The Vision 21 Planner:
A New Modeling Tool for Preliminary Cost and Performance Assessments of Vision 21 Plants

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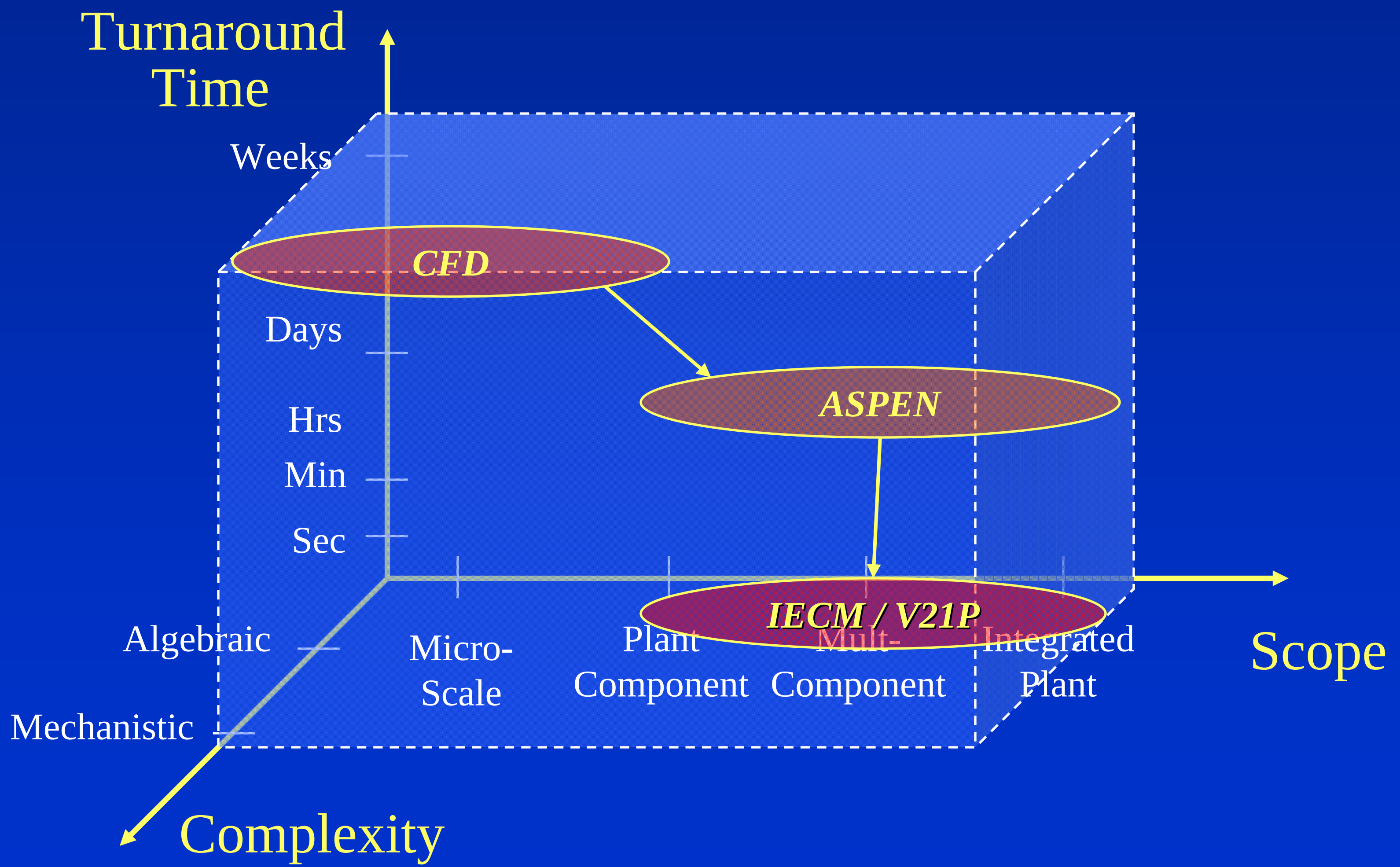
Vision 21 Modeling Needs

- A hierarchy of models tailored to the needs of different users and applications, ranging from:
  - Preliminary design and screening analysis, to
  - Detailed design of a "virtual" plant
- A range of capabilities for predicting the performance, reliability and cost of:
  - Individual plant components
  - Integrated Vision 21 plant designs

The Vision 21 Planner Would …

- Bring together performance and cost models for a variety of enabling technologies and Vision 21 system designs
- Run quickly and easily on a desktop or laptop computer for preliminary design and analysis
- Allow new process concepts and components to be easily incorporated into new Vision 21 designs
- Allow uncertainties to be characterized explicitly
- Facilitate rapid analysis of “what if” questions and the selection of promising designs for further study

Attributes of Different Models

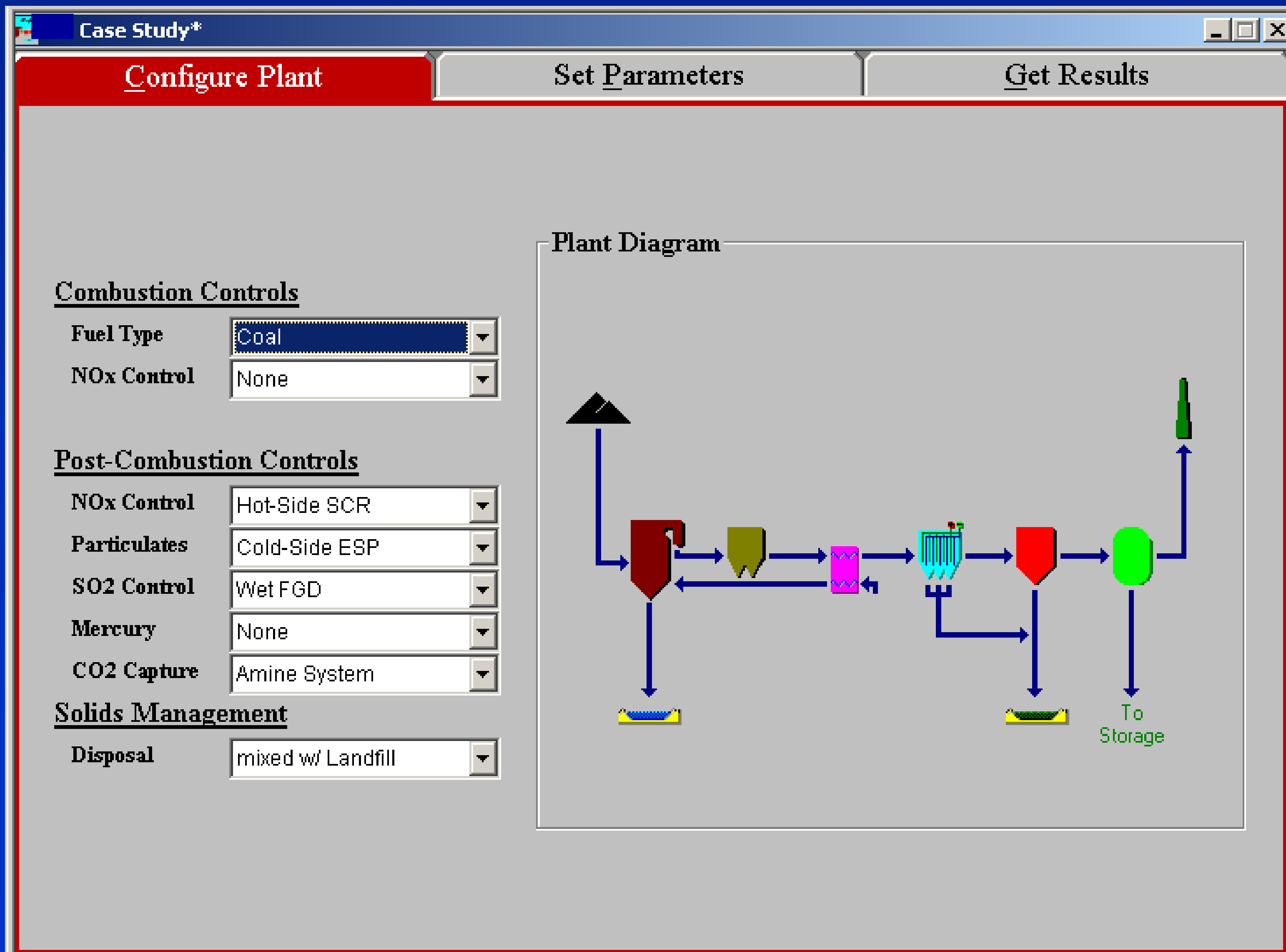


Modeling Approach

- Systems Analysis Framework
- Process Technology Models
- Engineering Economic Models
- Advanced Software Capabilities
  - Probabilistic analysis capability
  - User-friendly graphical interface
  - Easy to add or update models

Framework for the V21 Planner:

The Integrated Environmental Control Model (IECM)



Current IECM Technologies

Furnace Types
- Tangential
- Wall
- Cyclone

Furnace NO_x Controls
- LNB
- SNCR
- SNCR + LNB
- Gas reburn

NO_x Removal
- Hot-side SCR

Mercury Removal
- Carbon injection
- Carbon + water

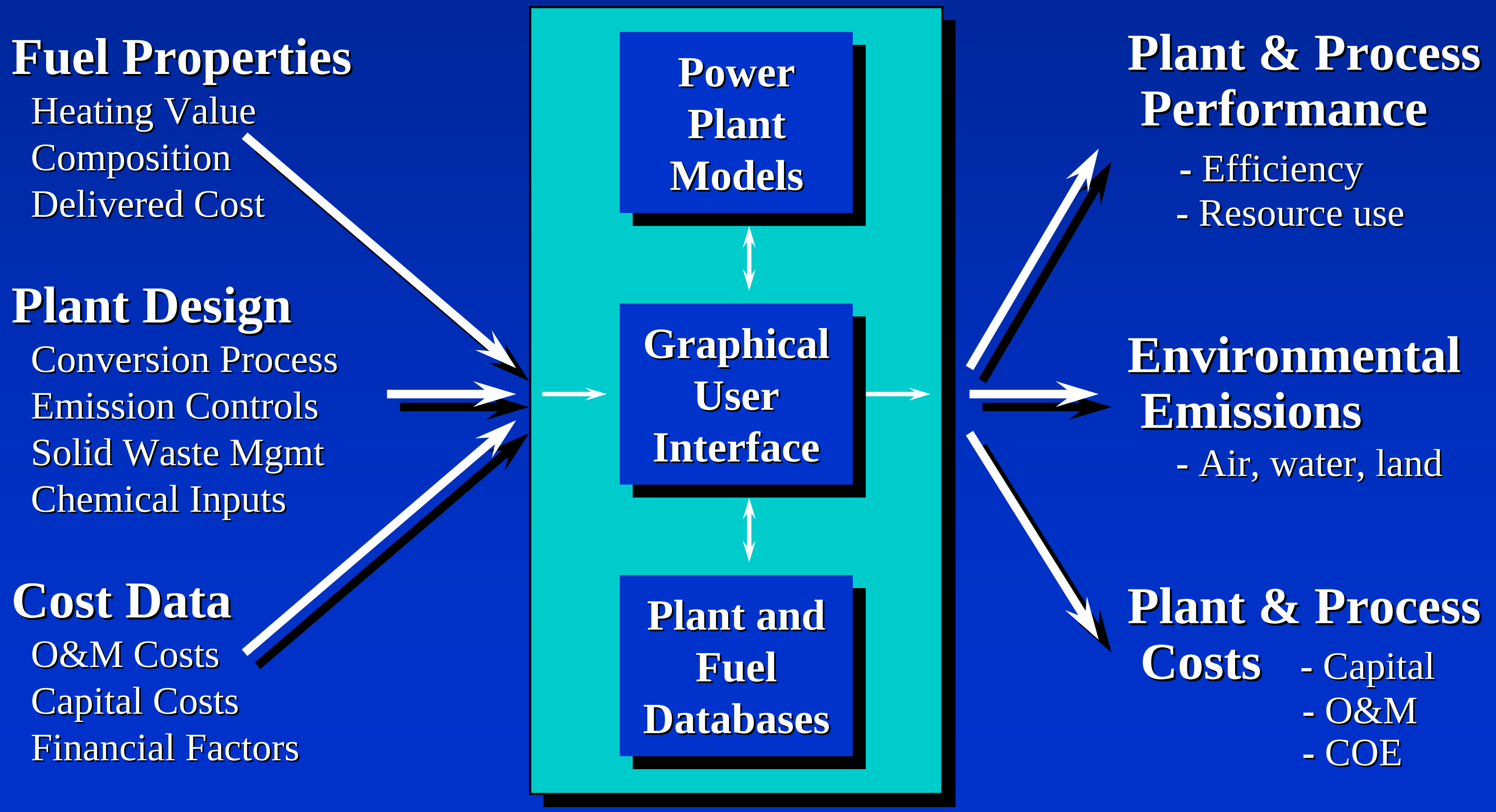
Particulate Removal
- Cold-side ESP
- Fabric filter
  - Reverse Air
  - Pulse Jet

SO_2 Removal
- Wet limestone
  - Conventional
  - Forced oxidation
  - Additives
- Wet lime
- Lime spray dryer

Combined SO_2/NO_x Removal
- Copper oxide
- NOXSO

Solids Management
- Ash pond
- Landfill
- Stacking
- Co-mixing
- Byproducts
  - Ash
  - Gypsum
  - Sulfuric Acid

Model Software Package



IECM User Group

ABB
AEP-SCR Engineering
Airborne Technologies
Akzo Nobel Functional Chem
Alberta Economic Development
Alberta Environment
ALCOA Power Generating, Inc.
Allegheny Energy Supply
Alliant Energy
Alstom Power Inc.
American Electric Power
Apogee Scientific, Inc.
Applied Technology Services
Argonne National Laboratory
ATCO Power
Babcock Borsig Power, Inc.
Babcock & Wilcox Co.
Bechtel Power Corp.
Black & Veatch Corp.
BOC Gases
Boiler Systems Engineering
Canada Environment
Canada Natural Resources
Carnegie Mellon University
Cinergy Power Generation
Clean Energy Int.
Cogentrix Energy, Inc.
CONSOL Energy, Inc.
Consumers Energy
CP&L
CPG, Inc.
CQ, Inc.

Croll-Reynolds
Department of Environmental Prot
Detroit Edison Co.
Diamond Power Specialty Co
Doyen & Associates, Inc.
Duke Engineering & Services.
Duke Fluor Daniel
Dynegy Midwest Generation
Electric Energy, Inc. (EEI)
Electricte de France
Emera Inc.
Emery Recycling Corporation
Enel Produzione
EnerenUE
Energy & Environ Research Corp.
Energy & Environ Strategies
Energy Systems Associates
Energy Technology Enterprises
ENSR, Inc.
Environmental Defense
Envirol & Renewable Energy Syst
EPRI, Palo Alto
Exportech Company, Inc.
FirstEnergy Corp.
Florida Power & Light Co.
FLS Miljo A/S
Fortum Power and Heat Oy
Fossil Energy Research Corp.
Foster Wheeler Development
Foster Wheeler USA Corp.
Fuel Tech, Inc.
General Electric Company

Goodwin Environmental
Great River Energy
Gyeongsang National University
H&W Management Science
Hamon Research Cottrell, Inc.
Harza Engineering
Holland Board of Public Works
IEA Coal Research
Illinois Clean Coal Institute
Illinois Dept. of Natural Resources
Illinois EPA
Illinois Institute of Technology
Indiana Dept. of Env. Mgt.
Intermountain Power Service Corp.
Jack R. McDonald, Inc.
Kansas City Power & Light Co.
KEMA Nederland B.V.
Kinectrics
Korea Electric Power Corporation
Korea Institute of Energy Research
Korea Western Power Co.
Krupp Polysius Corp.
LAB SA
Lehigh University
Lower Colorado River Authority
Mail Station PAß358
McDermott Technology, Inc.
MidAmerican Energy Co.
Minnkota Power Cooperative, Inc.
Mitsubishi Heavy Industries, Ltd.
Mitsui Babcock Energy Ltd.
National Park Service

National Power Plc.
NESCAUM
New Hampshire Dept. of Env. Svc
New Jersey DEP
Nicholson Environmental, Inc.
Niksa Energy Associates
NIPSCO
Niro A/S
North Carolina DENR
North Carolina State Univ
Ontario Power Generation
Pacific Corp.
Parsons Technology
Pavillon Technologies, Inc.
Pennsylvania Electric Assoc
PEPCO
PG&E National Energy Group
Pinnacle West Energy
Potomac Electric Power Co.
PowerGen
PPL Generation, LLC
PPL Montana, LLC
Predict Maintenance Tech
Princeton University
Progress Materials, Inc.
PSEG Power LLC
Public Power Institute
Reaction Engineering Intl
Research Triangle Institute
Rheinbraun Brennstoff GmbH
Sargent & Lundy, LLC

SaskPower
Savvy Engineering, LLC
Scientech
Sierra Pacific Power Co.
Southern Company Services, Inc.
State of New Jersey
Stone & Webster Engineering Corp.
Superior Adsorbents, Inc.
Syncrude
Tampa Electric Co.
Tennessee Valley Authority
Texas Natural Resource Conv Comm
TNO Envit, Energy & Process Innov
TransAlta
TXU Electric
U.S. DOE
U.S. EPA
University of California
University of New Orleans
University of Pittsburgh
URS Corporation
Utah Dept. of Env. Quality
W.L. Gore & Associates, Inc.
Washington Power
Western Kentucky Energy Corp.
Wheelabrator Air PollControl
Wisconsin Dept. of Nat Resources
Wisconsin Electric Power Co.
Wisconsin Energy Corp.
Wisconsin Public Service Corp.
Wisvest-Connecticut, LLC

Expanding the Framework to Vision 21 Plants

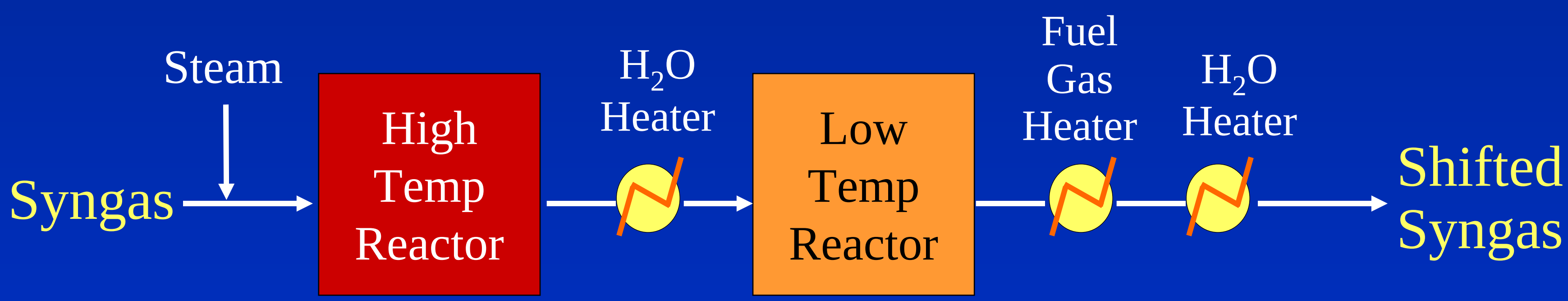
Major Components of V21 Plants

- Gasifiers
- Combustors
- Fuel Cells
- Gas Turbines
- Steam Turbines
- Air Separation Units
- Byproduct Recovery Systems
- Gas Purification Systems for:
  - Solids (ash)
  - Sulfur compounds
  - Nitrogen oxides
  - Mercury
  - Other trace elements
  - Carbon dioxide

Current Modeling Activities

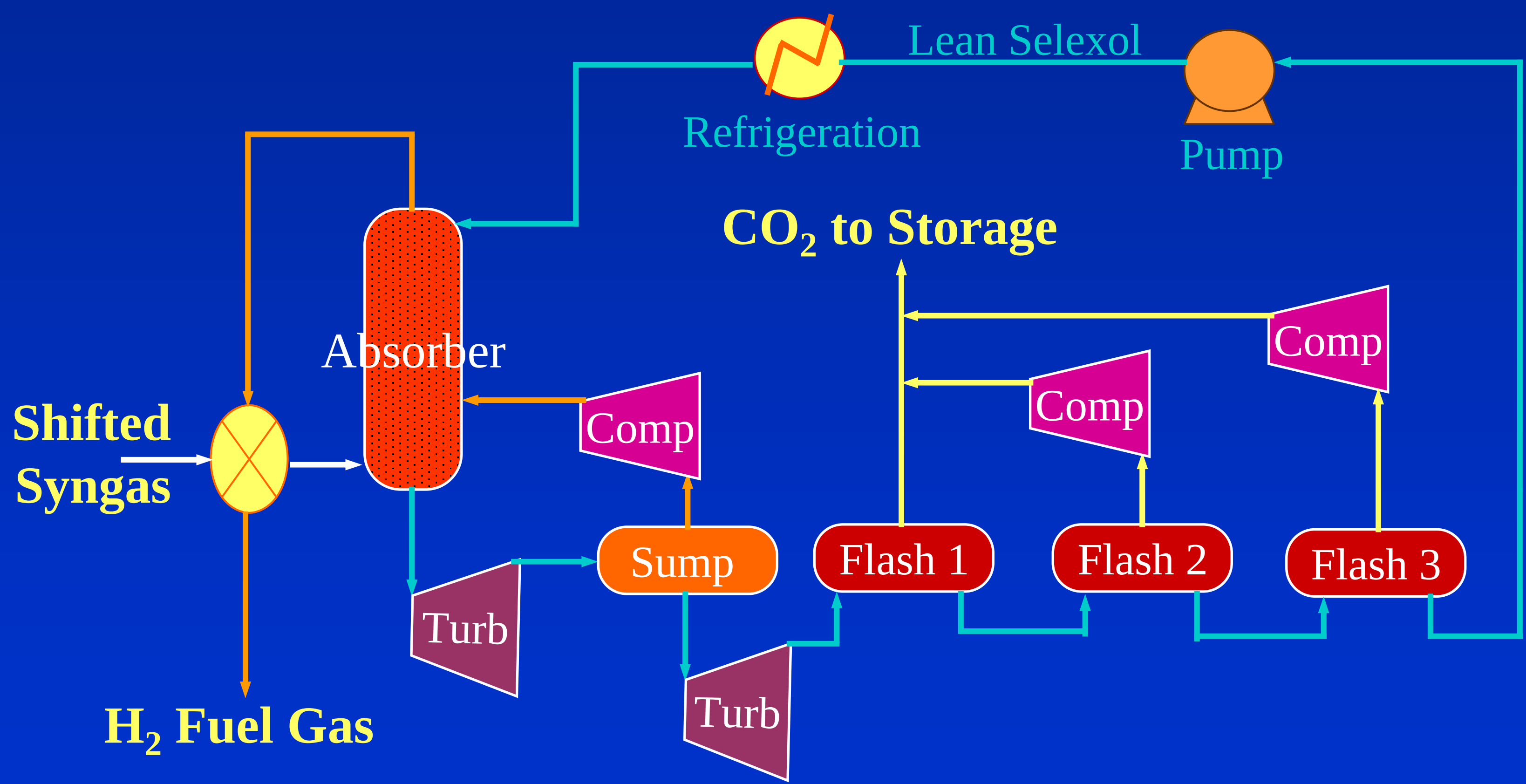
- Enhanced Software Capabilities
- Plant Component Models (perf & cost)
  - Air separation units
  - Oxygen-blown gasifiers
  - Advanced gas turbines
  - Solid oxide fuel cells
  - CO_2 capture systems
- Integrated Plant Models
  - Current IGCC with cold gas cleanup
  - Advanced IGCC with CO_2 capture and storage
  - Combustion-based systems w/ CO_2 capture
  - Hybrid plants with SOFC/gas turbines

Water-Gas Shift Reactor Model

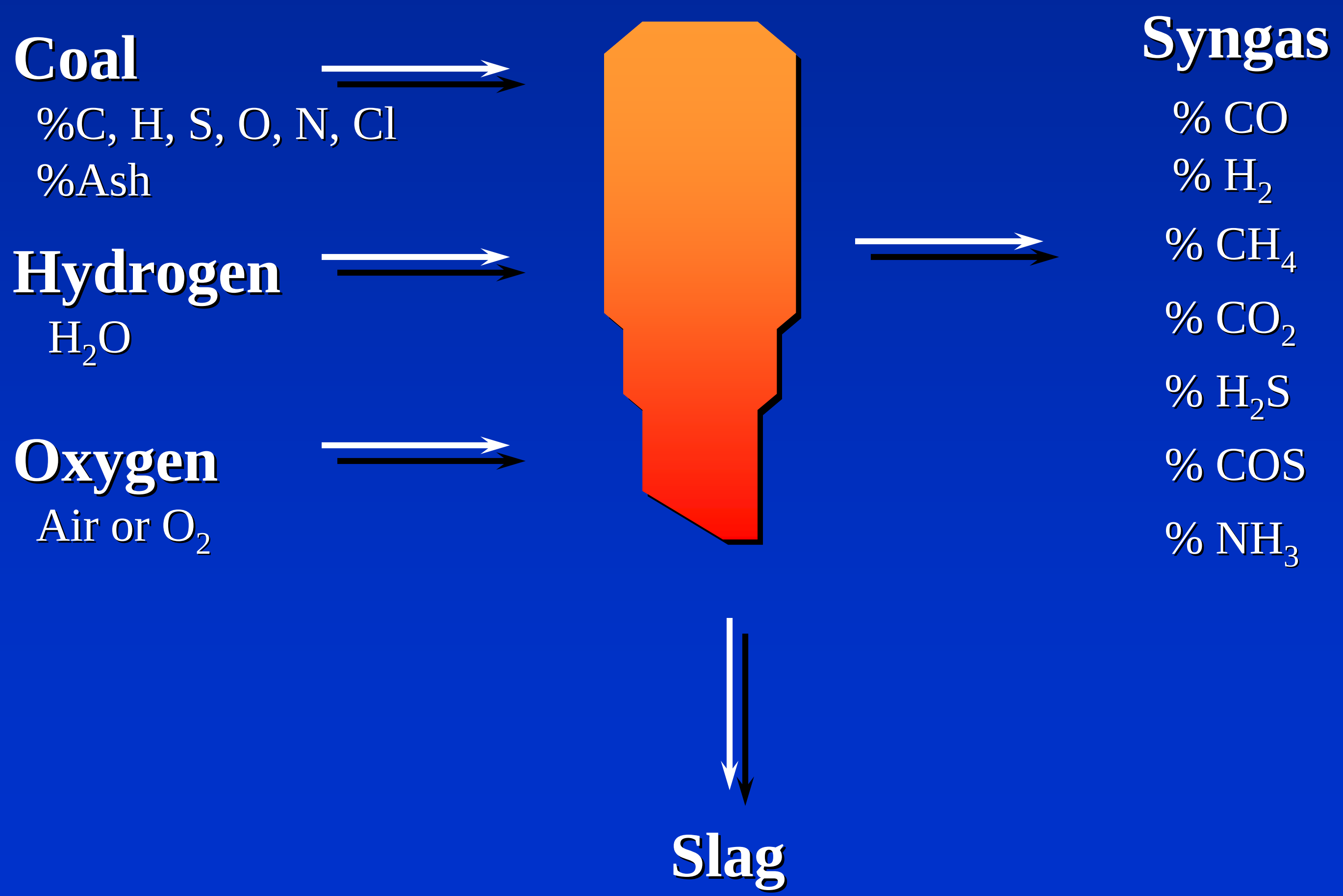


CO_2 Capture System Model

(Selexol Process)



Gasifier Models

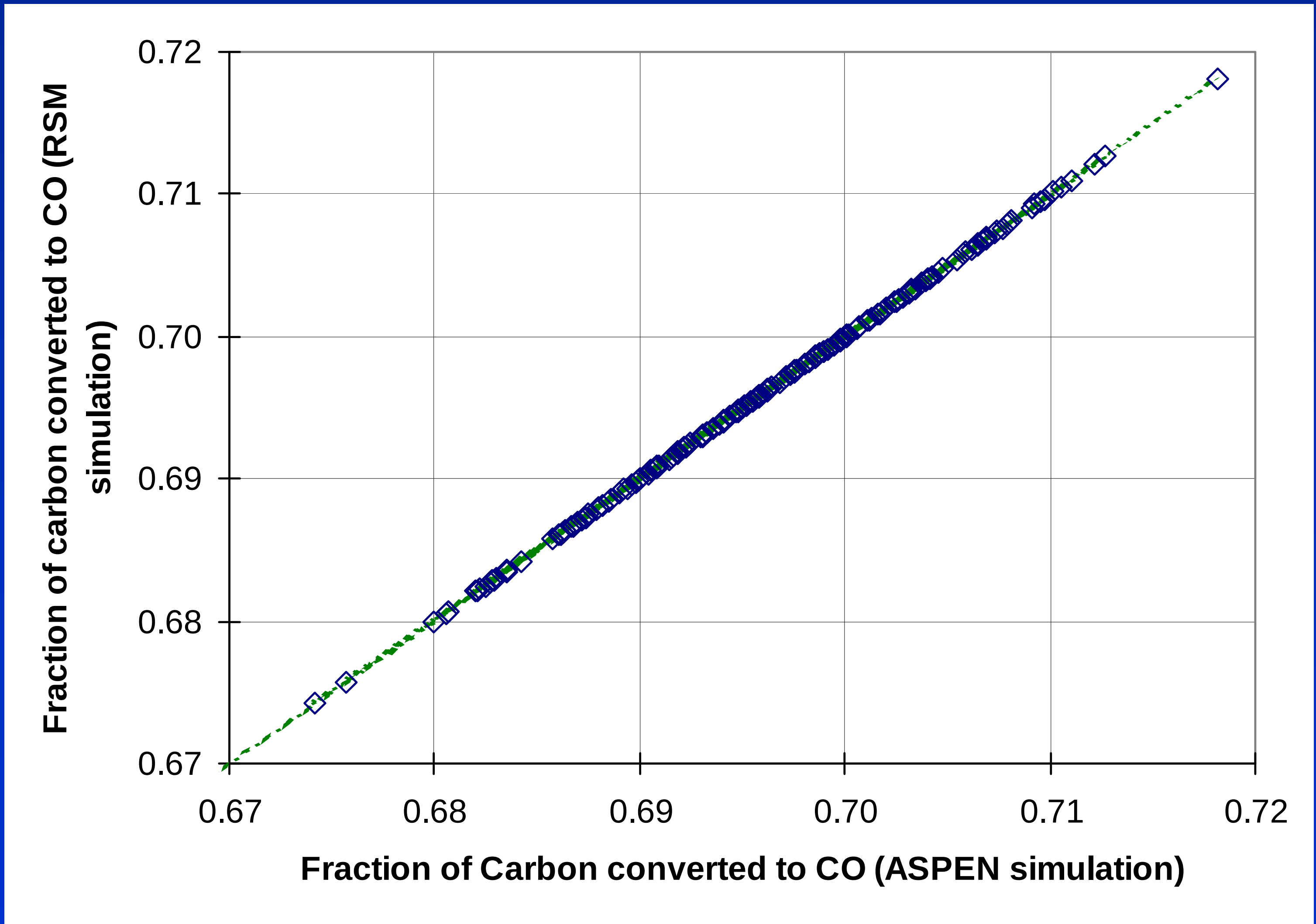


Gasifier Model Parameters

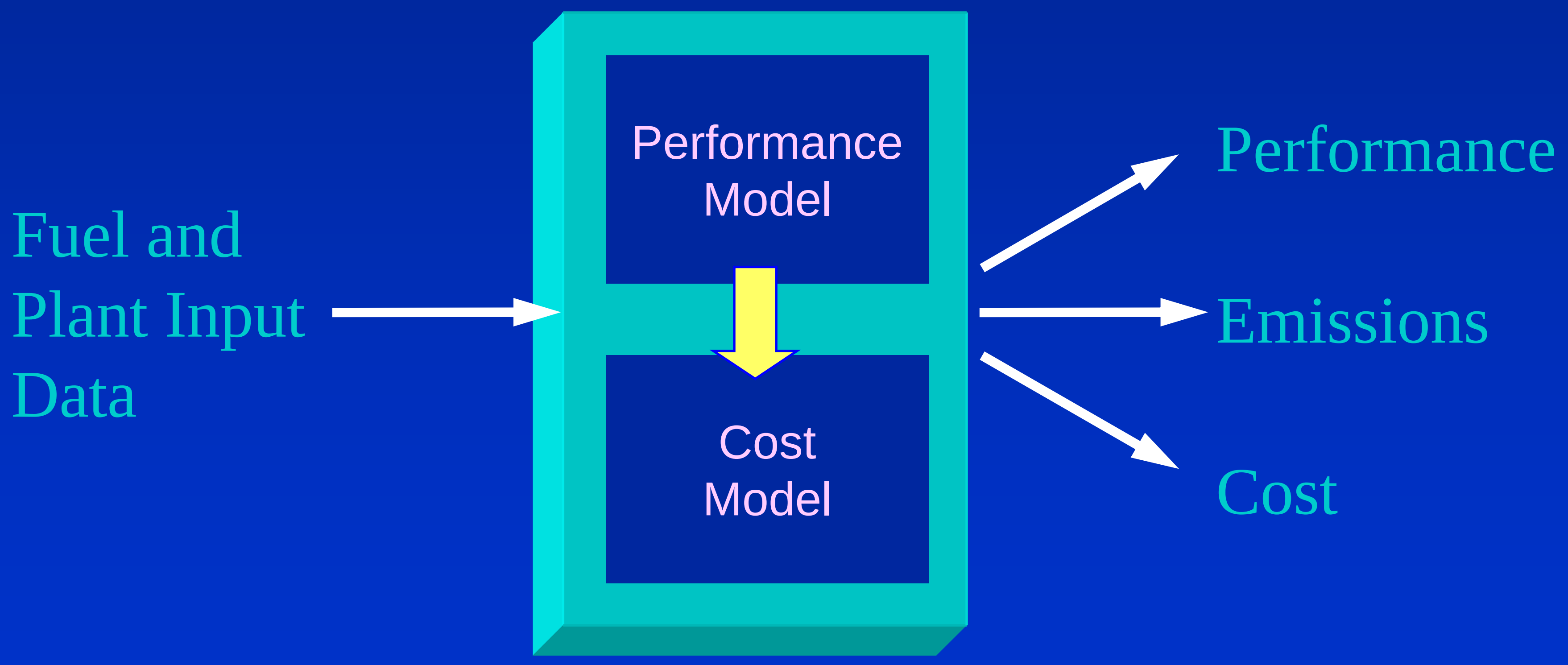
- Independent variables for V21 Planner include:
  - Gasifier type (Texaco, E-Gas, Shell, KRW)
  - Coal type (6 coal choices)
  - Water-to-coal input ratio
  - Oxygen-to-coal input ratio
  - Gasifier temperature
  - Carbon loss in gasifier
- Performance models derived from ASPEN-based IGCC flowsheets developed by DOE/NETL

Gasifier Response Surface Model

(Carbon partitioning to CO, E-Gas gasifier, PRB coal)



Linking Performance and Cost



Example IGCC Capital Cost Process Areas and their Dependent Variables

AIR SEPARATION UNIT
- oxygen feed rate to gasifier

COAL HANDLING AND SLURRY PREPARATION
- coal feed rate to gasifier

GASIFICATION
- as-received coal flow rate
- percent moisture in coal
- percent ash in coal feed
- solids mass flow leaving gasifier

LOW TEMPERATURE GAS COOLING
- syngas mass flow rate

SELEXOL UNIT
- syngas mass flow rate

CLAUS PLANT
- recovered sulfur mass flow rate

BEAVON-STRETFORD UNIT
- mass flow rate sulfur produced

BOILER FEEDWATER SYSTEM
- raw water flow to demineralizer
- polished water flow to polisher

PROCESS CONDENSATE TREATMENT
- scrubber blowdown flow rate

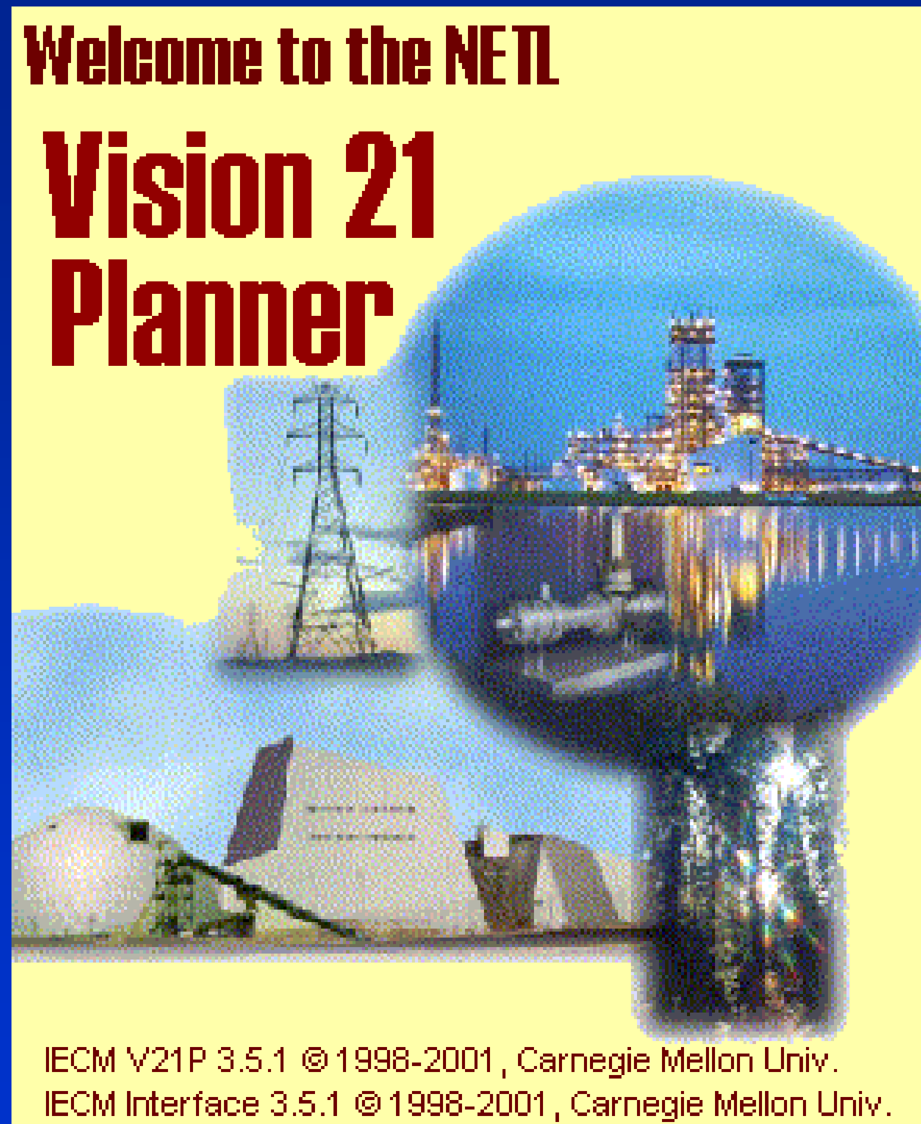
GAS TURBINE
- net gas turbine shaft work

HEAT RECOVERY STEAM GENERATOR
- high pressure flow to steam turbine

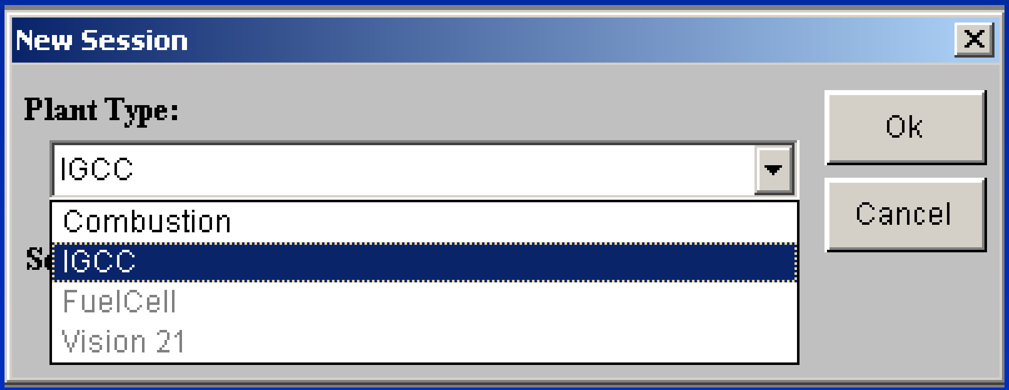
STEAM TURBINE
- net steam turbine shaft work

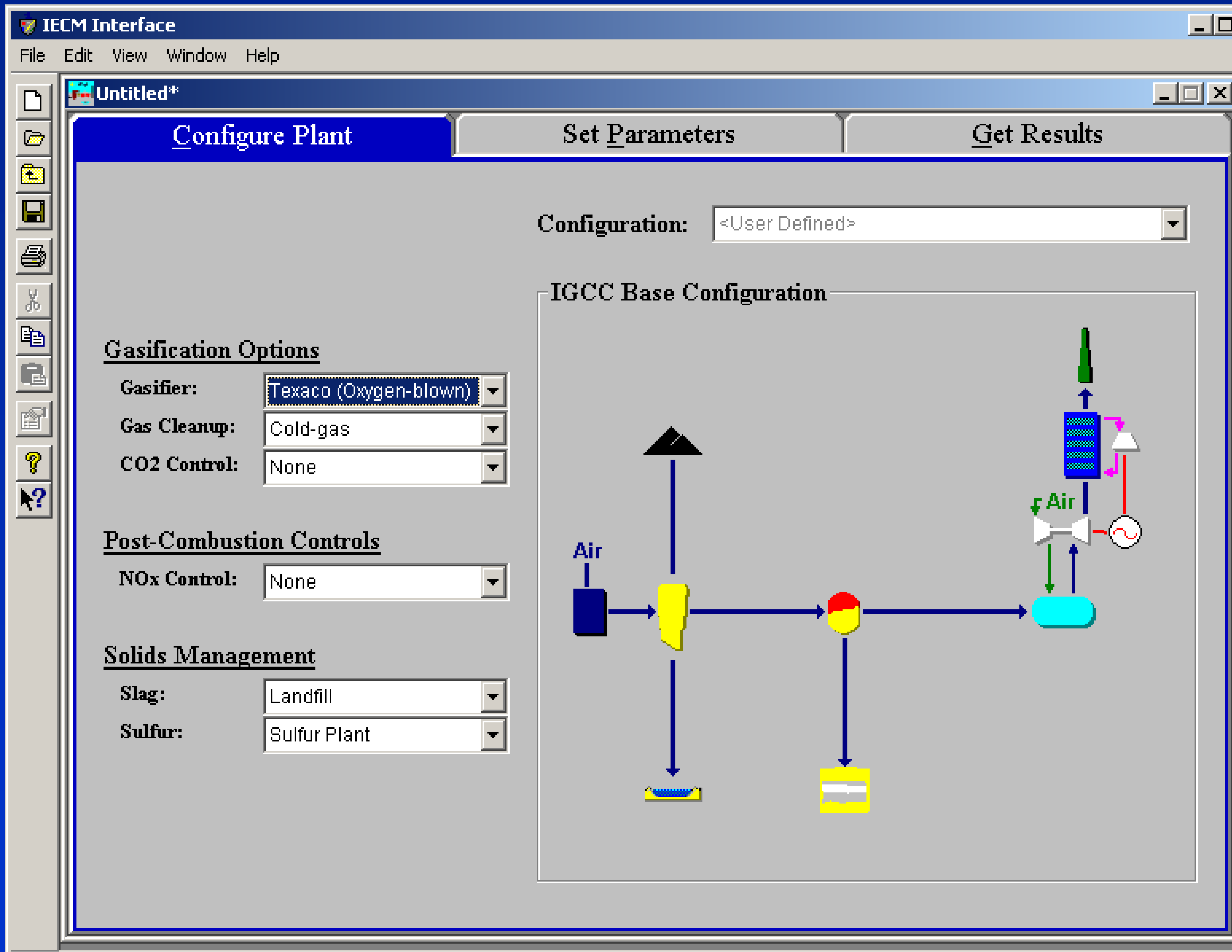
AUXILIARY EQUIPMENT
- miscellaneous power consumption
- steam cycle auxiliary power consumption

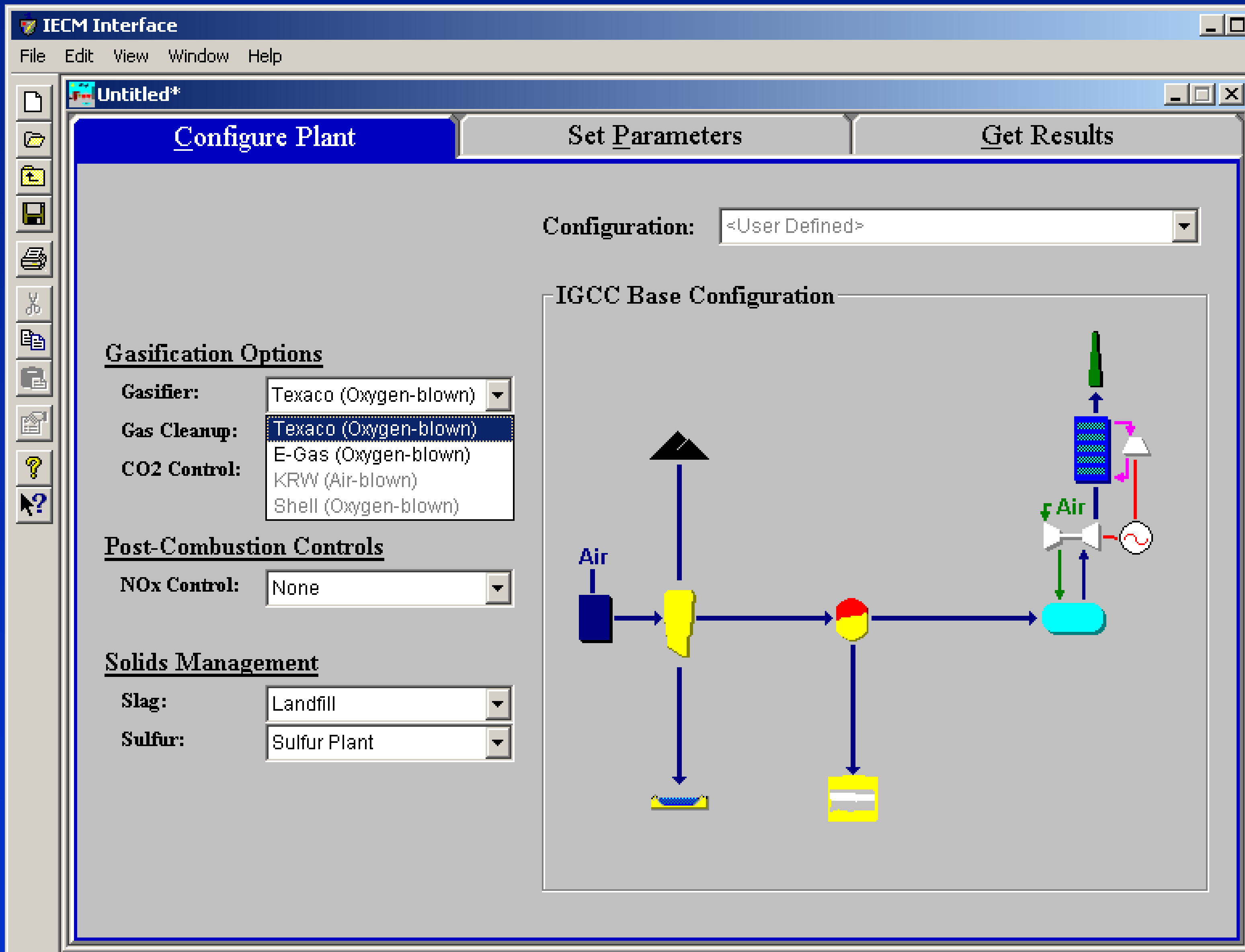
Prototype Graphical Interface



Open a New Session




IECM Interface
File Edit View Window Help
Untitled*
Configure Plant
Set Parameters
Get Results
Configuration:
<User Defined>
IGCC Base Configuration
Gasification Options
Gasifier:
Texaco (Oxygen-blown)
Gas Cleanup:
Cold-gas
CO2 Control:
None
Post-Combustion Controls
NOx Control:
None
Solids Management
Slag:
Landfill
Sulfur:
Sulfur Plant
Air
Air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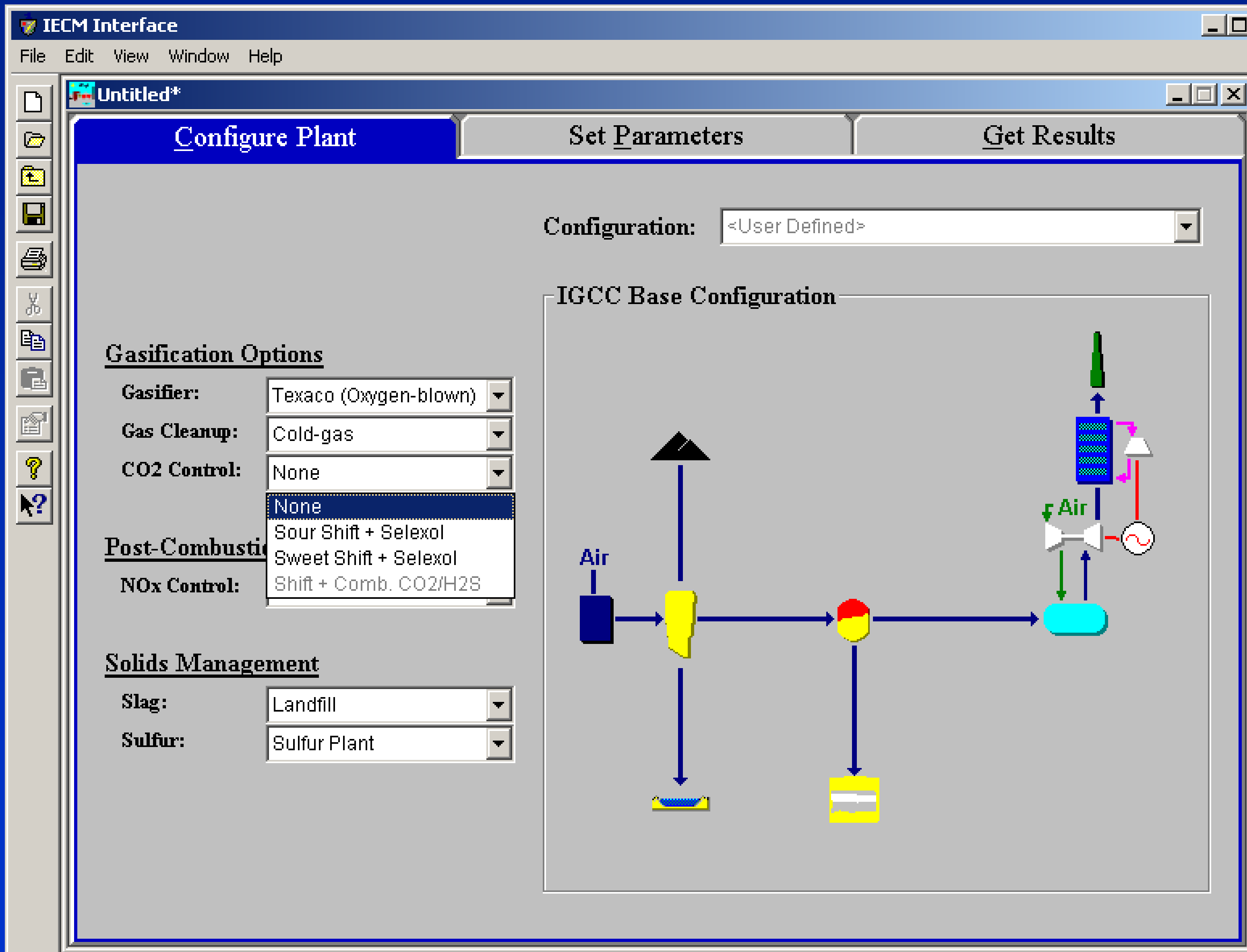
Gas Cleanup:
CO2 Control:
Texaco (Oxygen-blown)
E-Gas (Oxygen-blown)
KRW (Air-blown)
Shell (Oxygen-blown)
Post-Combustion Controls
NOx Control:
None
Solids Management
Slag:
Landfill
Sulfur:
Sulfur Plant
Air
Air



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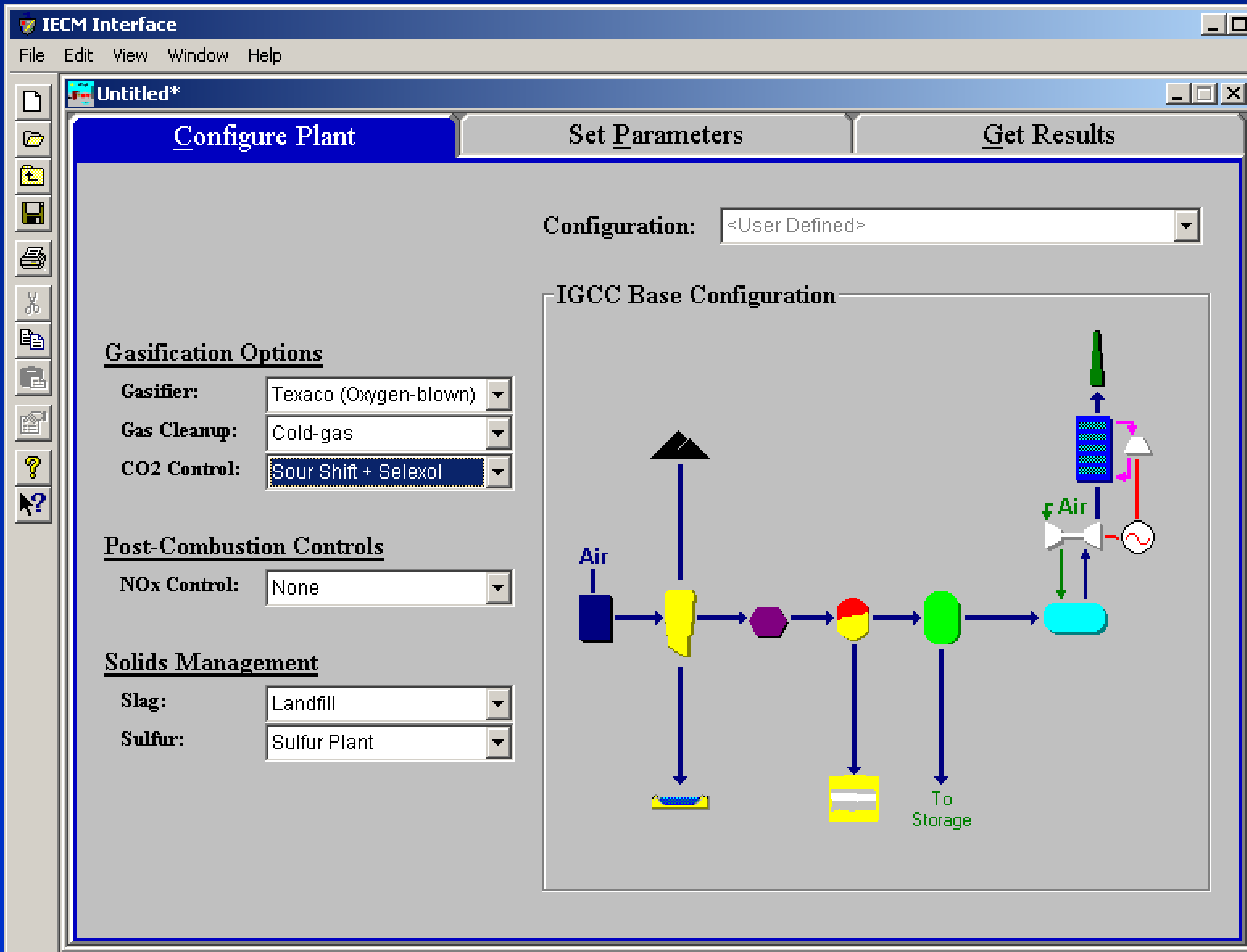
Cold-gas
CO2 Control:
None
None
Sour Shift + Selexol
Sweet Shift + Selexol
Shift + Comb. CO2/H2S
Post-Combusti
NOx Control:
Solids Management
Slag:
Landfill
Sulfur:
Sulfur Plant
Air
Air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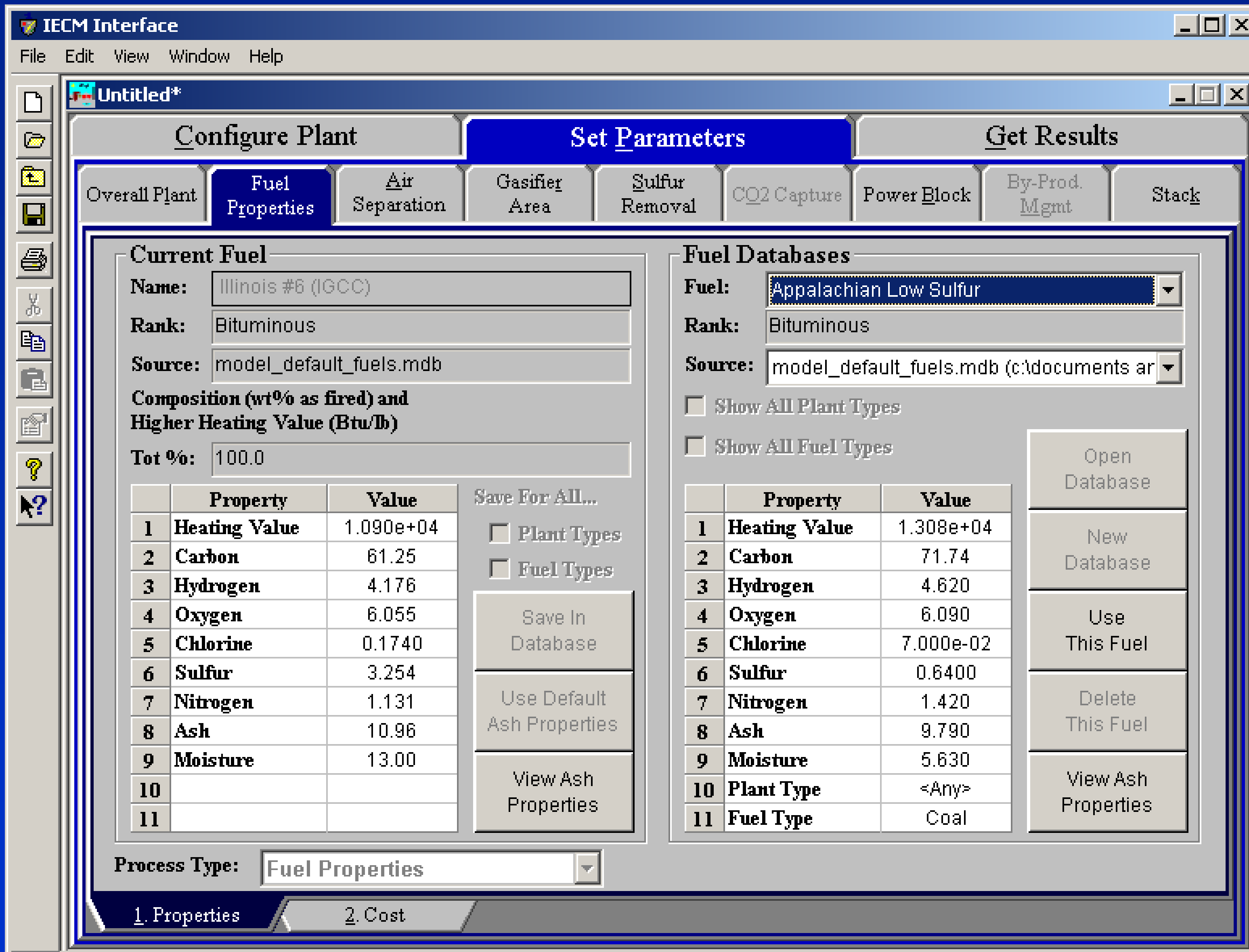
NOx Control:
None
Solids Management
Slag:
Landfill
Sulfur:
Sulfur Plant
IGCC Base Configuration
Air
Air
To Storage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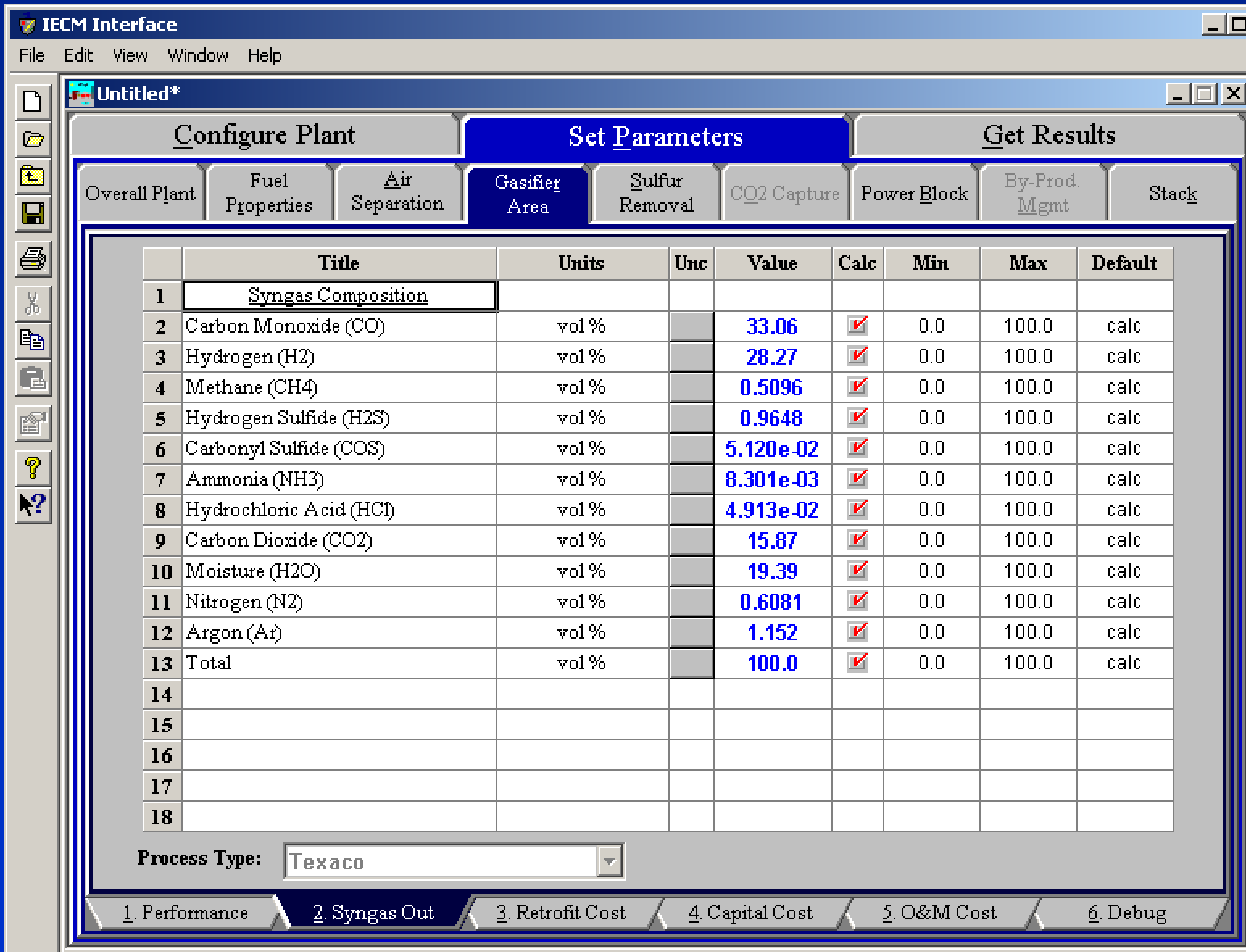
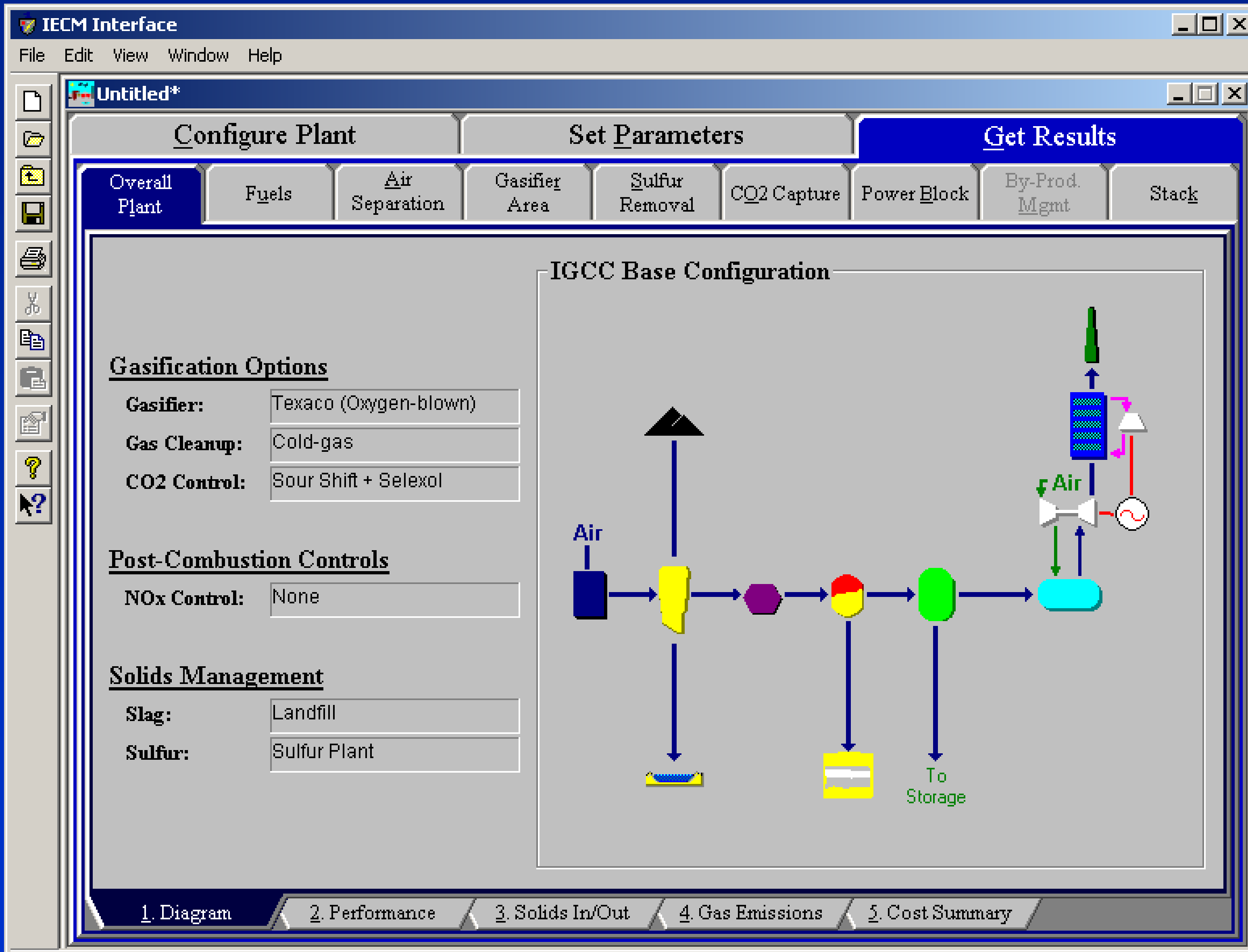
Configure Plant
Set Parameters
Get Results
Overall Plant
Fuel Properties
Air Separation
Gasifier Area
Sulfur Removal
CO2 Capture
Power Block
By-Prod. Mgmt
Stack
Current Fuel
Name: Illinois #6 (IGCC)
Rank: Bituminous
Source: model_default_fuels.mdb
Composition (wt% as fired) and Higher Heating Value (Btu/lb)
Tot %: 100.0
Property Value
1 Heating Value 1.090e+04
2 Carbon 61.25
3 Hydrogen 4.176
4 Oxygen 6.055
5 Chlorine 0.1740
6 Sulfur 3.254
7 Nitrogen 1.131
8 Ash 10.96
9 Moisture 13.00
10
11
Save For All...
Plant Types
Fuel Types
Save In Database
Use Default Ash Properties
View Ash Properties
Fuel Databases
Fuel: Appalachian Low Sulfur
Rank: Bituminous
Source: model_default_fuels.mdb (c:\documents ar
Show All Plant Types
Show All Fuel Types
Property Value
1 Heating Value 1.308e+04
2 Carbon 71.74
3 Hydrogen 4.620
4 Oxygen 6.090
5 Chlorine 7.000e-02
6 Sulfur 0.6400
7 Nitrogen 1.420
8 Ash 9.790
9 Moisture 5.630
10 Plant Type <Any>
11 Fuel Type Coal
Open Database
New Database
Use This Fuel
Delete This Fuel
View Ash Properties
Process Type: Fuel Properties
1. Properties
2. Cost



	Title	Units	Unc	Value	Calc	Min	Max	Default
1	Syngas Composition							
2	Carbon Monoxide (CO)	vol %		33.06	✓	0.0	100.0	calc
3	Hydrogen (H2)	vol %		28.27	✓	0.0	100.0	calc
4	Methane (CH4)	vol %		0.5096	✓	0.0	100.0	calc
5	Hydrogen Sulfide (H2S)	vol %		0.9648	✓	0.0	100.0	calc
6	Carbonyl Sulfide (COS)	vol %		5.120e-02	✓	0.0	100.0	calc
7	Ammonia (NH3)	vol %		8.301e-03	✓	0.0	100.0	calc
8	Hydrochloric Acid (HCl)	vol %		4.913e-02	✓	0.0	100.0	calc
9	Carbon Dioxide (CO2)	vol %		15.87	✓	0.0	100.0	calc
10	Moisture (H2O)	vol %		19.39	✓	0.0	100.0	calc
11	Nitrogen (N2)	vol %		0.6081	✓	0.0	100.0	calc
12	Argon (Ar)	vol %		1.152	✓	0.0	100.0	calc
13	Total	vol %		100.0	✓	0.0	100.0	calc
14								
15								
16								
17								
18								



IECM Interface
File
Edit
View
Window
Help
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Configure Plant
Set Parameters
Get Results
Overall Plant
Fuels
Air Separation
Gasifier Area
Sulfur Removal
CO2 Capture
Power Block
By-Prod. Mgmt
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Solids Management
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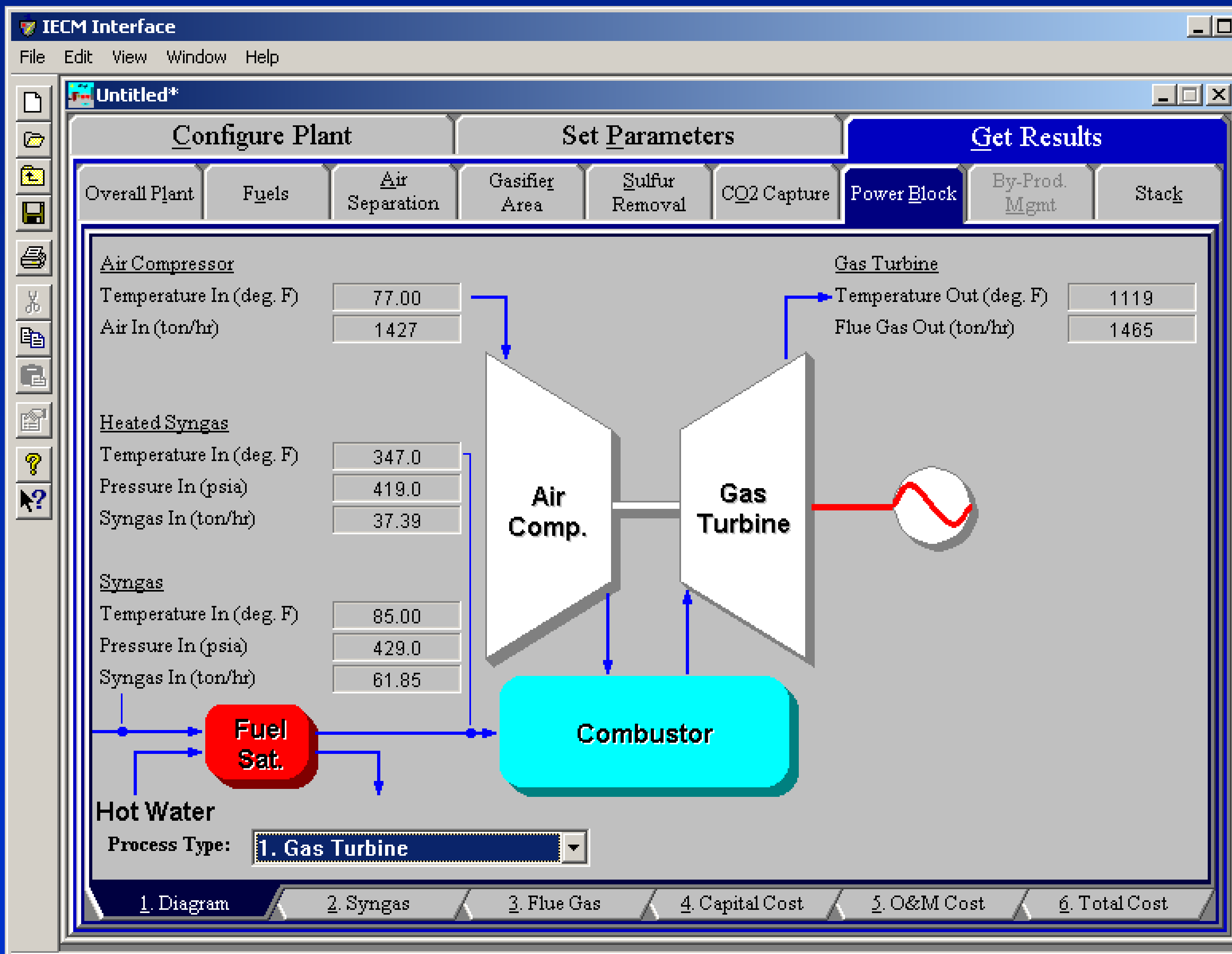
Landfill
Sulfur:
Sulfur Plant
Air
Air
To Storage
1. Diagram
2. Performance
3. Solids In/Out
4. Gas Emissions
5. Cost Summary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CO2 Capture
Power Block
By-Prod. Mgmt
Stack
Air Compressor
Temperature In (deg. F) 77.00
Air In (ton/hr) 1427
Heated Syngas
Temperature In (deg. F) 347.0
Pressure In (psia) 419.0
Syngas In (ton/hr) 37.39
Syngas
Temperature In (deg. F) 85.00
Pressure In (psia) 429.0
Syngas In (ton/hr) 61.85
Gas Turbine
Temperature Out (deg. F) 1119
Flue Gas Out (ton/hr) 1465
Air Comp.
Gas Turbine
Combustor
Fuel Sat.
Hot Water
Process Type: 1. Gas Turbine
1. Diagram
2. Syngas
3. Flue Gas
4. Capital Cost
5. O&M Cost
6. Total Cost

IECM Interface

File Edit View Window Help

Untitled*

Configure Plant | Set Parameters | **Get Results**

Overall Plant | Fuels | Air Separation | Gasifier Area | Sulfur Removal | CO2 Capture | **Power Block** | By-Prod. Mgmt | Stack

	Gas Turbine System	Direct Capital Costs (M$)
1	Gas Turbine	32.00
2	Heat Recovery Steam Generator	7.485
3	Steam Turbine	21.94
4	HRSG Feedwater System	2.201
5		
6		
7		
8		
9		
10		
11	Process Facilities Capital	63.63
12		
13		
14		
15		

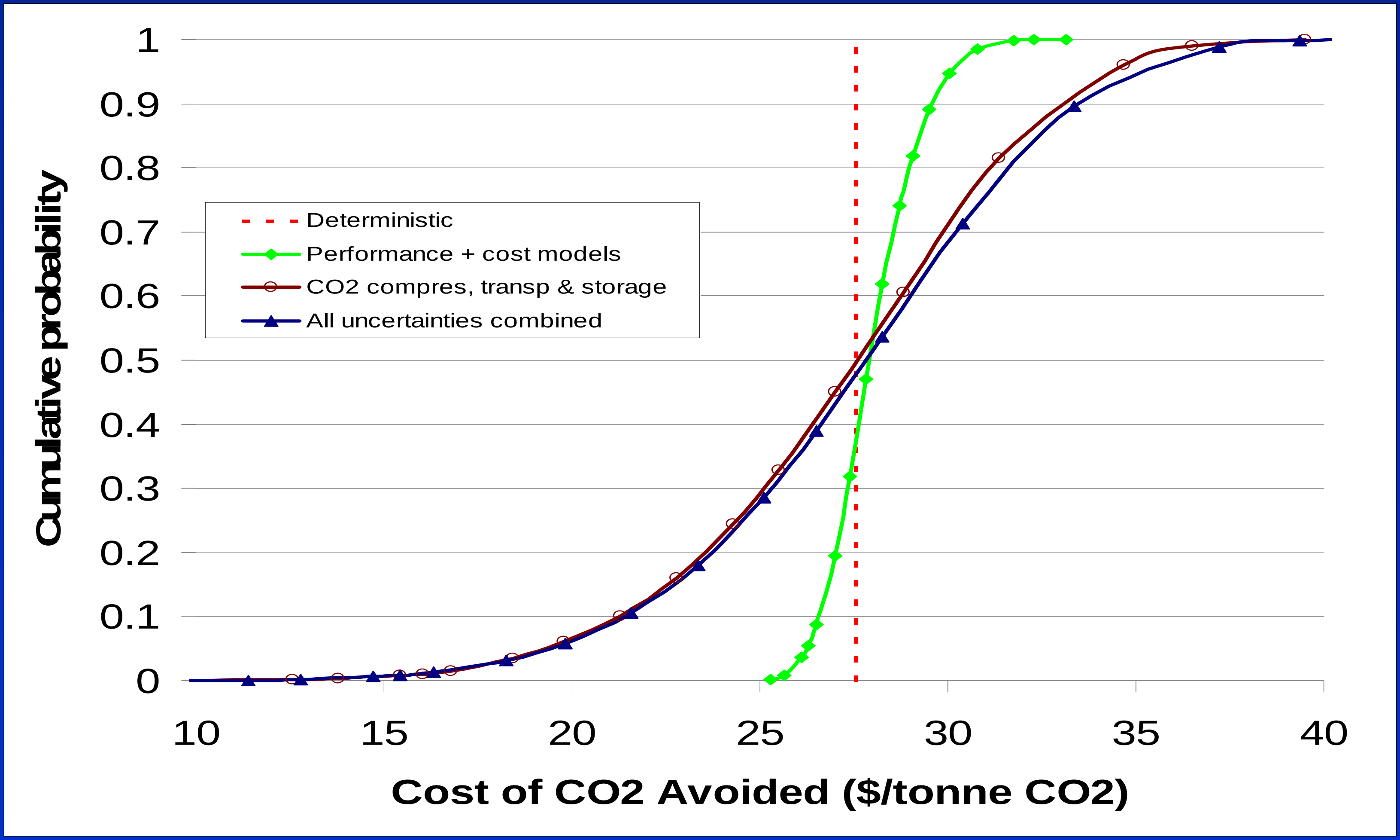
	Gas Turbine System	Indirect Capital Costs (M$)
1	Process Facilities Capital	63.63
2	General Facilities Capital	6.363
3	Eng. & Home Office Fees	6.363
4	Project Contingency Cost	9.544
5	Process Contingency Cost	4.736
6	Interest Charges (AFUDC)	9.656
7	Royalty Fees	0.3181
8	Preproduction (Startup) Cost	2.310
9	Inventory (Working) Capital	0.4532
10	Total Capital Requirement (TCR)	103.4
11		
12		
13		
14		
15	Effective TCR	103.4

Process Type: 1. Gas Turbine

Costs are in Constant 2000 dollars.

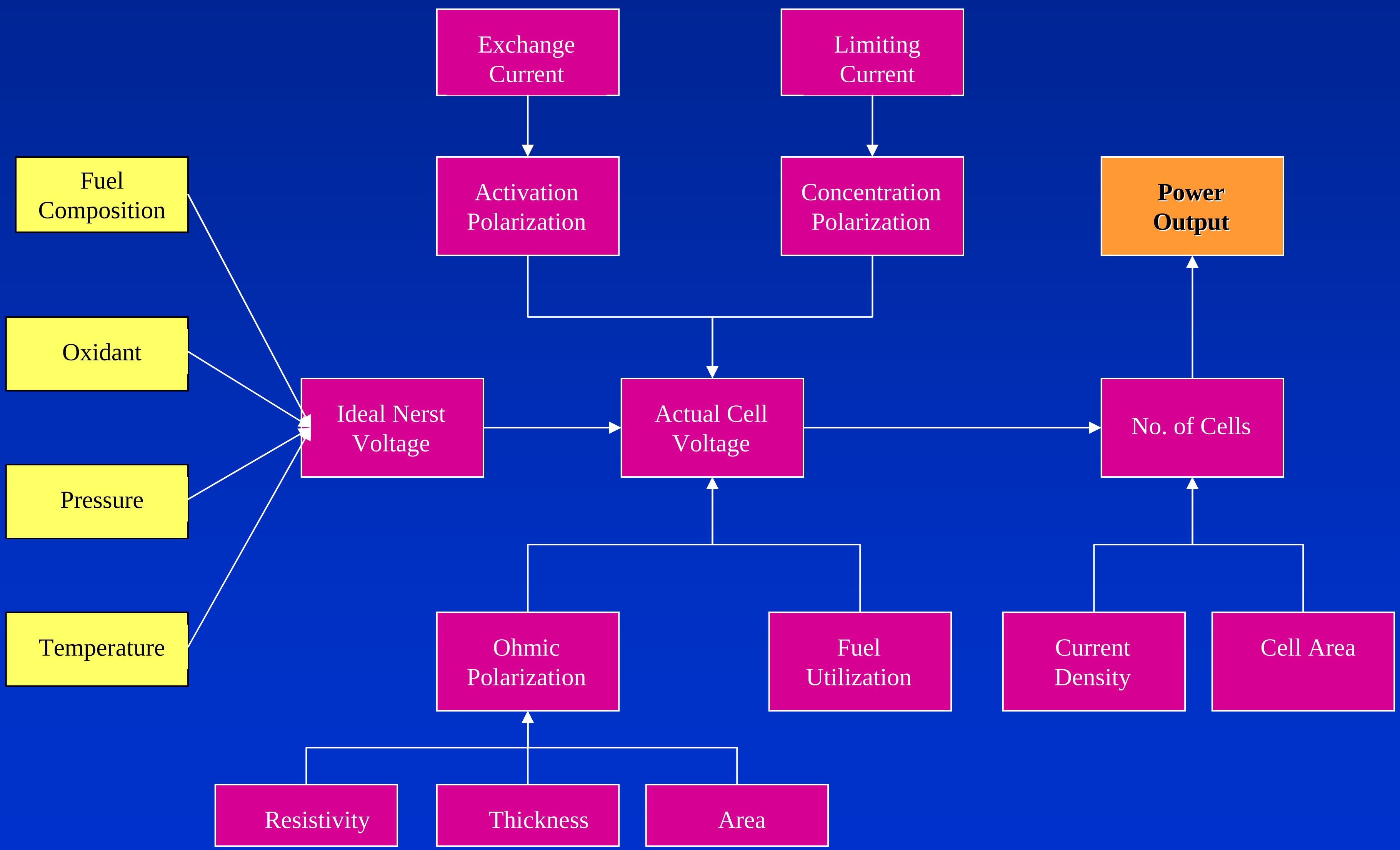
1. Diagram | 2. Syngas | 3. Flue Gas | **4. Capital Cost** | 5. O&M Cost | 6. Total Cost

Case Study Results for Cost of CO_2 Avoided

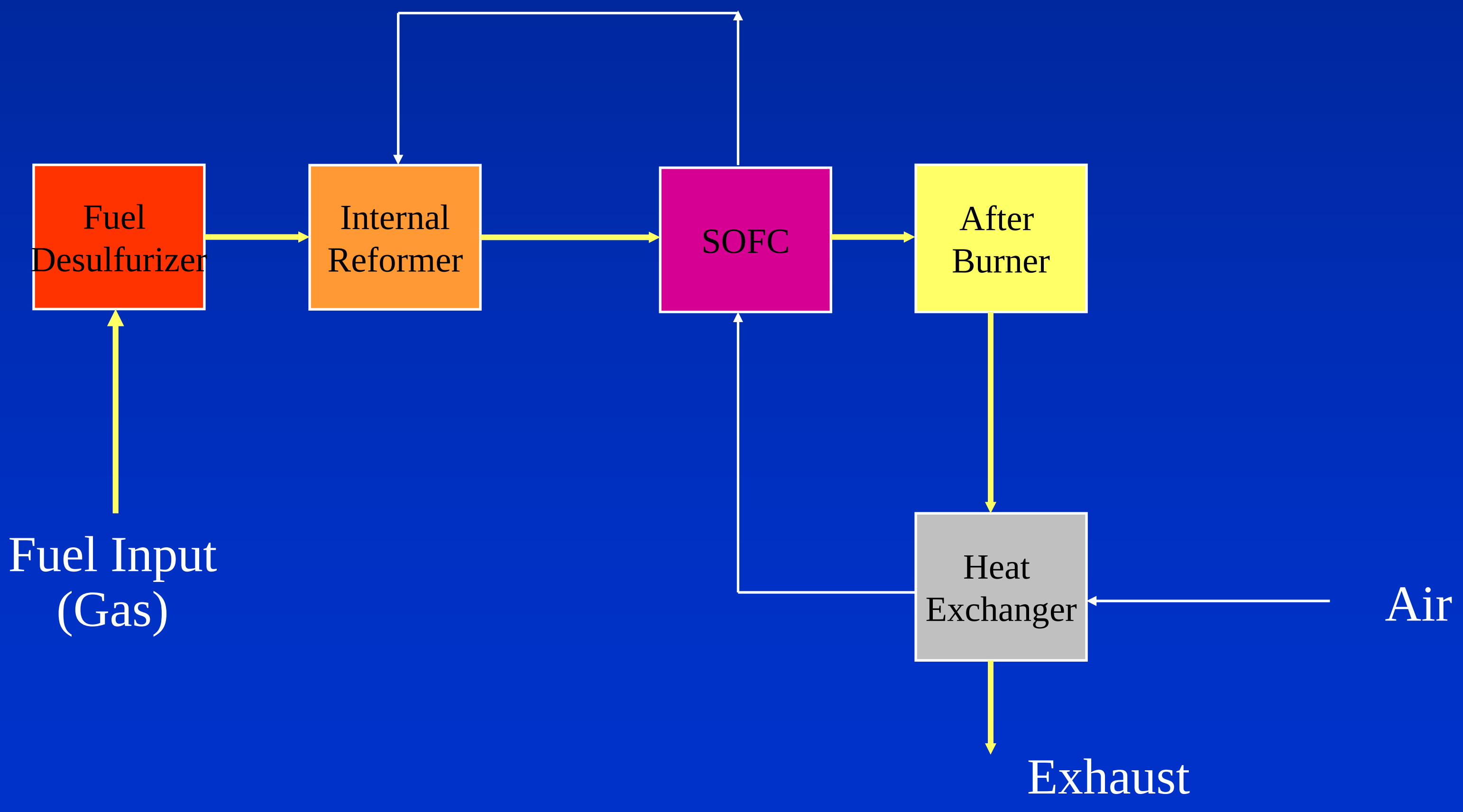


Coming Soon . . .

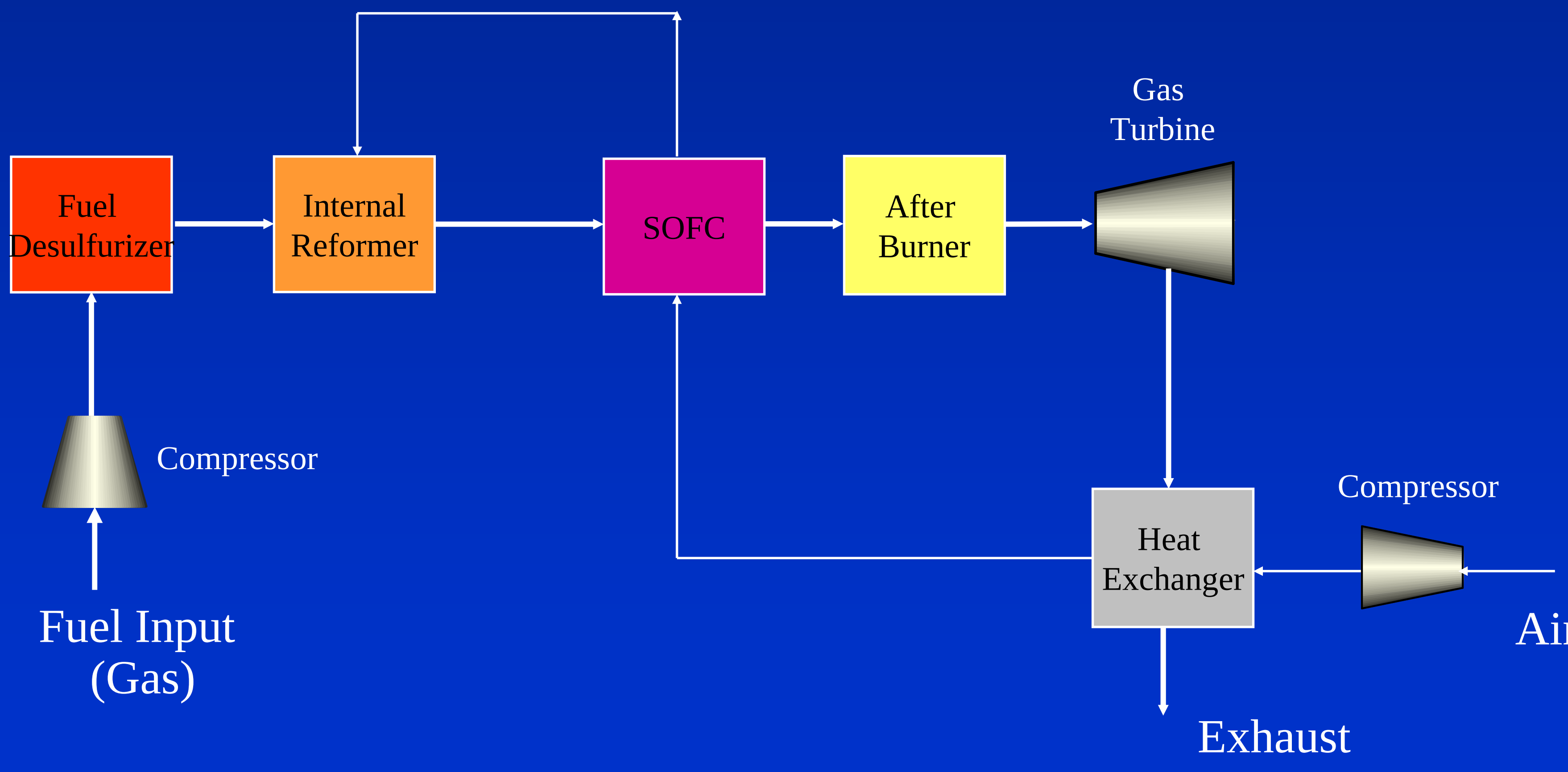
Solid Oxide Fuel Cell Model



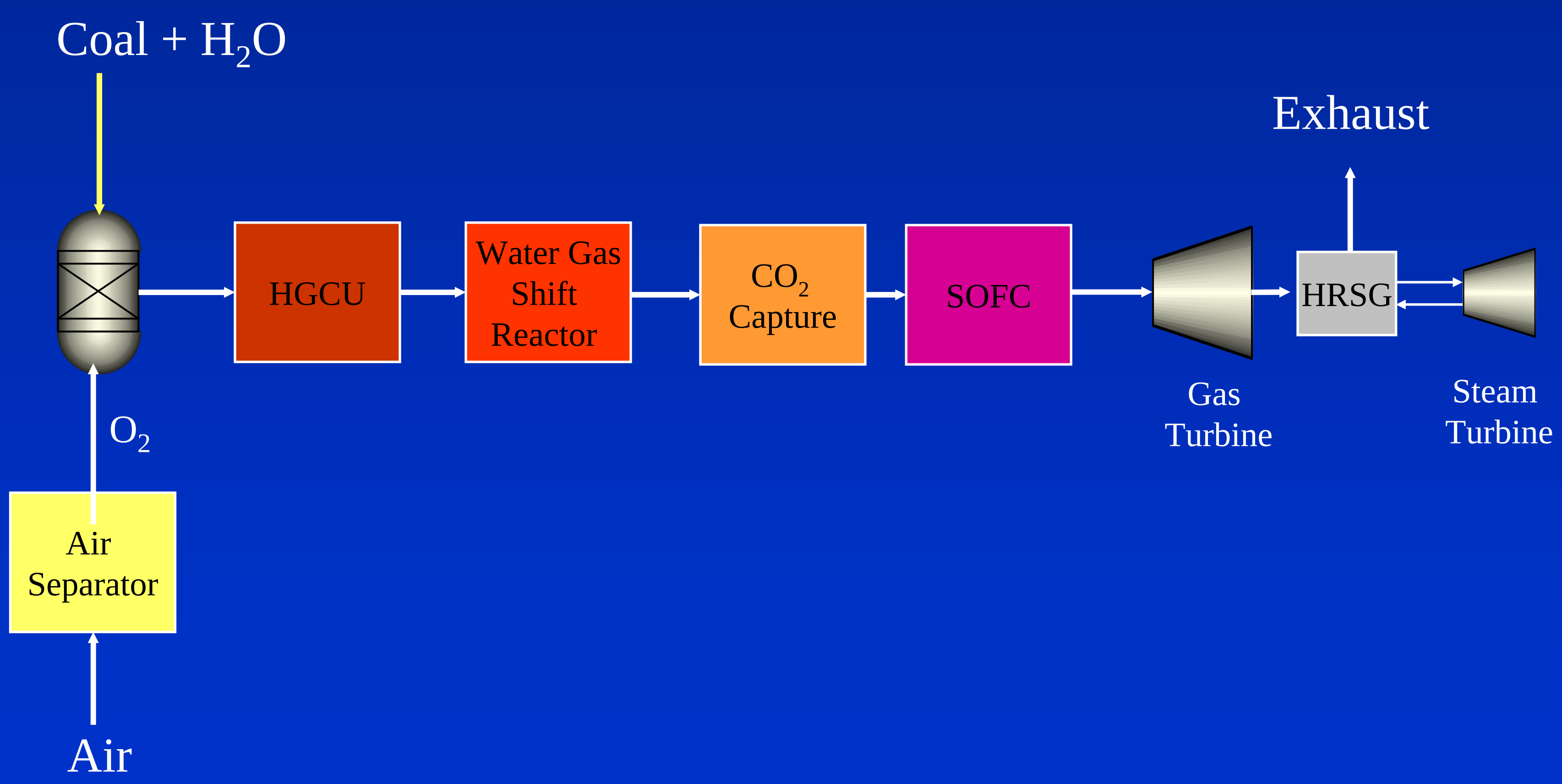
Stand-Alone Fuel Cell Plant



Fuel Cell – Gas Turbine Hybrid

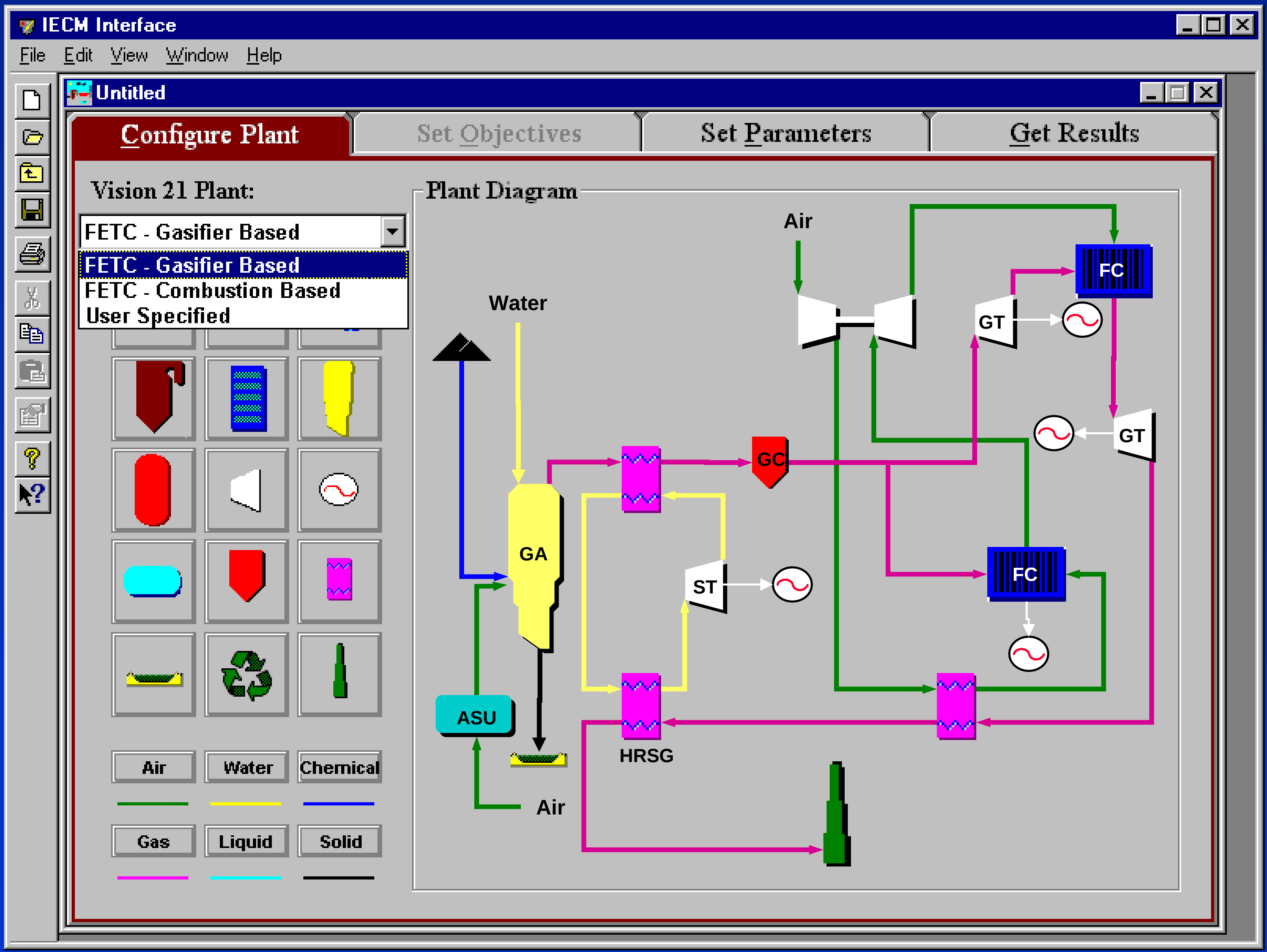


Gasification + Fuel Cell Plant

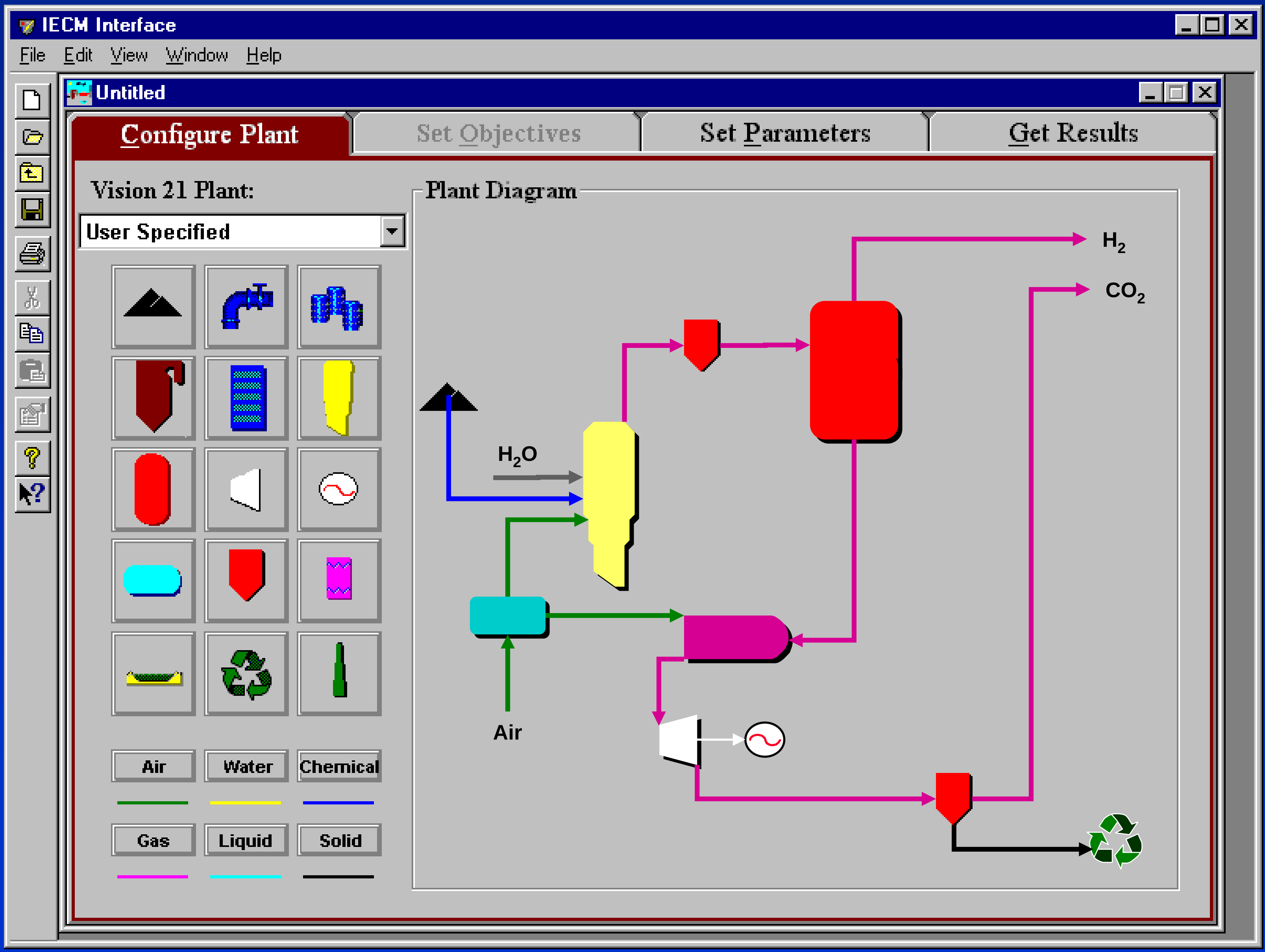


Coming Later . . .

Other Vision 21 Flowsheets



Configure a New System



Looking Ahead

- Finish implementing and testing prototype V21P model (including SOFC); distribute for beta testing and user feedback
- Continue to develop and improve modeling of:
  - Individual plant components (Performance/Cost)
  - Interactions and integration across components
- Develop "seamless" linkages with higher-level models
  - CFD models of key components (e.g., gasifiers)
  - Virtual Engineering simulation of an entire plant