NREL
National Renewable Energy Laboratory

Hydrogen from Biomass

Catalytic Reforming of Pyrolysis Vapors

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National Bioenergy Center in
Collaboration with the Clark Atlanta University Team

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Project Goals

- Demonstrate the production of hydrogen from biomass by pyrolysis –steam reforming for \$2.90/kg by 2010
- Barriers:
  - Vapor Conditioning
  - Catalyst Development and Regeneration
  - Reactor Configuration
  - Heat Integration
  - Deployment: H_2 + Co-products
- Milestone: Verify advanced catalysts and reactor configuration for fluid bed reforming of biomass pyrolysis liquid at pilot scale (500 kg H_2/day) with catalyst attrition rates < 0.01%/day. 4Q, 2009

Biomass Feedstocks

$$6\ CO_2 + 6\ H_2O \xrightarrow[\text{sunlight}]{} C_6H_{12}O_6 + 6\ O_2$$

Potential : 15% of the world's energy by 2050.

Fischer and Schrattenholzer, *Biomass and Bioenergy* 20 (2001) 151-159.

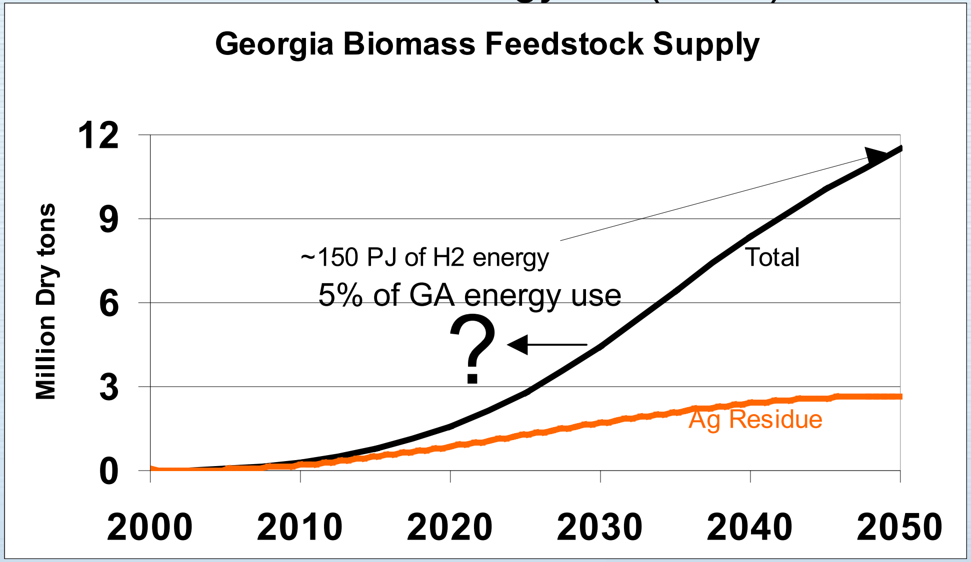
Crop residues

Forest residues

Energy crops

Animal waste

Municipal waste



Issues: Biomass Availability and Costs

Pyrolysis Process Concept

Biomass → PYROLYSIS → Carbon Residue

PYROLYSIS ↓ Bio-oil ↓ SEPARATION → Phenolic Intermediates

Co-products: Carbon Residue ↑, Phenolic Intermediates ↓

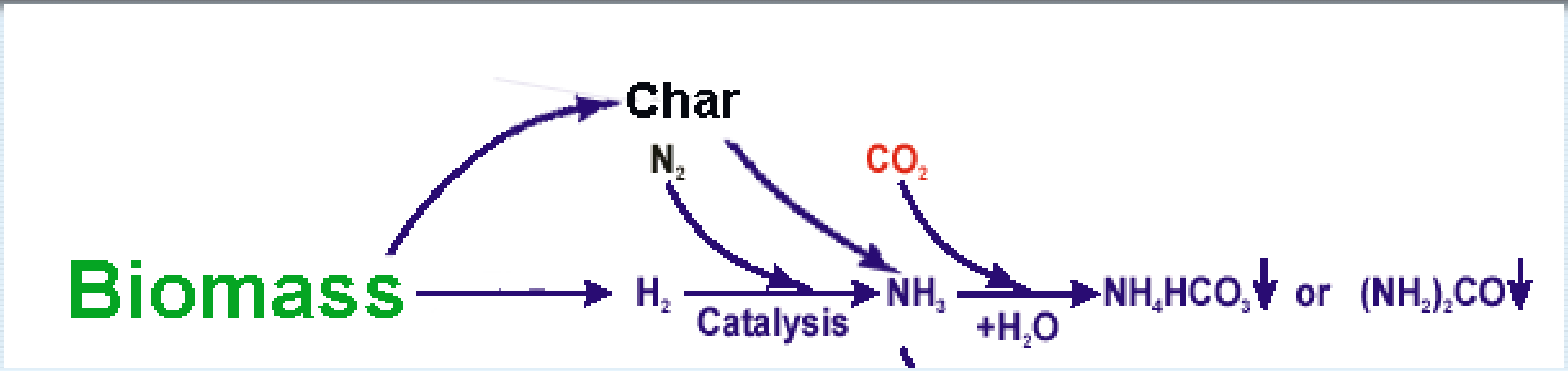
Phenolic Intermediates ↓ (*e.g., Resins*, *Octane additives*, *Fine Chemicals*)

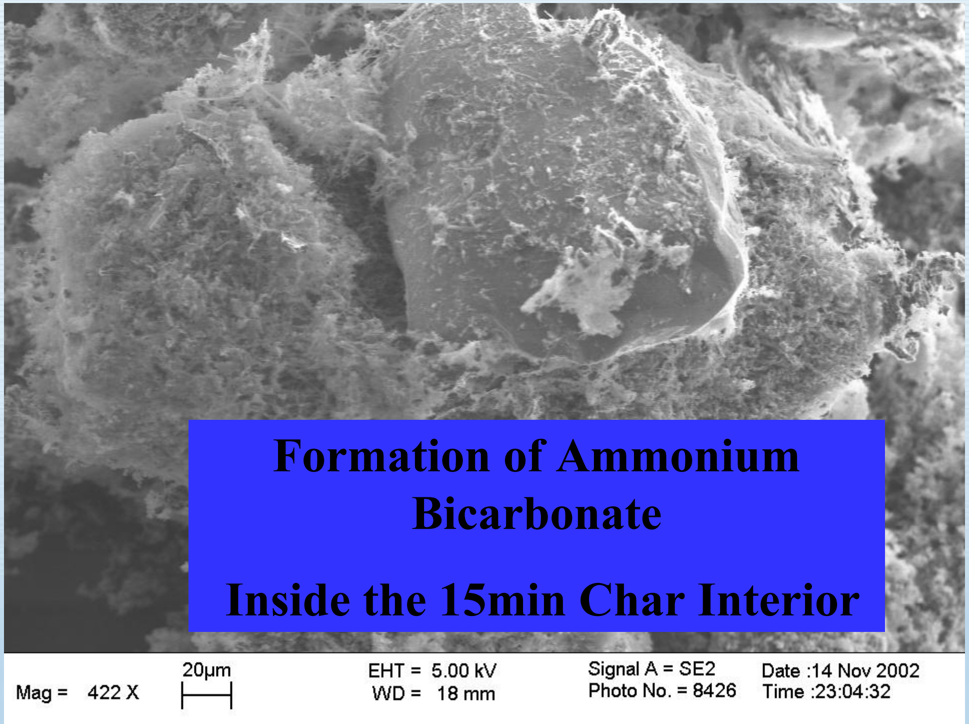
SEPARATION ↓ CATALYTIC STEAM REFORMING

H_2O → CATALYTIC STEAM REFORMING

CATALYTIC STEAM REFORMING ↓ H_2 (and CO_2)

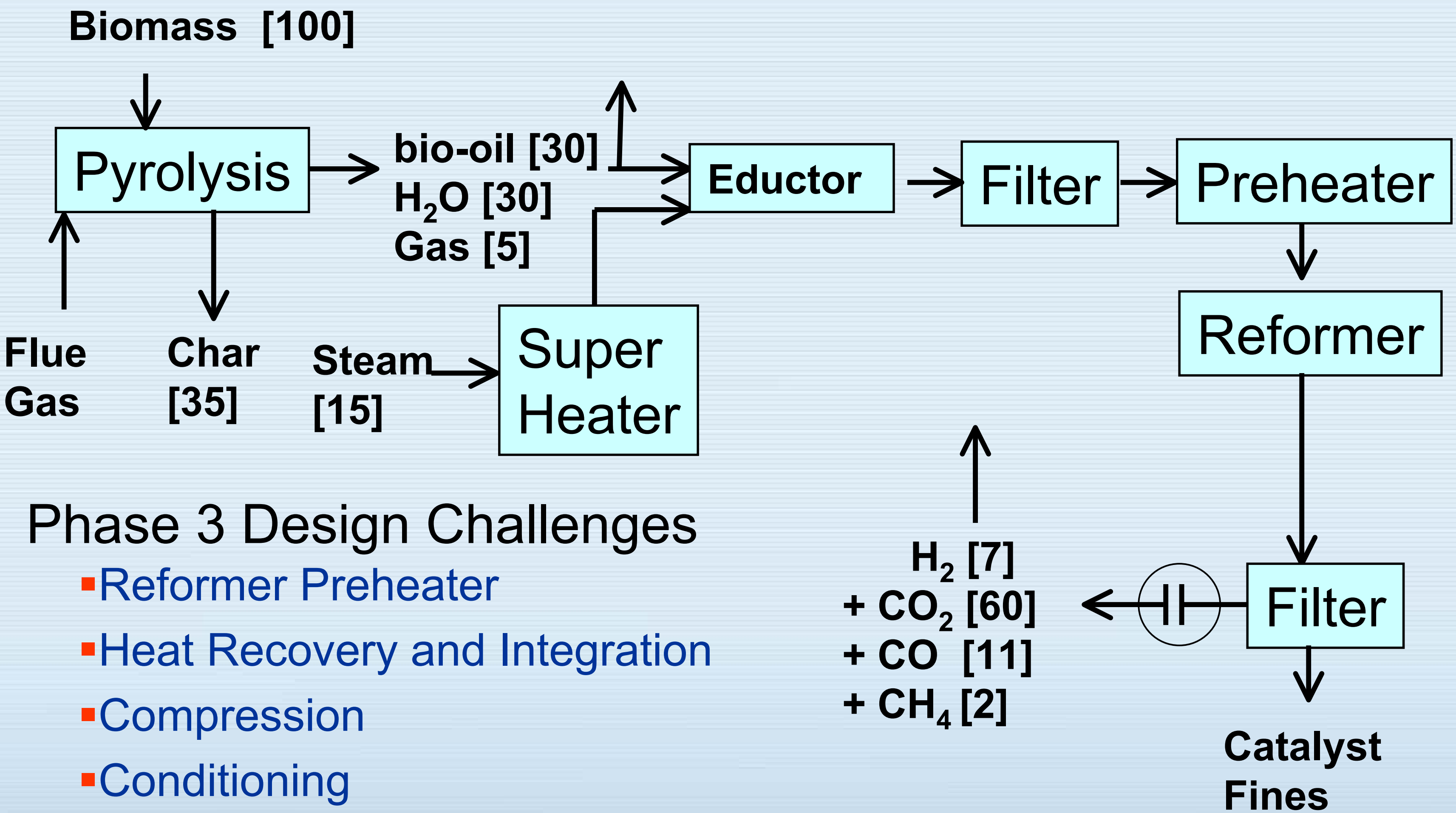
Biocarbon-Based Fertilizers





Courtesy D. Day, Eprida/ Scientific Carbons Inc.

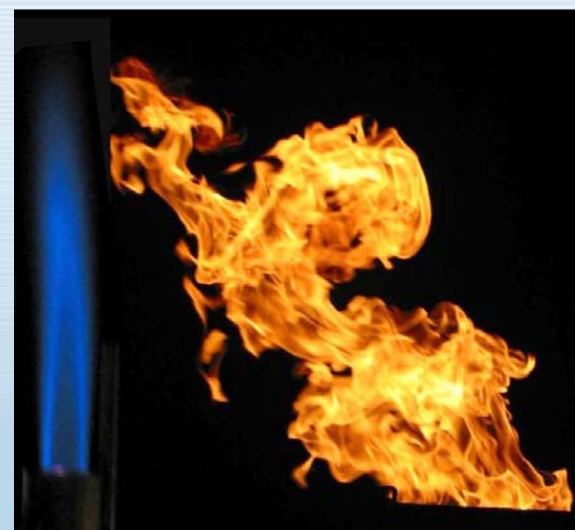
Phase 2 System



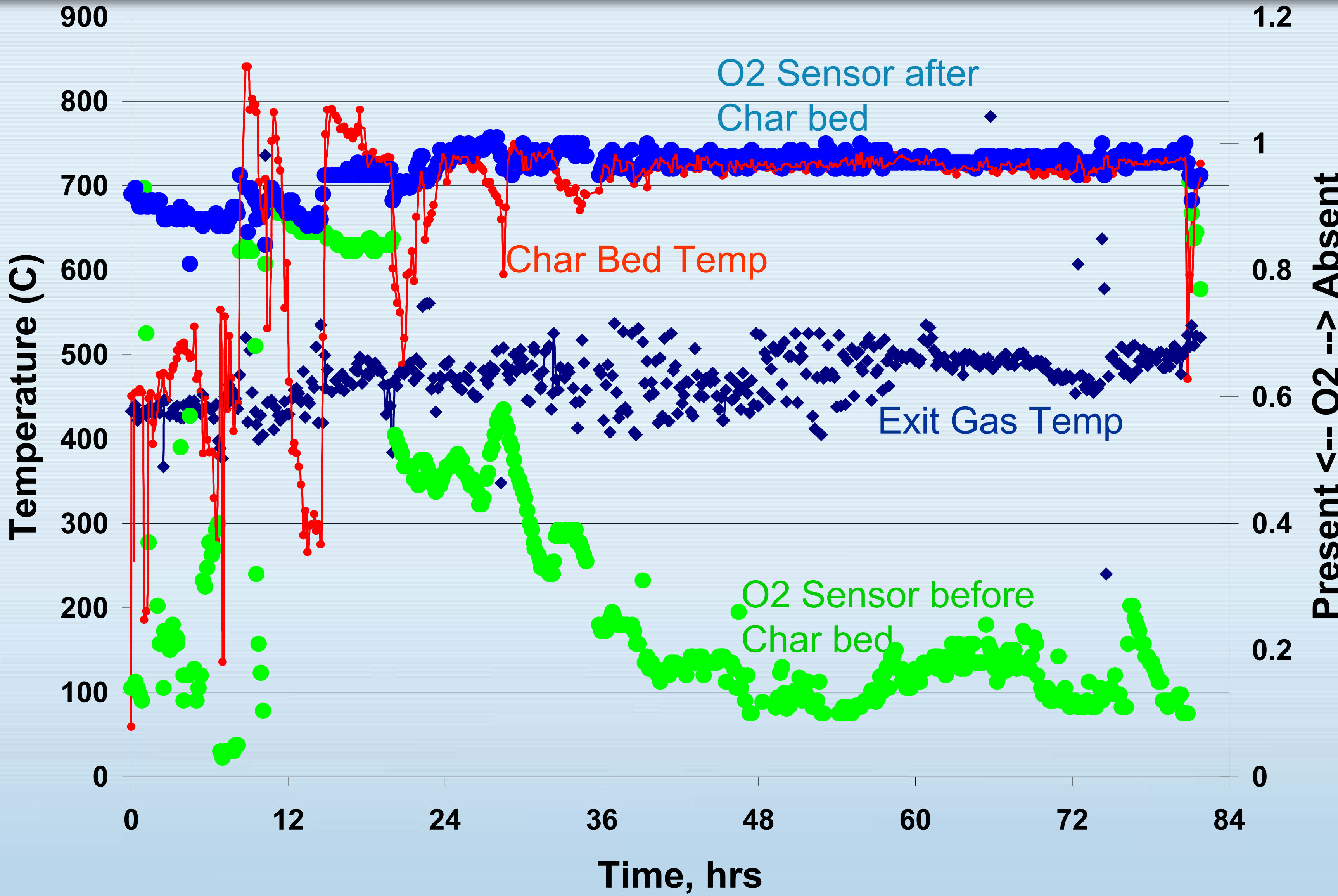
Phase 3 Design Challenges

- Reformer Preheater
- Heat Recovery and Integration
- Compression
- Conditioning
- Coproduct Optimization
- Pyrolyzer Heat Optimization

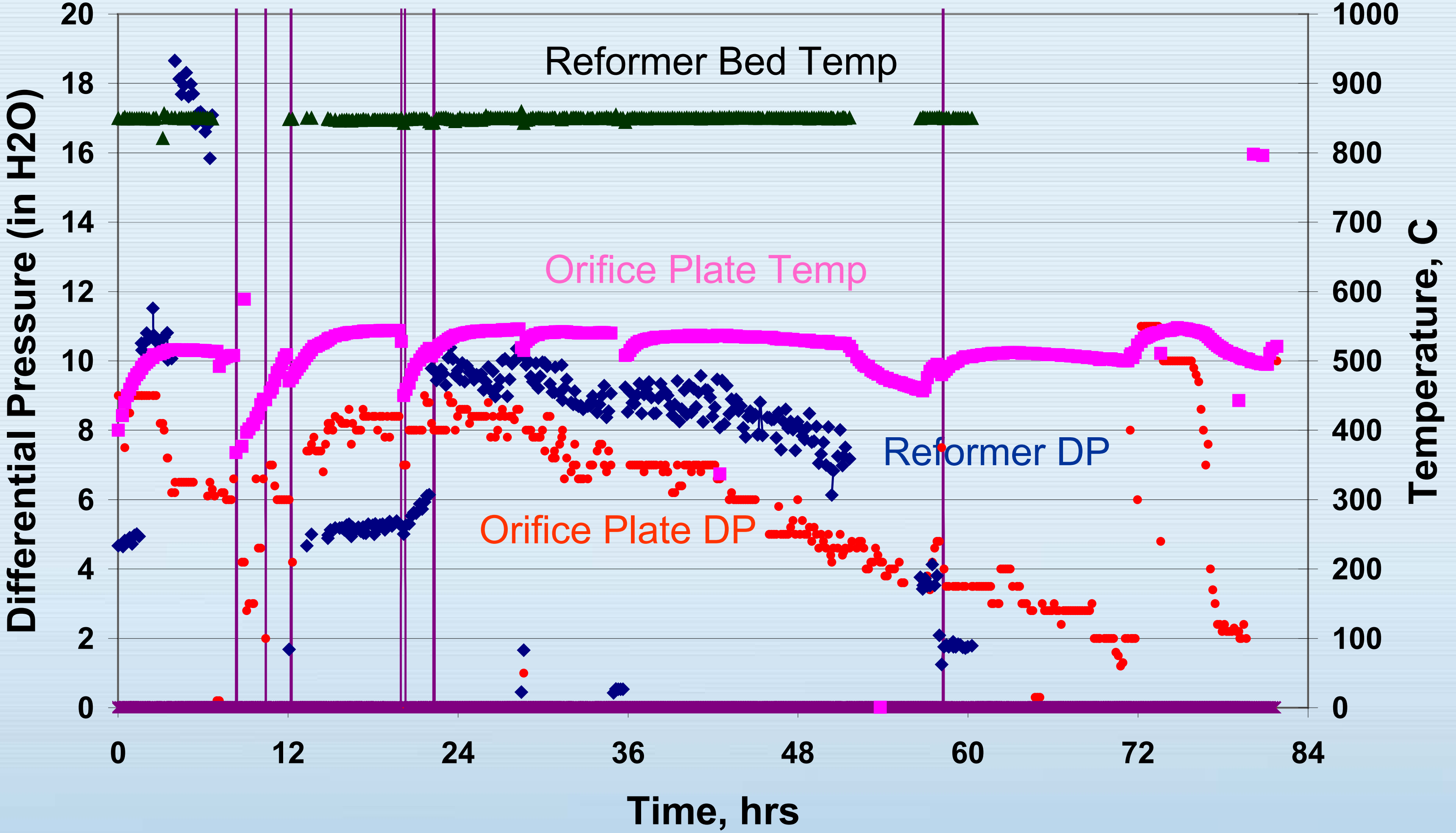
Blakely Georgia Site



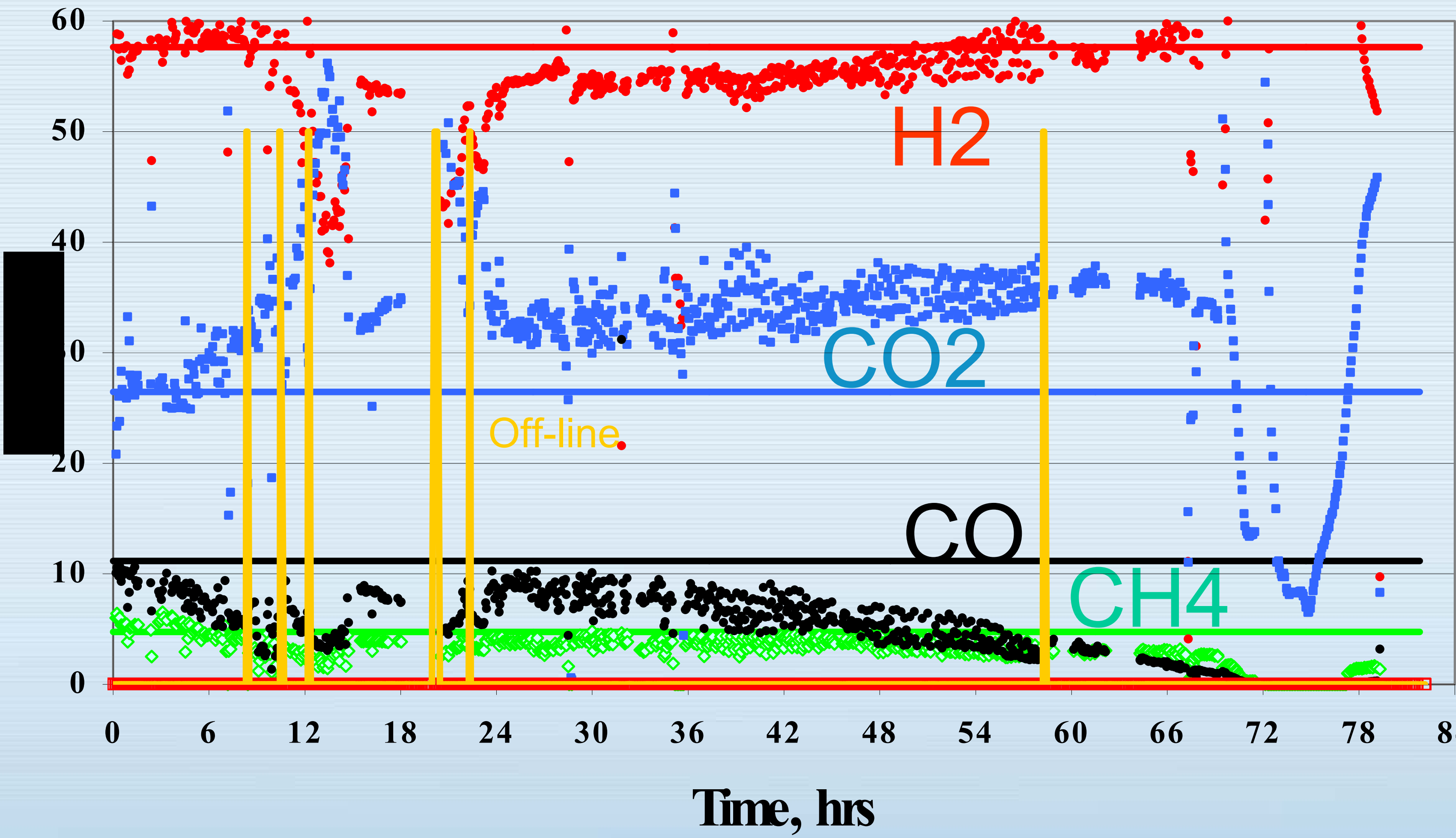
Pyrolysis Unit Performance



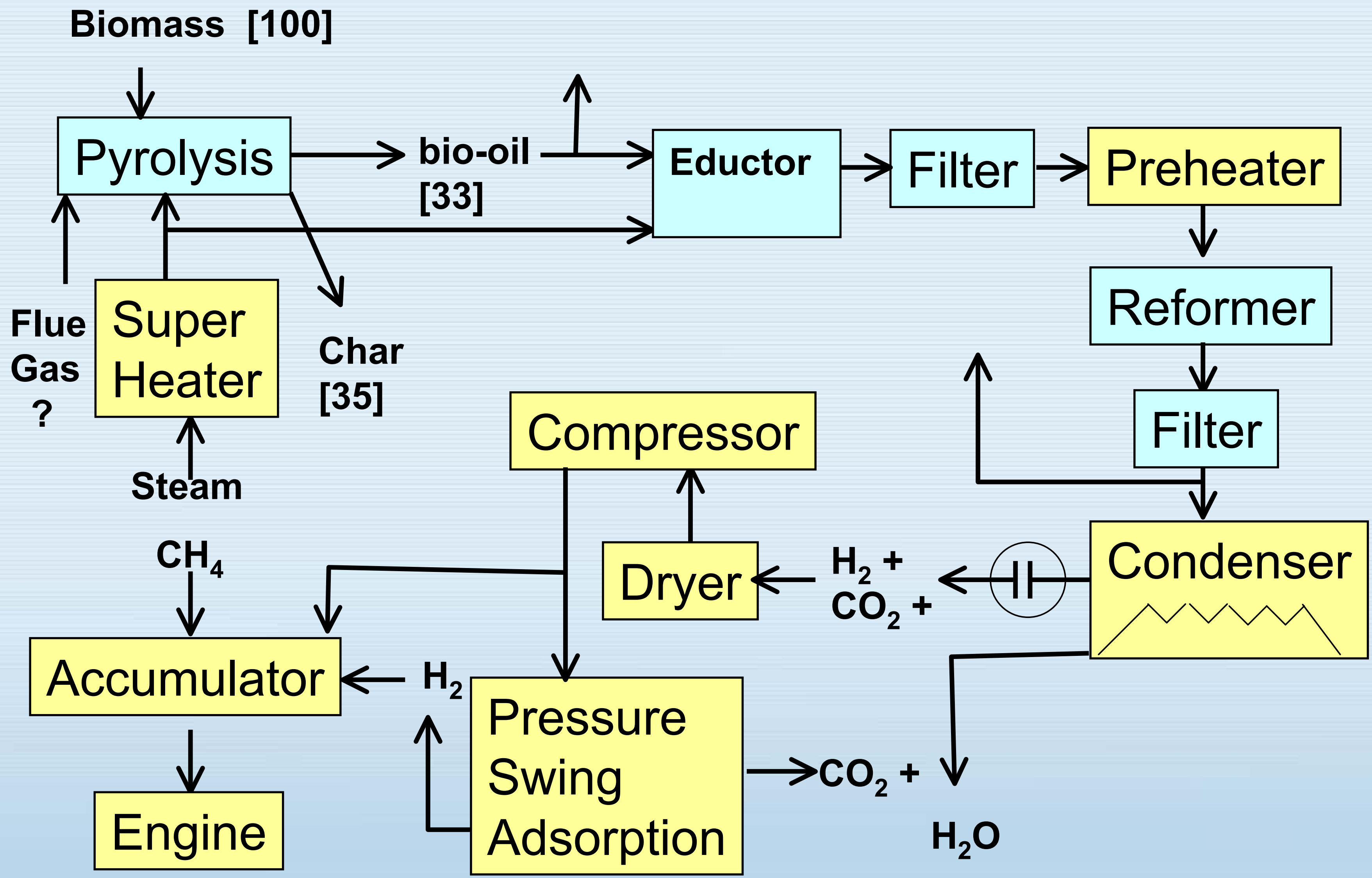
Reformer Performance



Gas Composition



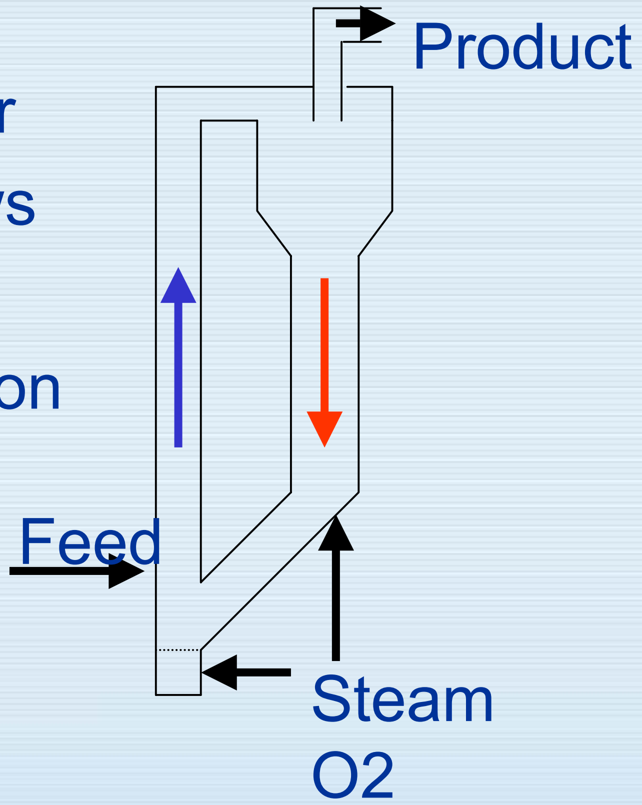
Phase 3 System



R&D	Demonstration		
	I: Initial	II: Design	III: Pilot
Process Understanding	Debugging	Development to Reduce Costs	Early Commercial
Component Technologies	Systems integration	Systems Demonstration	Communication
Scoping economics	Mass Balance	Mass & Energy Balances	Full time operation
ES&H	ES&H	ES&H	ES&H

: Circulating Fluid Bed

- Smaller Catalyst Particles → Harder
- Fluid Dynamics → Higher Gas Flows
- Direct Heating → Partial Oxidation
- Optimized Catalytic Coke Gasification

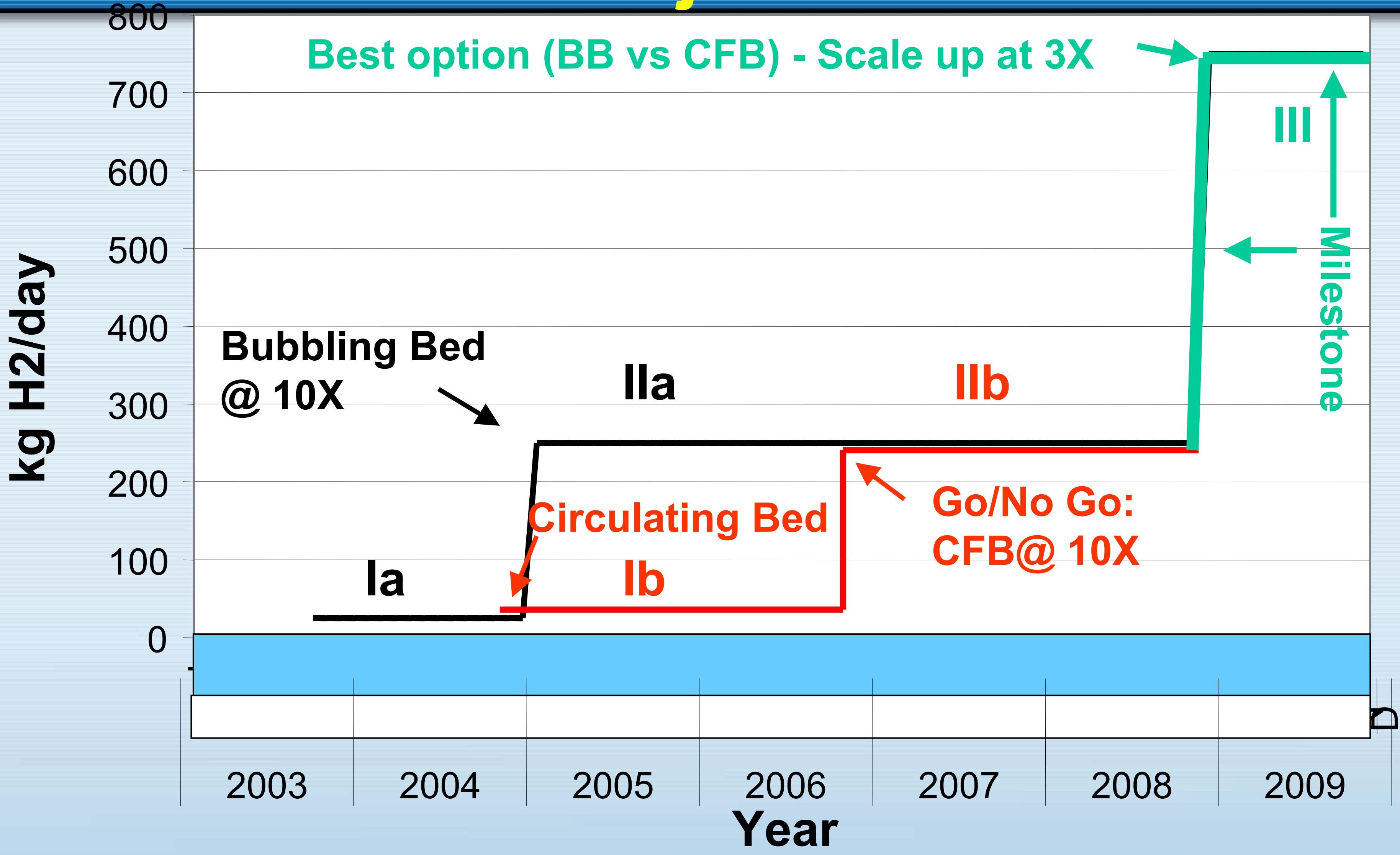


Reforming $C_xH_yO_z + H_2O \rightarrow H_2 + CO_x$

Water gas shift: $CO + H_2O \rightarrow CO_2 + H_2$

Coke Gasification: $C + H_2O \rightarrow CO + H_2$

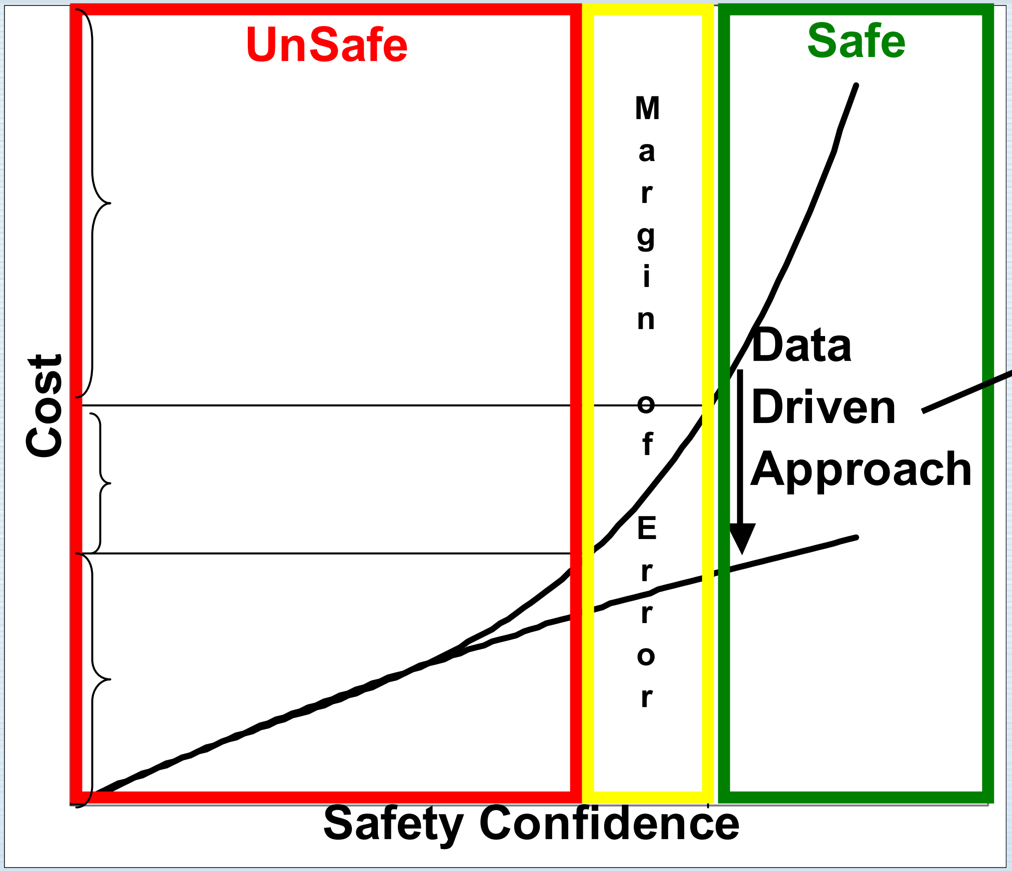
Project Time Line



FY02 Review Comments

- ***What are the Advantages of Pyrolysis/CSR vs Gasification/WGS?***
  - Distributed Resource→ Centralized Reforming
  - Coproduct → Better Economics
  - Smaller Scale → Lower Capital + Feedstock Cost
- ***Maintain a Communication Plan***
  - RACI Analysis for Phase III
- ***"Watch out for Safety"***
  - Feature Safety in Phase 3
  - Change Site to University of Georgia Biomass Research Facility to promote safety development and education and tech transfer to biomass industry

Safety Approach



U of GA Facility:
- Train the Trainers
- Process control for safety **AND** efficiency (lower cost)

Must Develop:
- A Facility to study system safety boundaries
- A Statistical Basis for Safety Confidence