

The Integrated Environmental Control Model (IECM)

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July 20, 1999

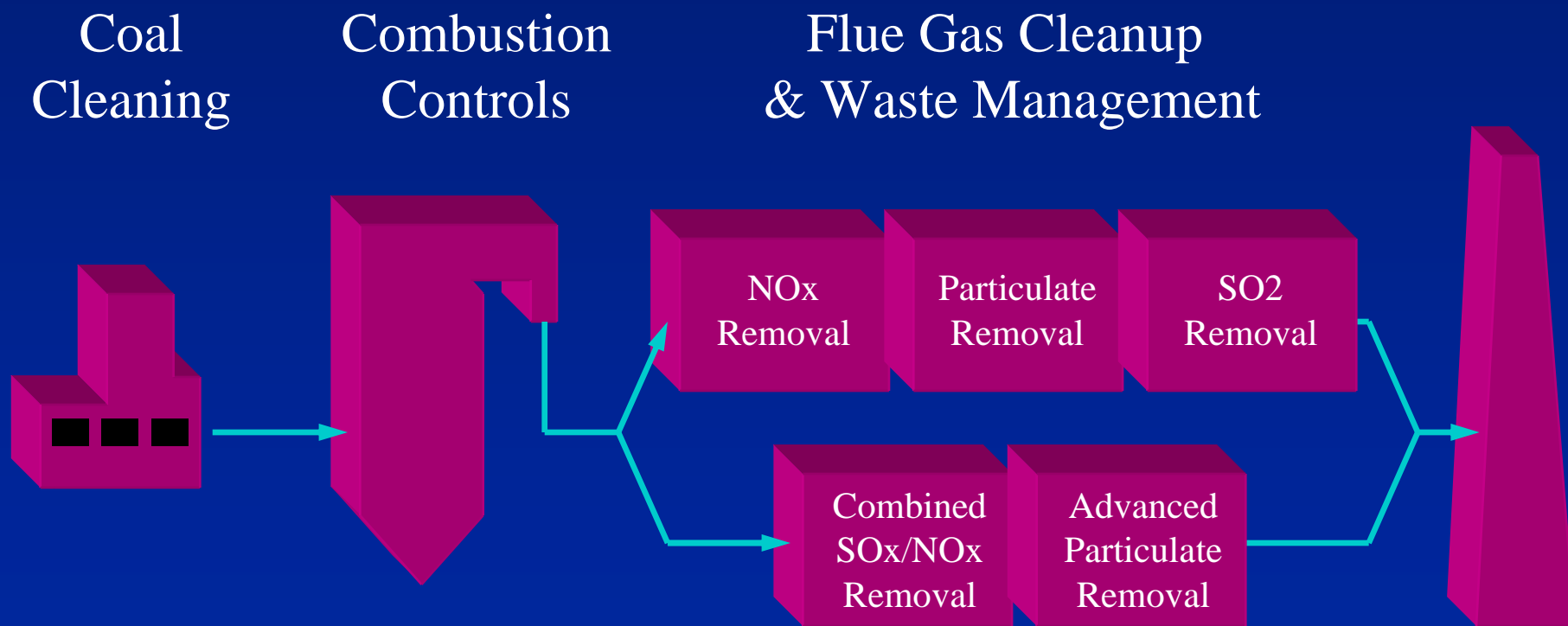
Objectives

- Develop reliable and easy-to-use models to estimate the environmental performance and cost of conventional and advanced technologies to produce electricity from coal
- Develop a framework for comparing alternative options on a systematic basis, including the effects of uncertainty

Approach

- Process Technology Models
- Engineering Economic Models
- Advanced Software Capabilities
- Systems Analysis Framework

Integrated Environmental Control Model (IECM)



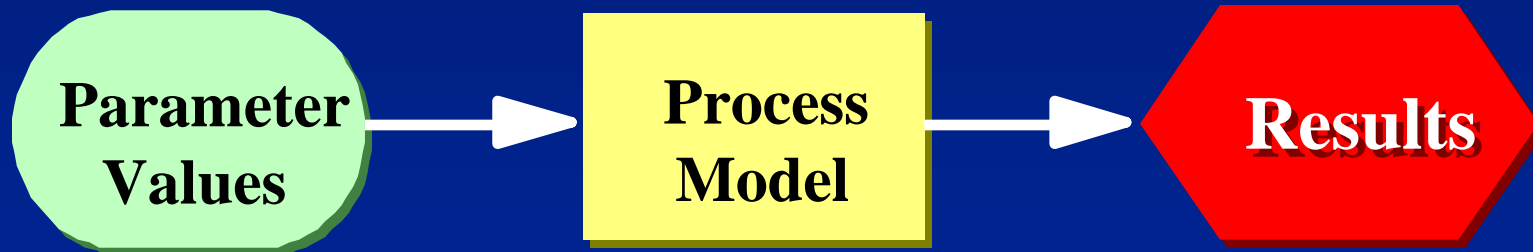
Process Performance Models

- Employ detailed mass and energy balances
- Empirical relationships and models used for complex process chemistry
- Calculate component and system mass flows, energy flows, and efficiency
- Calculate multi-media environmental emissions
- Approximately 10-20 performance parameters for each process technology

Process Cost Models

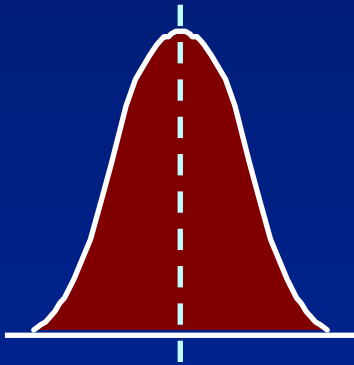
- Direct cost models for each major process area (typically 5-10 areas per technology)
- Explicit links to process performance models
- Calculate total capital cost
- Calculate variable operating costs
- Calculate fixed operating costs
- Calculate annualized cost of electricity
- Approximately 20-30 cost parameters for each process technology

Conventional Process Modeling (Deterministic Simulation)

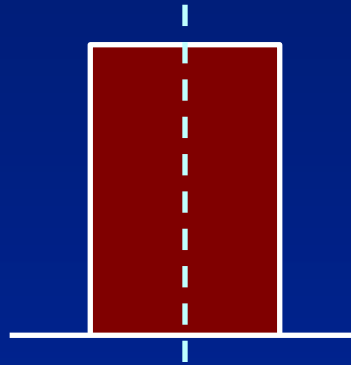


Parameter Uncertainty Distributions

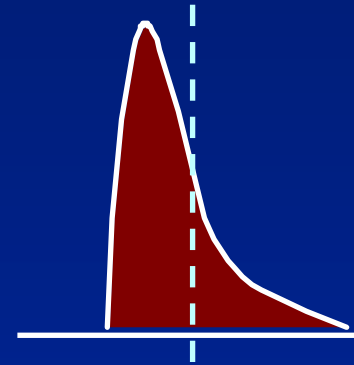
NORMAL



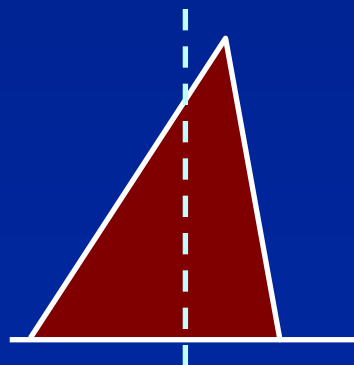
UNIFORM



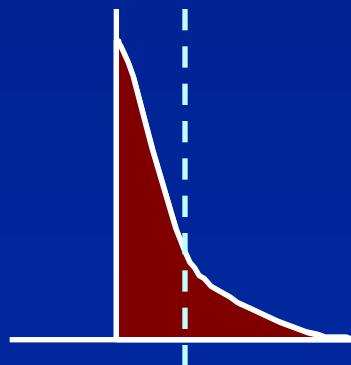
LOGNORMAL



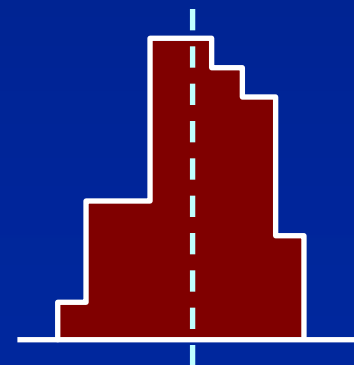
TRIANGULAR



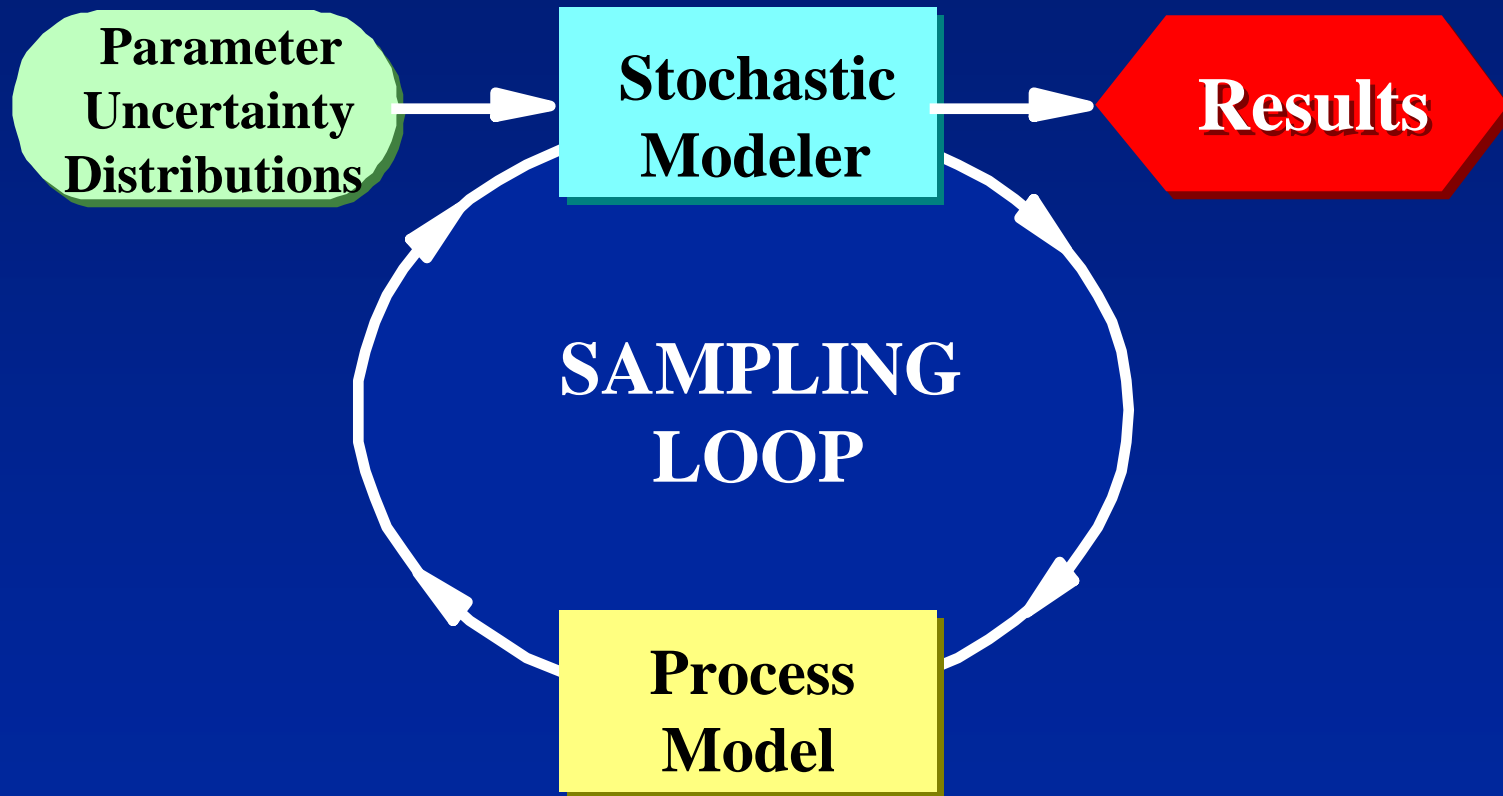
BETA



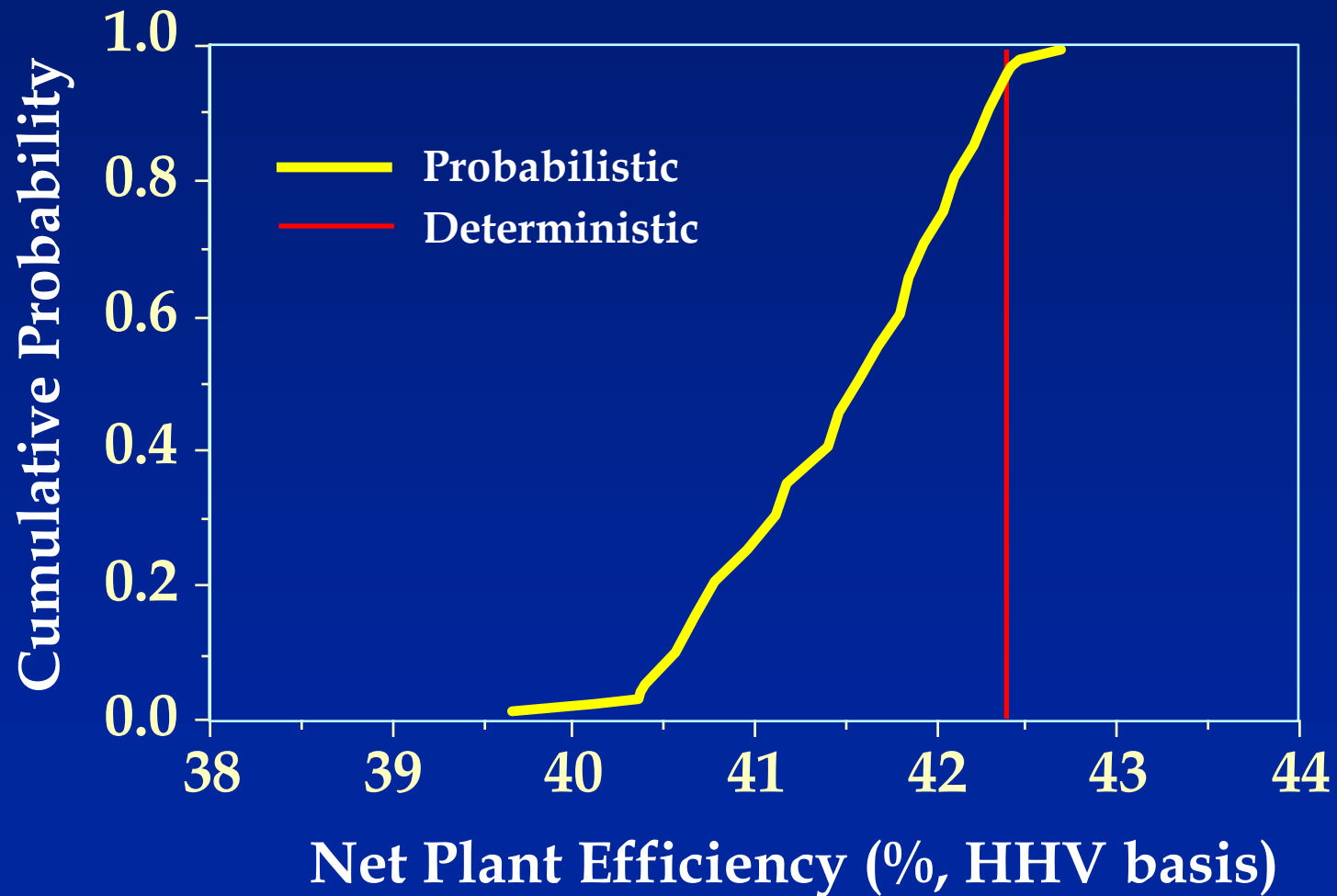
FRACTILE



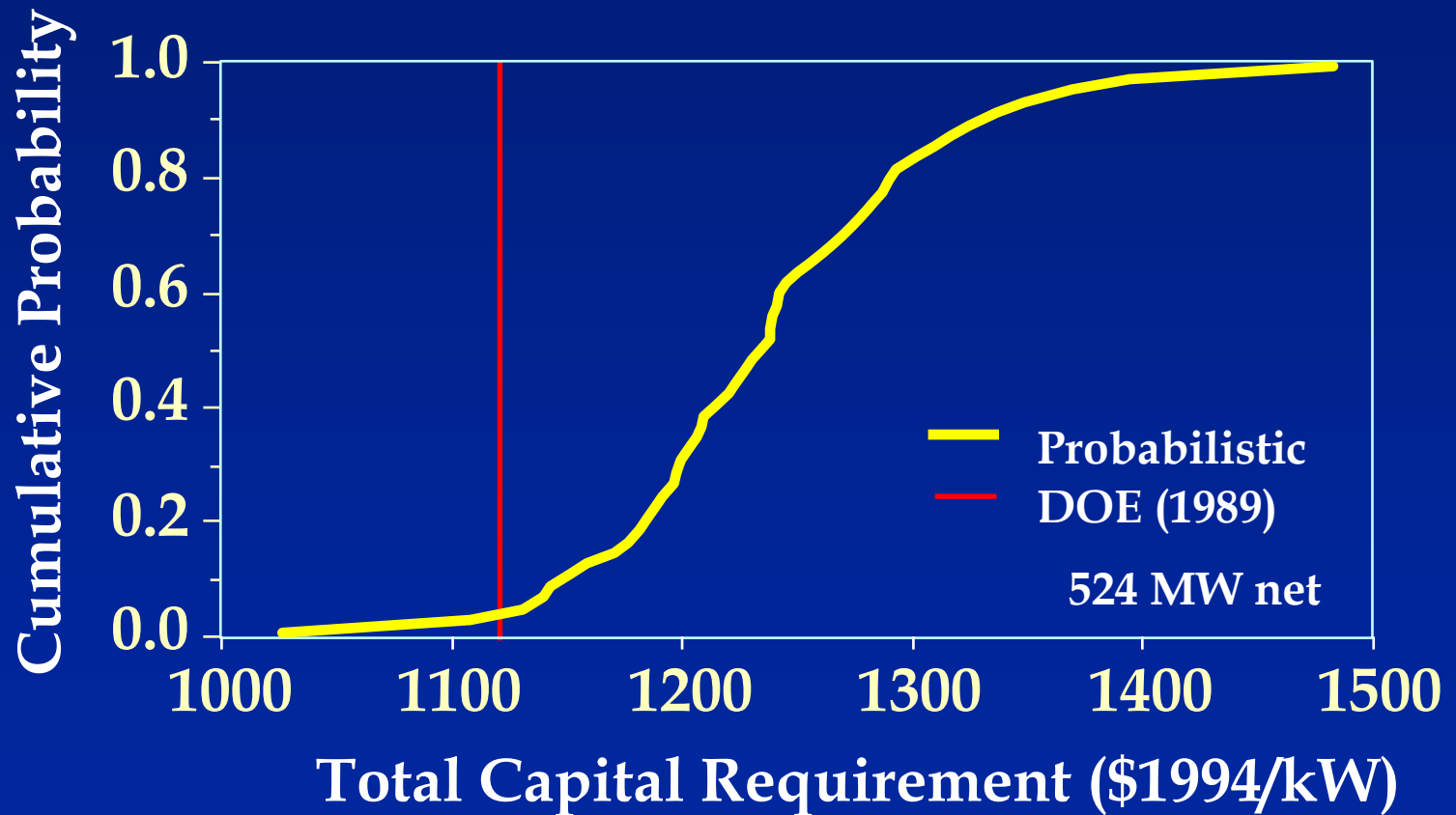
Stochastic Simulation



Calculated Plant Efficiency



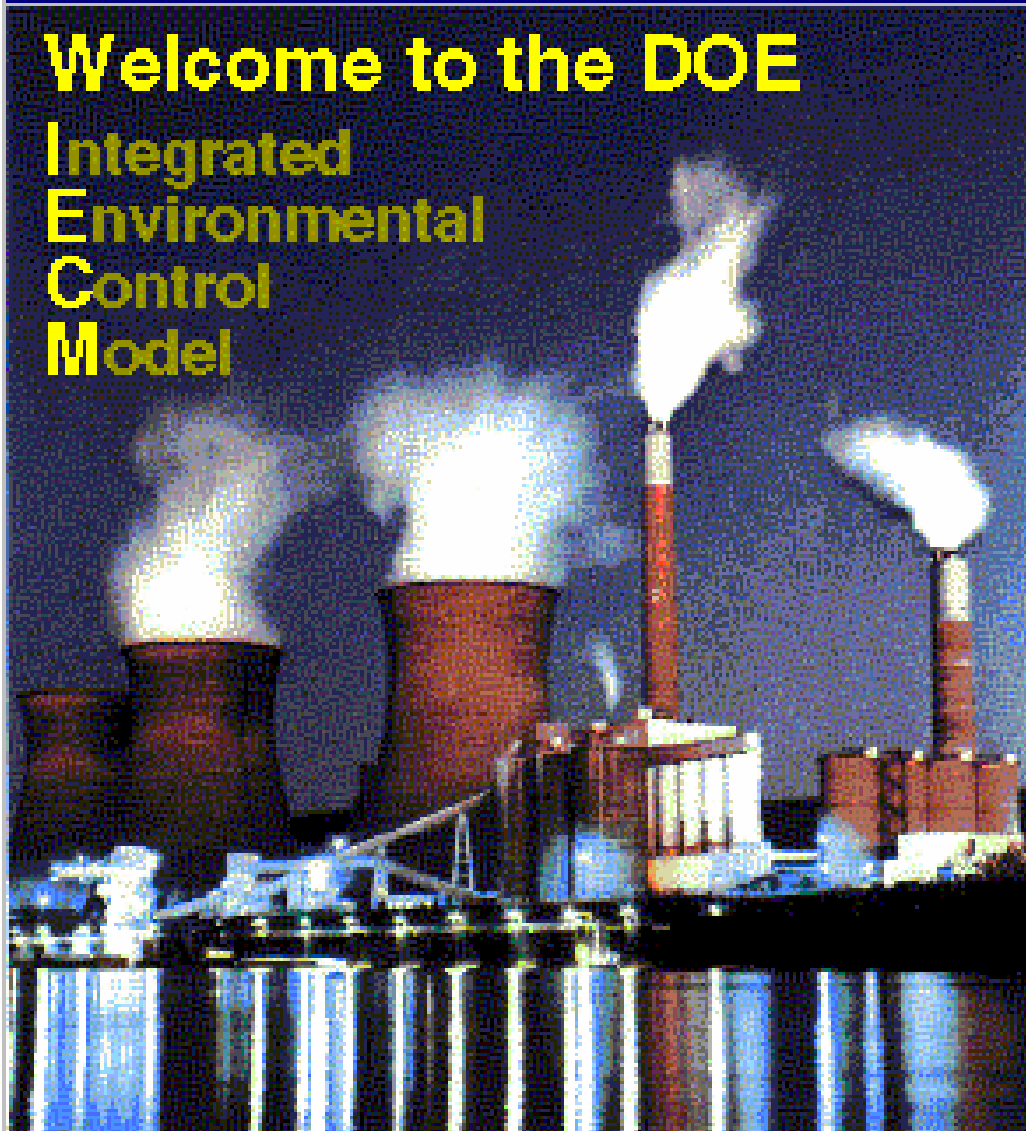
Total Plant Capital Cost



About the IECM Interface



Welcome to the DOE Integrated Environmental Control Model



IECM 3.1 ©1999, Carnegie Mellon University

IECM Interface 3.1 ©1999, Carnegie Mellon University

(live demo of the IECM)

The IECM is Now Available for Downloading by the Public

- **Web Access:**

- <ftp://ftp.fetc.doe.gov/pub/IECM>

- **FTP Access:**

- <ftp.fetc.doe.gov/pub/IECM>

- anonymous login

- any password

Additional Technology Options

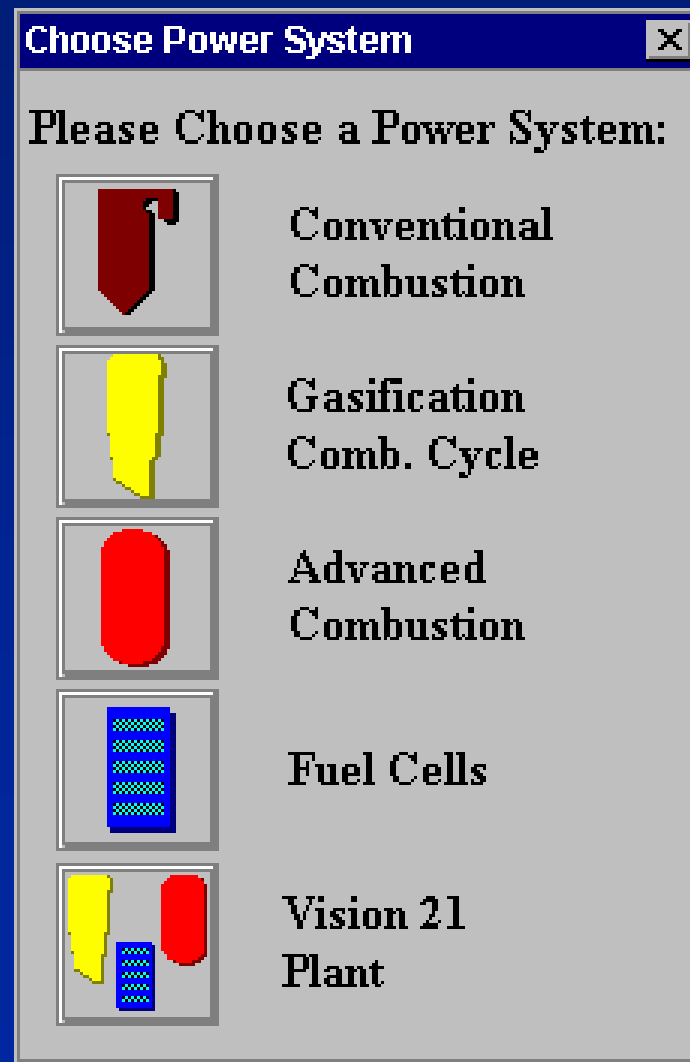
● *Planned*

- Combustion NO_x Controls
 - Selective Non-Catalytic Reduction (SNCR)
 - Low NO_x Burners
 - Overfire air
 - Low Excess Air
 - Lean Gas Reburn
 - Burners Out of Service
 - Selected combinations of the above

● *Proposed*

- Post-Combustion Controls
 - Air Toxics (mercury)
- Other Fuels
 - Natural Gas
 - Petroleum
 - Fuel Blending
- Alternative Power Generation Systems

Future Development: A Menu of Technology Options

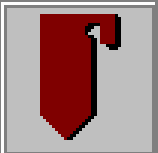
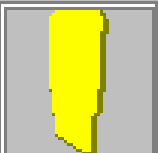
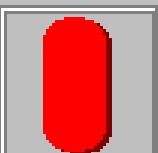
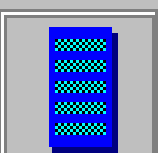
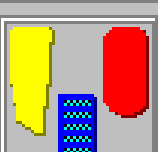


Select Gasification Combined Cycle (IGCC) Options



Choose Power System [X]

Please Choose a Power System:

	Conventional Combustion
	Gasification Comb. Cycle
	Advanced Combustion
	Fuel Cells
	Vision 21 Plant

Select KRW Gasifier

IECM Interface

File Edit View Window Help

Untitled

Configure Plant Set Objectives Set Parameters Get Results

Goal: Optimization

Gasification Options

Gasifier: KRW

Oxidant: KRW

Gas Cleanup: Lurgi
Texaco

Post-Combustion Controls

NOx Control: None

Solids Management

Slag: Landfill

Sulfur: Landfill

Plant Diagram

Ready NUM

Select Oxygen Plant

IECM Interface

File Edit View Window Help

Untitled

Configure Plant Set Objectives Set Parameters Get Results

Goal: Optimization

Gasification Options

Gasifier: KRW

Oxidant: Oxygen

Gas Cleanup: Air
Oxygen

Post-Combustion Controls

NOx Control: None

Solids Management

Slag: Landfill

Sulfur: Landfill

Plant Diagram

Ready NUM

Select Cold Gas Cleanup

IECM Interface

File Edit View Window Help

Untitled

Configure Plant Set Objectives Set Parameters Get Results

Goal: Optimization

Gasification Options

Gasifier: KRW

Oxidant: Oxygen

Gas Cleanup: Cold

Post-Combustion: Cold

NOx Control: None

Solids Management

Slag: Landfill

Sulfur: Landfill

Plant Diagram

The plant diagram illustrates a gasification process. It starts with a feedstock input (blue cylinder) entering a yellow gasifier. The gasifier has a slag outlet (yellow box) and a gas outlet (yellow cylinder). The gas then passes through a red gas cleanup unit, which has a gas outlet (pink cylinder) and a solid outlet (grey box). The gas then goes through a green power generation unit, which has a gas outlet (green cylinder) and a solid outlet (red circle with 'S'). The gas then passes through a blue condenser, which has a gas outlet (green cylinder) and a liquid outlet (green cylinder). The liquid then goes through a green separator, which has a gas outlet (green cylinder) and a solid outlet (red circle with 'S').

Ready NUM

Select NO_x Control

IECM Interface

File Edit View Window Help

Untitled

Configure Plant Set Objectives Set Parameters Get Results

Goal: Optimization

Gasification Options

Gasifier: KRW

Oxidant: Oxygen

Gas Cleanup: Cold

Post-Combustion

NO_x Control: SCR
None
SCR

Solids Management

Slag: Landfill

Sulfur: Landfill

Plant Diagram

The plant diagram illustrates a gasification process. It starts with a feed stream entering a yellow gasifier. From the gasifier, a gas stream goes to a red gas cleanup unit, and a solid stream goes to a yellow slag handling unit. The gas then passes through a pink shift reactor, a grey compressor, and a green gas turbine. The gas turbine exhausts to a blue heat exchanger, which then feeds into a green condenser. The condenser produces a liquid stream and a gas stream that goes to a sulfur recovery unit (S). The sulfur recovery unit produces a sulfur product and a gas stream that goes to a final gas turbine. The final gas turbine exhausts to a stack.

Ready NUM

Select Byproduct Recovery

IECM Interface

File Edit View Window Help

Untitled

Configure Plant Set Objectives Set Parameters Get Results

Goal: Optimization

Gasification Options

Gasifier: KRW

Oxidant: Oxygen

Gas Cleanup: Hot

Post-Combustion Controls

NOx Control: SCR

Solids Management

Slag: Landfill

Sulfur: Sulfur
Landfill
Sulfur
Sulfuric Acid

Plant Diagram

The plant diagram illustrates a gasification process. It starts with a blue gasifier on the left, which feeds into a yellow gas cleanup unit. From there, the gas flows to a red gasifier, then to a pink gas cleanup unit. The gas then passes through a grey gasifier, a green gas cleanup unit, and finally to a sulfur recovery unit (S) on the right. The sulfur recovery unit produces sulfur (S) and sulfuric acid (H2SO4). The diagram also shows a black triangle representing a stack, a blue gasifier, a yellow gas cleanup unit, a red gasifier, a pink gas cleanup unit, a grey gasifier, a green gas cleanup unit, and a sulfur recovery unit (S). A green recycling symbol is shown below the pink gas cleanup unit, indicating a byproduct recovery stream.

Ready NUM

Set Process Parameters

IECM Interface

File Edit View Window Help

Untitled

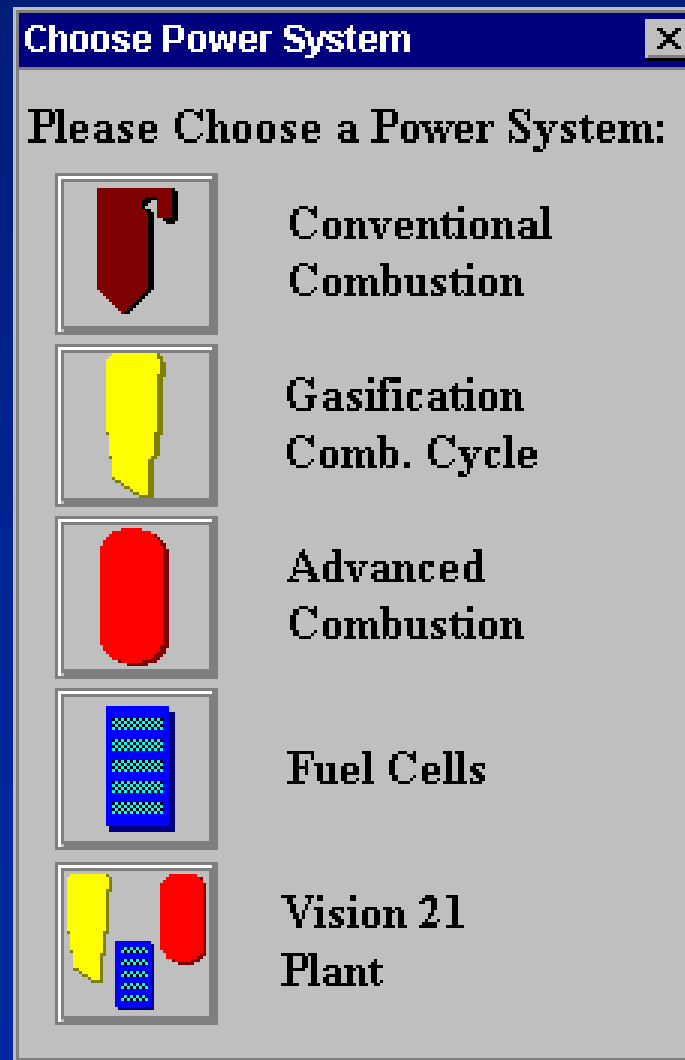
Configure Plant **Set Parameters** Get Results

Overall Plant Coal Properties **IGCC** Furnace Factors Emission Constraints NOx Control Particulate Control SO2 Control Solid Waste Mgmt

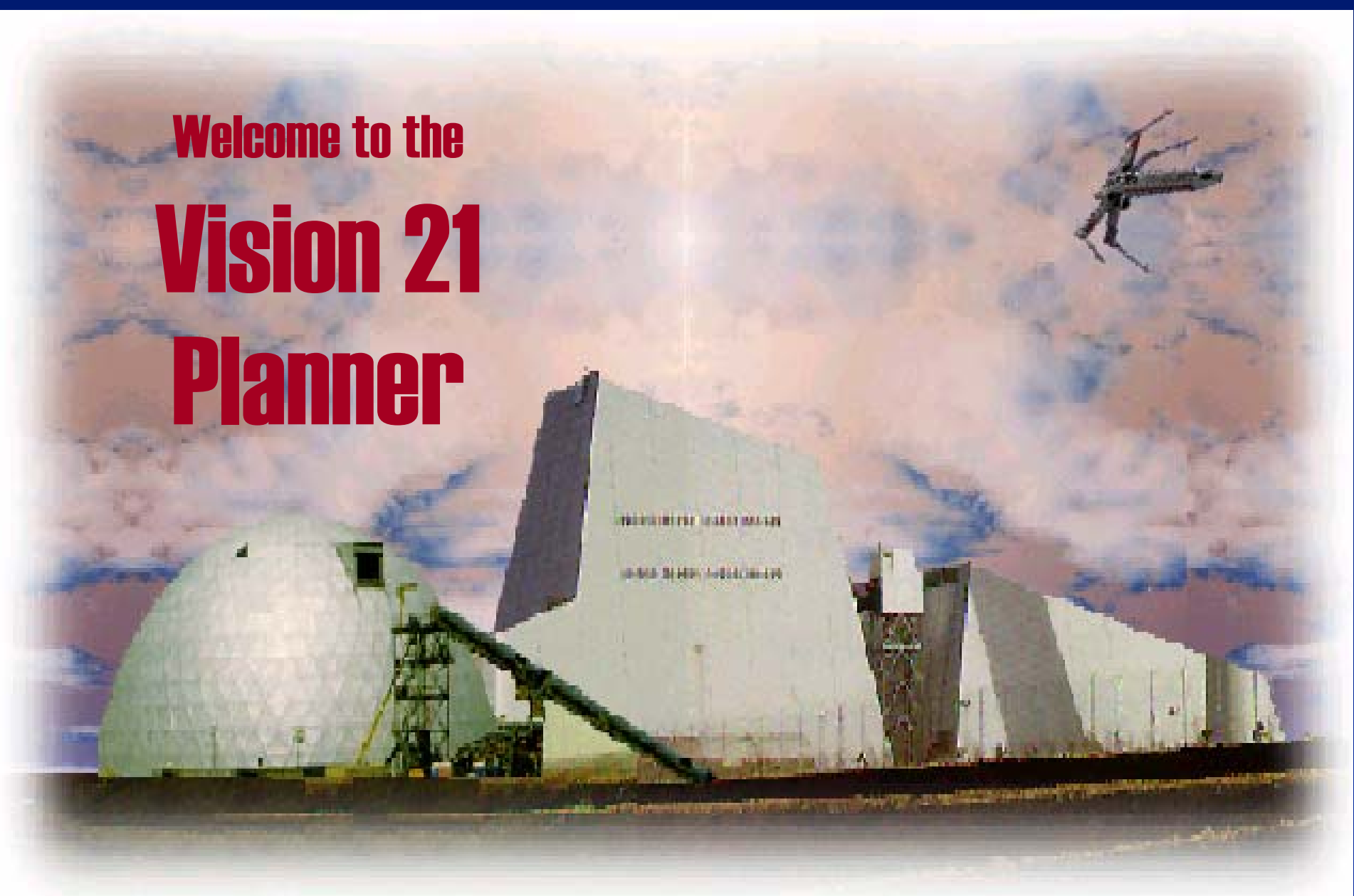
	Title	Units	Unc	Value	Calc	Min	Max	Default	DV
1	<u>Gasifier Design</u>								
2	Gasifier Carbon Conversion	%		95.0		90.0	98.0	95.0	
3	Gasifier Oxygen to Carbon Ratio	mol O2 / mol C		0.46		0.45	0.47	0.46	
4	Gasifier Steam to Carbon Ratio	mol H2O / mol C		0.46		0.445	0.455	0.46	
5	Coal-bound N Converted to NH3	%		10.0		5.0	15.0	10.0	
6	Sulfur Retained in Gasifier Bot Ash	%		90.0		80.0	95.0	90.0	
7									
8	<u>Emissions Control</u>								
9	Calcium to Sulfur Ratio	mol Ca / mol C		2.60		2.10	3.00	2.60	
10	Sulfation Unit Conversion	%		95.0		90.0	98.0	95.0	
11	NH3 Converted to NOx in Turbine	%		90.0		50.0	90.0	90.0	
12	SCR NOx Removal Efficiency	%		80.0		50.0	90.0	80.0	
13	SCR NH3 Slip	ppmw		10.0		5.0	20.0	10.0	
14									
15									
16									
17									
18									

1. Performance 2. Financing 3. Retrofit Cost 4. Capital Cost 5. O&M Cost 6. O&M Escalation

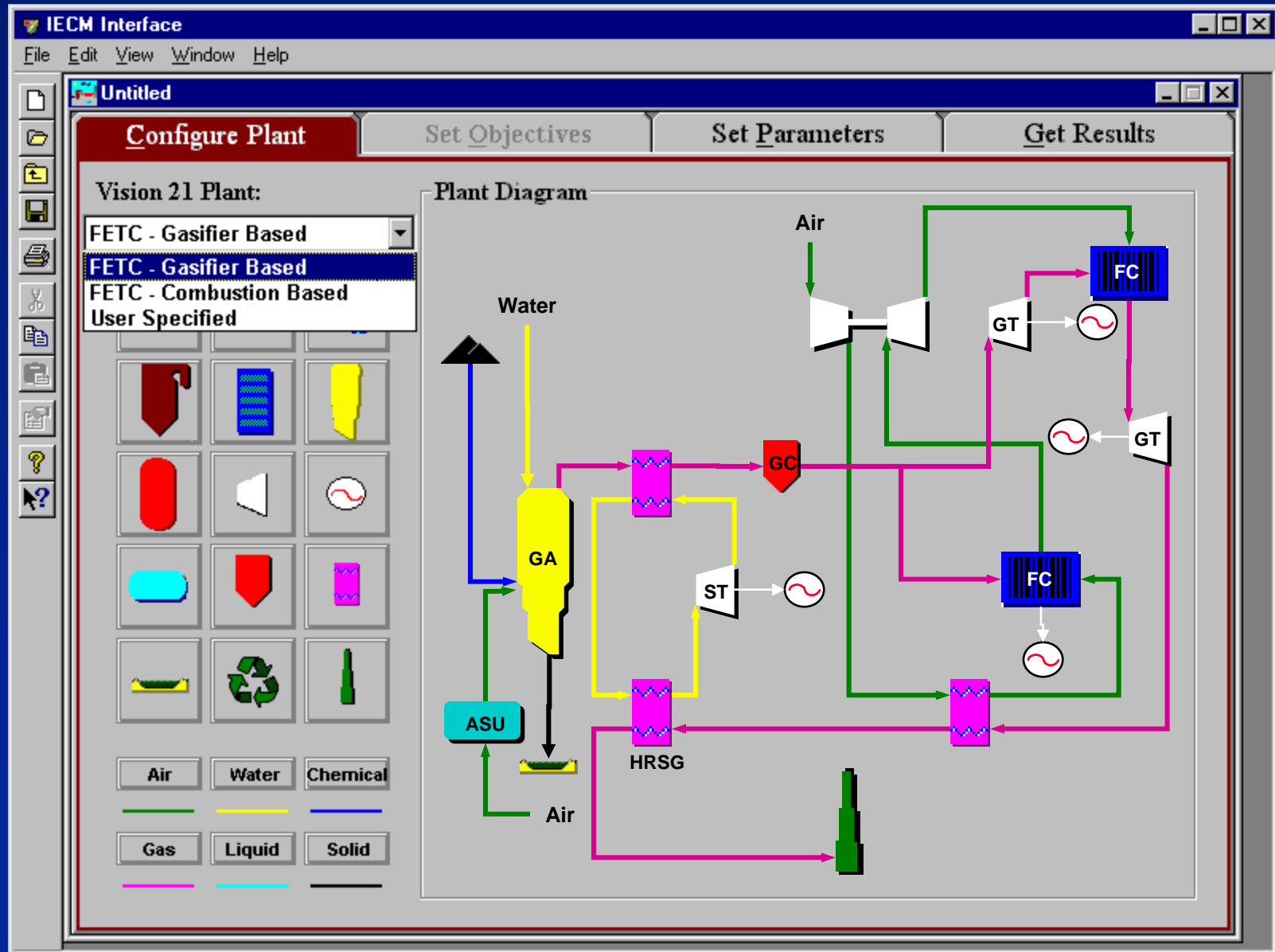
Open Vision 21 Plant Options



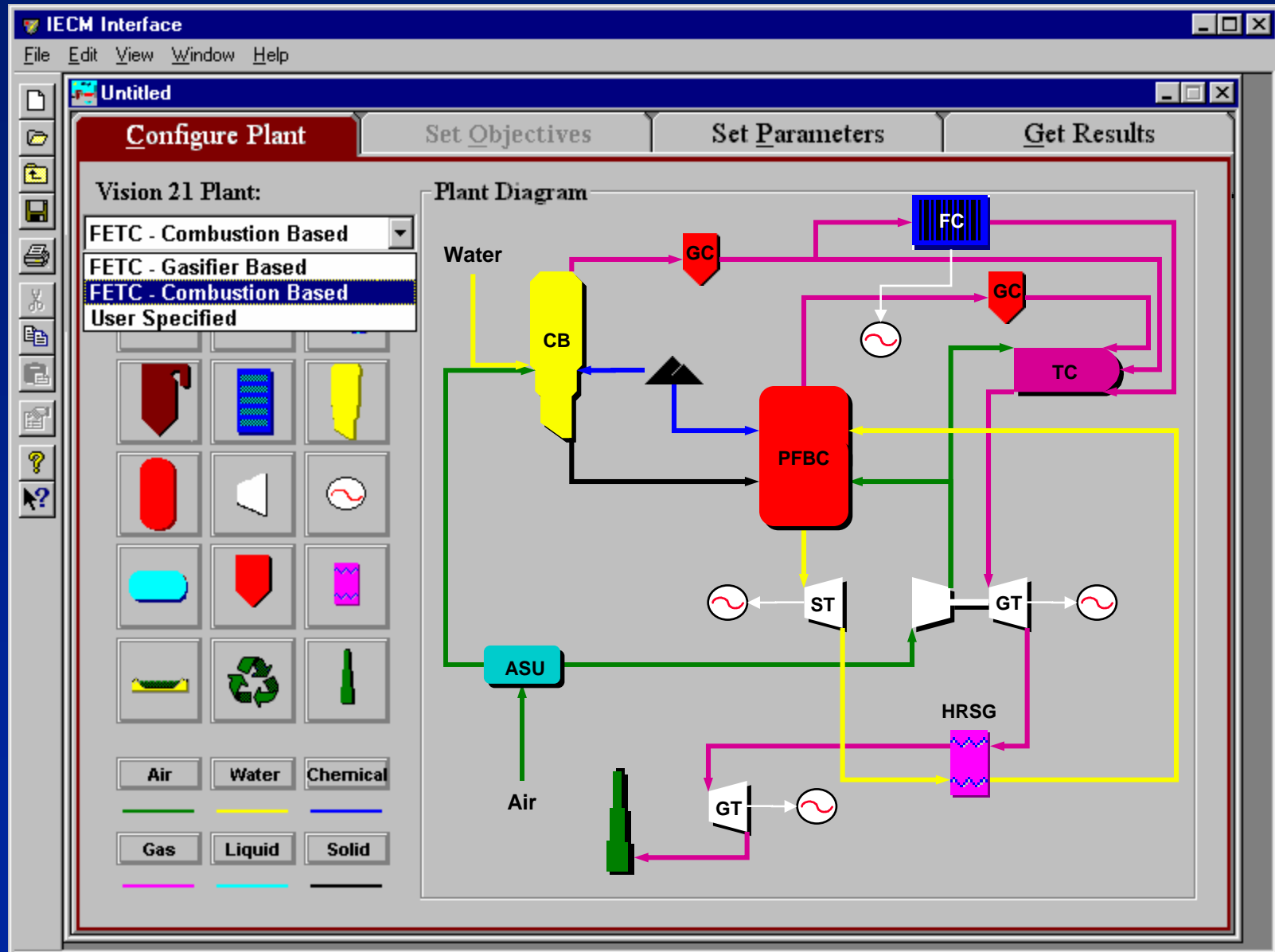
Welcome to the
**Vision 21
Planner**



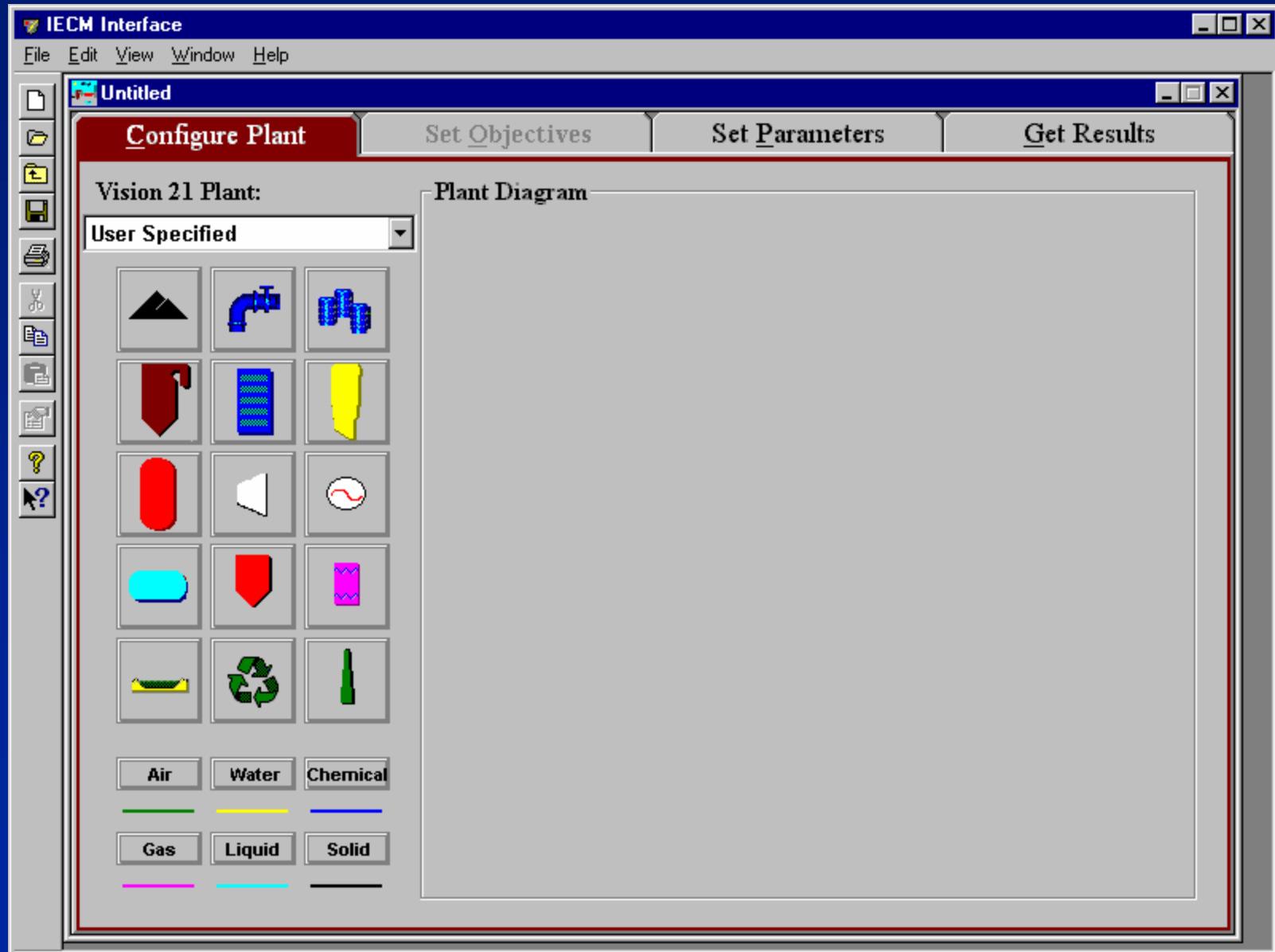
Select Existing Flowsheet - 1



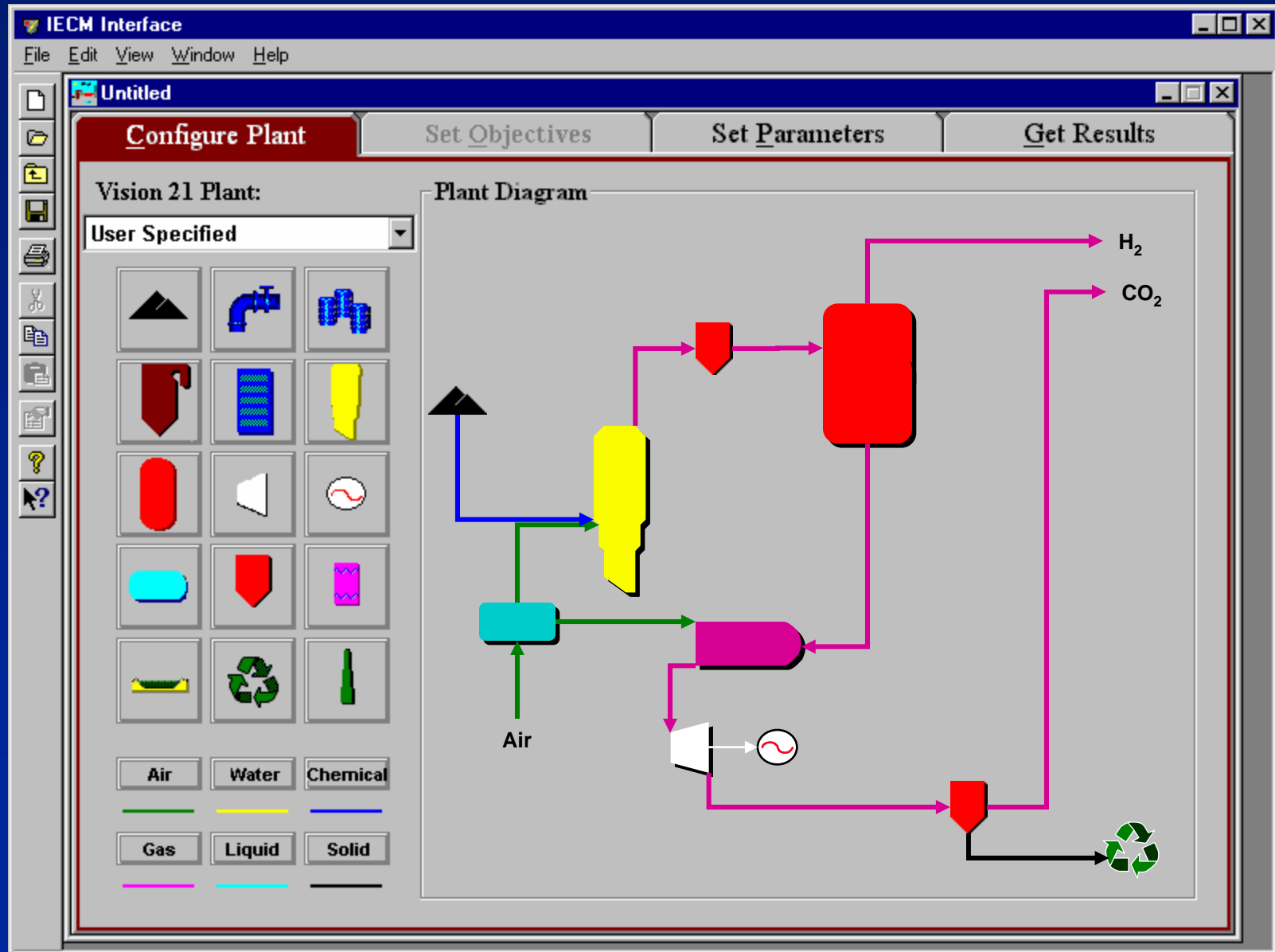
Select Existing Flowsheet - 2



Vision 21 Workbench



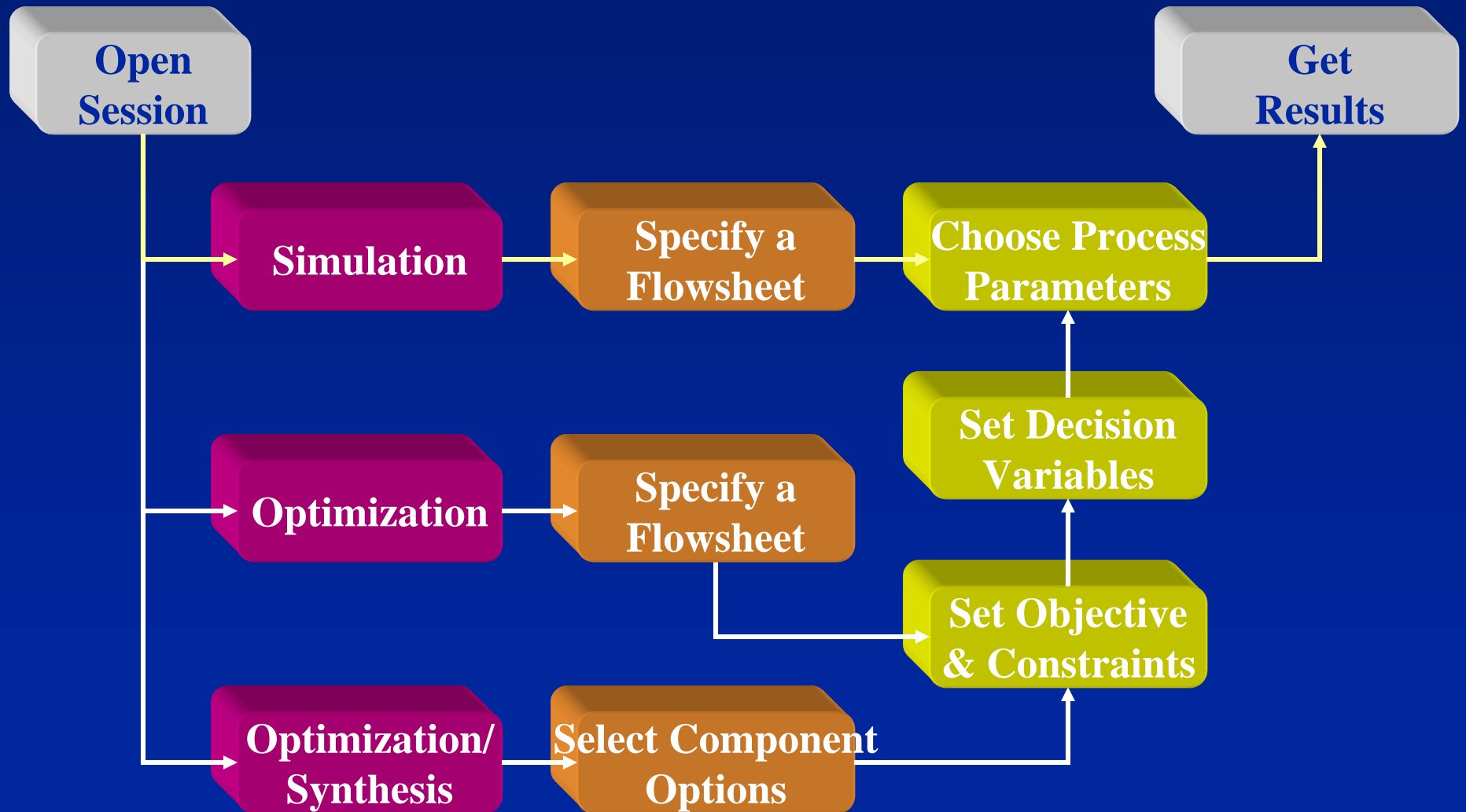
Configure a New System



Potential New Software Options

- Process Optimization
- Process (Flowsheet) Synthesis

Advanced Design Capabilities: Operation Overview



Select Optimization Mode

IECM Interface

File Edit View Window Help

Untitled

Configure Plant Set Objectives Set Parameters Get Results

Goal:
Simulation
Optimization
Synthesis

Combustion Controls

Furnace Type:
NOx Control:

Post-Combustion Controls

NOx Control:
Particulates:
SO2 Control:
SO2/NOx:

Solids Management

Recovery:
Fly Ash Disposal:

Plant Diagram

The plant diagram illustrates a complex industrial process flow. It begins with a furnace (red trapezoid) on the left, which feeds into a series of control units: a green trapezoid, a pink zigzag rectangle, a blue vertical stack of rectangles, and another red trapezoid. The flow is bidirectional between the furnace and the green trapezoid, and between the pink zigzag rectangle and the blue stack. The final red trapezoid has a stack (green vertical line) on top. Arrows indicate the direction of material flow between these components. Below the furnace and the final red trapezoid are yellow and blue rectangular components, likely representing ash recovery or disposal units.

Set Objective and Constraints

IECM Interface

File Edit View Window Help

Untitled

Configure Plant **Set Objectives** Set Parameters Get Results

Objective: Minimize Capital Cost

	Title	Units	CV	Min	Max
1	<u>Emissions (Final)</u>				
2	Particulates	lb/MBtu	<input type="checkbox"/>		
3	Nitrogen Oxides	lb/MBtu	<input checked="" type="checkbox"/>	0.06	0.6
4	Sulfur Dioxide	lb/MBtu	<input checked="" type="checkbox"/>	0.1	1.2
5	Carbon Dioxide	lb/MBtu	<input type="checkbox"/>		
6	Air Toxics	lb/MBtu	<input type="checkbox"/>		
7	Solids Wastes	lb/MBtu	<input type="checkbox"/>		
8					
9	Net Thermal Efficiency	Btu/kWh	<input type="checkbox"/>		
10					
11	<u>Overall Plant Costs</u>				
12	Capital Cost	M\$	<input type="checkbox"/>		
13	O&M Cost	M\$/yr	<input type="checkbox"/>		
14	Cost of Electricity	mills/kWh	<input type="checkbox"/>		
15					
16					
17					
18					

Set Parameter Values

IECM Interface

File Edit View Window Help

Untitled

Configure Plant **Set Objectives** **Set Parameters** **Get Results**

Overall Plant Coal Properties Base Plant Furnace Factors Emission Constraints NOx Control Particulate Control SO2 Control Solid Waste Mgmt

Goal: Optimization

Combustion Controls

Furnace Type: Tangential

NOx Control: Low NOx Burners

Post-Combustion Controls

NOx Control: Hot-Side SCR

Particulates: Cold-Side ESP

SO2 Control: Wet FGD

SO2/NOx: None

Solids Management

Recovery: None

Fly Ash Disposal: mixed w/ Landfill

Plant Diagram

```
graph LR; Furnace[Furnace] --> Hopper[Hopper]; Hopper --> Filter[Filter]; Filter --> CoolingTower[Cooling Tower]; CoolingTower --> Final[Final Component]; Furnace --> Mountain[Mountain Icon]; Final --> Bottle[Bottle Icon]; Furnace --> AshBox1[Ash Box 1]; Final --> AshBox2[Ash Box 2];
```

Select Decision Variables

IECM Interface

File Edit View Window Help

Untitled

Configure Plant Set Objectives **Set Parameters** Get Results

Overall Plant Feedstocks Fuel Upgrade **Energy Conversion** Gas Stream Cleanup Process Options Co-Products

IGCC **Conventional Boiler** Fuel Cell PFBC

	Title	Units	Unc	Value	Calc	Min	Max	Default	DV
1	Gross Electrical Output	MWg		500		1	3000	500	
2	Steam Cycle Heat Rate	Btu/kWh		7880		6000	11000	7880	
3	Boiler Efficiency	%		89.21	<input checked="" type="checkbox"/>	0	100	calc	
4	Capacity Factor	%		75		0	100	75	
5	Excess Air For Furnace	% stoich.		20.00	<input checked="" type="checkbox"/>	0	40	calc	
6	Leakage Air at Preheater	% stoich.		19.00	<input checked="" type="checkbox"/>	0	60	calc	
7	Gas Temp. Exiting Economizer	deg. F		700		250	1200	700	
8	Gas Temp. Exiting Air Preheater	deg. F		300		150	400	300	
9	Ambient Air Temperature	deg. F		80		-50	130	80	
10	Ambient Air Pressure	psia		14.7		12	15	14.7	
11	Ambient Air Humidity	lb H2O/lb dry air		0.018		0	0.03	0.018	
12	Collected Bottom Ash Solids	%		60.70	<input checked="" type="checkbox"/>	0	100	calc	
13	<u>Base Plant Energy Requirements</u>								
14	Coal Pulverizer	% MWg		0.6000	<input checked="" type="checkbox"/>	0	2	calc	
15	Steam Cycle Pumps	% MWg		0.65		0	2	0.65	
16	Forced Draft Fans	% MWg		1.5		0	4	1.5	
17	Cooling System	% MWg		1.8		0	2	1.8	
18	Miscellaneous	% MWg		1.3		0	4	1.3	

1. Performance 2. Financing 3. Retrofit Cost 4. Capital Cost 5. O&M Cost 6. O&M Escalation

Get Results (Run Model)

IECM Interface

File Edit View Window Help

Untitled

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

Overall Plant | Fuel (Coal)

Goal: Optim

Combustion Controls

Furnace Type: Tanger

NOx Control: Low NO

Post-Combustion Control

NOx Control: Hot-Sid

Particulates: Cold-S

SO2 Control: Wet FG

SO2/NOx: None

Solids Management

Recovery: None

Fly Ash Disposal: mixed w/ Landfill

IECM Analysis Progress

Iteration	Obj. Function Value	Optimizer Error Value
6	90.345 %	1.4e-01
7	90.462 %	2.4e-02
8	90.523 %	9.5e-04
9	90.549 %	5.4e-05
10	90.563 %	4.0e-07
11	90.568 %	1.7e-07
12	90.570 %	3.3e-09
13	90.570 %	6.2e-11

Calculating New Decision Variables

Pause Stop

Landfill Stack

1. Diagram | 2. Perf. Summary | 3. Flow Summary | 4. Cost Summary

View Results

IECM Interface

File Edit View Window Help

Untitled

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

Overall Plant | Fuel (Coal) | Boiler | Air Preheater | NOx Control | Particulate Control | SO2 Control | Pond | Landfill | Stack

Goal: Optimization

Combustion Controls

Furnace Type: Tangential
NOx Control: Low NOx Burners

Post-Combustion Controls

NOx Control: Hot-Side SCR
Particulates: Cold-Side ESP
SO2 Control: Wet FGD
SO2/NOx: None

Solids Management

Recovery: None
Fly Ash Disposal: mixed w/ Landfill

Plant Diagram

The Plant Diagram illustrates a complex industrial process flow. It begins with a furnace (represented by a red trapezoid) which feeds into a series of control units: a green trapezoid, a pink zigzag filter, and a blue vertical scrubber. The flow then splits into two paths. One path leads to a red trapezoid, which then feeds into a green vertical stack. The other path leads to a yellow trapezoid, which then feeds into a blue vertical pond. The diagram uses blue arrows to indicate the direction of material flow between these components.

1. Diagram | 2. Perf. Summary | 3. Flow Summary | 4. Cost Summary

Select Synthesis Mode

IECM Interface

File Edit View Window Help

Untitled

Configure Plant Set Objectives Set Parameters Get Results

Goal: Simulation
Simulation
Optimization
Synthesis

Combustion Controls

Furnace Type: Tangential
NOx Control: Low NOx Burners

Post-Combustion Controls

NOx Control: Hot-Side SCR
Particulates: Reverse Gas Fabric Filter
SO2 Control: Lime Spray Dryer
SO2/NOx: None

Solids Management

Recovery: None
Fly Ash Disposal: mixed w/ Landfill

Plant Diagram

The Plant Diagram illustrates a process flow starting from a furnace (red trapezoid) on the left. A blue arrow points from the furnace to a yellow trapezoid, then to a pink zigzag rectangle, then to a purple trapezoid, and finally to a blue vertical stack of rectangles. A blue arrow points from the stack to a green vertical stack of rectangles. A blue arrow points from the furnace to a yellow trapezoid at the bottom. A blue arrow points from the stack to a yellow trapezoid at the bottom. A black triangle is positioned above the furnace, and a green vertical stack of rectangles is positioned above the final stack.

Select Possible Technologies

IECM Interface

File Edit View Window Help

Untitled

Configure Plant Set Objectives Set Parameters Get Results

Goal: Optimization

Combustion Controls

Furnace Type: Tangential
 Wall
 Cyclone

NOx Control: Low Excess Air
 Burners out of Service
 Low NOx Burners (LNB)
 LNB + Overfire Air (OFA)
 Lean Gas Reburn
 Gas Reburn + OFA
 Coal Reburn
 None

Solids Management

Recovery: Gypsum
 Sulfur
 Sulfuric Acid
 None

Fly Ash Disposal: mixed w/ Bottom Ash
 mixed w/ Landfill
 None

Post-Combustion Controls

NOx Control: Hot-Side SCR
 None

Particulates: Cold-Side ESP
 Reverse Gas Fabric Filter
 Reverse Gas Sonic Fabric Filter
 Shake & Deflate Fabric Filter
 None

SO2 Control: Wet Lime FGD
 Wet Limestone FGD
 Wet Limestone w/ Additives FGD
 Spray Dryer
 None

SO2/NOx: Copper Oxide
 NOXSO
 None

Set Parameters

IECM Interface

File Edit View Window Help

Untitled

Configure Plant Set Objectives **Set Parameters** Get Results

Overall Plant Feedstocks Fuel Upgrade **Energy Conversion** Gas Stream Cleanup Process Options Co-Products

IGCC **Conventional Boiler** Fuel Cell PFBC

	Title	Units	Unc	Value	Calc	Min	Max	Default	DV
1	Gross Electrical Output	MWg		500		1	3000	500	
2	Steam Cycle Heat Rate	Btu/kWh		7880		6000	11000	7880	
3	Boiler Efficiency	%		89.21	<input checked="" type="checkbox"/>	0	100	calc	
4	Capacity Factor	%		75		0	100	75	
5	Excess Air For Furnace	% stoich.		20.00	<input checked="" type="checkbox"/>	0	40	calc	
6	Leakage Air at Preheater	% stoich.		19.00	<input checked="" type="checkbox"/>	0	60	calc	
7	Gas Temp. Exiting Economizer	deg. F		700		250	1200	700	
8	Gas Temp. Exiting Air Preheater	deg. F		300		150	400	300	
9	Ambient Air Temperature	deg. F		80		-50	130	80	
10	Ambient Air Pressure	psia		14.7		12	15	14.7	
11	Ambient Air Humidity	lb H2O/lb dry air		0.018		0	0.03	0.018	
12	Collected Bottom Ash Solids	%		60.70	<input checked="" type="checkbox"/>	0	100	calc	
13	<u>Base Plant Energy Requirements</u>								
14	Coal Pulverizer	% MWg		0.6000	<input checked="" type="checkbox"/>	0	2	calc	
15	Steam Cycle Pumps	% MWg		0.65		0	2	0.65	
16	Forced Draft Fans	% MWg		1.5		0	4	1.5	
17	Cooling System	% MWg		1.8		0	2	1.8	
18	Miscellaneous	% MWg		1.3		0	4	1.3	

1. Performance 2. Financing 3. Retrofit Cost 4. Capital Cost 5. O&M Cost 6. O&M Escalation

Get Results (Run Model)

The screenshot displays the IECM Interface software. The main window has a menu bar (File, Edit, View, Window, Help) and a toolbar on the left. The main area is divided into several tabs: 'Configure Plant', 'Set Objectives', 'Set Parameters', and 'Get Results' (which is highlighted in red). Below these are sub-tabs for 'Overall Plant', 'Fuel (Coal)', 'Boiler', 'Air Preheater', 'NOx Control', 'Particulate Control', 'SO2 Control', 'Pond', 'Landfill', and 'Stack'. The 'Overall Plant' sub-tab is active, showing various control settings for 'Combustion Controls' and 'Post-Combustion Controls'. A central 'IECM Analysis Progress' window is open, displaying a table of iteration results and a progress bar. The progress bar is at approximately 75% and is labeled 'Calculating New Decision Variables'. Below the table are 'Pause' and 'Stop' buttons. To the right of the progress window is a process flow diagram showing a boiler, a red heat exchanger, a stack, and a pond. At the bottom of the interface, there are four summary tabs: '1. Diagram', '2. Perf. Summary', '3. Flow Summary', and '4. Cost Summary'.

IECM Analysis Progress

Iteration	Obj. Function Value	Optimizer Error Value
6	787.3	1.4e-01
7	702.0	2.4e-02
8	669.8	9.5e-04
9	619.3	5.4e-05
10	627.5	4.0e-07
11	580.5	1.7e-07
12	526.2	3.3e-09
13	526.2	6.2e-11

Calculating New Decision Variables

Pause Stop

1. Diagram 2. Perf. Summary 3. Flow Summary 4. Cost Summary

View Optimal Flowsheet

IECM Interface

File Edit View Window Help

Untitled

Configure Plant Set Objectives Set Parameters **Get Results**

Overall Plant Fuel (Coal) Boiler Air Preheater NOx Control Particulate Control SO2 Control Pond Landfill Stack

Goal: Optimization

Combustion Controls

Furnace Type: Tangential
NOx Control: Low NOx Burners

Post-Combustion Controls

NOx Control: Hot-Side SCR
Particulates: Cold-Side ESP
SO2 Control: Wet FGD
SO2/NOx: None

Solids Management

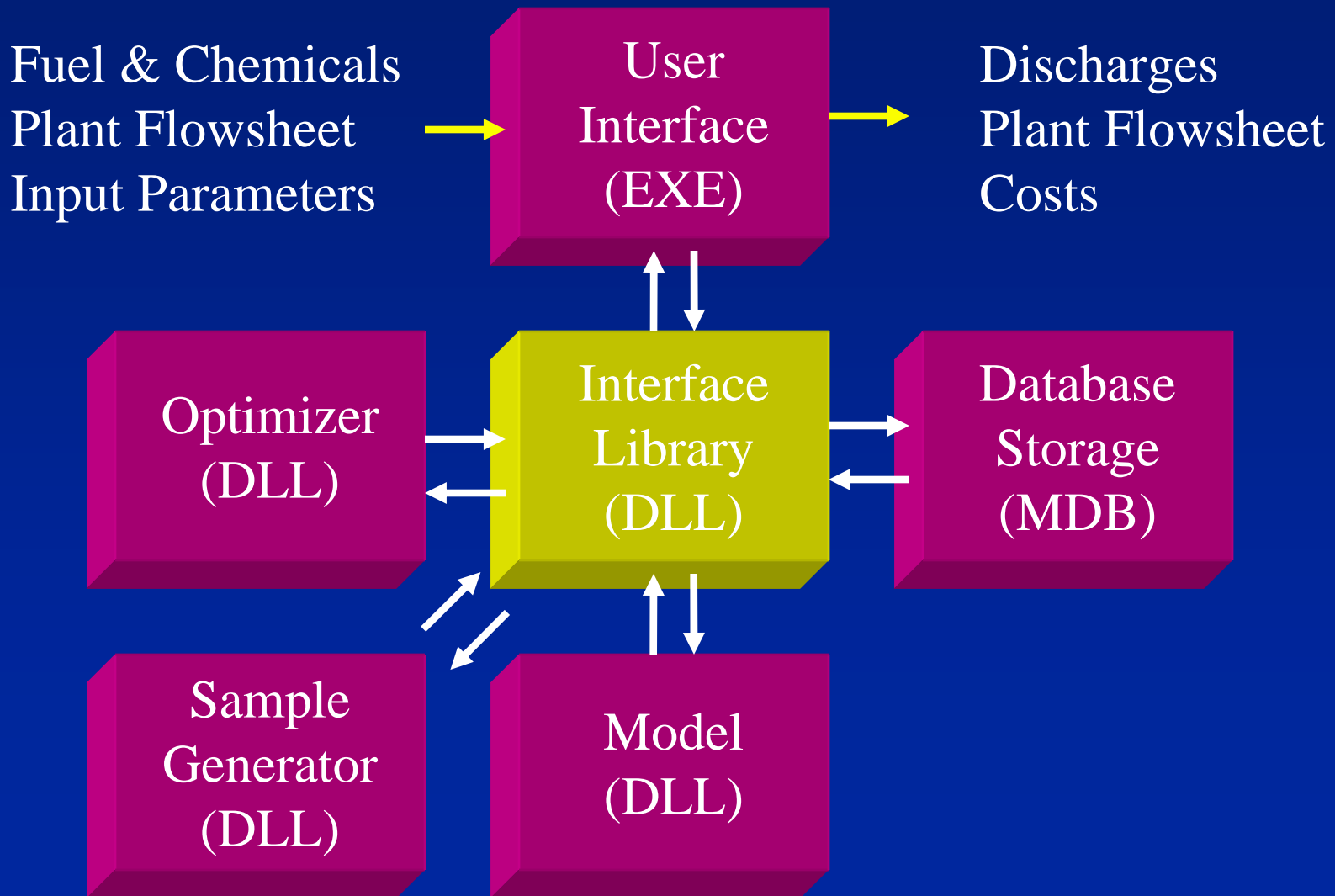
Recovery: None
Fly Ash Disposal: mixed w/ Landfill

Plant Diagram

The Plant Diagram illustrates a complex industrial process flow. It begins with a furnace (red) that feeds into a series of control units: a particulate control unit (green), a cold-side ESP (pink), a hot-side SCR (blue), and a wet FGD (red). The flow then splits into two paths: one leading to a stack (green) and another leading to a landfill (yellow). The diagram also shows a recovery unit (yellow) and a fly ash disposal unit (yellow) connected to the main process flow.

1. Diagram 2. Perf. Summary 3. Flow Summary 4. Cost Summary

IECM Programming Module Structure



Model Applications

- Process design
- Technology evaluation
- Cost estimation
- R&D management
- Risk analysis
- Environmental compliance
- Marketing studies
- Strategic planning

Please let us know what you think

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