

# Overview of the IECM

Ed Rubin

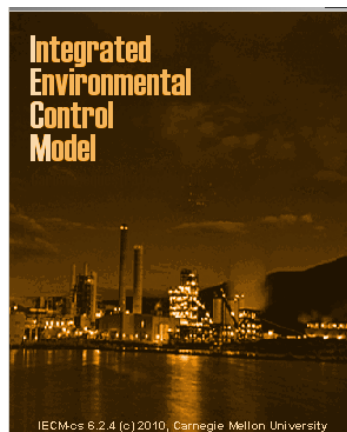
Department of Engineering and Public Policy  
Department of Mechanical Engineering  
Carnegie Mellon University

EPP Advisory Board Meeting

March 15, 2011

## The IECM Calculates Power Plant Performance, Emissions and Costs

- A desktop/laptop computer model developed for DOE/NETL; free and publicly available at:  
[www.iecm-online.com](http://www.iecm-online.com)
- Provides systematic estimates of performance, emissions, costs and uncertainties for preliminary design of:
  - PC, IGCC and NGCC plants
  - All flue/fuel gas treatment systems
  - CO<sub>2</sub> capture and storage options (pre- and post-combustion, oxy-combustion; transport, storage)

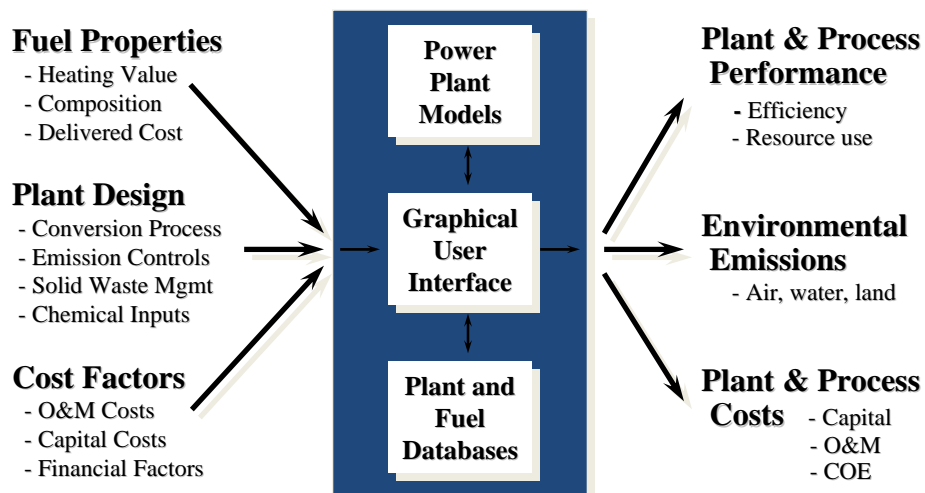


# Modeling Approach

- Systems Analysis Approach
- Process Performance Models
- Engineering Economic Models
- Advanced Software Capabilities
  - Probabilistic analysis capability
  - User-friendly graphical interface
  - Built-in graphs/charts capability
  - Easy to add or update models

*E.S. Rubin, Carnegie Mellon*

# IECM Software Package



*E.S. Rubin, Carnegie Mellon*

# IECM Technologies for Coal Plants

(excluding CO<sub>2</sub> capture, transport and sequestration)

## Boiler Types

- Subcritical
- Supercritical
- Ultra-supercritical

## Furnace Firing Types

- Tangential
- Wall
- Cyclone

## Furnace NO<sub>x</sub> Controls

- LNB
- SNCR
- SNCR + LNB
- Gas reburn

## NO<sub>x</sub> Removal

- Hot-side SCR
- Combined SO<sub>2</sub>/NO<sub>x</sub> systems

## Mercury Removal

- Carbon/sorbent injection

## Particulate Removal

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

## SO<sub>2</sub> Removal

- Wet limestone
  - Conventional
  - Forced oxidation
  - Additives
- Wet lime
- Lime spray dryer
- Combined SO<sub>2</sub>/NO<sub>x</sub> systems

## Solids Management

- Ash pond
- Landfill
- Stacking
- Co-mixing
- Byproducts

E.S. Rubin, Carnegie Mellon

# IECM Technologies for CCS

## • CO<sub>2</sub> Capture Options

- PC Plants: - Amine systems (post-combustion)  
(w/optional aux. NG boiler)
  - Oxyfuel combustion w/ flue gas recycle
- NGCC Plants: - Amine systems (post-combustion)
- IGCC Plants: - Water gas shift + CO<sub>2</sub> capture (pre-combustion)

## • CO<sub>2</sub> Transport Options

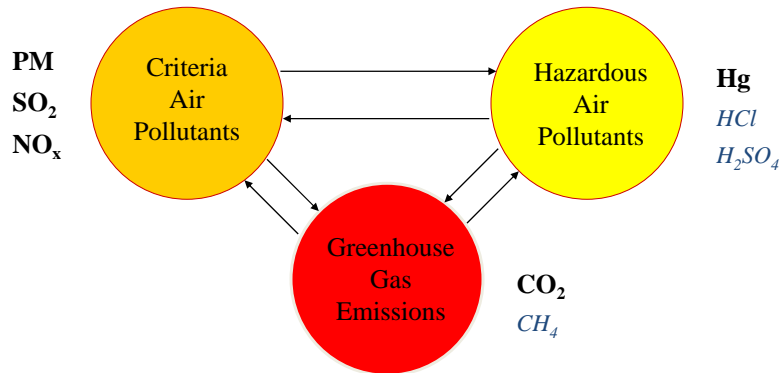
- Pipelines (six U.S. regions)
- Other (user-specified)

## • CO<sub>2</sub> Sequestration Options

- Geological: Enhanced Oil Recovery (EOR)
- Geological: Deep Saline Formation
- Others (user-specified): ECBM; Ocean

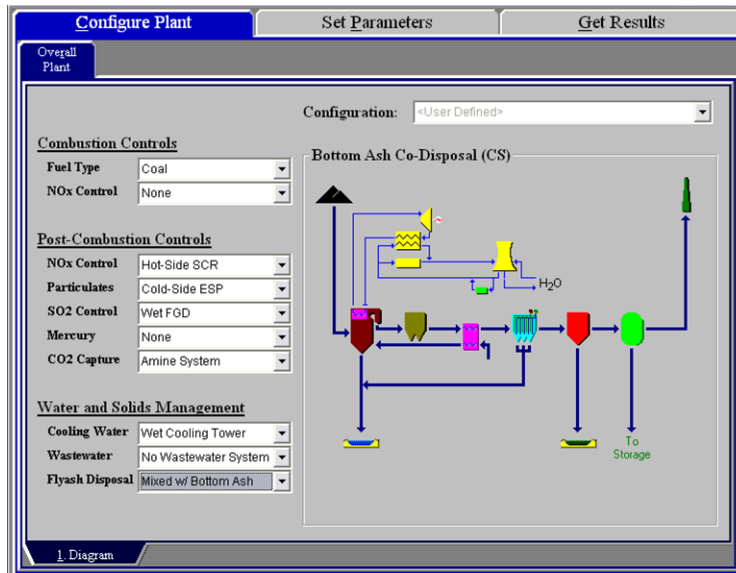
E.S. Rubin, Carnegie Mellon

# Models Account for Multi-Pollutant Interactions



E.S. Rubin, Carnegie Mellon

# Configure Plant Screen



E.S. Rubin, Carnegie Mellon

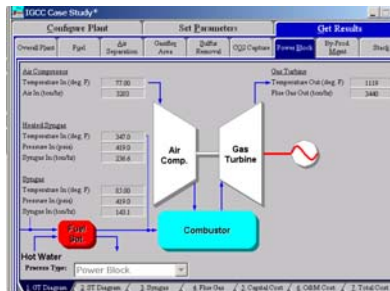
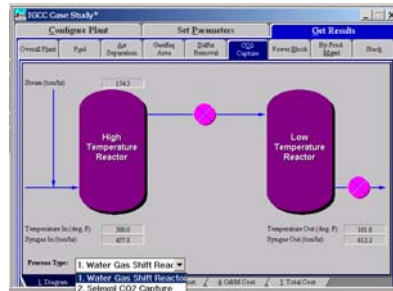
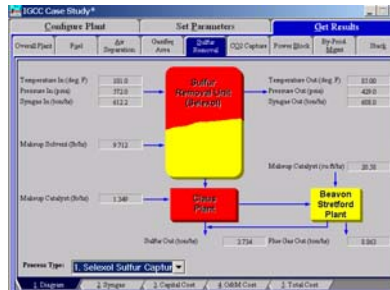
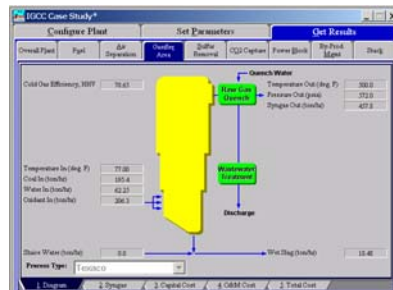
## Results for Plant Mass Flows

Plant Inputs			Flow Rate (ton/hr)	Plant Outputs			Flow Rate (ton/hr)
1	Coal		195.4	1	Slag		18.48
2	Oil		0.6697	2	Ash Disposed		0.0
3	Natural Gas		0.0	3	Other Solids Disposed		0.0
4	Petroleum Coke		0.0	4	Particulate Emissions to Air		2.591e-03
5	Other Fuels		5.860e-02	5	Captured CO <sub>2</sub>		464.9
6	<b>Total Fuels</b>		<b>196.1</b>	6	By-Product Ash Sold		0.0
7				7	By-Product Gypsum Sold		0.0
8	Lime/Limestone		0.0	8	By-Product Sulfur Sold		3.734
9	Sorbent		0.0	9	By-Product Sulfuric Acid Sold		0.0
10	Ammonia		0.0	10	<b>Total Solids &amp; Liquids</b>		<b>487.2</b>
11	Activated Carbon		0.0	11			
12	Other Chemicals, Solvents & Catalyst		4.856e-03	12	See Tab #4 for Total Gases		
13	<b>Total Chemicals</b>		<b>4.856e-03</b>	13			
14				14			
15	Process Water		62.25	15			

Process Type: Overall Plant

EES, Prubin, Casapapa, Mallesh

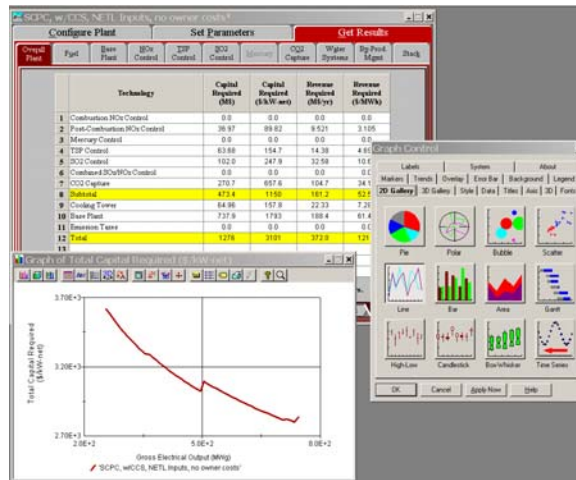
## Results for Specific Plant Components



EES, Prubin, Casapapa, Mallesh

## Advanced Graphing Options

- Can easily and quickly plot any model variable as a function of any other variable
- Can display results from up to six different runs on same graph
- All graphs and data easily exported for display or further processing



E.S. Rubin, Carnegie Mellon

## Model Applications

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

E.S. Rubin, Carnegie Mellon

# Some Recent IECM Users

ABB Lummus Global, Inc.  
AEP-SCR Engr  
Air Liquide  
Air Products plc  
Airbome Clean Energy  
Alzo Nobel Functionalchem  
Alberta Economic Dev.  
Alberta Env.  
Alberta Res. Council  
ALCOA Power Gen. Inc.  
Allegheny Energy Supply  
Alliant Energy  
Alstom (Switzerland)  
Alstom Power Boiler GmbH  
ALSTOM PowerCentrales  
Alstom Power Inc.  
Alstom Power Plant Lab.  
American Electric Power  
American Transmission Co.  
Antara University  
APAT  
Apogee Scientific, Inc.  
ARCADIS  
Argonne National Lab.  
ATCO Power  
Babcock & Wilcox  
Basin Electric Power Corp.  
Bathelle  
Bathelle Northwest  
Bechtel Power Corp.  
Black & Veatch Corp.  
BOC Gases  
Boiler Systems Engr. E.S.O.  
BP  
BP Intl Limited  
BP Power Ltd.  
BP Sunbury  
Canada Env.  
Canada Natural Resources  
Canadian Clean Power Coalition  
Carnegie Mellon University  
Chalmers University  
Chinese Academy of Sci.

Cinergy Power Gen. Services, LLC  
Clean Energy Systems Inc.  
Coal in Sustainable Dev. Tech Transfer  
Coaltek LLC / Jupiter Oxygen Corp.  
Cogentrix Energy, Inc.  
Columbia University  
CONSOL Energy, Inc.  
Consumers Energy  
Coop. Res. Centre for Greenhouse Gas  
COORETEC  
CO, Inc.  
Coul-Reynolds  
CSEnergy  
Dept. of Energy (DOE)  
Dept. of Energy, Instituto de Carboquimica  
Dept. of Env. and Natural Res. - NC  
Dept. of Env. Protection - NJ (DEP)  
Dept. of Env. Protection - PA (DEP)  
Dept. of Env. Quality - VA (DEQ)  
Dept. of Env. Services - NH (DES)  
Detroit Edison Co.  
DMCR/Dutch Ministry of Env. (VROM)  
DONG Energy Gen.  
Dont Inc.  
Doosan Babcock Energy Ltd.  
Dynegy Midwest Gen.  
E. On UK  
E.ON Energie AG  
Edison Mission Energy  
Electric Energy, Inc. (EEI)  
Electric Power Gen. Assoc.  
Electric Power Res. Inst. (EPRI)  
Electricite de France (EDF)  
Emera Inc.  
Enel  
AmerenUE  
Energetics, Inc.  
Energy E2  
Energy & Env. Res. Center (EERC)  
Energy & Env. Res. Corp.  
Energy & Env. Strategies  
Energy Res. Centre of the Netherlands  
ENSR, Inc.

Env. & Renewable Energy Systems  
Env. Defense  
Env. Protection Agency - IL (EPA)  
Env. Protection Agency (EPA)  
First Energy Corp.  
FirstEnergy Corp.  
Florida Power & Light Co.  
FLS Mjlo A/S  
Fluor Inc.  
Fluor Daniel Canada, Inc.  
Ford  
Fortum Power and Heat Oy  
Fossil Energy Res. Corp.  
Foster Wheeler Energy Oy  
Friedman, Billings, Ramsey & Co.  
Fuel Tech, Inc.  
Gas Tech. Inst. (GTI)  
Gassnowa  
GE Global Res.  
GE Infra. Energy  
General Electric Co.  
Generators for Clean Air (GCA)  
GM R&D Center  
Great River Energy  
Gyeongang National University  
H&W Mgmt. Sci. Consultants  
Hamon Res. Cottrell, Inc.  
Harvard University  
Hatch Acres  
Holland Board of Public Works  
IEA Clean Coal Centre  
IEA Env. Projects, Ltd.  
IEA Greenhouse Gas R&D  
IFP  
Illinois Clean Coal Inst.  
Illinois Dept. of Natural Resources  
Illinois Inst. of Tech.  
Imperial College  
Indian Inst. of Tech.  
Industries Limited  
INERCO  
Institut Teknologi (ITB)  
Inst. of Applied Energy (IAE)

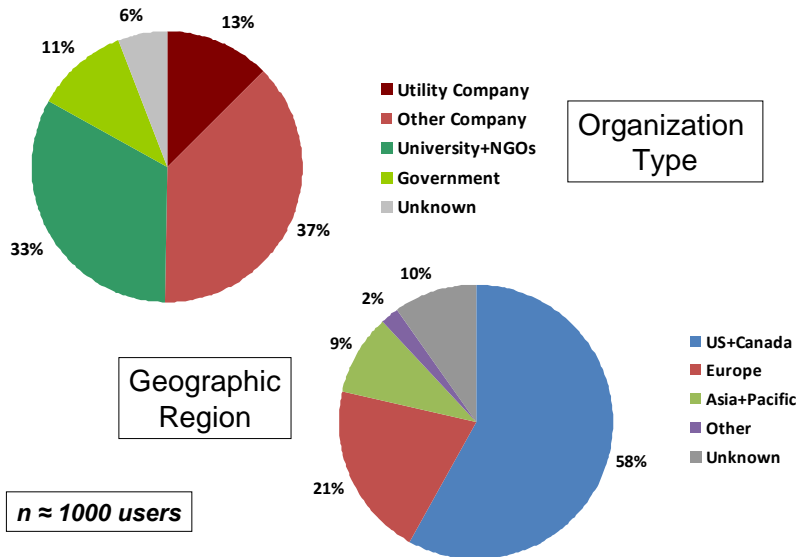
Inst. of Energy: EC/JRC  
Intermountain Power Service Corp.  
ISHKawajimaHama Heavy Industry  
Jack R. McDonald, Inc.  
Japan Petroleum Exploration Co.  
Kanazawa University  
Kansas City Power & Light Co.  
KEMA Nederland B.V.  
Kennecott Energy  
Kinetics  
Korea Electric Power Corp.  
Korea Inst. of Energy Res.  
Korea Western Power Co.  
LAB SA  
Lehigh University  
Lincoln Electric System  
Lower Colorado River Authority  
MacQuarie University  
Massachusetts Inst. of Tech. (MIT)  
Michigan State University  
MidAmerican Energy Co.  
Midwest Gen. EME, LLC  
Minskota Power Corp. Inc.  
Nanyang Technological University  
National Energy Tech. Lab. (NETL)  
National Power Plc.  
Nell and Gunter  
NESCALM  
New Energy & Ind. Tech. Org. (NEDO)  
Nicholson & Hall Corp.  
Niska Energy Associates  
NIPSCO  
Niro A/S  
Norman Plaks Consulting  
Norsk Hydro ASA  
Norxst Hydro ASA, Oil & Energy Res.  
North Carolina State University  
Norwegian University of Sci. and Tech.  
Nova Scotia Power, Inc.  
NRDC Natural Res. Defence Council  
NTNU/Stalatt  
NTPC Limited  
Ontario Power Gen.

OREC/Buckeye Power, Inc.  
Pace Global Energy Services  
Pacific Corp.  
Pacific Northwest National Lab. (PNNL)  
Pembina Inst.  
Pinnacle West Energy  
PRA Energy Group  
PowerGen  
Powergen Power Tech.  
PPL Gen. LLC  
Prairie Adaptation Res. Coll.  
Praxair Inc.  
Princeton University  
Reaction Engr Inst.  
Reaction Engr Intl  
Res. Inst. of Innovative Tech. Earth  
Res. Triangle Inst.  
RMB Consulting & Res., Inc.  
RWE Power AG  
SAIC  
Salt River Project  
Salt River Project (SRP)  
Sargent & Lundy  
SaskPower  
Saway Engr, LLC  
Sci. Applications Intl. Corp. (SAIC)  
Scientech  
SFA Pacific, Inc.  
Shell Chemical Co.  
Shell Global Solutions Intl  
Siemens  
Sierra Pacific Power Co.  
Sintel Energy Res.  
SNC Lavalin  
Southern Co. Gen.  
Southern Co. Services, Inc.  
Statil  
Stevan Coons Consulting  
Superior Adsorbents, Inc.  
Sycrude  
Tampa Electric Co.  
Tennessee Valley Authority (TVA)  
Terra Humana Clean Tech Engr Ltd.

Tetra Tech EM Inc.  
Texas A&M University  
Texas Municipal Power Agency  
TMMOMMER Consultants  
TNO Env. Energy and Process Innov  
Toshiba Corp.  
Transalio  
TU Dresden  
Twenty-First Strategies, LLC  
TAU Electric  
University of Aberdeen  
University of Bath  
University of Calgary  
University of California  
University of Edinburgh  
University of Lecce  
University of Maine  
University of Manchester InstSci. Tech.  
University of New Orleans  
University of Newcastle  
University of North Carolina  
University of Pittsburgh  
University of Queensland  
University of Regina  
University of Salzburg UNIFACS  
University of South Wales  
University of Stuttgart  
University of Texas  
University of Toronto  
University of Twente  
University of Waterloo  
URS Corp.  
Valens AB  
Vattenfall Utveckling AB  
W.L. Gore & Associates, Inc.  
Washington Power  
Wheabrator Air Poll. Control Inc.  
Wisconsin Dept. of Natural Res.  
Wisconsin Public Service Corp.  
Wolk Integrated Technical Services  
World Bank

E.S. Rubin, Carnegie Mellon

# Profile of IECM Users



E.S. Rubin, Carnegie Mellon

## Work in Progress

- Performance and Cost Models of Advanced CO<sub>2</sub> Capture Systems:

- Advanced liquid solvents *(Peter Versteeg)*



- Solid sorbent systems *(Justin Glier)*



- Membrane capture systems *(Haibo Zhai)*



- Advanced oxy-combustion *(Kyle Borgert)*



- Chemical looping combustion *(Hari Mantripragada)*



- International Cost Module *(Hana Gerbelova)*



- Software Development & Dist. *(Karen Kietzke)*



*E.S. Rubin, Carnegie Mellon*

## *Thank You*

*rubin@cmu.edu*

*E.S. Rubin, Carnegie Mellon*