The Environmental Design of Advanced Energy Systems

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Objectives

- Develop reliable and easy-to-use models to estimate the environmental performance and cost of conventional and advanced technologies to produce electricity from fossil fuels

- Develop a framework for comparing alternative options on a systematic basis, including the effects of uncertainty
Target Applications

- Technology assessment
- Process design
- Cost estimation
- R&D management

- Risk analysis
- Environmental compliance
- Marketing studies
- Strategic planning
Approach

- Process Technology Models
- Engineering Economic Models
- Advanced Software Capabilities
- Systems Analysis Framework
Integrated Environmental Control Model (IECM)

Coal Cleaning

Combustion Controls

Flue Gas Cleanup & Waste Management

NOx Removal

Particulate Removal

SO2 Removal

Combined SOx/NOx Removal

Advanced Particulate Removal
Probabilistic Software Capability

- Allows you to explicitly model and quantify the effects of uncertainty in performance, emissions and cost of a particular technology

- Allows you to compare different technologies and to quantify the probability of superior performance or lower cost
Example of a Probabilistic Result
Total Plant Capital Cost

Cumulative Probability

Total Capital Requirement ($1994/kW)

Probabilistic
DOE (1989)

524 MW net
IECM Software Package

Fuel Properties
- Heating Value
- Composition
- Delivered Cost

Plant Design
- Furnace Type
- Emission Controls
- Solid Waste Mgmt
- Chemical Inputs

Cost Data
- O&M Costs
- Capital Costs
- Financial Factors

Power Plant Model

Graphical User Interface

Session & Fuel Databases

Plant & Process Performance

Environmental Emissions

Plant & Process Costs
Welcome to the DOE Integrated Environmental Control Model

IECM 3.1 ©1999, Carnegie Mellon University
IECM Interface 3.1 ©1999, Carnegie Mellon University
**Configure Plant**

**Combustion Controls**
- **Furnace Type**: Tangential
- **NOx Control**: Low NOx Burners

**Post-Combustion Controls**
- **NOx Control**: Hot-Side SCR
- **Particulates**: None
- **SO2 Control**: None
- **SO2/NOx**: None

**Solids Management**
- **Recovery**: None
- **Fly Ash Disposal**: mixed w/ Landfill

**Plant Diagram**
**Combustion Controls**

- **Furnace Type:** Tangential
- **NOx Control:** Low NOx Burners

**Post-Combustion Controls**

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

**Solids Management**

- **Recovery:** None
- **Fly Ash Disposal:** mixed w/ Landfill
**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
<table>
<thead>
<tr>
<th>Title</th>
<th>Units</th>
<th>Unc</th>
<th>Value</th>
<th>Calc</th>
<th>Min</th>
<th>Max</th>
<th>Default</th>
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<tr>
<td>Gross Electrical Output</td>
<td>MWg</td>
<td></td>
<td>500</td>
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<td>500</td>
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<td>Steam Cycle Heat Rate</td>
<td>Btu/kWh</td>
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<td>7880</td>
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<td>6000</td>
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<td>%</td>
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<td>75</td>
<td></td>
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<td>75</td>
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<td>Excess Air For Furnace</td>
<td>% stoich.</td>
<td></td>
<td>20.00</td>
<td></td>
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<td>40</td>
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<td>Leakage Air at Preheater</td>
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<td>80</td>
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<td>60.70</td>
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<td>100</td>
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<td>% MWg</td>
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<td>1.3</td>
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<td>0</td>
<td>4</td>
<td>1.3</td>
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Maximum SO2 Removal Efficiency

<table>
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<tr>
<th>Plant Parameter</th>
<th>Units</th>
<th>Value</th>
<th>Minimum</th>
<th>Maximum</th>
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<tr>
<td>Maximum SO2 Removal Efficiency</td>
<td>%</td>
<td>95</td>
<td>90</td>
<td>99</td>
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</table>

**Distribution:**
- Triangular
- Normal
- Triangular
- Uniform
- Fractiles

**Normalized:**
- Min: 0.9000
- Mode: 1.000
- Max: 1.023

**Nominal:**
- Min: 85.50
- Mode: 95.00
- Max: 97.18

**Description:**

Triangular(a,b,c) describes a triangular-shaped distribution where the values a, b, and c represent the minimum, most likely and maximum values, respectively.

**Uncertainty Areas:**

- Base Plant
- Air Preheater
- Solid Waste Mgmt.
- NOx Control
- Particulate Control
- SO2 Control
- SO2/NOx Control

**Uncertainty Tools: Untitled**

**Select All**

**Select None**

**Sample Size:** 50

**Sampling Method:** Median LHS
<table>
<thead>
<tr>
<th>Technology</th>
<th>Capital Cost (M$)</th>
<th>Capital Cost ($/kW)</th>
<th>O&amp;M Cost (M$/yr)</th>
<th>Revenue Required (M$/yr)</th>
<th>Revenue Required (mills/kWh)</th>
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<tr>
<td>NOx Control</td>
<td>24.04</td>
<td>52.97</td>
<td>3.160</td>
<td>5.645</td>
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<td>TSP Control</td>
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<td>1.739</td>
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<td>64.13</td>
<td>141.3</td>
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<td>17.66</td>
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<td>Comb. SOx/NOx</td>
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<td>Subtotal</td>
<td>107.8</td>
<td>237.6</td>
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<td>Subtotal</td>
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<td>964.2</td>
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<td>99.73</td>
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<tr>
<td>Total</td>
<td>545.5</td>
<td>1202</td>
<td>73.32</td>
<td>126.6</td>
<td>43.70</td>
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Costs are in Constant 1996 dollars.
Example: CDF Graph of Total Variable Costs (M$/yr)

- Mean: 2.410
- 2.5 percentile: 1.900
- Median (50th percentile): 2.353
- 97.5 percentile: 3.148

Cumulative Probability

- x-axis: Total Variable Costs (M$/yr)
- y-axis: Cumulative Probability

95% confidence interval between shaded areas
The IECM is Available for Downloading

- **Web Access:**
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.
- Savvy Engineering
- Sierra Pacific Power Co.
- Southern Company Services, Inc.
- Stone & Webster Engineering Corp.
- Tampa Electric Co.
- University of California, Berkeley
- US Environmental Protection Agency
Additional Technology Options

- **In Progress**
  - Combustion NO\textsubscript{x} Controls
    - Selective Non-Catalytic Reduction (SNCR)
    - Low NO\textsubscript{x} Burners (LNB)
    - LNB + Overfire air
    - LNB + SNCR
    - Natural Gas Reburn
    - Tangential, Wall & Cyclone Firing

- **Proposed**
  - Post-Combustion Controls
    - Air Toxics (mercury)
  - Other Fuels
    - Natural Gas
    - Petroleum
    - Fuel Blending
  - Alternative Power Generation Systems
Opening Screen:
A Menu of Technology Options

Please Choose a Power System:
- Conventional Combustion
- Gasification Comb. Cycle
- Advanced Combustion
- Fuel Cells
- Vision 21 Plant
Open Vision 21 Plant Options

Choose Power System

Please Choose a Power System:

- Conventional Combustion
- Gasification Comb. Cycle
- Advanced Combustion
- Fuel Cells
- Vision 21 Plant
Welcome to the Vision 21 Planner
Configure a New System

- Vision 21 Plant:
  - User Specified
- Plant Diagram:
  - Air
  - H₂
  - CO₂
Advanced Design Capabilities: Operation Overview

1. Open Session
2. Simulation
3. Optimization
4. Optimization/Synthesis
5. Specify a Flowsheet
6. Specify a Flowsheet
7. Select Component Options
8. Set Decision Variables
9. Set Objective & Constraints
10. Choose Process Parameters
11. Get Results