and 4% of vertebrates will be affected. | vs | 18% of insects, 16% of plants and 8% of vertebra will be affected.

WATER AVAILABILITY

350 million urban residents exposed to severe drought by 2100. | vs | 410 million urban residents exposed to severe drought by 2100.

ARCTIC SEA ICE

ummers in ic at least very 100 years. | vs | Ice-free summers in the Arctic at least once every 10 years.

PEOPLE

9% of the world's population (700 million people) will be exposed to extreme heat waves at least once every 20 years. | vs | 28% of the world's population (2 billion people) will be exposed to extreme heat waves at least once every 20 years.

SEA-LEVEL RISE

46 million people impact | vs | 49 million people impacted by sea-level rise of 56cm by 2100.

COSTS

Lower economic growth at 2°C than a for many countries, particularly low-i countries.

OCEANS

ks to marine y, ecosystems eir ecological ns and services at C compared to 2°C.

CORAL BLEACHING

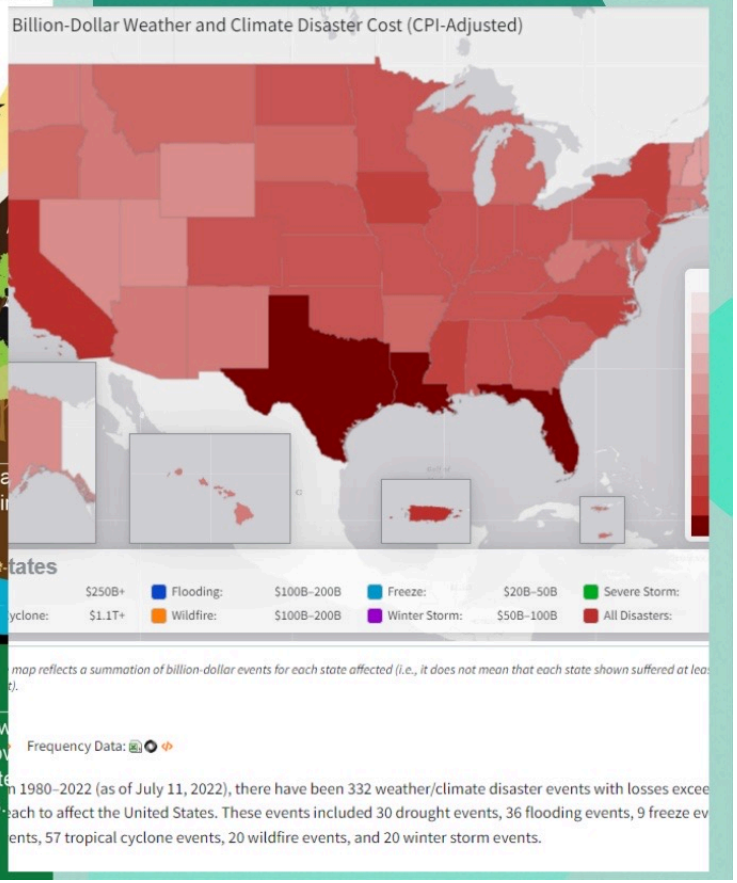
70% of world's coral reefs are lost by 2100. | vs | Virtually all coral reefs are lost by 2100.

FOOD

Every half degree w consistently lead to lo lower nutritional conte regions.

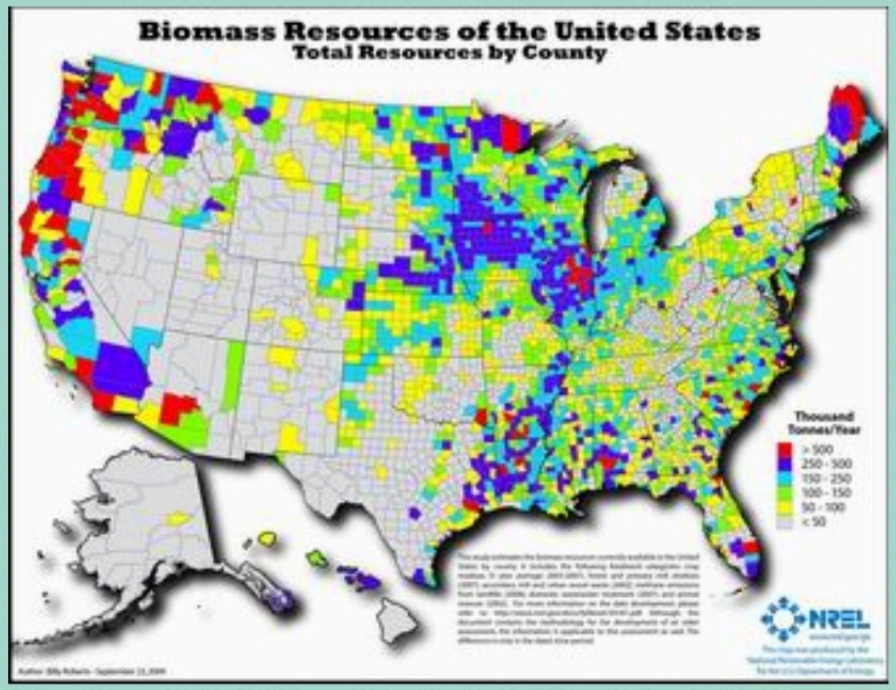
IPCC CONTINUES TO PROMOTE THE USE OF BIOCHAR!

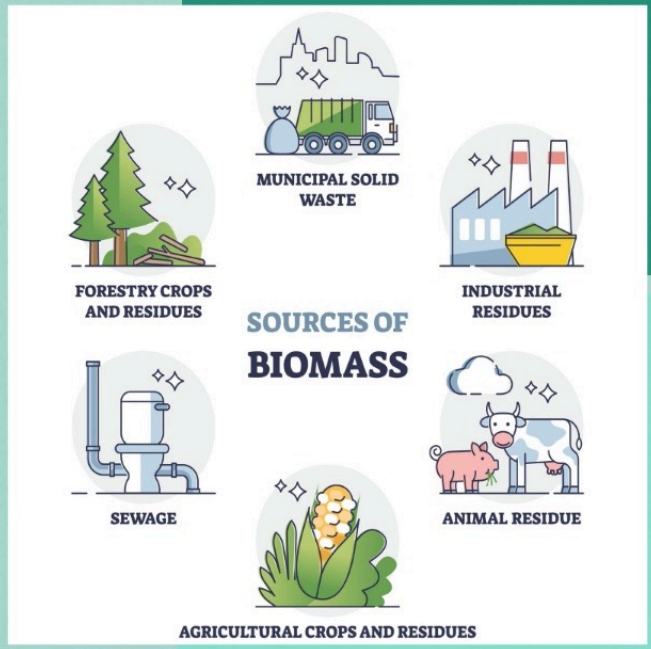
As of July 11, 2022, there have been 332 weather/climate disaster events in the US with losses exceeding $1B each.



BIOMASS/WASTE to BIOENERGY & BIOCHAR---

Climate-Smart Upcycling Opportunities- Co-Benefits for W.E.F. Resilience & Sustainability






CARBON MARKETS
$50B
McKinsey Quarterly/August 1, 2022
Spotting green business opportunities in surging net-zero world.
$50 billion per year
The Taskforce on Scaling Voluntary Carbon Markets has estimated that the market for carbon credits could be worth upward of $50 billion a year by 2030.
2040

SOLVING FOR EMERGING AND LEGACY ENVIRONMENTAL IMPACTS – OPPORTUNITIES FOR BIOCHAR INNOVATIONS

U.S. EPA's 4 Major Environmental Concerns

1. Water Issues
2. Air Issues
3. Waste and Land Pollution
4. Climate Change

United Nations Environmental Program (UNEP) – Top Environmental Challenges

1. Ecosystem Restoration
2. Managing Chemicals & Waste
3. Decoupling Growth from Resource Use
4. Green Finance
5. Worsening Impacts Due to Population Growth & Climate Change
6. Interconnected Risks

America's Top 15 Environmental Issues

1. Contaminated Soil
2. Air Pollution
3. Water Pollution
4. Waste Disposal
5. Climate Change
6. Loss of Biodiversity
7. Deforestation
8. Ocean Acidification
9. Reduction of Ozone Layer
10. Invasive species
11. Urban Extension
12. Nano pollution/Nanotoxicology
13. Toxins
14. Radioactive Pollution
15. Mine Pollution

MOST CURRENT POLLUTANT TREATMENT & REMEDIATION PROCESSESS ARE CLIMATE/CARBON INTENSIVE!

ADAPTABLE TREATMENT THROUGH DESIGNER CHARS

Chen, H., Gao, Y., Li, J. *et al.*, *June 2022*

BIPARTISAN INFRASTRUCTURE LAW(BIL)

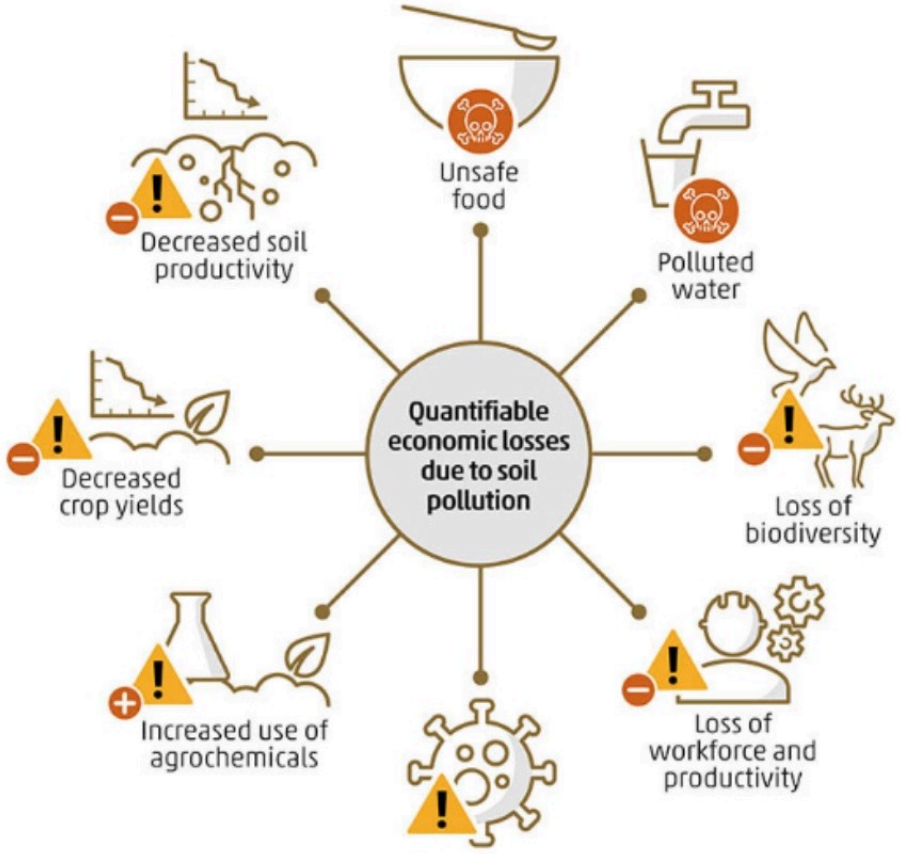
INFRASTRUCTURE	$BILLIONS	WHAT DOES IT SUPPORT?
ROADS & BRIDGES	$110 B	Funds new, dedicated grant program to replace and repair bridges and increases funding for the major project competitive grant programs.
PUBLIC TRANSIT	$39.2 B	Funds nation's transit system repair backlog, which DOT estimates is more than 24,000 buses, 5,000 rail cars, 200 stations, including clean transit options..
BROADBAND	$65 B	Grants to states for broadband deployment, makes broadband access more affordable for low-income families
PORTS & WATERWAYS	$16.6 B	Funding for waterway and coastal infrastructure, inland waterway improvements, port infrastructure, and land ports of entry
WATER INFRASTRUCTURE	$55 B	Includes $23.4 billion for the bipartisan Drinking Water and Wastewater Infrastructure Act of 2021. Provides a historic $15 billion for lead service line replacement and $10 billion to address Per- and Polyfluoroalkyl Substances (PFAS).
POWER & GRID	$65 B	Includes funds for grid reliability and resiliency and support for a Grid Deployment Authority; supply chains for clean energy technology; key technologies like carbon capture, hydrogen, direct air capture, and energy efficiency; and energy demonstr
RESILIENCY	$47.2 B	Funding for cybersecurity to address critical infrastructur wildfire mitigation, drought, and coastal resiliency weatheriz
CLEAN SCHOOL BUSES & FERRIES	$7.5 B	Includes historic $5 billion for the replacement of school buses, with a priority on l
ELECTRIC VEHICLE CHARGING	$7.5 B	National network of electric vehicle charging to provide convenient charging where people l disadvantaged, and ha
RECONNECTING COMMUITIES	$1 B	Funds for projects that remove barrier infrastructure funding planning, design, demolition, and

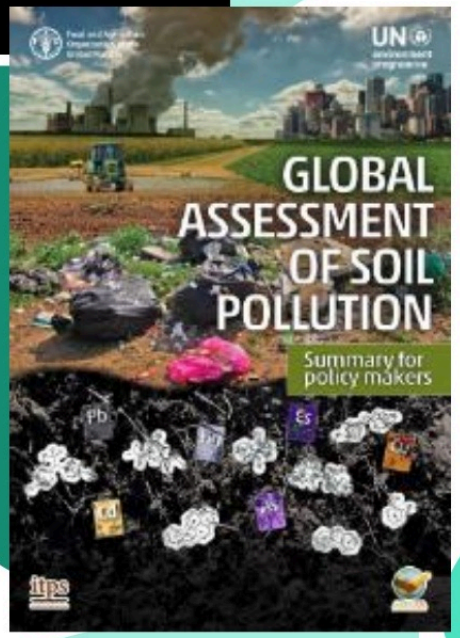
PUBLIC DOLLARS FOR RESILIENT INFRASTRUCTURE & HEALTHY COMMUNITIES

News Flash! Inflation Reduction Act passed (8/7) by Senate Dems. Largest ever federal investment targeting climate change - $370B

Global cost of soil contamination - $100's of Billions!

soil productivity and reduction of crop yields, contamination of food products and loss of marketability, reduction of biodiversity, and reduction of water quality.

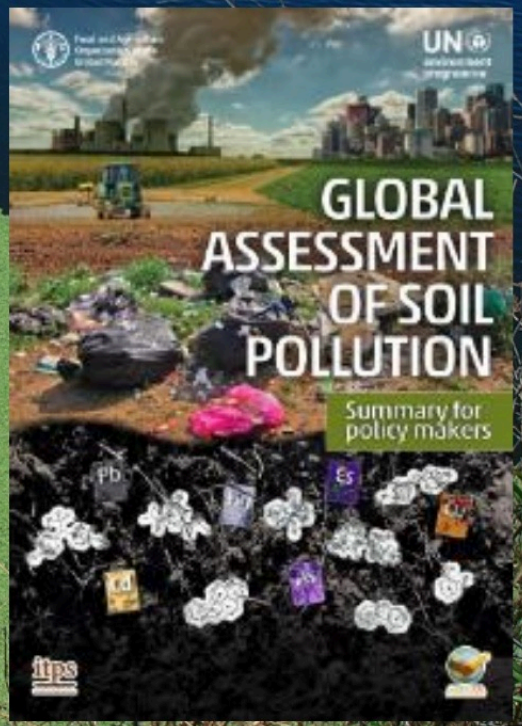




Global cost of water contamination - 100's of Billions!

US ECONOMIC IMPACTS

- CONTAMINATED GROUNDWATER REMEDIATION - $110 B
- FRESH WATER POLLUTION COSTS- $3.4 B/Yr
- NITROGEN POLLUTION - $ 340 B



Environmental Pollution CostsTrillion$/Year!!!

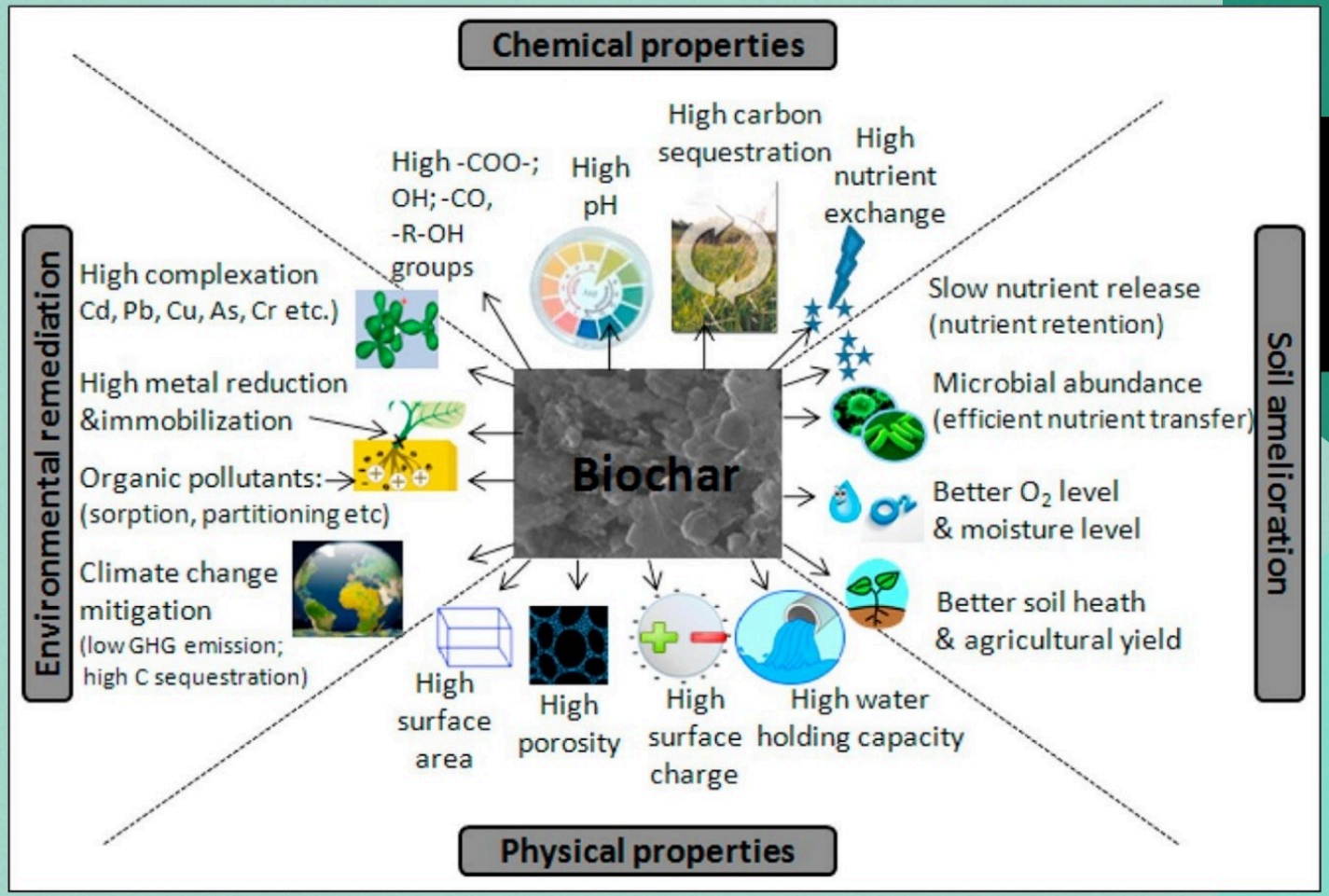
Lancett Commission Report (2017) on the global impact of environmental pollution:

"In 2015, diseases caused by air, water and soil pollution were responsible for 9 million premature deaths, that is 16% of all global death.

Exposures to contaminated air, water and soil kill more people than smoking, hunger, natural disasters, war, AIDS, or malaria."

Nearly all of these deaths (92%) took place in poorer nations. In wealthier nations that have worked to reduce pollution, the benefits of pollution control far outweigh the costs. **According to this Commission, the global financial costs of pollution are huge, totaling "$4.6 trillion per year**.

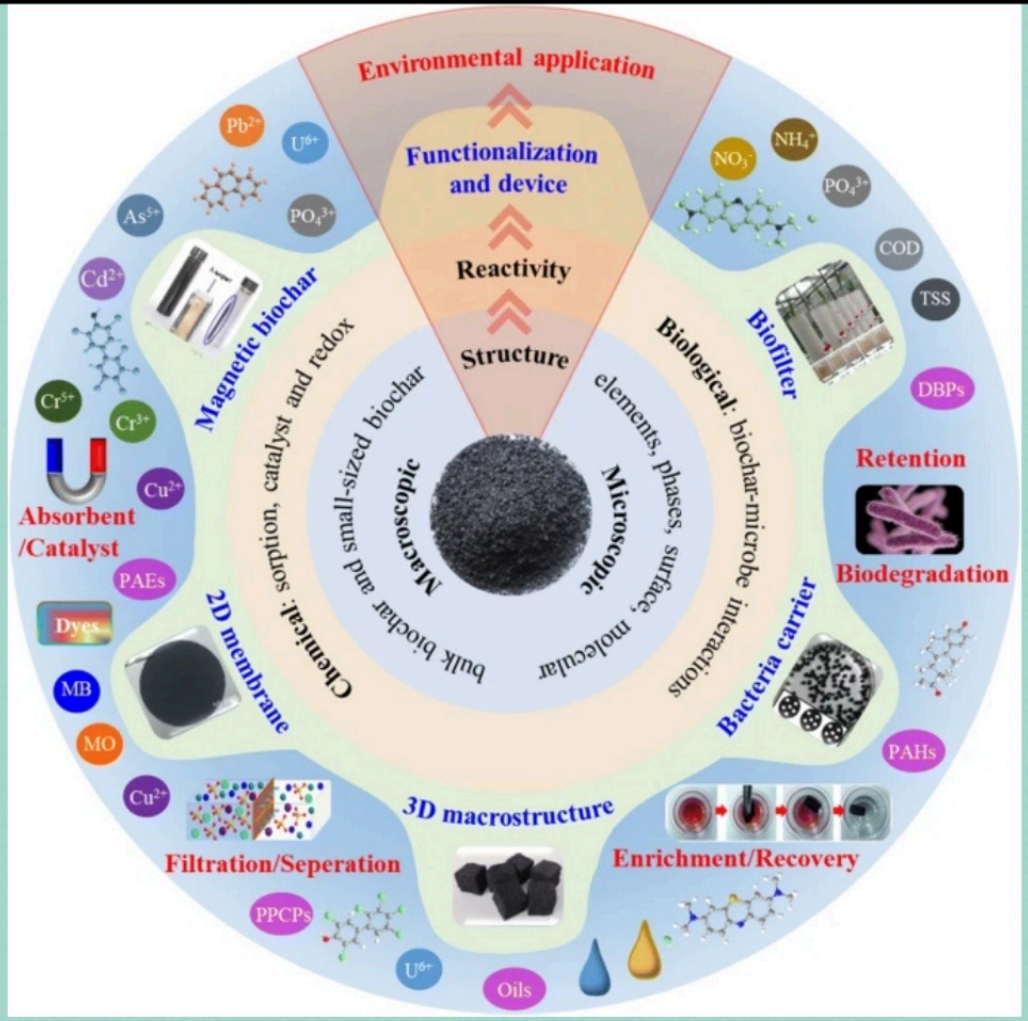
BIOCHAR'S unique properties enable significant scalability!



Biochars vary by feedstock and processes with unique properties to remove pollutants from soil, water and gas.

Yu, Wang et al, 2020

Biochar – Environmental Treatment Examples



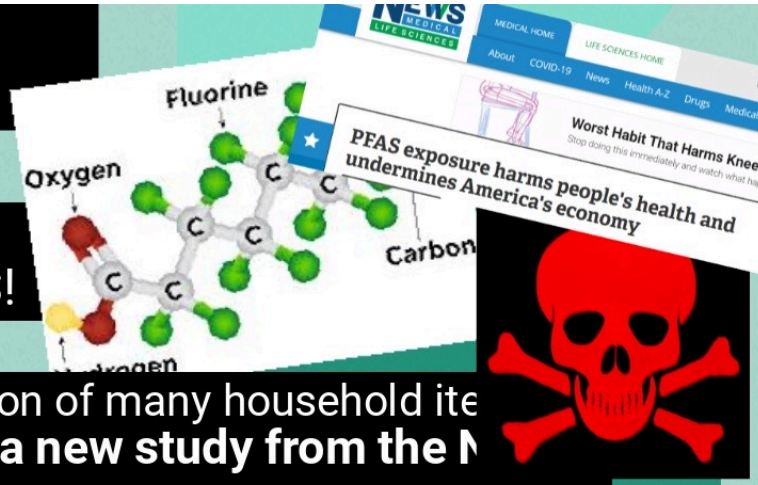
- BIOFILTER
- RETENTION/BIODEGRADATION
- BACTERIA/PATHOGEN INHIBITOR
- ENRICHMENT/RECOVERY
- FILTRATION/SEPARATION
- 2D MEMBRANE
- CHEMICAL ABSORBENT/CATALYST/REDOX

Lu, L., Yu, W., Wang, Y. *et al*. Application of biochar-based materials in environmental remediation: from multi-level structures to specific devices. *Biochar* **2,** 1–31 (2020). https://doi.org/10.1007/s42773-020-00041-7

PFAS

per- and polyfluoroalkyl substances

BIOCHAR IS EMERGING AS AN EFFECTIVE COST-EFFECTIVE ALTERNATIVE TREATMENT FOR PFAS!

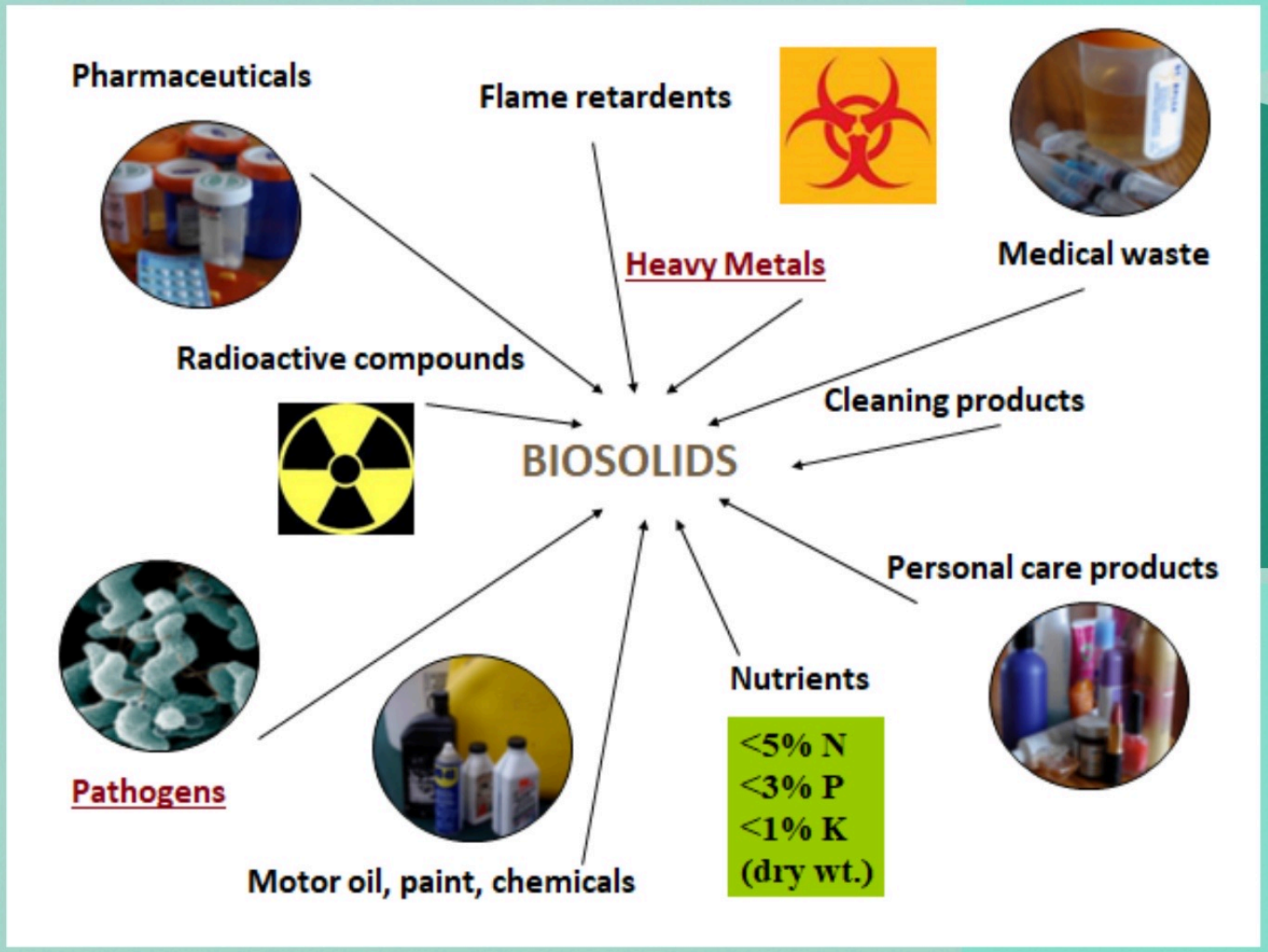


- Daily exposure to a class of chemicals used in the production of many household ite may lead to cancer, thyroid disease, and childhood obesity, **a new study from the N Grossman School of Medicine shows**.

- **The resulting economic burden of PFAS contamination is estimated to cost Americans a minimum of $5.5 billion and as much as $63 billion over the lifetime of the current population.**

- The chemicals are used, for example, in the production of water- and oil-resistant clothing, electronics, and nonstick cookware, and people are thought to ingest them as food comes into contact with packaging.

- The substances are believed to disrupt the function of hormones, signaling compounds that influence many bodily processes.


Pharmaceuticals
Flame retardents
Medical waste
Heavy Metals
Radioactive compounds
Cleaning products
BIOSOLIDS
Personal care products
Nutrients
<5% N
<3% P
<1% K
(dry wt.)
Pathogens
Motor oil, paint, chemicals

How Much Do We Waste?

Jul 13, 2022

Environmental PROTECTION

- Annually, 2.12 billion tons of waste is produced across the wo

1.3 billion tonnes is made up of food.

- At least 33 percent of the planet's waste is not managed in an environmentally safe way. .
- By 2050 global waste will grow to 3.40 billion..
- Annually, it is estimated the world's oceans are polluted by 10 million metric tons of plastic.
- In 2018, America was responsible for producing 292.4 million tons of municipal solid waste
- The waste management market in North America was valued at $208 billion in 2019. The U.S. accounts for most of the market.
- The U.S. manages 35.2 million tons of hazardous waste.
- Each year, estimates suggest the U.S. produces around 103 million tons of food waste.
- America currently has a recycling and composting rate of 32.1%.

North America Continues to Be the Most Successful Market for Biochar Manufacturers – Expanding 1.3X by 2031

DRIVERS

- Biochar producers in North America are increasingly focusing on innovating their offerings and biochar commercialization to expand their footprint in the global market.

- Growing demand for pyrolysis and gasification equipment
- Rising use of biochar in electricity generation are expected to fuel the biochar market value in the region.
- Burgeoning environmental concerns
- Growing availability of inexpensive feedstock have been creating significant demand for biochar products, in North America.

Biochar – Market Barriers & Growth Constraints

- **Biochar's expensive price point**
- **Fundamental structural barriers**
  - Lack of capital for producers
  - Immature carbon market
  - Lack of efficient technology for low emission biochar production, particularly for remote or mobile production, has been impeding the biochar market value over the recent past.
- **Biochar commercialization lacks consistency and standardization**
- **Concerns for unsustainable production process of biochar** - prominent factor limiting growth potential of biochar consumption.
- **Carbon removal market still challenging – inconsistent - far from mainstream.**
- **High investment costs, limited government support and lack of awareness among consumers**
- **Need for more research & development to support greater market diversification.**

IN SUMMARY...

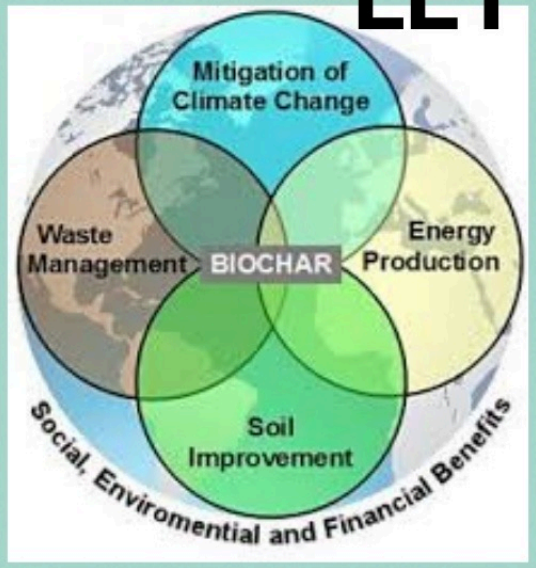
The Biochar Sector offers both mitigation and adaptation opportunities to cool a fast-warming planet and its devastating impacts to quality of life.

"Growing environmental concerns, rising acceptance of biochar as an appropriate substitute for chemical fertilizers, and cooperative government waste management regulations are expected to create greater opportunities for the growth of the biochar market over the next ten years," Fact Market Analyst.

Market Levers

- R&D
- Technology
- Finance
- Business Models
- Policy
- Outreach & Education

LET'S THINK-ACT-SCALE! RMI



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THANK YOU!

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Hugo Neu

North American Biochar and Bioenergy Conference 2022, Morgantown, WVA, August 9, 202