U.S. Department of Energy
Energy Efficiency and Renewable Energy

biomass program

Biomass Thermochemical Conversion OBP Efforts

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Presented to

Technical Advisory Committee

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Outline – Biomass Gasification

I. History and Definitions

II. The Technology

An array of :

- Benefits
- Gasifier designs
- Feeding & handling systems
- Conversion Systems for gas to products
- Specific problems associated with Biomass Syngas cleanup.
- Integration of biomass gasifiers w/ existing industrial systems

III. Strategic Direction

- EERE Priorities vs. OBP Goals
- OBP Level

IV. Programmatic Goals and Barriers

- Decrease cost of products
- Biorefinery by 2008, 2010
- WBS and Barriers. BLG fits in both TC and Integrated Biorefineries

V. Management Approach

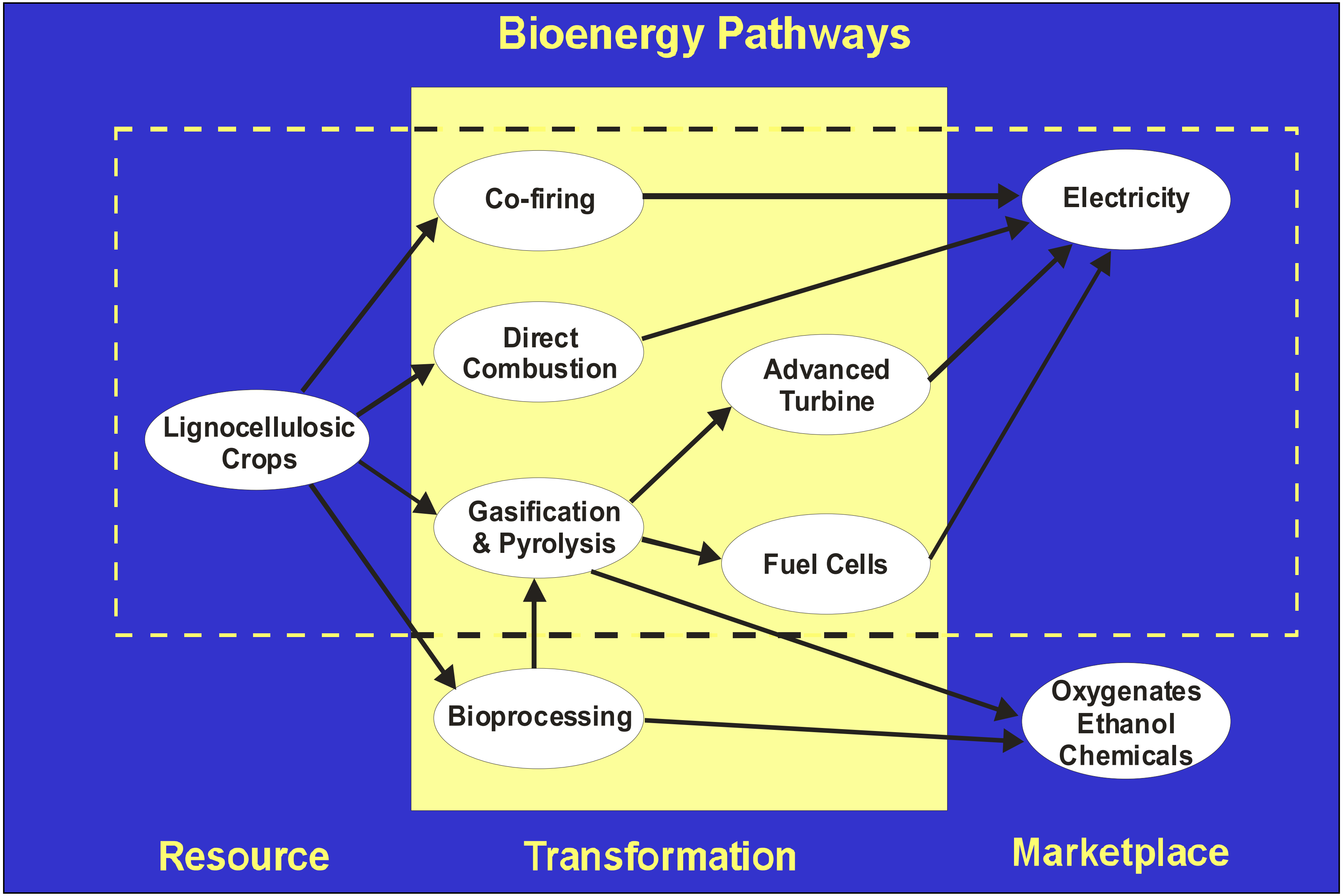
- Implement MYTP
- Develop & Strengthen Partnerships with Industry
- Utilize & Strengthen: Core R&D; Technical knowledge
- Implement Stage Gate process

History and Definitions

History

- 1839 Bischof gas producer
- 1861 Siemens gasifier – widespread adoption
- 1890 – 1920 “colonial” use of biomass fuels in gas engine/suction gasifiers – 100’s of MW installed (manufacturers – Crossley/Mellinger etc)
- 1926 Winkler fluidized bed gasifier – scaleable technology
- 1930 Comite Internationale du bois – vehicle gasifier development
- 1940 – 1948 15 GW of mobile gasifiers (600,000 vehicles x 25 kW)
- 1970s MSW gasification as an energy source and volume reduction
- 1973 vehicle gasifiers (again!), apps to developing country stationary power started
- 1980 Second oil shock – large demonstration projects for liquid fuels e.g. methanol
- 1980s both IGCC and synfuels from gasification proven
  - Coolwater IGCC (coal) proof of concept (EPRI/DOE)
  - SASOL (coal) Fischer Tropsch liquids
  - Eastman Chemicals acetic acid production from coal gasification
- 1990 Environment and renewable power objectives

History and Definitions

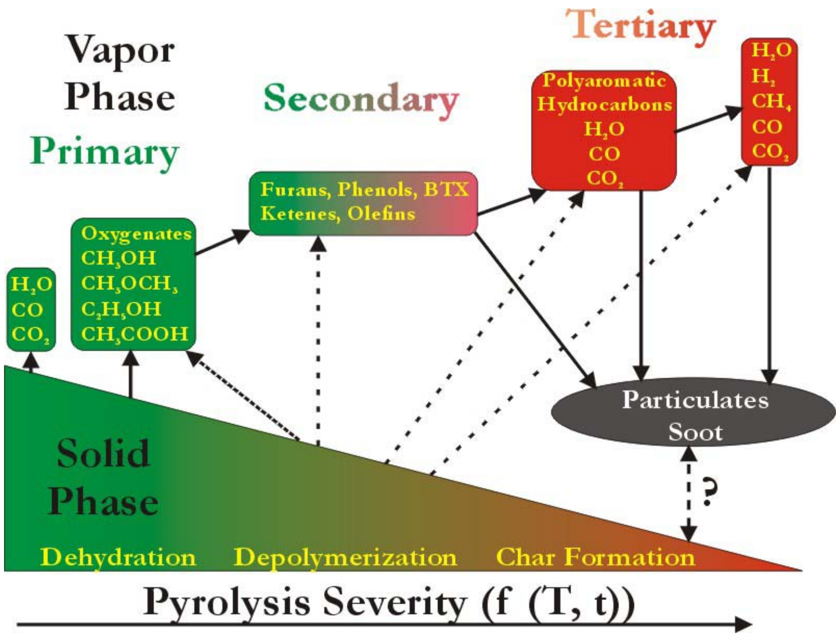


History and Definitions

Basic Definitions

Pyrolysis

- Thermal conversion (destruction) of organics in the absence of oxygen
- In the biomass community, this commonly refers to lower temperature thermal processes producing liquids as the primary product
- Possibility of chemical and food byproducts



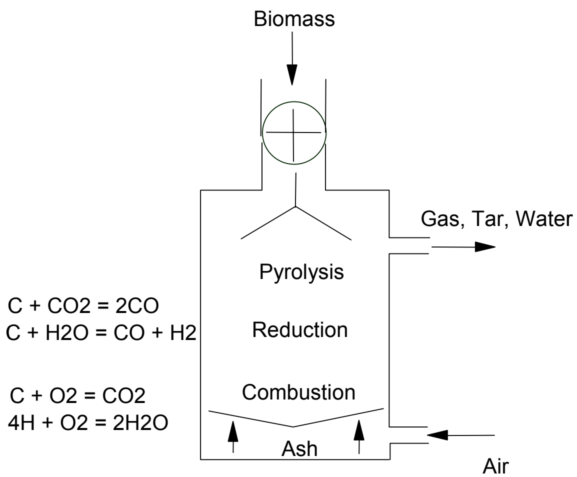
Gasification

- Thermal conversion of organic materials at elevated temperature and reducing conditions to produce primarily permanent gases (CO, H2, CH4, etc.), with char, water, and condensibles as minor products
- Primary categories are partial oxidation and indirect heating

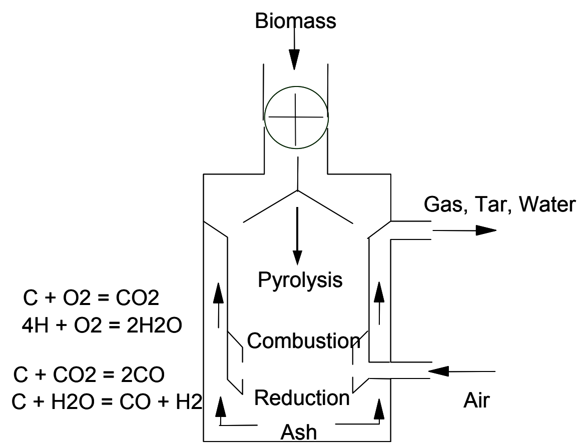
The Technology

	Company	Technology/Scale	Status
1970's	Garrett Energy and Eng.	Rapid pyrolysis - 6 tpd	inactive
	SERI	Downdraft gasification - laboratory	inactive
	Texas Tech Univ	02 fluid bed - laboratory	inactive
	Battelle Columbus Lab	Indirectly heated - laboratory	Initial licensing of technology
		Indirectly heated - 9 tpd	inactive
1980's	Battelle Columbus Lab.	Indirectly heated - 20 tpd	Initial technology licensing
	Univ. Missouri - Rolla	High P. air/O2 fluid bed - 10 tpd	development
	Inst. of Gas Tech.	High P. air/O2 downdraft - 20tpd	inactive
	SERI/SynGas, Inc.	Indirectly heated - 2.4 tpd	development
	MTCI	Indirectly heated - laboratory	inactive
	Univ. Of Nebraska	Indirectly heated rotary kiln - 6tpd	inactive
	Wright Malta	O2 fluid bed	inactive
	Texas Tech Univ.	High P catalytic - laboratory	inactive
	PNL	O2 - updraft -cofeed w coal - 5 tpd	inactive
	Dynecology, Inc.		
1990's			
	IGT/Westinghouse	High P. Air fluid bed/ Filter - 10 tpd	project complete
	PICHTR	IGT gasifier - Hawaii - 100 tpd	project complete
	Westinghouse	IGT gasifier - Hawaii - 100 tpd	project complete
	Battelle Columbus	Indirect - gas turbine - 20 tpd	project complete
	MTCI	Indirect - laboratory	project complete
	FERCO	Vermont Indirect - 350 tpd	commercial project development
	MNVAP	Carbona gasifier - 75 MW	inactive – design only
	Iowa State University	Air fluid bed - 25 tpd	active project
	Carbona	Air fluid bed - 3.8 MW	active project
	Community Power	Downdraft - 25 kW	active project
	FlexEnergy	Downdraft - turbine - 30 kW	active project
	EPA - Camp Lejune	Downdraft - ICE - 1 MW	active project
	Cratech	High P. air fluid bed - 10 tpd	active project
2000-2001	Gas Technology Inst.	w/ Calla - power	feasibility
	Nexant/PRM	air blown - power	feasibility
	MTCI	w/ Georgia-Pacific - black liquor	commissioning
	Carbona	Air fluid bed - 3.8 MW	design
	Community Power	Downdraft - 25 kW	operating
	Flex Energy	Downdraft - turbine - 30 kW	design

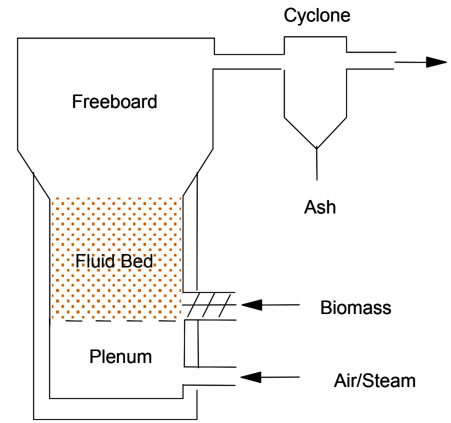
The Technology



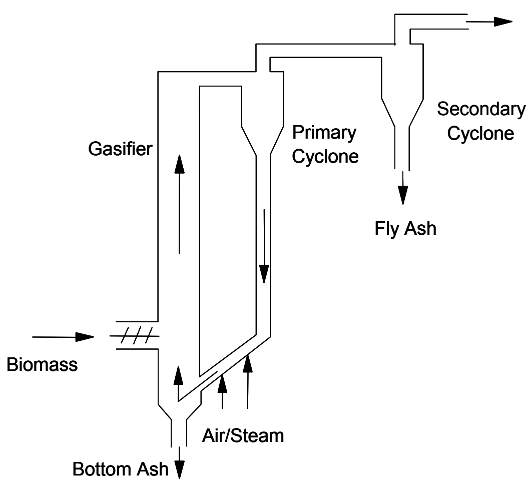
Updraft Gasifier
- Primenergy/PRM
- Lurgi



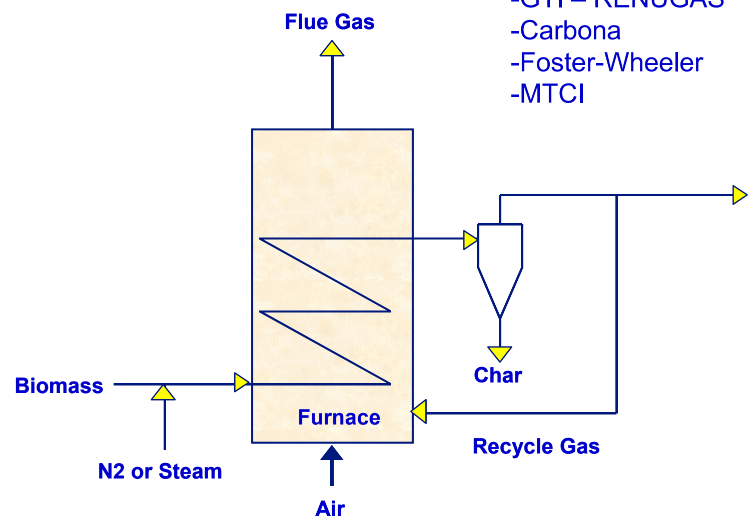
Downdraft Gasifier
- Community Power BioMAX



Fluid-Bed Gasifier
-EPI
-GTI – RENUGAS
-Carbona
-Foster-Wheeler
-MTCI



Circulating Fluid-Bed Gasifier
- FERCO



Entrained Flow Gasifier
- Brightstar

An Array of Benefits

- Efficiency
  - Nearly double existing biopower industry
  - Access to efficiency/economy of scale via cofiring/cofueling
- Environmental
  - Low emissions due to turbine/fuel cell requirements
  - Closed carbon cycle
  - Increased environmental regulation favors gasification/pyrolysis
- Economic
  - Decreased COE over today's biopower
    - Potentially competitive with fossil assuming tax credits
  - Rural economies
  - Pulping sector an immediate beneficiary due to needed capital replacements.
  - Economic activity (Investment of $15 Billion resulted from PURPA)
- Synergistic with fossil fuel developments
  - Liquid fuels – billions invested in syngas to fuels/chemicals
  - Electricity – turbines, fuel cells, CHP (cofiring with natural gas possible),
  - Hydrogen production
  - Potential for CO2 withdrawal via sequestration
- Versatility
  - Wide range of feestocks
  - Wide range of products

Gas Cleanup – Coal vs. Biomass

Biomass		Coal
↑	Oxygen	↓
↓	Sulfur	↑
↓	Ash	↑
↑	Alkali	↓
↑	H/C Ratio	↓
↓	Heating Value	↑
↑	Tar Reactivity	↓

- Use coal gasifier cleanup technology for biomass
  - Issues
    - Coal cleanup designed for large, integrated plants
    - Extensive sulfur removal not needed for biomass
    - Biomass tars very reactive
    - Wet/cold cleanup systems produce significant waste streams that require cleanup/recovery – large plant needed for economy of scale for cleanup/recovery
    - Biomass particulates high in alkali
- Feed biomass to coal gasifiers
  - Issues
    - Feeding biomass (not just wood) – many commercial coal gasifiers are entrained flow requiring small particles
    - Gasifier refractory life/ash properties – biomass high in alkali
    - Character/reactivity of biomass tars may have unknown impact on chemistry/cleanup
    - Volumetric energy density a potential issue
    - High reactivity can plug coal feeder systems.

      High temperatures at the entrance → the biomass softens, partially liquefies, then turns to a clump

Strategic Direction

DOE's Strategic Goal

To protect our national and economic security by promoting a diverse supply of reliable, affordable, and environmentally sound energy

EERE Strategic Goals

1. Dramatically reduce or even end our dependence on foreign oil
2. Create the new domestic bioindustry

OBP Program Goal

Develop biorefinery-related technologies to the point that they are cost- and performance-competitive and are used by the nation's transportation, energy, Chemical, and power industries to meet their market objectives.

2005: Demonstrate an integrated process for fuels production from biomass

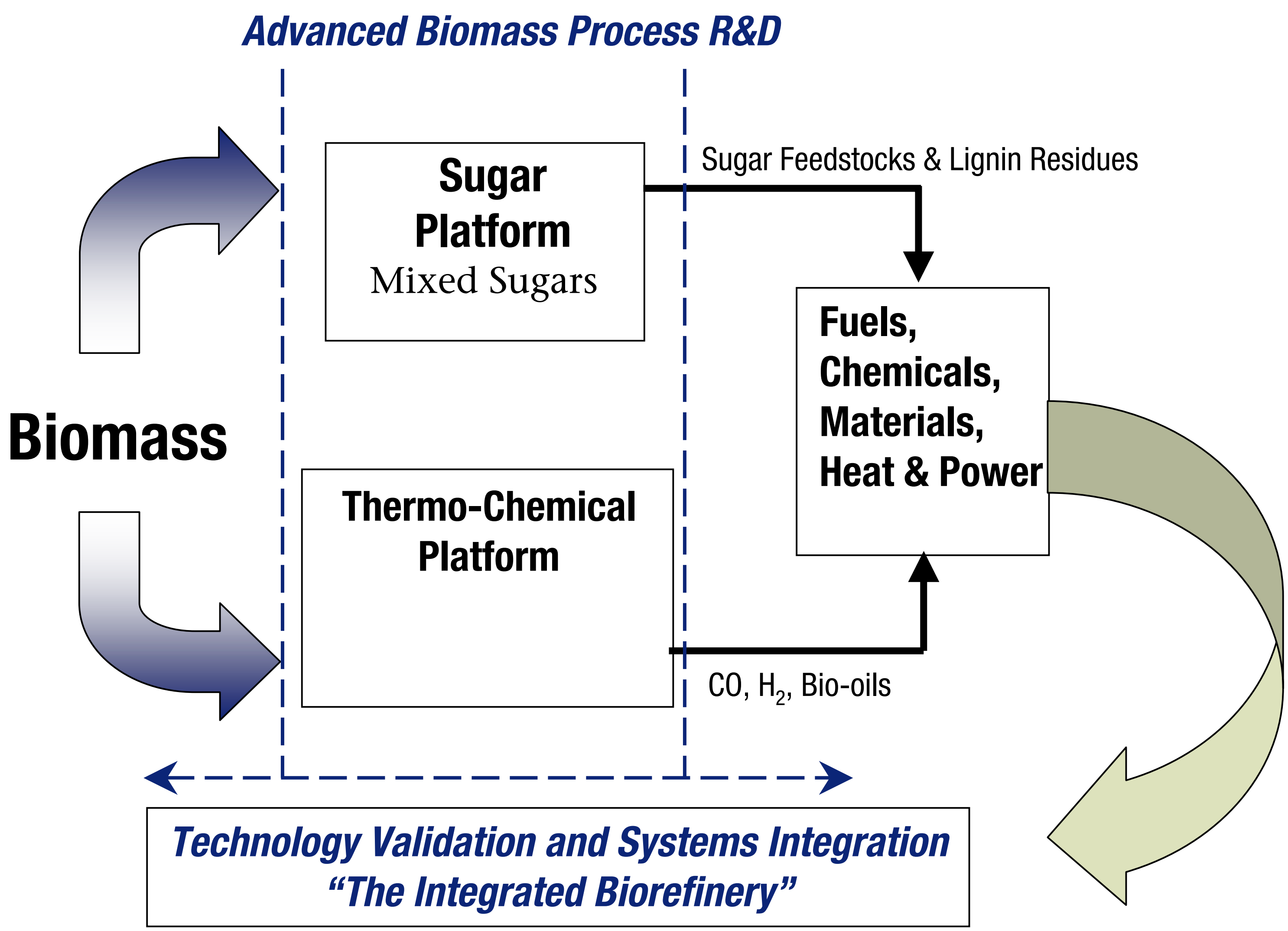
2007: Complete technology development necessary to enable start-up demonstration of a biorefinery producing fuels, chemicals, and power

2010: Help U.S. industry to establish the first large-scale biorefinery based on agricultural residues

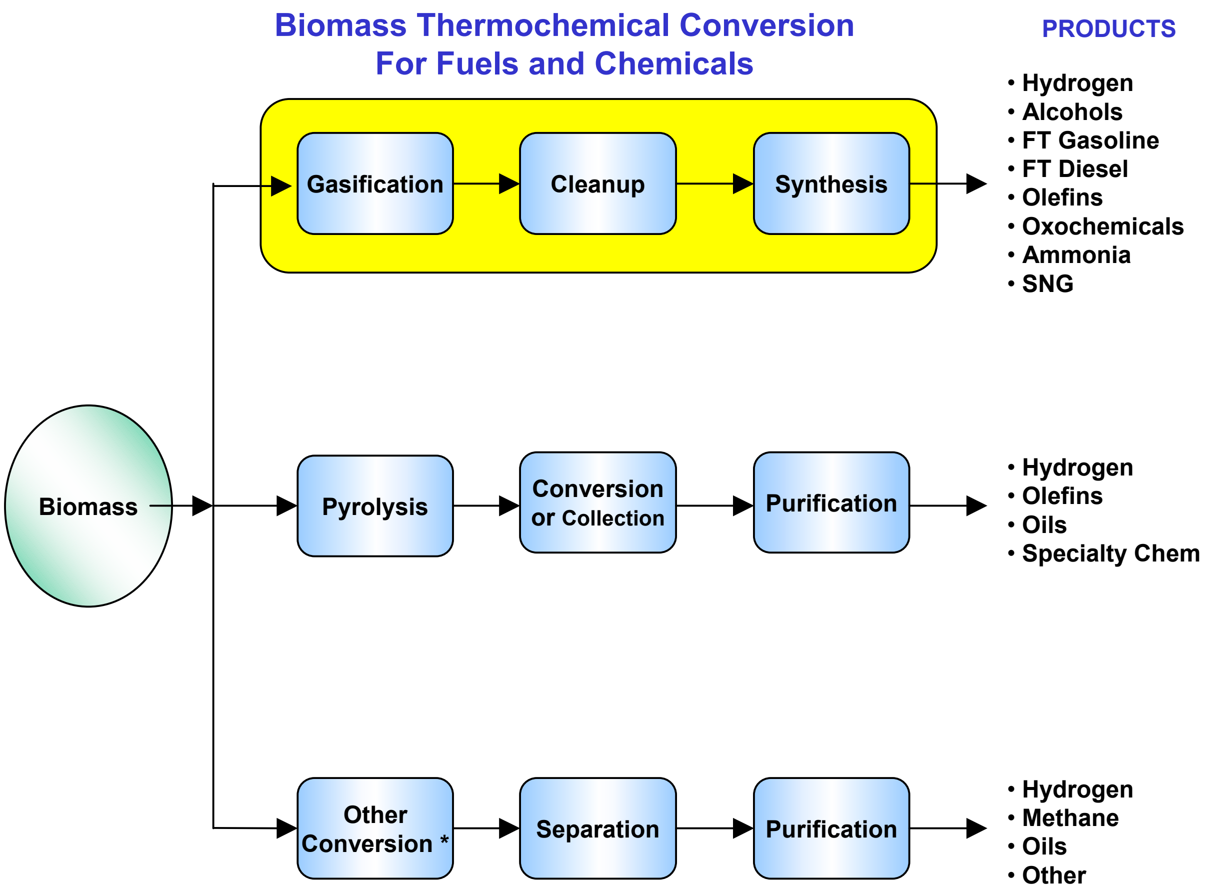
Technical Cost Goals

- $$ MMBtu syngas
- Industrial viability of four commodity scale products

Strategic Direction



Strategic Direction



* Examples: Hydrothermal Processing, Liquefaction, Wet Gasification

Programmatic Goals / Barriers

Objective – Thermochemical Platform

To produce inexpensive, clean intermediate products from biomass that are compatible with existing and advanced processes for fuels, chemicals, and power

Technical Cost Goals

- $6 per MMBtu syngas
  ($7.58 per MMBtu syngas)
- $0.07per lb sugars
- Industrial viability of four commodity scale products

Technical Barriers

Biomass Thermochemical Conversion

Gasification

- Feed & Pretreatment
- Gasification
- Gas Cleanup & Conditioning
- Syngas Utilization
- Process Integration
- Sensors and Controls

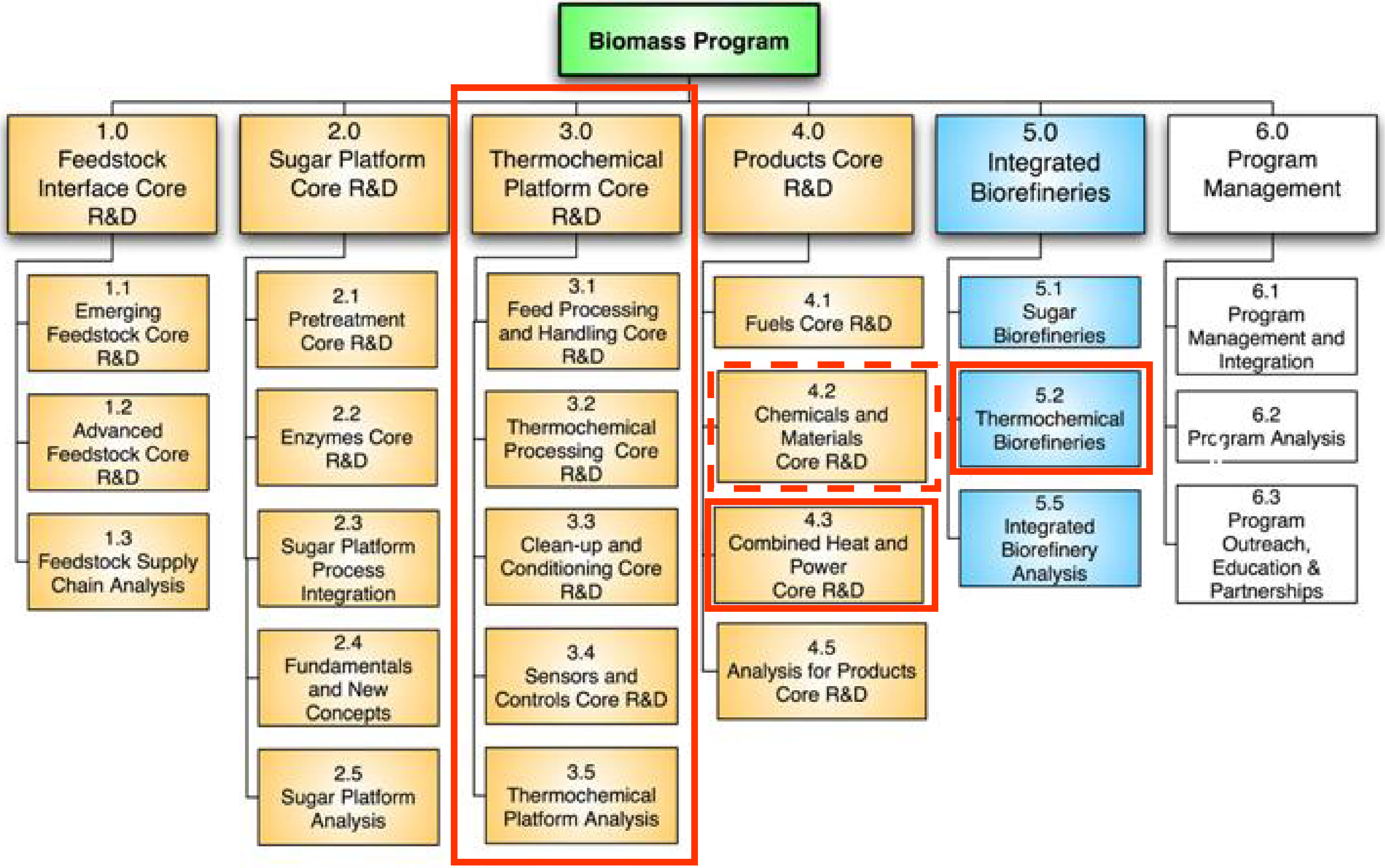
Pyrolysis

- Oil Handling
- Oil Properties
- Oil Commercial Properties

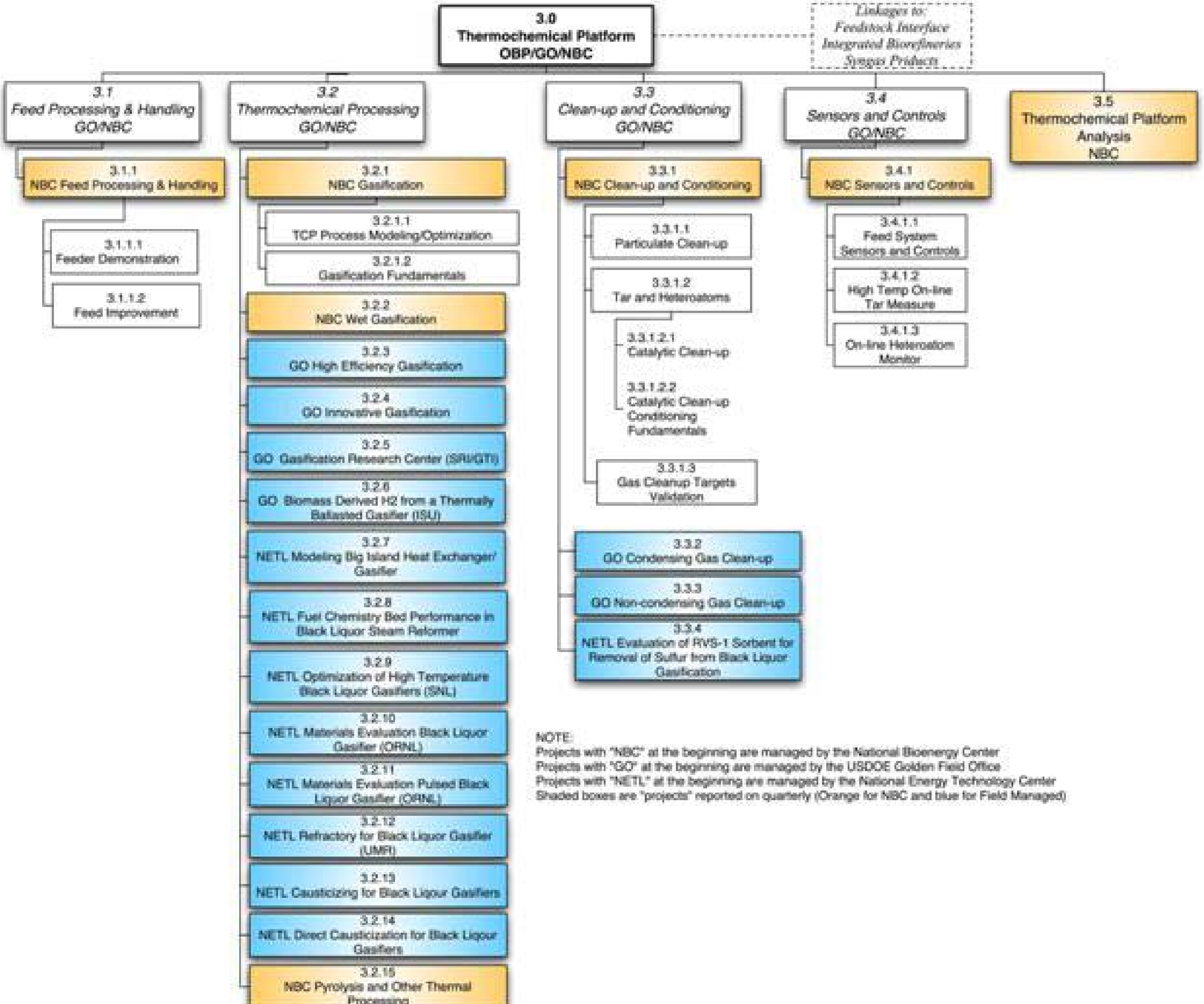
Black Liquor Gasification

- Containment
- Mill Integration
- Fuels Chemistry
- Sensors and Controls

Management Approach



Management Approach



NOTE:
Projects with "NBC" at the beginning are managed by the National Bioenergy Center
Projects with "GO" at the beginning are managed by the USDOE Golden Field Office
Projects with "NETL" at the beginning are managed by the National Energy Technology Center
Shaded boxes are "projects" reported on quarterly (Orange for NBC and blue for Field Managed)

Management Approach

Industrial Linkages

Why Pulp & Paper Industry??

- P&P industry has feed supply solved
- Existing infrastructure for feed and products
- Industry seeking added-value products
- Forest biorefinery
  - Transformational change to existing industry
    - Efficiency gain
      - Expansion of Black Liquor gasification strategy (Agenda 2020)
      - Focuses on next-generation changes
      - Up to 95% conversion of incremental feed to fuels/products (see Chemrec slides)
    - Economic gain
      - "New" products – fuels/chemicals
    - Conservation
      - Reduces fossil fuel consumption for energy and fuels/chemicals

Management Approach

Industrial Linkages

Why Petroleum/Petrochemical Industries??

- Interested in biomass
- Renewable source of hydrogen for traditional and bio-refineries
- Key issue is quantities of biomass available and cost
- Existing infrastructure for feed and products
- Has many final conversion issues solved
- Industry seeking added-value products
- Xform a Petroleum Refinery into a Biorefinery
- Outreach underway

Management Approach

Industrial Linkages

Why Gasification Technology Vendors??

- Interested in biomass
- Actively examining various market entry points
- Would like to be omnivorous w/ respect to *opportunity feedstocks*
- Existing infrastructure for moving technology into marketplace
- Comfortable with “unknowns”
- Have some initial links to “user industries”

Management Approach

Core R&D and Technical Knowledge

NBC Partnership

- Core R&D
- Cooperative R&D
- Process Development Units

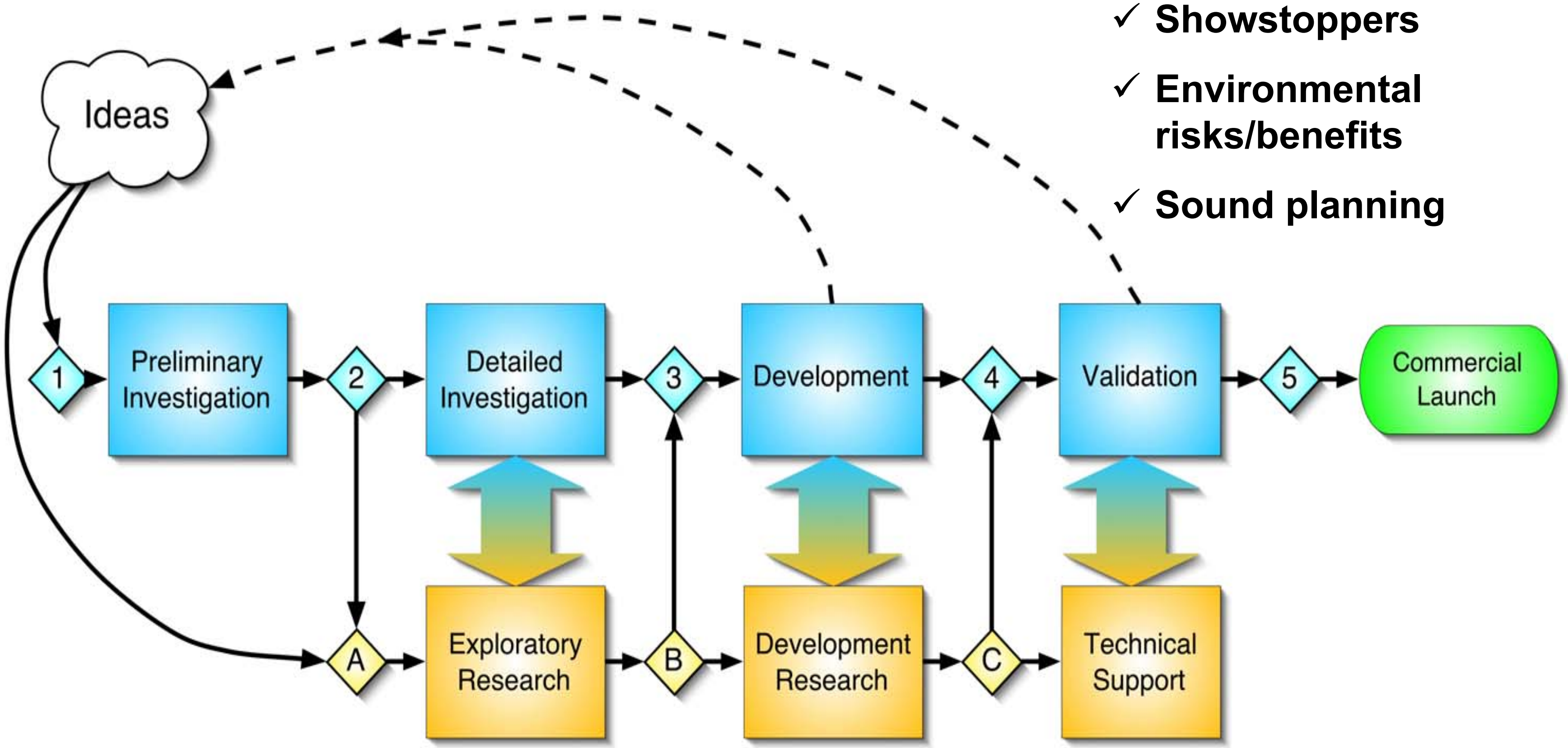
Technical knowledge (Laboratory and U.S. Industry)

- Industry Partnership Develop Efforts
- Cooperative R&D;
- Process Development Units
- Demonstration Projects

Management Approach

Gate criteria

- ✓ **Strategic fit**
- ✓ **Market risks and benefits**
- ✓ **Competitive advantage**
- ✓ **Showstoppers**
- ✓ **Environmental risks/benefits**
- ✓ **Sound planning**



Management Approach

DOE/USDA 2004 Solicitation – Thermochemical Areas

Cleanup & Conditioning
- Syngas cleanup (tars, N, alkali, heavy metals, Sulfur)
- Oils

Thermochemical Conversion
- Fundamental breakthrough research
- Conversion to fuels, chemicals

Petroleum refinery evaluations

Black Liquor Gasification
- Kraft

END

Outline – DETAILED

I. History and Definitions

II. The Technology
- An array of:
  - Gasifier designs (Single slide on various types and applications)
  - Feeding & handling systems
  - Conversion Systems for gas to products
- Specific problems associated with Biomass TC systems
- Specific problems associated with Biomass Syngas cleanup. (slide from Rich/Ralph)
- Integration of biomass gasifiers w/ existing industrial systems (pulp mills, petro refinery, chemical plants, etc.)

III. Strategic Direction
- EERE Priorities are OBP Goals
  - Decrease U.S. Dependency on Foreign Oil
  - Develop Bioenergy Industry
- OBP Level

IV. Programmatic Goals and Barriers
- Decrease cost of products
- Biorefinery by 2008, 2010
- WBS and Barriers. BLG fits in both TC and Integrated Biorefineries

V. Management Approach
- Develop & Strengthen Partnerships with Industry
- Implement MYTP
  - Dependent on approps
- Utilize: Core R&D; Cooperative R&D; Process Development Units; Demonstration Projects
- Utilize & strengthen technical knowledge within both Laboratory and U.S. Industry
- Stage Gate process
  - Active Management
  - Milestones

Biomass vs. Coal Properties

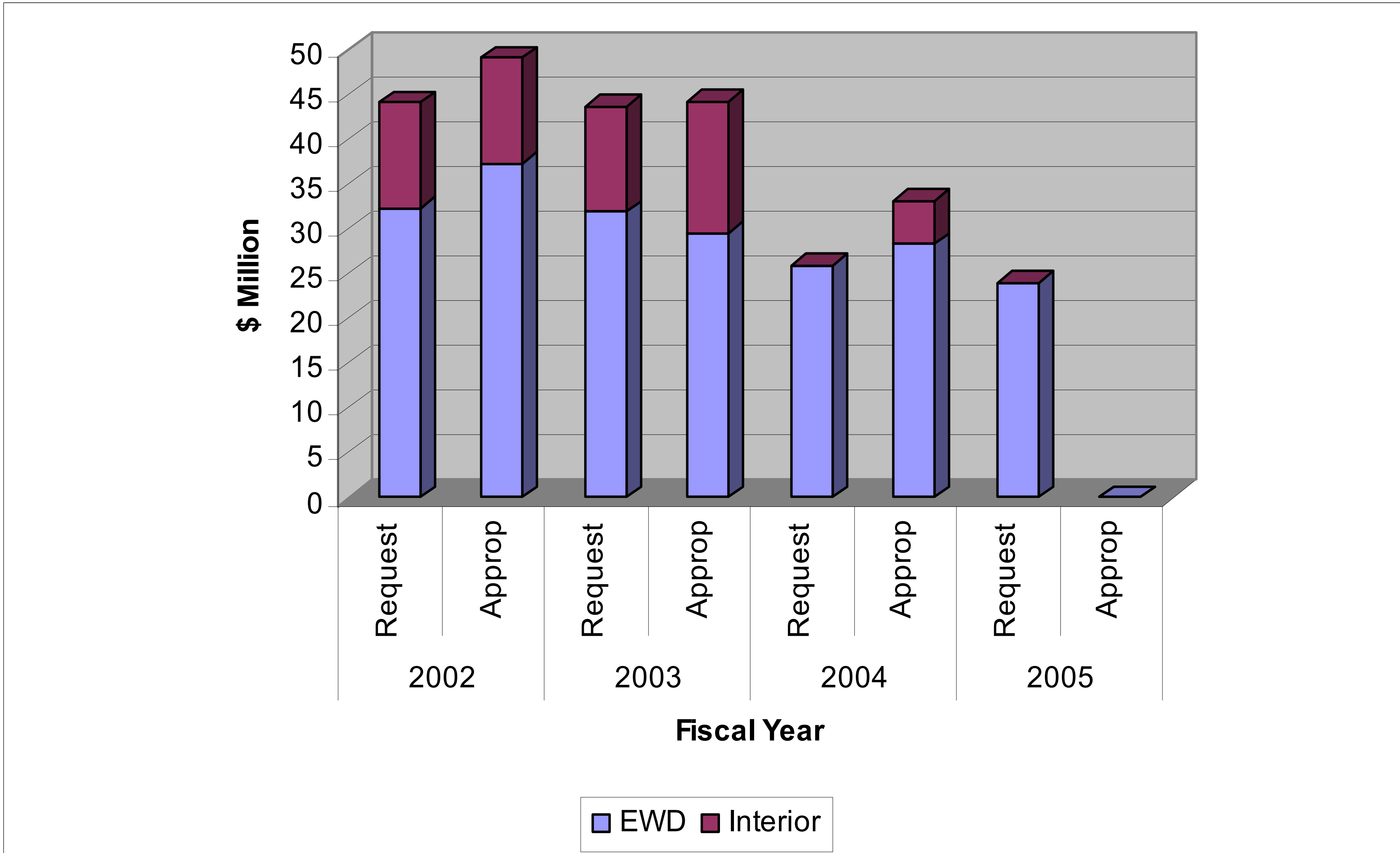
	Biomass 1	Biomass 2	Coal 1	Coal 2	Tar Sands
Name	Wood	Red Corn Cob	Grundy, IL. No 4	Rosebud, MT	Athabasca
Classification			HvBb	sub B	Bitumen
Proximate Analysis, wt% Dry					
Moisture	25-60	16	8.16	19.84	
Volatile Matter	77-87	ca. 80	40.6	39.02	
Fixed Carbon	13-21	--	45.47	49.08	
Ash	0.1-2	4	13.93	9.16	
Ultimate Analysis, wt % Dry					
C	50-53	45	68.58	68.39	83.6
H	5.8-7.0	5.8	4.61	4.64	10.3
N	0-0.3	2.4	1.18	0.99	0.4
Cl	.001-0.1	--	0.12	0.02	--
O	38-44	42.5	6.79	16.01	0.2
S	0-0.1	0	4.76	0.79	5.5
Ash	0.1-2	4	13.93	9.16	
H/C Atomic Ratio	1.4-1.6	1.5	0.8	0.81	1.47
HHV, Dry, Btu/lb	8,530- 9,050	7,340	12,400	11,684	17,900

Gas Cleanup Technologies

	Advantages	*Disadvantages*
Particulate Removal		
Wet Scrubbing	• Proven technology • 95% removal of > 1µm particles	• Aqueous waste stream • Aerosols • Thermodynamic efficiency losses
Cyclone separation	• Proven technology - > 90% removal of > 5µm particulate • High T operation	• Ineffective for sub-micron particles
Electrostatic Precipitators (wet and dry)	• Large-scale • High T operation • Small particles (<0.5 µm)	• High cost – capital and operating
Barrier Filters	• High T operation • Removes small particles	• Developing technology – materials issues vs. T • High pressure drop • Backpulsing/blinding
Tar Removal/Conversion		
Wet Scrubbing	• Proven technology for large scale • Commercially available	• Aqueous waste stream • Loss of tar fuel value • Thermodynamic efficiency losses
Catalytic Steam Reforming	• Improved heat integration w/ gasifier	• Developing technology • Catalyst disposal

U.S. Department of Energy
Energy Efficiency and Renewable Energy

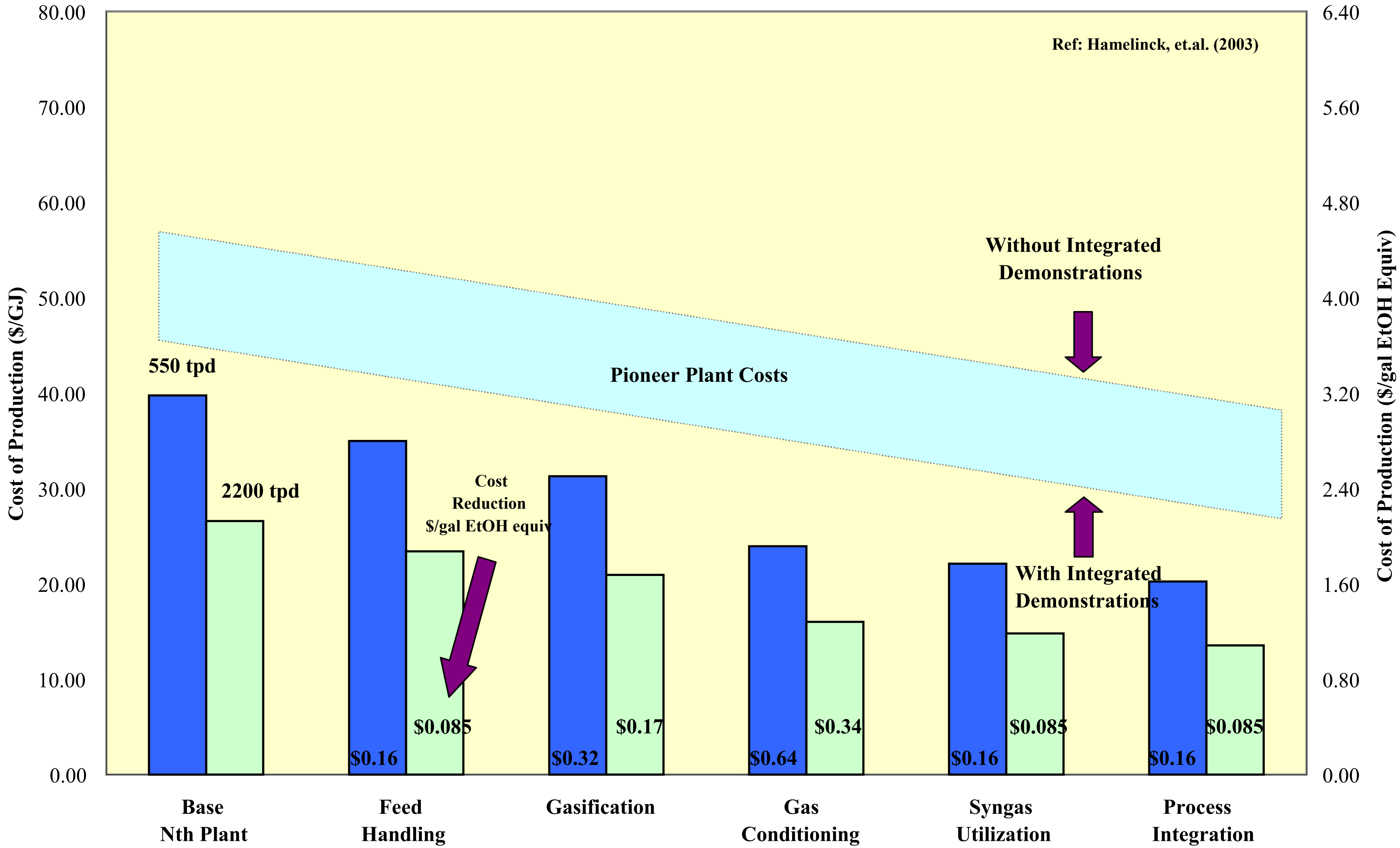
TC Platform Funding



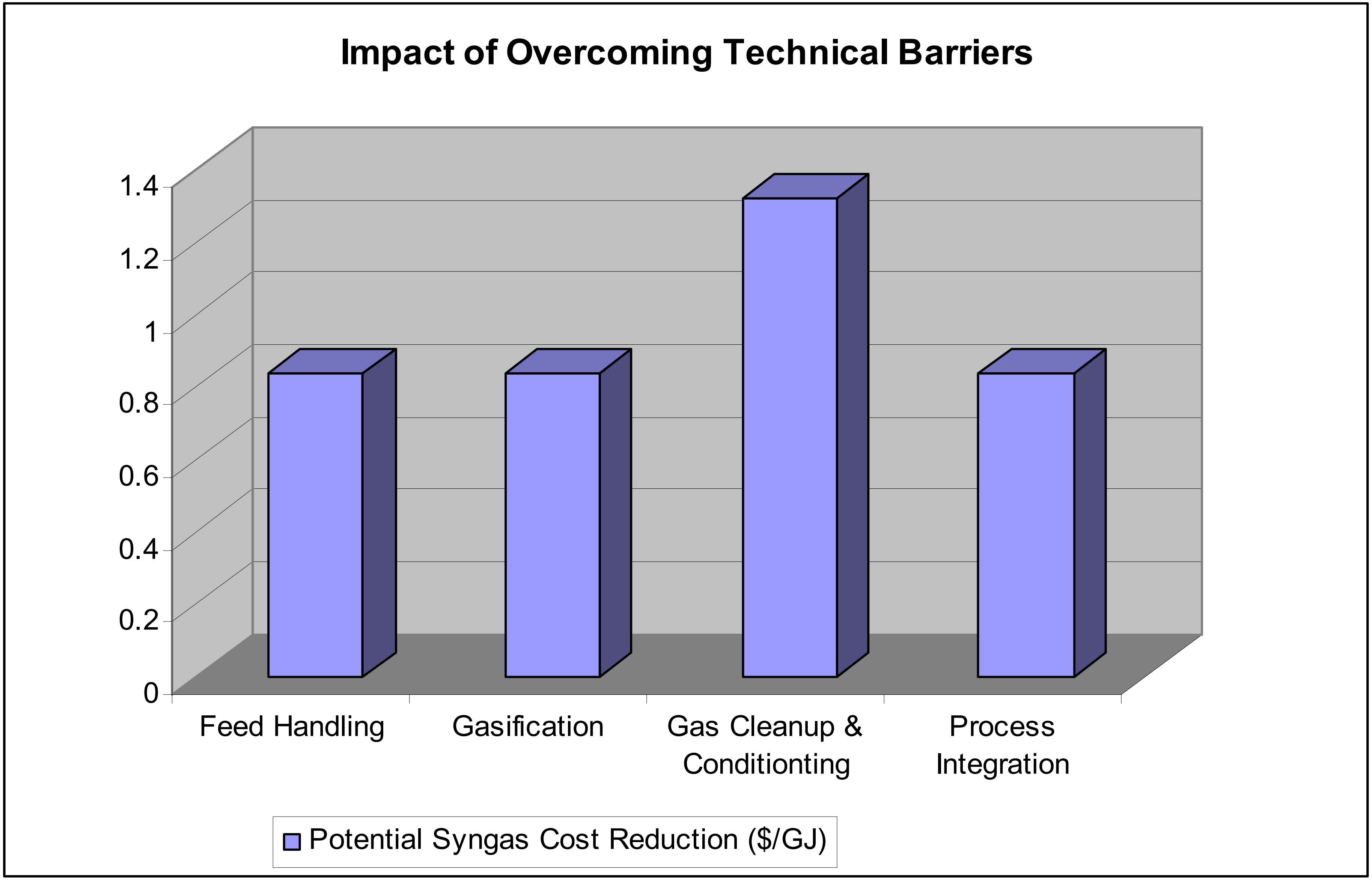
Source: www.mbe.doe.gov/budget

Note: Interior does not include crosscutting activity funding

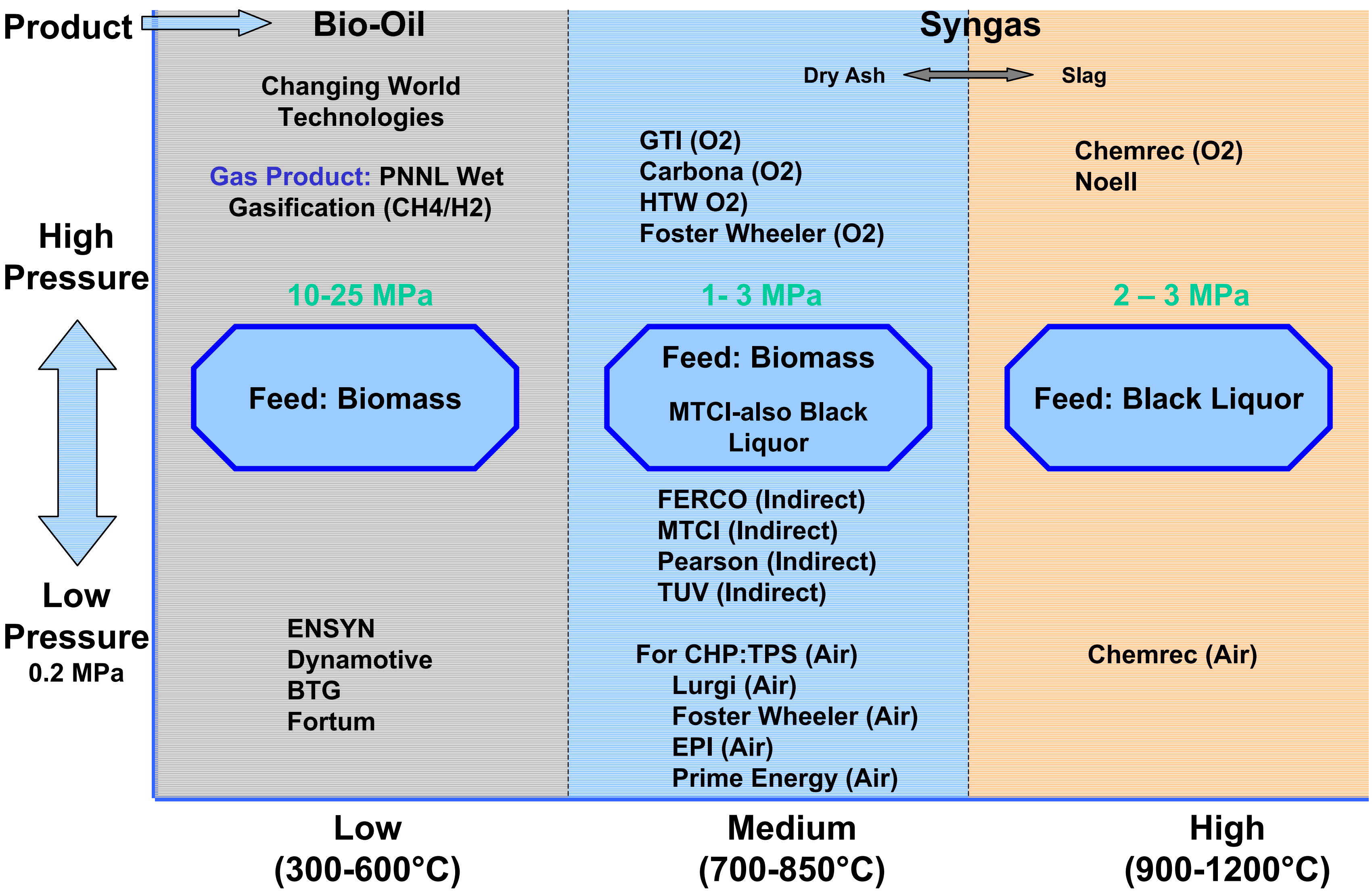
Syngas Platform Cost Curve for Fischer Tropsch Liquids



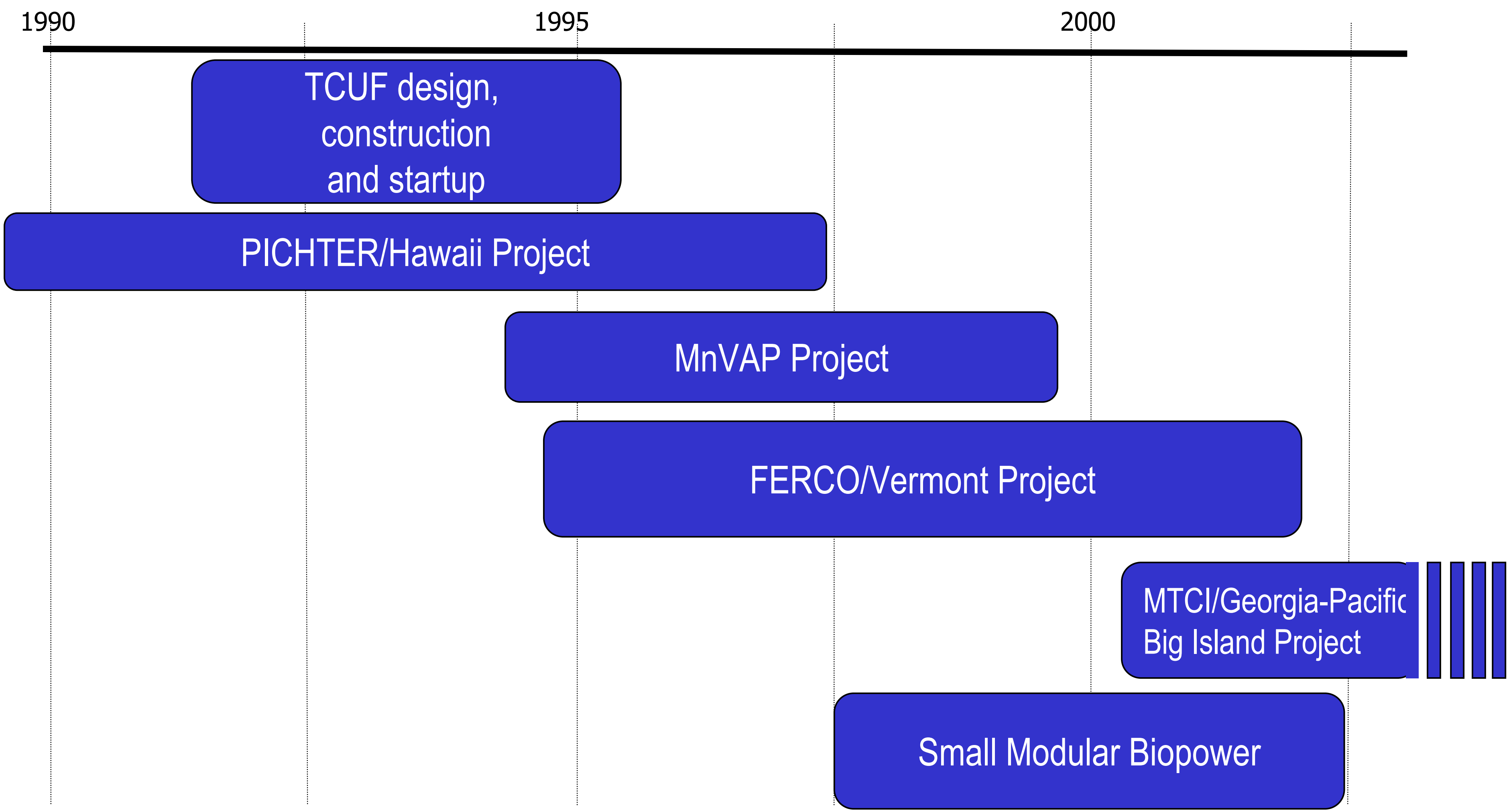
Relationship of Barriers to Intermediate Cost



Thermochemical Conversion Of Biomass and Black Liquor



Previous Partnerships



Thermochemical Platform Gate Review

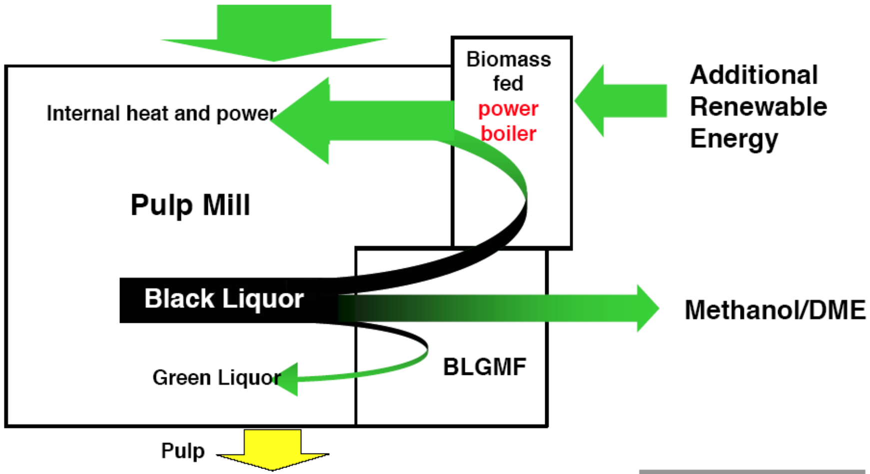
- First time applied outside of sugars platform
- Reviewed six projects
  - Gasification, Gas Cleanup, Biorefinery Utilities,Wet Gasification, Microchannel Reactor, Pyrolysis Oil Upgrading
  - Seven Industry Reviewers (oil, gas, pyrolysis)
- Outcomes
  - Terminate two projects
    - Biorefinery Utilities
    - Microchannel Reactor
  - Significantly modify two projects
  - Slightly modify two projects

Management Approach

Gasification Demos – Lessons Learned

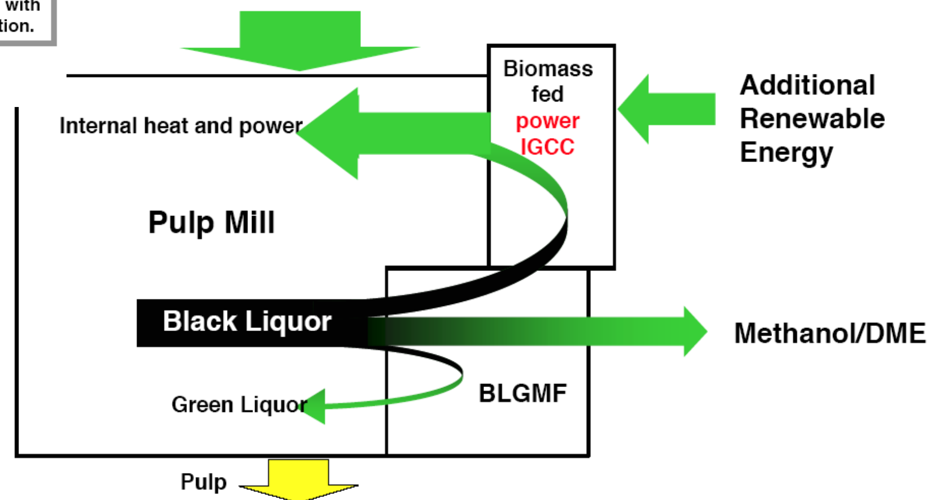
Lesson	Action
• Need for on-going in-depth technical review • Feedstock/feed system suitability • Comprehensive environmental assessment • Transfer of technologies from innovators to commercializers • Disparity in development and commercialization time-scales	• Implementation of Stage-Gate management • Comprehensive List of Barrier areas identified • Information for regulatory/permitting/financing entities – e.g. conceptual designs • Industry outreach & solicitations

Pulp Mill Possibilities



$$\text{Production Efficiency} = \frac{\text{Methanol/ DME}}{\text{Additional Renewable Energy}} = 65\text{-}75\ \%$$

Same Power Need with RB or BL Gasification.



$$\text{Production Efficiency} = \frac{\text{Methanol/ DME}}{\text{Additional Renewable Energy}} = 85\text{-}95\ \%$$

Same Power Need with RB or BL Gasification.

Source: Chemrec presentation to AF&PA

Outcomes of Government Actions

- Primary Energy – **doubled in 30 years.**
- Electricity Production – **tripled in 10 years (1% of U.S. Generating Mix).**
- Ethanol Fuels Production – increased a factor of **16 in 20 years** and capacity is increasing fast (2.89 bi gallons installed/construction 2002).
- Forest Products Energy Self-sufficiency **increased by nearly 50% in 20 years**.
- Residential heating with biomass replaced heating oil & grew by a **factor of 2** from 1970-1990. In 2000 it returned to 1970 levels with modern pellet stoves and commercial heating with biomass increased.
- Municipal solid waste management:
    - Safe and responsible.
    - Recycling rates **tripled in 20 years**.
    - MSW/landfill primary energy increased by a factor of **6 in 20 years**.
- Significant emissions reductions, including carbon, and landfill reduction were achieved.
- Significant economic development including rural ($15M invested, 66,000 jobs).