Conceptual Design of a Vision 21 Planning Model

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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

Current FETC Projects

Development of the Integrated Environmental Control Model (IECM)

Duration: September 1992 - April 1999
Amount: $1.3 million
COR: Gerst Gibbon

Development and Application of Optimal Design Capability for Coal Gasification Systems

Duration: September 1992 - February 2000
Amount: $1.5 million
COR: Gerst Gibbon

Advanced Design and Analysis Methods are Needed

- Increasing complexity of advanced processes
- Multiple options for component design & selection
- Strong interactions among system components
- Significant uncertainties in the performance and cost of new technologies

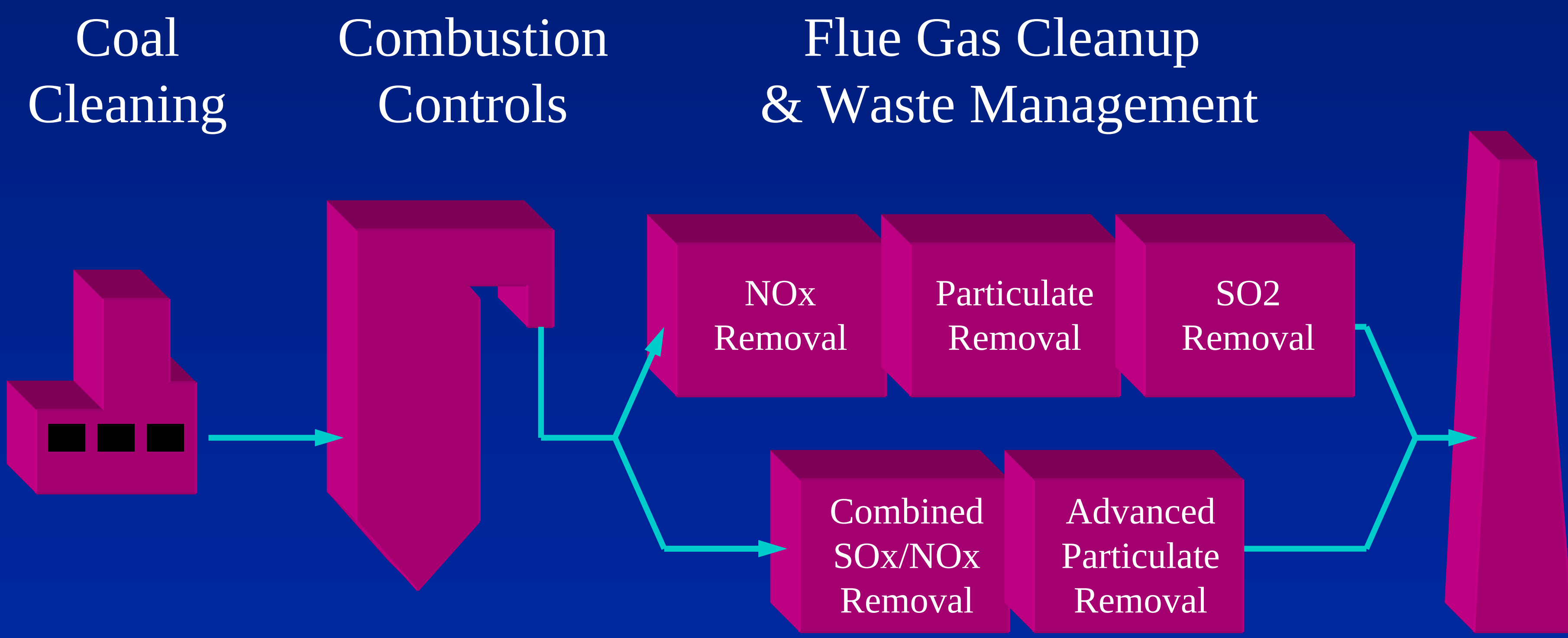
Approach

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

Technologies Modeled and Evaluated

- Pulverized Coal Combustion Plants
  - Selective catalytic reduction (SCR)
  - Wet lime/limestone FGD
  - Lime spray dryer
  - Electrostatic precipitators
  - Fabric filters
- Advanced Environmental Control Systems
  - Combined SO_2/NO_x removal
- Coal Beneficiation Processes

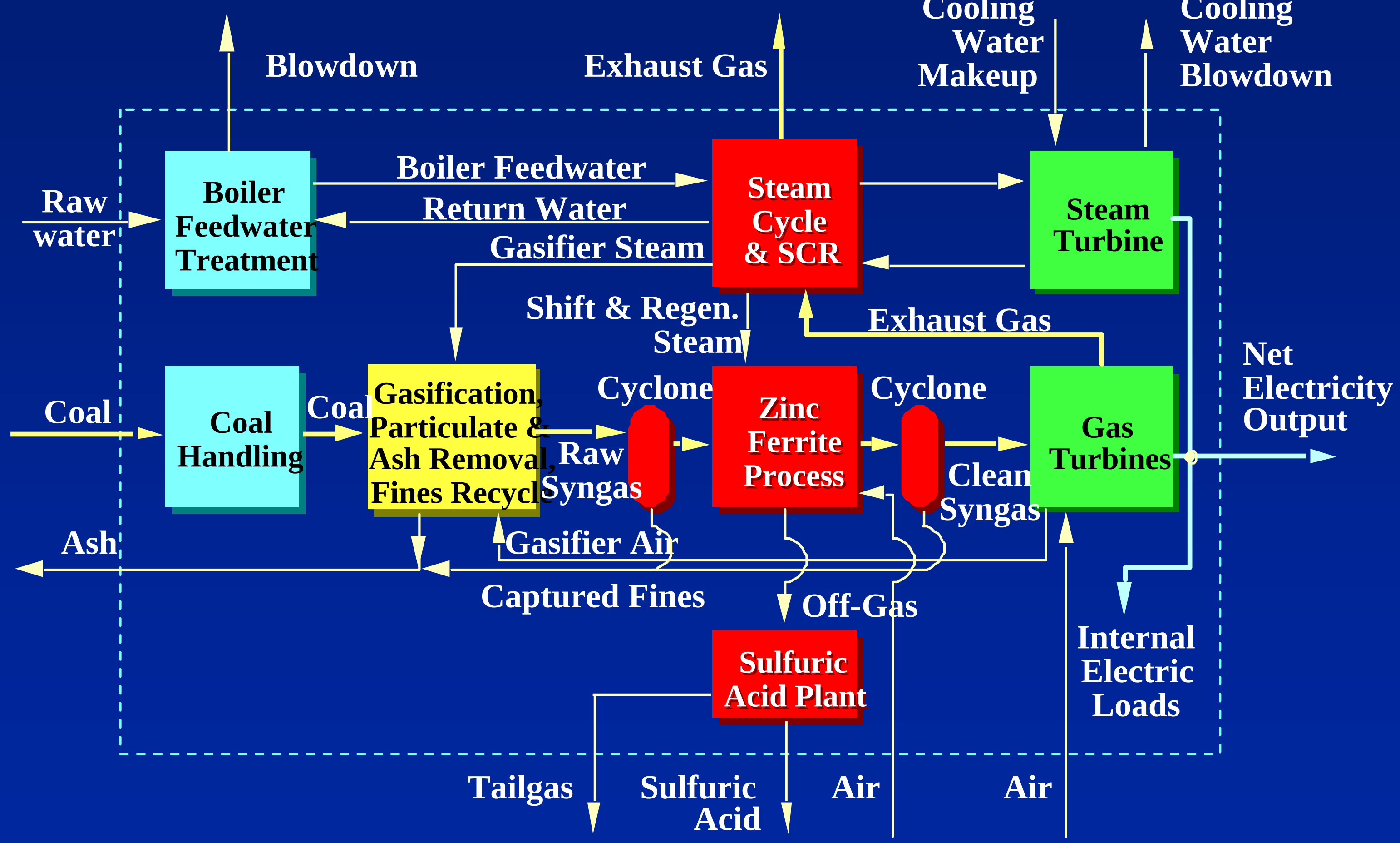
Integrated Environmental Control Model (IECM)



Technologies Modeled (con't)

- Integrated Gasification Combined Cycles (IGCC)
  - Air and oxygen blown gasifiers
  - Fixed bed and fluidized bed gasifiers
  - Hot gas and cold gas cleanup systems
  - Byproduct recovery options (e.g., sulfuric acid, Claus plant, direct sulfur reduction process)
  - Other environmental controls (e.g., SCR)
- Pressurized Fluidized Bed Combustion (PFBC)
- Externally-Fired Combined Cycle (EFCC)

ASPEN Model of an IGCC System



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

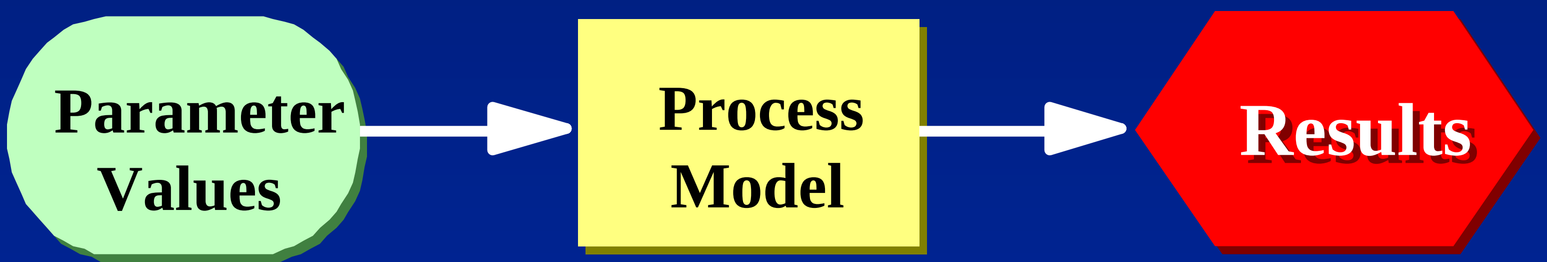
Process Cost Models

- 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

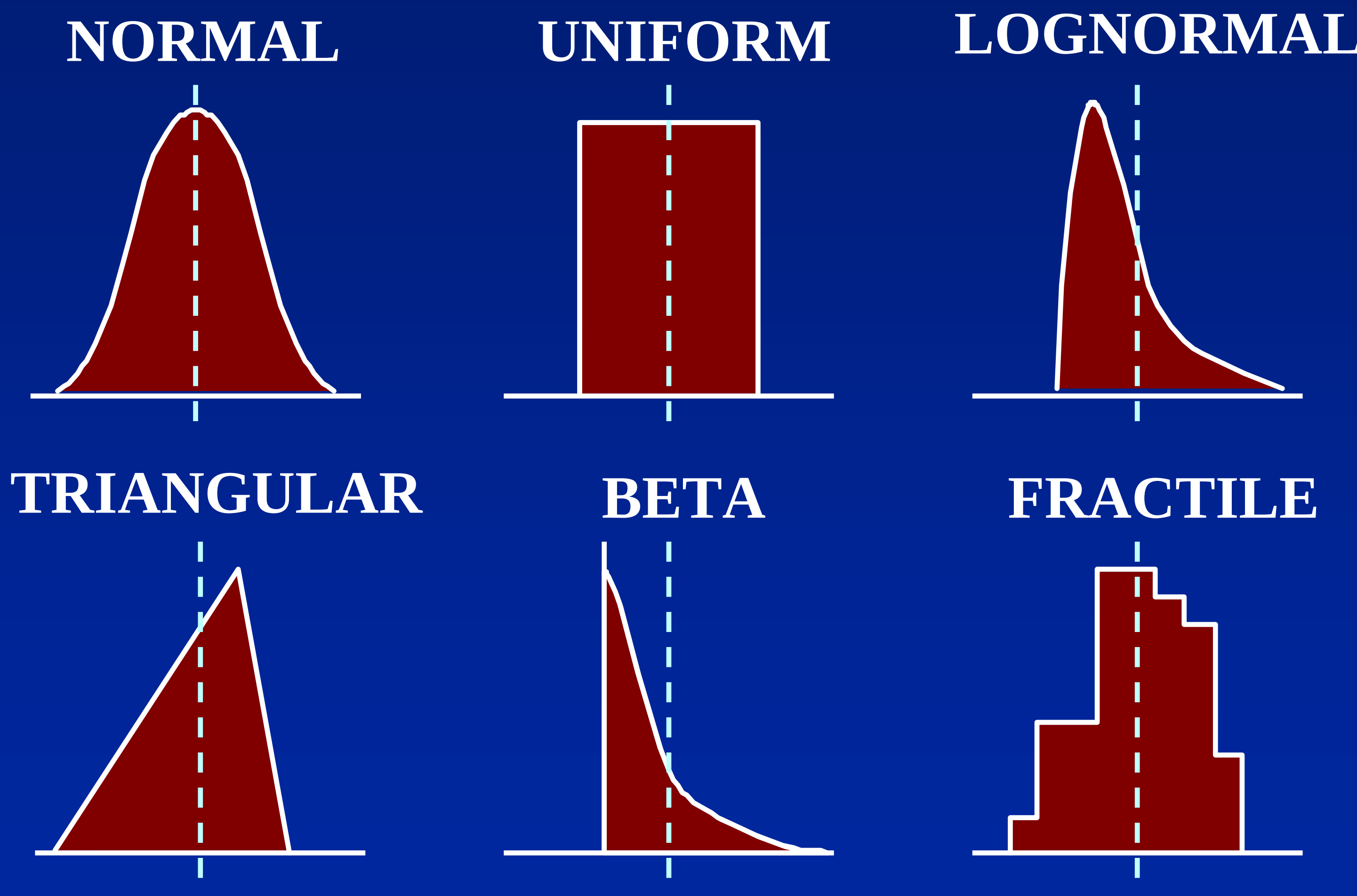
New Modeling Capabilities

System	Deterministic	Stochastic
Simulation	√	√
Optimization	√	√
Synthesis	√	√

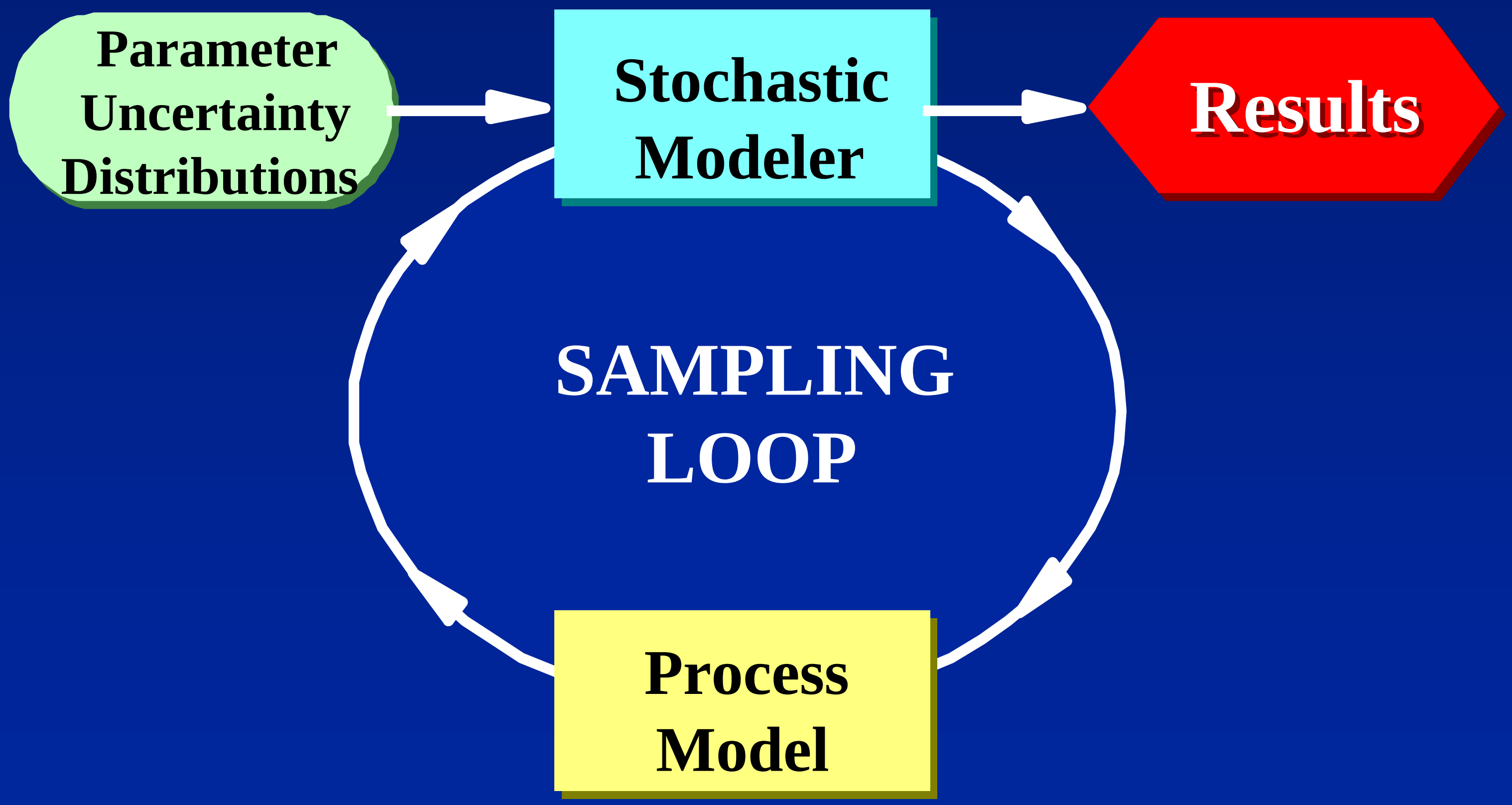
Conventional Process Modeling (Deterministic Simulation)



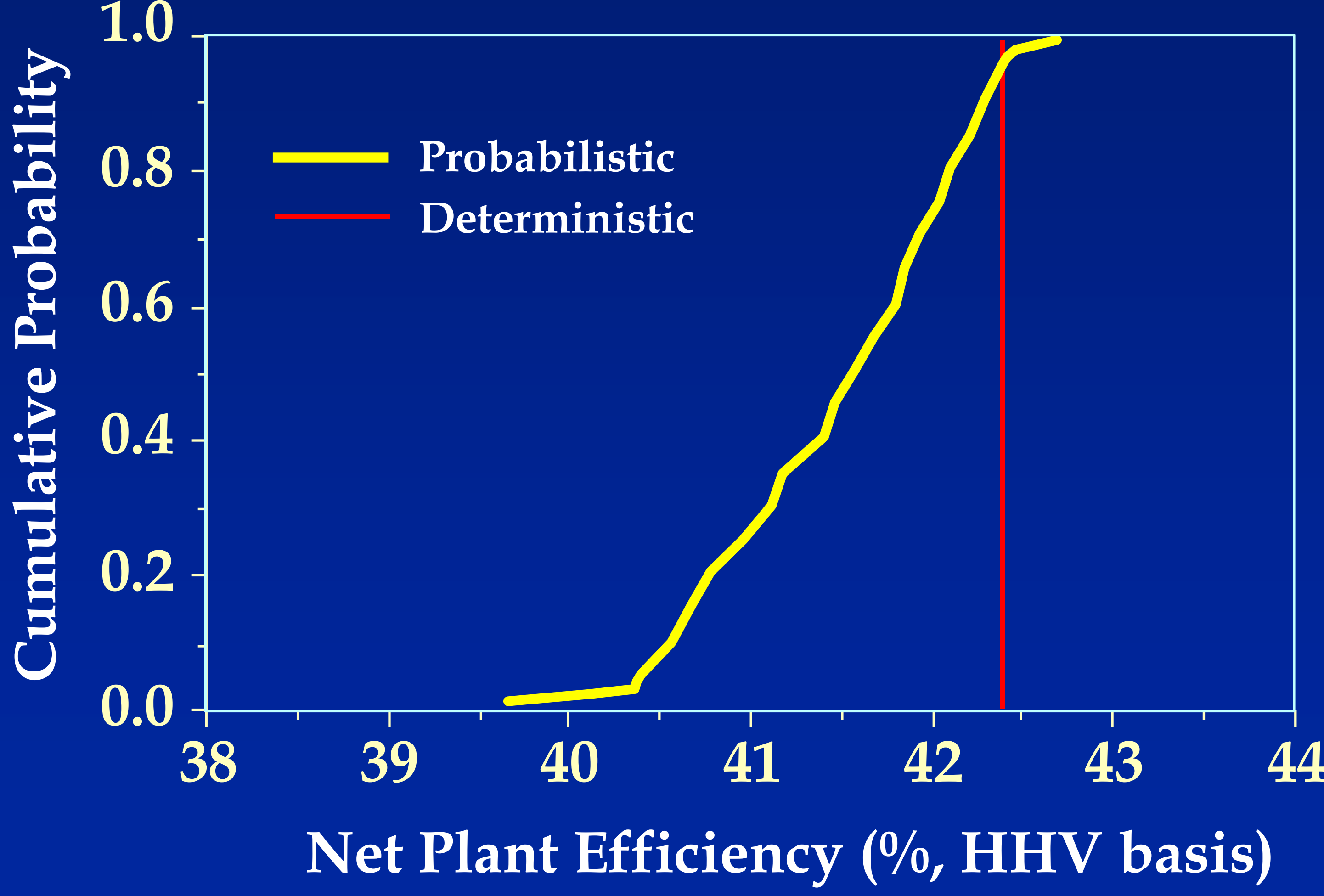
Parameter Uncertainty Distributions



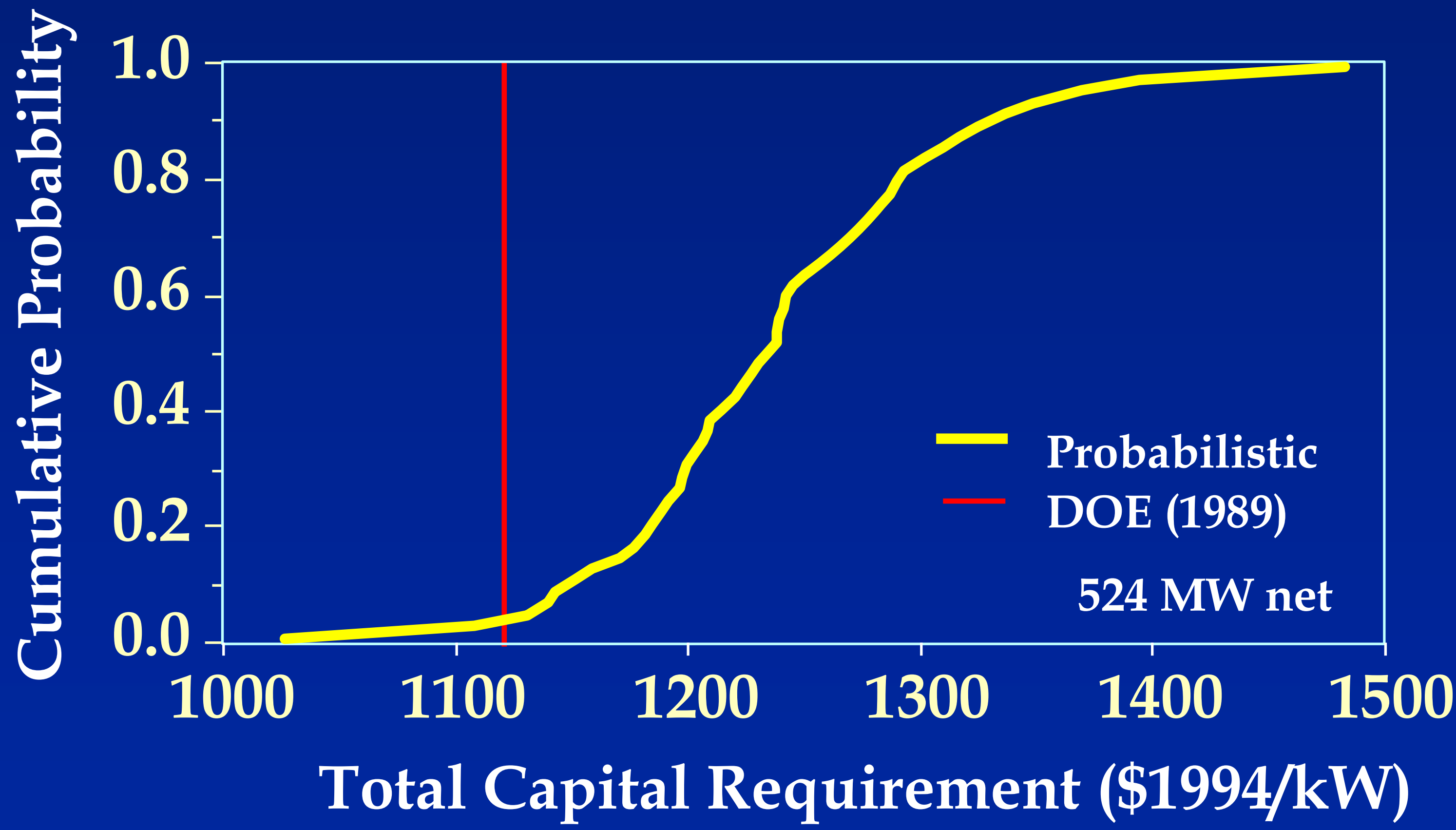
Stochastic Simulation



Externally-Fired Combined Cycle (EFCC) Plant Efficiency



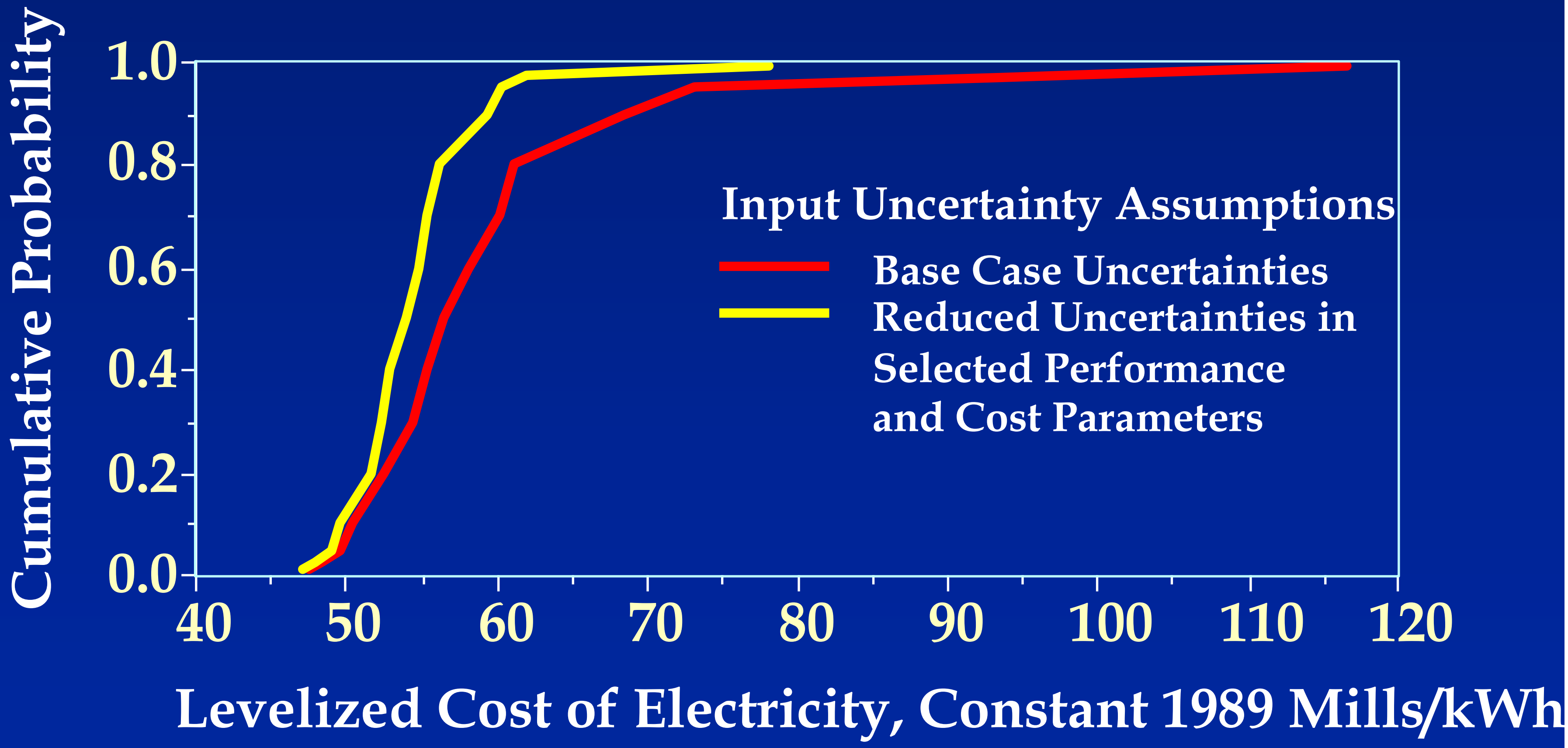
Second Generation PFBC System
Total Capital Cost



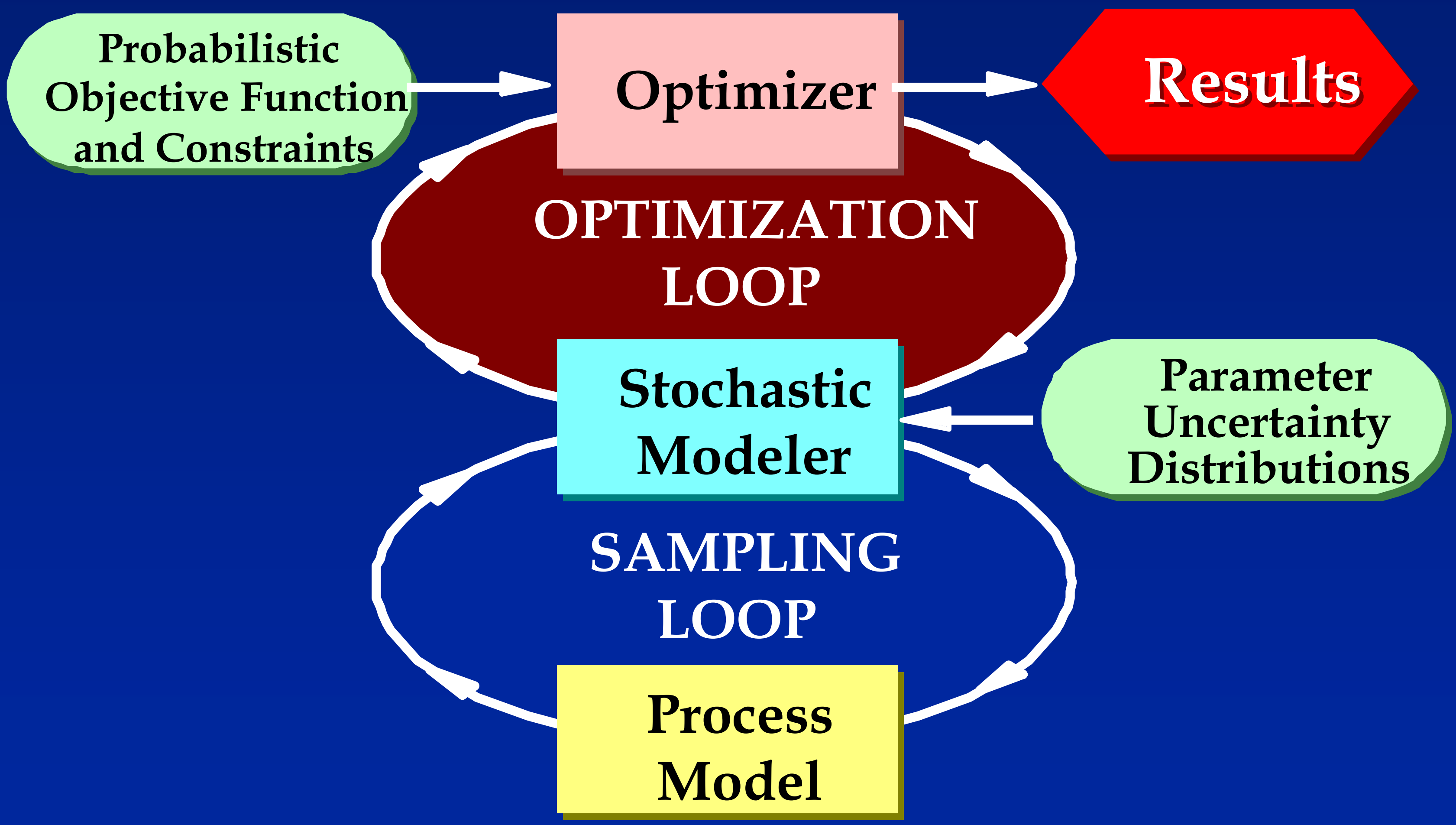
Some Questions Addressed by Stochastic Simulation

- What performance, emissions and cost can we expect given current uncertainties?
- What is the likelihood of performance shortfalls? Of cost overruns?
- What factors or process parameters contribute most to the overall uncertainty in performance and cost?
- How does this system or process compare to other competing technologies?
- What is the potential payoff of R&D to reduce the key uncertainties and risks?

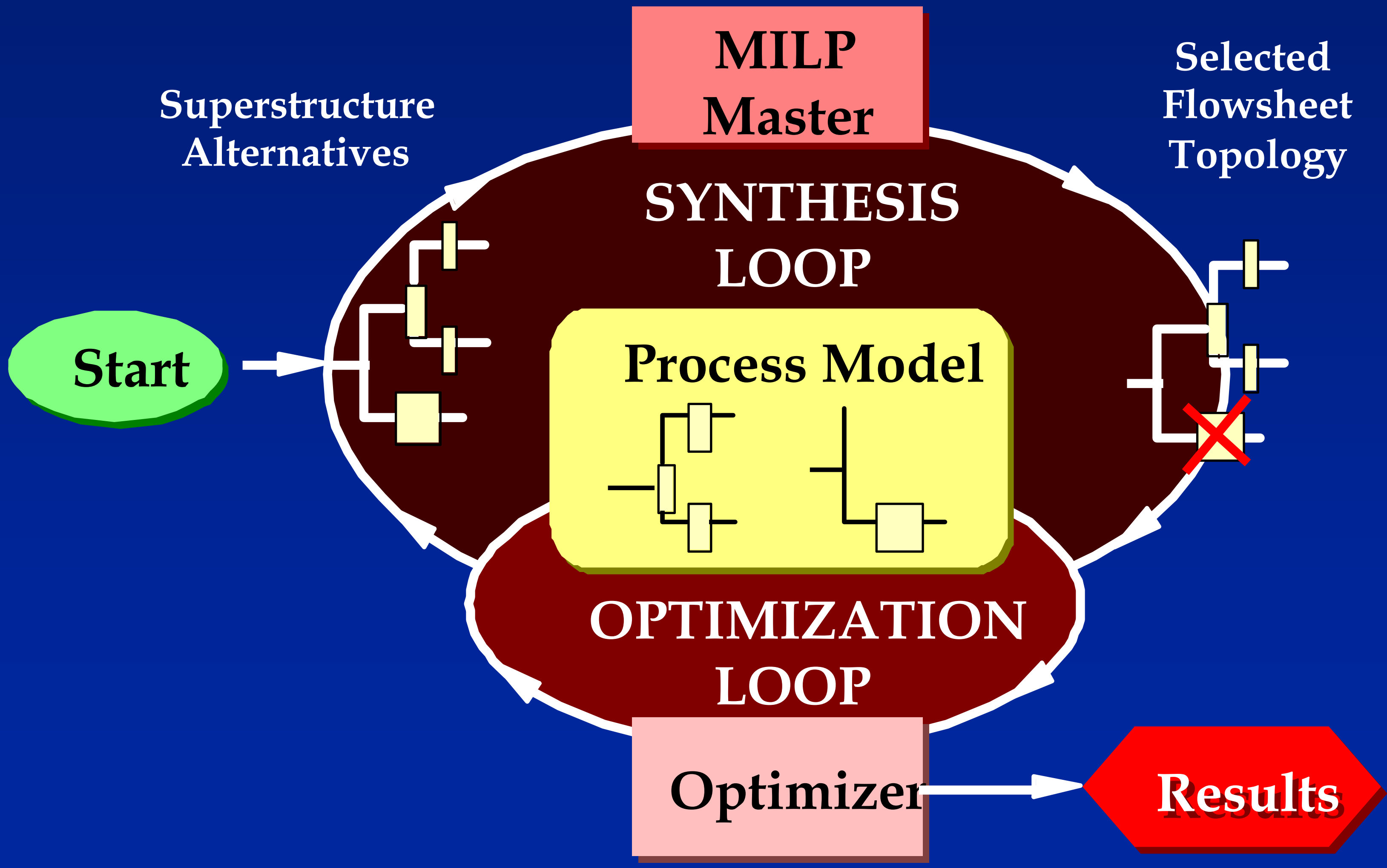
Value of Targeted Research in Reducing the Cost of an IGCC System



Stochastic Optimization



Process Synthesis



Some Questions Addressed by Optimization Capabilities

- Is there a better choice of parameter values for this process to improve its performance? To lower its cost?
- What levels of performance, emissions and cost can we expect from an optimized design?
- How do uncertainties in process performance and cost parameters affect the optimal design?
- What design choices will minimize the risk of a performance shortfall? Or the risk of a cost overrun?

Some Questions Addressed by Process Synthesis Capabilities

- How should the flowsheet be configured to achieve performance goals at lowest cost?
- What are the feasible flowsheet options to meet specified goals and constraints? Which options are not feasible?
- What are the cost savings (or performance and environmental gains) from moving to a more optimal design?

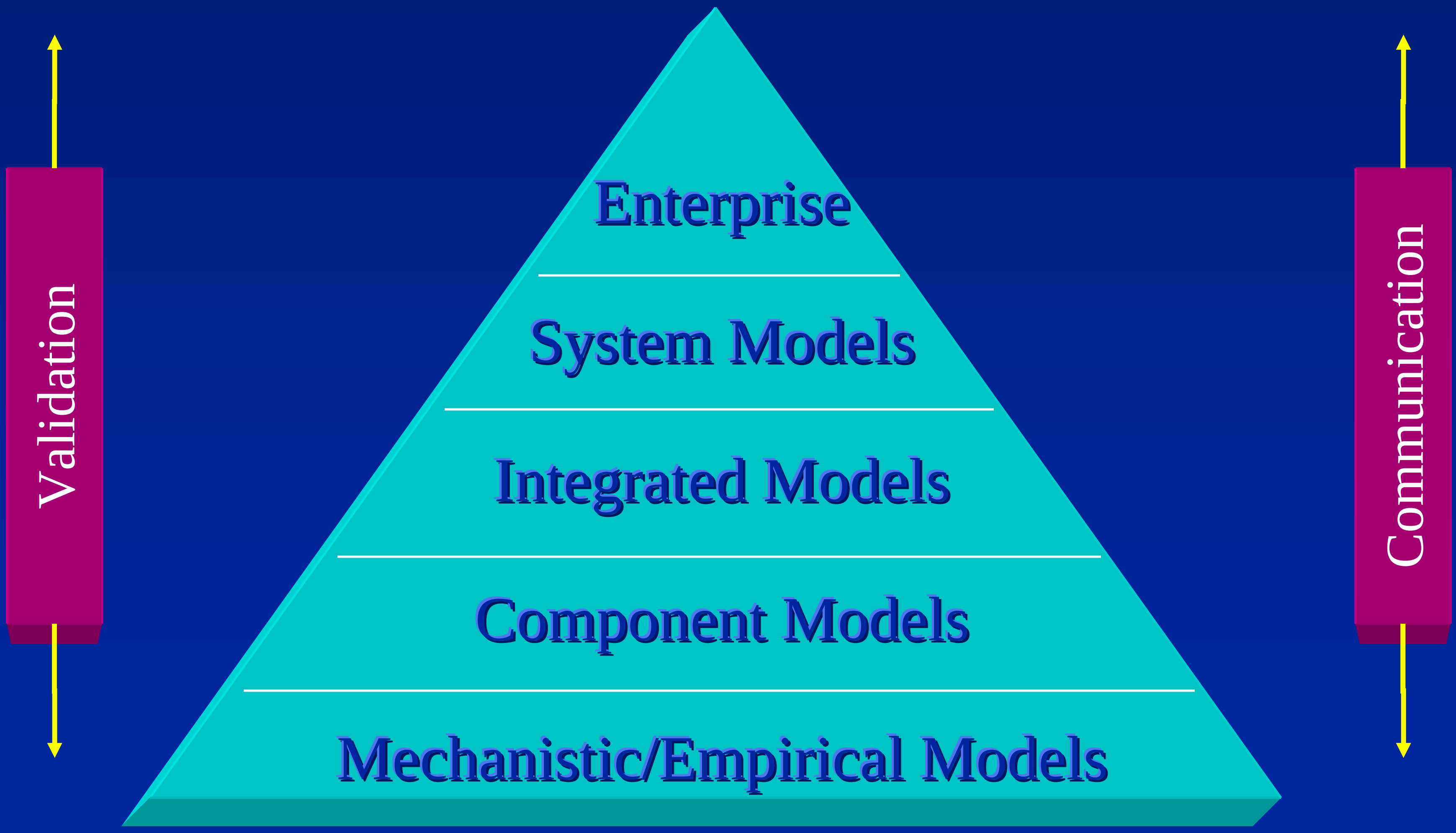
New Work in Progress

- Expansion of IECM modules
- Vision 21 systems analysis framework (The Vision 21 Planner)

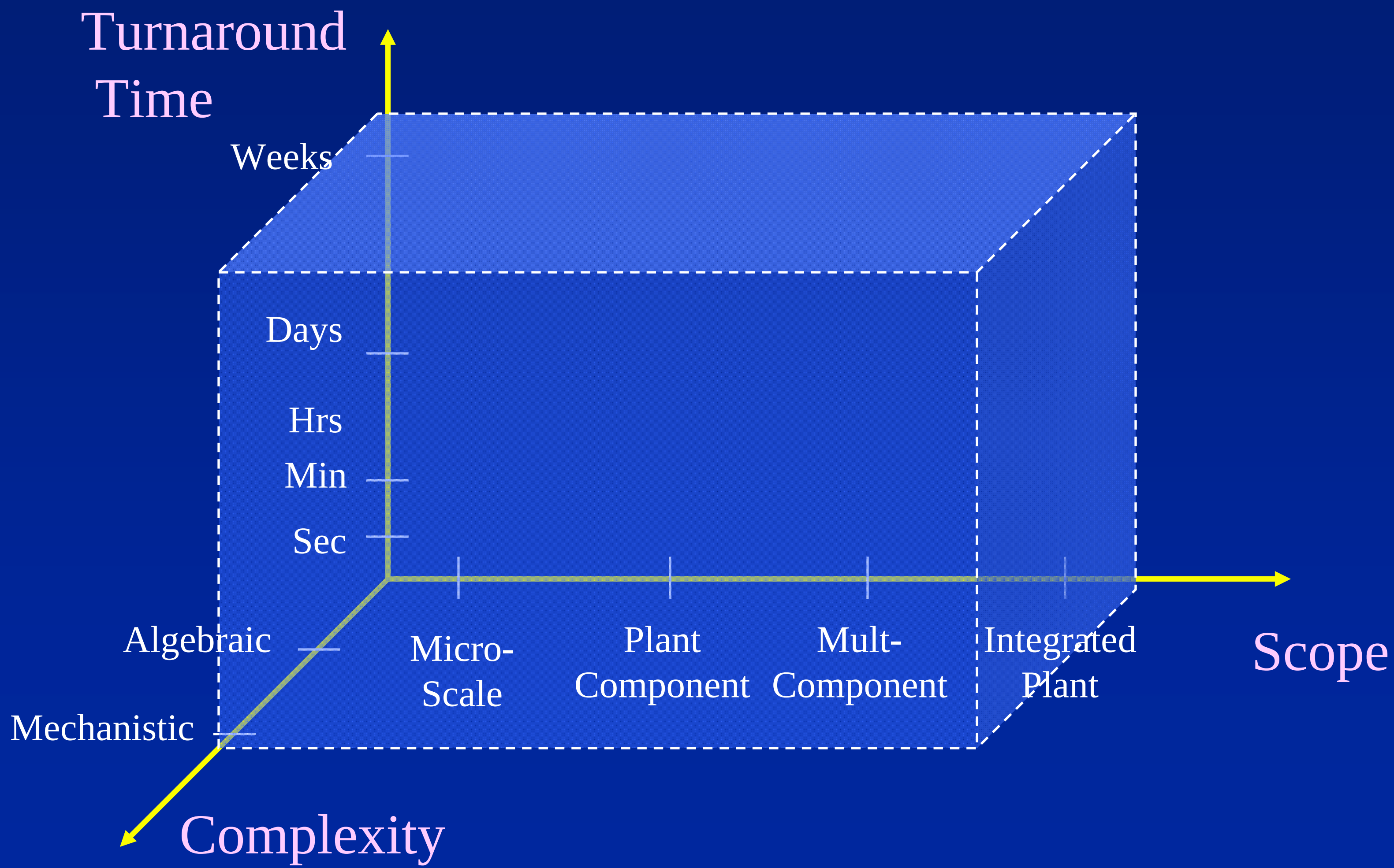
The Vision 21 Planner Would . . .

- 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
- Use publically available software
- Allow new process concepts to be easily modeled
- Allow uncertainties to be characterized explicitly
- Facilitate selection of optimal (most promising) designs

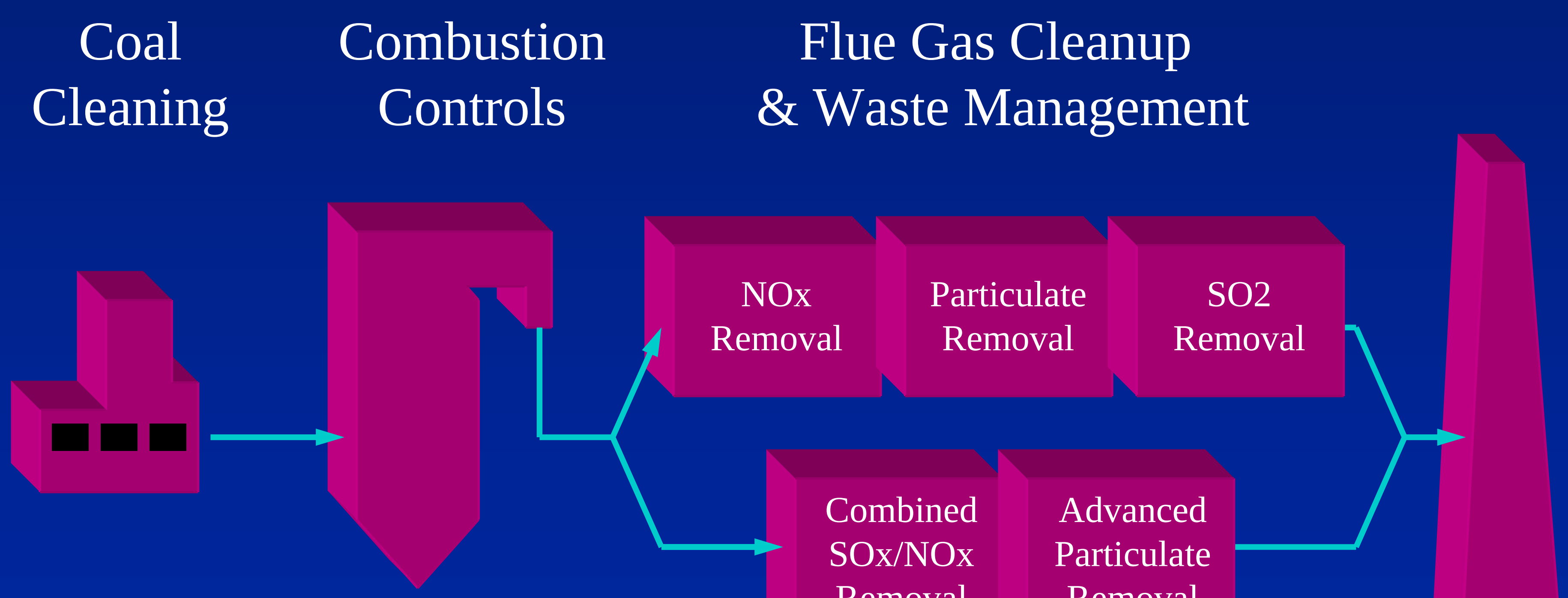
A Hierarchy of Process Models

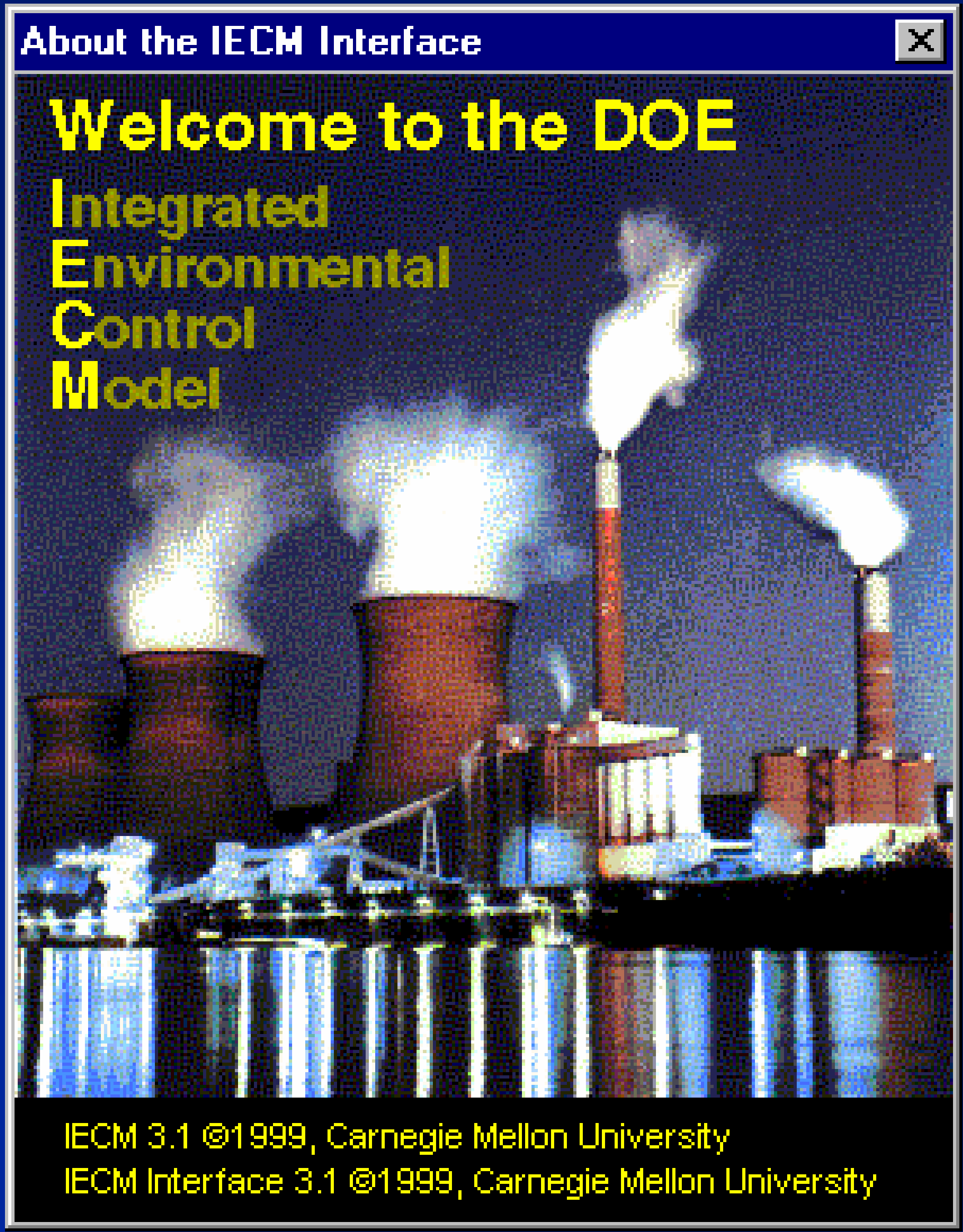


Attributes of Process Models



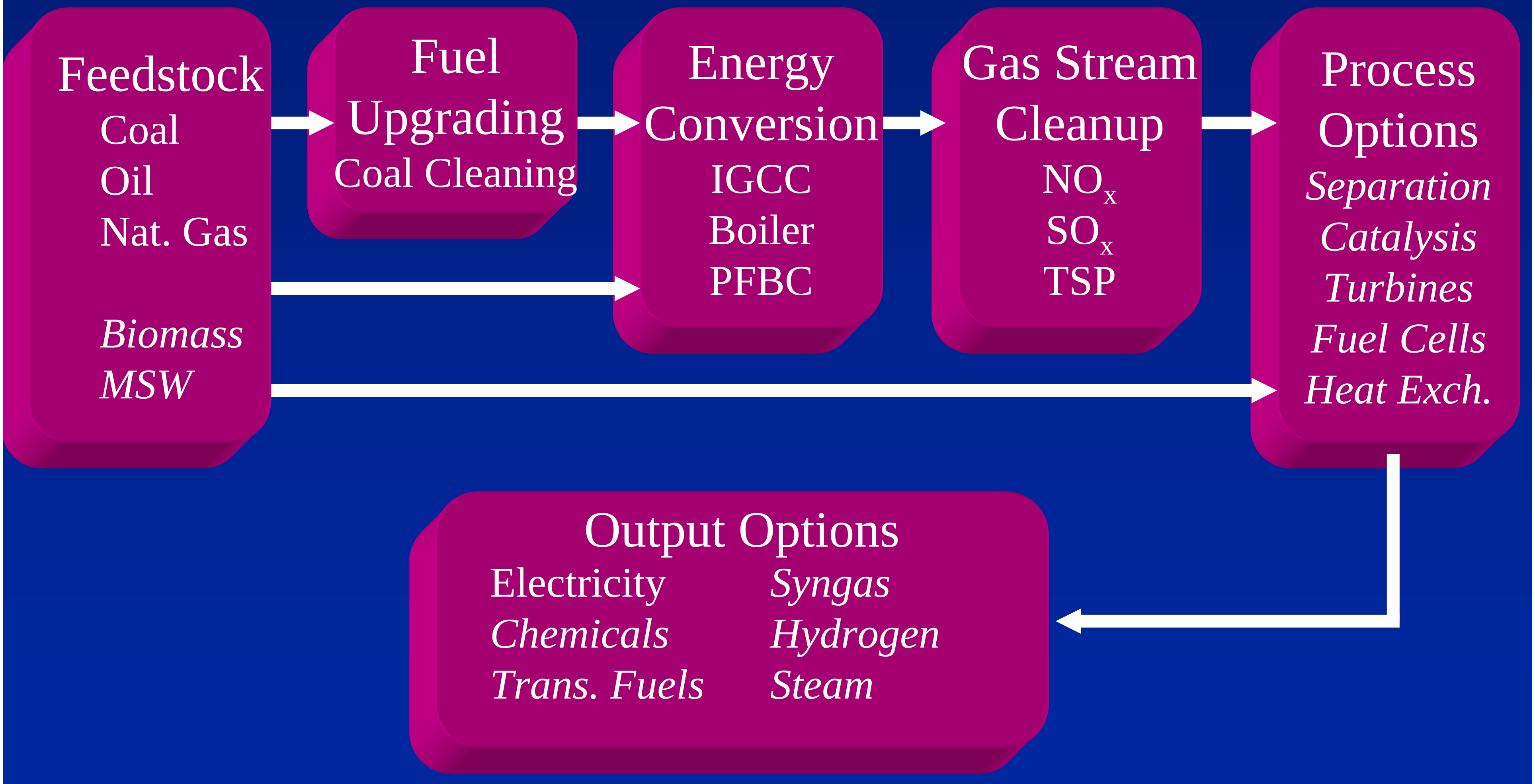
Integrated Environmental Control Model (IECM)



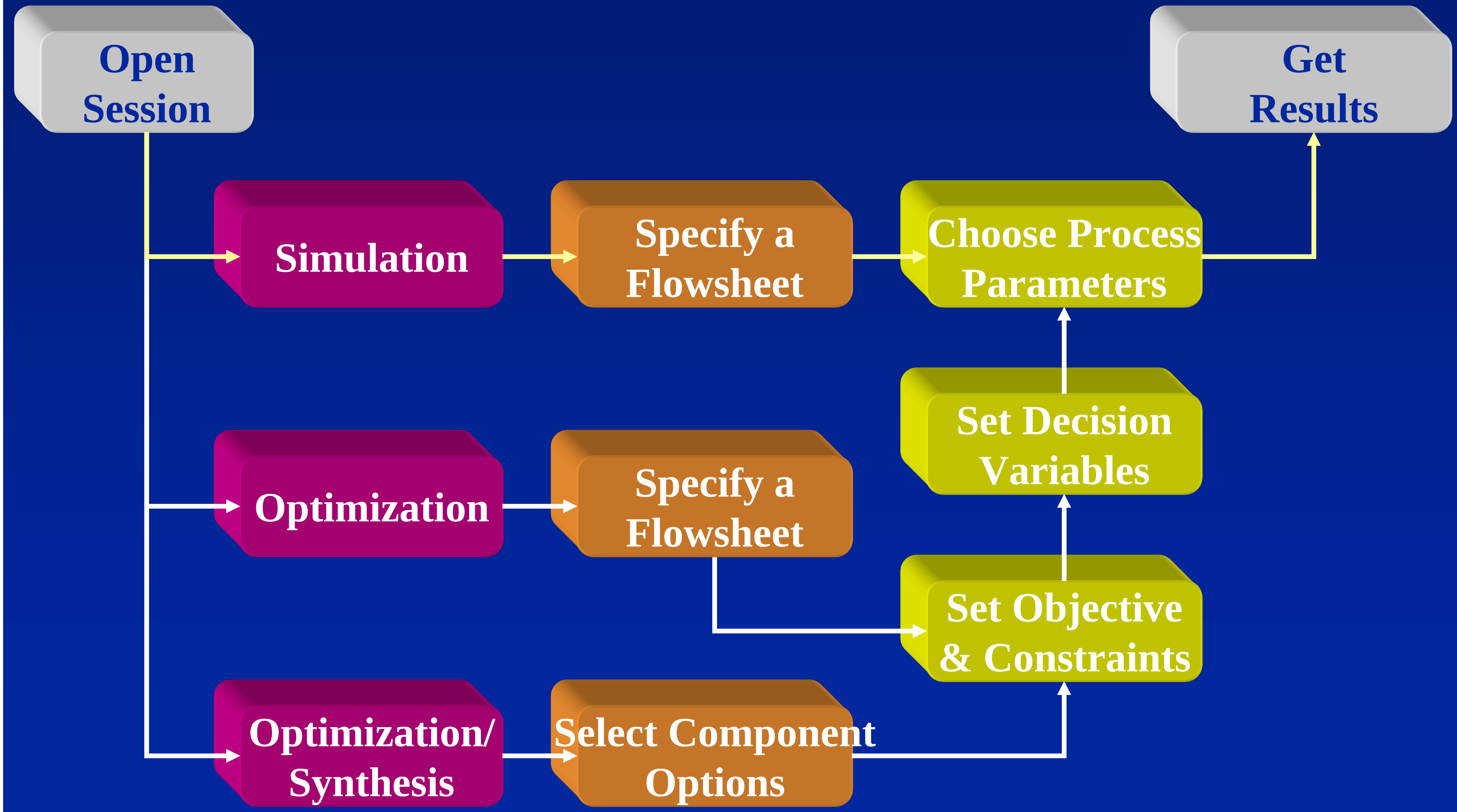

About the IECM Interface
Welcome to the DOE
Integrated
Environmental
Control
Model
IECM 3.1 ©1999, Carnegie Mellon University
IECM Interface 3.1 ©1999, Carnegie Mellon University

(live demo of the IECM)

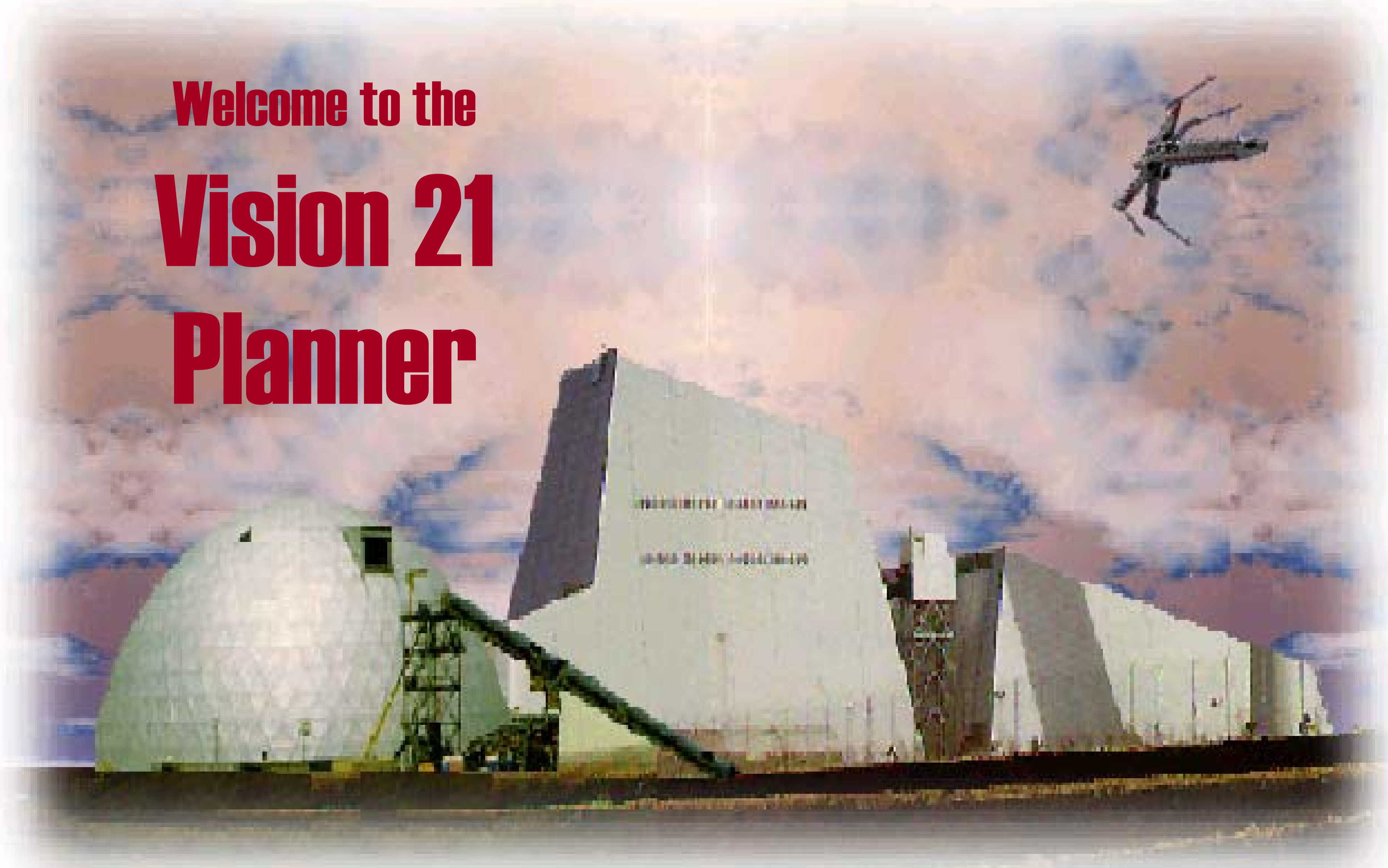
Schematic of the Proposed Vision 21 Planner



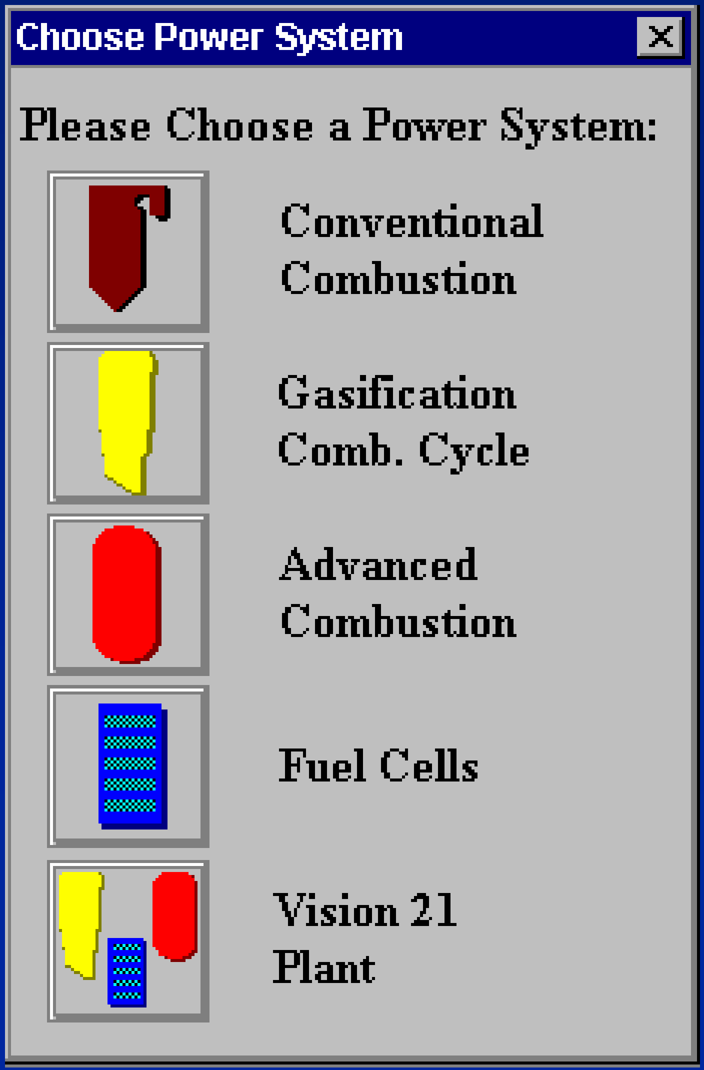
Vision 21 Planner: Operation Overview



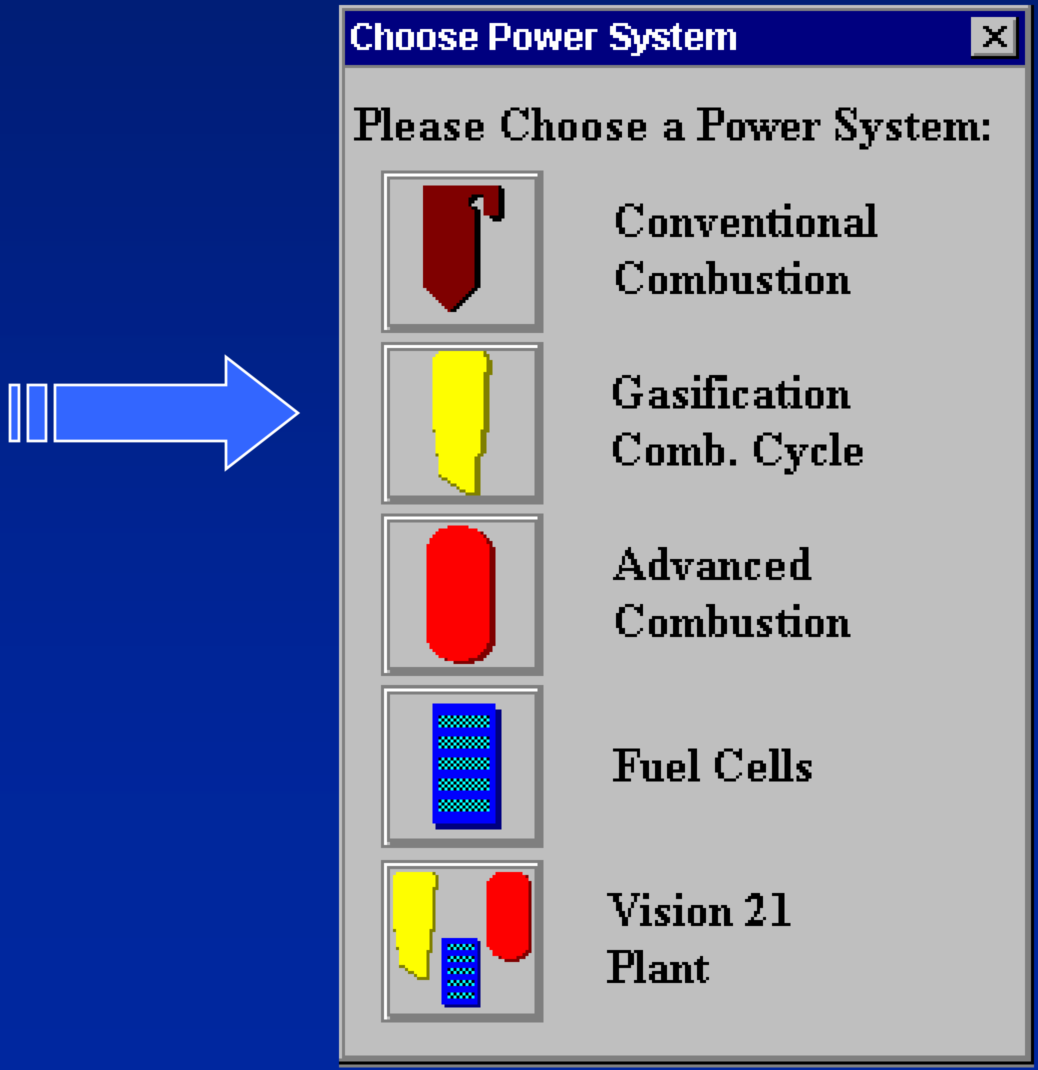
Welcome to the Vision 21 Planner



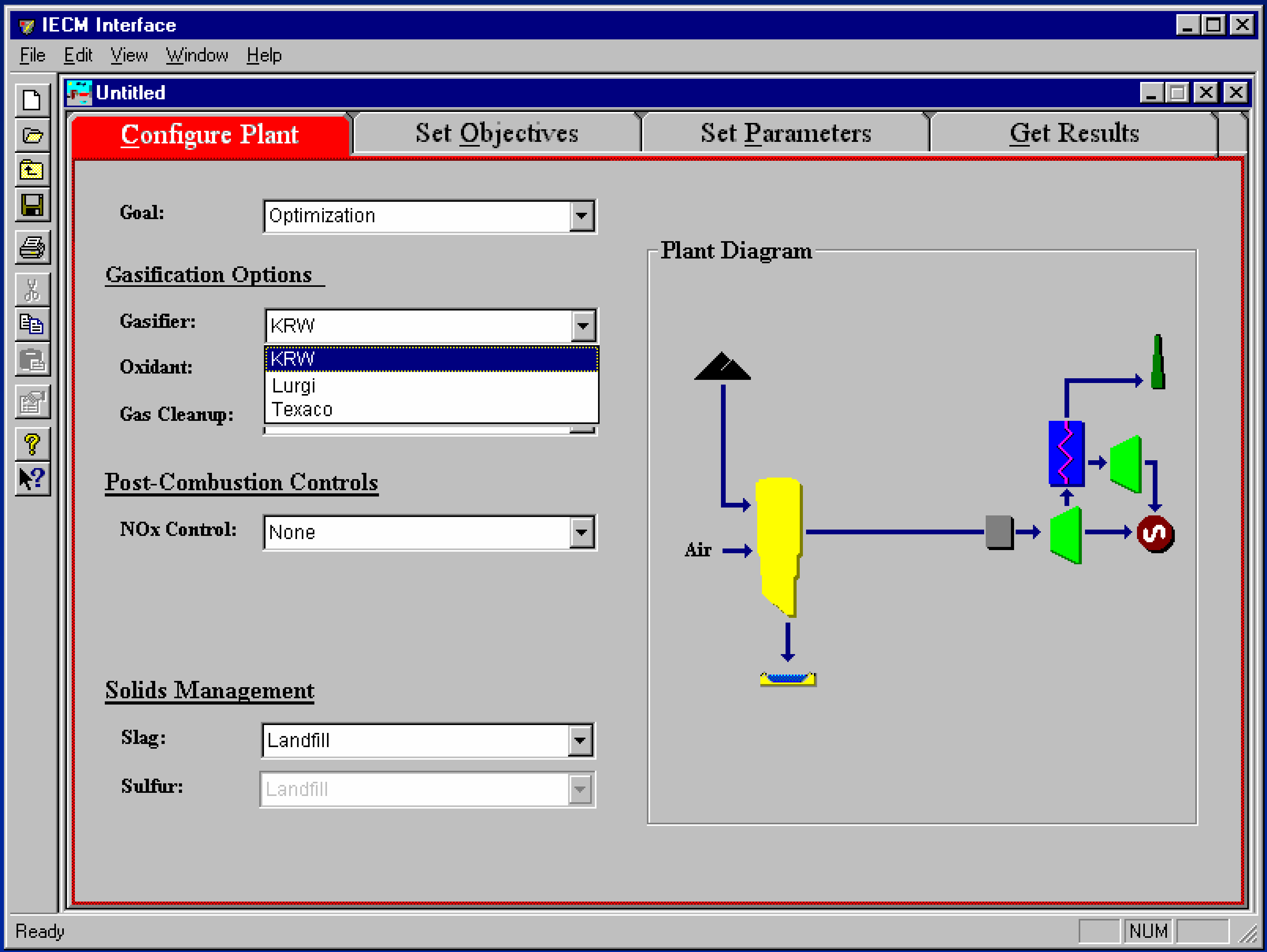
Opening Screen: A Menu of Technology Options



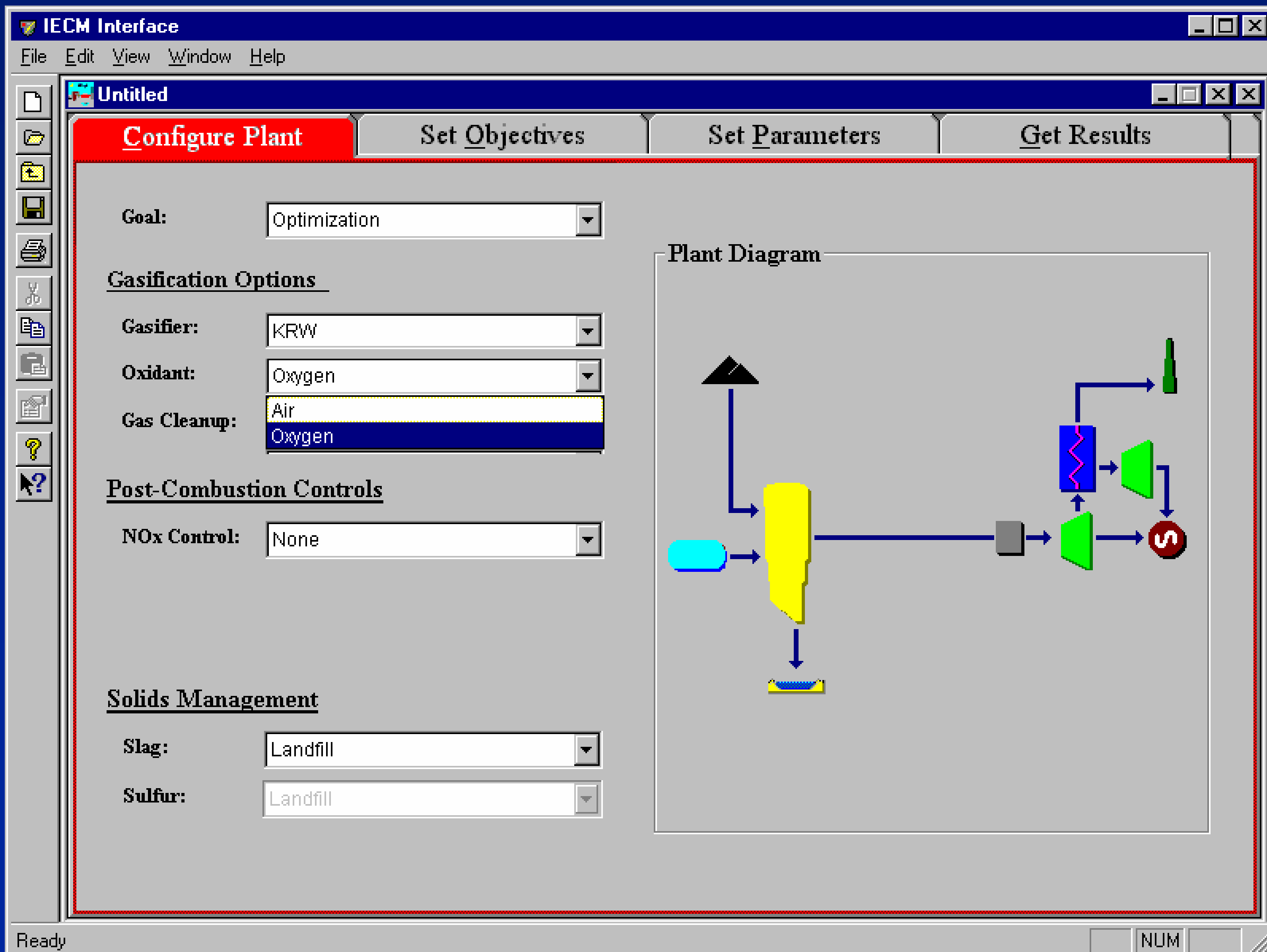
Select Gasification Combined Cycle (IGCC) Options



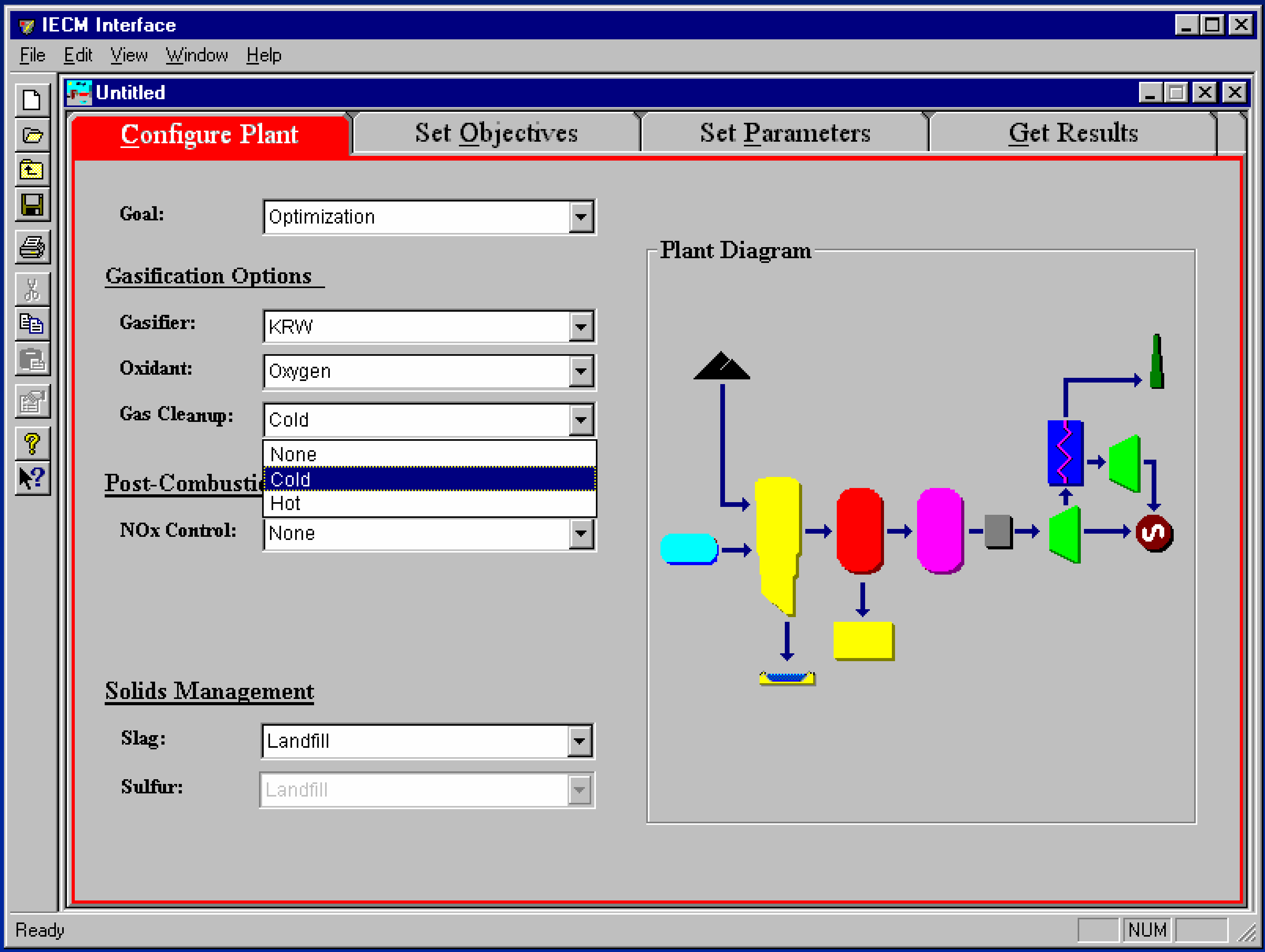
Select KRW Gasifier



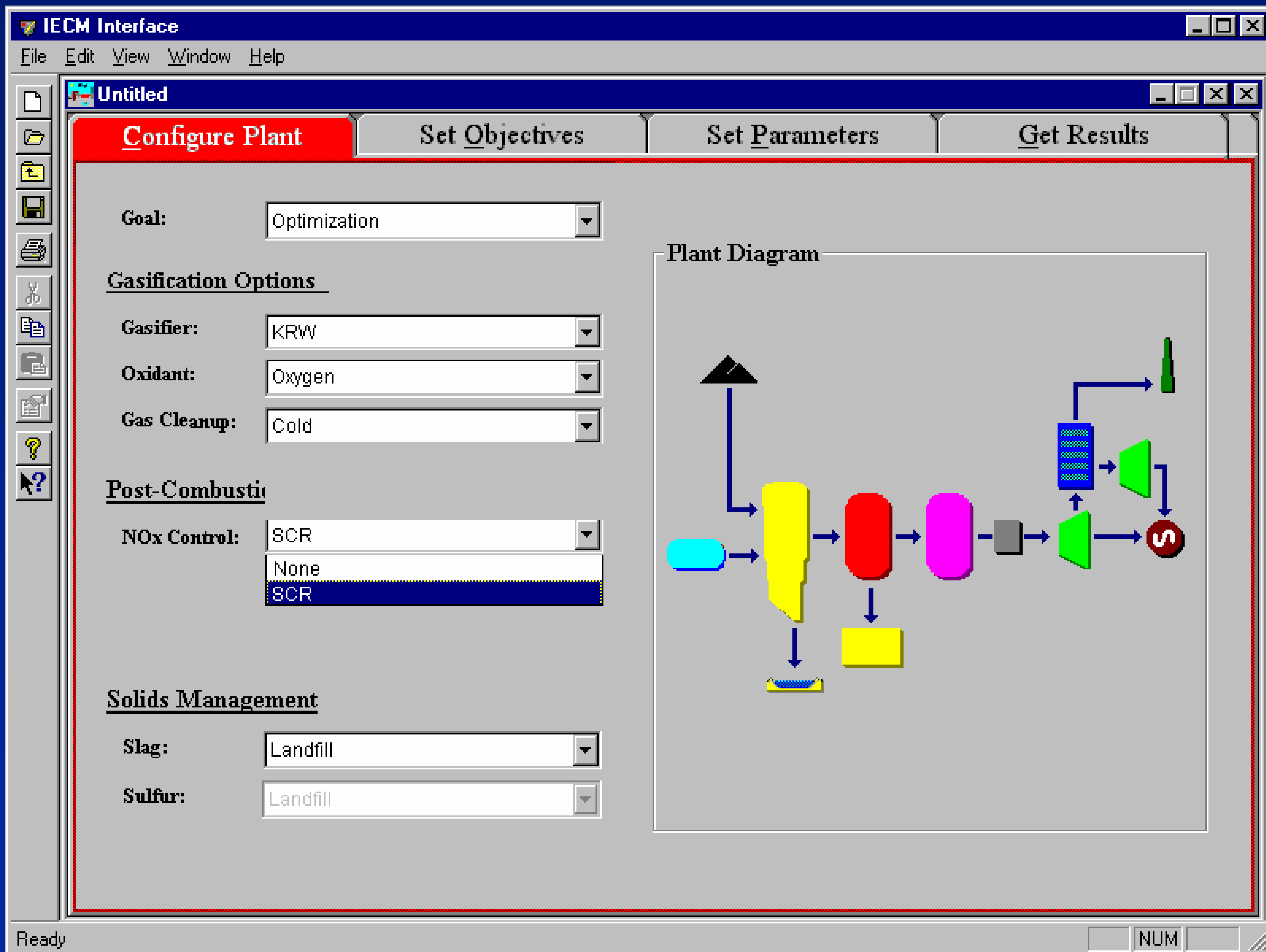
Select Oxygen Plant



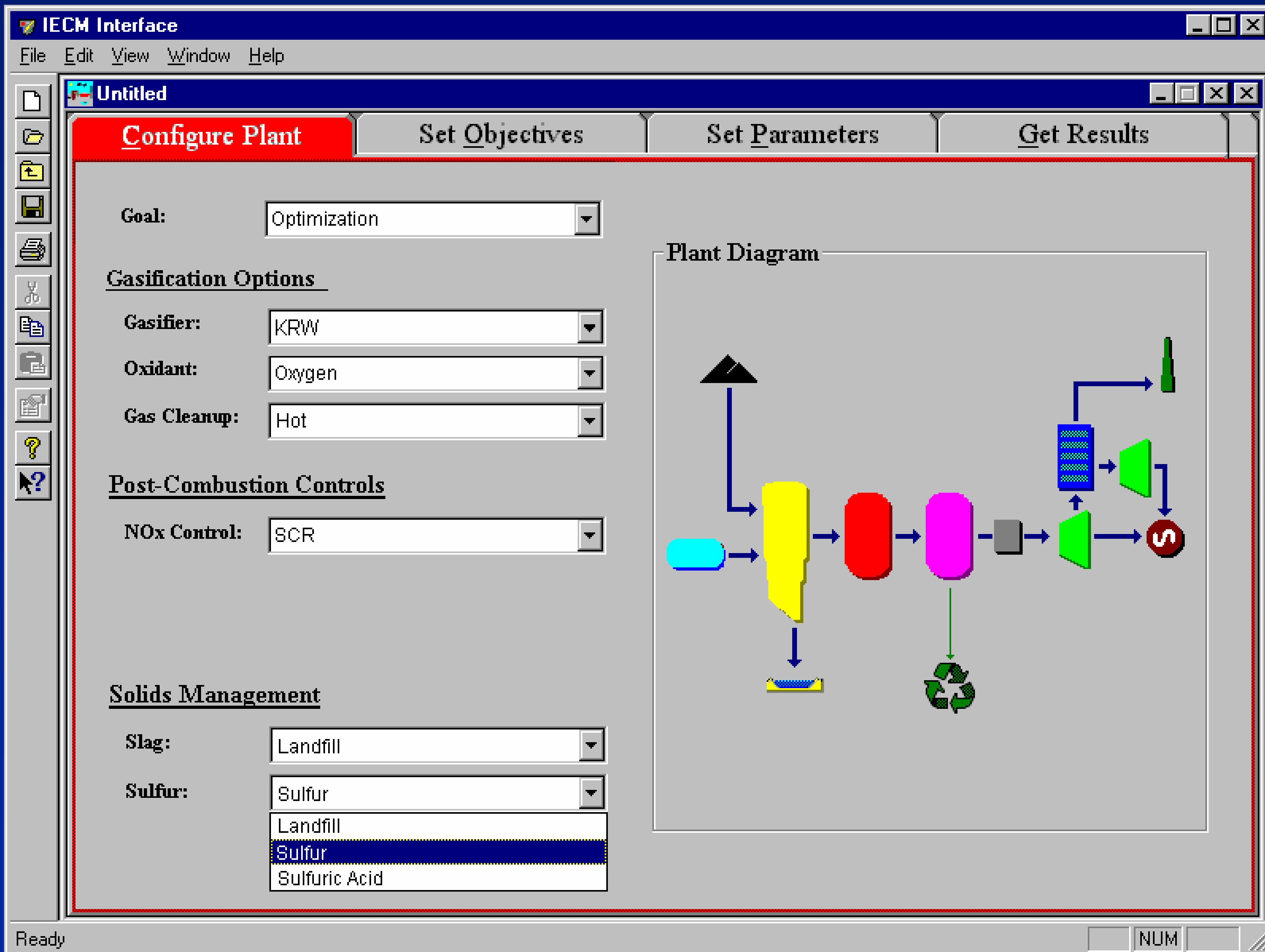
Select Cold Gas Cleanup



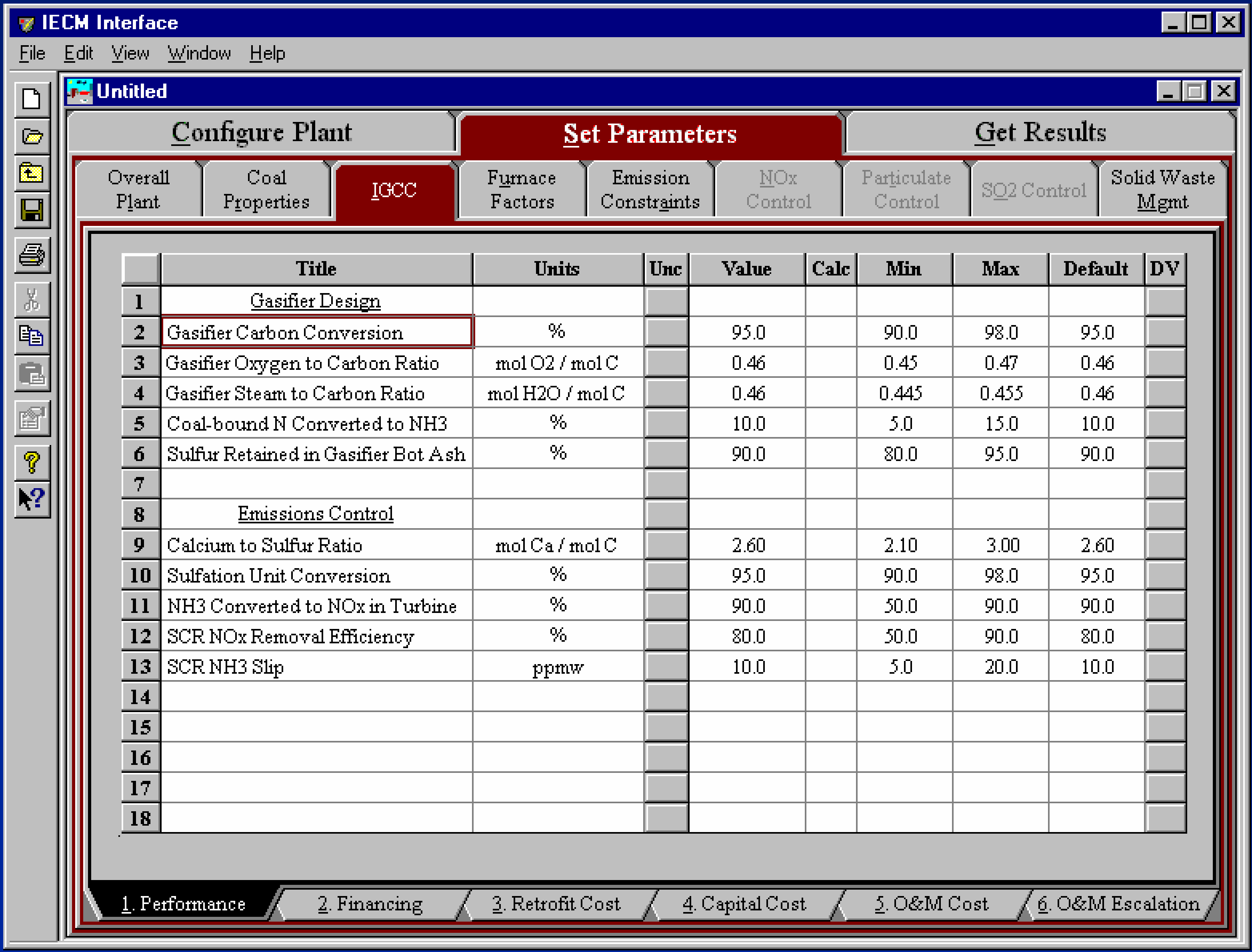
Select NO_x Control



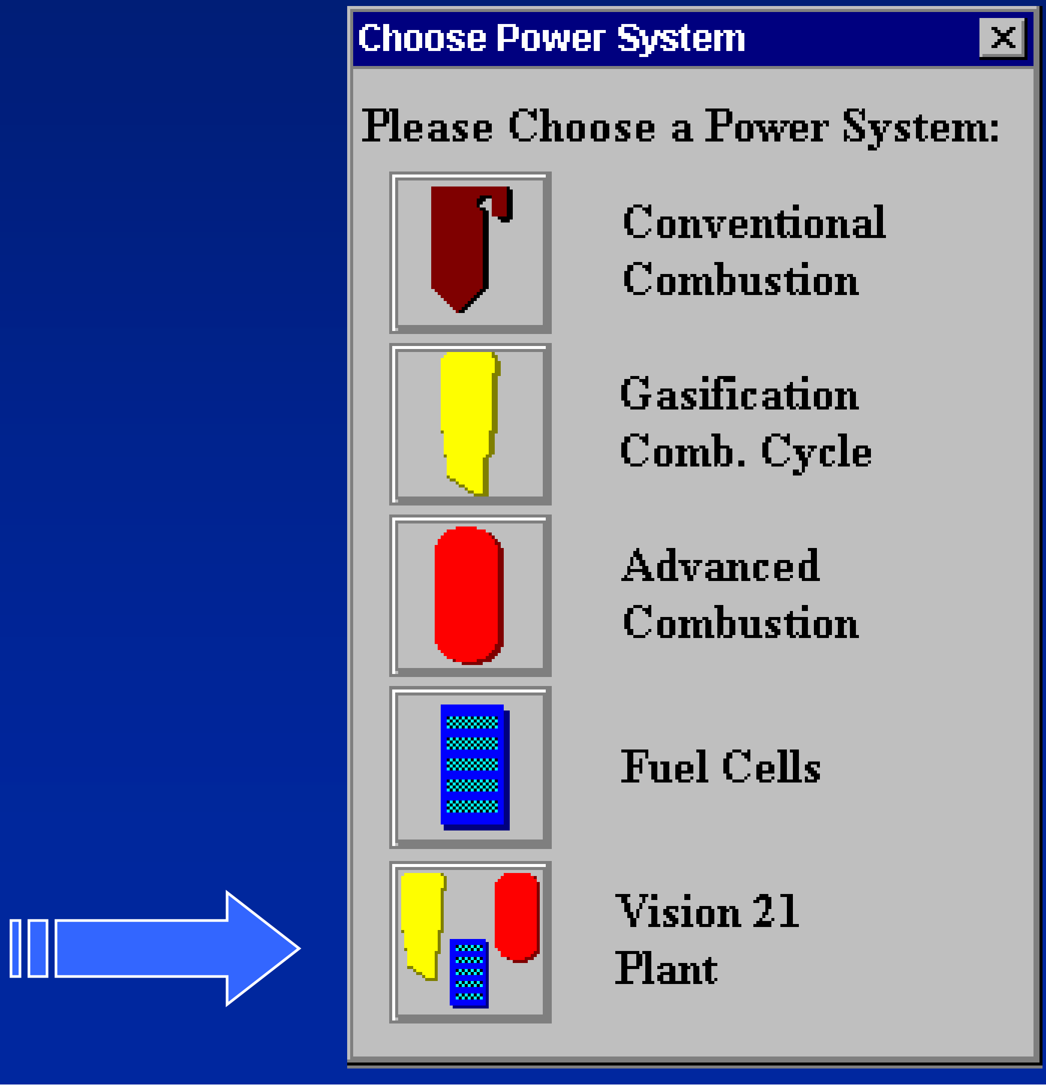
Select Byproduct Recovery



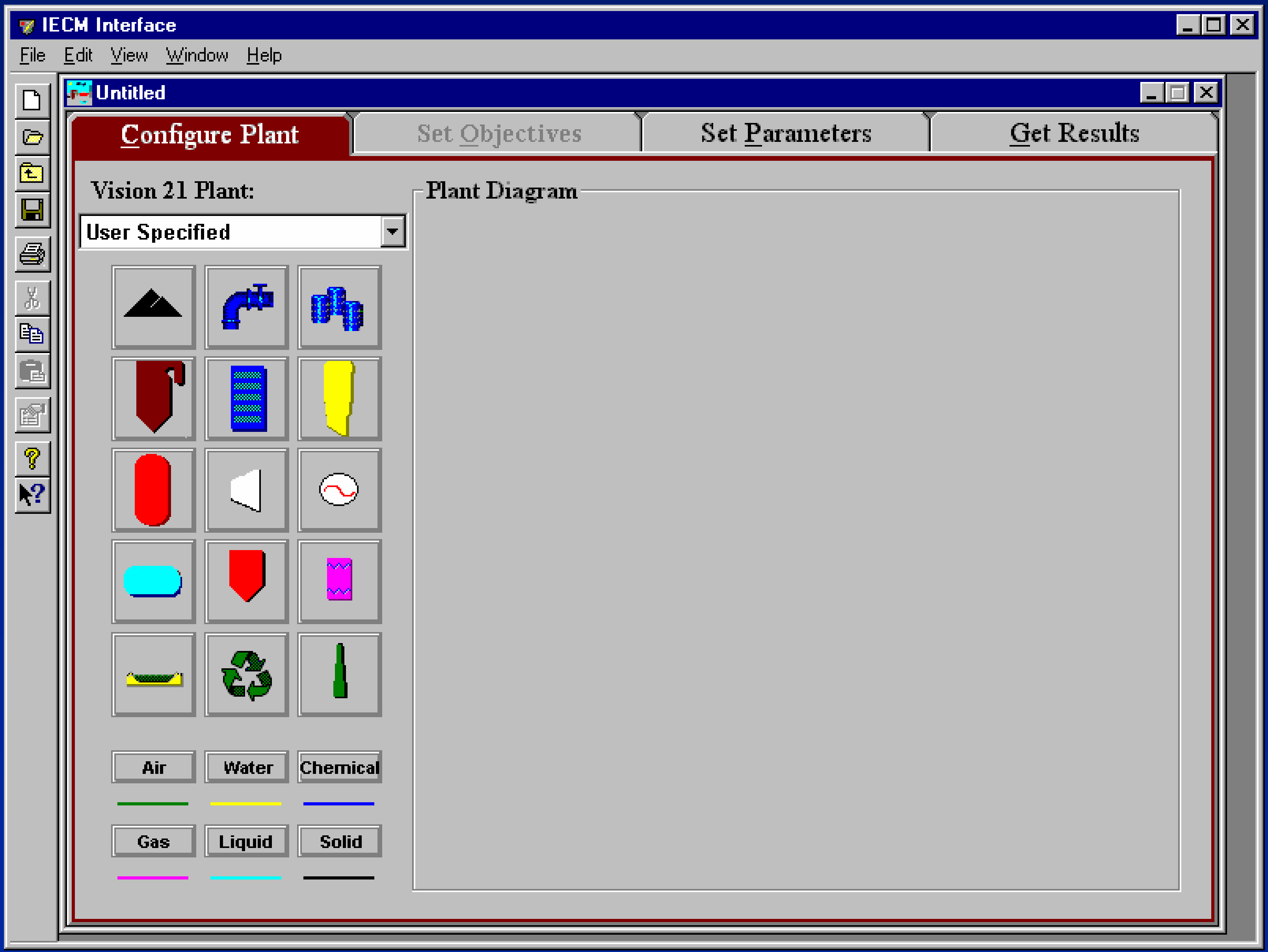
Set Process Parameters



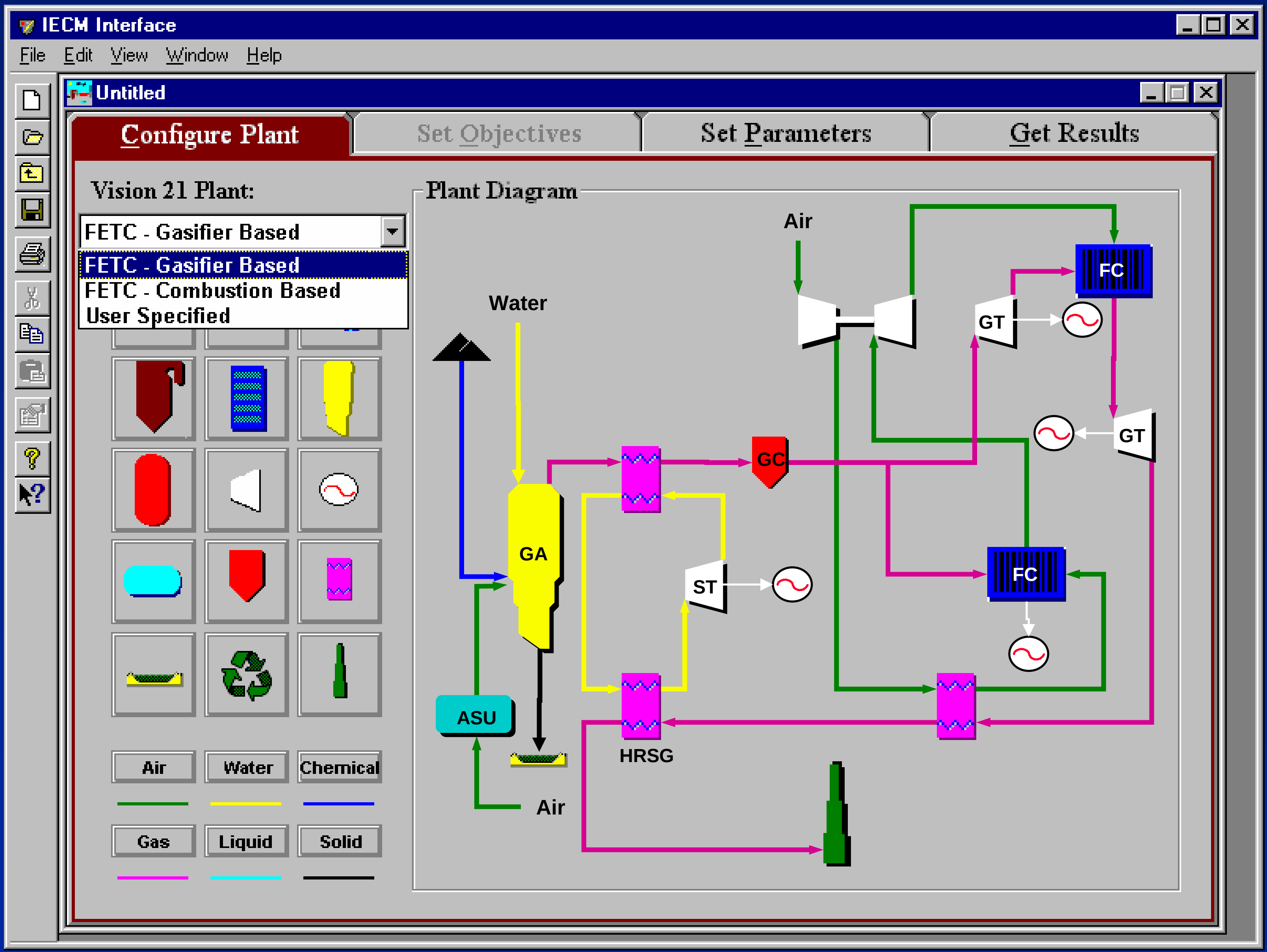
Open Vision 21 Plant Options



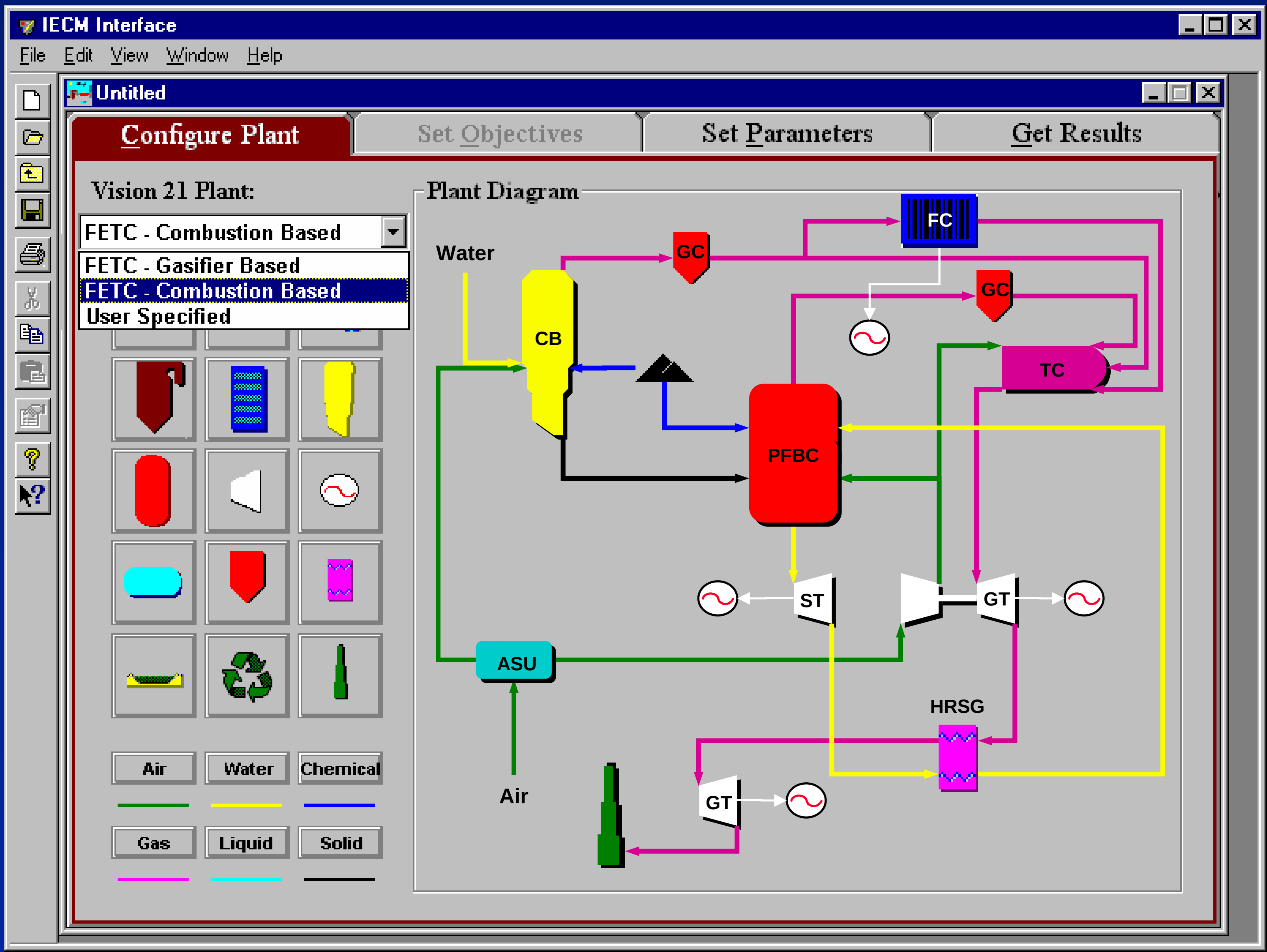
Vision 21 Workbench



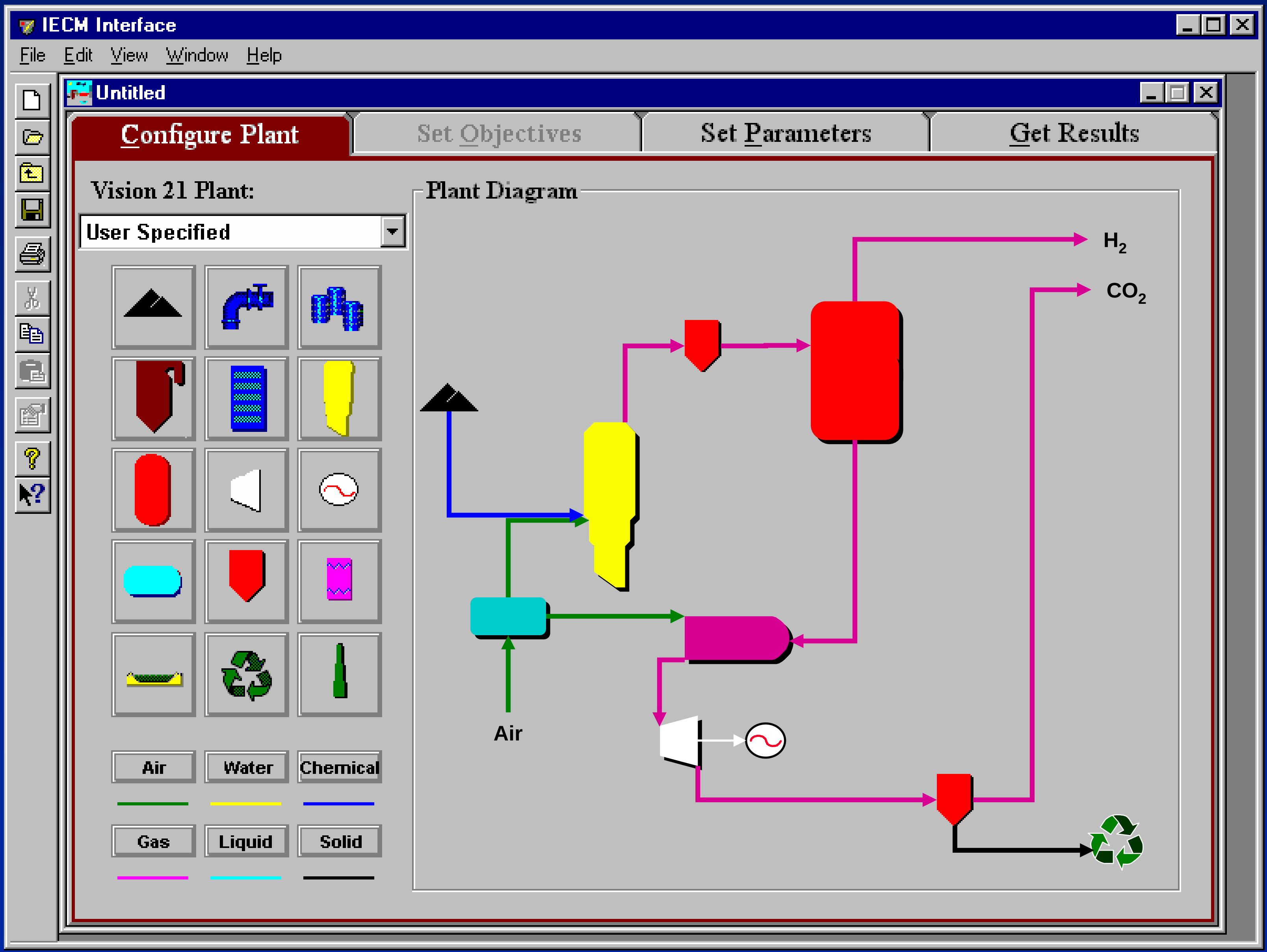
Select Existing Flowsheet - 1



Select Existing Flowsheet - 2



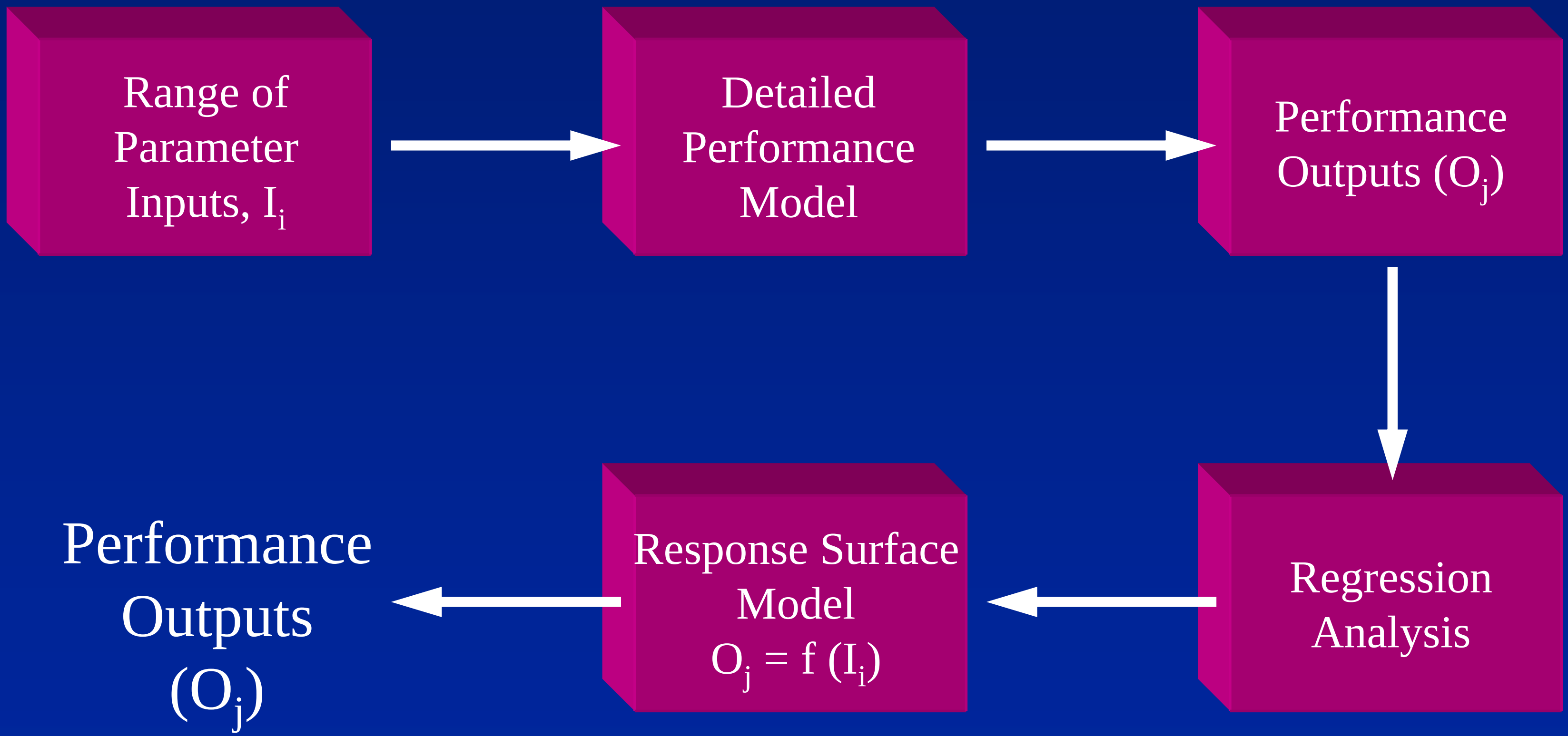
Configure a New System



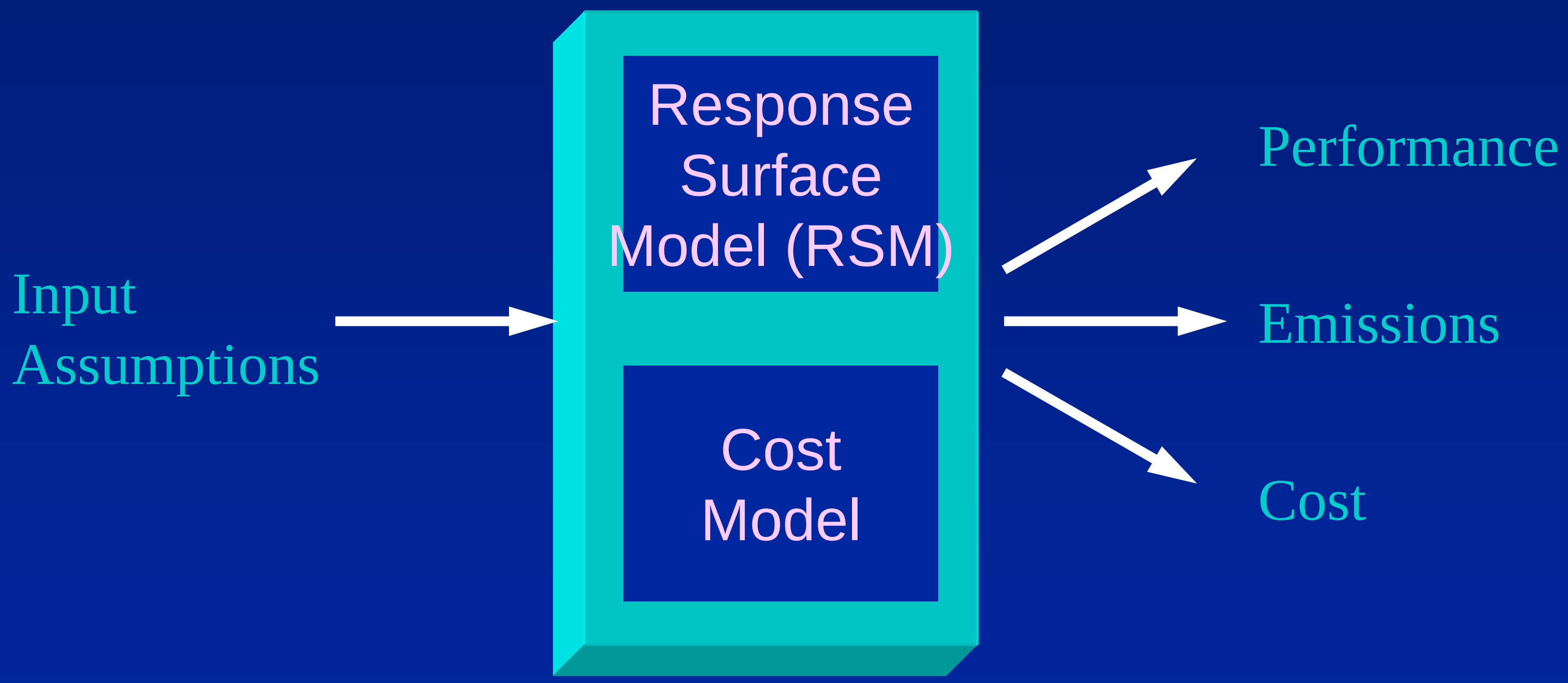
Linkage to More Detailed Process Models

- Where appropriate, use a Response Surface Model (RSM) to faithfully reproduce the results of a more detailed process model
- Captures effect of key process design variables
- Serves as a validation tool for desktop models
- Substantially reduces computational requirements and turnaround time

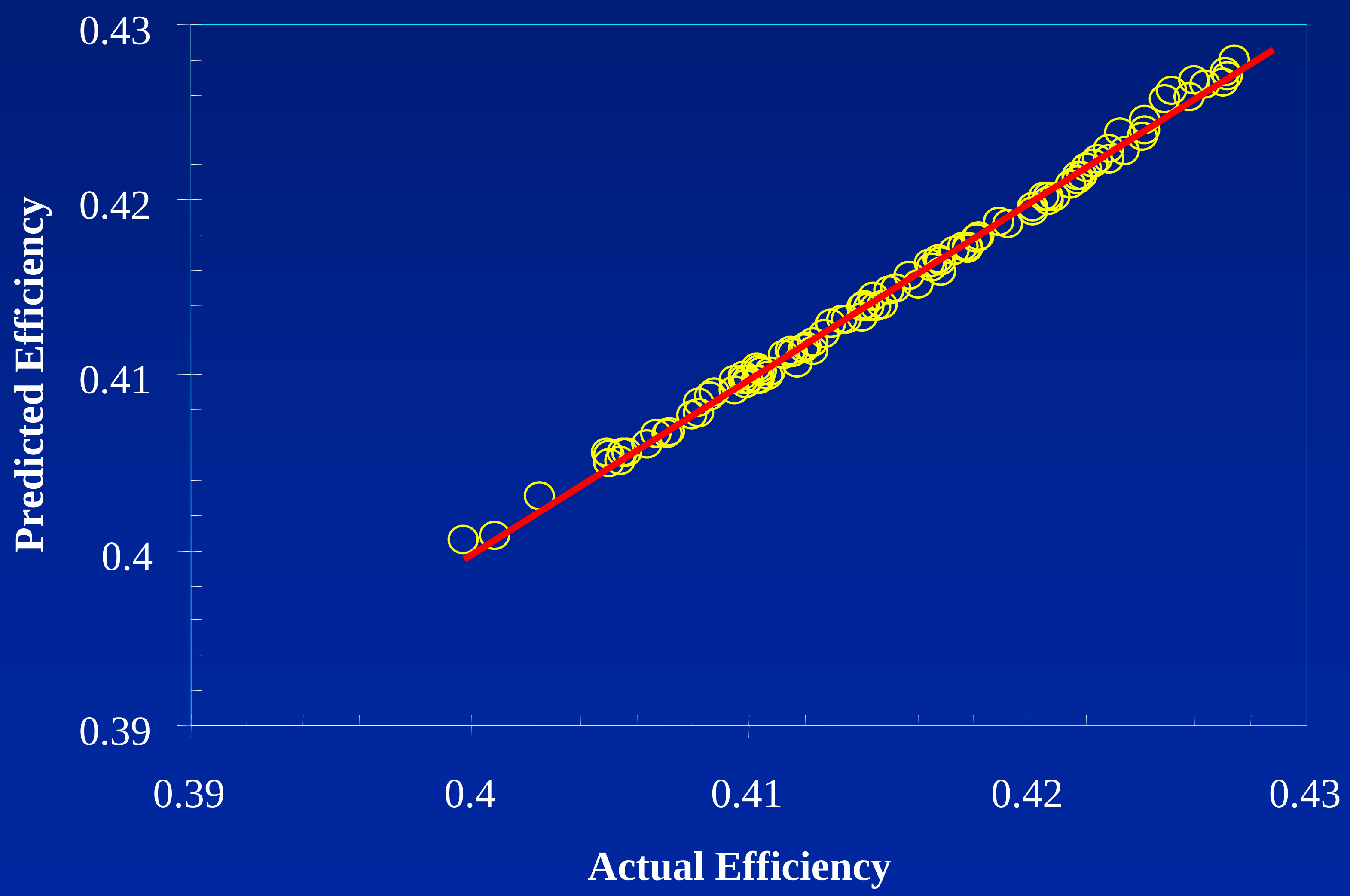
Response Surface Model Development



Desktop Model of a Process



Evaluation Of Desktop Model: IGCC Plant Efficiency



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

Model Applications

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

Where Do We Go from Here?

- Current project will implement and demonstrate:
  - Response surface models of several IGCC system configurations
  - Process optimization capability
- Further development would:
  - Use the Vision 21 Planner as a testbed for systems integration development
  - Add preliminary versions of enabling technology models
  - Add process synthesis capability
  - Explore system dynamics modeling

So, What Do You Think?