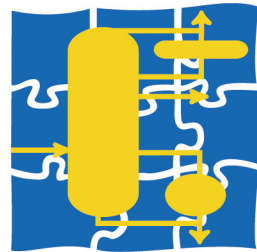


Applications of CAPE-OPEN standards to reactor and kinetic modeling

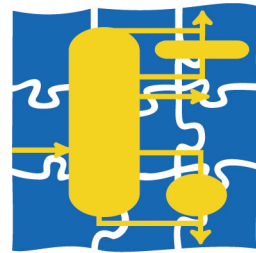
Michel Pons
Chief Technology Officer
EUROKIN Workshop, October 20, 2005



CO ▼ LaN



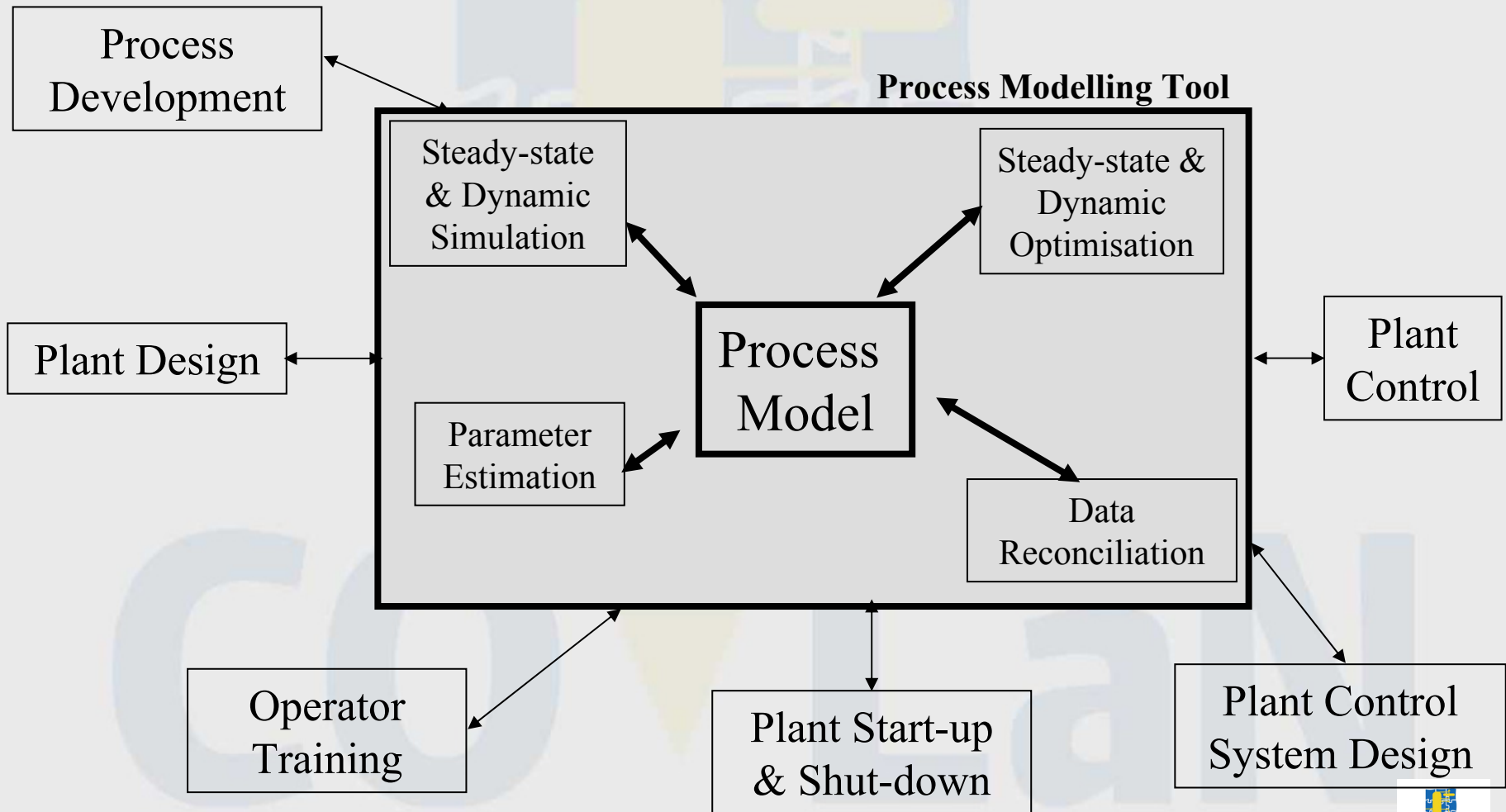
What is CAPE-OPEN?



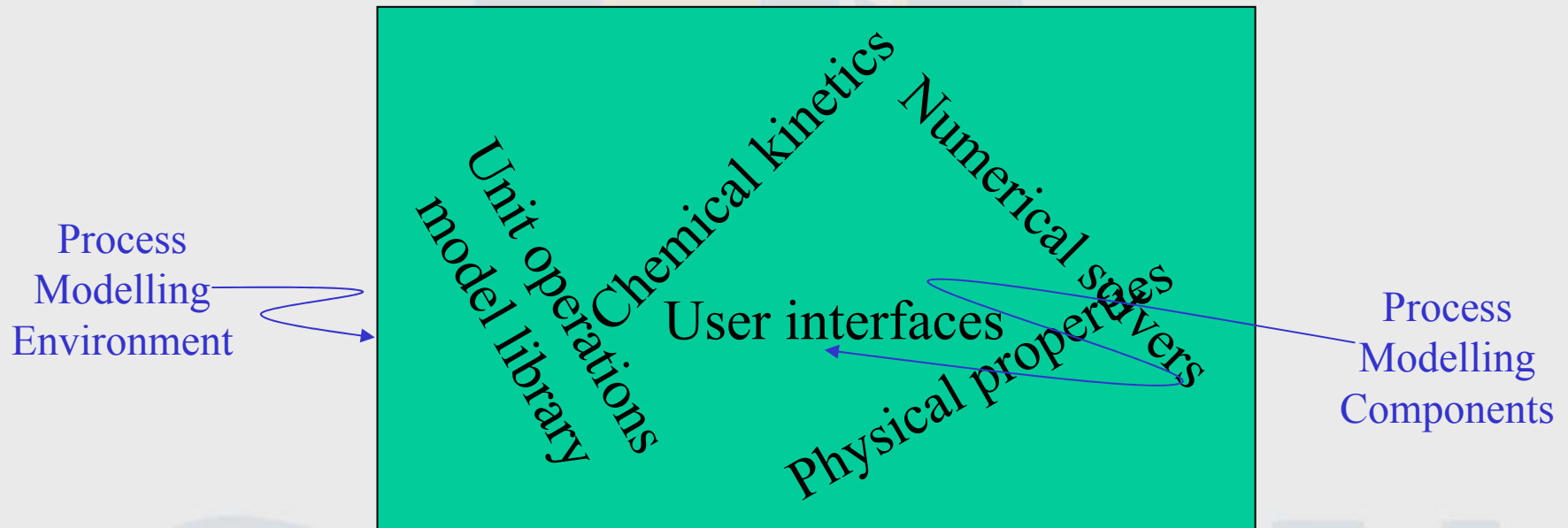
CO ▼ LaN



General-purpose process modelling tools

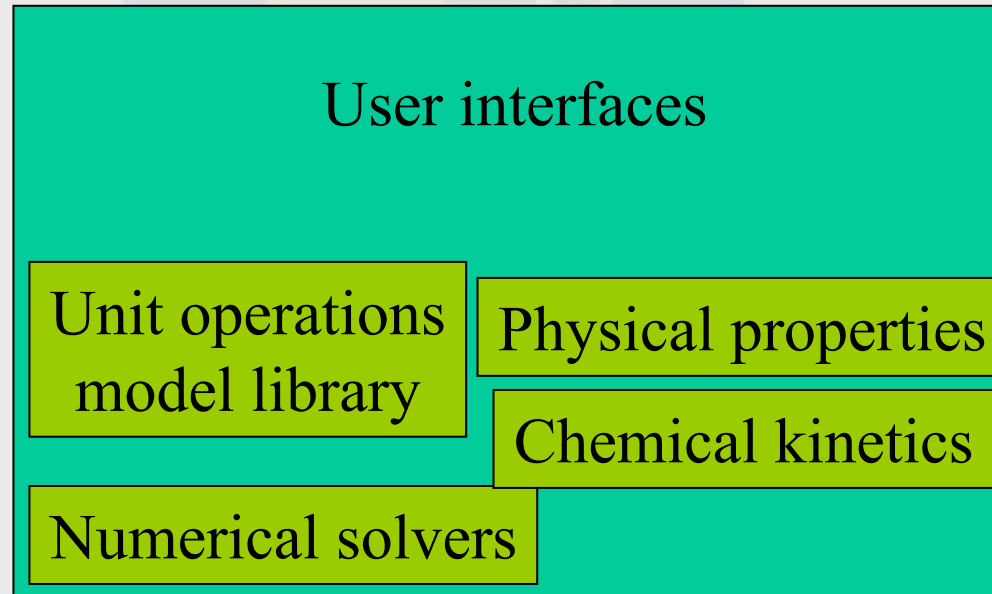


The anatomy of process modelling tools – a (somewhat) confusing reality

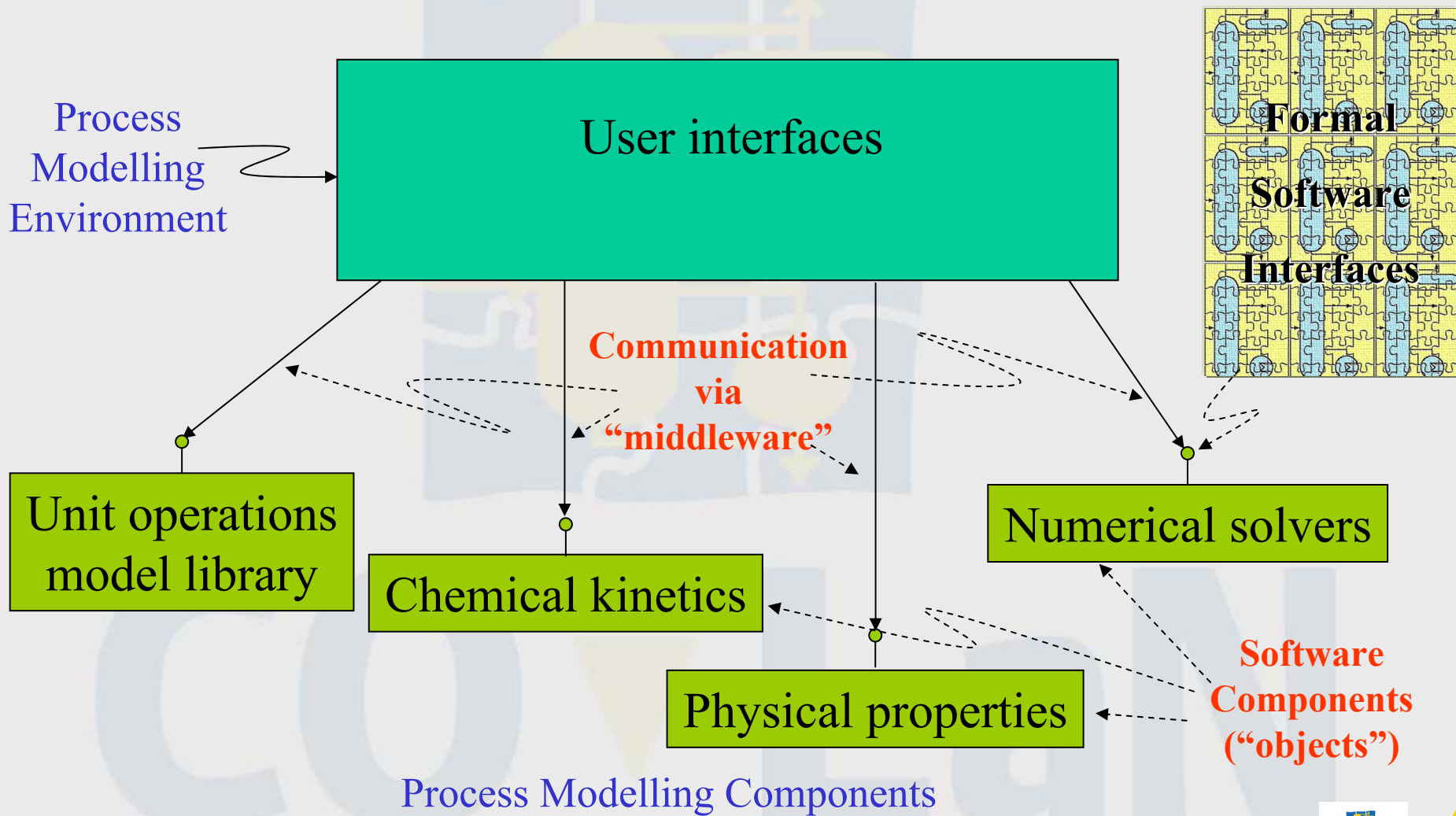


- Many interacting components...
- ...all tightly coupled with each other
- Component boundaries not always clearly delineated

Clarify boundaries between key components



...and break tool into 1 PME & multiple PMCs



CAPE-OPEN: a technology for integration

- ▼ A freely available industry standard for interfaces between software components making up process simulation tools
- ▼ The success of a collaboration between software vendors, end-users and academics
- ▼ A proven technology implemented in most process simulation tools
- ▼ A growing adhesion by process simulation market leaders

CO interfaces releases

0.9 (CAPE-OPEN)

0.93 (GCO 2001)

1.0 (GCO 2002)

Other
Services

Planning
& Scheduling

PME Services

SMST

Numeric

PEDR

Optimisation
MILP, MINLP

PDAE
Solvers

Solvers
LAE, NLAE, DAE

Unit
Operations

Unit Operations

Physical
Properties

Petroleum
Fractions

Thermodynamic and Physical
Properties

Physical Properties
Data Bases

Electrolytes

Reactions

Parameters Collections

Persistence

Common Interfaces

Error Handling

Identification

Utilities

Types and undefined values



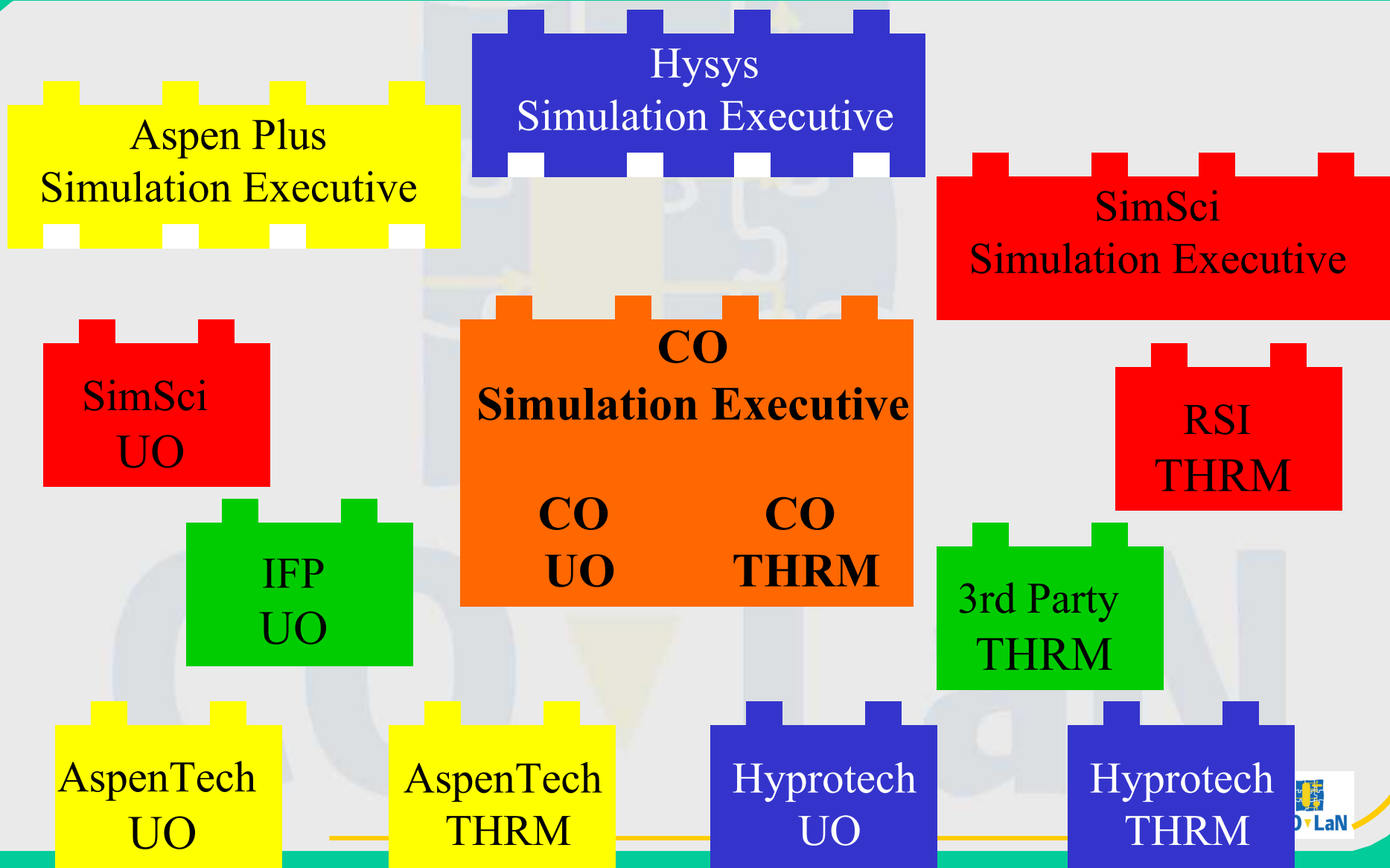


What CAPE-OPEN permits?

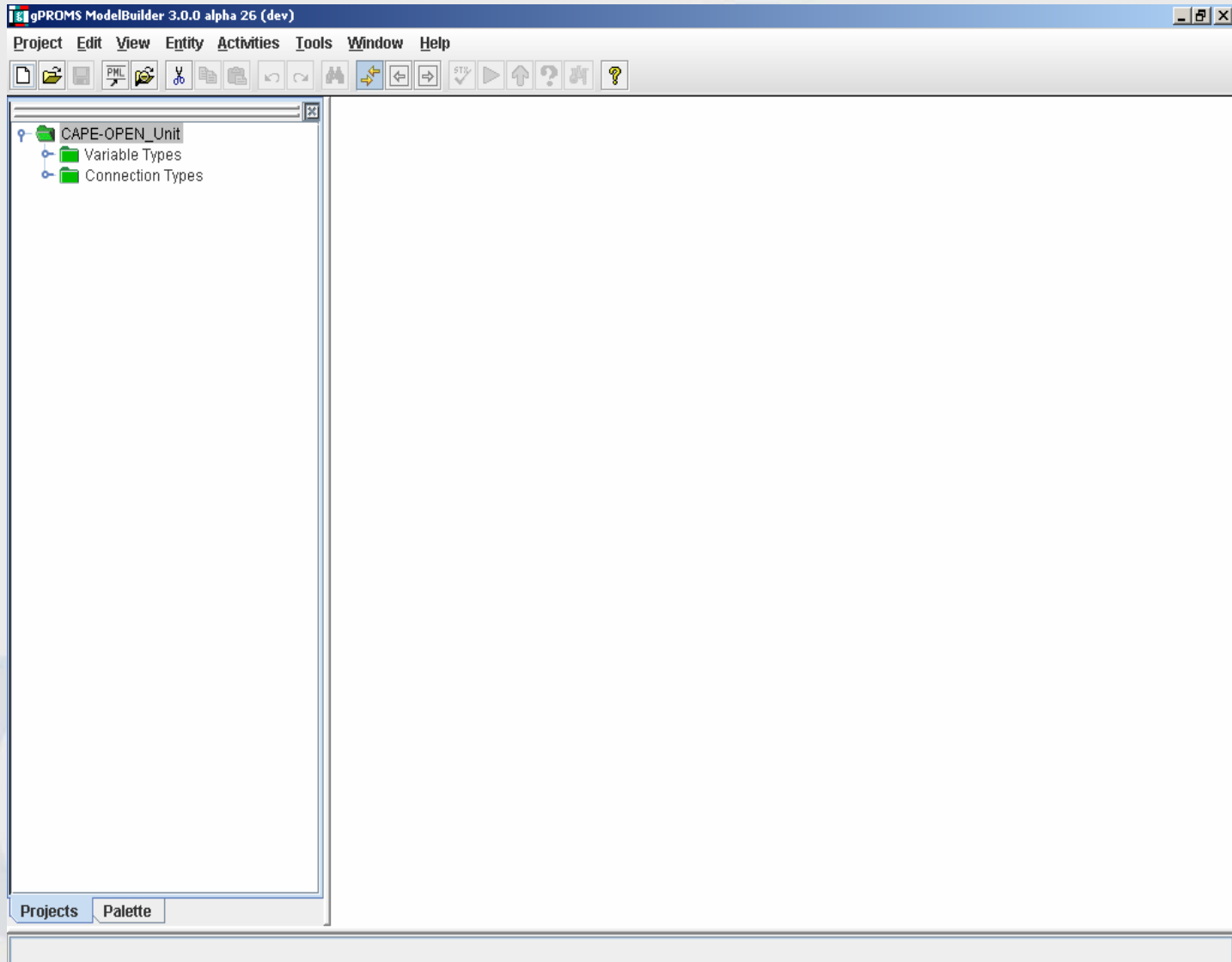
CO ▼ LaN



CAPE-OPEN supports all combinations of components



Load CAPE-OPEN library in ModelBuilder



Load/Create Mixer Model

The screenshot shows the gPROMS ModelBuilder interface. The left pane displays a project tree with 'PHMixer2' selected. The main editor shows the following code:

```
4 PORT
5   MidInlet AS CO_Material
6   TopInlet AS CO_Material
7   TopOutlet AS CO_Material
8
9 VARIABLE
10  junction_mass_specific_enthalpy AS mass_specific_enthalpy
11  junction_mass_fraction AS ARRAY(TopOutlet.no_components) OF mass_fractions
12  outFlow AS ARRAY(TopOutlet.no_components, 1) OF mass_flowrates
13  pressure AS no_type
14  DeltaP AS no_type
15  input_energy_rate AS energy_rate
16 # flashResult AS ARRAY(TopOutlet.no_components*3 + 11) of no_type
17
18 EQUATION
19
20 FOR i := 1 TO TopOutlet.no_components DO
21   0 = TopInlet.mass_flowrate * TopInlet.mass_fraction(i)
22     + MidInlet.mass_flowrate * MidInlet.mass_fraction(i)
23     - ( TopOutlet.mass_flowrate * TopOutlet.mass_fraction(i) );
24
25 END
26
27 TopOutlet.enthalpy_flow * TopOutlet.mass_flowrate = TopInlet.enthalpy_flow
28   * TopInlet.mass_flowrate + MidInlet.enthalpy_flow * MidInlet.mass_flowrate
29   + input_energy_rate ;
30
31 # Out flows
32 TopOutlet.mass_flowrate = TopInlet.mass_flowrate + MidInlet.mass_flowrate;
33
34 TopOutlet.mass_fraction = junction_mass_fraction ;
35
```

Callouts from the image:

- Mass balance:** Points to lines 20-24, which define a loop for component mass balance.
- Energy balance:** Points to lines 27-29, which define the energy balance equation.



Launch CAPE-OPEN export

The screenshot shows the gPROMS ModelBuilder 3.0.0 alpha 26 (dev) interface. The 'Tools' menu is open, and 'Export to CAPE-OPEN...' is highlighted. The project tree on the left shows a hierarchy including 'CAPE-OPEN_Unit', 'Variable Types', 'Connection Types', 'PHMixer2', 'Models', 'PHJunction', 'Tasks', 'Processes', 'Optimisations', 'Parameter Estimations', 'Experiment Designs', 'Experiments', 'Saved Variable Sets', and 'Miscellaneous Files'. The table below lists port specifications:

Port	Connection type	Dimensions	Direction	X	Y	Port set
MidInlet	CO_Material		Inlet	0	0,524	MidInlet
TopInlet	CO_Material		Inlet	0	0,238	TopInlet
TopOutlet	CO_Material			1	0,231	TopOutlet

No need to change model for CAPE-OPEN exportation

gPROMS supports CAPE-OPEN Material Object



Crypt gCO file

Export to CAPE-OPEN

Export directory: & Components\gPROMS\Unit plug\Test 100305 **Browse**

Unit name: PHJunction

Overwrite previously generated TASKs and PROCESS

Saved variable set	Include

Encryption password: afgsjhj

Decryption password (optional):

General | Ports | Parameters

Export **Cancel**

Exportation leads to a single file being created (extension gCO). Easily deployable.

Encrypting the gCO file enables deployment to other parties and ensures consistency

Define ports options and parameters settings

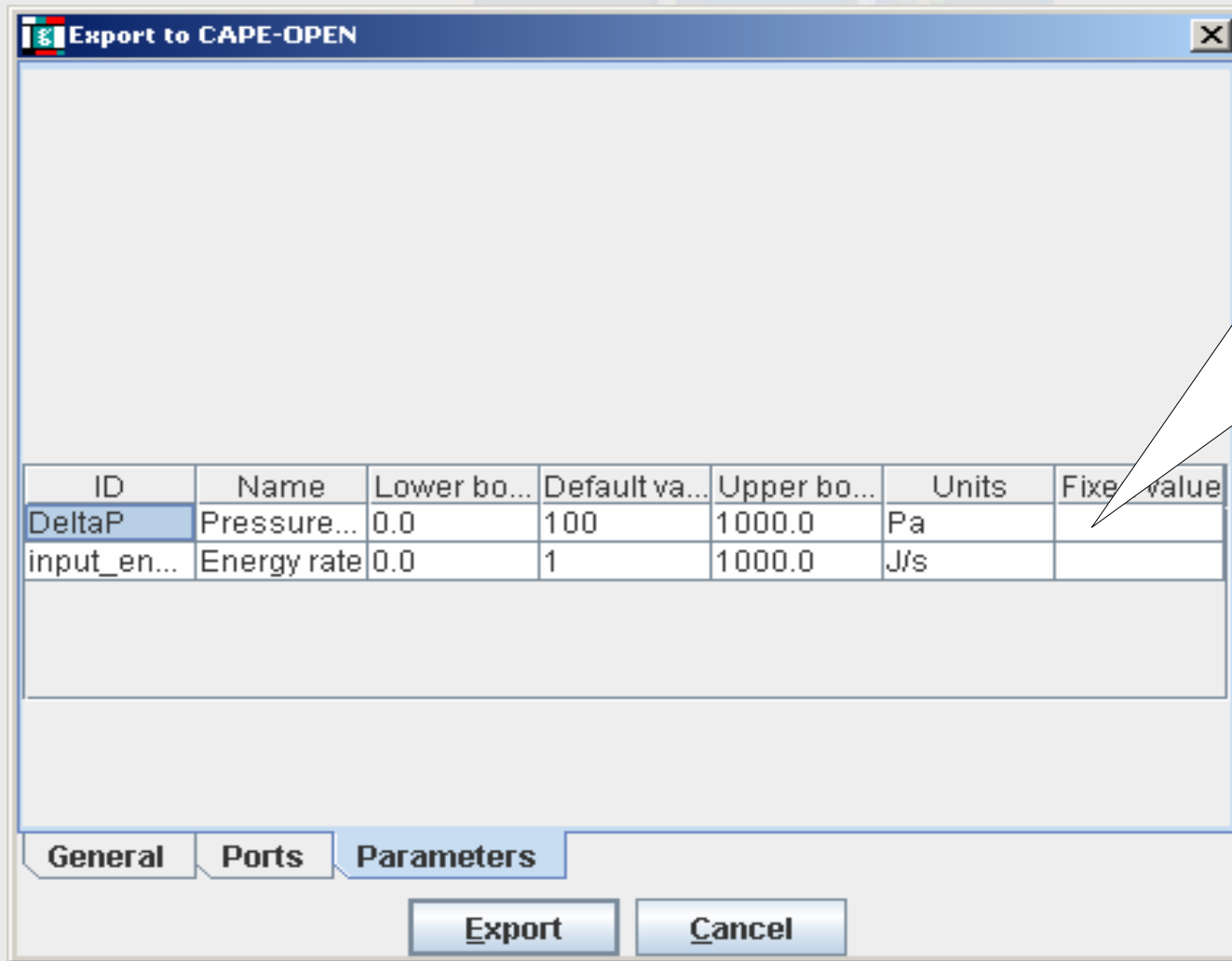
The screenshot shows a dialog box titled "Export to CAPE-OPEN" with a close button (X) in the top right corner. The dialog is divided into two main sections: "Ports:" and "Port variables:". The "Ports:" section contains a table with three columns: "Port", "Direction", and "Connection". The "Connection" column has two sub-columns for "Obligatory" and "Optional", each with a radio button. The "Port variables:" section contains a table with two columns: "Port variable" and "Direction", where "Direction" has "Get" and "Send" options with radio buttons. At the bottom, there are three tabs: "General", "Ports" (which is selected), and "Parameters". Below the tabs are two buttons: "Export" and "Cancel".

Port	Direction	Connection	
MidInlet	Inlet	<input checked="" type="radio"/> Obligatory	<input type="radio"/> Optional
TopInlet	Inlet	<input checked="" type="radio"/> Obligatory	<input type="radio"/> Optional
TopOutlet	Outlet	<input type="radio"/> Obligatory	<input checked="" type="radio"/> Optional

Port variable	Direction	
enthalpy_flow	<input checked="" type="radio"/> Get	<input type="radio"/> Send
mass_flowrate	<input checked="" type="radio"/> Get	<input type="radio"/> Send
mass_fraction	<input checked="" type="radio"/> Get	<input type="radio"/> Send
pressure	<input checked="" type="radio"/> Get	<input type="radio"/> Send
temperature	<input checked="" type="radio"/> Get	<input type="radio"/> Send

Ports connection may be mandatory or optional

Parameter default settings



The screenshot shows a dialog box titled "Export to CAPE-OPEN" with a close button (X) in the top right corner. The dialog contains a table with the following data:

ID	Name	Lower bo...	Default va...	Upper bo...	Units	Fixed value
DeltaP	Pressure...	0.0	100	1000.0	Pa	
input_en...	Energy rate	0.0	1	1000.0	J/s	

Below the table, there are three tabs: "General", "Ports", and "Parameters". The "Parameters" tab is currently selected. At the bottom of the dialog, there are two buttons: "Export" and "Cancel".

Each parameter is provided with a lower and upper bound as well as a default value.

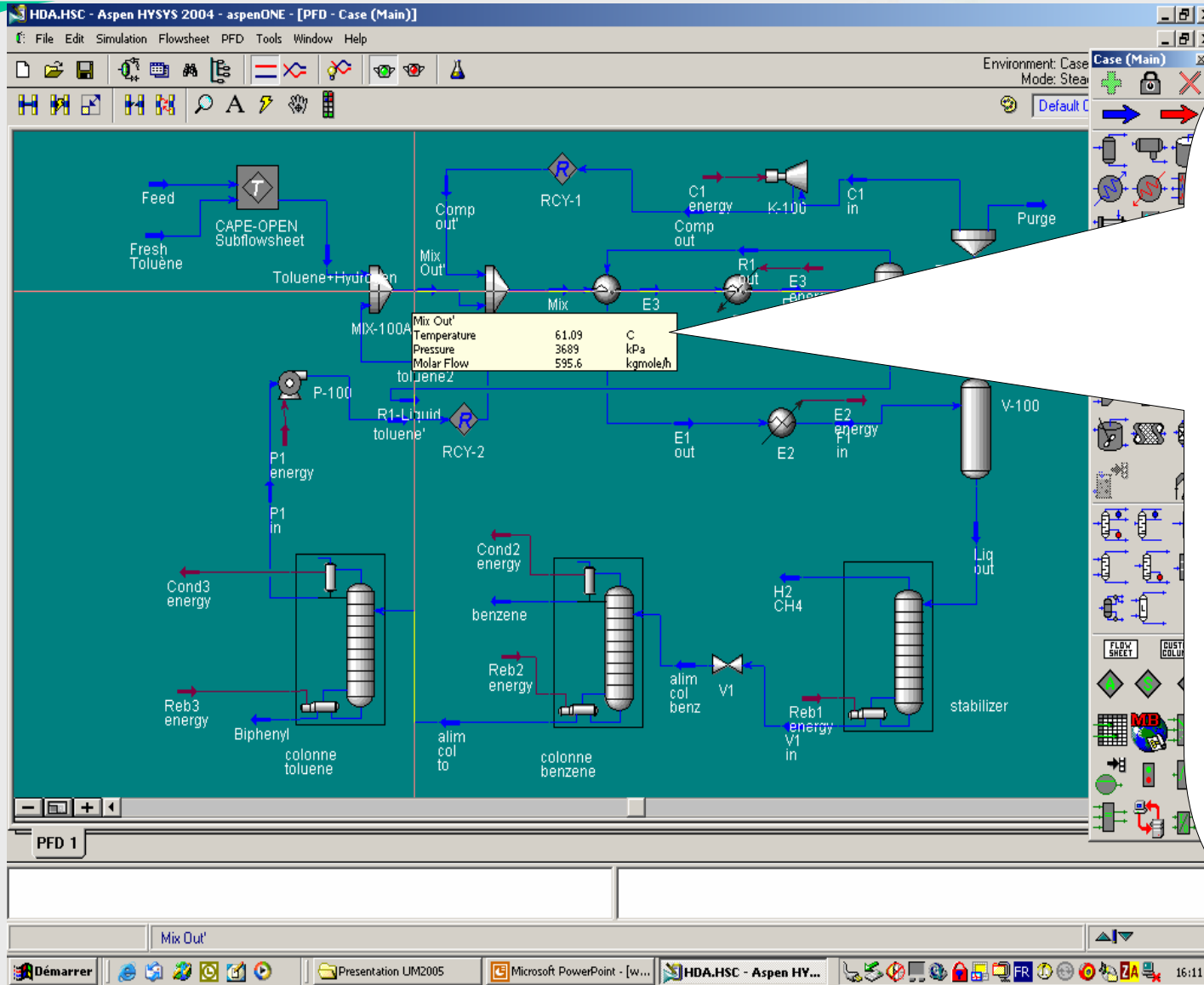


Running gPROMS model in Aspen HYSYS

CO  LaN



HDA process model in Aspen HYSYS 2004



Since gPROMS mixer model involves basic material and energy balances, results with Aspen HYSYS 2004 native mixer and gPROMS mixer should be strictly the same.

Native mixer deleted and solver on hold

The screenshot displays the Aspen HYSYS 2004 software interface. The main window shows a process flowsheet with various units including mixers (MIX-100B), reactors (RCY-1, RCY-2), heat exchangers (E1, E2, E3), columns (colonne toluene, colonne benzene, stabilizer), and pumps (P-100). A callout box points to a mixer unit that has been deleted, with the text "Mixer deleted". The status bar at the bottom indicates "Solver Holding".

Warning : Fluid Pkg Transition -- Not Solved
Warning : Fluid Pkg Transition -- Not Solved
Warning : Fluid Pkg Transition -- Not Solved

Column Flowsheet stabilizer Not Converged
Column Flowsheet colonne benzene Not Converged
Column Flowsheet colonne toluene Not Converged

Holding... Solver Holding

Mixer deleted



Replace native Mixer

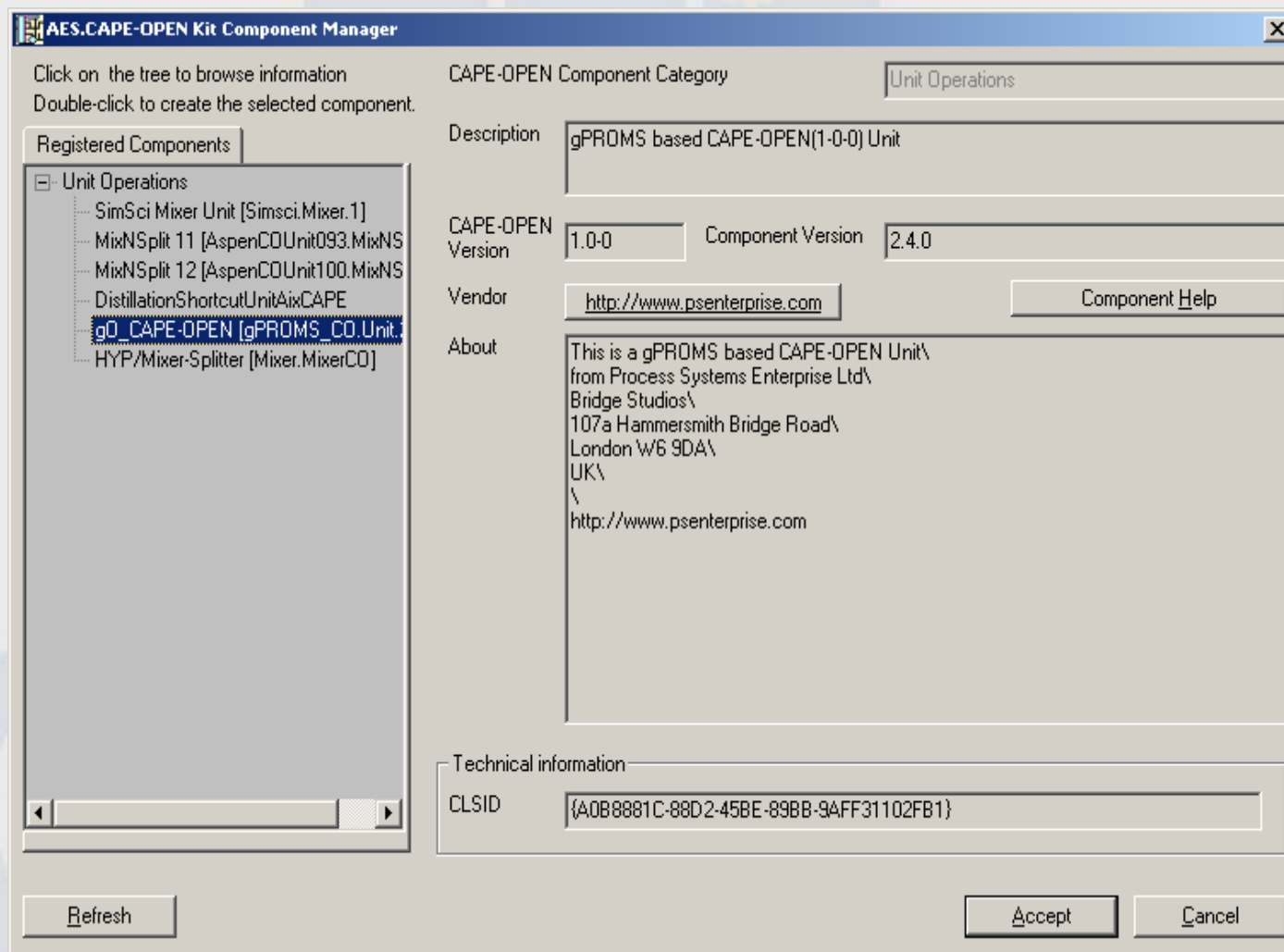
The screenshot displays the Aspen HYSYS 2004 software interface. The main window shows a process flowsheet with various units including mixers (MX-100B), reactors (RCY-1, RCY-2), heat exchangers (E1, E2, E3), columns (colonne toluene, colonne benzene, stabilizer), and pumps (P-100). A context menu is open over a mixer unit, listing options such as 'Add Stream', 'Add Operation...', 'Find Object...', 'Simulation Navigator', 'Notes Manager', 'Palette', 'Optimization Objects...', 'Reaction Package...', 'Fluid Package/Dynamics Model...', 'Dynamic Initialization...', and 'Flowsheet User Variables...'. The status bar at the bottom shows several warnings: 'Warning : Fluid Pkg Transition -- Not Solved' and 'Warning : Fluid Pkg Transition -- Not Solved'. The taskbar at the bottom indicates the system is running Microsoft PowerPoint and the Aspen HYSYS application.

Select CAPE-OPEN 1.0 UNIT Ops

The screenshot displays the Aspen HYSYS 2004 software interface. The main window shows a process flow diagram (PFD) for a benzene stabilization process. The PFD includes three distillation columns: 'colonne toluene', 'colonne benzene', and 'stabilizer'. The 'colonne benzene' and 'stabilizer' are highlighted with yellow boxes. The process involves various streams such as 'Biphenyl', 'alim col to', 'alim col benz', 'H2 CH4', and 'benzene'. Energy streams are labeled with 'Cond' and 'Reb' followed by a number and 'energy'. A 'V1' valve is located between the 'colonne benzene' and 'stabilizer' columns. The 'UnitOps - Case (Main)' dialog box is open in the top-left corner, showing a list of available unit operations. The 'CAPE-OPEN Unit 1.0 Ope' is selected in the list. The bottom status bar shows several warnings: 'Warning : Fluid Pkg Transition -- Not Solved' and 'Warning : Fluid Pkg Transition -- Not Solved'. The bottom-right corner of the status bar shows a table of convergence status for different columns:

Column	Flowsheet	Unit	Status
stabilizer	Column Flowsheet	stabilizer	Not Converged
colonne benzene	Column Flowsheet	colonne benzene	Not Converged
colonne toluene	Column Flowsheet	colonne toluene	Not Converged

Select gO:CAPE-OPEN wrapper



Select the gCO file to be used

The screenshot displays the Aspen HYSYS 2004 software interface. A file selection dialog box titled "Ouvrir" is open, showing the file "PHJunction.gCO" selected in the "Presentation UM2005" folder. The dialog also shows the file type as "Cape-Open Unit Files (*.gCO)".

The main process flowsheet is visible, showing a complex system of columns and energy streams. Key components include:

- Columns: colonne toluene, colonne benzene, and stabilizer.
- Energy streams: Cond3 energy, Reb3 energy, Biphényl, alim col to, Reb2 energy, benzene, alim col benz, H2 CH4, Reb1 energy V1 in, E1 out, E2 energy F1 in, E3 energy, R1 energy in, E3 out, R1 out, C1 energy, Comp out, C1 in, TEE-100, Vap out, Purge, and Lig out.
- Reboilers: Reb1, Reb2, Reb3.
- Condensers: Cond2, Cond3.
- Distillation Column: V-100.
- Heat Exchangers: E1, E2, E3.
- Reflux Drum: R1.
- Control Valve: V1.

The status bar at the bottom indicates several warnings: "Warning : Fluid Pkg Transition -- Not Solved" and "Warning : Fluid Pkg Transition -- Not Solved". The console window shows the following messages:

```
Column Flowsheet stabilizer Not Converged
Column Flowsheet colonne benzene Not Converged
Column Flowsheet colonne toluene Not Converged
```

Enter generic GUI provided by HYSYS

The screenshot shows a dialog box titled "CO-100" with a close button in the top right corner. Below the title bar is a search or filter field. The main area is titled "General properties" and contains the following fields:

- Unit Type: gPROMS_CO.Unit.2.4.0
- Unit Name: CO-100
- Unit description: gPROMS based CAPE-OPEN(1-0-0) Unit
- Report to be integrated in the HYSYS Report: No CAPE-OPEN report provided by the Unit
- Report result from LAST unit execution: (Empty text area)

At the bottom of the dialog, there are four tabs: "Material Connections", "Unit Variables", "General" (which is selected), and "Thermo". Below the tabs is a yellow status bar with the text "Not Solved" and a "Show Unit GUI" button.

Connect inlet and outlet ports to streams

The screenshot shows the Aspen HYSYS 2004 interface. The main window is titled 'UnitOps - Case (Main)'. On the left, there is a 'Categories' list with radio buttons for various equipment types. The 'Available Unit Operations' list shows '4 Stripper Crude'. The 'CO-100' unit operation window is open, displaying a table of 'Feed, Product Streams and Material Ports'.

Port ID	Port type	D	Material
MidInlet	Material	I	benzene
TopInlet	Material	I	Biphenyl
TopOutlet	Material	O	H2 CH4
			Purge
			R1-Liquid
			toluene2

Below the table, there are tabs for 'Material Connections', 'Unit Variables', 'General', and 'Thermo'. A yellow bar at the bottom of the unit window indicates 'Not Solved'. The status bar at the bottom of the application shows 'Warning : Fluid Pkg Transition -- Not Solved' and 'Column Flowsheet stabilizer Not Converged'.

Set up the gPROMS model

CO-100

Mix Out

Feed, Product Streams and Material Ports

Port ID	Port type	Direction	Material name
MidInlet	Material	Inlet	Toluene+Hydrogen
TopInlet	Material	Inlet	toluene2
TopOutlet	Material	Outlet	Mix Out

Material Connections Unit Variables General Thermo

Not Solved Show Unit GUI

All ports connected

CO-100

Unit Specific Data and Public Variables

Name	Type	Mode	Lower bound	Upper bound	Value	Valid
Energy rate	Real	IN	0	1000	1	
Pressure Drop	Real	IN	0	1000	100	

Reset Parameters

Material Connections Unit Variables General Thermo

Not Solved Show Unit GUI

Initial parameter settings

Set energy input / pressure drop to zero

gPROMS Cape-Open Unit Object

gPROMS Cape-Open Unit Object PSE

Unit Properties | Input Parameters | Report | Ports | Log | About

Parameter	Type	Value	Lower bound	Upper bound	Units
Energy rate	Real	1	0	1000	J/s
Pressure Drop	Real	100	0	1000	Pa

Change Value

Close

Energy rate

Value: J/s

Lower Bound:

Upper Bound:

OK Cancel

gPROMS Cape-Open Unit Object

gPROMS Cape-Open Unit Object PSE

Unit Properties | Input Parameters | Report | Ports | Log | About

Parameter	Type	Value	Lower bound	Upper bound	Units
Energy rate	Real	0	0	1000	J/s
Pressure Drop	Real	100	0	1000	Pa

Change Value

Close

Pressure Drop

Value: Pa

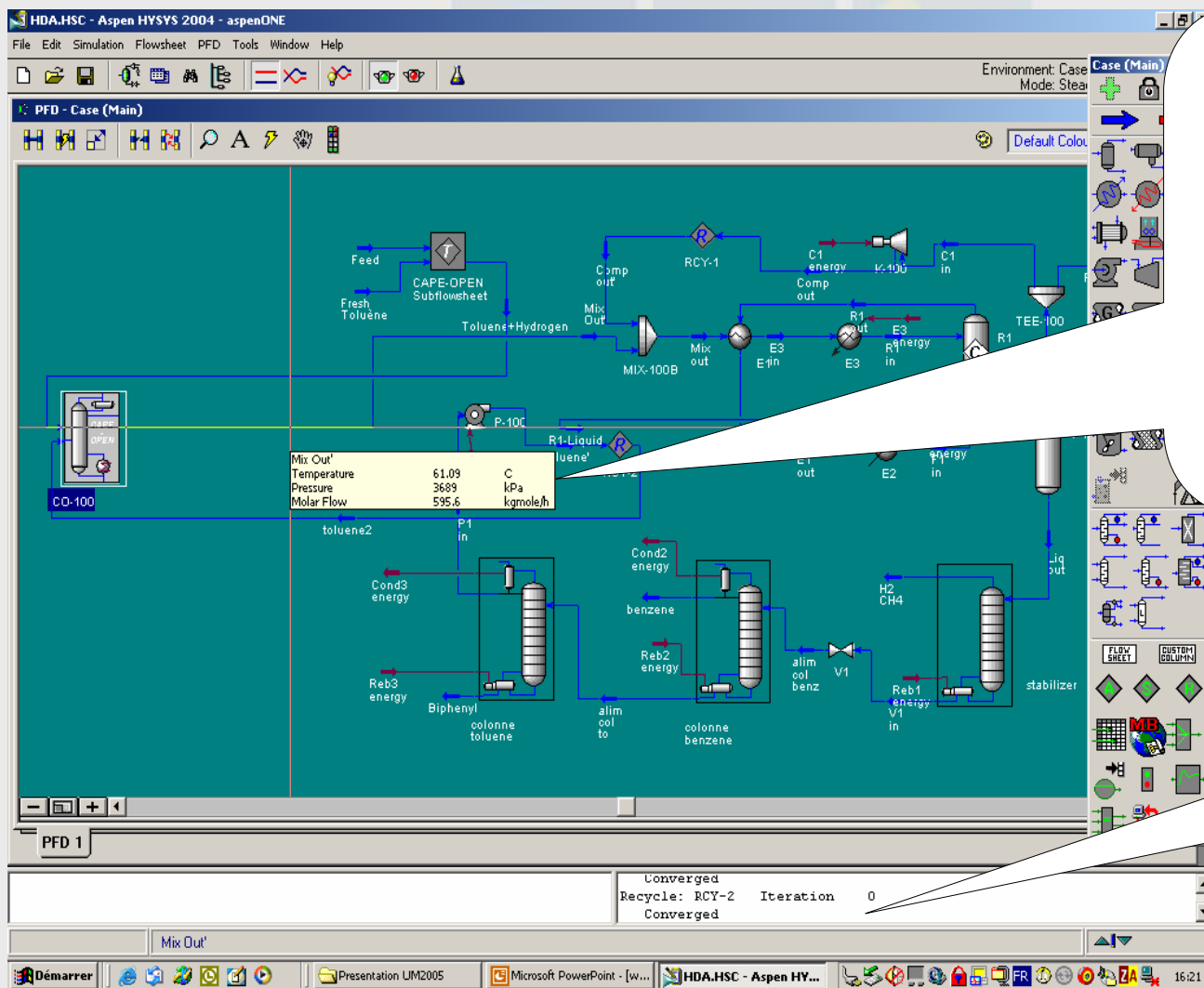
Lower Bound:

Upper Bound:

OK Cancel



gPROMS Mixer output results



Results obtained are strictly the same as with native Aspen HYSYS 2004 mixer model.

Simulation converged.

Other generic uses

- ▼ Same mixer model can be run as well in Aspen Plus or in PRO/II
- ▼ Same applies to thermodynamic components:
 - ⇒ A CAPE-OPEN Property Package out of Multiflash (Infochem) runs the same in Aspen Plus, Pro/II, Aspen Hysys, Simulis, gPROMS...

Direct benefits

Cheaper, better and faster design, operation and control of processes

⇒ Plug-and-play

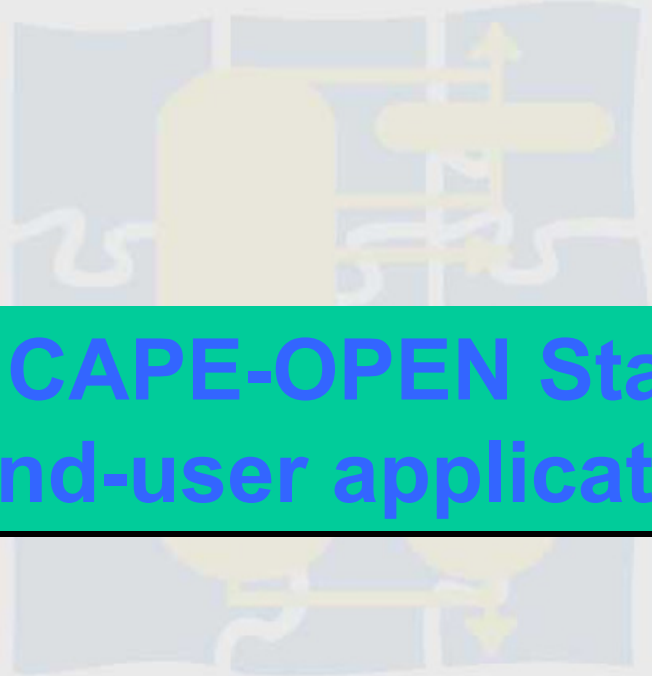
- **Ability to seamlessly integrate a component from the library of foreign objects (unit operations, thermo models, solvers etc.).**
- **Ability to seamlessly integrate in-house proprietary components in commercial environments.**

⇒ Niche software

- **Ability to link specific niche modules to the simulators. Small and niche software vendors will provide CO-compliant components.**

⇒ Return On Investment

- **Individual studies will cost less because of the technical advantages of being able to mix-and-match.**
- **Plug-and-play capacity will stimulate the market and create new opportunities.**



The CAPE-OPEN Standard: End-user applications

CO ▼ LaN



Examples

▼ ATOFINA

⇒ Detailed model of a reactive absorption column: very limited knowledge of CAPE-OPEN needed

▼ IFP

⇒ Detailed model of a catalytic reactor: advanced knowledge of CAPE-OPEN needed

▼ US DOE / Alstom Power

⇒ Detailed (CFD) model of a combustor: very limited knowledge of CAPE-OPEN needed

Rate-based model of absorbers



▼ Situation

- ⇒ Current tool no longer developed by AspenTech
- ⇒ Model embedded can't cope with fast liquid film reactions
 - **CO₂ absorption by NaOH aqueous solutions**

▼ Solution developed

- ⇒ gPROMS modeling
 - **Rigorous handling of Maxwell-Stefan equations**
 - **Appropriate model for fast kinetics in liquid film**

▼ Limitations

- ⇒ gPROMS requires a thermodynamic server
 - **OLI linked to gPROMS but OLI not licensed by ATOFINA**



Rate-based model of absorbers

▼ User requirements

- ⇒ gPROMS model using an Aspen Plus thermo
 - Typically ELECNRTL
- ⇒ gPROMS model used within an Aspen Plus model
 - To be used just as any Ratefrac unit model

▼ Technical solutions applied

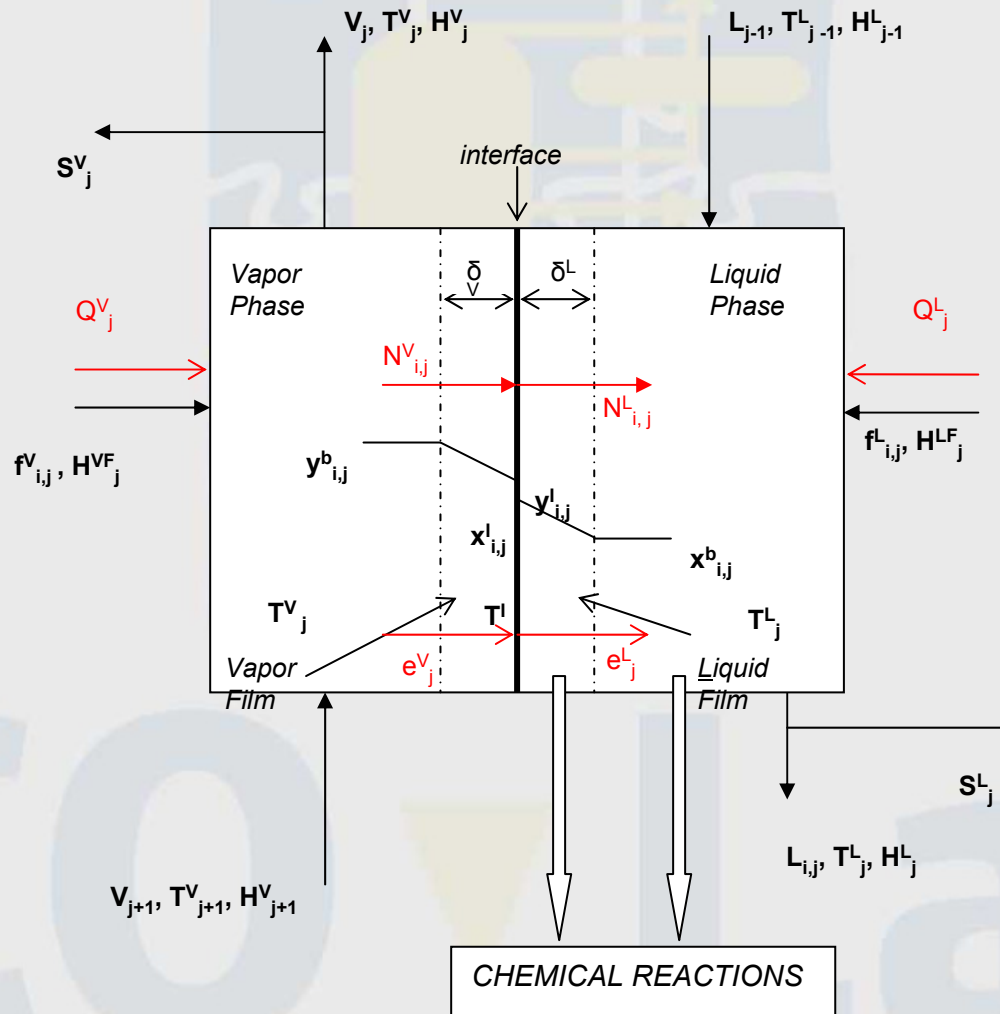
- ⇒ Make a CAPE-OPEN Property Package out of Aspen Plus based on ELECNRTL
- ⇒ Call this CO PP within gPROMS model through CO Thermodynamics and Physical Properties interfaces
- ⇒ Include the gPROMS model as a CO Unit Operation within an Aspen Plus flowsheet

Making a CO Property Package

- ▼ **Within Aspen Plus (no need to know any CO specific)**
 - ⊖ **Define chemical compounds**
 - ⊖ **Define methods to be used for each property**
 - ⊖ **Export as a CO Property Package (CO PP)**
- ▼ **Requires Aspen Plus license when being called upon**
- ▼ **Referenced through the name given to the CO PP file**
- ▼ **Registered in the Windows registry as a CO PP within the CO Thermo System supplied by AspenTech**



System modeled



10 species
50000 variables
Steady-state
6 min to converge

Thermodynamic calls

▼ gPROMS model calling A+ CO Property Package

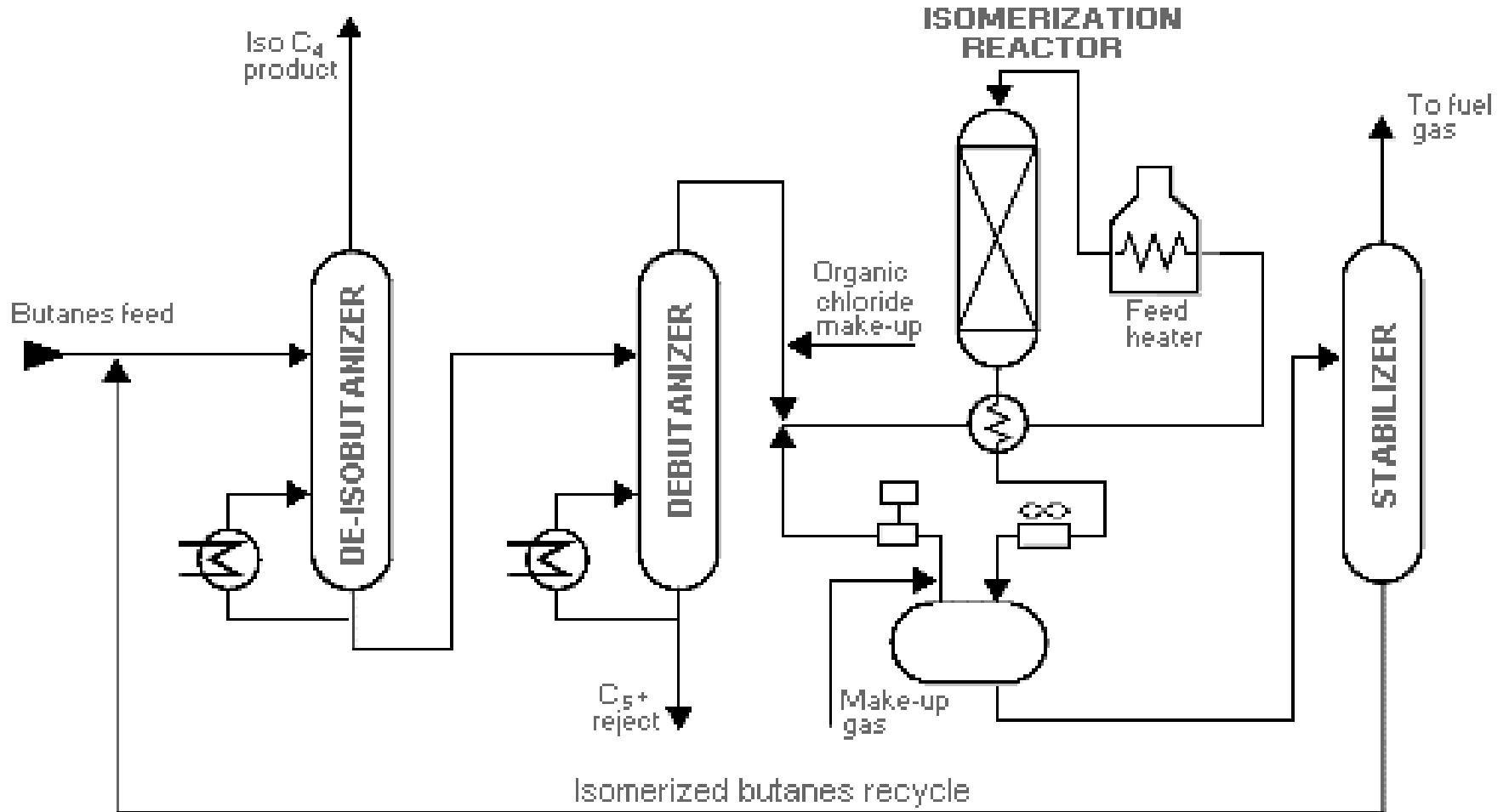
⇒ Properties requested from Aspen Plus

- Vapor Heat Capacity
 - Vapor Thermal Conductivity
 - Vapor Enthalpy
 - Liquid Activity Coefficient
 - Liquid Enthalpy
 - Liquid Volume
 - Liquid Thermal Conductivity
 - Surface Tension
 - Liquid Fugacity Coefficient
 - Liquid Viscosity
- (note: flash equations within the gPROMS model)

Calls to CO Property Package

```
UNIT
  Plant AS Column
SET
  WITHIN Plant DO
    PhysProps := "(PS)ATCOProperties.COPropertySystem.1<gPROMS121new>";
.....
FOR y := 0 TO 1 DO
  FOR z := 0 TO 1 DO
    FOR i := 1 TO 4 DO
      Molarfrac_aux(i, y, z) = Molarfrac(i, y, z) ;
    END
    FOR i := 5 TO 11 DO
      Molarfrac_aux(i, y, z) = 0 ;
    END
    FOR i := 1 TO NoVapSpecies DO
      VapHeatCapacity(i, y, z) = PhysProps.VapourHeatCapacity(T(y, z), P, frac(i, )) ;
    END
    Lambda_vapour(y, z) = PhysProps.VapourThermalConductivity(T(y, z), P,
      Molarfrac_aux(, y, z)) ;
    END
  END
END
```

C4 isomerization flow diagram



Process technical description

▼ Thermodynamic

- ⇒ Isobutane formation is promoted at low temperature
- ⇒ Catalyst to work at low temperature

▼ Catalyst

- ⇒ Butane is less reactive than long paraffins
- ⇒ Catalyst must provide important acidity
- ⇒ No zeolith catalyst

▼ Reaction mechanism

- ⇒ A bimolecular mechanism is modelled:
 - a reaction intermediate C8 produces i-butane
 - cracking product (C1- C3)
 - disproportionation product as C5 i-C5

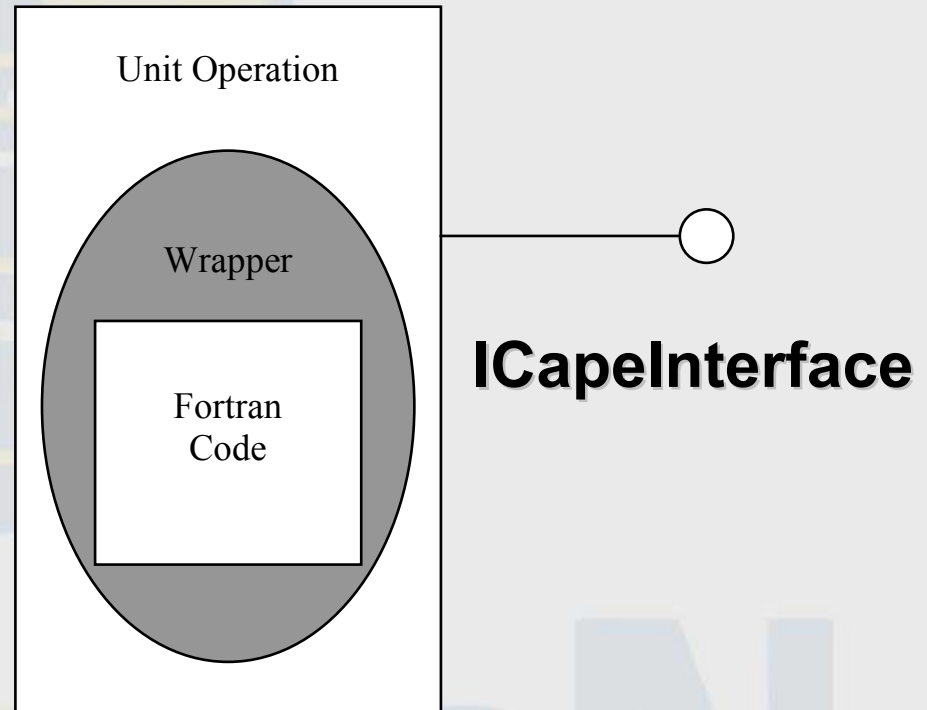
CO compliant component development

▼ Introduction

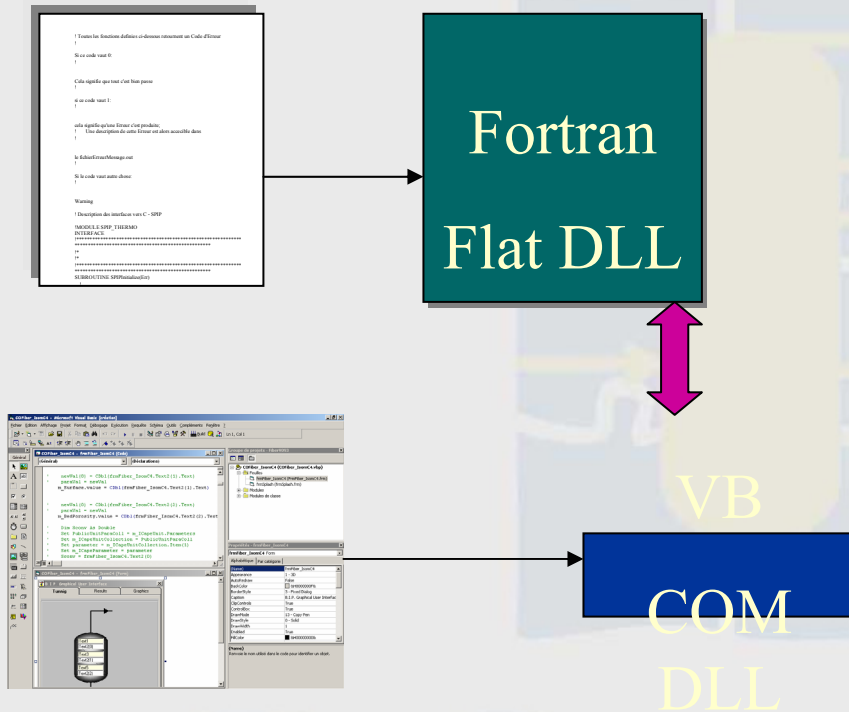
- ⇒ **Migrating a FORTRAN 90 Reactor Model to the CAPE-OPEN standard.**

▼ Description

- ⇒ **IFP / CAPE-OPEN BIP Reactor architecture:**



Implementation description



1. Create a Fortran DLL with Source file of the standalone Model.

2. Create a COM DLL using CO Unit Wizard

3. Connect these two DLLs

Fiber_All.hsc - HYSYS 3.0.1 - [PFD - Case (Main)]

File Edit Simulation Flowsheet PFD Tools Window Help

Environment: Case (Main)
Mode: Steady State

Default Colour Scheme

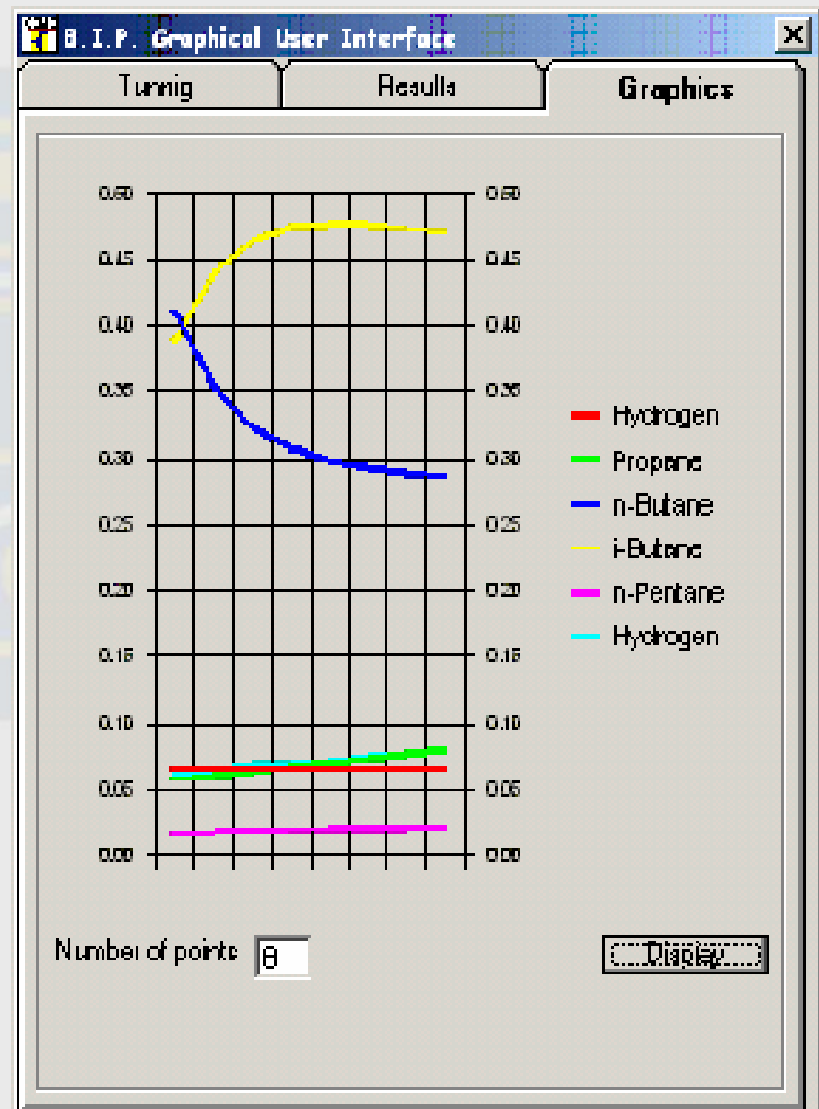
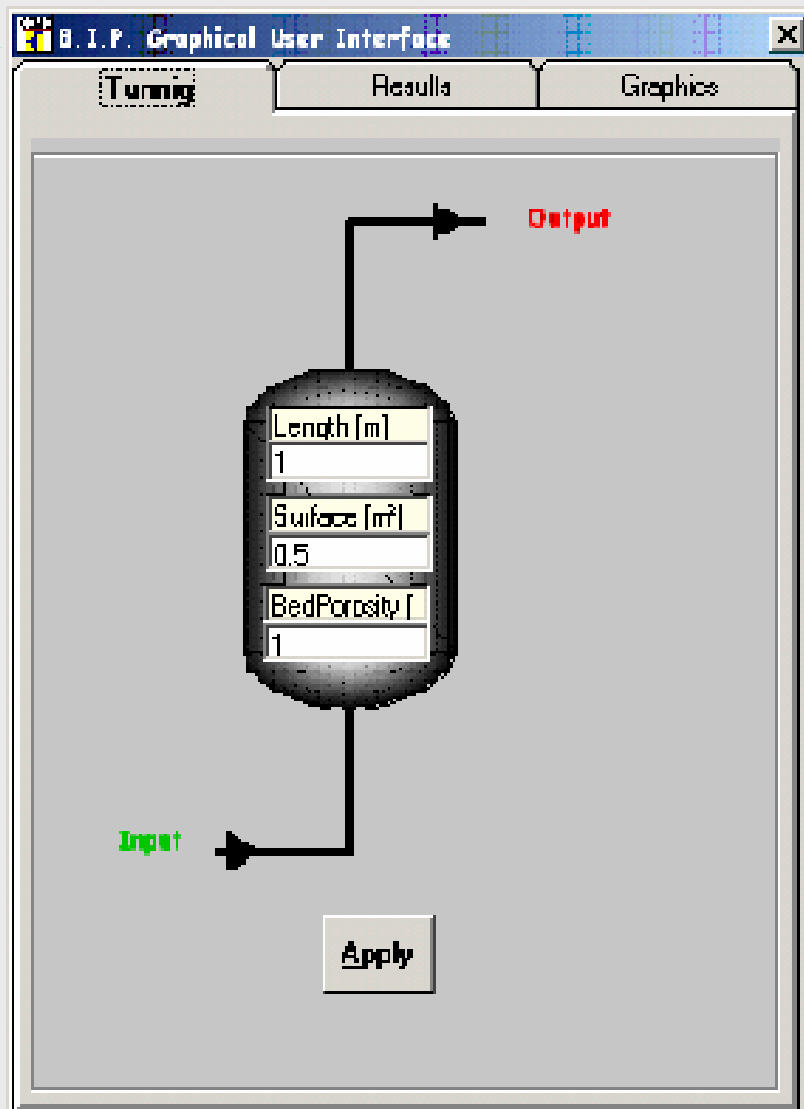
Case (Main)

Completed.
Saving case D:\DOCUMENT-1\rouxp\LOCALS-1\Temp\AutoRecovery save o
Completed.

PFD 1

FIBER Out





DOE Fossil Energy R&D Programs

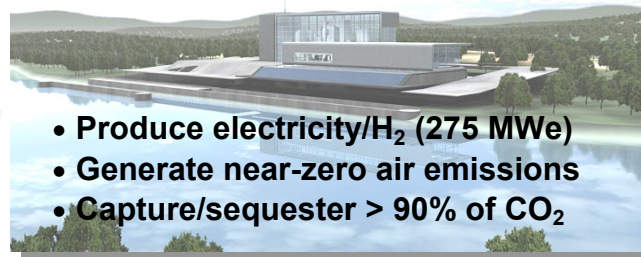
SECA
Fuel Cells



Gasification with
Cleanup & Separation

FutureGen

- \$1B, 10-year demonstration project
- Coal-fired, gasification-based plant



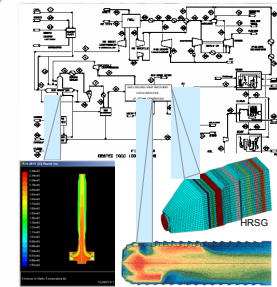
- Produce electricity/H₂ (275 MWe)
- Generate near-zero air emissions
- Capture/sequester > 90% of CO₂



Carbon
Sequestration



Gas Turbines



Systems Analysis
& Integration

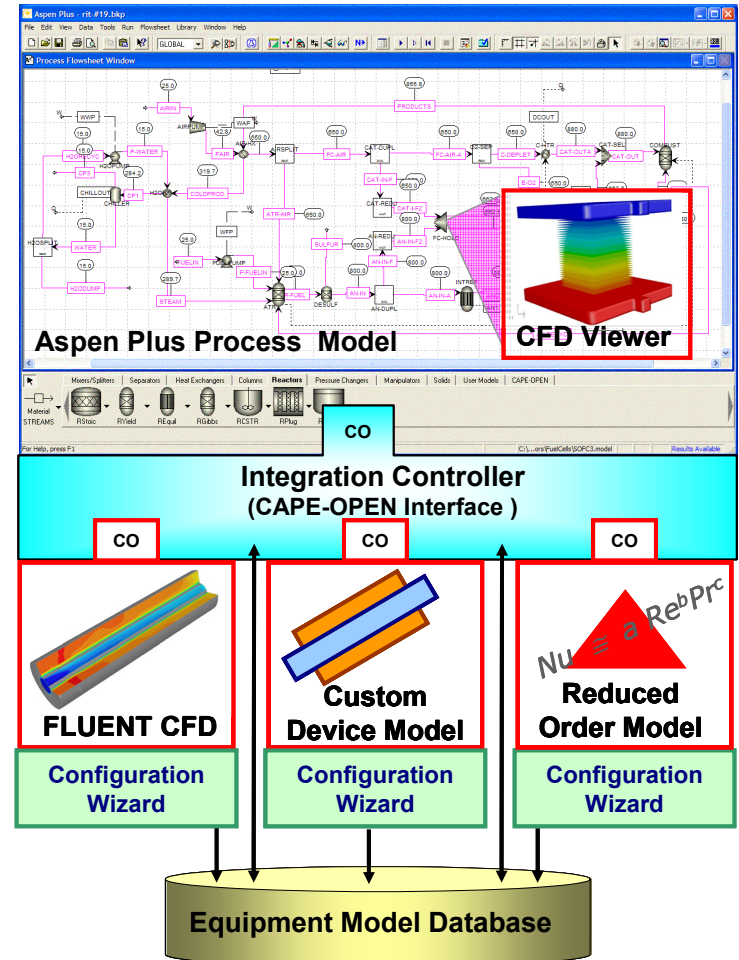


NETL's Advanced Power and Energy Co-Simulation (APECS)



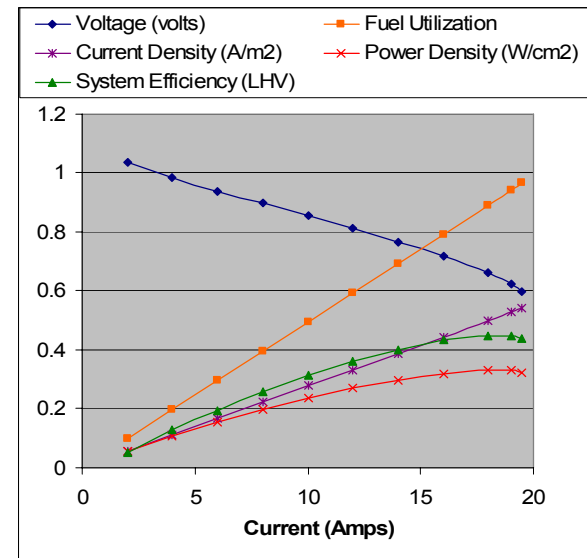
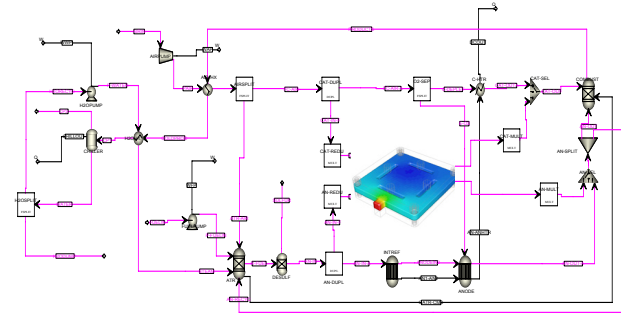
Major Components and Features

- **Process Models**
 - Aspen Plus®
- **Equipment Models**
 - FLUENT®
 - Custom Device Models
 - Reduced-Order Models (ROM)
- **Integration Controller**
 - CAPE-OPEN (CO) Interfaces
 - Unit Operations, Physical Properties, Reactions
- **Configuration Wizards**
 - FLUENT*
 - Custom Model** and ROM**
- **Model Database**
- **CFD Viewer**
- **Solution Strategies**
 - Speed (ROM)
 - Accuracy (CFD)
- **Remote Execution**
 - Windows/Linux
 - Serial/Parallel



APECS Application - SECA Fuel Cell APU System

- Aspen Plus process model of Auxiliary Power Unit (APU)
- FLUENT 3D CFD model of SECA solid oxide fuel cell
- Optimize process efficiency by varying CFD parameter (fuel cell current)
- Maximum system efficiency (LHV) of 45% at 18 amps
- Maximum system power of 4.3 kW
- Convergence in 6-10 Aspen Plus iterations requiring 45-60 minutes of CPU time



Zitney, S.E., Prinkey, M.T., Shahnam, M., and Rogers, W.A. (2004), "Coupled CFD and Process Simulation of a Fuel Cell Auxiliary Power Unit," In *Proc. of the ASME Second International Conference on Fuel Cell Science, Engineering, and Technology*, Eds. R. Shah and S.G. Kandlikar, Rochester NY, June 13-16, 2004, Paper 2490, pp. 339-345.



APECS Application - FutureGen Power Plant

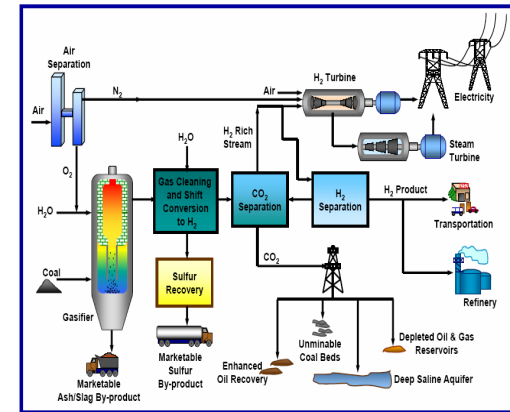


- **FutureGen Power Plant**

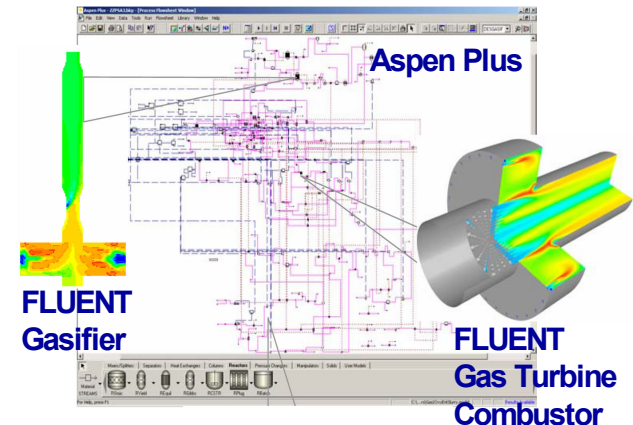
- IGCC with CO₂ capture and H₂ production (275 MWe)
- Large, integrated plant with aggressive design goals
- New, innovative equipment with lack of design data

- **APECS Application**

- Process model
 - Aspen Plus steady-state
 - Over 250 equipment items
- CFD models
 - FLUENT 3D Gasifier
 - FLUENT 2D GT Combustor



FutureGen Process Diagram



FutureGen APECS



Available CO compliant software

▼ Software providers

- ⇒ AspenTech: Aspen Plus, Aspen Properties, Aspen Hysys, COM Thermo, Distil
- ⇒ SimSci-ESSCOR: PRO/II
- ⇒ PSE: gPROMS
- ⇒ Belsim, Infochem, ProSim, Dechema, RSI, HTRI, Fluent, ...

▼ Operating companies

- ⇒ IFP, Total, BASF, Shell...

▼ Universities

- ⇒ INPT, UPC, RWTH.LPT, ChemSep, CMU...

▼ Government agencies

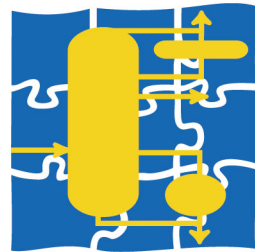
- ⇒ US EPA

Conclusion

- ▼ CAPE-OPEN provides a “simple” way to:
- ▼ Embed tailor-made unit operation models in flowsheeting tools
- ▼ Provide access to advanced thermodynamics within tailor-made unit operation models
- ▼ Encapsulate reaction packages for use within flowsheeting tools

Applications of CAPE-OPEN standards to reactor and kinetic modeling

Michel Pons
Chief Technology Officer
EUROKIN workshop, October 20, 2005



CO ▾ LaN

