

Report on Recent Accomplishments and Future Directions

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FY99 Projects and Funding

Enhancements to the Integrated Environmental Control Model (IECM)

Sponsor: Process Analysis Division
Amount: \$50 k
COR: Gerst Gibbon

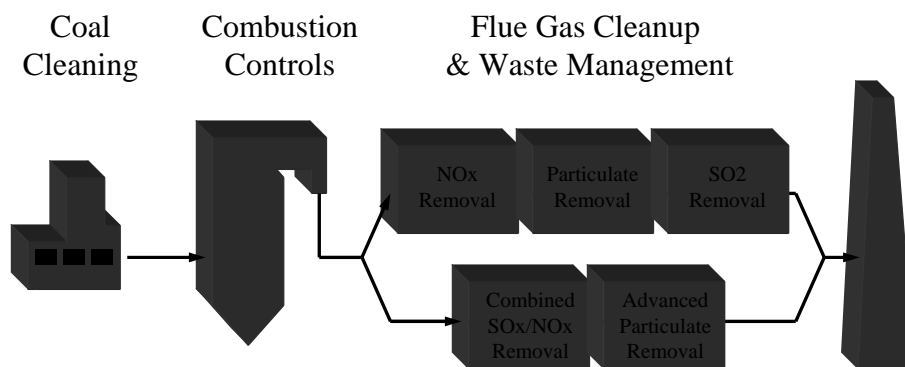
Development of a Framework for the Preliminary Design and Analysis of Vision 21 Plants

Sponsor: Advanced Research & Technology Development
Amount: \$150 k
COR: Gerst Gibbon (Bob Romanosky)

Highlights of Activities to Date

- Completed IECM Version 3.1 plus associated technical documentation and user manuals
- Developed new performance and cost models of selected process technologies for the IECM
- Began implementing new models in the IECM code and graphical interface
- Developed a plan to add process optimization options
- Developed a conceptual framework for a Vision 21 preliminary planning model

Integrated Environmental Control Model (IECM)



IECM Performance and Cost Models

- Detailed mass and energy balances, plus empirical relationships for complex process chemistry
- Calculates mass flows, energy flows, efficiency, and multi-media environmental emissions
- Component cost models (5-10 process areas per technology) explicitly linked to flowsheet performance parameters
- Calculates total capital cost, O&M costs, and COE
- Approximately 10-20 performance parameters and 10-20 cost parameters for each technology

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](ftp://ftp.fetc.doe.gov/pub/IECM)
 - anonymous login
 - any password

Preliminary IECM User Group

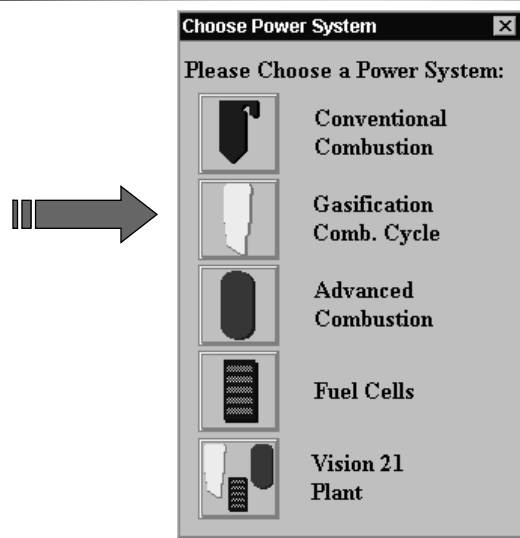
- ABB Power Plant Control
- American Electric Power
- Consol, Inc.
- Energy & Env. Research Corp.
- Exportech Company, Inc.
- FirstEnergy Corp.
- FLS Miljo A/S
- Foster Wheeler Development Corp.
- Lehigh University
- Lower Colorado River Authority
- McDermott Technology, Inc.
- Mitsui Babcock Energy Ltd.
- National Power Plc.
- Niksa Energy Associates
- Pacific Corp.
- Pennsylvania Electric Association
- Potomac Electric Power Co.
- Private Consultants
- Savvy Engineering
- Sierra Pacific Power Co.
- Southern Company Services, Inc.
- Stone & Webster Engineering Corp.
- Tampa Electric Co.
- University of California, Berkeley

New Performance and Cost Models Under Development

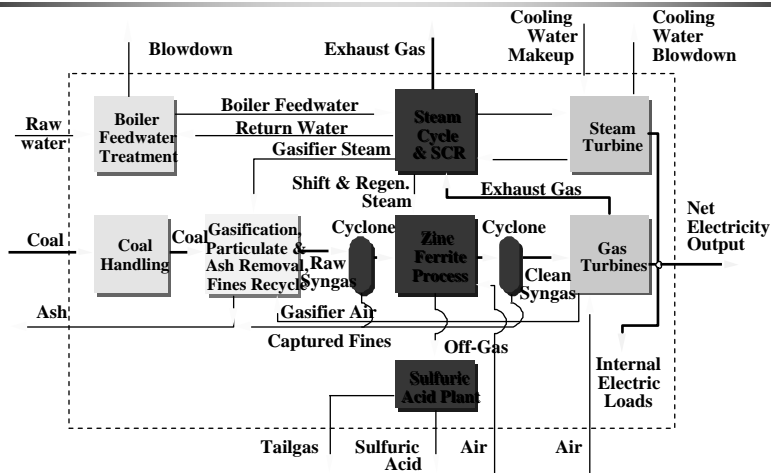
- In-Furnace NO_x Controls
 - Low NO_x Burners (LNB)
 - LNB + Overfire air
 - Gas Reburn
 - Selective Non-Catalytic Reduction (SNCR)
 - LNB + SNCR
 - Tangential, Wall, and Cyclone Firing
- Gasification Combined Cycle Systems
 - KRW Gasifier with Hot Gas Cleanup
 - Texaco Gasifier with Cold Gas Cleanup

(live demo of the new in-furnace
NO_x control options)

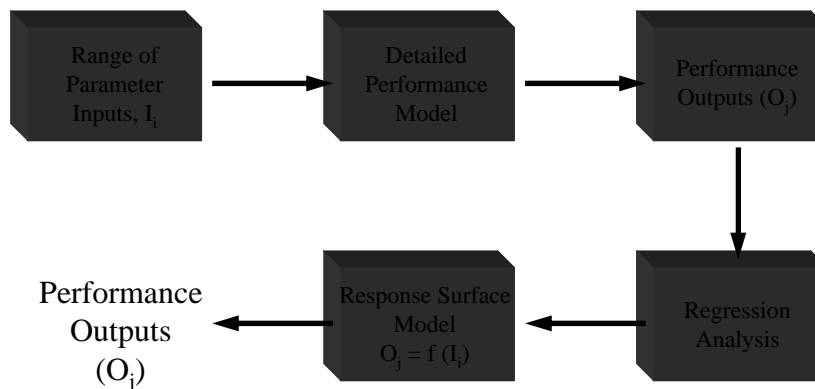
New Gasification Combined Cycle (IGCC) Options



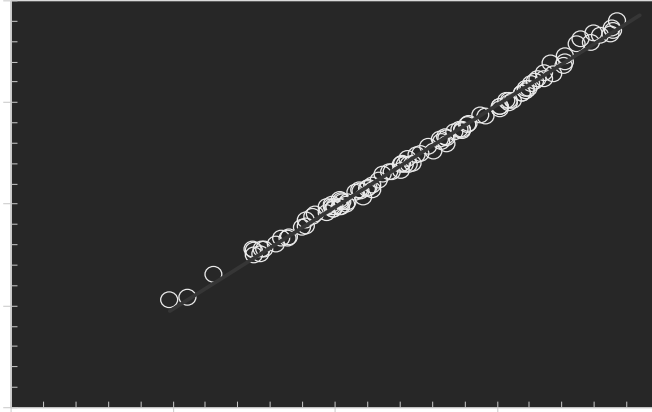
ASPEN Model of an IGCC System



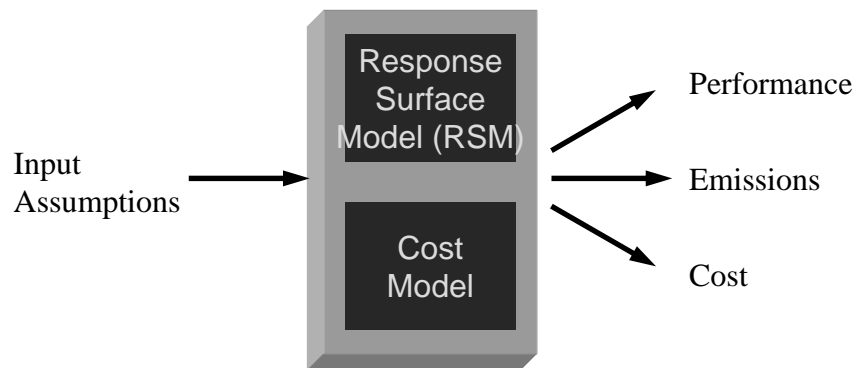
Response Surface Model Development



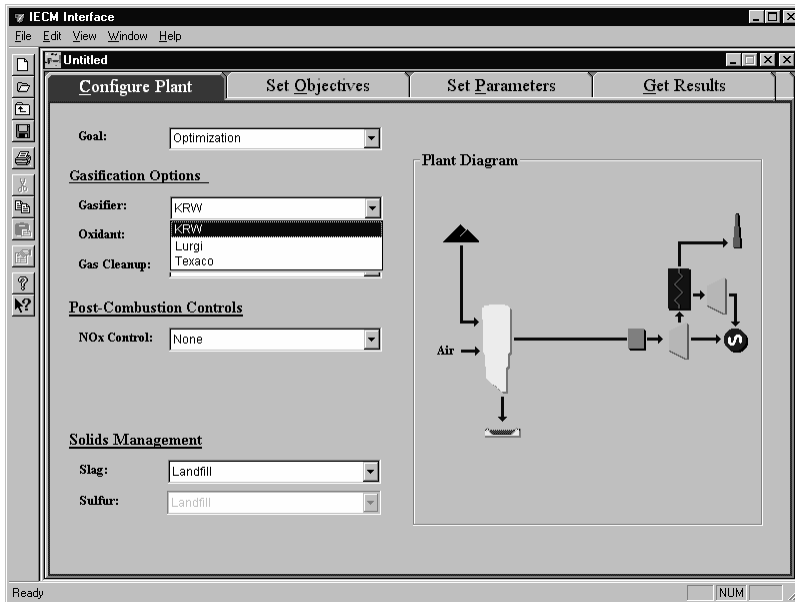
Evaluation of Desktop Model: IGCC Plant Efficiency



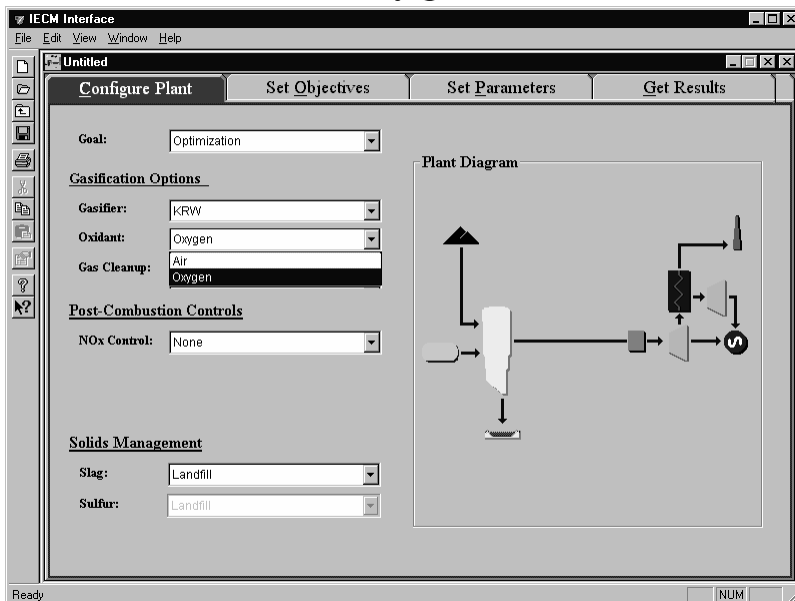
Desktop Model of a Process



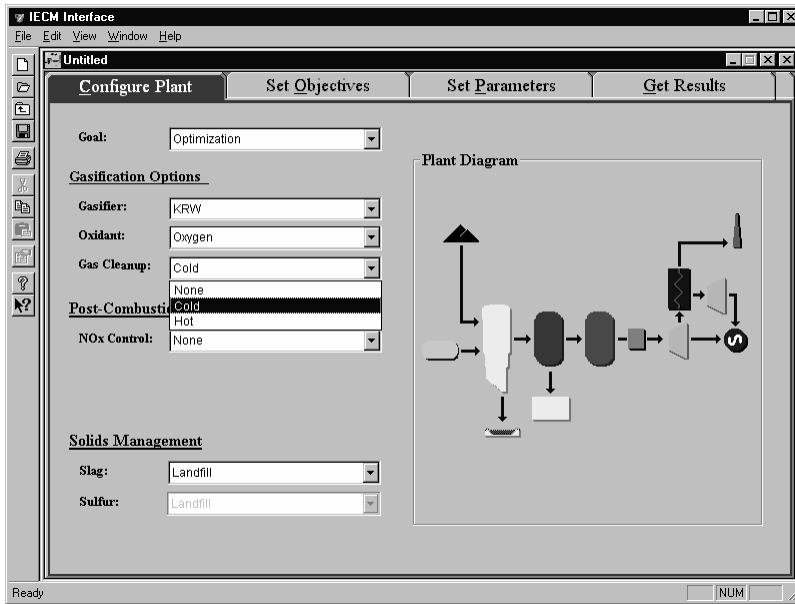
Select KRW Gasifier



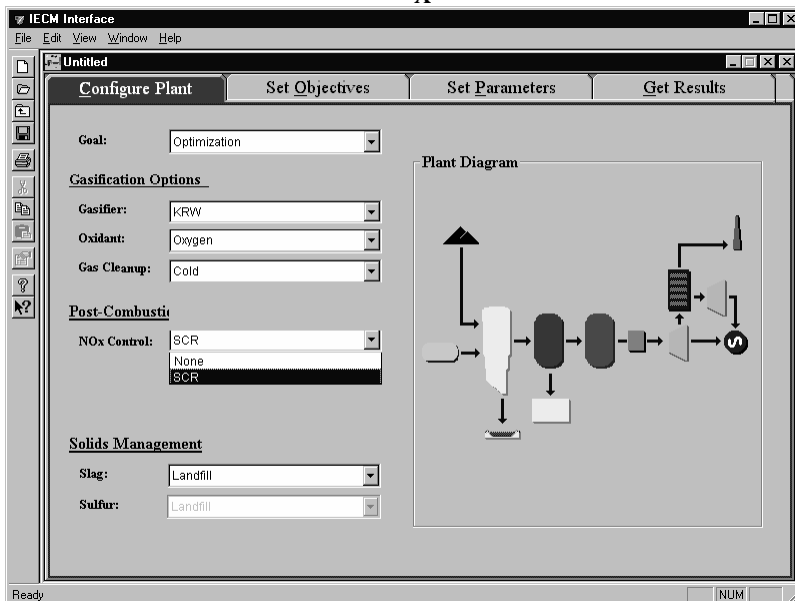
Select Oxygen Plant



Select Cold Gas Cleanup



Select NO_x Control



Select Byproduct Recovery

The screenshot shows the 'Configure Plant' tab in the IECM Interface. The 'Goal' is set to 'Optimization'. Under 'Gasification Options', the 'Gasifier' is 'KRW', 'Oxidant' is 'Oxygen', and 'Gas Cleanup' is 'Hot'. Under 'Post-Combustion Controls', 'NOx Control' is 'SCR'. Under 'Solids Management', 'Slag' is 'Landfill' and 'Sulfur' is set to a dropdown menu with options: 'Landfill', 'Sulfur', 'Sulfuric Acid', and 'Sulfur'. A 'Plant Diagram' is shown on the right, illustrating the gasification process flow.

Set Process Parameters

The screenshot shows the 'Set Parameters' tab in the IECM Interface. The plant is configured as an 'IGCC'. The table below lists various process parameters with their units, uncertainty, and control limits.

	Title	Units	Unc	Value	Calc	Min	Max	Default	DV
1	Gasifier Design								
2	Gasifier Carbon Conversion	%		95.0		90.0	98.0	95.0	
3	Gasifier Oxygen to Carbon Ratio	mol O ₂ / mol C		0.46		0.45	0.47	0.46	
4	Gasifier Steam to Carbon Ratio	mol H ₂ O / mol C		0.46		0.445	0.455	0.46	
5	Coal-bound N Converted to NH ₃	%		10.0		5.0	15.0	10.0	
6	Sulfur Retained in Gasifier Bot Ash	%		90.0		80.0	95.0	90.0	
7	Emissions Control								
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	NH ₃ Converted to NO _x in Turbine	%		90.0		50.0	90.0	90.0	
12	SCR NO _x Removal Efficiency	%		80.0		50.0	90.0	80.0	
13	SCR NH ₃ Slip	ppmw		10.0		5.0	20.0	10.0	
14									
15									
16									
17									
18									

At the bottom of the interface, there are tabs for: 1. Performance, 2. Financing, 3. Retrofit Cost, 4. Capital Cost, 5. O&M Cost, 6. O&M Escalation.

Potential New Models for the IECM (FY 2000)

- Mercury Control Technologies
 - In-Furnace
 - Post-Combustion
- Alternative Fuel Selections
 - Natural Gas
 - Petroleum
 - Fuel Blending
- Advanced Plant Designs
 - Additional Model Parameters
 - Additional Process Technologies

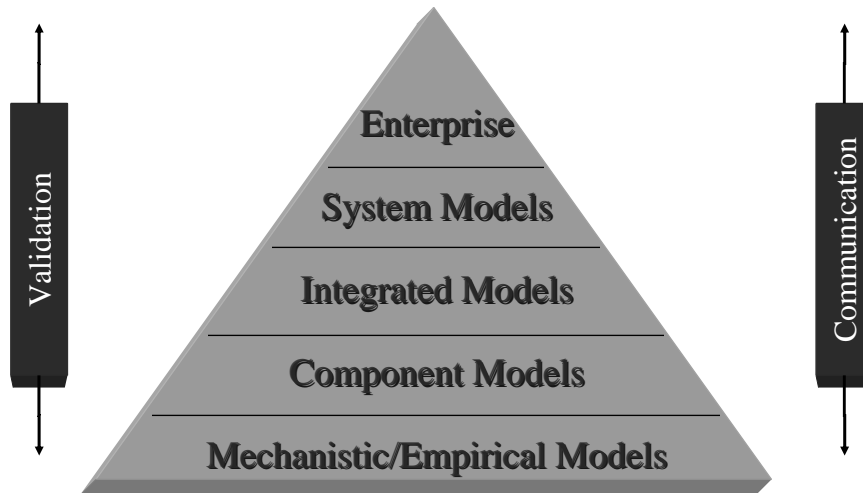
Conceptual Design of a Vision 21 Planner

- *A preliminary design model to analyze:*
 - Process Components
 - Systems Integration
 - Performance and Cost
 - Process Optimization
 - Current Uncertainties

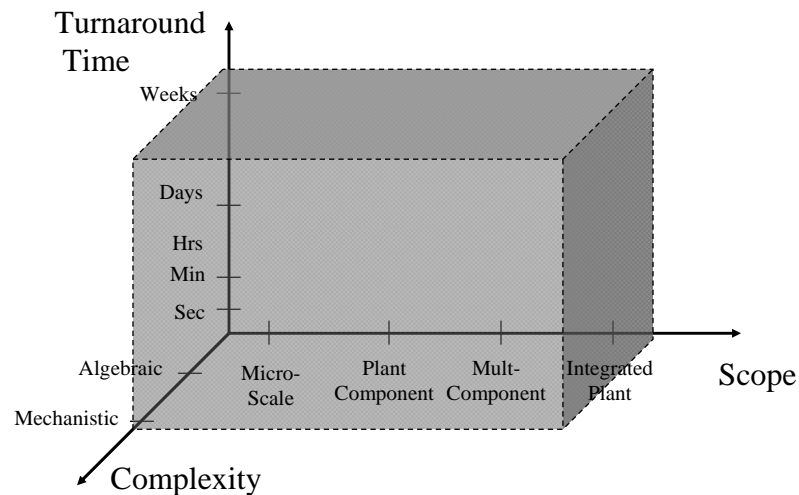
Objectives

- Develop a flexible and easy-to-use modeling system to estimate the performance, environmental emissions and cost of a preliminary Vision 21 plant design
- Develop a framework for comparing alternative options and on a systematic basis, including effects of uncertainty

A Hierarchy of Process Models



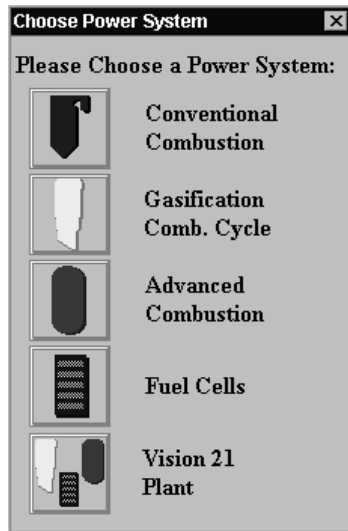
Attributes of Process Models



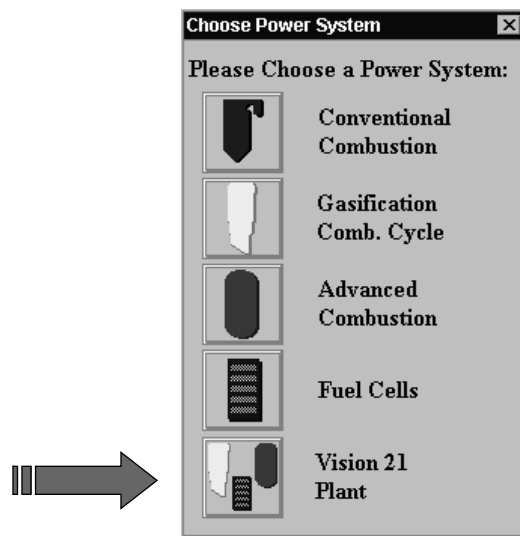
Benefits of Desktop Models

- Precise and accurate representation of detailed models
- Execution takes seconds, not hours
- Can run on any desktop PC
- Amenable to “what if” analyses
- Incorporates process performance, emissions, and cost models in one package
- Useful by analysts and decision makers who have no time, ability or resources (staff, software, hardware, funds) to run complex models

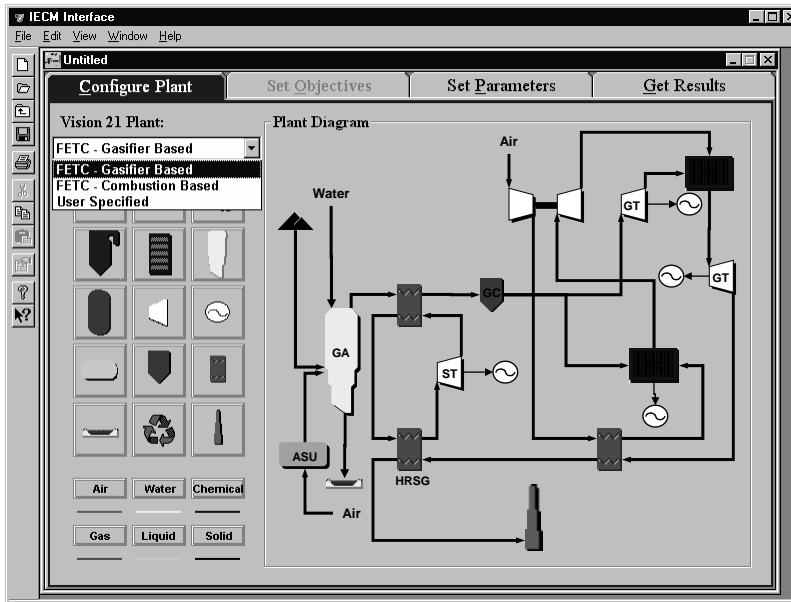
Opening Screen: A Menu of Technology Options



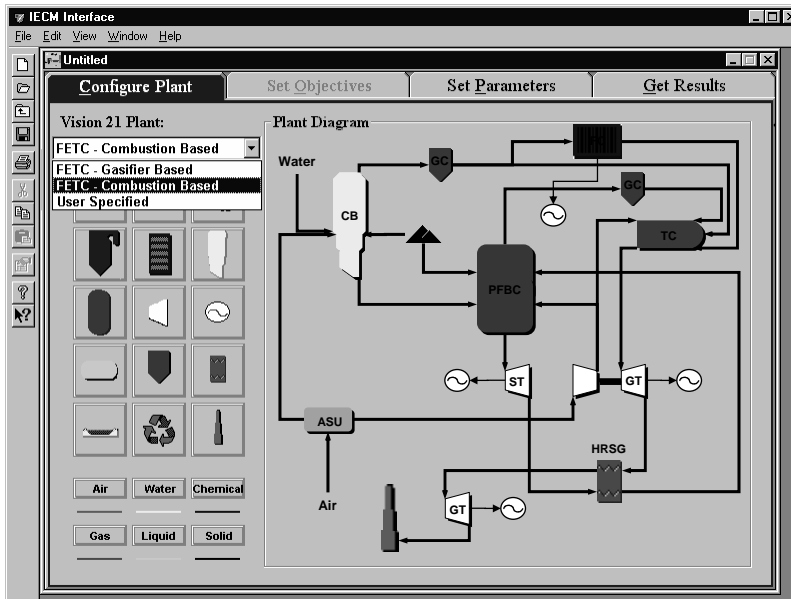
Open Vision 21 Plant Options



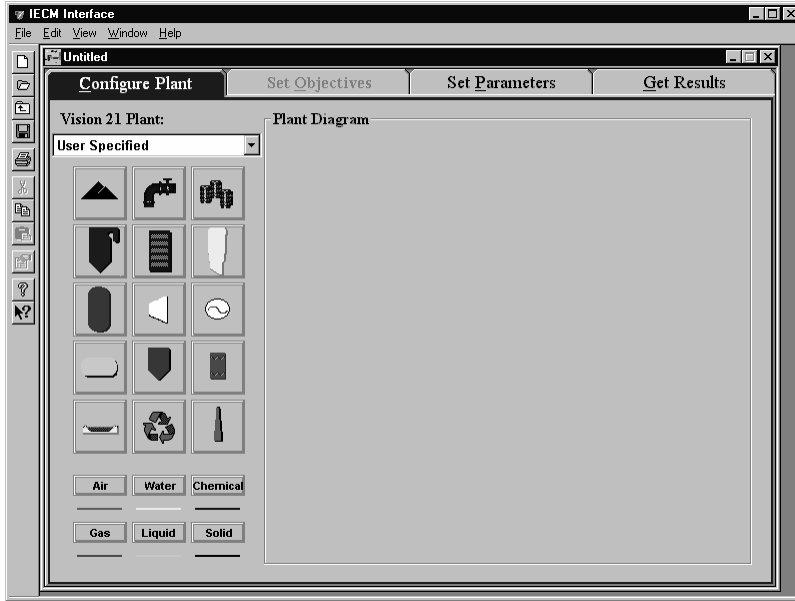
Select Existing Flowsheet - 1



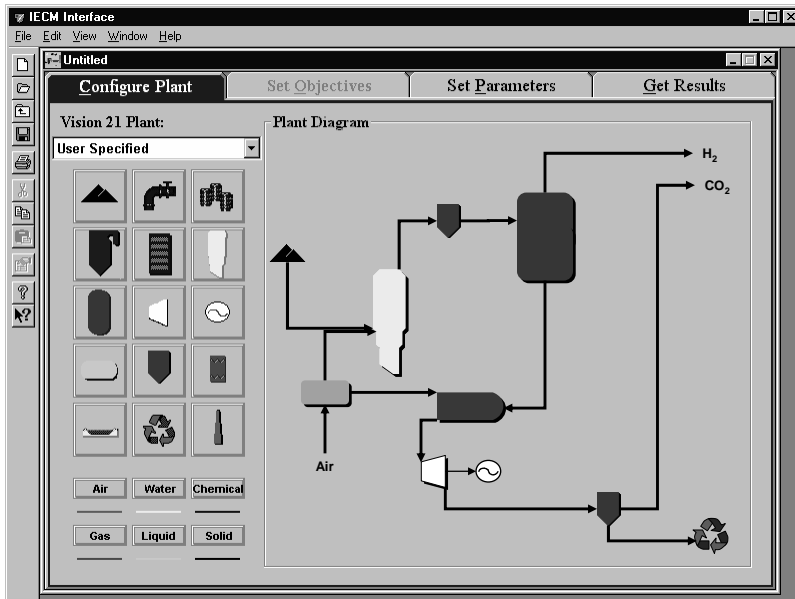
Select Existing Flowsheet - 2



Vision 21 Workbench



Configure a New System



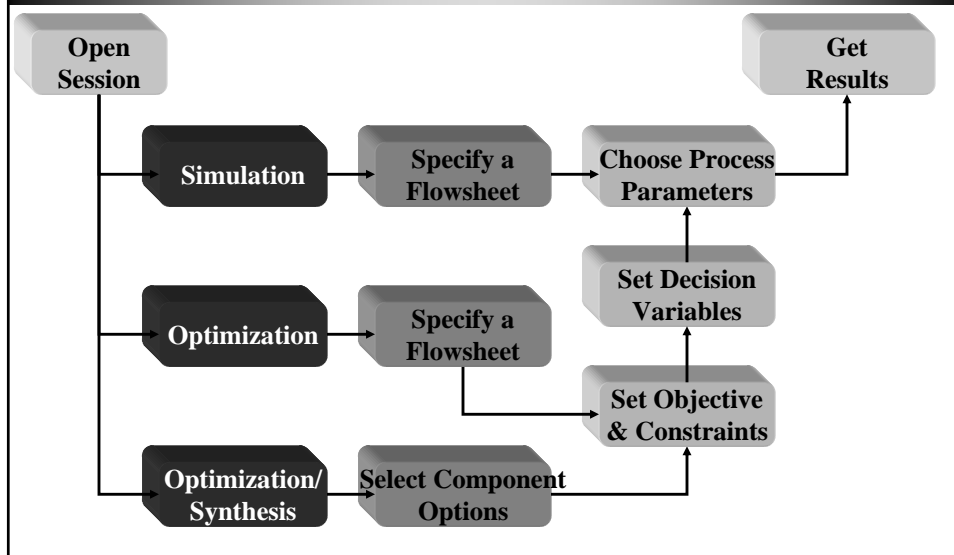
The Vision 21 Planner Would . . .

- Bring together a spectrum of performance and cost models for plant components and integrated systems, suitable for preliminary design and analysis
- Run quickly and easily on a desktop or laptop computer
- Allow new process concepts to be easily modeled
- Allow uncertainties to be characterized explicitly
- Facilitate selection of optimal (most promising) designs
- Be public domain software available to all

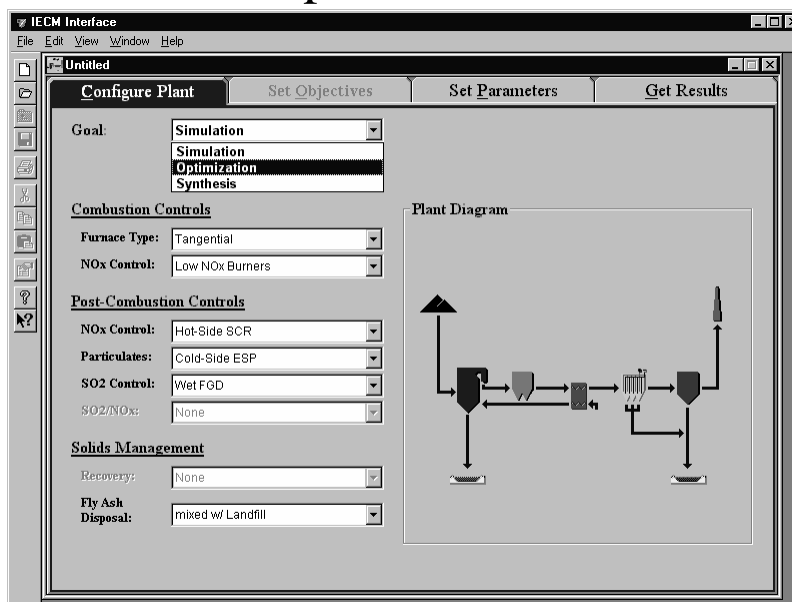
Potential New Software Options

- Process Optimization
(of a given flowsheet)
- Process Synthesis
(to define an optimal flowsheet)

Advanced Design Capabilities: Operation Overview



Select Optimization Mode



Set Objective and Constraints

The screenshot shows the 'Set Objectives' window in the IECM Interface. The 'Objective' dropdown is set to 'Minimize Capital Cost'. Below is a table with columns for Title, Units, CV, Min, and Max.

	Title	Units	CV	Min	Max
1	Emissions (Final)				
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	Overall Plant Costs		<input type="checkbox"/>		
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					

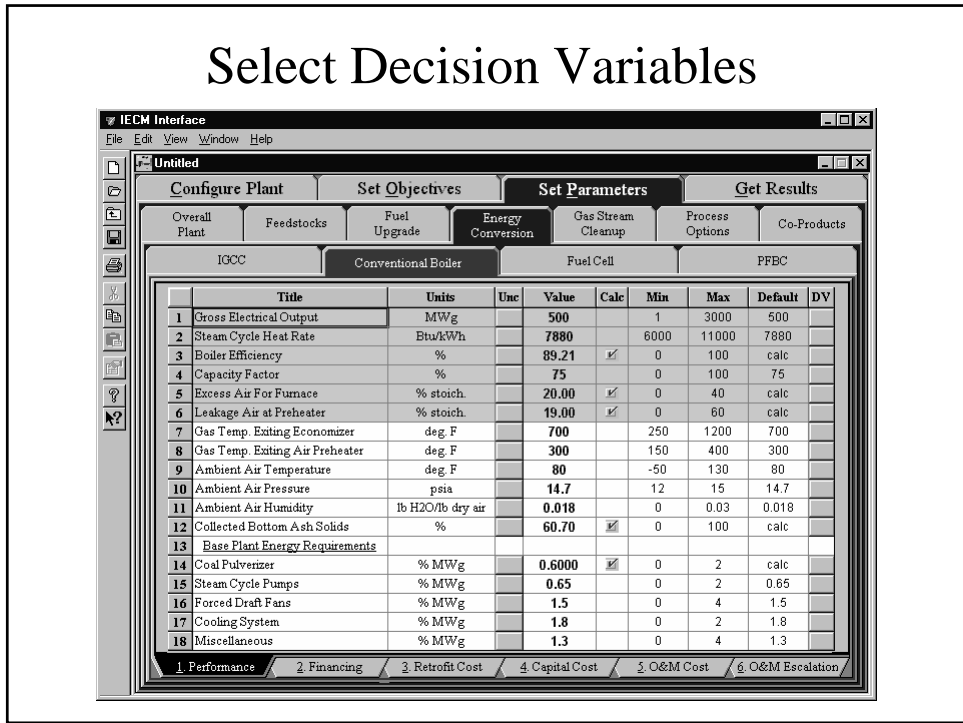
Set Parameter Values

The screenshot shows the 'Set Parameters' window in the IECM Interface. The 'Goal' is set to 'Optimization'. The window is divided into several sections for setting parameters:

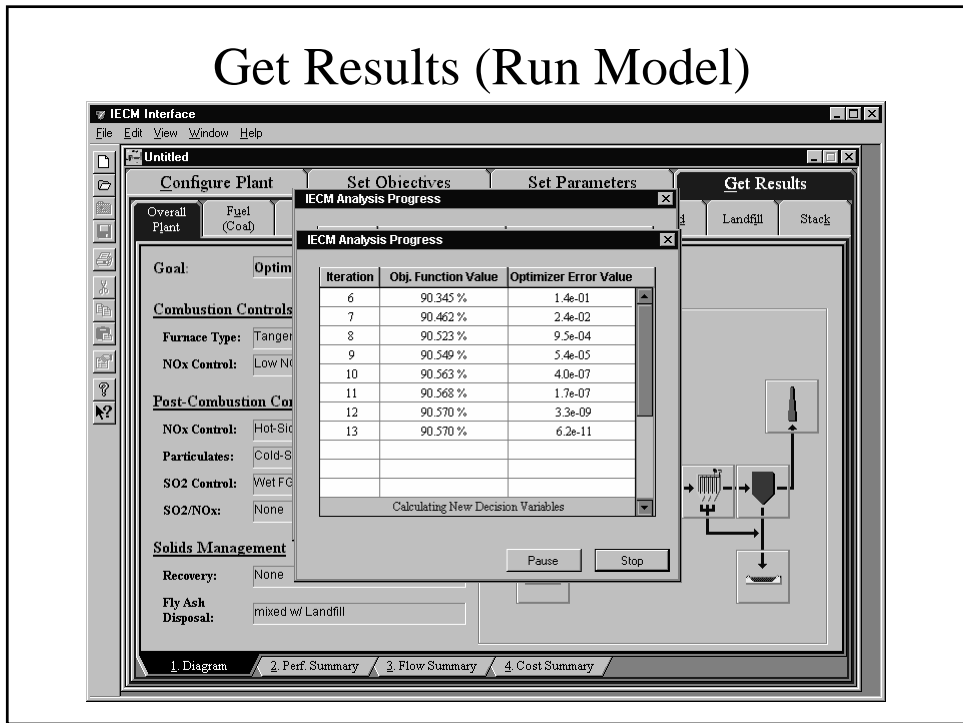
- Combustion Controls:**
 - Furnace Type: Tangential
 - NOx Control: Low NOx Burners
- Post-Combustion Controls:**
 - NOx Control: Hot-Side SCR
 - Particulates: Cold-Side ESP
 - SO2 Control: Wet FGD
 - SO2/NOx: None
- Solids Management:**
 - Recovery: None
 - Fly Ash Disposal: mixed w/ Landfill

On the right side, there is a 'Plant Diagram' showing a schematic of the combustion system, including a furnace, various control units, and a stack.

Select Decision Variables



Get Results (Run Model)



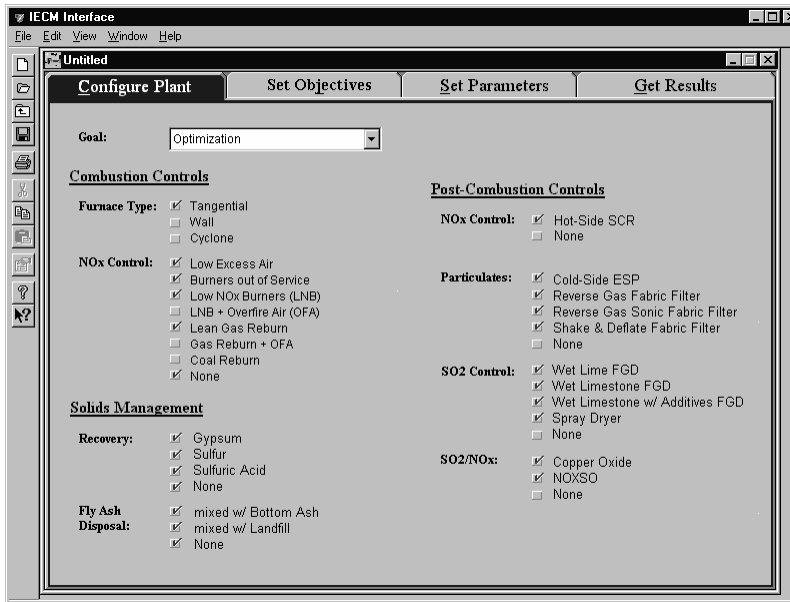
View Results

The screenshot shows the IECM Interface software window. The 'Get Results' tab is selected, and the 'Plant Diagram' is visible. The 'Goal' is set to 'Optimization'. The 'Combustion Controls' section includes 'Furnace Type: Tangential' and 'NOx Control: Low NOx Burners'. The 'Post-Combustion Controls' section includes 'NOx Control: Hot-Side SCR', 'Particulates: Cold-Side ESP', 'SO2 Control: Wet FGD', and 'SO2/NOx: None'. The 'Solids Management' section includes 'Recovery: None' and 'Fly Ash Disposal: mixed w/ Landfill'. The 'Plant Diagram' shows a process flow with a furnace, boiler, and various control units. The bottom of the window has a navigation bar with '1. Diagram', '2. Perf. Summary', '3. Flow Summary', and '4. Cost Summary'.

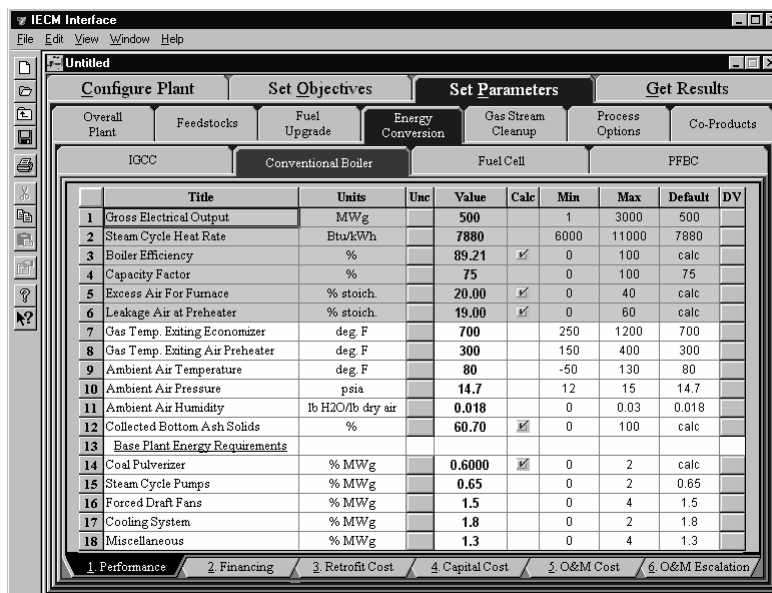
Select Synthesis Mode

The screenshot shows the IECM Interface software window. The 'Configure Plant' tab is selected, and the 'Goal' dropdown menu is open, showing options: 'Simulation', 'Simulation', 'Optimization', and 'Synthesis'. The 'Combustion Controls' section includes 'Furnace Type: Tangential' and 'NOx Control: Low NOx Burners'. The 'Post-Combustion Controls' section includes 'NOx Control: Hot-Side SCR', 'Particulates: Reverse Gas Fabric Filter', 'SO2 Control: Lime Spray Dryer', and 'SO2/NOx: None'. The 'Solids Management' section includes 'Recovery: None' and 'Fly Ash Disposal: mixed w/ Landfill'. The 'Plant Diagram' shows a process flow with a furnace, boiler, and various control units. The bottom of the window has a navigation bar with '1. Diagram', '2. Perf. Summary', '3. Flow Summary', and '4. Cost Summary'.

Select Possible Technologies



Set Parameters



Get Results (Run Model)

The screenshot shows the IECM Interface software with the 'Get Results' tab selected. An 'IECM Analysis Progress' dialog box is open, displaying the following table:

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

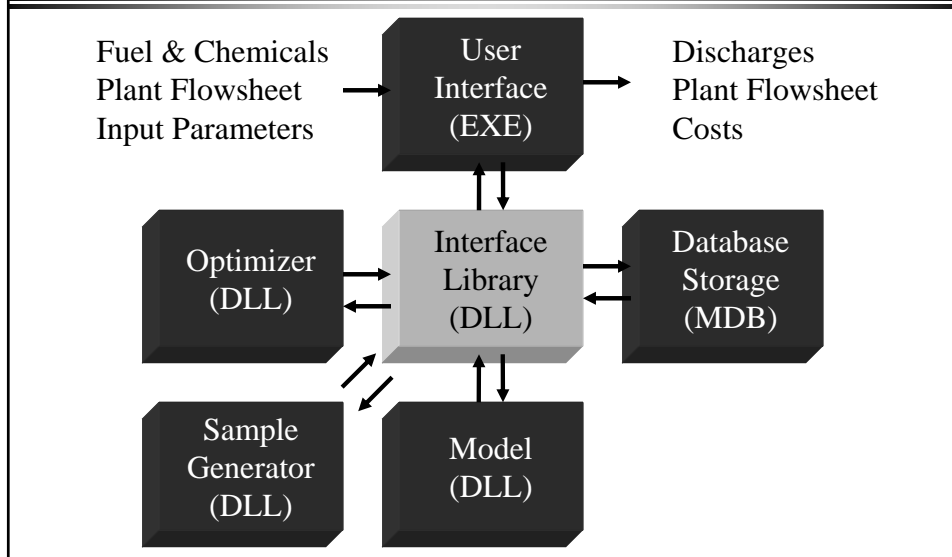
Below the table, the text 'Calculating New Decision Variables' is visible, along with 'Pause' and 'Stop' buttons. The background interface shows various configuration options for the plant, including 'Combustion Controls' (Furnace Type: Tangential, NOx Control: Low NOx) and 'Post-Combustion Controls' (NOx Control: Hot-Side, Particulates: Cold-Side, SO2 Control: Wet FGD).

View Optimal Flowsheet

The screenshot shows the IECM Interface software with the 'View Optimal Flowsheet' tab selected. The 'Plant Diagram' on the right shows a complex process flow involving a boiler, various control units, and a stack. The configuration parameters on the left are as follows:

- 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

Details of the Programming Module Structure



Where Do We Go from Here?

- To enhance the use of the IECM we could:
 - Add new models of environmental control systems and advanced technology options of interest to DOE (both performance and cost)
 - Add new output reports and software features
 - Conduct case studies of specific issues
 - Add process synthesis and optimization capabilities
 - Offer user training programs and user support

Where Do We Go from Here?

- To develop the Vision 21 Planner we would:
 - Implement preliminary versions of enabling technology models (both performance and cost)
 - Use the Vision 21 Planner as a testbed for systems integration development
 - Add process synthesis and optimization capabilities
 - Incorporate dynamics modeling of integrated systems
 - Develop linkages to more detailed models of process components and systems (modeling hierarchy)