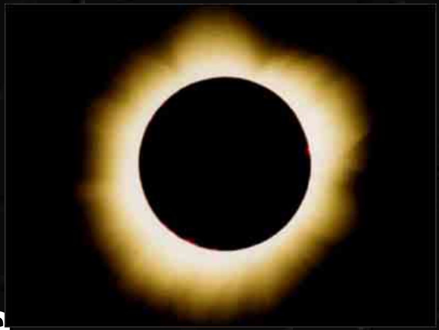
Renewable Hydrogen Production
With Carbon Sequestration

A Response to Environmental Imbalances and Movement Toward Sustainability and Socio-Economic Stability

Danny Day
Eprida

A Development Platform



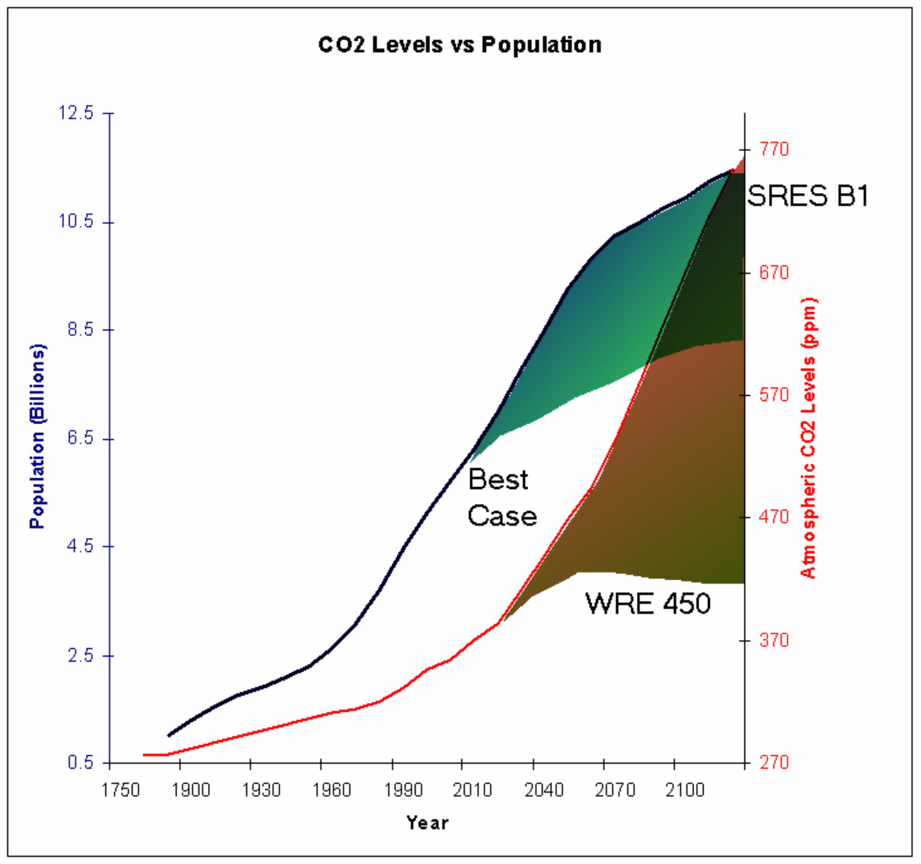
The Sun, Earth and Moon represent a relatively sustainable system for the next few billion years

Yet, imbalances from natural competition are found locally throughout the world and are a natural part of our evolving system

Fossil Fuel Exploitation

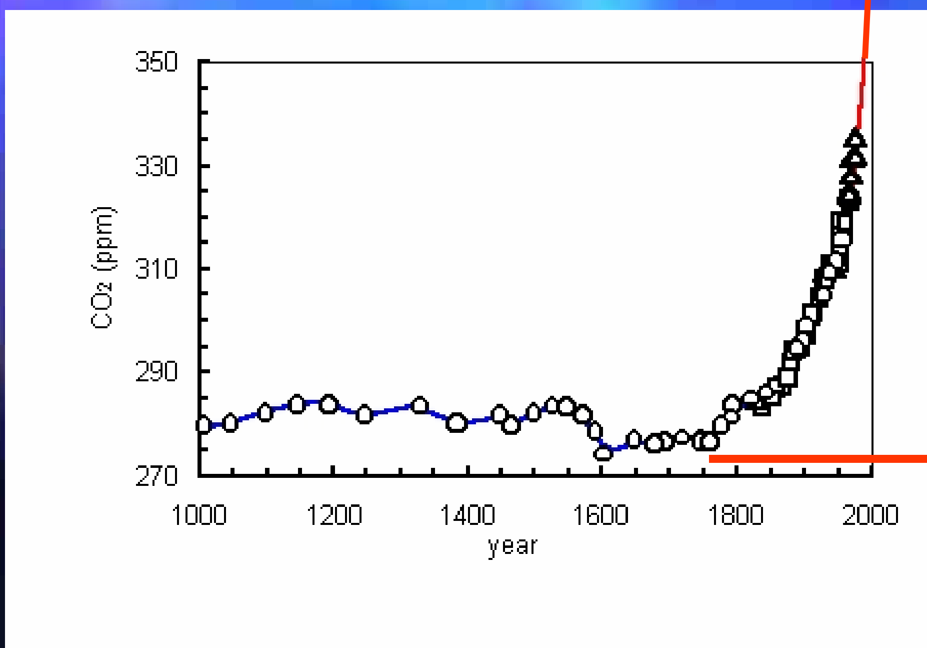
- The deforestation of England and the resulting turn to coal unlinked population growth from biosphere based energy and its natural limitations.
- The resulting localized population density and the accompanying byproducts of fossil fuel combustion presented the planet with accelerating imbalances

Population and CO2
The Future Possibilities

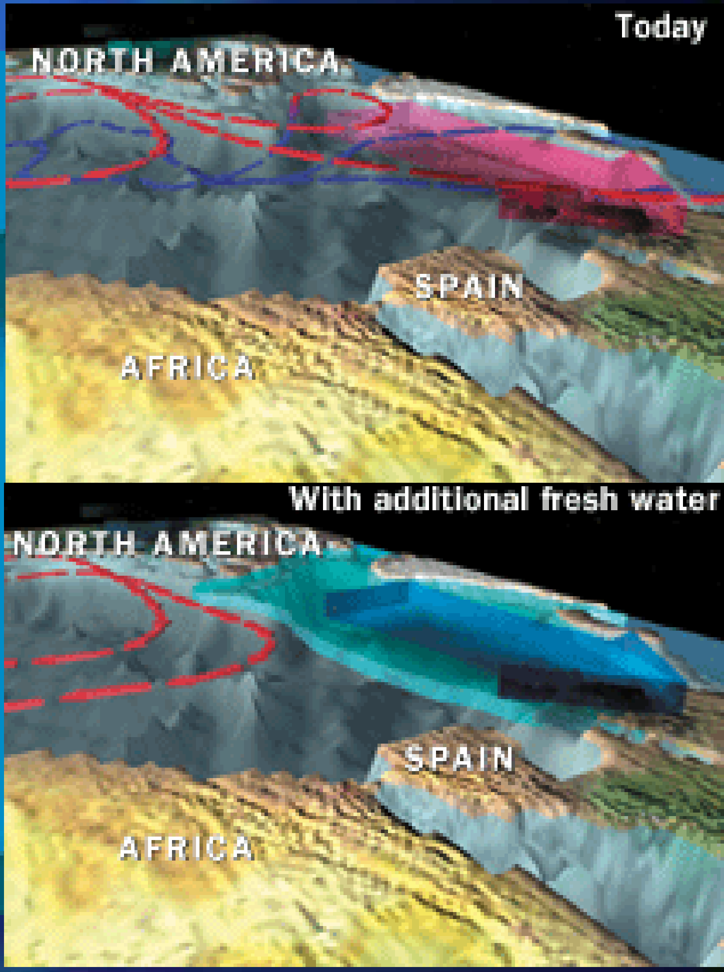


Stabilization may not occur even in our children's lifetime

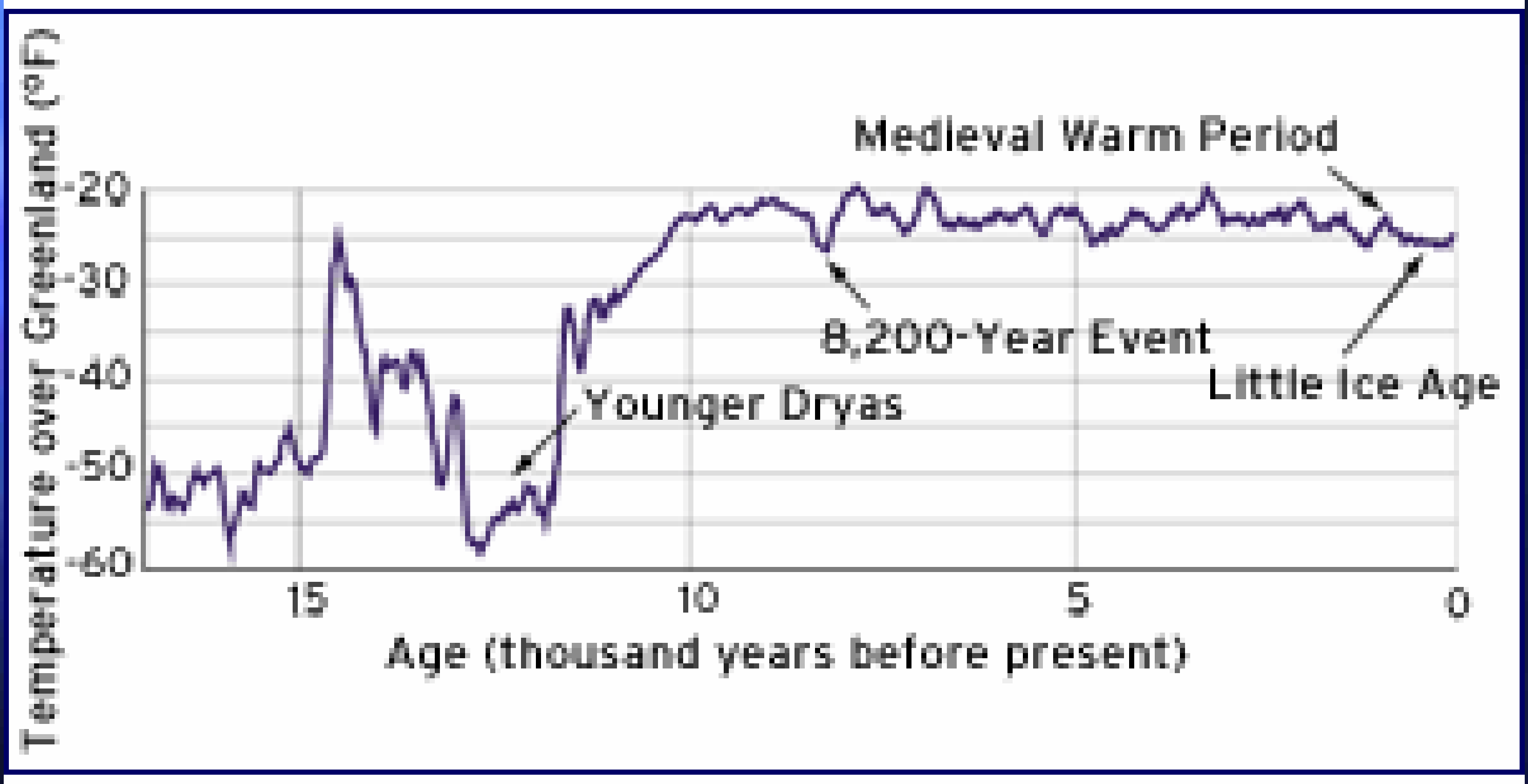
The Immediate Concern: Slowing the Rate CO_2 Buildup



The impacts are significant

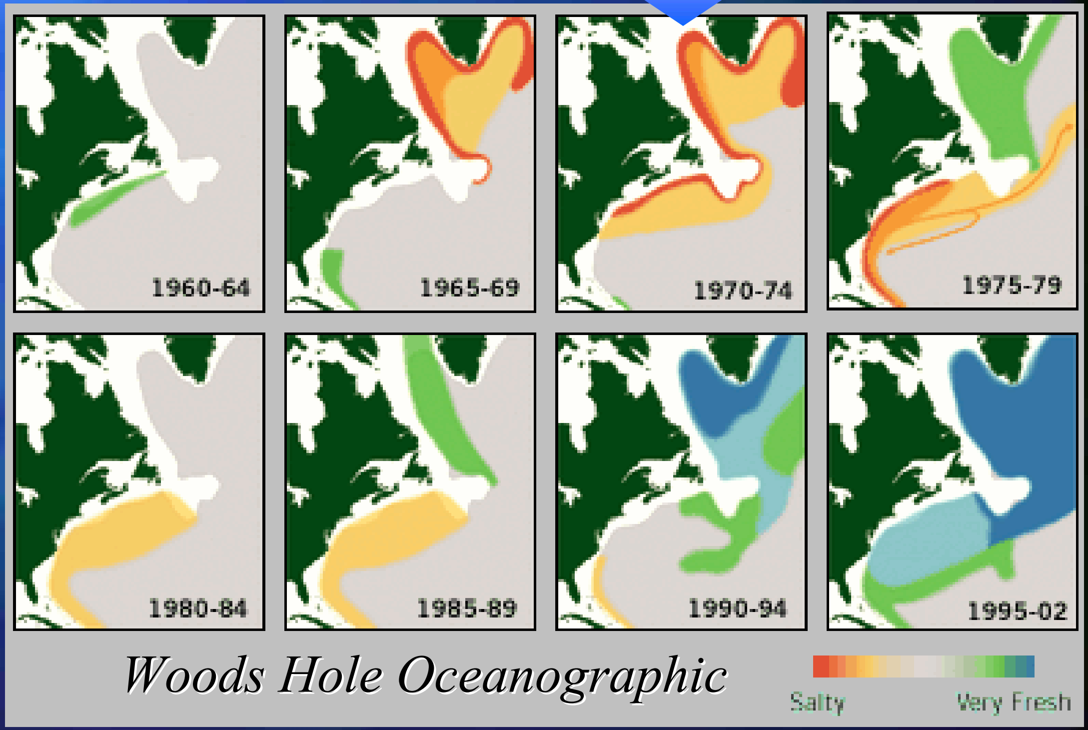


It has abruptly happened before

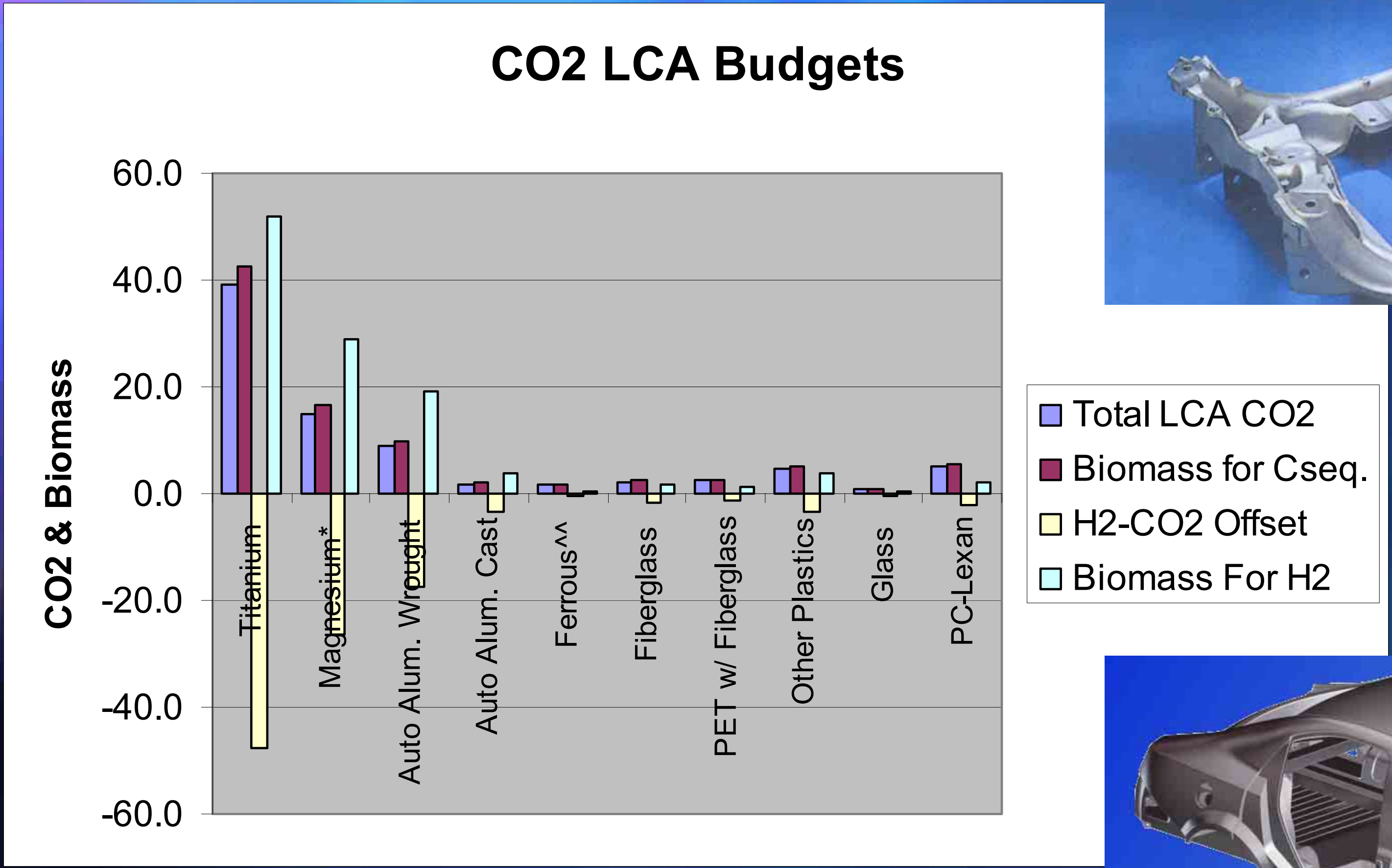


The issue is becoming a large global concern

The impact of melting glaciers has produced changes in salinity across large areas of the North Atlantic since 1995.

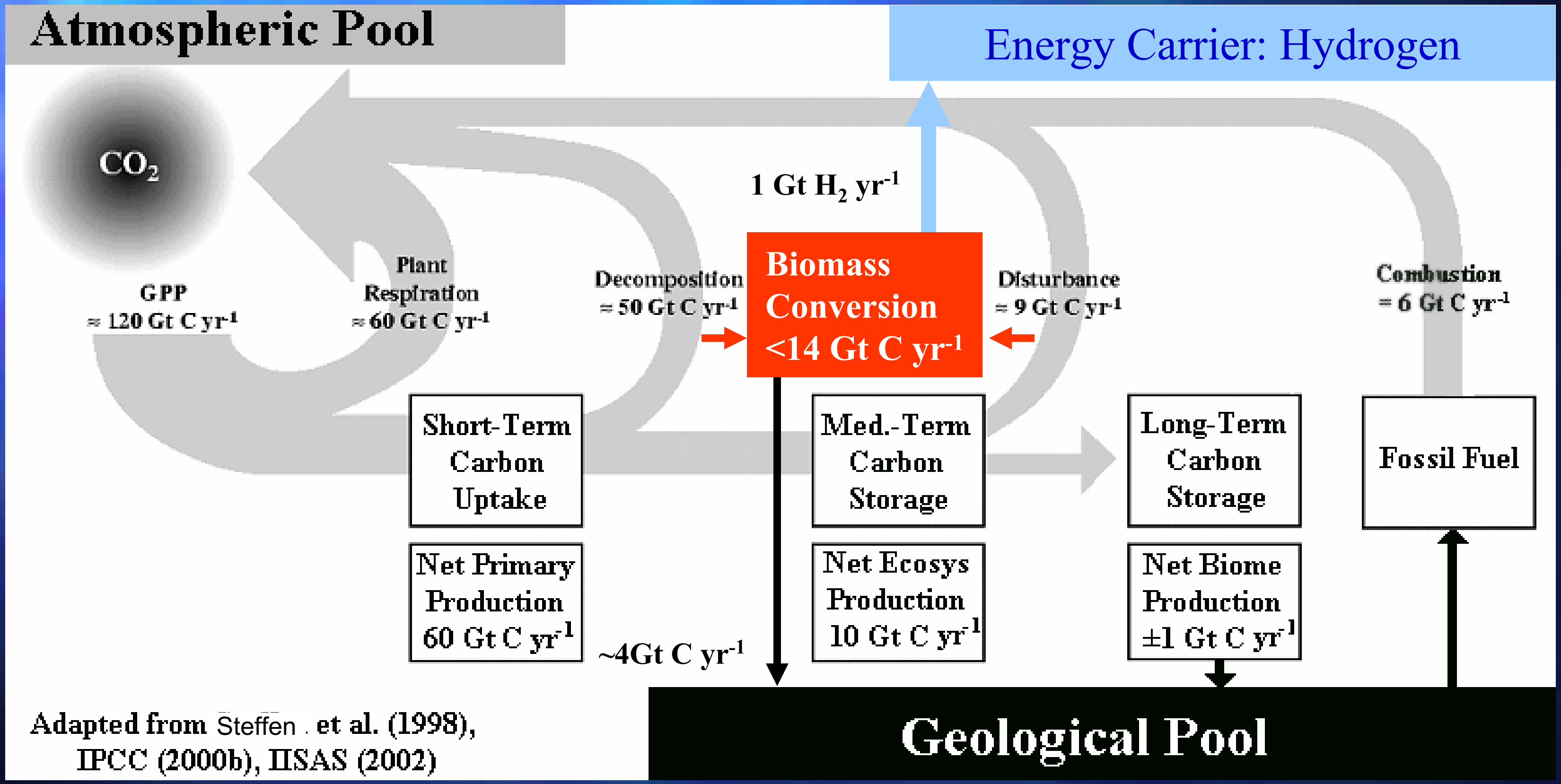


The Opportunity



Materials that represent sequestered atmospheric carbon

The Technical Potential of Hydrogen Production with Carbon Sequestration



What is possible? >1PPM=1.2Gt C or - 4/1.2=(3.3PPM/yr)

Renewable Hydrogen from Biomass Leverages Photosynthesis

100-Hour Demonstration of Hydrogen by Biomass Catalytic Steam Reforming (August 2002)

$$6CO_2 + 6H_2O + hv \rightarrow C6H12O6 + 6O_2 \rightarrow$$

Catalytic Steam Reforming
60% H2
20% CO_2
7% CO
3% CH_4

Plus 20-30% (by weight) Charcoal

Nature's thermal Oxy-Hydrocarbon processing

For millions of years nature has thermally processed biomass and sequestered a significant percentage of the carbon in the form of charcoal.

Char is a natural part of all soil carbon content

The stability of charcoal

- The half life of charcoal in the soil is measured in 1000’s of years (Skjemstad)
- Charcoal even in weathering environments can be found as old as 11,000 BP (Gavin)
- Unlike ash laden slag, it is a beneficial soil amendment
- Unlike CO2 pumped into the ground or ocean at a cost, charcoal has a saleable value.

Carbon in the soil

- Char is a pyrogenic carbon, often lumped under the classification of black carbon
- Black carbon is a term widely used for soot, an amorphous residue of combustion and a contributor to global warming.
- Char found in soils from forest and range fires has a carbon framework remaining after the pyrolysis of volatile organics.
- Charcoal has proven itself with over 2000 years of testing as a soil amendment in terra preta soils.

Pyrogenic sequestered carbon

With NPK and Charcoal — With NPK

Manaus, Brazil - Terra Preta Research, 2001
Christoph Steiner, University of Bayreuth
Institute of Soil Science and Soil Geography

(Taiwan, 2001)
Food and Fertilizer
Technology Center
for the Asian and
Pacific Region

- **Surface oxidation of the char increased the cation exchange capacity (Glaser)**
- **Char decreased leaching significantly (Lehmann)**
- **Char traps nutrients and supports microbial growth (Pietikainen)**
- **Char increased available water holding capacity by more than 18% of surrounding soils (Glaser)**
- **Char experiments have shown up to 266% more biomass growth (Steiner) and 324% (Kishimoto and Sugiura)**

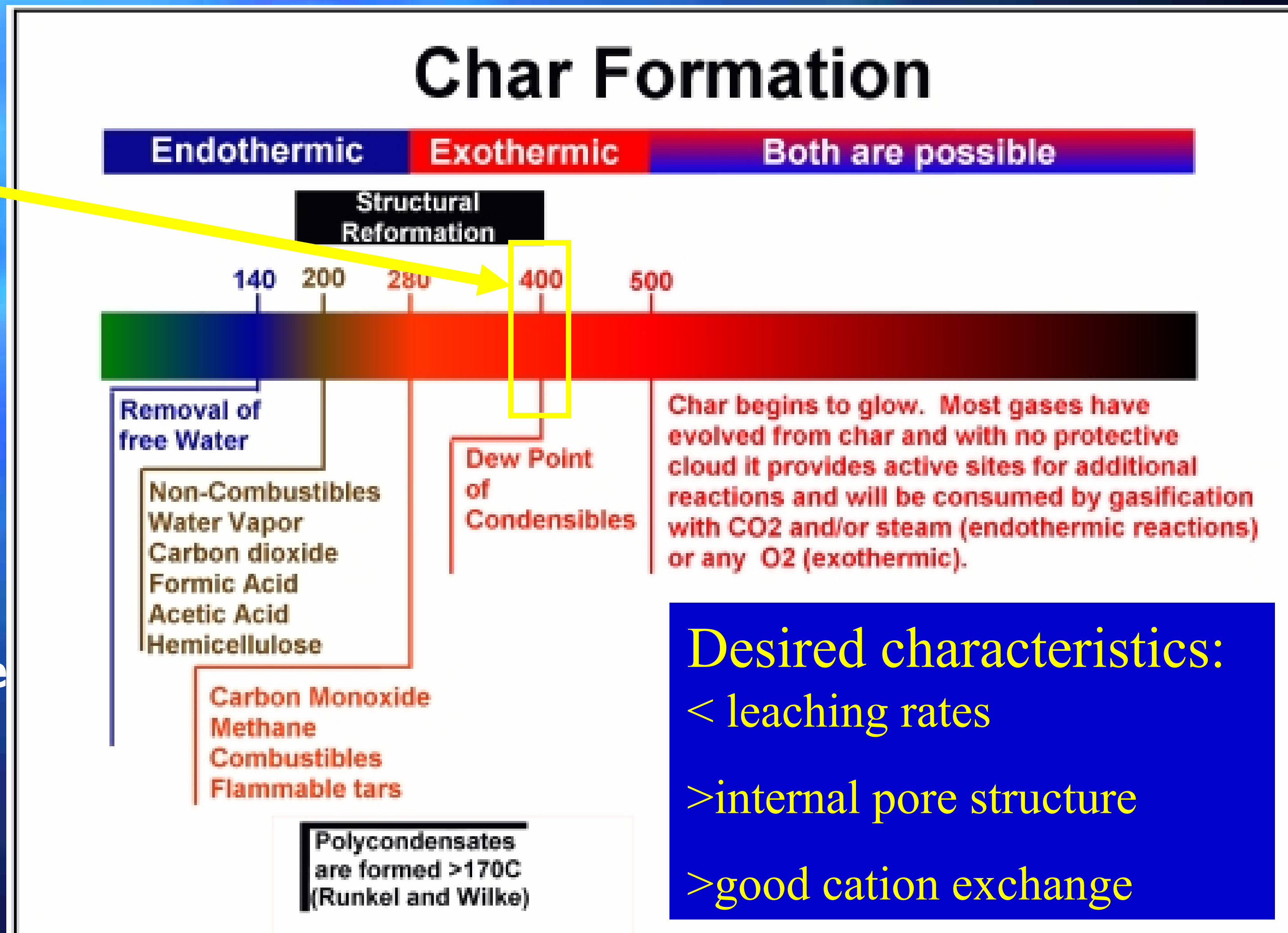
Economics: Pyrogenic carbon requires no additional energy

Target Range:

Mid-exothermic range

Appropriate Technology

Low comparative investment



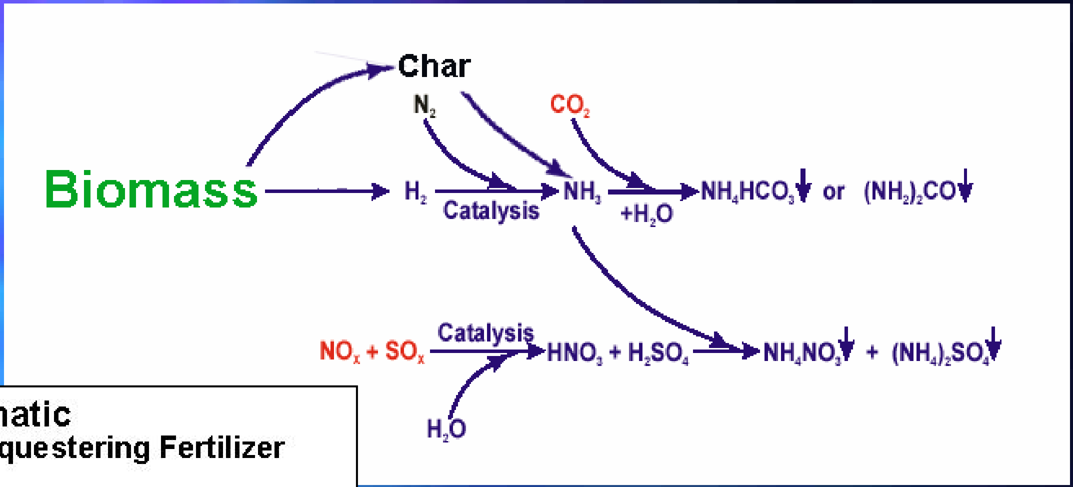
Desired characteristics:

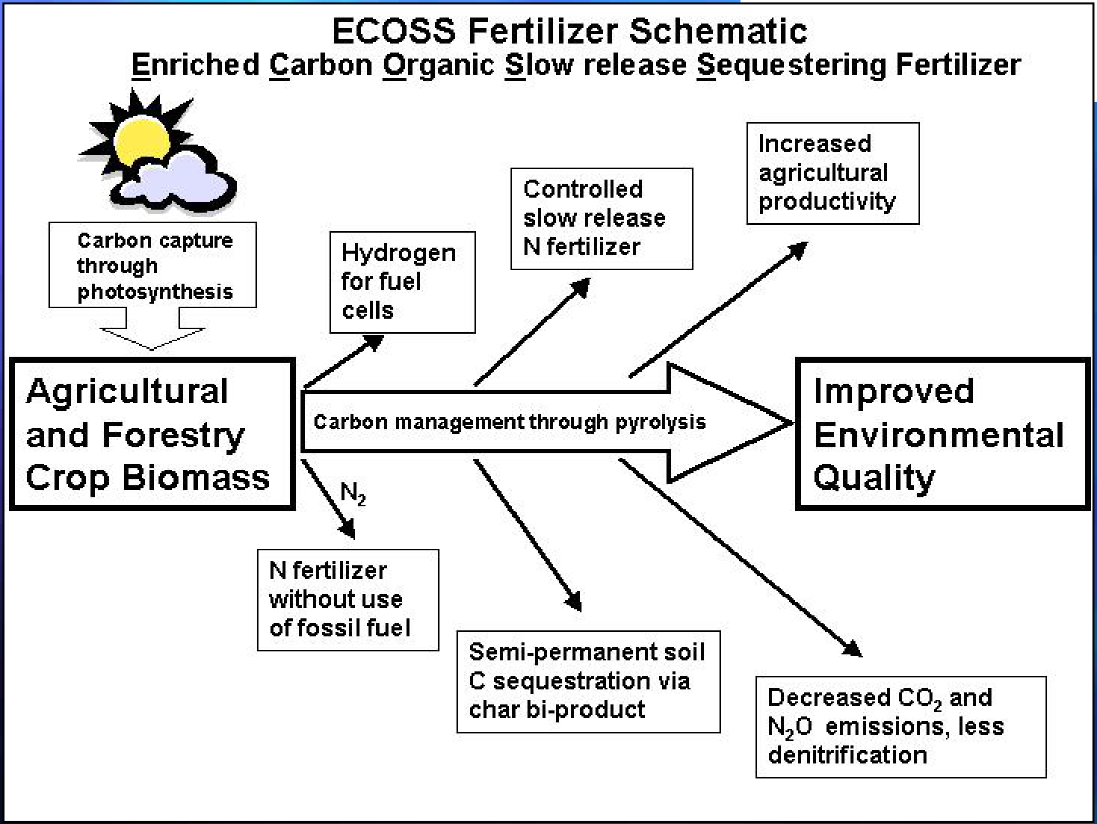
< leaching rates

>internal pore structure

>good cation exchange

The Process

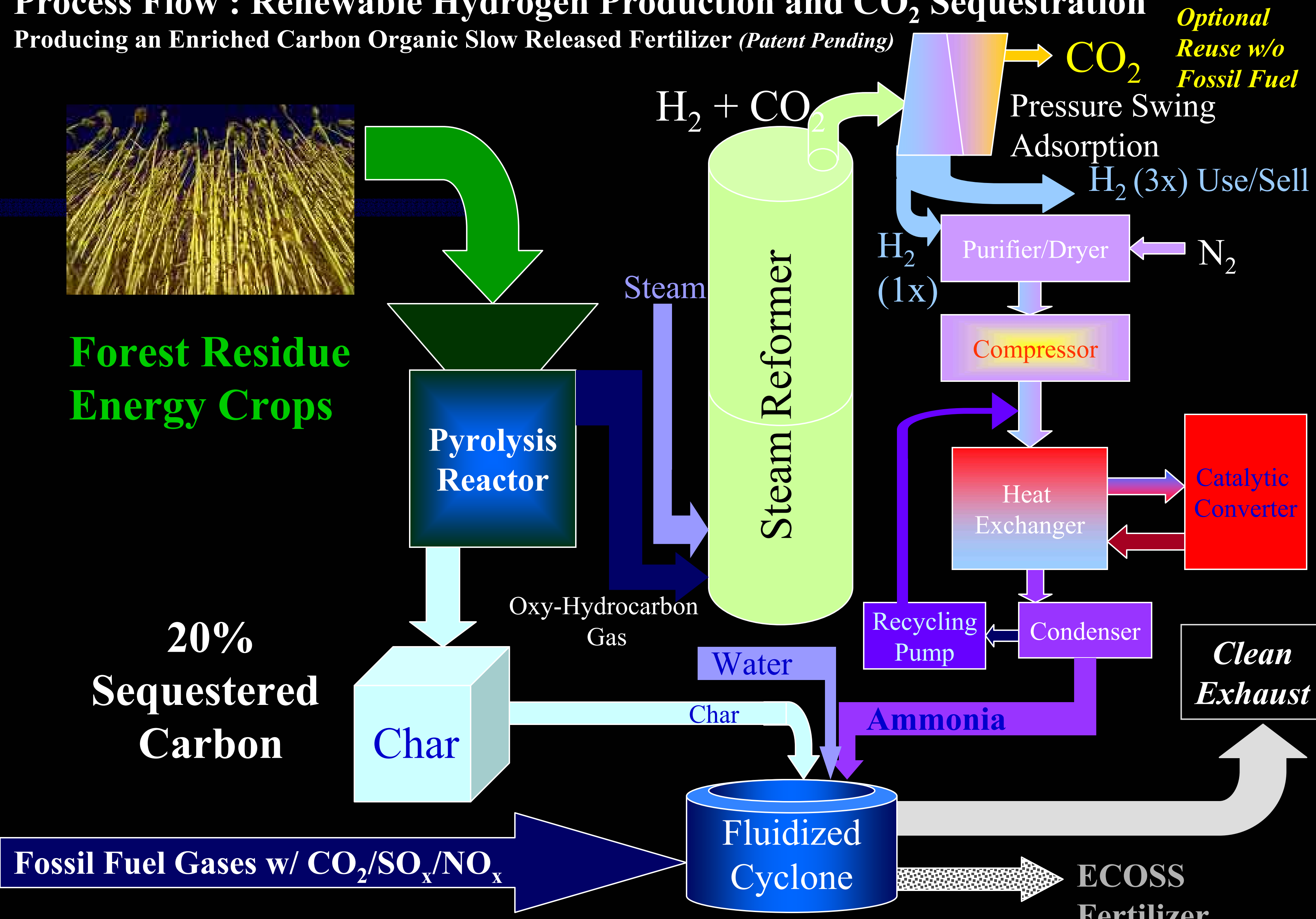




Renewable Hydrogen can produce a material that scrubs CO2, SOx and NOx from fossil fuel while producing a valuable co-product.

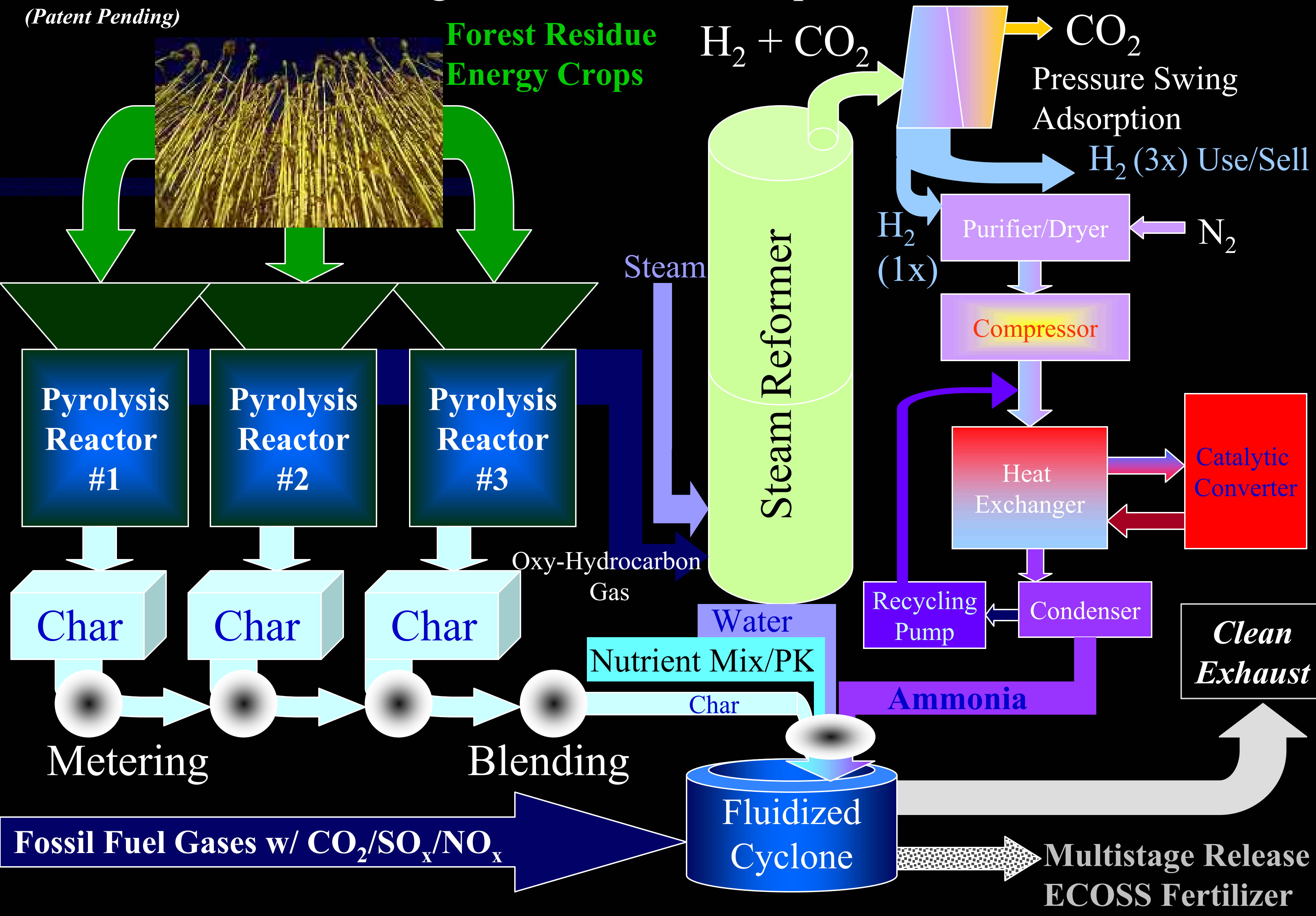
Process Flow : Renewable Hydrogen Production and CO_2 Sequestration

Producing an Enriched Carbon Organic Slow Released Fertilizer *(Patent Pending)*

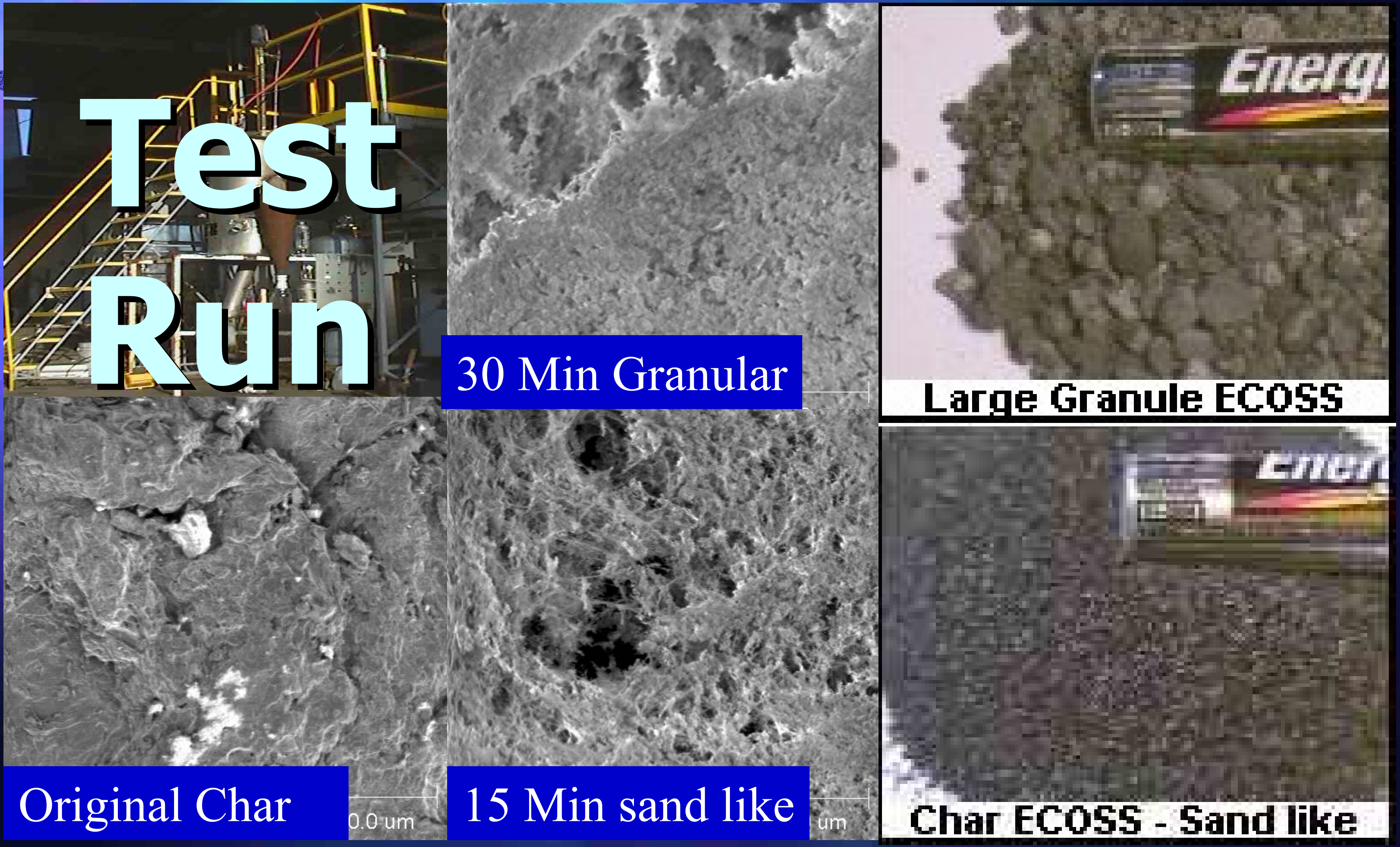


Process Flow : A Multistage Nutrient Release Sequestration Soil Amendment

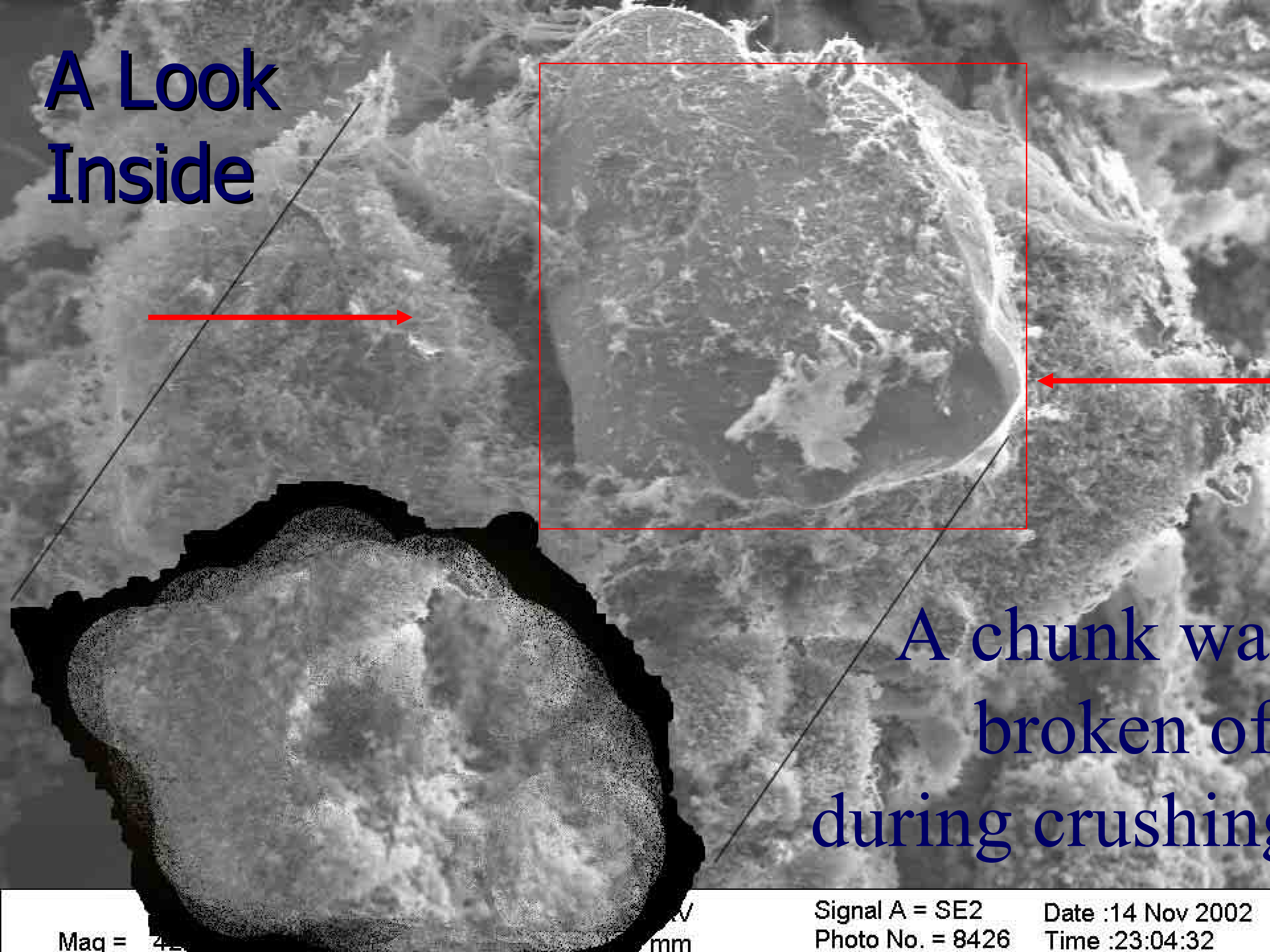
(Patent Pending)



- Operated at ambient pressure and temperature
- CO2 separation is not required

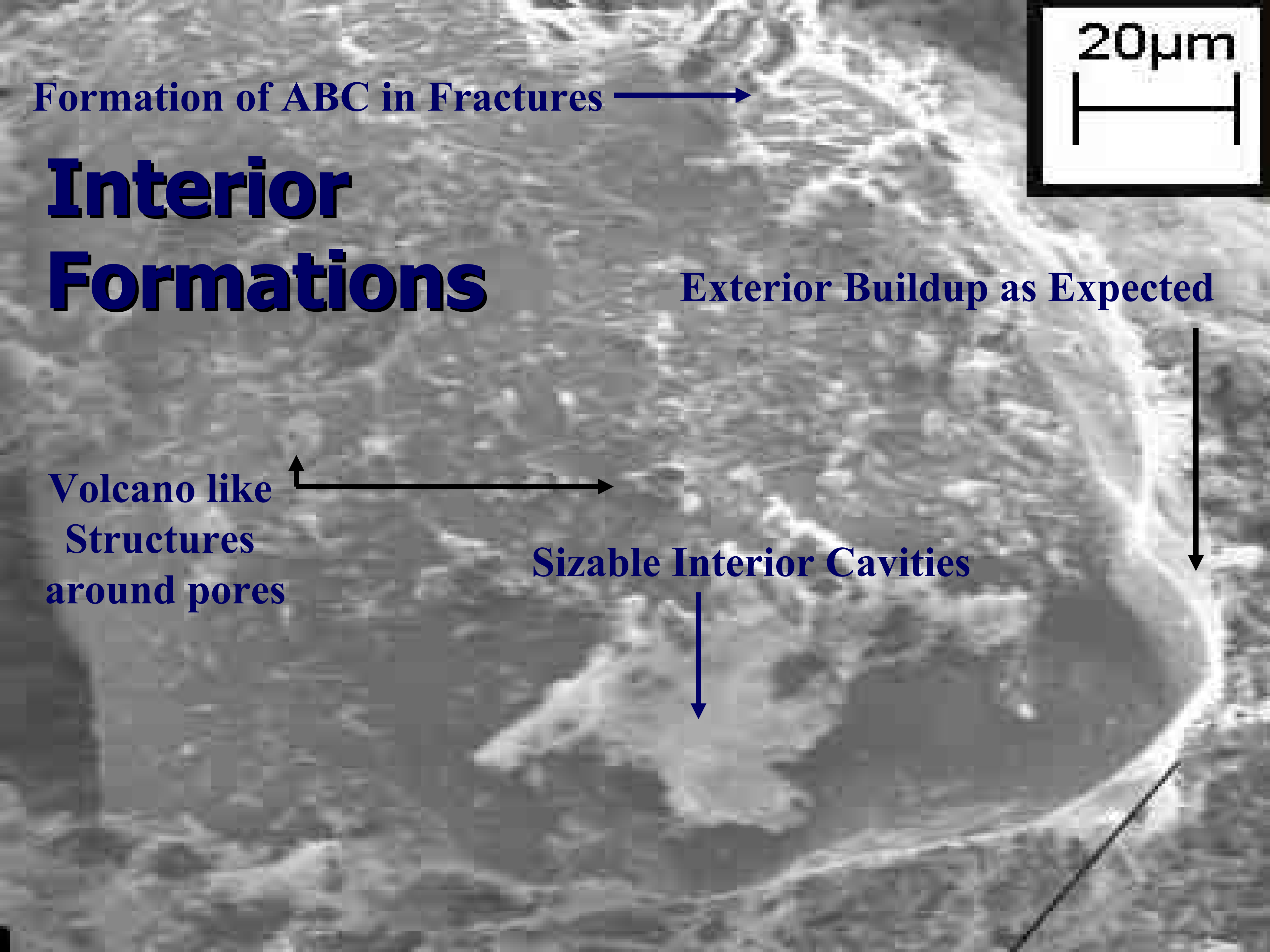


A Look Inside



A chunk wa
broken of
during crushin

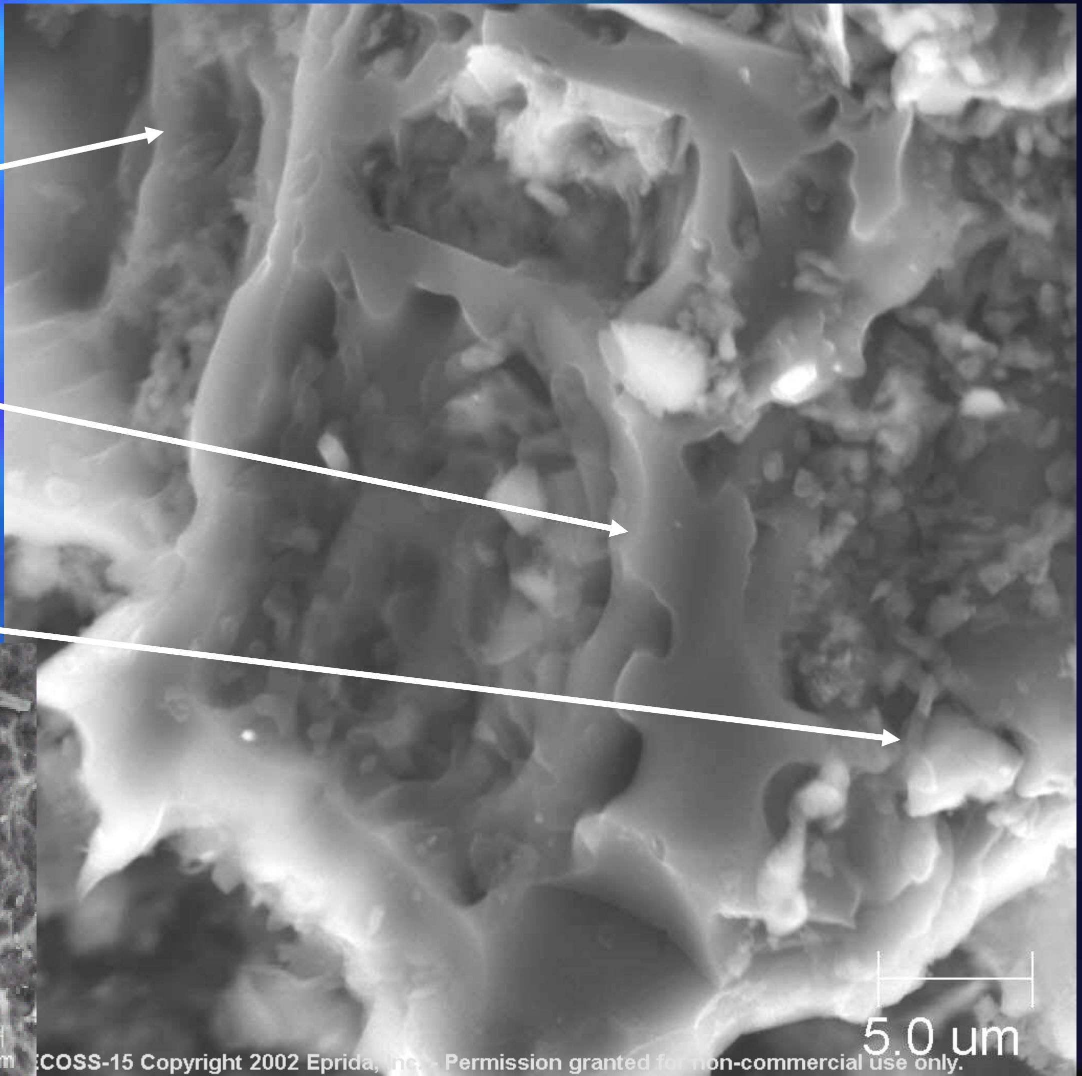
Interior Formations



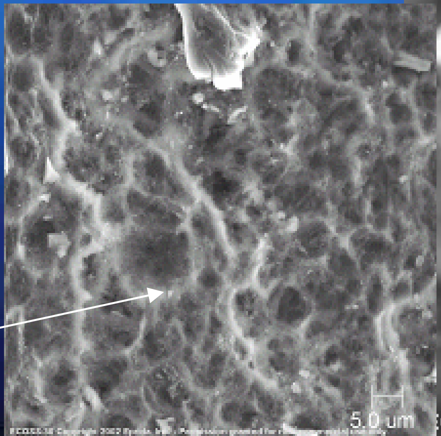
Crushed Interior 2000x

The residual cell structure of the original biomass is clearly visible

The ABC fibrous build has started inside the carbon structure



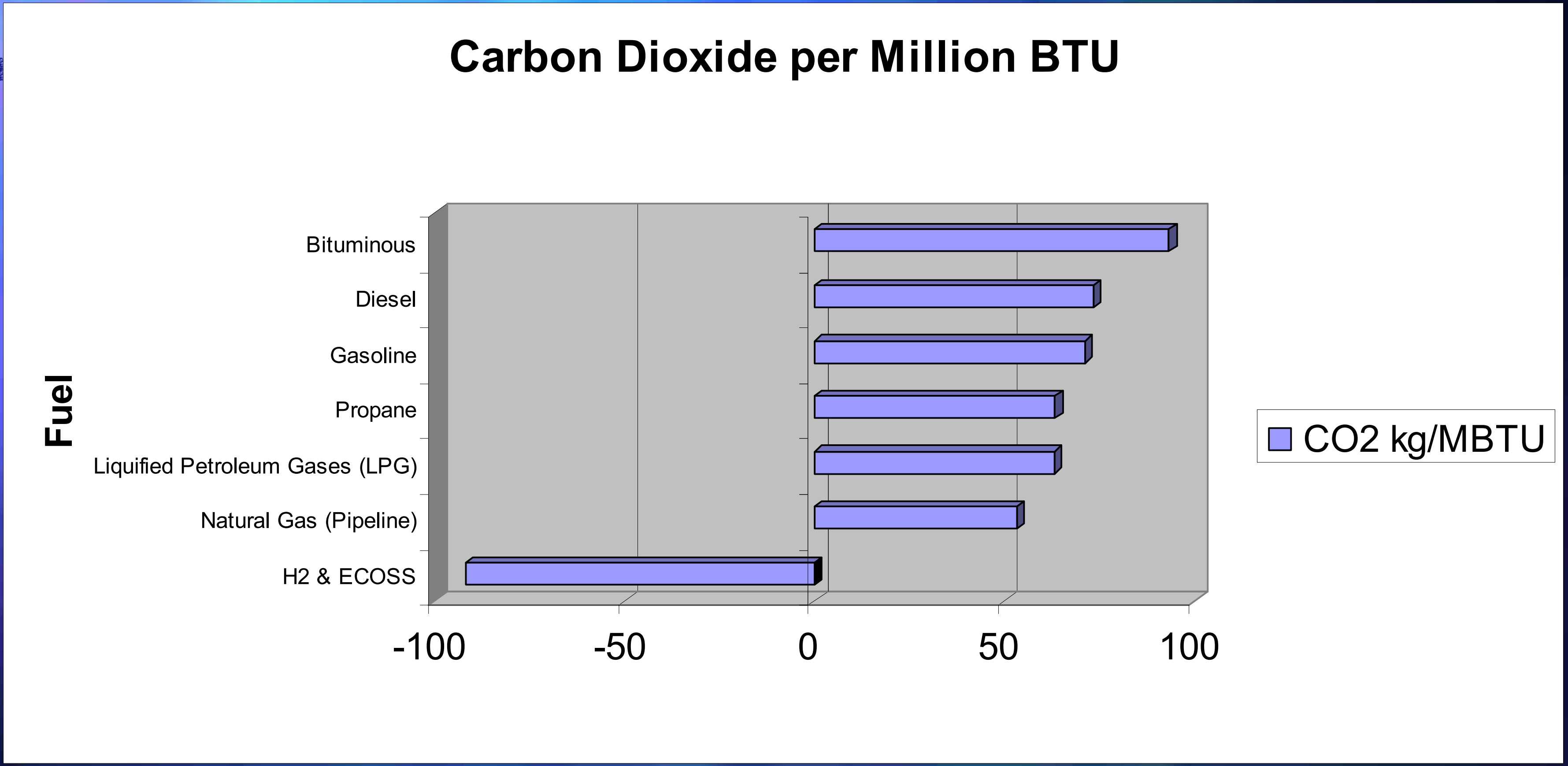
After complete processing, interior is full



A Systems Approach

- Future Carbon Management of the Ecosphere is Mandatory
- Soils have always had charcoal and it makes up a large part the stable terrestrial pool
- The largest use of hydrogen is fertilizer manufacturing, a large greenhouse gas producing industry
- It is has a bulk distribution channel for large scale sequestration co-products
- It's distributed production offers a way to utilize hydrogen as a direct feed to the grid and as transportation begins to naturally increase its demand, it will pull capacity in an economically viable manner

The Energy/Carbon Ratios



Current energy use ~400Ej/yr (Lysen) and CO_2 is increasing by 6.1 Gt/yr (IPCC). Each 1.0 MBTU H2/ECOSS represents 91kg (as measured, 150kg calculated possible) of sequestered CO_2, then 6.1Gt/91kg equals 0.07Ej or 0.01.8% of the current world consumption of energy.

Conclusion – H2

- Renewable hydrogen with large volume carbon sequestration technology is scalable and appropriate for almost all societies
- It is understandable by the vast majority of the world
- It is a breaks the ties of fossil fuel to fertilizer while supporting our growing understanding of complex systems required to supply the world's food and energy
- It can provides farmers a new contract crop that can keep farm workers employed during entire growing seasons for staged harvesting
- Production of a valuable co-product during hydrogen production is a requirement for economics while fossil fuel prices are so low.

Conclusions - Carbon

- The sequestering material displays characteristics which will reduce nutrient leaching and loss
- Production of a nutrient inside carbon pores for physical slow release mechanism possibly enhancing plant uptake and reducing fertilizer GHG emissions.
- Physical micro pore structure offers safe haven for enhanced microbial activity and increased soil fertility
- Intra-particle deposition of volatile fatty acids offer microbial energy source and enhancement of nitrogen compound processing.
- Increased cation exchange and water holding capacity provide better plant-soil efficiencies.
- The possibility exists to profitably sequester carbon while scrubbing for SOx and NOx and producing Hydrogen

Conclusion

- The solution will require agricultural and forestry involvement, but it is a mutually beneficial relationship and can help support the restoration of our soils.
- This lower cost sequestration technology will help keeps electric costs economical and support the competitiveness of both small and large businesses in America.

Finally, A Limiting Factor

Material Balance and Production Limits (Energy is not the limiting factor) *At theoretical maximum H2 –CO_2 conversion there would only be enough CO_2 to convert 61% of H2 to ABC and since our target nitrogen content for the pyrogenic carbon is 10%, (requiring 45% carbon by weight), our limit becomes the 20% carbon char (wt. 12) vs the 56% of ABC (mol.wt. 79). The limit is therefore the carbon char as a carrier utilizing only 27% of available hydrogen but sequestering 91kg of carbon dioxide (as measured experimentally) per million BTU of hydrogen utilized for energy. In addition, there is more than 91kg when the carbon sequestered in the form of additional plant growth and CO_2 equivalents from reduced greenhouse gas emissions from lower power plant and fertilizer NOx release.*

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