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NATIONAL  
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## ***Overview of the Energy and Power Evaluation Program (ENPEP-BALANCE)***

*Center for Energy, Environmental, and Economic  
Systems Analysis (CEEESA)  
Decision and Information Sciences Division (DIS)  
Argonne National Laboratory  
9700 South Cass Avenue  
Argonne, IL 60439*



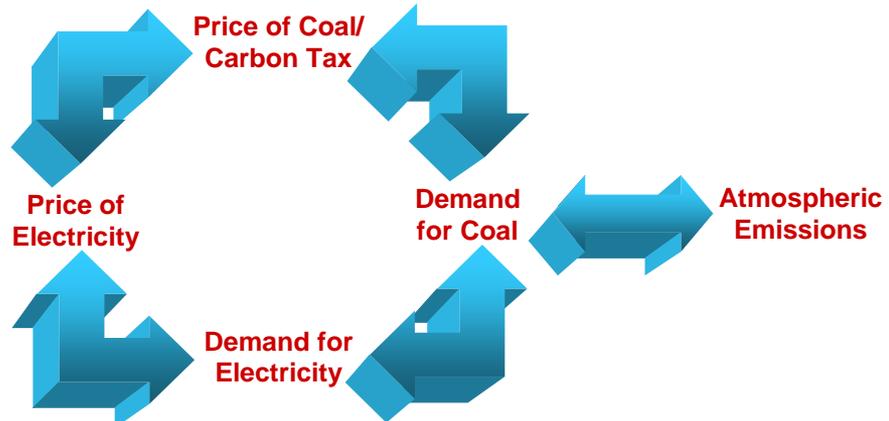
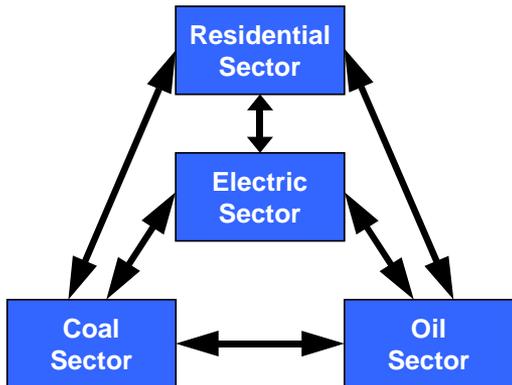
U.S. Department  
of Energy

UChicago ►  
Argonne<sub>LLC</sub>

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# ENPEP-BALANCE Is Designed to Analyze the Entire Energy System in an Integrated Framework

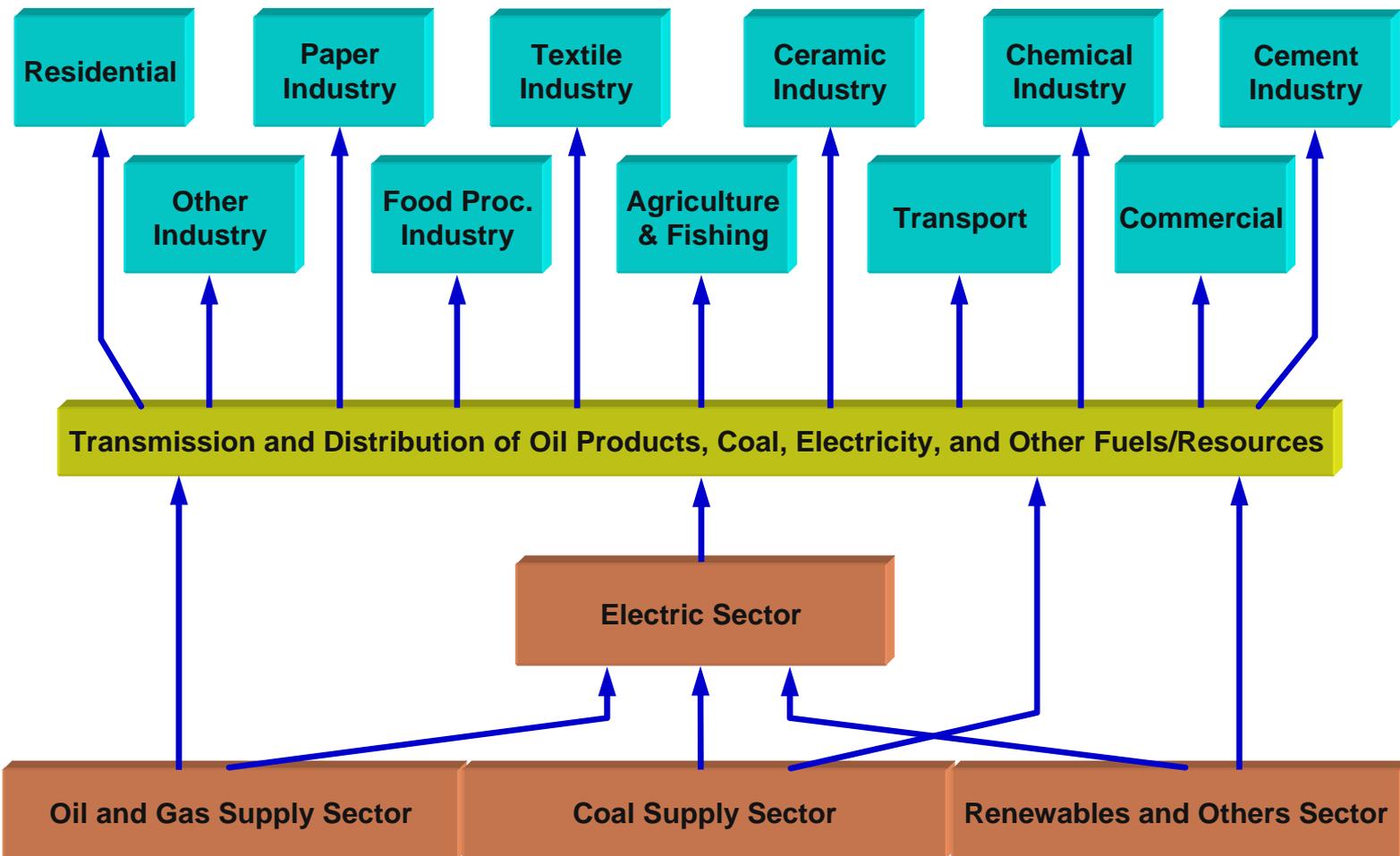
- Reveal cross-sectoral effects; provide structure for consistent energy “planning” program
- Integrated framework allows evaluation of feedback effects



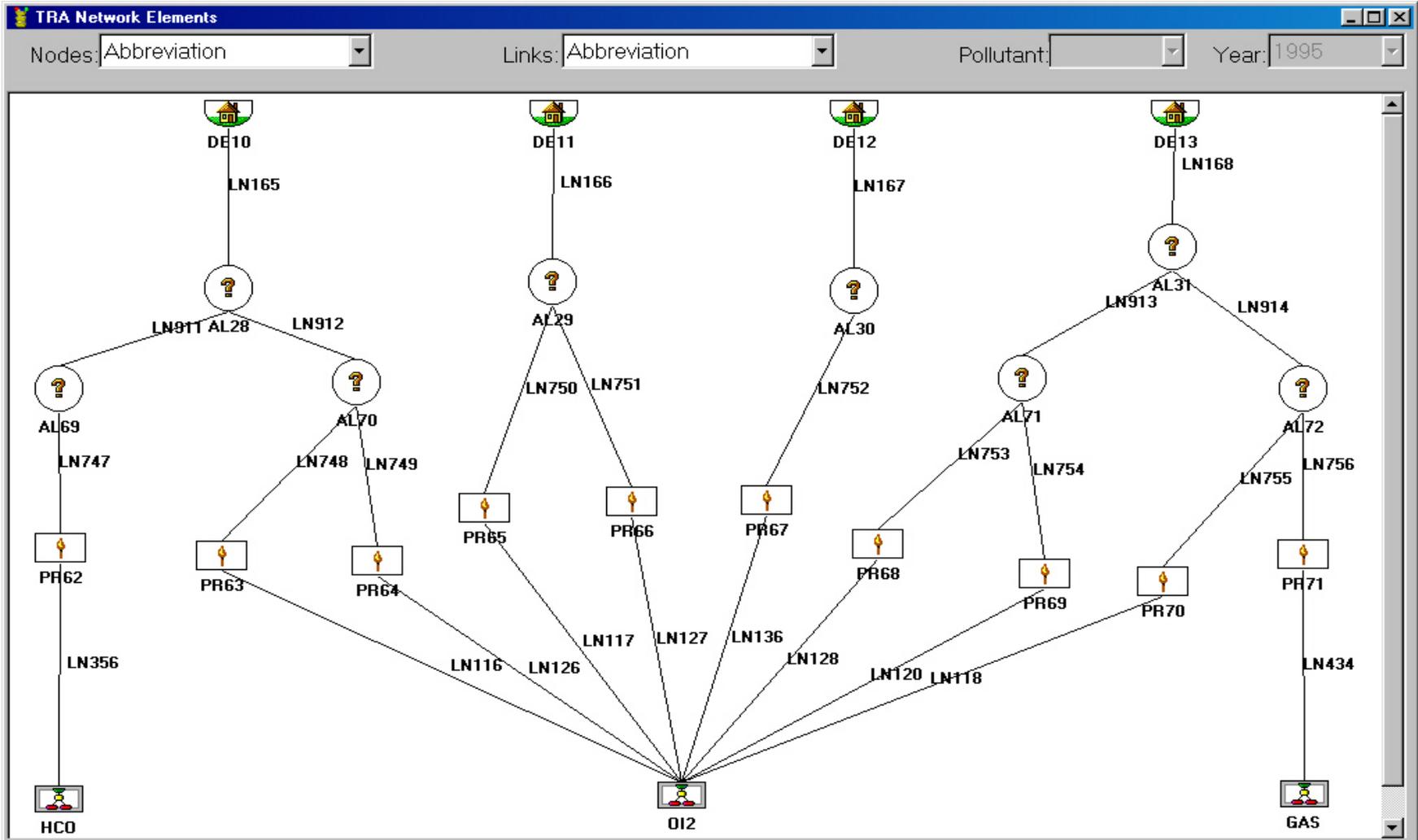
# ENPEP-BALANCE Determines the Equilibrium Supply/Demand Balance of the Energy System



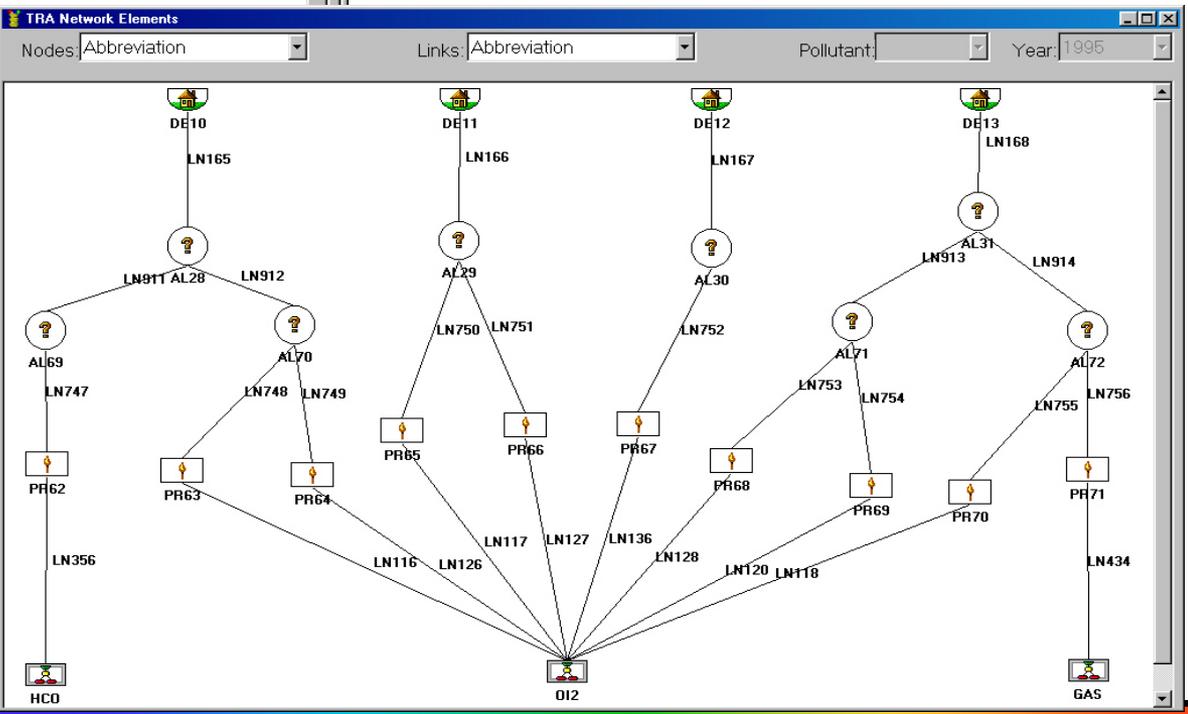
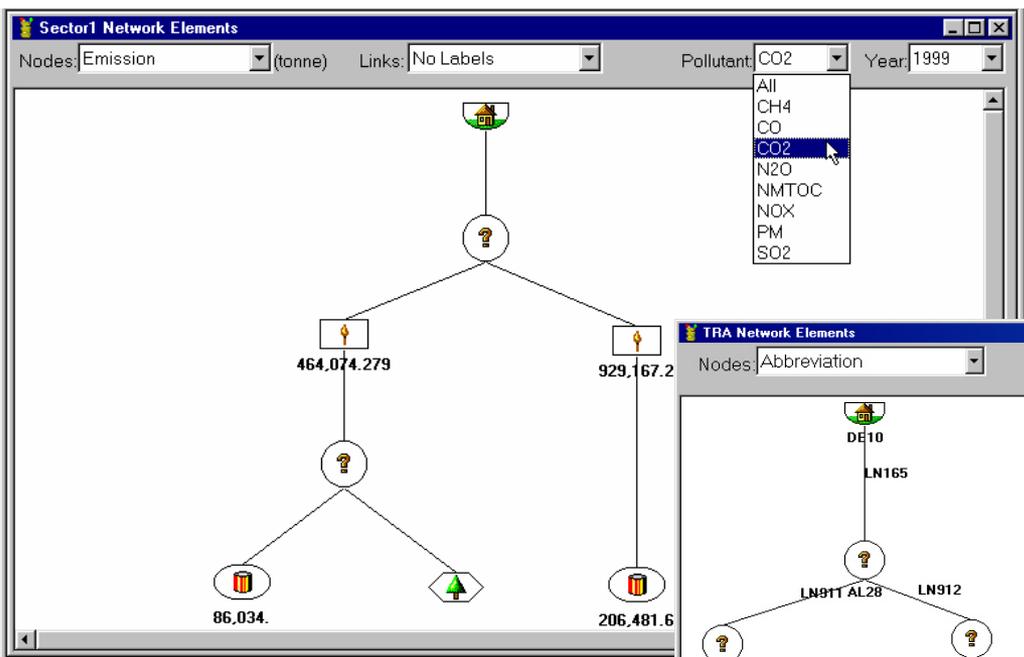
# ENPEP-BALANCE Uses an Energy Network to Simulate Energy Markets



# Networks Consist of Nodes and Links



# By Using Nodes and Links, Each Sector Is Modeled Differently Depending on Data Availability and Type of Issue Analyzed

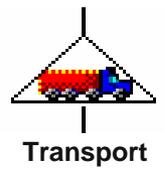
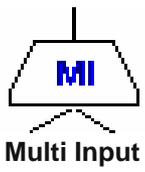
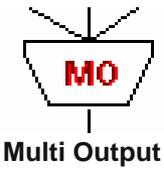
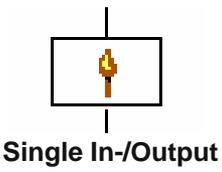


# The Following Node Types Are Available to Model Different Energy Activities

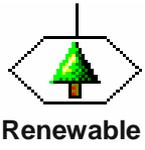
■ Demand



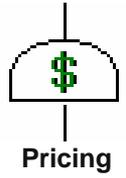
■ Conversion Processes



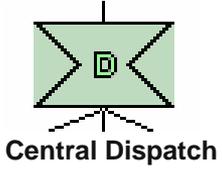
■ Resource Processes



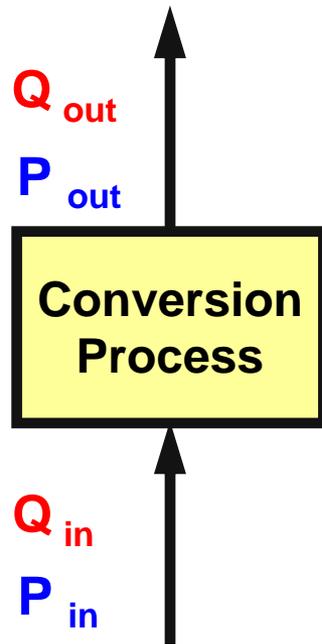
■ Economic Processes



■ Electricity Dispatch and Thermal and Hydro Units



# Nodes Are a Series of Simple Submodels, Each with a Set of Quantity and Price Equations



■  $\text{Quantity}_{\text{output}} = f(\text{Quantity}_{\text{input}})$

– Example conversion process

$$Q_{\text{out}} = Q_{\text{in}} \times E$$

**E: conversion efficiency**

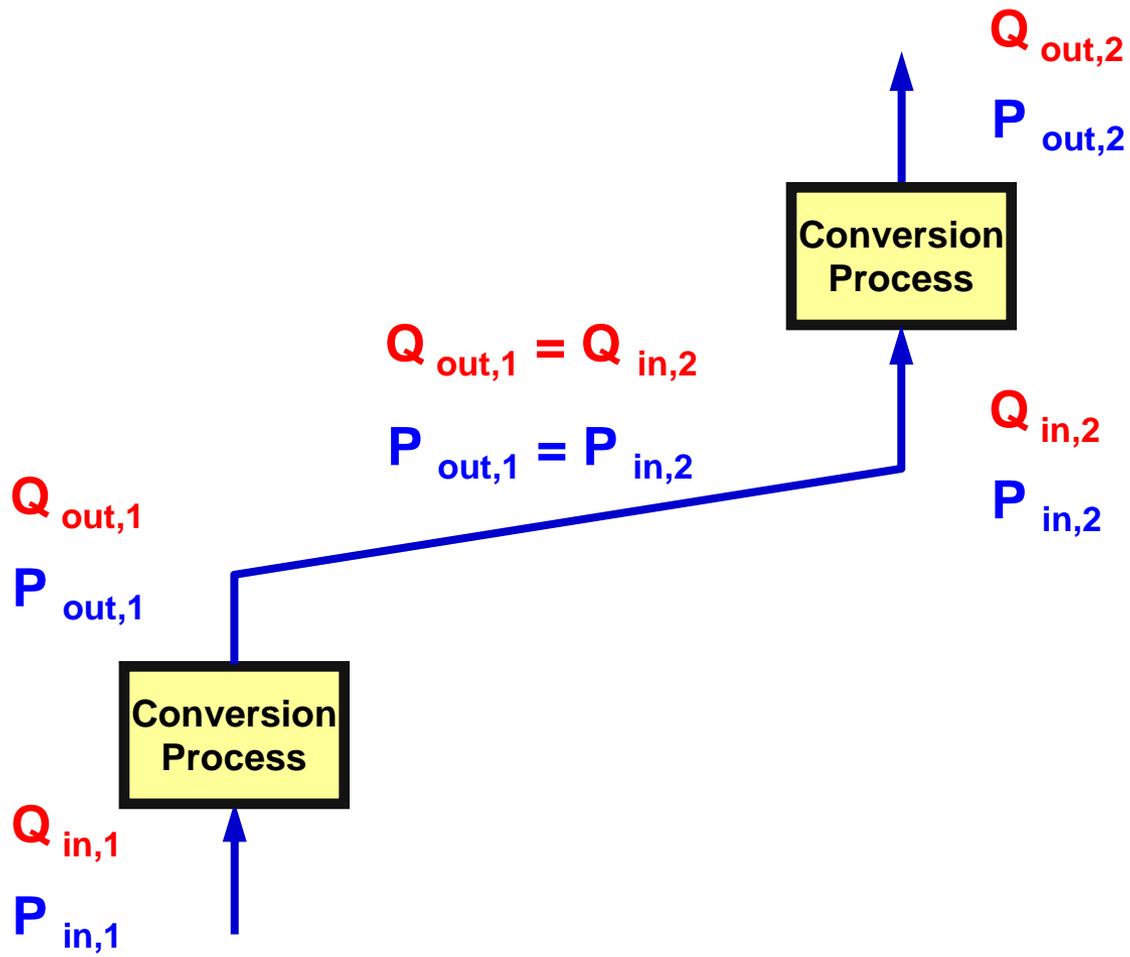
■  $\text{Price}_{\text{output}} = f(\text{Price}_{\text{input}})$

– Example conversion process

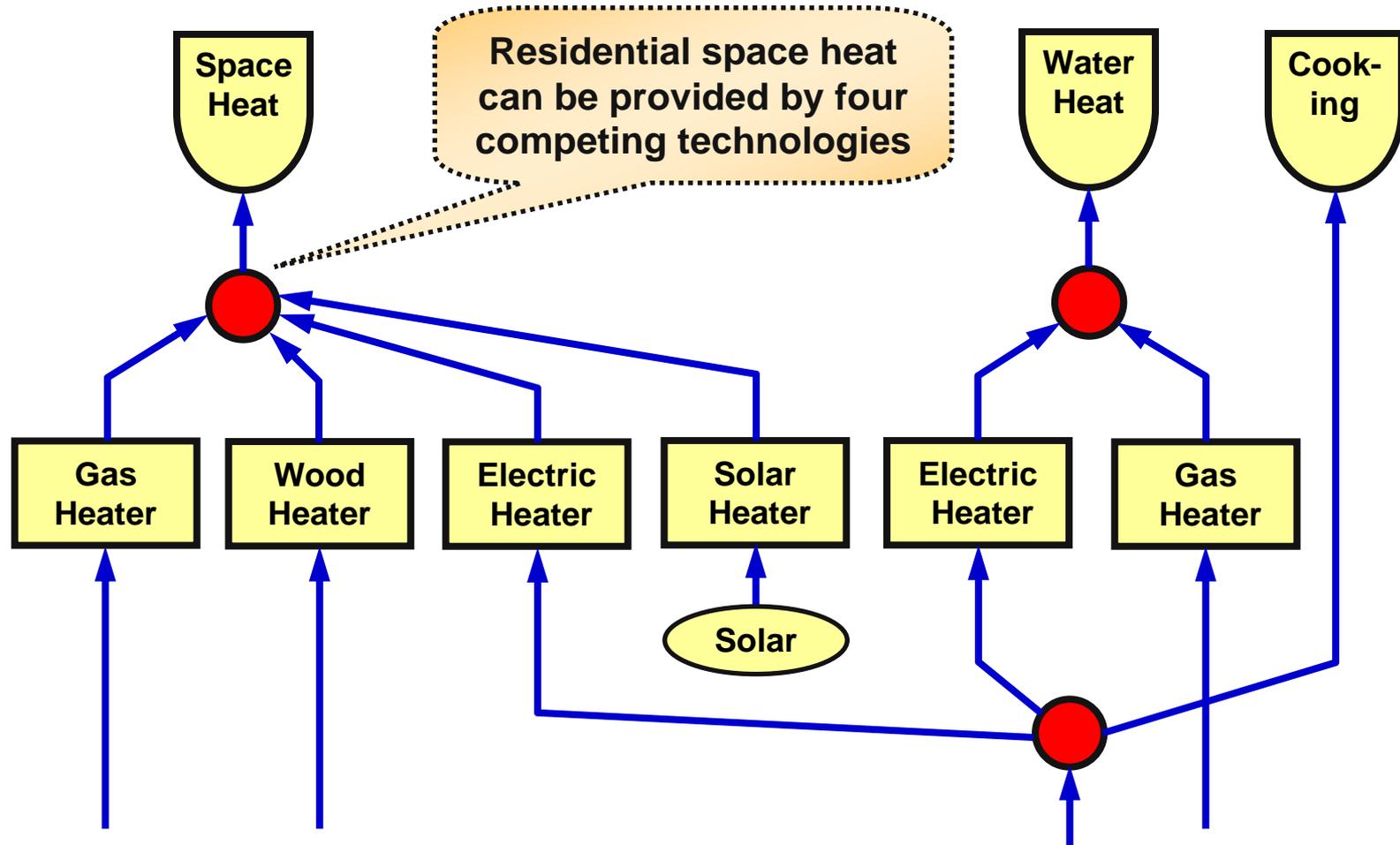
$$\text{Revenue} = \text{Cost}$$

$$Q_{\text{out}} \times P_{\text{out}} = Q_{\text{in}} \times P_{\text{in}} + \text{O\&M} + \text{Capital Recovery}$$

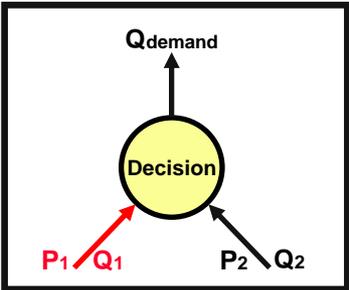
# The Links Connect the Nodes and Pass Information from One Node to Another



# At the Decision Nodes, Fuels and Technologies Compete for Future Market Shares

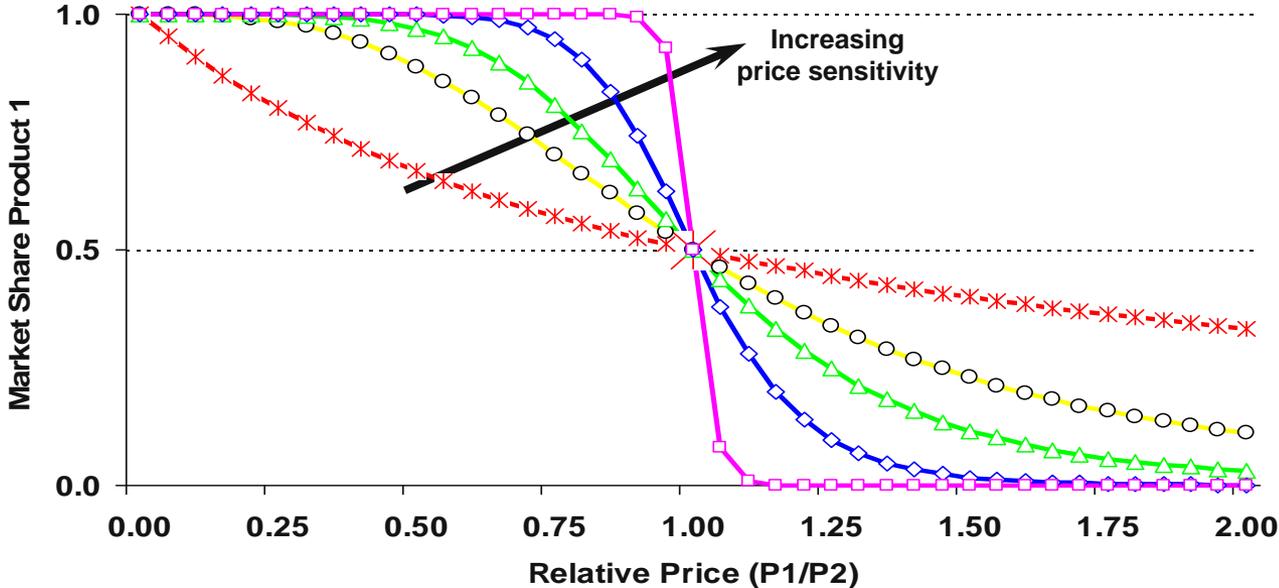


# ENPEP-BALANCE Uses a Logit-Function to Estimate Market Shares of Competing Commodities at the Decision Node



$$MS_1 = \frac{Q_1}{Q_1 + Q_2} = \frac{\left[ \frac{1}{P_1 \times PM_1} \right]^\gamma}{\left[ \frac{1}{P_1 \times PM_1} \right]^\gamma + \left[ \frac{1}{P_2 \times PM_2} \right]^\gamma}$$

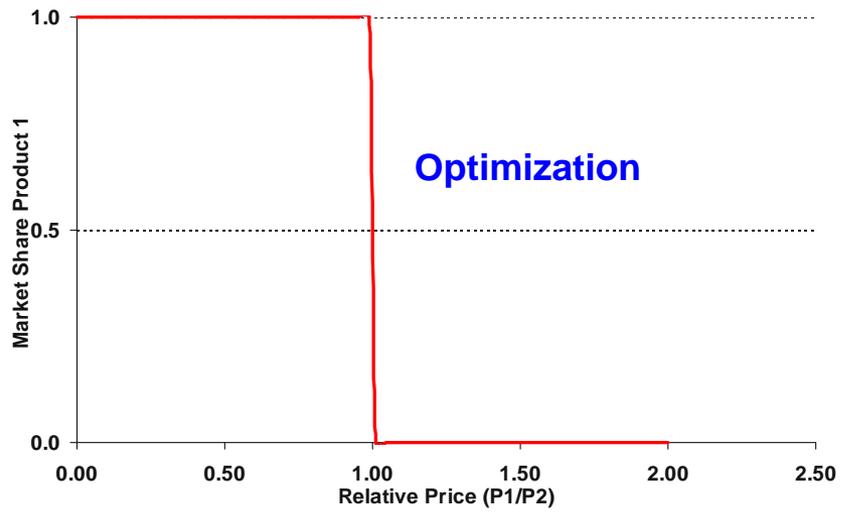
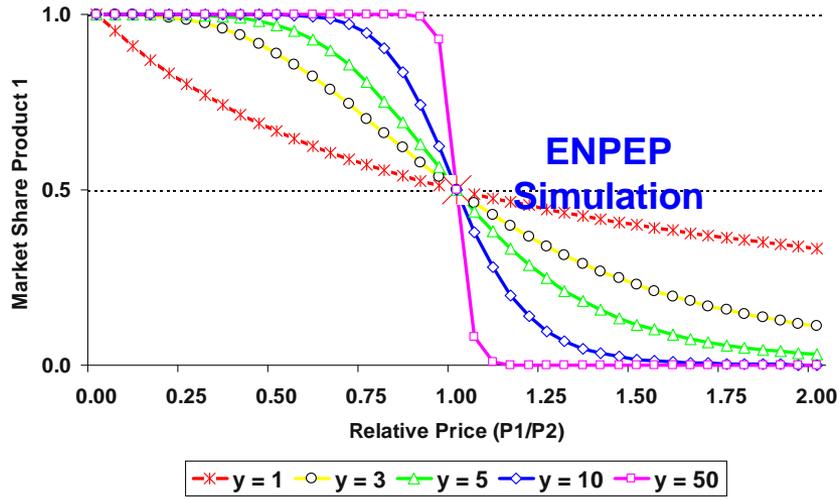
$\gamma$ : price sensitivity for this decision process  
 MS: market share  
 P: price  
 PM: premium multiplier  
 Q: quantity



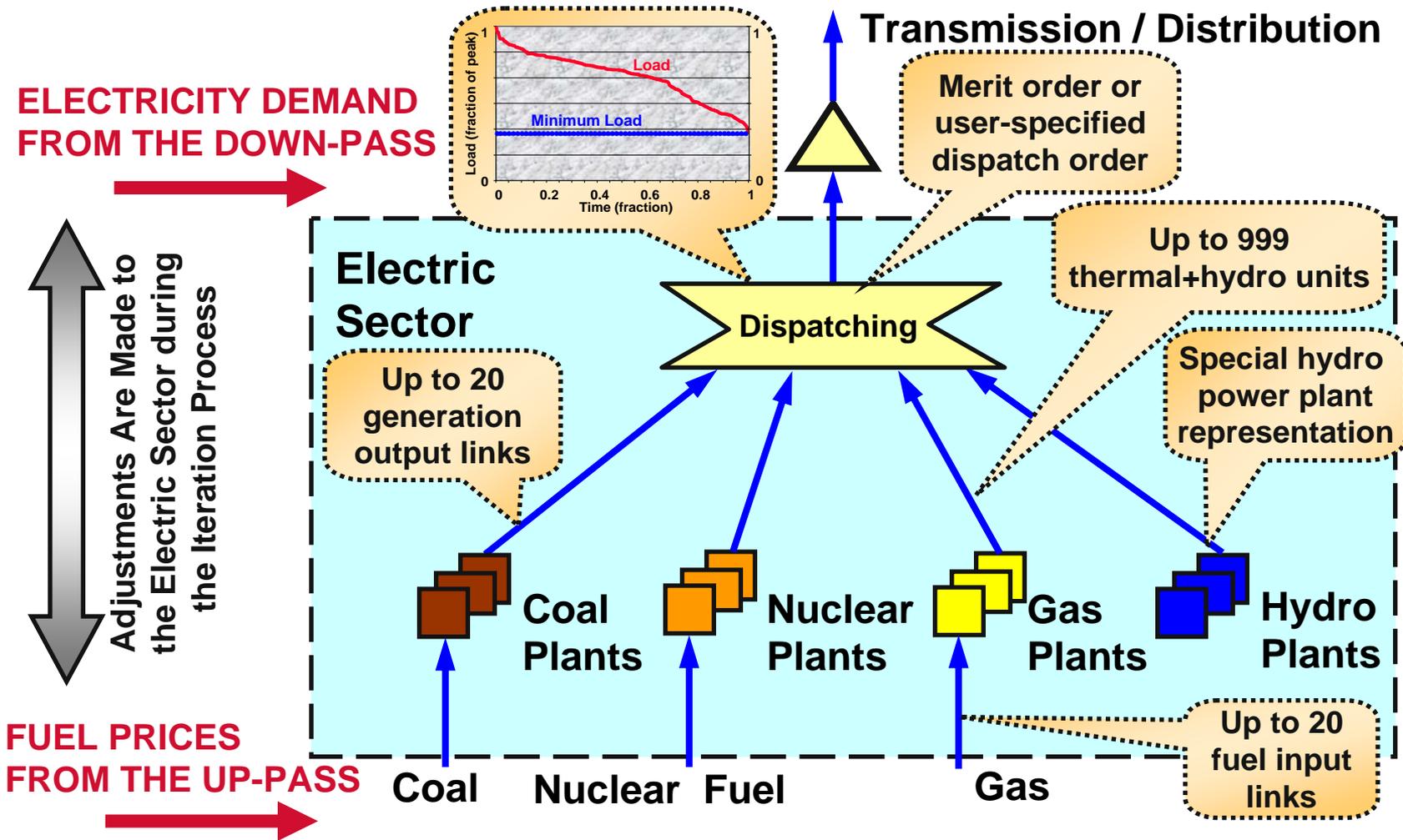
-\*- y = 1    -o- y = 3    -^-- y = 5    -d- y = 10    -□- y = 50

# The ENPEP-BALANCE Nonlinear Equilibrium Algorithm Is Based on Decentralized Decision Making

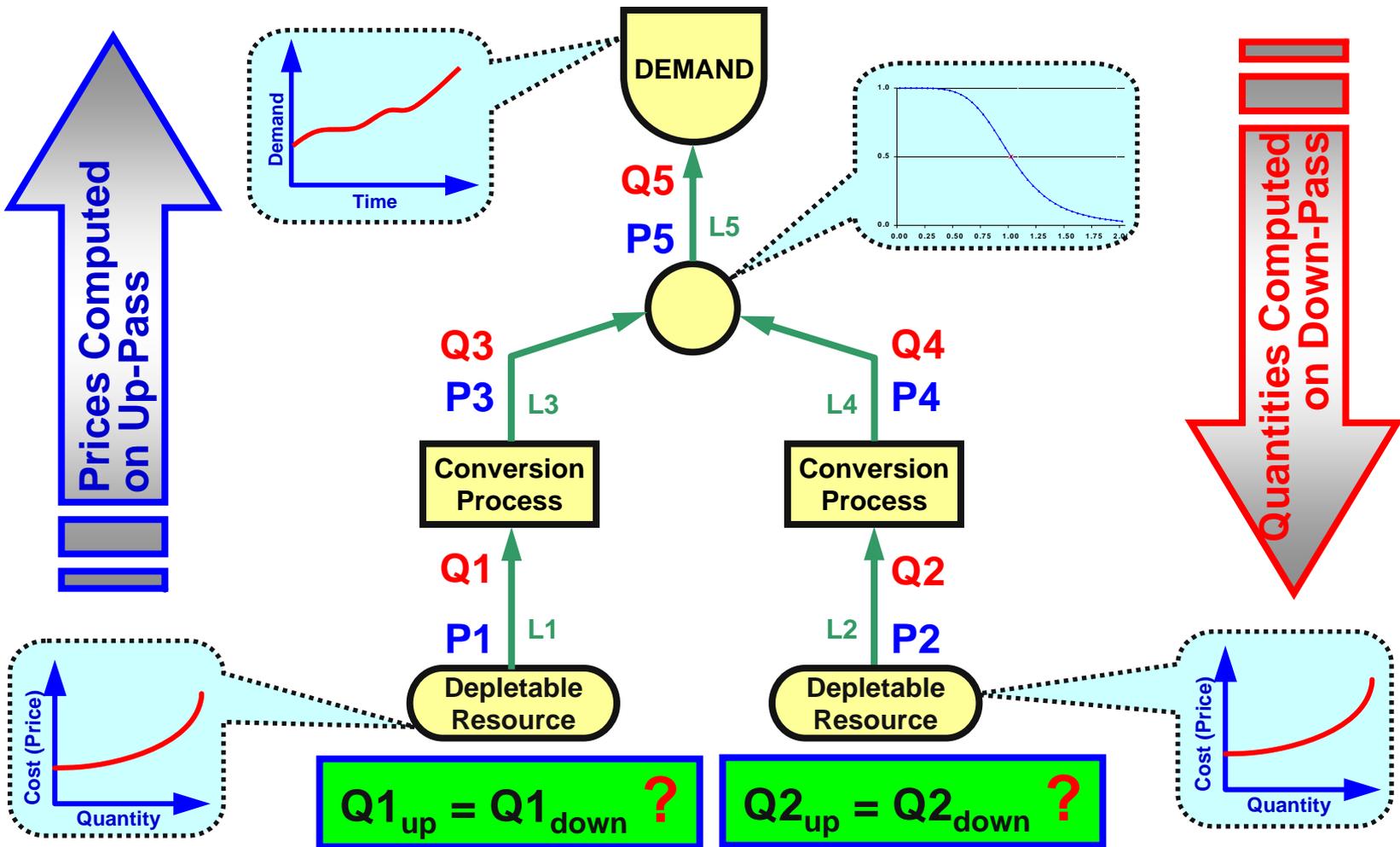
- Market share calculation assumes “ideal market” subject to government policies, fuel availability, and market constraints
- A lag factor accounts for delays in capital stock turnover
- The result is a nonlinear, market-based equilibrium solution within policy constraints, not a simple, linear optimization
- No single person or organization controls all energy prices and decisions on energy use
- All decision makers optimize their energy choices based on their own needs and desires



# The Electricity Dispatch Node Handles the Electric Sector in a Special Way *(more details on electricity in separate lecture)*



# ENPEP-BALANCE Uses an Up/Down Pass Sequence and the Jacobi Iterative Technique to Determine the Market Clearing Prices and Quantities at Market Equilibrium (more details on up-down in separate lecture)

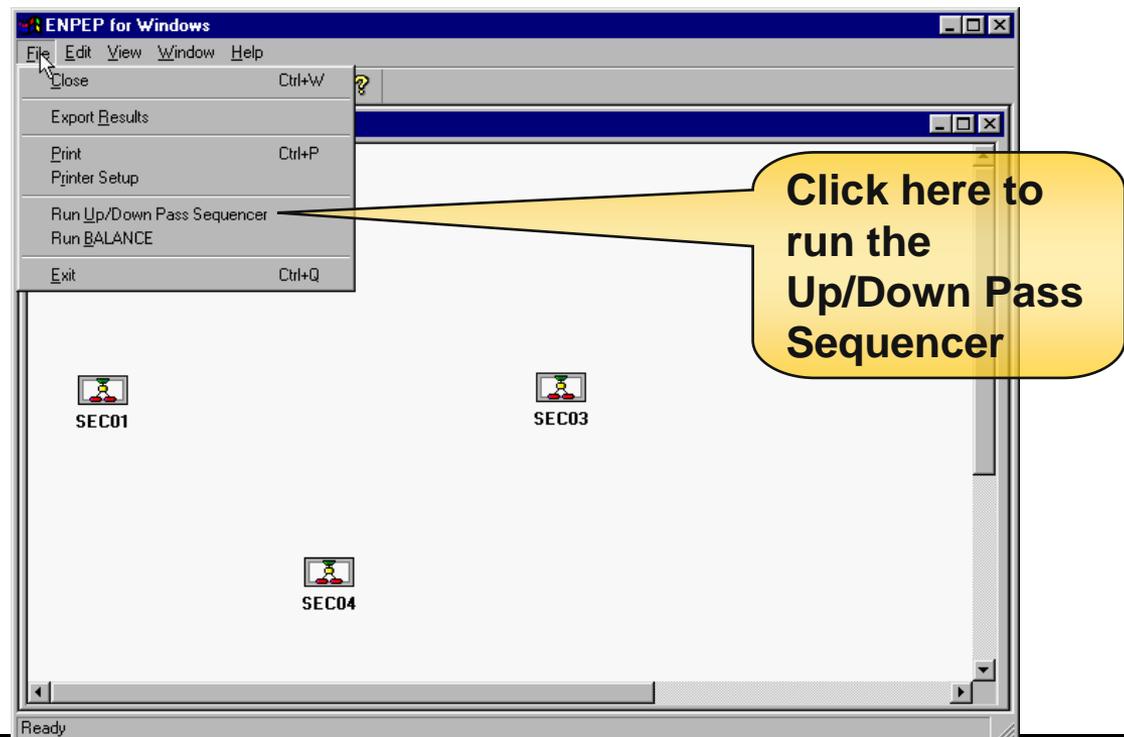


# The Up-Pass and Down-Pass Tell the Model in Which Sequence to Perform the Calculations (Which Node Comes When)

- Up-pass and down-pass sequences are repeated until convergence is achieved
- **CONVERGENCE IS ACHIEVED WHEN:**
  - $Q1 \text{ (down)} = Q1 \text{ (up)} \pm \text{Tolerance Level}$
  - $Q2 \text{ (down)} = Q2 \text{ (up)} \pm \text{Tolerance Level}$
  - The final result is a converged solution
  - The solution is in equilibrium across the whole network

# Execution of the Up/Down Pass Sequencer in ENPEP-BALANCE

- Run the Up/Down Pass Sequencer before running ENPEP-BALANCE for the first time
- This will determine the “node visitation sequence”
- Later, the Up/Down Pass Sequencer must be executed only if there has been a **CHANGE IN THE STRUCTURE** of the energy network
  - Add/delete nodes
  - Add/delete links



# The Calculated Up/Down Node Visitation Sequence Can Be Viewed in Tabular Form

BDEMO Case Up/Down Sequence

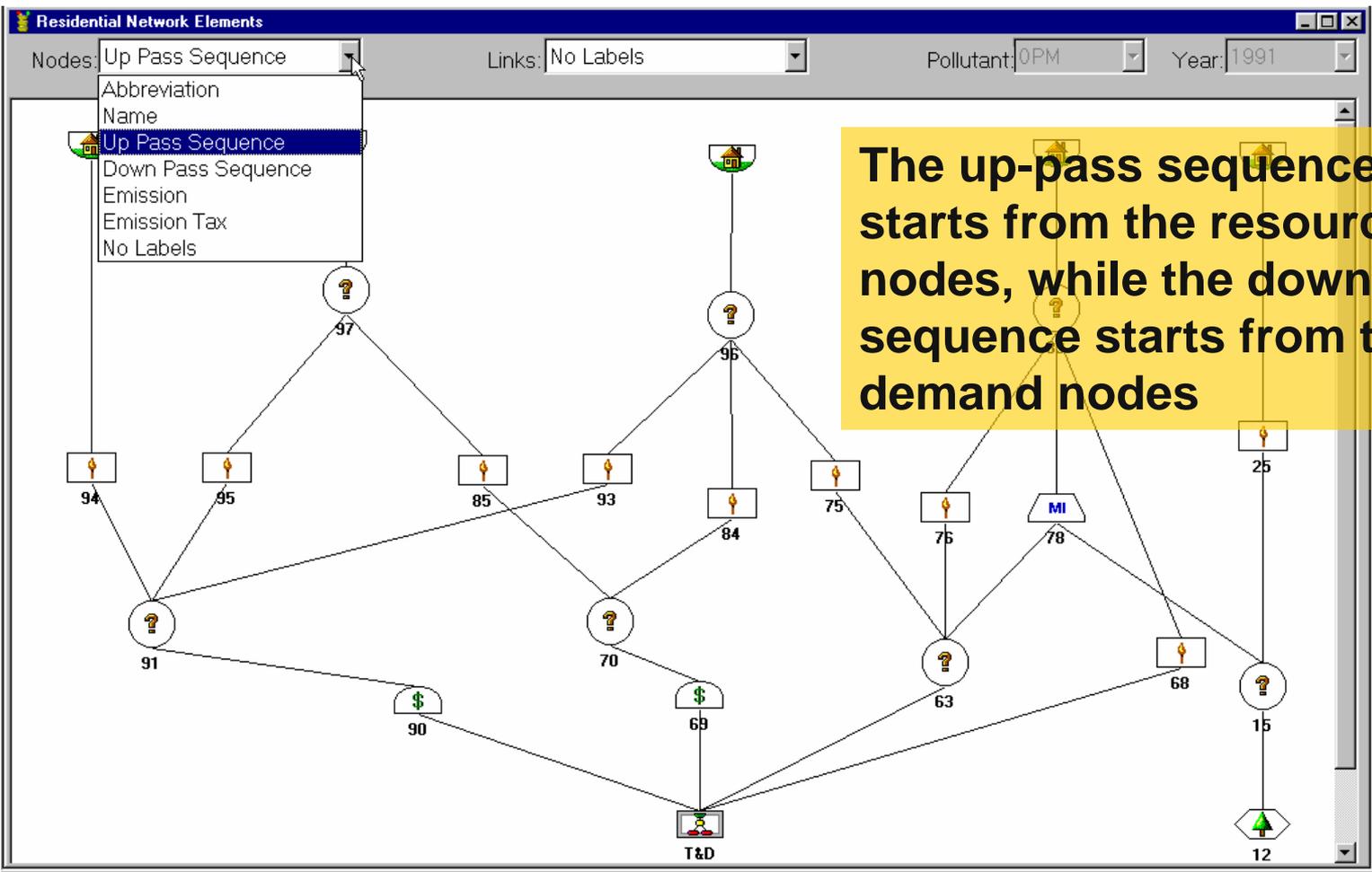
Up Pass Sequence | Down Pass Sequence

Node Type	Node Abbreviation	Node Name	Sector Abbreviation	Sector Name	Up Sequence
RS	I-LPG	LPG Import	SEC01	Sector One	1
RS	I-FO	FOIL Import	SEC01	Sector One	2
RS	I-OIL	I-OIL	SEC01	Sector One	3
RS	FO	Fuel oil	SEC04	Sector 04	4
RS	RS201	Depletable 201	SEC02	Sector 2	5
RS	TUSRC	Thermal Source	SEC03	Sector 3	6
RS	wcoal	Western Sumbit Coal	SEC03	Sector 3	7
RS	NGAS1	Natural Gas Node 1	SEC01	Sector One	8
RS	OIL1	Oil Node 1	SEC01	Sector One	9
RS	DMOIL	Domestic Oil	SEC01	Sector One	10
RN	ETH	Ethanol	SEC01	Sector One	11
RN	SOLAR	Solar	SEC01	Sector One	12
AL	ALOC1	Alloc. Node One	SEC01	Sector One	13
AL	ALOC4	Alloc. Node Four	SEC01	Sector One	14

OK Cancel

**This screen also allows the user to manually adjust the node visitation sequence, if necessary.**

# The Up/Down Node Visitation Sequence Can Be Viewed Directly in the Network



# Each Case Study Can Be Stored in a Different Database

The screenshot shows the 'BALANCE for Windows' application window. It features a menu bar (File, Edit, Window, Help) and a toolbar with icons for file operations. The main area is a table listing databases:

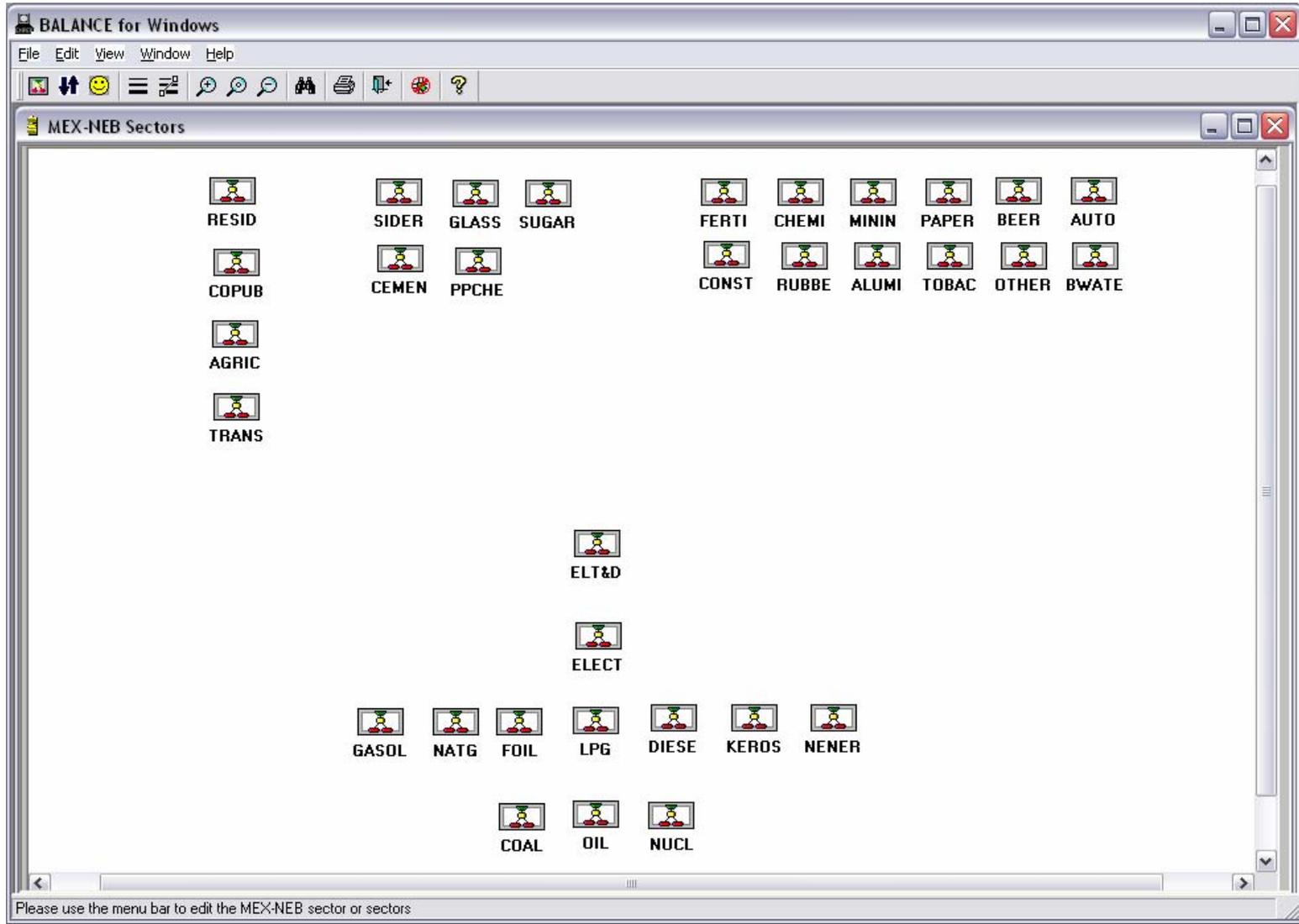
Study name	Last Opened	Description
demo	10/3/2002	This database contains two demonstration cases
vietnam-iaea	9/13/2002	Database with Vietnam GHG cases: Base Case, DSM Case, Efficiency Case, Nuclear Case
Mexico Electric Ag		Database with Mexican Electric Power Sector Case
Mexico Electric Sector	9/13/2002	
Mexico Electric	9/13/2002	

At the bottom of the window are buttons for 'Ok', 'Cancel', 'Delete', 'New', and 'Add'. The status bar at the very bottom shows the file path: C:\PROGRAM FILES\ENPEPWIN\BALANCE\database\demo.db

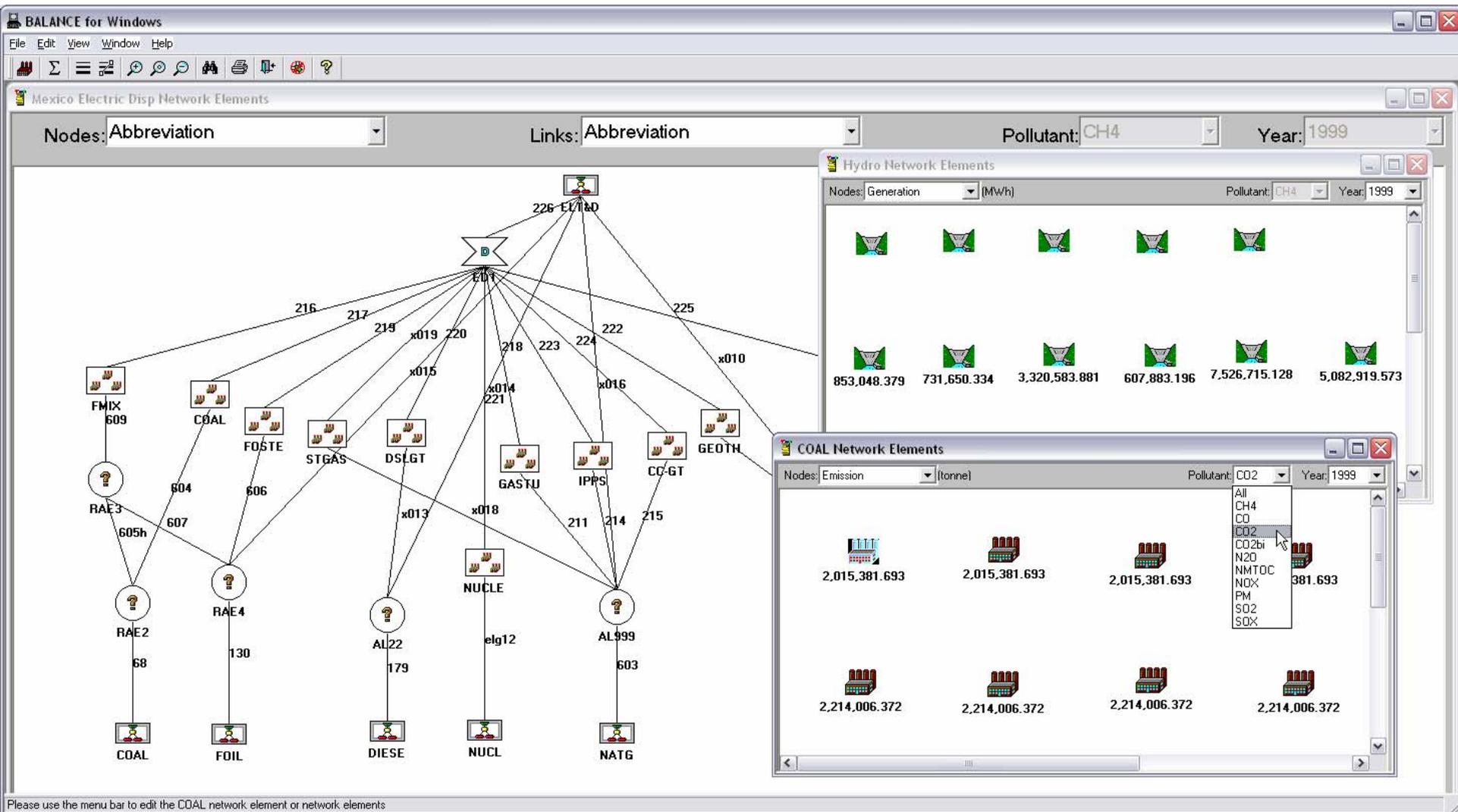
Three yellow callout boxes provide instructions:

- A callout pointing to the 'New' button: "Here is the path and name of the database file" (Note: this text is inside the callout, not pointing to the path in the status bar).
- A callout pointing to the 'New' button: "Create a new (blank) database".
- A callout pointing to the 'Add' button: "Add an existing database to this list".

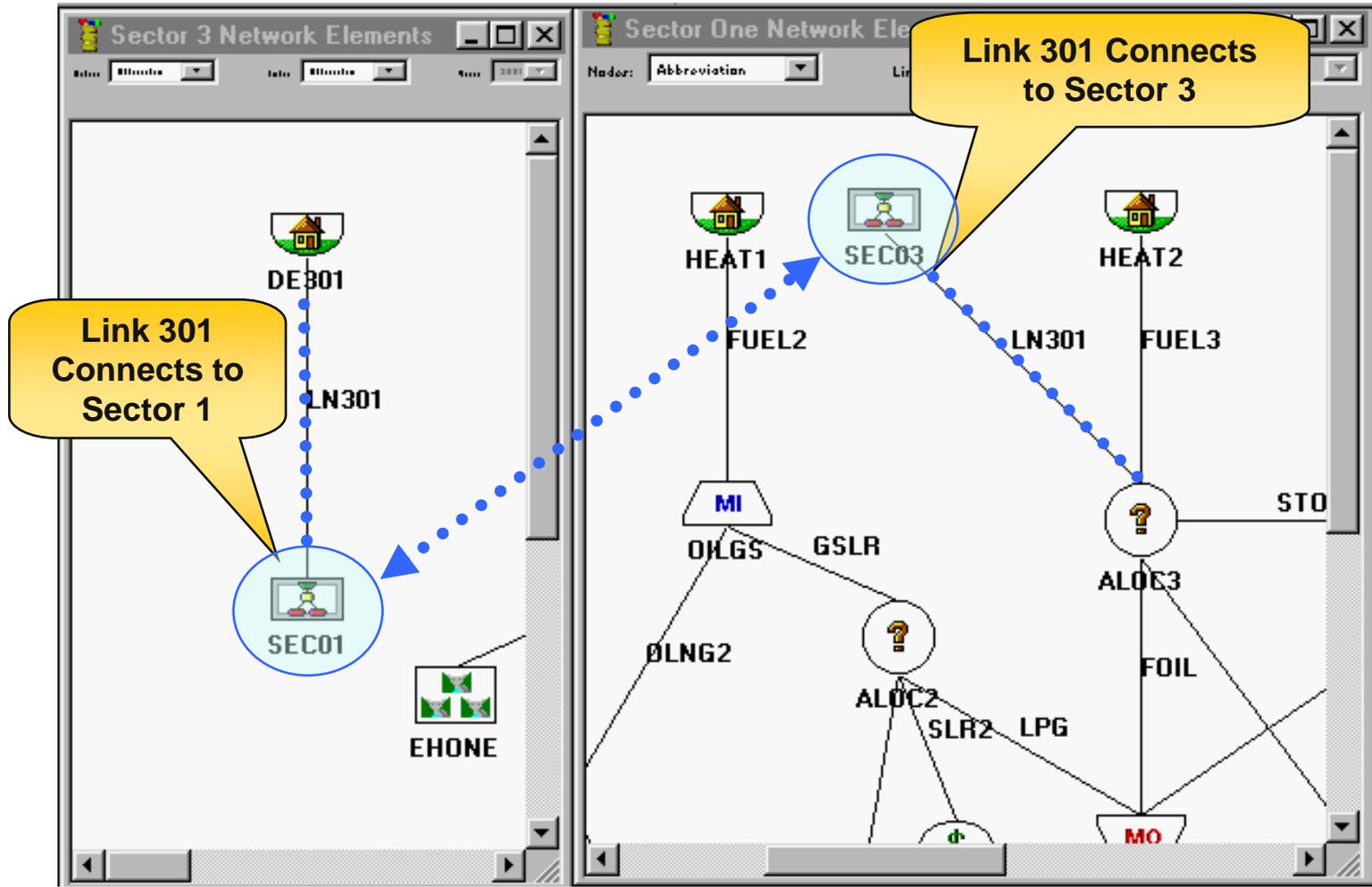
# The First Step in Developing an ENPEP-BALANCE Network Is to Define the Sectors Included in Your System



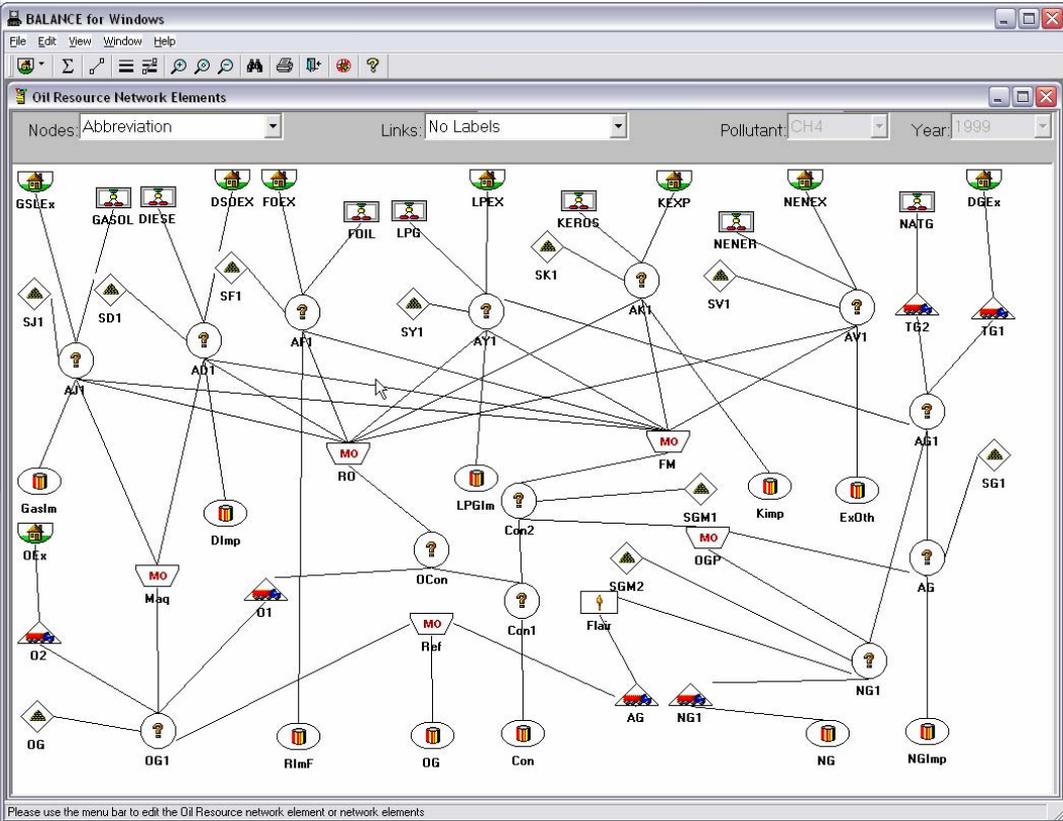
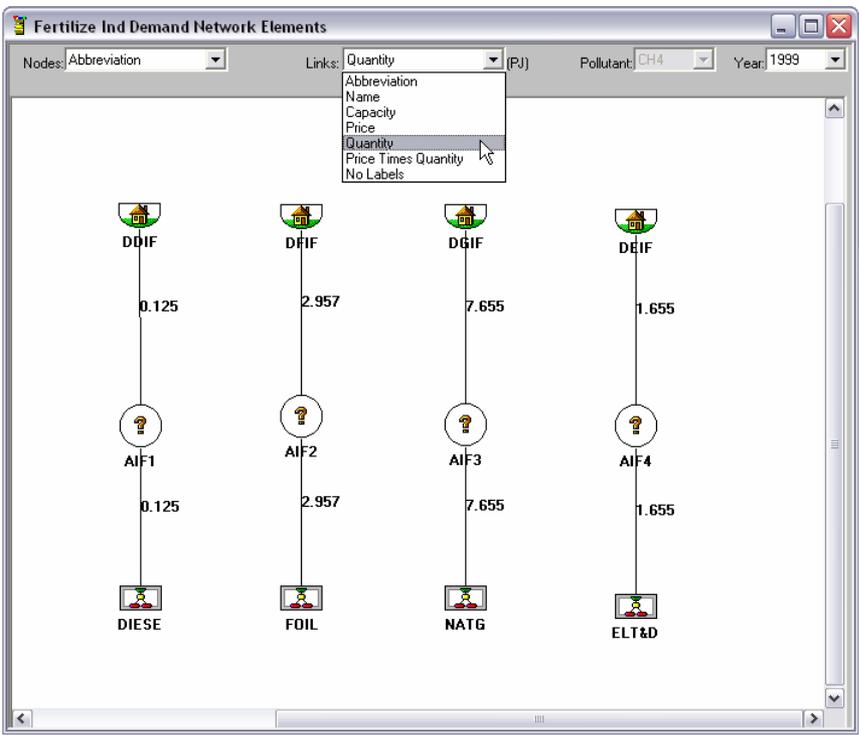
# Each Sector May Be Modeled Differently Depending on Data Availability and Type of Issue Analyzed: Power Sector Can Be Modeled at the Unit Level



# Intersectoral Links Can Connect Energy Networks of Different Sectors



# The Level of Detail May Vary from Simple to Complex: Example: Simple Fertilizer Industry and More Complex Oil & Gas Sector



# All Network Elements in ENPEP-BALANCE Can Be Accessed By Using a Standardized Simple Menu

The screenshot displays the BALANCE for Windows software interface. The main window shows a network diagram with nodes and links. A context menu is open over a node, showing options: Edit Input, Rename, and View Output. Three property windows are open, showing technical, economic, and emissions data for different process nodes.

**PIG4 Conversion Process Node Properties**

Year	Single Plant	All Plants	Typical	Output/Input
	Output Capacity (PJ)	Output Capacity (PJ)	Capacity Factor (Fraction)	Ratio (Fraction)
1999	12.390	100,000,000.000	0.750	1.000
2000				

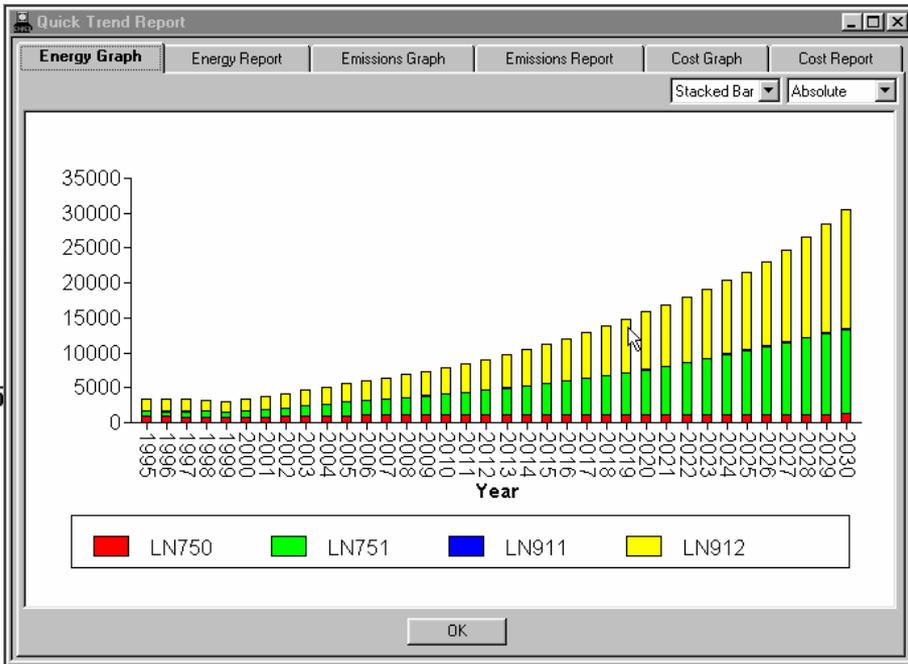
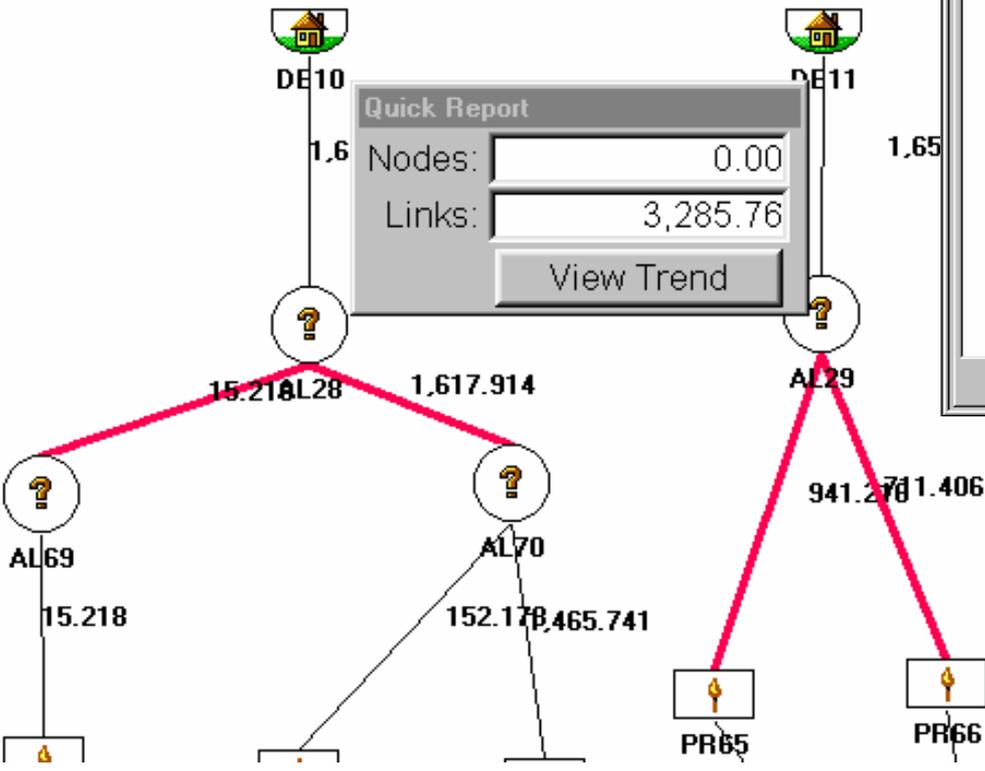
**PIG2 Conversion Process Node Properties**

Year	Single Plant Capital Investment (\$1000)	Operating and Maintenance Cost (\$/GJ)	Life Expectancy (Years)	Interest Rate (Fraction)
	1999	27,000.000	0.128	30.00
2000				
2001				
2002				
2003				
2004				
2005				
2006				
2007				
2008				
2009				

**PIG6 Conversion Process Node Properties**

Year	Pollutant Abbreviation	Uncontrolled Emission Factor Input Based (kg/GJ)	Chemical Scale	Scale Value (%)	Emissions Tax (\$/tonne)
		1999		CH4	
	CO	0.015			
	CO2	77.367	Carbon		
	CO2bi		Carbon		
	N2O	0.000			
	NMTOC	0.005			
	NOX	0.170			
	PM	0.682	Ash		
	SO2	0.995	Sulfur		
	SOX	1.410	Sulfur		
2000	CH4				

# Results Can Be Viewed Interactively for Individual Network Components and the Entire System



# ENPEP-BALANCE Uses a Standard Methodology to Determine the Uncontrolled and Controlled Source Emissions

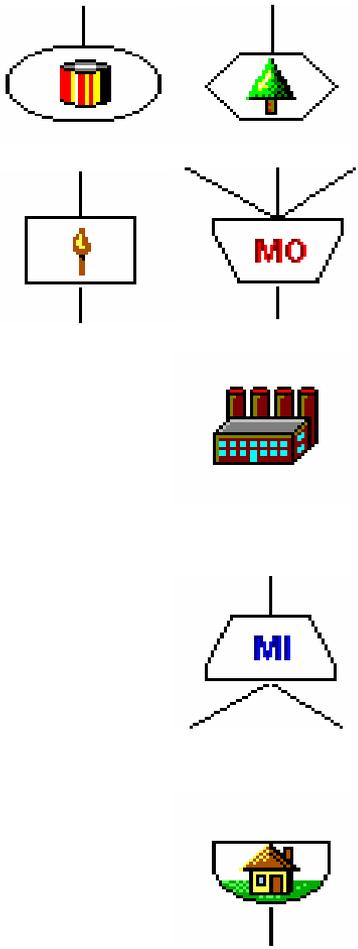


$$\text{Uncontrolled Emissions} = \text{Fuel Consumption} \times \text{Emission Factor} \times \text{Chemical Scale}$$

$$\text{Controlled Emissions} = \text{Uncontrolled Emissions} \times (100 - \text{Control Efficiency}) / 100$$

# Emissions Are Calculated and Reported by Node for Any Pollutant the User Specifies *(more details on emissions calculations in separate lecture)*

Run Parameters	Pollutants	Pollution Controls	Output Codes	Non-electric Units	Electric Units
Name	Abbreviation	Chemical Scale			
Methane	CH4				
Carbon Dioxide	CO2	Carbon			
Nitrous Oxides	N2O				
Non Methane Total Organic Compounds	NMTOC				
Nitrogen Oxides	NOX				
Particulate Matter Total	PM	Ash			
Sulfur Dioxide	SO2	Sulfur			
<u>Carbon Monoxide</u>	CO				



Technical Properties	Economic Properties	Emissions Properties	Control Properties		
Year	Pollutant Abbreviation	Uncontrolled Emission Factor Input Based (kg/Gj)	Chemical Scale	Scale Value (%)	Emissions Tax (\$/tonne)
1999	CH4	0.001			
	CO2	1.349	Carbon	77.60	20.00
	N2O	0.002			
	NMTOC	0.001			
	NOX	0.399			
	PM	0.184	Ash	17.50	
	SO2	0.698	Sulfur	4.50	100.00

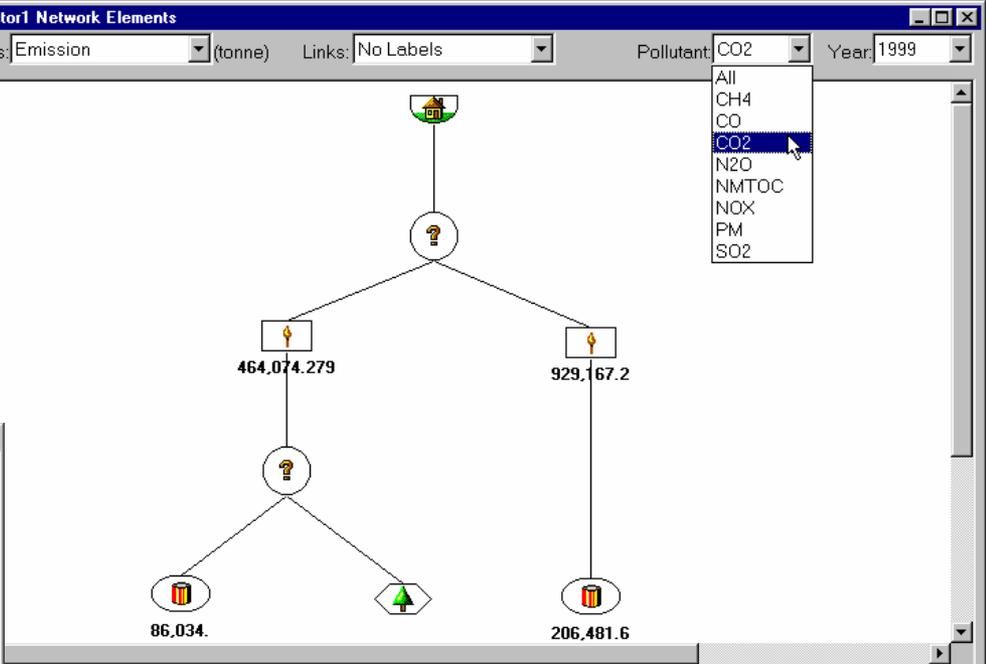
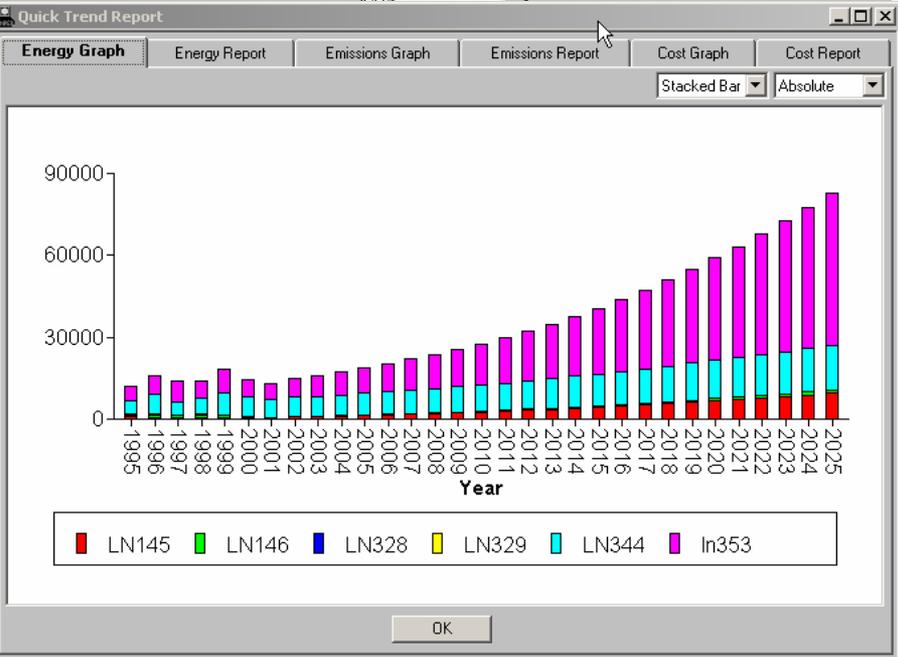
# Environmental Results Can Be Viewed Directly in the Network, in Tables, Simple Graphs, or Exported to EXCEL

Energy Report | Energy Graph | Environmental Report | Environmental Graph

Emission Factor

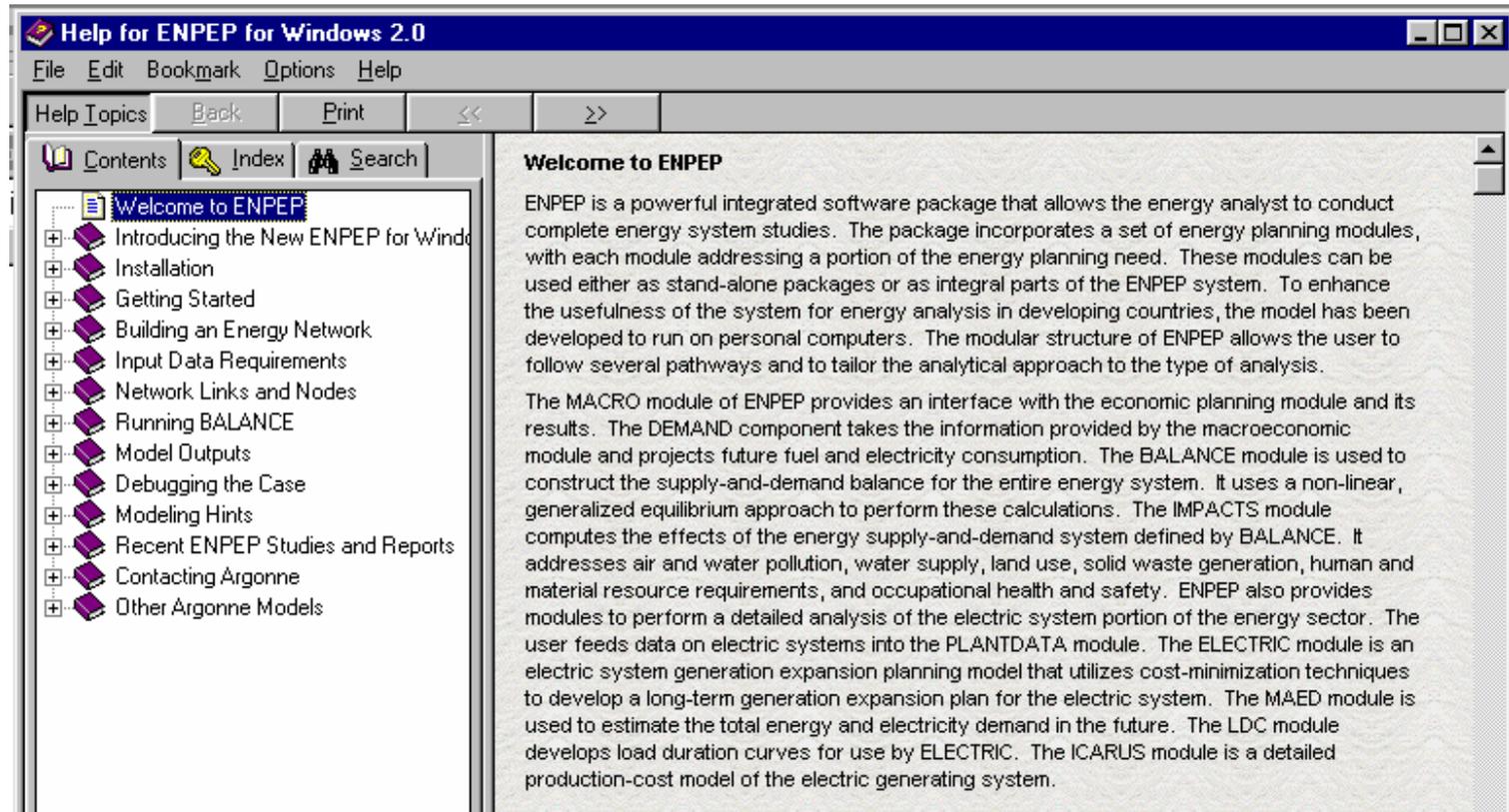
Year	Input Quantity (kBOE)	Pollutant Abbreviation	Times Scale Value (kg/Gj)	Emissions (tonne)
1999	1200	CO2	104.64515	720,243.281
2000	1245.777588	CO2	104.64515	747,719.114
2001	1292.328003	CO2	104.64515	775,658.800
2002	1340.535767	CO2	104.64515	804,593.232
2003	1389.497192	CO2	104.64515	833,980.013
2004	1439.415039	CO2	104.64515	863,940.841

Selected Pollutant: CO2



	A	B	C	D	E	F	G	H
1	DemoC	Export to TXT	Nodes emissions	13-Feb-01	11:40			
2								
3	Base	Nb of	Nb of	Nb of				
4	Year	Years	Nodes	Pollutants	Unit			
5								
6	1991	30	79	10	tonne			
7								
8								
9	Sector	Node	Type	Pollutant	1991	1992	1993	1994
10	AG	DE23	DE	OPM	1658.296	1741.211	1822.874	1906.544
11	AG	DE23	DE	1PM10	0	0	0	0
12	AG	DE23	DE	2SO2	14.31514	15.0309	15.73585	16.45812
13	AG	DE23	DE	3NOX	282.5357	296.6624	310.5759	324.8314

# A Help System Is Available to Provide Online Support



# Information on ENPEP-BALANCE Applications Is Available on Our Website

The screenshot shows the Argonne National Laboratory website for the Center for Energy, Environmental, and Economic Systems Analysis (CEEESA). The browser window is Mozilla Firefox, displaying the URL http://www.dis.anl.gov/ceesa/. The website header includes the Argonne logo and navigation menus for CEEESA Home, About Us, CEEESA Team, Models/Tools, Training, Projects/Activities, Publications, and Site Index. A search bar is also present.

The main content area features a large map of the Los Angeles area with a multi-agent simulation overlay, titled "Multi-Agent Simulation of Hydrogen Transition Issues". Below this, there are three columns of news and software information:

- What's New:**
  - NHI: For U.S. DOE's Nuclear Hydrogen Initiative, Argonne is developing a real options model to analyze the value of product flexibility, as well as other options, for various nuclear hydrogen technologies... [\(more\)](#)
  - CEEESA used a variety of modeling tools to analyze the competitiveness of nuclear power in Poland for DOE's Global Nuclear Energy Partnership program... [\(more\)](#)
  - Argonne/University of Illinois study identifies congestion issues as a potential impediment to competitive electricity markets in Illinois... [\(more\)](#)
- Popular Software Tools:**
  - EMCAS: Our newest and most advanced model, EMCAS, the Electricity Markets Complex Adaptive Systems model, uses agent based modeling to simulate today's power markets... [\(more\)](#)
  - GTMax: Our entry-model, the Generation and Transmission Maximization Model, is used by users worldwide to analyze generation and transmission... [\(more\)](#)
  - ENPEP-BALANCE:** Our Energy and Power Evaluation Program (ENPEP-BALANCE) is the premier energy system analysis software in use in over 80 countries and is now available **FOR FREE** to everyone... [\(more\)](#)
- Upcoming Training Courses:**
  - ENPEP-BALANCE** September 17-21, 2007: [REGISTER](#)
  - EMCAS** December 3-14, 2007 (By invitation only) [COURSE INFORMATION](#)
  - WASP-IV** New Dates: April 21-25, 2008: [REGISTER](#)

The ENPEP-BALANCE software advertisement is circled in red in the original image.

# As Do All Models, ENPEP-BALANCE Has Limitations

- The market share formula needs to be applied carefully to produce “reasonable” results (particularly check the transition from 1st to 2nd year)
- The solution is generated year by year and is said to be “myopic”
  - However, in today’s short-term-oriented energy markets, this may actually be an advantage
- If not set up in sufficient detail, it can be insensitive to price
- Nevertheless, the ENPEP-BALANCE approach has proven itself to be powerful and useful (if applied correctly)
- ENPEP-BALANCE is a tool
  - A tool should be used wisely
- Also, if the only tool you have is a hammer, then every problem starts looking like a nail

